Global Energy Interconnection
Development and Cooperation Organization
全球能源互联网发展合作组织

Coordinated Governance of Energy, Climate, and Biodiversity

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Foreword

Essential to the well-being and survival of human being, bio-diversity is an important issue confronting us and its protection is a shared task for all governments, the greater business community, and society at large. The Kunming-Montreal Global Biodiversity Framework (GBF) was adopted in December 2022 at the 15th Meeting of the Conference of the Parties to the UN Convention on Biological Diversity (COP15). It consists of four long-term goals to be achieved by 2050, 23 action targets for 2030, and a historical GBF fund established to support the full and effective implementation of the framework to ensure humanity is "living in harmony with nature" by 2050.

Global biodiversity loss can be attributed to five main causes—habitat loss, direct exploitation of biological resources, climate change, pollution, and invasive alien species. Unreasonable energy development has exacerbated these problems. The long-term, large-scale development and utilization of fossil fuels have resulted in large volumes of greenhouse gases (GHGs) and other harmful substances and climate change, pollution, and constraints on resources, posing a serious threat to global biodiversity. Consequently, the world stands in urgent need of an innovative pathway towards a more sustainable energy source capable of satisfying our needs without compromising the health of the environment. By accelerating the green and low-carbon energy transition, it is hoped to achieve carbon neutrality by the middle of this century, mitigate the loss of biodiversity caused by the development and utilization of fossil fuels, and coordinate governance of energy, the climate, and biodiversity.

Global Energy Interconnection (GEI) is a new energy system dominated by clean energy and centered on electricity, characterized by extensive grid interconnection, intelligence and efficiency. It is a systematic reply to the energy transition, climate change, and the conservation of biodiversity. Construction of the GEI will completely redefine the economic and social development once so dependent on fossil fuels and promote the production of clean energy, electrification of energy consumption, and more efficient allocation of energy, effectively addressing existing issues with energy supply, climate change, and ecology. It will also inject new momentum into joint climate change and biodiversity conservation efforts.

The GEI has been widely recognized by the international community as a viable systematic program for advancing the world energy transition and sustainable development and has been incorporated into the United Nations working frameworks for implementing the 2030 Agenda for Sustainable Development and the Paris Agreement. It has been included in the Policy Briefs of the UN High-level Political Forum on Sustainable Development (HLPF) for six consecutive years and incorporated into the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), among others. **UN Secretary-General António Guterres** has spoken of the GEI's importance to the two central concepts (sustainability and inclusivity) of the commitment to implementing the 2030 Agenda and the Paris Agreement. **The Secretariat of the United Nations Framework Convention on Climate Change (UNFCCC)** has stated that the GEI is representative of the global energy transition trend and an excellent tool for achieving the goals of the Paris Agreement. Finally, **the Secretariat of the Convention on Biological Diversity (CBD)** has said that the GEI fills the gap in coordinated climate change and biodiversity governance and provides a comprehensive, balanced, effective, and feasible action plan for the conservation of global biodiversity.

The Global Energy Interconnection Development and Cooperation Organization (GEIDCO) is committed to promoting energy transition and sustainable development. It has conducted in-depth studies on the green and low-carbon energy transition and the development of clean, efficient electricity. GEIDCO has formulated two "1+6" energy planning systems, one for Global and Continental Energy Interconnection Research, and the other Renewable Energy Development and Investment, and has released more than 80 innovative research findings. On this basis, it has further deepened its research on energy and power, climate, environment, biodiversity, and other sustainable development issues.

In recent years, GEIDCO has released a series of important reports worldwide, such as the *Global Energy Interconnection Action Plan to Promote the 2030 Agenda for Sustainable Development, Resolving the Crisis, The Road to Global Carbon Neutrality, Inclusive, Just, Resilient Energy Transition: GEI Solution and Practices*, and *Biodiversity and Revolution of Energy and Electric Power.* GEIDCO's latest report was released this year on the *Coordinated Governance of Energy, the Climate, and Biodiversity*. The report provides a systematic analysis of the mechanisms connecting energy, the climate, and biodiversity and proposes new ways to address climate change and conserve biodiversity through energy transition, providing a package of operable, replicable solutions for their coordinated governance. The report consists of four chapters:

Chapter 1 describes how energy, climate and biodiversity interact and highlights the significant role of the traditional fossil-fuel development model as a significant influence to climate change and biodiversity loss.

Chapter 2 discusses why it is important to address climate change and conserve biodiversity through energy transition, elaborates on how the GEI can promote global energy transition, and analyzes the role of the GEI in addressing climate change and conserving biodiversity, especially by reducing global carbon emissions, mitigating habitat loss, and contributing to ecological restoration.

Chapter 3 proposes 11 key measures for biodiversity conservation during construction in relation to in-situ conservation, ex-situ conservation, and ecological restoration. It also introduces typical cases of implementing these measures and their outcomes, providing a reference for stakeholders and practical ways to put the plan into action.

Chapter 4 offers 16 policy recommendations for promoting the coordinated governance of energy, the climate, and biodiversity across five dimensions: policy, finance, technology, cooperation, and action. The recommendations are all aimed at enhancing the consistency, integrity, and collaborative nature of the efforts and promote joint conservation of biodiversity.

It is hoped that the report might serve as a reference for the Secretariat of the Convention on Biological Diversity (CBD) and governments around the world as they develop policies and businesses and do their part to drive the new energy revolution, address climate change, and conserve biodiversity, thus contributing to the global carbon neutrality goal, reversing the loss of biodiversity, and building a global community with a shared fate. GEIDCO is ready to work with every part of society to promote the coordinated governance of energy, the climate, and biodiversity and create a better future where humanity can live in harmony with nature!

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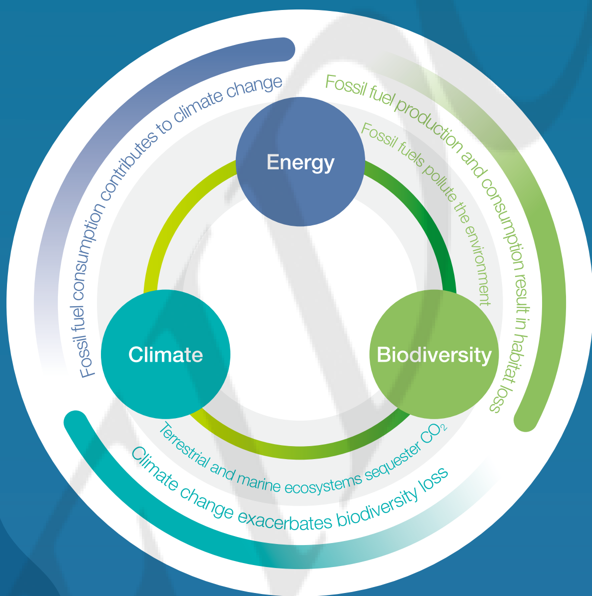
01

The Connection between Energy, Climate and Biodiversity

Fossil fuels were an important contributor to the jump in productivity that occurred in the Industrial Revolution. Indeed, they continue to contribute and, in the process, do great damage to the environment. The various stages of fossil fuel extraction, processing, conversion, and consumption generate enormous amounts of GHGs and other harmful substances, exacerbating climate change and polluting land, air, and sea. The result is habitat loss, degradation, and fragmentation, and it poses a serious threat to biodiversity. A proper understanding of the connection between energy, climate and biodiversity, illustrated, is crucial if we are to succeed in developing effective, coordinated governance and achieve the goals of the Paris Agreement and the GBF.



Connection between Energy, Climate and Biodiversity

1.1

Energy and Climate Change

Greenhouse gases in the atmosphere are the primary cause of climate change. GHGs allow shortwave radiation to penetrate to the surface of the earth and prevent longwave radiation from being emitted into space, upsetting the Earth-Atmosphere Energy Balance. The surplus energy accumulates in the atmosphere, causing the Earth's temperature to rise, as shown in Figure 1.1. By 2020, the average global temperature had increased by about 1.2°C over pre-industrial levels. The Kyoto Protocol defines six main GHGs: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6).

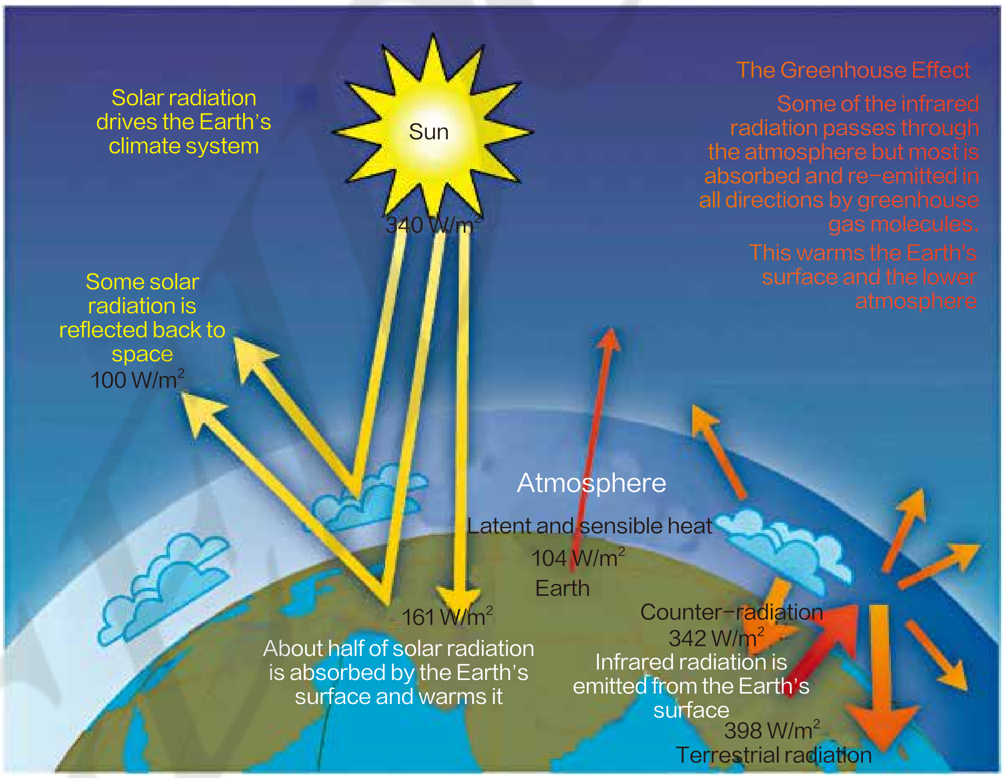


Figure 1.1 Illustration of the Greenhouse Effect

When fossil fuels are burned, they emit large amounts of CO_2 into the air, roughly 75% of global greenhouse gas emissions. Indeed, 86% of carbon dioxide emissions[1] result specifically from the burning of fossil fuels, seen in Figure 1.2. Clearly, any attempt to address climate change would have to involve a reduction of fossil fuel emissions.

[1] Source: UNEP, Emissions Gap Report 2020, 2020.

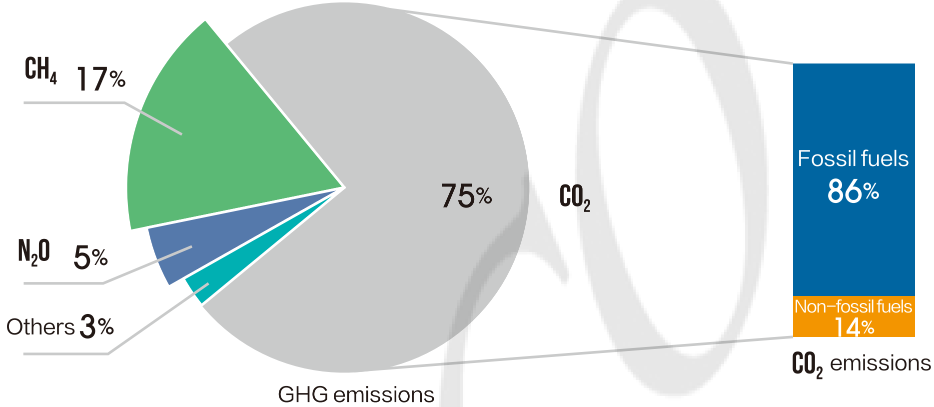


Figure 1.2 Global GHG and CO_2 Emissions

Column 1-1 Major Sources of Global Carbon Emissions[1]

In 2019, global GHG emissions reached 52.4 $GtCO_2e$. The consumption of fossil fuels produced 39 $GtCO_2e$, accounting for about 75% of global GHG emissions and 86% of global CO_2 emissions.

The enormous amounts of fossil fuels consumed by the **energy, industry, and transportation sectors,** shown in Figure 1, make them the main contributors to CO_2 emissions. In 2019, the energy, industry, and transportation sectors accounted for 41%, 20%, and 14% of global carbon emissions, respectively.

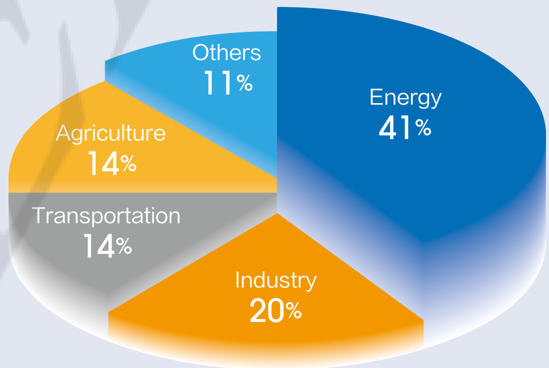


Fig. 1 2019 CO_2 Emissions by Sector

[1] Source: UNEP, Emissions Gap Report 2020, 2020.

By energy type, coal has the highest carbon emission factor of all fossil fuels, as illustrated in Figure 2. The combustion of 1 tce (tonne of coal equivalent) of coal, oil, and natural gas produces approximately 2.77 tonnes, 2.15 tonnes, and 1.65 tonnes of CO_2, respectively. In 2015, coal was responsible for 45% of CO_2 emissions while accounting for just 28% of the world's primary energy consumption.[1]

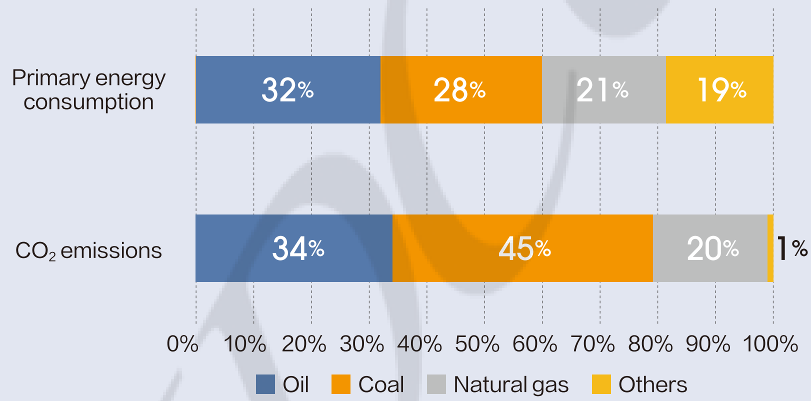


Figure 2 2015 Consumption and CO_2 Emissions by Fossil Fuel

Roughly **110** million tonnes of methane are produced annually as a result of the extraction and consumption of fossil fuels

Methane is emitted in large quantities during the extraction and consumption of fossil fuels. It is the chief constituent of natural gas and the second most abundant GHG after CO_2, accounting for 17% of global GHG emissions. Roughly 110 million tonnes of methane are produced annually as a result of the extraction and consumption of fossil fuels, the main source of methane emissions[2].

① Around 8% of the methane is released into the atmosphere during the production, processing, storage, transmission, and distribution of natural gas.
② The geological processes that form coal and oil produce significant amounts of methane, which is then released into the atmosphere when the fossil fuels are extracted.
③ The incomplete combustion of fossil fuels also generates methane, emitted when fossil fuels are used to generate electricity, heating, or fuel for vehicles.
④ The production and consumption of fossil fuels exacerbate global climate change, thawing permafrost, resulting in more frequent wildfires, and threatening, in turn, to release even more methane into the atmosphere.

❶ Source: International Energy Agency (IEA), CO_2 Emissions from Fuel Combustion 2017, 2017.
❷ Source: UN, https://news.un.org/zh/story/2021/05/1083682

1.2

Climate Change and Biodiversity

According to the *Convention on Biological Diversity,* opened for signature at the United Nations Conference on Environment and Development in 1992, "'Biological diversity' means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species (genetic diversity), between species (species diversity) and of ecosystems (ecosystem diversity)." **Species diversity** refers to the quantity and abundance of species within a community, a key indicator of a region's biological richness. **Ecosystem diversity** refers to terrestrial and aquatic ecosystems in a given area and may include mountains, forests, oceans, lakes, rivers, wetlands, grasslands, and deserts and subsequent effects on the physiology, life cycles, and distribution patterns of the species there. **Genetic diversity** refers to the diversity of genetic material (genes) within and between biological populations and encompasses the genetic variation of all organisms on Earth.

Studies by such authoritative international organizations as the United Nations Environment Programme (UNEP) and the World Wide Fund for Nature (WWF) have identified habitat loss, direct exploitation of biological resources, climate change, environmental pollution, and invasive alien species as the primary causes of biodiversity loss. Of these, climate change is the third most significant factor, after habitat loss and the direct exploitation of biological resources, in biodiversity loss, contributing to 14% of the biodiversity loss observed[1]. As global temperatures and precipitation continue to increase, climate change is projected to surpass habitat loss and direct exploitation of biological resources as the most severe threat to biodiversity within the next 50 to 100 years[2].

Rising global temperatures influence species distribution. Global warming has forced many plant and animal species to move their habitats in search of colder climes, often climbing in altitude. Research indicates that terrestrial species are moving towards the poles at an average rate of 17 km per decade, with marine species migrating poleward or diving to deeper waters at an average rate of 72 km per decade[3], as shown in Figure 1.3. The inability of most plant species to alter their geographical ranges quickly enough, however, means many trees and herbaceous plants have been driven by rising temperatures towards extinction.

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❶ Source: IPBES-IPCC, Co-sponsored Workshop Report on Biodiversity and Climate Change [R]. IPBES Secretariat & IPCC Secretariat, 2021.

❷ Source: Sintayehu DW (2018), Impact of Climate Change on Biodiversity and Associated Key Ecosystem Services in Africa: A Systematic Review. Ecosystem Health and Sustainability, 4, 225-239.

❸ Source: Pecl GT, Araujo MB, Bell JD, et al., Biodiversity Redistribution under Climate Change: Impacts on Ecosystems and Human Well-being, Science, 2017, 355 (6332): i9214.

