LAND MANAGEMENT, ENVIRONMENT & SOLID-WASTE: INSIDE EDUCATION AND BUSINESS IN CENTRAL ASIA
ERASMUS-EDU-2023-CBHE Project Number: 101129032

MICRO-CREDENTIAL

CIRCULAR ECONOMY
FOR LAND AND WASTE MANAGEMENT

14.- Economic and Social Dimensions

Reading: Central Asian examples.

Co-funded by the European Union

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Review

Legislative, Institutional, Industrial and Governmental Involvement in Circular Economy in Central Asia: A Systematic Review

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Abstract: As the world faces the detrimental effects of humanity on the environment, the circular economy has started receiving a lot of attention as a tool to keep the value of resources. Although in Europe, circular economy principles have become a trend much earlier, CACs still face challenges in adopting them. The current research aims to review the available literature on sustainability, green economy, and circularity development through the adoption of political, industrial, and financial instruments, followed by an assessment of the barriers and opportunities to circular economy development in the CACs. The novelty of this research lies in the systematic review of different state-of-the-art data resources (journal papers, policies, news, and reports) of CACs by different categories: policy regulations, energy, waste, education, water, and agriculture. This research addresses that the CACs have similar circular economy development barriers (e.g., wide use of fossil fuels, water shortage, and lack of effective waste management) and opportunities (e.g., orientation towards sustainable development, foreign cooperation, and green financing). Therefore, performing effective strategic plans that are already directed to circularity, ensuring stakeholders' involvement, and providing sufficient funding could benefit their circular economy development.

Keywords: sustainable development; Central Asia; waste; water; education; energy; GHG; agriculture; SDGs

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Citation: Tleuken, A.; Tokazhanov, G.; Jemal, K.M.; Shaimakhanov, R.; Sovetbek, M.; Karaca, F. Legislative, Institutional, Industrial and Governmental Involvement in Circular Economy in Central Asia: A Systematic Review. *Sustainability* **2022**, *14*, 8064. https://doi.org/10.3390/su14138064

Academic Editor: Marc A. Rosen

Received: 22 May 2022
Accepted: 27 June 2022
Published: 1 July 2022

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1. Introduction

Environmental pollution and potential scarcity of resources have pushed the world community to start a global trend toward sustainable development since the World Commission on Environment and Development published its seminal report called "Our Common Future" [1]. After that, the global community started to look for a favorable compromise where economic growth would not interfere with the boundaries of environmental safety, avoiding any catastrophes [2]. Various literature on systems and concepts to reduce consumption of natural resources and waste generation in the 1960–1970s led to a term called "circular economy" (CE) [3]. The circular economy has gained good attention from both academics and practitioners during the last decade since it transforms businesses into broadly discussed sustainable development directions [4]. Many scholars are studying that concept, and it is linked to 3-R principles: reduce, reuse, and recycle, along with obvious linkages to sustainable development [5].

Sustainable development mainly focuses on the existing linear economic model's last stage, related to waste management, recycling, and reuse [6]. Hence, the transition into a circular economy is partially in line with sustainable development goals. Moreover,

the circular economy is an effective tool for involving policy-makers and the business community to promote sustainable development [7].

CE transforms the conventional business model from gaining income via the simple sale of the product to making income through maintaining the materials, products, and resources in the flow over time [8]. Successful integration of the CE concept could result in a 48% reduction of emissions globally by 2030 and 83% by 2050 compared to the current situation, which supports sustainable economic and environmental development [9]. However, four main barriers prevent the transition to CE: institutional, cultural, technological, and market [10]. In terms of institutional barriers, changes in policies and regulations of the whole lifecycle are required to make a successful transition to a circular economy [6,11]. Cultural barriers in the CE transition are low interest and awareness of consumers and businesses caused by market immaturity, driven by a lack of government initiatives to promote a CE [12]. Market and technological barriers can be described by economic non-profitability due to low virgin material prices and the requirement to shift to the long-life design of products, respectively [10].

Worldwide, various economies are transitioning into circular economies, starting from big organizations like the European Union (EU) to countries like China and smaller economies like New York, London, and Tokyo [3]. Moreover, most CEOs worldwide have started announcing an interest in a CE for various reasons, including sustainability concerns, personal beliefs, and business interests [13]. Global leaders in such a circular business model are Coca-Cola, Apple, and Rolls-Royce [14,15]. China has one of the largest numbers of studies regarding CE implementation due to environmental, social, and health issues arising from its rapid economic development [4]. According to Ranta et.al. [16], increasing the effectiveness of implementation and enforcement of CE regulations are the two main issues for successfully establishing CE in China. In terms of the United States (US), mentioning CE in the national regulations would accelerate the legislative foundation of the CE system. For China and the US, source separation would be useful to increase recycling efficiency [16]. China's CE understanding includes air pollution, waste, and other resource concerns related to industrialization issues [17]. At the same time, the EU has a narrower view of CE, which only includes waste, resources, and some business opportunities [17].

CACs include the following countries: Kazakhstan, Kyrgyzstan, Uzbekistan, Turkmenistan, and Tajikistan [18]. CACs each have their own unique features, making their economic and political status different from each other. It is important to understand those features for the region's future development, including the implementation of CE principles.

The available research shows that the circular economy is a less researched concept in Central Asia. The authors' previous research includes studying barriers and opportunities of a CE in Kazakhstan [18,19]. Other existing papers have a narrow focus on a specific application of methods, such as the use of metallurgical slag [20], the legal framework for e-waste [21], emissions from municipal solid waste green clusters [22], pollution of water by oil [23] and sustainable energy transition [24]. That is, until today, no study has been conducted to investigate each country's circular economy implementation level and their commonalities and differences in approaching the circular economy.

The background literature review has also shown that the main issues in the framework of circular economy development are laws, finance, water, education, energy, waste, and agriculture. Reviewing legal actions and financing is important because they direct countries towards sustainability, green practices, and a circular economy. Water, waste, and energy are emerging problems in Central Asia because of the potential water crisis [25–27], air pollution through large greenhouse gas emissions [28], and a large amount of waste not being treated properly [29]. At the same time, agriculture is a historically important industry in CACs [30].

This study aims to systematically review the history and current economic situation of different sectors of each CAC and their circular economy levels, compare them by

finding common and different points, followed by a literature-based barriers and opportunities analysis.

First, the current study describes the methodology used for the systematic literature review (with an overlook to CACs' context). After that, the Section 3 provides the commonalities, differences, barriers, and opportunities of CACs for circular economy development. The reviewed literature with sources are further listed and compared in the Appendix A.

2. Materials and Methods

The systematic review methodology analyzes existing studies to indicate evidence that would answer the research question put forth in the beginning [26]. Before the study was conducted, the research team had decided on the scope and aim of the research, as well as the main criteria for the literature sources' choice or elimination during the searching process. It was decided to focus on such topics as policies and laws, international financing, water, education, research, energy, GHG, waste, recycling, and agriculture. Thus, the searching process helps to identify the answer to the main question, "What is the situation in certain sectors with circularity in CACs?" The Scopus and Web of Science databases were used in the searching process. The search query used in the Scopus database was the following: "TITLE-ABS-KEY (circular AND economy) AND TITLE-ABS-KEY (Kazakhstan OR Kyrgyzstan OR Tajikistan OR Turkmenistan OR Uzbekistan)". Ten results were found, out of which four results were decided to be included (see Figure 1 for inclusion criteria). The search request in the Web of Science database was the following: "ALL = (circular economy Kazakhstan OR circular economy Kyrgyzstan OR circular economy Tajikistan OR circular economy Turkmenistan OR circular economy Uzbekistan)". It resulted in 23 found publications, and 16 were selected for inclusion. Thus, after checking for duplicates, 18 sources were found only. These results demonstrate that circular economy research is new for the Central Asian region, proving the gap and need for the current paper. Alerts were turned on to find any recent publications if they appeared. As the circular economy is a recently developed concept and the number of academic sources is limited, the review of non-academic media sources is also included for better time-relevancy and a general understanding of the development. The data source used in this study is a Google search, resulting in 182 references being found. Next, the screening stage was based on reviewing the title and abstract. The prime criteria for recognizing relevant sources were concentrated on CACs and circular measures in the defined sectors (legislative, financial, and industrial). As a result, the total number of used sources for this article is 162. The conceptual analysis flow of the literature review inclusion and exclusion is given in Figure 1.

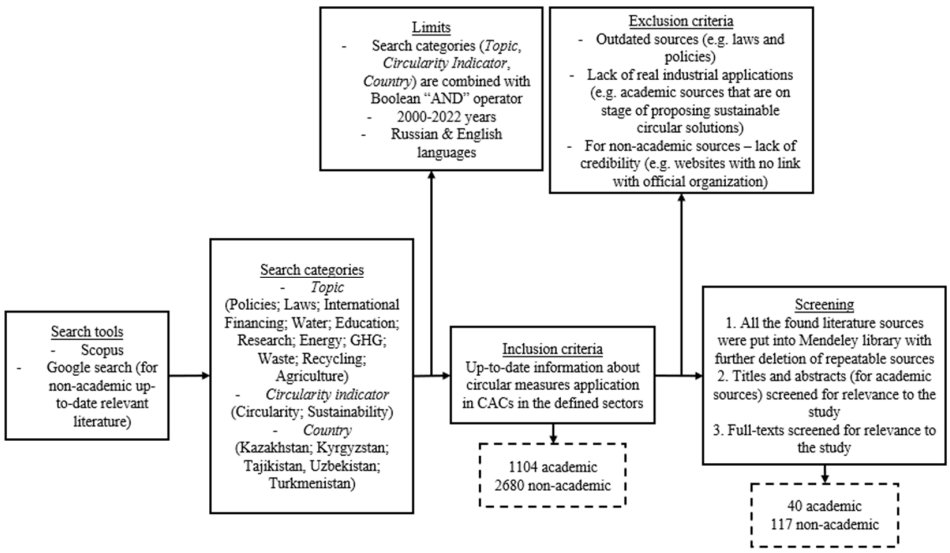

Figure 1. Schematic flow of the literature inclusion criteria.

3. Results & Discussion

3.1. An Overlook of the Contexts of CACs

Kazakhstan (KZ), placed at the center of Eurasia, is the largest country of the CACs (2.7 million m^2), with a population of around 19 million [31]. KZ adopted a presidential system of governance holding large oil and gas (9th in the world) and coal (8th in the world) resource deposits. In addition, It is one of the prime grain exporters (top 10) [31]. The climate is sharply continental, with cold winters (up to −20 °C) and hot summers (up to 30 °C). Strong evaporation rates and dry summers with rare rains force irrigation application in agriculture [25].

