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Energy Efficiency through Green Energy Projects in Central Asian Countries

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Declaration

I, Dilshoda Marufova, declare that the work presented in this Master thesis entitled “Energy Efficiency through Green Energy Projects in Central Asian Countries” is the results of my original research completed under supervision of Professor Pascale Combes Motel. I hereby confirm, that whereas I have consulted or quoted from a published work of others, I have acknowledged and cited their papers both in the main text and in final references. This thesis has not been submitted for any other degree or qualification.

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Zásady pro vypracování

The aim of the paper is to analyze the green energy projects which contribute to the energy efficiency by providing remote areas with the stable access to electricity and reduce the negative impact of the CO2 emissions and support environmental sustainability. Many developing countries suffer from energy-import dependency and lack of power supply of rural areas. They rely on limited resources of energy as coal, oil or gas what make their economy more prone to energy price fluctuations and will reduce the resiliency of the economy. Diversification of energy resources as adoption of the green energy technologies might be one of the effective policy tools to provide sustainable energy in a community and contribute to reducing environmental damage. However, sufficient financial support is required to further promote the implementation of green energy projects.
The recent study of Yoshino et al (2019) shows that there is a lack of green energy projects financing because of the lower rate return compared to fossil fuel projects and existence of risks for business corporations. Only few studies on this matter, specifically related to green energy solutions have been conducted. In the paper, challenges and approaches of green financing and investment on green energy projects will be analyzed and practical solutions and recommendations for filling the green financing gap will be provided.

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Abstract:

As renewable energy is lying at the heart of a country's sustainable development by providing an opportunity to transform societies and economies, this study aims to analyze the impact of the green energy projects on energy efficiency of Central Asian countries through the socioeconomic and environmental pillars of sustainable development. A full assessment of the potential and the key barriers to green energy development in the Central Asian region is conducted. The results of the study indicate that contributions of the evaluated case studies of Kazakhstan, Kyrgyzstan and Tajikistan have significant impact on many factors of sustainable development. The projects foster economic growth, improve the well-being of the local population, and have positive environmental impact in the countries.

Keywords: Green Energy, Energy Efficiency, Central Asia, Sustainable Development, Economic Growth, Social Services, Environmental Sustainability

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List of Abbreviations

Abbreviation	Definition
CA	Central Asia
CREEED	Centre for Renewable Energy and Energy Efficiency Development
DEA	Data Envelope Analysis
DREI	De-risking Renewable Energy Investment
EE	Energy Efficiency
FIT	Feed-in Tariff
GE	Green Energy
GEF	Global Environment Facility
GHG	Greenhouse Gas
IEA	International Energy Agency
INDC	Intended Nationally Determined Contribution
IRENA	International Agency for Renewable Energies
NAMA	Nationally Appropriate Mitigation Actions
RE	Renewable Energy
SDG	Sustainable Development Goal
SE4All	Sustainable Energy for All
SMEs	Small and Medium-Sized Enterprises
SWH	Solar Water Heating
TEO	Total Electricity Output
TFES	Total Final Energy Consumption
TPES	Total Primary Energy Supply
UN	United Nations
UNDP	United Nations Development Programme

1. Introduction

Energy lies at the heart of a country's sustainable development which provides an opportunity to transform societies and economies (IEA, 2018). Energy-import dependency and inadequate access to electricity in most of the countries appears to hinder their sustainable development affecting vulnerable groups of the population (UNDP, 2014). Reliance of the countries on the limited energy resources such as coal, oil or gas make their economy prone to energy price fluctuations and reduce their economic resilience (Yoshino, 2019). Therefore, it is crucial to offer an alternative energy resource to the existing traditional and limit the increasing fossil fuel consumption.

The importance energy issues for sustainable development were highlighted by the United Nations (UN) when announcing 2014-2024 the Decade of Sustainable Energy for All (SE4All). UN Sustainable Development Goal 7 (SDG 7) also calls for ensuring universal access to affordable, clean, and sustainable energy which aims toward improving energy efficiency and increasing the use of renewables in the countries (UNECE, 2019). Renewable energy (RE) which has received extensive attention worldwide for its outstanding contributions might be the future of the energy industry and an effective way to meet these challenges.

Renewable energy capacity continued to grow during COVID-19 pandemic, shrugging off the disruptions to economic activity and primary energy and CO2 emissions falling at their fastest rates. Solar and wind have the fastest growth rates among renewable energy resources, while hydropower remains by far the largest source (IEA, 2022).

Our study focuses on Central Asian region which consists of Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan countries. Central Asia (CA) is a resource-rich region not only with abundant oil and natural gas reserves but also with renewable energy resources. The economies of the region have low diversification of the energy and heavily rely on principal sources which is coal for Kazakhstan, gas for Turkmenistan and Uzbekistan and hydropower for Tajikistan and Kyrgyzstan (Jalilov, 2017).

Despite its access to diverse energy resources, Central Asian region is facing energy poverty due to the left post-Soviet outdated infrastructure, legacy of energy intensity and energy inefficiency which is not capable of fulfilling the growing electricity demand of the individual countries (UNDP, 2014). The region has tremendous potential for green energy (GE) development considering the climatic and geographic conditions, as potential of wind and solar energy, which remains unexploited (Shadrina, 2019). Therefore, implementation of the green energy projects in CA region might be an effective policy tool to meet growing energy demands within the countries and contribute to diversification of the energy resources. Apart from reducing the negative impact of the CO2 emissions and promoting environmental sustainability, it is believed to affect the improvement of energy efficiency, economic growth, and well-being of the society.

Our study investigates the potential for the introduction of the green energy technologies in the energy sector of the Central Asian countries. We conduct a full assessment of the possibilities and the key barriers to green energy development in the region. The objective of this research is to identify the impact of the green energy projects on energy efficiency (EE) of Central Asian countries through the socioeconomic and environmental pillars of sustainable development. The following two main research questions will be addressed on the paper.

- What are the possibilities and challenges for the green energy development in the Central Asian countries?
- What is the impact of the green energy projects on energy efficiency and sustainable development of the Central Asian countries?

To cover the proposed scope of the research, the methodological framework is applied, which includes insights from the reviewed existing research and builds upon the adapted practices. The green energy impact on sustainable development and energy efficiency is assessed by combination of quantitative and qualitative approaches in the form of case studies. By evaluating the three dimensions of the sustainable development the aim is to consider the main areas of sustainable development and have the general picture since the green energy projects affect not only energy efficiency, but also many other factors considered in the analytical framework.

The thesis is structured as follows: Chapter 2 contains of three subsections. The first section will define green energy while the second section outlines energy efficiency and its measurements. The last section will discuss how green energy and energy efficiency contribute to economic, social, and environmental dimensions of sustainable development. Chapter 3 contains of 4 subsections. The energy sector of CA countries is presented in the first section. Remaining sections of chapter will provide an overview of the RE sector of the selected CA countries. The research will be limited to three CA countries - Kazakhstan, Kyrgyzstan, and Tajikistan due to their potential on development of RE projects. Chapter 4 will present methodological framework and selected cases. Chapter 5 will discuss the results of the case studies' impact on energy efficiency and sustainable development. Lastly, Chapter 6 presents the conclusions of the study and some policy recommendations.

2. Literature Review

2.1. Definition & Characteristics of the Green Energy

Over the past two decades, there has been a need for alternative and cleaner energy sources over the traditional, to promote environmental sustainability, zero greenhouse gas (GHG) emissions, and potential to increase energy supply diversity. Therefore, renewable energy resources have become increasingly popular for these purposes.

There is a broad discussion on what constitutes renewable energy among international organizations and government authorities and these institutions have accepted definition which vary slightly in the types of resources and sustainability considerations.

The International Energy Agency (IEA) defines renewable energy as resources which are "derived from natural processes and replenished at a faster rate than they are consumed". Based on the IEA definition RE includes electricity and heat obtained from biomass, hydropower, solar, wind, ocean, geothermal resources, biofuels, and hydrogen resources (IEA, 2002).

The International Renewable Energy Agency's (IRENA) definition of RE has been ratified by 108 members (107 states and the European Union) as of February 2013: "renewable energy encompasses any forms of energy obtained from renewable sources in a sustainable manner, including solar, wind, hydropower, bioenergy, geothermal energy, and ocean energy" (IRENA, 2013).

The UN's SE4All definition constitutes RE as "energy from natural sources that are replenished at a faster rate than they are consumed, including hydro, bioenergy, geothermal, aerothermal, solar, wind, and ocean". The definition states "replenished at a higher rate than consumed" meaning that some definitions describe RE as being replenished at an equal or higher rate than consumed or that the replenishment rate may vary with the extraction rate (WB, 2020).

Renewable energy is also called "green" or "clean" energy and these terms are often used interchangeable. However, there is no significant distinction between clean, green, and renewable energy. Based on the definition of the National Grid Agency, clean energy is an energy of nuclear power which creates little or no CO2 emissions without polluting the atmosphere (2003).

There is also an essential distinction between green and renewable energy. Both terms are often used synonymously having the same meaning. However, not all RE sources are considered entirely green but most of the green energy sources are also renewable. Hydropower energy generated from fast-flowing water is considered renewable but the process of generating the power cannot be considered green, because of the industrialization and deforestation involved in the process of building large hydro dams (Melton, et al., 2015).

Definition of "green" itself can be interpretated in absolute terms considering a technology which can be green or not, or relative terms which means relative to other companies or assets. It can also be related to the activities as energy efficiency, sustainable energy, or water management, and based on certain indicators (OECD, 2012).

Zarnikau (2003) defines green energy as the energy which is generated using RE technologies such as solar panels, biomass projects, hydroelectric energy, geothermal projects, and wind farms. Based on the study of Kostakis and Sardianou (2012) the utilization of the green energy sources for the electricity generation does not emit GHG, offering a lasting solution to climate change issues. Kennedy (2013) highlights the advantages of green energy technologies which include no fuel costs once in service, few unplanned outages, and sometimes, less maintenance required to keep them running.

The definitions of renewable energy have cross-cutting and common meaning and the main goal is utilizing alternative energy sources which is eco-friendly. The study aims at analyzing renewable energy resources and the three terms: clean, green, and renewable energy are used interchangeably.

There is no accepted classification of green energy sources, however based on the literature review following types and technologies can be identified. Solar energy is the energy derived from the sun and being used in a range of technologies such as photovoltaics, solar heating, concentrator photovoltaics, concentrated solar power, and others. (Cedric, 2011). Solar energy is the largest of the RE and it is considered as the easiest and cleanest means of tapping RE.

However, despite the green energy being renewable and clean, there is an adverse environmental effect of these sources. Solar energy in this sense, also has adverse environmental impacts as pollution occurred during the process of using materials needed for deriving solar energy and the environmental damage a solar collector could cause on water resources and land (Abbasi, et al., 2000).

Biomass is defined as energy produced from a wide variety of living organisms ranging from wood and waste to crop fuels (Melton, et al., 2015). It is used as an energy source, directly by combustion to produce heat, or indirectly by converting it to various forms of biofuel (WB, 2020).

Biomass energy is widely used among developing countries for cooking and heating purposes. The energy emerges from firewood by extracting wood from forests which is one of the major factors of forests. The use of fuelwood in the households causes air pollution and affects health of the women and children (Vezmar et al., 2014).

Hydropower energy is obtained as a result of the turbines turned by water flow. Water flows can be generated naturally from the flow of river or from the installations, such as dams. Modern hydropower plants convert the energy produced by either flowing or falling water into electricity. In a reservoir system, water is accumulated in reservoirs before being released to a lower elevation; upon release, the falling water turns the blades of a turbine (UNECE, 2021).

Ecological impacts of hydropower plants and dams are one of the biggest. The hydropower dams might flood the habitat of some animals especially fish, change natural watercourses and movement paths of wildlife around the plant and thus alter the ecosystem (Abbasi et al., 2000). Notably, small-scale hydropower plants are considered renewable, whereas categorization of large-scale hydropower plants as such is debatable (Shadrina, 2020).

Wind power or harnessing the wind's kinetic energy through a turbine to generate electricity, is the world's second-largest source of renewable electricity generation after hydropower. Wind energy is derived from the use of wind turbines which generate electricity. However, wind power also has a negative environmental impact. Wind generators might negatively affect ecosystem, cause noise pollution, interfere with habitats, especially birds flying. Large windmills which generate large scale of electricity can reduce wind-speeds and lakes that are close to the windmills might become warmer because of reduced evaporation from their surface (Abbasi et al., 2000).

Geothermal energy production takes advantage of the earth's naturally occurring heat to generate electricity. Geothermal plants pump water down a well where the heat in the earth's crust naturally converts it to steam. That steam then rises and propels a turbine. Geothermal energy is not impacted by weather or climate change and can act as a stable, low-cost base load energy for power generation (UNECE, 2021).