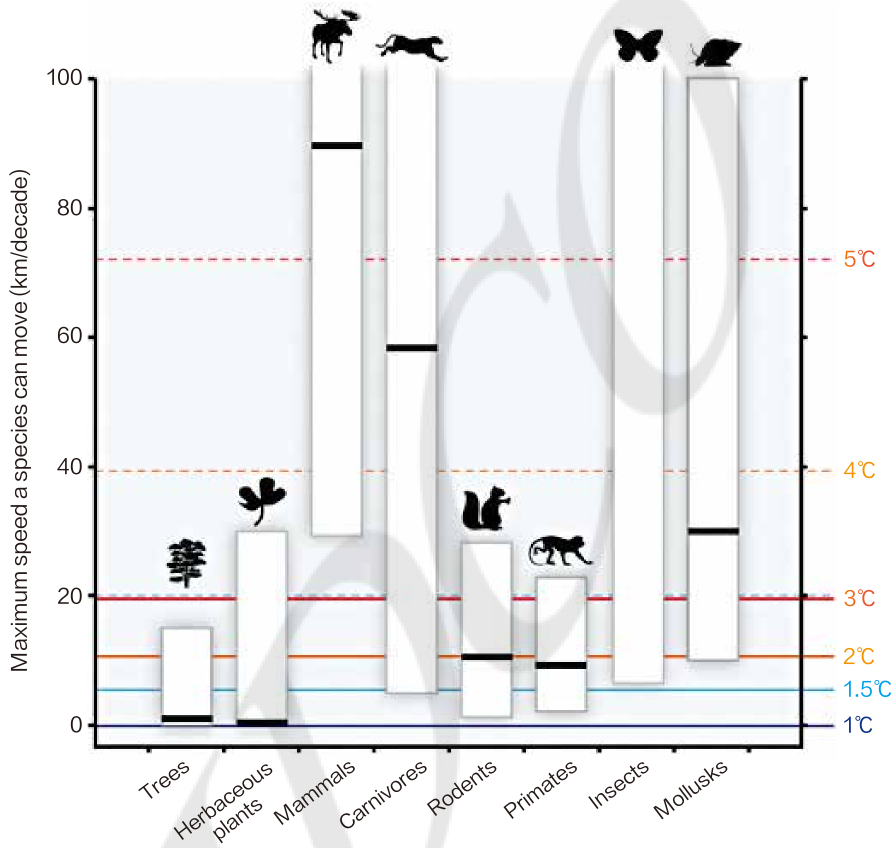

Figure 1.3 Global Warming and Species Distribution[1]

Ocean acidification affects marine biodiversity. Increased seawater absorption of CO_2 is intensifying ocean acidification. Seawater dissolves atmospheric carbon dioxide to form carbonic acid (H_2CO_3), which breaks down into bicarbonate ions (HCO_3^-) and hydrogen ions (H^+) and increases ocean acidification. The pH of surface ocean waters had varied by a mere ±0.3 over the previous 20 million years, but since the Industrial Revolution it has dropped from 8.2 to 8.1, increasing acidity by about 30%[2]. If the current trend holds, global seawater pH is expected to decrease by another 0.3 to 0.4 by the year 2100. Ocean acidification contributes to the dissolution of calcium carbonate secreted by calcareous organisms, such as shellfish and crustaceans, posing a serious threat to the survival of marine life and the breakdown of the entire marine food chain. The reduction of dissolved carbonate ions[3] in seawater also severely impacts coral reef ecosystems. Over the past 25 years, more than 50% of the coral reef in Bermuda has been completely bleached, as shown in Figure 1.4.

since the Industrial Revolution it has dropped from 8.2 to 8.1, increasing acidity by about 30%

The melting of glaciers affects organism survival. Snow lines are creeping upwards together with the rising temperatures, decreasing snow cover and threating creatures like the snow leopard and pika that inhabit high altitudes. The melting of polar glaciers has reduced natural habitat for polar bears, sea lions, and seals, among

1. Source: IPCC, Climate Change 2014, New York, USA: Cambridge University Press, 2014.
2. Source: WMO, Global Climate in 2015-2019, 2020.
3. The carbonate ion (CO_3^{2-}) is an alkaline ion that can be combined with hydrogen ions in water to form bicarbonate ions (HCO_3^-) or carbonic acid (H_2CO_3), a process that helps neutralize acidic substances and exhibits alkaline properties.

others, affecting their ability to rest, hunt, and reproduce. In one example, polar bears inhabiting the area stretching from the Beaufort Sea in Alaska across northeastern Canada experienced a population decrease of 40% between 2001 and 2010. To make matters worse, melting glaciers have released large amounts of previously trapped methane into the atmosphere, accelerating global warming and raising sea levels.

Figure 1.4 Coral Bleaching in Bermuda

Figure 1.5 Polar Bears at the Mercy of Climate Change

Extreme weather conditions endanger crops and small island ecosystems. Extreme weather events such as hurricanes, wildfires, and abnormally high temperatures have become more common in recent years. According to statistics from the International Disaster Database, extreme weather events have nearly quadrupled since 1980. Large swathes of the African continent have been affected by severe drought and a significant decline in cultivated land and crop yields[1]. Finaly, island species, which tend to be small in number, localized, and highly specific, are especially vulnerable to extinction following storms and wildfires.

Figure 1.6 Wildfire, San Bernardino County, California, USA, 2021

[1] Source: WMO, WMO Statement on the State of the Global Climate in 2019, 2020.

1.3

Energy and Biodiversity

The large-scale extraction and consumption of fossil fuels impact biodiversity directly and indirectly. This section focuses on the direct impact of fossil fuels on biodiversity. The indirect impact, primarily seen in the threats to biodiversity resulting from climate change, is discussed in Sections 1.1 and 1.2.

1.3.1 Habitat Loss Caused by Fossil Fuel Extraction and Consumption

Some issues that commonly follow the extraction and consumption of fossil fuels include subsidence, water and soil erosion, and habitat fragmentation, all of which severely degrade biological habitat, negatively impact the food sources local populations depend upon, and ultimately lead to biodiversity loss.

The extraction of fossil fuels exacerbates subsidence and water and soil erosion in mining areas. Coal mining creates empty pockets underground and removes support for overlying rock and soil, resulting in subsidence. According to statistics, every 10,000 tonnes of coal mined result in approximately 3,000 m^2 of mining-induced subsidence[1]. Additionally, the surface excavation, dumping of soil and slag, and destruction of land and vegetation that occur during the process reduce soil erodibility indices and result in obvious ecological degradation[2].

Column 1-2 Water and Soil Erosion in Huainan Mining Area, China

The Huainan mining area is rich in coal. Huainan mining area is located in East China's economically advanced hinterland of north-central Anhui Province, includes the cities of Huainan, Fuyang, and Bozhou, and has been blessed with an abundance of coal. The coal mining area extends about 70 km from east to west and 25 km from north to south, covering an area of approximately 1,600 km^2. It is home to East and South China's largest coal reserves, 28.5 billion tonnes in all[3].

Extensive coal mining causes water and soil erosion. Continuous mining has resulted in a subsidence of 120 km^2, or roughly 7.5% of the

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1. Source: Luo Kaisha et al., Study on Water Resources Utilization in Huainan Mining Area, Conference on Environmental Pollution and Public Health, 2010.
2. Source: Song Shijie, Analysis of Ecological Environmental Damage Caused by Coal Mining in Coal Mine Areas and Countermeasures, Coal Processing & Comprehensive Utilization, 2007.
3. Source: Chen Yongchun, Study on the Construction of Plain Reservoirs by Utilizing Coal Mining Subsidence Areas in Huainan Mining Area, Journal of China Coal Society, 2016.

total mining area. Land subsidence significantly reduces usable area, contributes to water and soil erosion, and as water accumulates in the subsidence, it erodes the topsoil, depleting nutrients, and polluting the water. Beyond polluting the water, it also triggers a water crisis and threatens biodiversity.

The Chinese government is actively implementing remediation measures. In September 2012, Anhui Province issued the *Comprehensive Management Plan for Coal Mining Subsidence Areas in Six Cities of Northern Anhui Province (2012-2020)*, which established comprehensive strategies and objectives for managing of coal mining-induced subsidence and introduced measures for land reclamation, traffic and water system management, and filling underground cavities. In 2019, Huainan City, Anhui Province, completed 17 abandoned mine remediation projects over a total of 700 hectares. In 2020, that number increased to 70 abandoned mine remediation projects, or 2,433 hectares.

Fossil fuel extraction leads to habitat fragmentation and negatively impacts biodiversity. To extract and transport fossil fuels, you must first build numerous roads and pipelines – barriers that fragment habitat by breaking up large areas of biological environment into smaller isolated patches, limiting the movement of animals and affecting their foraging and mating activities, among others, and inhibiting population growth.

1.3.2 Pollution from Fossil Fuel Production and Consumption

Substantial amounts of gas, liquid, and solid pollutants are generated during the extraction and consumption of fossil fuels. Material exchange in atmospheric circulation and the hydrological and geological cycles during production, transportation, conversion, and consumption spread the pollutants among habitats and create issues of a regional or global nature.

polluting 1 to 1.5 m^3 of fresh water for each tonne of coal mined

Coal production causes freshwater pollution. Acid mine drainage from coal mining and washing seep into rivers, polluting 1 to 1.5 m^3 of fresh water for each tonne of coal mined. Solid waste such as coal gangue separated during mining and washing accounts for 10% to 15% of coal output. It is generally stacked for storage. Rainwater infiltration, exposure to sunlight, and wind action may result in pollutants being carried into rivers, air, and the soil, causing secondary pollution.

Column 1-3 Severe Freshwater and Soil Pollution Caused by South African Coal Mining Activities

South African coal reserves – approximately 205.7 billion tonnes and proven reserves of 58.75 billion tonnes – account for roughly two-thirds of all African coal reserves. South Africa leads the continent for annual coal production, and it's a global leader. Excessive coal mining has left the Olifants River, which flows through the mining area, one of the most polluted rivers in Southern Africa. Heavy metals like lead and cadmium have killed fish and other aquatic life en masse. Even after the coal mining has stopped, the accumulation of solid waste encroaching upon arable land and concentrations of heavy metal in the soil destroy corn crops, reduce grain output, and trigger food crises.

Fig. 1 A Polluted River Flowing Through a Mining Area

Shale gas causes soil and freshwater pollution. The extraction of shale gas with hydraulic fracturing produces 30 to 130 m^3 of wastewater per 100 million m^3 of natural gas. In addition to the harmful chemical additives, wastewater also contains hydrocarbon compounds, heavy metals, and mineral salts leached from reservoir rocks, which can pollute soil, surface water, and groundwater.

Column 1-4 Pollution Caused by Marcellus Shale Gas Exploitation in the United States

The Marcellus Shale in the United States is the largest unconventional natural gas reservoir in the world. It is located in the eastern Appalachian Basin and spans New York, Pennsylvania, West Virginia, and eastern Ohio. The latest assessment report shows 13.85 trillion m^3 of recoverable shale gas, capable of satisfying the United States needs for natural gas for more than 20 years. Currently, Marcellus Shale exploitation accounts for roughly 1% of Pennsylvania's freshwater consumption and produces mud containing naturally occurring salts, toxic heavy metals, and radioactive materials leached from the rock. If not stored properly, the mud can leak and contaminate soil and water.

Fig. 1 Shale Gas Extraction

Oil extraction pollutes groundwater, soil, and the ocean. The wastewater, mud, and drilling fluids generated during oil extraction contain heavy metals, sulfides, etc. Leaks contaminating surface groundwater are inevitable during long-term storage. During oil extraction and marine transportation, accidents, human error, and any number of other reasons can cause spills, altering the physical and chemical properties of the soil, harming marine ecosystems, causing ecological imbalances, and threatening natural habitat.

Column 1-5 Deepwater Horizon Oil Spill in the Gulf of Mexico

On April 20, 2010, an explosion occurred on the Deepwater Horizon oil rig, leased to BP, spilling millions of gallons of oil into the Gulf of Mexico over the next 87 days. Following the disaster, fish populations in the surrounding waters decreased by 50%-80%, the number of rare whales dropped by 22%, and at least 800,000 birds and 170,000 sea turtles died. It was one of the worst environmental disasters in history, and its effects are felt to this day. Even in 2018, high levels of pollution continued to turn up in thousands of species inhabiting the waters, including yellowfin tuna, tilefish, and red drum – popular items on our dining tables. From 2011 to 2017, the concentration of oil pollutants in the liver tissue and bile of yellowedge grouper in this area increased by more than 800%.

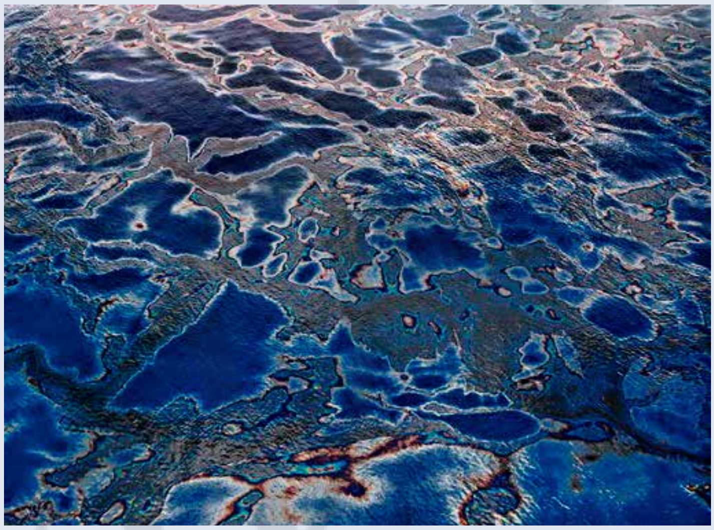

Fig. 1 Crude Oil in the Gulf of Mexico

The consumption of fossil fuels causes serious air pollution. Burning fossil fuels and biomass produces more than 90% of sulfur dioxide (SO_2), nitrogen oxides (NO_X) and 85% of fine particulate matter (PM2.5). Of these, SO_2 and NO_X are the main components of acid rain, while PM2.5 and secondary pollutants generated by SO_2 and NO_X are the main components of haze. Figure 1.7 shows major global air pollutants in 2015.

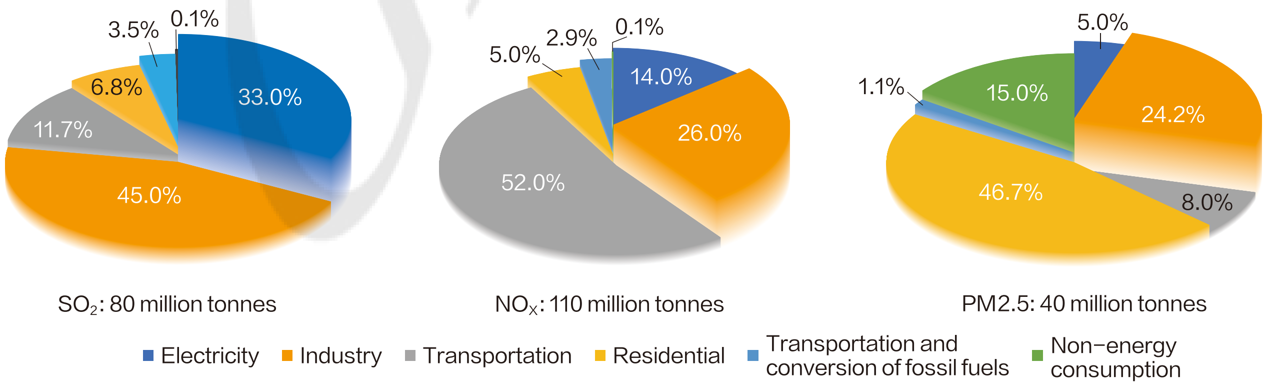

Figure 1.7 Big Three Global Pollutant Emissions for 2015

Column 1-6 Major Sources of Air Pollution

Air pollutants vary by sector. Annual global SO_2 emissions equal approximately 80 million tonnes, with power generation and industry accounting for 33% and 45% of total emissions, respectively. NO_X emissions come to 110 million tonnes, with transportation and industry accounting for 52% and 26% of total emissions, respectively. Finally, PM2.5 emissions total 40 million tonnes, with about half of PM2.5 emissions generated by residential energy consumption.

Different types of fossil fuels generate different air pollutants. As can be seen in Figure 1, coal is the main source of SO_2, accounting for about 55% of total emissions. 10,000 tonnes of coal burned produce 100 tonnes of SO_2 on average. Oil is the main source of NO_X, accounting for about 70% of total emissions. 10,000 tonnes of oil produce 170 tonnes of NO_X on average. Finally, biomass energy is the main source of PM2.5 emissions, accounting for about 65% of total emissions. 10,000 tonnes of biomass burned produce 123 tonnes of PM2.5 on average.

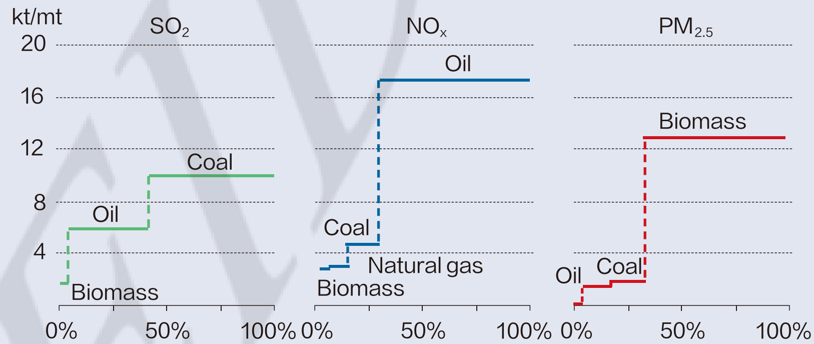

Fig. 1 Big Three Global Air Pollutant Average Emission Factors for 2015[1]

[1] Source: IEA, Energy and Climate Pollution, 2016.

02

A Systematic Program for Ending Climate Change and Conserving Biodiversity through Energy Transition

If we want to achieve the goals of the Paris Agreement and the GBF, as well as address issues of climate change and biodiversity in a coordinated way, we must be mindful of the great variety of ecosystems in air, land, sea, and taking a green and low-carbon development path through energy, economy, society, and environment to transform the traditional development model. Energy is essential to human survival and development, but the current energy system dominated by fossil fuels is not sustainable – we must promote sustainable economic and social development. We must accelerate energy transition and steer clear of unreasonable patterns of development if we are to address climate change and conserve biodiversity. GEI is an interconnected, intelligent, and cost-effective multi-energy coordination system dominated by clean energy and electricity. GEI focuses on the comprehensive upgrade of the traditional energy system to produce clean energy, electrify consumption, and allocate more efficiently. This initiative injects fresh momentum into the coordinated governance of energy, climate and biodiversity.

2.1

The Urgent Need for Energy Transition to Address Climate Change and Conserve Biodiversity

There is a dialectical relationship between human and nature, and it is a unity of opposites. Human society is the product of the long-term development of nature, and human activity cannot be separated from nature. At the same time, the development of human society has increased our ability to use and transform nature, often destructively, as is becoming increasingly obvious, and it must be dealt with if we are to survive and develop further. We must learn to respect the relationship with nature, to respect nature and protect it, to consciously limit human activity to what nature can bear, strike the necessary balance between environmental protection and economic development, and achieve harmonious coexistence.

How energy is developed impacts climate change and biodiversity. Energy is a pillar of civilizational progress. It can impact sustainable development deeply and tie together sustainable development goals, climate change, and biodiversity. It influences every facet of human production and life. Energy activity is inseparable from human activity. A reasonable scientific pattern of energy development could satisfy the needs of economic and social development in full, minimize the adverse impact on the environment, provide strong support for reducing emissions, conserving biodiversity, and achieving positive feedback. At present, however, global energy development is characterized by **"high pollution, high emissions, and high energy consumption".** Fossil fuels such as coal, oil, and gas account for roughly 80% of the world's primary energy consumption. The extraction, processing, conversion, transportation, and consumption of these fuels generate enormous amounts of waste gas, wastewater, and waste residues. Combustion and utilization of fossil fuels are responsible for about 70% of global GHG emissions and more than 85% of SO_2, NO_X, and PM2.5. The result has been worrisome, with temperatures on the rise and air pollution, water and soil erosion, and vegetation loss causing serious damage. Ultimately, this damage to the environment is a hurdle on the road to sustainable global development.