Turkmenistan (TKM) is an upper-middle-income country with a population of 5.8 million and the second-highest GDP per capita of the CACs [32]. The Caspian Sea, bordering the country's west, provides rich oil and gas deposits. TKM owns the world's fourth-largest, 10% of total global gas reserves [33]. Its increasing water deficiency and steady temperature rise make it vulnerable to climate change, impacting its entire economy, especially the water sector [34].

Tajikistan (TJK) is located at the south-eastern end of Central Asia. Its population is around eight million people, with an annual growth rate of 2.5%. Most of the population resides in rural provinces (approx. 74%) [35]. This highly mountainous country covers an area of 143.1 thousand square kilometers. It is a mountainous country (93% of its territory), mostly arid and warm, with considerable fluctuations in temperature ranges between +40 °C and −60 °C. It is ranked first for its water potential in Central Asia; however, it has very scarce fossil fuels (oil and gas) [35].

Kyrgyzstan (KGZ) is a relatively low-income economy CAC supported by agriculture, mineral extraction, construction, and information services. It covers about 199.95 thousand km^2 of an area with 6.6 million people (1.67% of annual growth), where 36% comprises the urban population [36]. China bounds KGZ on the east and south, Kazakhstan on the northwest and north, and Uzbekistan and Tajikistan on the south and west. It is the most mountainous country in Central Asia (almost 94%, with an average height of 2750 m above sea level) [37]. According to the World Bank Report, the real growth in the gross domestic product (GDP) averaged 4.5% annually, in line with the average among other CACs [36]. KGZ produces non-ferrous metals, machinery, light industrial products, and hydroelectric power, which provide more than 75% of the country's electric energy. Moreover, significant importance to the national economy relies on its gold mining, coal extraction, petroleum, and natural gas deposits.

Uzbekistan (UZB) is landlocked, bordering KZ, KGZ, TKM, TJK, and Afghanistan. As of 2020, it has a population of over 34 million [38], the largest in Central Asia. Uzbekistan is one of the world's largest cotton producers and the leading machinery and heavy equipment producer in Central Asia, possesses significant mineral, oil, and gas resources [27], and produces and exports vast amounts of natural gas. Uzbekistan demonstrates one of the highest GDP growth rates in the region, with its GDP predicted to increase by 6.2% last year [38]. The locations of the CACs are given in Figure 2.

3.2. Differences and Commonalities

To start with, an appropriate *legal, policy, and regulatory framework* is an important step in approaching the adoption of circularity. It both encourages and puts effective boundaries on making suitable decisions that play a role in environmental lifecycles. Based on the reviewed literature, the following information was enclosed (for the references, see the Appendix A, section "legal, policy, and regulatory framework"). In terms of legal, policy, and regulatory framework, all five countries represent their commitment toward circular development in terms of the legal framework they adopt. Kazakhstan is strongly oriented toward shifting to sustainable development and a green economy in its national strategy. Turkmenistan has put significant efforts into achieving sustainable development and is one of the first countries to accept all Sustainability Development Goals (SDGs) by integrating them into national socio-economic goals and strategies. Tajikistan's countrywide reforms

in the political and economic sectors of the country were made in the late 20th century. Kyrgyzstan's environmental safety and protection are still among the most significant parts of its national security as it is an essential step before conserving natural systems and maintaining environmental quality [39]. Since the country's leadership change in 2016, Uzbekistan has begun a course of economic rejuvenation by adapting systemic reforms to reduce the state's role in the economy, modernize its agriculture and industry, and attract foreign investment. In Table 1, the commonalities and differences are summarized.

Figure 2. CACs and their locations on a regional map.

Table 1. Commons and differences in the legal framework of circularity in CACs.

Commons	Differences
High level of interest in transitioning to circular practices among CACs An increasing number of legal and regulatory policies since the initial adoption of CE strategies Low-to-medium level of involvement from the private sector in the transition to circular economies across all CACs Low level of integration of CE legal and regulatory policies across industrial and construction sectors of CACs Formulation of environmental protection laws and policies across CACs Although national strategies direct the countries toward a greener economy, the execution leaves much to be desired	Varying levels of legal and regulatory framework implementation across CACs Imbalance in enforcement capability of legal and regulatory actions arising from differences in socioeconomic levels CE strategies are adopted on the basis of the specific needs of each CA country (e.g., Kazakhstan mainly aims to reduce GHG emissions with Kazakhstan 2050 strategy, while Tajikistan's CE strategy specifically addresses the utilization of its resources) Absence of legislative and regional collaborations within the Central Asia context in the implementation of CE strategies across sectors Variations in set priority areas within CACs considering the social, political, and economic status of each country

Being an important region, Central Asia attracts the attention of different *international organizations*, which have also developed *green financing* that can help promote and adopt circularity. As the local population may not be interested or motivated enough for the transition, foreign organizations, which have more experience in circularity, can assist in improving environmental friendliness. The adoption of strategic documents in CACs that are oriented towards sustainable development has opened up some possibilities for developing green financing in Central Asia. Thus, many international funds are motivated to invest in green projects in this region and establish green financing. The reviewed literature has shown the following (see the Appendix A, section "Involvement with international organizations and Green Financing"). Kazakhstan, in aiming to develop sustainability and circularity in priority sectors, has become a host to several international organizations seeking to develop green and circular projects in Kazakhstan. In turn, Tajikistan receives

the second-highest climate financing among all CACs due to the high vulnerability of the territory, established frameworks in its national plan, and relationship with donors. Overall, all the CACs, after gaining independence, started being actively integrated with international organizations, e.g., in Kyrgyzstan, more than 30 organizations are currently working. Table 2 contains the main commonalities and differences found.

Table 2. Commons and differences in international involvement toward circularity development in CACs.

Commons	Differences
The high amount of external financing mechanisms in the green sector, reaching up to $200 million for climate-related projects overall High interest of international organizations, especially in combating adverse climate change effects within CACs Central Asian Regional Economic Cooperation Program (CAREC) membership of CACs as an initiative by the EU, UNDP, and governments of CACs Similar types of international organizations involved in projects within Central Asia, such as ADB, EBRD, GCF, and CIF Despite large financing of green projects, the circularity output is not that extensive Sustainable Consumption and Production (SCP) is being actively developed in all CACs, with different implementations, including sustainable procurement, development of sustainable policies	Varying levels of financial commitment of CACs in sectors within the domain of the green economy Varying levels of involvement of international organizations in supporting green initiatives (due to socio-economic and political factors) The capacity of co-financing mechanisms of governments differs based on the economic levels of CACs and based on industries Involvement of international organizations depending on the sector (e.g., Turkmenistan and Tajikistan use external financing for water-based projects, Kazakhstan implements green initiatives for minimizing biodiversity loss and achieving carbon neutrality)

Given the risk of the *water* crisis in Central Asia [25,26] due to high salinity and the limited amount of water entering the country, both government and international funds give special attention to sustainable water management in this region (for more detailed information and references see Appendix A, section "water resources management"). Apart from saving water resources, another challenge is sharing the river basins between the neighboring countries, which risks equality of usage. For example, the United States attempted to help Central Asian water management through USAID regional water and vulnerable environment activities for shared river basins. In addition, hydropower is currently a "cleaner" alternative to fuel energy, which endangers local water resources. Therefore, effective water management is crucial for achieving circularity in the CA region. See Table 3 for observed commonalities and differences.

Table 3. Commons and differences in sustainable water management in CACs.

Commons	Differences
In general, all CACs face the risk of the water crisis All CACs need to develop effective management of shared (transboundary) water resources The agricultural sector consumes abundant local water resources, which might be inadequate due to outdated infrastructure Hydropower is currently the only cleaner energy alternative for the CACs, which is why circular water management needs to increase	Tajikistan and Kyrgyzstan possess more water resources than Kazakhstan, Turkmenistan, and Uzbekistan Lack of consensus on water resources usage—own different interests (agriculture, hydropower) are leading to water resources depletion

Central Asia gives substantial consideration to education and enlightenment activities by pursuing green and circular economy development. This perspective is an important stage in achieving a ubiquitous understanding of the sustainability concept's importance. Moreover, teaching in schools and universities can improve the adoption of circularity among the next generations. As research on "circular economy" is minimal in Central Asia, Figure 3 shows the number of papers published in Scopus on sustainable development from 2007 to 2021. Kazakhstan's research on sustainable development started in 2006 and reached its peak in 2020. Similarly, Turkmenistan's sustainability research began in 2007

and reached its maximum in 2021. Table 4 summarizes the similarities and differences, and the details can be found in Appendix A, section "education and research".

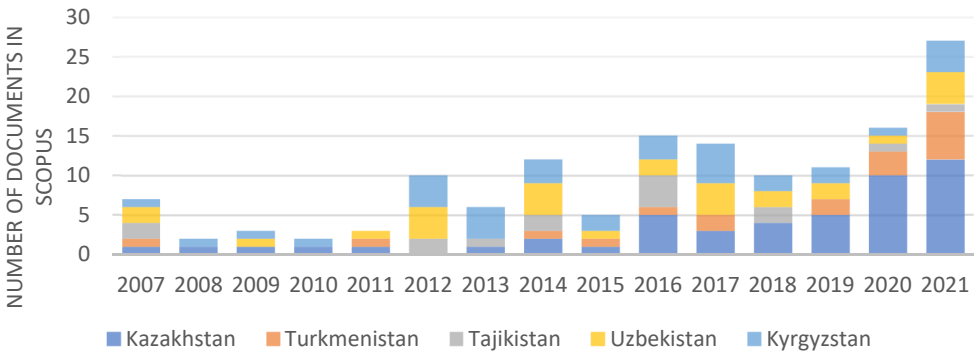

Figure 3. CACs' scientific research on sustainable development.

Table 4. Commons and differences in education and research in CACs.

Commons	Differences
Environmental education and education on sustainable development are implemented in schools and universities of all CACs The number of research on sustainable development is generally growing in CACs	Kazakhstan is leading in terms of conducting academic research on sustainability topics, while Tajikistan has the least amount of scholarly articles on sustainable development in the Scopus database

Decreasing *GHG emissions* is vital for the environment to prevent rapid climate change. In the meantime, Central Asia's GHG emissions constitute up to 1% of global GHG [28]. Since CACs are highly dependent on conventional energy sources, finding feasible ways to enhance renewables is essential yet challenging. Thus, for circular economy development in the region, consideration of energy and GHG emissions is crucial.

