# Chapter 3
# Circular Economy and Renewable Energy: A Global Policy Overview

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**Abstract** This chapter provides a comprehensive overview of global policies pertaining to the circular economy and renewable energy. The concept of a circular economy, which aims to minimize waste and maximize resource efficiency, has gained significant attention in recent years. Simultaneously, the importance of renewable energy sources in mitigating climate change and ensuring sustainable development has become increasingly evident. This study examines the interplay between these two critical areas and explores the policies implemented to promote their integration. By analyzing key initiatives and strategies, this paper aims to shed light on the current state of global policy frameworks and identify potential areas for improvement. It contributes to a better understanding of the challenges and opportunities associated with transitioning towards a more sustainable and energy-efficient future.

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## 3.1 Introduction

Since the 1700s, humans have relied on fossil fuels as the main source of power. These non-renewable fuels have supplied almost 80% of the world's energy demand, enhancing the process that makes a huge range of products and reducing the need for labor. The rapid rise in the global population and the growth in industrialization have led to a dramatic increase in the world's energy demand over the past decade. However, it appears that conventional fossil fuels would not be able to satisfy this requirement due to their grievous challenges, such as price inflation, climate changes, and environmental damages (ClientEarth 2022; UNEP 2022). The consumption of fossil fuels leads to environmental severe consequences regarding greenhouse gas (GHG) emissions.

The use of renewable energy (RE) has been considered one of the most critical components of the sustainable development strategy over the past decades (Sueyoshi et al. 2022). Since 1997, the Kyoto Protocol has been signed by many participating countries to reduce GHG emissions and the dependence on fossil fuels for economic development. The protocol also proposed the promotion, development, and increased use of new and renewable forms of energy valuable plans to facilitate RE (UN 1998; Lau et al. 2012). However, the use of fossil fuels for energy production at this current state has not subsided effectively, while the global greenhouse gas emissions have increased to 40–45% (Ritchie et al. 2022). The task of reducing GHG emissions has always been challenging. The most renowned plans, including the Kyoto Protocol, the Paris Agreement in 2015, and the EU Climate energy package in 2020, also encountered problems. For instance, Kyoto Protocol failed to reduce global GHG emissions since there was a lack of a comprehensive global agreement (Rosen 2015), while the Paris Agreement succeeded in requiring all countries to set emissions-reduction pledges, known as nationally determined contributions; however, there are no enforcement mechanisms to ensure they meet their targets. Furthermore, the United States, the world's second-largest emitter, formally withdrew from the Paris accord in 2020; however, the country rejoined the Agreement in 2021 under Joe Biden Administration. Tackling GHG emissions requires a new strategy of manufacturing, transportation, and energy consumption, which are also imperative to reduce the dependence on fossil fuels, effectively extend the life of materials beyond their original use and lower the carbon emission to achieve net zero emission by 2050 (USAID 2022a, b). The transition to RE complemented by energy efficiency could be able to cut almost 50% of global GHG emissions (United Nations 2018), however the high demands of RE sources, such as solar and wind energies, and storage systems in the next few decades during the transition to clean energy are forecasted to require a large number of critical metals (Indium, Silver, and Neodymium, etc.) and materials for RE equipment. Generally, the quantity of RE equipment is expected to grow exponentially in the next 30 years, estimated to increase to 10 million tons annually in 2050 (Peplow 2022). It would be a great concern for the environment and human health since mineral extraction (mining), oil, and gas are still major resources that provide the raw materials to support RE production. Thus, the RE industries could pay more attention to their whole lifecycle processes, manufacture, installation, use, and disposal, in terms of sustainable, low-carbon, and safe processes.

The circular economy (CE) approaches have recently been critically necessary to achieve the upscale of RE generation and integration. In a CE system, the RE materials, parts, and equipment possess multiple life cycles, which also means providing a low GHG emission supply chain for the materials, reducing wastes, and creating optimum benefits for the community in a transition to a cleaner energy economy (OECD 2019; Mutezo and Mulopo 2021). The CE strategies would keep wastes out of the landfill option, reducing the demand for the material for energy equipment manufacturing, and also can be able to generate about 4.5 trillion USD in additional economic output by 2030 (OECD 2019). This new business model also offers innovation opportunities and jobs focused on the reuse, repair, and remanufacturing industries. In that manner, the more sustainable use of materials and energy could add an extra 2 trillion USD annually to the global economy by 2050, raising the global domestic products by 8% and benefiting the low and middle-income nations (Goldman Sachs 2022).