The energy transition must be urgently accelerated if we are to address climate change and conserve biodiversity. The unreasonable development pattern of over-dependence on fossil fuels is the main culprit in climate change, habitat destruction, environmental pollution, and overconsumption of resources. If we fail to transform the existing pattern of energy development and accelerate the global clean and low-carbon transition as soon as possible, cumulative CO_2 emissions from the energy system alone are forecast to exceed 4.8 trillion tonnes by the end of this century[1], causing global temperature to rise by more than 3°C, which means irreversible climate disasters, and ravaging biodiversity. To address the crises threatening human survival, development, and the environment, we must accelerate energy transition, change the developing mode of fossil fuels, promote a new energy development model featuring **"zero emissions, no pollution, and high efficiency"**, which is green, low-carbon, and sustainable, and root out the very energy development pattern impacting climate and biodiversity so adversely. Only thus can we realize coordinated, sustainable development of energy, electricity, and the environment.

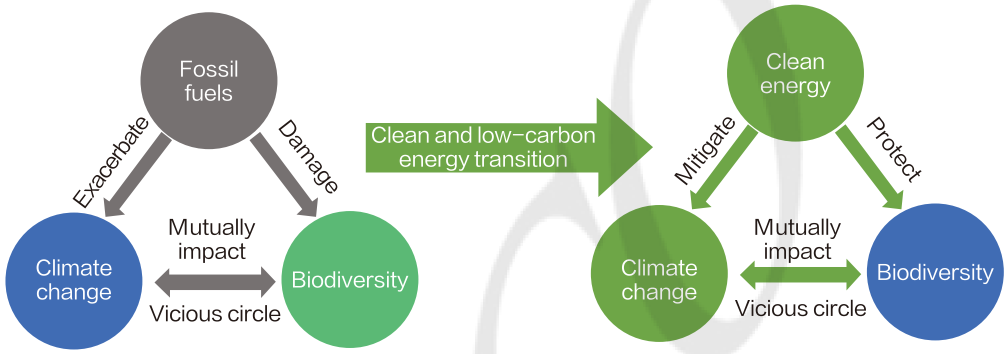

Figure 2.1 The Urgent Need for Energy Transition to Address Climate Change and Conserve Biodiversity

2.2

GEI Development as a Key Enabler of the Energy Transition

The need to address climate change and conserve biodiversity has lent particular urgency to accelerating the energy transition. The key is to make energy transition from high carbon to low carbon, low efficiency to high efficiency, and local balance to wider allocation. This will involve transforming the electricity development pattern to create an interconnected, intelligent, cost-effective multi-energy GEI dominated by clean energy and centered on electricity, converting centralized, distributed clean energy sources developed on a large scale into electricity locally, transmitting them to large power grids, and swiftly distributing them to households worldwide, establishing new energy production, allocation, and consumption systems, or three energy transformations.

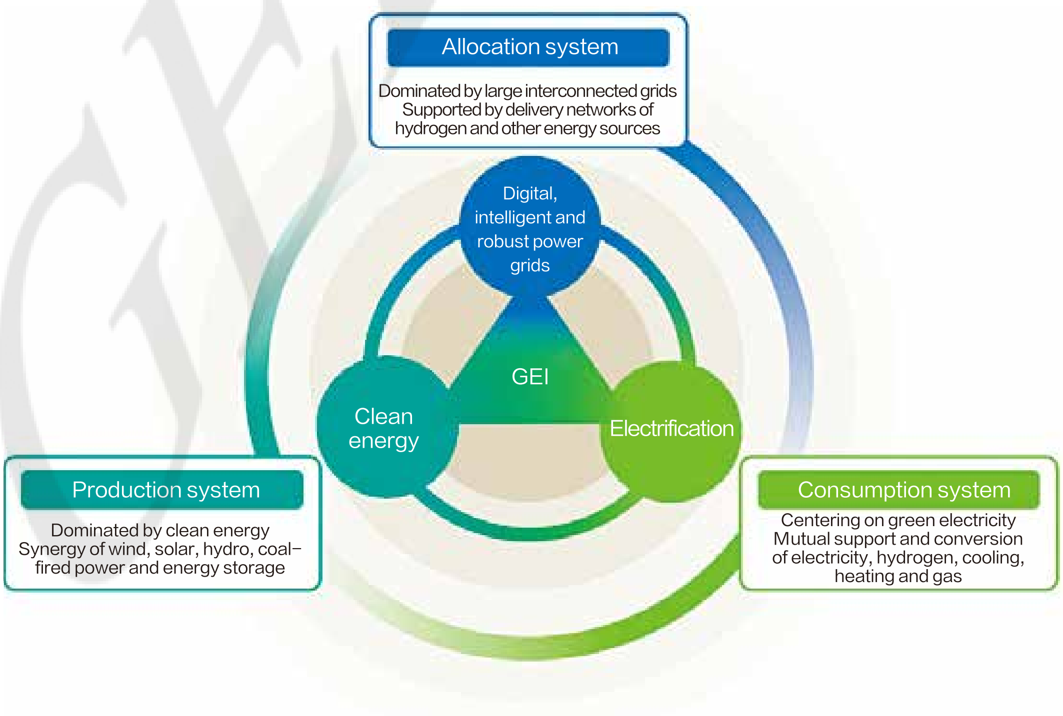

Figure 2.2 Essential GEI Framework

We must transition from fossil fuels to clean energy. The GEI aims to use digital, intelligent, robust power grids to promote the large-scale development of solar, wind, and hydroelectric energy, accelerate the replacement of fossil fuels in power generation and eliminate the existing dependence on them, and establish a clean energy production system featuring a synergy of wind, solar, hydro, and coal-fired power and energy storage. While meeting global energy and electricity demand in a clean and green manner, it effectively protects the environment and realizes the coordinated and sustainable development of energy, climate and biodiversity.

We must transition from coal, oil, and gas to electricity. Electricity is a secondary energy source that is clean, economical, and efficient. For each one percentage point increase in electricity use, energy consumption per unit of GDP can be reduced by 3.7%. The GEI will help replace fossil fuels with electricity in industry and transportation, among others, establish a consumption system around green electricity and complementary conversion of electricity, hydrogen, cooling, heating, and gas, address the high emissions, pollution, and rising energy costs associated with the use of coal, oil, and gas, and protect the environment and its many and varied inhabitants.

We must transition energy allocation from local balance to global interconnection. The traditional development pattern of local energy consumption and power balance must give way to an allocation system of interconnected large grids supported by delivery networks of hydrogen and other energy sources. It is likewise essential to address the uneven distribution of clean energy resources and loads, take advantage of differences in time zone, seasonal variations, resource disparities, and price differentials, and accelerate the large-scale development and efficient utilization of clean energy for the sake of the transition and clean development of global energy.

2.3 The GEI Pathway for Advancing Energy Transition

The project to build the GEI and promote energy transformation and transition is an enormous undertaking. Tasks include transforming an energy development pattern that is coal, oil, and gas-dominant, coordinating between energy production, consumption, and allocation, establishing a hub platform for conversion, utilization, and allocation, matching up supply and demand between energy sources, and opening up a new path of green, low-carbon, and sustainable energy development.

2.3.1 Clean energy production

1. Expediting the development of renewable energy

Clean energy is central to the building of the GEI. The goal is to develop clean energy sources like solar, wind, and hydroelectric energy on a global scale, increase their share in the energy mix, establish a clean energy development pattern, and reduce carbon emissions at the source. Installed clean energy capacity is expected to reach 15,800 GW and account for 59% of primary energy consumption by 2035 and 28,400

GW for 86% by 2050, representing 83% and 91% of the global total, respectively. This clean replacement is projected to reduce CO_2 emissions by about 1.8 trillion tonnes by the end of this century[1].

We must accelerate the development of solar energy. The theoretical potential of solar energy globally is about 150,000 PWh/year, with Asia accounting for 25%, Africa 40%, Europe 2%, North America 10%, Central and South America 8%, and Oceania 15%. Annual GHI of over 2,000 kWh/m^2 can be found mainly in the Sahara Desert of North Africa, southwestern Africa, Central and West Asia, southern North America, northern Chile, and northwestern Australia. Figure 2.3 shows the distribution of solar energy resources. Nine large solar power bases are planned for these areas, with development to occur at an accelerated speed. As shown in Table 2.1, installed solar capacity is projected to reach 1,700 GW by 2035 and 3,800 GW by 2050[2].

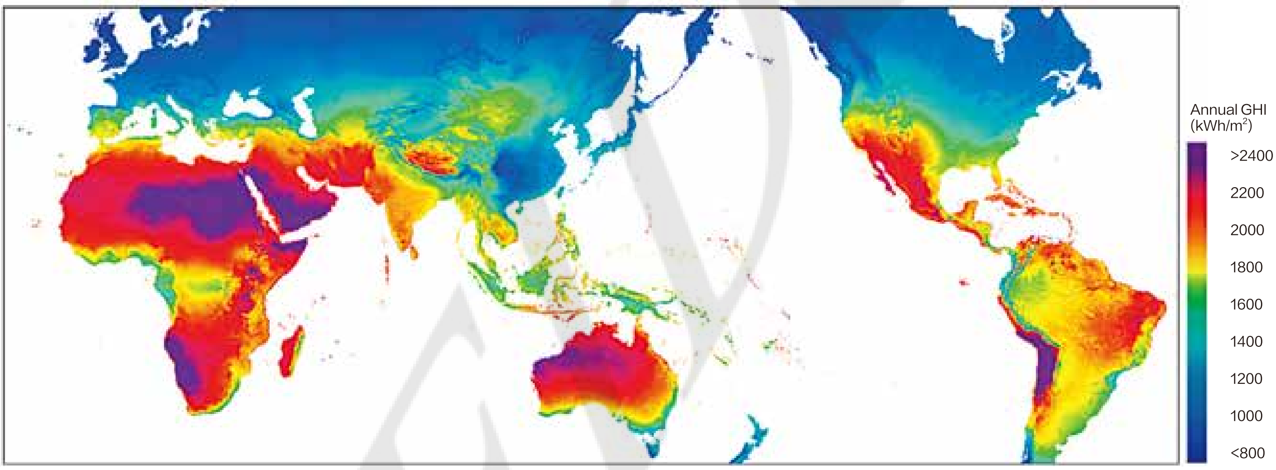

Figure 2.3 Annual Global Distribution of GHI

Table 2.1 Large Photovoltaic (PV) Bases Worldwide

Project	PV Base	Annual GHI (kWh/m^2)	Technically Exploitable Installed Capacity (100 GW)	Installed Capacity by 2035 (100 GW)	Installed Capacity by 2050 (100 GW)
Asia	Western China	1,800-2,000	15.7	5.5	12.1
	Central Asia	1,500-1,900	2.4	0.6	1.4
	West Asia	2,000-2,200	15.3	4.9	9.8
	South Asia	1,700-2,000	13.7	4	10.1

1. Source: GEIDCO, *Biodiversity and Revolution of Energy and Electric Power*, Beijing: China Electric Power Press, 2020.
2. Source: Global Energy Interconnection Development and Cooperation Organization, *Towards Sustainable Development——Global Energy Interconnection Roadmap to Promote the 2030 Agenda for Sustainable Development*. Beijing: China Electric Power Press, 2020.

Continued

Project	PV Base	Annual GHI (kWh/m^2)	Technically Exploitable Installed Capacity (100 GW)	Installed Capacity by 2035 (100 GW)	Installed Capacity by 2050 (100 GW)
Africa	North Africa	2,200-2,400	12	0.53	1.1
	Southern Africa	1,800-2,200	3.6	0.18	0.43
North America	Southern United States	2,000-2,200	8.7	0.91	1.77
Central and South America	Northern Chile	2,300-2,400	22	0.43	1.43
Oceania	Northern Australia	2,100-2,200	1	0.06	0.1
Total		–	94.4	17.1	38.2

We must accelerate the development of wind energy. The theoretical potential of wind energy globally is about 2,050 PWh/year, with Asia accounting for 24%, Africa 32%, Europe 7%, North America 21%, Central and South America 11%, and Oceania 5%. The wind speeds most conducive to harvesting are located primarily in Greenland, eastern North America, southern South America, northern Europe, northern Africa, and southern Oceania. Figure 2.4 shows the distribution of global wind energy resources. 14 large wind power bases are planned for these areas, with development to occur at an accelerated speed. As shown in Table 2.2, total installed wind capacity is expected to reach 900 GW by 2035 and 1,490 GW by 2050[1].

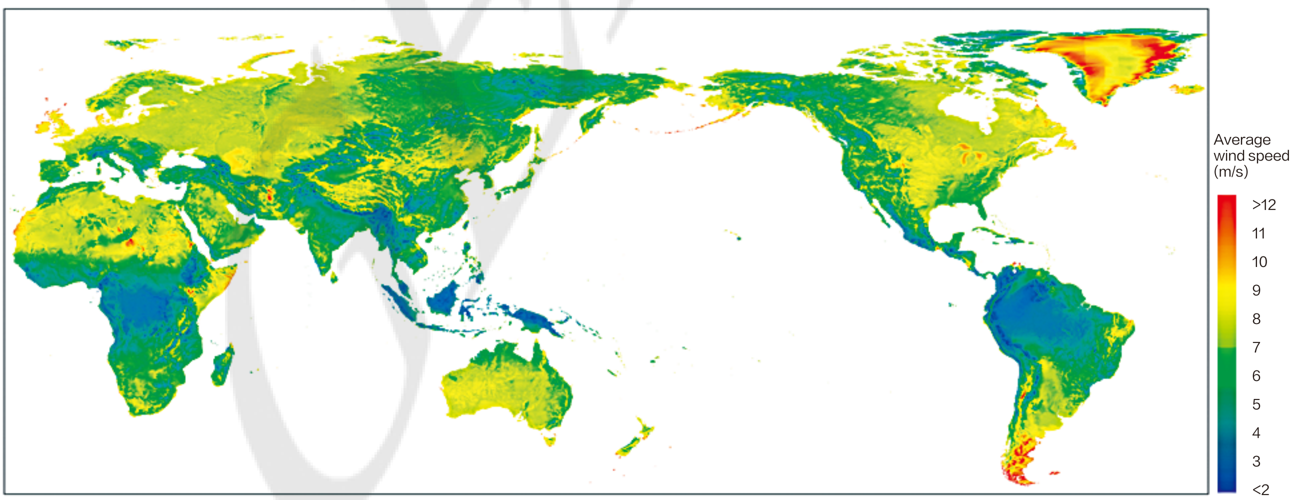

Figure 2.4 Annual Global Distribution of Average Wind Speed

[1] Source: Global Energy Interconnection Development and Cooperation Organization, *Towards Sustainable Development——Global Energy Interconnection Roadmap to Promote the 2030 Agenda for Sustainable Development*. Beijing: China Electric Power Press, 2020.

Table 2.2 Large Wind Power Bases Worldwide

Project	Wind Power Base	Average Wind Speed (m/s)	Technically Exploitable Installed Capacity (10 MW)	Installed Capacity by 2035 (10 MW)	Installed Capacity by 2050 (10 MW)
Asia	Sea of Okhotsk	6-7	260,000	500	2,000
	Sakhalin Island	6-7	8,900	2,500	4,500
	Central Asia	6-7	8,100	2,600	6,000
	Western and Northern China	6-7	101,000	57,700	81,100
Europe	North Sea	10-12	30,000	7,800	13,300
	Baltic Sea	8-10	16,300	4,500	6,530
	Norwegian Sea	10-12	4,800	500	1,600
	Greenland	11-13	3,000	1,200	1,430
	Barents Sea	8-10	8,000	1,200	3,360
Africa	North Africa	7-9	10,900	1,000	2,000
	East Africa	7-9	5,700	400	1,500
	Southern Africa	7-9	5,600	700	1,700
North America	Central United States	8-10	79,000	6,700	15,200
Central and South America	Southern Argentina	8-12	35,100	4,000	8,500
Total		–	576,400	91,500	148,720

We must accelerate the development of hydroelectric energy. The theoretical potential of hydroenergy resources globally is about 39 PWh/year, with Asia accounting for 47%, Africa 11%, Europe 6%, North America 14%, Central and South America 20%, and Oceania 2%. Rivers well-suited to the large-scale development include the Jinsha and Yarlung Zangbo Rivers in Southwestern China, the Mekong and Irrawaddy Rivers in Southeast Asia, the Indus River in South Asia, the Ob, Yenisey, and Lena Rivers in Russia, the Congo, Nile, Zambezi, and Niger Rivers in Africa, and the Amazon River in South America, as well as some within Norway and Sweden. The accelerated construction of 15 large hydropower bases would increase total installed hydropower capacity to 880 GW by 2035 and 1,300 GW by 2050[1]. See Table 2.3 for hydropower the bases on every continent.

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[1] Source: Global Energy Interconnection Development and Cooperation Organization, *Towards Sustainable Development——Global Energy Interconnection Roadmap to Promote the 2030 Agenda for Sustainable Development*. Beijing: China Electric Power Press, 2020.

Table 2.3 Large Hydropower Bases Worldwide

Project	Large Hydropower Base	Technically Exploitable Installed Capacity (10 MW)	Installed Capacity by 2035 (10 MW)	Installed Capacity by 2050 (10 MW)	evelopment Proportion in 2050 (%)
Asia	Russia	14,000	5,800	10,000	72
	Southwestern China	42,000	21,200	29,200	70
	Central Asia	6,000	1,800	2,400	40
	Mainland Southeast Asia	12,640	7,500	11,000	85
	South Asia	18,150	11,000	17,000	94
Europe	Northern Europe	12,000	9,250	10,600	88
	Türkiye	8,000	3,000	6,000	75
Africa	Congo River	15,000	4,000	11,500	77
	Nile River	6,000	3,000	4,800	80
	Zambezi River	1,600	1,000	1,500	94
	Niger River	2,000	1,000	1,600	80
North America	Western Canada	5,900	2,700	3,400	57
	Western Hudson Bay	1,400	1,000	1,100	77
	Labrador Peninsula	9,600	6,100	7,300	76
Central and South America	Amazon River	14,000	9,400	11,400	81
Total		168,290	87,750	128,800	76

2. Speeding up fossil fuel phase-out and cleaner consumption

Coordinated efforts are required to phase out coal, oil, and gas and introduce clean energy and may involve restrictive measures on investment in fossil fuels, reduced subsidies and restricted policy support, and stricter control over total consumption. Measures are also needed to ensure demand for fossil fuel peaks and decreases as soon as possible with a view to eliminating their use. The share of fossil fuels in primary energy is predicted to drop from 76% in 2016 to 30% in 2050[1]. The phase-out of global fossil fuels is illustrated in Figure 2.5.

We must accelerate the phase-out of coal in favor of cleaner consumption. The focus should be on promoting "consumption reduction, quality improvement, and efficiency enhancement" in the coal industry with safe and green coal mining, improved production technology and safety guarantees, and stricter controls over coal chemical production capacity and coal consumption. Stricter measures are likewise required

[1] Source: GEIDCO, *Biodiversity and Revolution of Energy and Electric Power*, Beijing: China Electric Power Press, 2020.