Figures 4–6 present the carbon emissions and national trends, renewable energy consumption, and fossil fuel consumption across CACs. Carbon dioxide emissions are highest in Turkmenistan and Kazakhstan and the lowest in Tajikistan and Kyrgyzstan (Figure 4). Renewable energy resources are highly utilized in Tajikistan compared to the rest of the CACs (Figure 5). It is also evident that greater utilization of renewable resources is an effective strategy for transitioning to a low-carbon economy. In Kazakhstan, Uzbekistan, and Turkmenistan, renewable energy constitutes a small proportion of the total energy consumed. Approximately 99% of the total energy within Kazakhstan and Uzbekistan is produced from non-renewable sources, including coal and gas. Tajikistan consumes a minor proportion of fossil fuels (approximately between 30% and 50% of the total) [40]. Table 5 summarizes the main similarities and differences in the energy and GHG emissions between the CACs; the details are given in Appendix A, section "energy and GHG emissions."

Effective *waste management* is a crucial step in achieving a circular economy, the ultimate goal of which is to eliminate waste. The current ecological state of the CACs is poor, as the waste is conventionally not appropriately treated [29]. Nevertheless, currently, CACs are oriented toward improving waste management. Commonalities and differences in waste management are described in Table 6 (see Appendix A section "waste management and recycling").

For the Central Asian region, *agriculture* plays a vital role in industrial development due to the availability of suitable lands. Since the Soviet Union, this region has been the main provider of agricultural supplies [30]. Nevertheless, agricultural activities are dramatically water- and land-exhausting, which puts the region at risk of drought. Therefore, the development of circularity in agriculture is vital for the region. The similarities and

differences of the agricultural management practices of CACs can be found in Table 7 (the literature review details can be seen in Appendix A "Agriculture" section).

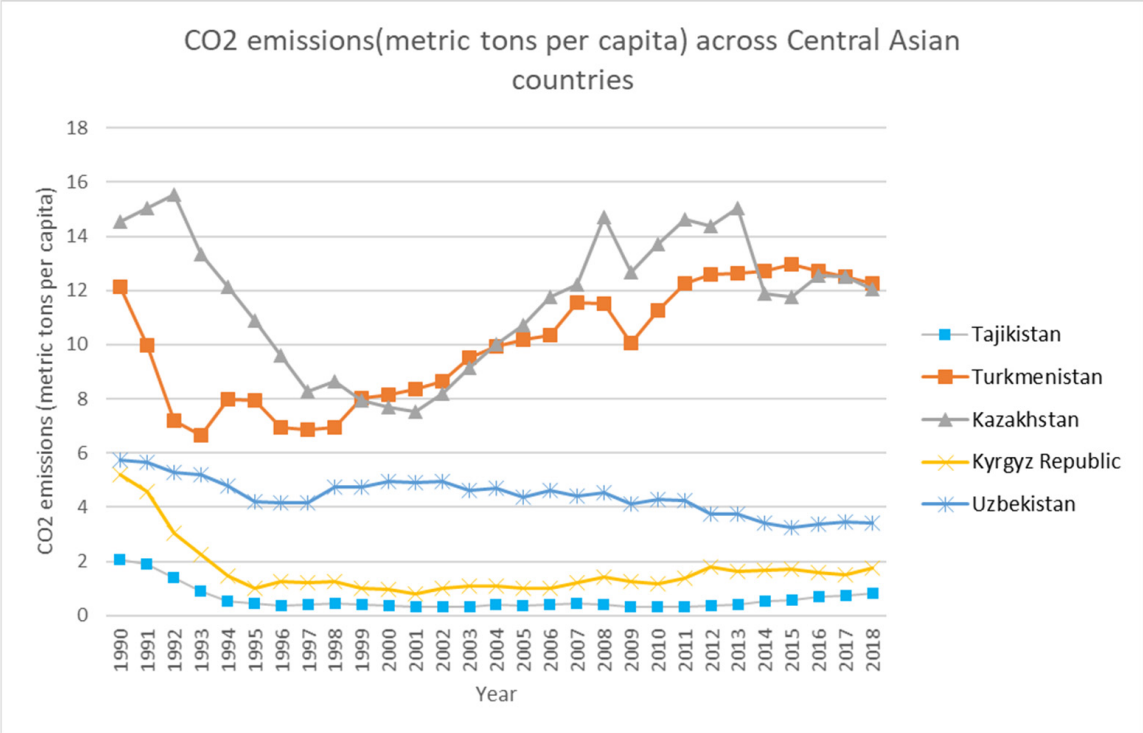

Figure 4. CO_2 emissions per capita emissions in CACs (Source: own elaboration based on the public data extracted from WorldBank.org, accessed on 1 February 2022).

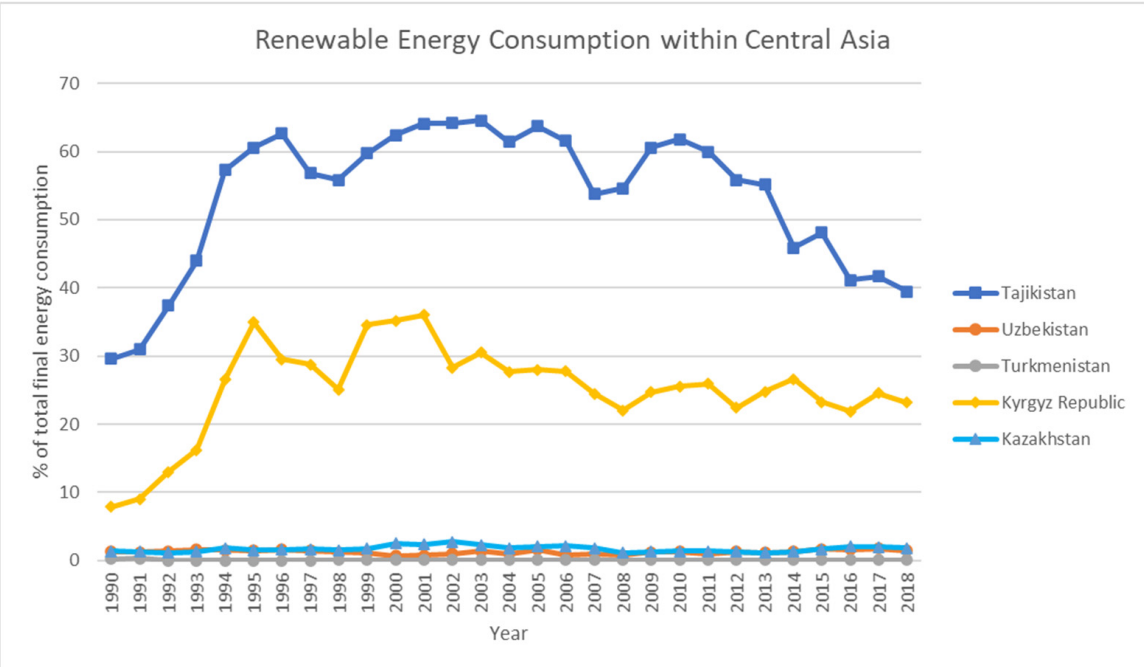

Figure 5. Renewable energy consumption across CACs (Source: own elaboration based on the public data extracted from WorldBank.org, accessed on 1 February 2022).

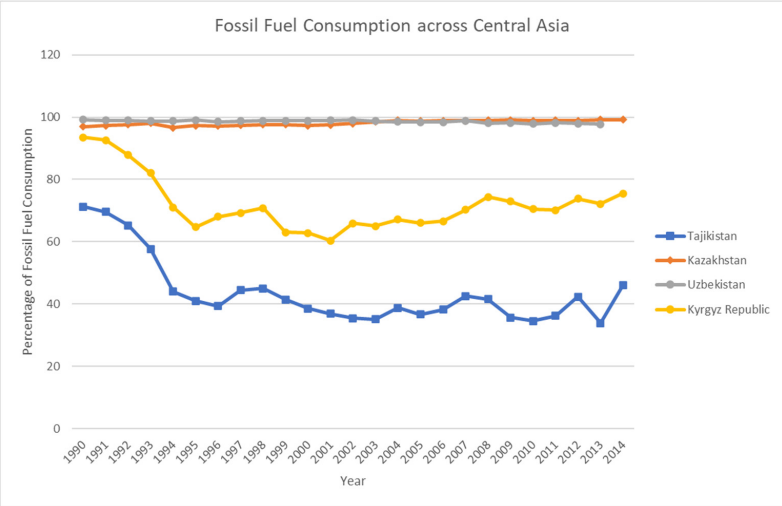

Figure 6. Fossil fuel consumption across CACs (Source: own elaboration based on the public data extracted from WorldBank.org, accessed on 1 February 2022).

Table 5. Similarities and differences in circular energy and GHG management in CACs.

Commons	Differences
All CACs have a heavy reliance on conventional fossil fuels Nevertheless, all countries plan to decrease GHG emissions by 2030, according to the Paris Agreement Kazakhstan and Turkmenistan emphasize increasing gasification to reduce coal reliance All countries employ hydropower as an alternative source of energy to fossils	Among all CACs, Tajikistan is leading in the adoption of renewable energy sources Kazakhstan's GHG is the largest in CA Uzbekistan has substantial solar power potential Kazakhstan and Turkmenistan have the highest CO_2 emissions Tajikistan is leading in terms of the least amount of CO_2 emissions

Table 6. Commons and differences in waste management in CACs.

Commons	Differences
Kazakhstan and Turkmenistan develop circular waste management practices, e.g., using worms to create vermicompost Kazakhstan, Kyrgyzstan, and Tajikistan face a problem with illegally created landfills, which endanger the earth and air pollution Kazakhstan and Uzbekistan have country-level strategies to develop waste management All countries have international guidance and support in waste management development Kazakhstan and Kyrgyzstan have a focus on the development of effective construction waste management	Modular structures fabrication factory has first opened in Kazakhstan, aiming to develop the circular construction sector The oil industry is the primary source of industrial waste in Turkmenistan Tajikistan is able to recycle mercury but is not implementing it

Table 7. Commons and differences in circular agriculture management in CACs.

Commons	Differences
All countries have significant potential in the agriculture sector, which is why circular development is especially important in this sector Turkmenistan and Uzbekistan aim to develop more sustainable fertilizers used for less air pollution The Kyrgyzstan, Turkmenistan, and Uzbekistan governments are implementing effective reforms to develop the agricultural sector towards making it more sustainable	Uzbekistan has the largest and most diverse agricultural sectors, including fishery Kazakhstan has the highest amount of implemented circular projects in the sector Tajikistan's agriculture is being severely affected by climate change Kazakhstan, being a large meat producer, develops circular practices in the beef sector

3.3. Barriers and Opportunities

Central Asia has certain barriers and opportunities for circular economy development, summarized in Figure 7. The most common regional barrier is the dependency on rainfall water in agriculture, which endangers food security in the case of droughts and, overall, water level. In addition, the local population is not motivated to adopt circular actions; thus, most people do not minimize water consumption. In the CACs, there is still a strong dependency on conventional fossil fuels. At the same time, a switch to renewables is financially exhaustive, could increase reliance on foreign electricity imports [24], and requires qualified personnel, which is usually lacking among the local population and is invited from foreign countries. Another barrier to CE is the lack of efficient waste management—waste sorting, processing, and recycling, faulty management of dangerous waste (e.g., medical or radioactive). Moreover, a lack of statistical data on waste amounts hinders conducting a comprehensive analysis of future implications.

