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Decarbonization Prospects in the Commonwealth of Independent States

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Abstract: The paper discusses existing trends and prospects for decarbonization in the Commonwealth of Independent States (the CIS), an international organization that regroups Armenia, Azerbaijan, Belarus, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Turkmenistan, and Uzbekistan. The CIS occupies a significant share of Eurasia, representing a large share of global energy consumption and production with a corresponding carbon footprint. These countries and their decarbonization prospects are rarely discussed in the English-language scientific literature. This paper fills in this gap by offering a comprehensive analysis based on statistical data, policy documents, and scenario-based future projections. The results underline that revisiting Nationally Determined Contributions, increasing energy efficiency, and decoupling GDP growth from greenhouse gas emissions are essential to the implementation of the Paris Agreement. The future energy mix should include larger shares of renewable energy, hydrogen, fossil fuels (highly efficient with carbon capture), and nuclear energy to achieve energy security and decarbonize the economy of the region in the long term.

Keywords: Commonwealth of Independent States; carbon neutrality; decarbonization; climate change; scenario analysis; energy efficiency

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1. Introduction

The Commonwealth of Independent States (the CIS) have been a significant player at energy markets over the past years, primarily due to large hydrocarbon reserves of Azerbaijan, Russia, Kazakhstan, Tajikistan, Turkmenistan and Uzbekistan [1]. Other the CIS member states—Armenia, Belarus, Kyrgyzstan, Moldova—are not rich in fossil fuels that predetermines high resource efficiency and/or faster deployment of renewables [2]. The first group of aforementioned six countries has been in a more advanced position with regard to tradition energy systems. The second group of aforementioned four countries are more motivated and advanced in energy transition. For instance, Belarus has the most significant improvements in energy efficiency, while increasing the share of renewable and nuclear energy [3,4]. These changes also make a positive impact on energy security. According to earlier assessments, Armenia and Belarus have had the highest improvements in energy security in 2000–2014. Over the same period, energy security, measured in several dimensions (energy availability and affordability, energy and economic efficiency, and environmental stewardship, including carbon dioxide emissions), has not changed significantly for Azerbaijan, Kazakhstan, and Tajikistan, slightly increased for Russia, and significantly decreased for Uzbekistan [5].

The climate-related problems and relevant responses appear to be specific for different country groupings: poor countries, countries of one region with close economic ties, or countries with the same combination of impact factors/drivers. A recent empirical study suggests that a 1% increase in renewable energy generation has a varied effect for CIS, Central and Eastern Europe (CEE) and New Members States of the European Union (NMS).

It increases CO_2 emissions in the CIS member states and CEE countries (by 0.04% and 0.02% respectively) but lowers CO_2 emissions by 0.02% in NMS. The study confirms the EKC hypothesis for the NMS and the CIS member-states, but not for CEE countries, where economic growth does not increase pollutant emissions [6].

Bruckner et al (2022) have shown that for low- and lower-middle-income countries in sub-Saharan Africa carbon emissions can more than double as a result of poverty alleviation, while adding only 1.6–2.1% or less to global carbon emissions. This conclusion might hold true for some of the CIS member-states, while for others it would be difficult to decouple economic growth from CO_2 emissions [7]. Therefore, we need to seek other factors (besides income level) to explain and project CO_2 emissions in the developing and emerging economies of the CIS.

Bolea et al. (2020) look at the phenomenon of countries' economic convergence to analyze the dynamics of CO_2 emissions inequality, with a particular focus on specific regional features in the 28 EU Member States and a few other, mostly developed, countries. For hydrocarbon exporting countries, like Russia, the contribution of domestic demand to emission growth is much lower than the contribution of international trade. The same is observed for countries with high volumes and growth rate of trade. For Central and Eastern Europe and Asian countries this trend is most accentuated. Moreover, for most countries observed in the study, trade is responsible for the largest part of global emissions. Additionally, the study proves a growing inequality in direct CO_2 emissions from the beginning of 2000s, which is reinforced after 2008. Those countries that had the highest level of emissions in the early 2000s have further increased their pollution within subsequent 15 years. On the contrary, countries with the lowest levels of pollution increased their emissions the least [8].

The CIS member states are very diverse, not only in terms of their energy systems, but also in terms of economic structure and performance, natural resources, and population size. All of these factors make an impact on greenhouse gas emissions in absolute and relative terms [2,9,10]. Despite individual differences of member-states, the CIS as a country grouping has some common features that differ this region from other world regions and make an impact on greenhouse gas emissions and climate response. Two earlier study that specifically focuses on the CIS, examined causal relationship between CO_2 emissions, energy consumption, and real output in 1992–2004. The authors confirmed long-term bidirectional causality between energy consumption and carbon dioxide emissions. Additionally, they demonstrated a quadratic (inverted U-shape) relationship between real GDP and CO_2 emissions which is indicative of the EKC hypothesis [11,12].

There is a lack of valid energy and climate studies on the CIS, especially those published in English. A fair number of studies on the topic have been published in Russian and are related, inter alia, to the discussion of the broader impacts of climate change on different territories and sectors of economy, international climate change regulation and cooperation, and CIS environmental policy [13–17]. However, they do not address the energy impact on climate and decarbonization issues. Therefore, this paper aims to fill in the research gap by offering an analyze the region-specific climate change problems, as well as existing and possible climate actions. This is done through a comprehensive evidence-based overview of existing energy and decarbonization trends in the region, as well as decarbonization scenario-based forecasts. This data analysis is enhanced with a document-based policy discussion on the opportunities and barriers for decarbonization in the CIS. The study contributes to research string on factors affecting greenhouse gas emissions and relevant climate response policies in various country groupings.

Climate-related challenges have been acknowledged by all the CIS member states that are also signatories of the Paris Agreement [18]. A significant barrier to climate actions is an interlink between energy-related carbon emissions and economic growth. Studies show moderate prospects for decoupling these factors, and in case of high mitigation challenge trajectory, the CIS, as well as most countries around the world, are likely to show either an expansive coupling or significant negative decoupling [19]. Simple solutions, like increasing the share of renewables, will not be enough. Evidence for the CIS member states point that an increase in renewable energy generation increases CO_2 emissions (by 1% and 0.04% respectively) [6]. Therefore, if the CIS member states would like to achieve both economic growth and climate goals, they have to develop a new, very different economic growth model based on different energy systems.