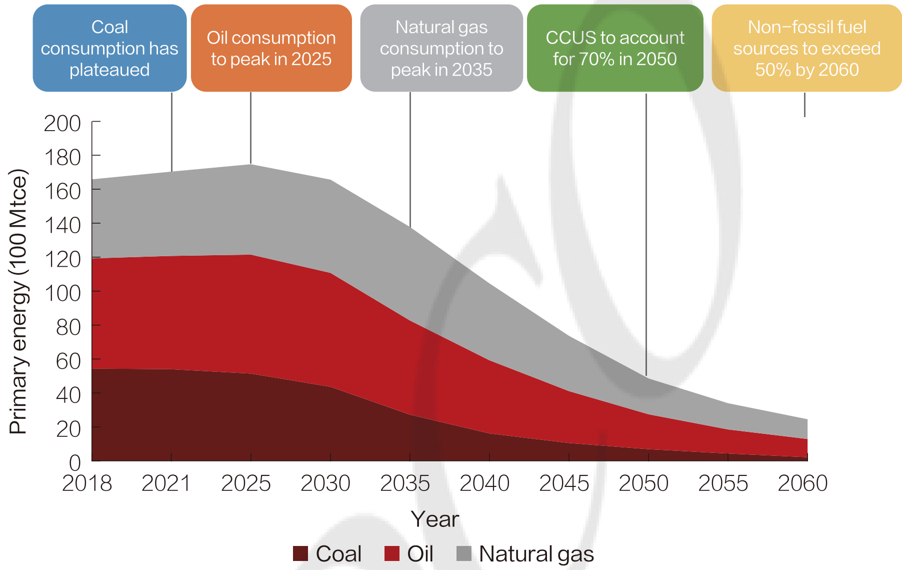

Figure 2.5 Phase-out of Fossil Fuels Globally

over coal power totals, energy conservation, and emissions as coal-fired power units are transformed, electricity and hydrogen energy replace coal at an accelerated pace, the use of civil and industrial bulk coal is reduced, and carbon capture, utilization, and storage (CCUS) becomes more widespread in coal-fired facilities. Coal consumption is predicted to decline gradually around the world to 0.68 Gtce by 2050, with the share of coal in primary energy consumption to drop to 3.5%.

We must control and reduce oil and gas consumption, with the emphasis on industry, transportation, and construction, among other fields. New technologies and equipment like electric boilers, electric vehicles (EVs), port shore power, electric heating, and electric cookers should be actively promoted in these sectors. Electrolytic hydrogen production and the electrosynthesis of fuels should also receive attention as oil and gas are replaced with clean electricity and control is exerted over the growth rate of final oil and gas consumption. Oil consumption is predicted to peak globally at 7 Gtce by 2025 and drop to 2.05 Gtce by 2050 for 11% of primary energy consumption. As developing countries replace coal with natural gas, natural gas consumption is projected to peak globally at 5.52 Gtce by 2035 before falling to 2.13 Gtce by 2050.

2.3.2 The electrification of energy consumption

1. The development of green transportation

Greater efforts are required to develop EVs, hydrogen vehicles, and green aviation and shipping and electrify the transportation sector. It is predicted that by 2050 there will be 1.6 billion EVs and 150 million hydrogen vehicles, or 75% and 7% of all vehicles, respectively. Electricity consumption in the transportation sector is expected to reach 1.29 Gtce and account for some 52% of energy consumption in the sector, with hydrogen energy expected to reach 0.25 Gtce, or 10%[1].

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[1] Source: GEIDCO, *The Road to Global Carbon Neutrality*, Beijing: China Electric Power Press, 2020.

We must accelerate the development of EVs. Breakthroughs in core technologies – high-power motors, high-performance lithium batteries, and graphene-based solid-state batteries – should be accelerated to improve range, shorten charging time, and reduce the cost of operating an EV. Improving coordination between charging network planning and urban planning to establish intelligent and efficient charging infrastructure that is well-thought-out and provides extensive coverage would do much to accelerate the development of EVs, which are expected to gain a cost advantage over traditional fuel vehicles, to be phased out gradually, by as early as 2025.

We must accelerate the development of hydrogen vehicles. Breakthroughs in core technologies – hydrogen fuel cells, proton exchange membrane electrolyzers, and high-speed hydrogen refueling stations – should be expedited to lower the cost of operating a hydrogen vehicle. Steps should likewise be taken to coordinate upstream and downstream development of the industrial chain, hydrogen production, transmission, and storage, and establish a hydrogen refueling network that is adequately sized, strategically distributed, and easily accessible to meet the development needs of hydrogen vehicles. The purchase cost of hydrogen vehicles is expected to come down to that of EVs by 2035 and make commercial promotion on a large scale more viable.

We must develop green shipping and aviation. The electrification rate for railways will rise as we promote the construction and transformation of high-speed electrified railways, speed up the construction of urban rail transit, subways, LRTs, and reduce the use of fossil fuels in vehicles. Equally important is R&D for electric ships and aircraft and hydrogen-powered ships and aircraft, developing supporting facilities for port shore power supply, carrying out demonstrations and applying what we learn, and gradually expanding promotional efforts to propel forward the green and low-carbon development of aviation and shipping.

2. Green industrial production

Electrification will spread through the steel and chemical industries as we promote electric and hydrogen steel production and the electrosynthesis of raw materials. Steel output from electric furnaces and hydrogen energy is expected to reach 1.2 billion tonnes and 800 million tonnes, or 46% and 30% of the global total, respectively, by 2050, effectively taking the two techniques mainstream. Electricity consumption in the chemical industry will reach 0.35 Gtce, raising the electrification rate to 16%, at which time electrosynthetic raw materials will be the main source of chemical raw materials and produce 160 million tonnes of ammonia and 310 million tonnes of methanol[1].

Green development must take hold in the steel industry. The short term focus needs to be on the research and development of large-capacity, high-power electric furnace steelmaking technology and equipment to gradually improve energy efficiency, expand production capacity, and reduce costs. **In the medium to long term,** as the cost of electrolytic hydrogen goes down, the development of hydrogen energy steelmaking should intensify along with the provision of policy support such as green hydrogen price subsidies, breakthroughs in core technologies, and the construction of

1 Source: GEIDCO, *The Road to Global Carbon Neutrality*, Beijing: China Electric Power Press, 2020.

demonstration projects to gradually replace traditional steelmaking.

Green production needs to move forward in the chemical industry. Measures should be adopted to promote the research and development of technologies and equipment such as high-temperature heat pumps and electric heating furnaces and accelerate their commercial promotion. It is also essential to promote the large-scale use of electric heating furnaces in the production of cement, glass, and ceramics to reduce the demand for fossil fuels there. Integrated high-efficiency water electrolysis hydrogen production and large-capacity CO_2 hydrogenation to methane and methanol demonstration projects will lay the foundation for the commercial electrosynthesis of raw materials.

3. The development of green buildings

Building energy consumption for heating, cooking, and hot water, energy efficient electric air conditioners and household appliances, and lighting is ready for the introduction of electrical power and the ideal place to introduce residents to the concept of a green and low-carbon lifestyle. Electricity consumption in the building sector is expected to increase to 3.4 Gtce by 2050, with the electrification rate to reach 68%. At the same time, the penetration rate for smart, energy-saving household appliances will reach 85%, with a green building renovation completion rate of 100%.

It's time for electricity replacement. It is imperative we increase the popularity of household appliances in underdeveloped countries and regions to ensure modern energy services are available, and supporting subsidies have been introduced to lower the purchase threshold. Technological innovation is still needed in high-power and high-performance electric heating, cookers, water heaters, etc., as is improvement to the reliability and intelligence of distribution networks to meet the diversified energy needs of residents. Finally, wider promotion of electric regenerative boilers and heat pumps should be complemented by storage of off-peak surplus clean electricity for heating to gradually replace coal and gas heating.

Energy conservation will come with improved efficiency. Support should be provided for increased research and development into energy-saving household appliances and smart home technologies, with efforts to improve the efficiency of equipment crowned by the introduction of preferential policies, subsidies, trade-in programs, and low-interest consumer loans. Efforts to improve the energy efficiency of electrical equipment should focus on energy-saving building renovations, the adoption of energy-saving lighting, and the use of variable frequency energy-saving systems to control central air conditioners and water pumps. Energy-saving technologies and new materials for exterior walls and roofs, solar reflective glass, and low emissivity glass should also be adopted in zero-carbon buildings to further reduce energy consumption.

4. Accelerating the development of green hydrogen

Hydrogen energy is an abundant, green, low carbon secondary energy source with a wide range of potential applications. Its flexibility and dual role as a fuel and raw material makes it an important supplement to electricity for deep decarbonization and flexible energy storage during energy transition and a crucial component of the future energy system. At present, less than 1% of hydrogen is produced from renewable energy (**green hydrogen**) globally – as much as 96% involves fossil fuels (**gray hydrogen**).

Green hydrogen production bases need to be built more quickly. With consideration for wind and solar resource endowment, water accessibility, and transportation, large green hydrogen production bases have been planned for Dammam and Ha'il, Saudi Arabia, the Moroccan city of Zag, Tunisia, northeastern Brazil, Chile, southern Argentina, and western Australia, to name just a few. The goal is to progressively expand production capacity while reducing costs and ensuring a sufficient global supply. The global annual output of green hydrogen is expected to reach as high as 340 million tonnes by 2050, which would be over 80% of total hydrogen output, and with an expected average production cost of USD 1-1.5/kg, green hydrogen would possess a distinct economic advantage over grey hydrogen.[1]

Column 2-1 Water for Electrolytic Hydrogen Production and Seawater Desalination

With the rapid development of hydrogen production by water electrolysis, water has acquired new significance for the green hydrogen discourse. Theoretical water consumption for electrolytic hydrogen production is 9 kg water/kg hydrogen. When loss in the production process is factored in, however, actual water consumption comes closer to 20 kg water/kg hydrogen. Annual output of green hydrogen is expected to reach 340 million tonnes globally by 2050, consuming nearly 7 billion m^3 of water, considerably lower than the current annual global agricultural water consumption of 2.8 trillion m^3, industrial water consumption of 800 billion m^3, and urban water consumption of 500 billion m^3.

For coastal regions abundant in wind and solar resources but lacking in freshwater, such as West Asia, North Africa, and South America, especially northern Chile, desalinated seawater is a viable option for electrolytic hydrogen production. With the mature technology of reverse osmosis, electricity consumption for seawater desalination is estimated to be about 3 kWh/m^3, at a general cost of USD 0.5-1/m^3. With the cost of transporting water and treating the leftover brine factored in, the cost of water for electrolytic hydrogen production rises to approximately USD 1.5-2/m^3, increasing the electricity consumption for electrolytic hydrogen production by 0.06 kWh/kg hydrogen, or only one-thousandth of the total, and the cost of electrolytic hydrogen production by USD 0.03-0.04/kg hydrogen, or less than 2% of the overall production cost.

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1 Source: GEIDCO, *Research on Global Renewable Energy Development and Investment*, Beijing: China Electric Power Press, 2020.

Hydrogen energy is expected to account for around **10%** of final energy consumption globally by **2050**, with consumption in excess of **410** million tonnes

The final energy consumption of Green hydrogen needs to be accelerated as soon as possible. The focus should be on introducing hydrogen energy to the chemical, metallurgical, and transportation segments, among others, where there may be difficulties introducing electricity. **In industry,** fuels and raw materials such as ammonia, methanol, and methane should be synthesized with green hydrogen; the metallurgical industry should apply hydrogen in steelmaking and high-quality heat supplies for cement, ceramics, glass, and others. **In transportation,** hydrogen-powered buses and heavy trucks with extended ranges and high payload capacities should be developed along with hydrogen-powered ships and aircraft. **In buildings,** existing natural gas pipeline networks and facilities should be integrated with hydrogen to reduce carbon emissions from heating and domestic hot water supplies. **In power generation,** hydrogen gas turbines and fuel cells should be developed to support the power system with flexible regulation and voltage. Hydrogen energy is expected to account for around 10% of final energy consumption globally by 2050, with consumption in excess of 410 million tonnes.

2.3.3 Efficient allocation of energy

1. Upgrading power grids

The power grid is essential to energy allocation and to matching supply and demand. It would be impossible to optimize allocation on a large scale without improving the transmission network, and the distribution network is indispensable to the development of distributed energy resources, facilitating electricity replacement, and delivering comprehensive energy services. To accelerate the clean production of energy and electrification of energy consumption, collaborative planning and development of transmission and distribution networks is needed, and upgrades in grid allocation, operations, and services should be sped up.

Transmission networks need to be upgraded. Measures should be taken to improve the planning of transmission networks and the development of the main network to improve the scale of the power grid, voltage levels, and capacity allocation. Power sources and grids require better coordination, and energy development bases and energy transmission channels require synchronized planning and construction if they are to ensure the large-scale delivery of clean energy. New strategies for power grid control and operations using virtual synchronous machines, grid-forming inverters, and other advanced technologies can help us plug large quantities of clean energy into the grid in the future and address the challenges of keeping the system up after fossil fuels have been phased out.

Distribution networks must be upgraded. The distribution network should be tailored to the situation in each region, with a focus on improving the flexibility and resilience of the network and enhancing its adaptability and reliability. **In load-intensive areas,** the connection between distribution and transmission networks and substation sites and line corridors needs to be improved to boost wheeling. **In power-intensive areas,** the analysis of new distribution network energy carrying capacity needs to be refined and flexible grid connection and efficient outbound transmission of distributed energy sources improved to minimize wind and PV curtailment.

2. Strengthening interconnection

There is a global tendency for areas rich in clean energy resources to be located hundreds, if not thousands, of kilometers away from load centers. For example, 85% of hydro, wind, and solar energy resources in Afro-Eurasia are concentrated on the energy belt from North Africa to Russia's Far East via Central Asia at an angle of about 45° to the equator, while demand for this power concentrates primarily in East Asia, South Asia, Europe, and Southern Africa, among others. The uneven distribution of resources and demand necessitates optimal allocation on a large scale. At the same time, wind and photovoltaic power generation are highly random and volatile. Efficient development and utilization are only possible with integration into a large power grid. To develop clean energy on a large scale, therefore, we must establish large, globally interconnected electrical power grids.

We must establish a global backbone grid. We will build robust transnational backbone grids accounting for resource endowment, demand, and governance to strengthen interconnections and establish a global electricity channel with advanced technologies, UHV, smart grids of multi-energy cross-regional outbound transmission, with support that transcends time zone and season. By 2035, Asia, Europe, and Africa will have connected their power grids to create an inter-regional, intercontinental power flow capacity of 330 GW, primarily of inter-regional and transnational power exchanges. By 2050, inter-regional and intercontinental channels will have strengthened to connect large clean energy bases to load centers, increasing the inter-regional and intercontinental power flow capacity to 660 GW[1] and creating a new pattern of global clean energy development, allocation, and utilization.

We must establish a global hydrogen energy allocation network. Green hydrogen will be a component of the future energy system. Factors such as resource endowment, infrastructure, and transportation must be taken into account and combined with local

Column 2-2 Different Hydrogen Transmission Models and Scenarios

The distance of transmission and scale of green hydrogen production and demand can vary significantly from scenario to scenario. Different transmission scenarios affect the technology to be used and the ratio of hydrogen to electricity transmission in the coupling system.

Flexible configuration and low costs make hydrogen tube trailers the optimal choice for a transmission distance of 100-200 km and scale less than 500 million m^3/year. For a larger scale, a scheme utilizing AC supplemented by pipeline transmission is preferred.

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[1] Source: GEIDCO, *Research and Outlook on Backbone Grids of Global Energy Interconnection*, Beijing: China Electric Power Press, 2019.

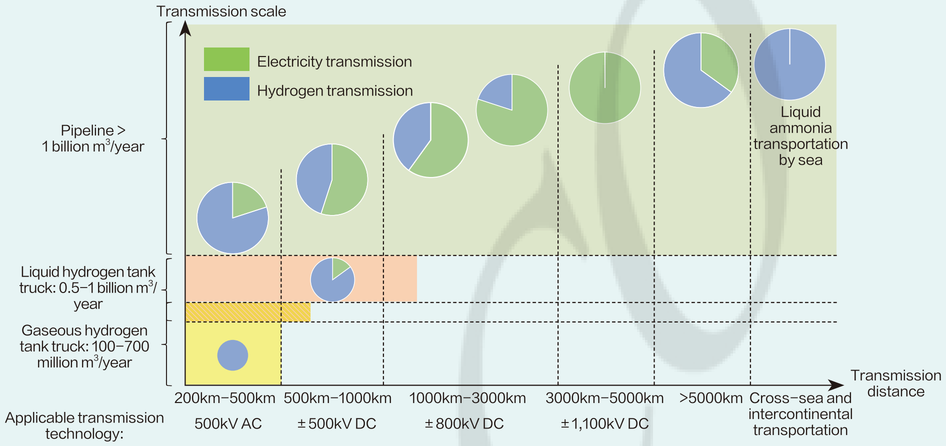

Fig. 1 Electricity and Hydrogen Transmission Optimization by Scenario

Liquid hydrogen tank trucks are used for a transmission distance of 200-1,000 km and scale less than 1 billion m^3/year. For a larger scale, ±500 kV DC and pipeline hydrogen transmission should be adopted concurrently. As the distance increases, the economic advantage of power transmission over hydrogen transmission will become increasingly evident.

In the case of a distance of 1,000-5,000 km, ±800 kV or ±1,100 kV UHVDC lines can be employed for power transmission and pipelines for hydrogen. As the distance increases, the economic advantage of power over pipeline hydrogen transmission will be more pronounced, and increasing the share of power can help lower overall costs.

When the transmission distance exceeds 5,000 km, single transmission based on existing technologies becomes a challenge and pipeline hydrogen transmission more economical. If the costs of submarine cables and hydrogen transmission pipelines exceed those on land, and shipping costs remain relatively unaffected by distance, it would be preferrable to transmit hydrogen by sea in the form of liquid hydrogen, liquid ammonia, or liquid organic compounds for storing hydrogen, etc.

development and utilization with large-scale optimization if we are to accelerate the establishment of hydrogen energy allocation networks. Hydrogen can be transmitted directly through pipelines in regions where the network infrastructure is advanced, such as Europe and North America. The proportion of hydrogen in natural gas pipelines can be increased gradually or part of the pipelines can be dedicated wholly to hydrogen. In regions with abundant clean energy resources and developed port facilities, such as West Asia and Australia, UHV transmission technology can be used to transmit green electricity to hydrogen production centers for hydrogen production and subsequent transmission across the seas in the form of liquid hydrogen or hydride. The expectation is for hydrogen energy to be extensively distributed across continents by 2050 the tune of about 50 million tonnes, which would account for 10% of global hydrogen energy demand.[1]

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[1] Source: GEIDCO, *The Road to Global Carbon Neutrality*, Beijing: China Electric Power Press, 2020.

3. The digital and intelligent development of power grids

Digitalization and intelligence support the high-quality development of power grids. Advanced information and communication technologies, like big data, cloud computing, IoT, mobile internet, AI, and blockchain are indispensable for adapting to the increase in new energy grid-connected consumption and support broader access to massive regulatory resources, distributed resources, energy storage and drive new technologies and formats, like smart cities and smart transportation.

We must establish a digital platform for energy services. A network service platform will unite and integrate the flow of information, capital, and business along the energy value chain. At the same time, platform coverage will gradually be expanded to encompass all businesses and processes to provide users with high-quality online services for electricity detection, energy efficiency diagnosis, and intelligent operation and maintenance, satisfying a diversity of personalized energy consumption needs, reducing service costs, and improving service quality.