2.2. Definition of Energy Efficiency

Although there is no universally acknowledged definition of energy efficiency, most definitions are based on the primary ratio of "useful output of a process to energy input," according to Bhattacharyya (2011). In a simple words, energy efficiency (η) is a measurement of how much effort or energy is saved in a process. Work or energy is wasted in many operations, such as waste due to heat, friction, or vibration. A flawless process would be 100% efficient, which is an ideal case. In mathematical form, the energy efficiency can be calculated by the following equation:

$$\textit{energy efficiency } (\eta) = (\textit{work out} / \textit{work input}) \times 100\ \% \qquad (1)$$

The progress in energy efficiency improvements can be measured by the compound annual growth rate of energy intensity. Energy intensity is defined "as the amount of energy needed to derive a unit of economic activity". The advantage of this indicator is the possibility of data gathering at an aggregate level; however, it lacks to account multi-dimensional nature of energy efficiency (IRENA, 2015).

The Kaya Identity which is a tool for analyzing the drivers of CO2 emissions by combining the indicators of GDP, population, total primary energy consumption, and world anthropogenic CO2 emissions is being considered in order to dive further into the measurement of energy intensity (Hwang et al., 2020). The equation takes a following form:

$$CO2 = CO2/TPEC * TPEC/GDP * GDP/POP * POP = f * e * g * P \qquad (2)$$

Where $CO2/TPEC = f$ represents carbon intensity of primary energy; $TPEC/GDP = e$ represents energy intensity of GDP; $GDP/POP = g$ embodies GDP per capita and P represents the population.

There are also parametric and non-parametric approaches of energy efficiency measurement. The Data Envelope Analysis (DEA) is considered as a non-parametric approach, which provides a deterministic measure of energy efficiency without imposing any distributional assumptions and functional forms. This makes the DEA vulnerable to the problems of omitted variable bias and measurement errors, which could introduce some biases in the energy efficiency estimates. But this weakness may be considered as an advantage since it makes the DEA immune to model misspecification problems (Adom, 2018).

The Stochastic Frontier Analytical method is a parametric approach which imposes functional forms and distributional assumptions and makes the method superior in terms of dealing with measurement errors and omitted variable bias. However, this advantage makes the method susceptible to model misspecification problems (Adom, 2018).

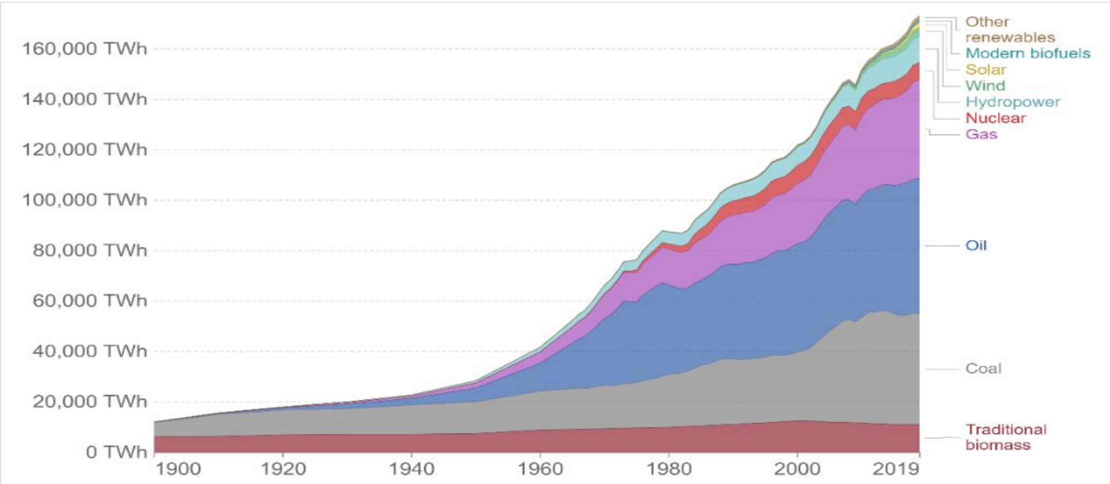
Orea and Kumbhakar (2004) have proposed a more robust technique - Panel Latent Class Stochastic Frontier Model. The method provides a one-stage estimation of energy efficiency considering the unobserved heterogeneity in production technologies. The approach is comparable to Caudill (2003) and Greene (2002) but differs since it relaxes the assumption of independence of the efficiency term over time.

It has been demonstrated that renewable energy is more efficient than nonrenewable energy when it comes to energy efficiency. Solar, wind, and hydroelectric energy are all renewable sources of energy that can be recycled without depending on an exhaustible or limited resource. Green energy technologies impact and improve energy efficiency, such as compared to a coal-fired water boiler that can reach efficiencies of around 85-90%, a solar thermal water heater reaches 100% efficiency (IRENA 2015). The use of a high-speed train instead of an airplane or electric bicycles are another example of energy efficiency through RE technologies.

2.3. Role of Green Energy Adoption on Sustainable Development

The fast-growing world population is creating more energy needs which leads to the use of fossil fuels and alternative energy sources. The use of traditional energy source generates environmental damages and geographical conflicts as greenhouse gas effects and depletion of fossil fuels, climate change and fluctuation in fuel prices. Based on Figure 1 global primary energy consumption mostly consists of traditional sources of energy, renewables such as solar and wind – were only added in the 1980s. However, traditional biomass was the dominant source of energy used across the world until the mid-19th century (Vaclav, 2017).

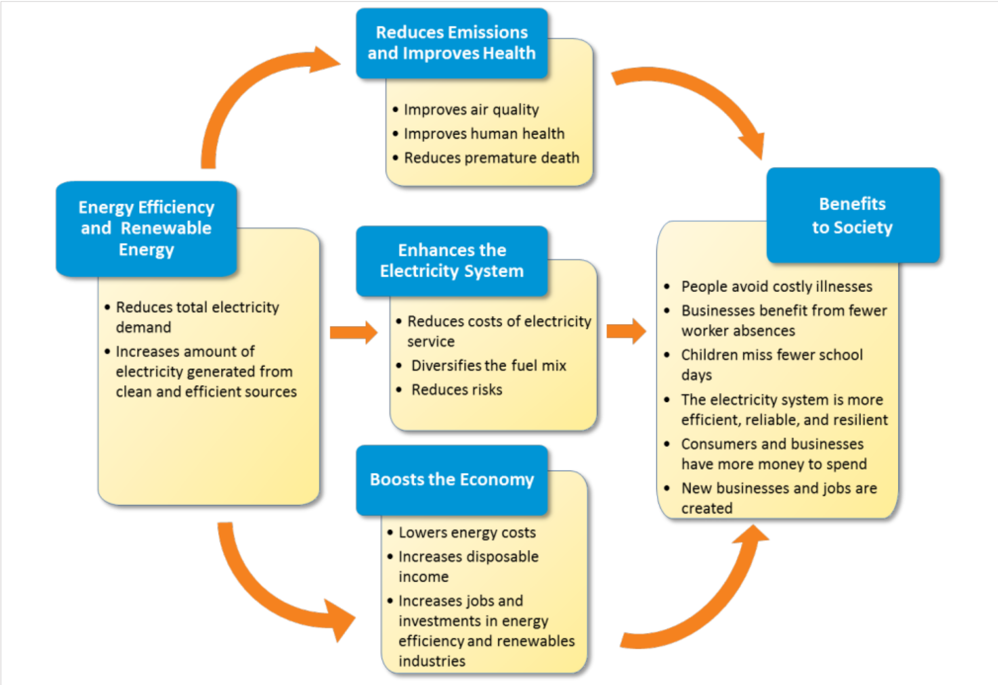
Figure 1. Global Primary Energy Consumption by Source



Source: BP Statistical Review of World Energy (2022)

Renewables are considered as sustainable energy which affects the society from economic, social, and environmental dimensions. Renewable energy generation and electricity savings lay out the basis of energy efficiency improvements and RE to the electricity system, affects reducing of CO2 to emissions, increasing of well-being of the society, and development of the economy, as depicted in Figure 2. Thus, UN highlighted on the agenda of SE4All three interlinked objectives as providing universal access to sustainable energy services, improvement in the energy efficiency and increasing the share of renewables in the global energy mix to 36% by 2030 (UNECE, 2019).

Figure 2. Renewable Energy Impact on Sustainable Development



Source: Environmental Protection Agency, 2011

The reduction of greenhouse gas emissions is a key in the debate about renewable energy in developing countries since it links technological change to development and climate change. Concerning environmental impacts, the literature review is limited to the impact on CO2 emissions and most scholars believe that green energy use has a positive effect on reduction of CO2 emissions.

Study conducted on energy use in New Zealand and Norway by Fei et al. (2014) results that green energy input reduces carbon dioxide emissions. Akella et al. (2009) states that after the installation of renewable energy technologies in remote areas the GHG emissions are exponentially reducing over the years. The research conducted by Shafiei and Salim (2014) results that an increase in RE consumption tends to reduce CO2 emissions. Zou et al. (2021) also pointed out the environmental impact of the GE sources by achieving reducing of the carbon emission of the power sector.

Green energy use has a significant impact on the country's economy, however there is no common conclusion on their relationship since some researchers believe that GE use promotes economic growth while others state the opposite. Inglesi-Lotz (2016) found out that renewable energy consumption promotes positive economic growth. Bhattacharya et al. (2016) in his study concludes that green energy use has a beneficial and long-term impact on economic growth. Hicks et al. (2011) pointed out that green energy projects provide benefits in local employment especially of rural areas labor, promotes local market and business, as well as country's financial bank services.

Cang et al. (2020) states that compared to traditional energy consumption, the economic growth rate supported by renewable energy is much higher. The study of Ya-li Wang (2021) who conducted research of Henan province shows that the clean and green energy use can reduce CO2 emissions and promote economic growth for developing energy dependent regions and countries. However, only Qi and Li (2018) mention a negative impact on economic growth from green energy consumption.

Xu (2021) highlights the importance of the national policies and regulations implementation on renewable energy use which might significantly promote the growth of per capita and regional GDP, and with the strengthening of the policy, the effect becomes more notable.

Most of the developing countries face high energy-import dependency and inadequate access to electrification of rural areas which hinders their sustainable development affecting vulnerable groups of population. In this context, renewable energy might decrease energy poverty by providing social benefits such as local employment, improvement of health, education, clean water, food production and communication services (Acheampong et al., 2021).

Arndt et al. (2019) states that solar photovoltaic systems can improve energy access in areas that are expensive or difficult to reach via the existing grid, typically in lower and lower-middle income countries. Bhide and Monroy (2011) discovered that off-grid solar installations can help increase rural electrification because solar resources are prevalent in many low to middle income countries.

Topcu and Tugcu (2020) found that green energy decreases income inequality in developed economies through investment subsidies, stable energy prices, and labor demand. They empirically assessed the impact of RE consumption on income inequality in 23 developed economies and found that an increase in renewable energy consumption corresponds to decreasing income inequality.

Along with the outstanding advantages of green energy resources, shortcomings of these projects also exist. Increasing shares of renewable energy technology poses technical, environmental, and socio-economic challenges (Li et al., 2019). The two main challenges associated with green energy projects is a need to higher investment and risk compared to traditional energy resources and a lower rate of return compared to fossil fuel projects.

Green energy projects installation has certain complexity, and they are condition sensitive, dependent on the seasonal changes and local infrastructure. The implementation of these projects requires technical proficiency, execution, forecasting, and planning procedures compared to other projects. The large RE facility installations as solar farms or hydro dams, which have larger impact, require bigger investment and financing.

3. Energy Situation of Central Asian Countries

3.1. General Overview of the Energy Sector of Central Asian Countries

The Central Asian region comprises the five former Soviet countries of Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan. The region is abundant with natural resources, however various geographical and political factors are unfavorable for the sustainable development in CA countries (Batsaikhan, 2017). The Central Asian countries are landlocked being geographically remote from the world's most important economic centers. They have limited connectivity with the outside world which is a major hindrance for expanding the trading and commercial sectors (Lin, 2005).

Table 1 summarizes the main statistics and demographics of socio-economic indicators of the region. The region is diverse with mix of middle and low-income countries. Kazakhstan is considered as the largest and most developed country among the CA countries. Uzbekistan is the most populated country while Turkmenistan is the least populated. Kyrgyzstan and Tajikistan have the smallest territory and considered as the least economically developed in the region. Share of CA countries population with access to electricity equals to 99.8% which is higher than many regions such as East and South Asia, Latin America, and others (SEforAll, 2020).

Table 1. Socio-Economic Indicators of the CA Countries

Indicator	Kazakhstan	Turkmenistan	Uzbekistan	Kyrgyzstan	Tajikistan
Surface area in km^2	2,724,902	488,100	447,400	199,950	141,380
Population in million	18.2	5.8	32.95	6.3	9.1
Share of rural population in %	43	43	50	64	73
Gross Domestic Product in billion	USD 170	USD 40.761	USD 50.49	USD 8.0	USD 7.5
Gross National Income/capita	USD 7970	USD 6380	USD 2000	USD 1130	USD 990

Source: World Bank, 2018

The region is endowed with rich and diverse energy resources, consisting of both traditional energy such as coal, natural gas, oil, and renewable energy resources, including solar, wind, hydropower, and biomass energy (Mehta et al., 2021). Despite the abundance of the energy resources, the CA countries are facing energy scarcity and crisis due to the geographical and environmental factors, outdated infrastructure, increasing demand of the energy consumption, and international factors (Shadrina, 2019).