The last two centuries are the warmest in the entire history of climate observations [20]. The average global temperature in 2020 (January–October) was approximately 1.2 °C higher than in the pre-industrial period [21]. Carbon dioxide (CO_2) concentration in the atmosphere in 2019 has reached a record 410.5 particles per million (ppm). CO_2 is preserved in the atmosphere for 100 years, thus contributing to lasting climate change effect. The pace of sea level rise has increased since the launch of satellite measurements in 1993 due to ice melting in Greenland and Antarctic. The world ocean is warmer than ever with ocean heatwaves spreading around and acidification rising by one quarter compared with pre-industrial level. Ocean and surface ecosystems degrading, while extreme weather phenomena are more devastating and widespread.

Increasing average annual temperature is also observed in the CIS member-states. Over the last 10 years in Azerbaijan the number and magnitude of floods in small rivers have increased. Armenia is prone to mud- and landslides the risk of which is high at 4.1% of its territory and one third of its communities. Large territories of the country have high likelihood of draughts, and around 40,000 persons annually suffer from floods. Climate change in Belarus manifests itself through increased winter runoff and decreasing spring-summer runoff of rivers, shorter ice sheet period, groundwater depletion, higher instances and intensity of floodwater. The Republic of Moldova is prone to draughts, floods, earthquakes, and landslides [9].

In the Russian Federation due to geographic position annual temperature rises 2.5 times faster than the world average, and in the Arctic—4 times faster. The World Wildlife Fund projects that by the end of the century the glaciers in the Caucasus and the Far East will diminish by 75%, in Central Europe—by 80%, in Central Asia—by 50%. For instance, Elbrus mountains have lost 23% of its glacier over the last 20 years. Due to these changes, conservative scenarios project that 25% of the Russia cities infrastructure may be demolished by 2050 [22].

Central Asia is considered to be one of the world regions most exposed to climate change. Countries in this region already face changes in season duration, quantity and distribution of precipitation, draughts, floods, and lower availability of water resources. Rising temperature will aggravate the problems. Changes and fluctuations of river runoff impact on hydropower plants output thus creating threats to energy security. Climate change also pose threats to agriculture, biodiversity, environment, and people's health, causing economic damage [23].

The largest hydropower potential in Central Asia is in Kyrgyzstan and Tajikistan. However, lack of infrastructure for power generation and transmission limits the effective use of this potential. Some settlements suffer from power outages, especially in winter. Power generating facilities and transmission lines are damaged due to rising temperatures and storms. Power plants in the Eastern Kazakhstan have already faced the problem of rising river water temperature that led to lower power generation due to underutilization of existing capacities. A possible drop in demand for heating due to warmer winters could be offset by increased energy demand for air conditioning and cooling during summer, as well as increased power demand for irrigation, population, and economic growth. In the absence of measures to ensure climate resilience and modernize the energy industry, the reliability, and capacity of hydropower facilities may decrease [10].

Emissions from the energy sector account for 60% of the total greenhouse gas emissions (GHG) emissions, so primary efforts should be directed to limit the impact of energy systems on climate, ecosystems, and health in order to reduce the carbon footprint of the entire energy supply chain and to support climate mitigation measures. At the previous stages of energy transition the main driver was the economic feasibility of new energy sources. At the present stage, it is lowering GHG emission to address global climate change [24].

The rest of the study is structured as follows. Materials and methods used in the study are described in the following section. The subsequent section offers results that are split into the analysis of existing trends and scenario-based future projections. The paper finishes with Conclusions that summarize the study findings and offers policy advice.

2. Materials and Methods

The CIS member states that are in the focus of this paper are Armenia, Azerbaijan, Belarus, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Turkmenistan, and Uzbekistan. In Section 3.2 the aggregated data available from the POLES model also includes Ukraine and Georgia. The reason we exclude these two countries from the qualitative analysis is that Georgia seized its membership in the CIS in 2009 due to the conflict in South Ossetia and Ukraine is de jure a member state of the CIS and ratified the Agreement on the establishment of the CIS, but it did not sign the statutes of this international organization and in 2018 the President of Ukraine issued a decree that seized any participation in the CIS activities.

The study relies on the analysis of research publications on the topic, official statistical data, existing forecasts, policy documents, and other available and reliable information sources (such as new agencies) to cover the most recent developments. The following methods were applied: literature review, comparative data and policy analysis, and elements of future studies. First, existing publications on energy systems, climate policies and actions in the CIS were collected from ScienceDirect. There were only a few publications focused specifically on the CIS, and a few more that cover the CIS member states among other world regions.

Second, statistical data was gathered and analyzed. The sources of statistical data on the CIS member states are official information sources of the relevant ministries and energy companies of the CIS member states, gathered in statistical data books published by the CIS bodies. International Renewable Energy Agency (IRENA) (Abu Dhabi, United Arab Emirates), International Energy Agency (IEA) (Paris, France), the United Nations Framework Convention on Climate Change (UNFCCC) (Bonn, Germany), other UN agencies and international organizations provided additional insights in policies and challenges that CIS countries face with regard to climate change.

Third, policy documents that were analyzed in this study were selected on the websites of relevant ministries, legislative bodies and legal databases of the CIS member states. As some of the new policy tools are analyzed, media publications were scrutinized in addition to the documents analysis, to cover the most recent developments and triangulate the data sources. Next, the scenario-based forecast data was reviewed, and the different trajectories were compared. The projections are based on POLES—a world energy-economy partial equilibrium simulation model that focuses on the energy sector and its perspectives until 2050. It was developed by EnerData together with the European Commission's JRC IPTS and University of Grenoble-CNRS (EDDEN laboratory). The simulation process is based on "year-by-year dynamic recursive modelling with endogenous international energy prices and lagged adjustments of supply and demand by world region" [25]. The following forecast groups of indicators are taken into account in the model: international resource markets (oil, gas, coal and biomass); 88 national/regional energy balances that cover supply, 64 that cover primary demand, transformation (specific technologies for liquids from gas and coal, biofuels, hydrogen and production), and final demand (15 sectors with over 40 technologies); and climate-related issues as (GHG emissions limitations, effort sharing between countries) [25]. The POLES model was the focus of several national and regional studies [26–29].