The reshaping of the RE industry into a more circular economy system is a critical paradigm shift that is benefited, encouraged, and very promising. In the CE, recycling becomes the last resort, not the first or the only option. This transition determines the role of product repairing and refurbishing, which may result in minimizing resource usage and contributes greatly to the reduction of global GHG emissions by almost 40% more (equivalent to 22.8 billion tons) (ECEEE 2021). According to the World Economic Forum (2020), the CE is vital for the energy transition in three ways, which not only solve the problem of GHG emissions but also strengthen the economy through (1) Recycling can conserve critical materials, (2) Using low-carbon, circular materials, (3) Designing circular systems (World Economic Forum 2020).

In order to achieve a successful transition to a cleaner energy economy, stakeholders, including government, industries in the whole supply chain, policymakers, and investors, would need to take concerted actions. RE policies oriented to CE could play crucial roles in promoting sustainable renewable energies on a large scale, which could overcome all existing barriers to achieving carbon neutrality by 2050. Such policies could affect the decision-making of producers, distributors, users, and disposers of renewable technologies. However, the energy strategies related to the targets of RE development may differ among the countries or regions, resulting in the different policies supporting RE and CE around the globe. In addition, there is currently a lack of connection between the CE and RE policies. The energy sector is rarely mentioned in the CE research and policies and vice versa. Moreover, policymakers are more interested in solar photovoltaic (PV) and wind energy technology than other renewable energy types. Also, except for the EU, the renewable energy development policy with a CE orientation is still unconnected, lacking coherence and systematicity.

Currently, national or regional policies on recycling, landfills, and extended producer responsibility are interested in the EU countries, the United States, China, India, and Japan. Despite the lack of national PV waste laws, some states in the US have introduced product stewardship policies, Sustainability Leadership Standard for PV Modules, Inverters, and the Silicon Valley Toxics Coalition's Solar Scorecard. These policies affect the design, manufacturing, and disposal management of PV modules and related products (Heath et al. 2022). According to the amendments by the Act on Partial Revision of the Electricity Business Act, Japan will start the decommissioning reserve scheme in 2022 (International Energy Agency 2021). Other countries such as the United Kingdom, Switzerland, Norway, Germany, France, Australia, Russia, China, and India have also introduced national regulations for recycling solar PV modules and storage (Sharma et al. 2019; Boelens et al. 2022).

To provide more insights into global policies of circular economy and renewable energy, we review specific policies on critical materials, scarce earth, manufacturing, installation/deployment, and disposal of renewable energy technologies with case studies. The critical material and element using, manufacturing and deployment of the RE system will be presented in Sects. 3.2, 3.3 and 3.4. On the other hand, Sect. 3.5 is devoted to the disposal solution following cases mentioned previously. Finally, we discuss the various aspects of mainstream CE in RE policy.

## 3.2 Policies on Circular Economy Oriented-Raw Materials and Elements

The flourishing of RE in transition to clean energy has a greater demand for virgin materials and rare earth minerals. According to Dang et al. (2021), millions of tonnes of composite and rare earth materials are extracted and processed. The wind turbine and PVs require rare earth elements for permanent magnets, while the battery energy storage systems (BESS) rely on lithium, nickel, cobalt, manganese, and graphite. The demand for minerals and rare earth elements would rise by over 40%; lithium would be up to almost 90%, and nickel and cobalt will be around 60 and 70%, respectively (IEA 2021). Mining is essential to the growth of renewable energy. The high demand for the minerals and elements may increase mining production, which causes negative environmental and social impacts, biodiversity loss, and even increases GHG emissions (Sonter et al. 2020; Rehbein et al. 2020). The mining policies related to BESS and RE also need to shift towards sustainability goals by recycling these materials. The materials used to produce components for renewable energy generation emit $CO_2$. In order to ensure that these sources are truly clean, policies to develop technology to reduce the $CO_2$ share in the entire equipment's life cycle need to be strengthened.

