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Lejla Terzić

University of East Sarajevo, Bosnia and Herzegovina

ORCID 0000-0002-5048-036X

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ASSESSING PROGRESS TOWARDS A CIRCULAR CARBON ECONOMY IN THE G20 COUNTRIES

Lejla Terzić

University of East Sarajevo, Bosnia and Herzegovina

ORCID 0000-0002-5048-036X

Abstract: As cornerstones of worldwide sustainable development, the circular economy and the circular carbon economy are profoundly interrelated. However, opinions differ on how to optimize the circular economy towards reducing carbon dioxide emissions. This article aims to investigate the different levels of readiness for the circular carbon economy within G20 member countries in the domain of economic efficiency. In that regard, a selection of circular carbon economy sub-indicators has been analysed. Through the use of secondary data, tendencies towards change in this variability were found. The degree of adoption of a circular carbon economy differs among the G20 economies. In terms of the various factors considered in the G20 member countries, the current analysis has determined that there continue to be substantial differences between the best performers and their enabling factors.

Keywords: circular carbon economy; circular economy; assessing progress; G20 countries

JEL codes: O57; Q01; Q50

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Introduction

The idea behind the circular economy stems from several ideologies and schools of thought that criticize the current economic structure, which is predicated on excessive resource use. The realization that natural resource efficiency and supply sustainability are essential for economies and enterprises has led to increased global interest in the circular economy and circular carbon economy over the past decade. Many governments and companies worldwide have embraced this idea, viewing the circular economy as a means of resolving what initially appear to be the opposing goals of sustainable development and economic expansion (Preston, 2012; Lieder & Rashid, 2016; Ghisellini et al., 2016; Rizos et al., 2016; Saputra et al., 2022). There is a huge knowledge gap as to what is needed to achieve circularity – i.e., financial resources and other measures- and it is still difficult to compare relative positions and determine where each country stands today in terms of moving towards net-zero emissions and a circular carbon economy. A portion of this results from each nation's reluctance to be compared to others due to the vast differences in their national conditions and growth paths. Different countries have varying strengths and weaknesses when it comes to mitigating the effects of climate change and making the transition to a net-zero energy system because of their unique historical circumstances and domestic assets. Because of this, the road to net zero will differ for every nation. However, international comparisons are helpful for several reasons, such as determining particular strengths and shortcomings as well as leaders along with those who are at risk of falling behind. Consequently, this can aid in promoting global collaboration to close gaps and assist all parties involved in the shift.

The lack of beneficial, common national assessment frameworks for net-zero transitions can also be attributed to a broader disagreement regarding which mitigation methods and technologies must be prioritized, or even accepted, in the overall set of policies. For instance, many nations feel left out of transition paradigms that emphasize the necessity of concentrating solely on energy efficiency and alternative sources of energy, as this seems unachievable in the relatively short run. Still, it is generally acknowledged that nations should employ all available technology as quickly, practically, and in the most economical way possible, considering the pressing need to lower emissions.

The economic implications of the circular economy have been highlighted by Bastein et al. (2013) and the European Environment Agency (2014), who contend that this transformation "is a vital requirement for a sustainable economic system that supports novel forms of revenue generation, increases competitiveness, and promotes employment". However, altering the prevailing linear economic framework that has existed since the beginning of the Industrial Revolution would involve a significant shift in the ways that we currently produce and consume goods. Innovative thinking about the circular economy, combined with innovative revolutionary technologies like virtual and technological advancements, will result in major shifts throughout the whole value chain that are not limited to particular sectors or components (Andrews, 2015; Vanner et al., 2014; Sánchez-García et al., 2024).

An expansion of the circular economy concept, the circular carbon economy emphasizes energy and carbon flows while subtly retaining the material, energy, water, and economic flows. As a result, when material flows and carbon flows conflict, the circularity of carbon flows takes precedence. Policymakers and other stakeholders involved in the energy transition and climate change measures can use the Circular Carbon Economy (CCE) Index to assess and contrast the progress and capacities of various nations towards the creation of a CCE. To achieve net-zero emissions, the CCE emphasizes reducing, reusing, recycling, and removing carbon emissions. The CCE Index enables cross-national comparisons, while its analysis can highlight best practices and areas in need of improvement. A cost-effective and environmentally conscious comprehensive management system based on new technologies, the CCE is a system that focuses on lowering CO2 emissions. With the capture of CO2 emissions, and subsequent economic utilization beyond its initial linear application, the CCE system attains balance by closing the carbon circle. The CCE Index's accuracy significantly depends on the availability and quality of data from various nations. The dependability of the Index might be impacted by missing or inconsistent information. It is made up of many different variables and metrics that prove challenging to understand and evaluate. This complexity could hamper its practical use by policymakers. The distinct economic, social, and environmental settings of every nation may not be adequately taken into account by the Index, which may result in an overly simplistic comparison between nations with radically dissimilar situations. It may have missed smaller countries that also influence global carbon emissions because it focuses primarily on large economies and hydrocarbon-producing countries.

The objective of the circular carbon economy is to attain net-zero emission levels or environmental balance by the second part of the 21st century. Economic activity, the environment, and society could all be significantly impacted by such a huge change. To create new regulations in the sector, scientists and policymakers must both have extensive knowledge of these effects. To enhance comprehension of the circular economy and its diverse aspects and anticipated effects, this paper offers an overview of the expanding body of research on the subject.

The paper is structured into four parts. Following the introduction, the second section presents a theoretical background of the academic literature, as well as the main circular economy and circular carbon economy processes. The data and methodology are presented in the third section. The Circular Carbon Economy (CCE) Index, through a comparative analysis of selected sub-indicators in G20 economies, is presented in the fourth section. The final part of the paper presents some conclusions.

Theoretical background

The circular economy can be defined as a novel economic framework representing sustainable advancement towards effective sustainable development, shifting from an economic system centred around consumption and recycling to one that extends the useful lifetime and utilization of resources and goods while minimizing waste. It is not entirely simple to convert the linear economy-which has dominated economic thought and practice since the beginning of the Industrial Revolution-into a circular system.

Such a drastic adjustment requires substantial changes to the way we now produce and use goods, which could have a big effect on society, the natural environment, and the economy. Comprehending these effects is essential for scholars and decision-makers who will be involved in creating regulations in this area; thus, a thorough understanding of the circular economy's principles, procedures, and anticipated impacts on various industries and value chains is necessary. This article aims to investigate the different levels of circular economy adoption that the G20 member countries have reached in terms of their efficiency.

A rising collection of literature from a variety of fields has appeared throughout the past few decades, influencing how we currently perceive and apply the circular economy and its concepts (Lieder & Rashid, 2016). Environmental ecology is a field of study grounded in the theory of systems with an integrated perspective (Erkman, 1997; EASAC, 2016). To optimize energy and resources, a transition to a responsible industrialized society would necessitate technological, fundamental, economic, and social reforms (Graedel & Allenby, 1995; Terzić, 2024a).

According to Frosch and Gallopoulos (1989, p. 149), in this specific situation, enhanced manufacturing procedures are necessary for system optimization because they "decrease the production of unrecyclable waste products in addition to the continuous utilization of restricted material and energy supplies”. Symbiosis in manufacturing anticipates the emergence of synergistic cooperation, including the transfer of assets between businesses, and utilizes concepts of environmental sustainability at the corporate level. Heck (2006) defines the circular economy as "an industrialized system that, by purpose and desire, is regenerative”. The idea of an ‘end-of-life’ is replaced with ‘reconstruction’; the usage of energy from renewable sources is increased; harmful chemical consumption is decreased (which hinders reuse); and waste is eliminated via improved processes, materials, goods, and economic structures. "Enabling effective movements of materials, energy, labour, and information to both ecological and social capital might" is the main goal.

Authors contend that resources which used to be regarded as waste must be efficiently directed back into an efficient manufacturing system through innovations in both product and procedure development and manufacturing. Symbiosis in industry anticipates the emergence of synergistic cooperation between businesses, including the interchange of goods and results, and is relevant to the concepts of environmental sustainability at the corporate level (Chertow, 2000; EASAC, 2016). Geographical closeness is not always a barrier to this kind of cooperation, which can result in the creation of knowledge-sharing and eco-innovation-promoting linkages (Lombardi & Laybourn, 2012; Terzić, 2024a; Terzić, 2024b).

An interconnected methodology called 'cradle-to-cradle design' aims to change the way manufacturing material movements are made. Cradle-to-cradle design, as opposed to conventional long-term sustainability concepts, aims at preserving and even improving the worth, performance, and efficiency of resources that are material for producing an overall beneficial environmental effect (Braungart et al., 2006; Ankrah et al., 2015). Conventional methods of sustainability focus on decreasing or removing the adverse environmental effects of people's activities.

A fundamental principle of the cradle-to-cradle concept is that goods, manufacturing procedures, and distribution networks may all be optimized for two distinct kinds of resources: biological and scientific elements. Although both are strong substances that must be processed further, the former are disposable and may be securely returned to the ecosystem upon being used. Sustaining or increasing the worth and efficiency of these resources will remain largely dependent on each participant in the supply chain using the knowledge generated by networking and data-containing processes (Braungart et al., 2006). Alongside these tangible features, the utilization of information sources on green energy, the advancement of ecosystems, and the preservation of diversity in culture and society are other fundamental tenets of the cradle-to-cradle concept (McDonough & Braungart, 2002).

Product-service systems (PSS) is an area of study that originated in the mid-1990s and was founded on the notion that an evolution towards business models that concentrate on the outcome of services provided instead of products sold would increase performance while providing environmental advantages (Tukker, 2015). PSS "consists of a combination of tangible goods and intangible services that have been developed and integrated in a way that both simultaneously have the possibility of satisfying eventual consumer requirements", according to Tukker and Tischner (2006).

The "final capability or fulfillment that the consumer wishes to accomplish as an initial stage for enterprise development" is given priority by these systems. While PSS has significant potential to increase sustainability and competitiveness in theory, its actual impact relies critically on several variables that must be carefully considered in every situation (Tukker, 2015). The 'blue economy' is an additional pertinent idea that discusses the economic case for resource optimization and sustainability. In this situation, creativity is the blue economy. Within this framework, innovation is regarded as a key tool for directing companies towards a change in procedures that is impacted by the structure and operations of natural ecosystems.

One approach would be using trash from a single good as material for a different industrial process to generate revenue (Pauli, 2010). Sauvé et al. (2016) and Kopnina

(2018) have defined a circular economy as the "manufacturing and consumption of products via enclosed transportation of materials that embrace environmental impacts associated with the exploitation of virgin resources and the formation of pollutants (including pollution)”. The circular economy is a theory that aims to change how resources are used in the economy. Factory waste could be a useful input in an additional procedure: goods could be enhanced, mended, or repurposed rather than being thrown away, according to Preston (2012). The circular economy as a concept has lately gained traction inside the EU, as shown in the Horizon 2020 research and innovation program, the European Commission's Work Program 2017, and the Circular Economy Package (European Commission, 2016; 2017).

According to Rizos et al. (2016), there are two primary approaches used to comprehend the idea of the circular economy: 1) terms and explanations that focus on the necessity of creating supply and demand cycles which minimize the use of natural resources; or 2) theories that aim to go beyond the idea of controlling resources and include novel perspectives. Since resources for newly developed goods are derived from previously recycled ones, the approach known as the circular economy requires that items be more durable and suitable for reusing or recycling. Therefore, every item is recycled, reprocessed, used as an alternative source of energy, repurposed, and, in the unlikely event, destroyed (Figure 1).

Source: UNIDO, 2021.

Figure 1. Circular Economy Model and Potential Outcomes

According to Korhonen et al. (2018), the term 'circular economy' refers to an economic structure based on public production-consumption mechanisms that optimize the value created by the linear movement of materials and energy between human society and the environment. In an ecological economy, using renewable energy is essential. Making the shift to a circular economy would necessitate tackling the problem of creating a sustainable energy source in addition to taking urgent action in several other environmental sectors, including agriculture, water, and soil management. The circular carbon economy (CCE) is an integrated and inclusive approach to transitioning towards more comprehensive, resilient, sustainable, and climate-friendly energy systems. According to Saputra et al. (2022), a circular carbon economy would allow economies to utilize all the available technologies, energy sources, and options for reduction based on the availability of resources, economic conditions, and national specificities.

The different steps of the circular economy and circular carbon economy processes can be separated into three groups: (a) utilizing materials which are less fundamental; (b) preserving the highest possible value for resources and outputs; and (c) altering utilization practices. The fact that these types of circular procedures are not incompatible should be emphasized. Although many of their components are usually interconnected, companies occasionally choose to implement a strategy that incorporates several circular procedures (Rizos et al., 2016; Geissdoerfer et al., 2017). Furthermore, a number of the ideas discussed in Section 2 may apply to numerous processes; for example, as seen in Figure 2, industrial synergy may be connected to both the use of renewable energy and more than one process. Synergy between industries may be connected to the building industry's remanufacturing procedures as well as the use of alternative sources of energy.

Figure 2 illustrates how a sizable amount of carbon that could be released into the environment is geologically collected and retained. It is necessary to recover or reuse the leftover carbon from hydrocarbons that would otherwise be discharged into the environment as fugitive carbon to achieve a carbon equilibrium or net-zero emission status. Carbon could be eliminated by regulating natural sinks appropriately. In the context of the circular economy, the word 'recycle' corresponds to the natural carbon process, often known as 'living carbon', whereby atmospheric carbon is transformed into biomass via photosynthesis and then collected for bioenergy. Those natural alternatives hold carbon longer than in geologic sequestration; but they also have the potential to swiftly discharge stored carbon directly into the atmosphere, as in the devastating fires that have occurred in Australia and Brazil. Although natural solutions are valuable adjuncts, they cannot permanently replace other methods of carbon removal.

Source: The King Abdullah Petroleum Studies and Research Center (KAPRSC), 2020.