The forecasted data allows constructing three energy and decarbonization scenarios that correspond to business as usual (EnerBase), moderate scenario based on existing NDCs (EnerBlue), and the visionary future scenario (EnerGreen). The scenario assumptions are summarized in Table 1.

Table 1. Energy and decarbonization the CIS scenario assumptions.

	EnerBase	**EnerBlue**	**EnerGreen**
Climate and energy policies	Policies and efforts to mitigate GHG emissions are not compatible with Nationally Determined Contribution (NDC) targets	Policies and efforts to mitigate GHG emissions are compatible with NDC objectives	Policies and efforts to mitigate GHG emissions (including NDCs) are in line with Paris Agreement goals
Energy demand	High demand growth and modest improvements in energy efficiency	Moderate demand growth is compensated by energy efficiency	Significant energy efficiency improvements coupled with the absence of energy demand growth
Energy supply and prices	Fossil fuels dominate the energy mix and their prices increase, modest renewable additions occur	The share of fossil fuel is slowly decreasing and their prices slowly increase, substantial renewable additions occur	The share of fossil fuel sharply decreases and their prices drop, substantial renewable additions occur
Carbon intensity *, 2019–2050	−1.9%	−2.9%	−7.0%
Energy intensity of GDP ** (final)	−1.4%	−1.9%	−3.3%

Notes: * CO_2 emissions released to produce one unit of gross domestic product (GDP). ** Energy consumption necessary to produce one unit of GDP. Source: based on [30].

Finally, the analyzed information and data was compared in order to identify regularities, future targets that are in line with the visionary scenario (the scenario that is in line with the Paris Agreement goals) and draw policy recommendations. The suggested future targets and policy recommendations target primarily the energy sector and energy intensity of the economy. As these are outlined for CIS as a country grouping, the cross-country cooperation tools that would facilitate the decarbonization path are outlined.

3. Results and Discussion

The existing design and shape of energy systems, along with climate and energy policy goals in the CIS, are critical for understanding the main decarbonization trends in these countries. These trends have not been discussed earlier in the literature and their elements form drivers and obstacles that will impact the future development paths in the region. These are discussed in Section 3.1. Section 3.2 offers the analysis of future energy and decarbonization development trajectories along with policy recommendations for reaching the Paris Agreement goals.

3.1. Exiting Trends in the CIS Based on Statistical Data and Policy Analysis

The key features of the CIS energy systems are partly determined by the conditions in which they were developed. Therefore, they are characterized by centralized systems, extensive power grids and gas pipelines, vertically integrated monopolies, and other features inherited from the central planning systems of the Soviet period. Additionally, since the mid-1990s countries have undertaken some common reform policies with mixed results [31]. These reforms have determined the directions for transformation of the energy sector.

The legacy of Soviet times was a well-developed and somewhat outdated energy infrastructure. 1990-ies have seen economic downturn and a corresponding drop in energy demand and investments in the sector. No due reforms were undertaken in this period. Additionally, galloping inflation and widening poverty have made it very difficult politically to increase tariffs for electricity, heat, and gas supply [31]. This was the time when cross-subsidies were first introduced as a temporary social protection measure and have been preserved since then in many CIS countries [32]. Political tensions in the region have an adverse effect on international energy cooperation and trade, thus decreasing the possible gains from economy of scale, technology transfer, and cross border nexus (water-gas-electricity) solutions. The situation is aggravated by extensive government interference in the energy sector that ranges from price regulation to the dominance of state-owned enterprises, thus limiting competition and other market mechanisms that are typically associated with higher efficiency and innovation.

Russia is largest economy in the CIS, and its economic and energy trends make an impact on the entire union. In 2020 Russia was the fourth largest CO_2 emitter from fuel combustion following China, the USA, and India. It was the last of G8 countries to declare plans for carbon neutrality to be achieved by 2060. In order to reach that goal, the country intends to decrease the shares of oil and coal, while increasing the use of hydrogen, ammonia, and natural gas in the coming years. By 2030 the Government aims at a 70% reduction (less than 2.2 $GtCO_2$-equivalent) in GHG emissions compared to 1990 level (3.1 $GtCO_2$-equivalent). Since the 1990 base year has seen a significant drop in GHG emissions, this target, in fact, means a further emissions increase compared with the existing (2019, pre-COVID level). Additionally, by 2050 Russia is considering a truly ambitions decrease in its GHG emission by 79% compared to 2019 level [33].

Despite the climate goals, Russia plans to increase all types of hydrocarbon extraction—oil, gas, and coal. In 2021 alone Russia's oil and gas condensate production rose by 2.2% to 524 Mt. Around half of that volume was consumed domestically (288 Mt) and the rest (225 Mt) was exported mostly to non-CIS countries (only 11 Mt was channeled to the CIS countries). Coal production grew almost by 9% in 2021 to 438 Mt, around half of it was exported (214 Mt) [34].

Kazakhstan, the second largest economy and oil producer in the CIS, intends to increase oil output by 21% by 2030 (to 104 Mt). The largest share of extracted oil in 2021 was exported (67.6 of 86 Mt), while natural gas was mostly consumed domestically (21.3 bcm) [35]. Consequently, the Intended Nationally Determined Contributions (INDC) of Russia and Kazakhstan are rather modest. The selected base year (1990) is the time of economic downturn, when the output of all industries fell significantly. Therefore, the GHG decrease intended by 2030 is, in fact, an increase compared with the pre-1990 level (Table 2). This is consistent with other studies that underlined similar discrepancies between supply and demand in certain time periods, i.e., demand decrease from 1993 to 1998 and production increase after 2000 and 2015. Compared to other world regions, the CIS countries total primary energy consumption needs in 2020–2030 are comparable with Latin America and Africa, and slightly higher than in the Middle East [36].