For instance, China is the largest producer of rare earth elements (REEs), including neodymium, dysprosium, and praseodymium, accounting for 58% of the world's rare earth element market (Mineral Commodity Summaries 2021). As promised to achieve carbon neutrality before 2060, the Chinese government has paid more attention to environmental impacts by issuing more stringent environmental policies and restricted export regulations (Mancheri et al. 2019).Additionally, China has considered recycling and waste management of REEs to improve resource efficiency since the waste collection and recycling system for rare earth elements is still ineffective (Ge et al. 2022). Currently, limited REEs have been recycled except for Nd-Fe-B permanent magnet due to high demand; other REEs containing final products have no or low recycled rate (Jo 2015). Changes in China's policies related to REEs and solid political tensions, such as the REEs war, scramble between the USA and China, or even the Russia-Ukraine war, could influence the global supply chain disruption (Hornby and Zhang 2019). This may influence other major REEs production countries, including Australia, the United States, Brazil, Russia, Myanmar, Burundi, India, Malaysia, Madagascar, Thailand, and Vietnam (Huleatt 2019).

Another example is Australia, which has become the second-largest REEs producer due to the above issue. The country plays a vital role in REEs production, reaching 21 kt in 2019 (Huleatt 2019; The U.S. Geological Survey 2020). The elevation of REE extraction and processing resulted in the country facing environmental challenges, which impulsed the development of eco-friendly mining techniques. However, at the same time, stringent policies were developed for reducing, reusing, and recycling strategies such as 2022 Critical Minerals Strategy (The Australia Government 2022). Countries with limited REE resources are considering circular economic strategies to mitigate the future shortage of materials and REEs (Metabolic 2021). For instance, The Netherlands proposes circular strategies, which focus on Rethinking, Reducing, Repairing, Refurbishing and Repurposing, and Recycle (Metabolic 2021). Even with the high demand for REEs, currently, recycling constitutes less than 5% of the global REE supply; many EU countries have paid more attention to critical raw materials, recycling, and sustainable waste management, particularly Critical Raw Materials Resilience (Communication COM 2020). Therefore, CE principles could be incorporated into REE mining to improve economic and environmental performance.

## 3.3 Policies on Circular Economy Oriented-Renewable Technology Manufacturing

RE technological manufacturing is one of concern regarding its environmental impacts. The manufacturing process uses and releases hazardous chemicals, requires a large amount of energy, components, and materials, including rare earth elements, and emits GHG (Peiró and Méndez 2013; Yue et al. 2014). However, there are currently no direct CE policies and regulations in the RE technology manufacturing phases. China is one of the world's largest producers of wind and solar energy, and the process of producing RE requires a tremendous amount of non-renewable energy (Lakatos et al. 2011), resulting in high carbon emissions (Xu et al. 2018). The solar industry in China has emitted twice the carbon footprint as that made in Europe due to a lack of environmental standards for solar PV production (Yue et al. 2014). After the COP26 summit in early November 2021, China has recently released more policies and regulations focusing on the stringent environmental protections related to energy production (Zhang et al. 2022). In 2022, China released the document "the Guiding Opinions on Accelerating the Establishment and Improvement of a Green, Low-carbon and Recycling Economic System." Accordingly, broader goals for China to transfer to a green economy, which pays attention to the efficient use of resources, energy, and environmental protection industry, are set (China Briefing 2022).

