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Paving the way for low-carbon development globally and along the Belt and Road

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Disclaimer

Foreword

Today, the world is undergoing profound changes unseen in a century. One of the key issues behind is global warming. Constrained by multiple factors such as natural resources, technological development and governance capacities, the carbon-intensive production and consumption patterns of mankind have resulted in a continuous increase in global greenhouse gas emissions. According to the National Aeronautics and Space Administration (NASA), 19 of the 20 hottest years in the past 100 years have occurred after 2001. As of March 29, 2020, the global sea level had risen by 94.2 millimetres compared with the average in 1993. What will the world look like in the future if this trend continues? With COVID-19 spreading around the world and causing such great suffering to humankind, if global warming is not curbed, we or the next generation will face thousands of epidemics just like the current one. Where is humanity headed? The only way out for us is to join forces and deal with this global challenge together! We and the next generation should promote the idea of building a community with a shared future for mankind.

As we all know, it is impossible to combat climate change overnight. To address this issue, it will require effective communication and coordination across the globe, and the establishment of feasible, practical rules and mechanisms for countries to implement or follow. Each country must, based on their own national conditions, truly incorporate their response to climate change into their development agendas. Low-carbon development has great potential in the participating countries and regions along the Belt and Road, yet there are also many difficulties and challenges still to face. There is no one-size-fits-all low-carbon pathway for all countries due to the significant differences in each country’s economic structure, natural resource endowment, technological abilities, and stage of development. Policy makers should, therefore, set priorities in accordance with their respective national conditions and sustainable development goals. In some developing countries where the access to electricity is less than the world average (89.6%), such as Myanmar (66.3%), Pakistan (71.1%), Ethiopia (45%), Madagascar (25.9%), Nigeria (56.5%), Uganda (42.7%) and Zambia (39.8%), improving people’s access to electricity might be more urgent than advancing clean electricity. In other words, the principle of “Common but Differentiated Responsibilities and Respective Capabilities” and fairness emphasized in the Paris Agreement should be fully respected.

Despite these challenges, we should continue to advocate green development concept and jointly build Green Silk Road. In fact, as early as 2015, China issued the *Vision and Actions on Jointly Building Silk Road Economic Belt and 21st-Century Maritime Silk Road*, stressing that efforts should be made to “promote green and low-carbon infrastructure construction and operation management, taking into full account the impact of climate change on the construction,” and to “promote ecological progress in conducting investment and trade, increase cooperation in conserving eco-environment, protecting biodiversity, and tackling climate change, and join hands to make the Silk Road an environment-friendly one”. At the Second Belt and Road Forum for International Cooperation in April 2019, President Xi Jinping stressed again that “We need to pursue green development. We may launch green infrastructure projects, make green investment and provide green financing to protect the Earth which we all call home.” Under these initiatives, in recent years countries and regions along the Belt and Road have made huge progress in areas such as green resource development, sewage disposal and green infrastructure. By the end of 2019, there have been 102 clean and renewable energy projects under the BRI, with a total value of US$104.95 billion.

China is also making huge efforts to advance low-carbon development. During the 13th Five-Year Plan period (2016-2020), China has made significant progress in transitioning towards a clean, low-carbon energy consumption structure. China is the world leader on various indicators, including installed capacity of hydropower, wind power, solar PV and under-construction nuclear power. By 2018, China’s carbon intensity per unit of GDP had fallen by 45.8% compared to 2005, thus having achieved two years ahead of schedule the target promised to the international community before the 15th Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) in 2009. By the end of 2020, China’s installed capacity of clean power generation reached 1.083 billion kilowatts. This exceeded the installed capacity of coal power for the first time, representing 49.2% or nearly half of the country’s total installed capacity, and the proportion of coal in China’s total energy consumption reduced to 56.8%. China is witnessing accelerated transition a clean, low-carbon energy consumption structure.

In September 2020, President Xi Jinping pledged to implement more vigorous policies and measures to peak China’s carbon emissions before 2030 and achieve carbon neutrality by 2060 at the United Nations General Assembly. This ambition is reflected in the recently adopted the *Outline of the 14th Five-Year Plan (2021-2025) for National Economic and Social Development* *and the Long-Range Objectives through the Year 2035*. According to the *Outline*, in the 14th Five-Year Plan period, China will expedite the transition of China's growth model to one of green development, and promote both high-quality economic growth and high-standard environmental protection. China will strive to increase the share of non-fossil energy in total energy consumption to around 20%. Energy consumption and carbon dioxide emissions per unit of GDP will be reduced by 13.5% and 18%, respectively.

As a new type think tank with Chinese characteristics dedicated to promoting international economic exchanges and cooperation, the China Center for International Economic Exchanges (CCIEE) has worked with the United Nations Development Programme (UNDP) to jointly develop a series of research projects on global governance in recent years. This fourth Global Governance Report focuses on the important theme of "paving the way for low-carbon development globally and along the Belt and Road", representing common visions and consensus from both sides. We hope that through our joint efforts, the low-carbon development capacities of countries and regions along the Belt and Road will be strengthened. We also hope that under the framework of the Paris Agreement and through the vigorous cooperation of the international community, the global challenge of climate change will be effectively addressed.

Zhang Xiaoqiang

Executive Vice Chairman and Director of Executive Board of CCIEE

Foreword

In 2020, COVID-19 laid bare the fragility of our world. It brought home the existential urgency of fixing our broken relationship with nature to avert catastrophic climate change. Indeed, the planet is currently on pace to reach the crucial threshold of 1.5 degrees Celsius above pre-industrial levels as early as 2030. The consequences of this are devastating and are already shaping our reality: extreme weather, biodiversity loss and rising sea-levels. If business-as-usual continues, by the end of this century, we may cause 3-5 degrees of warming. That would leave Shanghai's Bund and Pudong area underwater.

To prevent this from happening, decarbonizing our economies and taking immediate, globally coordinated action to move towards green trajectories is absolutely critical. China's announcement that it would peak carbon emissions before 2030 and reach net zero carbon emissions by 2060 is a vital commitment that can help set the stage for a transition towards decarbonization both domestically and overseas.

This report was developed jointly by the China Center for International Economic Exchanges (CCIEE) and the United Nations Development Programme (UNDP). The report focuses on providing three key pathways to facilitate low-carbon development within China and globally, including boosting innovation, development, and transfer of clean energy, channelling investment and financing flows towards low-carbon projects, and strengthening capacity-building.

Given fluctuations in the availability of renewable energy sources and the often wide geographic distances between where it is generated and where it is consumed, the report emphasizes the importance of enhancing energy flexibility (including through grid-scale battery storage) and network integration. These are key to facilitate higher shares of variable renewable energy sources in the energy mix. To bring out and strengthen the cost advantage of renewable energy over fossil fuels, the report recommends to evaluate investment and financing proposals using harmonized carbon indicators, and enhance policy incentives to support low-carbon energy projects.

Exploring the complex issues involved with decarbonization in Belt and Road partner countries, the report provides policy recommendations on how governments can accelerate the green economy transition. It encourages, in particular, stronger collaboration in harmonizing standards and developing innovative finance instruments with a view to enabling the increased deployment of renewables.

UNDP has been working with the Government of China on energy efficiency projects for more than 20 years. I would like to express my profound gratitude to CCIEE for their support in collaborating with UNDP and for contributing invaluable insights to this report. We hope that the findings can help promote low-carbon development in China and around the world. UNDP stands ready to support the transformation towards a carbon-neutral future.

Going forward, we must heed the warnings of our stressed planet. Returning to our pre-pandemic "old normal" is not an option. By taking swift and decisive action now to curb emissions and to support countries in developing responsibly, we can safeguard our planet and ensure a sustainable world for future generations.

Beate Trankmann

Resident Representative of UNDP China

List of Acronyms

ADB	Asian Development Bank
AFD	Agence Française de Développement
AfDB	African Development Bank
AIIB	Asian Infrastructure Investment Bank
ASEAN	Association of Southeast Asian Nations
BECCS	Bio-energy with Carbon Capture and Storage
BICE	Banco de Inversión y Comercio Exterior
BREP	Belt and Road Energy Partnership
BRI	Belt and Road Initiative
BNB	Banco do Nordeste, Brazil
BNDES	Brazilian Development Bank
BRT	Bus Rapid Transit
BVF	Baiterek Venture Fund
CAF	Corporación Andina de Fomento
CBA	China Banking Association
CBDR-RC	Common but Differentiated Responsibilities and Respective Capabilities
CBHB	China Bohai Bank
CBI	Climate Bond Initiative
CBRC	China Banking Regulatory Commission
CBS	Climate Bond Standards
CCB	China Construction Bank
CCHP	Combined Cooling, Heating and Power
CCICED	China Council for International Cooperation on Environment and Development
CCIEE	China Center for International Economic Exchanges
CCS	Carbon Capture and Storage
CDB	China Development Bank
China Eximbank	Export-Import Bank of China
CHP	Combined Heat and Power
CIB	China Industrial Bank
COP	Conference of the Parties
COP 15	15th Conference of the Parties
COVID-19	Coronavirus Disease 2019
CPC	Communist Party of China
CPP	Critical Peak Pricing

CSP	Concentrated Solar Power
CSRC	China Securities Regulatory Commission
CTF	Clean Technology Fund
CTGIC	China Three Gorges International Corporation
DBSA	Development Bank of South Africa
DER	Distributed Energy Resources
DG	Distributed Generation
DR	Demand Response
DSM	Demand-side Management
EBRD	European Bank for Reconstruction and Development
EC	European Commission
EECMP	Energy Efficiency and Conservation Master Plan
EIB	European Investment Bank
ESG	Environmental, Social and Governance
ETS	Emissions Trading System
EU	European Union
EUR	Euro
FACTS	Flexible AC Transmission System
FDI	Foreign Direct Investment
FNE	Northeast Financing Constitutional Fund, Brazil
FT	Financial Times
GBP	Green Bond Principles
GDP	Gross Domestic Product
GEIDCO	Global Energy Interconnection Development and Cooperation Organization
GHG	Greenhouse Gas
GIF	Global Infrastructure Facility
$GtCO_2$	Gigatonnes of Carbon Dioxide
Gtoe	Gigatonnes Oil Equivalent
GW	Gigawatt
HDI	Human Development Index
HELE	High Efficiency Low Emissions
IAS	International Accounting Standards
IASB	International Accounting Standards Board
ICBC	Industrial and Commercial Bank of China
ICMA	International Capital Market Association
IDB	Inter-American Development Bank
IDFC	International Development Finance Club
IEA	International Energy Agency
IFC	International Finance Corporation

IFIs	International Financial Institutions
IFRIC	International Financial Reporting Interpretations Committee
IFRS	International Financial Reporting Standards
ILO	International Labour Organization
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
JBIC	Japan Bank for International Cooperation
KDB	Korea Development Bank
KfW	Kreditanstalt für Wiederaufbau Development Bank of Germany
kWh	Kilowatt-hour
Lao PDR	Lao People's Democratic Republic
LCOE	Levelized Cost of Electricity
LDCs	Least-developed Countries
MDB	Multilateral Development Bank
MECS	Multi-energy Complementary System
MIIT	Ministry of Industry and Information Technology
MNR	Ministry of Natural Resources
MOF	Ministry of Finance
MOFA	Ministry of Foreign Affairs
MOFCOM	Ministry of Commerce
MOHURD	Ministry of Housing and Urban-Rural Development
MOST	Ministry of Science and Technology
MoU	Memorandum of Understanding
Mtoe	Megatonnes Oil Equivalent
MW	Megawatt
NAMA	Nationally Appropriate Mitigation Action
NDB	Nationall Development Bank
NDCs	Nationally Determined Contributions
NDRC	National Development and Reform Commission
NEA	National Energy Administration
NEFCO	Nordic Environment Finance Corporation
NGFS	Network for Greening the Financial System
ODA	Official Development Assistance
ODF	Official Development Finance
OECD	Organisation for Economic Co-operation and Development
PBOC	People's Bank of China
PGE	Power Generation Expansion

PPP	Public-Private Partnership
PRA	Project Readiness Assessment
RET	Renewable Energy Technologies
RRA	Renewables Readiness Assessment
SAC	Standardization Administration of China
SDGs	Sustainable Development Goals
SMEs	Small and Medium-sized Enterprises
Solar PV	Solar Photovoltaic
SGCC	State Grid Corporation of China
SPIC	Shanghai Electric Power Co., Ltd
STEM	Science, Technology, Engineering and Mathematics
TES	Total Energy Supply
TPES	Total Primary Energy Supply
Tsinghua PBCSF	PBC (People's Bank of China) School of Finance, Tsinghua
UAE	United Arab Emirates
UGG	United Green Group
UHV	Ultra-High Voltage
UHV-DC	Ultra-High Voltage Direct Current
UK	United Kingdom
UN	United Nations
UNDESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNEPFI	UNEP Finance Initiative
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UNFCCC	United Nations Framework Convention on Climate Change
UNPRI	The United Nations-supported Principles for Responsible Investment
US	United States
VRE	Variable Renewable Energy
WB	World Bank
WWF	World Wildlife Fund

Executive Summary

Coverage of the Report and Research Context

This series of Global Governance Reports is produced as part of the Global Governance Initiative, launched in 2012 by the United Nations Development Programme (UNDP) in partnership with the China Center for International Economic Exchanges (CCIEE). The series of research aim to provide innovative and foresight-based global public goods to tackle climate change and other public concerns and positively contribute to China's efforts towards the advancement of sustainable development globally.

This fourth Global Governance Report ("the report"), jointly developed by UNDP and CCIEE, follows in the footsteps of previous Global Governance Reports with a focus on paving the way for low-carbon development globally and along the Belt and Road.

This report was written in the context of the novel coronavirus of 2019 (COVID-19) pandemic, whose impact extends beyond health. The pandemic has affected countries' economic growth and energy security prospects and markedly set back progress towards the achievement of the Sustainable Development Goals (SDGs), most notably those on poverty, health, education and inequalities. It has also impacted the implementation of energy and infrastructure projects on the ground. The way countries shape their policy response packages to address the sustainability issues raised by the COVID-19 crisis will determine their development prospects for the coming decades. Therefore, paving the way towards low-carbon development assumes particular importance in the post-COVID world. This, together with the increasing importance of digital interactions and technology in general, has made the report even more relevant.

The relentless rise in global energy demand driven by economic growth, urbanization and increased access to electricity has made the call for clean energy deployment even more urgent. An over-reliance on hydrocarbon production and consumption has led to a persistent increase in greenhouse gas (GHG) emissions, which has further accelerated global warming, the effects of which are increasingly evident. If we pick the 20 warmest years of the last 100 years, we find that 19 of those have all occurred since 2001. By March 29, 2020, global sea levels have risen an extra

94.2 mm above 1993 averages.[1] Droughts, heat waves, and various threats to biodiversity continue to heavily impact ecosystems, and their increased incidence is intimately linked to human activity. The overwhelming evidence calls for new low-carbon development, investment and governance models that can engender efficient clean energy solutions towards low-carbon, climate-resilient, and green development pathways.

Both globally and along the Belt and Road, most countries still heavily depend on fossil fuels – which remain a vast and widely distributed energy source – for energy generation. While natural resource endowments differ, coal is widely available in many regions that have huge existing or potential energy demand but few alternative energy choices. With an average of more than two coal-burning power stations being constructed in the developing world each week, reducing GHG emissions and local pollution from fossil fuel combustion and processing remains one of the world's most significant challenges in the foreseeable future.

Against this backdrop, this fourth Global Governance Report provides in-depth and impartial analysis to enhance consensus on paving the way for low-carbon development along the Belt and Road and facilitating SDG attainment globally. Exploring the importance of low-carbon development to three pillars – social, economic and environmental – on balancing sustainable development, the report focuses on offering three key pathways, including boosting the innovation, development and transfer of clean energy technologies, channelling investment and financing flows towards low-carbon projects, and advancing low-carbon capacity-building. The report highlights that with the right set of policies and incentives (including through relative prices), low-carbon development along the Belt and Road can be attained in a cost-effective and impactful way, enhancing sustainability in all participating countries and making a critical positive contribution to global environment.

Structure of the Report and Research Methodology

The report is divided into three main parts:

- **A review** of the synergies and trade-offs when targeting balanced and equal development

1 National Aeronautics and Space Administration (n.d.). Global climate change: vital signs of the planet. Retrieved from https://climate.nasa.gov/vital-signs/sea-level/.

among social, environmental and economic dimensions, of the potential of the BRI to be a crucial pathway for low-carbon development, and of the potential gains arising from China's energy transition.

❖ **Three key pathways** to facilitate low-carbon development along the Belt and Road: boosting clean energy development, channelling sustainable finance and investment and strengthening capacity building. The discussion of each pathway includes a mapping of the context and trends, an in-depth analysis of opportunities and challenges, followed by a set of strategic measures and selected best practices with a focus on developing BRI partner countries.

❖ **A set of concrete, interlocking recommendations tailored for four key groups of stakeholders** engaged in BRI – policymakers, financial institutions, public and private investors, and international organizations.

The methodology of this report is based on an in-depth, world-wide mapping of advanced renewable technology options and approaches to curtailing emissions from fossil fuels; the 10 dimensions (encompassing 84 indicators) of the Environmental, Social and Governance (ESG) framework used by Multilateral Development Banks (MDBs) and National Development Banks (NDBs); and the core ESG principles and initiatives from the UNFCC, the Intergovernmental Panel on Climate Change (IPCC), the Conference of the Parties (COP) and the G20. The methodology uses an evidence-based approach in data collection and the analytical process, provides specific country-based studies, and adopts a pragmatic, forward-looking lens in the analysis (Box 1).

Box 1 Research methodology

The report involves the following aspects:

❖ **A systematic mapping of clean energy technologies, sustainable investment standards and benchmarks** in global context of low-carbon development. Chapter 3, which focuses on the power sector, contains a thorough analysis and mapping of 10 low-carbon energy sources with regards to their lifecycle greenhouse gas emissions, their current and future costs, the externalities they impose, and their development potential in the context of the BRI, as well as two advanced technologies, CCS and HELE. Chapter 4 maps out the standards, benchmarks, indicators of sustainable finance from global and regional organizations, national governments of developed countries and emerging economies, and other public and private financial institutions.

- **14 key indicators for 138 BRI partner countries** to illustrate their disparity and diversity in economic, governance and electricity development. These indicators include gross domestic product (GDP) per capita, employment to population ratio, ease of doing business, political stability, rule of law, Human Development Index, carbon dioxide (CO_2) emissions per capita, access to electricity, energy self-sufficiency, energy use per capita, electricity consumption per capita, fossil-fuel energy consumption, renewable energy output, and practical potential of *Photovoltaic* (PV) output. Data are retrieved from credible sources including the World Bank, the United Nations Department of Social and Economic Affairs (UNDESA) and UNDP.
- **Field visits, consultation and roundtable meetings with experts** to solicit comments from key stakeholders and experts. Face-to-face discussions in Huzhou, Zhejiang Province, with local policymakers, financial institutions and enterprises were conducted to explore key strength and experience in Huzhou's green finance reform.
- **Concrete measures with strategic thinking** in clean energy development, sustainable finance and capacity building areas to boost low-carbon development. Chapter 3 puts forward six concrete measures that encompass power system planning, demand-side management, thermal power flexibility enhancement, energy transition, and distributed energy development. Chapter 4 offers five innovative measures together with benchmarks and key assessment indicators to enhance sustainable finance, covering the entire investment process from the pre-investment stage to post-investment monitoring and reporting. Adopting an integrated approach to capacity-building and knowledge-sharing, Chapter 5 provides pragmatic, highly relevant measures of capacity-building at individual, institutional and systematic levels.
- **15 selected best practices and case studies** which are leading the way forward towards low-carbon development. They were chosen to encompass examples and technologies at all levels of development and a broad diversity of situations. Chapter 3 provides an insight of the energy transition in countries that have respectively low, medium, high and very high levels

of development. Chapter 4 identifies the latest best practices in sustainable investment that could set models for governments and market players, notably the EU's emission trading system and China's green finance markets. Chapter 5 selects best practices in capacity development, looking in particular at how they influence individual, institutional and systemic capacity.

❖ **Innovative and foresight-based recommendations** tailored for four main categories of BRI stakeholders to promote low-carbon development. These recommendations are built upon the consideration of existing best practices that have delivered large-scale impact or show potential for scale-up, and the consideration of varying development levels and the impact they may have on attaining SDGs.

Discussions in this report are based upon and do not challenge the principle of Common but Differentiated Responsibilities and Respective Capabilities (CBDR–RC) within the United Nations Framework Convention on Climate Change (UNFCCC), which acknowledges the different capabilities and differing responsibilities of individual countries in addressing climate change.

Main findings and key messages

Low-carbon development as the critical pathway for achieving the 2030 Agenda

Exploring the global context of progress towards sustainable development, the report emphasizes that further efforts are needed to achieve balanced and equitable development towards the 2030 Agenda. The 17 SDGs, encompassing social, environmental, and economic dimensions, have both strong synergies and policy trade-offs. For instance, poverty reduction is delayed by unemployment and disasters; meanwhile, access to basic infrastructure and affordable electricity helps alleviate poverty and leverage wider socio-economic benefits but has environmental consequences. This makes climate change a pivotal cross-cutting issue, interacting with livelihoods, disasters, infrastructure development, electricity generation, and the associated GHG emissions.

The report emphasizes the urgency to strengthen global commitments and partnerships in economic and political spheres, so as to cope with the intertwined effect of climate change and its challenges to other SDGs, and promote balanced progress towards achieving the 2030 Agenda. The report highlights low-carbon development as a prerequisite for achieving sustainability, and further illustrates low-carbon development as a credible, effective and efficient path to accelerate more climate friendly and environmentally sound development globally.

The BRI's potential and China's advantage in leveraging low-carbon development opportunities

Adopting a set of key indicators to present the diversity of BRI partner countries in terms their economic structure, resource endowments and technological development levels, the report highlights the necessity for individual countries to make contextualized policy priorities and low-carbon development roadmaps based on their national specificities and SDG impacts. Given the BRI's low-carbon vision and its scope of interconnectivity, the report emphasizes the BRI's high potential to advance low-carbon development in partner countries and beyond. This in turn would greatly contribute to both environmental and economic sustainability at a globally significant level.

The report presents key pathways and experience of China's low-carbon energy transition, and its prospect and potential for boosting global low-carbon development. In September 2020, China pledged to implement more vigorous policies and measures to peak China's carbon emissions before 2030 and achieve carbon neutrality by 2060 at the United Nations General Assembly.

The report highlights China's technological breakthroughs in renewable energy sectors, especially in electricity transmission, electricity storage, and manufacturing materials for wind and solar PV that may bring positive impact along the Belt and Road. China's renewables sector (which has contributed about 30% of global renewable power generation in 2019) can contribute to markedly improving the energy mix and low-carbon development globally. The report further offers the best practices of Chinese renewable technology firms and the innovative technological breakthrough of ultra-high-voltage direct current (UHV-DC) transmission to illustrate the potential contribution that China can make in advancing global low-carbon development.

Boosting clean energy development, transfer and deployment to advance low-carbon sustainable development along the Belt and Road

The report highlights the importance of developing and deploying low-carbon technologies at scale, to facilitate smooth transition towards low-carbon economy. The report emphasizes the pivotal role of power sector in low-carbon energy transition. The power sector, as one of the largest sources of GHGs such as CO_2, has huge potential in effectively cutting emissions, with the deployment of innovative power technologies.

The report provides a mapping of major renewable energy types and low-carbon technologies, and compares their cost competitiveness, environmental impact, geographical availability, and the potential of promoting and developing them along the Belt and Road. The report highlights the cost advantage of newly built renewables-based power generation over newly built fossil fuel plants, and the importance of learning curve effects that are set to strengthen this cost advantage in the future. Regarding fossil fuels, the report draws attention to Carbon Capture and Storage (CSS) and High Efficiency Low Emission (HELE) technologies. If made commercially viable at scale, these can help lower coal consumption per kilowatt-hour (kWh) and generate less GHGs than subcritical coal power generation technology.

A set of concrete measures of boosting the innovation, development and transfer of clean energy technologies are offered, to enhance power system flexibility, efficiency, balance and interconnectivity and help shift contemporary economic models towards inclusive, low-carbon and clean development pathways. These foresight-based measures include strategic power planning, integrated development of power generation, transmission, load and storage, transnational power system interconnectivity both physically and digitally, demand-side management, thermal power plants' retrofitting for higher flexibility, as well as effective complementarity of distributed and centralized energy generation. The report further selects best practices of boosting low-carbon energy transition and development in countries at various development stages, including Madagascar, Vietnam, South Africa, Denmark and Uruguay.

<u>Shaping sustainable investment and financing instruments to leverage resources towards low-carbon development</u>

The report argues that putting sustainable investment and financing instruments at the disposal of key stakeholders would be key to scaling up low-carbon projects along the Belt and Road. In order to channel resources towards low-carbon development, the harmonization of technical standards in carbon pricing — especially standards of measuring, reporting and verifying (MRV) emission allowances in accounting — needs to be promoted. Reasonable benchmarks, rules and procedures need to be further developed, to ensure long-term compliance in emissions trading pilots and facilitate carbon market development. The construction of a clear, enforceable system of green finance standards that is unified within a country and recognized internationally should be boosted to facilitate leveraging financial resources towards low-carbon development along the Belt and Road.

Further innovation in financial instruments, especially innovative green credit products, green bond products, green insurance and guarantee services, as well as enhanced policy incentives would generate full lifecycle support for low-carbon projects. Boosting blended financing through strengthened cooperation with multilateral development institutions would help clean energy investors diversify financing channels. As climate risks are not fully reflected in asset evaluations yet, this report calls for consolidating climate risk identification, assessment, monitoring and management in both pre-lending and post-lending stages. Relevant best practices are reviewed, including the European Union Emissions Trading System's internal standard harmonization on emission allowances, policy and legislative incentives from the Huzhou Green Finance Market, stress tests conducted by the Industrial and Commercial Bank of China (ICBC), and blended finance from the International Finance Corporation (IFC).

Strengthening countries' absorptive capacities to enhance low-carbon development

Capacity-building plays a key role in promoting low-carbon development. Opportunities and challenges in capacity-building are mainly related to addressing governance, institutional and policy bottlenecks to create an enabling environment, meeting demands for education and training brought by emerging employment opportunities in the low-carbon transition, as well as improving awareness, data collection and knowledge-sharing to optimize low-carbon transition trajectories. The report argues for strengthening these capacities at all levels — individual, organizational and systemic — to overcome such gaps and leverage potential opportunities. In the current context, this also includes assessing the potential impact of the COVID-19 pandemic and navigating low-carbon transition pathways ahead.

Building on this analysis, the report suggests key areas where expertise, experiences and lessons learned can be shared. These areas include boosting deep understanding of BRI stakeholders in energy transition trajectories and potential impact of the COVID-19 pandemic, environmental and climate risk identification and measurement, international consensus and regulations on carbon emissions management, as well as access standards, investment instruments and regulatory policies of green investment and financing.

In order to advance capacity in these areas, the report emphasizes strengthening absorptive capacity by promoting exchanges among BRI countries via multilateral platforms, and by boosting multi-layer collaboration among government, industrial and education sectors. Given the COVID-19 pandemic context, the report also stresses channelling economic stimulus and recovery plans towards low-carbon development, transferring and adapting skills from the fossil fuel industry to low-carbon sectors, as well as helping women and youth to enjoy equal job opportunities in the low-carbon transition. Best practices include the UNDP-China trilateral project on South-South cooperation on strengthening capacity in Renewable Energy Technology Transfer, IRENA's Renewables Readiness Assessment tool, as well as the capacity development experiences of Denmark and Uruguay.

Conclusions and recommendations for key stakeholders

The report highlights the pivotal roles that policymakers and financial institutions play in determining optimal development policies and pathways forward. Policymakers from China and BRI partner countries are at the forefront of leading and participating in low-carbon development globally and along the Belt and Road. The report recommends their further collaboration to enable higher deployment of renewables, strengthen cross-sector coordination and harmonize relevant policies and standards. Regarding financial institutions, including national development banks, commercial banks as well as multilateral development banks, the report encourages them providing crucial support for channelling investment and financing flows towards low-carbon projects.

The report highlights that enterprises and international organizations are also key stakeholders in boosting low-carbon development along the Belt and Road. State-owned and private enterprises, as the major market players in the investment, construction and operation of BRI projects, are encouraged to strengthen technological innovation, leverage diversified financing resources, and help address the gap of skill shortages in off-grid development and in the renewables job market. The report recommends international organisations further facilitating low-carbon development along the Belt and Road, in particular in helping stakeholders to reach consensus on low-carbon development, organizing dialogue platforms, promoting energy interconnectivity, and conducting joint research to offer pathways and solutions on addressing low-carbon development challenges.

Next Steps

Unleashing the potential of low-carbon pathways and finding effective solutions are crucial to global sustainable development. The BRI holds the promise of advancing low-carbon and sustainable development globally and along the Belt and Road. It is up to countries to choose their own development priorities and solutions. Leveraging joint efforts, China and BRI partner countries can effectively promote global sustainable development, and reap significant benefits for their own development. It is also necessary to take into serious consideration of potential negative impacts and challenges when embracing opportunities for low-carbon development under the BRI.

Engaging key BRI stakeholders through global-level knowledge-sharing and cooperation activities can facilitate their discussion and absorption of relevant experience and expertise. In the global context of COVID-19 pandemic, within its mandate for the SDGs and working with governments and other United Nations agencies, UNDP stands ready to support countries to develop and deliver on their post COVID-19 recovery plans and to help shape a low-carbon world.

Under the cooperation framework between UNDP and CCIEE, further stakeholder discussions and consultations on the report’s main themes, key findings, and workable low-carbon solutions will be organised on the platform provided by the 2021 High-level Policy Forum on Global Governance (GGF). The GGF facilitates policy dialogue among the China and BRI partner countries for the promotion of policy coordination between the public and private sector, and among the regions, provinces, and cities engaging with the Initiative.

Further rounds of consultation with relevant stakeholders will also be held through thematic studies, workshops and seminars, enabling BRI stakeholders from public and private sectors to move the world towards a low-carbon path that delivers climate-resilient, sustainable development to all.

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Part I Global context of low-carbon development, and prospects of the BRI to advance its attainment globally

Part I of the Report emphasizes low-carbon development as a critical pathway to implement the Agenda 2030. It also looks into the prospects of the BRI and China's energy transition experience in advancing global low-carbon development. Chapter 1 reviews the global progress towards achieving the SDGs that encompass social, environmental, and economic dimensions, and investigates the strong synergies and policy trade-offs among these Goals. Low-carbon development is a cross-cutting element interlinked with various SDGs, as livelihoods, disasters, infrastructure development, electricity generation could all impact or be impacted by greenhouse gas emissions. Based on existing consensus and pathways, low-carbon development is a common pathway towards economic sustainability and climate change mitigation.

Chapter 2 highlights the prospects and potential of the BRI on advancing global low-carbon development, as well as the experience of China's low-carbon energy transition. Section 1 analyses the disparity and diversity of economic structure, governance capacity, natural resource endowments, and energy development stages in countries and territories along the Belt and Road, mapping 8 indicators in economy, governance, and electricity development dimensions. Taking into account the BRI's scope of interconnectivity and five cooperation priorities, Section 1 recognizes the prospects of advancing low-carbon energy transition under the BRI. Section 2 demonstrates China's low-carbon development experience, and highlights the commitments, development and global impact of China's low-carbon energy transition, followed by best practices in enhancing corporate social responsibility and making power transmission technology breakthrough.

Chapter 1 Boosting low-carbon development: the key pathway to achieve balanced and equitable development for 2030 Agenda

1.1 Three pillars on balancing sustainable development: social, economic and environmental

The 2030 Agenda for Sustainable Development represents the commitments of member states of the United Nations to time-bound targets for Prosperity, People, Planet, Peace, and Partnership.[2] The 17 Sustainable Development Goals, adopted in 2015 as part of the 2030 Agenda, are based on this approach and set 169 targets to measure progress towards the achievement of sustainable development by 2030.[3] Since 2015, vigorous efforts have been made to facilitate SDG attainment at local, national and global levels. These efforts encompass the objective of creating an inclusive low-carbon society.

Figure 1.1 The Sustainable Development Goals

Source: United Nations[4]

The 17 SDGs, covering different areas and fields, aim to address the global challenges facing policymakers through embracing a more sustainable pathway and balancing three interconnected pillars: economic, environmental and social (see Figure 1.2). As the Brundtland Report stated in 1987, sustainable development places an emphasis on “the human ability to ensure that the current

2 United Nations (2015). Transforming our world: the 2030 Agenda For Sustainable Development. Retrieved from https://sustainabledevelopment.un.org/post2015/transformingourworld.

3 United Nations (2015). About the Sustainable Development Goals. Retrieved from https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf.

4 United Nations (2015). Sustainable Development Goals. Retrieved from https://sustainabledevelopment.un.org/?menu=1300.

development meets the needs of the present without compromising the ability of future generations to meet their own needs". [5] Therefore, forward thinking is indispensable to sustainable development — the perspective of future generations that rely on environmental conditions should be respected, while the well-being of our generations is addressed through fostering economic growth and higher living standards. Considering this, achieving the 2030 Agenda for Sustainable Development requires a development pathway that takes into account the synergies as well as the policy trade-offs between economic prosperity, human well-being, and environmental quality.

Figure 1.2 Three pillars of sustainable development

The concept of the three "mutually reinforcing components" of sustainable development was explicitly addressed as early as a 1997 United Nations Report on the progress in achieving the Rio Declaration. It put forward the picture of "balanced achievement of sustained economic development, improved social equity and environmental sustainability".[6] Economic growth is often regarded as the main driver for facilitating human development, as it creates wealth and motivates technological advancements. The social pillar depicts a human society that is inclusive

5 United Nations World Commission on Environment and Development (1987). Our common future. Retrieved from https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf.
6 United Nations Economic and Social Council (1997). Overall progress achieved since the United Nations Conference on Environment and Development, report of the Secretary-General, addendum: combating poverty. Commission on Sustainable Development (CSD). Fifth session. Retrieved from https://digitallibrary.un.org/record/231333.

and equitable to everyone, regardless of their gender, age, ethnicity, religion, disability and other factors that put them in different social groups. The environmental dimension addresses the protection and sustainability of this diverse planet and its creatures, so as to ensure long-term and inclusive development.

Given the interconnection between these three pillars of sustainability, the SDGs have been adopted as "integrated and indivisible".[7] Their connection is illustrated in the dynamics and mutual responsiveness of the pathways towards attaining individual SDGs. For example, achieving targets under poverty reduction heavily rely on secure income and reduced economic losses caused by disasters, and responsive climate action is key for mitigating the frequency and gravity of climate-related disastrous events. While poverty and adverse climate change are mutually reinforcing, access to employment opportunities, basic infrastructure and clean energy can potentially weaken this vicious circle by mitigating both poverty and climate change. Recent data on the progress towards SDG attainment can demonstrate the synergies and policy trade-offs for achieving the targets, as the analysis in the next section will show.

1.2 Progress of global sustainable development, and synergies between 17 SDGs and low-carbon development

1.2.1 Commitments and progress of achieving SDGs globally

With consensus on the forward-looking plan to end poverty and foster shared prosperity, governments have largely prioritized the integration of the SDGs into their national plans and policies. In a 2020 survey on SDG implementation efforts of some G20 and Organisation for Economic Co-operation and Development (OECD) members and countries with a population larger than 100 million, 25 out of 30 countries have endorsed the SDGs in official statements and 27 have incorporated SDGs into sectoral action plans since January 1, 2018, although only 12 of them refer to SDGs in their national budgets explicitly.[8]

7 United Nations General Assembly (2015). Transforming our world: the 2030 Agenda for Sustainable Development, resolution adopted by the General Assembly. A/70/L. 1. New York: UN General Assembly.
8 Sachs, J. *et al*. (2020). The Sustainable Development Goals and COVID-19. Sustainable Development Report 2020. Cambridge: Cambridge University Press.

It is evident that the implementation of the SDGs has generated some favourable trends. Extreme poverty (SDG 1) has continued to decline to 8.2% of the total global population in 2019,[9] down from 10% in 2015, 16% in 2010, and 36% in 1990.[10] This means a massive drop of the population living in extreme poverty — from 1.9 billion in 1990 to around 630 million in 2019. China alone has lifted 850 million people out of extreme poverty, contributing around 70% of the global gains.[11] While the overall trend is positive, gaps still remain in terms of the geographical parity in such poverty reduction progress. If the pace established before 2020 had continued, 6% of the world population would have been left in extreme poverty by 2030, failing to meet the target of ending poverty.[12] The COVID-19 pandemic will likely complicate progress significantly in the near and possibly even in the long term by pushing 71 to 100 million people into extreme poverty in 2020. [13]

Social protection, together with decent work and access to basic infrastructure, could help with poverty reduction efforts. Around 7.1% of those who have a job still lived in extreme poverty as of 2019. Only 45% of the world population is covered by social protection benefits, and the share in Asia is even lower.[14] Decent jobs and productive employment (SDG 8), provided in an inclusive and sustainable manner, are significant foundations for economic development and poverty reductions globally. Labour productivity has been increasing since 2010, reaching its highest annual growth rate in 2018 at 2.1%.[15] In 2018 and 2019, the global unemployment rate reached a low point at 5%, back to the pre-2008-crisis level. While the overall trend is appealing, regional inequality still stood at a very significant level, with the unemployment rate in Northern Africa and Western Asia (10.7%) almost twice that in Eastern and South-Eastern Asia (3.8%). The trend of labour productivity in 2019 showed a similar uneven regional pattern, declining in Latin America and the Caribbean, Northern Africa, Western Asia and sub-Saharan Africa while rising

9 United Nations (2020). End poverty in all forms everywhere. Retrieved from https://sdgs.un.org/goals/goal1.
10 World Bank (2018). Poverty and shared prosperity 2018: piecing together the poverty puzzle. Retrieved from https://www.worldbank.org/en/publication/poverty-and-shared-prosperity.
11 Liu, M., Feng, X., Wang, S., & Qiu, H. (2020). China's poverty alleviation over the last 40 years: successes and challenges. *Australian Journal of Agricultural and Resource Economics,* 64 (1), 209-228. Retrieved from https://onlinelibrary.wiley.com/doi/abs/10.1111/1467-8489.12353.
12 Guterres, A. (2019). Report of the Secretary-General on SDG progress 2019. Special Edition. United Nations. Retrieved from https://sustainabledevelopment.un.org/content/documents/24978Report_of_the_SG_on_SDG_Progress_2019.pdf
13 World Bank (2020). Projected poverty impacts of COVID-19. Retrieved from http://pubdocs.worldbank.org/en/461601591649316722/Projected-poverty-impacts-of-COVID-19.pdf.
14 United Nations (2020). The Sustainable Development Goals report. Retrieved from https://unstats.un.org/sdgs/report/2020/The-Sustainable-Development-Goals-Report-2020.pdf. All data in 1.2.1, unless otherwise indicated, are retrieved from this report.
15 Guterres, A. (2019). Report of the Secretary-General on SDG progress 2019. Special Edition. United Nations. Retrieved from https://sustainabledevelopment.un.org/content/documents/24978Report_of_the_SG_on_SDG_Progress_2019.pdf.

everywhere else. The outbreak of COVID-19 posed a severe challenge to employment. Global employment and labour productivity have been heavily impacted, threatening around 25 million jobs, worse than during the 2008-2009 financial crisis.[16]

The sudden surge of COVID-19 is a newly emerging factor affecting the health and livelihoods of people, exacerbating damages to sustainable development caused by environmental and social disasters (notably to SDG 1, SDG 3, SDG 8, and SDG 13). With its triple hit to health, income, and education, COVID-19 could cause the decline of global human development for the first time since the concept was introduced in 1990.[17] Meanwhile, poverty is often aggravated by disasters that cause tremendous direct economic losses—estimated at around US$3 trillion in total from 1998 to 2017 globally, increasing by more than 150% over the past 20 years.[18] Among these, climate-related geophysical disasters claimed an estimated 1.3 million lives, causing significant socio-economic consequences to countries most vulnerable to global climate change. Developing countries vulnerable to climate change are disproportionally affected, with low-income countries facing more than four times higher economic losses (relative to GDP) than high-income countries between 1998 and 2017. Countries are making efforts to develop and implement national and local disaster risk reduction strategies in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, with 85 countries having already reported such progress.[19]

Climate change (SDG 13) affects the progress towards all other sustainable development goals, since it not only exacerbates disasters, but also creates multiple, systemic risks to biodiversity and the biocapacity of the planet to sustain life. As these risks materialize, the ensuing severe weather events, sea level rise, and shortages of food and water have the potential to undermine social stability and economic security in all countries and increase the likelihood of conflict in fragile countries and regions. By March 2020, 191 parties have ratified the Paris Agreement, demonstrating a strong political commitment to mitigate climate change. Global average climate finance flows in 2017-2018 rose to US$579 billion, representing a US$116 billion

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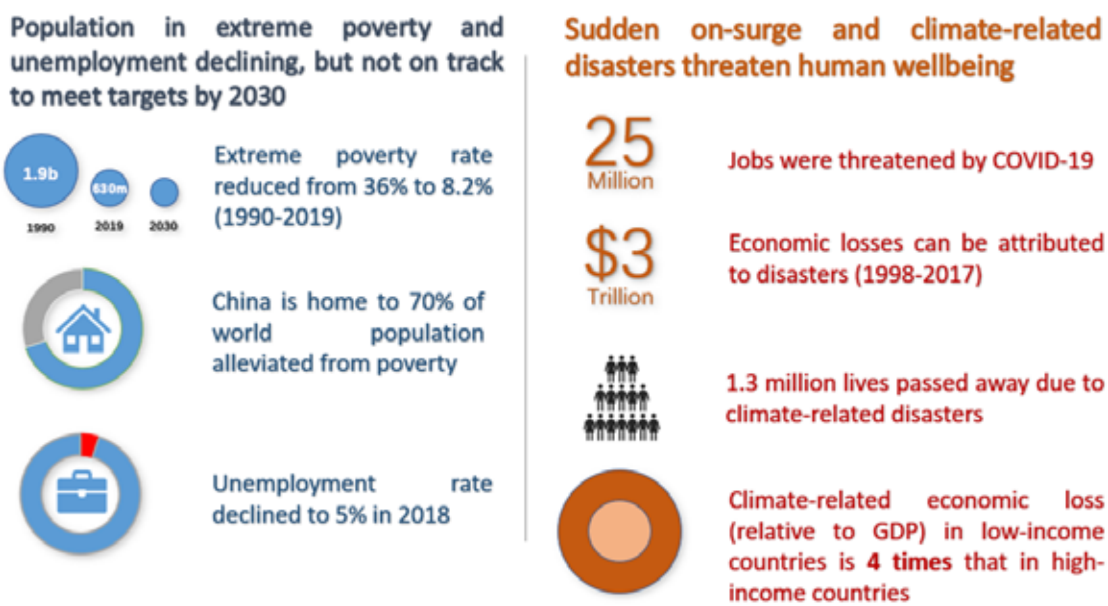
16 United Nations News (2020). COVID-19: impact could cause equivalent of 195 million job losses, says ILO chief. Retrieved from https://news.un.org/en/story/2020/04/1061322.
17 United Nations Development Programme (2020). COVID-19 and human development: assessing the crisis, envisioning the recovery, 2020 human development perspectives. Retrieved from http://hdr.undp.org/sites/default/files/covid-19_and_human_development_0.pdf.
18 Guterres, A. (2019). Report of the Secretary-General on SDG progress 2019. Special Edition. United Nations. Retrieved from https://sustainabledevelopment.un.org/content/documents/24978Report_of_the_SG_on_SDG_Progress_2019.pdf.
19 Ibid.

(25%) increase from the 2015-2016 average, and a US$212 billion (58%) increase from the 2013-2014 average.[20] While political commitment and climate finance have shown a positive trend, actions still fall far short of the requirement to achieve the 2030 emission goal compatible with the 1.5 ˚C and 2 ˚C scenarios, posing risks to the security and well-being of large population groups, all lives and the planet.[21]

Figure 1.3 Poverty, unemployment and disasters



Building resilience is of essential importance for the attainment of the SDGs at the local, national and international levels. This relies on not only meeting basic human needs, but also providing the foundations for well-being including basic infrastructure and facilities. Without available and accessible infrastructure such as roads, power supply, water facilities, railways and buildings, large vulnerable population groups will be exposed to challenges in terms of generating income and increasing livelihoods. This would further undermine their resilience to sudden disasters and trap them under the poverty line. Industrial development, relying heavily on the provision of infrastructure, can also create jobs and generate incomes for households since it often

20 Buchner, B. *et al.* (2019). Global landscape of climate finance 2019. Climate Policy Initiative. Retrieved from https://www.climatepolicyinitiative.org/wp-content/uploads/2019/11/2019-Global-Landscape-of-Climate-Finance.pdf.
21 Intergovernmental Panel on Climate Change (2018). Global warming of 1.5°C. Retrieved from https://www.ipcc.ch/sr15/.

involves labour-intensive manufacturing. While the market mechanism alone would not be sufficient for resilience-building, basic infrastructure can play an important role.

Infrastructure development (SDG 9) has been growing rapidly in recent years. Official development finance (ODF) flows for infrastructure[22] reached around US$56 billion in 2018, an increase of 40% in real terms since 2010. In 2018, the main sectors assisted were transport and storage (41%) and energy (36%). Despite the ODF increase, the finance flows received by middle-income countries (74%) is around twice as much as that received by least developed countries (26%).[23] Non-concessional lending and Foreign Direct Investment (FDI) flows are significantly higher, but fall short of the level needed to realize the SDGs by 2030. Business can play a broader role as a critical source of finance, so as to bridge the large annual investment gap. Manufacturing industries have hired around 14.2% of total employees in 2018, while the intensity of global carbon dioxide emissions from the sector has declined by more than 20% between 2000 and 2016.[24] This holds the promise of contributing to an eventual decoupling between GDP growth and CO_2 emissions.

Access to electricity (SDG 7), fundamentally supported by energy generation and electricity transmission infrastructure facilities, is another important foundation for economic prosperity and the well-being of households, corporations and nations. Despite the increase in the global electrification rate from 83% in 2010 to 90% in 2018, there were 789 million people across the world who lacked access to electricity in 2018. In Sub-Saharan Africa, only 47% of the population was able to access electricity in 2018, though this percentage has risen markedly since 2000 when it stood at 25%. While energy is needed to reduce poverty and enhance social equity, clean, low-carbon energy is necessary to reduce the impact on human health and the planet. Cleaner energy sources and access to electricity can also help improve women's health conditions and empowerment since they bear the greatest burden of household cooking without clean fuels.[25] In

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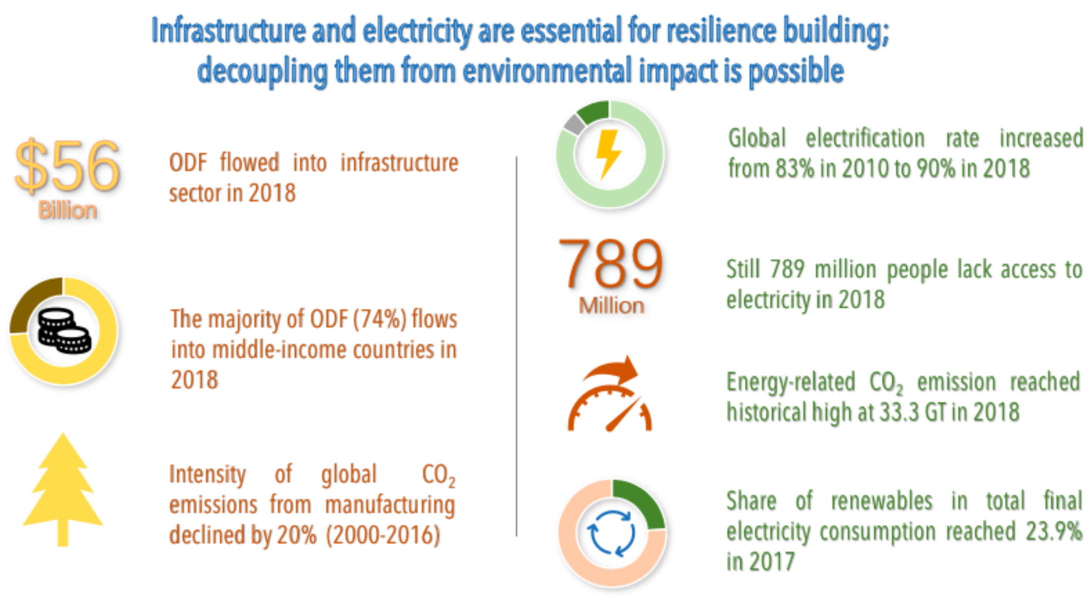
22 Including the Official Development Assistance and Other Official Flows provided by major bilateral and multilateral development partners (mainly OECD member countries) in supporting infrastructure projects and in mobilizing the private sector for infrastructure. Data retrieved from: Organization for Economic Co-operation and Development (2019). ODF for infrastructure at a glance by donor. Retrieved from https://public.tableau.com/views/Infrastructure_6/bydonor?:embed=y&:display_count=yes&publish=yes&:toolbar=no?&:showVizHome=no#1.
23 Ibid.
24 Guterres, A. (2019). Report of the Secretary-General on SDG progress 2019. Special Edition. United Nations. Retrieved from https://sustainabledevelopment.un.org/content/documents/24978Report_of_the_SG_on_SDG_Progress_2019.pdf.
25 ENERGIA, World Bank and UN Women (2018). Policy brief: global progress of SDG 7 – energy and gender. Sustainable Development Goals Knowledge Platform. Retrieved from https://sustainabledevelopment.un.org/content/documents/17489PB12.pdf.

2018 and 2019, energy-related CO_2 emissions reached an historical high at 33.3 gigatonnes (Gt),[26] highlighting the necessity to accelerate the green transition of energy production. The positive trend is that the share of renewables in total final electricity consumption has also been increasing, reaching 23.9% in 2017.[27] The decarbonizing of energy sources needs to be speeded up and scaled up to meet the SDG targets.

Global partnerships (SDG 17) are key in coordinating efforts and channelling resources from various stakeholders towards sustainable development. In 2018, total net official development assistance (ODA), bilateral ODA to least developed countries, and aid to Africa have all fallen from previous years. On the other hand, 84% of GDP and 90% of jobs in developing countries are driven by the private sector.[28] This again highlights the importance of leveraging private financial resources to fill the SDG financing gap, including in the sectors of infrastructure and energy. This could also help enhance resilience (Figure 1.4).

Figure 1.4 Infrastructure, electricity, and decarbonization



26 International Energy Agency (2020). Global CO_2 emissions in 2019. Retrieved from https://www.iea.org/articles/global-co2-emissions-in-2019.
27 International Energy Agency (2018). Renewables 2018: analysis and forecasts to 2023. Retrieved from https://www.iea.org/reports/renewables-2018.
28 Independent Group of Scientists appointed by the Secretary-General (2019). Global sustainable development report 2019: the future is now–science for achieving sustainable development. Retrieved from https://sustainabledevelopment.un.org/content/documents/24797GSDR_report_2019.pdf

1.2.2 Synergies and policy trade-offs between low-carbon and sustainable development

As illustrated in the previous section, different Goals and targets are strongly interlinked, and thus progress towards achieving one goal affects the attainment of another. Similarly, inadequate actions in achieving one target can critically undermine the attainment of another. In this sense, the social, economic and environmental pillars of sustainability cannot be regarded as being independent of each other. An integrated approach of balancing these three dimensions is therefore crucial for accelerating progress towards sustainably fostering higher-level well-being and a healthier environment for a growing population.

With the global population in extreme poverty standing at 630 million and likely to rise owing to the COVID-19 pandemic, improvements are needed to enhance social protection and empower people to generate income. However, the disparity of employment rates remains significant among different regions, with people in less developed countries more vulnerable to risks of job unavailability and insecurity. The pandemic, together with a higher frequency of natural disasters have stalled economic growth and reduced job security for countries around the world. Climate change, a key factor triggering disasters that have claimed 1.3 million lives (1998-2017),[29] is raising the alarm for many governments to take action. Accelerating poverty alleviation and mitigating the impact of disasters require resilience-building for households. This calls for protective policies as well as the provision of accessible physical infrastructure to meet basic human needs.

Increasing ODF flows in infrastructure fail to show a clear preference towards the group of countries in most need.[30] Around 789 million people still lack access to electricity worldwide.[31] Despite the abundance of untapped renewable energy potential, Sub-Saharan Africa is having difficulties in meeting targets addressing electricity access, poverty, hunger and malnutrition. With unstable ODA flows to developing countries, enhanced global partnership and the engagement with the private sector can greatly help facilitate resilience-building in regions of the world where it is most needed. The BRI, which provides Public-Private Partnership (PPP) opportunities in

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29 United Nations (2020). The Sustainable Development Goals report. Retrieved from https://unstats.un.org/sdgs/report/2020/The-Sustainable-Development-Goals-Report-2020.pdf.
30 Organization for Economic Co-operation and Development (2019). ODF for infrastructure at a glance by donor. Retrieved from https://public.tableau.com/views/Infrastructure_6/bydonor?:embed=y&:display_count=yes&publish=yes&:toolbar=no?&:showVizHome=no#1.
31 United Nations (2020). The Sustainable Development Goals report. Retrieved from https://unstats.un.org/sdgs/report/2020/.

infrastructure connectivity and policy coordination, can serve as an important driver to close the development gap.

Figure 1.5 The linkage between various SDG considerations

Tackling climate change is pivotal to the chain illustrated in Figure 1.5, as it calls not just for resilience-building but also for low-carbon solutions that ensure accessible clean infrastructure for those most in need. Poverty alleviation, employment, economic growth, disaster risk control, climate change tackling, infrastructure building, electricity access, and partnership enhancement cut across all three pillars of development. They also illustrate the intricate linkages among various Goals, highlighting the importance of leveraging the synergic effect among these three pillars. Balancing the three interconnected pillars of development can also help generate greater resilience—urgent because of escalating environmental degradation and also a requirement for socio-economic stability and prosperity.

1.3 Prospects and potential of addressing challenges in environmental sustainability by boosting low-carbon development

Among the three pillars of sustainable development, the social and economic dimensions have seen the most rapid advances in the past decades before the onset of the COVID-19 pandemic.

Regarding the social pillar, most people experienced marked improvements in life expectancy, with greater access to education as well as goods and services than ever before. This trend characterizes practically all countries, whether ranking at high, medium or low levels of human development according to the Human Development Index.[32] Since 1990, the global poverty rate has been falling, with a more rapid decline in the first 15 years of the 2000s.

32 United Nations Development Programme (2018). Human development report indices and indicators. Retrieved from

For the economic pillar, during the last few decades, the world experienced globally unprecedented economic growth buffeted but not halted by the financial crisis. Between 2000 and 2019, emerging markets as well as developing economies including those in Sub-Saharan Africa grew on average by more than 5% per annum despite recently slowing down.[33] This has enabled poverty reduction and improvement of livelihoods. China played a significant role in these global gains.

In stark contrast with social and economic indicators, environmental indicators such as water quality, global warming, and ocean and land degradation have all worsened in the past decade (apart from air quality in a number of large cities), according to the Global Environmental Outlook by the United Nations Environment Programme (UNEP) in 2019.[34] While high rates of economic growth have brought increasing living standards especially in today's industrialized and developed nations, long-term environmental costs and other externalities have been imposed. Environmental damage includes negative effects related to climate change, air, water and soil pollution, severe biodiversity loss, as well as degradation of natural resources and systems.[35] Continued increases in global average temperatures and the associated increase in weather volatility will remove the foundations of stability upon which social and economic development throughout the world are based.

Adding to the concern is the fact that among the four most adverse global trends that are not moving in the right direction, three fall into the environmental pillar. According to the Global Sustainable Development Report (2019),[36] rising inequalities, climate change, biodiversity loss, and waste from human activities are the four categories in which current adverse tendencies are having cross-cutting impacts across the entire 2030 Agenda. As data and analysis in the previous section have shown, without transformative actions, the negative trends can even move towards

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http://report2017.archive.s3-website-us-east-1.amazonaws.com/#one.

33 International Monetary Fund (n.d.). IMF Data Mapper. Retrieved from https://www.imf.org/external/datamapper/NGDP_RPCH@WEO/OEMDC.

34 United Nations Environment Programme (2019). Global environmental outlook 6. Retrieved from https://www.unenvironment.org/resources/global-environment-outlook-6.

35 Intergovernmental Panel on Climate Change (2018). Global warming of 1.5°C. Retrieved from https://www.ipcc.ch/sr15/.

36 Independent Group of Scientists appointed by the Secretary-General (2019). Global sustainable development report 2019: the future is now– science for achieving sustainable development. Retrieved from https://sustainabledevelopment.un.org/content/documents/24797GSDR_report_2019.pdf.

the tipping points where small additional perturbations can trigger an irreversible transition of the Earth's ecosystem.

Low-carbon development, especially through decarbonizing energy, could efficiently and effectively contribute towards solving existing challenges stemming from growing threats of climate change and lack of access to electricity. Industrialization was accompanied by an increase of global per capita energy demand, from 1.3 to 1.9 tons of oil equivalent from 1965 to 2015,[37] largely stemming from high and growing average consumption in developed countries. Given fast urbanization and the projected rising energy demand of the world's growing population, low-carbon development could critically contribute to transformative development paths that strike a balance between the three pillars of sustainability in the 2030 Agenda. One promising condition is that, as the SDG index measuring the annual status of SDG attainment of each member state shows, regions requiring higher access to energy (SDG 7), such as Northern Africa, Western Asia, Sub-Saharan Africa and Pacific Island Countries, are also those doing well in climate action (SDG 13).[38] This opens up the possibility of a promising future of low-carbon development that can provide highly efficient energy technologies and affordable clean energy options while ensuring climate change mitigation.

1.4 Consensus and pathways of low-carbon development globally

Although it is difficult to build a universal definition of a low-carbon development path given different circumstances in different countries and regions, the concept of "low-carbon development" centres on minimizing greenhouse gas[39] emissions in sustained socio-economic development.[40] As a significant part of global trends in sustainable development (as shown in Figure 1.6), low-carbon development is widely perceived as an effective way to tackle climate change and attain economic growth sustainably. This report, specifically focusing on low-carbon

37 Ibid.

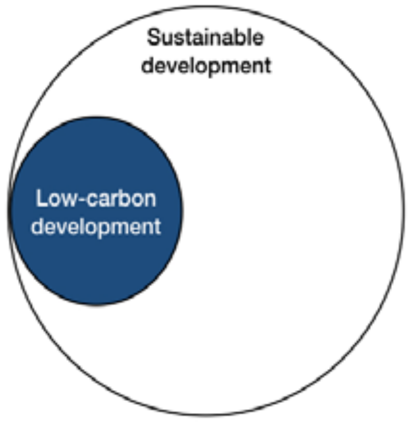
38 Sustainable Development Solutions Network (2020). Sustainable development report dashboards: transformations to achieve the Sustainable Development Goals. Retrieved from https://dashboards.sdgindex.org/map.

39 Greenhouse gases include Carbon Dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O), Ozone (O_3), Chlorofluorocarbon (CFC), Carbon Monoxide (CO), Sulphur Dioxide (SO_2). This report will mainly focus on CO_2 emissions which account for more than half of the global warming effect.

40 United Nations Economic and Social Commission for Asia and the Pacific (2010). Low-carbon development path for Asia-Pacific: challenges and opportunities for the energy sector. Retrieved from https://www.unescap.org/sites/default/files/Energy%20Resources%20Development%20Series%2041.pdf.

development, aims to provide a clear rationale for BRI countries and beyond to enable this as an integral part of progress towards SDG attainment.