Table 2. Intended Nationally Determined Contributions of the CIS countries, 2021.

The CIS Member-States	Intended Nationally Determined Contributions (INDC), 2021
The Republic of Armenia	By 2030 40% emission reduction from 1990 level. The country will keep its 2050 GHG mitigation—2.07 tCO_2eq/capita that was integrated in its Long-Term Low Emission Development Strategy (LT-LEDS). The new 2030 mitigation target is 40% reduction below the 1990 level.)
The Republic of Azerbaijan	By 2030 the Republic of Azerbaijan aims at 35% GHG emission reduction compared to 1990 level.
The Republic of Belarus	By 2030 the Republic of Belarus committed to reduce GHG emissions by at least 28% compared to the 1990 level, excluding the Land Use, Land-Use Change, and Forestry sector, and without any additional conditions.
the Republic of Kazakhstan	By 2030 a 15% reduction in GHG emissions compared to the base year.By 2030 a 25% reduction in GHG emissions compared to the base year, on the condition of international investments, access to green climate funds, low carbon technology transfer, and flexible mechanism for economy in transition.
The Kyrgyz Republic	Unconditional reduction of GHG emissions by 16.63% by 2025 and by 15.97% by 2030. Should additional international support be rendered, the reductin will make up 36.61% by 2025 and 43.62% by 2030.

Table 2. *Cont.*

The CIS Member-States	Intended Nationally Determined Contributions (INDC), 2021
The Republic of Moldova	By 2030 the Republic of Moldova is committed to an unconditional 70% net GHG emissions reduction target as compared to 1990 level. The previous commitment in NDC1 was 64–67%. The reduction target could be increased to 88% compared to 1990 level should access to low-interest financing, technology transfer and technical cooperation be assured.
The Russian Federation	By 2030 the Russian Federation aims at 70% GHG reduction compared to the 1990 level, consideraing the maximum absorptive capacity of ecosystems (primarily forests) and not t the detriment of the sustainable social and economic development in the country.
The Republic of Tajikistan	By 2030 the GHG emission reduction in Tajikistan will not exceed 60–70% of the 1990 emission level. Should international funding and technology transfer be provided the reduction will not exceed 50–60% of the 1990 emission level.
Turkmenistan	By 2030 should financial and technology support be provided, Turkmenistan could achieve zero emission icrease and may even achieve a reduction.
The Republic of Uzbekistan	By 2030 the Republic of Uzbekistan has increased its commitments and intends to reduce specific GHG emissions per unit of GDP by 35% compared with the 2010 level (in the NDC1 a 10% reduction was specified).

Source: [37].

The level of GHG emissions in the CIS countries calculated per unit or per capita remain high compared with most developed countries. For instance, per unit GHG emissions (CO_2 equivalent) per 1 kWh of generated electricity (thermal, nuclear, hydropower, renewables, fuel mix and fuel efficiency of thermal power plants.) in countries of Central Asia are much higher than in OECD countries and even the world average [38]. In 1990 this indicator for Kazakhstan, Uzbekistan and Turkmenistan surpassed the world average by 16.7%, 18.3% and almost 30% correspondingly. In Tajikistan and Kyrgyzstan in the same year, on the contrary, this indicator was lower than the word average by 87.2% and 68.6% correspondingly. These indicators were due to low carbon generating facilities (specifically large hydropower plants) that dominated the electric power industry of these two countries. This contradicts the findings stated by Lobova et al. [5].

In 2018 in Kazakhstan and Turkmenistan the GHG emissions in CO_2 equivalent per 1 kWh of generated electricity surpassed the word average by 39.2 and 86%, correspondingly. At the same time in Uzbekistan the same indicator was lower than the word average by 2.2%. This was a result of comprehensive approach to the energy sector development, including modernization of hydropower plants, construction of thermal power plants, and adoption of efficient combined cycle gas turbines (CCGT). In Tajikistan and Kyrgyzstan in 2018 the emission factor was significantly lower than the word average—by 87.3% and nearly by 90% correspondingly.

The best emission factor is noted in the electric power sector, of Tajikistan and Kyrgyzstan, where power is generated mainly at hydropower plants. On the contrary, two coal and fuel oil thermal power plants in each of these countries have low efficiency. Relatively high GHG emissions in CO_2eq per 1 kWh in Kazakhstan are due to high share of coal (nearly 70%) in the energy mix of Kazakhstan. In Turkmenistan that mostly relies on natural gas, its efficiency accounts to 445.7 goe/kWh compared with 345.5 goe/kWh in Uzbekistan.

Climate policies in each of the CIS countries have been adopted rather late, after 2010. Azerbaijan signed the Paris Agreement in 2016 and started the deployment of renewable capacities. One the key goals stated by Azerbaijan is to provide sustainable energy future. National renewable policy is stated in the State Strategy for the Use of Alternative and Renewable Resources that underlines wider use of renewables, more efficient use of hydrocarbons while sustaining energy security [39]. The predominant renewable energy sources in Azerbaijan are hydropower, wind, solar, biomass and geothermal energy Wind and solar potentials re particularly high, wind energy being most advantageous at the Absheron peninsula, Caspian Sea coast and islands in the North-West of Caspian Basin. Baku is developing a long-term energy strategy until 2050 that will cover power and natural gas supply, energy efficiency, and renewables.

According to the Action Plan by the Ministry of Energy of Armenia and the National Security Strategy (2007) the country aims to develop a sustainable and reliable export-oriented energy system, achieve higher level of energy security through diversification of supply routes and energy sources, the widest possible use of renewables and energy saving. Until 2025 the Strategy previews construction of new hydropower plants with 540 MW capacity and power generation 1800 GWh (including small ones with capacity 260 MW and power generation 500 GWh), wind power plants with capacity 200 MW and power generation 525 GWh, modernization of 648 MW thermal power plants aimed at 4200 GWh, construction of a new nuclear power plant unit with capacity 1000 MW aimed at 7500 GWh, modernization of power grids, and extension of natural gas supply network [40]. The country has also adopted a number of documents aimed at implementation of the Paris Agreement: National strategy for sustainable development of the energy sector, National program on energy saving and renewable energy sources 2010, three national action plans for increasing energy efficiency, Sustainable development program of the Republic of Armenia, and other [41].