Central Asian countries significantly rely on a principal source displaying low diversity of energy resources and energy characteristics of the countries are dissimilar as presented in Table 2. Kazakhstan possesses large coal and oil reserves. Turkmenistan has enormous natural gas resources and a well-developed thermal power sector. Uzbekistan is oil and natural gas self-sufficient. In contrast, Kyrgyzstan and Tajikistan have large hydropower resources which is the main indigenous natural source that is used for energy generation.

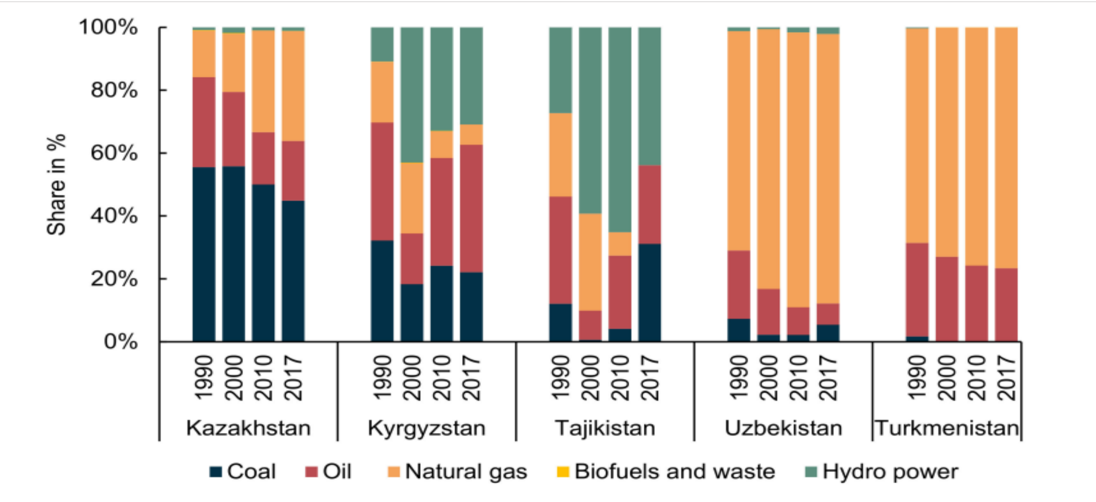
Table 2. Total Primary Energy Supply (TPES) of the CA countries by Source, 2016 (%)

	Kazakhstan	Kyrgyz Republic	Tajikistan	Turkmenistan	Uzbekistan
Coal	**43.25**	23.53	20.15	0	4.11
Oil	20.21	**44.54**	32.05	23.35	6.34
Gas	35.14	6.21	0.10	**76.61**	**86.85**
Hydro	1.22	25.70	**47.70**	0	2.70
Biofuels and waste	0.13	0.03	0	0.04	0.01
Geothermal, solar, etc.	0.04	0	0	0	0

Source: IEA, World Energy Balances, IEA, 2018

Main resources to supply primary energy in Kazakhstan, Turkmenistan, and Uzbekistan are the deposits of the fossil fuels which can be observed in Figure 3. Besides hydropower energy, other renewable energy resources are not utilized for energy generation. It has been a common practice for the last 25 years for this region to mostly utilize fossil fuel-based energy supply.

Figure 3. Total Primary Energy Supply in CA countries within 1990-2017

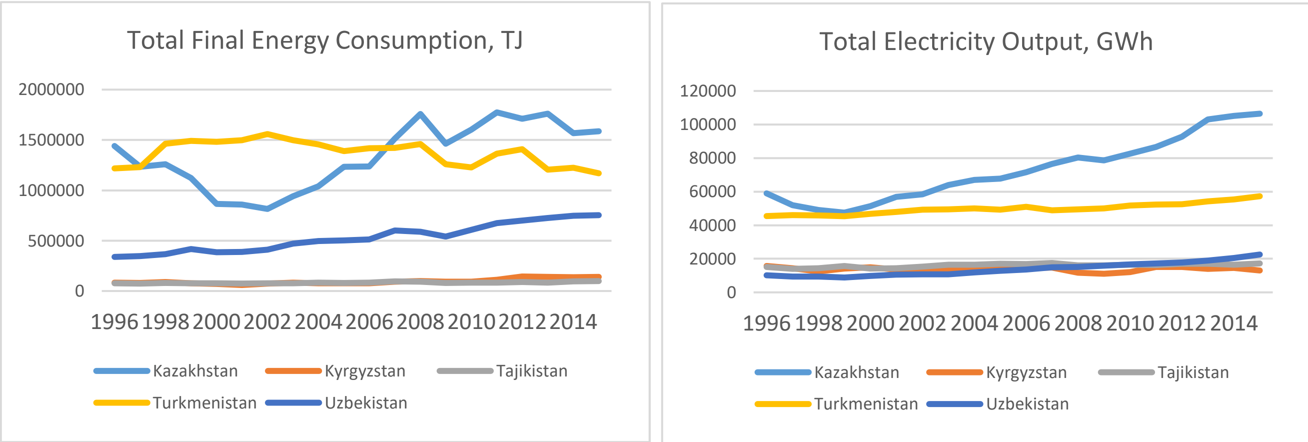


Source.: IEA, 2019

To provide more precise picture of the energy consumption of the region, the total final energy consumption (TFEC) and total electricity output (TEO) statistics is presented on Figure 44. Since 1996, the TEO and TFEC trends in the region have shifted in different ways. TFEC has been continuously increasing since 1996, mirroring the increasing energy demand of the region. The TFEC rates in Kazakhstan in 2015 was around 65% of its 1996 level when Turkmenistan's TFEC rates had increased by about 44%. The Kyrgyz Republic and Tajikistan increased their

TFEC at half while Uzbekistan did not see any significant fluctuations during the 1996 – 2015 period.

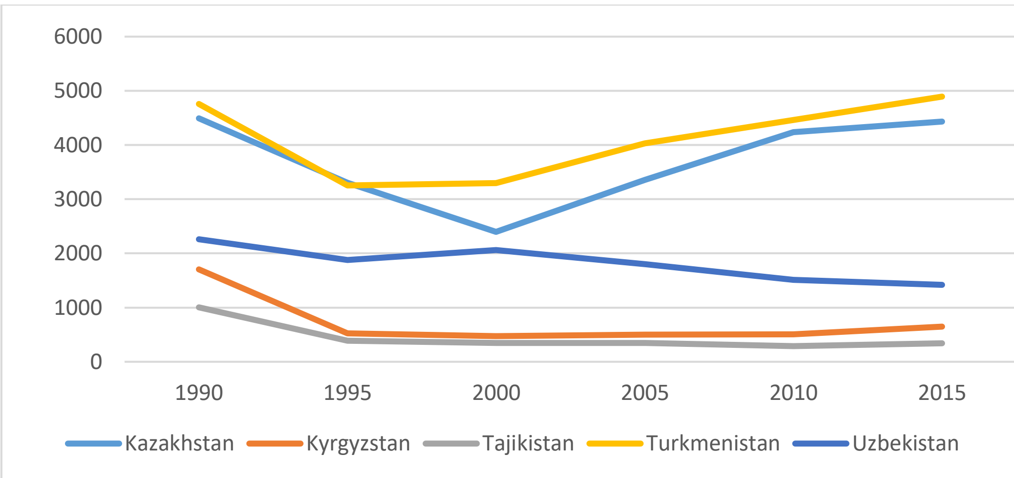
Figure 4. Total Final Energy Consumption and Total Electricity Output, 1990–2015



Source: SEforALL, World Bank Dataset

As it was observed in previous figure, the energy consumption trend of the region is not sustainable. Most of the countries display high energy consumption per capita and a high level of growth in energy consumption, as shown in Figure **5**5. Despite high rates of energy use per capita, significant gaps exist in urban and rural areas having access to energy services. Most rural residents have no access to central heating or the natural gas network. Urban residents often face seasonal blackouts and electricity shortages, electricity stability remains a major concern and issue in this region.

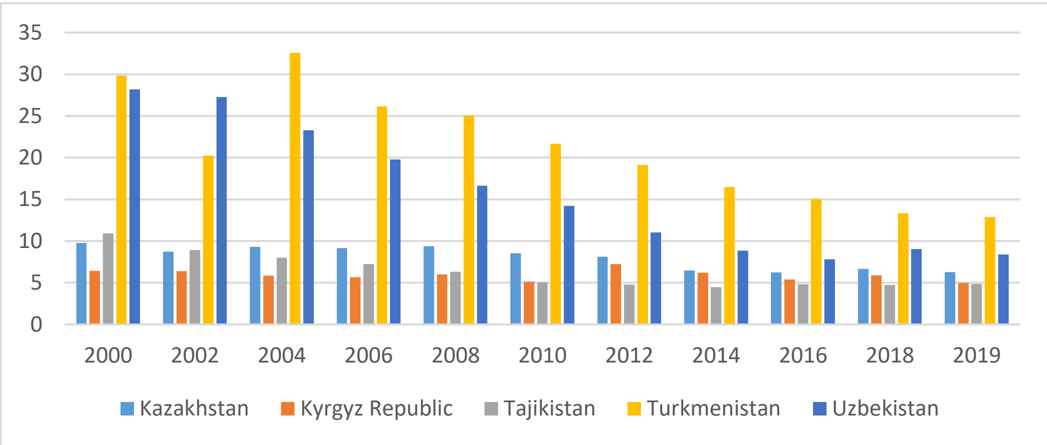
Figure 5. Energy Use Per Capita, 1990-2015, (kg of oil equivalent per capita)



Source: World Bank Dataset, 2022

The differences in energy intensities between CA countries can be observed in Figure **6**6 which is mostly due to the differences in GDP levels and varying levels of energy production and consumption efficiency. Turkmenistan and Uzbekistan are remaining among the countries with highest energy intensity level, while Kazakhstan has relatively low levels. The figure presents the decline in energy intensity of CA countries over 20 years; however, Tajikistan and Kyrgyzstan have almost same levels of energy intensity which has not changed significantly. Annual energy intensity improvement rates in region are very low and inadequate to meet SDG 7 target, which calls for annual energy intensity improvement of an average 2.6 per cent (IEA, 2020).

Figure 6. Energy Intensity Level of Primary Energy in CA Countries, 2000-2019



Source: World Bank Dataset

Based on the study of Shadrina (2019) who analyzed the potential of non-hydropower renewable energy, despite Central Asian region being abundant with RE potential, this field is yet to be developed and unleashed in these countries. Table 3 presents the RE potential of the region highlighting that besides the traditional energy resources, CA has an enormous potential for green energy, which can generate energy sustainably in the region.

Table 3. Renewable Energy Potential in Central Asian Countries

Country	Small-scale hydropower	Solar PV		Wind		Geothermal	Bioenergy
	(MW)	(MW)	(TWh/year)	(MW)	(TWh/year)	(TWh/year)	(MW)
Kazakhstan	4800 (≤35 MW) 2707 (≤10 MW)	3760,000	6684	354,000	11,388	54,000	300
Kyrgyzstan	900 (≤30 MW) 275 (≤10 MW)	267,000	537	1500	256	171	200
Tajikistan	30,000 (≤30 MW)	195,000	410	2000	146	45	300
Turkmenistan	1300	655,000	1484	10,000	1992	no data	not significant
Uzbekistan	1180 (≤10 MW)	593,000	1195	1600	1685	2	800

Note: MW = megawatts; TWh = terawatt hours
Source: Author's compilation based on UNIDO and ICSHP for small-scale hydropower; UNDP, 2014 for solar PV, wind and bioenergy in MW; Eshchanov et al., 2019 for solar PV and wind in TWh/year; Jorde et al., 2009 for geothermal in Kazakhstan; Botpaev et al., 2011 for geothermal in Kyrgyzstan; Doukas et al., 2012 for geothermal in Tajikistan and Jorde and Biegert, 2009 for geothermal in Uzbekistan

Tajikistan and Kyrgyzstan are superior for hydropower development because of their well-structured river networks. The abstracted dense river networks in Tajikistan and Kyrgyzstan make them superior for hydro energy (Eshchanov et al., 2019). The Tien Shan Mountain range in Kyrgyzstan and the Pamir Mountain range in Tajikistan are among the countries' extensive mountain ranges. Snow and glaciers cover a large part of the mountain ranges, turning to natural water resources in Kyrgyzstan and Tajikistan flowing through rivers, irrigation canals, and water streams. Thus, these countries have huge hydropower potential, and it is considered as the main source of energy in both countries, followed by imported oil, gas and coal.

The CA governments have provided support to develop renewable energy sector and have adopted a few important initiatives. In 2008, Kyrgyzstan has formulated an energy-related policy in 2008 to enhance the use of the alternative energy sources in the country. Tajikistan, meanwhile, has adopted a number of program documents aimed at expanding the renewable energy sector. However, no remarkable progress was observed in expanding the RE sector of Kyrgyzstan.