Figure 1.6 Sustainable development & low-carbon development



Trajectories of low-carbon development in various countries and regions are helpful in demonstrating common concerns, lessons learned and next-step priorities. The term Low-emission development strategies (LEDS) first appeared under the UNFCCC in 2008.[41] Before that, interest and practices in low-carbon development started to emerge in various countries. In a 2003 policy paper, *Our energy future — creating a low carbon economy*, the UK government first raised the concept of a "low-carbon economy", to deal with challenges such as shrinking indigenous energy supplies and mounting risks of droughts and flooding on its east coast.[42] It was also the first to make low-carbon development a national strategy. In 2004, Japan launched its research project on low-carbon society scenarios towards 2050; a dozen actions to reduce its CO_2 emissions by 70% by 2050 from its 1990 level were proposed in 2008, including a comfortable and green built environment, swift and smooth logistics, low-carbon electricity, local renewables for local demand, etc.[43] In 2009, the US Congress approved the *American Clean Energy and Security Act*, putting forward a cap and trade system.[44] This was followed by *The President's Climate Action Plan* in

41 International Energy Agency & Organization for Economic Cooperation and Development (2010). Low Emission Development Strategies (LEDS). Retrieved from https://sustainabledevelopment.un.org/index.php?page=view&type=400&nr=708&menu=1515.
42 UK Department of Trade and Industry (2003). Our energy future - creating a low carbon economy. Retrieved from https://fire.pppl.gov/uk_energy_whitepaper_feb03.pdf.
43 "2050 Japan Low-Carbon Society" Scenario Team (2008). Japan scenarios and actions towards low-carbon societies (LCSs). Retrieved from http://2050.nies.go.jp/report/file/lcs_japan/2050_LCS_Scenarios_Actions_English_080715.pdf.
44 111th US Congress (2009). H.R.2454 - American clean energy and security act of 2009. Retrieved from https://www.congress.gov/bill/111th-congress/house-bill/2454.

2013[45] and *The All-of-the-above Energy Strategy as a Path to Sustainable Economic Growth* in 2014.[46] The European Commission published in 2011 *A Roadmap for Moving to a Competitive Low Carbon Economy in 2050*, identifying a combined set of measures necessary for delivering its energy efficiency target.[47]

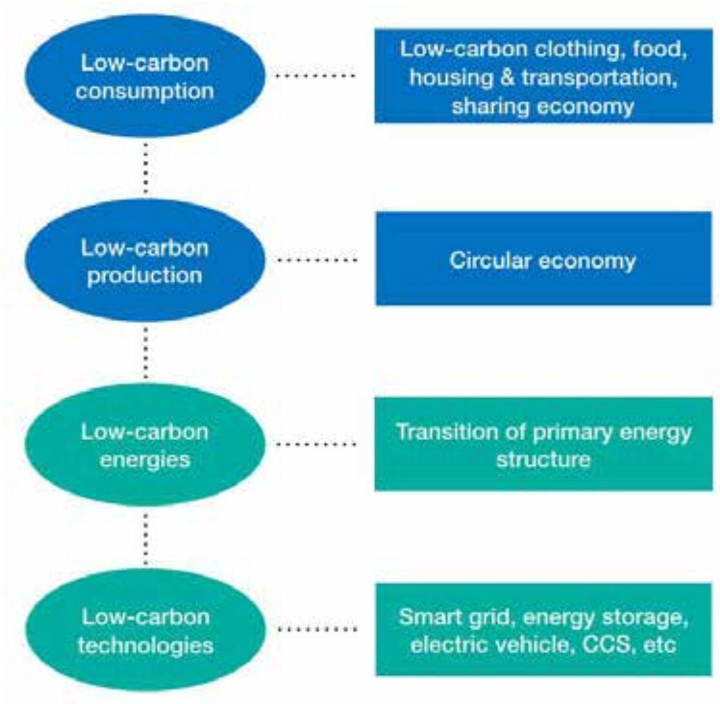
For China, the year of 2009 was a milestone in its low-carbon development, with CCICED publishing a policy research report, *China's Pathway Towards a Low Carbon Econom*y.[48] During the United Nations climate summit the same year, Chinese leaders unveiled a set of climate targets and plans. The nation's low-carbon investment and financing increased rapidly during the 12th Five-Year Plan period (2011-2015), while its emission intensity, defined as CO_2 emissions per unit of GDP, remained on a generally declining path. The 18th Communist Party of China (CPC) National Congress Report in 2012 jointly mentioned for the first time the concepts of "green development", "circular development" and "low-carbon development".[49] In 2017, the 19th CPC National Congress Report clearly emphasized the need to facilitate green, low-carbon, and circular development, build an energy sector that is clean, low-carbon, safe and efficient, and encourage simple, moderate, green and low-carbon ways of life.[50]

As shown in Figure 1.7, different countries and regions mainly focused on four aspects — innovating low-carbon technologies, exploiting low-carbon energy, promoting low-carbon production, as well as shaping low-carbon lifestyles and consumption patterns.[51] Despite efforts and progress in energy saving, lowering of energy consumption, development of renewables, and increase of carbon sinks, more needs to be done to accelerate low-carbon development in key sectors such as energy, heavy industry and transport. As demonstrated in previous sections, the energy and power sectors play a central role in mitigating climate change and securing a promising

45 Executive Office of the President of the United States (2013). The President's climate action plan. Retrieved from https://obamawhitehouse.archives.gov/sites/default/files/image/president27sclimateactionplan.pdf.
46 Executive Office of the President of the United States (2014). The all-of-the-above energy strategy as a path to sustainable economic growth. Retrieved from https://scholar.harvard.edu/files/stock/files/all_of_the_above_energy_strategy.pdf.
47 European Commission (2011). A Roadmap for Moving to a Competitive Low Carbon Economy in 2050. Retrieved from https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0112:FIN:EN:PDF.
48 China Council for International Cooperation on Environment and Development (2009). China's pathway towards a low carbon economy. Retrieved from http://www.cciced.net/ccicedPhoneEN/Events/AGMeeting/2009_3973/meetingplace_3974/201609/P020160922381047979521.pdf.
49 China.org (2012, November 16). Report of Hu Jintao to the 18th CPC National Congress. Retrieved from http://www.china.org.cn/china/18th_cpc_congress/2012-11/16/content_27137540_8.htm.
50 Xinhua (2017, October 18). Secure a decisive victory in building a moderately prosperous society in all respects and strive for the great success of socialism with Chinese characteristics for a new era. Retrieved from http://www.xinhuanet.com/english/download/Xi_Jinping's_report_at_19th_CPC_National_Congress.pdf.
51 Du Xiangwan (2016). "低碳发展总论" [Low-carbon Development Introduction]. China Environmental Publishing Group.

low-carbon development prospect, which thus means this sector is the main focus of discussion for this report.

Figure 1.7 Key aspects in low-carbon development



The pace of low-carbon development can be affected or motivated by certain socioeconomic and environmental conditions. For example, COVID-19 effects have translated into a demand shock in the energy sector, possibly having lasting consequences even though the long-term impact is still uncertain (see Box 1.1). Compared with other types of energy, coal and oil have been so far the hardest hit by the crisis in 2020, suffering from shrinking demand. For coal, this is mainly caused by the forecasted decline of global electricity demand and for oil, by a sharp demand decline in the transportation sector.[52] Meanwhile, renewable energy power generation is expected to increase in 2020.

52 International Energy Agency (2020). Sustainable recovery. World Energy Outlook Special Report. Retrieved from https://www.iea.org/reports/sustainable-recovery.

Box 1.1 Impact of COVID-19 on the low-carbon energy transition

The pandemic is the latest of several signs—along with declining biodiversity, land degradation, increasing water scarcity and climate change—that the world's development path is unsustainable and that environmental problems have major health implications.

The COVID-19 pandemic is globally synchronized (it affects all countries at nearly the same time). Given the necessary social distancing measures and the emerging economic consequences, it also has wide-ranging economic and social effects. These include labour retrenchment, higher trade transactions costs, streamlined value chains, rising social tensions and escalating inequality. They are exacerbated by the heightened uncertainty about the future evolution of both the pandemic and its impact as shocks in various seemingly unrelated areas propagate and interact.

The policy response in individual countries, together with the extent to which these are coordinated given interdependencies and externalities across countries is one of the key determinants of the depth and duration of the crisis—and of the post-crisis sustainability of development. The composition of the socioeconomic stimulus package is very important, since it exerts an impact on low-carbon development prospects both in the short term and long term, highlighting the need for careful environmental considerations.

Initial signs foreshadow large challenges. Dampened production, consumption and investment reduce demand for energy: by 8% for oil and coal, within a projected global primary energy demand fall of 6% in 2020.[53] This has already resulted in sharply falling and more volatile oil prices (somewhat less for more regulated coal prices, but those are also hit hard by falling industrial demand and as a main feedstock for generating electricity that is facing a 5% likely drop globally). In contrast, renewables-based power generation is expected to increase by 5% in 2020, on the back of sustained demand throughout the first half of the year despite the shock. However, it has also been hit: net capacity additions are expected to decline by 13% in 2020, before rebounding in 2021.[54]

53 Ibid.
54 International Energy Agency (2020). Renewable energy market update. Outlook for 2020 and 2021. Retrieved from https://www.iea.org/reports/renewable-energy-market-update.

These developments play havoc with short-term price comparisons of fossil fuels and renewables (in late April, there were instances of *negative* crude oil prices in some markets, reflecting lack of storage capacity in the face of oversupply). But the key considerations for low-carbon investment decisions and development remain long-term demand and price projections, global governance and the need for clean air and addressing climate change, as emphasized in this report. The COVID-19 crisis is serious and brings considerable human suffering. However, it underscores the importance of this report, which offers pragmatic suggestions based on careful analysis for an important aspect of sustainability: low-carbon development. In this area, and in avoiding a return to an unsustainable pre-crisis development path—as happened after the 2008 global financial crisis—the role of China and BRI partner countries is pivotal, owing to their combined share in output and in driving development, as well as in current and prospective GHG emissions.

Global climate governance has been deepened and extended through intragovernmental coordination mechanisms to implement the Paris Agreement, in addition to endeavours made by different countries. Conceptual scenarios are being tested with empirical cases, whereas further global coordination actions are called for. In its 2018 special report, the IPCC discussed how the global economy and socio-technical and socio-ecological systems can transition to 1.5°C pathways. Rapid and far-reaching global responses, in the context of systematic transitions across energy, land, urban and industrial systems, are needed for a low-carbon, climate-resilient future.[55] An increasing number of international organizations and multilateral institutions have also initiated low-carbon development projects, including UNDP, UNEP, the World Bank and the World Wildlife Fund (WWF).

So far, promising steps have been made towards achieving global consensus in the following areas in terms of developing a low-carbon development path:

- Integrating low-carbon policies with other policy priorities, e.g., economic growth,

55 Intergovernmental Panel on Climate Change (2018). Global warming of 1.5°C. Retrieved from https://www.ipcc.ch/sr15/.

energy security, access to energy, and innovation;

- Boosting essential system changes;
- Developing portfolio options and technologies;
- Promoting behaviour changes;
- Allocating necessary funding.

It becomes evident that low-carbon development, a promising solution to leverage the synergies and mitigate the policy trade-offs for SDG attainment, requires improvements of not only efficiency of energy consumption, lifestyle patterns, and carbon intensity of various industries, but also technologies and sources for energy production. The report draws attention to the great potential and technical means of low-carbon development in the energy and power sectors, with a focus on clean energy development, sustainable finance, and capacity building. It also notes the importance of market structure and of appropriate price signals.

Based on existing experiences and lessons of low-carbon development, this report highlights the huge potential of the BRI and China in helping attain sustainable energy supply and electrification (Chapter 2). As illustrated through in-depth analyses in later chapters, this could be achieved through boosting low-carbon technological solutions (Chapter 3), leveraging investment and financing resources towards low-carbon projects (Chapter 4), and consolidating capacity development at individual, institutional and systemic levels (Chapter 5) along the Belt and Road.

Chapter 2 Prospects of the BRI in advancing global low-carbon development and China's technological strength and pathways in low-carbon energy transition

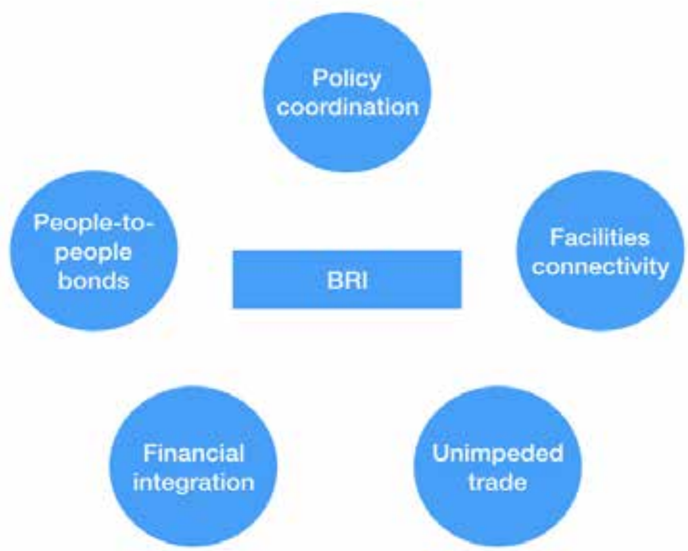
2.1 Context of energy development and prospects of low-carbon energy transition in countries and territories along the Belt and Road

2.1.1 Disparity and diversity of economic structure, governance capacity, resource endowments and energy development in countries and territories along the Belt and Road

Launched in 2013, the BRI's scale is significant both for its breadth in engaging international partners and its economic and financial scope. The definition of countries and projects falling under the "Belt and Road" umbrella is elusive. The "BRI partner countries" or "countries along the Belt and Road" in this report refer to countries that have signed BRI cooperation agreements/Memoranda of Understanding (MoUs) with China – contained in China's official documents and media portals, particularly the Belt and Road Portal. By January 2020, China has signed 200 BRI-related cooperation documents with 138 countries and 30 international organizations.[56] The cooperation among BRI countries is based on five pillars of interconnectivity, namely policy coordination, facilities connectivity, unimpeded trade, financial integration, and people-to-people bonds (see Figure 2.1).

56 Belt and Road Portal (2020). "已同中国签订共建"一带一路"合作文件的国家一览" [List of countries that have signed a BRI cooperation agreement with China] (link in Chinese, see references).

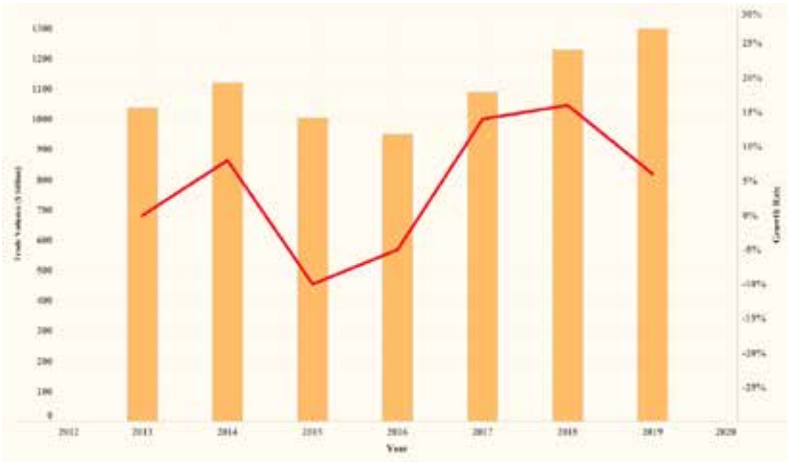
Figure 2.1 Five major pillars for BRI interconnectivity



Substantial progress has been made in each of these five interconnectivity pillars, which mirrors the BRI's rapidly increasing global weight. For example, the total trade volume between China and BRI partner countries exceeded US$7.8 trillion during 2013-2019 (see Figure 2.2).[57] In 2019 alone, the trade volume between China and BRI partner countries surpassed US$1.3 trillion, with an annual growth rate of 6%.[58]

57 Ministry of Commerce of the People's Republic of China (2020). "6 年时间中国与"一带一路"沿线国家货物贸易总额超 7.8 万亿美元" [China's trade volume with countries along the Belt and Road exceeded US$7.8 trillion in six years] (link in Chinese, see references).
58 Ministry of Commerce of the People's Republic of China (2020). "商务部：去年与"一带一路"沿线国家货物贸易额增长 6%" [Ministry of Commerce: trade volume with countries along the Belt and Road increased by 6% last year] (link in Chinese, see references).

Figure 2.2 Trade volume and annual growth rate between China and BRI partner countries (2013-2019)



Source: Belt and Road Portal, MOFCOM[59]

Investment cooperation also continues to deepen along the Belt and Road. Between 2013 and 2019, Chinese companies directly invested over US$110 billion in BRI partner countries. The total value of newly signed foreign contracted projects in countries along the Belt and Road during this period was nearly US$800 billion. A number of overseas economic and trade cooperation zones have been built in countries along the Belt and Road, with accumulated direct investments of US$35 billion, creating 320,000 jobs for locals and generating taxation and fees income of over US$3 billion for host countries.[60]

Statistics show that BRI economic and trade cooperation generally remains stable despite COVID-19. In the first four months of 2020, trade in goods between China and BRI partner countries rose by 0.9% year-on-year, whereas China's direct investment in the non-financial sectors of BRI partner countries was up by 13.4% year on year. Global interconnectivity and the transformation of global value chains are expected to deepen further, reflecting compelling patterns of comparative advantage along with growing trade and investment along the Belt and Road.

59 Belt and Road Portal (2019). "图解："一带一路" 倡议六年成绩单" [Illustration: six years' report card for Belt and Road Initiative] (link in Chinese, see references); Ministry of Commerce of the People's Republic of China (2020). "商务部：去年与"一带一路"沿线国家货物贸易额增长 6%" [Ministry of Commerce: trade volume with countries along the Belt and Road increased by 6% last year] (link in Chinese, see references).
60 Ministry of Commerce of the People's Republic of China (2020). "6 年时间中国与'一带一路'沿线国家货物贸易总额超 7.8 万亿美元" [China's trade volume with countries along the Belt and Road exceeded US$7.8 trillion in six years] (link in Chinese, see references).

Taking full consideration of the BRI's scale, the 2015 top-level policy document, *Vision and Actions on Jointly Building Belt and Road*, as a vital document defining the BRI's principles, priorities, and mechanisms, emphasizes that efforts should be made to "promote green and low-carbon infrastructure construction and operation management, taking into full account the impact of climate change on the construction", and to "promote ecological progress in conducting investment and trade, increase cooperation in conserving eco-environment, protecting biodiversity, and tackling climate change, and join hands to make the Silk Road an environmentally friendly one."[61] At the 2017 Belt and Road Forum for International Cooperation, recognition was given to the importance of "seizing opportunities presented by the new round of change in energy mix and the revolution in energy technologies to develop global energy interconnection and achieve green and low-carbon development," so as to "pursue the new vision of green development and a way of life and work that is green, low-carbon, circular and sustainable".[62] The vision that "the BRI must be open, green and clean" and that the United Nations's 2030 SDGs should be included as an integral part of Belt and Road cooperation was again underlined during the 2019 Belt and Road Forum.[63] Along with the introduction of specific policies and projects under the BRI, promoting low-carbon development has been repeatedly highlighted as an important guiding principle in Belt and Road cooperation.

In the context of the valuable commitment under a low-carbon vision, it is equally important to take full consideration of the diversity and different development stages of BRI partner countries for the fulfilment of that vision at the country level. Disparities between these countries especially in terms of economic and technological development, governance capacity, electricity infrastructure demand and natural resource endowments cannot be overlooked. Table 2.1 investigates three dimensions – economy, governance, and electricity – with eight indicators for 50 selected BRI partner countries across all continents. It shows the disparities not only among different regions, but also among BRI partner countries within a same region among countries

61 National Development and Reform Commission, Ministry of Foreign Affairs of the People's Republic of China, Ministry of Commerce of the People's Republic of China, and State Council (2015). Vision and actions on jointly building Belt and Road. Retrieved from http://2017.beltandroadforum.org/english/n100/2017/0410/c22-45.html.
62 Xinhua (2017, May 14). Full text of President Xi's speech at opening of Belt and Road Forum. Retrieved from http://www.xinhuanet.com/english/2017-05/14/c_136282982.htm.
63 China Daily (2019, April 27). Xi's full remarks at the leaders' roundtable meeting of the Second Belt and Road Forum for International Cooperation. Retrieved from https://www.chinadaily.com.cn/a/201904/27/WS5d9c5982a310cf3e3556f389.html.

participating in the BRI. (See Appendix I for the full dataset of all 138 BRI partner countries that have signed a cooperation agreement/MoU with China on BRI cooperation by January 2020).

Table 2.1 Key economic, governance, and electricity indicators for selected BRI partner countries (2019)[64]

Country	GDP per capita[65]	Employment to population %	Ease of doing business[66]	Political stability[67]	Rule of law[68]	Access to electricity %[69]	Practical potential of PV output[70]	CO_2 emissions per capita[71]
China	10262	65.1	77.9	53.8	52.4	100.0	3.88	7.18
Southeast Asia								
Cambodia	1643	81.8	53.8	58.6	25.5	91.6	4.13	0.63
Indonesia	4136	64.3	69.6	43.3	50.5	98.5	3.77	2.15
Lao PDR	2535	78.0	50.8	79.5	26.0	97.9	3.87	2.59
Malaysia	11415	62.2	81.5	61.9	77.4	100.0	3.74	8.09
Myanmar	1408	60.7	46.8	16.7	20.7	66.3	4.14	0.48
Philippines	3485	58.3	62.8	27.1	46.2	94.9	3.93	1.18
Singapore	65233	67.6	86.2	100.0	100.0	100.0	3.55	6.69
Thailand	7808	66.8	80.1	41.4	63.0	100.0	4.06	4.11
Viet Nam	2715	75.9	69.8	62.4	61.1	100.0	3.55	2.06
South Asia								
Afghanistan	502	43.5	44.1	2.9	5.3	98.7	5.02	0.25
Bangladesh	1856	56.5	45.0	26.7	39.9	85.2	3.88	0.53
Pakistan	1285	50.2	61.0	5.2	38.0	71.1	4.71	0.99
Sri Lanka	3853	51.7	61.8	53.8	61.1	99.6	4.21	1.10

64 For a few countries and indicators, 2019 data are not available yet, and therefore the most recently available data are used instead, as shown in following footnotes.
65 Current US$. For Iran, 2017 data.
66 Overall score 1-100. 100 = highest.
67 Percentile Rank, Upper Bound of 90% Confidence Interval. 100 = highest.
68 Percentile Rank, Upper Bound of 90% Confidence Interval. 100 = highest.
69 2018 data. % of population.
70 Practical photovoltaic power output of a PV system in the long-term, kWh/kWp/day. While kWp refers to kilowatts peak rating at which the solar electricity system generates energy at peak performance such as at noon on a sunny day, kWh/kWp/day refers to how much energy (kWh) is produced for every kWp of module capacity over the course of a day.
71 Metric tons, 2016 data. For Italy, 2014 data.

East Asia								
Mongolia	4295	56.1	67.8	84.3	52.4	98.1	4.76	8.30
Central Asia								
Kazakhstan	9731	65.6	79.6	56.7	46.6	100.0	3.69	13.89
Kyrgyzstan	1309	56.0	67.8	46.7	27.4	100.0	4.11	1.61
Tajikistan	871	37.4	61.3	41.4	16.3	99.3	4.34	0.61
Uzbekistan	1725	61.2	69.9	53.3	20.7	100.0	4.27	2.88
Middle East								
Iran	5520	39.6	58.5	10.5	33.7	100.0	4.92	8.32
Iraq	5955	37.5	44.7	3.8	5.3	99.9	4.68	5.19
Kuwait	32032	71.9	67.4	66.7	69.2	100.0	4.82	24.95
Lebanon	7784	44.1	54.3	11.4	27.9	100.0	4.83	3.69
Qatar	64782	86.7	68.7	88.6	80.3	100.0	4.92	38.90
Saudi Arabia	23140	52.6	71.6	46.7	65.4	100.0	5.16	17.37
Turkey	9043	45.7	76.8	13.8	51.4	100.0	4.32	4.67
United Arab Emirates	43103	80.2	80.9	87.1	83.7	100.0	5.00	22.04
Africa								
Egypt	3020	41.4	60.1	21.4	47.1	100.0	5.25	2.53
Ethiopia	858	77.9	48.0	15.7	46.2	45.0	4.70	0.14
Ghana	2202	64.9	60.0	61.9	61.1	82.4	4.02	0.59
Kenya	1817	72.7	73.2	20.0	46.6	75.0	4.50	0.37
Madagascar	522	84.6	47.7	53.3	21.6	25.9	4.76	0.16
Morocco	3204	41.2	73.4	48.1	56.7	100.0	5.01	1.74
Nigeria	2230	48.6	56.9	8.1	26.4	56.5	4.30	0.65
South Africa	6001	40.2	67.0	53.8	58.2	91.2	5.00	8.48
Uganda	777	69.0	60.0	37.1	50.5	42.7	4.46	0.14
Zambia	1291	66.1	66.9	56.7	46.6	39.8	4.83	0.31
Europe								
Bulgaria	9738	53.0	72.0	79.0	61.1	100.0	3.70	5.85
Italy	33190	44.7	72.9	74.8	69.7	100.0	3.99	5.3

Hungary	16476	54.5	73.4	89.5	75.0	100.0	3.44	4.64
Poland	15595	54.7	76.4	78.1	74.5	100.0	2.98	7.88
Romania	12920	52.5	73.3	78.1	71.6	100.0	3.52	3.52
Russian Federation	11585	59.0	78.2	41.4	32.7	100.0	3.36	12.00
Serbia	7402	47.9	75.7	57.1	57.7	100.0	3.52	6.41
Ukraine	3659	49.3	70.2	11.9	34.1	100.0	3.30	4.49
Oceania								
New Zealand	42084	67.1	86.8	99.5	100.0	100.0	3.68	7.33
America								
Chile	14897	58.2	72.6	66.2	87.0	100.0	5.36	4.71
El Salvador	4187	56.7	65.3	55.7	32.2	100.0	4.83	1.13
Panama	15731	64.0	66.6	69.0	57.7	100.0	3.97	2.65
Peru	6978	75.1	68.7	54.8	45.7	95.2	4.90	1.86
Uruguay	16190	58.4	61.5	96.2	78.8	100.0	4.30	1.98
World average	**11433**	**57.5**	**63.63**	**61.8**	**58.1**	**89.6**	**4.19**	**4.56**

Source: World Bank[72]

Statistics on the 50 selected[73] out of the 138 BRI partner countries, as shown in Table 2.1, illustrate diversified development stages of countries participating in the BRI.

In the economic development dimension, the indicators on GDP per capita, employment to population ratio, and ease of doing business index have illustrated the extent to which disparities in economic structure, labour force skillsets, and business environment of respective countries should be considered during low-carbon development planning and investment. Data on GDP per capita of the selected 50 countries vary from about US$500 to over US$60,000, while the world average as of 2019 is at US$11,433. Vast disparities also exist in terms of employment ratio – the highest ones stand at over 80% (e.g., Cambodia and Madagascar) whereas the lowest is less than half of the highest (e.g., Tajikistan at 37.4%). As for the business environment, statistics on the

72 Word Bank (n. d.). World Bank Open Data. Retrieved from https://data.worldbank.org/; World Bank and the International Finance Corporation (n.d.). Global Solar Atlas. Retrieved from https://globalsolaratlas.info.
73 The fifty countries were selected on the basis of proportionally considering the regional distribution of BRI partner countries and reflecting the diversity of GDP per capita (scale of economy) of the countries.

ease of doing business index vary from 86 in Singapore to 44 in Afghanistan and Iraq. While disparities are prominent among different regions, wide gaps are also seen within each region.

In the dimension of governance, data on political stability and the rule of law indexes also vary from one country to another. The indicator on political stability captures the unlikelihood of political instability and occurrence of violence motivated by political reasons such as terrorism, while the index on rule of law reflects compliance with rules and laws in a society. Disparities in the political stability index data are significant, ranging from almost 100 in Singapore, Uruguay and New Zealand, to the less than 10 in Nigeria, Iraq, Afghanistan and Pakistan due to terrorist attacks and civil wars. As for rule of law, a similar pattern appears – the spectrum ranges from almost full to around 10. While most countries' performance on these two indicators are at similar levels, there are also occasions in which their rule of law compliance outperforms political stability.

In terms of electricity infrastructure demand and natural resource endowments for renewables (here solar PV is investigated), BRI partner countries demonstrate both diversities and positive prospects. While the world average access to electricity is 89.6%, a majority of BRI partner counties have reached over 90% though 9 out of 50 BRI partner countries here are still significantly behind (e.g., Myanmar, Egypt, Madagascar and Nigeria). Meanwhile, many BRI partner countries' carbon emissions are lower than the world average of 4.56 metric tons per capita, though some countries have exceptionally high emissions at over 30 metric tons (e.g., Qatar). Natural resource endowments among BRI partner countries also vary, with the practical potential of solar PV output ranging from below 3 to above 5 kWh/kWp/day (world range from 2.51 to 5.38). One promising signal is that for the majority of countries where there is a high demand for better access to electricity, the practical potential for the output of renewables (e.g., solar PV) is above the world average of 4.19 kWh/kWp/day (e.g., Pakistan, Ethiopia, Madagascar and Zambia).

Given existing disparities in economic structure, human resources, institutional governance, natural resource endowments, and electricity infrastructure demand, there is no universal low-carbon development path for countries along the Belt and Road. More importantly, for many countries, even though the practical potential of renewables and electricity infrastructure demand is considerable, their governance and labour force conditions may be challenging. Similarly, for some other countries, while economic momentum and governance capacity are remarkable, their natural resource endowments might limit their potential. In this context, when it comes to defining development pathways, priorities need to be set by policymakers based on both national specificities and in consideration of the SDGs.

Cooperation under the BRI, including technology transfer, trade, investment and financing, as well as knowledge-sharing and capacity-building, would help these countries — especially developing ones — avoid the lock-in effect of high-carbon trajectories and associated development traps. For instance, in an open trade environment, countries exporting lower carbon intensity products or ones critical for lowering carbon intensity tend to be more competitive in international markets and often have more stable export revenue flows. This also helps optimize resource allocation, especially when these products are necessary for socio-economic development, e.g., building materials for efficient infrastructure, transportation equipment and communication devices.

Open trade along the Belt and Road also facilitates the diffusion and spill-over of low-carbon technologies, such as affordable renewable energy technologies and global energy interconnection. Likewise, green investment reinforces green technology diffusion as well. A series of studies on China have demonstrated that the technological spill-over effect brought by FDI facilitates the reduction of carbon intensity.[74] Along with environmentally friendly FDI in BRI countries, low-carbon technologies, management expertise and sustainability-enhancing ideas are expected to improve low-carbon production rates in host countries while boosting their economic welfare.

Meanwhile, Nationally Appropriate Mitigation Actions (NAMAs) are endorsed by many developing countries, which can also offer important tools to ultimately contribute to GHG emissions reduction while addressing the development needs of a country. Activities under the BRI could be complementary to the projects and actions outlined by NAMAs. All these help generate an emerging consensus in favour of minimizing ecological costs in economic growth, and lead to improved sustainability in development along the Belt and Road.

74 Huang, J. *et al.* (2018). The effect of technological factors on China's carbon intensity: new evidence from a panel threshold model. *Energy Policy*, 115, 32-42. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S0301421517308248.

2.1.2 Strength and prospects of advancing low-carbon energy transition, and progress of energy cooperation under the BRI

Energy cooperation is a priority area for the Belt and Road Initiative. Since the BRI was launched, China has established 24 bilateral energy cooperation mechanisms, founded or joined 10 multilateral energy cooperation mechanisms, and signed more than 100 cooperation documents in the energy field as of April 2019.[75]

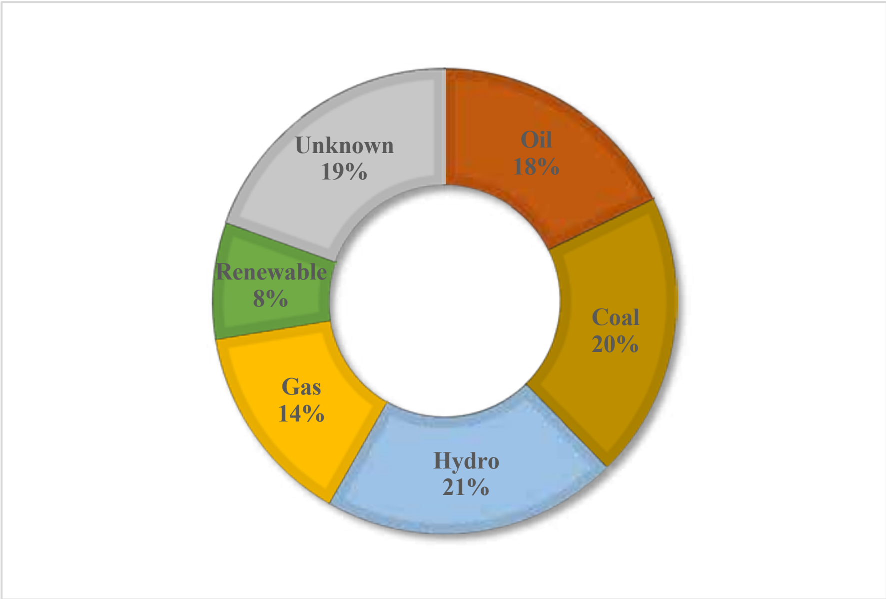
For instance, the Global Energy Interconnection Development and Cooperation Organization (GEIDCO) was launched in 2016 to serve as a conduit for a well-integrated energy system to realize the production, transmission and utilization of affordable energy globally, so as to tackle the challenges of energy shortage and geographical imbalance. Recent efforts focusing on feeding-in and transmission technologies and mechanisms for clean energy also demonstrate its commitment and potential in helping tackle climate change and environmental pollution. For instance, considering the intersection of "Smart Grid + Ultra-High Voltage (UHV) Transmission + Clean Energy" as the essence of global energy connectivity, GEIDCO facilitates scaling up renewables and making modern energy technologies accessible to all by promoting joint actions in trans-border infrastructure network connectivity along the Belt and Road.

In April 2019, the Belt and Road Energy Partnership (BREP) was officially established with 30 participating countries including Venezuela, Turkey and Iraq, and five observer countries.[76] According to the *Cooperation Principles and Concrete Actions of the BREP* (2019), participating countries would strengthen infrastructure connectivity, enhance energy investment, and promote cooperation in clean energy, energy efficiency, energy technology innovation and dissemination, capacity-building and personnel-training. Specifically, the BREP would provide platforms for bilateral and multilateral project cooperation and technology exchange in renewable energy, intelligent energy systems, clean use of fossil fuel and distributed energy, among others, in reciprocal, fair, transparent and market-based exchanges.[77]

75 Global Energy Interconnection Development and Cooperation Organization (2019). Development report on global energy interconnection for promoting the Belt and Road. Retrieved from https://img1.nengapp.com/tech/ydyl/fzbg_en.html.
76 Belt and Road Energy Cooperation (2019, April 25). The Belt and Road energy partnership (BREP) was officially established in Beijing. Retrieved from https://bremc.obor.nea.gov.cn/showOneNews?nd=17.
77 Belt and Road Energy Cooperation (2019). Cooperation principles and concrete actions of the Belt and Road energy partnership (BREP). Retrieved from http://obor.nea.gov.cn/detail/8210.html.

A series of energy projects have been launched since the BRI was proposed. From 2013 to the first quarter of 2020, among energy investments and construction contracts along the Belt and Road, 52% were devoted to fossil fuels — with coal representing 20% of the total share, oil 18% and gas 14%, while the rest was composed of hydropower projects (21%), other renewables (8%) and unspecified sources (19%), as shown in Figure 2.3.

Figure 2.3 China's investment and construction contracts in the energy sector along the Belt and Road, 2013-2020 (Q1)



Source: AEI[78]

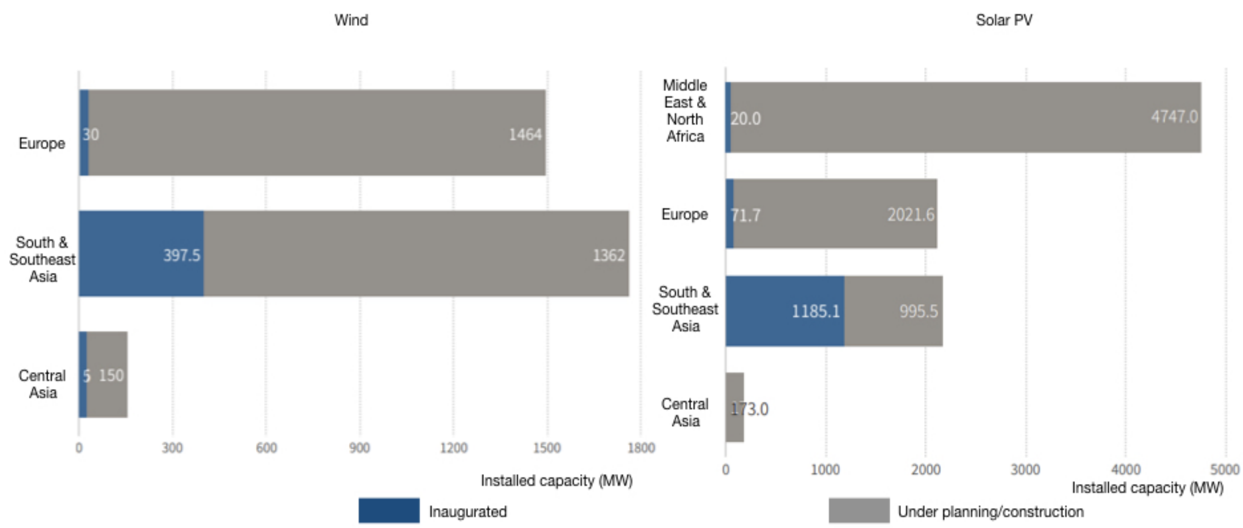
This composition of energy investment and construction contracts calls for more efforts in fostering low-carbon development in the energy sector along the Belt and Road. These are further complicated by the need to improve policy implementation and governance at various levels. Especially for developing countries, the low-carbon transition in the energy sector requires proper handling of potential social and political risks, including those that might increase the vulnerability of households facing a high or fluctuating price of electricity. Tackling existing barriers and environmental externalities requires not only foresight-based planning, but also concrete,

78 The American Enterprise Institute and the Heritage Foundation (n.d.). China global investment tracker. Retrieved from https://www.aei.org/china-global-investment-tracker.

actionable measures that take into account current and potential challenges at sectoral, local, national and global levels.

The past decade has witnessed a gradual shift towards a low-carbon transition along the Belt and Road. In renewables investment, from 2014 to 2018, the projected installed capacity of solar PV and wind projects invested under the BRI reached 12.6 GW.[79] Among them, solar PV projects of 1,277 MW and wind capacity of 433 MW have already been installed, with the rest under planning or construction. As shown in Figure 2.4, geographically the majority of installed wind power (80%) and solar PV (93%) equity investment projects of Chinese companies in BRI partner countries are located in South and Southeast Asia.

Figure 2.4 Geographic distribution of wind and solar PV projects under the BRI (2014-2018)



Source: Greenpeace & Sichuan Cyclic Economy Research Center[80]

The inauguration of these wind power and solar PV projects in BRI countries, including those under planning and construction, can lead to CO_2 emissions reduction of 15 megatonnes[81] each year (or 375 megatonnes in total over the 25-year expected lifespan of these projects). A 2018

79 Greenpeace and Sichuan Province Cyclic Economy Center (2019). " '一带一路'后中国企业风电、光伏海外股权投资趋势分析" [Analysis on the trend of Chinese enterprises' overseas equity investment in wind power and solar PV after the Belt and Road Initiative] (link in Chinese, see references).
80 Ibid.
81 1 megatonne is equal to 1 million tonnes.

study from the journal *China & World Economy* finds that the investment potential of solar and wind together represents 71% of the investment opportunities expected by the Nationally Determined Contributions (NDCs),[82] and from a technology perspective, solar PV is by now the most widely used renewable technology in the NDCs. Given China's technological advantage, the window of investment opportunity is especially compelling in the case of solar PV. Such investment and technological cooperation, together with BRI cooperation on other fronts such as policy coordination and facilities interconnectivity, would help BRI partner countries in their efforts to fulfil NDCs and advance towards low-carbon prospects.[83]

Table 2.2, compiling data from the 138 BRI partner countries that have signed cooperation agreements/MoUs with China on BRI cooperation by January 2020, illustrates the average levels on carbon emissions, electricity infrastructure demand, and solar PV potential of BRI partner countries in the following six main regions. It also compares these data with the average of all 138 partner countries and of the world (for full dataset, see Appendix I).

Table 2.2 Key indicators on electricity and low-carbon development of BRI partner countries by region

Average of BRI partner countries by region	CO_2 emissions per capita, 2016 (metric tons)	Access to electricity, 2018 (% of population)	Practical potential of PV output, 2019 (kWh/kWp/day)
East Asia & Pacific	3.91	91.34	3.94
South Asia	1.04	91.41	4.38
Europe & Central Asia	5.43	99.98	3.62
Latin America & Caribbean	4.59	98.57	4.43
Middle East & North Africa	10.55	93.48	4.94
Sub-Saharan Africa	0.98	51.00	4.49
138 BRI partner country average	4.26	83.80	4.22
World average	4.56	89.60	4.19

Source: World Bank[84]

82 Cabré, M., Gallagher, K.P. and Li, Z. (2018). Renewable energy: the trillion dollar opportunity for Chinese overseas investment. *China & World Economy,* 26: 27-49. Retrieved from https://onlinelibrary.wiley.com/doi/abs/10.1111/cwe.12260.
83 Ibid.
84 Word Bank (n.d.). World Bank Open Data. Retrieved from https://data.worldbank.org/; World Bank and the International Finance Corporation (n.d.) Global Solar Atlas. Retrieved from https://globalsolaratlas.info.

The BRI's potential in boosting low-carbon development is evident from Table 2.2. The average of all BRI partner countries in terms of carbon emissions is lower than the world average, apart from two regions –Europe & Central Asia and the Middle East & North Africa– that emit more carbon than the world average. Meanwhile, BRI partner countries on average have less access to electricity than the world average. Especially in Sub-Saharan Africa, countries' demand for electricity infrastructure is high. Taking into account emissions patterns and electricity infrastructure demands, the fact that BRI partner countries have a practical potential for solar PV output higher than the world average, especially in the Middle East & North Africa and Sub-Saharan Africa, indicates the considerable potential for low-carbon development along the Belt and Road. But as seen in Table 2.1, performance in these indicators is unbalanced, not only among regions but also within regions, and thus each country's specific characteristics and resource endowments need to be taken into consideration for low-carbon planning and investment.

Beyond solar PV and wind, low-carbon development along the Belt and Road covers a variety of sectors and will boost the emergence of an entire green industrial chain, encompassing low-carbon design, research and development, procurement, manufacturing, logistics, sales, services, consumption and recycling. In this process, low-carbon technological breakthroughs will be the key driving force, leading up to the upgrading of various areas, such as energy storage, electric vehicles, smart grid and smart community. Under the guidance of government agencies and responding to appropriate price signals, close cooperation among participants involved in the entire low-carbon industrial chain, including equipment suppliers, network operators and customers, will be key to maximizing resource utility, exploring brand-new business models, shaping win-win industrial patterns and realizing comprehensive social, environmental and economic benefits.

2.2 Key pathways and experience of China's low-carbon energy transition, and its prospect and potential for boosting global low-carbon development

China has considerable experience developing low-carbon technologies in the energy sector, with its state companies registering important success stories overseas. This progress has been bolstered by various supportive policies in the electricity sector that have allowed China to move forward towards low-carbon development.

2.2.1 Commitments and development of China's low-carbon energy transition and its impact globally

China's own development and domestic policies showcase the necessity, concrete measures, and positive outcomes of making strong efforts towards a low-carbon economy. Over the past decades of implementing low-carbon policies and encouraging technological innovations, China has significantly raised its investments in renewables, in particular in electricity production, setting the stage for a low-carbon oriented scenario.

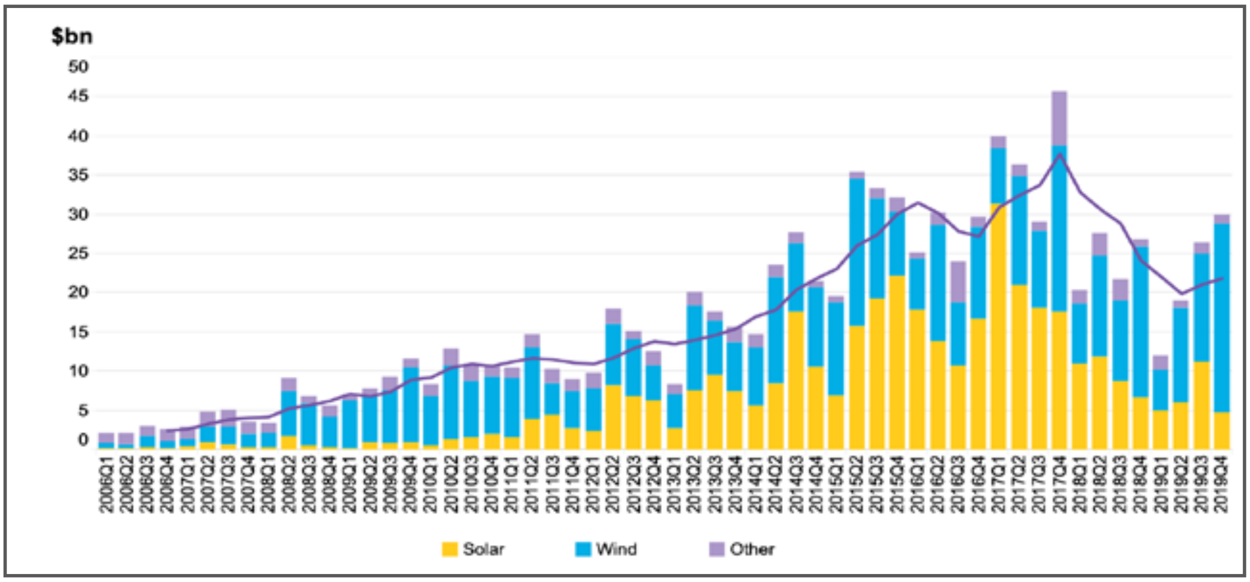
Data-informed evidence has showcased the progress of reducing carbon intensity in China. In 2018, the carbon intensity of China's GDP[85] dropped by 45.8% compared to 2005, showing a steady decline over the past few years.[86] This means achieving an internationally committed target two years ahead of schedule – China committed to reduce the carbon intensity of GDP by 40-45% compared to 2005 by 2020, at the margins of the 15th Conference of the Parties (COP 15) to the UNFCCC[87] in 2009.

Higher deployment of renewable energy generation, including renewable-sourced electricity production, is an important factor driving the decline of carbon intensity in China. The use of renewables (hydro, solar and wind) has made notable progress in China, as they only represented 1% of total primary energy supply in 1990, but that ratio reached 6% in 2017.[88] As the number one investor in the sector globally, China's variable renewable energy supply (wind, solar – not including hydropower) in quantity exceeded 70 megatonnes of oil equivalent (Mtoe) in 2017, four times more than in 2010, and more than 2,000 times higher than in 1990. [89] By the end of 2018, renewable energy generated 1.9 terawatt-hours of electricity in China, accounting for 26.7% of total electricity generation.[90]

85 Carbon emissions per unit of GDP.
86 Ministry of Ecology and Environment of the People's Republic of China (2019). "中国应对气候变化的政策与行动 2019 年度报告" [Annual report on policies and actions to address climate change (2019).] (link in Chinese, see references).
87 National Business Daily (2009, November 27). "中国承诺：到2020年碳减排40%~45%" [Commitment from China: reducing carbon intensity by 40% - 45% by 2020] (link in Chinese, see references).
88 International Energy Agency (2019). Data and statistics. Retrieved from https://www.iea.org/data-and-statistics?country=CHINAREG&fuel=Energy%20supply&indicator=Total%20primary%20energy%20supply%20(TPES)%20by%20source.
89 Ibid.
90 Ministry of Ecology and Environment of the People's Republic of China (2019). "中国应对气候变化的政策与行动 2019 年度报告" [Annual report on policies and actions to address climate change (2019)] (link in Chinese, see references).

The increase of renewables in total energy supply, consumption, and electricity production was directly driven by the increasing installed capacity and investment in the clean energy sectors. From 2017 to 2019, China's installed renewable energy capacity by sector went from over 340 GW to 356 GW for hydropower, 36 GW to 49 GW for nuclear power, 130 GW to 205 GW for grid-connected solar power, and from 164 GW to 210 GW grid-connected wind power.[91] China is also the world's largest investor in renewables, having invested US$83.4 billion in 2019, while seeing a 10% rise in wind investment to US$55 billion in the same year.[92] As Figure 2.5 shows, quarterly new investment in clean energy in China has been steadily increasing from 2006 to 2019 despite fluctuations in 2018.

Figure 2.5 Quarterly new investment in clean energy in China, by sector (2006-2019)



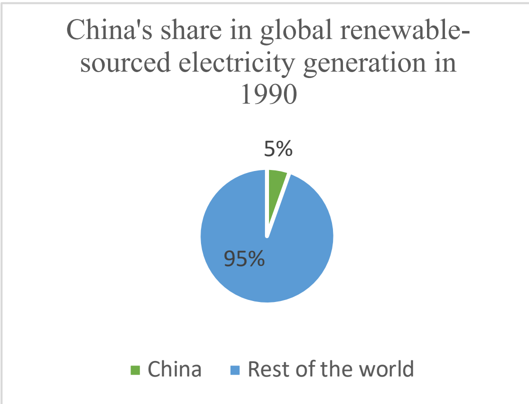
Source: BNEF[93]

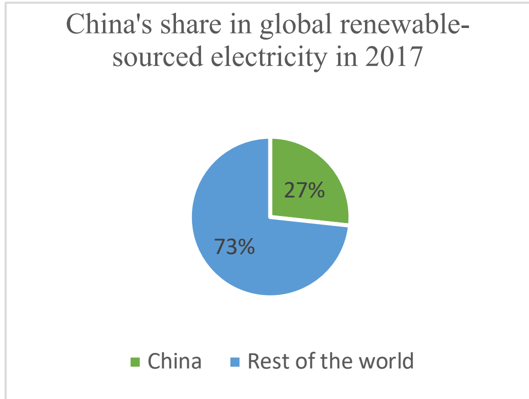
The scale and reach of China's energy sector also convey the potential of China's energy structure to impact the composition of overall energy supply and electricity generation in the world. The increasing renewable energy instalment and investment in China over the years has global

91 National Energy Administration (2020). "国家能源局发布 2019 年全国电力工业统计数据" [National Energy Administration releases 2019 national power industry statistics] (link in Chinese, see references).
National Energy Administration (2017). "2017 年全国电力工业统计数据" [2017 China national power industry statistics] (link in Chinese, see references).
92 Bloomberg New Energy Finance (2020). Clean energy investment trends in 2019. Retrieved from https://data.bloomberglp.com/professional/sites/24/BloombergNEF-Clean-Energy-Investment-Trends-2019.pdf.
93 Ibid.

implications. In terms of total primary energy supply, China has contributed 70% of the worldwide rise in hydropower and 37% in solar and renewables between 2010 and 2017.[94] Regarding electricity generation, as Figure 2.6 shows, China's share in global renewable-sourced electricity generation has increased from 5% to 27% from 1990 to 2017. These increases illustrate not only the rate of progress but also the rising impact that China's energy structure composition has on a global scale.

Figure 2.6 China's share in global renewable-sourced electricity generation (1990-2017)





Source: Caculated based on data from IEA[95]

While the increase of renewables has been promising, the existing utilization of carbon-intensive energy in both the world and in China also highlights the necessity of intensifying the energy sector's low-carbon transition. This would enable renewables to increase their share in overall total primary energy supply (TPES) – a goal that has proven elusive both globally and in China over the past nearly three decades. Global total energy supply has risen steadily from 8 to 13 gigatonnes of oil equivalent (Gtoe) from 1990 to 2018 globally. Retaining a leading role in supplying energy in the world and in China, fossil fuels (coal, oil and gas) represent 81% of worldwide TPES, the same proportion as in 1990.[96] In fact, the share of fossil fuels in TPES in China stood at 89% in 2017, up from 76% in 1990. Among these fossil fuels, coal remains

94 International Energy Agency (2020). TPES by source in the world and in China. Data and Statistics. Retrieved from https://www.iea.org/data-and-statistics?country=WORLD&fuel=Energy%20supply&indicator=Total%20primary%20energy%20supply%20(TPES)%20by%20source.
95 International Energy Agency (2020). Electricity generation by source in the world and in China. Data and Statistics. Retrieved from https://www.iea.org/data-and-statistics?country=WORLD&fuel=Energy%20supply&indicator=Electricity%20generation%20by%20source.
96 International Energy Agency (2020). TPES by source in the world. Data and Statistics. Retrieved from https://www.iea.org/data-and-statistics?country=WORLD&fuel=Energy%20supply&indicator=Total%20primary%20energy%20supply%20(TPES)%20by%20source.

dominant, accounting for 64% of the total primary energy supply in 2017.[97] As for electricity generation, fossil fuels still dominate globally, with coal and gas generating a total of 62% electricity worldwide. The proportion of coal-generated electricity in China was 68% in 2017.[98] Lowering carbon emissions in the energy sector will be an important component of realizing China's low-carbon aspirations. During the 75th session of the United Nations General Assembly in September 2020, China has vowed to reach carbon neutrality before 2060, an important milestone showing its strong commitment to a low-carbon transition.

Box 2.1 China commits to scale up its low-carbon transition in the post-COVID era

At the general debate of the 75th session of the United Nations General Assembly in September 2020, China demonstrated its commitment to pursuing "innovative, coordinated, green, and open development" and to "achieving a green recovery of the world economy in the post-COVID era". [99]

In taking decisive steps to honour the Paris Agreement, China has promised to "scale up its Intended Nationally Determined Contributions by adopting more vigorous policies and measures". Acknowledging the necessity of "launching a green revolution and moving faster to create a green way of development and life", China also set the goal of "having CO_2 emissions peak before 2030 and achieving carbon neutrality before 2060".

China showed its continued positive attitude towards "providing more global public goods" when it comes to global governance. Respecting the differences of countries and addressing them through consultation and dialogue are important principles the country follows.

What China promises, especially in reaching carbon neutrality before 2060, are important milestones in global low-carbon development, given the large impact of China economically and environmentally. More importantly, the knowledge, technology, and business models developed during this transition can have a large spill-over effect to other developing countries through international development cooperation and the BRI.

97 International Energy Agency (2020). TPES by source in China. Data and Statistics. Retrieved from https://www.iea.org/data-and-statistics?country=CHINAREG&fuel=Energy%20supply&indicator=Total%20primary%20energy%20supply%20(TPES)%20by%20source.
98 Ibid.
99 CGTN (2020, September 23). Full text: Xi Jinping's speech at the general debate of the 75th session of the United Nations General Assembly. Retrieved from https://news.cgtn.com/news/2020-09-23/Full-text-Xi-Jinping-s-speech-at-General-Debate-of-UNGA-U07X2dn8Ag/index.html.

The carbon neutrality goal of China also sets a call for more ambitious plans and action among stakeholders to accelerate the low-carbon transition in various sectors, including energy and the power sector. As a developing country with increasing energy demand, China would need to build on its current momentum of developing more technological breakthroughs and channelling greener finance flows to lower carbon emissions while keeping the power system stable, as the analysis in 2.2.1 indicates.

By the end of 2020, at least 36 countries[100] and the European Union have set a carbon-neutral goal in legislation, policy documents, or statements.

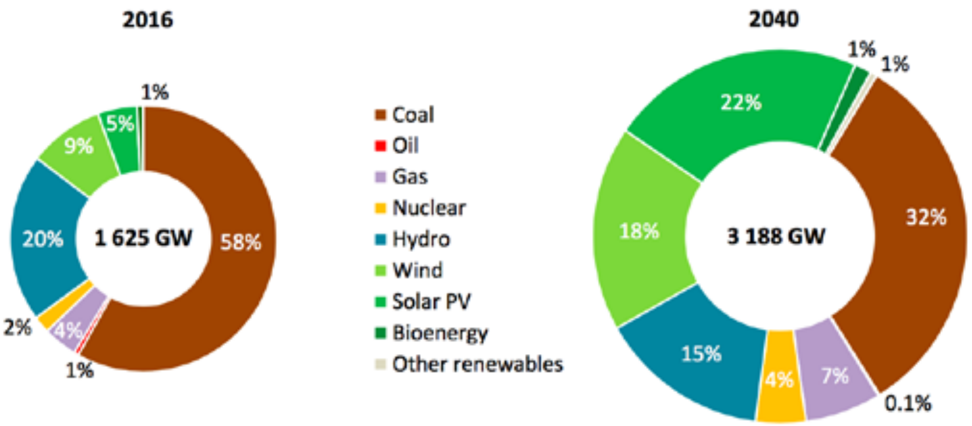
2.2.2 Pathways of China's low-carbon energy transition and prospects of its application along the Belt and Road

Considering the rapidly expanding renewable energy and the existing electricity generation structure, it is evident that the experience and lessons from China are worth distilling for global low-carbon development. As Figure 2.7 shows, while the proportion of renewables in installed power generation already stands at around 35%, China has significant potential to switch to cleaner sources of power by 2040.[101] This projection is based on the current pace and measures taken by China on scaling up low-carbon development, and progress may accelerate as practical steps are taken to implement China's newly announced net zero carbon pledge. Despite some existing gaps in terms of the proportion of fossil fuels versus renewables, the fast expansion of renewable energy installation and investment in China implies a possibility of scaling up the deployment of low-carbon energy with various incentives and supportive measures. Further supportive policy actions to influence consumption, production and investment decisions in China can contribute to tackling the challenges not only in China but also globally.

100 Including Argentina, Austria, Brazil, Bhutan, Canada, Chile, China, Colombia, Costa Rica, Denmark, Fiji, Finland, France, Germany, Grenada, Hungary, Iceland, Ireland, Japan, Maldives, Marshall Islands, Nepal, New Zealand, Norway, Panama, Portugal, Singapore, Slovakia, South Africa, South Korea, Spain, Sweden, Switzerland, United Kingdom, United States, Uruguay. For more information, see Climate Home News (2020, September 17). Which countries have a net zero carbon goal? Retrieved from https://www.climatechangenews.com/2020/09/17/countries-net-zero-climate-goal/.

101 International Energy Agency (2017). World energy outlook 2017. Retrieved from https://www.iea.org/reports/world-energy-outlook-2017.

Figure 2.7 Installed power generation capacity in China (2016 and 2040 projection)



Source: IEA[102]

The overarching regulation and planning at national strategic levels have emphasized the cutting-edge role of renewables in the national energy transition. This was demonstrated by the high level of attention given to the renewable sectors in national long-term planning, strategies and legislation related to the energy sector. The attainments of these goals and the implementation of these tasks are further facilitated by specific on-the-ground policies and guidelines in these aspects. Below are some of the representative overarching regulations and on-the-ground action plans.

Table 2.3 Main policies to boost the low-carbon energy transition in China

Policy	Target or measures set
13th Five-Year Plan for Economic and Social Development (2016-2020)	Carbon emissions to reduce by 18% per unit of GDP, a 1% improvement compared with the 12th Five-Year Plan period; replace small and medium-sized coal plants in certain areas with renewable projects; support the increase of renewable energy capacity and connectivity; grow energy storage, smart grids, and ultra-high-voltage electricity transmission technologies.
The 13th Five-Year Plan for Renewable Energy Development (2016-2020)	Non-fossil energy targeted to account for 15% (2020) and 20% (2030) of primary energy consumption; aims for 680 GW of installed capacity of renewables, producing 1.9 TWh, or 27% of total electricity generation by 2020.