Figure 2. Circular Economy and Circular Carbon Economy Processes

At $100 USD per tonne of CO2 (tCO2), usage including land management and forestry selection amounts to approximately 1.5 GtCO2 annually in a 'low' scenario and roughly 13 GtCO2 annually in a 'high' scenario. To realize such potential, nevertheless, certain obstacles would need to be overcome (Hepburn et al., 2019; KAPRSC, 2020). Removal and utilization are two distinct processes. Within some pathways of use, a small portion of CO2 is ultimately transformed into carbon that is durable. Many carbon-to-fuel methods don't reduce fugitive emissions unless the carbon is taken from bioenergy or direct air capture (DAC). Recycling can lessen the need for secondary resource extraction and has a positive impact on the environment in several ways, including lowering greenhouse gas emissions related to the consumption of natural resources (EEA, 2016; EC, 2017a).

The CCE is an integrated framework that relies on lowering CO2 emissions and managing them using a cost-effective, environmentally friendly, integrated management system through contemporary technologies. By absorbing CO2 emissions, closing the carbon circle, and utilizing them profitably after their initial linear utilization, the CCE system creates equilibrium. This strategy is different in that it doesn't just concentrate on lowering or preventing the rise in carbon emissions.

The effective utilization of resources is a distinct process that might result in the usage of fewer main resources. This process is associated with the idea of eco-conscious manufacturing, which centres on attaining process effectiveness for materials as well as energy resources (Terzić, 2024a; Terzić, 2024c). That may include the substitution of goods that are harmful or have an expiration date, as well as the responsible consumption of assets (Korhonen et al., 2018).

A fundamental prerequisite for the shift towards a circular economy is the increasing availability of energy from environmentally friendly sources. The use of fossil fuels is by necessity not regenerative when used to generate energy. However, the combined amount of energy consumed in the EU27 still comes from coal, natural gas, and oil (European Commission, 2017b). There are other detrimental side effects, such as air pollution, greenhouse gas emissions, and reliance on imports. The United States of America, China, and the United Kingdom are the top three countries in terms of their progress towards a circular economy.

The notion of a circular economy has gained recent momentum in the European Parliament, as it offers a solutions-oriented and optimistic outlook for attaining economic growth while adhering to tighter environmental regulations. The 7th Environment Action Programme highlights the importance of a structure that will provide producers and consumers with appropriate signals to encourage resource efficiency and the shift to a circular economy. Additionally, it is becoming more and more recognized as a commercial possibility, as evidenced by the Ellen McArthur Foundation's initiatives. Furthermore, a growing number of European nations list the circular economy as a top political concern. A new strategy to help the EU's transition to a circular economy was issued by the European Commission in December 2015 under the title Closing the Loop: An EU Action Plan for the Circular Economy; and it has been mentioned in the latest political documents of strategic importance, for example, the new EU action plan on the circular economy and the ensuing legislation (European Parliament, 2024).

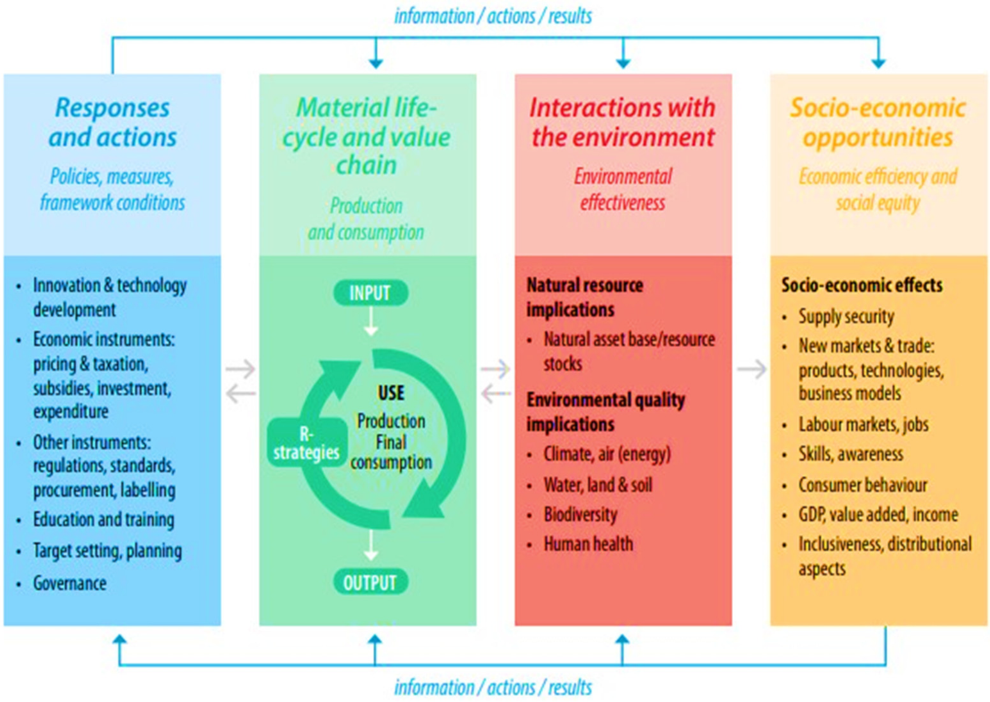
Italy, Canada, Colombia, and Mexico have all exhibited exceptional achievement across trend-specific components, mostly due to their relative strength in governmental policy and development. An Ellen McArthur Foundation (2014) initiative, along with its government and policy recommendations, arranges these metrics in a form that is helpful to the general population and legislators while also reflecting the interconnectedness and extendibility of a circular economy.

When feasible, an auxiliary evaluation structure that adheres to the European Sustainability Reporting Standards E5 (ESRS E5) assists in ensuring integration between the collection of data and the connection of CE ideas and descriptions to the phrases and definitions utilized in governmental data. It also organizes and combines fundamental data analysis. Adopting an adequate ESRS E5 dataset will yield exhaustive, similar, and uniform data and indices on behalf of governments.

Additionally, a theoretical framework evaluation will aid in determining requirements for capacity development in growing economies as well as emerging nations, particularly in strengthening and consolidating existing information databases on materials and waste circulation, R-strategies, and associated environmental consequences. The entire lifetime of materials, goods, and services is covered by the circular economy's theoretical and practical framework. The financial and material facets of a CE are included in its surveillance range. The following guidelines were followed when summarizing the CE theoretical framework that exists in the literature:

- Fair and impartial consideration of the key components of a circular economy and associated salient characteristics, in line with the fundamental terminology;
- The development of a framework along with a set of variables that might be utilized at different scales and in various geographic locations (multilevel monitoring);
- The recognition of key elements for which metrics are required, i.e., the ones that are of shared significance for resource effectiveness and circular economy regulations in G20 member nations as well as internationally. The framework incorporates the key elements of a CE together with the extensive range of subjects that must be addressed in each of the four sections.

Additional organization has been implemented through the designation of indicative concepts and subjects. Therefore, the Pressure-State-Response (PSR) model takes into account the following: human activity puts pressure on the environment, affecting both the quantity and quality of natural resources (state); and society reacts to these modifications by implementing sectoral, general economic, and environmental policies as well as by altering public perception and behaviour (referred to as the ‘societal response’). The benefit of the PSR model is that it draws attention to these connections and makes environmental and other issues more relatable to the public and decision-makers. However, this shouldn't overshadow the reality that ecosystems, environment-economy, and environment-social interactions all involve more intricate relationships. Its four main parts illustrate how the economy's manufacturing and consumption activities affect the ecosystem (natural resources), with a focus on resource life-cycle analysis, policy responses, measures, actions, and socio-economic opportunities (see Figure 3). As a result, it incorporates every aspect included in the Bellagio Principles (Jesinghaus, 2014). Four criteria are covered under the Bellagio Principles for evaluating developmental progress towards sustainability. Principle 1 addresses the foundation of any assessment: formulating a sustainable development mission and specific objectives that give the vision a workable definition in language that makes sense for the relevant decision-making units. The subject matter of any evaluation and the necessity of combining a practical emphasis on present priority concerns with an understanding of the system as a whole are covered in Principles 2 through 5. Although Principles 9 and 10 address the need to create an ongoing ability for assessment, Principles 6 through 8 address important aspects regarding how assessments are conducted. Owing to the extensive range of subjects that must be addressed in each of the four sections, additional organization has been implemented through the designation of indicative concepts and subjects.



Source: The United Nations Economic Commission for Europe (UNECE), 2021.

Figure 3. Conceptual Framework for Monitoring the Circular Economy and Circular Carbon Economy

This section outlines the phases of a substance's life cycle and value along the supply chain, including the usage of beginning materials for manufacturing and ultimate consumption, the creation of solid waste, and the R methods implemented to maintain the economic value of substances in their life cycle for as long as feasible. It takes into account the reversibility principle and the different processes reflecting the salient characteristics and key results of a CE. Correlated indices display the movement of materials into, through, and out of the economy. They must be connected to environmental concerns, such as warming temperatures, hazardous pollution, ecosystems, and the handling of natural resources, as well as standards of reference (standards, limits, starting points, plans, and goals).

Owing to the extensive range of subjects to be addressed, this fundamental component is additionally organized according to several criteria: the economic basis and productivity, which are measures of the quantity and quality of materials available for utilization by sectors or the economy as a whole, with special focus on the usage of materials such as for purchases or local extraction processes; materials used such as traces from private consumption and initial material spending; capital accumulation within an economy such as investments and additions to investments; and measures connecting material utilization with GDP, added-value, or additional socio-economic output factors via level of exertion or efficiency ratios.

There are metrics on produced waste (through the method of source sorting); recycling charges; circular implementation fees; contributions of additional raw materials within inputs to manufacturing or spending; sustainable components applied to manufacturing procedures; goods redirected from waste streams (fixed, recycled, employed); substances departing the economic cycle, i.e. inefficient ones or those destined to be destroyed; and relationships with commerce and globalization (worldwide dimensions of a CE). Supply and demand are ultimately responsible, and there are trade data-derived signs regarding solid waste, second-hand merchandise, and end-of-life merchandise. Both the import and export of components, as well as the actual trade imbalance and substance level of commerce, also play a role.

To promote a renewable economy, this aspect illustrates responses from policymakers (ecological, economic, industry-specific, and societal), civil society, and other actors. These include steps to alter perceptions and conduct as well as generate novel socioeconomic possibilities (such as emerging markets, chances to pursue learning and development, and creative solutions) that support the transition to a sustainable economy. This section discusses both the economic and social implications of the circular economy, emphasizing the importance of social justice and economic effectiveness in ensuring an equitable transition. Associated variables include the growth of emerging markets, commerce, and job possibilities; shifts in independence or safety of supply; educational attainment; the acquisition of skills (which is directly connected to the ability to innovate); and alterations in household, customer service, and business practices.

Although a carbon equilibrium or net-zero emissions can be envisioned using the circular carbon economy, this is highly unlikely to happen on its own. There won't be enough incentives to create or implement the infrastructure and technologies required for the circular carbon economy and its environmental targets in the absence of enabling policies. Throughout the next several decades, further developments and progress will contribute to closing the loop on the circular carbon economy. In the end, the relative importance of each component will depend on economic and social acceptability. The best chance of success is offered by policies that encourage investments towards resource efficiency via rewards for technological advances that support the four Rs: reduce, reuse, recycle, and remove. Because it can transcend the four Rs, hydrogen has the potential to play a special role in the circular carbon economy. Since green hydrogen, generated by non-biomass renewables, does not release carbon into the atmosphere directly, the amount of carbon that must be handled is decreased to the point where it replaces hydrocarbons.

Once hydrocarbons are converted into blue hydrogen, carbon is either taken up and stored in the earth's crust or utilized again for carbon usage. Table 1 presents crucial circular carbon economy concepts, including the four R processes and crosscutting.

Table 1. The Circular Carbon Economy (Key Concepts)

Reduce	**Reuse**	**Recycle**	**Remove**	**Crosscutting**
Energy efficiency Non-bio renewables Nuclear energy Fuel switching	Bioenergy Natural sinks	Carbon capture and utilization (permanence) – building materials – polymers	Carbon capture and storage (CCS) – enhanced oil recovery bioenergy – direct air capture – natural sinks	Hydrogen – green (reduce, recycle) – blue (remove)
Energy efficiency Renewables (including bioenergy) Nuclear energy	Neutralizing emissions – natural processes (bioenergy) – energy carriers (methanol, ammonia, urea)	Industrial feedstock conversion – 'emissions to value' – 'carbon recycling'	CCS – direct air capture – natural sinks	Hydrogen / Modern bioenergy + fuels Energy infrastructures

Source: KAPRSC, 2020; G20 Climate Stewardship Working Group, 2020.

The Total Circular Carbon Economy Index score includes the following indicators and variables: 1) the CCE Performers Score-energy efficiency; renewable energy; electrification; nuclear energy; fuel switching; natural sinks; carbon capture, utilization, and storage; and clean hydrogen-and 2) the Enablers Score-technology, knowledge, and innovation; finance and investment; business environment; policy and regulation; and system resilience.

Data and research methodology

The variables were generated using a variety of data sources, including the International Energy Agency, the International Renewable Energy Agency, the Nuclear Energy Agency, the Global CCS Institute, the Organization for Economic Co-operation and Development, the Circular Carbon Economy Index Scoreboard, and the King Abdullah Petroleum Studies and Research Center databases. Along with an appraisal of the available research, the research paper uses a comparative evaluation and synthesizing method founded on the Circular Carbon Economy Index and selected sub-indicators. Table 2 lists the Circular Carbon Economy Index and data sets for the CCE Index efficiency results.