In the United States, renewable energy manufacturing has good opportunities for renewal and growth in solar, wind, and energy storage. This country's goal is an annual of 30 GW between now and 2025 and 60 GW annually from 2025 to 2030 for solar power. Meanwhile, the goal is to deploy 30 GW offshore wind by 2030 and unlock more than 110 GW of deployment by 2050 (SEIA 2020). The new materials and manufacturing strategies are essential to reduce costs, waste management (no end-of-life challenges), and material use efficiency. A CE concept for energy materials has been mentioned (NREL 2020); however, there is still a lack of specific policies for CE. In the report, NREL emphasized designing clean energy technologies by reducing, reusing, and upcycling energy-relevant and energy-intensive materials, processes, and technologies. For instance, a study on Solar Futures showed that CE methods could be incorporated into the PV manufacturing stage (Garvin et al. 2022). Some manufacturers have designed for circularity by using secondary materials as end-of-life PV materials or used materials recovered from non-PV systems in PV manufacturing (recovering semiconductor materials, e.g., Cd and Te). Some used renewable electricity for PV manufacturing processes (Garvin et al. 2022). The closer CE policies regarding the RE may be defined in Regulation (EU) 2020/852, which aligns with Directive (EU) 2018/2001 in Europe. European Commission has mentioned CE in the manufacture of renewable energy technologies that postulated the RE manufacturers to produce much cleaner and safer energy through material efficiency, waste prevention, and recycling (EU Taxonomy Compass 2022).

## 3.4 Policies on Circular Economy Oriented-Renewable Technology Use (Installing/Operation)

The global transition to renewable energies is a concern when this makes conflicts over land use, land cover changes, graded soils, biodiversity loss, and food security (Hernandez et al. 2014, 2015). Power plants and transmission lines can damage forests, wetlands, and other natural areas (Biasotto and Kindel 2018). A global increase in large, centralized installations of RE systems, such as solar and wind energy, has received attention over the impact on land use and water resources. The deployment of these systems cleared large areas of aboveground vegetation, resulting in the degradation of soils and landscape that influence species movement, preying strategies, and natural selection (Leskova et al. 2022; Northrup and Wittemyer 2012).

In Japan, there are two ways to convert agricultural lands into renewable energy sites: switching the whole croplands and adopting shared-use systems (Kohsaka and Kohyama 2022). To date, the shared-use system, especially "solar sharing" is applied in most croplands, where land can be used for agriculture activities and renewable energy generation simultaneously (Kohsaka and Kohyama 2022). However, in March 2020, 80% of the cropland yield was not met due to the interference of solar power plants in farming activities, as recognized by the Ministry of Agriculture, Forestry, and Fisheries (MAFF) (Kohsaka and Kohyama 2022). Consequently, these regulations were deregulated drastically at the moment. MAFF decided to simplify the requirement by examining the proper and efficient utilization of cropland along the solar power plant, in place of requiring landowners to produce a yield of 80% in the converted cropland (Kohsaka and Kohyama 2022). Therefore, after ten years (expiration date), the operators of the solar power plants can renew the permit to convert cropland to other land uses without considering agriculture production yields (Kohsaka and Kohyama 2022). Recently, a draft amendment of the "Agriculture, Forestry and Fisheries Vitalization Act (Act No. 48 of 2007)" was submitted by MAFF (Kohsaka and Kohyama 2022). This will counter degraded croplands by allowing a collective transfer of cropland rights. In detail, when cropland is identified and categorized as degraded and is hard to reuse or cultivate again, the Agricultural Commission will notify the owners, municipalities, and other stakeholders (Kohsaka and Kohyama 2022). Then, there is a request for the recipient of the notice to send a notification to the Legal Affairs Bureau to change the land category (to "non-cropland" or "degraded cropland") (Kohsaka and Kohyama 2022). Under the Rural Renewable Energy Act, when the production conditions show the low-quality performance of cultivation for a considerable period, the law will be relaxed, allowing conversion from degraded cropland that is exempt from conversion to other land uses (Kohsaka and Kohyama 2022).

Enabling policies to ensure adequate operating conditions for renewables in energy systems and markets are usually recommended to promote the deployment and operation of RE (IRENA, IEA, and REN21 2018). Integrating policies, which account for technical issues in the installation and operation, and behavioral and social change related to the RE implementation are also needed. For example, the application of RE during the transportation phase is one of the promising approaches to reducing GHG and energy consumption. Companies in the field of automotive production can improve logistical circularity by implementing distribution-oriented strategies, including freight fuel economy improvements, the use of electric vehicles, and enhancing the efficiency of freight carriers and networks. These strategies involve several technical, social, and economic factors (Esteva et al. 2020). However, policies supporting logistics and transportation currently focus mostly on biofuels.