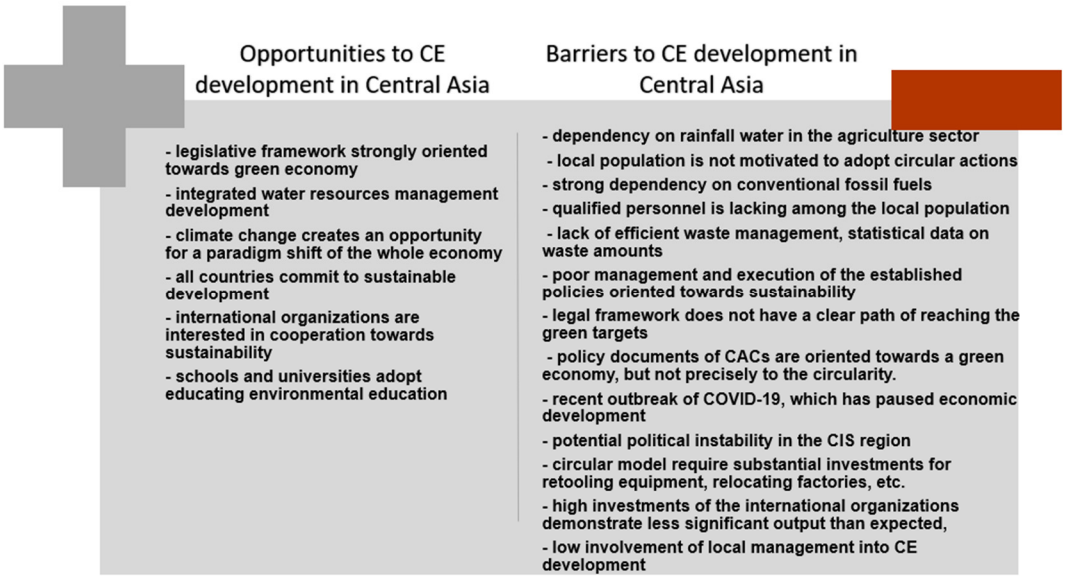

Figure 7. Summary of common barriers and opportunities to circular economy development in Central Asia.

Another barrier could be, as seen from previous experience, poor management and execution of the established policies that are oriented towards sustainability. In addition, the legal frameworks state "green" targets in most cases but do not have a clear path to reaching those. Moreover, the policy documents of CACs are oriented toward a green economy, but not precisely to circularity.

An external barrier common to all CACs is the recent outbreak of COVID-19, which has paused economic development and oriented all countries to switch to a lockdown mode of living and medical help to citizens. The hottest recent external barrier to circular economy development is the potential political instability in the CIS region (e.g., the invasion of Russia into Ukraine), which endangers all CACs in terms of international cooperation, as historically, the Central Asia region has always been politically allied to Russia.

Financial expenses also trouble the CE transition, as the circular model requires substantial investments for retooling equipment and relocating factories. Currently, the price of recycled end-product is typically higher than that of new raw alternative materials) [41]. Moreover, international organizations' high investments demonstrate a lack of significant output and less benefit than expected, which can be linked with low involvement of local management and a lack of interest and confidence in foreign professionals.

In **Kazakhstan**, the low price of water creates a barrier for the population to save it, especially for industrial and agricultural use. In addition, the economic development of Kazakhstan is strongly dependent on conventional fuels, making it financially complicated

to switch to renewables. In **Turkmenistan**, the main barriers to implementing a circular economy are institutional and regulatory issues, which lead to a low level of investor interest due to the faults in the governmental system. Korostova (2020) argues that a lack of public awareness, poor infrastructure, and lack of statistical collections impede the transition to CE [42]. In **Tajikistan**, the lack of adequate internal financing mechanisms for green initiatives delays the turnover to CE. Although bilateral and multilateral foreign agents are involved in different sectors of the economy, the lack of internal capacity to undertake large-scale projects encourages a high dependence on external agents and financing. The inability of the local private and public sectors to carry out infrastructure projects leads to the unsustainable use of the country's resources. In addition, production processes tend to overlook principles of circularity in manufacturing products and goods [43]. **Kyrgyzstan**'s major concerns arise from irrational land utilization, unsustainable resource practices (including air pollution from different kinds of plants, energy inefficient residential construction objects, and unsustainable water management) [44]. **Uzbekistan**'s main barrier to the circular economy is its strong reliance on cotton production, which requires enormous water resources. Since the river basins are transboundary, this practice also endangers the neighboring countries. Another significant challenge is the low level of skilled workforce, as locals tend to migrate to neighboring CIS countries seeking better salaries, creating a great demand for labor in the country.

Talking about common opportunities, strong orientation through the legislative framework oriented towards green economy and sustainability in CACs increase the potential of circularity spread. With the help of international organizations, developing integrated water resources management can improve the whole ecosystem, as now consideration of water resources is not separated from other sectors like energy and land use. Climate change, which threatens the agricultural sector, creates an opportunity for a paradigm shift of the whole economy toward more enhanced food and water security [45]. All countries publicly reiterated their commitment to sustainable development by increasing awareness of green economic strategies, including reducing resource consumption, introducing resource-efficient technologies, low-waste strategies, and recycling waste actions. In addition, many international organizations are interested in cooperation toward sustainability and providing funding. Talking about education, many schools and universities adopt education sustainability, thus, orienting on growing ecologically-conscious generations.

Kazakhstan is the first country in Central Asia to develop a sound circularity in Almaty city; thus, the government is pioneering the circular economy across all CACs. As the agricultural sector requires a large amount of water consumption, instead of producing water-intensive wheat, switching that to Uzbekistan would help save water resources, as Uzbekistan can produce more wheat with the same amount of water [46]. In terms of the energy sector, the current intensive use of coal as an energy source is slowly but surely being changed to natural gas and renewables. **Kyrgyzstan** has great potential for the partial transition to solar, hydro, and geothermal energy in the future, contrasting wind energy sources' development as the low monthly and yearly mean wind power density and speed in the foothill zones of the republic [47,48]. **Tajikistan** possesses more than half of the CA freshwater resources, and integrated management of them is required and would be beneficial. Tajikistan has a huge potential to successfully transition towards a low carbon economy by investing only 2% of the GDP in ten key sectors, which include agriculture, waste management, and water management [35]. Tajikistan also has a potentially rich agricultural sector, with vast areas of viable land and undeveloped mountainous regions. **Turkmenistan** has a great opportunity for renewable developments, especially solar energy, which can increase energy security [49].

4. Conclusions and Implications

In CACs, most green initiatives are introduced on a macro-level—governments develop policies and strategic documents, and international organizations help in policy development and provide funding for green projects. Thus, CE development is introduced

by the top-down approach. Information on the micro-level—how industrial companies develop circular practices—is minimal, leading to the conclusion that CE is not popular on the micro-level. Nevertheless, CE transition requires creating enabling conditions for a higher level of involvement of the civil society in the "greening" process across multiple sectors. It was also observed that CACs need to build their human capital, stimulating a new generation to understand and manage modern technologies with a circular economy footprint.

The systematic literature review shows that the leading country in terms of circular development among CACs is Kazakhstan, as it has already started implementing circular practices. Nevertheless, Tajikistan is the most "green" country because it uses more renewables than others. Turkmenistan is the least "circular" country; however, it might be linked to the minimal information available due to internal policies.

Comparing CACs to Southern and East Asian countries, Central Asia has a smaller population and is facing lower industrialization rates in contrast to fast-developing China and India; thus, their effect of circularity development on the global environmental scale is lower. Due to higher technology development, South and East Asian countries could advance technologically in circular applications. In addition, CACs depend on effective Chinese water resource management to get clean and sufficient inflows. In terms of human resource capital, CACs have a considerably lower population compared to Southern and Eastern Asian countries, which decreases the professional competition.

To sum up, executing effective policies oriented toward green and circular development, ensuring the meaningful participation of all interested parties (citizens, industry, and businesses), and financing adequate amounts from governments and international organizations, can help effectively achieve circular economies in CACs. This study can guide managerial and governmental figures to adopt circular solutions by providing commonalities and differences between the circular economy and CACs, and clearly defining barriers and opportunities.

The current research study contributes with the following: (1) Provides an overview of the circular economy development in CACs, thus, giving a general understanding of the current situation; (2) Potential areas and directions of further circularity development through outlining barriers and opportunities. The limitation of the research lies in the amount of the reviewed literature, as well as those have undergone the subjective opinions of the authors regarding their relevance to the study. Nevertheless, the authors attempted to add as much relevant literature as possible. In future research, it would be interesting to explore local stakeholders' interest in CE development in the different sectors reviewed in this study and also dive into circularity applications in industry.

Author Contributions: Conceptualization, F.K. and A.T.; methodology, F.K. and A.T.; investigation, A.T., G.T., K.M.J., R.S., M.S.; writing—original draft preparation, A.T., G.T., K.M.J., R.S., M.S.; writing—review and editing, F.K.; visualization, K.M.J., A.T.; supervision, F.K.; project administration, A.T.; funding acquisition, F.K. All authors have read and agreed to the published version of the manuscript.

Funding: The authors acknowledge the financial support from Nazarbayev University Faculty Development Competitive Research Grant Program (Funder Project Reference: 280720FD1904).

Data Availability Statement: Not applicable.

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

Appendix A

Table A1. Data references.