Column 2-3 State Grid Corporation of China (SGCC) digital IoV service platform

SGCC is responsible for the world's most complete vehicle network service platform. As of the end of 2023, it had connected more than 510,000 charging stations, served over 25 million registered users, and covered more than 50,000 kilometers of expressway. Platform charging services include station and pile navigation, plug and charge, non-inductive payment, and battery safety monitoring, enabling users to "cross China with a single app". A load aggregation system based on this platform provides charging facilities with channels to participate in green electricity trading, engage in demand response, and access the power grid auxiliary service market.

Fig. 1 SGCC's IoV Platform

We must make our power grids more intelligent. Advanced digital technology will make possible an intelligent control system for power grid operations with observable, measurable, and controllable generation, grid, load, and storage. In terms of auxiliary decision-making and intelligent grid regulation, artificial intelligence technology should be employed to optimize models, algorithms, intelligent regulation, and optimal management for safer, more reliable, stabler, and more efficient operations. Steps should also be taken to integrate energy and meteorological big data and improve adaptability to extreme weather and the climate resilience of the energy system.

We must build a digital platform for market trading. An online trading platform should provide complete, timely, and accurate market information for a variety of market entities and ensure quick and easy access to the unified power market. Active steps should be taken to explore a point-to-point energy trading mechanism based on blockchain technology and nurture new businesses, new models, and new formats, such as load aggregation services, comprehensive energy services, and virtual power plants.

2.4 The Significance of GEI in Addressing Climate Change and Conserving Biodiversity

Climate change and biodiversity loss are closely related to an unreasonable fossil fuel development pattern. Building the GEI will accelerate the thorough development of clean, electrified energy by shifting it away from fossil fuels and significantly reducing the impact of unreasonable energy development on the climate and environment. The new coordinated energy, climate and biodiversity development model will benefit the earth in five major ways – by mitigating global carbon emissions, controlling environmental pollution, reducing habitat destruction, promoting the sustainable use of biological resources, and facilitating ecological restoration – through 11 concrete steps:

1) Reducing GHG emissions, 2) Reducing air pollution, 3) Reducing freshwater pollution, 4) Reducing solid waste, 5) Mitigating habitat loss, 6) Reducing damage to forests, 7) Reducing marine pollution, 8) Replacing firewood with electricity, 9) Promoting the widespread application of electrofuels and electrosynthetic raw materials, 10) Controlling desertification, and 11) Promoting marine restoration, thus addressing climate change and preserving biodiversity, illustrated in Figure 2.6. This section will delve into how the GEI could make these 11 concrete steps possible and improve global ecology.

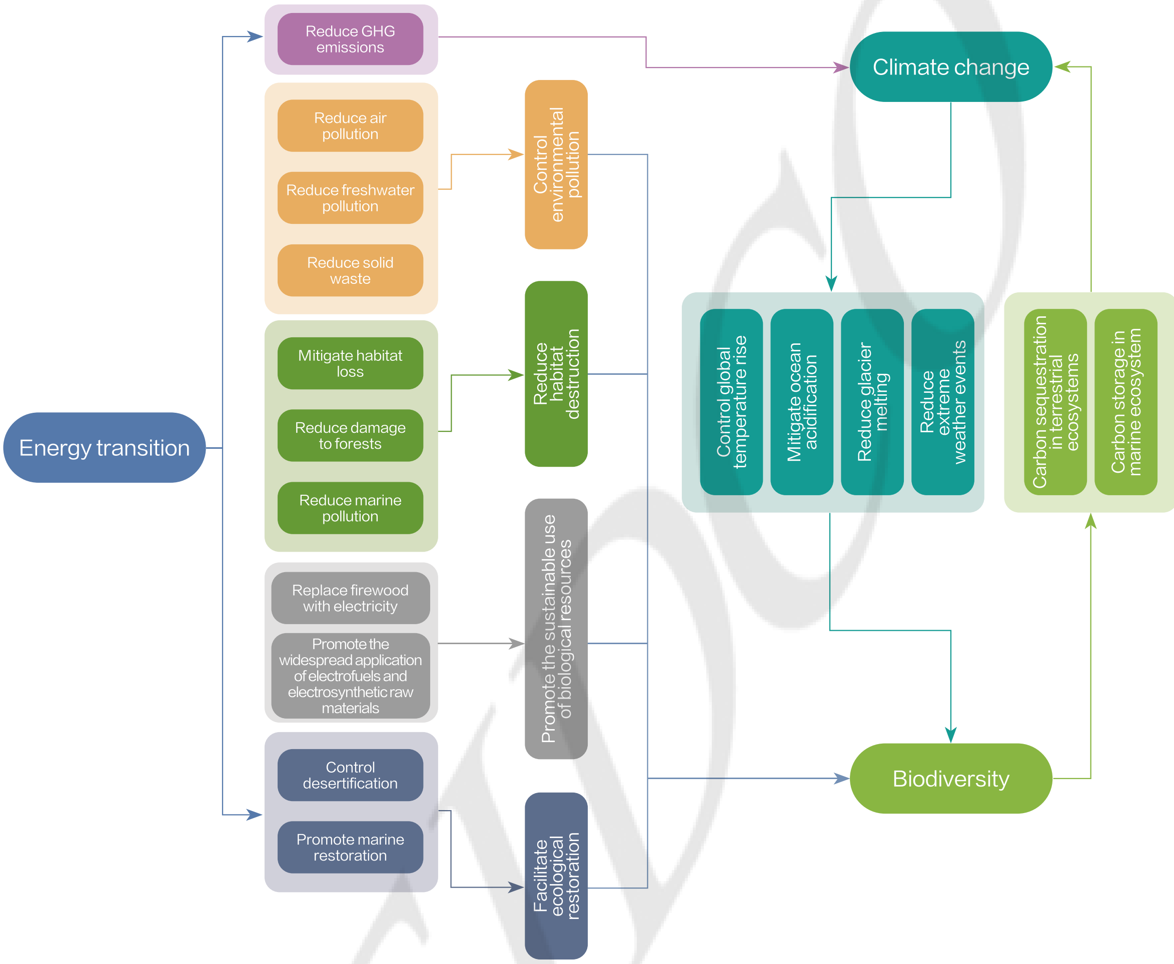

Figure 2.6 GEI Roles in Addressing Climate Change and Conserving Biodiversity

2.4.1 Addressing climate change

Building the GEI, introducing electricity and clean fuels on a large scale, and strengthening power grid interconnection will all accelerate the decarbonization of the energy system, reduce GHG emissions, and curb global climate change, thus effectively reducing the impact of rising temperatures, ocean acidification, glacier melting, and extreme weather events on biodiversity.

Rising temperatures must be brought under control. The speed of global clean energy development and the growth of electrification are expected to increase by more than 150% over the existing development model. By 2050, the share of primary energy that is clean and the global rate of electrification are projected to exceed 80% and 60% respectively. The energy-related carbon emissions will peak around 2025 and reach net zero around 2050, with the world achieving carbon neutrality. This will do much to protect terrestrial and marine habitats from rising temperatures and essentially maintain existing species distribution.

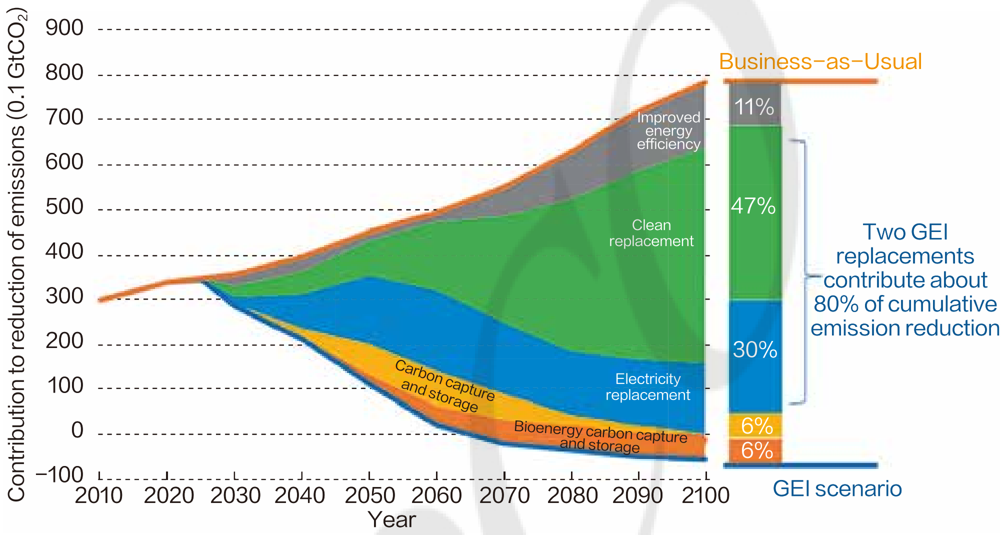

Figure 2.7 GEI Mitigation Path[1]

Ocean acidification must be dealt with. The GEI accelerates the decarbonization of the energy system, reduces the amount of carbon dioxide in the atmosphere, and effectively mitigates ocean acidification. For example, the large-scale development of port shore power can reduce carbon emissions by 98% during ship docking. After achieving carbon neutrality by 2050, the decline in the pH value of seawater will halt, and the acidity of seawater—currently elevated by 30%—will gradually regain balance through self-regulation[10], and existing threats to marine organisms, including coral reef and the overall marine ecosystem, will disappear.

The melting of glaciers must be reduced. The GEI well help hold the rise in global temperatures within 2°C, reduce the melting of glaciers, and prevent more serious damage to the Antarctic, Arctic, and Himalayan ecosystems. At the same time, the initiative will also bring the rise in sea levels under control, minimizing the impact on polar ecosystems and the destruction of coastal ecosystems caused by rising waters.

Extreme weather events must be decreased. Agriculture and small island ecosystems, with their small populations and fragile ecology, are particularly vulnerable to climate change. Plant diseases and pests and extreme weather events, such as drought, flooding, tropical storms, and wildfires, can lead to large-scale die-offs or even extinction. By addressing climate change, the GEI can stabilize and gradually lower the frequency and probability of extreme weather event around the world to reduce their impact on agriculture and small island ecosystems.

1 Data source: GEIDCO, *Resolving the Crisis*, Beijing: China Electric Power Press, 2020.

2.4.2 Reducing environmental pollution

By **2050**, annual SO2 emissions are projected to decline by **250** million tonnes, NOX by **240** million tonnes, and respirable particulate matter by **140** million tonnes, for a **70%** reduction over current levels

Air pollution must be reduced. Humanity's heavy dependence on fossil fuels has produced excess emissions of SO_2, NO_X, PM2.5, and other pollutants. The resulting air pollution has caused acid rain, toxic fog, haze, and great harm to animals and plants. The GEI will significantly reduce the air pollution caused by fossil fuels. By 2050, annual SO_2 emissions are projected to decline by 250 million tonnes, NO_X by 240 million tonnes, and respirable particulate matter by 140 million tonnes, for a 70% reduction over current levels, improving air quality and the environment globally.

Freshwater pollution must be reduced. Unreasonable energy consumption and industrial production have released significant amounts of harmful wastewater into rivers and lakes, posing a serious threat to aquatic life and the freshwater ecosystem. The GEI will significantly decrease wastewater discharge throughout the process, from extraction and transportation to utilization. Industrial wastewater, chemical oxygen demand, and ammonia nitrogen emissions from fossil fuel extraction and utilization will be reduced by more than 60% over current levels by 2050, greatly mitigating freshwater pollution and effectively protecting rivers and lakes.

Pollution from solid waste must be reduced. Solid waste pollutes soil, freshwater, and the world's oceans and impacts biodiversity negatively. The GEI will reduce the pollution caused to the soil by fossil fuel remnants like coal gangue, fly ash, coal slime, and alkali residues. It will also facilitate the large-scale development of biomass power generation and promote the recycling of solid waste like rice husks, straw, biogas, wood waste, and garbage. The installed capacity of waste incineration power generation is predicted to exceed 200 GW by 2050 and dispose of 2.6 billion tonnes of garbage annually, thereby effectively controlling pollution from solid waste.

Column 2-4 Biomass Power Generation

Biomass contains solar energy in the form of chemical energy, i.e., biomass is a carrier of energy synthesized by C_2 and water through plant photosynthesis and generates equal amounts of CO_2 and water upon full combustion. Essentially, biomass is a type of renewable energy with a lifecycle of zero carbon emissions, and it can be used to produce high-quality solid, liquid, and gas fuels through advanced biomass conversion technology and a variety of utilization methods. It be burned for cooking, indoor heating, industrial processes, power generation, and combined heat and power generation, among other uses. It can also be converted into combustible gas, charcoal, chemical products, liquid fuels (gasoline, diesel, etc.), and more through thermochemical conversion to replace natural gas, coal, and traditional transportation fuels. The joint application of biomass energy and carbon capture and storage (CCS) gives bioenergy with carbon capture and storage (BECCS) a negative CO_2 emission capacity, an important technical scheme for reducing carbon emissions.

As shown in Figure 1, global biomass output reached 1.89 Gtce in 2018, accounting for 9.2% of total energy production. Biomass consumption by scenario was as follows: residential life (9.6 Gtce), power generation and heating (0.3 Gtce), industrial production (0.29 Gtce), transportation (0.13 Gtce), commercial services (40 Mtce), and agriculture and forestry (20 Mtce). In 2020, global installed capacity of renewable energy totaled 2,800 GW. Notably, global installed capacity of biomass energy was 130 GW, or about 4.6% of the total.

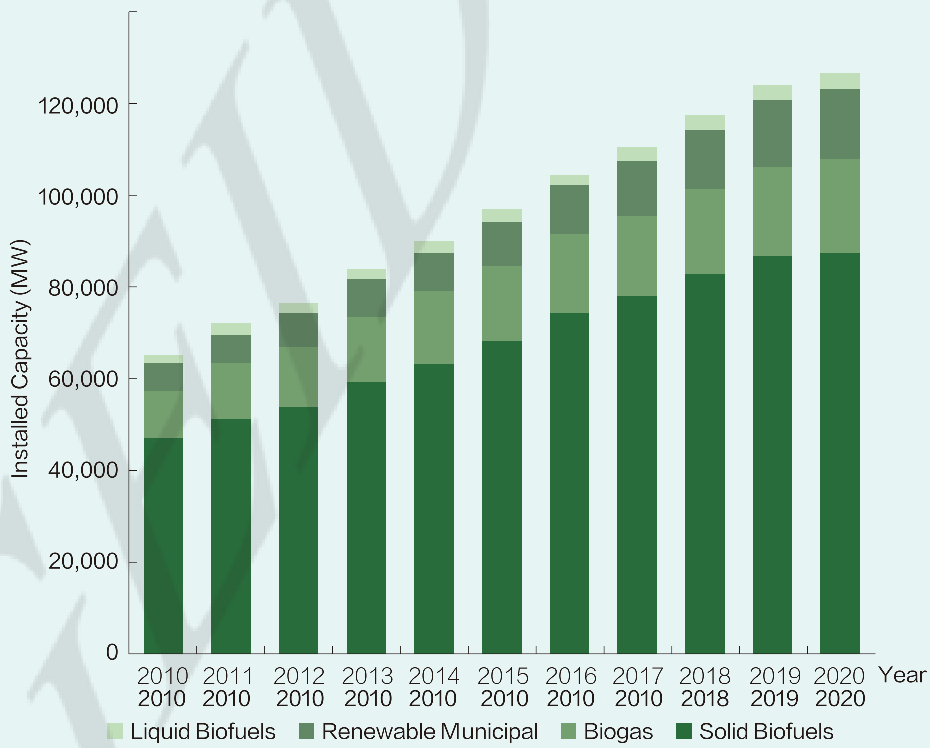

Fig. 1 Global Installed Capacity of Biomass Energy over the Years[1]

[1] Data source: official website of the International Renewable Energy Agency, https://www.irena.org/bioenergy

2.4.3 Reducing habitat destruction

Habitat loss must be reduced. Resource and infrastructure development impact the environment negatively, but more efficient land use and more environmentally friendly infrastructure can help. Building the GEI and integrating biodiversity conservation into the planning, development, and operations of energy and electricity initiatives will significantly improve the efficiency of resource development and reduce the impact of energy utilization on habitat. It is estimated the extinction of more than 40% of bird species and more than 60% of amphibians will be averted by 2050, thus effectively conserving biodiversity.[1]

Column 2-5 Environmental Impact Assessment of Phase II of the Belo Monte Hydropower UHVDC Transmission Project in Brazil

Phase II of the Belo Monte Hydropower UHVDC Transmission Project passes through the Amazon Rainforest, the "lungs of the earth", the Brazilian Highlands, and the hills surrounding Rio de Janeiro. The project spans 863 rivers across five major basins, including the Amazon Basin and the Tocantins, complex ecological systems, varied terrains, and great cultural differences. It is common to find dozens of epiphytes on a single tree in the tropical rainforest, necessitating a "transplant" for all rare species. Brazil's environmental protection law encompasses more than 20,000 regulations, earning it the title of the world's most environmentally regulated country. Approval procedures are complicated and conditions strict. The environmental impact assessment of Phase II of the Belo Monte Hydropower UHVDC Transmission Project has been described as "the most stringent in history".

To ensure project construction satisfied environmental regulations, the team from SGCC selected multiple areas along the line and spent a year meticulously observing and documenting everything they could about the species of animals and plants living there in the rainforest. They spent half a year conducting socio-economic surveys and assessments of the indigenous tribes, covering everything from population, economy, and education to healthcare and transportation. 11 hearings were held in 10 cities along the line to collect the opinions of local government agencies and residents regarding the environmental impact assessment. A total of 56 volumes of environmental reports and impact diagnosis and assessment reports were completed, and 19 schemes for geographical environment protection, animal and plant protection, and malaria prevention and control

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1 Data source: GEIDCO, *Resolving the Crisis*, Beijing: China Electric Power Press, 2020.

were proposed. After 25 months of hard work, the design scheme for Phase II of the Project finally passed Brazil's "most stringent" assessment in August 2017, demonstrating the harmonious balance that needs to be struck between project construction and ecological conservation.

Fig. 1 Environmental Protection of Phase II of the Belo Monte Hydropower UHVDC Transmission Project in Brazil

Ecological damage to forests must be kept to a minimum. Forests are the most biodiversity-rich ecosystems on land, providing habitat for more than 80% of animals, plants, and insects on earth. In recent years, however, the global forest ecosystem has been seriously damaged by climate change, environmental pollution, and deforestation, resulting in the accelerated extinction of species that rely on forests for their habitats. The GEI will significantly reduce the development of fossil fuels and effectively control climate change and environmental pollution. It is projected that by 2050 SO2 emissions will be reduced by 64-86% and NOX emissions by 56-84% (see Figure 2.8), greatly reducing the negative impact of climate change and acid rain on forest ecosystems.