One the energy main goals of the Republic of Belarus is achieving energy security while decreasing the impact on the environment. The following strategic documents have been adopted: National sustainable development strategy until 2035, National green economy action plan for Belarus 2021–2025, and several sectoral strategies aimed at modernizing energy generation and supply infrastructure in 2021–2025. Atmospheric emission is planned to be achieved through power plant mode optimization, the launch of two nuclear power plant units, increasing the share of renewables (to 7% in 2025 and 8% in 2030), timely decommissioning of outdated power plants and comprehensive energy saving programs (310 toe in 2021–2025) [3]. Transition to low carbon energy sector is to be assured through decreasing GHG emissions from power plants by approx. 7 mln tons per year in CO_2eq., decreasing the share of natural gas the dominant fuel for power and heat generation—to 60% in 2025 and 50% in 2030 [42].

In 2019 the Government of Kyrgyzstan adopted the 2019–2023 Green Economy Program with a related action plan [43]. The document sets seven priority areas: green energy, green industry, green agriculture, green cities low carbon and environmentally friendly transport, sustainable tourism, and waste management [44]. By 2023 it is planned to introduce at least 50 MW of renewable capacities, including small hydro, solar and biogas power plants. The following strategic documents were developed to achieve climate change objectives: National development strategy of Kyrgyz Republic for 2018–2040, Kyrgyz Climate Investment Program, and the Energy Sector Concept until 2030. The documents set an objective to increase the share of renewables in power generation from 1% to 5%, mainly due to small hydro. Institutional changes include the establishment of 2020 a Common coordination mechanism on green economy and climate change and the State committee on environment and climate.

Republic of Kazakhstan is amending its Energy Sector Development Concept until 2030 adopted in 2014. In 2013 the country adopted Concept on Transition towards Green Economy util 2050 [45]. Taking into consideration the condition of the electric power industry, climate, and environmental targets the new baseline scenario previews a balanced advancement of traditional and alternative energy sources. Implementation of this scenario will allow meeting the GHG obligations under the Paris Agreement, assure an optimal balance of fossil fuels and renewables, lower the impact of high renewable power tariffs on end consumers. Renewable power plants are planned both within the centralized power systems and off-grid. A new draft law aims at setting up a comprehensive energy saving regulation. With the growing economy that requires more energy resources, it is planned develop a Roadmap for energy saving and energy efficiency in 2022–2026. The country is also developing a Concept for low-carbon development until 2050; domestic energy consumption carbon tax, import and export carbon duties; and carbon fund.

Energy Strategy of Moldova until 2030 aimed at reaching 20% of renewables in the energy balance until 2020. In October 2020 the Government of Moldova reconsidered the Low-carbon development strategy until 2030 aiming to reach 70% unconditional and 88% of conditional GHG emissions compared with. The country approved the Environmental Strategy for 2014–2023 that set intermediary emission reduction targets in electric power industry, manufacturing, agriculture, and other sectors. Another goal is to widen forests up to 15% of the total territory of the country by planting them at 150,000 hectares of degraded land [9].

The Russian Federation adopted the Climate Doctrine [46], Government Decree "On stimulating the use of renewable energy sources at the wholesale market of power and capacity", State program for protecting the environment, Concept for setting up the system for monitoring, reporting, and verification of GHG emissions in Russia, Federal Law "On limiting the GHG emissions", and Presidential Decree "On limiting GHG emissions". In 2020 Russia submitted to UNFCCC the National Report of the Russian Federation on the Inventory of the Anthropogenic Emissions and Sinks of Greenhouse Gases Not Controlled by the Montreal Protocol in 1990–2018. According to tis cadaster the cumulative GHG emissions decreased by 47.6% compared with the year 1990 considering the input of land use and forests and by 30.3% without this input. The largest contributors to GHG emissions are the energy sector (78.9%), manufacturing (11.0%), agriculture (5.7%), and waste (4.4%) [47].

National Strategy of Tajikistan until 2030 defined energy indicators 10/10/10/10–500, which means increasing the installed capacity to 10 GW, decreasing grid losses to 10%, raising power exports to 10 bn kWh per year, diversification of power generation fuels by 10%, and additional 500 mln kWh per year from renewable power and energy efficiency. The Sustainable Energy for All program aims at increasing the share of renewables by 20% by 2030 compared with the 2021 level. Increased installed capacity, as per the National Strategy, is to be reached through renewables (wind, solar) and coal power plants. Coal use is explained by the need to assure energy security and substantial domestic deposits. The economy's dependence of hydropower plants leads to seasonal deficits of power in winter, thus 1 mln persons lack secure power supply [48].

Decarbonization of power generation will play a central role in reaching the Uzbekistan's climate goals. The country has already launched an ambitious renewables support program outlined in the Concept by the Ministry of Energy 2020–2030. Uzbekistan aims at carbon neutrality for the electric power sector until 2050. The corresponding Roadmap outline policy tools, technologies, and investments necessary to reach that goal. Advanced energy system modelling tools and scenario analysis are being applied to explore over a dozen of future trajectories in order to choose an optimal one [49].

The National Climate Change Strategy of Turkmenistan is the main national document the guides vision and strategic areas of climate actions [4]. The Strategy sets sustainable development priorities with special attention to efficient and coordinated adaptation process in the priority sectors and development of mitigation measures that contribute to an expedient transition to low-carbon path and meeting international obligations. By the end of 2023 the country plans to adopt the following laws and regulations: the Law "On climate change", the Law "On energy efficiency and energy saving", and regulatory acts on advancement of renewables.

3.2. Scenario-Based Decarbonization Forecasts

This section features possible future the CIS decarbonization and energy consumption trajectories. They are based on EnerData scenarios EnerBase, EnerBlue, and EnerGreen that correspond to business-as usual, moderate, and visionary future (green growth) development paths. The aggregate regional data includes Georgia and Ukraine, which has a limited impact on scenario data in this section. The main scenario assumptions are summarized in Table 1. In case realized for the CIS and the rest of the world, the first scenario will lead to a 5–6 degrees temperature increase, the second to 3–4 degrees temperature increase, and the third will be consistent with the 2 degrees target.