102 Ibid. This is a projection according to the New Policies Scenario which IEA defines as “where existing policies and announced intentions might lead the energy system, in the anticipation that this will inform decision- makers as they seek to improve on this outcome”.

Energy Development Strategy Action Plan (2014-2020)	Annual coal consumption to be held below 4.2 gigatonnes through 2020, and the proportion of coal in total energy consumption below 62%; the share of non-fossil fuels in the primary energy is targeted at 15% by 2020, up from 9.8% in 2013.
Energy Production and Consumption Transition Strategy (2016-2030)	Targets to reach 20% of non-fossil fuel in total energy consumption by 2030 and fill new energy demand mainly with clean energy between 2021-2030; targets to reduce carbon intensity of GDP by 60%-65% by 2030 compared with 2005; sets the goal that non-fossil fuels shall account for more than half of total energy consumption by 2050.
13th Five-Year Plan for Electricity Development (2016-2020)	Emphasized strengthening the grid through Ultra-High Voltage (UHV) transmission lines and smart grid. Pilots were later approved and implemented for over 60 million meters for 377 million network users, 27 pilot new energy microgrid projects of CNY 22 billion total investment; and 23 multi-energy complementary integration and optimization projects of CNY 19.6 billion total investment.[103]
Action Plan for the Development of the Smart Solar PV Sector (2018-2020)	Identified four main areas to scale up solar PV: promoting intelligent manufacturing of basic solar PV materials for the whole production cycle, upgrading the technological supply capacity of smart solar PV products, developing best-practice demonstration projects, and improving the sectoral development business environment.
The Clean Energy Consumption Plan (2018-2020)	Tackles the geographical imbalance of renewable energy production and consumption; sets measures to achieve the target of boosting utilization efficiency of wind, solar and hydropower at around 95%, striving to keep the wind and solar curtailment rate around or below 5%.
Law on the Prevention and Control of Atmospheric Pollution	To align with the goals set out in the above-mentioned documents, it provides that China should scale up clean energy and promote reduced and clean use of coal throughout all stages, obliging local governments to ban low-quality coal for residential use (Chapter IV, Section 1).

A series of means and tasks for achieving low-carbon energy development are emphasized by these strategies and plans, including but not limited to pushing forward technology innovation, improving investment and finance services to stakeholders, as well as building capacity in constructing infrastructure, balancing the electricity system, advancing technological innovation,

103 Swedish Smart Grid (2019). Smart grid market analysis: China. Retrieved from http://swedishsmartgrid.se/globalassets/publikationer/china_marketanalysis21mars.pdf.

and improving public service and governance. Selective reforms and marketization are also conducted in fields including electricity generation and transmission.

Electricity market reforms to engage multiple public and private investors were initiated as early as 1985, and the latest round was started in 2015. [104] Capacity development at all levels was also addressed to ensure a smooth transition and reduce socioeconomic risks. The key policy instruments include: promoting wholesale electricity pricing mechanisms, refining electricity trading systems and platforms, steadily reforming the electricity sales-side and distribution, enhancing fair access[105] to the electricity grid and electricity transmission and reinforcing an integrated electricity planning and supervising system.[106] In 2014, an electricity transmission and distribution reform pilot was launched in Shenzhen, which was expanded to the entire nation in September 2020.[107] With the National Development and Reform Commission (NDRC) setting transmission and distribution tariffs independently based on grids operators' costs to avoid opaque pricing, this reform can incentivize feed-in to the grid from renewable sources, fostering electricity supply integration.

With supportive policies and reforms, market efficiency, technological breakthrough, and innovative approaches are supported in the renewable sectors in China, as Box 2.2 shows.

Box 2.2 China's increasing role in renewable energy generation

China is developing a leading position in many of the technologies and approaches necessary to support the integration of high levels of variable renewable electricity generation. In particular:

104 Pollitt, M., Yang, C. H., & Chen, H. (2017). Reforming the Chinese electricity supply sector: lessons from international experience. Retrieved from https://www.eprg.group.cam.ac.uk/wp-content/uploads/2017/03/1704-Text.pdf.

105 It means fair access to the power grid and transmission of power from renewable energy sources. According to the 13th Five-Year Plan for Energy (launched in 2016), the National Energy Agency stipulates "guaranteed minimum full-load hours" for provinces. Grids enterprises must sign a contract for the purchase of these amounts each year and must award highest priority dispatch rights to these projects. Renewable power projects will receive the local feed-in tariff, or the price agreed on in the tender for the project.

106 China's Government Portal (2014). "李克强：要像对贫困宣战一样 坚决向污染宣战" [Li Keqiang: We will resolutely declare war against pollution as we declared war against poverty] (link in Chinese, see references).

107 State Council Information Office of China (2020). "国家发改委就输配电定价办法答问" [National Development and Reform Commission's response to the electricity price setting]. (link in Chinese, see references).

Distributed Energy: The capacity of distributed energy resources (DER) reached 60 GW in China in 2018, out of which 50 GW stems from solar PV.[108] Total distributed energy resources account for around 3% of total installed power capacity in China.[109]

Multi-energy projects: China has initiated a program of 23 demonstration projects, using integrated energy supply systems for end users.[110] One of them includes a 2.8 MW "1+3" project in Gui'an, Guizhou Province, which combines natural gas with water-source heat pump, solar thermal and compressed-air-energy storage.[111] The integration of different energy sources provides a flexible solution for meeting the energy needs of commercial and industrial complexes.

Digitalization: China is seeing the early application of business models involving real-time analysis of vast amounts of data for various applications.[112] Innovative virtual power plants have been implemented in China, including a large-scale project in Hebei Province in December 2019. This project relies on the Internet of Things and has a clean power reserve of around 20 GW.[113]

Demand-side response: Whilst the demand-side response has been relatively slow to develop in China, recent moves adopting more flexible policies, such as the adoption of time-varying and sectorally differentiated power prices, are encouraging more flexible consumption practices.[114]

Electricity storage: At the end of 2018, there was more than 1 GW of operational battery electricity storage with 683 MW built in 2018 alone.[115]

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108 Li, Q. et al. (2020). "分布式能源规模化发展前景及关键问题" [Outlook and critical issues of large-scale development on distributed energy resources]. *Distributed Energy*, 5 (2): 1-7 (link in Chinese, see references).
109 Ibid.
110 National Energy Agency (2016, July 7). "国家发展改革委 国家能源局关于推进多能互补集成优化示范工程建设的实施意见" [National Development and Reform Commission. National Energy Administration's opinions on promoting the construction of multi-energy complementary integration and optimization demonstration projects] (link in Chinese, see references).
111 People Online (2017, April 7). "贵安新区建设国内首座"1+3"多能互补分布式智慧能源站" [Gui'an New District builds the first "1+3" multi-energy complementary distributed smart energy station in China] (link in Chinese, see references).
112 International Energy Agency (2019). China power system transformation: assessing the benefit of optimized operations and advanced flexibility options. Retrieved from https://www.iea.org/reports/china-power-system-transformation.
113 People Online (2019, December 13). China's first virtual power plant put into operation. Retrieved from http://en.people.cn/n3/2019/1213/c90000-9640526.html.
114 International Energy Agency (2019). China power system transformation: assessing the benefit of optimized operations and advanced flexibility options. Retrieved https://www.iea.org/reports/china-power-system-transformation.
115 China Energy Storage Alliance (2019). "储能产业研究白皮书" [Energy storage white paper] (link in Chinese, see references).

Electric vehicles (EV): In 2020, China plans to reach 2 million EV production capacity.[116] Smart charging of these vehicles presents a valuable opportunity to improve power system flexibility.[117]

These "building blocks" contribute to the development of low-carbon technologies, such as solar PV, power storage, digitally enabled demand-side response, and electric vehicles.[118] They also further support the growth in China's manufacturing, digital communications and software industries.

As the analysis indicates, policy support has incentivized the advancement and scaling up of low-carbon energy technologies in China. At the same time, the diversifying finance flows and the continuing capacity development enabled by these policies as well as multi-stakeholder engagement are also indispensable factors for low-carbon energy development in China. These are especially important for laying a solid foundation for the upgrading of low-carbon technologies and subsequent scaling up. At the same time, the analysis in this Chapter also demonstrates the different scales and capacities of BRI partner countries in developing low-carbon energy. Household accessibility and affordability to electricity may be undermined in some cases, if shortfalls in policy support, technological spill-overs, financial resources, and capacity are not tackled.[119] This further highlights the importance of this report in analysing the challenges and advising solutions in these aspects, as the following best practices and the three complementary means to facilitate a low-carbon transition put forward in the following chapters further demonstrate.

116 Ministry of Industry and Information Technology of the People's Republic of China (2018). "工业和信息化部关于印发坚决打好工业和通信业污染防治攻坚战三年行动计划的通知" [Notice of the Ministry of Industry and Information Technology on printing and distributing the Three-year Action Plan for Resolutely Fighting the Pollution of the Industry and Communication Industry] (link in Chinese, see references).

117 International Energy Agency (2019). China power system transformation: assessing the benefit of optimized operations and advanced flexibility options. Retrieved from https://www.iea.org/reports/china-power-system-transformation.

118 Ibid.

119 United Nations Department of Economic and Social Affairs (2019). Accelerating SDG 7 achievement: SDG 7 policy briefs in support of the High-Level Political Forum 2019. Retrieved from https://sustainabledevelopment.un.org/content/documents/22877UN_FINAL_ONLINE_20190523.pdf.

2.2.3 Best practices in enhancing overseas social responsibility and making power transmission technology breakthrough in China's low-carbon energy transition

With the supportive overarching strategies and the encouraging policies for low-carbon development especially in the energy and power sectors, the best practices of Chinese firms and technologies have emerged with inspiring initial results.

(i) Best practices of private renewable-focused Chinese firms

In 2020, China could boast 27 companies among the biggest 200 carbon clean companies.[120] Ranking among the top 100, the Chinese private companies LONGi, JinkoSolar and Goldwind are worth mentioning, specifically their renewable energy technologies and commitment to corporate social responsibility.

LONGi Solar has developed programs to contribute to local green development and poverty alleviation through its technologies. The company is a world leader in manufacturing mono-crystalline silicon modules and wafers. It also specializes in the construction of both large-scale and distributed solar power units, and the development of off-grid PV systems and intelligent micro-grid systems. It has established branches in the US, Japan, and Europe, and production bases in Malaysia and India. In the city of Kuching in Malaysia, LONGi has achieved full vertical integration of its solar facilities. In 2019, LONGi Solar was appointed to operate a new 1 GW monocrystalline solar cell manufacturing plant in the Shama Jaya Free Industrial Park of Kuching.[121] This resulted in the creation of more than 2,000 local jobs. In India, jointly with JBM Group, a local leader in solar energy generation, LONGi built a solar plant of 600 acres with a 135 MW capacity in Maharashtra State, which is now the largest solar plant in the State. The plant was connected to the grid in June 2018 and has generated cumulative power of about 280 million kWh from June 2018 to November 2019. It is now providing the residents with jobs and stable access to clean electricity.[122]

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120 The ranking entitled "Carbon Clean 200" is released by the non-profit foundation As You Sow. Chinese companies were third in number behind the US and Japan. However, they ranked first in number in Q1 2019. As You Sow (2020). Carbon clean 200™: investing in a clean energy future. Retrieved from https://www.asyousow.org/report-page/2020-clean200.

121 Osborne, M. (2019, February 25). LONGi to build new 1GW mono solar cell plant in Malaysia. *PV-Tech*. Retrieved from https://www.pv-tech.org/news/longi-to-build-new-1gw-mono-solar-cell-plant-in-malaysia.

122 LONGi Solar (2019, November 11). JBM Group exclusively selected LONGi high efficiency monocrystalline modules for their 135MW Maharashtra project in India. Retrieved from https://en.longi-solar.com/home/events/press_detail/id/168_JBM_Group_exclusively_selected_LONGi_high_efficiency_monocrystalline_modules_for_their_13

JinkoSolar has been successfully leveraging international partnerships to start building the biggest solar power plant in the world. The world's largest solar panel producer,[123] JinkoSolar owns 7 production facilities and 14 overseas subsidiaries including in BRI countries.[124] In the United Arab Emirates, a project led by JinkoSolar, the Japanese firm Marubeni Corporation and the Abu Dhabi Water & Electricity Authority, is expected to construct the world's biggest solar plant, providing renewable electricity to 90,000 people. Started in 2019, the completion of the project will reduce CO_2 emissions by 1 megatonne per year with its 1.2 GW capacity.[125]

Last but not least, Goldwind has provided service solutions along the Belt and Road in the wind industry to improve accessibility to operations and maintenances. Headquartered in Xinjiang, the firm has participated in China's shift towards sustainable development. Its business scope involves production of wind turbines, wind turbine components, wind power generation sets, as well as operation and development of wind farms. In 2018, Goldwind built service solution factories in Pakistan and Brazil and sent staff to China for training. These enabled local problem detection, testing, maintenance and renovation of wind turbines and systems.[126]

(ii) Ultra-High-Voltage Direct Current (UHV-DC) technology

UHV-DC is a high-efficiency electric power transmission technology for long-distance transmission.[127] Soaring electricity consumption and long distances between power generation facilities and densely populated provinces in China have motivated heavy investment in grid efficiency, where UHV-DC is a key investment area. Many UHV-DC lines in operation by the State Grid Corporation of China (SGCC) link China's western and eastern regions.[128] With these long-distance connections, electricity generated in the western provinces with abundant energy

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5MW_Maharashtra_project_in_India.html.
123 JinkoSolar (2019, March 22). JinkoSolar announces fourth quarter and full year 2018 financial results. Retrieved from http://ir.jinkosolar.com/news-releases/news-release-details/jinkosolar-announces-fourth-quarter-and-full-year-2018-financial.
124 JinkoSolar (2020). About JinkoSolar Holding Co., Ltd. Retrieved from https://www.jinkosolar.com/en/site/aboutus.
125 Bloomberg (2019, October 31). World's biggest solar plant starts in Abu Dhabi, JinkoSolar says. Retrieved from https://www.bloomberg.com/news/articles/2019-10-31/world-s-biggest-solar-plant-starts-in-abu-dhabi-jinkosolar-says.
126 Goldwind. (2019, April 12). Goldwind's overseas service solution factories completed and put into operation. Retrieved from http://www.goldwindglobal.com/news/focus-article.html?id=2279.
127 UHV-DC lines can complement AC technology as they enable longer transmission lines that bring power from faraway resources to high-demand areas, such as urban centres. Moreover, certain transmission lines can be hybridized with a single electricity pylon holding both AC and DC cables. International Renewable Energy Agency (2019). Supergrids. Innovation Landscape Brief. Retrieved from https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_Supergrids_2019.pdf?la=en&hash=4C6639C08B1BEC582B700609C6D3C3B2E126AE70.
128 State Grid Corporation of China (n.d.). Homepage. Retrieved from http://www.sgcc.com.cn/ywlm/index.shtml.

resources (primarily renewable energy) can be transmitted to eastern cities with high electricity demand.

UHV-DC is an important technological breakthrough for long-distance electricity transmission, in particular for renewable power generation. With uneven geographical distribution of energy resources in China, the UHV-DC for long-distance transmission can better boost energy supply by increasing power transfer efficiency and reducing energy loss. Compared to a high-voltage DC line of±500 kV/3GW, the electricity loss rate of ±800kV/8GW UHV-DC line is reduced from 6.94% per thousand km to 2.79% per thousand km and its transmission cost per kilowatt per thousand kilometres is reduced from CNY 2.16 to CNY 1.56. Transmission capacity is thus nearly doubled for a given corridor width. As well, operating UHV-DC lines enhances the stability of electricity supply as they help diversify supply sources, and are adapted to various complex geographical and meteorological conditions in China. The constructed UHV-DC projects in China have already been tested by extreme conditions such as high temperatures, freezing disasters and heavy loads.[129]

The dissemination of UHV-DC technology has benefited the transmission of renewable energy in China. The Xiangjiaba-Shanghai transmission line, which exports the electricity generated by Xiangjiaba hydropower plant from southwest China to one of the countries' biggest cities located in the east, is an example of how UHV-DC opens up the market for renewables by linking together renewable power generation facilities and the energy consumption centres. The technology of this SGCC-led project was supported by ABB, a Swiss-Swedish corporation. Covering a length of 1,907 km and with a rated capacity of 6.4 GW, the line has the maximum capacity to transmit up to 7.2 GW of power from Xiangjiaba, Sichuan to Shanghai.[130] Since its completion in July 2010, this line has delivered hydropower from Sichuan to Shanghai with a total of 93.9 TWh by July 8, 2015, meaning a reduction of 43 megatonnes of coal used, as well as a decrease of 34 kilotonnes of smoke, 212 kilotonnes of sulphur dioxide, 224 kilotonnes of nitrogen oxides, and 84.5 megatonnes of CO_2.[131]

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129 State Grid Corporation of China (2019). "中国特高压直流输电技术现状和发展方向" [Current situation and development direction on China's UHV-DC transmission technology] (link in Chinese, see references).
130 ABB (2010, July 19). ABB commissions world's longest and most powerful transmission link. Retrieved from https://new.abb.com/news/detail/12798/abb-commissions-worlds-longest-and-most-powerful-transmission-link.
131 International Energy (2015, July 7). 5th anniversary of Xiangjiaba-Shanghai ±800kV UHV-DC project. Retrieved from https://www.in-

The achievements in emissions reduction made by UHV-DC projects in China are remarkable: by the end of 2017, a total of 12 UHV-DC projects were built nationwide with a total annual transmission of more than 450 TWh, of which clean energy accounts for more than 80%. This is equivalent to an annual reduction of 170 megatonnes of standard coal consumption and 450 megatonnes of CO_2 emissions. These projects serve as an essential part of the "Action Plan for Air Pollution".[132] The latest milestone was SGCC's Zhangbei Renewable Energy Flexible DC Power Grid Test & Demonstration Project, completed in June 2020.

In fact, there is great potential for utilizing the technology for long-distance transmission of electricity in a number of BRI countries. For example, in 2014 and 2015, SGCC won the bid for the first- and second-stage of a UHV-DC ±800kV project in Brazil, which can serve as a window for the other BRI countries to understand the availability and applicability of such technology for boosting renewable energy integration.[133]

Some challenges remain on the path for the further technological development of UHV-DC. First, a new generation of synchronous condensers which can balance voltage fluctuations and offer additional short-circuit capacity[134] is needed for improved grid stability. As well, equipment problems still occur too frequently, requiring higher recovery capacity in case of malfunction or overload. There is also room for better managing and synergizing all stages of electricity transmission, and for promoting flexible DC technology (e.g., voltage source converters) at the end-user level. [135] It is also important to further consider possible environmental externalities such as ecosystem segmentation during grid planning and construction.

Despite the challenges, the advancement of such technologies, together with the policy support introduced in 2.2.2, illustrates the significant potential of scaling up renewables by relying on technological progress and knowledge exchanges along the Belt and Road. The enhanced technology sharing platform provided by the BRI can also help address remaining technical issues.

en.com/article/html/energy-2234725.shtml.

132 Xinhua. (2018, May 30). "我国特高压有望成'走出去'新名片" [UHV-DC could become a new business card of China] (link in Chinese, see references).

133 Xinhua. (2015, August 4). China's State Grid builds "electricity super highway" in Brazil. Retrieved from http://en.people.cn/business/n/2015/0804/c90778-8931240.html.

134 Short-circuit capacity refers to the capacity of a power system in remaining operational while a short-circuit fault occurs, by quickly cutting off the faulty part.

135 State Grid Corporation of China. (2019). "中国特高压直流输电技术现状和发展方向" [Current situation and development trends of China's UHV-DC transmission technology] (link in Chinese, see references).

In conclusion, the Belt and Road Initiative and China are set to play a leading role in the transition towards a low-carbon development path in many ways. The BRI has a strong vision for low-carbon development and can cater to the needs of different categories of countries, in particular in the energy and power sectors where strong synergies exist with climate change mitigation. At the same time, China is projected to have a significant impact on global markets, trade and investment flows, and attainment of SDGs. Projections through 2040 show that China's policy choices, import needs and investments propagated through the BRI will have a huge impact on global low-carbon development, as well as on energy trade and investment. [136]

136 International Energy Agency (2019). China power system transformation: assessing the benefit of optimized operations and advanced flexibility options. Retrieved from https://webstore.iea.org/china-power-system-transformation.

Part II Measures on paving the way for low-carbon development along the Belt and Road

Part I highlights that promoting ambitious, far-reaching, balanced and reasonable energy transition tailored to diversified national conditions is pivotal to achieving SDGs and mitigating climate and environmental degradation caused by human activities (see Chapter 1). This report highlights the BRI's great potential in advancing low-carbon development and Chinese enterprises' competitive advantages in energy and power sectors (see Chapter 2). Part II provides three key pathways for low-carbon development along the Belt and Road, including clean technology development (Chapter 3), sustainable investment and financing (Chapter 4) as well as capacity-building (Chapter 5).

Chapter 3 Boosting innovation, development and transfer of clean energy technologies along the Belt and Road

This chapter focuses on energy and power sectors, and discusses the disparity and diversity of low-carbon transition globally and along the Belt and Road, based on analysis of low-carbon energy technologies, their environmental impacts and commercial scales, as well as natural resource endowments in countries and territories along the Belt and Road. Following the principle of formulating technical solutions tailored to contextualized conditions, this chapter provides insightful measures on advancing low-carbon development at technological levels, including strategic power planning, integrated development of power generation, transmission, load and storage, trans national power system interconnectivity both physically and digitally, demand-side management, thermal power plants' retrofitting for higher flexibility, as well as effective complementarity of distributed and centralized energy generation.

Section 1 of Chapter 3 analyses BRI partner countries' diversity in energy and power development. Based on mapping major renewable energy types and low-carbon technologies, this section compares their cost competitiveness, environmental impact, geographical availability, and the potential of promoting and developing them along the Belt and Road. Section 2 analyses the opportunities and challenges on facilitating clean energy development along the Belt and Road. Section 3 provides six concrete measures of boosting the innovation, development and transfer of clean energy technologies. Section 4 selects best practices of boosting low-carbon energy transition and development in countries at various development stages, including Madagascar, Vietnam, South Africa, Denmark and Uruguay.

3.1 Natural resource endowments and technological development on boosting low-carbon energy development in countries and territories along the Belt and Road

3.1.1 Disparity and diversity of energy consumption structure and electricity access ratio

The diversity in energy situations along the Belt and Road has an important role in their current and future low-carbon development pathways. Table 3.1 below maps out the diversity of 50 countries in terms of energy per capita, energy self-sufficiency, electricity access, electricity consumption per capita, renewable energy share in the power mix, fossil fuel energy share in energy consumption and the Human Development Index (HDI).

Along the Belt and Road, four main groups of countries can be identified in terms of achieving access to electricity and energy. The first group encompasses countries where full electricity access has not been achieved, typically below 90% of total population with some as low as 20%. These countries, such as Madagascar, Ethiopia, Zambia, Bangladesh and Myanmar, have very low energy use per capita and electricity consumption per capita. A second category of countries has made significant progress in terms of electricity access but has not yet reached a 100% access rate. In this group, off-grid and mini-grid facilities still play an important role as power supply is mostly decentralized. They typically enjoy higher energy use per capita and generally higher electricity consumption per capita than the first group. These include Lao PDR, Cambodia, Egypt, Philippines and Peru. The third group comprises countries such as Thailand, Ukraine, Chile, China and Mongolia that have full electricity access, but their energy use per capita is generally lower than 100 gigajoules (GJ) per capita and their HDI is lower than 0.8. Finally, the fourth group of countries has a very high level of development (higher than 0.8) such as Italy, United Arab Emirates (UAE), Singapore and New Zealand, with high electricity consumption per capita, high energy use per capita and full electricity access. This group also includes countries with high fossil fuel endowments that generally have the highest energy use per capita. Such a diversity of profiles along the Belt and Road brings specific challenges related to the extent and quality of electricity coverage, and high availability of energy.

Table 3.1 Energy and power among BRI partner countries

Countries	Energy use (TES) per capita (GJ, 2017)[137]	Energy self-sufficiency (%, 2017)[138]	Electricity access (% of population, 2018)	Electricity consumption per capita (kWh, 2017)[139]	HDI (2019)	Renewable energy output (% of total power generation, 2015)	Fossil-fuel energy consumption (% of total consumption, 2015)
World average	76.9	100.2	89.6	2,817	0.731	22.8	79.7
China	87.7	80.3	100.0	3,836	0.758	24.0	87.7
Southeast Asia							
Cambodia	21.2	58.4	91.6	423	0.581	46.4	30.6
Indonesia	37.7	192.7	98.5	927	0.707	10.7	66.1
Lao PDR	34.6	116.6	97.9	724	0.604	86.4	N/A
Malaysia	110.1	110.0	100	4,633	0.804	10.0	96.6
Myanmar	16.0	138.8	66.3	314	0.584	58.9	44.3
Philippines	22.1	47.3	94.9	742	0.712	25.4	62.4
Singapore	204.3	2.4	100.0	8,684	0.935	1.8	90.6
Thailand	83.7	54.5	100.0	2,684	0.765	8.5	79.8
Viet Nam	31.2	94.3	100.0	1,828	0.693	36.7	N/A
South Asia							
Afghanistan	3.5	67.0	98.7	127	0.496	86.1	N/A
Bangladesh	11.7	83.4	85.2	365	0.614	1.2	73.8
Pakistan	21.7	50.8	71.1	524	0.560	31.4	61.6
Sri Lanka	22.1	36.2	99.6	646	0.780	48.5	50.6
East Asia							
Mongolia	128.3	332.3	98.1	1,934	0.735	3.1	93.2
Central Asia							
Kazakhstan	183.2	220.6	100.0	3,822	0.817	8.9	99.2
Kyrgyzstan	26.7	54.3	100.0	1,821	0.674	85.2	75.5

137 Energy use (TES) per capita is calculated by dividing total energy supply by population. TES stands for total energy supply.
138 Self-sufficiency is calculated as the ratio between primary energy production and total energy supply, expressed in percentage.
139 Electricity consumption per capita is calculated by dividing electricity consumption by population.

Tajikistan	20.9	84.0	99.3	1,544	0.656	98.5	46.0
Uzbekistan	58.9	117.3	100.0	1,578	0.710	20.7	N/A
Middle East							
Iran	135.4	161.5	100.0	3,105	0.797	5.1	99.0
Iraq	65.9	392.0	99.9	1,003	0.689	373.0	96.0
Kuwait	383.0	436.8	100.0	10,270	0.808	0.0	93.7
Lebanon	54.1	2.1	100.0	3,190	0.730	2.6	97.6
Qatar	681.2	522.1	100.0	15,167	0.848	0.0	100.0
Saudi Arabia	271.6	303.5	100.0	8,358	0.857	0.0	100.0
Turkey	76.0	24.9	100.0	3,045	0.806	32.0	89.5
United Arab Emirates	323.6	318.6	100.0	12,260	0.866	0.2	86.1
Africa							
Egypt	41.1	85.2	100.0	1,554	0.700	826.0	97.9
Ethiopia	14.6	89.4	44.0	90	0.470	100.0	6.6
Ghana	10.9	164.9	82.4	420	0.596	50.9	52.5
Kenya	18.7	79.2	75.0	176	0.579	87.5	17.4
Madagascar	12.6	84.6	25.9	71	0.521	54.6	N/A
Morocco	23.9	10.3	100.0	894	0.676	14.3	88.5
Nigeria	34.4	158.4	56.5	135	0.534	18.2	18.9
South Africa	104.2	112.6	91.2	3,429	0.705	2.3	86.8
Uganda	16.2	90.1	42.7	69	0.528	93.0	N/A
Zambia	29.3	89.4	39.8	713	0.591	97.0	N/A
Europe							
Bulgaria	110.2	62.9	100.0	4,221	0.816	18.0	71.1
Hungary	114.7	42.4	100.0	3,959	0.845	10.6	68.20
Italy	108.4	22.1	100.0	4,916	0.883	36.7	78.6
Poland	114.9	61.4	100.0	3,557	0.872	13.8	90.1
Romania	71.2	76.5	100.0	2,272	0.816	39.8	72.5
Russian Federation	216.6	190.8	100.0	5,284	0.824	15.9	92.1
Serbia	92.9	67.7	100.0	4,041	0.799	26.9	83.9
Ukraine	84.5	65.0	100.0	2,654	0.750	4.4	75.4
Oceania							
New Zealand	203.0	79.4	100.0	8,269	0.921	80.1	59.9

America							
Chile	88.8	33.9	100.0	3,866	0.847	43.6	73.3
El Salvador	27.4	50.8	100.0	965	0.667	57.8	48.4
Panama	48.0	21.1	100.0	2,219	0.795	65.3	80.7
Peru	29.8	95.0	95.2	1,445	0.759	52.7	79.6
Uruguay	62.9	62.6	100.0	3,143	0.808	88.6	46.3

Source: UNDESA,[140] World Bank[141] and UNDP[142]

Among these four categories, countries generally have very diverse energy situations with widely varying natural endowments in fossil fuels and renewable energy. Countries with an energy self-sufficiency percentage higher than 100% benefit mainly from abundant fossil fuel reserves. Conversely, countries with high shares of renewables mostly rely on hydropower, and in some exceptions on geothermal energy, for generating electricity. Wind and solar PV power generally remain at lower levels of penetration. Variable renewable energy such as wind and solar have high potential in developing countries, but a penetration rate in centralized grids higher than 10% has mostly been achieved so far by countries with high- or very high-levels of development.[143]

Other differentiating factors between countries lie in their potential for renewables. Countries with high solar PV potential are generally mostly situated in the Middle-East and Northern Africa. At the bottom of the list, Europe and New Zealand have among the lowest potential for solar PV.[144] Wind potential is generally higher on island or in coastal countries, but also shows considerable variation.[145]

These differences create varying challenges at regional, national and local levels. This also needs to be translated into differentiated solutions, especially in terms of low-carbon power system

140 Total Energy Supply (TES) per capita, self-sufficiency, and electricity consumption per capita are retrieved from UNDESA. United Nations Department of Economic and Social Affairs (2020). Energy statistics pocketbook 2020. Retrieved from https://unstats.un.org/unsd/energystats/pubs/documents/2020pb-web.pdf.
141 World Bank (n.d.). Electricity access. Databank. Retrieved from https://data.worldbank.org/indicator/eg.elc.accs.zs; World Bank (n.d.). Fossil-fuel energy consumption (% of total consumption). Databank. Retrieved from https://data.worldbank.org/indicator/EG.USE.COMM.FO.ZS; World Bank (n.d.). Renewable electricity output (% of total electricity output). Databank. Retrieved from https://data.worldbank.org/indicator/EG.ELC.RNEW.ZS.
142 United Nations Development Programme (2019). Human development report 2019. Retrieved from http://hdr.undp.org/sites/default/files/hdr2019.pdf.
143 International Energy Agency (2019). Status of power system transformation. power system flexibility. Retrieved from https://www.iea.org/reports/status-of-power-system-transformation-2019.
144 World Bank (2020). Global photovoltaic power potential by country. Retrieved from https://www.worldbank.org/en/topic/energy/publication/solar-photovoltaic-power-potential-by-country.
145 See Appendix II on onshore and offshore wind for more details. Technical University of Denmark, World Bank (2020). Global wind atlas. Retrieved from https://globalwindatlas.info/.

planning, demand-side management, as well as through combinations of diversified energy technologies based upon actual needs and resource endowments, as well as economic and industrial characteristics.

3.1.2 Analysis of 10 major renewable energy types: cost competitiveness, GHG emissions and geographic availability

The most recent trends on costs, learning curve, geographic availability, lifecycle emissions and other environmental externalities of the seven major types of renewable energy are listed in Table 3.2. Other types of low-carbon energy also include less widespread renewables such as marine (tides and waves), or other forms such as nuclear power or hydrogen, as listed in Table 3.3. A more detailed presentation on the different renewables can be found in Appendix II.

Table 3.2 Cost competitiveness, environmental impact and geographical availability of renewables along the Belt and Road

Renewable power	Cost competitiveness with fossil fuels and future trends[146]	Geographical availability and China's interest in the energy	Greenhouse gas emissions (gCO_2e/kWh) and main environmental externalities[147]
1. Solar photovoltaic 	Newly built solar PV is already cheaper than newly built fossil fuel-based power generation at a global level (see Section 3.2.1). As a result of learning curve effects (decreasing installation costs and higher capacity	Worldwide geographical availability. China accounted for 45% of global net	~6gCO_2e/kWh. Negative externalities include mining, manufacturing,

146 Here we use levelized cost of electricity. Bloomberg New Energy Finance (2020, June). LCOE forecast. Bloomberg data terminal. Retrieved from https://bba.bloomberg.net; United Nations Environment Programme (2019). Emissions gap report 2019. Retrieved from https://www.unenvironment.org/resources/emissions-gap-report-2019; International Renewable Energy Agency (2020). Renewable power generation costs in 2019. Retrieved from https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Jun/IRENA_Power_Generation_Costs_2019.pdf.

147 For lifecycle assessment, we use a lifecycle reference framework with a projection in 2050 provided by Pehl, M. *et al.* (2017). Understanding future emissions from low-carbon power systems by integration of lifecycle assessment and integrated energy modelling. *Nature Energy,* 2, 939–945. Retrieved from https://www.nature.com/articles/s41560-017-0032-9. For current comparable emissions levels for coal technologies, we refer to World Coal Association (2020). Explaining high efficiency low emissions coal. Retrieved from https://www.worldcoal.org/explaining-high-efficiency-low-emissions-coal. For externalities, we refer to Intergovernmental Panel on Climate Change (2018). Global warming of 1.5°C. Retrieved from https://www.ipcc.ch/sr15/.

	factors, see Appendix III), it can be expected that solar PV will continue to further achieve cost advantages over fossil-fuel power plants in most geographical locations. Its major technological drawbacks are its variability and uncertainty.	capacity additions in 2018.	land use and biodiversity.
2. Concentrated solar power 	CSP is a more flexible and dispatchable source of renewable energy than solar PV. Its costs are not yet competitive with fossil fuels, but CSP is expected to benefit from a steep learning curve in the next decade (see levelized cost of electricity in Appendix III).	Most CSP projects are located closer to the equator, particularly in desert regions. China is the major investor of the sector.	~11gCO_2e/kWh. Negative externalities include mining, manufacturing, land use and biodiversity.
3. Onshore wind 	Electricity from newly built onshore wind is already cheaper than from newly built fossil fuel power plants on average at the global level and is projected to become cheaper than existing plants within the next decade. Its main drawbacks include variability and uncertainty of output.	Worldwide geographical availability. China is the world leader in capacity additions, accounting for 46% of global net capacity additions in 2018 (see Appendix II).	~4gCO_2e/kWh. Negative externalities include mining, manufacturing, land use and biodiversity.
4. Offshore wind 	Offshore wind benefits from huge potential and stronger winds, but has higher installation and transmission connection costs. As a result, less offshore wind has been installed than onshore wind. Due to a steep learning curve, significant capacity additions and reduction of costs are expected in the next decade (decline of logistics, operations and maintenance costs;	Worldwide geographical availability. China accounted for 40% of global net capacity additions in 2018.	~4gCO_2e/kWh. Negative externalities include mining, manufacturing and biodiversity.

	increase of capacity factor). Offshore has the same drawbacks as onshore wind.		
5. Bio-energy 	Costs of bio-energy are already competitive with fossil fuels at a global level. Bio-energy has been experiencing declining costs since 2010 but at a relatively marginal level due to a less pronounced learning curve.	Worldwide geographical availability. China has considerable expertise of the sector.	~100gCO_2e/kWh (highly variable). Negative externalities include land use and transport.
6. Geothermal 	Geothermal power generation plants can only be built in a limited number of geographical locations. Due to this constraint, costs have remained relatively constant since 2010.	Limited scope for deployment. China has relatively limited experience with the technology.	~10-50gCO_2e/kWh. Negative externalities are debated.
7. Hydropower 	Hydropower costs generally have competitive advantages over fossil fuels but future costs are not expected to decline further. Nonetheless, hydropower provides dispatchable electricity that is easy to integrate into power systems.	Worldwide availability but limited potential for large hydropower due to considerable existing infrastructure. China leads the world in global capacity and rate of new build. Deployment opportunities are increasing along the Belt and Road.	~100gCO_2e/kWh (highly variable). Negative externalities include mining and manufacturing, land use, flooding risk and biodiversity.

Table 3.3 Other low-carbon energy sources

Renewable power	Introduction and key trends
1. Marine energy 	Significant research and development efforts are devoted to a wide range of technologies capable of harvesting energy from tides and waves. Compared with other renewables, progress has been slow due to technical difficulties and unfavourable natural conditions.[148] The huge potential of ocean energy resources will ensure that this remains an active area of renewable energy development. However, these technologies do not represent a credible and cost-effective alternative at present or in the near team.
2. Hydrogen 	Hydrogen can be stored and used as a fuel for a gas turbine plant to provide power when required by the electricity system. It therefore has the potential to provide valuable flexibility for the system and offset the variability of solar and wind power. Also, if the electrical energy required to drive the process is generated from renewable sources, the lifetime emissions will be low. However, since this technology requires an excess of renewable electricity, it should be considered as a longer-term storage option for creating a flexible power system rather than a renewable power generation technology.[149] Hydrogen can be a more credible near-term energy solution in transportation, such as for fuel cell vehicles.
3. Nuclear 	The long operational lifetime and high volume of electricity produced by nuclear power means lifetime emissions are extremely low and at similar levels to the best performing renewable technologies. Unlike wind and solar PV, nuclear power plants can run without any interruptions for a year or more. Once a nuclear power plant is operational, it is cheap to run even factoring in the currently customarily charged costs of managing radioactive fuel and waste disposal.[150] The levelized cost of electricity produced is therefore dominated by highly expensive construction costs. However, nuclear safety and nuclear waste[151] remain big concerns for nuclear power.

Solar PV and onshore wind are the most readily available, technologically mature, safe, and impactful types of renewable energy to mitigate climate and environmental effects. Their cost is

148 International Renewable Energy Agency (2014). Tidal energy: technology brief. Retrieved from https://www.irena.org/publications/2014/Jun/Tidal-Energy.
149 International Renewable Energy Agency (2019). Hydrogen: a renewable energy perspective. Retrieved from https://irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_Hydrogen_2019.pdf.
150 This does not include costs for nuclear waste management. World Nuclear Association (2017). Nuclear power economics and project structuring. Retrieved from https://www.world-nuclear.org/information-library/current-and-future-generation/nuclear-power-in-the-world-today.aspx.
151 World Nuclear Association (2020). Storage and disposal of radioactive waste. Retrieved from https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-waste/storage-and-disposal-of-radioactive-waste.aspx.

already the lowest in many countries, and is set to decline further. [152] They have the potential to be developed on a large scale progressively and efficiently, while overcoming certain technical, financial and capacity constraints.

Electricity produced from concentrated solar power (CSP), geothermal sources, biomass and hydropower can contribute to an SDG-compatible energy transition in regions where resources are readily available and can be accessed with limited impact on the environment.[153] Indeed, their high capacity and flexibility mean that they can represent valuable system assets for many countries.[154] However, except for CSP, it is unlikely that the costs of these technologies will reduce at the same rate as wind and solar PV.[155]

The development and deployment of such technologies need be managed with the best available knowledge to mitigate any potential negative externalities as no energy is fully “clean”. Mining, manufacturing and recycling of renewable resources needs to be dealt with according to standards compatible with SDG attainment. Financing solutions need to assist in avoiding the lock-in of technology that is cheap in the near-term but has large cumulative costs, rendering it uncompetitive if a long horizon is considered. But generally speaking, renewables are much less impactful in terms of lifecycle GHG emissions.

3.1.3 Clean and efficient coal-fired power generation technologies: Carbon Capture and Storage, and High Efficiency and Low Emissions

Besides renewables, Carbon Capture and Storage (CCS) technologies when coupled with High Efficiency Low Emission (HELE) plants, are also gaining increasing attention. “Clean fossil” power generation – often termed a HELE plant – covers a range of technologies that are generally associated with coal-fired rather than gas-fired power plants. Supercritical, ultra-supercritical and advanced ultra-supercritical technologies represent technologies that enable a higher efficiency rate and lower CO_2 intensity thanks to the use of higher steam temperatures. HELE technologies enable a lower consumption of coal per kWh and they thus generate less CO_2 and other greenhouse

152 International Renewable Energy Agency (2020). Renewable power generation costs in 2019. Retrieved https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Jun/IRENA_Power_Generation_Costs_2019.pdf.

153 Ibid.
154 Ibid.
155 Ibid.

gases such as nitrogen oxides (NOx) and sulphur dioxide (SO_2) compared to traditional subcritical coal power plants.[156]

Despite these achievements, these technologies are not able to bring down CO_2 emissions to levels comparable to renewables without carbon capture and storage (CCS)[157], a technology which is not ready for large-scale commercial deployment.[158] In the industrial sector, the role of CCS is recognized as being key in hard-to-abate sectors such as cement in the next few decades[159] while CCS for carbon dioxide removal is still at the research stage.[160]

In the power sector at a global level, there are two currently operating large-scale projects that have been developed for coal power generation with CCS: one in the US (Petra Nova) and one in Canada (Boundary Dam).[161] Boundary Dam is facing significant cost problems whose reasons are still debated.[162] The other project, Petra Nova in Texas, managed to get developed within its budget and timeline, encompassing a US$1 billion investment to retrofit an existing coal power plant.[163] However, it is a textbook example of a stranded asset as the project was based on boosting oil production of a nearby oil field using the captured carbon for enhanced oil recovery.[164] The project's financial stability was based on the premise of an oil barrel's price exceeding US$75.[165] Since the launch of the CCS facility in 2017, the price of oil per barrel has been around US$50, preventing the project from making any profit.[166]

This trend is also observable in other parts of the world. For example, China is currently following a roadmap elaborated by its Ministry of Science and Technology (MOST) in 2019: its

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156 World Coal Association (2020).
Explaining high efficiency low emissions coal. Retrieved from https://www.worldcoal.org/explaining-high-efficiency-low-emissions-coal.

157 International Energy Agency (2019). World energy outlook. Retrieved fromhttps://webstore.iea.org/download/summary/2467?fileName=Arabic-Summary-WEO2019.pdf.

158 Intergovernmental Panel on Climate Change (2018). Global Warming of 1.5°C. Retrieved from https://iea.blob.core.windows.net/assets/1f6bf453-3317-4799-ae7b-9cc6429c81d8/English-WEO-2019-ES.pdf.

159 Ibid.

160 United Nations Environment Programme (2019). Emissions gap report 2019. Retrieved from https://www.unenvironment.org/resources/emissions-gap-report-2019.

161 Global Carbon Capture and Storage Institute (2020). Global status of CCS 2020 report. Retrieved from https://www.globalccsinstitute.com/resources/global-status-report/.

162 Global Carbon Capture Storage Institute (2019). Is CCS expensive? Decarbonization costs in the net-zero context. Retrieved from https://www.globalccsinstitute.com/wp-content/uploads/2020/05/Cost_Brief_Final_May_2020.pdf.

163 Ibid.

164 Helman, C. (2017, January 11). Ambitious Texas carbon capture project turns rocky for NRG at USD 50 oil. *Forbes*. Retrieved from https://www.forbes.com/sites/christopherhelman/2017/01/11/nrg-energy-ceo-carbon-capture-is-very-challenging-at-50-oil/#364fc1ac5b22.

165 Ibid.

166 United States Energy Information Administration (2020). US crude oil first purchase price. Retrieved from https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=f000000__3&f=m.

first-generation power plants with CCS facilities should be operational by the mid-2020s, with second-generation technology power plants being deployed around 2030. Significant deployment is thus not expected before the 2030s, and commercial CCS deployment is not expected before 2035.[167] This creates a problem of timing since significant efforts need to be made during the 2020s in the power sector to meet the objectives of the Paris Agreement.

3.2 The BRI's opportunities and challenges on facilitating clean energy development

The International Energy Association (IEA) and the International Renewable Energy Agency (IRENA) have developed detailed scenarios for the energy and power sectors that are compliant with the Paris Agreement.[168] Both agencies now agree on the objective of at least 50% of renewable energy by 2030 in the global power mix.[169] They also call for more solid, ambitious low-carbon policies across countries and regions to increase electricity access rates and renewables. In particular, as resources from hydropower are limited, significant demand growth should be met predominantly by wind and solar so that 35% of global power production is met by variable renewable energy (VRE) in 2030,[170] and 61% by 2050.[171]

167 MOST explained that "in summary, current first-generation CO_2 capture technologies have gradually become more mature but are still associated with high energy consumption and costs, and there still remains a lack of engineering experience regarding large-scale demonstrations in China. Second-generation capture technologies can drastically reduce energy consumptions and costs but are still in the laboratory research and trial stages, and are only expected to be promoted and adopted widely by around 2035". Ministry of Science and Technology of the People's Republic of China (2019). Roadmap for carbon capture, utilization and storage technology development in China. Not available online.

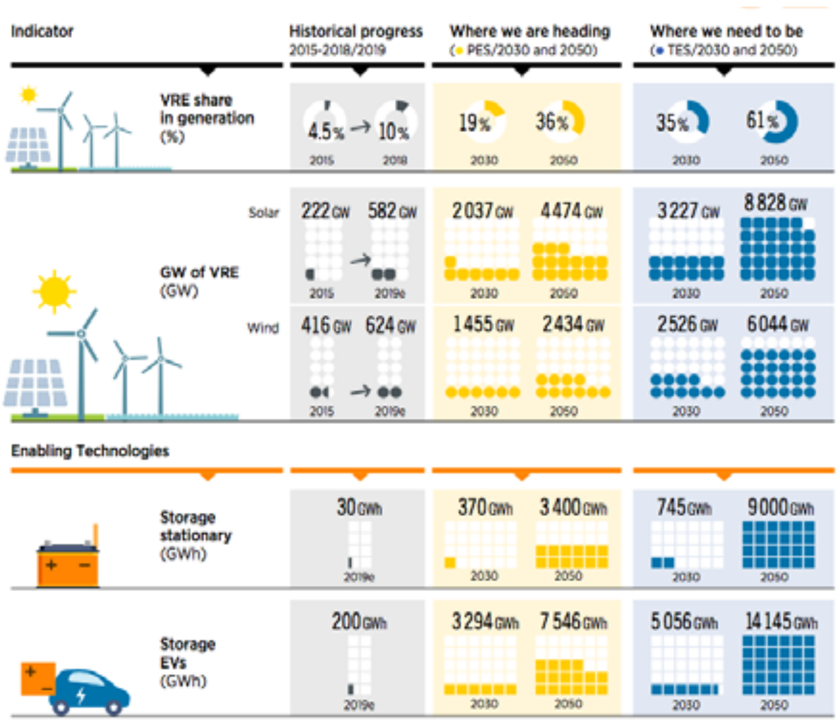
168 International Renewable Energy Agency (2020). Global renewables outlook: energy transformation 2050. Retrieved from https://www.irena.org/publications/2020/Apr/Global-Renewables-Outlook-2020.

169 International Renewable Energy Agency, *et al*. (2020). Tracking SDG 7: The energy progress report. Retrieved from https://www.irena.org/publications/2020/May/Tracking-SDG7-The-Energy-Progress-Report-2020.

170 With non-variable renewables such as hydropower and bioenergy making up the difference with the 50% target mentioned above.

171 International Renewable Energy Agency (2020). Global renewables outlook: Energy transformation 2050. Retrieved from https://www.irena.org/publications/2020/Apr/Global-Renewables-Outlook-2020.

Figure 3.1 Roadmap for variable renewables and storage for 2030 and 2050



Source: IRENA[172]

Electrification brought by a much higher share of renewables will benefit other sectors such as transportation or infrastructure. According to an IRENA 2019 report, renewable energy and electrification of these sectors will help deliver 75% of emissions reduction and place the world on track towards low-carbon development that meets the Paris Agreement.[173] Adopting these roadmaps for energy and electrification would enable Belt and Road partner countries to leapfrog decades of economic development. In light of such visions, several key opportunities and challenges for scaling up clean energy development along the Belt and Road deserve attention.

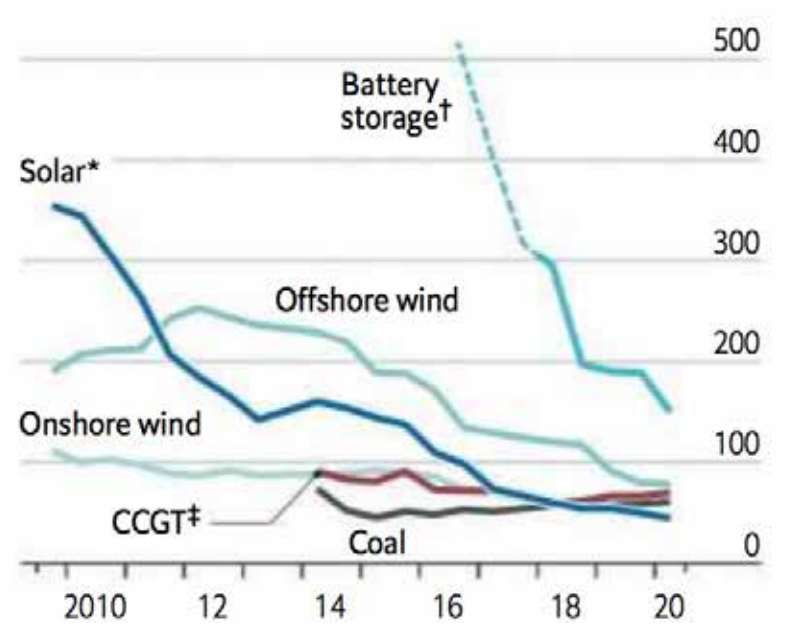
3.2.1 Key opportunities of advancing low-carbon energy development: cost competitiveness of scaling up clean energy development, technological innovation and global consensus

(i) The costs of renewables versus fossil fuels have been diminishing, a trend that is expected to continue to be driven by the learning curve effect. Recent evidence and analysis

172 Ibid.
173 International Renewable Energy Agency (2019). Transforming the energy system and holding the line on rising global temperature. Retrieved from https://www.irena.org/publications/2019/Sep/Transforming-the-energy-system.

have proven that costs of renewables are getting increasingly competitive compared to fossil fuel projects. As Figure 3.2 shows, the cost of renewable-based electricity (in current levelized terms) in the world shows a clearly diminishing trend, even undercutting the cost of coal. This is particularly true for the widely deployed solar and wind technologies. Most analysts and experts expect this trend to continue. It is worth noting that the electricity storage industry has experienced strong cost reductions as well. Figure 3.2 shows how, in the last 5 years, costs for battery storage have fallen more than four-fold. This represents a considerable opportunity for energy systems as increased storage capacity can provide the necessary stability by offsetting renewables' variability to meet demand peaks. According to current scenarios, power generation stemming from stationary storage is expected to be multiplied by 10 in the next 10 years to reach 370 GWh and by more than 100 before 2050 to reach 3.4 TWh.[174] As costs are expected to continue to decrease significantly in the next few years, this evolution represents a potential game-changer for low-carbon development in the energy and power sector.[175]

Figure 3.2 Current levelized cost of electricity (LCOE) globally in December 2019 (US$ per MWh)



* Average of fixed and tracking systems;

174 International Renewable Energy Agency (2020). Global renewables outlook. Energy Transformation 2050. Retrieved from https://www.irena.org/publications/2020/Apr/Global-Renewables-Outlook-2020.
175 International Energy Agency (2019). World energy outlook. Retrieved from https://iea.blob.core.windows.net/assets/1f6bf453-3317-4799-ae7b-9cc6429c81d8/English-WEO-2019-ES.pdf.

† Battery storage;

‡ CCGT: combined cycle gas turbine.

Source: The Economist[176]

Using further data from a Bloomberg New Energy Finance (BNEF) terminal, a cost comparison between energy types using levelized costs of electricity (LCOE)[177] confirmed that on average new coal power generation was more expensive than new solar PV and onshore wind power generation both in the world and in China as of end-2019 (see Table 3.4).[178]

Table 3.4 Current levelized cost of electricity (LCOE) in December 2019

LCOE (US$, MWh, nominal)	World	China
Coal	57.6-123.3*	61.9
Onshore Wind	48.2	53.0
Solar PV - non-tracking device	51.7	43.7

Source: BNEF[179]

(ii) Costs of renewables are likely to further diminish in the next 10 years due to learning curve effects. As the production of renewables becomes increasingly important, experience and know-how improve simultaneously. Associated with a higher capacity factor[180] and economies of scale, this translates into lower production costs for renewable energy. On the one hand, the learning curve for renewables is particularly significant due to the important proportion of manufacturing and installation costs in the total lifecycle cost of renewable energy sources. On the other hand, oil, coal and gas whose total costs are mostly defined by their fuel costs, cannot benefit from learning curve effects as much as renewables. According to IEA's review of the solar PV

176 The Economist (2020, May 23). Not-so-slow-burn: Once more with renewables. Retrieved from https://www.economist.com/schools-brief/2020/05/23/the-worlds-energy-system-must-be-transformed-completely.

177 LCOE is the average lifetime levelized cost of electricity generation. It includes investment, operations and maintenance, and fuel expenditure while taking into account the discount rate and the economic life of the system. These cost comparisons do not include environmental externalities such as air pollution or greenhouse gases.

178 New refers to newly built. Bloomberg New Energy Finance (BNEF) is a research organization specialized in the clean energy sector.

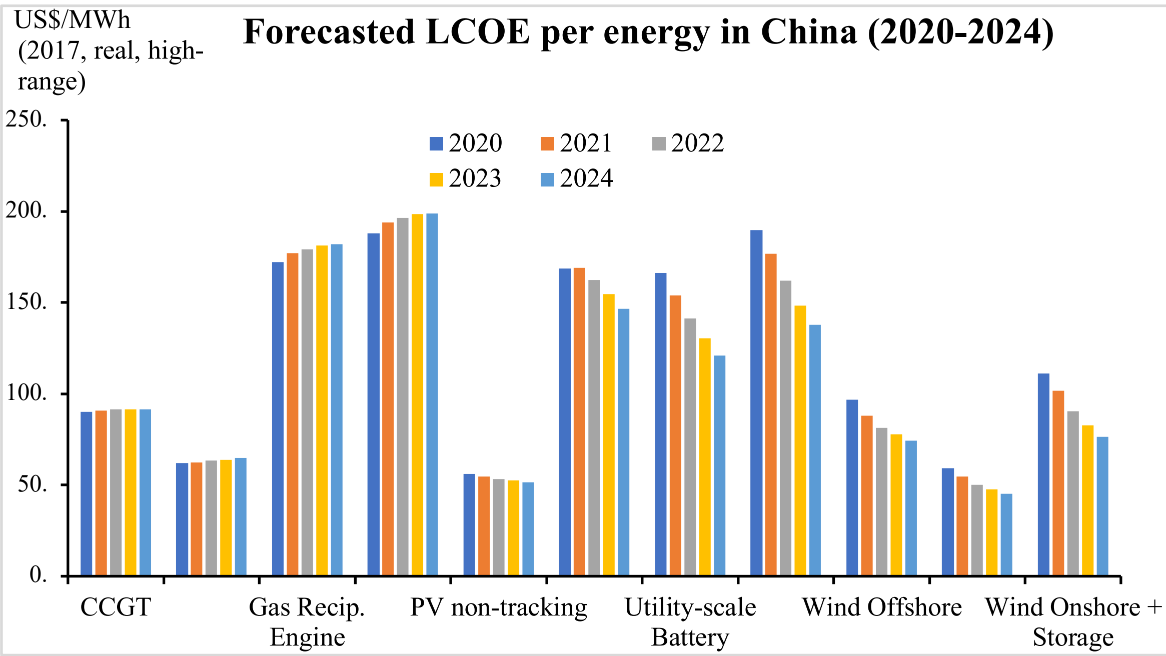
179 For the global coal LCOE, the range between the lowest LCOE (South Korea; 57,61) and the highest (Australia; 123,28) for 17 countries is indicated. The 17 countries are Australia, Chile, China, Germany, Greece, India, Indonesia, Japan, Malaysia, Philippines, Poland, South Korea, Thailand, Turkey, United Kingdom, United States, and Vietnam. Data for Russia and South Africa for December 2019 was not available. Bloomberg New Energy Finance (June 2020). LCOE forecast. Bloomberg data terminal. Retrieved from https://bba.bloomberg.net.

180 International Renewable Energy Agency (2020). Renewable Power Generation Costs in 2019. Retrieved from https://www.irena.org/publications/2020/Jun/Renewable-Power-Costs-in-2019#:~:text=Electricity%20costs%20from%20utility%2Dscale,respectively%2C%20for%20newly%20commissioned%20projects.

module's monthly prices in fourteen countries[181] from 2013 to 2019, the learning curve effect is evident: countries' solar PV price per watt dropped by 29% – 67% throughout the years. Among these, China's solar PV price per watt dropped by 64%, Brazil's by 59%, Saudi Arabia's by 67% and South Africa's by 29%.[182]

In China, this downward trend of costs of renewables is set to accelerate, boosted further by the effect of rapidly rising scales of deployment in the next few years with solar PV and onshore wind becoming increasingly cheaper, while the LCOE for coal and gas is expected to slightly increase in the next five years. The percentage price advantage relative to coal is forecasted to grow from 9% for non-tracking solar PV and 4% for onshore wind 2020 to 13% and 30%, respectively by 2024, as Figure 3.3 shows.[183]

Figure 3.3 Trend analysis on LCOE per energy type in China[184]



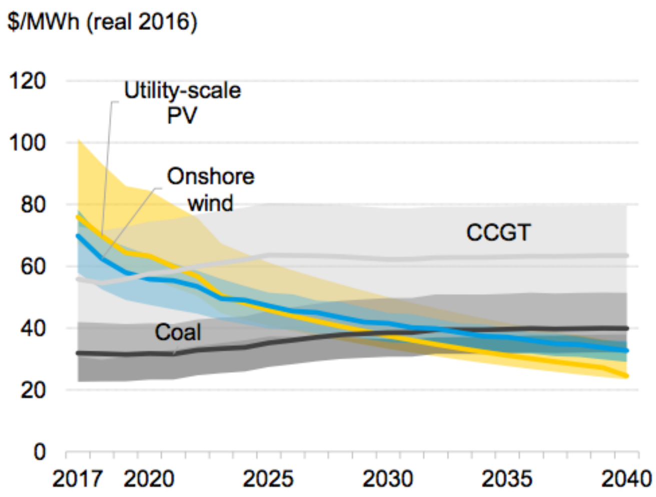
Source: BNEF[185]

181 Including Australia, Brazil, Canada, China, France, Germany, India, Italy, Japan, Republic of Korea, Saudi Arabia, South Africa, United Kingdom, United States.
182 International Renewable Energy Agency (2020). Renewable power generation costs in 2019. Retrieved from https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Jun/IRENA_Power_Generation_Costs_2019.pdf
183 These are high-range forecast estimates from Bloomberg Terminal. Bloomberg New Energy Finance (2020, June). LCOE forecast. Bloomberg data terminal. Retrieved from https://bba.bloomberg.net.
184 High-range forecast. Bloomberg New Energy Finance makes LCOE forecasts based on low, medium and high ranges.

185 Bloomberg New Energy Finance (June 2020). LCOE forecast. Bloomberg data terminal. Retrieved from https://bba.bloomberg.net.