Table 2. The Circular Carbon Economy (CCE) Index: concepts, indicators, sources

CCE concepts	CCE indicators (selected)	Secondary sources
Reduce – Minimize fugitive carbon by employing energy efficiency, non-bio renewable energy, nuclear energy, and fuel switching – Minimize fugitive carbon by employing energy efficiency, non-bio renewable energy, nuclear energy, and fuel switching	Energy efficiency Energy intensity of GDP at purchasing power parities	The International Energy Agency (IEA)
	Renewable energy Share of renewables in primary consumption	The International Renewable Energy Agency (IRENA)
	Nuclear energy Share of nuclear electricity in primary consumption Fuel switching Change in the share of oil, coal, lignite, and derived gas in electricity production and the overall share of oil, coal, lignite, and derived gas in electricity production	The Nuclear Energy Agency (NEA) The King Abdullah Petroleum Studies and Research Center (KAPRSC)
Reuse – Reuse captured carbon through carbon utilization – Convert CO2 into durable carbon, including building materials and polymers	Carbon utilization	The International Energy Agency (IEA)
Recycle – Minimize fugitive carbon by encouraging mitigation through living carbon, using bioenergy and natural sinks	Bioenergy and natural sinks Ecosystem services, including carbon sequestration and storage, biodiverse habitats, nutrient cycling, and coastal protection (from the Environmental Performance Index)	The International Renewable Energy Agency (IRENA) The King Abdullah Petroleum Studies and Research Center (KAPRSC)
Remove – Store captured carbon by converting CO2 into 'durable carbon': enhanced oil recovery, bioenergy with CCS, direct air capture, and natural sink removal	Carbon capture and storage and direct air capture Total capture capacity of CCS projects (operational, in construction, advanced development, and early development)	The Global CCS Institute (GCCSI)

CCE concepts	CCE indicators (selected)	Secondary sources
Cross-cutting – Green hydrogen: 'reducing' and 'recycling' – Blue hydrogen: 'removing'	Clean hydrogen Total capacity of green hydrogen projects (commissioned, financed/under construction, and announced/planning begun)	The International Energy Agency (IEA)
Enabling policies	Enabling policies indicators	The Organization for Economic Co-operation and Development (OECD)
CCE Index	**Technology, knowledge, and innovation** – Research and development expenditure – Clean energy technology patents – Academic research intensity – Industrial technical collaboration with universities – Medium and high-tech industrial contributions to the economy – International high-technology interactions	The King Abdullah Petroleum Studies and Research Center (KAPRSC)
	Finance and investment – Circular carbon economy investments – Access to sustainable finance – Financial development – International financial connectedness – Carbon pricing	
	Business environment – Regulations supporting business activity – Trade and transport infrastructure – Renewable energy investment and deployment opportunities – Carbon capture and storage potential – Environmental, social, and governance risks – Political, economic, and financial risks – Human capital	
	Policy and regulation – Policy and regulatory support for energy efficiency and renewable energy – Carbon capture and storage policy – Natural sinks protection policies – Reporting of emissions – Climate change policy	
	System resilience – Regulations supporting business activity – Trade and transport infrastructure – Renewable energy investment and deployment opportunities – Carbon capture and storage potential – Environmental, social, and governance risks – Political, economic, and financial risks Human capital	

Source: Author's summarization, based on KAPRSC data, 2020.

The study used secondary data gathered between 2022 and 2023 to compile the CCE Performers Score Index, the CCE Enablers Score Index, and the CCE Index. The Circular Carbon Economy Index includes the following indicators: business environment, technology, knowledge and innovation, financing and investment, policy and regulation, and system resilience. Consequently, a comprehensive tool was developed to measure the CCE scores in G20 member countries. Moreover, the KAPSRAC states that the variables in the CCE Index assess the results of CCE performers in addition to the outputs of CCE enablers. The indices contain unique CCE enabling parameters organized into five main groups (KAPRSC, 2020).

The application of hydrogen in a circular carbon economy is meant to be multidimensional. Due to the numerous supply chains that arise from various combinations of production processes, transport and storage alternatives, and the wide range of possible applications (direct or by utilizing derived goods), it is exceptionally challenging to evaluate the hydrogen sector's overall role. Therefore, determining whether a technology or emissions management/reduction option helps reduce atmospheric emissions of carbon dioxide (CO2) or other greenhouse gases (GHG) was the primary goal in constructing the various components of the Performers sub-index. Achieving the objectives of the Paris Agreement and staying within the global carbon budget will depend on avoiding and lowering these emissions in the short and medium terms.

The primary reduction or emissions handling technologies, policies, and options-which are categorized as the "four Rs": reduce, recycle, reuse, and remove-have been used by the majority of these researchers for the framework of the CCE Index. The methodology does not incorporate R-based categories to account for the reality that various authors and stakeholders have assigned different technologies and alternatives to distinct Rs. Rather, the Index assembles the fundamental CCE tasks, which are consistent among the different conceptualizations.

Compared to certain theoretical versions of the circular economy, the circular carbon economy does not impose a hierarchy regarding the precedence of the 4Rs. The energy and carbon administration system's interrelationships are governed by the 4Rs of the circular carbon economy, which state that greater emphasis on one R requires less emphasis on others. All four of the Rs will need to be involved for global evolution to ultimately fulfil the climate stability objectives of the Paris Agreement.

The contributions made by reduce, reuse, recycle, and remove depend on a myriad of variables, including the price and effectiveness of technologies, the availability of resources, which is influenced by geographical and geological sciences, public acceptance, enabling policies, and national circumstances. The CCE Index's objective is to assess economic achievement and advancement in the direction of the circular economy by creating a strong analytical foundation.

This will broaden and strengthen the theoretical base of the CCE principle and allow its realistic implementation. The final CCE Index will be a composite statistic that evaluates several CCE features across national contexts. The CCE Index serves two main purposes: first, it is meant to facilitate further debates about how to assess, determine, and compare the advantages and disadvantages of various nations concerning their progress towards a CCE; second, it is meant to assist in detecting fields where advancement has been established and in which additional policy initiatives either are necessary or would be advantageous.

The Performers and Enablers values were computed separately and combined to provide the overall CCE Index score. Consequently, three aggregate scores constitute the CCE Index: the CCE Performers score, the CCE Enablers score, and the overall CCE Index score. In a pair of time aspects, the Index evaluates and compares countries that produce hydrocarbons and have large economies. States' present performance on several CCE operations (such as renewable energy, energy efficiency, fuel switching, or carbon capture and storage) is measured by the CCE Performers sub-index. The Enablers sub-index evaluates a country's readiness to move towards the CCE in light of important enabling variables.

A country's score on the CCE Index ranges from 0 to 100. Neither the indicator itself nor the Index or sub-index categories apply points. When a nation's rating compares to its highest-ranking contemporaries or arbitrary optimal levels, it ought to be understood as a measure of how close it is to achieving perfection. Stated differently, a score of 66, for instance, would represent two-thirds of the highest possible score. To aid in cross-country comparisons, the CCE Index additionally offers a rank for every nation at the overall Index and sub-index stages.

There are forty-three indicators in the CCE Index for 2023. Thirty criteria assess supporting characteristics, while eight measures evaluate effectiveness. The performer and enabler values are initially computed separately, and the results are then added together to provide the overall CCE Index rating.

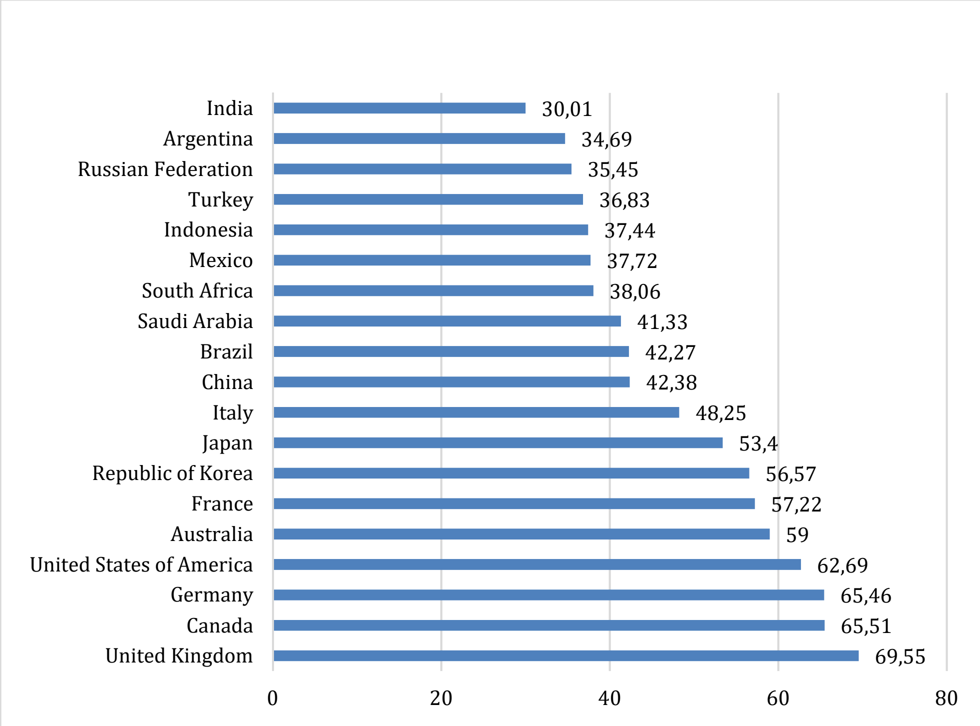
The largest average benefits to national assessments when it comes to the proportional shares of individual CCE operations are made by reducing energy consumption, electrification, green energy, and energy effectiveness. Nonetheless, notable distinctions exist between particular nations, which is consistent with the CCE's guiding principle that diverse nations will adopt distinct paths to achieve carbon circularity. The majority of nations are making headway in moving away from fuels with high carbon intensity in the electricity sector. In fields where the availability of innovation (nuclear energy) or financial resources to invest in new developments (such as hydrogen and emissions capture and the storage process) are prerequisites, achievement is more uneven. The success rates of different countries in preserving their current forestry resources also differ. Nations' development in the production, dissemination, and assimilation of pertinent knowledge is captured by information, technology, and innovation, which helps them realize every opportunity for the CCE transition. Furthermore, several of the less-than-average rated countries appear to have relatively restricted worldwide high-technology contact (i.e., transmission and assimilation of information via exports of technology and acquisitions).

The economic environment indicators (ease of doing business and achieving success) and the energy sector (energy safety and system reliability) are included in the business atmosphere and energy security metrics. These indicators can help to attract private actors and funding to support CCE transitions.

A nation's overall socioeconomic perspective is determined by a combination of wider economic, social, and environmental issues which influence variables like job opportunities, vitality equity investments, economic diversification, human capital efficiency, ecological wellness, and environmental adaptability. These indicators are collectively referred to as socioeconomic background variables.

Research results: A comparative analysis of G20 economies based on selected indicators from the CCE Index

The G20 member states – the United Kingdom, Canada, Germany, the United States of America, Australia, France, the Republic of Korea, Japan, Italy, China, Brazil, Saudi Arabia, South Africa, Mexico, Indonesia, Turkey, the Russian Federation, Argentina, and India – were the countries in which this paper's investigation was conducted. Each member nation's data collection encompasses the years 2022-2023, as well as the expansion of the CCE Index period from 2022-2023. Utilizing a range of criteria from the CCE Index for 2022-2023, Figure 4 shows the total Circular Carbon Economy Index score in the G20 member states. Policymakers should take these elements into consideration when implementing adequate strategies for CCE economic policies because most of the G20 member states face certain barriers to achieving a circular carbon economy. According to the total CCE score, the leaders in the G20 group for the 2022-2023 period are the United Kingdom (69.55), Canada (65.51), Germany (65.46), the United States of America (62.69), Australia (59), and France (57.22).



Source: Derived by the author using data from the CCE Index 2022-2023.

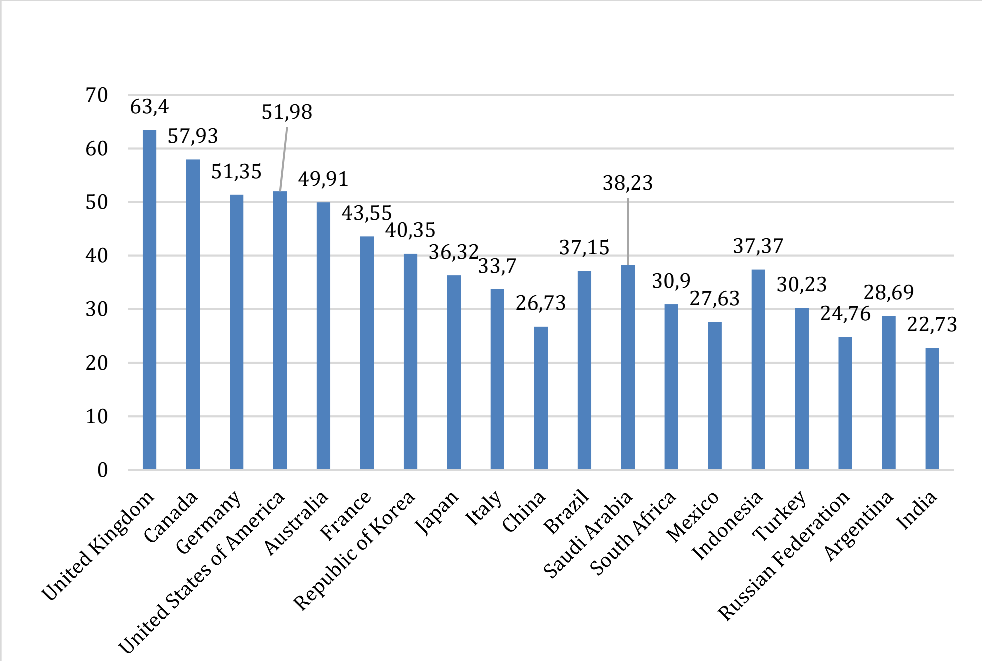
Figure 4. Total Circular Carbon Economy Index Score (G20, 2022-2023)

The nations that have greater scores in one sub-index than others account for the proportionate disparities in the overall CCE Index ratings, which are merely averages of the Performers and Enablers scores for each nation. A nation that scores highly on the overall CCE Index is doing well both now and in terms of its ability to move beyond the CCE and ultimately towards a fully zero-emissions circular economy. Significant inter-country differences are also shown by the score range, particularly between the top and bottom ranks.