Integrating policies with several instruments for system integration, technology innovation, energy access, and sustainability considerations are therefore vital to enhance the operation of RE.

## 3.5 Policies on Circular Economy Oriented-Renewable Technology Disposal (Decommissioning)

With an average lifespan of 10–40 years, many of the world's RE, such as solar PV modules and onshore and offshore wind turbines, installed during the 1990s and early 2000s, come time for their decommissioning. Large amounts of annual waste, including solar panels, wind turbine blades, and used batteries, are anticipated worldwide in the early 2030s (Davis et al. 2021). Many countries have begun to express concern about managing the material flows of decommissioned wastes and energy storage technologies. Country-specific policies have been published related to end-of-life types of RE, landfill bans, and extended producer responsibility (EPR) (Invernizzi et al. 2020; USAID 2021).

EU is one of the leading countries or regions in implementing policies in managing wastes from electrical and electronic equipment used in the renewable energy industry, such as using solar PV modules, to contribute to sustainable production and consumption. The European Waste Electrical and Electronic Equipment Directive (EU WEEE Directive) was released in 2013 and is currently applied in 28 EU countries. This regulation mentioned that PV manufacturers are responsible for the costs of collection, handling, and treating PV module waste (Official Journal of the European Union 2012). To support the implementation of the PV module recycling program, Germany has introduced two financial mechanisms of Business-to-consumer (B2C) transactions, Business-to-Business (B2B) transactions (Sharma et al. 2019). While 85% of the turbine's components, including the tower, generator, and gearbox, can be reused or recycled easily, rotor blades made of composite materials are challenging to recycle. To avoid the landfills of turbine blades, several countries in Europe, including Germany, the Netherland, Austria, and Finland, have introduced blade landfill ban regulations and tax incentives (WindEurope 2021). Furthermore, most member countries have adopted a new Circular Economy Action Plan, a new Batteries Regulation, which ensures that batteries placed in the EU market are sustainable and safe throughout their life cycle within the overall Circular Economy Action Plan (EC 2020). Accordingly, the regulation intends to mandate labeling requirements and a carbon footprint declaration for all relevant equipment.

In the United States, solar decommissioning regulations have been prepared at federal and state levels, which vary by federals, states, and local jurisdictions (Curtis et al. 2021). These policies require solar developers to submit the decommissioning plan before construction or operation. In addition, acknowledging asset owner decommissioning responsibilities and what constitutes abandonment, a detailed cost estimation, proof of financial assurance, removal equipment, site restoration, and post-decommissioning monitoring, reporting, assurance, and closure requirements are also required provided (Curtis et al. 2021). The gap in these policies was not designed with the new solar technologies, but the importance of policies was to establish a framework for enabling a CE for solar photovoltaic energy generation (Curtis et al. 2021; BNEF 2021). Additionally, the US has prepared policies related to the secondary market for solar PV equipment components, which aim to keep solar PV modules and their constituent materials in use for extended periods (Boelens et al. 2022). Secondary markets and services are becoming increasingly essential to manage material flows and establish a circular economy for PV modules (Boelens et al. 2022).

Japan, China, and India have also introduced national recycling regulations for solar PV modules, wind turbine blades, and energy storage (Sharma et al. 2019). In China, the central government published a new policy, The implementation Plan for speeding up the "Promotion of the Comprehensive Utilization of Industrial Resources," related to the circular economy principle (Ministry of Industry and Information Technology 2022). The regulation was issued on the recycling of industrial materials, and the central government laid out plans to promote the development of technologies for the reuse of retired solar and wind facilities and to improve recycling systems for EV batteries (Ministry of Industry and Information Technology of China 2022). Unlike China, India has not yet had a policy on managing waste derived from used solar power panels or manufacturing processes (Jain et al. 2022). India considers solar waste a part of electronic waste under the Ministry of Environment, Forest and Climate Change (MoEF&CC). However, Ministry for New and Renewable Energy is considered to propose an action plan to evolve a "circular economy" in the solar panels through the reuse/recycling of waste generated (Jain et al. 2022).