Furthermore, according to BNEF's 2017 New Energy Outlook, costs for existing coal-fired power plants, which only include marginal costs, will be more expensive on average than new solar PV in China within the next decade and more expensive than onshore wind before 2035.[186]

Figure 3.4 Comparison of projected PV and onshore wind costs with existing coal and gas plants in China



Source: BNEF[187]

This creates a valuable window of opportunity for financial institutions and energy entrepreneurs to promote renewables. McKinsey estimates that renewables will represent 40% of average annual global energy investments to 2025 while another 40% will be on transmission, distribution and storage.[188] Investing in low-carbon technologies now is expected to bring a higher return at lower risk, especially considering that the value of assets in high-emission energy would drastically reduce in the medium- and long-term due to global action in reducing GHG emissions.[189]

186 Existing coal-fired power generation costs only include marginal costs, which makes it hard to compare with new renewables' LCOE which include investment and construction costs. Despite this lack of a level playing field, some international organizations and research institutions have forecasted new renewables will outcompete existing coal in the coming years. Bloomberg New Energy Finance (2017). New energy outlook. Retrieved from https://data.bloomberglp.com/bnef/sites/14/2017/06/NEO-2017_CSIS_2017-06-20.pdf.

187 Ibid. CCGT is combined cycle gas turbine. The shading shows the range of values. For coal and gas plant this is largely driven by fuel cost uncertainty.

188 Heiligtag, S. *et al*. (2019). Fueling the energy transition: Opportunities for financial institutions. McKinsey & Company. https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/fueling-the-energy-transition-opportunities-for-financial-institutions.

189 Mercure, J.-F. *et al*. (2018). Macroeconomic impact of stranded fossil fuel assets. *Nature Climate Change*, 8: 588-593. Retrieved from https://www.nature.com/articles/s41558-018-0182-1.

It deserves attention that the cost decreases of renewables stem from technological innovations, the learning curve effect and economies of scale, as well as supportive governmental policies in favour of renewables due to environmental and climate-related concerns.[190] Contrary to fossil fuels whose total costs are vastly impacted by the price of coal, oil and gas, the costs of renewables' energy generation are usually composed of manufacturing, installation and operations and maintenance costs. Thus, the comparative advantage of renewables lies in the wide accessibility, renewability and near-zero cost of raw materials i.e., sun, wind, water. As these do not represent any significant costs, the overall lifecycle costs of renewable energy are particularly sensitive to innovation. Simultaneously with technological progress, renewables have also benefited from significant economies of scale, learning curve effects (as discussed above) and more competitive supply chains. Moreover, the development of renewables has also benefited from supportive governmental policies towards renewables in order to help them rapidly attain scale, curb the effects of pollution and mitigate climate change (see Chapter 2 for China, and Section 3.4 for the examples from Madagascar, Vietnam, South Africa, Uruguay and Denmark). For developing countries along the Belt and Road, further capacity-building is thus indispensable to foster such technological innovations, learning curve effects, competitive supply chains and an enabling policy environment.

3.2.2 Major challenges in promoting low-carbon energy development: financing climate, governance context and technological transfer capacities in developing countries

The biggest obstacle to implement a low-carbon transition consists of socio-economic barriers as energy touches upon all sectors of a society. Important changes brought by energy transitions take time and affect vast parts of the population. In countries with a high share of extreme poverty, a low-carbon transition represents all-encompassing societal change. Consequently, it is therefore hard to develop long-term solutions and plan ahead accordingly when achieving other SDGs such as curbing poverty, eradicating hunger and ensuring access to health services are even more immediate concerns for the affected population. This challenge is made more difficult by the recent outbreak of COVID-19 and its consequences which are set to last and affect the most vulnerable

190 International Renewable Energy Agency (2020). Renewable power generation costs in 2019. Retrieved from https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Jun/IRENA_Power_Generation_Costs_2019.pdf.

individuals across the globe. The substantial COVID-19-related slowdown makes political stability an even greater challenge in countries which are plagued by frequent crises, and which often have more fragile political and judicial institutions.

This socio-economic challenge for a low-carbon transition in the power sector is complexified by problems of access to finance and markets. Financing and investment in developing countries are a problem not just at the national, but also at the international level, as the efforts from developed countries agreed on during the Paris Agreement have been partly initiated but are still far from the levels set in 2015 to mitigate climate change, complicated further by COVID-19. From 2021 to 2023, around US$1 trillion per year will be needed to achieve sustainable and low-carbon development in the energy and power sectors according to a post-COVID-19 assessment jointly made by IEA and IFC.[191] For companies investing in the renewable energy and grid sectors in developing countries, market uncertainties and obstacles remain. They translate into higher weighted average costs of capital and adversely affect investment.[192]

Capacity gaps also add difficulty to low-carbon development pathways in the energy and power sectors.[193] This is the case in terms of shortage of local human resources and technical and management skills to upgrade grids and develop renewable projects. This capacity gap extends to insufficient knowledge and “know-how” at the governmental and institutional levels to implement low-carbon transitions in the power sector. Capacity gaps are also seen in terms of data collection, and management, reporting and verification (MRV). This problem is transdisciplinary and ranges from environmental externalities and energy performance indicators to project management and assessment frameworks.

The very diversified natural resource endowments which countries have make it hard to develop a “one-size-fits-all” solution. Countries with lower potential than average in hydropower, wind, solar and geothermal naturally encounter more problems in developing a low-carbon energy mix due to weather or geographical conditions. They also find problems in selling this energy at a cross-border level due to higher costs and lack of competitiveness. Similarly, countries which

191 International Energy Agency (2020). World energy outlook. Retrieved from https://www.iea.org/reports/world-energy-outlook-2020.
192 Steffen B. (2020, May). Estimating the cost of capital for renewable energy projects. *Energy Economics*, Vol. 88, C. Retrieved from https://www.sciencedirect.com/science/article/pii/S0140988320301237.
193 Please see Chapter 5 for a detailed analysis of capacity gap issues in low-carbon development sectors.

benefit from high endowments in fossil fuels (coal, gas, oil) have many jobs that rely on mining, manufacturing and exportation, with sectors often concentrated in mining and industrial areas. In these countries, it is therefore harder to attain the gradual phasing out of fossil fuels without relying on transition funds for the affected sectors of the population. However, such funds are not always available in these areas.

The electricity access situation of countries along the Belt and Road is also diversified, which also adds a challenge to integrate higher shares of VRE. Those with an important electricity access deficit will find it challenging to focus on a low-carbon transition when vital infrastructure such as schools and hospitals do not have full and secure access to energy.[194] Electricity access must not only be assured, but it needs to be stable, secure and continuous, therefore leading to a vast disparity in countries' situations when aiming for a low-carbon development path. Similarly, areas which have achieved important results in electricity access relying on off-grid development will have very different arrays of measures than those who have relied on centralized systems. Very often, in developing countries, both systems exist and develop concomitantly. This electricity and energy access deficit is complemented by technical and technological gaps where renewables' supply chain or digital access is often not achieved.

Technologically, integrating VRE into the power system is associated with several technical challenges. First, they are defined by their variability and uncertainty. This brings issues of matching supply and demand for energy systems which is the biggest technical challenge for grid integration. Second, VRE (solar PV, wind) is also location-specific, which means that the transmission network needs to be planned and developed to connect with these locations. Even if their capacity factor has increased in the last decade, VRE still has a lower capacity factor than fossil fuels (see Appendix III). Third, their non-synchronous generation of power requires adaptation in voltage and frequency control. These power grid adaptations have costs.[195] Different countries face different situations in overcoming these technical challenges.

194 United Nations Department of Economic and Social Affairs. (2020). Energy statistics pocketbook 2020. Retrieved from https://unstats.un.org/unsd/energystats/pubs/documents/2020pb-web.pdf.
195 Adapted from Cochran J. *et al*. (2015). Grid interaction and the carrying capacity of the US Grid to incorporate Variable Renewable Energy. National Renewable Energy Laboratory. Retrieved from https://www.nrel.gov/docs/fy15osti/62607.pdf.

The global deployment of variable renewables has highlighted that the extent to which the challenges create problems and costs for system operations is highly context-specific. The technical cost of electricity integration becomes an important challenge especially when the penetration of variable renewables reaches a certain threshold. The source of major costs includes short-term balancing requirements (reserve costs), meeting peak demand (capacity costs), curtailment costs, transmission and network costs, system inertia costs and other conventional thermal plant efficiency reductions.[196] It is also crucial that efficient market design is available, so that system integration costs do not translate into burdensome prices for households and industries which will see their production cost affected.

3.3 Concrete measures of boosting the innovation, development and transfer of clean energy technologies

There are a variety of factors that drive or influence the innovation, development and transfer of clean energy technologies. Such factors include the individual countries' natural resource endowments, governance, electricity development, trans-regional energy interconnectivity, pricing mechanisms of electricity transactions, market behaviours in balancing supply and demand sides. Building on evidence-based research, this section provides six interlinked key pathways to boost clean energy development: (i) strengthen strategic planning to enhance the flexibility, efficiency and interconnectivity of power systems; (ii) develop pricing mechanisms, incentive subsidies and big data platforms to upgrade demand-side management and improve the effectiveness of peak shaving, valley filling and load shifting; (iii) promote multi-energy systems and boost regional connectivity to untap technical and geographical potential; (iv) improve load forecasting and scheduling capacity to enhance the balance of supply and demand; (v) accelerate thermal power plants' retrofitting to facilitate their role as power system stabilizers and to support higher shares of VRE integration; (vi) plan and develop battery storage and distributed energy simultaneously with centralized grid development.

196 United Kingdom Energy Research Centre (2017). The costs and impacts of intermittency. Retrieved from http://www.ukerc.ac.uk/publications/the-costs-and-impacts-of-intermittency-2016-update.html.

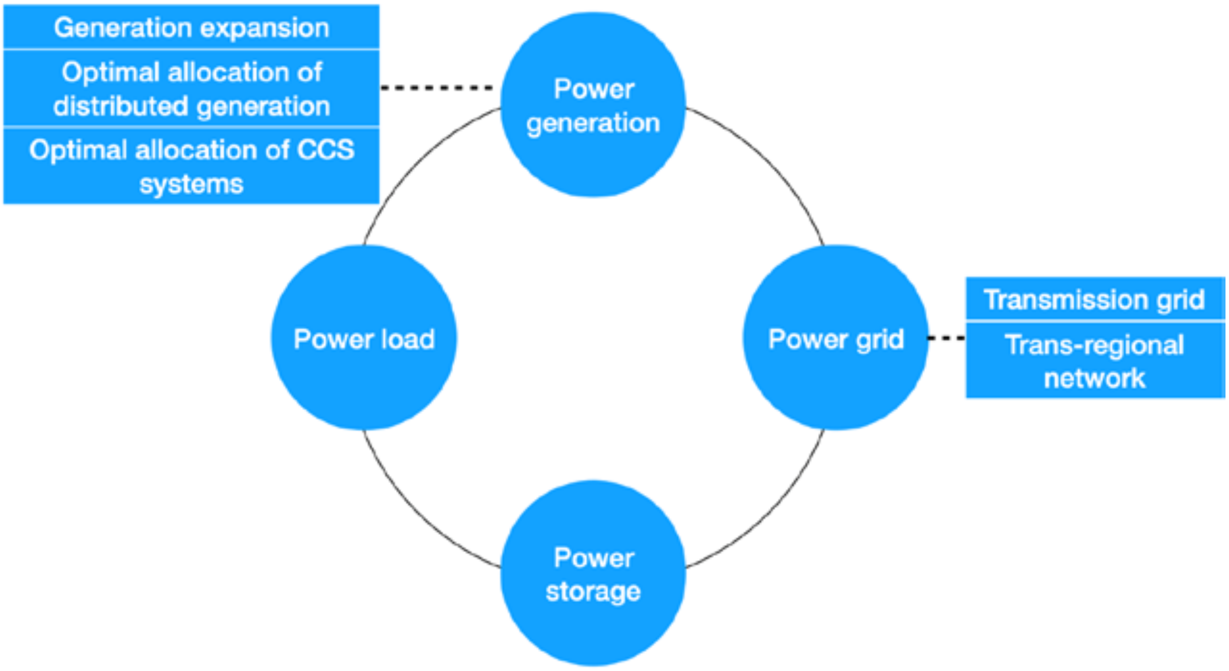
3.3.1 Formulate strategic development planning to enhance the flexibility, efficiency and interconnectivity of power systems

While conducting power system planning with a low-carbon development objective, **policymakers are encouraged to fully consider a country's specific socio-economic context, resource endowments, governance and development levels**, as well as its current stage in electricity sector development (increasing and achieving electricity access, electricity sufficiency, electricity stability and security, or stage of low-carbon transition). Having such fundamental understanding in strategic planning of power development is key to efficiently reducing carbon emissions while improving and ensuring power stability and security.

Integrated planning of trans-regional and trans-national transmission networks is needed, which is a prerequisite for the large-scale exploitation of low-carbon energy such as wind and hydropower. In this integrated planning, policymakers should pay equal attention to both centralized and distributed power resources.

Foresight and long-term planning are crucial in transmission infrastructure projects, as they can take around 10 years to develop. Meanwhile, the emergence and introduction of technologies along the BRI which reduce power systems' carbon impact – such as renewables development, ultra-high voltage direct current lines, flexible AC transmission systems (FACTS), distribution automation systems, introduction of HELE plants to substitute outdated and more polluting subcritical fossil fuel thermal plants and deployment of carbon capture and storage (CCS) – have exerted a profound impact on power system planning. **To be successful in this transformation, each country should balance economic costs with the benefits of emission reductions.** It should also plan the construction and operation schedule of future generation units and transmission lines, on the basis of calculating and predicting future power growth, load curve and power distribution.

Figure 3.5 Integrated planning of flexible power systems



Scientific planning of power generation and that of power grids are based on power load prediction. In countries with high penetration rate of VRE generation, storage technologies play an important role in dealing with VRE generation fluctuation, alleviating transmission congestion and reducing transmission investment.[197]

The planning of power generation expansion (PGE) needs to be strengthened. Carbon emissions trajectory models integrating overall emissions cut targets and annual emissions cut constraints can be introduced when deciding the types, capacity and locations of newly built power plants. Allocated capacity, sites and types of distributed generation also need to be anticipated, to facilitate localized power supply and reduce transmission losses and emissions. In countries where coal power would remain a major source of energy in the foreseeable future due to resource endowment restrictions, optimal allocation of CCS systems in conventional thermal power plants can be further examined, targeting maximum emissions reduction while minimizing costs.[198]

197 Wang, S. (2019). "面向大规模可再生能源并网的储能规划研究" [Energy storage planning for large scale renewable energy integrated power systems] (link in Chinese, see references).
198 Lou, S., Lu, S., Wu, Y., and Yin, X. (2013). "低碳电力系统规划与运行优化研究综述" [An overview on low-carbon power system planning and operation optimization]. *Power System Technology* (link in Chinese, see references).

The planning of low-carbon power networks should be based on reasonable power generation planning and load prediction. It is important to enable the integration of wind, solar and other clean energy sources, to better support low-carbon power system. Reasonable planning of transmission networks are therefore necessary. This includes taking into account the coupling of low-carbon capacities of generation, transmission and consumption.

Planning of transregional and transnational transmission networks is also necessary as it is a prerequisite of optimal exploitation of low-carbon energy such as wind, solar and hydropower. In this process, in order to handle diversified economic, and social and environmental elements in transregional and transnational network planning, collaboration and communication mechanisms need to be set up, through joint efforts by governments, regional and international energy organizations, power companies and think tanks. Scenario analysis can be adopted, taking into consideration various elements such as climate change impacts, potential generator installation, ratio of clean energy sources, load growth rates, and load curve characteristics.[199] Quantitative and qualitative evaluation of installation portfolio and network interconnectivity could then be conducted.

Aligning industrial policies and fiscal subsidies with renewables development is also necessary, especially at the initial stage, to provide incentives for investors in clean energy and to ensure a level playing field between the renewable energy source (RES) and fossil fuel projects. A marketized approach can be later introduced to promote non-subsidized generation of clean energy (as long as fossil fuel subsidies are also eliminated), as clean energy has acquired sufficient scale to become competitive.

Policymakers also are encouraged to proactively lead public engagement to avoid delays or obstacles arising through lack of public acceptance. Dialogue platforms and communication channels can be developed to raise public awareness, address public concerns, and prepare public acceptance especially among affected populations to accommodate increasing shares of VRE sources. Workshops could be held regularly to facilitate public engagement in low-carbon projects. Standardization for mining, manufacturing and recycling of renewable resources need to be

199 Zhou, Y., Jiang, H., Xiao, J., and Liang, C. (2020). “清洁低碳发展背景下跨国互联电力系统规划方法” [Planning methods for transnationally interconnected power systems under the background of clean low-carbon development]. *Electric Power*.

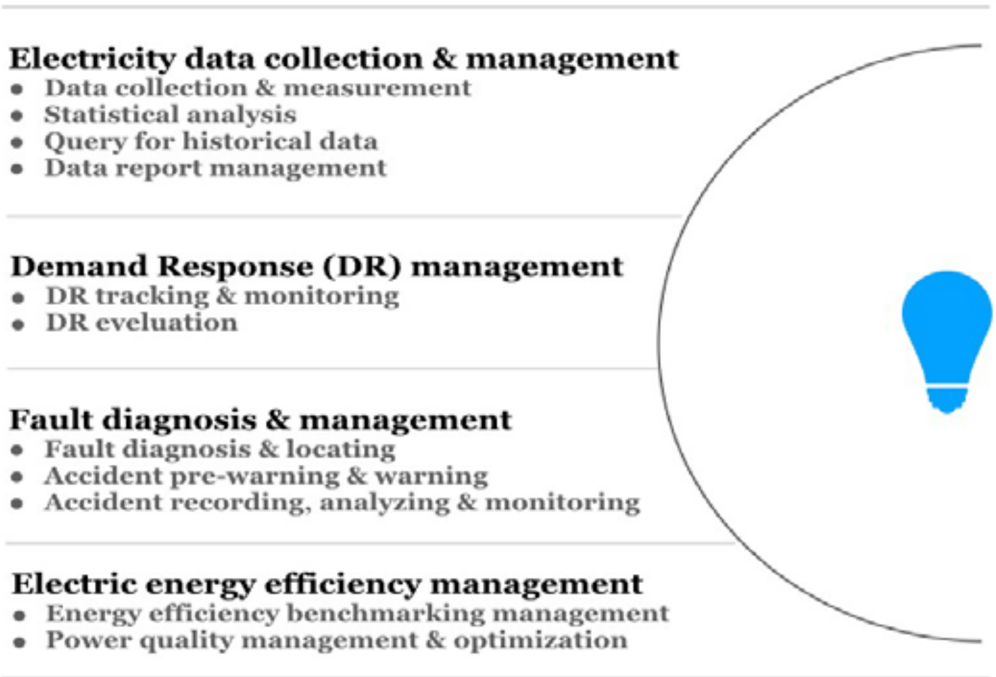
deepened, so as to address public concerns and increase compatibility with SDG attainment. Transition funds for affected populations, industries and workers need to be designed together with long-term power system planning, to mitigate social inequality and preserve cohesion.

3.3.2 Develop price mechanisms, incentive subsidies and big data platforms to upgrade demand-side management and improve the effectiveness of peak shaving, valley filling and load shifting

Standardizing and upgrading demand-side management (DSM) is key to boosting energy efficiency, especially for countries that are planning to rapidly advance renewables deployment or are already undergoing deep changes in their electricity consumption structure. Modelling studies consistently show the critical role of demand-side measures in meeting ambitious mitigation targets in the scenario of limiting global warming to 1.5°C above preindustrial levels.[200] DSM in a specific country should be based on multiple appeals from energy users, electric energy service providers, power grid corporations and government agencies in this country. Tailored guidance measures for energy users should be provided, to stimulate them to enhance energy efficiency and commonly boost an efficient, safe, green and reliable power system.

200 Mundaca, L., Ürge-Vorsatz, D. and Wilson, C. (2019). Demand-side approaches for limiting global warming to 1.5 °C. *Energy Efficiency*, 12, 343–362. Retrieved from https://link.springer.com/article/10.1007/s12053-018-9722-9.

Figure 3.6 Basic functions of a DSM evaluation



Source: MIIT[201]

At the macro level, the use of big data technologies should be boosted in the construction of a demand-side management platform to facilitate electricity information interaction and energy efficiency evaluation. Basic functions of a DSM platform, as shown in Figure 3.6, would need to include electricity data collection and analysis, demand response management, fault diagnosis and monitoring, as well as electric energy efficiency management. In this process, building standards for DSM should be emphasized and prioritized in fiscal budgets, which helps better integrate low-carbon goals into DSM system design.

As the global smart grid market is expected to triple in size and reach some US$61 billion between 2017 and 2023, and Asia Pacific is expected to become the largest market with the fastest growth for smart grid technologies,[202] the construction of DSM platforms in developing countries

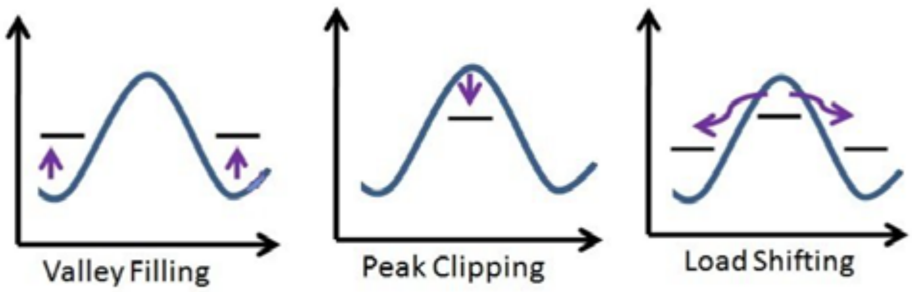
201 Ministry of Industry and Information Technology of the People's Republic of China. (2019). 《工业和信息化部关于印发“工业领域电力需求侧管理工作指南”的通知》[Notice of the Ministry of Industry and Information Technology on issuing the “Guidelines for the Work of Power Demand Side Management in the Industrial Field”]. (link in Chinese, see references).

202 Tiseo, I. (2020). Global Smart grid market size by region 2017-2023. Statista. Retrieved from https://www.statista.com/statistics/246154/global-smart-grid-market-size-by-region/.

is expected to be accelerated. In order to solve problems such as inadequate data sharing and data flow on electricity usage that exist in many developing countries, data interaction channels among government agencies, enterprises and residential units need to be broadened. This helps release the potential of massive data resources and lay a solid foundation for DSM digitization and upgrading.

At the micro level, upgrading DSM for end-users is equally important, as these industrial, transport and residential users are the implementing entities. **Specific demand response (DR) strategies include pricing signals and incentive subsidies.** For price signals, **appropriate time-pricing can help reduce energy peaks and fill troughs. This is commonly referred to as peak shaving, valley filling or load shifting** (see Figure 3.7). Interruptible load tariffs, capacity bidding and demand bidding programs can also be considered when applicable.[203]

Figure 3.7 DSM load shape methods



Source: Adapted from Bhamidi, L. and Sadhukhan, A.[204]

Diversified DR pilot programs can be set up. DR measures should also be tailored based on actual needs, industrial characteristics and emissions cut targets in a specific development stage in a specific region. In Europe, while the EU stresses DR platform development and smart power consumption standards revision, different European countries carry out DR based on their own plans and rules. For developing countries along the Belt and Road that are late-comers in DSM, pilots can be set up to explore diversified means to stimulate industrial and household loads to participate in demand response programs.

203 Hesser T., *et al*. (2012). Renewables integration through direct load control and demand response. In Sioshansi, F. P. (ed.) *Smart Grid*. Academic Press: 209-233. Retrieved from https://www.sciencedirect.com/science/article/pii/B9780123864529000097.
204 Bhamidi, L. and Sadhukhan, A. (2017). Multi-objective optimization for demand side management in a smart grid environment. 2017 7th International Conference on Power Systems. Retrieved from https://www.researchgate.net/figure/DSM-load-shape-methods_fig1_325935562.

In China, DR policies have undergone changes to facilitate DR programs (see Table 3.5). Pilots have been set up since 2013 in cities such as Beijing, Suzhou and Foshan to explore new DR measures and models, such as peak clipping and valley filling in parallel, and demand-side bidding. Digitalization is boosted in this process, to realize more precise load adjustment and faster demand response. Enterprises from sectors such as metallurgy, cement and the petrochemical industry are pilot practitioners in upgrading micro-level management of power consumption. Their experiences can be shared in other sectors, to promote the construction of better models of power consumption prediction, efficiency analysis and optimization.

Table 3.5 Developed and currently trending DR programs in China

Price-based programs	Incentive-based programs	Policy-guided programs
Time-of-use rates	Interruptible/curtail-able load	Power rationing
Critical peak pricing (CPP)	Direct load control	Orderly power
Two-part pricing		

Source: Tahir, M. F. *et al.*[205]

DSM schemes to promote energy-saving behaviours are an alternative DSM strategy, especially for countries that lack appropriate technologies and capital costs, as DSM programs are often challenging to implement, and sometimes more expensive than announced, which makes it challenging for low and middle-income countries.[206] These alternative schemes can focus on changing consumption patterns and promoting a circular, zero-waste and sharing economy. Studies show that energy-saving behaviour can lower energy demand by over 20%. In Bangladesh, the Energy Efficiency and Conservation Master Plan (EECMP), a DSM program, shows that enhancing efficiency in the use of home appliances could lower electricity demand in the

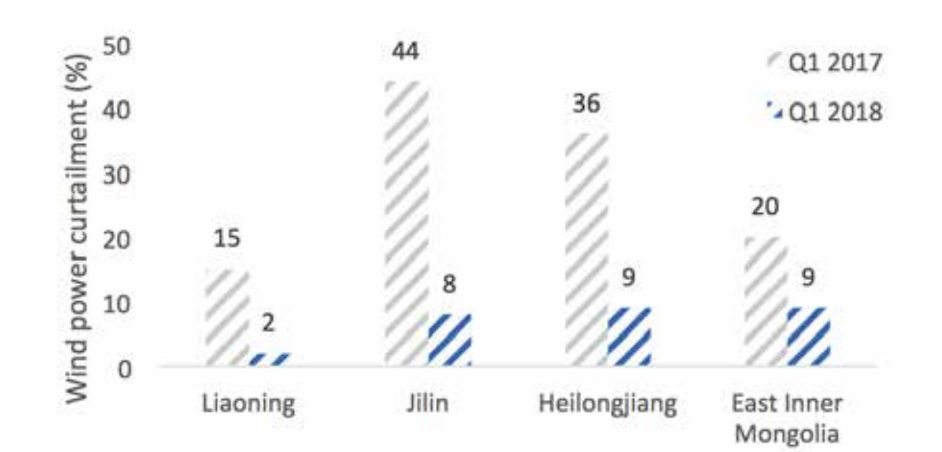
205 Tahira, M. F., Chen, H. *et al.* (2020, November). Significance of demand response in light of current pilot projects in China and devising a problem solution for future advancements. *Technology in Society*, 63, 1-12. Retrieved from https://www.sciencedirect.com/science/article/pii/S0160791X19306700.
206 Charles River Associates (2005). Primer on demand-side management: with an emphasis on price-responsive programs. World Bank. Retrieved from https://openknowledge.worldbank.org/handle/10986/8252.

residential sector by 28.8%, whereas the inclusion of energy-saving behaviour as a DR strategy in residences along with the EECMP might reduce demand by up to 50.7%.[207]

3.3.3 Promote multi-energy systems and storage technologies to facilitate regional connectivity, enhance energy efficiency and address geographical constraints

Diversifying the technology mix and ensuring an appropriate balance between dispatchable and partially dispatchable resources help reduce the challenges associated with deployment of large proportions of variable renewable energy. The concept of resource diversification is a familiar approach in helping ensure supply security in traditional power systems, and the high share of variable renewables introduces new dimensions to this aspect of system planning. By retrofitting its coal plants in the northeast, China was able to implement technological diversification and greatly decrease wind curtailment[208] between 2017 and 2018 (see Figure 3.8). Energy diversification is possible at all stages of electricity access, with a stronger reliance on off-grid and decentralized solutions for countries which do not possess a nationwide centralized grid.

Figure 3.8 Wind curtailment in Northeast Chinese provinces in the first quarters of 2017 and 2018



Source: IRENA[209]

207 Khan, I. (2019). Energy-saving behaviour as a demand-side management strategy in the developing world: the case of Bangladesh. *International Journal of Energy and Environmental Engineering*, 10, 493–51. Retrieved from https://link.springer.com/article/10.1007/s40095-019-0302-3.

208 “Wind curtailment, where the system operator cuts the amount of wind generation that can be sold onto the power grid for a specified amount of time, is usually caused by one of the two factors: a transmission system that is incapable of accommodating the full dispatch of wind facilities (involuntary curtailment) or a mismatch between supply and demand (voluntary curtailment).” Quoted from Fine, S. *et al*. (2017). Penetration of Variable Energy Resources (VERs); US Outlook and Perspectives. In: Jones, L. (ed.) *Renewable Energy Integration: Practical management of variability, uncertainty and flexibility in power grids.* Academic Press, 15-26. Retrieved from https://www.elsevier.com/books/renewable-energy-integration/jones/978-0-12-809592-8.

209 The retrofitting for Northeast China includes a decrease of the minimum load level for thermal power plants and the creation of an ancillary

Geographic diversification of renewables and necessary physical interconnections should be enhanced. One main reason is that the ability to diversify resources locally is restricted, and in most circumstances, the most effective route towards diversification involves increasing the size of the balancing area and diversifying geographically. This measure better suits countries which already have a stable and secure centralized grid but can also help countries with lower access to electricity, which benefit from regional interconnectivity.[210]

Regional power trading and energy exchange platforms are important complements to the physical interconnectivity infrastructure. Facilitating power and energy trading both within a country and in cross-border scenarios, such platforms could help create a more competitive, transparent, and dynamic energy balancing ecosystem in which the supply and demand across regions could be matched with market-driven efficiency. Regional power trading also helps maximize the low-carbon potential of the region, since the aggregated renewable resources profile and flexible resources in a region is more diversified than for an individual country.211 Many regions are pioneering in developing such trading mechanisms to enable energy balancing, such as in South Asia, the Arab Region, the Greater Mekong Subregion and Southern Africa.212

Cogeneration, e.g., combined heat and power (CHP) and combined cooling, heating and power (CCHP) enhances overall energy efficiency. Successful countries such as Denmark, Finland or Sweden have been able to decarbonize and increase their energy efficiency thanks to co-generation of district heating and power.[213] Co-generation or multi-generation with renewable energy have also been successful in countries such as in Iceland with geothermal energy. The advent of smart devices and advanced communications technologies, combined with measures (both existing and prospective) allowing energy to be stored on or near premises (e.g., in the form

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service market. Beyond this example, typical retrofitting for conventional power plants (coal, gas) include shorter start-up time and lower start-up costs, lower minimum load and improved part-load efficiency, higher ramp rate and shorter minimum uptime and runtime. These technological modifications go hand in hand with market design and regulatory changes. International Renewable Energy Agency (2019). Flexibility in conventional power plants: Innovation landscape brief. Retrieved from https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_Flexibility_in_CPPs_2019.pdf?la=en&hash=AF60106EA083E492638D8FA9ADF7FD099259F5A1.

210 This is the case of Lao PDR which is connected to the ASEAN Power Grid.

211 Word Bank (2018). Harmonization of energy support schemes to enable regional electricity trade – Case of MENA. Retrieved from https://www.financeministersforclimate.org/sites/cape/files/inline-files/Session%203-4.%20Waleed%20Alsuraih_CMI_PAEM%20support%20schemes%20harminzation%20and%20trade%20FNL.pdf.

212 Alam, F. *et al*. (2017). Regional power trading and energy exchange platforms. *Energy Procedia*, 110, 592-596. Retrieved from https://www.sciencedirect.com/science/article/pii/S1876610217302205; Regional Electricity Regulators' Associate and Word Bank (2009). International experience with cross-border power trading. Retrieved from https://openknowledge.worldbank.org/handle/10986/12716.

213 International Energy Agency (2019). Energy policies of IEA countries: Sweden 2019 review. Retrieved from https://www.iea.org/reports/energy-policies-of-iea-countries-sweden-2019-review.

of hot water or ice[214]) for later delivery of the related energy services, presents the prospect that a significant proportion of residential and commercial electricity load will become controllable even with uncontrolled fluctuations in VRE supply.

Developing a multi-energy complementary system (MECS) is pivotal to integrating various types of energy from the supply side, improving energy efficiency, lowering the rates of wind, solar and hydro curtailment, and boosting energy interconnectivity. Meanwhile, it enables optimal coupling of electricity, heating, cooling and gas, and maximizes energy utilization for users. Key technological links for developing MECS include multi-energy analysis and planning, collaboration of optimization and control systems, as well as massive energy storage management.[215]

Grid balancing services from renewables need to be maximized along with the growing deployment of renewables. Whilst the deployment of variable renewables is generally regarded as creating additional requirements for additional grid balancing services, advanced variable renewable resources' flexibility can be maximized. Typical examples of such services include "downward dispatch" while at full output or reducing output to enable upward or downward dispatch.[216] It is also possible for variable renewables to provide other services such as synthetic inertia. Providing services to aid system balancing generally requires clarity in connection codes over the nature of the services that must be provided as well as incentive mechanisms to provide compensation for any lost revenue arising from reduction in output.[217]

Advancing energy storage technologies are also key to facilitating diversified energy mixes. This helps provide system flexibility, generally with very fast response rates such as pumped hydro storage or electro-chemical battery energy storage systems. While pumped hydro is the most common form of grid-scale energy storage, electro-chemical battery energy storage systems have benefited from quickly decreasing costs (see Section 3.2.1). This technology is ideally suited to

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214 United States Environmental Protection Agency (n.d.). Electricity Storage. Retrieved from https://www.epa.gov/energy/electricity-storage.
215 Zhong, D. *et al*. (2018). "多能互补能源综合利用关键技术研究现状及发展趋势" [Research status and development trends for key technologies of multi-energy complementary and comprehensive utilization system]. *Thermal Power Generation* (link in Chinese, see references).
216 International Energy Agency (2019). Status of power system transformation. Retrieved from https://www.iea.org/reports/status-of-power-system-transformation-2019.
217 Ibid.

benefit from learning curve effects so costs are likely to continue to fall. Hence, it may become a cost-competitive energy resource in a few years.[218]

The modularity of batteries coupled with VRE **guarantees geographical and size flexibility**.[219] Solar PV projects coupled with storage technologies accounted for 40% of the estimated total new utility-scale battery projects.[220] They are also increasingly popular coupled with household solar PV systems and even present the prospect of "grid independence" in sunnier regions. The deployment of battery storage systems also requires modification to market rules since they do not conveniently fall into the category of generation or demand.

Shared governance needs to be promoted, to ensure market and balancing rules allow for the full sharing of resources, including reserves and ancillary services. In many jurisdictions, there remains a strong desire for self-sufficiency, and this can act as a material barrier to the full sharing of resources. The alignment of market rules calls for the reduction of local control over the power system, and shared governance of markets. It may become a deterrent to full market integration unless the objectives of the various regulators involved are sufficiently aligned.[221]

Regional organizations and other multilateral institutions can help boost this diversification process. In 1997, the Association of Southeast Asian Nations (ASEAN) has launched the ASEAN Power Grid that aims to connect its 10 Member-States and has already successfully connected Thailand with Cambodia, Lao PDR and Vietnam. To support ASEAN's target of having 23% of its primary supply from renewables by 2025, new interconnection projects are on the way to fully extend the regional grid.

At a global level, China has initiated the creation of the Global Energy Interconnection Development and Cooperation Organization (GEIDCO, see Box 3.1). US$7 trillion – out of the

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218 Kittner, N., Schmidt O., Staffell I. and Kammen, D. (2020). Grid-scale Energy Storage. In: Junginger M., and Atse L. (eds.) *Technological Learning in The Transition to a Low-Carbon Energy System: conceptual issues, empirical findings, and use in energy modeling*. Academic University Press, 1st edition., 119-143. Retrieved from https://www.sciencedirect.com/science/article/pii/B978012818762300008X.

219 International Energy Agency (2019). Status of power system transformation: power system flexibility. Retrieved from https://www.iea.org/reports/status-of-power-system-transformation-2019.

220 Renewable Energy Policy Network for the 21st Century (2019). Renewables 2019 : Global Status Report. Retrieved from https://www.ren21.net/gsr-2019/.

221 In the United States, the western synchronous interconnection does not have a single organized market, but instead uses a voluntary Energy Imbalance Market that covers participants in eight western states. In Europe, a mechanism has been created to allow netting of system imbalances across borders, thereby effectively creating larger balancing areas without requiring a single system operator.

US$27 trillion energy investments planned by 2050 – is envisaged to be devoted to power grid construction along the Belt and Road to cater to the world's rising demand for power.[222]

Box 3.1 GEIDCO: towards a global electricity grid

Created in March 2016 with headquarters in Beijing, GEIDCO is a non-profit international organization aiming to foster the development of a global energy interconnection system. GEIDCO has the ambition to put in place a global backbone grid, whose longest intercontinental transmission lines will rely on UHV technology.

GEIDCO was created to address critical concerns that require a coordinated international response and to make the most of potential opportunities given the:

- Growing need to connect local, regional, national and cross-border electricity markets in terms of infrastructure and trading modalities, including prices and payments;
- Necessity to strengthen and harmonize global electricity market governance mechanisms;
- Potential large benefits of effective global grid interconnectivity, including its critical contribution to developing the low-carbon economy.

Although often overlooked, grid interconnectivity is an important component of the BRI's transition towards sustainable development. GEIDCO estimates that there are abundant resources, with global clean energy potential exceeding 100,000 TW. Effectively capturing and transmitting through a global grid, less than 0.1% of this potential would meet today's global energy needs. Moreover, available know-how makes global grid interconnection feasible thanks to advanced and mature UHV transmission technologies. GEIDCO advocates in favour of a global energy interconnection.

To this end, it aims to forge a global consensus on the need for global connectivity, and on the potential of improving energy efficiency in production and consumption. In

222 Global Energy Interconnection Development and Cooperation Organization (2019). Six agreements signed and Plan for Belt and Road Energy Interconnection released. Retrieved from https://m.geidco.org/article/633.

order to support sustainable development in remote areas and promote the inclusion of rural populations, the BRI can help leverage global connectivity both through hard components such as supporting infrastructure building, and soft ones, notably by building capacity and by using harmonized technical standards. A more comprehensive grid interconnection means better infrastructure, which leads to lower-cost and fairer energy access. It can also contribute to increased capacities and resilience of people and places in the context of the globalized economy.

3.3.4 Improve load forecasting and scheduling to ensure energy management efficiency, scheduling of reserves, power system flexibility and supply-demand balance

Powerful energy management is needed to balance the utilization of various energy resources, coordinate energy production at different locations, adjust energy intensity over time, facilitate transactions and settlements, and therefore bridge supply and demand.

Alleviating the digital gap is pivotal in the energy management process. Digitalization tools, which facilitate massive data collection, mapping and analysis while linking all generation, grid, load and storage components, should be boosted. These tools include Internet of Things, big data, virtual power plants and smart metering.

Better load prediction – including both backcasting and forecasting – for renewable generators in operational timescales is needed, to help ensuring adequate flexibility and scheduling of reserves.[223] This includes both backcasting based on energy consumption quotas, and forecasting based on scenario analysis. A centralized forecasting and scheduling capability that is able to process large amounts of data is necessary to minimize reserve costs.[224] Sophisticated centralized short-term forecasting of output from variable renewables using digital techniques has been introduced in regions with high levels of penetration. Comparison of real-time observations on local energy consumption can be used to calculate load indexes.

223 National Renewable Energy Laboratory (2016). Forecasting wind and solar generation: improving system operations. Retrieved from https://www.nrel.gov/docs/fy16osti/65728.pdf.
224 Ibid.

Forecasting and scheduling processes will need to evolve. Generally, the identification and procurement of system flexibility has become a key market design challenge despite attention in many jurisdictions continuing to be focused on refining models to procure firm capacity at system peak conditions.[225] Traditional approaches to system operations, planning and market design have been based on the presumption of dispatchable generation and relatively predictable demand patterns. For example, it has been convenient to assume that all forced generation outages are random and independent events and demand uncertainty can be approximated using a simple "normal" distribution curve. This has allowed calculations to be easily undertaken that relate a security standard or a value of lost load directly to a capacity requirement at times of peak load, which has underpinned traditional approaches to planning long-term system capacity requirements. However, these assumptions will become increasingly inappropriate as generator availability becomes driven by strong systemic factors such as the dependence of wind turbine availability on weather conditions.

In these circumstances, it is far more complex to work out the capacity requirements that will deliver a particular security standard. Indeed, it is likely that pure capacity alone will not be enough and the ability of back-up generation to sustain output for an extended period could also be important. With high penetration of VRE generation, the biggest challenge for balancing supply and demand will arise when rapid increases in demand are coincident with rapid reductions in generator output and vice versa. This suggests that system flexibility is the most important aspect of the security of supply service and should be valued above traditional capacity and energy security products.

Regulation needs to evolve to address this change. It is apparent that forecasting and scheduling processes will need to evolve, and, in many instances, system operators will need to adapt their current processes. For example, **the introduction of shorter balancing periods has proven a valuable approach in many situations**.[226] However, it is important that these

225 The requirement for capacity mechanisms has been an important topic in EU energy policy discussions in recent years. This might involve auctions to directly procure firm capacity as in the UK or more indirect mechanisms such as the introduction of scarcity pricing as adopted by the Electricity Reliability Council of Texas (ERCOT).

226 International Renewable Energy Agency (2019). Innovation landscape for a renewable-powered future: solutions to integrate variable renewables. Retrieved from https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Feb/IRENA_Innovation_Landscape_2019_report.pdf.

developments do not compromise the ability to integrate neighbouring balancing areas and allow full sharing of balancing resources.

3.3.5 Further accelerate thermal power plants' retrofitting to strengthen their role as power system stabilizers and integrate higher shares of VREs

In some countries along the Belt and Road, due to limited geographical availability of renewable energy and high fluctuations of supply, thermal power will remain a major energy source in upcoming years. In order to boost low-carbon development, **it is necessary to adopt technologies such as combined heat and power (CHP), ultra-low emissions and energy-saving retrofits to reduce pollutants from thermal power industries**.

Accelerating thermal power retrofits is needed, so as to improve the peak regulation ability of the power system and therefore better respond to the variability of VRE generation. This includes engineering refurbishment of certain physical components and operational modifications, to unlock the flexibility of thermal power infrastructure, which serves as a power system stabilizer.

The engineering refurbishment of thermal power plants specifically aims to lower minimum load,[227] ensure stable combustion, enhance ramp rates,[228] shorten start-up time, and lower minimum uptime and runtime.[229] It is expected that by such retrofits, the peak regulation ability of both CHP units and condensing units can be enhanced by about 20%.[230]

The potential of such refurbishment is vast. In India, reducing minimum generation levels for one third of the country's thermal plants from 70% to 55% of capacity has reduced VRE curtailment from 3.5% to 1.4% and has downsized the annual operating costs of the power system by 0.9%.[231] Further reduction is encouraged to bring the rate of VRE curtailment down. Meanwhile,

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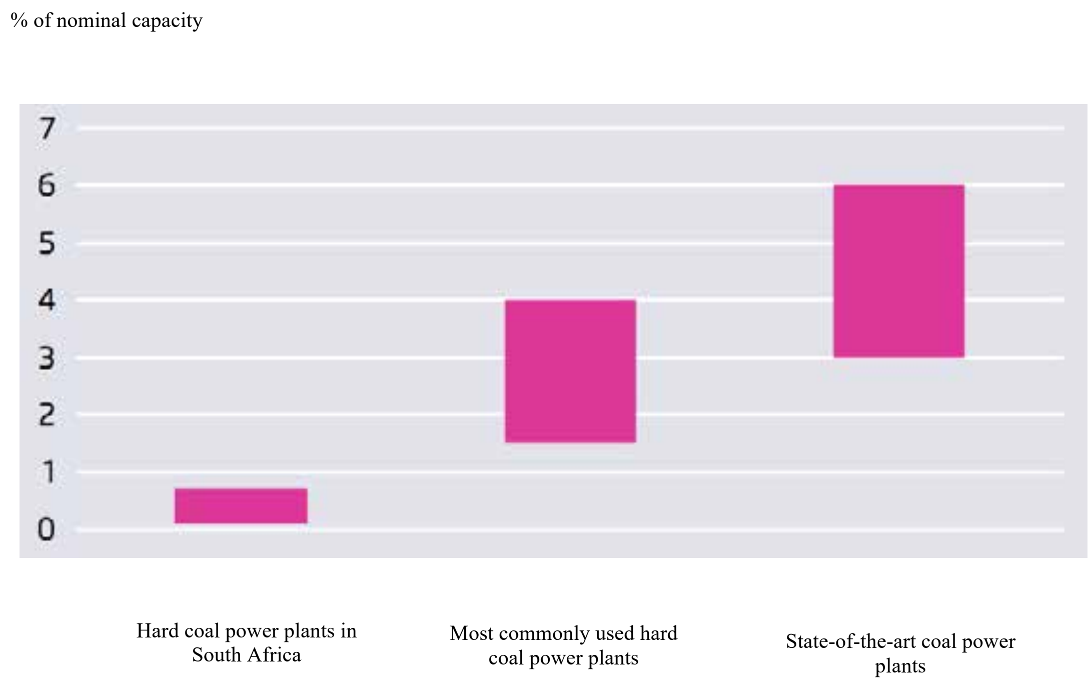
227 The minimum load "describes the lowest net power output a power plant can deliver while maintaining stable operation". Agora Energiewende (2017). Flexibility in thermal power plants with a focus on existing coal-fired power plants. Retrieved from https://www.agora-energiewende.de/fileadmin2/Projekte/2017/Flexibility_in_thermal_plants/115_flexibility-report-WEB.pdf.
228 "The ramp rate describes how fast a power plant can change its net power during operations." Ibid.
229 International Renewable Energy Agency. (2019). Flexibility in conventional power plants. Innovation landscape brief. Retrieved from https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_Flexibility_in_CPPs_2019.pdf?la=en&hash=AF60106EA083E492638D8FA9ADF7FD099259F5A1.
230 Shi, Y., Zuo Y., and Meng, Y. (2017). "中国火电产业的历史轨迹与发展展望" [Historical track and prospect of China's thermal power industry]. *Science and Technology Management Research* (Link in Chinese, see references).
231 Central Electricity Regulatory Commission (2016, 6 April). Notification No. L-1/18/2010-CERC. Retrieved from http://www.cercind.gov.in/2016/regulation/124_1.pdf.; National Renewable Energy Laboratory (2017). Greening the grid: pathways to integrate 175 GW of renewable energy into India's electric grid. Retrieved from https://www.nrel.gov/docs/fy17osti/68720.pdf.

with a higher ramp rate, a power plant can adapt itself quicker to variation in demand. In countries like South Africa, the ramp rate for coal-fired power plants stands between 0.1% to 0.7% (see Figure 3.9), much lower than the standard average which ranks between 1% to 4%. Higher ramp rates would enable a plant to alter its production quickly to meet system needs.

Figure 3.9 Ramp rates of hard coal power plants in South Africa compared to most commonly used and state-of-the-art designs



Source: Agora Energiewende[232]

Grid codes[233] and market rules need to be updated, to encourage flexible operation of thermal power plants and create an enabling environment for the deployment of such retrofits. In India, grid code has been amended to enable an interstate generating station to lower the technical minimum output by 15% of the unit's installed capacity. The amended grid code also sets out a higher ramp rate, which has stimulated engineering retrofits and flexibilization studies

232 Agora Energiewende (2017). Flexibility in thermal power plants with a focus on existing coal-fired power plants. Retrieved from https://www.agora-energiewende.de/fileadmin2/Projekte/2017/Flexibility_in_thermal_plants/115_flexibility-report-WEB.pdf.
233 Grid Codes are technical documents that define the performance standards that all facilities connected to a power network must meet to ensure the safe and secure operation of the grid.

by several power plants.[234] In Northeast China, the retrofit of thermal power plants to lower their minimum load has been incentivized through price mechanisms in the electricity ancillary service market, and such experience has been promoted in other parts of China (see more about power market design in Appendix IV).

3.3.6 Plan and develop distributed energy resources and compensate centralized grid development based on natural resource endowments and power demand

The choice between centralized or distributed power system development should be based on the specific natural resource endowments and development level of their targeted markets or countries. For example, if renewable resources are located in unpopulated areas far from cities, centralized development of renewable power plants becomes a good choice and brings cost competitiveness. In contrast, in regions where synchronously integrated power systems are absent and local policymakers do not envisage the necessity to build them, distributed generation such as distributed energy resources (DERs) can help boost a system's flexibility. For areas where a centralized grid is not accessible, decentralized systems can be an alternative to satisfy local energy demand (see Box 3.2).

Box 3.2 Decentralized systems

Whilst synchronously integrated power systems are the norm for all developed and most developing countries, they do not exist in many regions in Africa or the Asia-Pacific region (see the case of Madagascar in Section 3.4.1). Distributed renewable energy systems such as mini-grids and off-grid solutions are the most cost-effective means to provide electricity access in these rural and remote regions. Indeed, these systems provide the main source of energy provision and local policymakers often do not envisage the need to develop an integrated power system due to their low cost-effectiveness.[235] According to REN21 2019 *Global Status Report*, off-grid solar systems' estimated sales have risen from 0.9 million in 2010 to 23.5 million units in 2018.[236]

234 International Renewable Energy Agency (2019). Flexibility in conventional power plants. Innovation Landscape Brief. Retrieved from https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_Flexibility_in_CPPs_2019.pdf?la=en&hash=AF60106EA083E492638D8FA9ADF7FD099259F5A1.
235 Renewable Energy Policy Network for the 21st Century (2019). Renewables 2019: Global Status Report. Retrieved from https://www.ren21.net/gsr-2019/.
236 Ibid.

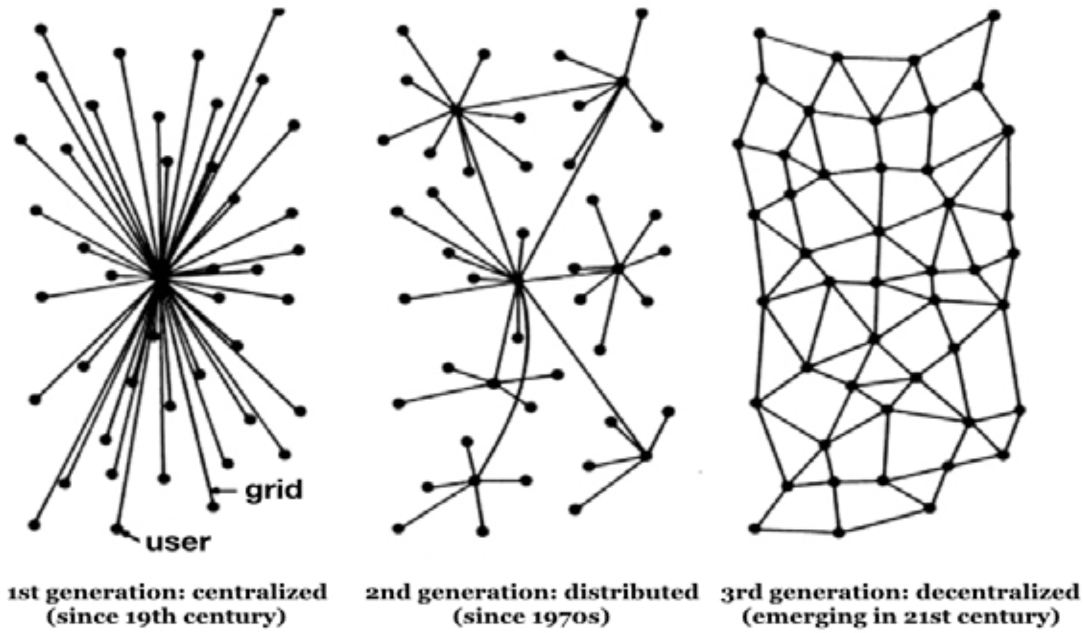
These decentralized energy systems do not have the same system integration issues that face renewables connected to integrated systems, although technology innovations involving intelligent components and cloud-based software platforms have enabled larger-scale deployment and help ensure a more efficient use of the energy provided. The main challenge for the deployment of such systems often involves designing appropriate business models that can secure the necessary investment given the low energy requirements and the relative poverty of the communities being served.

The combination of distributed low-carbon energy grid and centralized smart grid would be key to the future development of the energy Internet. For countries that seek rapid urbanization, distributed energy sources such as natural gas and solar power are important for satisfying increasing energy needs. In both cities and rural areas, households or communities can be energy consumers and energy producers simultaneously, which enhances energy efficiency.

The system of distributed generation (DG), as the core of DER,[237] has resulted in a three-generation evolution (see Figure 3.10). While the first generation was still essentially a centralized system, the second generation managed to develop multiple energy centres. Along with the development of information and communication technology, and increasing access to the Internet, the third generation DG system has emerged to deal with growing energy demand and climate change mitigation needs. VRE generation, including wind power, solar power and biomass CHP, is boosted in this decentralized system. Terminal users are meanwhile also energy producers who produce power and heat through rooftop solar PV or fuel cell batteries, and energy transmission, distribution and transaction are enabled by the energy Internet.

237 Distributed energy resources (DER) are defined as “various resource types and technologies including distributed generation plants such as rooftop solar PV, and other enabling technologies such as behind-the-meter batteries, EVs, residential heat pumps and demand response, among others.” International Renewable Energy Agency (2019). Innovation landscape for a renewable-powered future: solutions to integrate variable renewables. Retrieved from https://www.irena.org/publications/2019/Feb/Innovation-landscape-for-a-renewable-powered-future.

Figure 3.10 Evolvement of distributed generation



Source: Long, W. [238]

Technological innovation in flexible electricity storage facilities is a cutting-edge field for the development of a distributed power system. It enables the exchange of electricity surplus and untaps the autonomy of terminal users by breaking the limits set by time and geography. The role of energy producers and consumers, especially small-scale ones, becomes fluid with the availability of flexible and affordable energy storage facilities that help subsequent user-to-user electricity exchange. Alongside the evolution of distributed generation, electricity storage facilities for end-users could become an important area of investment.

Diversified business models can be explored to further improve service markets, which would in turn facilitate distributed energy development. For instance, pilot programs of online transaction platforms adopting block chain technologies can be encouraged, to facilitate a higher share of distributed energy resources. Service platforms for transport electrification, building electrification and smart cities enabled by distributed energy resources should be developed, based

238 Long, W. (2019). "第三代分布式能源系统及其应用" [The third generation of distributed energy system and application]. *Journal of HV & AC* (link in Chinese, see references).

on smart infrastructure and digitalization tools, as well as integrated control and automation technologies.

3.4 Best practices in boosting low-carbon energy transition and development

The following section highlights best practices for the energy transition in selected countries. It first focuses on a country with a low level of human development (Madagascar), then on those with a medium level (Vietnam), high level (South Africa) and very high level of human development (Denmark, Uruguay).

3.4.1 Madagascar: formulating strategic energy development plan and policies to enable higher shares of VREs

One of the poorest countries in the world, Madagascar has initiated political and energy reforms to have 80% of its energy mix stem from renewable energy by 2030. In particular, it plans to have its VRE sources jump from near 0 to 10% in the next 10 years. The success of such an ambitious reform is conditional on overcoming many challenges, including political and economic instability, and on attracting international investment.

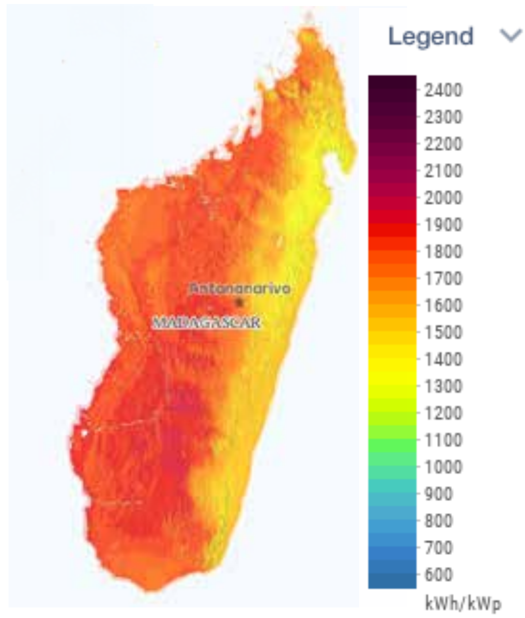
The ambition is based an already favourable electricity mix for the low-carbon development of the country, composed of hydropower (54%) and thermal power plants (46%), and reliance mostly on imported oil.[239] The country's energy reform is propelled by an extremely high renewable energy potential (hydropower, solar, wind) and a political willingness to scale up renewable energy and electrification. The country’s hydropotential is underexploited and could represent up to 7.8 GW (10 times more than the current use),[240] while the sun can provide on average 2,000 kWh/m^2/year (see Figure 3.11).[241] Furthermore, wind capacity is particularly interesting in the South and the North of the island.

The country is devoted to increasing access to electricity by developing renewable energy. For example, in 2019 a hydropower plant was planned to be constructed in Antananarivo, the

239 Madagascar’s Ministry of Water, Energy and Hydrocarbons (2018). Investment plan for renewable energy in Madagascar. Retrieved from https://www.climateinvestmentfunds.org/sites/cif_enc/files/srepinvestment_plan_for_madagascar_final.pdf.
240 Ibid.
241 World Bank. (2020). Global solar atlas. Retrieved from https://globalsolaratlas.info/map.

capital of Madagascar, jointly by a Malagasy and Italian company. Combined with two solar power plants, a total capacity of 35 MW will be used to fill the energy gap in and around Antananarivo.[242]

Figure 3.11 Map of Madagascar's solar potential



Source: World Bank[243]

The success of such an ambitious reform is, however, conditional on overcoming many challenges, including political and economic instability, and on attracting foreign investment. As one of the least developed countries in the world, Madagascar is facing important challenges when it comes to its energy and electrification policy.[244] It ranked 162th of 189 in the Human Development Index (0.521), and its GDP per capita in 2019 was US$1,453.[245] From 2009 to 2013, the country had to face a political crisis. Moreover, the electricity access rate is 15%, one of the lowest in the world. The country's population is dissatisfied with the national operator which is heavily indebted and unable to provide a stable power supply. Meanwhile, energy needs are rising while the country is already facing issues from climate change.

242 Africa Energy Portal (2019, August 30). Madagascar: 35 MW hydroelectric power plant in project in Antananarivo. Retrieved from https://africa-energy-portal.org/news/madagascar-35-mw-hydroelectric-power-plant-project-antananarivo.
243World Bank (2020). Global solar atlas. Retrieved from https://globalsolaratlas.info/map.
244 United Nations Development Programme (2019). Human development indicators: Madagascar. Human Development Reports. Human Development Reports. Retrieved from http://hdr.undp.org/en/countries/profiles/MDG.
245 Ibid. PPP 2011.

Since 2015, the country has initiated an ambitious energy policy (the *New Energy Policy*) that has been detailed further by the *Investment Plan for Renewable Energy Policy* in 2018.[246] It emphasized the ambition to foster renewables with two major objectives for 2030: increasing the electricity access rate from 15% to 70% of the population, and push renewables to 80% of the overall energy mix despite the country having important oil reserves. On-grid power is to be boosted by several hydropower projects and integrating the wind and solar sectors' contributions to 10% of the power supply while off-grid renewables will be developed using mini-hydro, bio-gas from rice balls and solar PV.[247] These measures are complemented by other policies including the modernization of cooking equipment and boosting energy efficiency.