Uzbekistan to foster development of renewable energy sector is undertaking the measures and establishing energy legislation on this field. However, the country despite its potential, uses very limited solar, wind and hydropower energy to produce electricity, its potential has remained untapped. Turkmenistan's government has not taken any actions towards renewable energy development, and it is hugely reliant on natural gas power generation (IEA, 2022).

Table 4. Renewable Energy Regulatory Policies

	RE target	Biofuels obligation/ mandate	Electric utility quota obligation/ RPS	Feed-in tariff/ premium payment	Heat obligation/ mandate	Net metering	Tendering	Tradable REC
Kazakhstan	✓	-	-	✓	-	✓	-	-
Kyrgyzstan	✓	-	-	✓	-	-	-	✓
Tajikistan	✓	-	-	-	-	-	-	✓
Turkmen.	-	-	-	-	-	-	-	-
Uzbekistan	✓	-	-	-	-	-	-	-

Note: RPS = renewable energy portfolio standard; tradable REC = tradable renewable energy certificate.
Source: Central Asia Data Gathering and Analysis Team, 2019

Table 4 demonstrates that most of the CA countries, except for Turkmenistan, have set precise goal for green energy capacity expansion. Feed-in tariffs have been adopted in Kazakhstan and Kyrgyzstan, while tradable renewable electricity certificates have been introduced in Kazakhstan and Tajikistan. Turkmenistan has yet to adopt a policy supporting renewable energy.

All the five CA countries have ratified the Paris Agreement and the targets set by the countries are based on the intended nationally determined contribution (INDC) submitted by the countries. Kazakhstan's targets are also in line with launched the Green Economy Plan in 2013 which aims to achieve 50% share of the country's energy by renewables by 2050. Other countries have also submitted their INDC, committing to reduce GHG emissions by 10-20% by 2030.

Central Asian region is experiencing a severe energy security issues, despite its diverse energy resources and extensive access to electricity (WB, 2020). The Central Asian infrastructure of the power grid was built at the Soviet times and by now it is outdated and is ineffective for meeting the growing electricity demand of the certain countries (Toralieva, 2009). The seasonality of supply and demand of the power sectors of individual countries suffer from lack of availability to supply population with electricity (Laldjebaev, 2018).

The provision of reliable, modern, and affordable energy services remains a challenge, especially in rural CA regions. Due to the poor and outdated infrastructure of the energy generation systems and geographical isolation of the region from the main energy production centers, rural distant communities have difficulties with meeting basic energy needs (Mehta et al., 2021).

Another issue in Central Asia remains uneven distribution of electricity generation capacity remains. Mountainous countries as Kyrgyzstan and Tajikistan produce their energy from the principal source, which is water resources, whereas Kazakhstan generates more than 80% of its electricity with coal-fired power plants, since the country has large coal reserves (IEA, 2020).

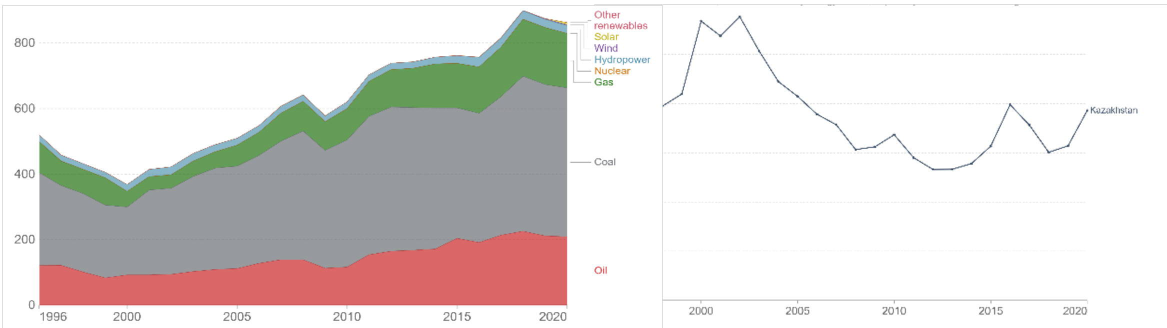
Remaining sections of the chapter will provide an overview of the renewable energy sector of the selected CA countries by source and sectors. The research will be limited to three CA countries - Kazakhstan, Kyrgyzstan, and Tajikistan due to their potential on development of RE projects. Kazakhstan has a huge potential for RE development and it has the largest fossil fuel-based energy production. Tajikistan and Kyrgyzstan are the least developed CA countries and there is a need for diversification of the energy sector.

3.2. Renewable Energy Sector of Kazakhstan

Kazakhstan had been one of the world's fastest-growing economies until 2015, based on development of the country's abundant oil, coal, and gas resources, as well as export-oriented policies. The country is the greatest oil producer in the region, with the world's 12th-largest proven crude oil reserves (IEA, 2021). It boasts 4% of the world's estimated coal reserves, and coal-fired thermal power stations generate more than 80% of the country's total electricity (Karatayev, 2014).

According to Figure 7, Kazakhstan's primary energy consumption consisted of 3.35 quadrillion btu in 2019. Despite the countries significant primary energy consumption fluctuations in recent years, it has tended to rise from 2000 to 2019. As of 2019, renewable energy sources account for barely 4% of total primary energy consumption in the country.

Figure 7. Energy Consumption by Source and Share of Primary Energy from RES



Note. 'Other renewables' include geothermal, biomass and waster energy
Source: BP Statistical Review of World Energy and IEA

Despite the abundance of traditional energy sources, the government has adopted the strategic plan of "Kazakhstan 2050", which sets a goal for renewable energy to provide half of the country's total energy consumption by 2050. This significant step was taken considering the green energy development potential of the country and the impact of climate change on agriculture of the region. Another factor is the possibility of lowering domestic consumption in order to unlock the export potential of traditional energy sources.

The Government of Kazakhstan has demonstrated support to develop renewable energy and has adopted a few important initiatives, which boosted investors interest in renewable energy projects. To facilitate the achievement of RE targets the Law on renewable energy source was adopted in 2009. The RE law stipulates two tariffs as fixed tariffs set for solar, wind, and other renewable energy sources, which the Settlement Centre applies for purchasing power from the RE producers; and feed-in-tariff, which is applied by the Settlement Centre for providing RE power to traditional energy firms.

The government of the country launched the Kazakhstan 2050 Strategy in 2012, setting the long-term goals for the economic development of the country. According to the document, by 2050, the country's energy consumption of the alternative and green energy technologies must be increased up to 50%. It also states that most of the traditional companies should shift to ecologically sustainable methods of production.

In May 2013, the Green Economy Concept was adopted, setting the ambitious targets as outlined in Table 5 which includes 10% share of renewable energy in generation by 2030 and 40% share of RE in generation by 2050. The country is aiming to achieve the targets set by updating the outdated infrastructure, installation of energy efficiency technologies, increasing the clean fuels usage, and complying with environmental standards.

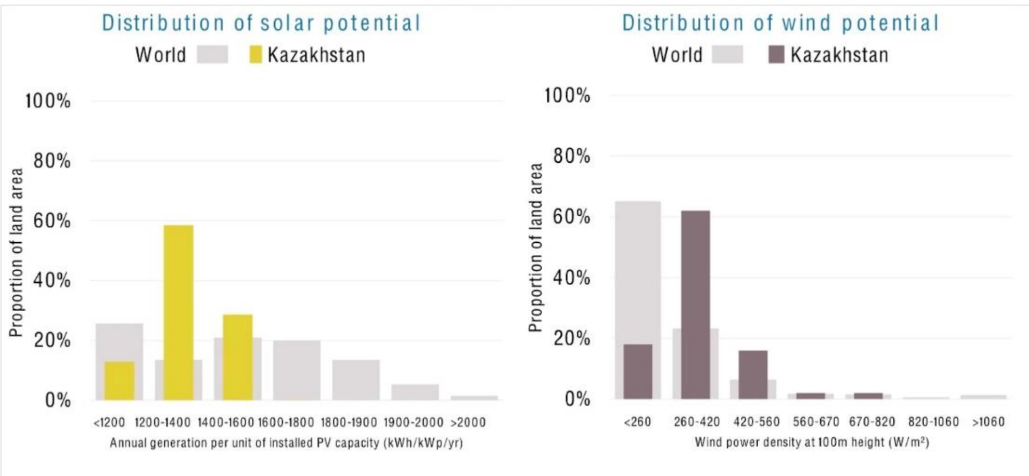
Table 5. Targeted Installed Capacity in Green Economy Development Scenarios

	2012	2030	2050
Share of renewable energy in total power production (%)	0.3	10.05-11.05*	40
Total installed capacity, excluding large hydro (GW)	0.18	5.5	30
GHG emissions (billion tonnes)	91	77-79*	59-65*

Source: Concept for Transition to Green Economy of Kazakhstan (Government decree N79, May 30, 2013

Kazakhstan has significant wind and solar potential which is presented on the Figure 8. Its steppe and arid geography make the country suitable for wind energy technologies. About half of Kazakhstan's land area consists of an average wind speed which is convenient for energy generation (4–6 m/s) with Caspian Sea having the strongest potential (Kazinform, 2020). The National Program for Development of Wind Energy until 2015 and up to 2030 sets the target to produce 900 million kWh per year by 2015 and 5 billion KWh per year by 2024 of the wind energies. The Program also provides for wind energy support in rural areas and specifies the list of measures to achieve the targets.

Figure 8. Solar and Wind Potential of Kazakhstan



Source: IEA, 2020

Kazakhstan's most of the areas are in high insolation that is suitable for solar power generation, particularly in the south of region, receiving 2200 to 3000 hours of sunlight per year, equating to 1300-1800 kW/m² annually (Kazinform, 2020). Both types of the solar energy generation as concentrated solar thermal and solar PV are advantageous in the country. In addition to solar PV, concentrated solar thermal has the benefit of not requiring water for its operation, enabling it to be used in dry and semi-arid areas, and the materials for the installations are all domestically manufactured in Kazakhstan (Kazinform, 2020).

The number of the green energy projects is increasing in Kazakhstan. Only in 2019, with participation of both local and foreign investors, 21 renewable energy facilities were launched in the country. In 2017, stations with renewable energy sources generated more than one billion kWh. In 2019, this indicator increased to almost 2.5 billion kWh (Ministry of Energy, 2020).

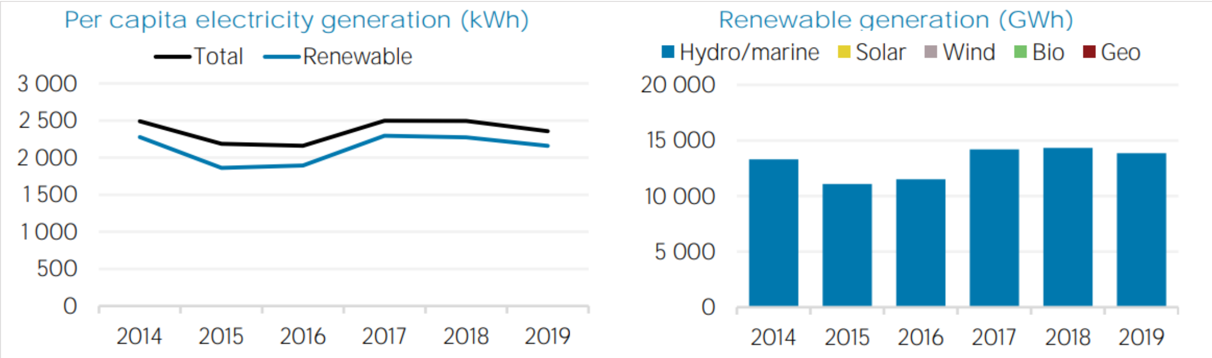
According to Kazakh Ministry of Energy (2020), 97 green energy facilities are operating in the country with over 50% of the renewable power generated by solar power plants. In February 2019, the largest solar power plant 'Saran' in the Central Asia located in Kazakhstan, started its operation. The project provides the potential of 100-megawatt capacity energy generation, and its cost is $137 million.

3.3. Renewable Energy Sector of Kyrgyzstan

The Kyrgyz Republic is a geographically landlocked, lower-middle-income country. It is rich with water resources and hydropower is considered as the main energy resource. The country's energy sector accounts for 4% of the GDP and 16% of industrial production, with hydropower representing the two-thirds of the total energy production. Kyrgyzstan exploits minor portion of coal, gas and oil, but most of the hydrocarbons are being imported. In fact, more than half of its energy needs are met by traditional energy as imported oil and gas, particularly during the winter season when hydropower generation is significantly (IRENA, 2021).

Renewable energy potential for Kyrgyzstan is mainly untapped and the practical use of it is less than 1% (UNECE, 2018). The share of installed renewable energy electricity capacity would be around 80% if large hydropower plants are classified as 'green' energy. However, if we only consider small hydropower facilities as renewable energy sources, the installed capacity then will be dropped to 1.3 percent (UNDP, 2020). The renewable generation and per capita electricity generation is presented on Figure 9 which shows that electricity is only generated from hydropower source.