There is a considerable divide in the effectiveness of empowering variables between nations; and closing this gap might greatly aid those nations in achieving their goal of net-zero or carbon neutrality. When it comes to directing public and private players towards a shared objective, like emissions objectives, policies and laws are essential. This component addresses emissions more generally and includes laws and policies pertinent to the various CCE operations. The aforementioned factors encompass assistance with renewable energy sources, energy conservation, carbon sequestration, and reporting. In contrast with the remaining parameters, the score dispersion in this particular category is less unbalanced.

This suggests that while nations are enacting measures to put their economies in an improved position during the present energy transition, many of them still have substantial shortcomings in this field. The top six nations in the overall CCE Index scored the highest in the 2023 CCE Performers sub-index.

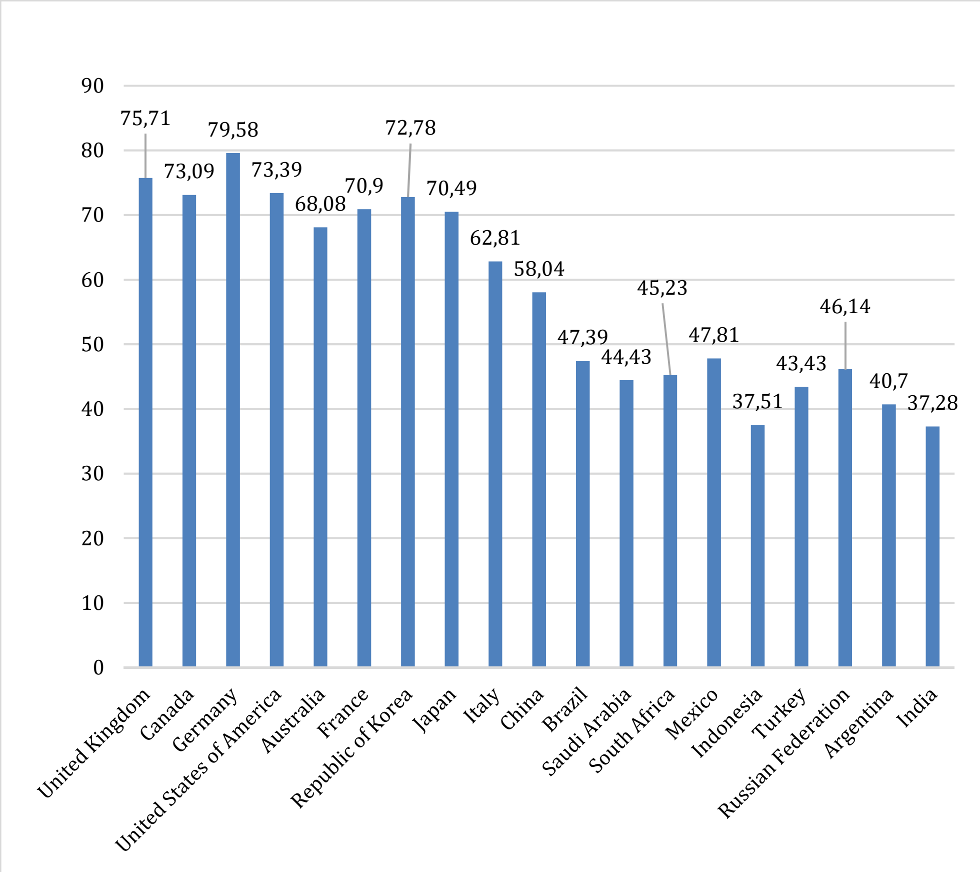
Higher-performing nations typically scored well on three, four, or five separate CCE indicators. Figure 5 shows the Circular Carbon Economy Index Performers score in the G20 member states. The CCE Index leader according to the highest Performers score for the 2022-2023 period is the United Kingdom (63.4), while India (22.73) has the lowest score among G20 member states according to this indicator. The degree to which countries have been participating in the different CCE activities is gauged by the CCE Performers sub-index.



Source: Derived by the author using data from the CCE Index 2022-2023.

Figure 5. Circular Carbon Economy Index: Performers Score (G20, 2022-2023)

Figure 6 shows the Circular Carbon Economy Index Enablers score in the G20 member states. The CCE Index leaders according to the highest Enablers scores for the 2022-2023 period are Germany (79.58), the United Kingdom (75.71), the United States of America (73.39), Canada (73.09), and the Republic of Korea (72.78). India (37.28) and Indonesia (37.51) are the lowest-positioned G20 member states according to their scores.

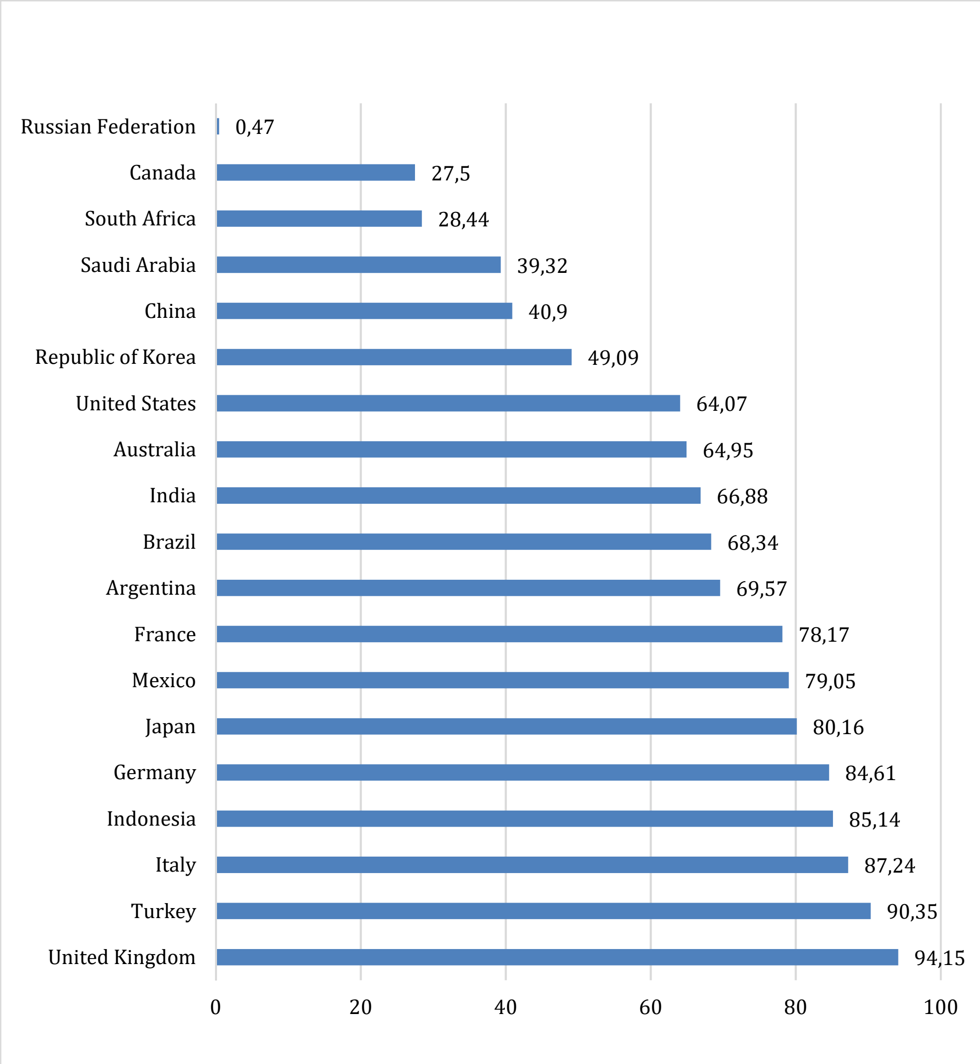


Source: Derived by the author using data from the CCE Index 2022-2023.

Figure 6. Circular Carbon Economy Index: Enablers Score (G20, 2022-2023)

The CCE Enablers sub-index gauges a nation's capacity to quicken its transition and has five sub-dimensions, as follows: finance and investment; business environment and energy security; technology, knowledge, and innovation; policies and regulations; and socioeconomic background. Every dimension concentrates on a specific area that is essential to facilitating and assisting with CCE changes.

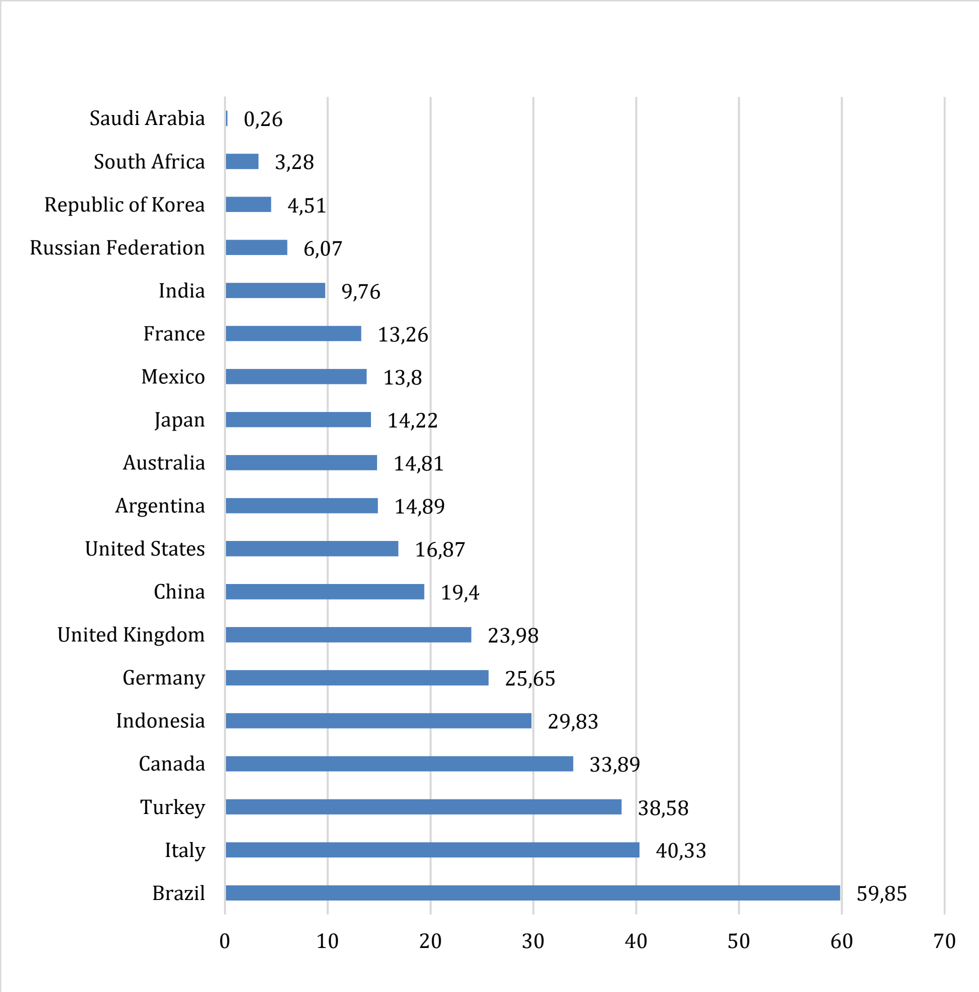
Figure 7 shows the Circular Carbon Economy Index's Energy Efficiency score in the G20 member states. The Energy Efficiency leaders according to the highest scores for the 2022-2023 period are the United Kingdom (94.15), Turkey (90.35), and Italy (87.24). The Russian Federation (0.47) is the lowest-positioned G20 economy according to its Energy Efficiency score.



Source: Derived by the author using data from the CCE Index 2022-2023.

Figure 7. Energy Efficiency in the G20 Member Countries, 2022-2023

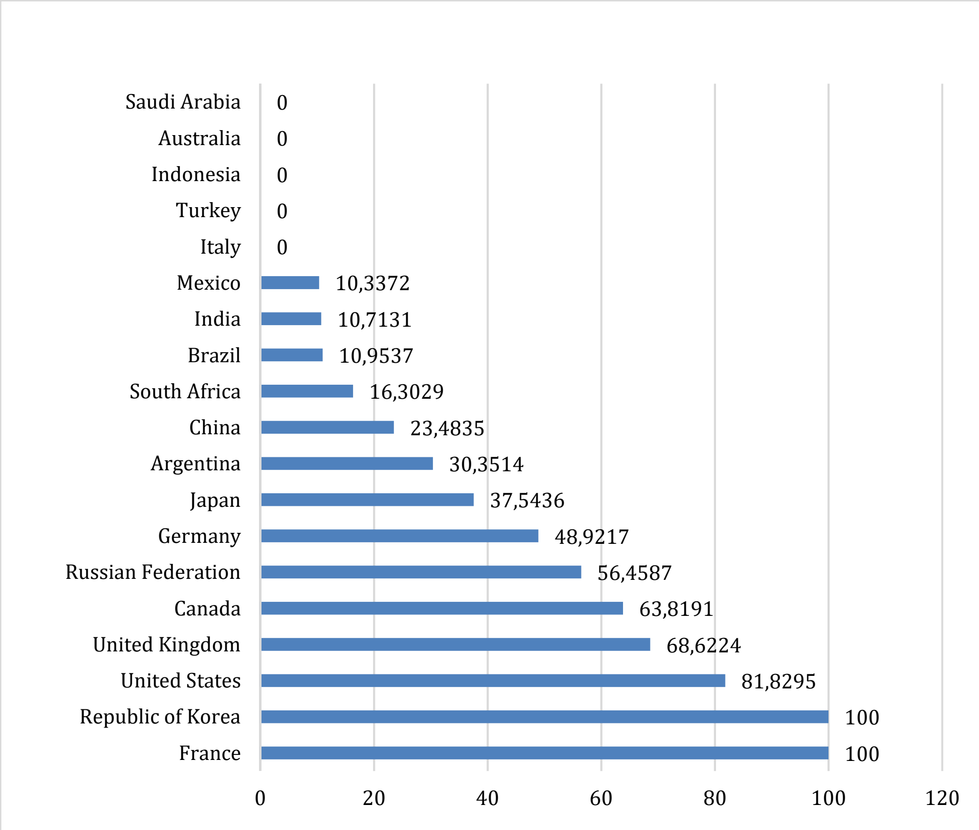
Figure 8 shows the Circular Carbon Economy Index's Renewable Energy score in the G20 member states. The Renewable Energy leader according to the highest score for the 2022-2023 period is Brazil (59.85, significantly higher than that of most G20 economies). Saudi Arabia (0.26) is the lowest-positioned G20 country according to its Renewable Energy score.