The main macroeconomic drivers for energy consumption and decarbonization are economic and population growth. It is forecasted that after 2026 economic growth in the region will be within 1.0–1.55% per year, gradually decreasing to 2050. Population growth will be modest—from 292.7 mln in 2020 to in 299.3 mln in 2050. There will be a corresponding growth in GDP per capita from US$18.13 in 2020 to US$26.85 in 2050 (in constant US$, at purchasing power parities).

It is projected that total primary energy consumption in the CIS will grow in the business-as usual scenario, and level-off in moderate scenario following the same pattern as in Russia (Figure 1). Only if countries shift to the green growth their consumption will lower substantially in line with the national climate obligations and energy efficiency plans. The green trajectory will require significant efforts and a revision of the existing growth model and sources.

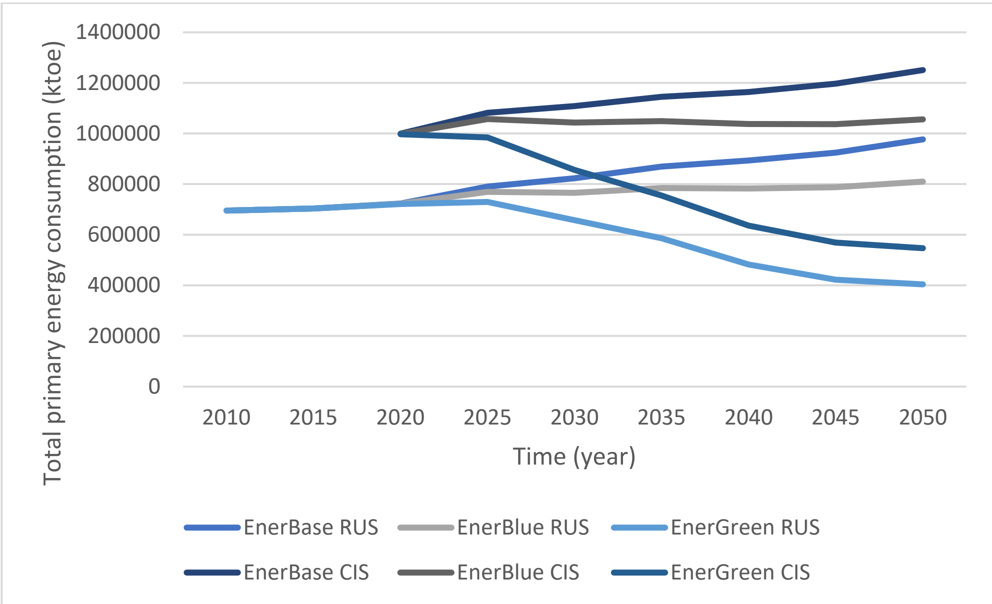

Figure 1. Total primary energy consumption forecast in the CIS countries and Russia, ktoe. Source: based on data from [30].

The largest share of final energy consumption has aways belonged to the industry and it is projected to remain this way until 2050. This sector has also the largest potential for consumption reduction. In the visionary scenario residential, tertiary and agriculture sectors will overtake industry and lead the final consumption. Despite low penetration of electric and hydrogen vehicles, transport has made and will make the lower contribution to the total final energy consumption (Figure 2).

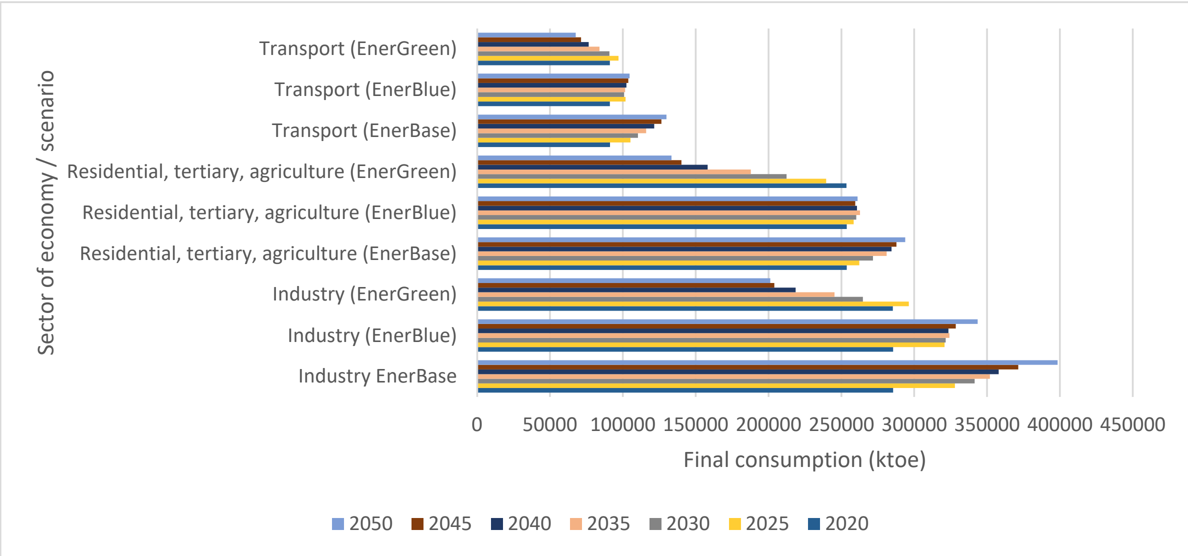

Figure 2. Total final energy consumption in the CIS countries by sector, ktoe. Notes: Other sectors' final consumption is insignificant and constitutes 0.00–0.02 in 2030–2050 in all scenarios. Source: based on data from [30].