Legal, policy, and regulatory framework	
Kazakhstan	• In 2013, a decision was announced to switch to a green economy model, which is expected to better manage environmental initiatives and improve water management [50]. • The country is the first in Central Asia to initiate a legal framework for the green economy transition through the implementation of several legislations, such as The Environmental Code (2007), The Law About Support the Use of Renewable Energy Sources (2009), and The Concept on Transition towards a Green Economy (2013), which focus on the improvement of sustainable water management, modernization of agriculture, enhancement of energy efficiency, waste management, and a decrease in air pollution [51–54]. • Kazakhstan Strategy-2050 and The Green Concept, the most crucial documents for future development, outline the country's strong focus on a green economy [49]. • Interesting to note that the circularity in CA is starting from Almaty, the largest city in KZ, which is also a hub of many regional centers [49,55]. Another important document—The Environmental Code—was established in 2007 and updated in 2019 and 2021 [56]. • The new code intensifies the obligation of industrial companies for pollution and emissions through increased payment, introduces public participation in the projects that might affect the environment, and establishes increased financing of green projects [56]. • According to the green economic concept, Kazakhstan aims to achieve a 15% GHG emissions reduction by 2030 and 40% by 2050 [56], while alternative resources would compensate for 50% of the energy requirements until 2050 [57]. "Kazakhstan-2050" strategy established several sustainable directions in terms of social, economic, and environmental sustainability [58]. • It also emphasizes the challenges of water scarcity, energy, and natural resource consumption and aims to achieve the same energy mix target with 50% electricity generation by green and alternative energy sources by 2050.
Turkmenistan	• Institutional mechanisms supporting the circular economy are governmental support, benefits for implementing waste-free, low-waste, resource-saving technologies and industries, and research to create progressive low-waste technological processes [59]. • Korostova (2020) investigated the legislative state of Turkmenistan regarding waste. "On waste" Law of Turkmenistan is a significant improvement in the country's waste management. The law's primary goals are waste reduction, circular economy introduction, and recycling of landfills [42]. • Other laws of Turkmenistan related to the environment include "On Nature Protection" (2014), "On the Protection of Atmospheric Air" (1996), Sanitary Code of Turkmenistan (2009), "On Radiation Safety" (2009), "On Chemical Safety" (2011), "On Hydrocarbon Resources" (2008), and "On Ecological Expertise" (2014) [42]. • Moreover, other regulatory frameworks such as regulation on state ecological expertise (1996), the National Oil Spill Prevention and Response Plan in Turkmenistan (2001), rules of protection of coastal waters of Turkmenistan from pollution from ships (2005), safety rules in the oil and gas industry (1995), and the Presidential Decree "On licensing of import, production and sale of chemicals" (2010) exist to help effectively manage waste and protect the environment [42].
Tajikistan	• The reforms were made by following the best practices of other countries and national traditions. Until 2015, Tajikistan adopted the NDS (National Development Strategy), which provides mid-term poverty mitigation implemented every three years. The government approved the Concept for Transition to Sustainable Development in 2007, which identifies the vision, goals, principles, objectives, and mechanisms by integrating environmental, economic, and social factors to achieve Sustainable Development. Currently, the government of Tajikistan has undertaken measures to address the efficiency of governance efficiency by encouraging entrepreneurship, increasing the attractiveness of investment opportunities, and solving limitations in the current infrastructure [35]. • Tajikistan's potential options in the transition towards a green economy mainly include its natural resources, infrastructure, and human resources. With over half of the total freshwater resources of CA in Tajikistan, it has an immense hydropower potential of around 527 billion kWh annually. In terms of overall hydropower resources, Tajikistan is ranked among the top 10 globally and ranked first for hydropower potential per square kilometer [35]. • The legal system in Tajikistan mainly follows a top-down approach, encompassing several actors that consider international agreements, constitutional laws, Majlisi Milli, and presidential decrees, among others. In terms of the environment, several new environmental regulations have been adopted since 2010 to tackle existing and emerging issues in Tajikistan [60].
Kyrgyzstan	• According to data provided by the investment portal of the Kyrgyz Republic, several old laws were approved for the environmental protection and the natural use of existing resources (e.g., Environment Protection" Protection of Atmospheric Air, Specially Protected Natural Areas, Biosphere Areas in the Kyrgyz Republic, Radiation Safety of Kyrgyz Population) [36]. In addition, the State Agency for Environmental Protection and Forestry under the Government of the Kyrgyz Republic is currently in charge of environmental protection, ecological security, and nature management policies [61].

Table A1. *Cont.*

Legal, policy, and regulatory framework	
Uzbekistan	• Since then, the country's place in the World Bank's "Doing Business" ranking has moved from 84th in 2015 to 69th in 2020 [62]. • The third Environmental Performance Review (EPR) of Uzbekistan, prepared under the auspices of the United Nations Economic Commission for Europe (UNECE), highlights Uzbekistan's progress toward sustainability goals over the past decade [63]. • There are such reforms linked to CE as the electrification of railways, ongoing municipal waste management reform, the introduction of enterprise-specific targets to reduce energy consumption, investments to expand water supply and sanitation, and environmental education. The review assessed the country's progress based on 64 2030 Agenda for Sustainable Development targets. Uzbekistan shows strong interest in transitioning to a green economy and adopting sustainable development principles, judging from its latest policy trends. In 2019, the country approved the strategy for the transition into a green economy for the period of 2019–2030, which prioritized improving energy efficiency in the industrial and consumer sector, introducing renewable energy, developing clean transport, improving water management and waste management systems, restoring forestry, developing financial and non-financial mechanisms to support the green economy, mitigating and adapting to climate change [64]. • The strategy has set particular implementation targets, including the reduction of GHG emissions per GDP unit by 10% from the 2010 level, doubling the energy efficiency index, growing renewables' share in electricity generation to 25%, improving water-use efficiency, increasing the productivity of agricultural food production by 20–25%, and other targets mainly concerning energy efficiency. • Uzbekistan ratified the Paris agreement and pledged to achieve the nationally determined contribution of bringing GHG emissions down by 10% from the 2010 level [65], which has also been reflected in the Strategy 2019–2030. Among the institutional arrangements relevant to the circular economy is the expansion of business entities' participation in organizing the collection, transportation, disposal, processing, landfilling, and use of waste. In addition, Uzbekistan's government creates favorable conditions for investing in the provision of services for collecting and removing household waste based on public–private partnerships (PPP) and is currently monitoring waste management in the country. On the way to introducing a circular economy model in the Republic of Uzbekistan, programs targeted for 2020–2021 were approved in the construction sector and equipment to landfills for construction and household waste [66]. • A new version of the law "On Waste" is being prepared, and negotiations are underway with foreign investors to implement joint waste recycling projects. At the same time, certain challenges to introducing a circular economy in Uzbekistan exist. An insufficient level of PPP implementation in household waste management and an unsatisfactory state of use of the available secondary material resources and the system of household waste recycling can be observed. The absence of a system for alternative biodegradable materials and a systemic failure to respond to offenses in environmental protection hamper the progress adequately. The lack of modern innovation and ICT in sustainability and waste management resulted in a slower advancement of circular economy [66].
Involvement with international organizations and Green Financing	
Kazakhstan	• CAREC (The Regional Environmental Centre for CA) is an autonomous international organization that aims to aid CA in tackling environmental concerns that was established in 2001 by the EU, UNDP, and governments of CA [67]. • The German Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety (BMU) conducted a pilot project in Kazakhstan that considers climate risks in the macroeconomic model, which could help in creating relevant policies and strategies [68,69]. • SWITCH-Asia is an international organization that promotes sustainable consumption and production (SCP). They assisted in local SCP plan development (e.g., Eco-Code); provided guidance on energy efficiency in buildings, agri-food, and textiles; as well as provided financial assistance to projects that implement SCP principles in tourism [70]. • Whereas the UN Special Programme for the Economies of CA (SPECA) focuses on sustainable development in CA, Azerbaijan, and Afghanistan, they have developed Innovation Strategy for Sustainable Development in 2019 [71]. • Another example is WECOOP (EU-CA Environment, Climate Change, and Water Cooperation)—its mission consists of the development of policies in CACs, mainly directed toward the prevention of climate change and water scarcity, and is financed by the European Commission [72,73]. • The investment needs for Green Concept implementation are projected to increase 30 times from 2014 to 2050 [53]. For instance, at the EU–CA Working Group on Environment and Climate Change session, it was stressed that improving the environmental situation requires substantial financing [73]. • Kazakhstan is the leading CA country in foreign climate investments [49], reaching around 2 billion USD over the last ten years, coming primarily from GCF, CIF, and EBRD. This financial aid is oriented toward green projects. The Global Environmental Facility (GEF), implemented by UNDP, has focused on projects that improve greeneries in cities, landscapes in the north of Kazakhstan, and wild apple species in the mountains. The Biodiversity Finance project, also supported by UNDP, conserves natural biodiversity [49]. • The government also supports green initiatives; for example, the Damu Entrepreneurship Development Fund provided green bonds to SMEs in 2020 to develop green projects [49]. • Other examples include UNEP activities in Kazakhstan to develop the PAGE framework since 2018. Such activities supported the development, drafting, and revision of several actions and laws, including the National Development Strategy 2050, Green Economic Concept, Low Carbon Development Strategy, Environmental Code, National Project on Waste Management, sustainable public procurement, and waste [49]. • Another project, Green CA by German partners, aims to develop access to data and risk analysis for better management and anticipation of climate change in 2021–2024 [74].