Source: Derived by the author using data from the CCE Index 2022-2023.

Figure 8. Renewable Energy in the G20 Member Countries, 2022-2023

Figure 9 shows the Circular Carbon Economy Index's Nuclear Energy score in the G20 member states. The Nuclear Energy leaders according to the highest scores for the 2022-2023 period are France (100) and the Republic of Korea (100). Saudi Arabia, Australia, Indonesia, Turkey, and Italy are the lowest-positioned G20 member states according to their Nuclear Energy scores. France and the Republic of Korea's ratings are 100 times higher than those of Saudi Arabia, Australia, Indonesia, Turkey, and Italy because of their lack of nuclear plants.

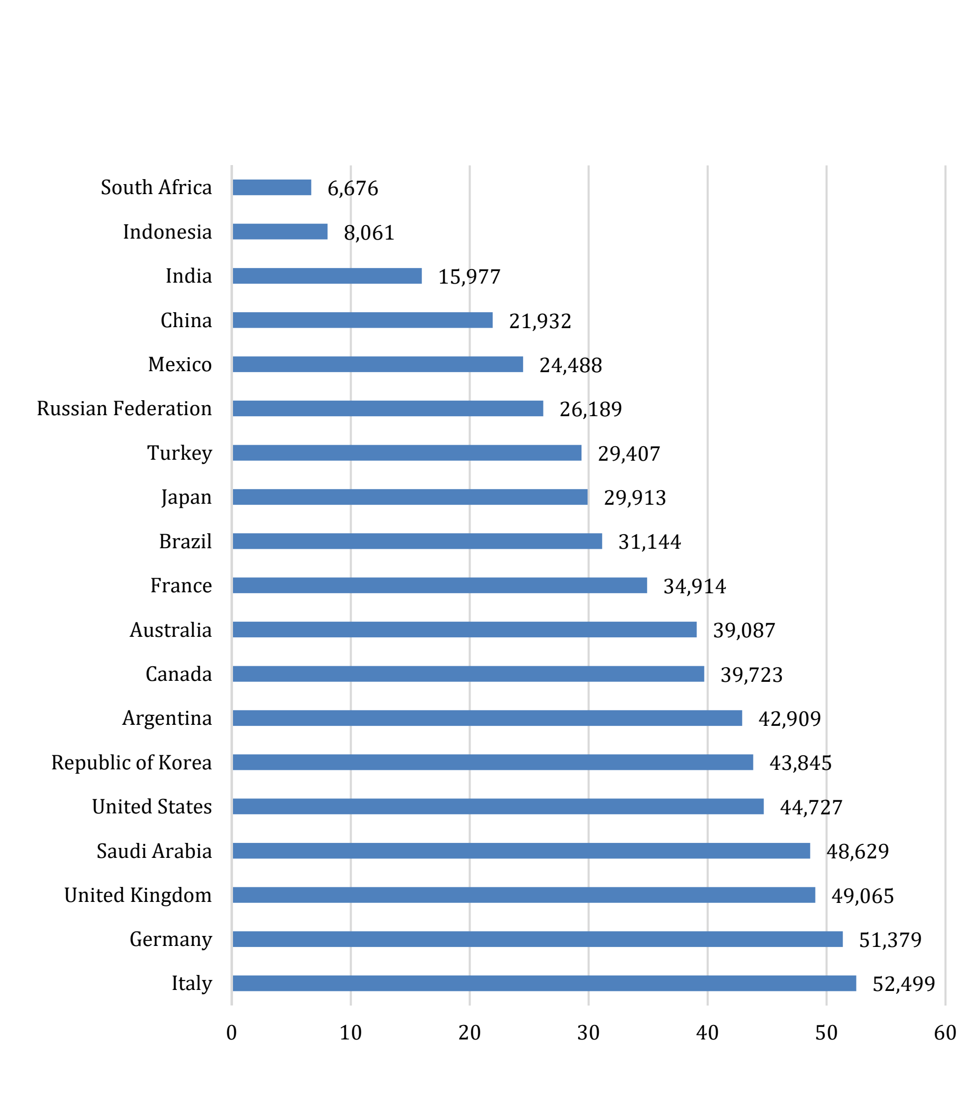


Source: Derived by the author using data from the CCE Index 2022-2023.

Figure 9. Nuclear Energy in the G20 Member Countries, 2022-2023

The CCE Performers sub-index includes fuel switching as one of its measured activities. It entails switching from fossil fuels with high carbon content, including oil and coal, to fuels with lower carbon content, comprising natural gas or even zero carbon content, as renewable energy sources.

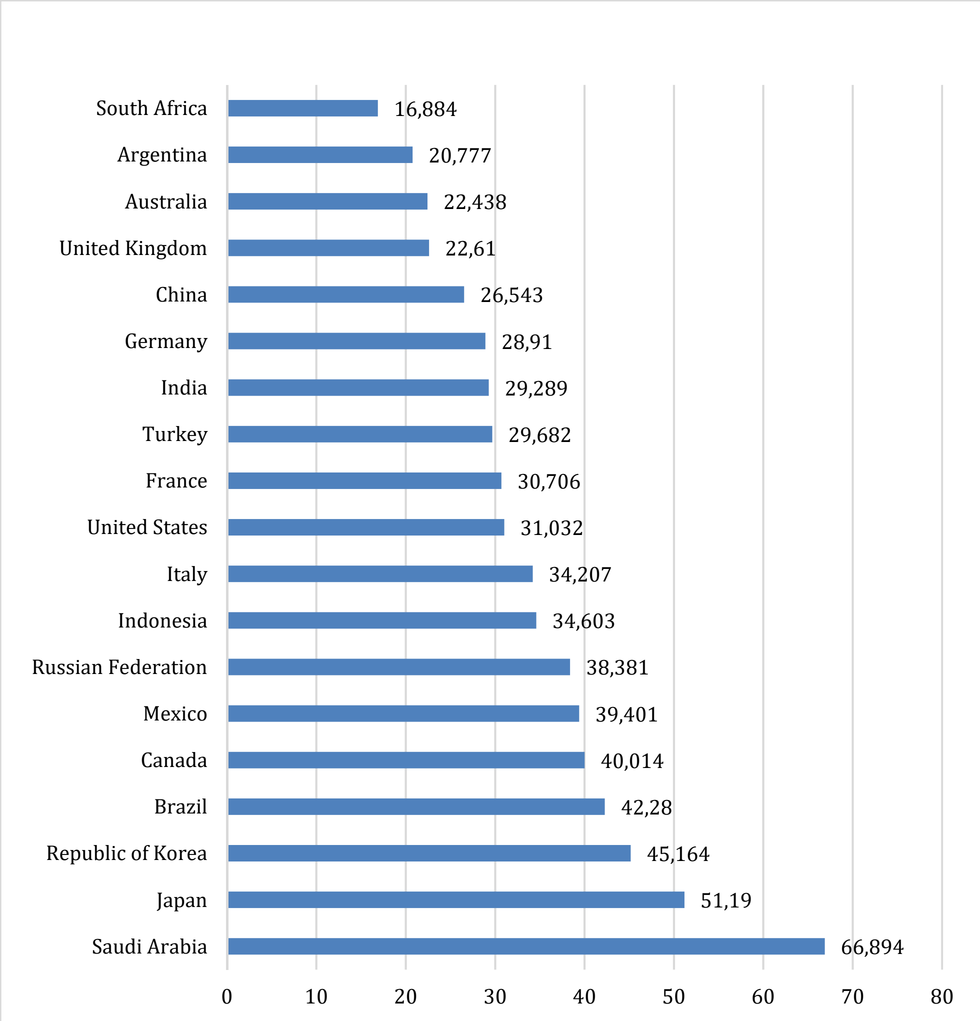
Figure 10 shows the Circular Carbon Economy Index's Fuel Switching score in the G20 member states. The Fuel Switching leaders according to the highest scores for the 2022-2023 period are Italy (52.499), Germany (51.379), the United Kingdom (49.065), Saudi Arabia (48.629), and the United States of America (44.727). South Africa (6.676) and Indonesia (8.061) are the lowest-positioned G20 member states according to their CCE Fuel Switching scores. Italy's is 7.8 times higher than that of South Africa and 6.5 times higher than the Fuel Switching score in Indonesia.



Source: Derived by the author using data from the CCE Index 2022-2023.

Figure 10. Fuel Switching in the G20 Member Countries, 2022-2023

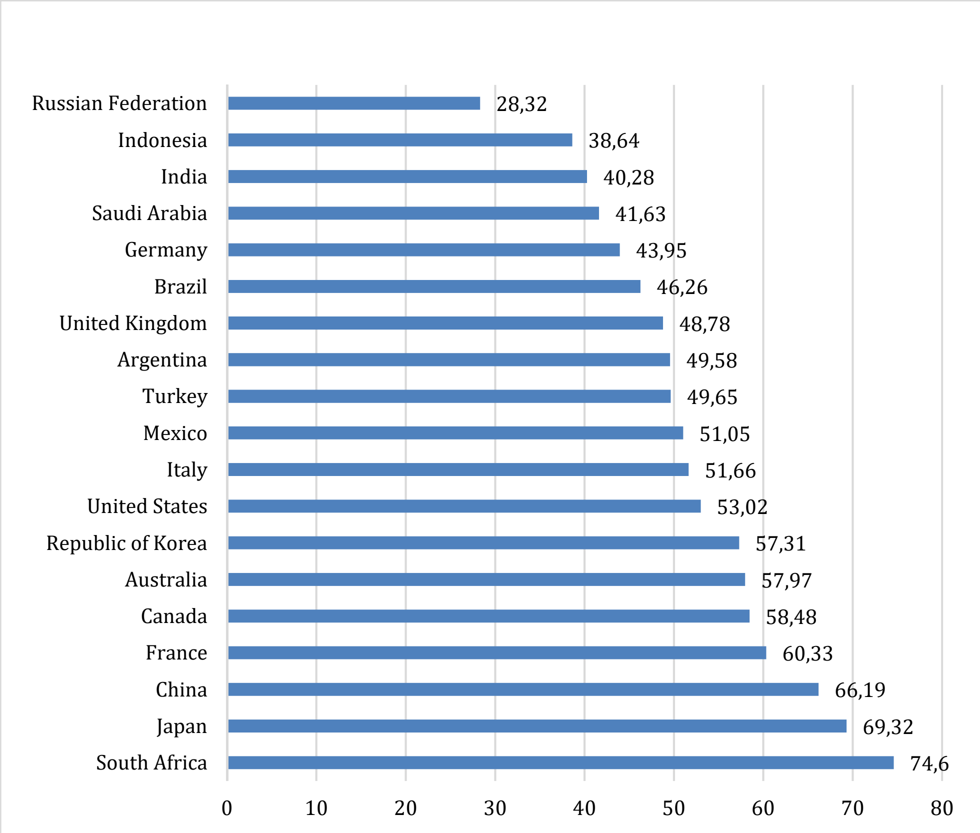
Figure 11 shows the Circular Carbon Economy Index's Natural Sinks score in the G20 member states. The leading country according to the highest Natural Sinks indicator score for the 2022-2023 period is Saudi Arabia (66.894). South Africa (16.884) is the lowest-positioned G20 economy according to its CCE Natural Sinks score.



Source: Derived by the author using data from the CCE Index 2022-2023.

Figure 11. Natural Sinks in the G20 Member Countries, 2022-2023

Figure 12 displays the G20 member nations' scores for Electrification under the Circular Carbon Economy Index. South Africa (74.6) is the G20 leader in Electrification for the 2022-2023 period, while the Russian Federation (28.32) is the member state with the lowest score in terms of CCE Electrification. The Electrification score in South Africa is 2.6 times higher than that observed in the Russian Federation and nearly twice that of India.

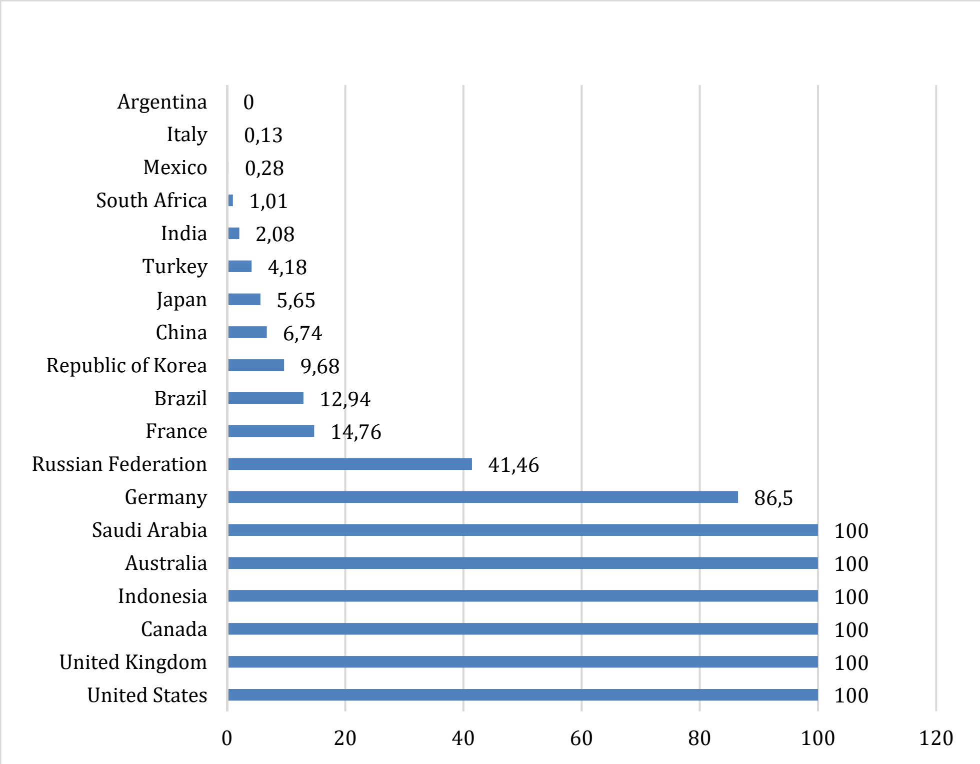


Source: Derived by the author using data from the CCE Index 2022-2023.