Figure 9. Renewable and Per Capita Electricity Generation in Kyrgyzstan



Source: IRENA, 2020

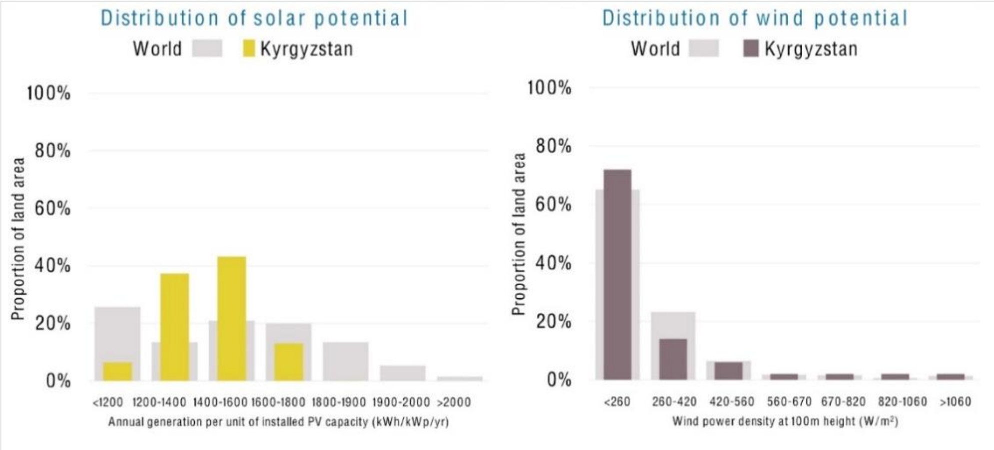
Kyrgyzstan faces seasonal shortages and electricity blackouts; the energy demand is higher in the country during winter as compared to summer. Winter demand of energy consumption for urban population increased by 78 percent between 2009 and 2012, mainly because of the urbanization and the necessity for heating in the cities. Rural residents experience electricity blackouts more often than urban population, especially in the winter period electricity disruptions happen daily (FAO, 2016). According to the results of energy delivering services quality survey in 2015 by the World Bank, around 12% of Kyrgyz households had interruptions of power supply, while almost 65% of households had frequent power cuts throughout the year and 0.5% had experienced daily power outages.

Kyrgyzstan entered a low-water inflow cycle in 2019, which will continue over the next 3-5 years (UNDP, 2020). This means that river input will drop significantly, and jointly with climate change issues, could have a negative effect on the energy system's future sustainability. Aging infrastructure and significant losses with combination of weather-related shocks and growing demand are other challenges for the country.

Lack of the governmental transparency has led to a loss of trust among the population; according to the results of the household surveys conducted in 2019, more than 65 percent of respondents highlighted the high electricity tariffs and pointed out the need for reducing the cost of the tariffs. The electricity tariff for households is significantly subsidized at 0.01 USD per kWh, while for businesses it is 0.03 USD per kWh with a production cost of 0.026 USD (Mehta et al., 2021).

The country has the potential of developing small hydropower plants, wind power plants, solar and biomass power plants as well. The solar and wind potential of the Kyrgyzstan is presented on Figure 10.

Figure 10. Solar and Wind Potential of Kyrgyzstan



Source: IRENA, 2020

The potential of the Kyrgyz Republic for renewable energy is being used only for own energy needs and not that actively. Thus, Government of the country is working towards increasing of interests on Renewable energy projects and developing regulations and incentives on this area. In 2008 the "Law on Renewable Energy" first was adopted in order to bring attention to the development of the renewables market in Kyrgyzstan. In July 2019 significant changes were introduced to the RE Law.

The government supports renewable energy entities by providing certain quotas. Quota for RE are usually set by the State Committee on industry, natural and energy and resources of the Kyrgyz Republic and defined as "the amount of installed electric capacity of power plants using RE by regions and RE types for a specific time period, whose generation of electricity will be reimbursed at a maximum rate for the end users, times the feed-in tariff (FIT) coefficient".

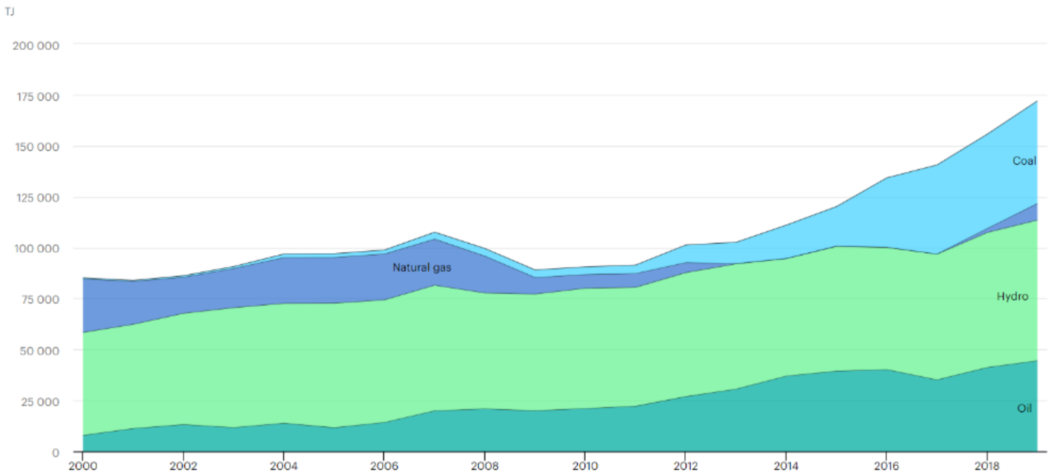
There is a Kyun government agency in the country which is devoted to examining alternative energy resources and supplies, especially solar, wind, geothermal and coalbed methane gas. Kyun government agency is one of the four main energy ministries in Kyrgyzstan, directly under the Cabinet of Ministers and which has the same level of authority and power as the other energy ministries (Dorian, 2006).

3.4. Renewable Energy Sector of Tajikistan

Tajikistan is the smallest Central Asian country, situated upstream of the Syr Darya and Amu Darya river basins and thus, is endowed with great hydroelectric potential. The country's primary energy source is hydropower, which is followed by imported oil, gas, and coal. Water resources available in the country is a driving force, accounting for more than 90% of total electricity generation within the power sector framework (Nabiyeva, 2015).

Tajikistan is one of the top ten countries in the world with the highest hydropower potential (IEA, 2010). Over 90 percent of the country's total electricity is generated by large hydropower plants. However, the region is implementing only small share of its potential, and only 5% of the country's total small hydropower potential is currently being utilized (UNDP, 2014). The sources of the primary energy supply of the country are shown in the Figure 11.

Figure 11. Total primary energy supply of Tajikistan by Source



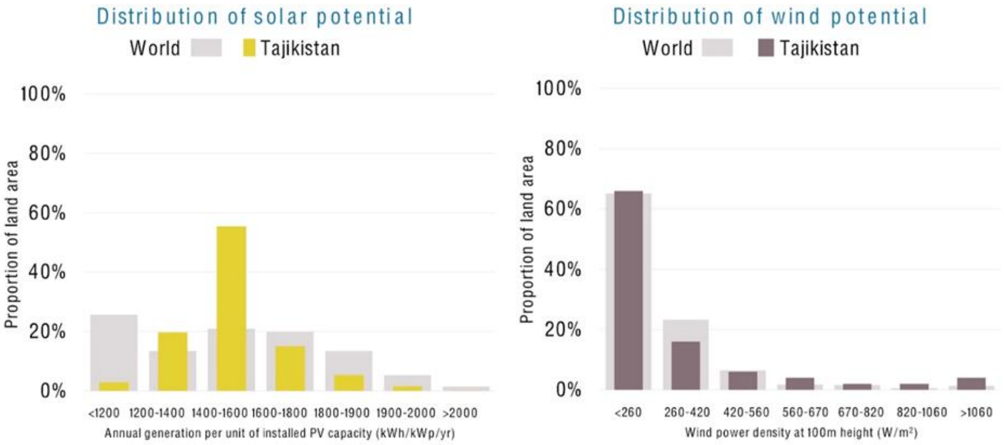
Source: IEA, 2019

Tajikistan's power supply system is dominated by hydropower plants; however, their output capacity is vastly seasonal and in winter, due to low river flows during peak demand, it is insufficient to fulfill an estimated peak load of 3,500 MW. The system's capacity is lowered to 2,250 MW during winter season, which is 1,250 MW less than required for meeting energy needs of the population. Although nearly all Tajik houses are connected to the national grid, over 70% of the population suffers from severe electrical shortages throughout the winter (WB, 2012). The freezing winter of the region causes a reduction in natural water flow, making power generation dependent to available water flow, similar to Kyrgyzstan.

Three quarters of the country's population living in rural remote villages accounts for only 8 to 11% of the country's electricity consumption (Nabiyeva, 2015). One of Tajikistan's major concerns is a lack of sufficient access of rural population to energy services. Many rural households are forced to heat their homes by burning wood, shrubs, and cotton stems due to electricity shortages and the lack of adequate conventional energy supplies (UNDP, 2011). As a result, the country's forest cover has decreased by 172,000 hectares since 1990 (GIZ, 2010).

Tajikistan’s significant potential for other types of renewable energy, particularly solar as shown in Figure 12, provides a feasible alternative to address the energy challenges, however this potential is mainly untapped.

Figure 12. Solar and Wind Potential of Tajikistan



Source: IRENA, 2020

Tajikistan’s government highlights the importance of the RE development and recognizes the existing challenges related to energy insecurity, inefficiency of the energy use and limited access, as well as the resulting social and environmental issues. Various measures and action have been introduced in the country to address the existing challenges and promote energy efficiency and renewables market.

The chamber of the Tajik parliament has introduced in 2016 the National Development Strategy until 2030, which includes energy security among its main strategic objectives. It outlines the the strategic goal for the energy sector's development as achieving a 10% share of alternative energy sources in the national power supply by 2030.

The government has adopted number of laws, to provide an overall legal framework for Tajikistan's green energy sector development. Law on the “Energy Efficiency and Energy Saving” and the "Use of Renewable Energy Sources" as well as a few corresponding by-laws were introduced. The Government of the country also promotes RE with project-specific feed-in tariffs. which are based on the project’s costs and guaranteed for 15 years (UNDP, 2012).

4. Methodology and Case Selection

4.1. Methodological Framework

The main objective of the present research is to identify the impact of the green energy projects on energy efficiency of Central Asian countries, composed by Kazakhstan, Kyrgyzstan, and Tajikistan. Analyzing the impact of the green energy projects of the selected CA countries is a challenging task, as certain peculiar factors are included in the process.

In the literature reviewed, it was discovered that RE has a huge potential to contribute to the sustainable development process of the countries by providing a wide variety of economic, environmental, and social benefits, as diversification of energy supply, reduction of GHG emissions, improving rural opportunities, job creation and others.

The socioeconomic and environmental characteristics of CA countries make them suitable to benefit from green energy projects, such as a relatively large share of rural population, lack of diversification of the energy sources, the seasonality of supply and demand of the power sectors, high unemployment rates, outdated energy infrastructure, and others.

Only numerous empirical studies have focused on the impact of green energy sources on the three pillars of sustainable development which are economic, environmental, and social dimensions. Moreover, even less studies have conducted on the analyzing of the impact of RE on CA countries through the case studies, the papers have been too general by focusing on the environmental benefits only.

To cover the proposed scope of the research and address the existent gap, the methodological framework is applied, which includes insights from the reviewed existing research and builds upon the adapted practices (Table 6). The aim of the papers is the identify and evaluate the impact of renewable energy resources to the sustainable development and energy transition of the specific territory.

The methodological framework is adapted from Burguillo (2009) & Rio (2007) who have developed a theoretical framework for the analysis of the impact of renewable energy projects on local sustainability, with two sustainability approaches. Substantive sustainability is considered as the first approach which refers to the impact on the green energy project on the economic, social, and environmental dimensions of sustainability. Second approach is procedural sustainability which assumes to also consider the opinions and interests of all stakeholders involved during implementation of the project.