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Kazakhstan	• The CA Climate Information Platform for collecting data relevant to climate change mitigation contains geodata, online courses, and a database of relevant documents under the support of the World Bank (WB) [75]. The financing of sustainable agricultural projects by the WB has reached $340 million [49]. • Moreover, the Astana International Finance Centre (established in 2018) aims to be the head office for financing the Eurasian Economic Union, and it has a Green Finance Centre, which covers the development of green financing in Kazakhstan. • The Asian Development Bank (ADB) auctioned its first green bond valued at 32 million USD in 2020 [49]. Helping in the development of a green economy is one of the prime directions of the EBRD in Kazakhstan. Thus, the bank plans to develop and execute an approach to make Kazakhstan carbon neutral by 2060 (in energy and gas infrastructure). EBRD also promotes a green economy among SMEs by granting up to 75% co-financing businesses for green consulting services [76]. Local Kazakhstani banks also support EBRD in green financing [77].
Turkmenistan	• The government is involved in the "Leave no one behind" Agenda 2030 and co-financing SDG projects. According to UN Progress Repost 2016–2017, the government spend $4,091,893 for SDG projects [78]. • In 2016, a project named "Sustainable Cities in Turkmenistan: Integrated Green Urban Development in Ashgabat and Awaza" aimed to increase the city lighting systems, energy efficiency, and sustainable transport solutions, as well as city-scale sustainability and waste reduction [79]. • Another sustainability-related project by UNDP is "Energy Efficiency and Renewable Energy for Sustainable Water Management in Turkmenistan," which aims to achieve an environmentally friendly water supply, reduce greenhouse gas emissions related to water management, and provide a plan for the prevention of the desalinization of lands [80]. • Most of Turkmenistan's green/climate financing comes from the GEF and Adaptation Fund, which is $20 million out of a total of $200 million funding for climate projects. The remaining part is co-financed by the government [49]. • Foreign investments mainly focus on the oil and gas industry, while the state controls the remaining energy sector. GEF and Adaptation Fund resources are used via project collaborations of the Ministry of Agriculture with UNDP. In addition, Germany provided support for a project related to sustainable forestry and pasture management, focusing on mitigation and adaptation [49]. • GCF is developing a project focusing on increasing the resilience of the country's water sector towards climate change, mainly aimed at developing effective governance mechanisms and processes for adaptation planning to climate change [34].
Tajikistan	• UNDP actively participates in the development area, and WB and International Monetary Fund (IMF) provide financial support [81]. • Construction work on Rogun Hydropower station was financed mainly from the national budget and external investments and loans. The World Bank was also involved during the Feasibility Study stage of the project. Rehabilitation work on the Nurek Hydropower Plant was financed by multilateral banks, including WB, ADB, and Eurasian Development Bank. In Golovnaya Hydropower Plant, renovation works were carried out through the support from ADB, while Kairakkum Hydropower Plant managed to increase its capacity and improve the resilience of the dam using funds from EBRD and Climate Resilience pilot programs. New metering and billing systems were introduced in the Sugd Province through external financing from the EU, EBRD, and European Investment Bank [49]. • In agriculture, water and waste management sectors, multilateral and bilateral funding sources were utilized. The WB was involved in the rural water supply and sanitation project, initiated to improve access to basic water supply and sanitation services. The Khatlon Region Water Supply Project, supported by Japan, is aimed at developing the necessary infrastructure to address the water access needs of the region. In addition to capacity building for local water companies in the Northern Tajikistan region, rehabilitation of drinking water infrastructure was supported by Switzerland, EBRD, and GEF [49]. • Environmental protection, disaster risk aversion, and climate monitoring projects were other sectors implemented and financed by the government and external agents. Climate-proofing for flood protection works in the Pyanj River Basin was carried out through support from the Climate Investment Fund (with co-financing from ADB). In addition, early warning systems were developed during the execution of this project. In the Pamir Mountains in Khatlon Province, strengthening of critical infrastructure as well as protection against natural disasters was performed through funding from the WB. Tajikistan Hydromet modernized its tools and methods while advancing meteorological and hydrological solutions through financing streams from GCF [49]. • The total amount financed for climate and green initiatives in the past decade is estimated to exceed $1 billion through multilateral banks such as WB, EBRD, and ADB, among others [49]. • Most of Tajikistan's climate financing comes in the form of concessional loans and grants. This funding includes ADB, EBRD, CIF, and GCF, as well as Canada, Germany, Norway, and the EU [49]. Using national and international funding sources, Tajikistan has carried out different projects across several sectors, including energy, transport, industrial, agricultural, water, waste management, environmental protection, and disaster risk aversion.

Table A1. *Cont.*

Kyrgyzstan	• United Nations Industrial Development Organization (UNIDO) supported (1993) the development of renewable energy sources, agriculture business, and processing; Economic Cooperation Organization (ECO) had a key role in establishing favorable conditions for economic development and consistent integration of region stats into the economic relations of the country [80]. • According to the survey provided by the WB, Kyrgyzstan has a relatively high level of green economy commissioning and coordination, which operates as a driver of climate-related activities [49]. • The only document developed to rationalize the use of natural resources and apply green technologies to reduce pollution in Kyrgyzstan is the National Sustainable Development Strategy dated 2013. The strategy states that in recent years, the socio-economic and political activities of the country have experienced radical changes for the development of the country's future as the nation and its people have already paid a high price for creating a strong, prosperous and sustainable society [82,83]. • Even though most of the green financing in Kyrgyzstan comes from international sources, the government has initiated a policy framework to promote green financing among diverse investment sources [49]. • According to the WB, the republic has received more than $150 million from international climate funds in the last ten years. Moreover, a similar amount was provided for energy efficiency, disaster risk reduction, and water resilience by multilateral banks such as EBRD, ADB, and WB [49]. • From 2011 to 2016, the following investments were recorded in green financing: 6.5 billion Kyrgyz currency (equivalent to 1% of national GDP) was provided by the government, 4.8 billion Kyrgyz currency was contributed by the private sector, and 1.2 billion Kyrgyz currency came from development partners and international financing [84].
Uzbekistan	• In 2021, UNECE Uzbekistan produced a set of recommendations that will guide the country's sustainability reforms and innovation [85]. The recommendations concern innovation policies, strengthening institutions, and improving policy implementation mechanisms. Uzbekistan is also expected to participate in two projects by UNECE, the Trees in Cities Challenge, a global campaign aimed at greening urban areas, and the UNECE Road Safety Performance Review [85]. • WB also provides extensive support to Uzbekistan regarding financing, consulting services, and analytics. During the round table "Support for environmental, low-carbon development of industry and economy" in 2021, organized by the Ministry of Economic Development and Poverty Reduction and WB, the latter underlined that the WB had allocated around $600 million for investments in energy efficiency [86]. • In 2020, UNIDO and the Ministry of Economic Development and Poverty Reduction signed a Joint Declaration to promote cooperation in various areas, including, amongst others, green industry, a circular economy, renewable energy, energy efficiency, agro-industrial clusters, and light industry modernization. UNIDO cooperation has lasted for over 27 years and currently comprises 15 completed projects focusing on technical assistance and policy advice for national investment promotion, sustainable employment and entrepreneurship development, export-oriented trade, cleaner production, business incubators, and enterprise development [87]. • From 2013 to 2020, the German Federal Ministry for Economic Cooperation and Development (BMZ) commissioned the "Sustainable economic development in selected regions of Uzbekistan" project, co-funded by the EU. The key objective of the initiative was to support the growth of small and medium-sized businesses and create employment opportunities in rural areas of Uzbekistan. The project focused on developing an environmentally sound economy and promoting environmentally friendly technologies and EU agricultural and environmental standards in Uzbekistan [88]. • In 2019, the EU extended its SWITCH-Asia Programme to include CA, including Uzbekistan. The SWITCH-Asia Programme supports Sustainable Consumption and Production (SCP) and the transition to a low-carbon circular economy by providing grants and policy support to the government in promoting the SCP [89]. • A critical aspect of SWITCH-Asia's work is the enhancement and implementation of SCP tools and circular economy approach in the textile sector. That work dimension is aimed at greening the supply chain, reducing water and energy consumption, substituting chemicals, and stimulating the transition to sustainable production practices in Uzbekistan's textile and garment sector [89]. SWITCH-Asia has also planned to prepare a scoping study on textiles and garments and a benchmarking analysis of Uzbek textile enterprises. Uzbekistan plans to launch a green bond sale to support the green economy transition agenda [90]. • Through the Green Economic Financing Facility (GEFF), with a fund size of USD 60 million, EBRD is known to provide loans to Uzbeki financial institutions (banks, microfinance organizations, and leasing companies). These loans are dedicated to investment in green technologies and services in Uzbekistan's private sector [91]. • Uzbekistan has the presence of green financing instruments in the commercial banking sector. For instance, in 2021, Uzpromstroybank, one of the oldest financial institutions in Uzbekistan primarily owned by the state, received the "Best Green Bank" award for offering a line of green financial products including green loans for businesses and green mortgages. Uzpromstroybank's green finance initiatives are partially backed by the IFC's US $75 million loans [92]. • The bank has also adopted the Environmental and Social Risk Management Policy and System Procedure [93]. • Another state-owned bank, Sanoat Qurilish Bank, the largest lender to key industrial sectors in Uzbekistan, has a green finance department and collaborates with EBRD, IFC, and other institutions [90].

Table A1. *Cont.*

Water resources management	
Kazakhstan	• Kazakhstan's water level is 40% lower than the world's average water level [94]. USAID is developing a project that is planned to be implemented in 2020–2025 and aims to improve water management of the Syr Darya River basin, which is shared by Kazakhstan, Tajikistan, and Uzbekistan [95]. • World Bank, in turn, funds initiatives on Climate Adaptation and Mitigation Program for Aral Sea Basin [74]. • The Astana Integrated Water Master Plan, funded by the Japan Fund for Poverty Reduction, aims to improve water management for both industrial (i.e., agricultural activities) and social (i.e., urban water provision) purposes in Nur-Sultan through 2019–2020 [96]. • Another initiative—Blue Peace CA, funded by GIZ, the World Bank, the EU, and Geneva Water hub—aims to ensure equity among the Central Asian countries in terms of water resource use [97]. • Due to the loan funds from the Islamic Development Bank (IDB) and the EBRD, irrigation and drainage system projects are being executed in the South and Western Kazakhstan regions.
Turkmenistan	• Turkmenistan's economic development is highly dependent on the availability of water resources, whereas the amount of water is decreasing each year [98]. • USAID funds research on Turkmenistan's prime river basin—the Amu Darya—which faces negative consequences from climate change [99]. • In 2015, UNDP started a project that helps improve local policies and, thus, aims to improve water management infrastructure [80].
Tajikistan	• Tajikistan has an abundant water resource with an availability of 981.5km^3/year. Approximately 576 km^3 of the total water resources are glaciers and snowfields. Tajikistan has over 1300 natural lakes, with a total volume agglomerating to 46.3 km^3. In addition, the total annual flow of the 947 rivers/intermittent rivers makes up about 64 km^3 of the total, of which 62.9 km^3 comes from the Amu Darya River Basin [59]. • Tajikistan is not part of international and transboundary regulations, including the 1992 Convention on the Protection and Use of Transboundary Watercourses and Lakes and the 1997 Convention on the Law of the Non-navigational Use of International Watercourses [100]. • Agriculture takes up most water resources, over 10 billion cubic meters; industrial and municipal uses are relatively minimal, making up less than one cubic meter each. Total and agricultural water use has also been reduced slightly since 1994, while municipal use increased within this period [101]. • Since 2014, foreign institutions such as the EU, ADB, USAID, and WB have proven effective in utilizing water resources in Tajikistan, and thirty-two projects financed by approximately 20 donor institutions were implemented in the water and sanitation sector [61].
Kyrgyzstan	• Hydropower plays a significant role in the energy sector of Kyrgyzstan, accounting for over 90% of electricity production [47]. • The region has thousands of river streams over 150 thousand km long, creating a huge potential for hydropower energy development. Moreover, the current operational volume of hydropower energy in Kyrgyzstan comprises 252 medium and large-sized rivers, making more than 80 billion kW*h per year [102]. • According to information provided by the Kyrgyz State Water Resources Agency, Kyrgyzstan is the only country in CA whose water resources are almost completely fulfilled by its territory, making water and hydropower energy one of its primary wealth sources [103]. • On the other hand, some potential losses occur in water management areas [104]; a decline in the water volume of diversions due to the reduction in irrigated areas and a decline in the efficiency of water delivery from more than 80% to nearly 60%. The Water User Law-2002, Water Code-2005, and National Water Strategy-2011 are the primary legal regulations for water resource management in the Kyrgyz Republic [105].
Uzbekistan	• Uzbekistan has two large rivers, the Amu Darya and the Syr Darya, with total lengths of 2660 km and 2982 km, respectively [106]. • About 52% of water in those rivers' basins is used by Uzbekistan [104], and most Uzbek rivers dry up in their course. Uzbekistan has the largest territory of irrigated agriculture in Central Asia, with about 10% of its part [107]. • Around a quarter of the population is employed in agriculture [108]. • Around 90% of water in Uzbekistan is consumed by the agriculture sector, with the remaining 10% consumed by industry and households, and water loss remains a problem [107]. • Around 33% of water is lost because of inadequate irrigation techniques and obsolete infrastructure. As of now, the government subsidizes water-saving practices in agriculture. According to experts, over the next 10–20 years, climate change will lead to an increase in the average annual temperature, an increasingly hot and dry climate, and a shortage of water in Uzbekistan [109]. • The Aral Sea depletion might significantly exacerbate the situation [107]. Accelerating the simultaneous introduction of more productive crops and resource-saving irrigation systems is necessary.