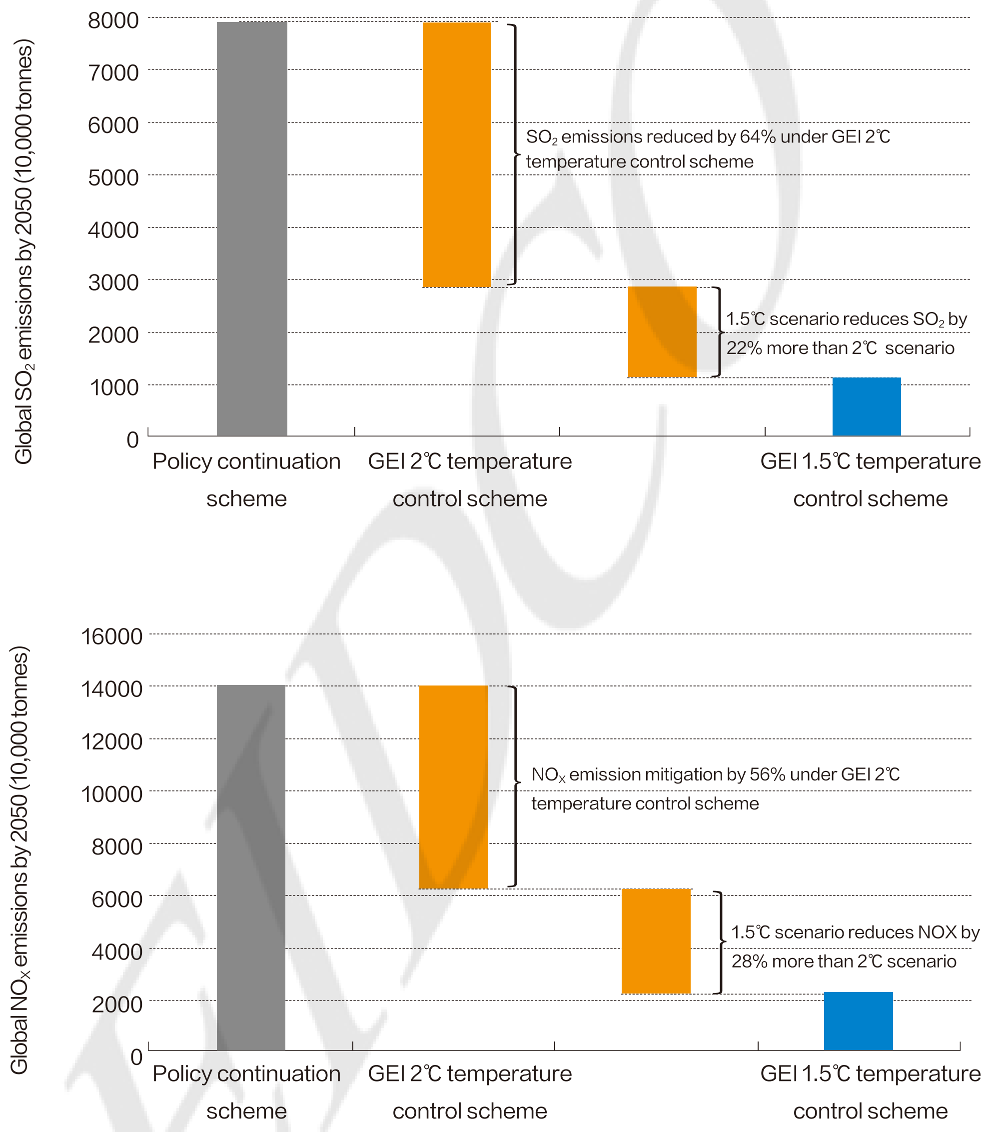


Figure 2.8 Global SO2 and NOX Emissions by 2050[1]

Damage to marine ecology must be reduced. Fossil fuels damage the environment in many ways, through offshore oil leakage, thermal pollution from coastal power plants, and ocean acidification due to CO_2 emissions – all seriously affecting the marine ecosystem. The GEI will replace these fossil fuels with clean energy, shift the focus from oil to electricity, and provide steady clean electricity to support the economic and social development of the nations. The initiative will also promote the gradual withdrawal of offshore oil development and transportation to protect the marine ecosystem and foster a more harmonious coexistence between mankind and the ocean.

[1] Source: GEIDCO, *Resolving the Crisis*, Beijing: China Electric Power Press, 2020.

Column 2-6 China Energy Interconnection Protects the Marine Ecosystem

Coastal areas tend to be economically developed, populous energy load centers. Numerous thermal and nuclear power plants are distributed along the coastline, discharging large amounts of waste heat into the ocean for cooling purposes. This practice poses a serious threat to the marine ecosystem. As of the end of 2023, China had successfully put 39 UHV projects (including 19 AC and 20 DC) into operation, transmitting clean electricity from China's west and north to its eastern coastal regions. Inter-provincial and inter-regional transmission capacity has reached 180 GW, with annual electricity transmission surpassing 3,000 TWh. This development helps power plants in these eastern coastal areas reduce electricity generation by 170 GW, greatly lowering thermal pollution of the ocean, and positively contributing to China's eastern coastal ecosystems.

2.4.4 The sustainable use of biological resources

Firewood needs to be replaced by electricity. 685 million people worldwide have no access to electricity, and 2.1 billion rely on wood-based fuels for cooking[1]. The lack of clean cooking fuels and modern power facilities forces hundreds of millions of people in Africa and South Asia to cut down forests for fuel. The GEI will provide a clean and economical alternative for those without access to electricity. Global accessibility to electricity is expected to approach 100% by 2050, with the levelized cost of electricity to decrease by 40%, making affordable, reliable, and sustainable modern energy available for all, reducing deforestation and protecting forest resources.

Food preservation equipment needs to be more widely accessible. In some countries and regions, power shortages or the high cost of electricity make refrigeration and preservation equipment such as refrigerators and cold storage facilities unrealistic. Consequently, it becomes difficult to preserve food, resulting in substantial food waste and increased human consumption of biological resources. The GEI will provide these countries with a clean and economical electricity supply and promote the widespread adoption of refrigeration and preservation equipment as well as the economical use of biological resources. According to a Food and Agriculture Organization of the United Nations research report, raising the prevalence of refrigeration equipment in developing countries to that of developed countries could potentially reduce food waste by 25%[2].

1. Data source: https://news.un.org/zh/story/2023/07/1119682
2. Data source: FAO, How Access to Energy Can Influence Food Losses

2.4.5 Ecological restoration

Land desertification must be brought under control. Equipment for generating clean energy, like PV and solar thermal facilities, can slow down surface wind speed, reduce rainfall impact and soil moisture evaporation, and prevent the rapid expansion of deserts. It is estimated that 1 GW of eco-friendly PV projects reduces CO_2 emissions by about 1.2 million tonnes per year, and the area of wind prevention and sand fixation can reach 4,000 hectares, equivalent to planting 640,000 trees and remarkably beneficial[1]. Building the GEI simultaneously to carrying out clean energy development and control in areas of mild desertification will create an artificial green and low-carbon ecosystem and control desertification.

Column 2-7 PV-based Desertification Control in Inner Mongolia, China

The Kubuqi Desert in Dalad Banner, Inner Mongolia Autonomous Region, China, is the seventh largest desert in China, with a total area of about 1.45 million hectares, about 61% of which are moving dunes. The desert is rich in solar energy resources, with an average solar radiation of over 3,180 hours, advantageous for PV industry development.

In December 2017, the local government invested RMB 3.75 billion to build a 500 MW PV power station on the edge of the desert. The project was connected to the grid for power generation in December 2017 and by the end of 2019 had generated 0.81 TWh of electricity with an output value of RMB 280 million. In June 2019, China's National Energy Administration decided to build an additional 500 MW PV power station in the area. Upon completion, the Phase II project will integrate with the Phase I project to form China's largest centralized PV power generation base in a desert and the world's largest PV desertification control initiative.

Fig. 1 Kubuqi Desert PV Project in Inner Mongolia, China

[1] Source: https://www.sohu.com/a/295484536_263319

Marine ecology needs to be restored. The GEI will speed up the development of port shore power and electric ship technologies and equipment and the construction of green ports, smart ports, and offshore wind power facilities. Installed capacity of global offshore wind power is expected to reach 200 GW by 2050, driving the development of related industries and creating a new engine for the development of the green marine economy. Access to plenty of clean electricity will make it easier to protect the marine ecosystem and establish a three-dimensional marine ecological monitoring network system integrating remote sensing satellites, drones, sea surface stations, shore stations, and early warning systems.

03

Measures for Biodiversity Conservation in Energy and Power Project Construction

Biodiversity is a fundamental condition for human survival. Protecting biodiversity is a shared responsibility of the entire international community. In recent years, an increasing number of energy and power enterprises have begun to embrace the importance of ecology and green development. They have also begun to incorporate the protection of biodiversity into every stage of energy and power project planning, construction, and operation, actively exploring pathways for harmonious coexistence between energy and electricity development and different ecosystems. There are three main types of successful practices we can take from the efforts of global energy and power enterprises seeking to protect biodiversity: in-situ conservation, ex-situ conservation, and ecological restoration. This chapter will provide a reference for stakeholders coordinating governance of energy, climate and biodiversity and practical ways to put their plan into action.

3.1

In-situ Conservation

In-situ conservation refers to the protection of ecosystems, habitat, and populations in their natural surroundings. When implementing power projects, in-situ conservation consists primarily of setting up artificial nests on transmission towers, converting overhead lines to underground cables, building fish ladders in hydropower stations, reducing the direct discharge of cooling water from coastal coal-fired thermal power plants into the sea, and providing green power to ecological research bases.

3.1.1 Setting up Artificial Nests

Certain rare large raptors in highland grassland areas prefer to nest high. However, these areas often lack tall trees, making stable, elevated transmission towers a preferred nesting option. Unfortunately, the materials the birds carry for nesting, such as wires and sticks, can easily trip lines, and birds can even be injured or killed by high voltage shocks. To prevent such accidents, power enterprises have experimented with building artificial nests and structures to attract falcons on the transmission towers, providing birds with options for normal activities, keeping them from perching on the overhead conductors of transmission lines, and safeguarding them from high voltage shocks.

Column3-1 Building Artificial Nests on Transmission Towers

Located in the hinterland of the Qinghai-Tibet Plateau, the Sanjiangyuan National Nature Reserve is the largest natural reserve in China. It boasts one of the highest concentrations of biodiversity at high altitudes in the world, and it is home to such large birds as hawks, falcons, and golden eagles. From 2011 to 2016, a large power grid was gradually extended to the Sanjiangyuan National Nature Reserve in Qinghai, as projects such as Qinghai-Tibet Power Grid Interconnection and Yushu Power Grid Interconnection were put into operation. To prevent local birds from perching and nesting in ways that threatened their safety, the State Grid Qinghai Electric Power Company installed a total of 168 artificial nests, 20 nest brackets, and 46 perches along the ±400kV Chaila Line (Qinghai Section), successfully attracting birds to build 56 nests and hatch 138 fledglings. Furthermore, bird activity was frequent on the 10kV and 35kV transmission towers in Yushu Tibetan Autonomous Prefecture and Golog Tibetan Autonomous Prefecture, Qinghai Province, with a total of 3,280 artificial nests in place. During operation and maintenance, it was found that 570 of these nests had been utilized by birds, 242 nests built, and 436 fledglings hatched. These efforts have not only effectively safeguarded the sound development of birds in the Sanjiangyuan National

Nature Reserve but also reduced the number of trips caused by birds by 98% year on year.

Fig. 1 A worker installing an artificial nest on a transmission tower

3.1.2 Converting Overhead Lines to Underground Cables

Resolving conflict between power facilities and the living space of wildlife is a key challenge in biodiversity conservation. For instance, the construction and operation of overhead lines occupy land, encroach upon wildlife habitat, and in certain areas lead to soil compaction and water and soil erosion. To address the issue, some enterprises have converted existing overhead lines into underground cables in ecologically resource-rich areas or natural reserves, an approach that preserves the geomorphic environment and minimizes disturbance to wildlife habitat while enhancing the overall safety and reliability of the power grid.

Column3-2 Converting Overhead Lines to Ground Cables

Yancheng is located on the eastern coast of China and is home to the world's largest mudflat and the largest radial sand ridge group. It is a critical area for migratory birds, with nearly 20 species listed in the IUCN Red List of Threatened Species. During the grid connection of offshore wind power projects, State Grid Jiangsu Electric Power relocated power facilities and overhead lines to underground cables in natural reserves and wetland parks. Cable tunnels were used in conservation areas, preserving the original geomorphic environment and protecting nearly 100 hectares of migratory bird habitat from human activity. At present, 17 species of rare birds, including reed parrotbill and Baer's pochard, have been observed returning to their natural habitat.

Fig. 1 Overhead lines converted to underground cables

3.1.3 Building Fish Ladders

Fish migrate between different bodies of water at different times for reproduction and survival. For instance, some species periodically swim back and forth – upstream to spawn before returning downstream once again. This migration is crucial for the fish populations. To facilitate the migration, some power enterprises build fish ladders or elevators during the construction and operation of hydropower projects to allow the fish migrate, supporting the natural reproductive process and doing their part to protect the aquatic ecosystem near dam areas.

Column 3-3 Fish Ladders Built in Hydropower Stations

The Juktan River is located in northern Sweden. In the 1960s, multiple hydropower stations began construction along the river, disturbing the migration of salmon and trout. At the same time, the hydrological environment downstream changed, affecting the survival of fish and waterfowl. In 2016, Vattenfall, the energy company operating the hydropower stations, initiated an ecological restoration project on the Juktan River basin. The project involved upgrading the hydropower stations and constructing fish ladders to ensure salmon and trout could return upstream to spawn, effectively restoring their spawning habitat. Additionally, the company modified the dam's water volume regulation patterns so the downstream flow would more closely resemble the seasonal distribution that existed before the dam was built, minimizing damage to fish habitat.

3.1.4 Reducing the Discharge of Cooling Water into the Sea

Many coastal coal-fired thermal power plants discharge heated cooling water directly into nearby seas after minimal treatment, increasing sea temperatures and adversely affecting the local marine ecosystem. To prevent the ecological damage caused by rises in temperature, some enterprises have integrated the smokestack with the cooling tower, significantly reducing the amount of cooling water required for the units, minimizing the rise in sea temperature, and providing notable environmental benefits and economic advantages.

Column 3-4 Smokestack-Cooling Technology at Türkiye's Hunutlu Power Station

The Hunutlu Power Station in Türkiye is located in the Yumurtalık district of Adana province, adjacent to a beach that serves as a nesting site for the endangered green sea turtle. Green sea turtles come here to lay their eggs on the beach between May and September, a season that is protected. To avoid negatively impacting this rare and endangered species during their nesting activities, the Hunutlu Power Station tweaked their plant-wide once-through cooling water scheme to a twice-through "smokestack-cooling tower integrated" system, reducing discharge volume to just 1.7% of the original once-through scheme and moving the seawater intake point back 1,000 meters. As a result, the temperature rise caused by the discharged water was reduced from 7°C to below 1°C, significantly minimizing the impact on the marine ecosystem.

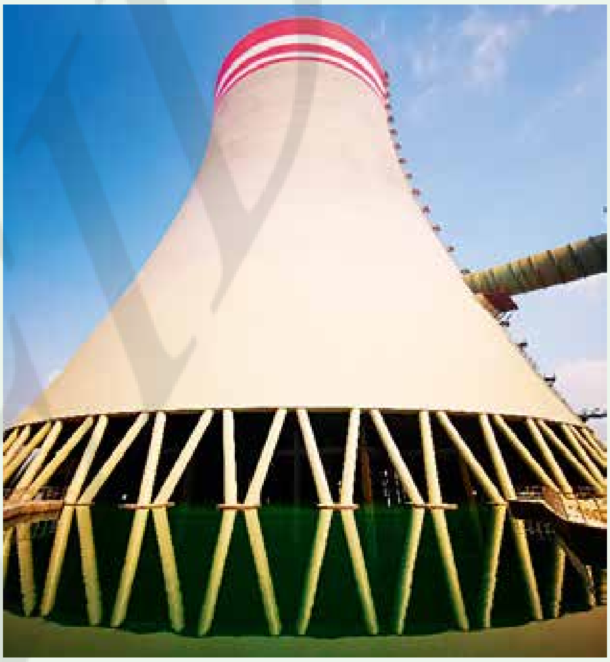


Fig. 1 Smokestack-Cooling Technology at Türkiye's Hunutlu Power Station

3.1.5 Supplying Green Power

Many endangered species around the world thrive only in a specific remote mountain, dense forest, isolated island, or natural reserve habitat. Researchers engaged in biodiversity conservation often make trips to these sparsely populated locations to observe and study. A reliable power supply is required for the equipment used to attract, monitor, and conduct scientific research and to support the daily work and life of the researchers in the conservation areas, precisely where electrical infrastructure is weakest. During research, equipment can shut down with power outages or sustain damage from unstable voltage, which hampers conservation efforts. To address these issues, some power enterprises target the primary habitat of rare species and develop green power supply systems in and around the habitat, providing reliable and clean electricity for biodiversity conservation research and practical work, enhancing the diversity, stability, and sustainability of the ecosystem.

Column 3-5 Building a Zero-carbon Microgrid and a Research Base on Renewable Energy

The golden snub-nosed monkey is an endangered animal under first-class national protection in China. To better protect this species, the local government established a research base dedicated to tracking, observing, and studying the behaviors of the Sichuan golden snub-nosed monkeys in the Jinhouling habitat. Yet, the use of electricity for scientific research and fire for daily living threatened the natural habitat. In response, State Grid Hubei Electric Power built a "PV + energy storage" microgrid at the research base, electrifying production and daily activity to minimize the impact on the monkey's habitat. Thanks to years of efforts, the population of the golden snub-nosed monkey in Shennongjia has increased from just over 500 at the establishment of the nature reserve to over 1,300 today, more than doubling in 30 years.

Fig. 1 "Zero-carbon" Golden Snub-nosed Monkey Research Base

3.2

Ex-situ Conservationc

Ex-situ conservation complements in-situ conservation. It involves relocating species whose survival and reproduction are severely threatened in their natural habitat to zoos, botanical gardens, or breeding centers for special protection and management. When implementing power projects, ex-situ conservation measures may consist of something like establishing rare fish protection centers and launching public welfare projects aimed at protecting rare and endangered plant species.

3.2.1 Building a Rare Species Conservation Center

To minimize the impact of hydropower projects on rare fish and aquatic organisms, some power enterprises have, under the guidance of government departments, teamed up with scientific research institutions to establish rare species conservation centers. These centers carry out ex-situ conservation for rare plants affected by construction land use and reservoir inundation. Rare fish that have difficulty adapting are migrated to the conservation centers for protection and management by professional personnel.

Column3-6 Building Artificial Nests on Transmission Towers

The Yangtze River is one of the most biodiverse aquatic systems in the world and home to over 4,300 aquatic species, including 424 different fish, 183 endemic. During the construction of the Three Gorges Dam hydropower project, the China Three Gorges Corporation conducted research on the conservation of rare and endemic Yangtze River fish like the Chinese sturgeon, establishing a conservation center for rare fish in the Yangtze River basin and successfully tackling several “world-first” technical challenges, including the breeding and release of Chinese sturgeon, induced spawning with synthetic oxytocin, large-scale fry cultivation, and the full artificial breeding of the second generation. Additionally, over 20 rare fish species were successfully bred, including Coreius guichenoti and Leptobotia elongata. At the same time, a garden for rare and endemic Yangtze River basin plants was built, with 29,000 individual plants of more than 1,300 species under ex-situ protection. The initiative marked the first successful flowering and fruiting of Davidia involucrata in the low-altitude areas of Central China. Significant technical challenges were also overcome, including the artificial propagation of the Myricaria laxiflora seeds and the non-proliferation of spores and non-differentiation of prothallia in Adiantum nelumboides, with spore proliferation rates reaching 100% and the differentiation rate of prothallia exceeding 90%.