Figure 12. Electrification in the G20 Member Countries, 2022-2023

Electrification, renewable energy sources, and energy efficiency account for a sizable portion of any country's average score. The majority of nations are moving towards alternatives to fuels with high carbon intensity in the electricity sector, but progress is being made even in fields that need the availability of technology, like nuclear energy, or the financial means to make investments in novel technologies like hydrogen and CCS.

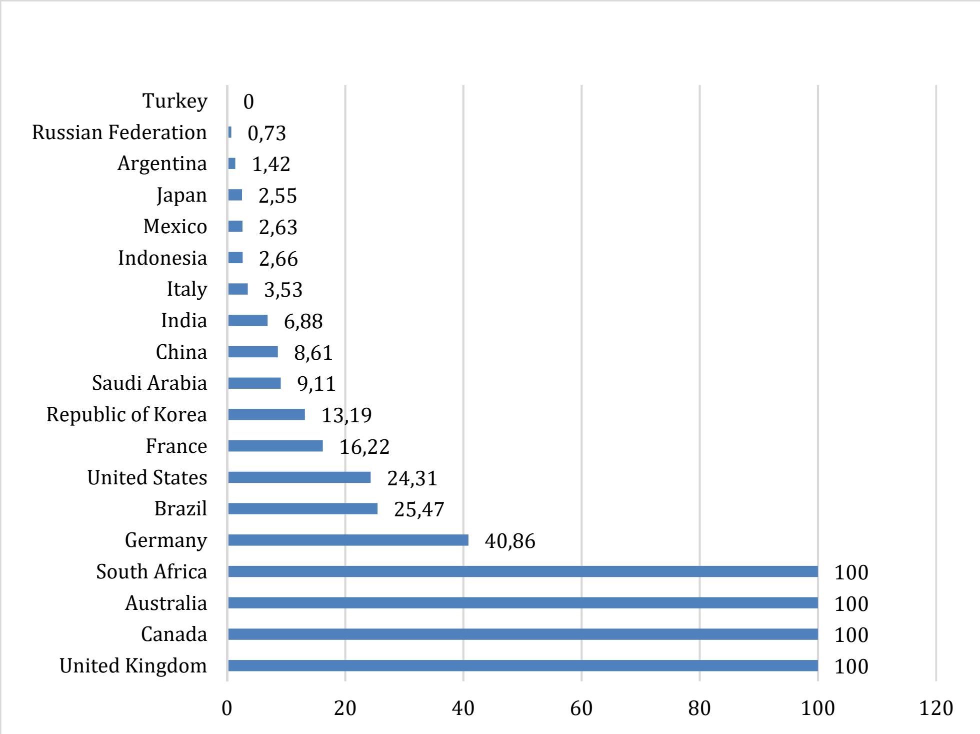
The G20 member nations' progress in carbon capture, use, and storage are displayed in Figure 13 of the Circular Carbon Economy Index. Based on the highest possible score (100) for the 2022-2023 period, the United States, the United Kingdom, Canada, Indonesia, Australia, and Saudi Arabia are the G20 leaders in Carbon Capture, Utilization, and Storage. For this sub-index, the lowest scoring members are Argentina (0), Italy (0.13), Mexico (0.28), South Africa (1.01), and India (2.08).



Source: Derived by the author using data from the CCE Index 2022-2023.

Figure 13. Carbon Capture, Utilization, and Storage in the G20 Member Countries, 2022-2023

Figure 14 presents the Circular Carbon Economy Index's Clean Hydrogen score in the G20 member states. The Clean Hydrogen leaders according to the highest possible scores (100) for the 2022-2023 period are the United Kingdom, Canada, Australia, and South Africa. Turkey (0), the Russian Federation (0.73), and Argentina (1.42) are the lowest-positioned G20 member states according to their CCE Clean Hydrogen scores. The top four scores are 100 times higher than the CCE Clean Hydrogen score in Turkey. Additionally, it emphasizes that in seeking carbon circularity, consideration must be given to cost-effectiveness as well as other policy factors, which include sustainability for the economy and society. Although the majority of the hard-to-abate industries are found in emerging and other developing economies, these nations have not adopted clean hydrogen as quickly as they could have because of difficulties obtaining and utilizing funding to support these highly capital-intensive new technologies.



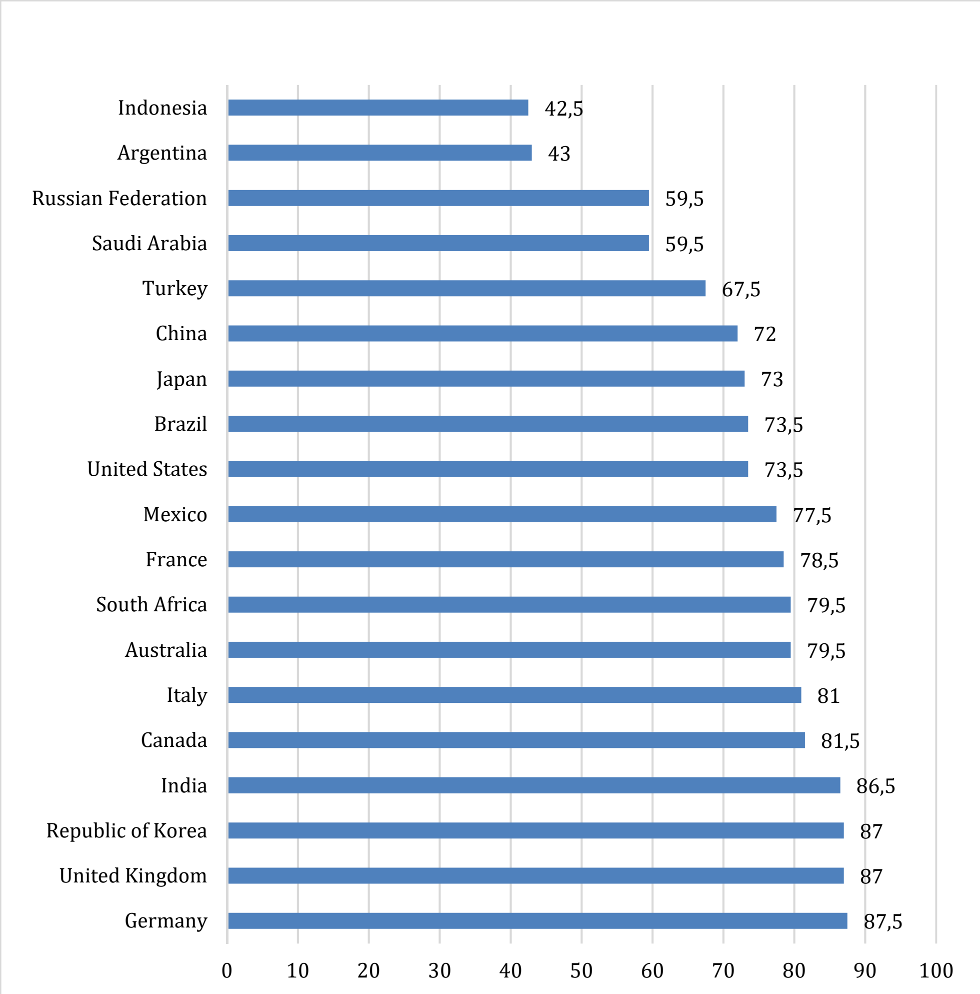
Source: Derived by the author using data from the CCE Index 2022-2023.

Figure 14. Clean Hydrogen in the G20 Member Countries, 2022-2023

Figure 15 displays the Circular Carbon Economy Index's Policy and Regulatory Support for Energy Efficiency and Renewable Energy score in the G20 member states. Leaders in this area according to the highest scores for the 2022-2023 period are Germany (87.5), the United Kingdom (87), the Republic of Korea (87), and India (86.5).

Indonesia (42.5) and Argentina (43) are the lowest-positioned G20 member states according to their CCE Policy and Regulatory Support for Energy Efficiency and Renewable Energy scores.

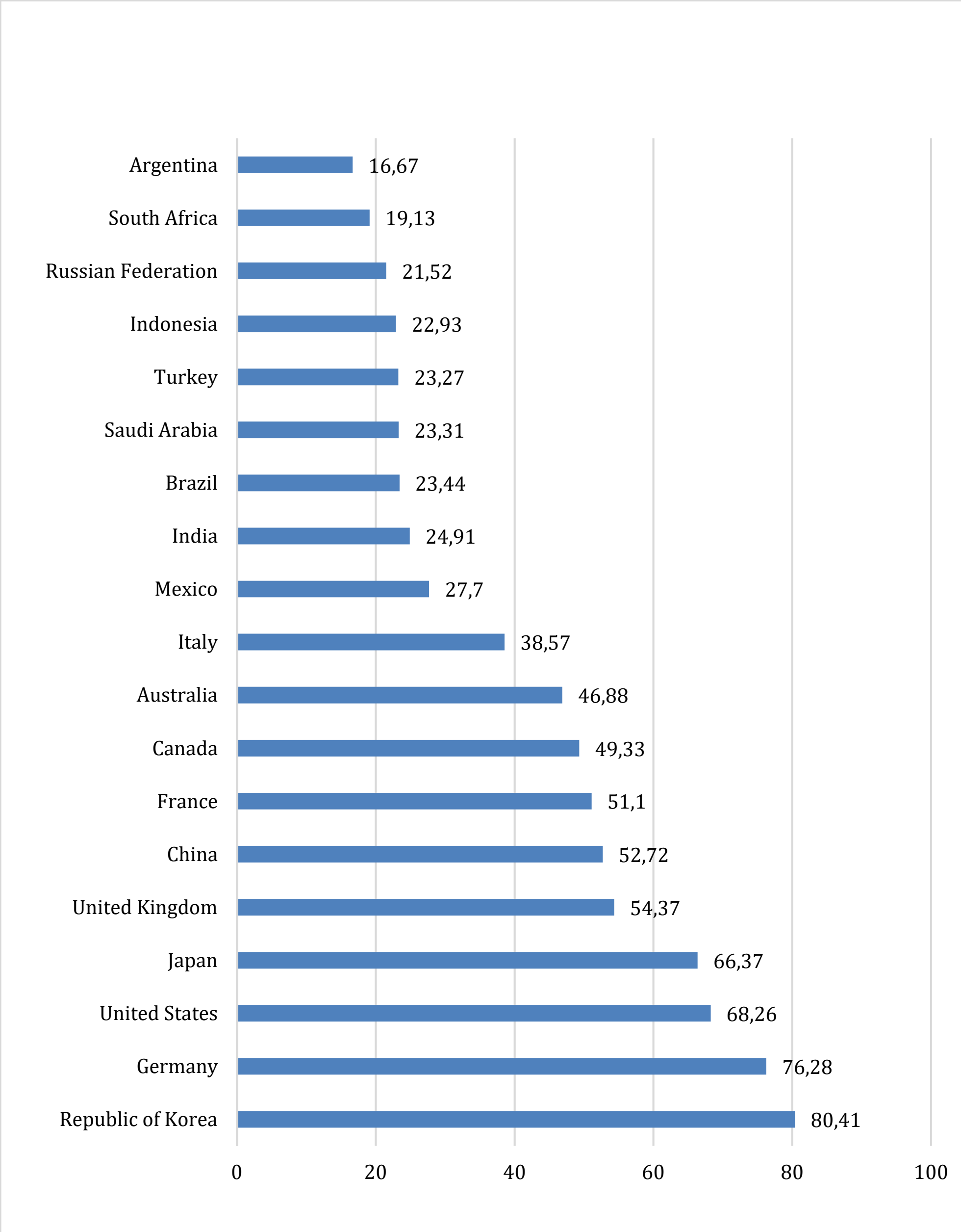
The CCE Index makes it possible to pinpoint sectors that require expedited adaptation as well as those that require or would benefit from worldwide collaboration to ensure that no one remains behind. One way to identify sectors where international collaboration could assist in improving development is to map out failures in implementation between the G20 nations, including specific nations' capabilities and weaknesses. Innovations such as clean hydrogen are considered essential for the decarbonization of industries that are difficult to mitigate.



Source: Derived by the author using data from the CCE Index 2022-2023.

Figure 15. Policy and Regulatory Support for Energy Efficiency and Renewable Energy in the G20 Member Countries, 2022-2023

Countries' achievement in producing, disseminating, and absorbing pertinent knowledge is captured by technology, knowledge, and innovation, which helps them realize their full capabilities for the CCE transition. Since many sustainable technologies are currently in the R&D (research and development) phase, they represent a great deal of potential to enable revolutionary developments that will quicken the transition to renewable energy.



Source: Derived by the author using data from the CCE Index 2022-2023.