Table A1. *Cont.*

Education and research	
Kazakhstan	• Kazakhstan hosts the annual Central Asian leadership program, which was established in 2009 [109]. It focused on educating young professionals about opportunities in sustainable development in CA. In 2021 it narrowed its focus from "sustainability" to "circular economy." • Under the support of UNESCO, the Kazakh–German University has developed a special master's program that is oriented toward raising professionals in sustainable water resource management and organizing local eco-business incubators [110]. • Another example of the circular economy—the Green Campus at Nazarbayev University—aims to decrease GHG emissions and enhance waste management on campus through students' engagement in the local projects [111]. For example, Sustainability Living Lab at the Green Campus provides funding for green projects. • Overall, Kazakhstani schools and universities encourage awareness of circularity through different workshops, online courses, and games, and some of the initiatives are funded by UNDP [55].
Turkmenistan	• Individual and collective efforts to promote sustainable development can be seen in the education sector of Turkmenistan. School teachers are role models for waste collection and reusing them for different purposes, increasing students' awareness about waste pollution and creating behavioral changes among children [112]. • Moreover, the Government of Turkmenistan, in a partnership with UN Agencies, organized educational sessions in summer camps for children aimed at increasing ecological awareness [112]. • Moreover, according to the Ministry of Nature Protection of Turkmenistan, environmental extracurricular works such as contests, thematic parties, poster competitions, and environmental lectures are part of the educational program. • In addition, the 'ecology' subject was added to the school curriculum to implement the Rio convention successfully. While the higher school subject "Doctrine of Saparmurat Turkmenbashi on Nature Conservation" is aimed to teach the main concepts of human–nature interactions, ecology, rational nature management, and the solutions to regional and global environmental issues [113].
Tajikistan	• Environmental education in Tajikistan is incorporated at all levels of the education system. Tajik youths are aware of environmental issues early on and continue throughout their secondary and tertiary education. Informal education, mainly through specialized NGOs, also contributes to the educational awareness of the environment among the population. In Tajikistan, environmental education occurs in the following stages [60].
Uzbekistan	• Currently, the concept of Education for Sustainable Development (ESD) in Uzbekistan, adopted in 2008, is implemented in the systems of formal (based on state educational standards) and informal (based on extracurricular, optional, and additional classes) education. ESD is integrated into curricula and courses as an independent academic discipline and is integrated into other traditional academic disciplines [106]. • The National Committee on Environment promotes the improvement of the level of environmental education of the general population, organizes professional development of employees of its system, and provides methodological and material assistance to other departments and organizations in these matters. • Together with the Ministry of Public Education and the Ministry of Higher and Secondary Special Education of the Republic of Uzbekistan, seminars on environmental education and ESD, recommendations on the organization of environmental education for students of various classes are being prepared, and special programs for environmental clubs at schools have been developed [106]. In all higher educational institutions and some specialized secondary and vocational educational institutions, the subject of "Ecology" and "Environmental protection" is included in the curriculum. On average, every year, about 310 environmental specialists graduate from the universities of Uzbekistan [106].
Kyrgyzstan	• According to information provided by UNESCO, fourteen schools in Kyrgyzstan introduced the online pilot of five modules related to sustainable development topics into the educational program of students in the 5th and 6th grade [114]. The pilot showed a high interest in the topic of both teachers and students, potentially creating a possibility of development of that area in the educational system.
Energy and GHG emissions	
Kazakhstan	• Kazakhstan's economy heavily relies on coal energy. The local energy sector accounts for 85% of the country's GHG emissions. Kazakhstan's GHG emissions are the largest in CA and one of the largest in the world. The New Environmental Code defines quota distribution and carbon trading for GHG [56], which is expected to rise 15 times from 2021 [115]. • In 2016, the Paris Agreement was signed and ratified. The same year, the NDC (Nationally Determined Contribution) was released. The first Nationally Determined Contribution aims to reach a 15% reduction of greenhouse gas emissions by 2030 compared to 1990. From 2015 to 2020, EBRD conducted 15 green projects, financing around 237 million euros. These actions reduced CO_2 emissions by 2.5 million tons and coal consumption by 2.7 million tons [76]. • The bank also allocated 30 million USD to invest in modernization towards the energy efficiency of households and SMEs under the Green Economic Financing (GEF) program. In 2009, a new law supporting renewable energy sources was released [116]. • Almaty and Nur-Sultan, the two largest cities, aim to increase gasification levels up to 60% from the current 50%, while renewable energy sources use aims to increase up to half of the total energy use in 2025 [49]. • It is also planned to develop national standards on green energy to boost local market development in renewable energy [117].

Table A1. *Cont.*

Energy and GHG emissions	
Turkmenistan	• The main greenhouse gas (GHG) emission sources in Turkmenistan are oil and gas, agriculture and transport, energy industries, and housing and communal services. Turkmenistan, which ratified the Paris agreement in 2016, plans to mitigate GHG emissions in 2020–2030. It includes energy efficiency and conservation, sustainable consumption of natural resources, and increased implementation of alternative energy sources [118]. • According to World Bank data, the GHG emission of Turkmenistan has a decreasing trend starting from the year 2015 [119]. • Turkmenistan aims to reach zero growth or even reduce GHG emissions with technological and financial support from developed countries [118].
Tajikistan	• The Tajikistan government, along with some designated bodies, is responsible for monitoring the various activities of energy agents, addressing consumer and property rights, and determining energy market pricing [60]. • Analyzing the policy framework shows an absence of long-term planning and gaps in the energy sector, posing a great threat to making the energy sector resilient to climate. • The 2007 Comprehensive Program, which aimed to expand renewable energy resources, considered production and better infrastructure for broader adoption of wind, solar, biomass, hydropower, and geothermal powers [60]. • Due to the country's hydroelectric power generation potential, over a third of its energy is produced from its water resources [120]. Consumption levels reside between 20–30% of consumed energy [121]. According to the Ministry of Melioration and Water Resources of the Republic of Tajikistan, only 5% of Tajikistan's Hydroelectric potential has been utilized so far [34].
Uzbekistan	• Uzbekistan's population has been significantly increasing and is expected to grow from 32.7 million in 2018 to around 37 million in 2030. At the same time, the country's economic growth rates and GHG emissions are expected to rise significantly. • A major part (82%) of the total emissions come from the electricity generation sector, demanding concrete measures to reduce its carbon footprint. As of 2019, Uzbekistan does not use any renewable energy sources except hydropower for electricity generation. That is despite the fact that the country has substantial solar power generation potential, estimated at 2.0 mln GWh a year [63].
Kyrgyzstan	• Kyrgyzstan's main energy resources are coal, gas, electricity, thermal energy, hot water supply, and fuels. However, forecasts from leading energy agencies point to the growing electrification of the energy sector as one of the main trends in the development of the global energy system, along with the rapid deployment of clean energy technologies and their declining costs [122]. • A long-term transition to a service-oriented economy with a cleaner energy consumption structure is expected. It means that the share of electricity in the consumption of fuel and energy resources may increase in the future perspective—Kyrgyzstan imports around 90% of its natural gas and oil [23]. • However, according to the NDC, about 60% of all GHG emissions are concentrated in the energy sector due to the implementation of significant infrastructure projects between 2010–2020 [123]. • The mitigation program declared some goals to reduce GHG emissions under the business-as-usual (international support) scenario by 16.63% (36.61%) by 2025 and by 15.97% (43.62%) by 2030 [123].
Waste management and recycling	
Kazakhstan	• Waste management in Kazakhstan is one of the most complex problems at present. Lack of proper and strict regulations and low interest in ecological impact has resulted in more than 3500 illegal landfills in Kazakhstan [95], while around 5.0 mln MSW is created in Kazakhstan [124]. By 2021, approximately 32 billion tons of waste were collected, and only 15% of household waste and one-third of industrial waste were recycled [125]. • Following the Green Concept, waste recycling should reach 40% by 2030 and 50% by 2050 [124]. The waste is also reconsidered in the new environmental code. Thus, a particular hierarchy is created to help reuse, recycle, or dispose of the waste. In addition, the trucks that transport waste should be equipped with GPS to avoid illegal landfilling [126]. Moreover, education of the public on waste sorting is also outlined in the new code. • With the support of international experts from PAGE, the Draft National Project on Waste Management was developed [127]. In 11 cities, 12,196 containers for separate collection of MSW and 147 waste collection points were established [59]. Several initiatives work on the improvement of waste management locally. Thus, in 2014, a consortium on the development of vermiculture was developed, and they have successfully tried using special worms for organic waste processing [128]. • EBRD and TengizChevrOil developed an education course for SMEs on waste management; around 85 companies have already passed it [125]. Kazakhstan Waste Recycling is an initiative that collects paper, plastic, and aluminum from the citizens of Almaty, thus achieving five thousand tons of recycling per month [55]. • The International Green Technologies and Investment Center (IGTIC), launched in 2018, aims to promote and support green tech business in Kazakhstan. One of the examples of their work is a project on solid waste management development in Kazakhstani resorts with the involvement of foreign experience to implement green technologies [129,130]. • Another example, EBRD, has provided $30 million to improve waste management in the eastern part of Kazakhstan [49]. • The construction sector, which creates the most industrial waste, faces fast growth due to rapid economic development [18], holding 6% of the country's GDP [130]. • Moreover, national policies are oriented towards an increase in residential construction. Therefore, sustainable and circular principles in the construction sector are inevitable for diminishing environmental effects. One of the most recent developments—the modular structure fabrication factory—started in Kazakhstan's capital in 2021 [18], and it would aid the development of circular principles in the construction, making the structures easier to deconstruct and reuse. • Nevertheless, although local construction codes do not yet require the application of the circular principles (except for environmental impact assessment of the projects), the only interest of the construction companies lies in the economic feasibility [19]. • Several initiatives are oriented toward making the local construction sector more circular. Thus, KazGBC trains construction professionals in green building principles; Almaty MasterPlan develops greener principles, aiming to make Almaty a "City for people"; ArchCode encourages citizens to participate in debates on deciding the fate of the architectural heritage [55]. • International organizations also aid in developing green construction: thus, EBRD develops a project that establishes centralized construction and demolition waste recycling facility to decrease new resource recovery. Moreover, EBRD elaborates on a roadmap and technology that enable low-carbon cement development. Some examples of industry-focused research with a particular focus on the construction sector are given in [18,19,131–134].