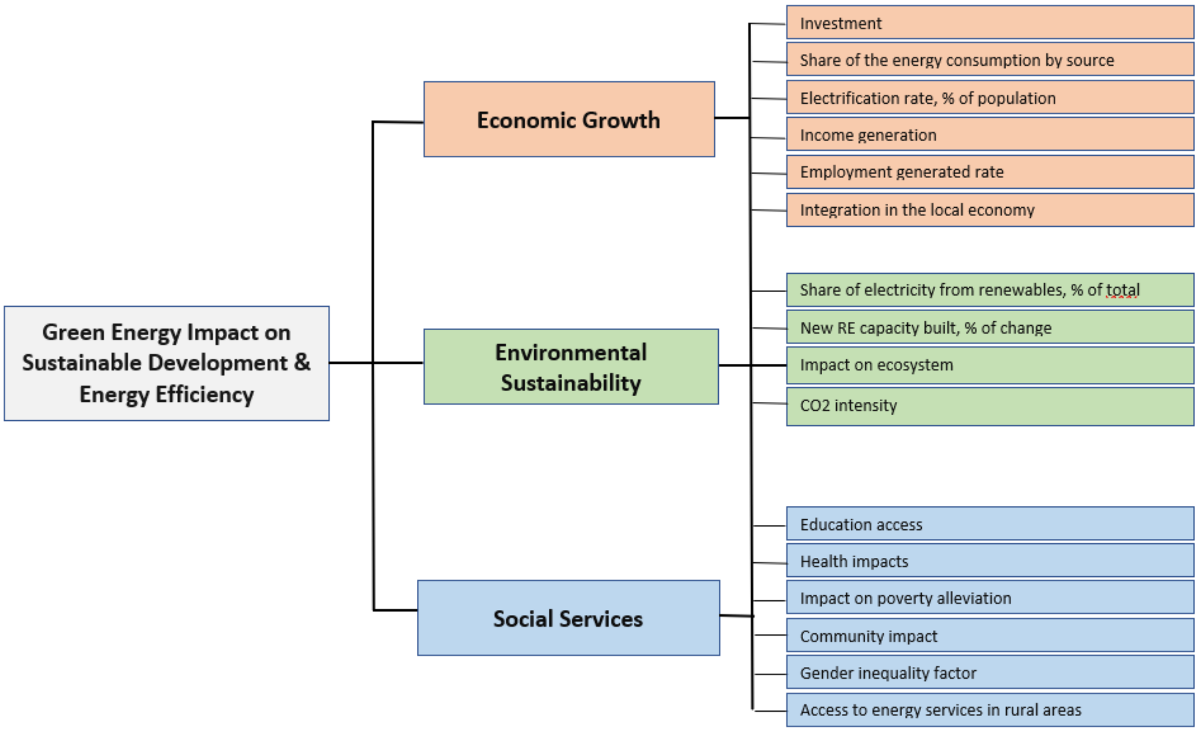
The framework built to focus on evaluating all the three interacting dimensions of the green energy projects which are economic, environmental, and social aspects by adapting the proposed two sustainability approaches. However, we also focused on environmental dimension which is not considered in the Burguillo's proposed framework. The paper analyses the impacts of renewable energy projects mostly on the socioeconomic sustainability of a given territory and has mainly focused on the employment and income generation effects, as well as social cohesion and human development factors.

The adapted framework has clearly distinguished the three interacting dimensions which will be analyzed by defined parameters of each field. By evaluating the three dimensions of the sustainable development the aim is to consider the main areas of sustainable development and have the general picture since the green energy projects affect not only energy efficiency, but also many other factors considered in the analytical framework.

We also consider the framework built by Shadrina (2020) who assesses the Central Asian economies RE deployment status, by applying the two-stage analytical framework. First stage analyzes the potential of the CA countries' energy systems to meet their needs in energy sector which was presented in the previous chapter by us. The second stage analyzes the preparedness of the national energy systems for energy transition to RES through examining techno-economic, social, and political changes. We have adapted the second stage by analyzing the dimensions proposed as energy sector change, environmental sustainability, capital and investment, human resources, infrastructure, and business environment.

The green energy impact on sustainable development and energy efficiency is assessed by combination of quantitative and qualitative approaches in the form of case studies. Both methodologies have their advantages and disadvantages and provide useful information. Case studies enable to analyze the economic and social relationships which are usually not identified in the quantitative studies. In contrast, case studies propose an approach, which captures every actor and is effective for detailed socioeconomic effects which are not recognized by more aggregated analysis.

Table 6. Methodological Framework of GE Impact on Sustainable Development and Energy Efficiency



Source: Adapted by author from Shadrina (2020), Burguillo (2008) & Rio (2007).

As it was discussed, green energy projects affect several dimensions of the socioeconomic and environmental sustainability of a given territory. In total, sixteen parameters are used to analysis the potential impacts through the selected case studies. The economic growth and social services areas include each seven parameters while environmental sustainability only four parameters. The parameters provided in the framework are described in Table 7.

The literature review presented concludes that green energy projects may have significant impacts on economic growth rates and income and employment generation, yet some aspects of this statement deserve special attention.

Table 7. Classifying Parameters of Green Energy Projects on Country's Development and Energy Efficiency

Parameter	Description
Investment	What is the total number of the funding within the project? What is the type of funding?
Share of the energy consumption by source	Does the project affect the energy consumption share by source in the area?
Electrification rate, % of population	Is there any significant change on electrification rate of rural and urban areas? Did the remote rural areas receive access to electricity?
Income generation	Did the project affect income generation capacity of the population and increase their income?

Employment generated rate	Did the project create significant number of jobs? What is the number of jobs created within the project?
Integration in the local economy	Has the project integrated to the local economy? How has the project impacted local economy?
Share of electricity from renewables, % of total	Is there any difference on the share electricity from renewables within the project?
New RE capacity built, % of change	What is the capacity built within the project? Is there any change? What new policies, measurement on RE were adopted?
CO2 intensity	Is there any change of CO2 intensity in the country within the project?
Impact on ecosystem	Is there any harm to the ecosystem on the area of project implementation?
Education access	Do the number of specialists on RE increase? Do local people received specific trainings, which effect education/training/ skills levels of the population?
Health impacts	Is there any affect to health of the population?
Impact on poverty alleviation	Do the benefits of the project fall on low-income groups? Does it contribute to poverty alleviation?
Community impact	Is there any affect to the community where the project implemented?
Gender inequality factor	Does the project consider gender inequality factor and improve the participation women in the activities?
Access to energy services in rural areas	Does the project improve the access of the rural areas on energy services?

Source: Author's elaboration adapted from Burguillo, 2022

4.2. Case Selection

We provide an overview of the case studies selected, along with the short description of the projects, in this section. The cases of the Central Asian countries – Kazakhstan, Tajikistan and Kyrgyzstan have been selected for the research which was studied during the internship conducted and also due to the potential on development of RE projects of the countries.

Kazakhstan is the most developed among all the CA countries while Kyrgyzstan and Tajikistan are the least urbanized and developed countries. Kazakhstan's economy heavily relies on fossil fuel-based energy production; however, the country has huge RE development potential and the country's target to achieve 40% of the renewable energy by 2050 is very impressive which has to be analyzed more comprehensively. Kyrgyzstan and Tajikistan, both rely on hydropower and there is a need for diversification of the energy sector. The abundance of wind, solar and hydro energy sources in the countries described in section 2, and the lack of development of renewable energy projects, have the potential to resolve the issue of the energy poverty and electricity shortages during the peak seasons.

The cases selected are the projects implemented by the United Nations Development Program (UNDP) on renewable energy development and the information on the case studies was provided by the agency during the conducting of the Internship. UNDP supports Government of CA countries by providing relevant expertise in renewable energy projects and contributing to cleaner energy transition. Country Offices of UNDP implement several projects on green energy in every CA country. The data on the case studies are provided by the UNDP which consists of annual and final project reports, mid-term evaluation reports, as well as budget and work plans for each year.

This study also draws upon internationally published data, policy documents, national and local media, scholarly work, and knowledge gained from personal communications with the respective experts and countries' policymakers.

The first case study is the "**Derisking Renewable Energy Investment Project**" (DREI) which is being implemented by the UNDP in Kazakhstan. The budget of the project is US $55 million. The project was planned for 5 years, the implementation started in 2017 and until 2022, however it is extended due to end of February 2023 due to the pandemic which caused delays in implementation of the project.

The project's goal is to increase investment attractiveness and promote private sector investment in RE sector of Kazakhstan and meet the country's 2030 and 2050 renewable energy targets. The program has introduced energy market transformation mechanisms which aims to scale-up the development of green energy in electricity generation from 0.77% to 10% by 2030, resulting in a 10-fold increase in renewable energy-based energy generation.

Based on the global DREI[1] methodology developed by UNDP, the project in Kazakhstan includes development of policies in support of private-sector investment in both large-scale and small-scale renewable energy, as well as development and delivery of financial mechanisms in support of small-scale renewable energy. In large-scale RE, the program promotes international investment through wind and solar energy technologies. In small-scale RE, the project faces towards investment in "Renewable energy resources for urban life" initiative, on-grid small-scale renewable energy applications, targeting urban households and businesses. Technologies include solar PV, solar water heating and small-scale wind. The program also develops business and finance models as third-party ownership models for small-scale RE developers.

[1] 'Derisking Renewable Energy Investment' is a methodology developed by UNDP in 2013, which is a model for quantitative and qualitative comparison of the cost-effectiveness of different public instruments in promoting renewable energy investment.

The **“Energy Access Small and Medium Enterprises Development Project”** is the second case study implemented in Kyrgyzstan and built based on previous experiences from the UNDP Green Villages Initiative. The project is funded by the Fund for International Development, and the budget was US $2,41 million**.** The project duration was 3 years, starting from 2018 to 2021. The goal of the project was to develop a comprehensive strategy for increasing engagement of private sector in provision of energy access by enhancing the risk-return profile of private investment in energy access goods and services.

Improved energy access, which encompasses public buildings, residences, and the private sector, is estimated to directly benefit over 30,000 people in 40 villages. Within the project, solar water heaters, heat pumps, and photovoltaic systems were proposed for 11 public buildings of Kyrgyzstan.

The project focuses on developing green energy policy framework and capacity development, providing access to business and finance models for green energy SMEs, and providing access to sustainable energy services in distant rural areas. The goal of the project was to provide household level RE technologies, such as small hydro power plants, solar thermal, PV systems, mini-grids and biogas. It should be highlighted that the project was implemented jointly in Kyrgyzstan and Tajikistan.

The last case study is the **“Green Energy and Small and Medium Enterprise Development Project”** in Tajikistan. The main purpose of the project is to facilitate the transformation of the country’s energy sector, by supporting the emergence of private energy entrepreneurs, who can provide affordable and sustainable energy services and products, especially to the rural population. The five-year project started on July 2018 and the planned closing date is 2023. The total budget of the project is US $24,4 million which is co-financed by Global Environment Facility (GEF) and UNDP.

The project design purports to scale up private investments in green energy in rural areas focusing primarily on solar energy. The project was designed to address an important development challenge in Tajikistan: the need to provide affordable energy to rural areas. The project includes three interconnected components dealing with policy de-risking, financial de-risking, and incentives, and last cross-cutting component that facilitates knowledge related gaps. The project develops mechanisms to lower policy barriers for green energy SMEs which receive access to green energy financing and develop and improve GE products and services in the local market.

5. Results & Discussion

5.1. Derisking Renewable Energy Investment Project in Kazakhstan

Economic growth: The project has mainly focused on redirecting investment flows into sustainable energy of the country and addressing the issues of high financing costs of RE technologies by developing new financing mechanisms. A new type of renewable energy auction, called project auction was developed within the project which provides information to investors related to a project implementation site, technical conditions, the main parameters of the project and others. Presentation of the project auction was held in 2019 which attracted great interest of investors.

Developed RE auction mechanism resulted the lowest price for renewable electricity in Kazakhstan (12.49 Kazakh tenge per kWh (US $0.03/kWh)) in 2019, which is 2.3 times lower than the initial ceiling price and approximately 1/3 lower than the price of 18.6 tenge per kWh (US $0.04 per kWh) obtained during first zonal auction in the country.

The impact of the program on employment rates and the number of jobs created within the project is high in relative terms. The project team consists of 10 members and international and local consultants are being hired regularly. There is also a project board which consists of 10 members. Based on the mid-term evaluation, $1,743 million of the project budgets covered payments of the project staff. There are also 3000 direct project beneficiaries from which 50% are women, who received financial incentives and participated on the project trainings.

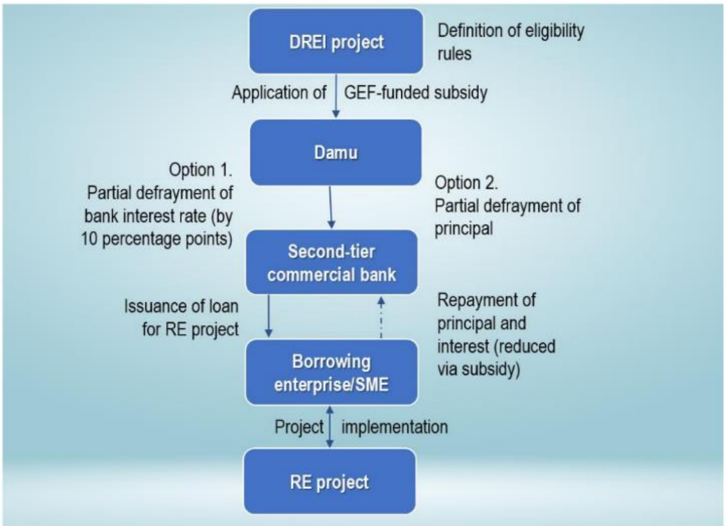
The project has mainly focused on improving RE investment environment of the country and has developed three types of financial instruments as interest rate subsidies, principal subsidies, and green bonds. A principal subsidy is a type of subsidy which is supposed to cover a part of the loan principal, varying in size based on the project. This subsidy has been implemented in the Nationally Appropriate Mitigation Actions for Low-carbon Urban Development project (NAMA)[2]. The two loan subsidy schemes are depicted in Figure 13.