## 3.6 Discussion

CE has the leading role in sustainable development policies, such as reducing reliance on fossil fuels and pollution by utilizing renewable energy, reducing the manufacturing sector's carbon footprint through mandatory carbon credit, cutting down on wasted consumption, and increasing energy efficiency. CE also creates the prerequisite and basis for sustainable energy development, keeping global warming within 1.5 °C and achieving net-zero targets. According to Black et al. (2021), net zero commitments globally cover at least 61% of global GHG emissions and 68% of the global GDP. Plans for CE have been developed in many regions and countries, such as Latin America, the Caribbean, Colombia, Chile, Uruguay, Mexico, Brazil, Peru, Ecuador, Paraguay, El Salvador, Cuba, and the Dominican Republic. RE uses many novel materials during its lifetime, divided into 4 stages: raw materials-production-consumption-disposal. CE will turn this process into a closed cycle, in which disposed products can be recycled into raw materials. In RE policies, the government needs to mandate the cost of project decommissioning after a 25–30-year lifespan for the developer, for example, collecting 78 million tons of PV panels or recycling

43 million tons of wind turbine blades by 2050 (USAID 2021). Possible solutions are lifetime extension or increasing funding for research in raising the recovery rate of decommissioned equipment, according to the 4R principle in CE: reusing, repurposing, recycling, and recovering (or reusing, remanufacturing, refurbishment, repairing, or even 6Rs, namely: reuse, recycle, reduce, recover, remanufacture and redesign) (Mutezo and Mulopo 2021; Hao et al. 2020). CE is related to processes such as Manufacturing, Supply Chain Management, Biogas for Electrification, and Waste Management (Hao et al. 2020).

Since the Fukushima Nuclear Power Plant accident in 2011 to replace decommissioned nuclear power plants or plants in the process of decommissioning around the world, the demand for renewable energy to fill the power generation gap has become more evident in many countries. Despite the Covid epidemic, the Feed in tariff (FiT) for RE has led to a spike in installed capacity of up to 825 GW of wind and 843 GW of solar power in 2021 (USAID 2021). The FiT policy shows the role of government in leading development, especially for the financial impact on RE projects. In most countries, the purchasing price of electricity produced by RE has been significantly higher than that of traditional energy sources, bringing reasonable profits to investors. It has helped attract significant financial investments for wind and solar power projects. After the FIT tariff period, when the market has been formed, and RE technology is mature, market liberalizing and auction mechanisms will become popular. Government policy would follow these routes to facilitate the market, ensuring that CE issues are integrated and avoiding focusing solely on selecting projects for low bids. During this energy transition, the development of RE associated with CE requires phasing out of traditional fossil fuel-powered power plants in a sustainable way to avoid labor loss and waste of investment capital while promoting environmentally friendly power sources at a reasonable cost. Most countries have undergone massive RE development due to the high FIT prices, followed by policies for sustainable development to gradually achieve 100% RE targets in some regions and countries.

However, it is also important to note that the source of policies promoting RE also has a part of CE, which is $CO_2$ emission reduction, mentioned from the very first years of RE development (Eric 2011). Calculations in countries such as China, the US, Canada, Germany, India, Russian Federation, Korea, Iran, and the UK all show that RE development can reduce a certain amount of $CO_2$ and reduce environmental harm in energy use, pursuing the goals of the Nationally Determined Contributions (NDC) (Dara et al. 2022). For example, India has a very persistent policy in developing RE to achieve climate change goals such as Electricity Act 2003, Integrated Energy Policy 2006, National Action Plan on Climate Change (NAPCC) 2008, FiT, renewable portfolio obligation, fiscal incentives, Optimal energy mix for 2021–2030, transition in energy mix and growth in RE based electricity in 2015–2020. However, CE policies such as solid waste treatment in RE have received almost no attention (Sawhney 2021). CE principles are also applied in Africa during the transition from fossil fuel to RE, especially across their Big Five economies (Algeria, Nigeria, Egypt, Morocco, and South Africa) (Mutezo and Mulopo 2021).