The decrease in energy consumption in the green scenario will occur due to reduction in coal consumption and an increase in nuclear power, renewables, and hydrogen (Figure 3). In all scenarios the main decarbonation factor is the deployment of renewables, while CCS (for coal, gas, and bioenergy) is an add-on option that may bring substantial outcomes only after 2040. CCS is taken into consideration in the power sector data in "Transformation" indicator group that covers various technology considerations (nuclear revival or phase-out, CCS, wind and other). Of all renewables, hydro will grow the most, followed by solar, wind, and bioenergy. Hydropower already represents a high share in the CIS energy mix, primarily due to large power plants in Russia. Other alternative energy sources will grow fast, but from a very low base. Therefore, within a 10-years timespan they will not be able to occupy a noticeable share.

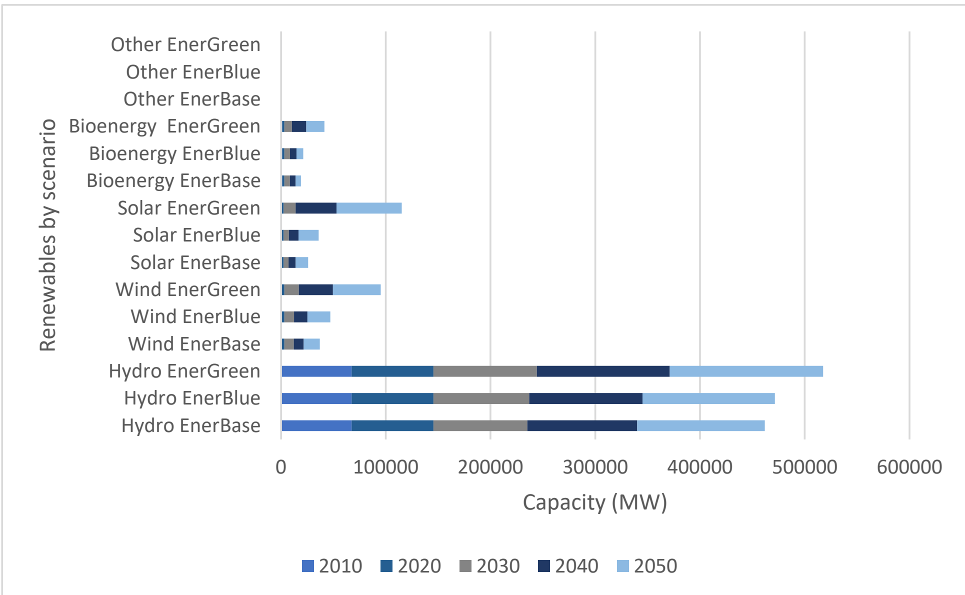

Figure 3. Renewable-based electric capacities in the CIS, by technology, MW. Notes: other sources include marine, geothermal, hydrogen fuel cells. Source: based on data from [30].

Total CO_2 emissions in the CIS countries have been following the economic growth pattern with a significant drop in 1990 marked with lasting economic and social repercussions (Figure 4). It may be noted that in 2010 most the CIS member -states have reached nearly the same level of emissions as in 1990, when Russia alone, according to various estimates, emitted 3.1–3.49 $GtCO_2$eq. [30,38]. CO_2 emissions vary substantially among the CIS member-states. The largest emitters are Kazakhstan, Russia, and Turkmenistan, while relatively low emissions are registered in Armenia, Georgia, Kyrgyzstan, and Tajikistan [31].

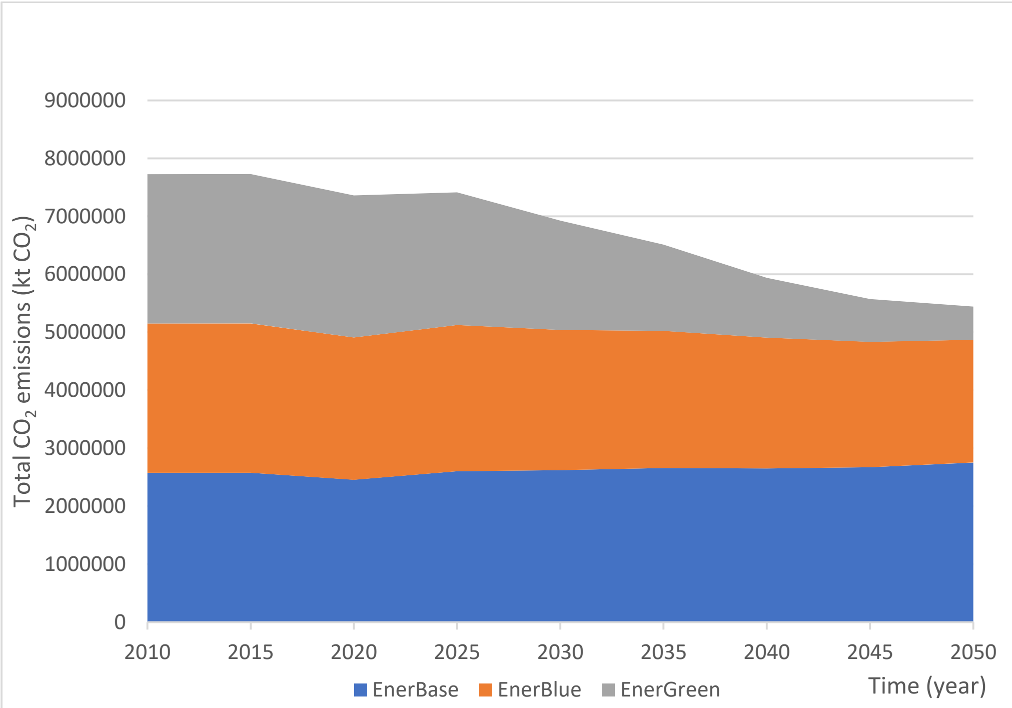

Figure 4. Total CO_2 emissions (incl. industrial processes) in the CIS, kt CO_2**.** Source: based on data from [30].

One of the significant limitations for CO_2 and corresponding energy consumption decrease in developing countries is a corresponding limit to economic (DGP) growth. Empirical evidence from countries around the globe suggests that other factors being constant a 1% increase in GDP per capita is, on average, associated with a 1% increase in CO_2 per capita [50]. This is also true for studies about countries in this region [51]. Figure 5 shows CO_2 intensity to GDP in the CIS member states will decrease significantly in EnerBlue and even more in EnerGreen scenario.