Fig. 1 Breeding of Chinese Sturgeon at the Rare Species Conservation Center

Fig. 2 Protection and Cultivation of Adiantum Nelumboides at the Rare Species Conservation Center

3.2.2 Public Welfare Projects for the Protection of Rare and Endangered Plants

Energy and power projects often use land and build infrastructure that can negatively impact the surrounding natural environment and biodiversity. Project areas may even contain rare plants and famous old growth. To protect the rare plants within the project area, some enterprises have initiated public welfare projects for the protection of endangered plants, engaging specialized organizations to find places outside the project area suitable for the growth of the rare plants and transplanting them there. Enterprises have also collaborated with nearby forest farms and other institutions to transplant rare plants to permanent conservation sites.

Column 3-7 Public Welfare Project for Protection of Rare and Endangered Plants

The Yangjiang Pumped Storage Power Station, with an installed capacity of 1.2GW, is located in Yangjiang City, Guangdong Province, China, adjacent to the Ehuangzhang Provincial Nature Reserve, extremely rich in plant species. Investigations revealed several rare and endangered wild plants, including national first-class key protected plants, Euryodendron excelsum H. T. Chang, Paphiopedilum purpuratum, and Pholidota chinensis. China Southern Power Grid organized a public welfare project for the protection of rare and endangered plants, engaging the Ehuangzhang Nature Reserve scientific research and technical team to carry out field investigations. They found an area behind the lower reservoir dam of the Yangjiang Pumped Storage Power Station suitable for transplanting Euryodendron excelsum H. T. Chang. In 2023, 2,100 seedlings were planted behind the dam, with 1,900 surviving, a survival rate of 90%.

Fig. 1 Successfully Transplanted Rare Wild Euryodendron Excelsum H. T. Chang

3.3

Ecological Restoration

Ecological restoration refers to the use of nature's ability to repair itself coupled with appropriate human assistance to restore original ecological functions with water and soil conservation, microclimate regulation, and biodiversity maintenance, as well as economic development and utilization. In power projects, ecological restoration primarily involves specific measures for implementing PV-assisted sand control, promoting ecological restoration in coal mining areas, encouraging fish proliferation and release at hydropower stations, and restoring coral reef ecosystems.

3.3.1 PV-assisted Sand Control

Approximately 41% of the Earth's surface is arid or semi-arid. Due to special climatic conditions and the nuances of geography, ecosystems in arid regions are more vulnerable than humid and semi-humid regions, making ecological restoration more challenging. In response, some enterprises have implemented PV-assisted sand control projects, integrating PV power generation with sand control. PV power stations increase the supply of clean energy while the sand control projects improve environmental conditions. This approach generates significant benefits in terms of energy conservation, reduced emissions, and ecological management.

Column 3-8 PV-assisted Sand Control Project in Zhangwu County, Fuxin City

Zhangwu County is located in Fuxin City, in the northwest of Liaoning Province, China, on the southern border of Horqin Sandy Land. It is situated in a transitional zone between the temperate monsoon climate and the dry continental climate, with annual precipitation ranging from 300 to 500 mm. According to the latest data, Zhangwu has approximately 140,000 hectares of land stricken by desertification and faces severe challenges in wind prevention and sand control. The China HuaNeng Group has invested in a PV-assisted composite sand control demonstration project in this area, with an installed capacity of 0.5GW. The project employs an "ecological + characteristic agriculture model" under the solar panels and between the arrays, promoting an approach of "power generation on panels, ecological restoration below panels, and planting between panels" and aims to combat desertification and restore the affected land by "fixing sand with sunlight".

(a) Before

(b) After

Fig. 1 PV-assisted Sand Control Project in Zhangwu County, Fuxin City

3.3.2 Ecological Restoration in Coal Mining Areas

Coal is an important energy resource and has played an enormous role in economic and social development worldwide. However, prolonged mining activities have also caused significant damage to the environment around mines. Some power enterprises are actively engaged in environmental management and restoration in mining areas, working to return the ecological balance in the areas to their natural states or as close as possible to ensure the sustainable use of the land.

Column 3-9 Ecological Restoration Project in Open-pit Coal Mines

The Heidaigou and Haerwusu open-pit coal mines in Inner Mongolia, China, have an annual output of 69 million tonnes, ranking them among the most productive in the world. For ecological restoration in local mining areas, CHN Energy Investment Group (CHN Energy) has explored the establishment of three technical systems: water and soil erosion control, ecological reconstruction, and standardized procedures for land reclamation and greening while vigorously promoting ecological restoration in coal mines following the principles of "landform reshaping, soil reconstruction, vegetation restoration, landscape recovery, and biodiversity reorganization and protection". Thanks to their efforts, the green area has grown to 6,566 hectares, with vegetation coverage increasing from 25% to over 80%. The ecosystem in the mining area has achieved positive succession and a virtuous cycle, and biodiversity has benefitted significantly.

(a) Before

(b) After

Fig. 1 Before and After Ecological Restoration in Open-pit Coal Mines

3.3.3 Encouraging Fish Proliferation and Release at Hydropower Stations

Fish proliferation and release is a primary solution for restoring fish resources around hydropower stations. Some enterprises place great emphasis on coordinating between hydropower development and ecological protection, engage in fish proliferation and release, intensify research on domestication and reproduction

Column 3-10 Fish Proliferation and Release at Jinsha River Hydropower Base

There are 518 kilometers of protected river in the upper reaches of the Jinsha in Sichuan-Tibet. While developing the Batang Hydropower Station in the area, the China Huadian Corporation did its due diligence on the protection of rare fish and addressed challenges facing the entire process of "collection and preservation, domestication and breeding, fry cultivation, and labeling and releasing" at high altitudes. As a result, a total of 4.075 million fish, including Gymnocypris potanini firmispinatus and Schizopygopsis malacanthus, have been released into this section of the river.

(a) Fish Proliferation and Release Station

(b) Proliferation and Release Event

Fig. 1 Fish Proliferation and Release at Jinsha River Hydropower Base technology for rare and endemic species, and implement targeted releases to align with the functional needs of the river basin. All of these efforts contribute to the protection of the aquatic environment in the areas surrounding hydropower stations.

3.3.4 Restoring Coral Reef

Climate change and human activity have put marine ecosystems under great pressure. Coral reef ecosystems provide essential habitat and breeding grounds for numerous marine organisms, serve a variety of ecological functions, and are economically valuable. Some enterprises engaged in providing safe and reliable electricity for economic and social development have shown great concern for the contribution coral reef makes to the protection of surrounding marine areas, innovatively repurposing fly ash from coal-fired plants to create fish habitat and contributing to the restoration of coral reef.

Column 3-11 Coral Reef Restoration in the Sea Area Around Indonesia's Kendari Thermal Power Plant

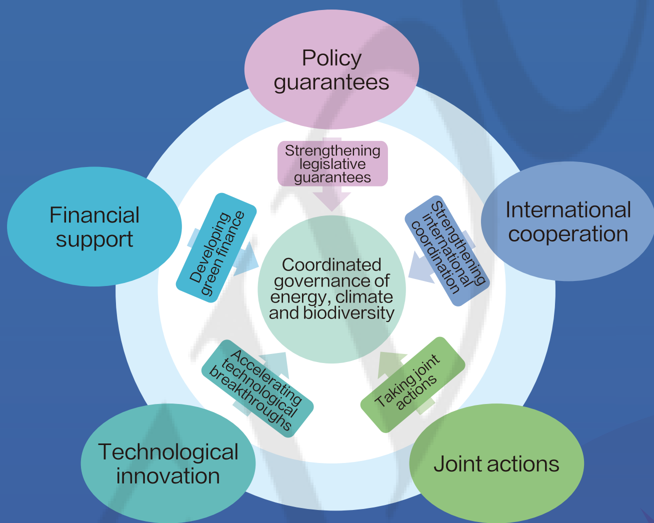
The Kendari Thermal Power Plant is a coastal coal-fired unit located in Sulawesi Province with an installed capacity of 2×56MW. It utilizes seawater for cooling and supplies 60% of the Sulawesi power grid's electricity. The plant has implemented a restoration project for the surrounding coral reef in conjunction with the Faculty of Fisheries and Marine Sciences at Halu Oleo University, surveying the coral reef in the region to better understand its current condition and distribution and identify any underlying ecological issues. Healthy coral fragments or seedlings were selected for cultivation and then transplanted into damaged areas, resulting in a significant recovery of coral populations and creating more suitable habitat for marine organisms.

Fig. 1 Coral Reef Restoration

04

Policy Suggestions for Coordinated Governance of Energy, Climate and Biodiversity

A sound mechanism for the coordinated governance of energy, climate and biodiversity that is inclusive and beneficial to all is necessary if we are to speed up the energy transition, address climate change, protect biodiversity, and achieve the goals of the Paris Agreement and the GBF. This chapter puts forward 14 policy recommendations for the coordinated governance of energy, climate and biodiversity across five dimensions: policy guarantees, financial support, technological innovation, international cooperation, and joint actions, providing actionable references for decision-making and intellectual support for the UN, governments, international organizations, enterprises and institutions, and the public to promote energy transition and better climate and ecological governance.



Theoretical Framework for Coordinated Governance of Energy Transition, Climate Change and Biodiversity

4.1

Strengthening Policy Support

The coordinated governance of energy, climate and biodiversity should be founded upon solid policy guarantees, but the policies and regulations of a single field can hardly address the problem of coordinated governance of energy, climate and biodiversity in their entirety. Consequently, mutual support and synergy are needed from the policies and regulations governing the three. This coordinated governance is still in its infancy, but a sound coordinated global framework is urgently needed to improve national policies and the legal system and ensure the necessary guidance and legal guarantees are in place for the work that lies ahead.

4.1.1 Establishing a coordinated global framework for governance

The international community has established independent frameworks for each of energy, the climate, and biodiversity and relatively complete policies and regulations for the coordinated governance of energy and the climate, and the Kyoto Protocol and the Paris Agreement have set legally binding goals and actions for promoting energy transition and climate governance. However, a coordinated governance mechanism has yet to be established for energy and biodiversity. People often ignore the impact of energy on biodiversity and fail to see a connection between the two, failing, as a result, to pay adequate attention to their coordinated governance. In addition, the coordinated governance of the climate and biodiversity as it stands now is far from ideal. For example, the mechanisms of implementation found in the UNFCCC and the CBD are fragmentated, and the channels for exchanging information and sharing data between the two conventions present problems of their own. The GBF has not formulated legally binding goals and actions for leveraging biodiversity to mitigate climate change. To address the aforementioned problems, we must act urgently on the following tasks.

The issues requiring coordinated governance need to be identified. We must integrate the international platforms that already exist to govern energy, the climate, and biodiversity and hold thematic events on the sidelines of important international conferences like the UN Climate Change Conference, the UN Biodiversity Conference, and the Clean Energy Ministerial where we can identify the issues that most need coordinated governance. For example, we can raise the important topic of energy transition at the UN Biodiversity Conference to draw the attention of governments, enterprises, and institutions, strengthen cooperation and speed up action on coordination.

Coordinated governance objectives need to be synchronized. We should strengthen the top-level design, make use of existing global governance platforms and international mechanisms for cooperation, and encourage all parties to formulate short-term goals and long-term plans for the coordinated governance of energy, climate and biodiversity on the basis of the carbon emission reduction targets in the Paris Agreement and the GBF's goal of achieving 30% conservation of land, sea and inland waters by 2030. At the same time, greater efforts should be made to promote global, regional, and national coordination and implementation of energy, climate and biodiversity governance development goals. For example, Nationally Determined Contributions (NDCs) and biodiversity conservation targets should be considered when formulating national energy transition goals. Alternatively, countries could update their NDCs to better reflect the role of biodiversity in mitigating climate change and choose targets more appropriate for biodiversity conservation.

A coordinated compliance mechanism should be established. We should harness the cooperation mechanism between the IPCC and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (see Column 4-1) to accelerate the establishment of regular communication mechanisms with international energy organizations like the International Energy Agency (IEA), the International Renewable Energy Agency (IRENA), and GEIDCO to strengthen communication and information sharing, avoid conflicts in institutional mechanisms and governance measures, and identify the scientific research, monitoring, evaluation, and capacity building projects most conducive to achieving synergy.

Column4-1 IPCC and IPBES Report on Coordinated Governance of Climate and Biodiversity

The IPCC was established under the UNFCCC to support the global response to climate change, and the IPBES was established under the CBD in the interests of biodiversity conservation. In December 2020, the two institutions teamed up for the first time, convening a session with 50 well-known global biodiversity and climate experts and jointly releasing the *Work Report on the Interactions Between Biodiversity and Climate* in June 2021, which consisted of the following eight elements:

1) The principles governing interaction between biodiversity and climate change;

2) The negative impact of climate change on biodiversity;

3) Ways to reduce the negative impact of climate change on biodiversity;

4) How biodiversity adapts to climate change;

5) The significance of measures in land use, change of land-use, and development of forestry to climate change mitigation and biodiversity conservation;

6) The possible negative impact on biodiversity of actions to address climate change;

7) The impact of the development of clean energy on biodiversity;

8) Mechanisms of evaluation and incentives.

4.1.2 Strengthening national policy and legal guarantees

Under the global coordinated governance framework, countries introduce corresponding laws, regulations, and supporting policies according to their national conditions and work to optimize the coordination of planning in related fields and among government departments, so as to provide the strong policy and legal guarantees required for the coordinated governance of energy, climate and biodiversity.

Legislative guarantees need to be strengthened. Countries are called upon to formulate or revise laws and regulations impacting energy transition, addressing climate change, and conserving biodiversity and to incorporate them into national development plans and policy systems for the purpose of identifying and plugging existing gaps, resolving conflicts, and creating synergy where possible. Environmental assessment laws should be updated to include biodiversity. Possible impact on biodiversity should be assessed when preparing and approving plans for energy transition and climate governance, such as in relation to clean energy development or power grid construction, and measures taken to avoid or reduce possible damage to the environment. In addition, countries are encouraged to incorporate carbon emission reduction into the performance appraisal system of local governments, formulate assessment indicators for adapting to climate change, and carry out regular assessments. Finally, biodiversity conservation and ecosystem services should be listed in the assessment system as key indicators to urge local governments to more readily embrace the coordinated governance of climate change and biodiversity conservation.

Better coordination of planning must be encouraged. Some countries have formulated a master plan for the coordinated governance of climate and biodiversity, such as with China's *National Plan for Coordinated Response to Climate Change and Biodiversity Conservation* or the Netherlands' *Adaptation Strategy for Climate-Proofing Biodiversity*. However, no policies or plans coordinating climate and biodiversity with energy transition have been published to date. There is an urgent need for countries across the globe to establish a more systematic approach to planning, a model for analyzing project costs and benefits, and a process adapted to manage the three more synergistically in accordance with their national conditions and with the objective of reducing costs, replacing the independent development model presently informing planning in favor of a national development plan that promotes the synergistic management of energy, climate and biodiversity.

Interdepartmental collaboration must be improved. The governments of many countries have been faced with problems in energy, climate and biodiversity rooted in an excessive number of managing entities, resource dispersion, a decentralization of power, and inadequate interdepartmental collaboration. It is, therefore, of the utmost importance that we establish a mechanism for coordinating among departments and promoting "horizontal collaboration and vertical connection" and for more efficient and collaborative decision-making, operation, and management. When formulating and introducing relevant policies, the correlation between energy, climate and biodiversity should be evident and inconsistent policy orientations and decentralized implementation should be dealt with immediately.

4.2 Strengthening Financial Support

The coordinated governance of energy, climate and biodiversity would benefit from greater financial support. At present, while certain green projects can benefit the environment in significant ways, economic return can be low and result in difficulties with financing. According to the Asian Infrastructure Investment Bank (AIIB), a huge financing gap exists in energy transition, climate governance, and biodiversity conservation. So while giving full play to the role of existing funds, international support should be engaged to accelerate the development of green finance and ensure sufficient resources are available to promote coordinated governance of the fields in question.

4.2.1 Leveraging financial resources

Available financial resources continue to play a central role in the implementation of green projects, and we should not hinder them. On the contrary, we should urge central banks everywhere to get on board with monetary policy instruments in support of sustainable development and green projects such as “PV-based desertification control” and “algae-fixing for fish gathering” that facilitate energy transition, carbon reduction and fixation, and animal and plant protection, and provide low-cost funds for green credit and bonds. We should promote the establishment of special national and local funds with subsidies or rewards for enterprises implementing green projects, finance guarantee funds, and mobilize more social funds with specialized agencies and a multi-party risk sharing mechanism.

Column 4-2 People’s Bank of China Carbon Reduction Support Tool

Desiring to do its part to achieve the carbon peak and carbon neutrality targets, the People’s Bank of China (PBOC) launched the carbon emission reduction facility (CERF), a structural monetary policy instrument that helps financial institutions looking to provide loans for clean energy, energy conservation, environmental protection, carbon emission reduction technology, and other key areas.

The PBOC’s “system for direct funds” allows financial institutions to apply for financial support after providing loans to eligible enterprises. For qualified loans, the PBOC provides commercial lenders with funds worth 60% of the principal at the rate of 1.75%, with a term of one year and two extensions. To ensure policies are well-targeted and effective, the PBOC requires financial institutions to disclose information about carbon emission reduction lending, which is verified by third-party professional institutions and subject to public scrutiny.

The CERF focuses on three areas: clean energy, energy conservation and environmental protection, and carbon emission reduction technology. Clean energy includes wind power, solar and biomass energy, pumped storage, hydrogen and geothermal energy, ocean energy, heat pumps, high-efficiency energy storage (including electrochemical energy storage), smart grids, large-scale wind power and PV generation-grid-load-storage integration projects, county-wide application of household distributed PV systems, trans-regional clean electricity transmission systems, emergency and standby power for peak-shaving, among others. Energy conservation and environmental protection focuses on enhancing energy efficiency in industry, new power system transformation, etc. Finally, carbon emission reduction technology focuses primarily on carbon capture, storage, and utilization.

In 2023, the PBOC announced that it would be continuing to expand structural monetary policy instruments, including the CERF, in support of the development of green finance. As of the end of December 2022, the PBOC had used these policy instruments to support financial institutions in the issue green eligible loans to the tune of RMB 516.2 billion, contributing to the development of green finance and the green and low-carbon transformation of the economy.

Column4-3 "Algae-Fixing for Fish" Green Project

"Algae-fixing for fish" is a green initiative to restore the environment and develop ecological aquaculture by cultivating ocean seaweed. It is effective for restoring marine ecology, increasing marine diversity, and benefiting local fishermen. The initiative has been widely applied in Marine Ecological Civilization Comprehensive Experimental Area in Changdao, Shandong Province, with an equal emphasis on ecological, social, and economic benefits, and contributed significantly to the development of a modern marine ranching fishery system. It has passed through three stages: the construction of seagrass and seaweed fields by placing reefs, sowing seeds, and transplanting plants; the construction of sea fishing bases by transforming the sea environment and introducing fish; and the development of an ecological fishery industry led by marine ranching.