Figure 16. Technology, Knowledge, and Innovation in the G20 Member Countries, 2022-2023

Figure 16 shows the Circular Carbon Economy Index’s Technology, Knowledge, and Innovation score in the G20 member states. Leaders in the G20 for the 2022-2023 period are the Republic of Korea (80.41), Germany (76.28), the United States of America (68.26), and Japan (66.37), while Argentina (16.67) is the lowest-positioned G20 economy according to its Technology, Knowledge, and Innovation score.

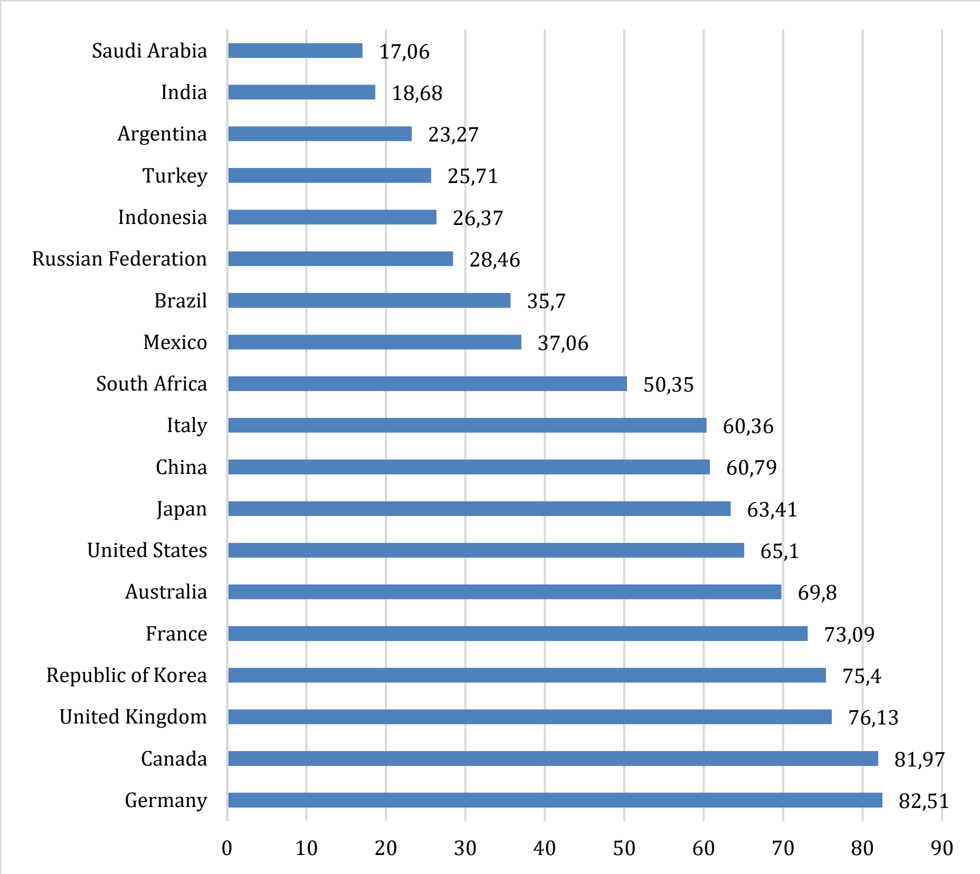
These findings reveal notable technological deficiencies, specifically in knowledge-creation metrics such as research and development spending, clean energy technology patents, and university research volume. Furthermore, several of the nations with below-average rankings seem to have relatively restricted worldwide high-technology contact (i.e., dissemination and absorption of knowledge via exports of technology and acquisitions).

The areas with the most differences between nations include finance and investment as well as technology, knowledge, and innovation. Concerning the former, there are particular weaknesses in many developing nation members' ability to access sustainable financing and make use of carbon market tools. As regards the latter, a more detailed analysis of the data shows that the development of clean energy technology is largely centred in the developed G20 member countries (such as the United States, Japan, Germany, and the Republic of Korea), with relatively little diffusion across the group’s developing member countries.

The main challenges that nations confront in speeding their progress towards a CCE are shortages in technology, expertise, and innovation as well as limited access to CCE financing. Although the deployment of clean technology has advanced in many industrialized economies, the creation, dissemination, and absorption of necessary knowledge has progressed more slowly in rising and developing nations. Corresponding to this, many countries face trouble utilizing sustainable financing, in part due to the inadequate institutionalization of necessary regulations.

Figure 17 shows the Circular Carbon Economy Index’s Finance and Investment score in the G20 member states. The leaders for the 2022-2023 period are Germany (82.51) and Canada (81.97).

Saudi Arabia (17.06) and India (18.68) are the lowest-ranked G20 economies according to their CCE Finance and Investment scores. The primary sources of financing for sustainability initiatives, as well as the monetary and economic tools intended to finance CCE transitions, are covered by the Finance and Investment metrics. In addition to ensuring a country's ability to take advantage of both domestic and international finance, it is imperative to create steps to increase sustainable funding and investment.

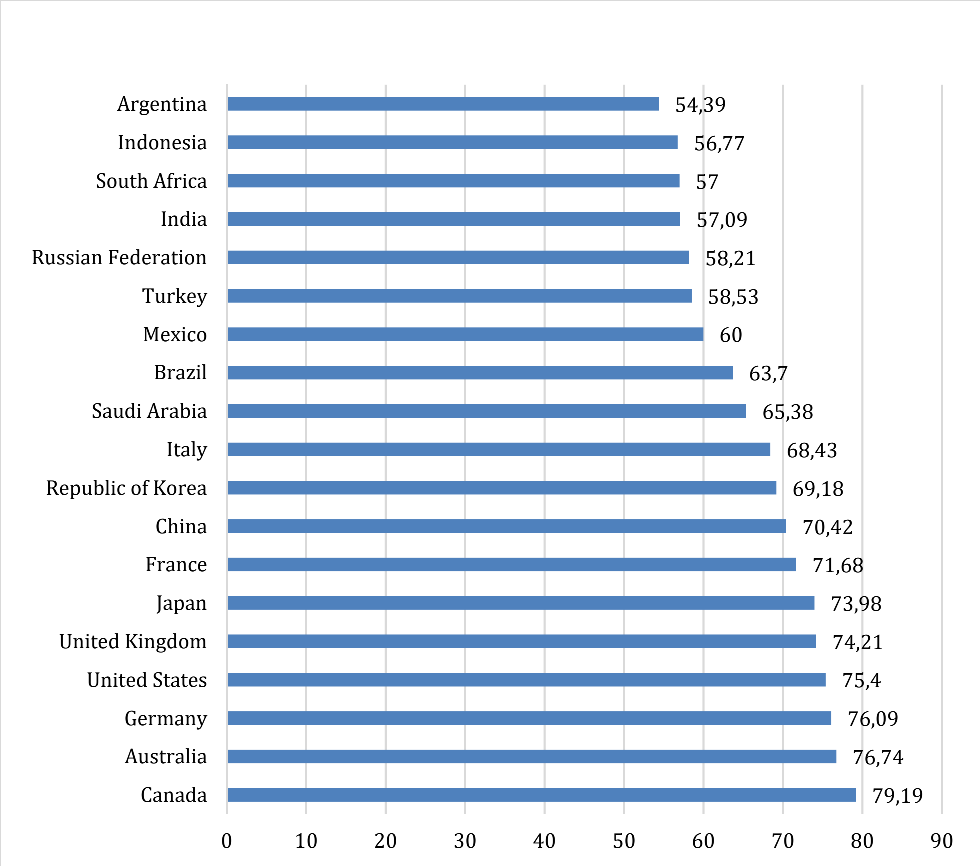


Source: Derived by the author using data from the CCE Index 2022-2023.

Figure 17. Finance and Investment in the G20 Member Countries, 2022-2023

Consequently, metrics of both ‘traditional’ and ‘green’ finance and investment are combined in the Finance and Investment dimensions. Nations' varying opportunities for sustainable financing (green, social, and sustainable bond markets and funding) and investments (both public and individual investments in CCE-associated renewable solutions) are the main causes of this enormous variation. Conversely, most nations have decent or fairly adequate access to traditional financing.

Figure 18 shows the Circular Carbon Economy Index’s Business Environment score in the G20 member states. The leader according to the highest score for the 2022-2023 period is Canada (79.19). Argentina (54.39) is the lowest-scored G20 country according to its CCE Business Environment score.

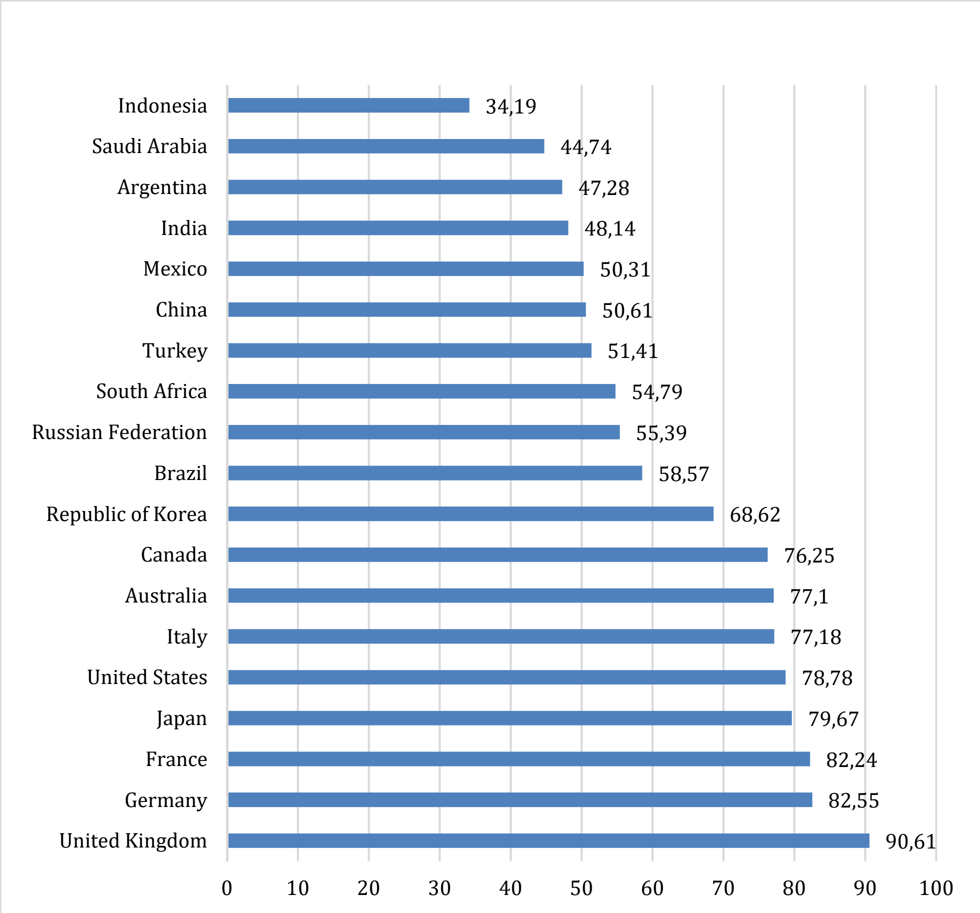


Source: Derived by the author using data from the CCE Index 2022-2023.

Figure 18. Business Environment in the G20 Member Countries, 2022-2023

The energy sector (energy safety and system reliability) and economic conditions (the ease of doing business and transportation effectiveness) are two more general enablers that are included within the Business Environment and Energy Security indicators. These can help attract the interest of private entities and funding for different phases of the CCE transition.

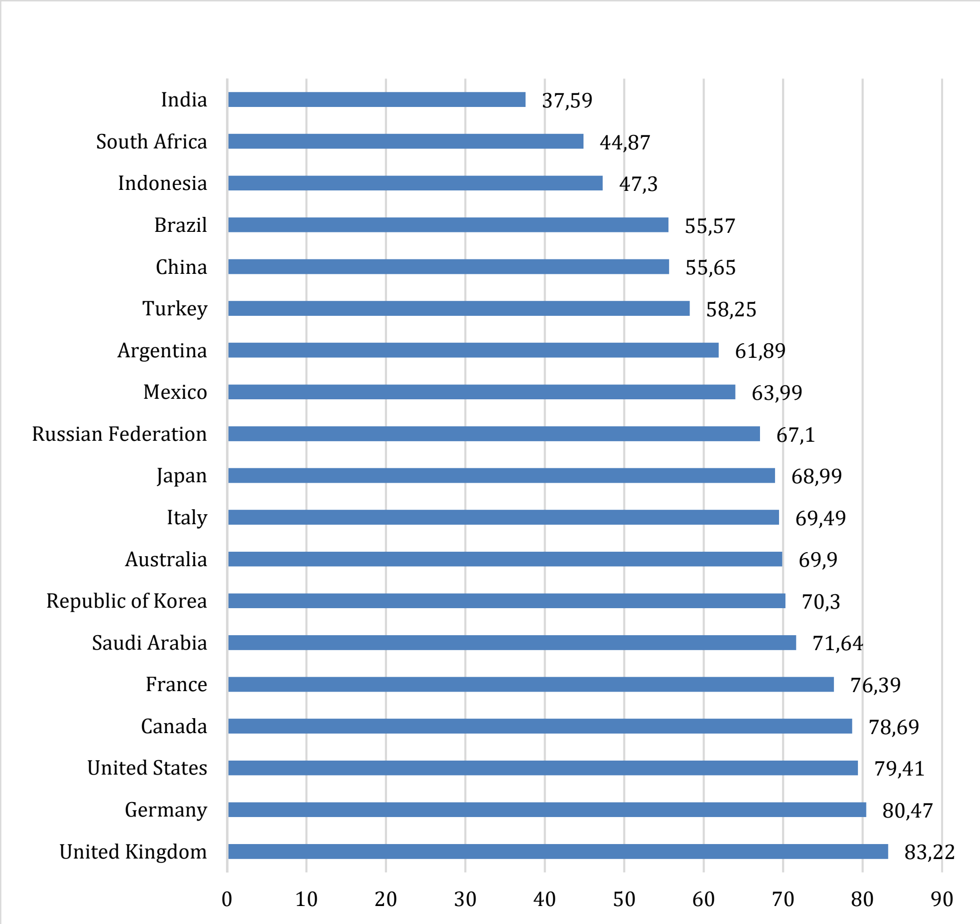
Figure 19 presents the Circular Carbon Economy Index's Policies and Regulation score in the G20 member states. According to the highest scores for the 2022-2023 period, the best performers are the United Kingdom (90.61), Germany (82.55), and France (82.24). Indonesia (34.19) is the lowest-scored G20 country according to its CCE Policies and Regulation score.