All scenarios will allow to decouple GDP growth from CO_2 emissions. This decoupling will be rather limited in the business-as-usual scenario, but very noticeable in the other two scenarios. Clearly such changes require significant efforts that should start with revisiting NDCs, redesigning energy systems, and reconsidering sources of economic growth.

Decarbonization in the energy sector and industry will require a significant reduction or phasing out of coal. This is particularly a challenge for Russia and Kazakhstan that rely on coal both for domestic consumption and a source of export revenues. Phasing out coal will require its substitution with another economic activity both in terms of budget receipts and employment. Some cities grew up around coal mines. The existing program of coal sector restructuring in Russia involves environmental monitoring for liquidated coal mines, reclamation and rehabilitation operations, relocation of people from dilapidated to new housing, social support to workers that were laid off after liquidation of coal mines [52]. This program may be scaled up, its costs shared between the state budget and business, and new segments may be included to cover professional retraining and relocation. There is room for experience exchange between Russia and Kazakhstan in this area.

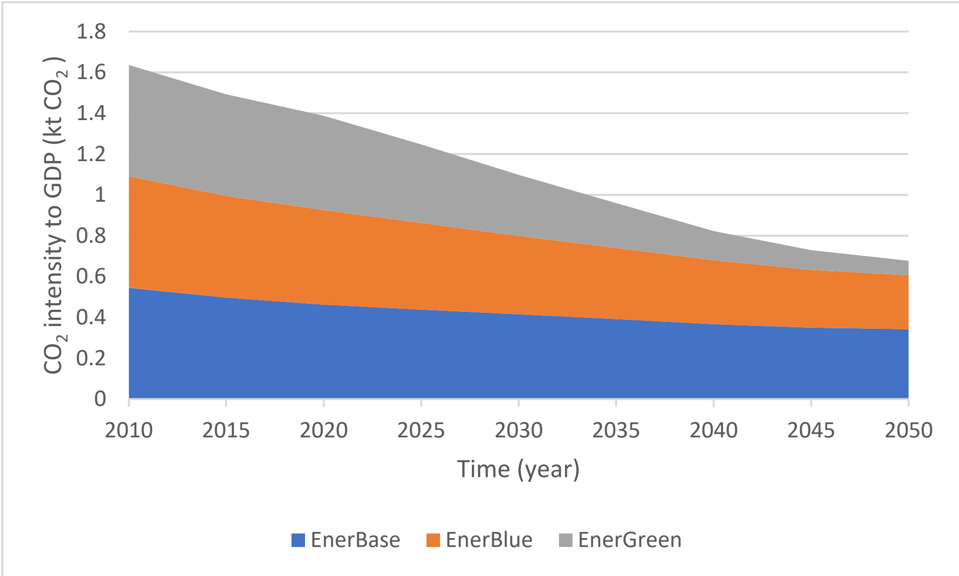

Figure 5. CO_2 intensity to GDP, kt CO_2 ($kgCO_2$/$15, constant US$, purchasing power parities). Source: based on data from [30].

A significant increase of renewables and, later, hydrogen will be another backbone of green growth. At present the share of renewables in the larger economies, and, consequently, in the entire union is negligibly low. At the same time, renewables support programs have been adopted in all CIS countries and their share in the energy mix has been growing fast from a low basis. These efforts have to be reinvigorated and continued. A CIS-wide R&D and/or innovation support and technology transfer program (similar to ERA.Net and innovation projects in the European Framework Program "Horizon 2020" [53]) could facilitate the process. The leading role here belongs to the Intergovernmental Council on Science, Technology, and Innovation cooperation and partly rely on the 2019 Agreement on cooperation in basic research. The decision on common science fund is still pending [54].

As the progress towards decarbonization should happen rather fast, nuclear power will play a significant role due to zero GHG emissions. As nuclear fuel extraction and utilization may not be called environment friendly, the future belongs to 4th generation fast neutron closed loop nuclear reactors. The new technologies are being tested by Russia and other countries-members of the World Nuclear Association [55]. Compared with renewables, nuclear power projects have significantly higher capital costs, time of implementation, and capacity factor.

4. Conclusions

The study has shown that following the past developments, current trends and Nationally Determined Contributions, CIS countries will not in line with the Paris Agreement goals. Climate change will have significant social and economic effects for the countries in the region. Armenia, Belarus, Kyrgyzstan, Moldova have advanced further than the others in terms of renewables deployment and energy efficiency gains. Some Commonwealth states revised and submitted their updated NDCs that, however, will either not reduce the absolute amounts of GHG emissions, or will assure a very small reduction.

The future CIS climate policy and action scenarios largely depend on the biggest economies and emitters—Russia and Kazakhstan. Only immediate and sustained action can eventually decarbonize their energy sectors. All countries have a role to play and a contribution to make. Particular attention should be paid to revising the long-term national energy strategies, phasing out coal mining and use, while addressing the social and economic implications. In addition to the energy industry special focus should be kept on decarbonizing industry—the main source of CO_2 emissions on the demand side.

Increasing energy efficiency and renewable energy sources are the main drivers of the CIS climate efforts. Large hydropower will continue to dominate the renewable energy mix. Additionally, natural gas (with high efficiency factor and carbon capture, storage, and use—CCUS), nuclear energy, and hydrogen may be part of the energy mix and serve not only climate, but also energy security goals. As in other world regions, decarbonization of the energy systems will be a challenge, and the CIS member states are looking for innovative approaches and research and technology cooperation. Due to existing cooperation mechanisms, this cooperation may contribute to more green innovations and the economy of scale in their application. Integrated infrastructure of electric power and other energy systems are the key for achieving sustainable and balanced energy sectors of the CIS member states.

The negative social and economic consequences of climate change will affect the energy and water infrastructure of the CIS economies. Therefore, they must take steps to improve resource availability and policies towards a more integrated nexus approach. Achieving carbon neutrality will require the rapid deployment of resource efficiency technologies for the energy industry and various manufacturing processes to bridge the gap until the next generation of low, zero, or negative carbon emission innovative technologies are commercialized.

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