In order to do this, the Malagasy renewable energy transition will rely on economic and political stability, but also on investments under the umbrella of international organizations such as the World Bank, or the EU, with support from the UN. While the World Bank has already lent US$100 million to the country since 2016 to reform its power grid, the International Finance Corporation has launched the *Scaling Solar* initiative in Madagascar to develop solar projects with the help of public-private partnerships.[248]

Key take-aways from Madagascar's case:

Although one of the poorest countries in the world, the country has committed to developing a policy path in line with climate action without jeopardizing its future economic and social development. If successful, **Madagascar's ambitious policy will enable it to leapfrog decades of development in terms of power generation, grid development, as well as environmental and climate policy.** It will also provide economic, social and environmental benefits for Madagascar's population, contribute to the global attainment of the SDGs, and represent promising opportunities in the renewable sector for Chinese and other companies to export their expertise along the Belt and Road.

246 Ibid.
247 Madagascar's Ministry of Water, Energy and Hydrocarbons (2018). Investment plan for renewable energy in Madagascar. Retrieved from https://www.climateinvestmentfunds.org/sites/cif_enc/files/srepinvestment_plan_for_madagascar_final.pdf.
248 World Bank (2018). The force of the sun: Madagascar embarks on renewable energy production. Retrieved from https://www.worldbank.org/en/news/feature/2018/10/10/the-force-of-the-sun-madagascar-embarks-on-renewable-energy-production.

As in many least-developed countries, international organizations and the private sector's cooperation will be vital to help the country achieve its national energy targets.

3.4.2 Vietnam: encouraging and supporting investment and financing flows towards VRE projects

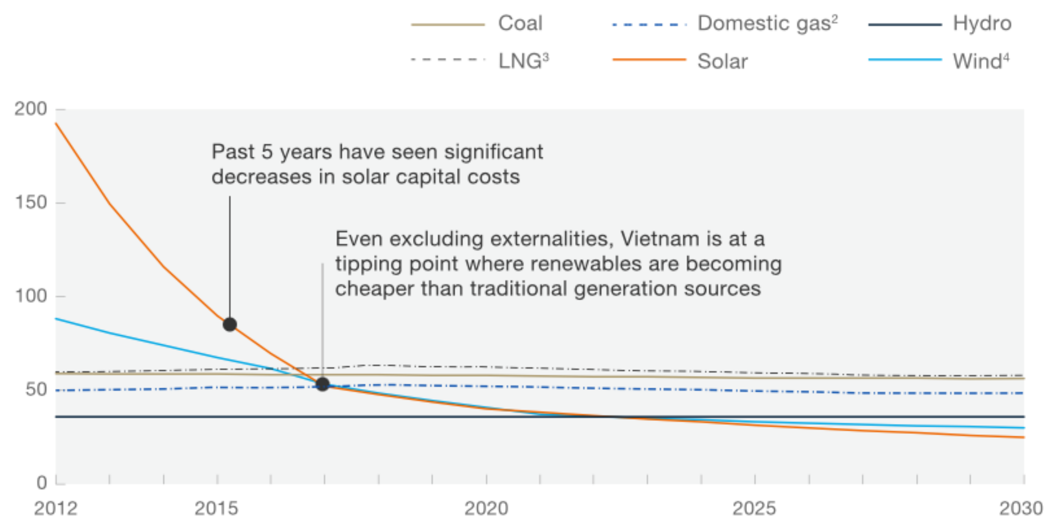
Vietnam is a medium-level human development country with an HDI of 0.693, ranking 118th out of 189 countries.[249] Its population enjoys a 100% access rate to electricity. Buoyed by a GDP growth that has hovered between 5% and 7% since 2000, Vietnam's electricity demand has increased by 60% over the last five years and is expected to double by 2030 to reach 120 GW.[250] This will have an important effect on GHG emissions and will require investment of around US$150 billion to update Vietnam's power grid.[251] Due to these trends, Vietnam has shifted from being a net exporter of coal and oil to a net importer. Benefiting from a high hydropower potential (40% capacity of power generation), the energy policy of Vietnam had been fossil fuel oriented until 2017, but then room was created for a major increase in VRE investments. The current policy is investing massively in both fossil fuel resources and renewable energy.

As a Member-State of ASEAN, the country has made the indicative commitment in 2016 to set its renewable energy target to 23% of its primary supply by 2025. This indicative commitment was restated at the New York United Nations Climate Action Summit in 2019 by ASEAN.[252] From virtually no VRE in its electricity mix in 2017, Vietnam is now one of the leading Southeast Asian countries in wind and solar development. Enjoying high sun potential and setting pricing policies right, its solar capacity has jumped from 0 to 5GW in 2020.[253] Expanding a bit less fast, wind capacity is set to reach 6 GW by 2030, with the world's largest offshore windfarm to be built in the south of the country (capacity of 3.4 GW). Offshore capacity is estimated at around 309 GW, nearly triple the total electricity need for Vietnam in 2030.[254] This fast expansion is partly due to

249 United Nations Development Programme (2019). Human development indicators: Vietnam. Human Development Reports. Retrieved from http://hdr.undp.org/en/countries/profiles/VNM.
250 Vu, K. (2019, July 31). Vietnam will face severe power shortages from 2021: Ministry. Reuters. Retrieved from https://www.reuters.com/article/us-vietnam-energy/vietnam-will-face-severe-power-shortages-from-2021-ministry-idUSKCN1UQ11M.
251 Rogers, M. (2019, May 1). Vietnam's renewable energy future. McKinsey & Company. Retrieved from https://www.mckinsey.com/business-functions/sustainability/our-insights/sustainability-blog/vietnams-renewable-energy-future.
252 Association of Southeast Asian Nations (2019, September 23). ASEAN Joint Statement to the United Nations Climate Action Summit 2019. Retrieved from https://asean.org/storage/2019/09/AJSCC-to-UN-Climate-Action-Summit-2019-ADOPTED.pdf.
253 The Economist (2020, January 25). Vietnam grapples with an unexpected surge in solar power. Retrieved from https://www.economist.com/asia/2020/01/25/vietnam-grapples-with-an-unexpected-surge-in-solar-power.
254 Ha, T. (2019, November 19). Gusty growth: Vietnam's remarkable wind energy story. *Eco-business*. Retrieved from https://www.eco-business.com/news/gusty-growth-vietnams-remarkable-wind-energy-story/.

the decreasing cost of renewable energy that is likely to continue in the next 10 years (see Figure 3.12).[255] The fast expansion is also due to a favourable policy initiated in 2017 (first by feed-in-tariffs and since 2019 by competitive auctions) and favourable natural resource endowment in the south of the country.[256]

Figure 3.12 Vietnam's average LCOE, US$ per megawatt-hour



Source: McKinsey[257]

However, its important planned development of coal mines still prevents the country's current policy to be compatible with a 1.5°C scenario as recommended by the IPCC 2018 report. Vietnam is thus at a crossroads in terms of policy choices.[258]

Key take-aways from Vietnam's case:

Wind and solar energy can be developed extremely fast. Shifting from a traditional support of fossil fuels to support its growth, Vietnam has illustrated that in less than 3 years (2017-2020), it is possible to increase its VRE power generation from 0 to 10%. By doing this, Vietnam has

255 Breu, M., Castellano, A., Frankel, D., and Rogers, M. (2019). Exploring an alternative pathway for Vietnam's energy future. McKinsey & Company. Retrieved from https://www.mckinsey.com/featured-insights/asia-pacific/exploring-an-alternative-pathway-for-vietnams-energy-future.
256 The Economist (2020, January 25). Vietnam grapples with an unexpected surge in solar power. Retrieved from https://www.economist.com/asia/2020/01/25/vietnam-grapples-with-an-unexpected-surge-in-solar-power.
257 Breu, M., Castellano, A., Frankel, D., and Rogers, M. (2019). Exploring an alternative pathway for Vietnam's energy future. McKinsey & Company. Retrieved from https://www.mckinsey.com/featured-insights/asia-pacific/exploring-an-alternative-pathway-for-vietnams-energy-future.
258 Teske, S., Morris, T., Nagrath, K., Dominish, E. (2019). Renewable energy for Viet Nam. University of Technology Sydney. Retrieved from https://www.uts.edu.au/sites/default/files/article/downloads/Teske-Morris-Nagrath-2019-Renewable-Energy-for-Viet-Nam-report.pdf.

already reached its 2025 objectives. Such investments could quell Vietnam's thirst for power, as its offshore wind potential alone is 3-times bigger than its expected energy needs in 2030.

Like many developing countries, **Vietnam stands at a crossroads:** it is a fast-growing country and the associated rapid increase in energy demand raises the risk of a lack of access to energy. In 2021, Vietnam will have to adopt an energy plan that will define its strategy over the next 10 years. Choosing a scenario that would favour integrating more VRE in its system over coal development would result in 10 times less GHG emissions, markedly less lifetime costs and would also help avoid being burdened by large amounts of stranded assets in the future (see Figure 3.12 on costs).

3.4.3 South Africa: gradually phasing out coal projects to mitigate stranded assets risk

A high-level human development country with an HDI of 0.705 (ranking 113th out of 189 countries), South Africa is a country **highly dependent on coal**.[259] Its total primary energy demand is 74% reliant on coal, while 89% of its electricity is based on coal.[260] GHG emissions per capita are much higher than the world average due to this coal-intensive energy mix. Despite its prevalence, the main national operator has not been successful in providing power for growth and has been hampered by rising electricity costs for consumers and industries caused by poor management and investment decisions.[261]

In 2019, South Africa has made **highly ambitious changes** in its energy policy as confirmed by its climate policy announcement during the UN Climate Action Summit in September 2019 and the adoption of its *Integrated Resource Plan* in October 2019. Benefiting from a high potential in wind and solar renewables and decreasing costs that exceeded the IEA's initial expectations,[262] South Africa has made the pledge to decommission more than 10 GW of its coal capacity.[263] Due to its decision to continue building new coal units simultaneously, this will only result in a net decline of 3 GW of capacity from 2019 to 2030. Meanwhile, solar PV, wind and hydropower would add 24 GW of capacity to the country's power grid, thus pushing VRE up to 21% of power

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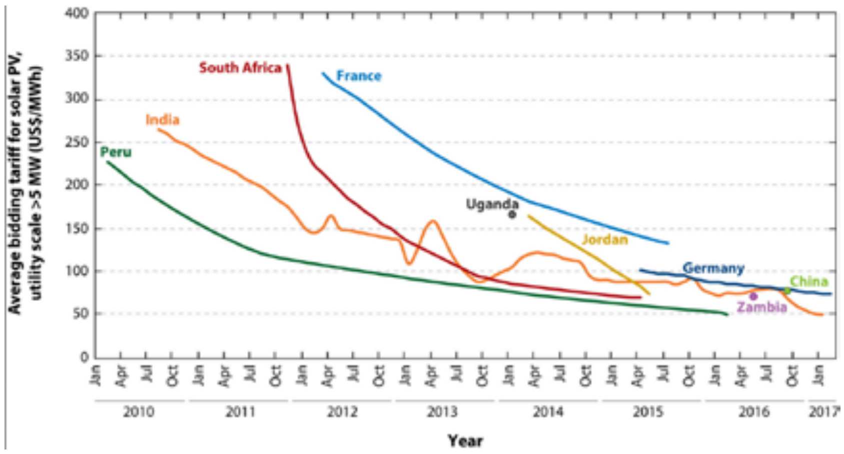
259 United Nations Development Programme (2019). Human development indicators: South Africa. Human Development Reports. Retrieved from http://hdr.undp.org/en/countries/profiles/ZAF.
260 International Energy Agency (2019). South Africa energy outlook: analysis from Africa energy outlook 2019. Retrieved from https://www.iea.org/articles/south-africa-energy-outlook.
261 Ibid.
262 Arndt, C. *et al*. (2019). Faster than you think: renewable energy and developing countries. *Annual Review of Resources Economics*, 11, 149-168. Retrieved from https://www.annualreviews.org/doi/10.1146/annurev-resource-100518-093759.
263 The short-term capacity gap for distributed generation (see last column) is estimated to be 2 GW according to South Africa's Energy Department. South Africa's Energy Department (2019). Integrated resource plan. Retrieved from http://www.energy.gov.za/IRP/2019/IRP-2019.pdf.

generation. Although some observers have argued that these efforts are not enough to meet the country's commitment to comply with the Paris Agreement and criticized the capacity increase of coal,[264] this is still an unprecedented commitment to phase out coal in the next 10 years for the world's fifth biggest exporter of coal. The policy of phasing out coal is envisaged to continue up to 2050, with only 12 GW of coal capacity left by then, a decline of 66% compared to its 2019 level.

Figure 3.13 Electricity costs for solar PV in South Africa and in comparator countries



Source: Arndt, C.[265]

Key take-away from South Africa's case:

Although a major coal producer, South Africa has taken strong policy leadership on low-carbon development in the power sector by aiming at quickly scaling up renewables including solar PV and wind. This demonstrates the importance of foresight-based planning that incorporates considerations of the falling relative price of renewables, and of fossil fuel assets likely to become stranded.

3.4.4 Denmark and Uruguay: optimizing regional network interconnectivity to enhance power system flexibility

Denmark and Uruguay are the countries in the world with the highest deployment of renewables. Their success is due to several factors. Both countries are relatively small, but they

264 Ibid; Carbon Brief (2018, October 15). The Carbon Brief profile: South Africa. Retrieved from https://www.carbonbrief.org/the-carbon-brief-profile-south-africa.
265 Arndt, C. *et al*. (2019). Faster than you think: renewable energy and developing countries. *Annual Review of Resources Economics*, 11, 149-168. Retrieved from https://www.annualreviews.org/doi/10.1146/annurev-resource-100518-093759.

took advantage of their location in the vicinity of larger neighbours (Argentina and Brazil for Uruguay) or seamless access to regional networks (the EU and the northern network for Denmark). Such network conditions favour the integration of variable generation especially since they allow on-demand trading to address unpredictable excess demand or supply arising from a high share of VRE.

Beyond their geographical location, both countries were able to develop a portfolio of technologies that could support much higher deployment of renewables while reducing uncertainties due to the variability of individual forms of renewables. Countries can increase the flexibility of their domestic generation in many ways, depending on their natural resources and infrastructure. For instance, Uruguay's oil-fired generation together with its hydro capacity have complemented and thus paved the way for its wind and solar growth. Denmark has achieved domestic flexibility by complementing national heat and power demand through a network of co-generation units providing both heat and power.[266]

Denmark and Uruguay can serve as examples for other countries along the Belt and Road on how countries could better assess their potential and flexibly leverage opportunities.

Denmark is the country with the **highest deployment of variable renewables in the world**. This is due to several factors: Denmark has been able to integrate more than 50% of variable renewables because of favourable natural conditions, strategic public policy choices and good synchronous connection between Northern and Central Europe.[267] It now has a target to no longer depend on fossil fuels by 2050.[268]

In particular, the 1973 and 1979 oil crises led to the implementation of new energy policies in the 1980s, key among which was the development of its wind industry.[269] This process

266 Wynn, G. (2018, November 13). Uruguay nears world record wind and solar market share. *Energy and Carbon*. Retrieved from https://energyandcarbon.com/uruguay-poised-overtake-denmark-wind-solar-leader-market-share/.
267 See Section 3.2 on system inertia and synchronous connections. International Energy Agency (2017). Denmark 2017 review. Energy Policies of IEA Countries. Retrieved from https://webstore.iea.org/download/direct/266?fileName=EnergyPoliciesofIEACountriesDenmark2017Review.pdf.
268 Danish Energy Agency (n.d.). The Danish energy model: innovative, efficient and sustainable. Retrieved from https://ens.dk/en/our-responsibilities/global-cooperation/danish-energy-model.
269 International Energy Agency (2017). Denmark 2017 review. Energy Policies of IEA Countries. Retrieved from https://webstore.iea.org/download/direct/266?fileName=EnergyPoliciesofIEACountriesDenmark2017Review.pdf.

accelerated in the 1990s when renewables still accounted for just 4% of Danish domestic electricity use. The share of wind power then rose to more than 50% of the country's power generation.[270]

Denmark is a significant example since it has essentially transitioned its energy system from a dependence on coal and oil towards renewables without relying on significant amounts of gas to provide grid services. Instead, it has been able to accommodate high proportions of wind power through optimization of its own grid and integrating its power network with neighbouring counties.

The case of Uruguay is also very interesting as it underwent the energy transition in a very short time with a strong investment in solar PV and wind from 2015 to 2019. More than 95% of Uruguay's electricity now comes from renewables, and 57% of Uruguay's total primary energy supply (TPES) is based on renewables.[271] This shift was facilitated by the country's lack of natural resources in fossil fuels (coal, oil, gas) and timely, strategic public policy choices.

This trend has intensified in the last four years, as important investments have been devoted to solar PV and wind power energy. As a result, Uruguay's share of wind power has risen from 1 to 33% since 2015.[272] Though several challenges still remain, such as over-generation and high residential electricity prices, in 2018 renewable energy accounted for 3% of the country's GDP.[273]

Key take-away from Denmark's and Uruguay's cases:

Like Vietnam, Uruguay's energy transition demonstrates the possibility of a quick and successful energy transition while making the best use of complementarities offered by renewable energy.

Highly dependent on coal and oil in the past, Denmark has shifted away from fossil fuels to become a world leader in the energy transition. It benefited fully from regional interconnectivity within the European Union and is now able to export its technological skills worldwide. It is also relatively free of risks posed by future stranded fossil fuel assets.

270 International Energy Agency (2020). Data and statistics: Denmark, power generation. International Energy Agency Database. Retrieved from https://www.iea.org/data-and-statistics?country=DENMARK&fuel=Energy%20supply&indicator=Electricity%20generation%20by%20source.
271 Uruguay XXI (2019, December 18). Uruguay, leader in renewable energies. Retrieved from https://www.uruguayxxi.gub.uy/en/news/article/uruguay-lider-en-energias-renovables/.
272 Proano, M. (2018, November 16). What's next for the energy transition in Uruguay? Energy Transition. Retrieved from https://energytransition.org/2018/11/whats-next-for-the-energy-transition-in-uruguay/.
273 Ibid.

Chapter 4 Channelling investment and financing flows towards the innovation, development and deployment of low-carbon projects

Providing sustainable investment and financing instruments for key stakeholders is pivotal to promoting low-carbon projects along the Belt and Road. To channel investment and financing flows towards low-carbon development projects, this chapter conducts an in-depth analysis of frameworks, standards and indicators of sustainable investment and financing globally and along the Belt and Road, and highlights the necessity of harmonizing carbon pricing standards, especially monitoring, reporting and verification standards for emission allowances in accounting. This chapter identifies the necessity to further innovate financial instruments, especially green credit products, green bond products, green insurance and guarantee services, and the necessity to strengthen policy incentives for relevant innovative products and services. This chapter also calls for promoting blended financing, and strengthening the identification, assessment, monitoring and management of environmental and climate risks in pre- and post-lending stages to provide full-cycle support for low-carbon projects.

Section 1 maps sustainable investment and financing regulations, standards, principles and guidelines in China, countries and territories globally and along the Belt and Road, and identifies their differences and commonalities. Section 2 presents an in-depth analysis of the challenges in promoting sustainable investment and financing towards low-carbon projects along the Belt and Road. Section 3 puts forward five concrete measures to channel investment and financing flows towards low-carbon projects. Section 4 provides best practices of different market players worldwide that promote investment and financing towards green and low-carbon development. These include EU ETS' harmonization of accounting standards for carbon emission allowances, Huzhou Green Finance Market's utilization of policy and legislative incentives to build green finance ecosystem, ICBC's environmental risk assessment technology and model in stress test, and IFC's blended finance aiming at exploring diversified financing channels to support low-carbon development.

4.1 Context of global sustainable investment and financing, and climate of sustainable investment and financing in countries and territories along the Belt and Road [274]

4.1.1 Global sustainable investment and financing regulations and standards: Multilateral Development Banks and International Organisations

Multilateral Development Banks (MDBs) are at the forefront of reshaping the global financial order towards a low-carbon path. Almost all MDBs have their own Environmental and Social Frameworks (ESFs) to change investment behaviour towards a more sustainable direction. The Operational Policy of the World Bank (WB), Safeguard Policy Statement of Asian Development Bank (ADB), Operational Policy of Inter-American Development Bank (IDB), Performance Requirements of the European Bank for Reconstruction and Development (EBRD), Environmental and Social Standards of the European Investment Bank (EIB), and the Environmental and Social Framework of Asian Infrastructure Investment Bank (AIIB) are typical examples. They are regularly updated and there is a trend of convergence. For instance, the Environmental and Social Standards (ESS) of all six MDBs listed above cover the following 10 areas:

Table 4.1 Summary of MDBs' environmental and social standards

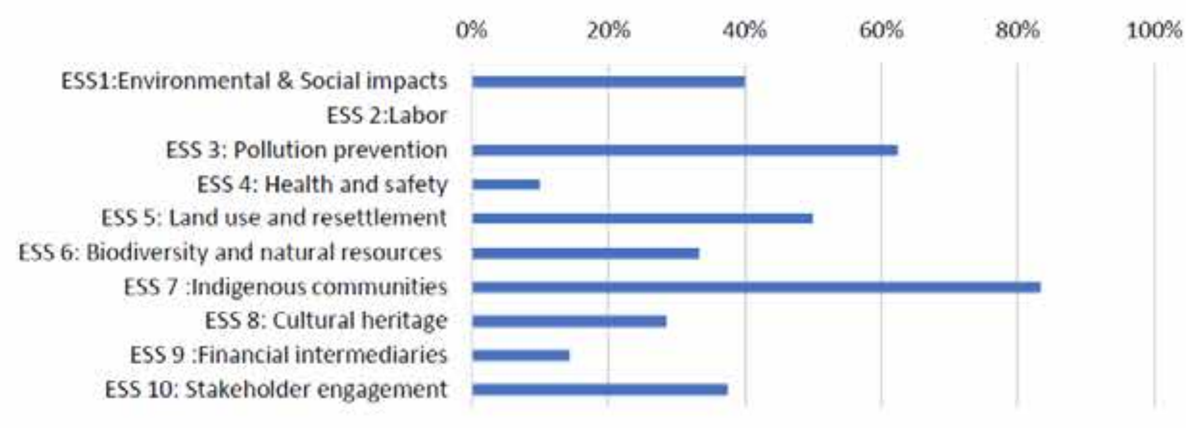
ESS	WB	IDB	ADB	EBRD	EIB	AIIB
Environment and social impacts	✓	✓	✓	✓	✓	✓
Labour and employment[275]	✓	/	/	✓	✓	✓
Pollution prevention	✓	✓	✓	✓	✓	✓
Health and safety	✓	✓	✓	✓	✓	✓
Land use settlement	✓	✓	✓	✓	✓	✓
Biodiversity and natural resource conservation	✓	✓	✓	✓	✓	✓
Indigenous community	✓	✓	✓	✓	✓	✓
Cultural heritage	✓	✓	✓	✓	✓	✓
Financial intermediary	✓	✓	✓	✓	✓	✓
Stakeholder engagement	✓	✓	✓	✓	✓	✓

274 All standards of sustainable finance that this reports looks into are mature environmental and social frameworks, standards or principles already adopted by MDBs, NDBs, or other financial institutions.
275 The only two exceptions here are IDB and ADB. IDB does not address labour and employment considerations in its Environment and Safeguards compliance policy, though the bank has an Operational Policy on Labour sector. ADB has labour considerations in its Social Protection Strategy (2001), but these are not specific to the bank's operations.

Source: UNDP and CDB[276]

The degree of commonality among these investment standards is remarkable. These 10 categories of environmental and social standards encompass 88 specific aspects. Most of the 88 specific aspects are covered by more than a half of the MDBs mentioned above in their policy documents (see Figure 4.1). Specific aspects that all MDBs cover in their ESS include: environmental and social assessment, Environmental and Social Commitment Plan, project monitoring and reporting, management of hazardous and non-hazardous waste, infrastructure and equipment safety, involuntary land resettlement, impact on biodiversity, engagement with indigenous people, definition of cultural heritage, definition of financial intermediaries, information disclosure, etc.

Figure 4.1 ESS commonalities among the MDBs



Source: UNDP and CDB[277]

Turning to National Development Banks (NDBs) involved in international finance, they also incorporate environmental and social concerns into the entire infrastructural project cycle. Prominent NDBs include KfW Development Bank of Germany (KfW), Korea Development Bank (KDB), Japan Bank for International Cooperation (JBIC), Vnesheconombank of Russia and Development Bank of Southern Africa (DBSA), all of which have ESFs in place except

276 United Nations Development Programme and China Development Bank (2019). Harmonizing investment and financing standards towards sustainable development along the Belt and Road. Retrieved from https://www.cn.undp.org/content/china/zh/home/library/south-south-cooperation/harmonizing-investment-and-financing-standards-.html.
277 Ibid. The research found that despite most MDBs having labour standards, the content of the standards is quite different. This is why there is no common specific areas targeted by the labour standards of MDBs.

Vnesheconombank. However, Vnesheconombank also has an overall stated objective of promoting sustainable development projects.

Compared to MDBs, the ESFs of NDBs cover a smaller part of the 10 ESS standards listed above. However, they still have great impact on enhancing the sustainability of finance. For example, 24 NDBs globally joined the International Development Finance Club (IDFC), which in turn, provides a framework that enables them to work together to influence the flow of private funds.

Beside MDBs and NDBs, other financial and non-financial entities have also made efforts in integrating Environmental and Social Governance (ESG) content into their decision-making and operation processes. The United Nations system is closely cooperating with private investors and government institutions, for instance, to more effectively channel financing and investment flows towards projects which could enable developing and developed countries alike to pursue low-carbon development.

The *United Nations Principles for Responsible Investment* (UNPRI), with 2,370 signatories as of the end of 2019, provides six principles on ESG issues with which potential investors need to comply.[278] Since its launch in 2006, UNPRI has also been actively taken on board by other entities of the UN system. UNEP is also active in this field: the UNEP Finance Initiative created the *Principles for Responsible Banking* and *Principles for Sustainable Insurance* that relevant stakeholders can follow to increase the sustainability of banking and insurance.[279] Meanwhile, the United Nations Global Compact, a policy platform that provides a framework for companies to make commitments to achieve sustainability, seeks to lead business operations and strategies towards the fulfilment of SDGs by setting out 10 principles on concerns such as human rights and labour, to name but a few.[280]

Along the Belt and Road, the EU and ASEAN are among the main regional organizations, representing the efforts of developed and developing countries in supporting sustainable finance.

278 United Nations Principles for Responsible Investment (n.d.). 2018/19 in numbers. Retrieved from https://www.unpri.org/annual-report-2019/2018/19-in-numbers.
279 United Nations Environment Programme (n.d.). About United Nations Environment Programme finance initiative. Retrieved from https://www.unepfi.org/about.
280 United Nations Global Compact (n.d.). What is the UN Global Compact? Retrieved from https://www.unglobalcompact.org/what-is-gc.

The EU is one of the pioneers of sustainable finance. It has established a detailed EU taxonomy of sustainability and developed an EU ecolabel to mark the environmental excellence of products and services. The EU taxonomy and ecolabel help accelerate the "greening" process of companies. The EU also created benchmarks for low-carbon development, including the EU climate transition benchmark and the EU Paris-aligned benchmark, which contain minimum standards addressing the risk of greenwashing and minimum disclosure requirements on climate-related information and a variety of ESG indicators. Moreover, the EU has its own Green Bond Standard, which is widely applied by investors around the world.[281]

ASEAN, as a regional organization that engages several important BRI partner countries, initiated the ASEAN Green Bond Standards to support its regional growth of sustainable finance. It is developed based on the Green Bond Principles (GBP) of the International Capital Market Association (ICMA), which are internationally accepted and widely used by green bond issuers.[282]

Voluntary sets of standards have also been created at the initiative of investor-focused groups of financial institutions to gear investment and financing towards climate action. The Climate Bond Initiative (CBI), for instance, is a self-regulated not-for-profit organization seeking to mobilize the bond market for climate change solutions and sustainable finance. Its Climate Bond Standard (CBS) and Certification Scheme is one of the prevailing standards available, and is currently used by green bond issuers, governments, investors, and financial markets wishing to prioritize investments consistent with the 2°C global warming limit of the Paris Agreement.[283]

As a key player in capital markets, the private sector has also significantly contributed to the gradual shift towards sustainable finance at various levels. The ICMA is a trade association of participants in capital markets which has issued the GBP, on the basis of which proceeds are exclusively applied to eligible environmental and/or social projects. Equally fundamental, and complementary to the above, the Equator Principles were established in 2003 as a voluntary set of

281 European Commission (2018). Communication from the Commission to the European Parliament, the European Council, the Council, the European Central Bank, the European Economic and Social Committee and the Committee of the Regions. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018DC0097&from=EN.
282 ASEAN Capital Markets Forum (2018). ASEAN Green Bond Standards. Retrieved from https://www.theacmf.org/images/downloads/pdf/AGBS2018.pdf.
283 Climate Bond Initiative (n.d.). Climate bond standard and certification. Retrieved from https://www.climatebonds.net/standard.

standards by a group of financial institutions and have now been adopted by 96 institutions to ensure that their projects are developed in a socially responsible manner.

4.1.2 China's principles and guidelines in sustainable investment and financing under the BRI

At present, countries along the Belt and Road have developed their own standards and economic tools for sustainable finance, primarily designed to enhance the "greenness" of incoming or outbound investment and financing flows. One of these countries is China, where financial institutions have made remarkable progress since 2012 in setting up comprehensive overarching regulations on sustainable finance. These are becoming best practices in China and could potentially provide guidance for other BRI partner countries seeking to implement their own domestic standards and economic tools in support of low-carbon development efforts.

There are three major concerns for the legislation on sustainable finance: the definition of a "green" finance product, the requirements on environmental disclosure and the incentives. For the first issue, the China Banking Regulatory Commission (CBRC) introduced the *Green Credit Guidelines* as early as 2012. These provide a green credit policy framework built on credit statistics and evaluation systems. The CBRC *Guidelines* demonstrate the magnitude of institutional support made available in China for green credit and investment activities across 12 major industry sectors. At the end of 2015, the People's Bank of China followed suit by issuing its *Green Bond Guidelines* which clarify other specific aspects of green financing. These were updated by the China Securities Regulatory Commission (CSRC) for listed companies in March 2017. Two years later, the *Green Industry Guiding Catalogue* and its explanatory documents were jointly issued by the National Development and Reform Commission (NDRC), the Ministry of Industry and Information Technology (MIIT), the Ministry of Ecology and Environment (MEE), the Ministry of Natural Resources (MNR), the Ministry of Housing and Urban-Rural Development (MOHURD), the People's Bank of China (PBOC) and the National Energy Administration (NEA). These provide comprehensive and detailed guidelines on which projects and industries count as "green" in China. It sets "green financial common standards" and provides a unified reference for green credit standards, green bond standards, green enterprise standards and local green financial standards. Importantly, in May 2020, PBOC released the latest draft of the *Green Bond-Supported Project*

Catalogue (2020) for public consultation, which exclude all forms of coal projects from the list of projects eligible for green funding.

Legislation on environmental disclosure is an essential part of government efforts for tackling information asymmetry. In the *Guideline for Establishing the Green Finance System*, PBOC, NDRC, MEE, CBRC, CSRC, the China Insurance Regulatory Commission and the Ministry of Finance (MOF) jointly proposed the establishment of a mandatory environmental information disclosure system for listed companies. On the other side, the *Green Bond Guidelines* of PBOC imposes the same duties on bond issuers.

Furthermore, PBOC, the central bank of China, has also formulated incentive policies to leverage private investment. They included the incorporation of sustainable finance aspects into the Macro Prudential Assessment (MPA) of the banking system and identification of green credits and green bonds as criteria for granting commercial banks access to Medium-term Lending Facilities. Further, in May 2019, PBOC published the *Notice by the People's Bank of China of Supporting the Issuance of Green Debt Financing Instruments in Green Finance Reform and Innovation Pilot Zones*, which issued a number of regulatory incentives for the development of green debt financing instruments while strengthening China's green finance market overall.

In addition to such forward-looking domestic legislation and regulations, China is also contributing to rulemaking for sustainable finance in the international arena.

The year 2017 witnessed a milestone on the path towards a green BRI. In April, MEE, the Ministry of Foreign Affairs (MOFA), NDRC, and the Ministry of Commerce (MOFCOM) jointly issued the *Guiding Opinions on Promoting Green BRI Construction*. The *Opinions* highlights the principles of "ecological civilization", "eco-environmental protection" and "green development" in BRI implementation. In the *Opinions*, the ministries call on countries along the Belt and Road to jointly build pragmatic and efficient eco-environment protection cooperation and exchange systems, support and service platforms and industrial and technological cooperation bases, and formulate and implement a series of environmental risk prevention policies and measures within 3 to 5 years; to build a relatively complete eco-environment protection service, support and guarantee system, implement a batch of flagship projects of eco-environment protection, and make tangible achievements within 5 to 10 years.[284]

Then in May, MEE released the *Belt and Road Ecological and Environmental Cooperation Plan* to promote the green transformation of the regional economy, and to support the 2030 Agenda. The *Plan* identifies targets for 2025 and 2030, as well as key tasks including strengthening eco-environmental policy communications, promoting green efforts in international cooperation on production capacity and infrastructure development, facilitating green trade, expediting green investment, launching eco-environmental protection projects and activities, promoting people-to-people connectivity and enhancing capacity-building.[285]

At the end of 2017, the Leading Group of Promoting BRI Construction of the State Council launched the *Action Plan for Harmonization of Standards for Jointly Building the Belt and Road (2018-2020)*. The *Action Plan* requires standardization of cooperation along the Belt and Road, including cooperation in environmental protection for the purpose of building a Green Silk Road. It made several proposals for the technical standards of green products, green trade, green infrastructure, refrigeration, air conditioning and lighting.[286]

In November 2018, the Green Finance Committee of the China Society for Finance and Banking and the City of London's Green Finance Initiative jointly published the Green Investment Principles, aiming to incorporate low-carbon and sustainable development into the BRI.

4.1.3 Commonalities of sustainable investment and financing regulations

It can be concluded contextually that most of the above-mentioned regulations and policies on sustainable finance and investment are increasingly converging in content and coverage. For example, most of these standards require the financiers and investors to embed sustainability into

284 Permanent Mission to the United Nations Industrial Development Organization (2017). MOFCOM issues the Guidance on Promoting Green Belt and Road with three line ministries. Ministry of Commerce of the People's Republic of China. Retrieved from http://vienna2.mofcom.gov.cn/article/headnews/201705/20170502571393.shtml.

285 Ministry of Ecology and Environment of the People's Republic of China (2017). "一带一路生态环境保护合作规划" [Cooperation Plan of Ecological And Environmental Protection along the Belt and Road] (link in Chinese, see references).

286 Standardization Administration of China (2018). "标准联通共建'一带一路'行动计划(2018-2020年)" [Action plan to build the Belt and Road through Standard Unicom] (link in Chinese, see references).

investment decision-making, devise a forward taxonomy of green products, disclose information, formulate right incentives, and mobilize market participants to innovate in the market.

These commonalities mirror the experiences that have been accumulated in international development financing and investment in the past few decades. However, gaps are also evident, for instance, on what “green” or “sustainable” finance is.[287] There are non-official but widely used standards like GBP and CBS, as well as standards made at international, regional and country levels. But these differ in several aspects. Without obvious ranking of these standards, parties to transactions are free to pick any one of them to prove their “greenness” and may have to seek a third party for credible verification at high cost.

These gaps are especially prominent when it comes to sustainable development. Past experiences often do not provide adequate solutions or guidance for addressing future risks. Climate change, widening inequalities, and global epidemics all bring risks to the rule-based international trade and financial system, and they are prominent constraints on sustainability. It would take foresight and decisive, coordinated action to consistently include considerations on these issues into global financing and investment.

Existing country-level green finance policies reveal that a mature institutional arrangement of green finance would require harmonization — or at least compatibility — of green finance guidelines, rules of attestation, risk management and ESG disclosure. Many developing countries along the Belt and Road are still at an early stage in this regard. For example, while most ASEAN countries now have official roadmaps for development and governance of green finance within their own countries, very few of their banks have developed strategies to manage the assessment and disclosure of climate-related risks.[288]

The project-financing and rulemaking of the vast market along the Belt and Road cannot be simply dependent on an individual government alone. A harmonized best practice set of standards across BRI countries would require taking into consideration the concerns of each stakeholder along the Belt and Road and developed countries sharing their experiences with developing

287 International Renewable Energy Agency (2020). Renewable energy finance: green bonds. Retrieved from https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Jan/IRENA_RE_finance_Green_bonds_2020.pdf.
288 World Wildlife Fund (2019). Sustainable banking in ASEAN. Retrieved from https://d2ouvy59p0dg6k.cloudfront.net/downloads/wwf_sustainable_finance_report_2019.pdf.

countries that are still at an early stage of defining their standards. In this process, diverse kinds of entities are expected to participate, explore their potential and improve this market towards jointly accepted normativity. These entities include development organizations and investors from both public and private sectors. Effective cooperation among these stakeholders will make this market more orderly, sustainable and efficient.[289]

4.2 Challenges in promoting sustainable investment and financing towards low-carbon projects along the Belt and Road

Challenges to sustainable investment and financing along the Belt and Road exist in the economic, social and environment spheres. These challenges affect low-carbon projects and highlight the importance of controlling financing costs. For instance, case studies show that instead of using bilateral contract negotiations to secure a fixed price for renewables production, policymakers in various countries have increasingly turned to competitive bidding and auctions to procure renewable energy supply. The resulting intensive competition for renewables projects has led to declining electricity prices in some countries, and to increasing pressure on investors to control financing costs to offer competitive bid prices. While acknowledging the existence of various challenges that might impede greater corporate investment, this section specifically focuses on three important financing-related challenges at the technical level, setting the stage for concrete solutions and best practices provided in subsequent parts of this chapter.

4.2.1 Data collection of greenhouse gas emissions [290]

The availability of accurate data is the foundation for fair and efficient functioning, effective policymaking and for ensuring compliance in emissions trading markets. But due to technological and other problems, the capability, quality and coverage of data collection are imperfect, especially in developing countries. Data that are incomplete, or to which access is restricted could lead to serious consequences, including inaccurate cap setting or limited choices in the allowance

289 United Nations Development Programme and China Development Bank (2019). Harmonizing investment and financing standards towards sustainable development along the Belt and Road. Retrieved from https://www.cn.undp.org/content/china/en/home/library/south-south-cooperation/harmonizing-investment-and-financing-standards-.html.
290 Carbon dioxide is the most important GHG, but there are many others. Ideally all GHG emissions should be monitored.

allocation method.[291] For designers of a GHG data collection system, key challenges involve the following.

First, the regulations on environment and climate change are evolving. Therefore, the data collection system needs to be as transparent and flexible as possible to be credible and to be able to adapt itself to the potential changes of emission thresholds, Monitoring, Reporting and Verification (MRV) requirements, carbon policies and incentives, etc.[292]

Second, economies with limited capacities are not able to afford the full cost of developing and maintaining a data collection system. To have a data collection system, the designer can either develop a new one or customize an existing or third-party system. However, development of a new system calls for extensive monetary and human resources. A customized system might not be flexible enough to respond to the new regulatory environment or integrate other specialized requirements. This could cause inaccurate data collection and calculation.[293] Maintenance of a system also generates costs. These considerations raise the need for financial and capacity building support to these countries (see Chapter 5).

Third, there are various methods of calculation among different sectors. For example, the petrochemical industry tends to pay less attention to calorific value than the power generation industry when calculating emissions. The reason is that there are more combustion activities related to the total emissions of the power generation industry. Calorific value is needed in the calculation of consumption rate of fossil fuels used for power generation. Therefore, it is viewed as an important indicator of production efficiency and internal management. Conversely, combustion emissions do not comprise a large part of the total emissions of the petrochemical industry. It does not need a great amount of purchased fuel either. As a result, this industry does not pay much attention to calorific value in its daily operation. It is not hard to conclude that the data availability among industries varies.[294]

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291 Zeng, X. *et al*. (2017). Data-related challenges and solutions in building China's national carbon emissions trading scheme. *Climate Policy*, 18 (1), 90-105. Retrieved from https://www.tandfonline.com/doi/pdf/10.1080/14693062.2018.1473239.
292 Partnership for Market Readiness (2016). Greenhouse gas data management. World Bank. Retrieved from https://openknowledge.worldbank.org/bitstream/handle/10986/23741/K8658.pdf?sequence=5&isAllowed=y.
293 Ibid.
294 Zeng, X. *et al*. (2017). Data-related challenges and solutions in building China's national carbon emissions trading scheme. *Climate Policy*, 18 (1), 90-105. Retrieved from https://www.tandfonline.com/doi/pdf/10.1080/14693062.2018.1473239.

4.2.2 Climate and environmental risk identification and mitigation, and integration of carbon indicators

The current risk control management system used by financial institutions and international rating agencies is still lacking a set of fair, transparent and comprehensive indicators that can help fully assess climate risks associated with a project.

Although nowadays physical risks related to environment and climate change are obvious (e.g., extreme weather), efforts are inadequate to quantify them for use in the assessment of finance risk. The financial contagion (including but not limited to market losses, credit tightening) may feed back to the macro economy by lowering household wealth, reducing consumption, etc. The impact on the economy also remains uncertain due to the lack of unambiguous risk assessment at the micro finance level.

Indicators are missing for the assessment of physical risks, and also for managing the transition to a low-carbon economy. Risks can arise from a variety of sources, notably restrictions imposed by climate policy, introduction of a new technology, changes in consumer preferences, along with physical risks. If they materialize, they can lead to stranded assets, divestment from certain types of investment or higher energy prices.[295]

These aspects can hinder the accurate risk weighting of green and brown assets, leading to unreasonable financing costs and disincentivizing investors from financing renewable energy.

4.2.3 Constraints of sovereign guarantees in some countries along the Belt and Road

Given the capital-intensive nature of renewables investment and need for upfront capital, the cost of financing plays an important role in investors' decision-making. Due to high debt levels, some BRI countries are not able to provide sovereign guarantees for the financing of power projects involving renewable energy projects, which further pushes up financing costs for investors.[296] It also raises the importance of demonstrating the long-term commercial viability of planned infrastructure projects. Moreover, a debt standstill is now imperative in many developing

295 Network for Greening the Financial System (2019). A call for action: climate change as a source of financial risk. Retrieved from https://www.ngfs.net/sites/default/files/medias/documents/ngfs_first_comprehensive_report_-_17042019_0.pdf.
296 Greenovation Hub (2020). Investment and financing models, challenges and recommendations of renewable energy projects by Chinese companies in the Belt and Road countries. Retrieved from http://www.ghub.org/en/bri-re-report/.

countries in Africa and other parts of the world because of the ongoing economic implication of the COVID-19 outbreak.[297] Facing the COVID-19 pandemic and the significant socio-economic challenges it continues to pose for governments around the world, especially those in low-income countries, G20 economies announced their debt service suspension initiative in April 2020, allowing the world's poorest countries to suspend authorization and interest payments on official bilateral credit through June 2021.[298]

4.3 Concrete measures to channel investment and financing flows towards low-carbon projects

Based on the previous analysis of context and challenges, this section proposes solutions that help BRI partner countries to channel investment and financing towards sustainable low-carbon projects. These solutions have five aspects — (i) harmonization of technical standards and regulatory rules, (ii) innovation of financial instruments and diversification of financing channels, (iii) preferential policies for green products, (iv) pre-lending risk identification and management, as well as (v) post-lending evaluation and environmental impact management.[299] These solutions are designed to cover various phases of coordinated action, mobilize capital towards green and low-carbon investments, and facilitate the role of the financial sector in achieving sustainable development. These solutions cover not just efforts by banks and banking authorities to steer their investment portfolios towards green investment, including lending policies, requirements for stress testing, and a robust underlying taxonomy, but also financing techniques and regulatory measures to adapt the risk/return equation to make green investments more attractive.

297 World Bank (2020). World Bank Group and IMF mobilize partners in the fight against COVID-19 in Africa. Retrieved from https://www.worldbank.org/en/news/press-release/2020/04/17/world-bank-group-and-imf-mobilize-partners-in-the-fight-against-covid-19-in-africa.

298 World Bank (2020). COVID 19: Debt Service Suspension Initiative. Retrieved from https://www.worldbank.org/en/topic/debt/brief/covid-19-debt-service-suspension-initiative.

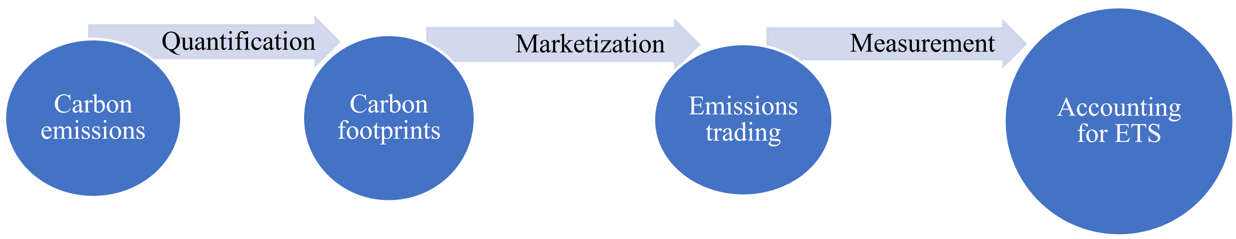
299 While this report focuses on technical standards, benchmarks and indicators in green finance, another relevant study can be found in an upcoming UNDP report, "Scoping Paper on Promoting Green Finance for Sustainable Development". This upcoming report provides an overview of existing policies and actions related to green finance in Mongolia and Kazakhstan, seeking to identify opportunities and challenges in green lending and direct investments, including China's.

4.3.1 Explore carbon pricing harmonization, carbon emission measurement and certification standards of green finance

Harmonizing emissions measurement standards, especially technical standards of MRV emission allowances in accounting, is an important step in international actions of coordinating carbon pricing.

According to the World Bank, 64 carbon pricing initiatives have been implemented or are scheduled for implementation, covering 12 $GtCO_2$ and representing 22.3% of global GHG emissions in 2020.[300] Emission Trading System (ETS) and carbon taxes, two complementary components of fully fledged carbon pricing, are gaining momentum among countries and business as means to reduce emissions and drive investments and financing towards cleaner options. To foster consistent, comparable, and policy-relevant measurement and disclosure of carbon emissions, it is important to harmonize emissions measurement standards based upon Paris Agreement objectives and respect for development rights. The expected levels of development in different countries should also be taken into account.

Figure 4.2 Carbon footprint, emission rights and emissions trading



Traded emission rights are an important instrument to bring carbon into ETS accounting (see Figure 4.2). However, urgent unsolved issues remain from a financial perspective, for instance how to measure, report and verify carbon emission rights in financial statements. International standards remain undeveloped, lack universal acceptance, and fail to clearly define relevant principles, guidelines, rules and modalities, especially for verification, reporting and accountability for emissions trading.[301]

300 World Bank (n.d.). Carbon pricing dashboard. Retrieved from https://carbonpricingdashboard.worldbank.org/.
301 Gallego-Alvarez, I. Martínez-Ferrero, J. & Cuadrado-Ballesteros. B. (2016). Accounting treatment for carbon emission rights. *Systems* 4, 12.

In 2004, the *IFRIC 3 Emission Rights* document was published, specifying for the first time accounts and measurements under the "cap and trade" system.[302] It caused a huge controversy, and was soon withdrawn by the International Accounting Standards Board (IASB), which acknowledged that "the IFRIC-3 creates unsatisfactory measurement and reporting mismatches".[303] In order to develop solutions to eliminate these mismatches and amend existing standards on the accounting for emission allowances, the IASB started the project "Emissions trading schemes" in 2004 (renamed as "Pollutant pricing mechanisms" in 2015).[304] A measure of international consensus has emerged in this process. For instance, IASB and the Financial Accounting Standards Board agreed to make the measurement of purchased allowances and liabilities consistent and decided that purchased allowances should be initially and subsequently measured at fair value.[305] But there was no breakthrough in the project. It remains unclear whether an emission allowance should be defined as an intangible asset, financial instrument, or inventory (see Table 4.2).

Table 4.2 Variations in asset classification of emission allowances

Asset classification of emission allowance	International accounting standards
Intangible assets	IAS 38
Financial instruments	IFRS 9
Inventories	IAS 2

Source: IFRS[306]

In the absence of precise guidelines by accounting standard setters, companies have adopted various approaches to account for carbon emission allowances. A study on companies in the EU ETS reveals that the 28 sample entities have a propensity to recognize allocated emission allowances as intangible assets in their financial statements, but the techniques in recognizing these permits are diverse, and there is ambiguity in disclosures, e.g., "Nil Value", "Nominal Value",

Retrieved from https://www.mdpi.com/2079-8954/4/1/12/xml.
302 IFRIC stands for International Financial Reporting Interpretation Committee under the International Accounting Standards Board.
303 International Accounting Standards Board (2005). IASB withdraws IFRIC interpretation on emission rights. Retrieved from https://www.iasplus.com/en/binary/pressrel/0507withdrawific3.pdf.
304 International Financial Reporting Standards (n.d.). Pollutant pricing mechanisms. Retrieved from https://www.ifrs.org/projects/work-plan/pollutant-pricing-mechanisms/#project-history.
305 International Financial Reporting Standards (2010). IASB Update. Retrieved from http://media.ifrs.org/IASBUpdateNov2010.html.
306 Ibid.

"Cost". The lack of precise guidance from the accounting standard setters regarding emissions accounting could also be one of the reasons why many companies have chosen not to disclose any relevant information.[307]

China's carbon trading market was launched later than that of the EU — seven pilot local emissions trading projects were set up in 2013. In 2016, the MOF released interim provisions of accounting standards for carbon emissions trading (draft for consultation). An updated version was officially issued in December 2019, according to which emission allowances are recorded as "other current assets" in financial statements, while a new account of "1489 Emission Allowance Assets" is added in the financial statements of key enterprises.[308] This paves the way for improving and adjusting relevant regulations along with the development of the carbon market.

Drawing experiences and lessons from existing practices in harmonizing standards (e.g., MRV regulations in the EU ETS, see more in Section 4.4.1), further clarification of the value of an emission allowance through standardized MRV in accounting, would enable investors to better assess the impact of carbon pricing on relevant projects. This in turn would pave the way towards a level playing field for low-carbon development. China's exploration in technical standard harmonization would also provide useful experience for BRI partner countries in developing their own carbon markets.

Policymakers need to set up reasonable and predictable benchmarks, rules and procedures to promote stable long-term compliance by companies. Based on coordination among government agencies or other supervisory bodies, investors, and third-party verification agencies, responsibilities of key stakeholders should be defined, and the costs and consequences of non-compliance should be further calibrated and clarified.

In China's seven pilot ETS, compliance rates have been generally increasing in recent years (see Table 4.3). But compliance is mostly concentrated before the deadline, whereas these trading entities are less proactive in other periods of the year.[309] Meanwhile, both financial and non-

307 Ayaz, H. (2017). Analysis of carbon emission accounting practices of leading carbon emitting European Union companies. *Athens Journal of Business & Economics,* 3 (4), 463-486. Retrieved from https://www.athensjournals.gr/business/2017-3-4-5-Ayaz.pdf.

308 Ministry of Finance of the People's Republic of China (2019). "关于印发《碳排放权交易有关会计处理暂行规定》的通知" [Notice on issuing interim provisions of accounting standards for carbon emissions trading] (link in Chinese, see references).

309 Tian, C. and Xu, C. (2019). "我国碳交易试点的成效分析与政策建议" [Effectiveness analysis and policy recommendations for the carbon

financial penalties against delays or non-compliance vary among pilots (see Table 4.4). While each pilot ETS is expanding in scale swiftly, third-party verification agencies may find it difficult to finish verification in time, which contributes to delayed compliance.

Effective MRV mechanisms lay a solid foundation for reliable emission statistics and processing of emissions trading. This helps boost low-carbon transition in energy- and emissions-intensive sectors covered by ETS pilots. In China, besides power, the remaining seven key sectors covered by China's ETS pilots are building materials, iron and steel, non-ferrous metals, chemicals, petrochemicals, paper-making and aviation.[310] China's further explorations in regulatory mechanisms of MRV would benefit not just its own national-level carbon market construction, but also relevant development in BRI partner countries.

Table 4.3 Compliance performance rates[311] in seven carbon trading pilots of China (2013-2017)

Pilot ETS	2013	2014	2015	2016	2017
Shenzhen	99.4%	99.7%	99.8%	99%	95.5%
Shanghai	100%	100%	100%	100%	100%
Beijing	97.1%	100%	100%	100%	/
Guangdong	98.9%	98.9%	100%	100%	100%
Tianjin	96.5%	99.1%	100%	100%	100%
Hubei	/	100%	100%	100%	100%
Chongqing	/	70%	/	/	/

Source: Tian, C. and Xu, C.[312]

trading pilot of China]. *Journal of North China University of Technology* (link in Chinese, see references).

310 National Development and Reform Commission (2017). "国家发展改革委办公厅关于做好 2016、2017 年度碳排放报告与核查及排放监测计划制定工作的通知" [Notice on promoting annual emissions reporting and verifying (2016 & 2017) and making emissions monitoring work plan] (link in Chinese, see references).

311 Compliance mechanisms, including emissions reporting, third-party verification, and emission allowances submission, are key to controlling carbon emissions. Entities with forcible obligations to reduce emissions are required to submit emission allowances to offset their emissions in last year. "/" means the data were not disclosed.

312 Tian, C. and Xu, C. (2019). "我国碳交易试点的成效分析与政策建议" [Effectiveness analysis and policy recommendations for the carbon trading pilot of China]. *Journal of North China University of Technology* (link in Chinese, see references).

Table 4.4 Penalties for delays or non-compliance in China's seven carbon trading pilots

Pilot ETS	Penalties for non-performance	Amount of allowances deducted from the following year's allocation for companies failing to surrender enough allowances to match their emissions	Penalties for failure of reporting	Other penalties
Shenzhen	Three times market price	/	CNY 50,000-100,000	Negative impacts on subsides, credit & performance review
Shanghai	CNY 50,000-100,000	/	CNY 30,000-100,000	Negative impacts on project approval, subsidies & credit
Beijing	Three to five times market price	/	up to CNY 50,000	/
Guangdong	CNY 50,000	Twice	up to CNY 50,000	Record in social credit system
Tianjin	/	/	/	Cancellation of preferential treatment for three years
Hubei	One to three times market price	Twice	CNY 10,000-30,000	Negative impacts on project approval, subsidies, credit & performance review
Chongqing	Three times market price	/	up to CNY 50,000	Cancellation of subsidies for three years & negative impacts on performance review

Source: Tian, C. and Xu, C. [313]

It is up to national authorities to choose their own carbon-pricing instruments based on their national situation and context. Carbon taxes have been levied in countries such as Finland, Sweden, Denmark, Japan, and the UK. The increasing global use of carbon pricing is also generating more

313 Ibid.

discussions and studies on the complementarity between ETS and carbon taxes, rather than on using one instrument to replace the other.[314] Generally, traded emissions permits are considered optimal for large, immobile emitters that are smaller in number and whose emissions are relatively simpler to monitor, while carbon taxes are seen as a better fit for a very large number of mobile, hard-to-monitor emitters.

Exploring carbon tax methods based on carbon reduction goals and forecasting of economic development and climate change is an important foundation for establishing scientific, reasonable carbon tax rates and internalizing the externalities of carbon emissions. While in a few countries, e.g., Poland and the Czech Republic, a carbon tax is directly levied on GHG emissions, most countries define a carbon tax rate on the carbon dioxide content of fossil fuels. There are policy recommendations from scholars in China that policymakers in the country should consider gaps between different energy sources in terms of carbon content and carbon dioxide coefficients, to ensure that different taxable energy sources are comparable.[315]

These carbon pricing and emission standards provide a foundation for carbon finance services that can be vigorously developed by financial institutions for carbon emission rights trading, project-based emission reduction trading, and trading of various derivatives. In a broader sense, leveraging financial resources towards low-carbon development along the Belt and Road calls for harmonized, clear and enforceable green finance standards. In this process, the following principles should be respected.

Both market rules and international consensus need to be respected while implementing national strategies on green development and an economic structural transition. This helps guarantee that relevant green finance standards boost fair market competition, and facilitate the compatibility with international green finance market.

Basic and key technical standards used commonly in different sectors should be prioritized. These include statistical standards, information disclosure and sharing standards and risk management standards. On this basis, standards of green finance products and services, as well as

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314 Environmental Research Center at Duke Kunshan University (2019). "中国碳定价顶层设计的经济学分析" [Economic analysis of top-level design of China's carbon pricing] (link in Chinese, see references).
315 Liu, L. and Zhang, Y. (2018). "基于碳排放权交易市场的碳税制度研究" [Research on carbon tax system based on the market of carbon emissions trading]. *Taxation Research* (link in Chinese, see references).

of credit ratings and evaluation should also be coordinated and improved, so as to comprehensively standardize green finance throughout its design, implementation, monitoring and management procedures.[316]

Top-down and bottom-up approaches should be integrated in building a green finance standards system. On the one hand, government agencies responsible for green finance standards planning, making, enforcing, promoting and monitoring need to reinforce coordination, and promote standards harmonization and mutual compensation among different sectors and different regions in the country. Such standard harmonization efforts also need to expand to cover not just for large-scale project financing, but also liquid capital loans for small and medium-sized enterprises (SMEs). On the other hand, green finance pilots should be encouraged, to test feasibility and performance of green finance standards in specific sectors. These include detailed content, coverage, formats and rules of green finance in these sectors. This helps identify and assess green projects, and helps standardize green finance products. Successful experiences from pilots in sectors such as green agriculture and green industrial parks can be shared and applied at a national level. This facilitates establishing nationwide standards of green labelled products and enterprises, and boosts regulatory changes at a national level.

Foresight and openness must be emphasized in standard-making. This leaves space for not only the development of green finance along with technological progress and mechanical innovation, but also gradual and orderly harmonization with international standards. In this process, dialogue and cooperation with intergovernmental organizations and multilateral financial institutions need to be enhanced, to reinforce exchange and collaboration on green finance standards and policies.

4.3.2 Innovate green finance instruments and develop diversified financing channels

Innovation in financing instruments, especially innovative green credit products, should be encouraged to facilitate low-carbon development along the Belt and Road. There are three main ways of innovating green credit products: (i) creating new, independent credit products based on macroeconomic environment and market practices, e.g., factoring or Islamic finance, (ii)

316 Chen, Y. (2018). “推动绿色金融标准体系建设” [Promoting the construction of green finance standards system]. *China Finance* (link in Chinese, see references).

innovating in terms of application conditions, functions and models of credit products, e.g., introducing new guarantee methods or risk mitigation tools, and (iii) combining credit products with other financial instruments, e.g., combining credit service with financial leasing, or with export credit insurance.[317]

China's innovative green credit practices (see Table 4.5) started in the 11th Five-Year Plan period (2006-2010). Further innovation in green credit could be explored through increased application of credit asset securitization in green credit, and through facilitating finance for green investment and consumption by households. In order to channel financial resources towards low-carbon projects, innovation can be made in areas such as interest rates, scale of loans, and payment methods, based on evaluations of the "greenness" of target projects. Added services such as financial consulting and financial management can also be provided by financial institutions for environmentally friendly enterprises.[318]

Table 4.5 Major types of innovative green credit products in China

Innovation methods	Cases
Cooperating with multilateral development organizations/IFIs and innovating based on their cooperation among branches and internal departments, risk management tools & technological support	China Climate Finance Advisory Program at IFC
	China energy efficiency and renewables program at AFD
	China Energy Efficiency Financing Program at the World Bank
Credit products targeting specific emerging markets	Credit products targeting energy performance contracting, e.g., energy efficiency retrofit loans, factoring & usufruct pledge financing
	Credit products targeting ETS, e.g., carbon assets pledge financing & emission allowances mortgage financing
Integrated financial services beyond green credit products	Systematic green finance services package provided by Chinese commercial banks

317 China Banking Association (eds.) (2018). "绿色信贷" [Green bonds and loans]. China Financial Publishing House.
318 Li, J. (2019). "低碳经济视角下中国绿色金融发展研究" [Research on China's green finance development in the perspective of low-carbon economy]. *Communication of Finance and Accounting* (link in Chinese, see references).