Source: Derived by the author using data from the CCE Index 2022-2023.

Figure 19. Policy and Regulation in the G20 Member Countries, 2022-2023

A nation's overall socioeconomic landscape is determined by a combination of broader elements with societal, economic, and ecological benefits like employment, energy equality, diversification of the economy, human capital efficiency, ecological wellness, and environmental resilience. These parameters are collectively referred to as socioeconomic background gauges. Figure 20 presents the Circular Carbon Economy Index's System Resilience score in the G20 member states. According to the highest scores for the 2022-2023 period, the best performers are the United Kingdom (83.22), Germany (80.47), and the United States (79.41). India (37.59) is the lowest-scoring G20 country according to its CCE System Resilience score.



Source: Derived by the author using data from the CCE Index 2022-2023.

Figure 20. System Resilience in the G20 Member Countries, 2022-2023

Regarding the interpretation of the CCE Performers sub-index findings, two points should be noted. The first has to do with the difficulty of developing a uniform weighting system to assess various CCE initiatives. The body of research on CCE highlights that solutions need to be based on the unique national circumstances of each country, including its endowment in natural resources and its development requirements and strategies. For instance, one state may decide to focus primarily on energy efficiency and renewable resources, while another may be able to increase its reliance on natural sinks, and yet another might be in a better position to implement large-scale carbon capture and storage (CCS) or produce hydrogen.

To maximize CCE benefits and minimize constraints, the following guidelines are suggested for decision-makers: (a) give non-end-of-life strategies priority to encourage an immediate increase in demand for essential supplies of raw materials; (b) modify the mixture of circular procedures with the benchmark of the green energy transition; and (c) carry out additional bio-projects that help create mutually beneficial relationships for the combined green waste governance and energy efficiency transitions. In summary, circular practices that are customized for present and local situations minimize carbon emissions with greater efficiency. Subsequent studies ought to concentrate more on the characteristics of various circular practices that change over time, the causes of both individual and household actions, and societal sustainability.

Conclusion

Based on the criteria used to evaluate efficiency and progress towards a circular carbon economy in the G20 member countries, the study's findings have indicated that there remains a significant gap between the leading and lagging countries. The nexus between the circular economy and the circular carbon economy is related to approaches to attaining green growth through environmentally conscious enterprises that maximize the use of readily available natural resources without endangering our ecologically sustainable development. The G20 member states have established stringent guidelines aimed at mitigating the adverse effects linked to climate change, such as becoming carbon neutral by lowering the production of greenhouse gases. Authorities, businesses, and beneficiaries must all be committed to achieving these objectives and sufficiently flexible to implement the required adjustments.

The G20 economies have to enact circular economy policies if they are to attain carbon neutrality and remain effective in developing environmentally friendly energy solutions. Taking into account the previous points, it can be concluded that the circular economy will be affected by variables whose sub-indicators have contributed to the analysis of CCE and green energy transition readiness among G20 member countries. An analysis of the inequality in CCE scores among the G20 economies from 2022 to 2023 reveals that differences across the states are not decreasing and, consequently, there is still substantial disparity in terms of CCE progress.

The results of the research highlight how important it is for G20 countries to strengthen efforts towards a circular economy and to encourage environmental awareness and sustainability. To compare the successes of national innovation initiatives, it is imperative to use the CCE Index, which comprises resource effectiveness gauges that are developed from relevant and reliable information. This may be a key element and a fundamental source of quantifiable information illuminating the degree of national CCE adoption in the G20 member states. Classifying the Index based on segments may have practical ramifications for beneficiaries as they decide how to most effectively promote a circular carbon economy while achieving the objectives of maximizing resource utilization and sustainable development. The CCE Index results are vital indicators, even though they offer G20 member states nation-specific values that demonstrate how effective each country is at the national level when coping with recently emphasized environmental challenges.

Countries should utilize the CCE Index to determine and reach consensus on the primary areas of achievement gaps that need immediate attention both worldwide and within the G20 group as they move towards net-zero emissions. G20 member states should also establish measurable goals to monitor their progress regarding the CCE. The CCE Index might be used by the G20 to map the top leaders in particular CCE technologies or enabling sectors and determine how they can help developing nations both inside and outside the group to achieve net-zero emissions. Finding fields where cross-country collaboration may help speed up progress can be aided by identifying shortcomings in implementation throughout the G20 as well as in developing nations worldwide, alongside mapping individual states' strengths and weaknesses. Innovative approaches such as clean hydrogen and carbon capture and storage (CCS) are considered essential for the decarbonization of difficult-to-abate industries. Although the majority of such industries are found in emerging and other developing economies, the implementation of clean hydrogen and the CCS system in these nations has lagged because of difficulties in obtaining and utilizing funding for such expensive technologies.

Conflicts of Interest

The author has no conflicts of interest to declare.

References

Andrews, D. (2015). The circular economy, design thinking and education for sustainability. *Local Economy*, 30(3), 305-315.

Bastein, T., Roelofs, E., Rietveld, E., Hoogendoorn, A. (2013). *Opportunities for a Circular Economy in the Netherlands*. TNO. Report commissioned by the Netherlands Ministry of Infrastructure and Environment.

Braungart, M., McDonough, W., Bollinger, A. (2006). Cradle-to-cradle design: creating healthy emissions – a strategy for eco-effective product and system design. *Journal of Cleaner Production*, Vol. 15, 1337-1348.

Chertow, M.R. (2000). Industrial Symbiosis: Literature and Taxonomy. *Annual Review of Energy and the Environment*, Vol. 25, 313-337.

Ellen MacArthur Foundation, McKinsey & Company. (2014). *Towards the Circular Economy: Accelerating the scale-up across global supply chains*. Ellen MacArthur Foundation.

Erkman, S. (1997). Industrial ecology: an historical view. *Journal of Cleaner Production*, Vol. 5, No. 1-2, 1-10.

European Commission. (2016). *Closing the Loop – An EU Action Plan for the Circular Economy*; Communication No. 614 (COM 2015). Brussels, Belgium: Commission of European Communities.

European Commission. (2017a). *Roadmap – Strategy on Plastics in a Circular Economy*. Communication from the Commission to the European Parliament, the Council, the European Economic Social Committee, and the Committee of the Regions.

European Commission. (2017b). *The role of waste-to-energy in the circular economy*. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions.

European Environment Agency, EEA. (2014). *Resource-efficient green economy and EU policies*. Luxembourg: Publications Office of the European Union.

European Parliament. (2024). *The new circular economy action plan*. Legislative train, 08.2024. Available at https://www.europarl.europa.eu/legislative-train/carriage/new-circular-economy-action-plan/report?sid=8301.

Frosch R. A., Gallopoulos, N. E. (1989). Strategies for manufacturing. *Scientific American*, Vol. 261, No. 3, 144-152.

G20 Climate Stewardship Working Group. (2020). *Managing Emissions in the Context of the Circular Carbon Economy Platform* (Presidency Report).

Geissdoerfer, M., Savaget, P., Bocken, N. M. P., Hultink, E. J. (2017). The Circular Economy – A new sustainability paradigm? *Journal of Cleaner Production*, Vol. 143, 757-768. https://doi.org/10.1016/j.jclepro.2016.12.048.

Ghisellini, P., Cialani, C., Ulgiati, S. (2016). A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production,* Vol. 114, 11-32.

Graedel, T. E., Allenby, B. R. (1995). *Industrial Ecology.* Englewood Cliffs, New Jersey:

Prentice Hall.

Heck, P. (2006). *Circular economy related international practices and policy trends: Current situation and practices on sustainable production and consumption and international circular economy development policy summary and analysis*. Institut für angewandtes Stoffstrommanagement (IfaS).

Hepburn, C., Adlen, E., Beddington, J., Carter, E., A., Fuss, S., Dowell, N. M., Minx, J. C., Smith, P., Wiliams, C. K. (2019). The technological and economic prospects for CO2 utilization and removal. *Nature*, 575 (7781), 87-97. https://doi.org/10.1038/s41586-019-1681-6.

International Energy Agency, IEA. (2024). Available at https://www.iea.org/.

International Renewable Energy Agency, IRENA. (2024). Available at https://www.irena.org/.

Jesinghaus, J. (2014). Bellagio principles for assessing sustainable development. In: Michalos, A.C. (ed.) Encyclopedia of quality of life and well-being research. Dordrecht: Springer, 360-361.

KAPRSC (2020). *CCE Guide Overview: A guide to the circular carbon economy*. King Abdullah Petroleum Studies and Research Center.

Kopnina, H. (2018). Circular Economy and Cradle to Cradle in Educational Practice. *Journal of Integrative Environmental Sciences*, 15(1), 119-134.

Korhonen, J., Nuur, C., Feldmann, A., & Birkie, S. E. (2018). Circular economy as an essentially contested concept. *Journal of Cleaner Production*, Vol. 175, 544-552. https://doi.org/10.1016/j.jclepro.2017.12.111.

Lieder, M., Rashid, A. (2016). Towards circular economy implementation: a comprehensive review in context of manufacturing industry. *Journal of Cleaner Production*, Vol. 115, 36-51.

Lombardi, R. D., Laybourn, P. (2012). Redefining Industrial Symbiosis. Crossing Academic-Practitioner Boundaries. *Journal of Industrial Ecology*, Vol. 16, N 1, 28-37.

McDonough, W., Braungart, M. (2002). *Cradle to Cradle: Remaking the Way We Make Things*. New York: North Point Press.

Nuclear Energy Agency, NEA. (2024). Available at https://oecd-nea.org/.

Organization for Economic Co-operation and Development, OECD (2024). Available at https://www.oecd.org/.

Pauli, G. (2010). *The Blue Economy: 10 Years, 100 Innovations, 100 Million Jobs.* Taos, New Mexico: Paradigm Publications.

Preston, F. (2012). *A Global Redesign? Shaping the Circular Economy.* Briefing Paper.

London, UK: Chatham House.

Rizos, V., Behrens, A., van der Gaast, W., Hofman, E., Ioannou, A., Kafyeke, T., Flamos, A., Rinaldi, R., Papadelis, S., Hirschnitz-Garbers, M., Topi, C. (2016). Implementation of Circular Economy Business Models by Small and Medium-Sized Enterprises (SMEs): Barriers and Enablers. *Sustainability*, Vol. 8, No. 11, 2-18.

Sánchez-García, E., Martínez-Falcó, J., Marco-Lajara, B., Manresa-Marhuenda, E., (2014). Revolutionizing the circular economy through new technologies: A new era of sustainable progress. *Environmental Technology & Innovation*, Vol. 33, 103509. https://doi.org/10.1016/j.eti.2023.103509.

Saputra, R., Khalid, M., Walvekar, R., Pariatamby, A. (2022). *Circular carbon economy. Emerging Carbon Capture Technologies: Towards a sustainable future*. Amsterdam: Elsevier, 427-462.

Sauvé, S., Bernard, S., Sloan, P. (2016). Environmental sciences, sustainable development and circular economy: Alternative concepts for trans-disciplinary research. *Environmental Development*, Vol. 17, 48-56.

Terzić, L. (2024a). An investigation of the interlinkages between green growth dimensions, the energy trilemma, and sustainable development goals: Evidence from G7 and E7 economies. *Ekonomista Journal*, 2024 (1), 24-53. https://doi.org/10.52335/ekon/183586.

Terzić, L. (2024b). Innovation and Transition Performance as Drivers of Economic Growth and Prosperity: The Case of the EU. *Economic Thought Journal,* 68 (6), 621-641. https://doi.org/10.56497/etj2368602.

Terzić, L. (2024c). The importance of resource efficiency indicators in assessing eco-innovation in the European Union countries. *Journal of Theoretical and Applied Economics,* Vol. XXXI, No. 1 (638), Spring 2024, 15-28.

The European Academies Science Advisory Council, EASAC. (2016). *Priorities for critical materials for a circular economy*. EASAC policy report 29.

Toxopeusa, M. E., de Koeijer, B. L. A., Meij, A. G. G. H. (2015). Cradle to Cradle: Effective Vision vs. Efficient Practice? *Procedia CIRP*, 29, 384-389.

Tukker, A. (2015). Product services for a resource-efficient and circular economy – a review. *Journal of Cleaner Production*, Vol. 97, 76-91.

Tukker, A., Tischner, U. (2006). Product-services as a research field: past, present and future: Reflections from a decade of research. *Journal of Cleaner Production*. Vol. 14, 1552-1556.

UNECE (2021). *Sustainable Development Goals. Integral Circular Economy Report*. Available at https://unece.org/trade/CircularEconomy.

UNIDO (2021). *Circular Economy Report*. Available at https://www.unido.org/unido-circular-economy.

Vanner, R., Bicket, M., Withana, S., ten Brink, P., Razzini, P., van Dijl, E., Watkins, E., Hestin, M., Tan, A., Guilcher, S., Hudson, C. (2014). *Scoping study to identify potential circular economy actions, priority sectors, material flows & value chains*. Study prepared for the European Commission, DG Environment.

Lejla Terzić, PhD, is Associate Professor, Faculty of Economics, and Dean of Academic Affairs at the University of East Sarajevo in Brčko, Bosnia and Herzegovina. ORCID 0000-0002-5048-036X, lejla.terzic.efb@gmail.com.

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