Green bonds developed and subsidized by the project were released for sale on the Astana International Exchange in August 2020. The financial tool is being deployed under a

[2] NAMA is a project in Kazakhstan launched by the UNDP and the Government of Kazakhstan to contribute to achieving the country's voluntary target to reduce GHG emissions, while improving urban services and the quality of life of citizens in Kazakh towns and cities, at a fixed level of 25 percent in most cases.

comprehensive Responsible Party Agreement with the Entrepreneurship Development Fund 'Damu'.

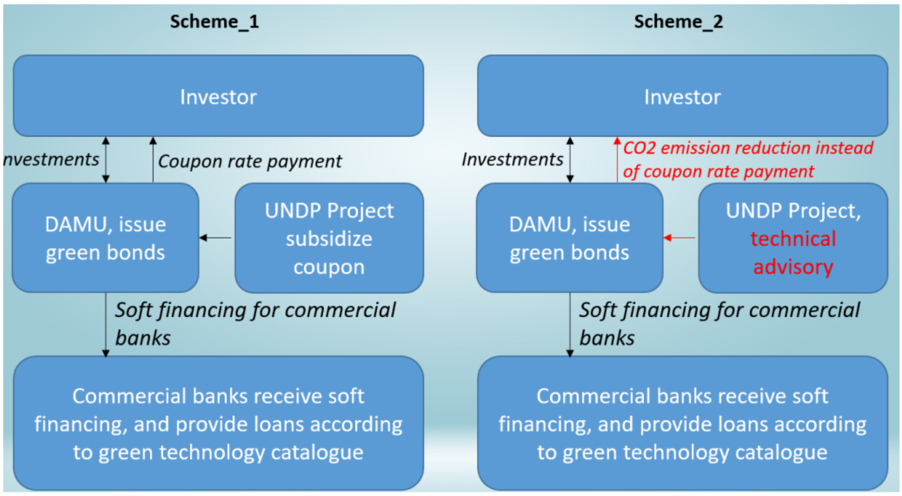
Figure 13. Subsidized Loan Schemes under the Damu-Drei Agreement



Source: Midterm Review. De-risking Renewable Energy Investment, 2020

Figure 14 presents the scheme of the green bonds, which is being implemented by DAMU and green bond sales revenue provide soft financing to the banks for them to lend financing to qualifying green energy projects, that meet the project's eligibility criteria. The subsidy managed by the program would be used to cover the bonds' 11.75 percent coupon rate. Furthermore, the initiative has conceived a process in which the bond buyer receives verified GHG emission reduction credits in place of the interest rate.

Figure 14. The Mechanism of Green Bond Developed by the DREI Project



Source: Midterm Review. De-risking Renewable Energy Investment, 2020

The DREI project has referred to two possible projects for solar PV plant and solar hot-water heaters in a single-family residential neighborhood in Almaty which has received green bond funding. However, only numerous pipelines of projects have been developed so far, with an insufficiently clear sense of target market areas and potential.

The web portal module for renewable energy sources was developed which is an electronic library and interactive map of renewable energy stations, with the possibility of making changes. The developed module of the web portal consists of 4 modules and was transferred to the balance of LLP "Financial Settlement Center of Renewable Energy", for further use and operation.

There are no quantitative results of the project contributing to the electrification rate of the urban and rural population and share of the energy consumption by source since there is no data provided on the project. However, there might be a positive effect foreseen from the installed 50 MW solar facility resulting in the replication of the mechanism for hundreds of additional megawatts of capacity and displacing electricity demand from the national grid.

Environmental Sustainability: In the beginning of 2022, an installation of 50 MW solar plant was completed in southern part of Kazakhstan in the village of Shaulder in Turkestan, which is a highly isolated site during most of the year in open terrain. The solar plant is covering an area of 100 hectares, where a new electrical substation and approximately 100,000 panels are installed. The facility is being connected to the local grid system through a new power line with a length of almost 7 kilometers. According to Kazakh Invest data, the solar power plant is planned to generate more than 82,000 MWh of electricity in the initial year of operation, which is aiming to cover 2% of the Turkestan region's electricity deficit. Over the plant's lifetime, the project is estimated to cut greenhouse gas emissions by around 1.2 million tons of CO2 equivalent.

The project set the investment targets of 1 GW in wind energy and 250 MW in solar PV which is in line with the Green Economy Concept Note of the country. However, based on the mid evaluation report, the project has not yet documented any achieved results in terms of the quantitative indicators of CO2 emissions reductions and development of new small-scale RE capacities, but major concrete progress has been done with the completion of a 50 MW solar facility, which projects GHG reductions of about 1,2 million tons per year starting from 2022 and steadily decreasing over 25 years.

The project conducted full environmental impact assessment and public hearings as part of a pre-feasibility study, during the process of 50 MW solar facility installation in Shaulder. The generation of noise, waste and visual pollution were observed during both the construction and operation process of the facility; however, risks were found to be negligible.

During the construction of the facilities, garbage, noise, and visual pollution were noticed, as well as potential discrimination of women in accessing limited-scale and temporary finance.

Social Services: The project delivered regional workshops and trainings on raising awareness and explanation of participation procedures in RE auctions in six regions of Kazakhstan, were organized for 70 participants from business and municipal authorities. It organized and executed three study tours, to the Netherlands, Denmark, and Finland, for enhancing capacity of public servants and decision-makers, to adopt the best practices in the field of policy, norms, and mechanisms of RE projects support in the country and introduce the most suitable practices. As a result, 25 policy makers were trained.

In accordance with its Gender Action Plan, the project has devoted close and steady attention to women's engagement throughout the implementation period of the program. Women constituted 5 of the 10 participants in the study tour to the Netherlands and 2 of the 6 participants in the study tour to Finland. Women also actively participated in the trainings by 40 percent of the women receiving trainings on zonal and site-specific RE auctions. Women constituted 30 percent of the 140 participants who attended the webinar on financial instruments in April 2020. Most importantly, the project has developed and agreed with Damu that gender preferences will be applied to the scoring of eligibility criteria for the subsidized loans, in the form of extra bonus points for the businesses represented or run by women.

There is no data of the project’s impact to health, community, and poverty alleviation factors. Local community and low-income groups have not benefitted from the project directly at the moment; however, the newly developed financial mechanisms and solar plant might bring a positive impact in the near future.

5.2. Energy Access SMEs Development Project in Kyrgyzstan

Economic Growth: The project collaborated with three microfinance institutions and banks as part of enabling access to finance. It introduced 2 newly developed business models for green SMEs which are the initial steps of establishing more complex models to increase and improve access to modern, affordable, and sustainable energy services.

The Government of Kyrgyzstan approved the regulation "On the conditions and procedure for the implementation of activities for the generation and supply of electricity using renewable energy sources" in October 2020, which was developed within the project, by established Working Group, facilitation of multi-party stakeholder dialogue and high-level policy advocacy. As a result, 17 new companies have registered as RE entities, as a result of this policy, with the intention of constructing renewable energy facilities and generating electricity starting from 2020. The Regulation has also addressed the demand for a structured approach for investors.

There are no quantitative results of the project contributing to the electrification rate of the urban and rural population and share of the energy consumption by source since there is no data provided in the project. However, within the project, three of the most promising solutions were proposed as solar dryers, solar chargers, and pre-packaged solar PV systems. Over 25 such technologies, especially small solar dryers have been purchased through local microfinance institutions and are being utilized by small cooperatives for their business operations.

Environmental Sustainability: Within the project, installed 9 small solar power plants, water heating and energy efficient solutions, provided access to clean energy services in several remote rural regions in Kyrgyzstan, benefiting more than 10,000 people. In addition, the project supported growing market for maintenance and repair services for the already existing installed RE facilities by providing repair and rehabilitation services to three solar PV and solar water heating systems.

The project focused on specific businesses and customers by adapting and providing technology and market solutions in order to promote renewable energy development in the country. The most reliable and low cost as solar dryers, solar chargers, and pre-packaged solar PV systems were offered as part of the Energy Access SME Development Project to the market. The technologies are considered as the most promising solutions of the region's electricity issues as seasonal blackouts and unstable electricity for the production activities of local SMEs.

Solar chargers produce electricity for several light bulbs, and easily charge electronic devices supporting functioning of a small fridge which is very convenient for the remote rural residents and tourist camps. Within the project, two types of the solar charges were offered to the local market, available at different sizes and capacities as the 50W and 300W, which cost from 347 USD to 835 USD. The larges solar charger was already utilized during the 'Kol Fest' which is an eco-art and music festival occurring every year, on the southern coast of Issyk-Kul, which is a remote area of the country. The charger provided sufficient electricity for over 100 festival participants smartphones and power banks, who would have otherwise been left without power.

The festival participants were charged 25 US cents per charge allowing a small business to pay back the entire amount of the solar charger cost within one summer season.

Social Services: Capacity development activities of the local population on RE technologies consisted of an integral part of the project. Consultative and technical support were provided to 2 small and medium enterprises of the country on biogas plant and solar drier through the project's partner Center for Renewable Energy and Energy Efficiency Development (CREEED).

Within the project, 288 people were trained on green energy technologies such as PV systems, solar driers, biogas plants, energy efficient cook stoves, and solar thermal systems. Moreover, 210 children at the Jetigen international children camp were trained on solar energy in Kyrgyzstan.

The project focused on rural areas and vulnerable people who face electricity shortages and blackouts, especially during winter season. The beneficiaries of the project were mostly schools, childcare, and elderly centers. Based on the project results, 7920 households accessed to green energy through small-scale technologies.

Solar collectors were installed in a school of the small village of Eshperovo in the Ton district of the Issyk-Kul oblast which collect energy to be used for heating water and buildings. The project specialists installed the collector and water reservoir, and the process took only a week. The device is successfully heating 500 litres of water which is required for maintaining students' hygiene and to comply with health and safety requirements, especially important during the COVID-19 pandemic.

Within the project the air-to-air heat pumps were installed in the Center for Disease Prevention and State Sanitary and Epidemiological Supervision of Sulukta Town and in paramedical and midwifery stations in the center of Zhin-Zhigen of Kyrgyzstan. Such a heating system provides the required indoor temperature for normal operation of the laboratory. This contributes to reliable and accurate test results and study outcomes, as well as ensuring the equipment's regular operation and having a favorible impact on the specialists' health.

The project created a virtual platform 'www.greenenergy.kg' in collaboration with local and international partners, for promoting financing access to energy aiming to develop and improve the market for sustainable energy solutions and promote investments in renewable energy projects. Most families in the capital have allocated solar collectors in their houses through the platform which provides information on green energy technologies and the platform collects a number of companies working in this area. The reason for facing towards the RE is the power shortage in the country, the prices for energy-efficient house equipment going down and the solar energy available more than 300 days a year. The capacity of 25 kW facility is usually installed in the apartment to cover basic family needs as water and apartment heating, cooking, using of electrical appliances and others

The project was closely engaged with target households and villages struggling with harsh energy shortages, as formal and informal groups, organizations, associations, and cooperatives, given their role in providing energy services and the importance of promoting transparent energy governance. Existing entrepreneurs and SMEs have been continuously engaged in the project activities, ensuring wider community outreach as local RE technicians, and locally owned RE businesses, with a perspective to unlock their technical capacities and increase efficiency of the RE systems.

The project has considered the need to ensure representation of women in all phases of the project activities, including trainings, awareness raising and pilots. The project engaged with women, women's cooperatives, and organizations to gain insights of women's energy needs and to identify the agents of local change. The project ensured representation of Kyrgyz women through development of woman-oriented renewable energy solutions as solar dryers. Over 30 household solar dryers were supported through 20% grant co-financing from the project. The specific measures as provision of incentive scheme for microcredits for women and targeting maternity hospitals and centers for the persons with disabilities under the public sector buildings' pilots, were implemented to target women and vulnerable segments of the society.

The last component of the project mainly focused on bringing energy access in rural areas, closely coordinating the project stakeholders at three different levels which are household level, public buildings level, and village level. The project supported 11 public buildings with energy efficient solutions as new solar power facilities and water heating, including maintenance of their available RE equipment. In total, the project activities promoted access to sustainable energy services in 31 public buildings located in rural areas. By doing so, the project promoted green energy access by reaching up to more than 16,000 households in remote rural areas.

Within the project the existing solar photovoltaic system in Nizhnaya Serafimovka residential care home for the elderly and people with disabilities which is in a rural area of Kyrgyzstan has been completely restored through upgrading the electrical wiring and battery capacity. An off-grid solar power system was installed as part of the UNDP project, in 2013 but the batteries had been running for several years and finally reached their lifetime limit. The equipment is used during on-grid power blackouts, so that various medical devices could work and for lighting around the building. Thus, the management doesn't have to reduce funds received for basic needs of the care home residents since it doesn't have to pay certain electricity bills.

The first solar PV power plant was installed in the Myrzaiym Child Educational Center located in the town of Isfana which has become a model for successful application of energy-saving solutions. The installed facility has substantially improved working conditions at this center where more than 100 children are being trained. The power plant includes 2-kW solar panels, 12 batteries, and an inverter. The power plant installed solves the issue of heating and hot water because of the blackouts which the centre often faces. This technology heats the classes and the building warm, which keeps the children and their food warm.