Innovation methods	Cases
	Innovation of green services in settling, financial management & retail finance, e.g., low-carbon credit cards
	Bank-government-enterprise cooperation, e.g., environmentally friendly SMEs credit fund

Source: CBA[319]

Boosting blended financing by advancing cooperation with multilateral development institutions is important for solving bottlenecks in financing for low-carbon projects along the Belt and Road. Extending the sources of financing to include these and other cooperating banks can also contribute to a much-needed diversification of financing channels. Progress towards harmonizing financing and investment standards along the Belt and Road can facilitate the entry of new financial institutions to this area.

Chinese investing entities in renewable energy projects along the Belt and Road are increasingly diversified, compared with the situation in traditional electric power projects. Starting more than a decade ago, three categories of investment entities are now active: (i) state-owned electric power enterprises, e.g., China Three Gorges International Corporation, China Power Investment Corporation, Shanghai Electric Power, Zonergy and Longyuan Power; (ii) enterprises receiving construction contracts for relevant projects, e.g., Power China, and (iii) manufacturers of solar PV and wind turbine equipment, e.g., Goldwind, LONGi Solar, and JinkoSolar.

Chinese financial institutions remain the dominant financing sources for renewable energy projects by Chinese investment entities along the Belt and Road, according to a study by Greenovation Hub and Tsinghua PBCSF. Compared with their international counterparts, Chinese investors have leveraged blended finance much less frequently, seeking financing more from Chinese banks, rather than blending commercial financing with development financing from multilateral development institutions.[320]

319 China Banking Association (eds.) (2018). “绿色信贷” [Green bonds and loans]. China Financial Publishing House.
320 Greenovation Hub and Tsinghua PBCSF (2020). Investment and financing models, challenges and recommendations of renewable energy projects by Chinese companies in the Belt and Road Countries. Retrieved from http://www.ghub.org/wp-content/uploads/2020/05/bri-re-report.pdf.

Case studies of wind and solar PV power projects in BRI partner countries found four distinct types of financing models detailed in Table 4.6. Multilateral development institutions including EBRD, ADB and IDB have widely participated in leading loans to finance projects such as the Baikonur solar power plant in Kazakhstan (invested by the United Green Group (UGG) of the United Kingdom and Baiterek Venture Fund (BVF) of Kazakhstan), the Boguslav solar PV farm in Ukraine (invested by Scatec Solar of Norway), the Villanueva solar PV plant in Mexico (invested by Enel Green Power of Italy).

Table 4.6 Financing models for wind & solar PV power projects in BRI partner countries

4.3	Financing models	Cases					
		Name of project	Investors	Financing institutions	Installed capacity (MW)	Investment volume	Inauguration
1	Recourse loans [321] provided by Chinese policy banks/commercial banks, with export credit insurance underwritten by Sinosure	Dawood wind farm, Pakistan	Power China	ICBC	49.5	US$115 million	April 2017
		Quaid-e-Azam Solar Park, Pakistan	Zonergy	China Eximbank, CDB, Bank of Jiangsu & CBHB	900	US$1.5 billion	Phase I (300 MW) connected to grid in June 2016
2	Non-recourse syndicated loans, through coordination of multilateral development institutions, provided	Cafayate solar PV project, Argentina	Canadian Solar	CAF, BICE of Argentina & Banco de la Ciudad	100.1	US$50 million	July 2019
		Baikonur solar power plant, Kazakhstan	UGG of UK & BVF of Kazakhstan	ADB, EBRD & CTF	50	US$52.4 million	December 2019

321 In a loan with recourse, the borrowers who provide a personal guarantee are responsible for paying the remaining balance out of their own pocket. In a non-recourse loan, the lender has no legal right to turn to the borrower for the remaining balance. As such, they will typically have to take a loss. Khleif, R. (2020, November 13). Why non-recourse loans aren't always non-recourse. Forbes. Retrieved from https://www.forbes.com/sites/forbesrealestatecouncil/2020/11/13/why-non-recourse-loans-arent-always-non-recourse/?sh=24e03d784e5d.

4.3	Financing models	Cases					
		Name of project	Investors	Financing institutions	Installed capacity (MW)	Investment volume	Inaugurat ion
	by local/international commercial banks	Boguslav solar PV farm, Ukraine	Scatec Solar of Norway	EBRD, NEFCO & Swedfund	54	EUR 54 million	May 2020
		Villanueva solar PV plant, Mexico	Enel Green Power of Italy	EIB, Bancomext, CaixaBank, Natixis, IDB & MUFG	828	US$710 million	May 2018
3	Non-recourse syndicated loans provided by local/international commercial banks	Mozura wind farm, Montenegro	SPIC[322] & Maltese government	Consortium led by Deutsche Bank	46	EUR 90 million	April 2019
		De Aar wind farm, South Africa	Longyuan Power	Nedbank & IDC	244.5	CNY 2.5 billion	October 2017
		Pirapora solar PV plant, Brazil	Canadian Solar	Pirapora I: IDB, IDB Invest & BNDES Pirapora II: BNB & FNE Pirapora III: BNDES & The Climate Fund in Brazil	399		Pirapora I: November 2017 Pirapora II: December 2017 Pirapora III: June 2018

322 SPIC here stands for Shanghai Electric Power Co., Ltd.

4.3	Financing models	Cases					
		Name of project	Investors	Financing institutions	Installed capacity (MW)	Investment volume	Inauguration
		Sweihan solar PV plant, UAE	JinkoSolar	Consortium of 8 commercial banks	1,177	US$900 million	July 2019
		Redsol solar PV plant, Malaysia	Scatec Solar & Fumase (Malaysia) Sdn Bhd	BNP Paribas	47	US$47 million	Fourth quarter of 2019
4	Funded by contractor during construction, with short-term financing sought from banks as receivables factoring, and medium- and long-term financing sought later in commercial operation	Dau Tieng solar PV power complex, Vietnam	Vietnamese Xuan Cau Group & B.Grimm Power of Thailand	Short-term financing during construction advanced by Power China and sought from Chinese banks as receivables financing	420	THB[323] 13.7 billion (US$420 million)	June 2019

Source: Greenovation Hub and Tsinghua PBCSF, World Bank, CAF[324]

There are examples, though less frequently, of Chinese investment entities that have managed to cooperate with multilateral development institutions in financing for renewable energy projects in BRI partner countries. For instance, in an 80 MW solar PV plant invested by JinkoSolar in Argentina, IDB Invest led a US$60 million A/B loan[325] in 2018 to finance the plant's construction,

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323 Thai Baht.
324 Greenovation Hub and Tsinghua PBCSF (2020). Investment and financing models, challenges and recommendations of renewable energy projects by Chinese companies in the Belt and Road Countries. Retrieved from http://www.ghub.org/wp-content/uploads/2020/05/bri-re-report.pdf.; World Bank (n.d.). Baikonur solar power plant. Retrieved from https://ppi.worldbank.org/en/snapshots/project/Baikonur-solar-power-plant-9529.; CAF Development Bank of Latin America (2018). CAF, BICE, and Banco de la Ciudad finance Cafayate solar plant to promote the production of cleaner energy in Argentina. Retrieved from https://www.caf.com/en/currently/news/2018/12/caf-bice-and-banco-de-la-ciudad-finance-cafayate-solar-plant-to-promote-the-production-of-cleaner-energy-in-argentina/.
325 The IDB attracts banks and institutional investors as co-financiers through its A/B loan program. Under this program, the IDB offers the A portion of the loan from its own resources. The IDB partners with other financial institutions provide the B loans.

operations and maintenance.[326] This A/B loan structure is widely adopted by IFIs to help bring in commercial banks to finance well defined components of the projects.

Preferred creditor status and taxation rates, as well as longer-term loans could be granted in syndicated loans led by multilateral institutions. If granted, these could enable the investor to save on export credit insurance, lowering costs for financing in relevant projects. Multilateral development institutions can also play a positive role in policymaking concerning the energy transition in emerging economies. This helps reduce or diversify risks in specific projects (see more in Section 4.4.4). Investors will therefore find it useful to explore and consolidate cooperation with multilateral development institutions that are cooperating in supporting BRI projects through sustainable financing.

Putting in place special green investment funds under the BRI, through cooperation with long-term international capital, is an important and promising avenue for the future. In recent years, institutional investors are increasingly open to ESG globally, pivoting towards portfolios of wind, solar and hydro assets. This brings opportunities for cooperation. Owners of relevant projects along the Belt and Road could consider selling equity or income stream rights to international infrastructural funds, pension funds or insurance companies. This would also help these project owners to recoup their capital faster from their projects.

Further innovation of green bond products should be encouraged, on the basis of improving environmental protection thresholds for companies to be listed. Such innovation should focus on developing products for long-term green investment, rather than stimulating short-term speculation that might trigger chaos in stock markets. International practices in green bond issuance and derivatives such as carbon emission rights trading can be learned. Pilots can be set up to explore securitization of green assets based on natural resource assets in balance sheets and to broaden channels for green bond issuance.

Innovation of green insurance services, which can also be important instruments that support a low-carbon economy, should be accelerated. Preferential rates of insurance premiums can be considered for green enterprises in various sectors such as agriculture and transportation. Results

326 Inter-American Development Bank (2018). IDB invest finances the construction of an 80 MW solar plant in Argentina. Retrieved from https://www.iadb.org/en/news/idb-invest-finances-construction-80-mw-solar-plant-argentina.

of climate and environmental risk evaluation can be linked with insurance premium rates and credit access, to stimulate enterprises to enhance their capabilities in climate and environmental risk management. For households and individuals, energy efficiency insurance services can be developed to encourage low-carbon consumption.

Differentiated guarantee services for green enterprises and projects, based on their green ratings, can be explored while providing green guarantee support for enterprises. Different levels of subsidies can be provided to compensate guarantee fees, based on enterprises' level of "greenness". For non-green companies or projects, guarantees can be withheld, or enhanced rates of guarantee fees can be applied.

Joint collaboration by government agencies, financial institutions, insurance companies and investing enterprises is needed for exploring flexible models and products of sharing risks and dividing gains, and for boosting emerging financial models. The latter include financial leasing, emission rights mortgage financing, infrastructure asset securitization, private and public sector equity as well as crowd-funding. In recent years, several renewable energy companies investing in BRI partner countries have sought financing by listing on the stock market, e.g., Azure Power from India (2016) and Neoen from France (2018). These cases also provide good reference points for environmentally sustainable projects under the BRI that seek to attract institutional investors managing long-term capital.

4.3.3 Strengthen policy incentives on green finance products

Preferential policies for green bonds — both financial incentives and supporting facilities — should be scaled up to support the low-carbon and circular economy along the Belt and Road. These incentives include green bond issuance subsidies, interest discounts, tax benefits, credit enhancement, fast track for issuance approval, special support funds, and green bond project pipelines. Policymakers need to carefully weigh the pros and cons of each of these instruments and decide on the best mix given their country's context, relying on experience gained in other countries. In light of the significant environmental externalities stemming from green investment, further incentives would also be socially desirable.

The global green bond market was launched in 2007, when EIB issued the Climate Awareness Bond. The World Bank issued its first green bond a year later. China's green bond issuance, though started only in 2015, has witnessed vigorous growth in recent years. In 2019, Chinese issuers collected CNY 339.1 billion in green bond proceeds from 214 domestic and foreign green bond issues, accounting for 21.3% of the global green bond market in that year.[327]

Based on guidelines for supporting green bond development provided by PBOC, NDRC and CSRC, local governments across China also have various policy instruments at their disposal to encourage green bonds (see Table 4.7, and also Section 4.4.3). However, although the green bond issuance system is clear, barriers to the further development of the green bond market remain. These include unclear definition of what is "green", weak monitoring, and lack of enforcement actions if the use of the bond deviates from green principles.

Policymakers need to sustain policy incentives to lower green bond financing costs and foster a solid long-term pipeline of bankable green projects to boost green bond issuance, while promoting the concept of responsible investment and guiding companies to form their own initiative towards green investments. The green bond issuance quota could be relaxed, and scope of investment extended, together with putting in place credible enforcement mechanisms, to attract IFIs into the green bond market. Issuance approval procedures should also be streamlined and prioritized. The necessity of providing more policy incentives in this regard has been indicated in pilots like the green bond market in the Guangdong-Hong Kong-Macao Greater Bay Area.[328]

Table 4.7 China's local government policy instruments for green bonds

Category	Policy instruments	Description
Policy signal	Specific supporting document	Develop specific documents encouraging green bond issuance (or green finance development)
	Task force	Set up a dedicated task force encouraging green bonds (or green finance) development
	Pilot program	Initiate green bond pilot programs for the whole or part of the region

327 Xinhua (2020, January 10). "2019 年中国绿色债券市场发展回顾" [Review of development of China green bond market 2019] (link in Chinese, see references).
328 China Industrial Bank Guangzhou Branch (2020). "粤港澳大湾区绿色债券市场国际化及其发展路径研究" [Research of internationalization and development path of green bond market of Guangdong-Hong Kong-Macau Greater Bay Area]. *South China Finance* (link in Chinese, see references).

Category	Policy instruments	Description
Supporting facilities	Fast track	Create a fast track for approving green bond issuance
	Project pipeline	Create a list of projects eligible for green bond financing
	Green bond coalition	Establish a green bond coalition (between regulators, intermediaries and evaluation agencies)
	Training and forums	Host green bond forums, trainings or project match-making meetings
	Stimulate the demand for green financing	Promote the green transition of the local economy
Financial incentives	Cost sharing	Develop cost sharing mechanisms through issuance subsidy, guarantee subsidy, and interest discount
	Credit enhancement	Provide credit enhancement through guarantee fund, debt-loan portfolio and special construction fund portfolio
	Tax benefits	Provide tax deduction or exemption to issuers and/or investors based on central government policy framework
	Encourage private investments	Encourage private investors within and outside the jurisdiction to invest in green bonds
Recognition	Recognition	Recognize green bond issuers and other participating institutions
	Media coverage	Encourage media coverage of green bonds and green projects
	Review and award	Include green finance pioneers into other review and award programs

Source: CBI and SGF[329]

Overall guidance on green finance priorities could usefully complement existing important policies. This would help financial institutions better rank various possible projects that conform with the guiding catalogue of green credit projects when providing green credit services. Since

329 Climate Bonds Initiative and Syntao Green Finance (2017). Study of China's local government policy instruments for green bonds. Retrieved from https://cn.climatebonds.net/files/files/ChinaLocalGovt_02_13_04_final_A4.pdf.

1995, China has issued a comprehensive set of policies for green credit, including *Guiding Opinions on the Credit Work for Energy Conservation and Emissions Reduction* in 2007 and key performance indicators of green credit implementation in 2014. Sorting projects by priority facilitates the building of more efficient green credit portfolios in financial institutions, and a more robust green credit market.

Policy incentives for green funds, which are less developed compared with those for green credit and green bonds, need to be consolidated to enhance the overall efficiency of green finance policies. The *Integrated Reform of the Plan for Promoting Ecological Progress*, issued by China's central authorities in 2015, proposes to develop green funds, but concrete implementing policies have yet to be formulated. Improved supporting policies could bolster the development of green funds and encourage SMEs to participate in green finance projects, which in turn could help alleviate financial pressures on them.

Experience could be drawn from international practices. For instance, the Dutch government's Green Funds Scheme launched in 1995 mainly invests in the form of deposit or low-risk investment. The Dutch government provided a 2.5% discount on income tax payments as an incentive for individual investors investing in a green bank or purchasing shares in a green fund. Private capital leveraged for green projects amounted to 6 billion euro in 2010, greatly exceeding foregone tax revenues (150 million euros in the same year).[330]

4.3.4 Identify and evaluate environmental and climate risks in pre-lending stage

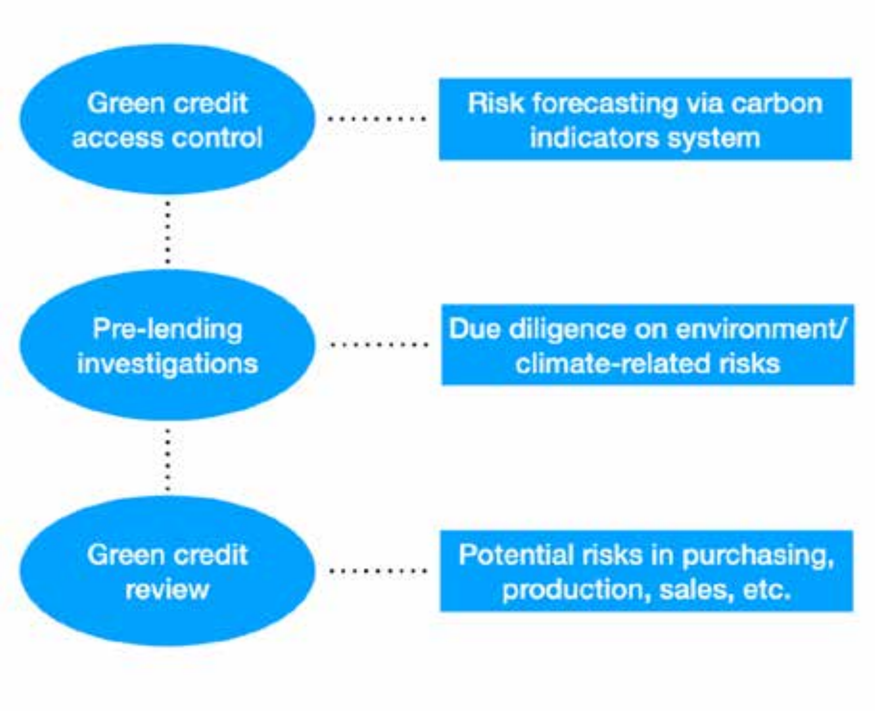
Forecasting environment- and climate-related risks[331] with carbon indicators to consolidate green credit access management is a necessary step in pre-lending risk control. Pre-lending management of environment and climate-related risks include key steps such as green credit access control, pre-lending investigations, and green credit review and approval (see Figure 4.3). Establishing access principles to rule out unqualified or highly risky projects from the very beginning is key to avoiding the pitfall of having to manage avoidable risks that materialize, and

330 Ibid.

331 The NGFS distinguishes environment- and climate-related risks. Environment-related risks (credit, market, operational and legal risks, etc.) are posed by the exposure of financial firms and/or the financial sector to activities that may potentially cause or be affected by environmental degradation (such as air pollution, water pollution and scarcity of fresh water, land contamination, reduced biodiversity and deforestation). Climate-related risks are posed by the exposure of financial firms and/or the financial sector to physical or transition risks caused by or related to climate change (such as damage caused by extreme weather events or a decline of asset value in carbon-intensive sectors).

to maximizing sustainable investment returns for BRI partner countries, China and global stakeholders.

Figure 4.3 Key steps of environment & climate risk control in the pre-lending stage



Policies and indicators need to be developed to better handle environmental risks in finance. Environment- and climate-related risk factors from both structural and contingent sources should be screened, assessed, monitored and disclosed right from the design phase of a project. Yet these risks, especially climate-related financial risks have not been fully reflected in asset evaluation. There is a need for global collective leadership and coordinated action in climate modelling and policy principles to better capture climate-related economic and financial risks, with a critical role for international organizations and fora.[332] Accepted carbon indicators, necessary data collection and baseline setting principles should be provided for financial institutions. Experts have started to build such carbon indicators (see Table 4.8), which could be developed further.

332 Network for Greening the Financial System (2019). A call for action: climate change as a source of financial risk. Retrieved from https://www.ngfs.net/sites/default/files/medias/documents/ngfs_first_comprehensive_report_-_17042019_0.pdf.

Table 4.8 Forewarning indicators of financial risks in a low-carbon economy

Indicator categories	Indicator	Calculation method
Low-carbon development indicators	Growth rate of carbon assets	Carbon assets increment/total carbon assets at the beginning of the year
	Low-carbon technology input rate	Annual low-carbon technology expense/carbon revenue
	Growth rate of carbon profit margin	Carbon profit increment this year/total carbon profit last year
Carbon debt-paying indicators	Current ratio of carbon assets	Current carbon assets/current carbon liabilities
	Debt ratio of carbon assets	Total carbon liabilities/total carbon assets
	Carbon equity ratio	Total carbon liabilities/shareholders' rights in carbon assets
Low-carbon profitability indicators	Carbon profit margin	Carbon profit/carbon revenue
	Carbon profit rate of cost	Carbon profit/carbon cost
	Carbon yield	Net carbon profit/average carbon capital

Source: Nie, Y.[333]

Thorough and complete pre-lending due diligence can help channel credit resources towards quality clients. It needs to cover borrowers' sector-specific operation permits, environmental compliance, precautionary measures on carbon emissions, as well as long-term environmental impacts on the affected community and beyond. Third-party investigation and monitoring agencies could be employed in projects where particular environment and climate-related risks are expected to arise. A comprehensive green credit review, especially rating of environmental performance in raw materials purchasing, production, quality tests, sales and transportation, is also needed. It could adopt the fixed-base method, to compare ratings of target clients' environment and climate-related risks with sectoral benchmarks.

A practical climate-related risk forecasting and management toolkit should be further developed, integrating specific characteristics of projects along the Belt and Road into existing

333 Nie, Y. (2018). "低碳经济视角下企业财务风险预警研究" [Research on the early warning of the financial risks from a perspective of low-carbon economy]. *Communication of Finance and Accounting* (link in Chinese, see references).

risk evaluation frameworks. Both qualitative and quantitative risk assessment tools could be adopted to navigate long-term scenarios and to reckon financial risks and potential impacts, e.g., risk transmission mechanisms in cross-border financial supervision. International agencies could also carry out more studies to systematically include carbon indicators in their risk rating system. These would help provide a fuller picture of potential financial risks. This would set the stage for exploring risk assessment models for BRI-specific low-carbon projects as well as risk management measures to help create a fair, efficient and stable environment for investment and financing.

In order to facilitate the abovementioned key steps of environmental and climate risk control in the pre-lending stage, the development of publicly accessible, one-stop online databases and information service platforms should be accelerated. This platform would cover loans, equity and guarantees in real time, employing artificial intelligence, big data and other advanced technologies, connecting financial institutions, enterprises, consumers and government agencies and regulators, helping them share data. This would help streamline lending approval procedures and overcome obstacles such as asymmetric information, hefty regulatory costs and SMEs' lack of access to green finance. The information platform can help financial institutions to label green investors precisely and automatically through ESG assessment models. For regulators, this information system can help track compliance with energy-saving and emissions-cutting commitments and the performance of financial institutions in managing green credit and supporting green industrial development.

It is also important to help solve green finance disputes in a highly efficient and low-cost way, and enable win-win scenarios for key stakeholders including government agencies, financial institutions, enterprises and judicial organs. To this end, the introduction of detailed judicial guidelines needs to be accelerated, especially in terms of improving green finance environments and standardizing risk control systems. Innovative mediation centres can be established, to integrate financial mediation and judicial authorization.

Voluntarily reporting, self-regulatory and self-disciplinary mechanisms in the green finance industry can play a complementary role in guiding investors towards low-carbon and sustainable projects. Specifically, banks, stock exchanges and insurance organizations can establish self-assessment and peer review mechanisms in areas such as access to green credit, information disclosure, interest rate pricing, green insurance product innovation, and green investment. These mechanisms can also strengthen financial institutions' compliance with relevant laws and regulations of green finance, and provide ways of quickly identifying issues and for reporting significant climate and environmental risks.

4.3.5 Track and manage environmental and climate risks after lending

Evaluation mechanisms for green finance efficiency should be in place in the post-lending period to enable constant monitoring of green projects. Data transparency and BRI-wide knowledge-sharing platforms using common definitions should be encouraged. Third-party vigilance and wisdom should be fully utilized in long-term tracking and management of climate and environment risk impact, including think tanks, lawyers, and environmental protection organizations. Government agencies, both at central and local levels, can arrange a special budget for thematic studies to accelerate theoretical and practical innovations in green finance. Research and communication platforms can be set up to share green finance reform experiences and boost relevant capacity building.

Scenario analysis, stress tests and constant project reporting, monitoring and evaluation of environment and climate-related risks need to be further developed. Environmental performance could then be tracked based on defined indicators, baselines, targets and requirements common to BRI countries and included in legal agreements. The Network of Central Banks and Supervisors for Greening the Financial System (NGFS) is promoting the development of quantitative parameters and a more specific data-driven narrative as a foundation for these scenarios, helping supervising authorities to explore these questions in their own jurisdictions. The latest studies show that shrinking demand and lowering costs of new energy power generation would give rise to intensified price competition and rising financing costs for fossil-based investment in a 2°C scenario. As a result of these factors, the non-performing loan ratio of China's major coal power enterprises would rise from less than 3% in 2020 to 22% in 2030; considering only rising carbon price and financing costs, this ratio would still rise to 11% in 2030.[334]

Climate-related stresses need to be incorporated into sector-wide or even market-wide stress tests, especially into targeting sectors where stranded assets may increase due to climate change,

334 Ma, J. and Sun, T. (2020). "气候变化对金融稳定的影响" [The impact of climate change on financial stability]. *Modern Finance Guide* (link in Chinese, see references).

changes in relative carbon prices or societal preferences, or over-capacity, e.g., fossil fuels, real estate, infrastructure, vehicle transport. Sensitivity analysis is needed to study the impacts of updated policy standards and regulatory rules (e.g., enforced environmental information disclosure) on project compliance. Within China, ICBC was the first bank to conduct a stress test of environmental risks (see more in Section 4.4.4).

Multilayer environmental information disclosure frameworks and mechanisms should be established, to incentivize borrowers to conscientiously fulfil the obligations of green development. Regular communication between financial institutions, government agencies and media outlets is needed to ensure timely exchange of updated information in emissions control regulations and compliance behaviours.

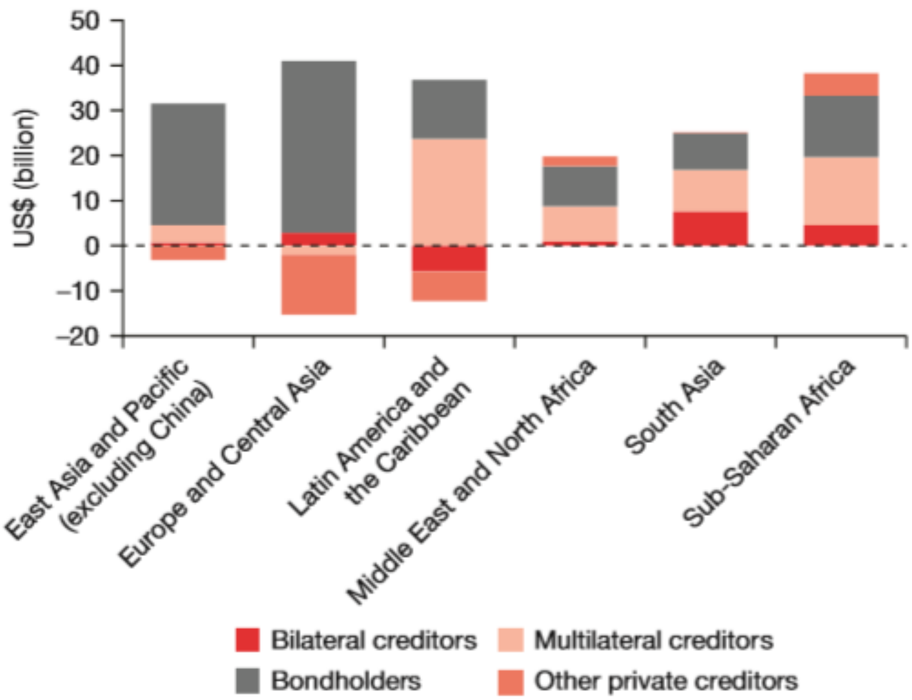
Assessment of debt sustainability and improved efficiency of debt management are especially important in the energy transition along the Belt and Road. Some BRI partner countries, with relatively high levels of debt, are strongly constrained in providing sovereign guarantees for electricity power projects, including those based on renewable energy. For example, in the hydropower sector, according to the Science Data Bank, by 2019 among the 110 existing hydropower projects under the BRI, 25.5% are located in Africa, second only to Asia. The investments in African hydroelectric projects under the BRI, dominated by Chinese giants such as the Power Construction Corporation of China, the China Energy Engineering Group, and CTGIC, amounted to US$5.0 billion in East Africa, US$15.7 billion in Central Africa, US$6.7 billion in South Africa and US$11.9 billion in West Africa by 2019.[335]

Some countries in these regions have hefty debt burdens to deal with. According to World Bank statistics, in South Africa, Angola and Ethiopia, all embracing large-scale hydropower investments under the BRI, the ratio of external debt stocks to gross national income was 55%, 60% and 30% in 2019, respectively. In terms of the composition of net long-term debt inflows to public and publicly guaranteed borrowers in 2019, Sub-Saharan African countries accounted for the largest share at 24% (see Figure 4.4).[336]

335 Yin, F., Wu, M., Xiao. J., and Niu, Z. (2019). Datasets of China's overseas hydropower stations (2002-2019). Science Data Bank. Retrieved from http://www.scidb.cn/journalDetail?dataSetId=633694461364273152&version=V1&dataSetType=journal&tag=2&language=zh_CN.

336 World Bank (n.d.). International debt statistics 2021. Retrieved from https://openknowledge.worldbank.org/bitstream/handle/10986/34588/9781464816109.pdf?sequence=2&isAllowed=y.

Figure 4.4 Long-term debt inflows to public and publicly guaranteed borrowers, regional



Source: World Bank[337]

In order to adequately assess debt sustainability and ensure long-term risk control for environmentally friendly projects along the Belt and Road, several factors must be taken into consideration. These include host countries' existing debt service obligations, debt service profile, debt structure, debt repayment situation, and the individual project's potential ability to generate sufficient financial returns to cover its full running costs and the debt service obligations created.[338] Management frameworks should be set up when contracting or guaranteeing new debt, to clearly stipulate all parties' responsibilities. Prudent auditing systems must be in place, defining risk-identifying procedures and conflict-resolution measures. Terms and conditions of financing for BRI projects need to be disclosed in time, without breaking national laws and business confidentiality, to help accurate, transparent assessment of borrowing countries' debt sustainability.

337 Ibid.
338 United Nations Development Programme and China Development Bank (2019). Harmonizing investment and financing standards towards sustainable development along the Belt and Road. Retrieved from https://www.cn.undp.org/content/china/en/home/library/south-south-cooperation/harmonizing-investment-and-financing-standards-.html.

4.4 Best practices in channelling investment and financing towards green and low-carbon development

4.4.1 EU ETS: harmonizing accounting standards for carbon emission allowances

One of the concerns for an ETS is an unfair or unstable carbon price which could disincentivize the entities from cutting their carbon emissions. The EU ETS, the world's first international ETS, has gone through three phases to overcome this issue. Its experience can provide useful lessons to other countries in the world.

The overall goal of the EU ETS is to reduce the emissions in 2020 by 20% compared to 2005. To this end, the EU divided its actions into three phases: phase 1 (2005-2007), phase 2 (2008-2012), and phase 3 (2013-2020). In the first and second phases, each member state could decide the allocation of its own emission allowances through the National Allocation Plan. Furthermore, the allowances of each member state were given out for free in accordance with its historical GHG emissions. This so-called "grandfathering" approach actually violates the polluter-pays principle. As early actions are not taken into account, high emitters can be rewarded with more allowances than lower emitters.[339] Moreover, in the first phase caps were not based on accurate estimations due to the lack of data of various industries, while in the second phase the 2008 financial crisis led to unexpected reductions in emissions. As a consequence of these imperfect plans and the black swan event of the financial crisis, during these two phases there was a large surplus of allowances issued compared to actual emissions,[340] which resulted in low and volatile carbon prices that frustrated the market participants.

Based on the lessons it learned from the earlier phases, in the third phase the EU replaced the National Allocation Plan with a uniform cap across its territory, which was set up to decrease year by year; it substituted grandfathering with benchmarking, which determines allowances based on the production performance instead of historical emissions; it also introduced an auction mechanism to gradually take the place of free allocation.[341]

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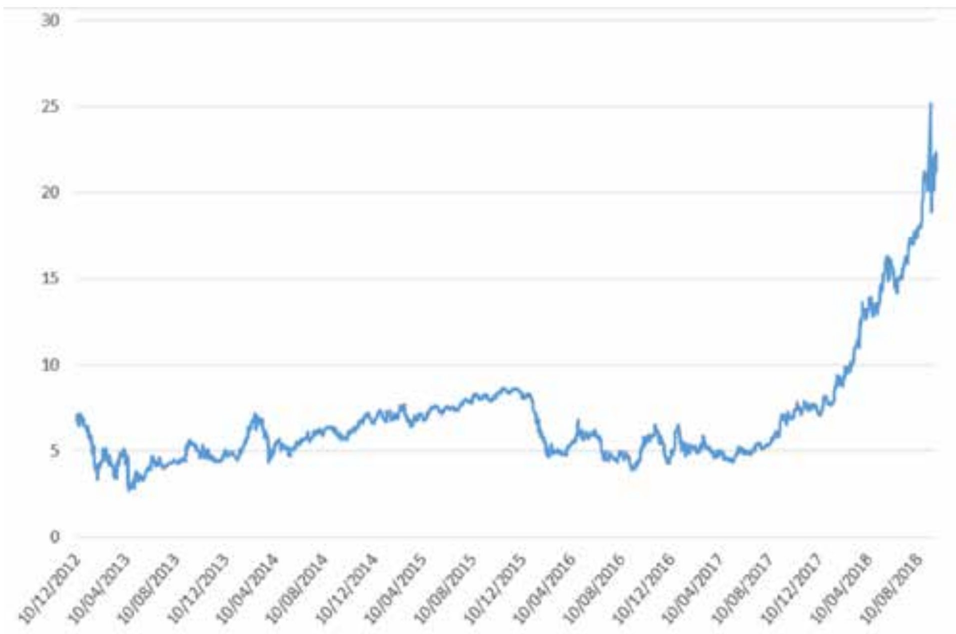
339 European Emissions Trading System (n.d.). EU ETS product benchmarks. Retrieved from https://www.emissions-euets.com/product-benchmarks.
340 European Commission (n.d.). Phases 1 and 2 (2005-2012). Retrieved from https://ec.europa.eu/clima/policies/ets/pre2013_en.
341 European Emissions Trading System (n.d.). EU ETS product benchmarks. Retrieved from https://www.emissions-euets.com/product-benchmarks.

In the third phase, there are still some other tools that complement the current allocation system in dealing with the surplus of allowances. The short-term method is back-loading, i.e. postponing the auction of 900 million allowances from 2014-2016 to the period of 2019-2020. By transferring the back-loaded allocation to the reserve temporarily, policymakers reduced short-term market supply and improved market balance. The long-term solution is the Market Stability Reserve (MSR), which began operations in January 2019. When the total allocation in circulation exceeds 833 million tons, 12% (which will rise to 24% by 2023) of the allocation supply will be withdrawn from the auctions and deposited in the MSR. When the allocation in circulation drops below 400 million tons, the allocation of 100 million tons will be released from the MSR to the market.[342] Thanks to the new allocation mechanisms and the complementary tools, the carbon price has risen and become more stable since the beginning of the third phase.

Figure 4.5 EU carbon allowance futures prices (2012-2018)



Source: IFRI[343]

In addition to price management, the EU launched an MRV mechanism to support compliance with allocations. Each installation operator covered by the EU ETS is required to

342 European Commission (n.d.). Market stability reserve. Retrieved from https://ec.europa.eu/clima/policies/ets/reform_en.
343 Roig-Ramos, C. (2018). Blooming price on the European Emission Trading System. Institut Français des Relations Internationales. Retrieved from https://www.ifri.org/sites/default/files/atoms/files/roig_carbon_prices_eu_2018.pdf.

submit an emissions report annually. The data for each year is verified by an accredited verifier by March 31 of the following year. Upon verification, the operator must submit the equivalent number of allowances by April 30 of that year.[344]

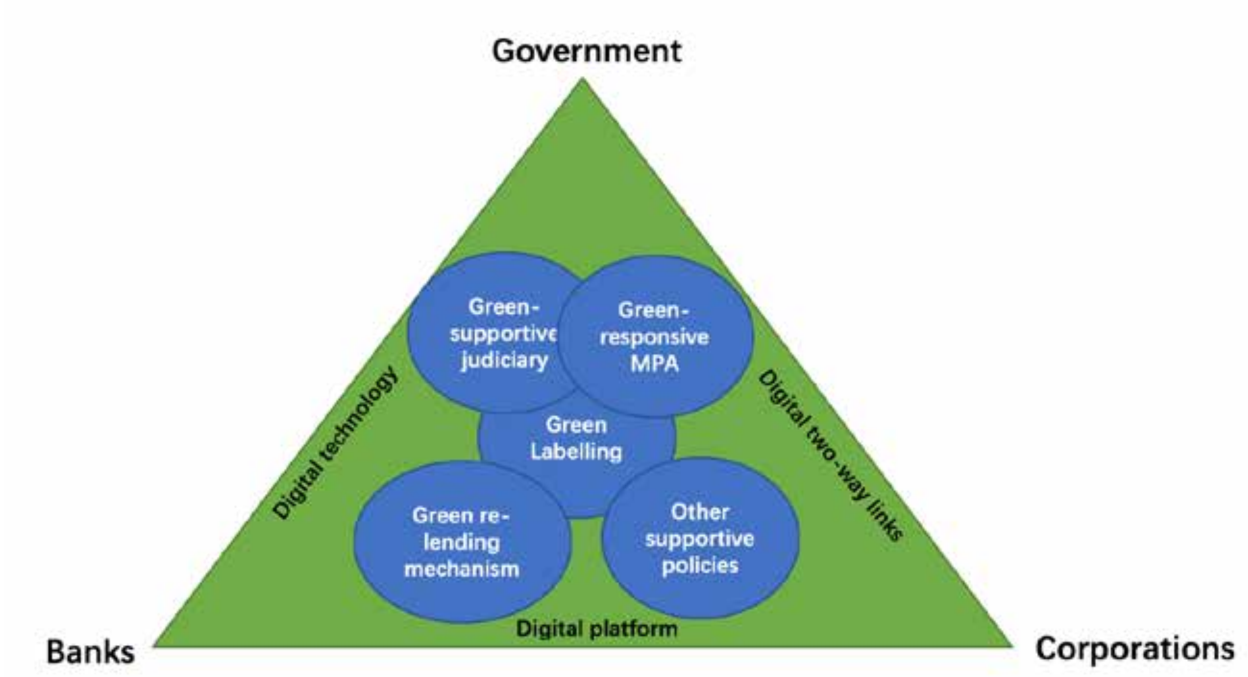
In conclusion, the third-phase EU ETS provides an inspiring model. Decrease in the total allowances, enlargement of the share of allocations auctioned, and market reserve mechanisms to regulate supply and demand are the three major factors that have contributed to the more realistic prices of emissions and long-term stability of the EU market. From these experiences, other policymakers and market participants in the world can learn how to form long-term and stable expectations in the carbon market.

4.4.2 Huzhou Green Finance Market: utilizing policy and legislative incentives to build green finance ecosystem

Huzhou City in East China's Zhejiang Province started its green finance market development in 2015 and was selected as a national Green Finance Reform and Innovation Pilot Zone in 2017. In the past few years, the city has gradually built a supportive green finance ecosystem (see Figure 4.6), in which green industrial funds of CNY 40.75 billion (US$6.1 billion), 28 labelled green bonds, innovative green credit products covering all of Huzhou's 34 industrial parks for small and micro enterprises, as well as loan insurance of CNY 192 million (US$28.7 million) for 105 small and micro green enterprises were issued or introduced by mid-2020.[345] The fast and healthy development of the green finance market in Huzhou city has largely relied on the overall policy and legislative incentives, especially thanks to the harmonization of standards, the low level of transaction costs, and the safe, predictable regulatory environment of the market.

344 European Commission (n.d.). Monitoring, reporting and verification of EU ETS emissions. Retrieved from https://ec.europa.eu/clima/policies/ets/monitoring_en.
345 The statistics were acquired from the Financial Work Office of the People's Government of Huzhou during UNDP's field visit to Huzhou in September 2020.

Figure 4.6 Huzhou's supportive green finance ecosystem



Harmonizing green project labelling standards was the primary condition upon which the self-driven green finance ecosystem in Huzhou was established. As identified by research and practices in the field of green finance, appropriately labelling projects or corporations as "green" is one of the first and foremost challenges that a comprehensive green finance market encounters.[346] A stringent, clear and credible standard of labelling can significantly reduce transaction costs, and thus incentivize the investors and lenders to conduct operational activities in a greener way.

The Huzhou green finance market started to establish a green labelling standard system by issuing the *Methods for Identifying Green Projects in Huzhou City*, and *Methods for Identifying Green Corporations in Huzhou City* in April 2018, based on international and national standards and experiences, taking into consideration the context of the city. Each of these two standards relies on a set of indicators that are measurable from a corporation's dataset, checkable for the government, and monitorable for third parties. Foreseeing the difficulty of collecting data from numerous SMEs, the *Methods* innovatively divides projects or corporations into "green" or "non-

346 Ehlers, T., and Packer, F. (2017). Green bond finance and certification. *BIS Quarterly Review*, September. Retrieved from https://www.bis.org/publ/qtrpdf/r_qt1709h.htm.

green" categories as the first step. Within the "green" category, entities are further classified into three levels, namely deep green, mid green, and light green, to which a finance discount of 12%, 9% and 6% on the basis of the benchmark interest rate are granted, respectively.[347]

In August 2018, the two *Methods* were then further developed into four Standards for the identification of green finance project, green finance corporations, green banks, and green finance business divisions of financial institutions respectively.[348] These four standards have set a clear definition for each standardized entity, an evidence-based set of indicators, and a comprehensive description without any duplication.

The second set of major incentives was formed based on coordinated policies among different government organs. The Huzhou Branch of the People's Bank of China has established a green re-lending mechanism, providing cheap funding for commercial banks to issue green loans at a lower price. In 2017, the first funding package amounted to CNY 500 million (US$71 million). Financial institutions aiming to apply for this funding are expected to meet a prerequisite entrance requirement. This motivates banks to establish a Green Finance Business Division, an Environmental Risk Assessment Mechanism, a Green Lending Performance Evaluation Mechanism, and Green Lending Systems. Meanwhile, post-lending evaluation was incorporated into the local PBOC's MPA system, incentivizing banks to increase green lending continuously as MPA scores are basic references for the PBOC to evaluate the performance of banks.

The judicial system has also issued a total of 18 measures to legally secure an enabling financial and business environment for the green finance market in Huzhou from three main aspects.[349] First, legal services for green finance entities were strengthened. The measures encourage the listing of green corporations and actively reduce the judicial cost of listing. Financial institutions were also supported in the innovation of green financing, including the pledge and mortgage of emission rights, franchise of energy conservation and environmental protection projects, right to use the environmental governance PPP projects and rights to the core benefit of green engineering projects. Second, judicial protections for green finance were effectively

347 The People's Government of Zhejiang Province (2019). "湖州绿贷通助推高质量发展" [Huzhou Lvdaitong promotes high quality development of green finance] (link in Chinese, see references).
348 China Green Finance Committee (2018). "湖州制定全国首批绿色金融地方标准" [Huzhou formulates the first batch of local standards for green finance] (link in Chinese, see references).
349 China Green Finance Committee (2018). "绿色金融动态" [Latest news of green finance] (link in Chinese, see references).

implemented. The measures drastically improved the efficiency of accepting green finance cases by opening green channels to green finance disputes and providing online filing services. A target of over 90% case conclusion rate and 85% case enforcement rate has been set for green-finance-related cases, requiring unified scheduling and planned actions. Third, the measures heavily punished crimes in the field of green finance, including crimes relating to illegal fund-raising, embezzlement, bribery, and violence.

Coordinated actions among various government organs were also taken for a secure and profitable green finance market. For example, judicial organs work closely with PBOC, public security organs, taxation, land and market supervision organs to establish a green credit system, as well as a green finance risk warning and management mechanism.

The third essential component of the Huzhou Green Finance Market is the use of digital technology as a bridge between the government, financial institutions and SMEs. While uniform standards, preferential legislative frameworks, and accessible green banking systems have laid a solid foundation to attract green finance activities, the application of digital technology has facilitated the self-driven development of a green finance market given the convenience it created.

For the four Standards on the labelling of green projects, corporations, banks, and business divisions respectively, an online labelling platform has been introduced and updated by the government to quickly facilitate the precise, automatic, and responsive labelling of green market entities. The platform is connected to the local environmental big data system, which enables instant automatic data extraction and machine labelling. The judicial system also initiated a "Internet + Judiciary" mechanism in which verdicts on green finance-related cases can be directly issued and published online.

With the government organs managing to reduce the transaction costs of starting or dealing with a green finance business, a special one-stop shop green finance online platform was also introduced to link directly the business units – the banks and the corporations. Incorporated with the online labelling system and connected to data centres in the bureaus of commerce, taxation, court and etc., the e-financing system enables banks to easily determine the category and credit of a project or corporation applying for green lending. On the other hand, a corporation can easily register on the platform and post a green finance request, after which the banks are able to assess the case immediately and compete to get a deal within a short period of time. Through such a one-stop shop e-green finance platform, 10,721 corporation have obtained credit from banks totalling CNY 107 billion (over US$15.1 billion) by 2019.[350]

4.4.3 ICBC stress test: environmental risk assessment technology and model

ICBC is the first bank in China to use a stress test methodology to forecast the impacts of environment and climate-related risks that it and its clients face. In addition to considering its social responsibilities, ICBC also determines the allocation of its financial resources and optimizes its business structure based on the commercial risks that may be triggered by environmental stress.

By applying the methodology, ICBC quantifies environmental risks by internalizing them into its credit rating system. According to its studies, environmental externalities may augment the financial risks of a commercial bank in three dimensions.[351] First, they may aggravate the credit default risks. The tightened standards and climate change may negatively affect the cash flow and balance sheet of the bank's clients, weaken their repayment ability and thereby increase the credit risks faced by the bank. Second, the bank may be burdened by the risks of joint liability for pollution. In many countries, commercial banks are jointly liable for pollution as creditors, because legislators intend to prevent them from supporting environmentally unfriendly enterprises. Third, reputational risks are inevitable to the bank as environment risks are increasingly impacting investment returns and generate media attention.

On the basis of this quantitative analysis, ICBC can measure how the internalized environmental risks transmit to its daily operation using the following steps, in line with its established practice in the industries of thermal power production and cement.[352]

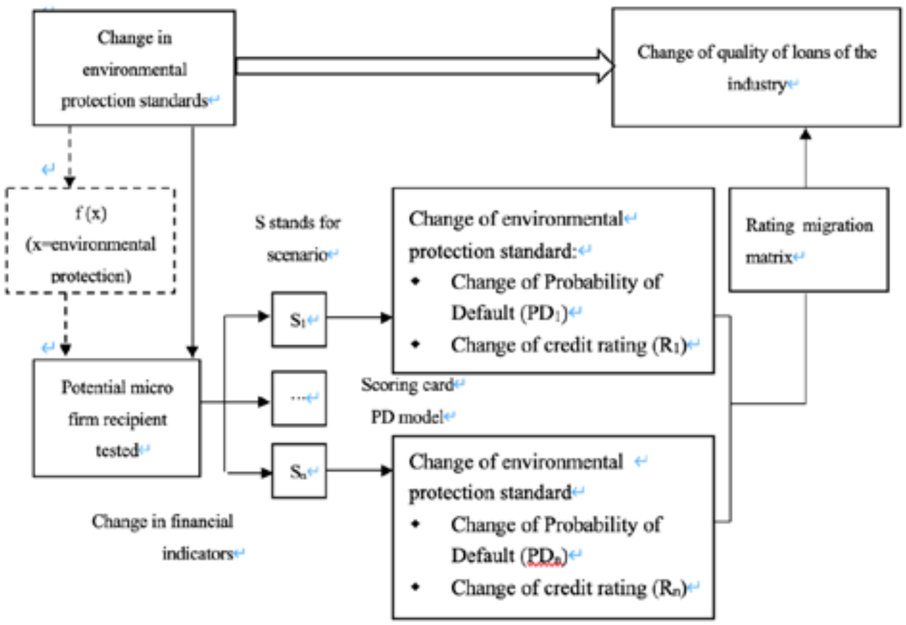
350 China Green Finance Committee (2018). "绿色金融动态" [Latest news of green finance] (link in Chinese, see references).
351 Zhang, H., Zhou, Y., and Ma, J. (2016). Impact of environmental factors on credit risk of commercial banks: research and application by ICBC based on stress test. ICBC and Green Finance Committee. Retrieved from http://www.greenfinance.org.cn/upfile/upfile/filet/ICBC%E7%8E%AF%E5%A2%83%E5%8E%8B%E5%8A%9B%E6%B5%8B%E8%AF%95%E8%AE%BA%E6%96%87_2016-03-19_08-49-24.pdf.
352 China Banking Association (eds.) (2018). "绿色信贷" [Green bonds and loans]. China Financial Publishing House.

The first step is to list and categorize the environmental pressures. For example, in the thermal power production and cement industries, pressure can be mainly attributed to punishment as a result of exceeding the emissions limit on air pollutants and charges for waste. The cement industry may also be hit by policy requirements on co-processing industrial waste in cement kilns. In a word, these highly polluting industries in China are generally pressured by the changes in environmental protection policies.

The bank would then build three levels of stress scenarios (mild, moderate and severe), taking into account a series of policies and standards that have been formulated or are about to be launched. In this way, the likelihood that one of the scenarios will cover the actual outcome will be relatively high.

The final step is to carry out the stress testing. Due to the lack of historical data on the impact of China's environmental standards on the quality of bank loans, this stress test uses a "bottom-up" approach, i.e., it analyses the main impact of environmental policy changes on corporate finance. New financial statements under the stress scenario can be worked out based on the interrelation of the financial statements; changes in the enterprise's credit rating and default rate under the stress scenario can be obtained through ICBC's existing customer rating model; and the increase in the non-performing loan rate of the relevant industry under the stress scenario can be predicted through the relationship between the default rate and non-performing loan rate.

Figure 4.7 Financial transmission model of the stress test[353]



Source: Zhang, H., Zhou, Y., and Ma, J.[354]

Based on these steps, ICBC gives recommendations to these two industries. The thermal power production industry will go through significant cost pressures imposed by stricter environmental standards but is likely to ultimately remain stable because of continuous economic growth and the huge demand for electricity. Nevertheless, small and medium-sized enterprises will be under structural impact caused by the change of the standards, confronted with "obvious financial pressures" and downgraded credit ratings. As for the cement industry, the test finds that stricter environmental standards will exert considerable financial pressure on the cement industry, seeing it enter a low-growth stage with continuous reduction of capacity as part of the capacity not able to comply with new standards is phased out.[355]

353 The function of the rating migration matrix in the model is to capture the probability that a certain obligor will migrate from one credit state to another over a given period.
354 Zhang, H., Zhou, Y., and Ma, J. (2016). Impact of environmental factors on credit risk of commercial banks: Research and application by ICBC based on stress test. ICBC and Green Finance Committee. Retrieved from http://www.greenfinance.org.cn/upfile/upfile/filet/ICBC%E7%8E%AF%E5%A2%83%E5%8E%8B%E5%8A%9B%E6%B5%8B%E8%AF%95%E8%AE%BA%E6%96%87_2016-03-19_08-49-24.pdf.
355 University of Cambridge Institute for Sustainable Leadership (2016). Environmental risk analysis by financial institutions: a review of global practice. Retrieved from https://www.cisl.cam.ac.uk/resources/publication-pdfs/environmental-risk-analysis.pdf.

Overall, ICBC's stress testing is an example of foresight-based thinking. It is carried out at the industry level and prioritizes high pollution and high energy consumption industries. Different from traditional stress testing that mainly focuses on the effects of extreme events, ICBC also takes other factors into consideration. For example, in China the government has issued a series of policies to realize ecological civilization, reduce emissions, and control pollution. This will exert great pressure on highly polluting industries. Therefore, when ICBC designs the scenarios, it builds in such impacts not seen in the past but expected in the future, and usually considers the change of environmental standards as an influential factor.

4.4.4 IFC blended finance: exploring diversified financing channels to support low-carbon development

IFC is a typical multilateral development financial institution that uses blended finance to support sustainable development. By combining its commercial funding and concessional funding provided by its development partners, IFC can leverage abundant financial resources into large-scale development projects with considerable risks and uncertain returns.[356] Its co-investment partners include local and international commercial banks, development institutions, central banks, funds, insurance companies, etc.[357]

The ability of private commercial banks to meet the long-term financing demands of energy-related projects in emerging markets is often constrained by liquidity rules. Yet, since many public sector banks are also under pressure in financing large projects, the potential of untapped financing from private investors needs to be explored. To engage more private financial institutions in development finance for emerging market infrastructure and unlock private capital flows, IFC launched a Managed Co-Lending Portfolio Program (MCPP), a syndication program that covers infrastructure, financial institutions and the real economy.[358] For financing emerging market infrastructure, MCPP Infrastructure buys loans originated by IFC, pools them into a "loan fund", then restructures them into "tranched" securities with different levels of credit risks: a higher-risk

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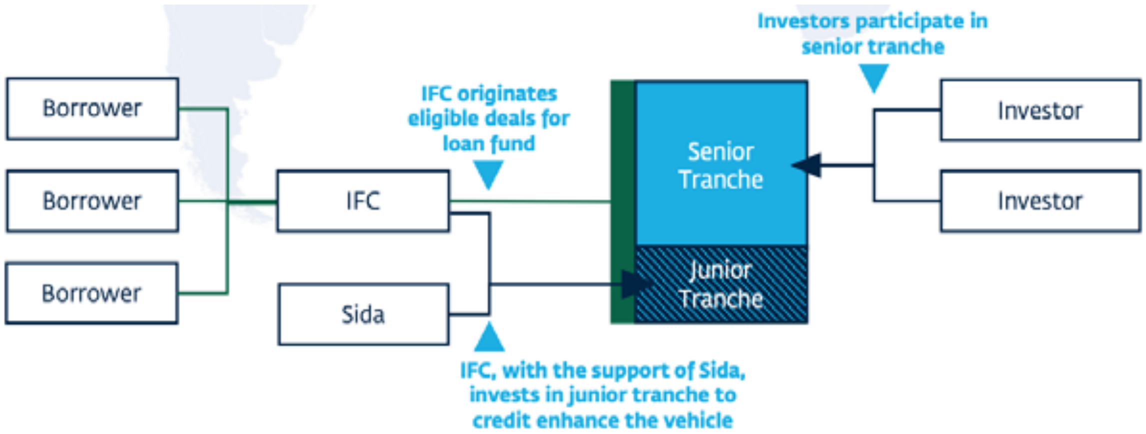
356 International Development Association (2016). Further details on the proposed IFC-MIGA private sector window in IDA18. Retrieved from http://documents.worldbank.org/curated/en/947651474898912390/pdf/Further-Details-on-the-Proposed-IFC-MIGA-Private-Sector-Window-in-IDA18.pdf.

357 International Finance Corporation (2017). Partnering with IFC syndications. Retrieved from https://www.ifc.org/wps/wcm/connect/d492479a-aca0-48e3-8ed4-2905f62a3859/Syndications+Brochure_SEPTEMBER+2017_FINAL+9-8-2017.pdf?MOD=AJPERES&CVID=lYR-gnI.

358 International Finance Corporation (n.d.). Managed Co-Lending Portfolio Program (MCPP). Retrieved from https://www.ifc.org/wps/wcm/connect/corp_ext_content/ifc_external_corporate_site/solutions/products+and+services/syndications/mcpp.

"first-loss" tranche, which is retained by IFC, and a less risky "second-loss" tranche suitable for institutional investors. The fund is guaranteed by the Swedish International Development Cooperation Agency (Sida). In this way, IFC scales up its debt mobilization from private institutions.

Figure 4.8 How the MCPP Infrastructure works



Source: IFC[359]

Under this structure, investors only need to commit a certain amount of money in advance, which is invested alongside IFC funds in certain countries and sectors according to IFC's strategy. In exchange, IFC is obliged to disclose the entire pipeline of projects to the investors and make investment decisions without cherry-picking projects.

The key advantages of this structure are that IFC can manage risks and maximize loans for infrastructure in developing countries both through loan syndication and securitization. The intermediation gaps between the products and the investors are filled and investors can gain exposure to a diversified pool of assets. This mobilizes more institutional investments into infrastructure in emerging markets. Moreover, the guarantees and tranching of the portfolio reduce the risk for institutional investors to a level at which they can meet fiduciary and regulatory requirements.[360]

359 International Finance Corporation (n.d.). MCPP Infrastructure. Retrieved from https://www.ifc.org/wps/wcm/connect/4c9e0868-1232-4212-b4f2-a5c39d177afa/MCPP+Infrastructure+Flyer+2018.pdf?MOD=AJPERES&CVID=mcoa4bt.
360 Overseas Development Institute (2018). Private infrastructure financing in developing countries. Retrieved from https://www.odi.org/sites/odi.org.uk/files/resource-documents/12366.pdf.

IFC and its borrowers can also benefit from MCPP Infrastructure. By mobilizing third-party financing, the program leverages IFC's own balance sheet and expands its business. In addition, it also reduces uncertainty in financing and transaction costs for borrowers.

So far, MCPP Infrastructure has attracted committed capital of US$2 billion from institutional investors, including Eastspring Investments, the Asian asset management business of Prudential plc, and other major global insurers.[361]

361 Ibid.

Chapter 5 Strengthening capacity-building to enhance low-carbon development capabilities in countries and territories along the Belt and Road

Capacity-building is essential to promoting low-carbon development. This chapter identifies the gaps in low-carbon capacity-building along the Belt and Road, including regulatory and economic barriers, institutional and policy bottlenecks, insufficient education and training, as well as the lack of important data, information and awareness. This chapter emphasizes the importance to strengthen low-carbon capacity-building in key areas. These include boosting deep understanding of BRI stakeholders in energy transition trajectories and potential impact of the COVID-19 pandemic, environmental and climate risk identification and measurement, as well as international consensus and regulations on carbon emissions management. It is necessary to encourage the establishment of multilateral education centres, training seminars, and online knowledge platforms, strengthen multi-layer collaboration among government agencies, industries, education, and research institutions, utilize consensus and opportunities of low-carbon energy transition, and encourage industries and education sector to support women and youth’s equal access to job opportunities.

Section 1 reviews the context of low-carbon capacity-building in countries and territories along the Belt and Road, and analyses major demand and challenges in low-carbon capacity-building. Section 2 analyses key areas for low-carbon capacity-building along the Belt and Road. Section 3 puts forward diversified measures of advancing low-carbon capacity-building. Section 4 provides best practices in promoting low-carbon capacity-building globally, including UNDP-China trilateral project on Renewable Energy Technology Transfer, IRENA’s renewables development prospects evaluation instrument, as well as Denmark and Uruguay’s pathways and advantages of fostering skills, workforce and technologies.

5.1 Context of low-carbon capacity-building along the Belt and Road

5.1.1 Three key levels of capacity-building: individual, institutional and systemic

Capacity development is defined “as the process through which individuals, organizations and societies obtain, strengthen and maintain the capabilities to set and achieve their own development objectives over time". In UNDP's parlance, capacity is the "how" of making development work better.[362] In the case of finance and investments in infrastructure for low-carbon development, this involves enhancing countries' absorptive capacity and reducing the risks of putting in place poorly performing assets.

Capacity development is a long-term process that includes individual skills and training but also covers issues related to "institutional change, effective leadership, empowerment and public participation".[363] The analysis in this chapter will look into the key stakeholders engaging in capacity-building activities both as "receivers/trainees" but also as "initiators/trainers". These stakeholders, from China and BRI partner countries, are the ones involved in the implementation of the BRI on the ground. The analysis focuses on the importance of partnerships within and between countries; on key areas and sectors that need to be strengthened and what expertise is most needed; on the format of practical activities that can provide concrete steps forward and solutions; and, using a foresight element, on the opportunities that can be leveraged in such a transition.