Table A1. *Cont.*

Waste management and recycling	
Turkmenistan	• The majority of waste in Turkmenistan is caused by oil production. Oil waste lies under the responsibility of the producing companies. Household waste is collected from primary collections spots in urban areas and, in addition, door-to-door collection in rural areas, which is then buried in landfills allocated by the Ministry of Agriculture. No private or international sector is participating in waste collection. However, some private companies are recycling recoverable materials [42]. • UNDP summarized Turkmenistan recycling, including plastic, paper, and organic waste. In partnership with UNDP and GEF, private companies recycle paper and plastic waste. The recycled materials are used to produce corrugated and packaging cupboards, food containers, and plastic bottles for detergents. At the same time, organic waste is used to create vermicompost with the help of worms, which increases the fertility of the land and can be used in farms and greenhouses [135]. • The UNDP/GEF project established plastic waste collection containers in the first phase of the waste management campaign and partnered with innovative plastic recycling companies (e.g., Begler Yoly), which produce plastic containers for food products, fruits, vegetables, and bottling detergents. Thus, all trimmings, residues, and defective products are fully reused [136].
Tajikistan	• There are over 70 landfills in Tajikistan, with 700–800 tons of garbage being disposed of in landfills every day [137]. Each year, the waste generation figures are increasing due to the lack of capability of the government to deal with these large quantities of waste [138]. Landfills also produce gas, negatively affecting nearby neighborhoods and settlements [139]. Aside from the foul smell, these gases contribute at least 25 times more than normal carbon emissions [140]. • Landfill sites are highly flammable, posing a threat to the inhabitants nearby and the flora and fauna surrounding these sites. The problem of unauthorized landfills has also emerged due to poor waste management practices and policies. These sites can present an existential threat to communities and compromise community health on a larger scale [141]. • Waste processing, particularly plastic, has been partially implemented in the Dushanbe landfill. The Dushanbe landfill can also recycle mercury materials; however, it has never been used [141]. • The absence of waste sorting is another challenge in proper waste management, arising from a lack of awareness about proper waste disposal. Houses and communal areas are also not equipped with the necessary containers for garbage disposal. Thus, approximately 97% of waste products cannot be segregated and, therefore, are impossible to recycle [141].
Uzbekistan	• Uzbekistan has a strong intention to solve waste management issues. In 2019, the "Solid Waste Management Strategy 2019–2028" was introduced by the President of Uzbekistan, with the main aim of establishing an effective infrastructure for waste management [142]. • The long-term mitigation strategy creates an opportunity for potential investors to implement projects in the area. Some of the waste management area projects are initiated by the participation of international organizations. For instance, in 2022, a loan of 70 million USD was approved by the European Bank for Reconstruction and Development to modernize the region's solid waste management (SWM) infrastructure [143]. • The project's key objective is to finance the building of sanitary landfills, waste transfer stations, waste sorting plants, and the supply of special equipment for the area, which will help bring environmental benefits and result in GHG emission reduction. The recommended measures proposed by the United Nations in its environmental performance review to improve the waste management initiatives were: the development of a new set of laws on waste management; elaboration on prioritizing the modernization of existing landfills; introduction of a waste classification system based on the physical (chemical) characteristics; considering the establishment of a state-owned company specialized in medical waste management; preparation of the chemical's profiles by the application of big data; and the provision of training on safe waste management [144].
Kyrgyzstan	• Kyrgyzstan is not an exception to the problems of waste management. Recent work by the UN agency indicates that the controlled disposal and collection coverage rates of 50 and 95% are determined in low- and middle-income cities [145]. • More than 400 landfills were determined in Kyrgyzstan in 2018, 75% of which are unauthorized ones. The main landfill is named Tazalyk and is located 10 km north of the city, receiving a huge amount of waste, including household, commercial, green, medical, and other types of waste [146]. • The recycling rate for Bishkek was determined to be around 18% because the majority of recyclers are informal ones (more than 9000), 75% of whom are street pickers who are either retired (33%) or homeless (44%) [146]. • The total tonnage of waste collected by the informal recycling sector is around 35,000 tons per year, while the city landfills collect more than 200,000 tons of waste per year [146]. • The Kyrgyz Republic has relatively reasonable controlled disposal and waste collection coverage levels compared with countries with a similar income level. On the other hand, according to data provided by UNDP, more than 100 million tons of consumption and production waste are stored in 60 dumps, resulting in about 1000 tons of garbage collected daily. More than 16 million tons of solid waste and garbage are currently in landfills near cities and villages in Kyrgyzstan [147]. • To diminish industrial construction waste, currently, the UNIDO initiative in Kyrgyzstan supports the production of environmentally friendly, innovative, and cost-effective construction materials by conducting feasibility studies and helping in funding activities [148]. • According to UNECE, most of Kyrgyzstan's buildings follow the Soviet construction models with low energy-efficiency [149]. Therefore, the existing construction market has a huge potential in terms of investments in material production, the export market's development, and the renovation of existing construction standards.

Table A1. *Cont.*

Agriculture	
Kazakhstan	• Agriculture activities in Kazakhstan hold around 5% of the country's total GDP, and Kazakhstan is the largest wheat producer in the world [30,150]. • Taking into account the importance of agricultural activities for the country, the government seeks productive and, at the same time, environmental-friendly agricultural practices. Thus, the World Bank recently invested in the Sustainable Livestock Development Program, which aims to develop sustainable beef production in Kazakhstan in 2021 [151]. Apart from competitive and efficient beef production, it aims to diminish environmental effects by implementing green growth policies in the beef sector. • Examples of circular agricultural projects include (1) Amiran—a dairy product that has a sustainable value chain; (2) Quan—an organic fruit and vegetable market; (3) KazEcoFood and Agaricus—grow mushrooms in chicken manure; (4) Arba Eco Ayul—growing organic vegetables and fruits; (5) KazHemp—produce paper from hemp; (6) Flyworx—use drones to map the land for agriculture and evaluate them [55].
Turkmenistan	• Turkmenistan has developed a national program called "Fundamental Directions of Economic, Political, and Cultural Development of Turkmenistan in the period up to 2020", which includes sustainable development of the agricultural sector of the country focusing on water use, innovations in irrigations, renovation of collector-drainage systems, soil and moisture conservation, land reclamation, and standardization of fertilizer and chemicals use [50]. • UNDP identified four major barriers to implementing agricultural sector climate resilience: (i) agrometeorological monitoring, delivery of climate information, and forecasting; (ii) limited abilities to existing agricultural services offered by district administrations and associations; (iii) limited access to resilient technologies; (iv) policies and regulatory frameworks are incomplete [50].
Tajikistan	• Tajikistan's diverse agricultural sector employs over 40% of the total workforce. Agricultural outputs include potatoes, onions, wheat, melons, and other products. Local consumption is given priority; however, over 120,000 tons of food products are exported annually, constituting approximately 3% of total exports [152]. Due to adverse climate change impacts, yields from agricultural processes have experienced a decline. • In Tajikistan, agricultural projections are grim, with a 5–10% decline in production by 2050. In addition, drought and heatwaves are expected to increase, destabilizing agricultural production. • The melting of snow and glaciers is another effect of climate change that can affect agricultural practices. As mentioned earlier, water resources are shrinking; as a result, creating potential problems in irrigation and agriculture in the long-run [152].
Uzbekistan	• Uzbekistan is the largest producer of cotton in the world [30]. • Agriculture generates a third of the country's GDP. The agricultural sector is one of the biggest income sources for Uzbekistan's rural population, which makes up over 60% of the entire population. In addition to satisfying demand within the country, the agricultural sector yields a surplus for export. • Uzbekistan is one of the top 10 producers of cherries, grapes, apricots and dried apricots, raisins, and persimmons [144]. • Measures implemented by the government of Uzbekistan have increased investments in the agricultural sector. Between 2014 and 2017, investments have grown by roughly 64%. Agricultural output has also increased steadily, resulting mainly from productivity growth in agricultural lands. Crop diversification is another measure adopted by the government to increase productivity and yield of the agricultural sector [144]. • The main agricultural activities in Uzbekistan include crops such as wheat and cotton to maintain food security and drive export revenues, respectively. Animal husbandry is another agricultural sector with meat output steadily growing between 2010 and 2018. Poultry products have also increased two-fold, and the number of cattle grew by 45%. The fishery is a third branch of the agricultural sector as part of the government initiative. Fishing occurs in natural water bodies as well as artificial water reservoirs established by the government [144]. • Circularity approaches in agriculture aim to improve production output by minimizing environmental damage, reducing external input, and introducing closed-loop practices [153]. By applying these principles, Central Asian countries like Uzbekistan can potentially reduce the lost value due to land degradation, which amounts to roughly 3% of GDP [154]. • Altering fertilizer use can reduce carbon emissions by over 16 million tons yearly [153].
Kyrgyzstan	• Agriculture is considered one of Kyrgyzstan's most important economic sectors as it contributes about 22% to the national GDP and creates about 35% of the republic's workforce [155]. • Governmental land-reform policies became a significant catalyst for the development of the agricultural sector leading to rapid economic expansion. • Despite the rise of the agricultural sector during the past decades, the human capital levels remain relatively low, and the majority of the workforce does not have adequate skills related to the lack of experience of farmers [155]. • The fundamental problems in the circular agriculture industry are (1) Transport infrastructure—as the vast territory part is mountainous, the road and railway infrastructure play a significant role, (2) Storage infrastructure—the capacity of existing storage is low, resulting in the reduction of quantity and quality of the products, more than 15% of goods are spoiled before reaching the market [155]. • The development of the agriculture sector of KGZ is slowed by many socio-economic problems that have to be solved to reach the success of becoming a part of a broader development social policy strategy [155].

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