Among the types of RE, CE can be suitable and close to developing bioenergy sources when most of the fuels burned to generate electricity are products of other industries such as forestry, animal husbandry, and organic waste. The policy on bioenergy in some countries like Vietnam is also not suitable, leading to a very limited share of this source in power generation and national energy planning. In particular, CE-related policy approaches for bioenergy should also consider the side effects of these fuel-based power sources, such as relatively high $CO_2$ emissions, wood-burning fuels, and encroachment of croplands upon natural habitats (Kopnina 2017).

In order to ensure power supply security with high RE integration into the power system, it is necessary to rely on energy storage sources. In other words, BESS has a significant role and is used more and more with 2 million tons of waste per year from electric vehicles and grid-connected energy storage systems (USAID 2022c). Demand for mineral resources such as lithium, cobalt, or rare earth to produce BESS or wind generators will increase. The mining policies related to BESS and RE also need to shift towards sustainability goals such as recycling these materials. The sources of materials used to produce components for renewable energy generation are increasingly emitting more $CO_2$.

The issue of land and water reserved for building renewable energy sources should also be considered in the development of CE. Because these sources are often small-scale, scattered, and installed near residential areas, to preserve the land so as not to conflict with other uses, it is necessary to have clear guiding policies from the government.

Policies for RE development and CE will have an unavoidable trade-off. When developing RE, it is also possible that some aspects affect the natural environment, such as paving the way for wind turbines in the mountains, encroaching on marine life and the natural landscape of offshore wind turbines, particularly in vulnerable areas in Southeast Asia (Pratiwi and Juerges 2020). In these regions, if CE issues are combined, financial constraints, policy-making processes, public attitudes, harmonizing the interests of the parties involved, or even the limited scientific and technical potential for the construction, installation, and operation of RE sources are also significant barriers. The task of government policies is to be practical and remove barriers quickly and as much as possible so that the country can soon achieve its sustainable development goals.

Additionally, tax policies related to energy use are considered a powerful tool to shape economic activities and achieve green growth and recovery of the global economy (Taxing Energy Use 2019). For instance, the $CO_2$ tax introduction is considered a valuable and necessary tool for limiting $CO_2$ emissions from fossil fuel usage and promoting sustainable energy development. Until now, 46 nations and 32 subnations have been introduced or scheduled to apply carbon pricing mechanisms, namely $CO_2$ tax and emissions trading system (ETS). In fact, the $CO_2$ tax rate depends on every nation/sub nation and varies in a large range: from <1 USD/ton of $CO_2$ (e.g., Mexico, Poland, and Ukraine) to >100 USD/ton of $CO_2$ (e.g., for Sweden, its $CO_2$ tax is 119 USD/ton) (World Bank 2022). However, most carbon prices/tax rates are too low, with almost half of the covered emissions priced at less than 10 USD/ton of $CO_2$. According to the High-Level Commission on Carbon Prices, it is estimated that carbon prices of at least 40–80 USD/ton of $CO_2$ by 2020 and 50–100 USD/ton of $CO_2$ by 2030 are required to cost-effectively reduce emissions in line with the temperature goals of the Paris Agreement (World Bank 2022). The IEA Sustainable Development Scenario also stated that a carbon price ranging between 75 and 100 USD/ton of $CO_2$ is needed to stay on track with a Paris-compatible trajectory.

## 3.7 Conclusion

It can be seen that RE itself is not necessarily green development, but if RE is combined with CE, the goal of sustainable development and natural protection can be achieved. Equipment for the RE industry must be produced, distributed, and recycled responsibly, safely, economically, and sustainably. CE can help these devices to reach the lowest emission cycle, reduce waste, create jobs, achieve gender equality, and empower the community. Harmonious development and protection goals should be known to the people, and scientific and technical research should be promoted for the simultaneous development of RE and CE. Government policy could consider: incorporating CE concepts into all RE development strategies; creating a network for all stakeholders to actively contribute to sustainable development goals; developing safety and quality assurance standards in new and recycled products; developing human resources, tools, and resources for CE, etc. It can be said that, without CE, RE will take a turn that may not be as clean as people expect. The government should formulate long-term goals and strategies for circular economy-based RE development. Smart regulations will encourage product take back, recycling, and reverse supply chains. Designing the circular economy into the energy transition will allow us to move faster and more sustainably in getting to net zero.

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