Within this framework, the analysis underlines the impact of capacity-building activities at **three key levels**: (i) individual – connected to the acquisition of knowledge, skills exchange and training but also to generating ownership; (ii) organizational and institutional - connected to strengthening functions and delivery at the implementation level by defining objectives, guidelines and instruments; and (iii) systemic – focused on creating an enabling environment that entails policy and regulatory aspects as well as accountability frameworks.[364] To promote low-carbon development, capacity-building is needed to strengthen the abilities of individuals and organizations that can in turn facilitate the effective and efficient use of resources by creating a conducive enabling environment.

There are diversified types of capacity building activities. A series of scholarships and tailored training programs can be designed and offered. Knowledge centres could also be established, focusing on creating the necessary framework of expertise transfer and facilitating

362 United Nations Development Programme (2008). Capacity development practice note. Retrieved from http://content-ext.undp.org/aplaws_publications/1449053/PN_Capacity_Development.pdf.
363 Ibid.
364 International Renewable Energy Agency (2012). Capacity-building strategic framework for IRENA (2012 – 2015). Retrieved from https://www.irena.org/publications/2012/Nov/Capacity-Building-Strategic-Framework-for-IRENA-2012--2015.

funding for short- and long-term education programs. Knowledge digitalization and exchange via online platforms should also be prioritized, to offer help for attaining economies of scale and fostering innovation.

5.1.2 Demand and challenges in low-carbon capacity-building along the Belt and Road

Capacity gaps or soft barriers to low-carbon development can be identified in areas such as improving low-carbon development policies and governance mechanisms, responding to emerging demand in job markets amid low-carbon transition, and strengthening data collection and knowledge sharing. In these areas, opportunities also arise especially given emerging industries and expanding job markets.

Capacities in improving and implementing low-carbon development policies should be strengthened, and gaps in low-carbon governance need to be addressed, so as to create an enabling environment for low-carbon development along the Belt and Road. Expertise is needed, especially among policymakers, to design effective policies and regulations that reflect and complement national development strategies as well as environmental policies. **Capacity gaps leave the policy environment fragmented and saddled with complicated procedures and regulations, lacking harmonized and appropriate standards,**[365] **and may open opportunities for corruption.** This calls for strengthening individual capacity targeting mainly the professionalism and technical expertise of policymakers, but also for building organizational capacity by setting up specific offices or institutions in charge of implementing such policies. Systemic capacity also needs to be built to strengthen the overall enabling environment. There is both a strong potential and significant room in most countries along the Belt and Road for improving such capacity.

Growing demands for education and training in low-carbon development are yet to be met. As the deployment of renewables in the global energy system increases, so will the world's renewable energy workforce. According to IRENA, in the planned energy scenario – based on current government plans[366] – **the number of people employed in the renewables sector could**

365 Ibid.

366 According to the International Renewable Energy Agency, the Planned Energy Scenario is a "perspective on energy system developments based on governments' current energy plans and other planned targets and policies (as of 2019), including Nationally Determined Contributions under the Paris Agreement unless the country has more recent climate and energy targets or plans". International Renewable Energy Agency (2020). Global renewables outlook: energy transformation 2050. Retrieved from https://www.irena.org/publications/2020/Apr/Global-Renewables-Outlook-2020.

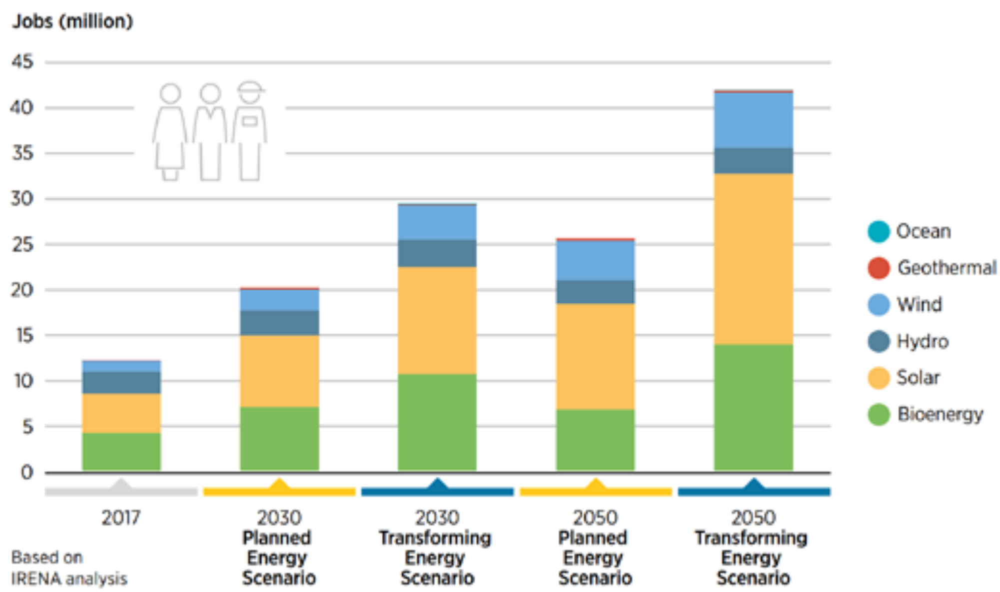
increase substantially, and grow to 23.6 million in 2030 and 28.8 million in 2050. However, in a transforming energy scenario – based on a more ambitious, yet realistic energy transition pathway[367] – the renewables job market could account for 30 million jobs by 2030 and 42 million globally by 2050. Moreover, related areas such as energy efficiency and systems flexibility would create a further 21 million and 15 million jobs respectively.

This means that a stronger commitment to low-carbon development will bring an increasing number of people to work in the sector and its supply chains, especially at the local level (see Figure 5.1). Such capacity includes the manufacturing and distribution of renewable energy equipment; renewable energy project development; construction and installation associated with the development of renewable energy capacity; renewable plant operations and maintenance; and other activities connected to the development of the value chain.[368] The development of local supply chains and the availability of low-cost operations and maintenance support are key, as the absence of local skills and capabilities can keep renewables costs high and present risks to operational efficiency and reliability.

367 According to the International Renewable Energy Agency, the Transforming Energy Scenario "describes an ambitious, yet realistic, energy transformation pathway based largely on renewable energy sources and steadily improved energy efficiency (though not limited exclusively to these technologies). This would set the energy system on the path needed to keep the rise in global temperatures to well below 2 degree Celsius (°C) and towards 1.5°C during this century". International Renewable Energy Agency. (2020). Global renewables outlook: energy transformation 2050. Retrieved from https://www.irena.org/publications/2020/Apr/Global-Renewables-Outlook-2020

368 International Labour Organization (2011). Skills and occupational needs in renewable energy. Retrieved from https://www.ilo.org/wcmsp5/groups/public/---ed_emp/---ifp_skills/documents/publication/wcms_166823.pdf.

Figure 5.1 Global renewable energy jobs for the planned scenario and the transforming scenario in 2017, 2030 and 2050



Source: IRENA[369]

Especially for developing countries, off-grid development and decentralized energy systems are expected to bring about new job opportunities, along with greater access to clean energy in rural and remote areas. Although currently limited in Africa and Asia, the number of decentralized energy jobs will double by 2023. The 2019 Powering Jobs Census shows that decentralized energy sector employment already matches that in the traditional energy sector in India, Kenya and Nigeria. The off-grid development field provides a rate of job creation five times higher than in the fossil fuel-based power sector. Most of these employment opportunities will involve good working conditions and cater to a highly skilled – and paid – middle-income workforce that will necessitate enhanced education in science, technology, engineering and mathematics (STEM).

However, an important skills gap remains, especially in operations and maintenance. Gaps are also evident in other sector-related areas, such as business management, sales and distribution. A strong focus on technical and vocational education and training and career strategy which

369 International Renewable Energy Agency (2020). Global renewables outlook: energy transformation 2050. Retrieved from https://www.irena.org/publications/2020/Apr/Global-Renewables-Outlook-2020.

involves government, industry, education institutions, and investors would be vital to close the skills gap for the sector.[370] Some examples draw a compelling picture of skills shortages and job opportunities that can be leveraged if skills gaps are properly addressed.

In **Kenya**, decentralized renewable energy sources represented direct and indirect employment opportunities for 17,000 individuals in 2017 with 10,000 formally employed in the sector. This figure is expected to rise by a further 70% by 2023.[371] Key skills needed include sales and distribution, management and business administration, and after-sales service. In the country, 18% of the electricity produced by power plants is lost through transmission or distribution, making decentralized energy generation an interesting, highly cost-effective solution for producing clean and affordable energy.[372] This potential advantage is reinforced by high connection costs to the grid and abundance of solar energy in the country.

Nigeria's population totals 190 million people, a fifth of Africa's total population. The country is impacted by energy unreliability. Local and decentralized renewable projects have been able to solve local power shortages the centralized system could not cope with, at a small scale. 13,000 persons were either directly or indirectly employed in the decentralized renewable sector with 4,000 formal jobs as of 2019.[373] The latter figure is expected to rise thirteen-fold to 52,000 formal jobs by the end of 2023. Key skills needed will include operations and maintenance, sales and distribution, and management and business administration.

In the **Philippines**, 2.7 million inhabitants do not have access to electricity. Due to the geography of the archipelago and the fact that it needs to import 100% of its coal and oil to generate power, decentralized microgrids provide a cheap, workable and environmentally superior solution that is being developed throughout the country. Similarly, local mini-hydropower projects have yielded hundreds of jobs (Antique in Western Visayas, Davao in Mindanao, and Hedcor in Luzon) that have gone mostly to the local community.[374]

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370 Power For All (2019). Powering jobs census 2019: the energy access workforce. Retrieved from https://www.powerforall.org/resources/reports/powering-jobs-census-2019-energy-access-workforce.
371 Ibid.
372 Brite Bridges (2018). How decentralized energy solutions are closing the access gap in Africa. Retrieved from https://briterbridges.com/how-decentralised-energy-solutions-are-closing-the-energy-access-gap-in-africa.
373 Power For All (2019). Powering jobs census 2019: the energy access workforce. Retrieved from https://www.powerforall.org/resources/reports/powering-jobs-census-2019-energy-access-workforce.
374 Renner M. (2017). Rural renewable energy investments and their impact on employment. International Labour Organization working paper. Retrieved from https://www.ilo.org/wcmsp5/groups/public/---ed_emp/documents/publication/wcms_562269.pdf.

The education and vocational training systems need to adapt to labour demand in emerging job markets amid the low-carbon transition. This process requires time to adapt, design new programs, target funding and strengthen skills, considering that renewables are a relatively new sector. **The greatest hindrance is skills shortage to develop local supply chains.**[375] **The lack of consultation with the private sector also represents an issue to be properly addressed to ensure skills developed meet existing and future demand**.[376] In addition, an increasing part of these newly created jobs require digital and information technology (IT) skills as a 2016 McKinsey study highlights.[377] This is already an issue in developed countries,[378] and represents an even bigger – and clearly foreseeable – issue in developing countries.

Energy data collection, knowledge sharing on low-carbon transition, and social awareness need to be improved. Data, information and awareness are categories that touch all three levels in capacity-building as they include the strengthening of key aspects in organizational and individual capacity that are vital to sustain capacity development at the systemic level.[379]

Domestic energy data collection needs to be further improved in countries along the Belt and Road, to facilitate the abovementioned knowledge-sharing. In some countries, data collection has traditionally focused on conventional energy systems, and existing methodologies are inadequate to ensure full and timely coverage of renewables. New understandings of the necessity of know-how sharing are needed, to facilitate coordinated actions globally and along the Belt and Road towards low-carbon prospects. For instance, data-driven and scenario-based climate and environmental risk analysis is vital for decision-making by key BRI stakeholders. This requires not just national authorities' willingness to conduct their own analysis, but also their awareness and commitment to share data and hands-on experience as prerequisites for developing low-carbon transition pathways.

375 Taylor Hopkinson (2017). Tackling skills shortage in the renewable energy sector by 2020. Retrieved from https://www.taylorhopkinson.com/wp-content/uploads/Skills-shortage-Report-Taylor-Hopkinson.pdf.

376 International Labour Organization (2011). Skills and occupational needs in renewable energy. Retrieved from https://www.ilo.org/wcmsp5/groups/public/---ed_emp/---ifp_skills/documents/publication/wcms_166823.pdf

377 Booth, A., Mohr, N., and Peters, P. (2016). The digital utility: new opportunities and challenges. McKinsey & Company. Retrieved from https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/the-digital-utility-new-opportunities-and-challenges.

378 European Wind Energy Technology Platform (2013). Workers wanted: the EU wind energy sector skills gap. Retrieved from http://www.windplatform.eu/fileadmin/ewetp_docs/Documents/reports/Workers_Wanted_TPwind.pdf.

379 International Renewable Energy Agency. (2012). Capacity-building strategic framework for IRENA (2012 – 2015). Retrieved from https://www.irena.org/publications/2012/Nov/Capacity-Building-Strategic-Framework-for-IRENA-2012--2015.

5.2 Major areas for low-carbon capacity-building

5.2.1 Energy transition trajectories, and potential impact of the COVID-19 pandemic

Strengthening expertise sharing on energy transition trajectories and practices and equip policymakers along the Belt and Road with the necessary tools to implement energy transition policies facilitate them making informed decisions in short- and long-term planning. These tools include having access to reliable data and information on the latest technology developments, their performance and their costs. They also include the ability to plan using foresight on the costs, benefits and risks of investments to attain energy infrastructure that is resilient to climate impacts while correctly assessing risks associated with stranded assets arising from investments in fossil fuel power plants. Mechanisms for risk assessment should incorporate foresight on both operational performance and on borrowers' ability and willingness to repay in light of climate risks and possible asset stranding. Beyond policymakers, those tools could also support investors in their pre-feasibility assessments and in securing financing for their assets.

The creation or strengthening of knowledge centres offering tailored training and capacity-building activities can help further bridge existing gaps in expertise of energy transition trajectories. They could help exploit synergies relevant to various sectors at all levels in both developing countries along the Belt and Road and more developed ones lagging in energy transition. In the long run, these knowledge centres would help create international education cooperation mechanisms and set up new research and knowledge-sharing institutions, so as to facilitate exchanges of students, teachers and researchers specializing in low-carbon development.

Further complementary actions could include funded awareness programs on the energy transition to ensure that national and local policymakers, stakeholders, communities and populations improve their understanding of the needs of an energy transition and of the changes brought by climate change. Such awareness programs could effectively diminish the knowledge deficit and also generate approval and participation of key stakeholders, which would strengthen political will and commitment. To enable a significant shift away from current carbon-intensive pathways, these programs need to be closely linked with the financing mechanisms described in Chapter 4. China and other countries with experience in technology transfer and expertise in renewables could benefit from their unique competitive edge in these aspects.

As the COVID-19 pandemic advances, many uncertainties remain on the economic recovery, growth prospects and the effects on the energy sector and energy security. Against this backdrop, upgrading climate ambitions, by for instance reducing the role of fossil fuels, could prove to be politically challenging especially for developing countries.[380]

However, an opportunity might arise from the crisis especially for China and the BRI partner countries. The ways countries will shape their stimulus packages to address socio-economic issues brought by the COVID-19 crisis will determine their development prospects for the coming decades. Therefore, Chinese and BRI partner countries' decision-makers could choose to maximize their efforts for the energy transition. In this scenario, **these countries could use their potential to be at the forefront in clean energy investment and the low-carbon economy, shaping the post-coronavirus world.** This would enable policymakers along the Belt and Road to take advantage of the BRI as a platform to exchange information and experiences in overcoming socio-economic challenges during the pandemic and better shape low-carbon policies that could sustain their development aspirations in the post-COVID-19 period.

On these issues, specific training could be provided to government officials. Such training can take the form of online seminars, for instance on the impact of the COVID-19 pandemic on low-carbon development prospects; or conferences, focused on new relevant themes such as digital infrastructure and opportunities for low-carbon development. Institutes or experts can deliver tailor-made sessions to strengthen individual capacity, enhance policy discussion, and promote consensus on major areas.

5.2.2 Environmental and climate risk identification and measurement, international consensus and regulations on carbon emissions management

In order to overcome barriers in low-carbon policy implementation, it is necessary to consolidate in-depth understanding of global and regional consensus under existing frameworks of laws and regulations related to climate change. It is also necessary to advance understanding of

380 Tu K. (2020). COVID-19 post-pandemic impact on China's energy sector: a preliminary analysis. Columbia University: Center on Global Energy Policy. Retrieved from https://energypolicy.columbia.edu/research/commentary/covid-19-pandemic-s-impacts-china-s-energy-sector-preliminary-analysis?utm_source=Center+on+Global+Energy+Policy+Mailing+List&utm_campaign=1a88b172af-EMAIL_CAMPAIGN_2019_09_24_06_19_COPY_01&utm_medium=email&utm_term=0_0773077aac-1a88b172af-102313325.

relevant laws, regulations and standards, energy market design, as well as mechanisms and practices of implementing them on the ground.

As analysed in the previous section, **regulatory, institutional and policy barriers** can significantly hinder the implementation of low-carbon policies. For instance, a report by AfDB[381] has showcased how in most African countries the poor design of energy reforms, regulatory systems, and weaknesses in harmonization of standards, worsened by the lack of implementation capacity, including at the institutional level, has hampered the potential of low-carbon development. These gaps raise countries' risks and hinder the creation of favourable conditions for attracting and absorbing investment for low-carbon development in the energy sector. The majority of BRI partner countries experience at least some of these gaps and have an infrastructure risk rating in the highest risk category.[382]

To overcome such challenges, capacity-building activities need to be strengthened, to bridge knowledge gaps in regulatory reforms and institutional presence both at national and regional levels.[383] Specifically, such capacity building can help BRI stakeholders and policymakers expand their knowledge of the needed institutional mechanisms and regulatory frameworks to facilitate low-carbon development.

5.2.3 Access standards, investment instruments and regulatory policies of green investment and financing

Underinvestment in low-carbon development, especially in developing countries, is to a significant extent due to the lack of an enabling environment that attracts private investment and allows countries to make the best use of their resources. For instance, in the energy sector, appropriately chosen policy measures will enhance the financial and operational viability of power utilities as they transition towards greater deployment of renewable energy resources. Institutional

381 African Development Bank (2013). Energy sector capacity building diagnostic and needs assessment study. Retrieved from https://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/Energy_Sector_Capacity_Building_Diagnostic_and_Needs_Assessment_Study.pdf.
382 From Ji, J. and Liang, H. (2018). Annual report on investment security of China's "the Belt and Road" construction. Blue Book of Investment Security of "the Belt and Road" Construction. No. 2. Beijing: Social Sciences Academic Press (China)., which reported United Nations Development Programme and China Development Bank (2019). Harmonizing investment and financing standards towards sustainable development along the Belt and Road. Retrieved from https://www.cn.undp.org/content/china/zh/home/library/south-south-cooperation/harmonizing-investment-and-financing-standards-.html.
383 African Development Bank (2013). Energy sector capacity building diagnostic and needs assessment study. Retrieved from https://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/Energy_Sector_Capacity_Building_Diagnostic_and_Needs_Assessment_Study.pdf.

reforms that strengthen regulatory reform and favour private sector participation can catalyse private sector investment, especially when well-developed finance and investments instruments are easily available and efficiently used. National utilities that integrate themselves into larger regional energy markets can reinforce their own financial sustainability and efficiency.[384]

Access to expertise on how to shape policies to better channel private and public funding is crucial to the implementation of low-carbon development as well as SDG attainment. This requires strengthening the capacity and expertise on government policies and developing a flexible and open business mindset towards low-carbon development, especially at the individual and organizational level. Policy discussions and dialogues would serve very well the purpose of bringing all stakeholders together, while specific training would help policymakers and regulators strengthen their abilities in designing efficient market rules. A system of certification could recognize the efforts of those in the private sector who are willing to be the first movers in promoting low-carbon development in their business models.

In this area, capacity-building activities at the individual level could target more specifically investors, both private and public from China and other BRI partner countries who might not be familiar with international guidelines and standards and/or with the specificities of the countries where they are investing. Such capacity-building activities could take the form of training courses but also of policy discussions to promote an open exchange of views. At the organizational level, training institutions, schools or universities (e.g., business management schools) could be selected to develop relevant training programs.

Though these actions are mainly directed at individual and organizational capacity development, the systemic level will also benefit from the creation of a capable cadre of officials, who could greatly contribute to creating an enabling environment able to attract private financing for investments in low-carbon development. They could also facilitate mechanisms for effectively regulating and managing not just the supply side, but also the demand side of the power market, and in effectively pursuing enhanced global connectivity in grids. It is therefore in the individual

384 African Development Bank (2013). Energy sector capacity building diagnostic and needs assessment study. Retrieved February 2020 fromhttps://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/Energy_Sector_Capacity_Building_Diagnostic_and_Needs_Assessment_Study.pdf.

and joint interest of all BRI partner countries to support such activities and given the network effects and externalities, of other countries as well.

5.2.4 Key elements for effectively implementing large-scale low-carbon infrastructure projects

Individual and organizational capacity to conduct long-term planning and to suitably structure large-scale infrastructure projects is another important factor, especially for developing countries. Significant, inadequately addressed capacity limitations can markedly diminish the effectiveness of countries' attempts to accelerate investment in sustainable infrastructure.[385]

As stressed by the World Bank,[386] the process is not straightforward, especially in least developed countries (LDCs) and fragile contexts, implying a need to keep **several factors** in mind. For instance, government may have a limited commitment to financial stabilization and recovery objectives, given the political sensitivity of some measures such as tariff adjustments for cost-recovery and its consistent enforcement, crucial to guaranteeing the electricity sector's long-term financial viability. The time horizon of these and related investment projects should therefore allow for the time needed by the government to implement its policies. Infrastructure project design in low-carbon infrastructure projects also needs to avoid common pitfalls for investment loans, notably unrealistic time frames, overambitious agendas, or unduly complex conditionality. Complementary interventions—such as coupling investment operations with directly relevant capacity-building assistance—and sustained support based on careful analysis can effectively support countries to overcome their capacity gaps.

This type of technical capacity-building at both the individual and organizational level can usefully be organized with the support of financial institutions that cooperate directly with the government and are interested in investing in these countries. Ideally, cooperation among various financial institutions (such as development banks) can help make available an effective mix of

385 Pinto, H. (2017). Closing the infrastructure gap by building country capacity. The Global Infrastructure Facility. Retrieved from https://blogs.worldbank.org/ppps/global-infrastructure-facility-closing-infrastructure-gap-building-country-capacity.

386 World Bank (2016). Financial Viability of the Electricity Sector in Developing Countries: Recent Trends and Effectiveness of World Bank Interventions. Retrieved from https://ieg.worldbankgroup.org/sites/default/files/Data/reports/lp_financial_viability_electricity_sector_0.pdf.

international experience and country-specific knowledge. This type of capacity-building mechanism can be further investigated, tested and scaled up when proven successful.

5.3 Diversified measures of advancing low-carbon capacity-building

5.3.1 Encourage the establishment of multilateral education centres, training seminars and online knowledge platforms

In terms of strengthening capacities in key areas of low-carbon development, it is difficult for a single country to proceed without jeopardizing its short-term economic interests unless others play along. This calls for a critical mass of countries, cities, states and corporations to agree on coordinated global collective action to facilitate lasting improvements.

The BRI can facilitate the development of various online knowledge exchange platforms to support countries' efforts to implement low-carbon development policies. Policymakers could use this platform to share lessons learned and experiences including success stories and challenges, and identify opportunities for common gains. Such exchange could include the opportunities of aligning and connecting national grids and markets to neighbouring countries and the larger region. Moreover, cooperation among BRI countries could become even more effective if all stakeholders join the efforts to enhance multilateral knowledge exchanges, and if this is done in a way that allows all willing countries to participate.

These forms of cooperation would bring together various stakeholders, notably **world-class researchers and global innovative thinkers, policymakers and practitioners from China, BRI partner countries and globally, as well as specialists from international organizations such as UN agencies, development agencies and multilateral development banks that work at the forefront of low-carbon development**. They would also support BRI partner countries to shape low-carbon policies through trainings, exchange programs and other institutional linkages.

UNDP, with its mandate centred on long-horizon sustainable development, represents the joint long-term interest of all member states. As such, it can play an important role in facilitating capacity building to enhance SDG implementation and the provision of global public goods. UNDP and the UN are well-positioned to support the definition and implementation of policies to support countries' efforts in containing climate change, environmental degradation and addressing resource scarcity. Given their significant convening power and ability to work together with governments in their capacity development, UN agencies can contribute to building consensus, strengthening knowledge and providing institutional support to a low-carbon transition.

Box 5.1 Observatory/Platform

Objective. To provide authoritative views on future costs and deployment potential of the full range of energy system resources, including the key uncertainties around these projections and how these uncertainties can be effectively managed including through targeted research and innovation spending.

How it operates. The Observatory would have no executive authority but the data it produces would form the basis of system planning exercises (system architecture) that would determine specific investment priorities.

Governance/funding. The organization should operate under a clear mandate to provide an independent view on future energy system technology costs and deployment potential based on best available information. Funding should be provided primarily from public rather than private sources.

Transparency. There should be full transparency of the processes used to produce conclusions, including the underlying data and sources. This should provide evidence for a thorough peer review of assumptions adopted and of the conclusions.

Whole system expertise. The success of the Observatory would depend on its reputation for independence and technical rigor. This would need to be established through "whole system expertise". The process must include a balance of energy system expertise to ensure equal weighting is placed on emerging and mature technologies operating in a range of market contexts. The Observatory could seek input from leading international experts to achieve this balance.

Executive authority would be retained by Governments and embodied in the mandate and actions of the relevant system architect.

Outcome. The outputs would need to be structured in a form that would enable system architects to identify the optimal set of energy system investments in different regions/countries.

Ideally, these data would be contained in annual "state of the energy transition" reports, augmented as needed with ad hoc deep dives into technologies, regions, or other relevant topics.

The data would not only cover power generation and network aspects but also those relating to investments that reduce and allow greater control of consumption and those that promote the take-up of electric vehicles and technologies to provide heating and cooling such that they improve overall system flexibility. This requires a much greater focus on behavioural aspects of the energy system and how the usage of energy will change going forward to align developmental, economic and environmental needs.

Local issues will inevitably interact with some of the assumptions used by the system architect – however, the existence of Observatory data would ensure any differences are evaluated based on conscious policy decisions and well-informed technical research.

5.3.2 Strengthen multi-layer collaboration among government agencies, industries and research institutions to enable tailored capacity-building

Governments – together with the private sector and common citizens – are at the cusp of the low-carbon transition. Their main role is to put in place the right policies and regulations to attract investments, while providing incentives for relevant stakeholders to engage in the transition at various levels and stages.

The provision of policies and regulations will not be sufficient, if those policies and regulations are not consistently implemented. There is need for improved management and governance based on renewed political will and commitment towards low-carbon development. Measures for efficient implementation include relevant data and information made publicly available, improved accountability, and effective transparency mechanisms that would allow low-carbon policies to make significant headway on the ground, among others. Heightened transparency will also help governments counterbalance fossil fuels-based technology lobbying forces that can hinder the transition towards low-carbon development.

Coordination among key stakeholders is also key to ensuring that capacities align with the needs posed by a low-carbon transition. Concerted action is especially needed with industrial and education sectors, guided by government agencies, to appropriately incentivize these stakeholders. PPPs could represent a productive approach for better representing the interests of various sides.

In this regard, China's industrial policy underpinning the development of the supply chain of its solar PV industry is a good example. Of particular interest is the Yangtze River Delta manufacturing cluster, where well-developed industrial infrastructure is complemented by low power prices and the availability of suppliers from connected sectors, as for instance the glass industry that provides primary and intermediate goods for solar equipment manufacturing firms. Sustained strong support from the government at the central, provincial and municipal levels is a key factor for success. BRI partner countries can refer to this example on how to develop viable **local supply chains**.[387]

Success also depends on guidance and incentives for the education sector, which designs training activities—**from vocational training of skilled workers to granting degrees for renewables engineers**—aligned with the industry's evolving labour demand. Investment by higher education institutions **in research and development on sustainability and in technological niche aspects** according to each country's comparative advantage can also contribute significantly.

5.3.3 Utilize consensus and opportunities of low-carbon energy transition, promote technical capacity building from demand side

Expanding job opportunities is a crucial aspect in planning low-carbon economic development. Whilst the main reason for governments to prioritize low-carbon policies has been to reduce CO_2 emissions, more recently the focus has expanded to also include the broader socio-economic benefits that this expanding sector and job market can bring, especially for developing countries including those along the Belt and Road.

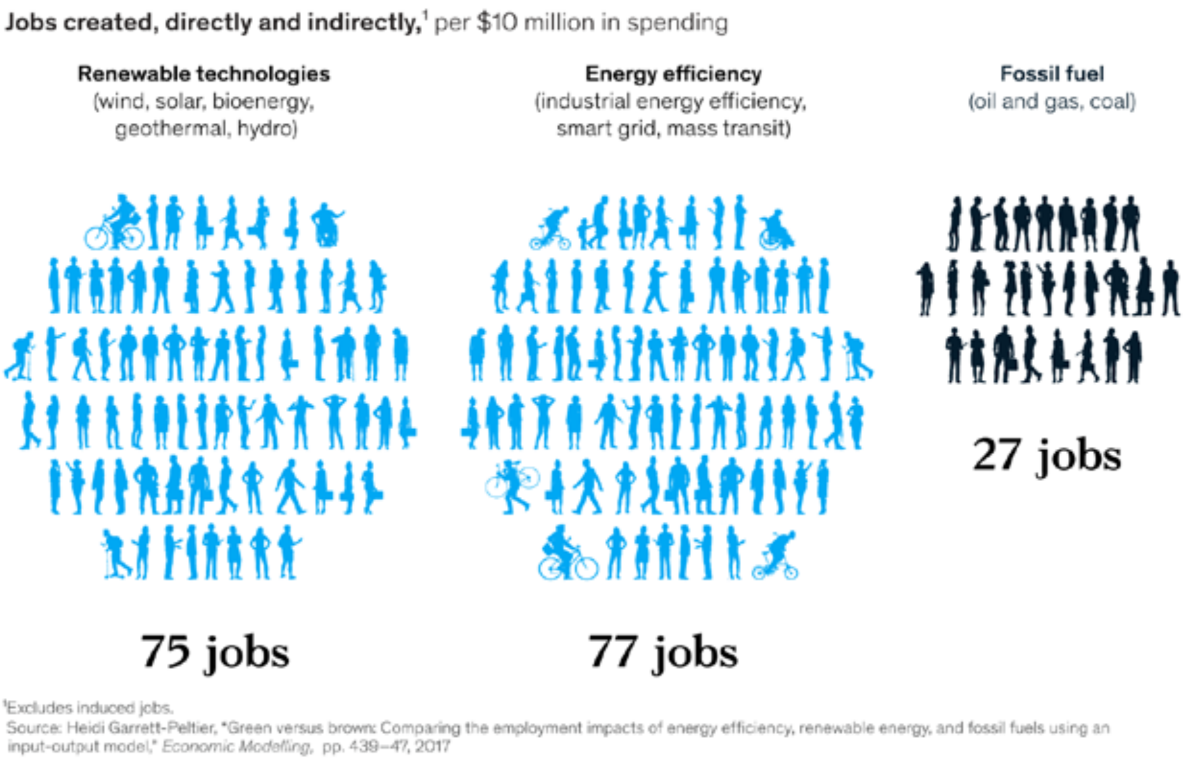
A new consideration about the socio-economic benefits of low-carbon development in the wake of the COVID-19 pandemic is whether low-carbon stimulus funds can help governments generate sufficiently strong economic and social returns in the near as well as the longer term. To address these concerns, a recent study drafted by an outstanding group of economists[388] has

387 Ball, J., Reicher D., Sun X., and Pollok C. (2017). The New Solar System: China's Evolving Solar Industry and its Implications for Competitive Solar Power in the United States and the World. Stanford: Steyer-Taylor Center for Energy Policy and Finance. Retrieved from https://law.stanford.edu/wp-content/uploads/2017/03/2017-03-20-Stanford-China-Report.pdf; International Renewable Energy Agency. (2019). Renewable Energy and Jobs – Annual Review 2019. Retrieved from https://www.irena.org/publications/2019/Jun/Renewable-Energy-and-Jobs-Annual-Review-2019.

388 Hepburn C. *et al.* (forthcoming 2020). Will COVID-19 fiscal recovery packages accelerate or retard progress on climate change? Forthcoming in the *Oxford Review of Economic Policy* 36 (S1). Retrieved from https://www.smithschool.ox.ac.uk/publications/wpapers/workingpaper20-02.pdf.

concluded that “green economic-recovery measures have performed at least as well as alternative measures did”. On social issues, notably employment opportunities, several studies have already suggested that government spending on low-carbon technologies and energy efficiency is creating more jobs than spending on fossil fuels (see Figure 5.2). Clean energy technologies are also creating better jobs in terms of quality (for instance in health conditions and level of pay), and this trend is set to continue as new technologies mature.[389]

Figure 5.2 A comparison between jobs created in renewables, energy efficiency and fossil fuels



Source: McKinsey[390]

389 Garrett-Peltier, H. (2017). Green versus brown: comparing the employment impacts of energy efficiency, renewable energy, and fossil fuels using an input-output model. *Economic Modelling*, 61, February, 439-447. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S026499931630709X.
McKinsey & Company. (2020). How a post-pandemic stimulus can both create jobs and help the climate. Retrieved from https://www.mckinsey.com/business-functions/sustainability/our-insights/how-a-post-pandemic-stimulus-can-both-create-jobs-and-help-the-climate#; Citizens Climate Lobby (2020). Jobs: fossil fuels vs clean energy. Retrieved from https://citizensclimatelobby.org/laser-talks/jobs-fossil-fuels-vs-renewables/.
390 McKinsey & Company. (2020). How a post-pandemic stimulus can both create jobs and help the climate. Retrieved from https://www.mckinsey.com/business-functions/sustainability/our-insights/how-a-post-pandemic-stimulus-can-both-create-jobs-and-help-the-climate#.

Therefore, channelling investments towards low-carbon development assumes a particular importance in the post-COVID world as it would help maximize the positive impact of the economic stimulus by boosting job creation while protecting the climate, helping place development on a sustainable path.

The fossil-fuel sector in several countries has already experienced job losses due not only to climate policies and the increasing deployment of renewables, but also to overcapacity, industry consolidation, and rising automation in extraction.[391] In China, for instance, the government has plans to close 5,600 mines owing to excess supply and shifts in the structure of the economy that is expected to lead to the loss of 20% of the total workforce in the coal sector. In India, the world's largest coal producer, coal sector employment has fallen by 36%, from 2002/03 to 2015/16. In the EU, the coal sector has severely decreased in the past 30 years. The global oil and gas industry has also faced job losses of at least 440,000 people in 2015 and 2016.[392]

The shrinking fossil fuel job market and the expanding one for renewables offers an opportunity to relocate skilled personnel from one sector to the other.[393] Several skillsets in the fossil-fuel sector can be easily absorbed into the renewable energy sector. For instance, the expertise gained in offshore oil and gas can be adapted for offshore wind projects; drilling workers from the oil industry could work in geothermal projects. In addition, the workforce related to electrical and IT areas used in the fossil-fuel sector (such as engineers, technicians, etc.) can be readily employed in operating renewable power projects.[394] In order to ensure a smooth capacity transition and limit social discontent, policies aiming at these outcomes should be prioritized and incentivized, leaving resources to support the transition of the smaller number of workers with less easily transferable skill sets. This is another area where the BRI could play a key leadership role.

391 International Renewable Energy Agency (2017). Renewable energy and jobs: annual review. Retrieved from https://www.irena.org/publications/2017/May/Renewable-Energy-and-Jobs--Annual-Review-2017.
392 Ibid.
393 International Renewable Energy Agency (2018). Renewable energy and jobs: annual review 2018. Retrieved from https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/May/IRENA_RE_Jobs_Annual_Review_2018.pdf.
394 Ibid.

5.3.4 Encourage industries and education sector to support women and youth's equal access to job opportunities in low-carbon transition

The gender gap in renewable energy source (RES) employment is not as severe as in the overall energy sector. **According to the 2020 IRENA Annual Review,[395] women represented an average of 32% of the RES workforce.** This share is substantially higher than the 22% average reported for the global oil and gas industry. The multidisciplinary dimension of the renewables sector appears more attractive and receptive to women that the traditional fossil fuel sector.

However, considerable challenges to employment and promotion of women in the renewable energy sector remain. According to a recent study on the gender dimension in renewables, [396] women hold only 28% of STEM jobs. Their presence is lower than in non-STEM positions (35%) and especially in administrative jobs (45%). Thus, much still needs to be done to ensure their participation in the sector, as for instance facilitating their access to relevant training and enhancing their career development prospects in the higher-paying segments of the industry.

The renewable energy sector could represent an important venue for boosting the labour market participation of women, but also of young people. To this end, capacities could be usefully built for counterbalancing gender and age discrimination in this sector with excellent long-term prospects. **Measures could include creating targets for diversity, devising more flexible working conditions including support for parenting, mentorship and training, as well as fair and transparent hiring processes and ensuring equal pay.**[397] Coupled with incentives for industry and the education sector for training young people and employing them, such capacity-building could offer particularly large benefits in developing countries with low rates of female participation in labour markets, and with high rates of youth unemployment. In addition, considering the important climate change and environmental risks posed to future generations, specific youth talent programs – targeting all genders - could be promoted to form a new generation

395 International Renewable Energy Agency (2020). Renewable energy and jobs – annual review 2020. Retrieved from https://www.irena.org/publications/2020/Sep/Renewable-Energy-and-Jobs-Annual-Review-2020.
396 International Renewable Energy Agency (2019). Renewable energy: a gender perspective. Retrieved from https://www.irena.org/publications/2019/Jan/Renewable-Energy-A-Gender-Perspective.
397 International Renewable Energy Agency (2018). Renewable energy and jobs: annual review 2018. Retrieved from https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/May/IRENA_RE_Jobs_Annual_Review_2018.pdf.

of policy makers in BRI partner countries and China that can be at the forefront in enhancing low-carbon development policies.

In all of these actions, the BRI could serve as a platform where countries could learn from each other on how to better incentivize and coordinate government actions, industry and education policies; and how to develop the best training activities and centres on low-carbon technologies. Specific exchange programs could be organized in this context, among industries (ideally involving the corporate sector), training centres, or government officials. Facilitating improved employment prospects for women and youth would help position the BRI as an Initiative that promotes equal and fair opportunities.

5.4 Best practices in advancing low-carbon capacity-building

This section builds on the discussion in previous sections. It analyses selected best practices in capacity development, with a focus on how they influence the individual, organizational and systemic levels. In particular, it looks at:

Cooperation mechanisms between policymakers and international organizations to create an enabling environment, showcasing the mechanism for capacity-building cooperation and low-carbon technology transfer between China, Ghana and Zambia within a South-South cooperation framework supported by Denmark and UNDP. This example highlights capacity development at the systemic level and the potential for scaling up such mechanisms of cooperation. It also demonstrates the importance of multilateral knowledge exchanges.

Implementation tools that support policymakers in better assessing the potential of renewables-based alternatives and efficiently planning their countries' energy transition. The example of IRENA's renewable readiness assessment tool and the example from the Global Infrastructure Facility (GIF) showcase practical, readily accessible tools to support capacity development at all levels, individual, organizational and systemic.

Country examples and lessons learned, showcasing countries that have succeeded in attaining high levels of renewables deployment such as Denmark and Uruguay, and the organizational and capacity development lessons that BRI partner countries can learn from these cases.

5.4.1 UNDP trilateral project on Renewable Energy Technology Transfer

Implemented and managed by UNDP from June 2014 to December 2019, the China-Ghana and China-Zambia South-South cooperation projects on renewable energy technology transfer are excellent examples of multilateral cooperation projects in capacity development at the systemic level.[398] They involve a diverse group of countries: China, Ghana and Zambia within the South-South cooperation umbrella, and Denmark as project sponsor. Building on China's unique recent development experience in achieving 100% electrification of the country, the projects improved the capacity and policy frameworks of Ghana and Zambia to create an enabling environment to adopt and use renewable energy technologies, in particular solar PV, biomass and hydro.

Thanks to this project, **Ghana** has removed key regulatory barriers and strengthened an enabling environment to effectively transfer renewable energy technologies through the approval of its *Renewable Energy Master Plan*. By supporting training facilities for capacity-building in the local renewable energy industry, as well as developing institutional financing mechanisms and business models for the private sector, Ghana has also increased its use of renewables. This has helped promote off-grid community-based electrification, overcoming geographic barriers and financial constraints that rural areas often face with electrification, and greatly contributing to developing rural areas in Ghana that had an electrification access rate of only 40%.[399]

Zambia, a country heavily relying on hydroelectric energy,[400] also benefited from this project through the adoption of a renewable energy strategy framework developed in cooperation with Chinese experts. Two capacity-building centres were also built with support from Chinese institutions and experts: (i) the Solar Energy Centre, established within the University of Zambia, acts as a training and demonstration centre with equipment donated by the Zambian Ministry of Energy; and (ii) the Kafue Gorges Regional Training Centre that contributes to the capacity-building of personnel working with mini-hydro plants in Zambia.

398 This project involves the respective UNDP country offices, the Energy Commission of Ghana, the Ministry of Energy of Zambia, the Ministry of Science and Technology of China and the Government of Denmark.
399 United Nations Development Programme (n.d.). China-Ghana South-South cooperation on renewable technology transfer description. Retrieved from https://www.gh.undp.org/content/ghana/en/home/operations/projects/environment_and_energy/china-ghana-south-south-cooperation-on-renewable-energy-technolo.html.
400 World Atlas (n.d.). What are the biggest industries in Zambia. Retrieved from https://www.worldatlas.com/articles/what-are-the-biggest-industries-in-zambia.html.

China has also gained from these projects especially in strengthening its capacity in implementing South-South cooperation mechanisms mobilizing a broad range of Chinese institutions and creating a *de facto* network for renewable technology transfer between China and African countries, including the establishment of project management and coordination structures. In doing so, Chinese has institutionalized the lessons learned in the establishment of a South-South Renewable Energy Technology Transfer Centre inside China's Ministry of Science and Technology. The Centre aims to continue up-scaling the South-South cooperation mechanism to share and transfer Chinese experiences in renewable energy technologies. As a direct follow-up to this successful project, a similar project has been now funded and implemented by China with Sri Lanka and Ethiopia using the South-South cooperation mechanism.

5.4.2 IRENA: renewables development prospects evaluation instrument

Since 2011, IRENA – an important intergovernmental organization that provides countries with support in their transition to scale up renewable energy – has designed and refined a tool to support countries to assess their potential for higher deployment of renewables and support them on the way forward. IRENA[401] describes this **Renewables Readiness Assessment (RRA)** as "a comprehensive tool for assessing the suitability of conditions in different countries for the development and deployment of renewable energy, along with the actions required to improve those conditions". This tool supports capacity development at all levels, systemic, organizational and individual.

Countries initiate the process and jointly with IRENA define their short- and medium-term policies to scale up renewables, assess the current situation, future prospects of renewable energy deployment, and identify the needed actions. The assessment process covers five areas as reported by IRENA: "(i) national energy policy and strategy; (ii) institutions and markets; (iii) resources and technologies; (iv) the establishment of a business model; and (v) the capacity needed to scale up renewables". [402] The RRA is implemented in four phases: a) the invitation and demonstration of intent between IRENA and the government, leading to a formal agreement; b) detailed country assessment and action plan on future steps, including a tailor-made report; c) the validation and

401 International Renewable Energy Agency (n.d.). Renewable Readiness Assessment (RRA). Retrieved from https://www.irena.org/rra.
402 Ibid.

finalization of the action plan through stakeholder consultations; d) follow-up actions by all stakeholders involved in policy, capacity needs assessments, supply chains and so on.

The main outcome when applying this tool is to provide policymakers the necessary knowledge to efficiently support new projects by strengthening policies and regulations and overall environment. This includes supporting countries in leveraging resources at the national and international level. So far, IRENA has produced ten such assessment reports in Africa, six in Asia and the Pacific, five in Latin America and one in the Middle East.

Also relevant for the BRI context is the Global Infrastructure Facility's Project Readiness Assessment (PRA) that supports governments in assessing the quality of project preparation by identifying key gaps, providing recommendations for improvement, and building the necessary knowledge to take informed decisions on investments and tender. This tool can be very beneficial for the efficiency of sustainable infrastructure projects. The PRA tool can be used at the pre-feasibility or a subsequent stage. It assesses six necessary areas, as reported by GIF: "(i) technical solution; (ii) commercial structure and financing; (iii) affordability; (iv) the role of government; (v) regulatory environment; and (vi) social and environmental impacts." [403] A pilot has been successfully carried out in Brazil for a transport project, with the technical assistance jointly provided by the World Bank and Inter-American Bank. [404] This tool can potentially strengthen capacity in planning and structuring infrastructure projects of many countries along the Belt and Road and be implemented in cooperation with Chinese or other financial institutions.

5.4.3 Denmark and Uruguay: pathways and advantages of fostering skills, workforce and technologies

Denmark and Uruguay are among the countries with the highest deployment of renewables in the world (see Chapter 3). Their success is due to several factors, but policies that target individual and organizational-level capacity development are particularly relevant in both cases and provide valuable insights for countries engaging in the BRI.

403 Global Infrastructure Facility (n.d.). GIF Project Readiness Assessment (PRA). Retrieved from https://www.globalinfrafacility.org/gif-pra.
404 Ibid.

Denmark, taking advantage of being one of the first movers in the wind sector, has created a **world-class and exportable expertise** in the wind energy sector that has proven beneficial for its GDP. Denmark currently possesses an established value chain of suppliers, a diverse and highly specialized workforce thanks to a structured education and training network including universities, training centres and engineering companies. This is also true for offshore wind energy as the country was the first to develop an offshore wind farm in 2002 and now produces 15% of its electricity from offshore wind energy.[405]

Consequently, Denmark has built a competitive advantage in skills, workforce and technology and is now successfully exporting its technology. The exports of Danish "green energy" technology accounted for US$6.1 billion in 2015 and represented an important export area for the country. Its specialization in renewables enabled the country to build a competitive advantage in wind energy, district heating, energy efficiency, smart grids and system integration.[406] Denmark is now sharing its wind expertise with Vietnam, Mexico and South Africa to help them integrate wind energy into their electric grid.[407]

Uruguay has managed the transition in a very short time as seen in Chapter 3, leading to considerable shifts in its labour market. The energy transition led to significant economic benefits with the employment of 44,000 persons in 2016 in "green jobs", 2.7% of Uruguay's total workforce.[408] Though several key challenges remain, the government has tackled the capacity transition with **sound coordination policies among various sectors, government, industry and education.**[409] Among the initiatives taken, several are worth noting:

- PPPs that led to the creation in the city of Durazno of the first National Centre for Training in Operation and Maintenance in Renewable Energies (CEFOMER) in 2018;
- International cooperation with the ILO: Uruguay is one of three pilot countries to implement ILO's relevant policy framework *Guidelines for a just transition towards*

405 International Energy Agency (2019). Offshore wind outlook 2019. Retrieved from https://www.iea.org/reports/offshore-wind-outlook-2019.
406 International Energy Agency (2017). Energy Access Outlook 2017. Retrieved from https://www.iea.org/access2017/.
407 State of Green (2013). Denmark and South Africa have joined forces to reduce greenhouse gas emission. Retrieved from https://stateofgreen.com/en/partners/state-of-green/news/denmark-to-share-wind-power-expertise-with-south-africa/.
408 ILO classifies "Green Jobs" as jobs that meet certain quality standards. International Labour Organization (2016). Green jobs: progress report 2014-15. Retrieved from https://www.ilo.org/wcmsp5/groups/public/---ed_emp/---emp_ent/documents/publication/wcms_502730.pdf.
409 Proano, M. (2018, November 16). What's next for the energy transition in Uruguay? Energy Transition. Retrieved from https://energytransition.org/2018/11/whats-next-for-the-energy-transition-in-uruguay/.

environmentally sustainable economies and societies for all.[410]

The country's effective response—through industrial policies, PPPs and the setting up of specific training centres—to skills shortages and significant capacity gaps are relevant for other countries as well, especially along the BRI.

410 Ibid.

Conclusions and Policy Recommendations

This report emphasizes that a key factor in meeting the surging demand for sustainable development in countries globally and along the Belt and Road is supporting low-carbon development and being more closely aligned with the Sustainable Development Goals of the United Nations 2030 Agenda. It has illustrated the Belt and Road Initiative's potential for spearheading low-carbon development and how it can also benefit from it.

There are several barriers to tapping this low-carbon development potential under BRI. These include the cost of developing and deploying low-carbon technologies, the lack of tools and methods to identify and assess climate-related financial risks, and underdeveloped capacities at individual, organizational and systemic levels to support a low-carbon transition. Another is the incomplete consideration in energy pricing of all costs and benefits of each option that creates an uneven playing field with entrenched fossil-fuel technologies.

Investors are looking for sustainable investment opportunities along the Belt and Road. They face key challenges in energy projects, including uncertain project profitability, disparities in laws and the business environment and cultural gaps, as well as debt sustainability, environmental and social risks.

Navigating these challenges will largely depend on how key stakeholders – individually and as a group – will seize the opportunities that low-carbon development offers. Clean energy technologies, sustainable investment and finance, as well as capacity-building can play an essential role in boosting climate resilient and inclusive low-carbon development. In each of these three key aspects, coordination and consensus are needed among policymakers and regulatory authorities at national, state, province and city levels, investors, financial institutions, international organizations and fora, corporations, as well as other stakeholders. Such wide-ranging cooperation is necessary to drive the absorption of low-carbon technologies, leverage sustainable financial resources, and enhance awareness and capacities in BRI partner countries.

The report argues that China plays a significant role in these three key aspects of the low-carbon transition along the Belt and Road. It can build on its strong comparative advantages in deploying low-carbon and efficient energy technologies, practices in green finance, and can encourage further technical assistance and knowledge sharing. These would help partner countries meet their development needs while strengthening capacities and supporting their own transitions towards a low-carbon, green development path.

Considering the abovementioned challenges and opportunities, the following sections provide a series of concrete key recommendations clustered by the four main groups of stakeholders engaging in BRI implementation: policymakers, financial institutions, public and private investors, and international organizations. These recommendations, taken together, offer a pathway to realize the BRI's considerable, globally significant low-carbon development potential, and to reap benefits for individual stakeholders, the BRI partner countries and the world at large. Importantly, solid actions would take place, as each group sets policies, regulations and incentives and reacts to the dynamics created. Meanwhile, these recommendations call for collective action, as low-carbon development cannot be achieved by any single stakeholder. A smooth transition requires effective information flows and coordination among these groups. For instance, the recommendations below call for banks and governments to consolidate cooperation at technical levels, including working together to put in place harmonized standards for sustainable investment and finance.

Recommendations for policymakers

Policymakers from China and BRI partner countries are at the forefront of leading and participating in low-carbon development globally and along the Belt and Road. Policymakers from China and BRI partner countries can work together to strengthen cross-sector coordination and the harmonization of relevant policies and standards, and to enhance power system flexibility, energy efficiency, and trans-regional interconnectivity. Their joint efforts are also needed to enable higher deployment of renewables, promote the innovation, deployment and development of clean energy technologies, and boost investment and financing to support low-carbon development projects. Specific recommendations include:

- **Fully consider each country's differentiated context when facilitating low-carbon development and transition of power systems.** Factors to be considered include socio-economic context, natural resource endowments, governance and development levels, access to electricity, grid development, energy self-sufficiency, stability and security of power supply, as well as the stage reached in the country's low-carbon transition.

- **Further develop integrated and flexible power systems to facilitate higher shares of variable renewable energy (VRE) sources into the grid**. Coordinate coupling of power generation and grid expansion based on prediction of load and storage capacities. Introduce carbon emissions trajectory models to decide types, capacity and locations of newly built power units. Integrate low-carbon flexibility at all levels in the power sector (generation, transmission, distribution, storage, demand-side management) as well as in other sectors with high emissions (industry, buildings, transport).

- **Encourage investment in energy transmission technologies** that are starting to play a larger role in providing power system flexibility, including ultra-high voltage direct current (UHVDC) lines, and flexible AC transmission systems (FACTS). Boost Internet access, big data and digital innovations to further strengthen power networks.

- **Align industrial policies and fiscal subsidies with renewable development**, especially at the initial stage, to enable renewables to reach scale, provide incentives for investors in clean energy, and ensure a level playing field for RES and fossil fuel projects**.** At a later stage, a marketized approach can be introduced to promote non-subsidized generation of clean energy. In addition, take into account gradual reduction of fossil fuel subsidies.

- **Optimize tailored electricity market design, including market pricing structures and rules** to remove economic barriers for renewable energy sources and promote low-carbon electricity systems. Further deepen power sector reform, especially improve electricity trading rules and price monitoring mechanisms, to promote optimal resource allocation on both the supply and demand sides. Facilitate electricity market competition to enable better price discovery of renewables, and take advantage of price signals to guide solar PV and wind power investment, development and consumption.

- **Boost information transparency to facilitate interconnectivity and integration of electricity markets** at various levels, which helps realize large-scale consumption of clean energy and safe operation of grids. Modify market rules to facilitate the deployment of battery storage systems. Further promote the coupling of VRE generation with batteries.

- **Raise awareness and prepare the public especially among affected populations to accept** accommodating an increasing share of VRE sources. Guarantee transition funds and further develop dialogue platforms, workshops and other communication channels to address public concerns and facilitate public engagement in low-carbon projects. Introduce specific regulations to mitigate power price increases and fluctuations for vulnerable households. Promote common technical standards for mining, manufacturing, recycling and financing of renewable resources to allay public concerns and increase compatibility with SDG attainment.

- **Strengthen demand-side management (DSM)** and build national-level platforms to enable electricity data collection, measurement, and analysis, electric energy efficiency management, as well as demand response (DR). Such platforms should also provide fault diagnosis and warning functions.

- **Further develop pilot programs to explore diversified means including pricing signals and incentive subsidies to stimulate demand response from industries and residents.** Such programs can include appropriate time-pricing to help peak shaving, valley filling or load shifting, capacity bidding and demand bidding, and interruptible load tariffs, as well as carbon pricing. Whether price-based or incentive-based, pilot programs should be tailored to selected areas or sectors.

- **Explore DSM schemes to promote energy-saving behaviours and lower energy demand** as an alternative DSM strategy, especially for low and middle-income countries that lack appropriate technologies and capital costs. These alternative schemes can focus on changing consumption patterns and promoting a circular, zero-waste and sharing economy.

- **Support the deployment and innovation of multi-energy compensatory systems (MECS) and geographical diversification of power mixes** to increase the deployment of renewables, especially of solar PV and onshore wind that are the most readily available, technologically mature, and impactful types of renewable energy to mitigate climate and environmental effects. Implement regulation that allows for technological diversification such as retrofitting of existing power units.

- **Adopt key technologies to boost cogeneration and multi-generation**, both for renewables and fossil fuels in areas where they represent a major source of energy. These technologies include combined heat and power (CHP), combined cooling, heating and power (CCHP), retrofits, as well as smart devices and advanced communication technologies. Ensure an appropriate balance between dispatchable and partially dispatchable resources.

- **Promote regional and international energy interconnectivity** projects to overcome geographical barriers. Proactively participate in and boost regional and global collaboration in various stages of trans-regional and trans-national network planning, including scenario analysis, quantitative and qualitative evaluation of installation portfolios and network interconnectivity, as well as trans-regional and trans-national planning optimization. Enable cross-border power trading to maximize energy production.

- **Boost centralized forecasting of output from variable renewables** in operational timescales, to ensure adequate flexibility and scheduling of reserves**.** This includes both backcasting based on energy consumption, and forecasting based on scenario analysis. Increase time granularity and promote digital innovation techniques to improve centralized forecasting and scheduling capacity, thereby facilitating the availability of necessary data in real time and the processing of large amounts of data.

- **Enhance the efficiency of energy management with digitalization tools** to bridge supply and demand. Such tools, including Internet of Things, big data, virtual power plants and smart metering, can be utilized to facilitate massive data collection, mapping and analysis while linking generation, transmission, distribution, load and storage. More efficient energy management supports balancing the utilization of various energy resources, collaborating energy production at different locations, adjusting energy intensity over time periods, as well as facilitating transactions and settlements.

- **Support the acceleration of thermal power generators' refurbishment** to enhance thermal power flexibility and better respond to variability of VRE generation. Refurbishments include lowering minimum loads, ensuring stable combustion, enhancing ramp rates, shortening start-up times, and lowering minimum uptimes and runtimes.

Optimize allocation of carbon capture and storage technologies on already existing conventional thermal power plants to minimize emissions in areas where fossil fuels are expected to remain a major source of energy due to resource endowment constraints. Adopt technologies such as CHP, ultra-low emissions and energy-saving retrofits to reduce pollutants from thermal power industries.

- **Update grid codes and market rules to create an enabling environment for the deployment of thermal power retrofits** and encourage flexible implementation of thermal power development plans. Grid code amendments, based on specific resource endowments and development levels, can set out lower technical minimum output of the units' installed capacity and higher ramp rates, to stimulate engineering retrofits and flexibilization practices. Price mechanisms in the electricity ancillary service market can be explored to incentivize thermal power plants to lower their minimum loads.

- **Promote distributed generation, grid-scale battery storage, demand response and electric vehicles, to help enhance electricity access.** Encourage the usage of smart devices and advanced communications technologies that allow energy to be stored on or near premises (e.g., in the form of hot water, ice, or in the future, hydrogen) for later delivery of the related energy services. Make full use of new technologies and amend regulations to develop "virtual power plants" through flexible and meticulous management of supply and demand.

- **Formulate decisions on centralized or distribute energy resources (DER) development based on specific natural endowments and development levels** of targeted markets or regions. If renewable resources are located in unpopulated areas far from cities, centralized development of renewable power plants becomes a good choice and brings cost competitiveness. In contrast, in regions where synchronously integrated power systems are absent and local policymakers do not envisage the necessity to build them, DER development can be an alternative to satisfy local energy demand.

- **Diversified business models can be explored to further improve electricity service markets**, which would in turn facilitate distributed energy development and efficiently compensate centralized smart grids. Pilot programs of online transaction platforms adopting block chain technologies can be encouraged, to facilitate a higher share of distributed energy resources. Service platforms for transport electrification, building electrification and smart cities enabled by distributed energy resources should be developed, based on smart infrastructure, digitalization tools, as well as integrated control and automation technologies.

- **Speed up the harmonization of emissions measurement standards**, especially technical standards of measuring, reporting and verifying emission allowances in accounting. Further explore regulatory mechanism of MRV, to foster reliable, consistent and comparable measurement of carbon emissions and regular data disclosure.
- **Facilitate setting up reasonable and predictable benchmarks, rules and procedures** to promote long-term compliance by companies in emissions trading markets. Define responsibilities of key stakeholders, especially companies with enforceable obligations to cut emissions, based on coordination among government agencies and other supervisory bodies and on communication with investors and third-party verification agencies. Further clarify costs and consequences of delayed compliance or non-compliance behaviours, including failures to report emissions in time or submit emission allowances to offset emissions in the previous year.
- **Scale up financial incentives and supporting facilities**, to facilitate the development of green bond policies. Incentive instruments should be carefully balanced and could include green bond issuance subsidies, interest discounts, tax benefits, credit enhancement, fast-tracks for issuance approval, and special support funds. Foster a long-term pipeline of green projects to facilitate green bond issuance and help guide firms to choose green investments on their own initiative.
- **Improve the streamlining of various policies and procedures for green finance products.** Relax the green bond quotas as much as feasible and extend the scope of bond issuance to attract engagement of IFIs. Provide an overall guidance on green finance priorities to help financial institutions better rank various possible projects that conform with the guiding catalogue of green credit projects. Consolidate incentives of green funds

and formulate concrete implementation policies to encourage SME participation in green finance projects.