A seagrass bed, also known as an underwater grassland, is one of three typical offshore marine ecosystems (mangroves and coral reef are the other). It is an underwater paradise and a real maternity ward for marine organisms. It is also an important carbon sink of extremely high ecological value. Experimental Area staff have cultivated 1.6 hectares of seaweed, sown 1.08 million seeds, and transplanted 216,000 plants. This has gradually restored the resources in nearby offshore areas, with crab, octopus, Thais clavigera Kuster, and limpets returning to the area. The East Asian finless porpoise population has grown to more than 2,000, attracting tourists to the area. There are a number of marine ranches in the sea equipped with intelligent automatic feeding machines, automatic underwater net-washing robots, and aquaculture big data management systems. More than 1.3 million cubic meters of artificial reef have been placed in the marine ranches together with more than 30 million fry of various types as part of the "marine engineering + ranching" approach. The construction of marine ranches is also taking tourism into the sea. The Experimental Area in Changdao has integrated the development of marine ranching and leisure tourism with 14 recreational fishery outfalls, 11 provincial recreational sea fishing grounds, 11 municipal recreational fishery bases, 36 sea fishing boats, and a new "fishery breeding + leisure entertainment" pasture complex.

Fig. 1 Spotted Seals in the "Algae-Fixing for Fish" Marine Ecological Civilization Comprehensive Experimental Area, Changdao, Shandong Province

4.2.2 International financial support

Green finance cooperation platforms now exist, like the Global Environment Facility (GEF), Green Climate Fund (GCF), Adaptation Fund (AF), Global Biodiversity Framework Fund, Global Development and South-South Cooperation Fund, and Silk Road Fund, and international financial institutions like the World Bank, Asian Development Bank, and AIIB have also stepped up to support the development of green finance. It is important that countries capitalize on these platforms and work with international financial institutions to find financial support and reduce the cost of financing green projects. The platforms can also facilitate technical exchanges, capacity building, and other activities to improve the energy transition, climate governance, and biodiversity conservation among other things.

Column4-4 Global Biodiversity Framework Fund

Resolutions like the COP15 *Financial Mechanism* speak of a GEF[1] framework fund for achieving the long-term objectives of the GBF. In August 2023, the Seventh GEF Assembly was held in Vancouver, Canada, with representatives of 185 member states agreeing to establish a Global Biodiversity Framework Fund. During the Assembly, the Government of Canada announced a contribution of CAD 200 million to the Framework Fund, with the United Kingdom contributing GBP 10 million. The Council of the Framework Fund has 32 members, 18 from developing countries and 14 from developed.

The Framework Fund focuses primarily on providing support for the following eight categories:

1) Biodiversity conservation and restoration, land and ocean utilization, and spatial planning;

2) Indigenous management of land, territories, and waters;

3) National plans for incorporating biodiversity conservation into policies, regulations, and plans;

4) National Biodiversity Finance Plans, National Biodiversity Strategies and Action Plans, and financing of various kinds;

5) Improvement to national policies and regulations and the sustainable use and conservation of biodiversity;

6) The impact of the development of agriculture, forestry, fishery and aquaculture, tourism and other industries on biodiversity, and incentives for the sustainable use of land, oceans and resources;

7) Improved management of invasive alien species and effective risk

[1] Established in 1991, GEF is an important financial mechanism of the *Convention on Biological Diversity* and the *Cartagena Protocol on Biosafety to the Convention on Biological Diversity*.

control;

8) Capacity building for the implementation of the *Cartagena Protocol on Biosafety to the Convention on Biological Diversity* and the *Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biological Diversity*.

Three principles for Framework Fund aid:

1) Fund allocations need to take existing financing into account;

2) Fund allocations need to take into account the special needs of the least developed countries and small island countries;

3) Given the uneven distribution of global biodiversity resources, funds should be allocated to reflect the varying potential of different regions to contribute to global biodiversity conservation.

4.2.3 Developing green finance

Green financial innovation is a must. National governments must be encouraged to incorporate green finance into their evaluation systems of financial institutions, financial institutions must be encouraged to pursue green financial innovation, and green financial products and services such as green loans, bonds, funds and insurance need to be expanded to meet the diversified financial needs of various market entities. Support should also be given to the development of financial technology, the R&D, application, and promotion of advanced technologies such as artificial intelligence, big data and blockchain in green finance, the digital and intelligent development of green finance, and the innovation and upgrading of green financial products, services, and business scenarios.

The standards for green financing need to be upgraded. Efforts should be made to encourage national governments to improve the green classification catalogue; green energy transition, carbon emission reduction, and biodiversity conservation activities need to be clearly defined; the scope of support for green finance should also be clarified; sound economic, social and environmental accounting methods and databases need to be established; efforts should be made to eliminate problems arising from missing data or inconsistency in carbon accounting and information disclosure; and financial institutions should be more standardized, authoritative, and transparent. Finally, there is an urgent need to accelerate the research and formulation of green financial standards in product services, credit assessment, and risk management, among others, to ensure the standardized and efficient operation of the green financial market.

There should be a system of mutual recognition of green financial standards. Green financial standards, green classification catalogues, carbon accounting, and information disclosure are not currently coordinated or uniform across countries. In one example of the disconnect that exists in the green classification catalogue, China explicitly supports nuclear power development, while the European Union (EU) disputes whether nuclear power is in fact "green". In the next step, it is essential that global or regional green financial standards achieve mutual recognition, costs of cross-border fund circulation be reduced, and the development and improvement of the international green capital market be advanced.

Column4-5 China's Green Classification Catalogues

Three sets of standards exist at present for defining green activities in China: the PBOC's *Green Bond Endorsed Projects Catalogue*, the National Development and Reform Commission's *Green Industry Guidance Catalogue*, and the China Banking and Insurance Regulatory Commission's *Statistical Standards for Green Credit*. These standards vary in applicability, scope, and detail and should be brought into alignment as soon as possible. For example, unlike the *Green Industry Guidance Catalogue*, the *Green Bond Endorsed Projects Catalogue* has removed project categories related to the clean utilization of fossil fuels; these two standards detail the technical identification standards and parameter requirements for green economic activities, but the *Statistical Standards for Green Credit* provides only a classification list.

China joined the EU's International Platform on Sustainable Finance (IPSF) in 2019 as a founding member. Its primary goal is to mobilize the private sector to participate in green project construction and provide sufficient financial guarantees for member states to promote green transition. The IPSF has improved mutual recognition of green financing standards between China and the EU. They issued the *Common Ground Taxonomy: Climate Change Mitigation* during COP26 in 2021 with a list of 61 green economic activities recognized by both sides in six major fields: energy, manufacturing, construction, transportation, solid waste, and forestry. The two sides added another 19 green economic activities to the document in June 2022. At present, nearly 80% of green economic activities recognized by China and the EU align, though differences persist in energy and agriculture. For example, China supports the manufacturing of nuclear energy equipment and the construction of nuclear power plants, while the EU disputes whether nuclear energy is in fact clean.

4.3

Strengthening Technological Innovation

Technological innovation and integration is a driving force behind the industrial transformation and upgrade. To realize the coordinated governance of energy, climate and biodiversity, a sound innovation mechanism must be established for related fields, with deeper integration of existing technologies and innovation. Countries should be encouraged to strengthen technological cooperation within the framework of the UN to achieve greater innovation and breakthroughs in cutting-edge technologies for subsequent promotion and application.

4.3.1 Improving the innovation mechanism

Greater integration of varying disciplines should be encouraged. We can build on traditional energy and electricity, climate, environment, and others to create a single discipline that integrates systems science, biology, and economics with an innovation mechanism and inter-disciplinary cooperation in research, and green and low-carbon technological innovation, all driven by originality and talent. Collaboration should be encouraged among enterprises, universities, research institutes, and end-users to build a cooperative public service platform that will harness talent, finance, material, and information in a horizontal collaboration mechanism characterized by strategic organizational coordination of knowledge, endogenous growth throughout the industry chain, and the transformation of innovation achievements through major project demonstrations.

4.3.2 Accelerating technological breakthroughs

Technological collaboration in energy, climate, biodiversity, and other fields must be encouraged among international platforms like GEIDCO, IPCC, and IPBES to accelerate collaborative global and regional innovation. Barriers preventing innovative enterprises, universities, and research institutes from combining their various advantages to the greatest effect must be removed so that research in basic theory and disruptive technology can benefit the coordinated governance of energy, climate and biodiversity and eventually establish a green and low-carbon technological innovation system for energy transition and ecological protection that will inevitably result in new disruptive technologies in clean energy power generation and allocation, electricity replacement, carbon capture and storage, extreme weather disaster prediction and adaptation, and biodiversity monitoring and conservation.

Column4-6 Building China's Biodiversity Monitoring and Observation Networks

China has established monitoring and observation networks for various ecosystems and species that play an important role in theoretical research on biodiversity, technology demonstration and promotion, and species and habitat protection and provide diversified information services and support for scientific research, education, the popularization of science, and production, among others. These networks include the Chinese Ecosystem Research Network (CERN) and the China Biodiversity Observation Network (China BON).

CERN was first established in 1988 and has built 44 stations in different ecological zones and across a diversity of ecosystems: forest, grassland, desert, wetland, farmland, urban, and others. CERN has also established an ecological observation system consisting of 48 integrated observation sites, 120 auxiliary sites, 1,100 fixed observation points, and 15,000 fixed survey plots for meteorological, hydrological, soil, and biological sampling, among others.

China BON was founded in 2011 and has established 380 bird observation areas, 159 amphibian, 70 mammal, and 140 butterfly, for a total of 11,887 sample lines and points. With more than 700,000 pieces of observational data collected annually, China BON knows firsthand what changes are taking place in species diversity across key regions.

4.3.3 Strengthening standard coordination

Enterprises and research institutes should be encouraged to cross national boundaries and use GEIDCO, the International Organization for Standardization (ISO), the International Electrotechnical Commission (IEC), and similar institutions to create an international standard for addressing climate change and protecting biodiversity with the GEI and regular release and revision mechanisms for the relevant technical standards. International cooperation among enterprises, universities, and organizations should begin immediately on technical standards and procedures for R&D, construction, equipment manufacturing, operation and maintenance, and market transactions promotion the coordinated governance of climate and biodiversity through energy transition.

4.4 Strengthening International Cooperation

Our chances of overcoming global challenges in energy, climate and biodiversity conservation increase greatly when we work together. These challenges transcend any single country or region and necessitate the collaborative involvement of the

UN, sovereign states, international organizations, enterprises, institutions, social organizations, and the public. International cooperation can be accelerated by establishing specialized agencies to coordinate international assistance and technology transfers that are ultimately in the public interest.

4.4.1 Establishing specialized agencies

Countries on every continent should be encouraged to take part in the establishment of international organizations for regional energy transition and ecological protection, mitigating climate change, and conserving biodiversity. By incorporating energy transition into policy and regulatory activity and carrying out strategic planning and environmental impact assessments regionally and nationally, we can ensure that all capital flows align with our stated values. At the same time, regional organizations should build platforms for dialogue among the nations, coordinate planning research, project matchmaking, fund raising, and other work, and promote resource sharing, the concept of complementarity, and mutually beneficial cooperation.

4.4.2 Increasing international assistance

We must coordinate assistance better. Developed countries should be encouraged to help underdeveloped countries and small island states coordinate their governance of energy, climate and biodiversity, especially with the development of clean technologies and capacity building. Underdeveloped countries should establish departments for enlisting international assistance for this endeavor, integrate every manner of resource, and improve the effectiveness of aid projects seeking to address climate change and protect biodiversity through energy transition.

Special plans are needed for poverty alleviation. The power infrastructure in many underdeveloped countries is inadequate, making it a challenge to balance national development with environmental protection alone. Action in favor of energy transition can be combined with poverty alleviation to promote universal access to power, reduce emissions, and improve the ecological situation. Mechanisms of international cooperation should be established by the state to encourage the private sector in resource-rich but economically underdeveloped areas to develop clean energy, transform resources into economic benefit, redirect energy development when needed, and promote ecological protection and the reduction of carbon emissions in the region.

A special assistance fund should be established. Governments everywhere should turn to existing policy-based financial institutions to raise funds through taxation, and by other means, to make up for the shortcomings of big demands on capital, a long construction cycle, and the slow return on investment that can accompany ecological engineering and green development projects. Developed countries should be encouraged to provide medium and long-term interest-free or low-interest loans to underdeveloped countries to promote clean energy development and power grid interconnection projects in the interests of greater reductions to carbon emissions and the conservation of biodiversity.

4.4.3 Facilitating technology transfers

Unbalanced technological development is becoming increasingly problematic. Developed countries should respond by sharing their new technologies and establishing regional centers for technological cooperation that can be used to transfer the technologies to underdeveloped countries through assistance programs, business consulting, and financing to support targeted local research and development, equipment manufacturing, construction, and commercial operations to bring the benefits of green and low-carbon development to more people. Underdeveloped countries, in turn, need to ready their ability to receive transfers of cutting-edge technology from developed countries and participate in global innovation in practice.

4.5 Strengthening Joint Actions

In light of the seriousness of energy transition, escalating climate change, and ongoing biodiversity loss, it is imperative that we take immediate action to implement demonstration projects, create new business models, build regional and global integrated electricity-carbon trading markets, and accelerate the coordinated governance of energy, climate and biodiversity.

4.5.1 Project demonstration

National and regional demonstration projects for the coordinated governance of energy, climate and biodiversity should increase and institutions in energy, environmental protection, and ecology should explore new opportunities together, conduct joint feasibility studies, build project libraries, and raise funds. The central role of the state and international organizations in demonstration projects, the allocation of resources, investment in innovation, publicity, and mobilization provides the support needed for every stage, from project approval, design, and implementation to the evaluation of results. This role should be strengthened and countries should be encouraged to make more projects and improve the quality and efficiency of these projects.

4.5.2 Creating new business models

More should be made of the "ecological environment + industry" model. Profit challenged environmental projects in the interests of public welfare need to be integrated with profitable industry, such as, for example, water conservation with aquaculture and PV desertification control with green animal husbandry, to internalize the economic value generated by environmental management, economize, and attract investment. The "ecological environment + industry" model may require additional financial support in the early stages through industrial development funds and fiscal subsidies, but with the gradual increase of economic benefits in the later stages, more financial institutions and enterprises will participate in the large-scale industrial development.

New payment models must be developed for ecosystem services. A market-oriented compensation mechanism is needed for ecosystem protection, standardized evaluation of the value of ecological products, trading, the realization of end products, and ensuring that environmental protectors benefit, users pay, and those who cause damage are held accountable. For example, afforestation by enterprises will generate forward earnings for carbon sinks, forest land development rights, and other ecological products. Financial institutions can use this as a basis for credit to provide loans to these enterprises. Or in another example, China, the United States, and others have proposed wetland mitigation banks as a part of which wetland protectors generate credit by restoring or protecting existing wetlands or building new ones, and developers can purchase the credits from the protectors through government-regulated trading platforms for appropriate compensation.

Column4-7 Wetland Mitigation Banks

A wetland mitigation bank is not a financial institution in the traditional sense but an ecological compensation mechanism that allows wetland developers to purchase credits through a platform before project implementation to offset any losses to the wetland ecosystem. The operational mechanism of a wetland mitigation bank consists of the following aspects:

1. Wetland credit generation: Wetland protectors generate wetland credits by restoring or protecting existing wetlands or building new ones.

2. Market-oriented transaction: Wetland credits are sold to developers who cause damage to wetlands, allowing the organizers to benefit.

3. Government regulation: The establishment of the wetland mitigation bank, monitoring and evaluation of wetland compensation, and wetland management by developers are all subject to government review and regulation.

4. Financial guarantees: A wetland mitigation bank ensures compensation is in place through deposits, insurance premiums, and mortgages to achieve the policy goal of “zero net loss” for wetlands.

4.5.3 Building an electricity-carbon market

The platform and data advantages of the GEI play directly into a joint trading platform for electricity and carbon emission rights, market-oriented allocation of global energy resources, the development of clean electricity, reduced carbon emissions, and ecological protection. The top-level design of power and carbon trading rules should be preserved and spot and derivative trading in power and carbon markets integrated collaboratively to attract diversified market entities and increase market benefits and value contributions. The market management system should be improved for standardized trading with operational rules for the integrated electricity-carbon trading market as global green funds and traders are encouraged to engage in clean development. Finally, the mechanism for market regulation should unify information disclosure and operational oversight for electricity and carbon trading markets.

Column4-8 Research on Framework of Integrated Electricity-Carbon Trading Market

Innovative GEIDCO research on the electricity-carbon market has been released in the *Research Report on the Global Electricity-Carbon Market*. The research presents the **electricity-carbon market** as a mechanism for the parties engaged in electricity production, allocation, and consumption to trade electricity-carbon products and related services through bidding. It reflects a deeper integration of the electricity and carbon markets through management institutions, trading products, operational modes, etc. Greater openness, competitiveness, and synergy ensure replicable, verifiable statistical solutions for energy transition and reduced carbon emissions. **Electricity-carbon products** incorporate carbon costs and electricity. A system is employed to measure and track carbon, associate an enterprise’s power generation behavior with carbon prices and their reduction of emissions with clean electricity consumption, and create new trading products around electricity.

In the production chain, when power generators sell electricity-carbon products, they trade electricity and carbon emissions to increase the competitiveness of clean energy through the dynamic adjustment of carbon prices and to promote its replacement with clean energy.

In terms of allocation, power grid enterprises promote interconnection and advance large-scale development, wide-range allocation, and the use of high-quality and low-cost clean energy.

In terms of consumption, energy consumers in industry, construction, transportation, and other fields are integrated with the power sector. Energy consumers bear the cost of carbon emissions when purchasing energy, creating a price advantage for clean electricity over fossil fuels. At the same time, these enterprises continuously reduce carbon emissions during production through low-carbon R&D, innovation, upgrading, transformation and other activities, obtain energy subsidies, and encourage electrification.

As regards financing, financial institutions develop diversified electricity-carbon financial products, provide trading on derivatives, electricity-carbon financial futures, options, and forward contracts, create hedging tools for the parties to the transactions, and provide necessary asset management and consulting services.

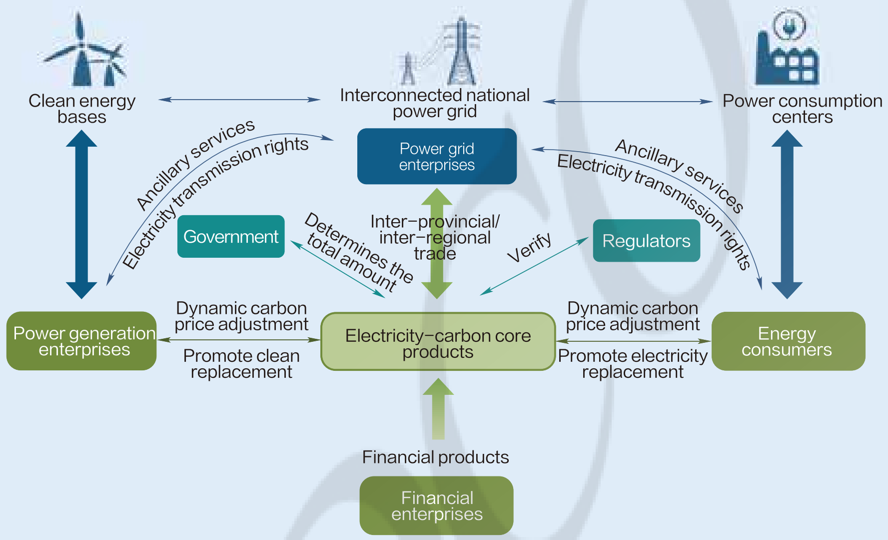


Fig. 1 Schematic Diagram of the Electricity-carbon Market