5.3. Green Energy and SME Development Project in Tajikistan

Economic Growth: Within the project, green energy market of Tajikistan was analyzed in 2019, in order to evaluate country's potential and needs for development of the green energy technologies. The study included financial analysis of four RE products and estimated the amount of the financial incentives required and to be provided for their promotion. Comprehensive research of the energy sector's legislative and policy framework of the country was also conducted by the Frankfurt School.

The research includes a financial analysis of four renewable energy sources in order to estimate the amount of financial incentives to be offered. The Frankfurt School also performed a thorough examination of structure.

The program also addressed policy barriers faced by Green Energy enterprises/SMEs by providing technical assistance to the government of the country and supporting the development and implementation of the Law on Energy Saving and Energy Efficiency.

Solar PV plants and solar water heating (SWH) collectors have been installed at 53 project sites which are in total 33 off-grid site areas and 20 on-grid sites. The RE facilities were installed in remote rural districts including schools, medical centers, tourist guesthouses and SMEs centers. The overall number of people directly benefiting from the green energy facility installation reach up to 1,600 people and around 11,000 people, 30% of which are consists of women, benefiting indirectly from implementation of the project.

There are no quantitative results of the project contributing to the electrification rate of the urban and rural population and share of the energy consumption by source since there is no data provided in the project.

Environmental Sustainability: The project piloted a business model 'RESCO' in collaboration with the private entity 'Pamir Energy' to address the issues of SMEs involved in agricultural activities and provide support for development of their activities. The company and the site selected is located in Murghab region, which is a remote rural district of the country. The project installed a solar power plant 'Alichur' which generates electricity through mini grid solar PV technology and produces about 3KW energy which supplies 250 households with electricity. The project provided financial support to the 2 pilot projects by covering their technical costs and subsidizing 50% of the capital costs. Approximately 1,600 people have received access to energy services through the installed 36 mini-grids in rural areas of the country.

Based on the mid-term project review report, it can be concluded that the project has significant impact to the environmental factors of the country. Table 8 presents short summary of the project environmental parameters. The installed RE capacity within the project increased largely, which lead to increase of the new users' numbers of the RE energy services and decrease of the CO2 emissions.

Table 8. Summary of Environmental Achievements within the Project

Indicator	Target achieved
Volume of investment mobilized and leveraged for low GHG emission developments	US $ 30 Million
Change in modern energy coverage by users	17,000 new users of RE products/services
tCO2eq, direct emissions reductions	53,000
Increase in installed RE capacity per technology (MW for electricity and m2 for SWH)	0.350 MW solar PV; .400 MW small hydro; & 5,000 m2
Lifetime RE production per technology (MWh)	15,330 MWh solar PV 43,800 MWh Small Hydro

Source: Mid Term Review Report, UNDP, 2021

Social Services: A Study Tour on the best practices was organized in 2019 to Kyrgyzstan for 10 representatives of the government employees, private sector, and civil society representatives who are active in the energy sector. Training for installation of a solar generating capacity in

Jamoat Alichur, Murghab region of GBAO was conducted in December 2020. As a results of the study, 15 technicians including 2 women were trained solar technology.

In 2020, the project conducted a campaign on awareness raising and marketing on promoting solar energy technologies within the households. The focus group of the campaign were especially female-headed households and small businesses. The planned activities were carried through the initiative "Energy Bus" covering about 18,000 people.

The initiative launched a statewide marketing and awareness raising campaign in 2020 to raise understanding about solar technology and their benefits for homes, particularly for female-headed households and enterprises.

The platform 'www.neruisabz.tj' has been launched in 2019 for providers, financers, and users of EE and RE technologies. The main objective of the platform is to provide comprehensive information about the green energy technologies which accessible in Tajikistan, as well as support in market engagement opportunities.

The program is also focused on actively involving women on the project planned activities. Women across 10 rural district communities of Tajikistan were provided with on-job trainings on the process of installation, operation, assembling, and maintenance of renewable energy facilities. Workshop was conducted on "Strengthening opportunities for women in energy sector of Tajikistan". A documentary film was produced as well, on "Promotion of small-scale EE/RE technologies for rural women in 10 villages of Tajikistan" in 2020.

5.4 Discussion: Comparison of the Selected Green Energy Projects Parameters on Country's Development and Energy Efficiency

We summarize the impact of the three studied green energy projects in this section in order to represent the potential influence of the case studies on the socioeconomic and environmental dimensions of sustainable development and energy efficiency by taking into account the parameters provided in Section 4. Table 9 summarizes the impacts of the selected GE projects based on the parameters described previously and which are further discussed in the rest of this section.

Table 9. Summary of the Comparison of the Selected Green Energy Projects Parameters on Country's Development and Energy Efficiency

Parameters	Kazakhstan	Kyrgyzstan	Tajikistan
Economic Growth Parameters			
Investment	55 M$	2,4 M$	24,4 M$
Duration of the project	5 years	3 years	5 years
Share of the energy consumption by source	0	0	0
Electrification rate, % of population	+/0	+	+
Income generation	+/0	+	+/0
Employment generated rate	+	+	+
Integration in the local economy	++	++	++
Environmental Sustainability Parameters			
Share of electricity from renewables, % of total	+/0	0	+/0
New RE capacity built, % of change	++	++	++
CO_2 intensity	0	0	0
Impact on ecosystem	-/0	0	0
Social Services Parameters			
Education access	++	++	+/0
Health impacts	0	+	+
Impact on poverty alleviation	0	+	++
Community impact	0	++	+
Gender inequality factor	++	++	++
Access to energy services in rural areas	+/0	++	++

Note: (++) highly positive influence on the variable considered; (+) positive influence; (+/0) very small positive impact; (0) no impact; (-/0) very small negative impact; (-) very negative influence.

Economic Impacts

Investment. The budget of the projects highly varies in all the three countries compared to each other. Kazakhstan has the largest financing, while Kyrgyzstan has the smallest. The last project's duration is also 2 years shorter than the other projects. These factors affect the comparison of the projects, since the larger budget and longer duration of the project allow the countries to implement more activities covering wide variety of factors.

Share of the energy consumption by source. There are no quantitative results of the projects contributing to increase of the share of the energy consumption by source since there is no data provided in the project. However, there might be a positive impact foreseen from the RE facilities installed in all the three countries which may lead to replication of the mechanism for hundreds of additional megawatts of capacity and displacing electricity consumption from the national grid.

Electrification rate, % of population. They are negligible in the case of Kazakhstan. The local population has not benefited from a cheaper energy supply there has not been a significant impact on the flexibility or security of energy supply in the areas. However, the case of Kyrgyzstan and Tajikistan has clearly improved electrification of the local population, especially rural communities and vulnerable groups of people by installing small RE facilities in the regions.

Income generation. It is clearly discovered in the case of Kyrgyzstan how RE technologies contribute and support the activities of SMEs, by allowing them to fulfill their daily trading activities and increase the revenues. The projects of Kazakhstan and Tajikistan provide financial incentives and loans to the beneficiaries of RE projects, however the contribution to generating of the income is not clearly showed.

Employment generated rate. All the three country projects generated employment for the implementation of the project and in construction and production of the RE technologies. An installation of 50 MW solar plant in Kazakhstan led to highest number of jobs created within the local area and the number of jobs tend to increase due to need of maintenance of the program. Other two cases created number of jobs for the SMEs by providing RE technologies and financial incentives which has long term effect.

Integration in the local economy. The project of Kazakhstan is targeted to improvement of the investment environment of RE projects in the country while Kyrgyzstan and Tajikistan focus more on the provision of the energy access to the rural areas of the countries due to the energy poverty and electricity shortages during peak seasons. Kazakhstan's project was well integrated into the local economy by developing three types of financial instruments for easing the financing RE projects and attracting investors into the field.

Environmental Impacts

New RE capacity built, % of change. All the three projects developed new RE capacity and significantly increased the potential of RE use of the countries. In Kyrgyzstan, the project developed and tested several new renewable energy-using solutions, including solar driers, that provides an opportunity to start a new small business, which also allows the business owner to sell or to use the clean power from the RE sources.

Share of electricity from renewables, % of total. There is a positive environmental impact in the three cases. However, there are no quantitative results.

CO2 intensity. There is no required data in all three cases, for the calculation of the energy and CO2 intensity comprehensively. However, all the projects lead to reduction of the CO2 emissions.

Impact on ecosystem. None of the three projects have led to a high impact on ecosystem of the local area. Environmental impact assessment and public hearings as part of a pre-feasibility study, during the process of 50 MW solar facility installation in Shaulder was conducted in Kazakhstan's case. The generation of noise, waste and visual pollution were observed during both the construction and operation process of the facility; however, risks were found to be negligible.

Social Impacts

Education access. The projects have a high impact on education access of the population on RE technologies. All the three programs have provided trainings and organized study tours on best practices. Moreover, projects developed platform on promoting awareness of the local population on GE technologies.

Health impacts. In contrast to the two cases, the RE facility installation within the Kyrgyz project positively affected health of the local population, medical workers, elderly people, and children, by solving the issues of heating and electricity shortages.

Community impact. All the three cases, have positive impact to the country's communities. The projects have been supported by the local authorities and the local population. They have been actively participating in the project activities. Policy and legislation development within the projects led to improvement of RE legislation and installation of the RE technologies led to positive publicity on the municipality.

Gender inequality factor. The projects have devoted substantial and steady attention to the engagement of women throughout the implementation period, in accordance with their Gender Action Plans. The projects have considered gender preferences and were actively involving women on the project activities.

Access to energy services in rural areas and impact on poverty alleviation. In contrast to the project of Kazakhstan, which has not improved access to energy services in rural areas, a positive effect can be identified in the other two projects. The project focuses on rural areas who often face blackouts, the beneficiaries are mostly, schools, childcare, and elderly centers.

6. Conclusion

This study aimed to analyze the impact of the green energy projects on energy efficiency through the three main pillars of sustainable development focusing on economic, environmental, and social dimensions. The proposed scope of the research was covered by the adapted methodological framework through combination of quantitative and qualitative approaches in the form of case studies. The cases of the Central Asian countries, Kazakhstan, Tajikistan, and Kyrgyzstan have been evaluated due to their socioeconomic and environmental characteristics suitable to benefit from the green energy projects.

The results of the study indicate that contributions of the evaluated case studies in three different locations have significant impact on many factors of sustainable development. The projects foster economic growth in the long-run or short-run period and promote generation of employment and income opportunities and diversification of energy market services. All the three projects mainly focused on improving the investment environment of renewable projects by developing accessible financial mechanisms and providing financial incentives and loans to the SMEs.

The green energy projects also tend to improve the well-being of the local population by providing access to social services. In contrast to Kazakhstan, the projects of Kyrgyzstan and Tajikistan mainly focused on improving energy access in remote rural areas due to the energy poverty and electricity shortages during peak seasons in the countries. They have installed a number of solar power plants in most of the rural regions and social centres which provide energy services for daily activities of the communities. The programs make a significant contribution to the education, health, and poverty alleviation in the three countries, as well. Moreover, all the three projects have considered gender preferences and were actively involving women on the project activities.

Each of the case studies have positive environmental impact such as reduction of CO_2 emissions but the direct effect is not yet observed by the countries. Since the environmental benefits will be observed in the long-run, and the two of the projects are still ongoing, there was a difficulty of evaluating environmental impact of the programs in the countries. However, all the three projects have developed new renewable energy capacity and significantly increased their potential use in the regions.

The study has also assessed potential and challenges of the energy sector of the Central Asian region by focusing on the renewable energy market of Kazakhstan, Kyrgyzstan, and Tajikistan. Despite Central Asia being a resource-rich region with diverse energy resources, the countries are facing energy issues such as outdated infrastructure, the seasonality of supply and demand of the power sectors, lack of the rural remote areas access to electricity and others. The economies of the region have low diversification of the energy and heavily rely on principal sources which is coal for Kazakhstan, gas for Turkmenistan and Uzbekistan and hydropower for Tajikistan and Kyrgyzstan.

There is a motivation for green energy development in CA countries, however the question of green financing of the projects is rising sharply in these countries. Thus, to attract investment for the projects, local authorities can have communication and cooperation with domestic and foreign partners by organizing platforms as regional events and conferences which could engage different stakeholders. However, the countries need to set their priorities clearly and effectively communicate it to the stakeholders.

Provision of tax incentives and low-interest loans on renewable energy products by the countries to small and medium enterprises, would be an effective policy tool to attract small businesses on implementation of renewable energy activities.

Green energy projects have a positive impact on the country's development, especially in rural areas, however these programs are not able to significantly contribute to the economic and social aspects of these regions alone. Thus, along with implementation of such projects, the country should provide support by focusing on improving access to energy, education, and health services.

The difference of the evaluated projects’ objectives, investment amount and the duration are considered as the limitation of the study which effected the comprehensive comparison of the cases studies. It would be insightful to evaluate the environmental impact of the projects after certain period to discover their effect on environmental sustainability.

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