- **Boost harmonization of green financing and investment standards at best practice levels along the Belt and Road.** Accelerate building a clear and enforceable system of green finance standards. Both market rules and international consensus need to be respected while implementing national strategies on green development and economic structural transitions. Accelerate the introduction of detailed judicial guidelines especially in terms of improving the green finance environment and standardizing risk control systems. Green finance pilots should be encouraged to test feasibility and performance of green finance standards in specific sectors.
- **Support the development of online database and information services platform** to connect financial institutions, enterprises, consumers and government agencies in real time, thus helping overcome information asymmetry, lowering regulatory costs, and alleviating SMEs' lack of access to green finance.
- **Enhance individual and organizational capacities to better plan and implement** energy transition trajectories and low-carbon development prospects, including sharing lessons learned and experiences and providing assessment on potential impacts of the COVID-19 pandemic.
- **Support and fund capacity-building, through grants whenever possible**. Strengthen the individual technical capacity of government officials in charge of energy policies and regulatory frameworks, and support the strengthening of organizational capacity through the establishment of dedicated institutions to implement them. Implement medium-term twinning and secondment exchange programs for government officials from BRI partner countries to share experience and knowledge.
- **Diversify capacity-building activities with tailor-made training, seminars and policy discussions** on low-carbon development and renewable energy deployment. Topics could include policy and regulation, management, engineer and IT-related areas. Address the gap of skill shortage in the renewable job market and off-grid development to leverage

socio-economic opportunities in developing countries. Adapt and transfer skills from the fossil fuel industry to low-carbon sectors to promote a smooth capacity transition.

- **Channel post-pandemic economic stimulus and recovery plans towards low-carbon development** to boost job creation in clean technologies and energy efficiency, targeting in particular women and youth employment to promote equal and fair societies.

Recommendations for financial institutions

Financial institutions including national development banks and commercial banks in China and countries and territories along the Belt and Road, as well as multilateral development banks can provide crucial support for channelling financial resources towards the innovation, development, promotion and implementation of low-carbon projects. Specific recommendations include:

- **Integrate climate-related financial risks into monitoring mechanisms**. These risks include potential interruption of services, local resource shortages, rising commodity prices, reduced corporate profitability and solvency caused by extreme weather and long-term climate change. Strengthen cooperation and exchange, to deeply understand national policies, technologies, models and innovative pathways as well as best practices in identifying and mitigating climate change-related financial risks. Boost data sharing and joint research, to constantly optimize identification and measurement models of climate-related risks.

- **Strengthen cooperation with international organizations and local agencies**, to gain in-depth understanding of the policy environment, resource endowments, market and industrial characteristics of BRI partner countries. This sets a solid foundation for innovating green finance products and services, conducting comprehensive due diligence, and diversifying financing channels.

- Enhance international cooperation in **formulating and developing more harmonized, open and forward-looking investment and financing standards** to facilitate sustainable development. Strengthen international cooperation in green financial asset pricing and international green technology transfer.

- **Further explore standards and mechanisms of "monitoring, reporting and verification" (MRV) emission allowances** in accounting. Promote the standardization of accounting methods related to emissions trading at national level, to clarify the value of emission allowances, and help investors precisely assess the impact of carbon pricing on related projects.

- **Draw on mature experiences of carbon options and carbon futures in international carbon markets**, and develop new carbon financial instruments, to promote low-carbon transition in key emissions-intensive sectors industries such as power, chemicals, petrochemicals, building materials, iron and steel, non-ferrous metals, paper-making and aviation.

- **Build green finance reform innovation pilots** with international impacts, to explore the feasibility and effectiveness of relevant green finance standards and rules in specific sectors. Promote the sharing and application of successful pilot experiences – especially from areas such as green agriculture and green industrial parks – at the national level and in countries along the Belt and Road.

- **Identify fundamental and key standards that can be commonly used**, including statistical standards, information disclosure and sharing standards, and risk management standards. Further explore and improve standards of green finance products and services, as well as of credit ratings and evaluation.

- Boost further innovation and development of environmental, social and governance (ESG) assessment models, AI and big data technologies, to **explore data capture, auto-identification, and smart labelling technologies for green financing entities**. Strengthen data sharing with government agencies, enterprises and consumers, to help build online databases and information services platforms.

- **Further innovate green credit products**, by introducing in new guarantee methods and risk relief tools, and by combining credit products with financial instruments such as export credit insurance and financial leasing. Match loan interest rates, loan sizes, and repayment methods, based on the "greenness" rating of target enterprises and projects.

Explore increased application of the securitization of credit assets, to provide green credit products for household green investment and consumption.

- **Scale up the innovation of green bond products**, improve access requirements, especially environmental rules, for listed companies. Develop long-term investment-oriented green products, to avoid short-term speculation behaviour. Issue green bonds to support companies committed to renewables development and environmental protection. Draw on international practices in green bond issuance and emission rights derivatives that attract various types of investors. Explore the securitization of green assets based on natural resource balance sheet, and broaden the channels of green bond issuance.
- **Further develop innovative green insurance services**. Provide preferential rates for green enterprises in agriculture, transportation and other sectors. Link environment and climate-related risk assessment with insurance rates, to motivate companies to improve their relevant risk management capabilities. Develop energy conservation and emission reduction insurance services for households and individuals, to encourage low-carbon consumption. Explore differentiated guarantee services, and prudently guarantee or increase guarantee rates for non-green enterprises or projects.
- **Boost blended finance** to diversify financing channels for sustainable and low-carbon projects. Promote the establishment of BRI green investment special funds, to channel investment portfolios towards wind, solar and hydropower assets, and ease green finance bottlenecks.
- **Explore flexible, risk sharing and revenue sharing financing models and products** through strengthening cooperation with government agencies and enterprises. Establish multi-level environmental information disclosure framework and mechanisms, to encourage borrowers to proactively fulfil green development obligations. Strengthen communication with government agencies, media, and enterprises to exchange up-to-date information on regulatory and compliance practices.
- **Explore harmonized carbon indicators**, refine necessary data collection and baseline setting principles, and adopt carbon indicators in evaluating environmental and climate risks. Establish scientific and rigorous access principles, to exclude projects that do not

meet low-carbon development requirements or have significant potential environmental risks in the pre-lending stage.

- **Improve post-lending assessment of environmental and social impact**, to enable constant monitoring of green projects. Fully utilize third-party expertise, including lawyers, think tanks and environmental organizations, to advance environmental and climate risk scenario analysis, and improve long-term tracking and management of climate and environment risk impact. Incorporate climate-related stresses into sector-wide or market-wide stress tests, especially into targeting sectors where stranded assets may increase due to climate change, changes in relative carbon prices or societal preferences, or over-capacity.

- **Fully assess debt sustainability and improve debt management efficiency** to optimize long-term risk management in projects along the Belt and Road. Take into consideration host countries' existing debt service obligations, debt service profile, debt structure, debt repayment situation, and the individual project's potential ability to generate sufficient financial returns to cover its full running costs and the debt service obligations created. Further improve prudent auditing systems, risk-identifying procedures and conflict-resolution measures. Under the premise of not violating national laws and business confidentiality, timely disclose terms and conditions of financing for BRI projects.

- **Develop voluntary reporting, self-regulatory and self-disciplinary mechanisms in green finance industry**, to guide investors towards low-carbon and sustainable projects. Banks, stock exchanges and insurance organizations can establish self-assessment and peer review mechanisms in areas such as access to green credit, information disclosure, interest rate pricing, green insurance product innovation, and green investment. These mechanisms help strengthen financial institutions' compliance with relevant laws and regulations of green finance, and provide ways of quickly identifying issues and for reporting significant climate and environmental risks.

Recommendations for state-owned and private enterprises

State-owned and private enterprises, as the major market players in the investment, construction and operation of BRI projects, can play a key role in promoting low-carbon development along the Belt and Road. Specific recommendations include:

- **Strengthen cost competitiveness and technological innovation** in corporate development**,** use big data and digital services to engage in more renewables projects along the Belt and Road. Formulate enterprise energy investment plans, based on partner countries' economic and technological development, governance capacity, electricity infrastructure demand and natural resource endowments. Support RES deployment in power systems at regional and national levels, which helps increase power system flexibility, and minimize their own GHG emissions.
- **Explore and adopt cutting-edge energy storage technologies** – including greater modularity of batteries – and grid balancing services, to facilitate the geographical diversification and physical connection of energy across regions.
- **Proactively engage in data and information sharing, and improve measurement techniques** on electricity load prediction and centralized forecasting. These help advance scenario analysis and forecast real-time electricity load performance and energy consumption.
- **Accelerate refurbishment of coal-fired generator units**, to enhance thermal power flexibility to better respond to the variability of VRE generation and clean energy development. Specific objectives of such refurbishment include enhancing ramp rates, ensuring stable combustion, lowering minimum loads, shortening start-up times, as well as lowering minimum uptimes and runtimes.
- **Boost digitalization and upgrade power consumption management at corporate level**, to enable more precise load adjustment and faster demand response. Enterprises from the metallurgy, cement and petrochemical sectors which are pilot practitioners in upgrading micro-level management of power consumption can share their experience, to help stimulate wider demand-side participation.

- **Deepen public consultation and communication** throughout project design, operation and evaluation, to address public concerns especially among affected populations. Properly handle complex social risks such as land expropriation and involuntary resettlement, through public consultation, complaint handling, and guarantee of cost compensation for affected populations and special treatment for fragile minorities.
- **Strengthen cooperation with multilateral financial development institutions and leverage blended financing resources proactively**, to diversify financing channels for low-carbon projects and alleviate reliance on domestic commercial banks. Take full advantage of multilateral financial development institutions' preferred creditor status and tax rates, as well as the longer maturity of syndicated loans to lower costs for financing the construction, operations and maintenance of low-carbon facilities.
- **Deepen cooperation with institutional investors** who are increasingly adapting to global ESG standards and pivoting towards portfolios of wind, solar and hydro assets. Draw experience from financing models adopted by successful renewable energy companies investing along the Belt and Road.
- **Enhance capacity-building in each stage of energy-related infrastructure project development** to mitigate potential risks. Support capacity-building activities and cooperation mechanisms with government institutions to better plan and manage investment energy projects, to enable the enhancement of absorptive capacity for green financing and investments.
- **Further integrate investment business with capacity-building activities** in low-carbon sectors. Conduct careful analytical work to mitigate the likelihood of having unrealistic time frames, overambitious agendas, or unduly complex conditionality in low-carbon infrastructure projects, to avoid regular risk.
- **Strengthen evaluation and utilization of local capacities** in local supply chain during low-carbon energy transition. Pay attention to fostering and developing capacities in sectors, including the manufacturing and distribution of renewable energy equipment, renewable energy project construction and installation, power plant operations and maintenance, and other activities connected to the development of the value chain.

- **Offer more technical training and vocational education opportunities to existing and emerging local labour market,** to further bridge the skills gap in energy infrastructure operations and maintenance services, especially in business management, sales and distribution.
- **Strengthen tailored training programs** to enable enterprise employees, especially women and young staff, have the opportunity to learn about advanced techniques and knowledge related to the low-carbon energy transition through various channels, including apprenticeships, cross-enterprise exchange programs, online digital learning opportunities, and degree sponsorship programs.
- **Develop diversified corporate missions and goals.** Take further steps to provide equal job opportunities and payments to women, men, and youth in the low-carbon transition. Formulate more flexible working conditions and adapt fair, transparent hiring processes, to ensure equal payment and ensure effective implementation of corporate missions and goals.

Recommendations for international organizations

International organizations including UN, EU, and ASEAN can play a pivotal role in facilitating low carbon development along the Belt and Road. In particular, they can make great contribution in facilitating stakeholders to reach consensus on low-carbon development, organizing dialogue platforms at regional and global levels, promoting energy interconnectivity among regions, and conducting joint research to offer pathways and solutions on addressing low-carbon development challenges. Specific recommendations include:

- **Promote policy dialogues on low-carbon development** among BRI partner countries, and facilitate stakeholders achieving evidence-based consensus. Help raise awareness, build consensus, and share expertise and solutions on leveraging opportunities and resources to tackle climate change through dialogue at individual and institutional levels. Encourage the design and improvement of regulatory frameworks, including laws, regulations, standards and mechanisms, to help advance low-carbon policies in line with specific national development strategies and environmental aspirations. Promote appropriate accountability measures to bolster effective implementation of low-carbon policies.

- **Strengthen strategic planning, collaboration and communication on trans-regional and transnational transmission networks**. Support further cooperation among governments, power enterprises, think tanks, as well as regional organisations and other multilateral institutions, e.g., the ASEAN Power Grid and the GEIDCO. Promote joint scenario analysis, on the basis of considering climate change impacts, power generation potential, share of clean energy sources, load growth rates and load curve characteristics.

- **Strengthen global collective leadership and coordinated action in climate modelling and policy principles**, to effectively capture climate-related financial risks. Contribute to the development of internationally accepted carbon indicators, market valuation of carbon assets, as well as necessary data collection and baseline setting principles for financial institutions in risk assessment and control.

- **Organise or participate in workshops and seminars to share expertise and best practices on demand-side management (DSM)** at both the macro and micro levels. Experiences from successful price-based and incentive-based pilots can be shared at national, regional and global levels, to help build better models on power consumption prediction and energy efficiency analysis. Facilitate stimulating behavioural change in consumption patterns, implement a circular, zero-waste and sharing economy to enable lower energy demand.

- **Develop joint research and knowledge exchange platforms to improve climate and environmental risk tracking and management**. Promote discussions among think tanks, lawyers and environmental protection organizations, as well as central and local government agencies. Encourage joint thematic studies on accelerating theoretical and practical innovation of green finance risk management, to strengthen expertise sharing on green finance reform.

- **Provide evidence-based policy advice and guidelines, conduct or facilitate specific training programs** to enhance individual, sectoral, and institutional capacities. These enable better planning and implementation of energy transition trajectories and low-carbon development prospects. Experiences and lessons learned can be shared, and assessment on the potential impact of the COVID-19 pandemic can be conducted.

- **Carry out joint research and provide knowledge products such as regional guidelines** in key areas. Boost international consensus among different accounting standard setters on basic norms (e.g., asset classification of emission allowances in financial statements), to facilitate market entities adopting an appropriate approach to account for carbon emission allowances.
- **Develop communication platforms to share expertise and innovative practices for firms to develop distributed energy**. Boost knowledge sharing on auction processes and indirect mechanisms such as scarcity pricing. In particular, strengthen the dissemination of specific knowledge on regulatory work.
- **Promote stakeholders to jointly develop key indicators that affect low-carbon energy investment in host countries**, including those on renewable energy potential, existing energy mix, capital availability, national planning priorities, as well as local and institutional capacity.
- **Promote shared governance of the power system**, facilitate enhancing technological and geographical diversification of VREs, and bolster the development of and cooperation on regional and global energy interconnectivity.
- **Encourage and support private and public stakeholders from China and BRI partner countries familiarizing themselves with international guidelines** and standards, and with the specificities of the countries where they are investing.
- **Coordinate both developing and developed countries to** establish and adapt vocational training and exchange programs in accordance with labour demand in emerging job markets amid low-carbon transition. Strengthen communication with private sector to ensure that skills developed meet existing and future demand.
- **Help consolidate technical expertise and professionalism** of policymakers and specific offices or institutions in charge of policy implementation. Develop capacity-building

programs to build an overall enabling environment for the effect implementation of low-carbon policies.

- **Provide pathways and measures for policymakers** along the Belt and Road, to help achieve targets, tackle problems and boost effective implementation of energy transition policies. These pathways include providing reliable data and information on latest technology developments, and conducting foresight-based analysis on costs, benefits and risks of energy infrastructure. Provide tools to further support BRI stakeholders consolidating environmental and social assessments on local BRI projects. Facilitate capacity-building in countries along the Belt and Road, which helps countries independently carry out development planning while taking into account environmental factors.

Conclusions

This report highlights that BRI has tremendous potential in facilitating and accelerating global low-carbon development. Embracing low-carbon development pathways within BRI is crucial to tackling climate change globally (Sustainable Development Goal 13).

Channelling finance and investment flows towards low-carbon development projects, as well as facilitating the innovation, development and transfer of clean energy technologies along the Belt and Road, is the key position of this report. Cooperation among BRI stakeholders is necessary and important for effectively taking forward abovementioned recommendations, as well as realising climate resilience, and achieving SDGs and the 2030 Agenda.

Appendix

Appendix I Key indicators for all BRI partner countries (2019)

Below is the full dataset reflecting three dimensions – economy, governance, and electricity – with eight indicators for all 138 BRI partner countries that have signed cooperation agreements/MoUs with China on BRI cooperation as of January 2020 (except for Cook Islands, Cote d'Ivoire, Niue for which most data are not available). It shows the disparities not only among different regions, but also among BRI partner countries within the same region. It is the original dataset for Table 2.1 and Table 2.2.

Country	GDP per capita[411]	Employment to population ratio%[412]	Ease of doing business[413]	Political stability[414]	Rule of law[415]	Access to electricity %[416]	Practical potential of PV output[417]	CO_2 emissions per capita[418]
East Asia & Pacific								
Brunei Darussalam	31087	58.8	70	97.6	79	100.0	3.9	18.3
Cambodia	1643	81.8	54	58.6	26	91.6	4.1	0.6
China	10262	65.1	78	53.8	52	100.0	3.9	7.2
Fiji	6220	55.3	62	94.8	67	99.6	3.8	2.3

411 Current US$, 2019 (World Bank). For Micronesia, Tonga, Cuba, and Yemen, we use the latest available data from 2018. For Iran, we use the latest available data from 2017. World Bank (2020). World Bank open data. Retrieved from https://data.worldbank.org/ For South Sudan and Venezuela, we use IMF figures. International Monetary Fund (2020). WEO database. Retrieved from https://www.imf.org/en/Publications/WEO/weo-database/2020/October/download-entire-database.
412 "The employment to population ratio is the proportion of a country's population that is employed. Employment is defined as persons of working age who, during a short reference period, were engaged in any activity to produce goods or provide services for pay or profit, whether at work during the reference period." World Bank (2020). World Bank open data. Retrieved from https://data.worldbank.org/indicator/SL.EMP.TOTL.SP.ZS.
413 Overall score 1-100. 100 = highest.
414 Percentile Rank, Upper Bound of 90% Confidence Interval. 100 = highest.
415 Percentile Rank, Upper Bound of 90% Confidence Interval. 100 = highest.
416 2018 data. % of population.
417 Practical photovoltaic power output of a PV system in the long term, kWh/kWp/day.
418 Metric tons, 2016 data.

Indonesia	4136	64.3	70	43.3	51	98.5	3.8	2.2
Kiribati	1655	N/A	47	99.5	86	100.0	4.8	0.6
Korea, Rep.	31762	60.4	84	75.2	89	100.0	3.8	12.1
Lao PDR	2535	78.0	51	79.5	26	97.9	3.9	2.6
Malaysia	11415	62.2	82	61.9	77	100.0	3.7	8.1
Micronesia, Fed. Sts.	3568	N/A	48	96.7	70	82.1	3.9	1.3
Mongolia	4295	56.1	68	84.3	52	98.1	4.8	8.3
Myanmar	1408	60.7	47	16.7	21	66.3	4.1	0.5
New Zealand	42084	67.1	87	99.5	100	100.0	3.7	7.3
Papua New Guinea	2845	46.0	60	29.5	32	59.0	3.7	0.9
Philippines	3485	58.3	63	27.1	46	94.9	3.9	1.2
Samoa	4316	40.0	62	98.1	91	100.0	4.1	1.3
Singapore	65233	67.6	86	100.0	100	100.0	3.6	6.7
Solomon Islands	2128	83.4	55	82.4	63	66.7	3.7	0.3
Thailand	7808	66.8	80	41.4	63	100.0	4.1	4.1
Timor-Leste	1294	64.3	39	68.6	20	85.6	4.3	0.4
Tonga	4364	59.1	61	98.1	80	98.9	4.0	1.3
Vanuatu	3058	66.8	61	98.1	75	61.9	3.5	0.5
Vietnam	2715	75.9	70	62.4	61	100.0	3.6	2.1

Europe & Central Asia								
Albania	5353	48.9	68	62.4	47	100.0	4.0	1.6
Armenia	4623	46.2	75	43.3	58	100.0	4.1	1.8
Austria	50277	57.8	79	94.8	100	100.0	3.3	7.0
Azerbaijan	4794	62.8	77	35.7	42	100.0	3.8	3.9
Belarus	6663	61.2	74	68.6	31	100.0	2.9	6.1
Bosnia and Herzegovina	6073	37.8	65	46.7	54	100.0	3.6	6.5
Bulgaria	9738	53.0	72	79.0	61	100.0	3.7	5.9
Croatia	14853	47.6	74	91.0	72	100.0	3.6	4.2
Cyprus	27858	58.5	73	78.1	81	100.0	4.7	5.7
Czech Republic	23102	59.4	76	94.3	87	100.0	3.0	9.7
Estonia	23660	60.3	81	84.3	90	100.0	2.8	12.6
Georgia	4769	58.5	84	46.2	70	100.0	3.7	2.7
Greece	19583	42.8	68	68.6	67	100.0	4.1	5.8
Hungary	16476	54.5	73	89.5	75	100.0	3.4	4.6
Italy	33190	44.7	73	74.8	70	100.0	4.0	0.0
Kazakhstan	9731	65.6	80	56.7	47	100.0	3.7	13.9
Kyrgyz Republic	1309	56.0	68	46.7	27	100.0	4.1	1.6
Latvia	17836	57.4	80	74.8	86	100.0	2.9	3.6

Lithuania	19456	57.7	82	93.3	87	100.0	2.9	4.5
Luxembourg	114705	56.1	70	99.5	100	100.0	2.9	15.4
Moldova	4499	40.7	74	47.1	48	100.0	3.4	1.8
Montenegro	8832	46.3	74	59.5	63	100.0	3.8	3.2
North Macedonia	6093	45.3	81	59.0	54	100.0	3.9	3.4
Poland	15595	54.7	76	78.1	75	100.0	3.0	7.9
Portugal	23145	55.1	77	96.7	89	100.0	4.3	4.7
Romania	12920	52.5	73	78.1	72	100.0	3.5	3.5
Russian Federation*	11585	59.0	78	41.4	33	100.0	3.4	12.0
Serbia	7402	47.9	76	57.1	58	100.0	3.5	6.4
Slovak Republic	19329	56.2	76	91.4	77	100.0	3.3	6.0
Slovenia	25739	55.9	77	92.4	88	100.0	3.4	6.1
Tajikistan	871	37.4	61	41.4	16	99.3	4.3	0.6
Turkey	9043	45.7	77	13.8	51	100.0	4.3	4.7
Ukraine	3659	49.3	70	11.9	34	100.0	3.3	4.5
Uzbekistan	1725	61.2	70	53.3	21	100.0	4.3	2.9
Latin America & Caribbean								
Antigua and Barbuda	17790	N/A	60	96.2	79	100.0	4.8	5.9

Barbados	18148	58.5	58	94.8	75	100.0	4.7	4.5
Bolivia	3552	69.3	52	38.6	19	95.6	4.9	2.0
Chile	14897	58.2	73	66.2	87	100.0	5.4	4.7
Costa Rica	12238	54.7	69	75.2	77	100.0	4.1	1.6
Cuba	8822	52.7	N/A	83.3	53	100.0	4.5	2.5
Dominica	8300	N/A	61	97.6	84	100.0	4.0	2.5
Ecuador	6184	65.3	58	53.8	42	100.0	3.4	2.5
El Salvador	4187	56.7	65	55.7	32	100.0	4.8	1.1
Grenada	10966	N/A	53	96.2	73	95.3	4.5	2.4
Guyana	5468	49.5	56	53.8	48	91.8	4.2	3.1
Jamaica	5582	60.7	70	73.3	51	98.9	4.4	2.8
Panama	15731	64.0	67	69.0	58	100.0	4.0	2.7
Peru	6978	75.1	69	54.8	46	95.2	4.9	1.9
Suriname	6855	47.4	48	62.4	61	97.4	4.3	3.1
Trinidad and Tobago	17277	58.3	61	59.5	58	100.0	4.3	31.8
Uruguay	16190	58.4	62	96.2	79	100.0	4.3	2.0
Venezuela, RB	2299	54.5	30	12.4	1	100.0	4.4	5.5
Middle East & North Africa								
Algeria	3948	36.3	49	23.3	31	100.0	4.9	3.7

Bahrain	23504	72.8	76	36.2	77	100.0	4.9	22.2
Djibouti	3409	54.0	61	50.0	27	60.4	4.8	0.7
Egypt, Arab Rep.	3020	41.4	60	21.4	47	100.0	5.3	2.5
Iran, Islamic Rep.	5520	39.6	59	10.5	34	100.0	4.9	8.3
Iraq	5955	37.5	45	3.8	5	99.9	4.7	5.2
Kuwait	32032	71.9	67	66.7	69	100.0	4.8	25.0
Lebanon	7784	44.1	54	11.4	28	100.0	4.8	3.7
Libya	7684	40.5	33	3.8	5	67.0	5.1	7.8
Malta	29416	54.6	66	96.7	86	100.0	4.6	2.9
Morocco	3204	41.2	73	48.1	57	100.0	5.0	1.7
Oman	15474	70.4	70	82.9	78	100.0	5.2	14.2
Qatar	64782	86.7	69	88.6	80	100.0	4.9	38.9
Saudi Arabia	23140	52.6	72	46.7	65	100.0	5.2	17.4
Tunisia	3318	38.7	69	28.6	62	99.8	4.7	2.6
United Arab Emirates	43103	80.2	81	87.1	84	100.0	5.0	22.0
Yemen, Rep.	968	33.1	32	2.9	5	62.0	5.2	0.4
South Asia								
Afghanistan	502	43.5	44	2.9	5	98.7	5.0	0.2

Bangladesh	1856	56.5	45	26.7	34	85.2	3.9	0.5
Maldives	10791	65.5	53	61.9	56	100.0	4.4	3.0
Nepal	1071	82.6	63	46.2	45	93.9	4.0	0.3
Pakistan	1285	50.2	61	5.2	38	71.1	4.7	1.0
Sri Lanka	3853	51.7	62	53.8	61	99.6	4.2	1.1
Sub-Saharan Africa								
Angola	2974	72.2	41	50.0	21	43.3	4.7	1.2
Benin*	1219	69.3	52	49.5	39	41.5	4.2	0.6
Burundi	261	78.0	47	11.4	9	11.0	4.2	0.0
Cabo Verde	3604	53.0	55	94.3	77	93.6	4.7	1.0
Cameroon	1498	73.5	46	11.9	19	62.7	4.3	0.3
Chad	710	69.4	37	14.3	14	11.8	4.8	0.1
Comoros	1394	41.4	48	58.1	24	81.9	4.3	0.3
Congo, Rep.	2011	62.9	40	27.6	18	68.5	4.3	0.7
Equatorial Guinea	8132	58.0	41	54.8	10	67.0	3.7	4.7
Ethiopia	858	77.9	48	15.7	46	45.0	4.7	0.1
Gabon	7667	42.3	45	54.8	33	93.0	3.6	2.6
Gambia, The	751	54.0	50	62.4	51	60.3	4.6	0.2
Ghana	2202	64.9	60	61.9	61	82.4	4.0	0.6

Guinea	1064	58.9	49	29.0	17	44.0	4.4	0.3
Kenya	1817	72.7	73	20.0	47	75.0	4.5	0.4
Lesotho	1158	52.0	59	49.5	49	47.0	5.1	1.2
Liberia	622	74.2	43	53.8	24	25.9	3.9	0.3
Madagascar	522	84.6	48	53.3	22	25.9	4.8	0.2
Mali	891	65.7	53	5.7	28	50.9	4.7	0.2
Mauritania	1678	41.5	51	42.4	43	44.5	4.7	0.7
Mozambique	492	75.6	55	33.8	22	31.1	4.4	0.3
Namibia	4958	47.5	61	79.5	70	53.9	5.4	1.8
Niger*	555	71.7	57	13.3	44	17.6	4.8	0.1
Nigeria	2230	48.6	57	8.1	26	56.5	4.3	0.6
Rwanda	802	82.8	77	64.3	63	34.7	4.1	0.1
Senegal	1447	42.7	59	59.5	55	67.0	4.6	0.7
Seychelles	17402	N/A	62	89.5	65	100.0	4.3	6.4
Sierra Leone	505	55.3	48	57.1	32	26.1	4.1	0.1
Somalia	N/A	42.0	20	4.3	1	35.3	4.8	0.0
South Africa	6001	40.2	67	53.8	58	91.2	5.0	8.5
South Sudan	369	63.5	35	4.3	5	28.2	4.5	0.2
Sudan	442	40.4	45	10.5	19	59.8	4.9	0.0
Tanzania	1122	81.8	55	48.6	42	35.6	4.5	0.2

Togo	676	76.0	62	29.5	42	51.3	4.1	0.4
Uganda	777	69.0	60	37.1	51	42.7	4.5	0.1
Zambia	1291	66.1	67	56.7	47	39.8	4.8	0.3
Zimbabwe	1464	79.0	55	26.7	14	41.0	4.9	0.8

Appendix II Detailed Description of Key Renewable Technologies

Renewable energy refers to the set of resources that rely on energy sources that replenish themselves naturally over a short time span – generally considered to be a human lifespan - and do not diminish. Most types of renewable energy originate from the sun. Solar energy is the conversion of sunlight into usable energy forms,[419] whilst the sun's radiation generates uneven heat and air exchange, leading to winds whose energy is captured by turbines. Bioenergy is produced from the stored energy in plants who depend on the sun to grow. Other renewable energy sources which do not rely directly on solar energy are geothermal energy, which is heat derived within the sub-surface of the Earth,[420] and hydropower, which is produced by the flow of water and driven by gravity and the sun in keeping the water cycle going.

Renewable energy contrasts with energy production based on burning fossil fuels which irrevocably diminishes these resources. Renewable energy is a major topic for the future of global energy systems, not only because renewable energy resources do not diminish, but also because they produce lower levels of greenhouse gas emissions than fossil fuel energy systems and it is these emissions that are now driving dangerous levels of climate change. Some renewable energy technologies can have adverse impacts on the environment. For example, large hydroelectric resources can affect fisheries, land use, and the negative social impacts of forced relocation. Some types of renewable energy do not always produce low-carbon emissions, as large hydropower or certain sources of bioenergy can sometimes have lifecycle emissions around the same level as fossil fuels.[421]

Solar photovoltaics

Solar photovoltaics (PV), also called solar cells, are electronic devices that convert sunlight directly into electricity, using the PV effect.[422] Solar PV technology is generally used on a panel with individual cells assembled into cells and electrically connected. Multiple modules are wired together to build modular PV systems that

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419 International Energy Agency (n.d.). Solar. Retrieved from https://www.iea.org/fuels-and-technologies/solar.
420 International Renewable Energy Agency (n.d.). Geothermal energy. Retrieved from https://www.irena.org/geothermal.
421 Pehl, M. *et al*. (2017). Understanding future emissions from low-carbon power systems by integration of lifecycle assessment and integrated energy modelling. *Nature Energy*, 2, 939–945... Retrieved from https://www.nature.com/articles/s41560-017-0032-9.
422 International Renewable Energy Agency (n.d.). Solar energy. Retrieved from https://www.irena.org/solar.

produce electricity in both off-grid and grid-connected applications.[423] Indeed, one of the great advantages of solar PV is that it can be installed on the rooftops of individual buildings or combined to produce utility-scale power production facilities with the capacity of several hundred MWs.

The amount of electricity produced by solar PV depends on the intensity of the solar radiation and, therefore, more power is produced in sunnier regions.[424] However, the difference in the intensity of solar radiation is offset by improved efficiency of the conversion process at lower ambient temperatures. For example, these two factors almost directly offset each other such that solar panels work nearly as well in Idaho as they do in Florida despite the significant difference in solar radiation.[425] Indeed, one of the countries that has led the deployment of solar PV is Germany which sits at a relatively northerly latitude.

Whilst solar PV is a renewable energy source, it will have some impact on the environment through the manufacturing process and use of land. However, recent studies suggest that lifecycle emissions for solar is around ~6gCO_2e/kWh which is two orders of magnitude lower than that of the cleanest fossil-fuel technologies involving carbon capture technologies.[426]

Solar PV costs are increasingly competitive with fossil fuels in a wide range of geographies and deployment levels. As a result, the IEA reports that power generation from solar PV is estimated to have risen by over 30% in 2018, to more than 570TWh, which is over 2% of global electricity generation, and with significant deployment in most global markets.[427]

Typically, around half of the capital cost of solar PV is associated with production of the hardware and the largest element of this is the cost of the modules. A further quarter of the costs is devoted to installation of the panels. It is, therefore, ideally positioned to benefit from learning curve effects and its costs have fallen significantly in all regions (see Figure 3.3 and 3.4). The overall cost of power produced by a solar PV plant is driven by a combination of the installation

423 International Energy Agency and International Renewable Energy Agency (2013). Solar photovoltaics technology brief. Retrieved from https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2015/IRENA-ETSAP-Tech-Brief-E11-Solar-PV.ashx?la=en&hash=229A7B44B1FD2456A671462327F089C5AA847689.
424 The World Bank and the International Finance Corporation (2020). Global solar atlas. Retrieved from https://globalsolaratlas.info.
425 North American Solar Stores (2019). Solar works nearly as well in Idaho as it does in Florida. Retrieved from https://www.northamericansolarstores.com/solar-pv-everywhere/.
426 Pehl, M. *et al.* (2017). Understanding future emissions from low-carbon power systems by integration of lifecycle assessment and integrated energy modelling. *Nature Energy*, 2, 939–945. Retrieved from https://www.nature.com/articles/s41560-017-0032-9.
427 International Energy Agency (2019). Solar photovoltaics: an analysis. Retrieved from https://www.iea.org/reports/solar-pv.

costs and the capacity factor (for explanation of capacity factor, see Appendix III).[428] In addition to the reduction in installation costs, capacity factors for solar PV have also been increasing, leading to an overall reduction in the cost of electricity produced.[429]

However, for energy systems to take advantage of these cost reductions, it must be possible to cost-effectively connect solar PV and integrate the power it produces. Solar PV does not currently provide the same range of system services as those provided by fossil fuel-based plants. This includes reserve capacity to help balance supply and demand, inertia to help maintain system frequency, and other services related to voltage and reactive power. This currently imposes an upper limit on the proportion of solar PV that can be accommodated within a power system.

Concentrating solar power

Concentrating solar power (CSP) technologies use mirrors to concentrate solar rays which heat fluid, generating steam to drive a turbine to produce electrical power. CSP is employed to produce electricity in large-scale power plants.[430] Integrated thermal energy storage systems can be integrated into CSP plants, and this stored heat energy can be used to generate electricity during cloudy periods or overnight. This makes CSP a more flexible and dispatchable source of renewable energy than solar PV.

The rate of deployment of CSP has been much slower than for solar PV and, therefore, it has not been able to benefit to the same extent from learning curve effects. This has been exacerbated by the variety of designs, especially involving the nature and extent of thermal storage. However, designs are now converging[431] and the benefits of thermal storage in improving the capacity factor is outweighing the increased installation costs. With construction costs falling steadily and capacity factors rising,[432] the total cost of electricity produced by CSP is declining.

428 Operations and maintenance costs are less significant.
429 International Renewable Energy Agency (2020). Renewable power generation costs in 2019. Retrieved from https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Jun/IRENA_Power_Generation_Costs_2019.pdf.
430 International Renewable Energy Agency (n.d.). Solar energy. Retrieved from https://www.irena.org/solar.
431 No Linear Fresnel plant, or CSR without thermal storage has been built since 2014.
432 One driver of higher capacity factors in recent years is deployment in areas with higher direct normal irradiance (DNI). CSP projects commissioned in Spain in 2010 – 2013 were typically sited in areas with DNI in the 2,000 –2,200 kWh/m2/year range, while sites with DNI of 2,500 – 3,000 kWh/m^2/year became the norm in 2014 – 2018. International Renewable Energy Agency (2019). Renewable power generation costs in 2018. Retrieved from https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Jun/IRENA_Power_Generation_Costs_2019.pdf.

Whilst the lifecycle emissions of CSP are slightly higher than for solar PV – calculated at ~ 11gCO_2e/kWh[433] – they remain significantly lower than for the cleanest fossil technology. CSP operates more efficiently at high levels of solar radiation and, therefore, most CSP projects are located closer to the equator, particularly in desert regions. The cost of electricity produced by CSP is diminishing.

China is playing a critical role in the development of CSP. The 13th Five-Year (2016-2020) plan for solar energy development set a target of 5 GW of CSP capacity by 2020 and several plants are currently under construction. Given the limited opportunities hitherto for this technology to benefit from the learning curve effect, it is possible that costs could fall significantly over the near future. IRENA suggests that recent auction and Power Purchase Agreement (PPA) programs indicate that the cost of electricity from CSP could fall into the range of US$0.06/kWh to US$0.10/kWh over the next four years from previous values of around US$20/kwh.[434]

The great advantage of CSP is the **ability to provide dispatchable renewable power**, thereby increasing overall system flexibility and allowing high shares of solar PV and wind to be integrated onto power systems. The other major advantage of CSP is that it is one of the few renewable resources that produces high temperature heat which is vital in several industrial processes.[435] However, these twin benefits only have the potential to be realized in areas with good direct solar resources, and intermittently.

Onshore wind

People have been capturing and using energy from wind in transport, industry and agriculture throughout history.[436] The wind-induced mechanical power of huge multi-blade rotors – more than 100 metres in diameter – is now used to produce electricity. Onshore wind turbines have been deployed steadily around the globe over the last 20 years.

433 Pehl, M. *et al*. (2017). Understanding future emissions from low-carbon power systems by integration of lifecycle assessment and integrated energy modelling. *Nature Energy*, 2, 939–945. Retrieved from https://www.nature.com/articles/s41560-017-0032-9.
434 International Renewable Energy Agency (2019). Renewable power generation costs in 2018. Retrieved from https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Jun/IRENA_Power_Generation_Costs_2019.pdf.
435 Ibid.
436 International Energy Agency and International Renewable Energy Agency (2016). Wind Power Technology Brief. Retrieved from https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA-ETSAP_Tech_Brief_Wind_Power_E07.pdf.

The construction of an onshore wind plant involves two important trade-offs. The first is between installation costs and capacity factor. It is necessary to find a location that is easy to access and sufficiently spacious to allow construction whilst ensuring that the area has good wind resources. The variation in average wind speeds from one area to another can be very large, as illustrated in the World Bank and the Technical University of Denmark's Global Wind Atlas. The amount of electricity generated by a turbine is proportional to wind speed. Theoretically, higher wind speeds create more output power, since stronger winds enable the blades to rotate faster, generating more mechanical power and more electricity from the generator. Turbines are designed to operate between the cut-in speed and cut-out speed – the former stands for the point where the wind turbine starts to produce power. Between the cut-in speed and the rated speed, power output increases rapidly as wind speed increases up to the rated capacity. Thereafter, output remains relatively constant until the cut-out speed where generation ceases for safety reasons.

The second important trade-off involves the size and number of individual turbines and the impact this has on the local environment. Taller turbines enable access to higher wind speeds and larger diameters can enhance power output across the range of operating wind speeds.[437] However, large turbines covering large areas can be unpopular with local communities and these concerns have slowed the potential deployment of onshore wind, particularly in Europe.

Onshore wind turbines now produce over 20% of renewable electricity – second only to hydropower. Wind power is the renewable energy source with the lowest level of lifecycle emissions.[438] Onshore wind continues to be deployed at scale in many regions (see Figure A2.1).

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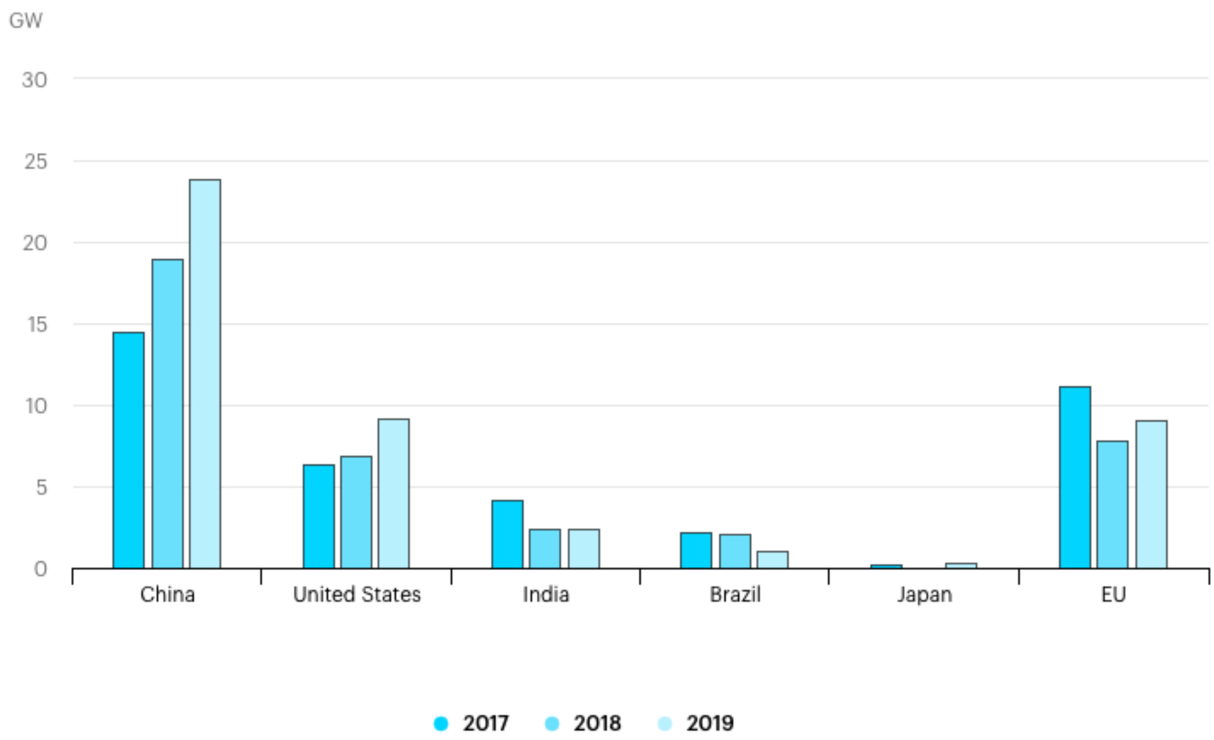
437 There is also a trade-off involved in the slightly higher costs for taller towers and longer blades, but this is generally outweighed by the increase in capacity factor.
438 Pehl, M. *et al*. (2017). Understanding future emissions from low-carbon power systems by integration of lifecycle assessment and integrated energy modelling. *Nature Energy*, 2, 939–945. Retrieved from https://www.nature.com/articles/s41560-017-0032-9.

Figure A2.1 Onshore wind annual capacity additions



Source: IEA[439]

The rate of deployment of onshore wind turbines has ensured that learning curve effects have driven improvements in manufacturing and installation which, in combination with improvements in capacity factors driven by larger turbine sizes, have resulted in significant reductions in lifetime electricity costs.

Onshore wind is already cheaper than new fossil fuel-fired power generation in most regions with good access to wind resources (see Figure 3.2) and, alongside solar PV, is projected to become cheaper than existing plants within the next decade (see Figure 3.4). China continues to lead the world in the deployment of onshore wind.[440] It is playing an important role in driving forward these trends and is well-placed to exploit the benefits.

439 International Energy Agency (2019). Onshore wind. Tracking Report. https://www.iea.org/reports/onshore-wind.
440 Renewable Energy Policy Network for the 21st Century (2020). Renewables 2020: global status report. Retrieved from https://www.ren21.net/gsr-2020.

However, as is the case with solar PV, the major drawback facing onshore wind energy involves the challenges it presents for electricity grids and power systems as a result of the variability and uncertainty of its output and distributed nature of its location. Creative solutions for providing ancillary services and other dispatchability-related services will need to be introduced if the potential of onshore wind is to be realized (see Section 3.2).

Offshore wind

Wind turbines situated offshore represent an extreme example of the first trade-off discussed above for onshore wind. Wind resources tend to increase in intensity and stability at distances that are further offshore. However, this benefit in potential capacity factor is offset by increases in installation costs associated with deeper water and harsher environments. In addition, the cost of the transmission connection will rise significantly. The richest offshore wind resources tend to be over waters exceeding 50m to 60m in depth. It is not practical to attach turbines to the seabed in such locations and, although floating offshore foundations do offer potential in this situation, these remain at the development stage. The second trade-off relevant for onshore wind does not tend to apply to offshore facilities since community acceptance has not proved to be a significant issue. [441]

As a result, significantly less offshore wind has been installed than onshore wind. Global offshore wind power installations total 4.5 GW,[442] mainly concentrated in Europe (especially UK and Germany) and China. However, significant projects are under development in North America and Oceania in the coming years.

There have been steady declines in the costs of installation, logistics and operations and maintenance driven by learning curve effects, offset in part by increases in costs driven by the move to deeper waters. In combination with the increases in capacity factor achieved through larger turbines located in areas of better wind resource, overall costs have declined (see Appendix 3). However, this is based on relatively sparse data given the low level of deployments.

441 The main concerns have been associated with the need for transmission connection assets onshore.
442 International Renewable Energy Agency (2019). Renewable power generation costs in 2018. Retrieved from https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Jun/IRENA_Power_Generation_Costs_2019.pdf.

Recent auctions for renewable feed-in-tariffs in Europe suggest that offshore wind might achieve significant cost reductions of 45-50% over the next five years. These cost reductions would enable offshore wind to join solar PV and onshore wind in competing with the cost of fossil-fuel power plants.

Offshore wind has significant potential for future expansion given the extent of the wind resources available and the cost reductions that are now becoming apparent. However, it possesses the same variability challenges as onshore wind, albeit operating at higher capacity factors, and careful planning of offshore transmissions assets will be required to minimize grid connection costs. China has established a leading position in offshore wind deployment although it will need to tackle system integration issues if it is to retain this position (see Section 3.2).

Bioenergy power generation

Biomass is biological matter that can be used as fuel which is burnt to create the heat necessary to generate electricity. Sources of biomass include wood, grasses, agricultural crops (such as corn and sugar cane), landfill waste, and manure. Whilst burning biomass releases similar amounts of CO_2 as burning fossil fuels, it is considered renewable since the CO_2 it releases is balanced by the CO_2 absorbed in plant growth. Indeed, if a bioenergy power plant is equipped to capture the CO_2 it produces and can store it underground, it could be a net absorber of CO_2 (termed BECCS – bioenergy with carbon capture and storage).

In addition to any CO_2 released by fossil energy that is used to grow, harvest, and process fuel from biomass, the use of land to produce biomass can be detrimental if it involves the conversion of high carbon stock forests. The estimated average lifecycle emissions are currently ~100gCO_2e/kWh which is an order of magnitude higher than for solar and wind and about the same as the level of fossil fuels with CCS and large hydro plants.[443] This suggests that many forms of bioenergy power generation cannot be considered truly “green” even though they are renewable. The introduction of robust sustainability frameworks will thus be key to the further development of bioenergy.

443 Pehl, M. *et al*. (2017). Understanding future emissions from low-carbon power systems by integration of lifecycle assessment and integrated energy modelling. *Nature Energy*, 2, 939–945. Retrieved from https://www.nature.com/articles/s41560-017-0032-9.

Costs vary significantly and are much lower for those with easy access to low-cost agricultural and forestry residues than more sophisticated options such as biomass gasification or municipal solid waste generators with more stringent emissions controls. Bioenergy does not benefit to the same extent from the learning curve as solar and wind technologies, since the costs of procuring and transporting biomass represents a key component of overall costs. Overall costs of bioenergy power production have not fallen significantly over the past decade, but the capacity factor is much higher than that for wind and solar plant and comparable to levels typical of flexible fossil capacity. Despite the above-mentioned drawbacks, bioenergy does have the advantage that it can operate as a dispatchable power plant capable of providing the same system services as a conventional fossil-fuel power plant. Apart from restrictions to the size of individual units, resulting from the ability to transport enough biomass to fuel the plant, bioenergy power stations can be easily integrated into existing power systems. This has ensured that bioenergy has remained a popular source of renewable electricity and contributes at similar levels to global production as solar PV.[444]

Geothermal power generation

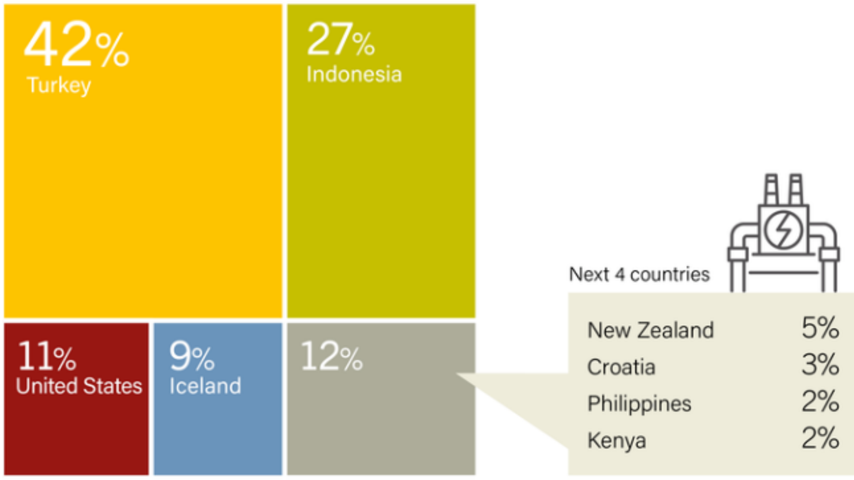
Geothermal energy is produced by the heat of the Earth's sub-surface. This energy, carried in water and/or steam, can be harnessed for heating and cooling or to produce clean electricity.[445] Conventional geothermal generation involves tapping heat sources within 3km of the surface. There are several mature technology options but only a limited geographical range where suitable resources are available. Accessing heat at greater depths (ten kilometres) would significantly increase available resources but such systems remain under development. The overall lifecycle emissions of geothermal technologies are higher than wind and solar but lower than fossil with CCS and are estimated to lie in the range 10-50gCO_2e/kWh.[446] These emissions arise primarily during the construction phase although some technologies release CO_2 from the fluids that are injected into the Earth.

Geothermal power generation plants can only be built in a limited number of geographical

444 International Renewable Energy Agency (2019). Renewable power generation costs in 2018. Retrieved from https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Jun/IRENA_Power_Generation_Costs_2019.pdf.
445 Moderate- to low-temperature geothermal resources also have an important role to play in heating buildings.
446 Eberle, A. *et al.* (2017). Systematic review of life cycle GHG for geothermal electricity. Retrieved from https://www.nrel.gov/docs/fy17osti/68474.pdf.

locations. The relatively small number of projects and variety of technical designs has meant that opportunities to benefit from the learning curve are limited. Figure A2.2 shows that capacity additions in 2018 were focused in two countries: Turkey and Indonesia. Costs have remained relatively constant since 2010. However, where good and accessible high-temperature resources exist, geothermal power generation provides reliable base load power at costs competitive with fossil-fuelled power generation. Geothermal power generation does not appear to be a promising focus for BRI investments given the limited scope for deployment and China's relatively limited experience with the technology.

Figure A2.2 Geothermal power capacity additions by country in 2018[447]



Source: REN21[448]

Hydroelectric power generation

Hydroelectric power is produced when dams are built across waterways to contain the flow of a river. The flowing water is used to drive turbines to generate electricity.[449] Besides dams, there are two other main forms of hydroelectric power: pumped storage and run of the river. The overwhelming majority of hydroelectric power is produced by large dams, which has been an established technology for many decades. Around 60% of all renewable electricity is now produced by hydroelectric power generators[450] and

447 Renewable Energy Policy Network for the 21st Century (2019). Renewables 2019. Global Status Report. Retrieved from https://www.ren21.net/gsr-2019/.
448 Ibid.
449 International Renewable Energy Agency (n.d.). Hydropower. Retrieved from https://www.irena.org/hydropower.
450 Renewable Energy Policy Network for the 21st Century (2020). Renewables 2020: global status report. Retrieved from

some of these facilities are now extremely old. Indeed, one of the key challenges facing this technology is the refurbishment and updating of old facilities. New hydroelectric capacity continues to be built around the globe, although opportunities to exploit new resources are now limited in mature markets such as Europe. China leads the world in hydroelectric power both in terms of total capacity (28% of global capacity[451]) and rate of new build.[452]

Despite the large number of deployments at various sizes, the **costs of hydroelectricity are not reducing.** This is due to the maturity of the technology and the fact that new resources tend to be in more challenging locations with higher construction and grid connection costs. Nonetheless, hydropower does provide dispatchable electricity that is easy to integrate into power systems and the lifetime costs of electricity it provides are low and competitive with fossil fuel generators (see Figure 3.2). Overall costs have remained relatively constant over recent years (see Appendix 3, Figure A3.7).

The significant drawback of hydroelectric power generation is the potentially high social and environmental costs, heavily undermining ecosystems and populations where they are built. The **overall average lifetime emissions are relatively high** and at the same level as that of fossil with CCS and of bioenergy. The estimated average lifecycle emissions are currently ~ 100gCO_2e/kWh but this footprint is highly variable.[453] The lifecycle emissions are dominated by rotting organic matter flooded by the dam. These emissions are highest in warm regions with shallow dams and considerable variations in water level.

Deployment opportunities are increasing in India, Africa, and Southeast Asia where there is untapped resource potential, promising economics, and a strong desire to improve affordable electricity access. This will provide attractive investment opportunities for the BRI given that China has extensive experience in deployment of hydroelectric power generation.

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https://www.ren21.net/gsr-2020.

451 Renewable Energy Policy Network for the 21st Century (2019). Renewables 2019. Global Status Report. Retrieved from https://www.ren21.net/gsr-2019/.

452 International Energy Agency (2019). China power system transformation: assessing the benefit of optimized operations and advanced flexibility options. Retrieved from https://webstore.iea.org/china-power-system-transformation.

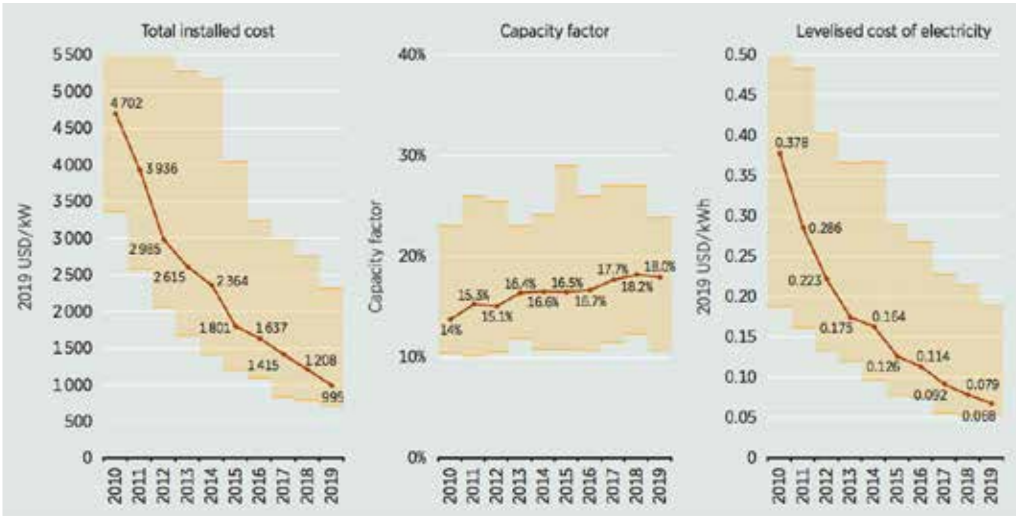
453 Pehl, M. *et al.* (2017). Understanding future emissions from low-carbon power systems by integration of lifecycle assessment and integrated energy modelling. *Nature Energy*, 2, 939–945. Retrieved from https://www.nature.com/articles/s41560-017-0032-9.

Appendix III Rising Capacity Factors for VRE

Capacity factor measures how often a power plant operates over a given period of time by calculating the ratio of its actual power output to its maximum potential output during that specific period. The average capacity factor of variable renewables, especially solar PV, CSP and wind, has increased significantly in the last decade, as shown in Figures A3.1, A3.2, A3.3 and A3.4. Solar PV's capacity factor has risen from 14% to 18% from 2010 to 2019, while that of onshore wind rose from 27.1% to 35.6%. The capacity factor of CSP, an energy source easier to dispatch than solar PV, has also witnessed a jump from 30% to 45.2%. Offshore wind, despite a less linear curve, has also experienced a similar trend, with a capacity factor that reached 43.5% in 2019 from 36.8% in 2010. Combined with a decrease in total installed costs, this upward trend in VRE capacity factors has helped push down levelized costs of electricity, making VRE increasingly competitive with fossil fuel-fired power plants.

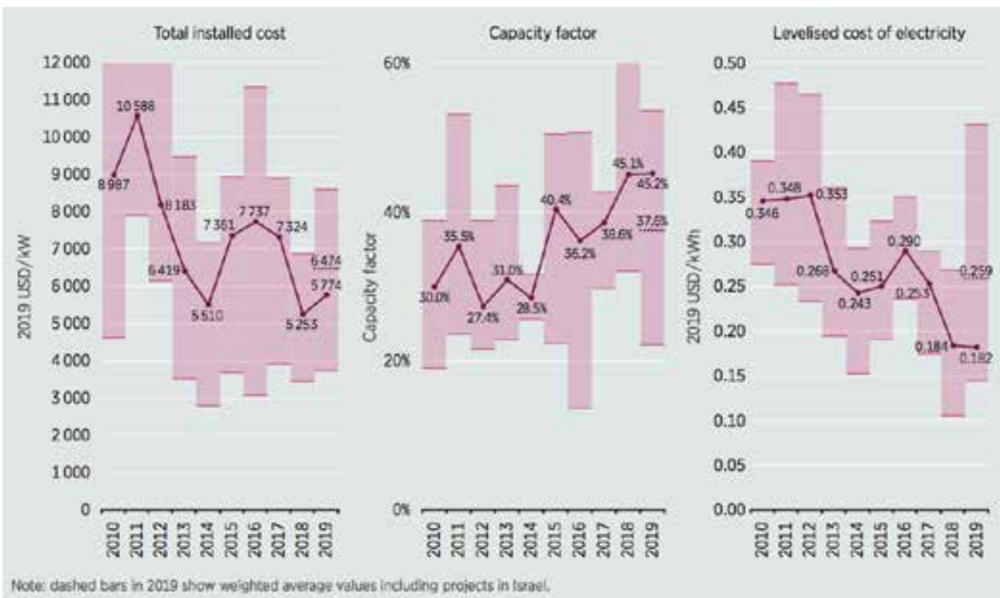
Other renewable energy sources have not performed as well: hydropower's capacity factor rose but more modestly in the last decade (Figure A3.7) while bioenergy's capacity factor remained around the same level in 2019 compared to 2010 (Figure A3.5). Geothermal was the only one to witness a significant decrease, from 87% to 79.4%, though enjoying a naturally higher capacity factor than VRE (Figure A3.6). These trends in capacity factors were all reflected in each energy source’s LCOE from 2010 to 2019 (Figure A3.5; A3.6 and A3.7).

Figure A3.1 Global weighted average total installed cost, capacity factor and levelized cost of electricity for solar PV (2010-2019)



Source: IRENA[454]

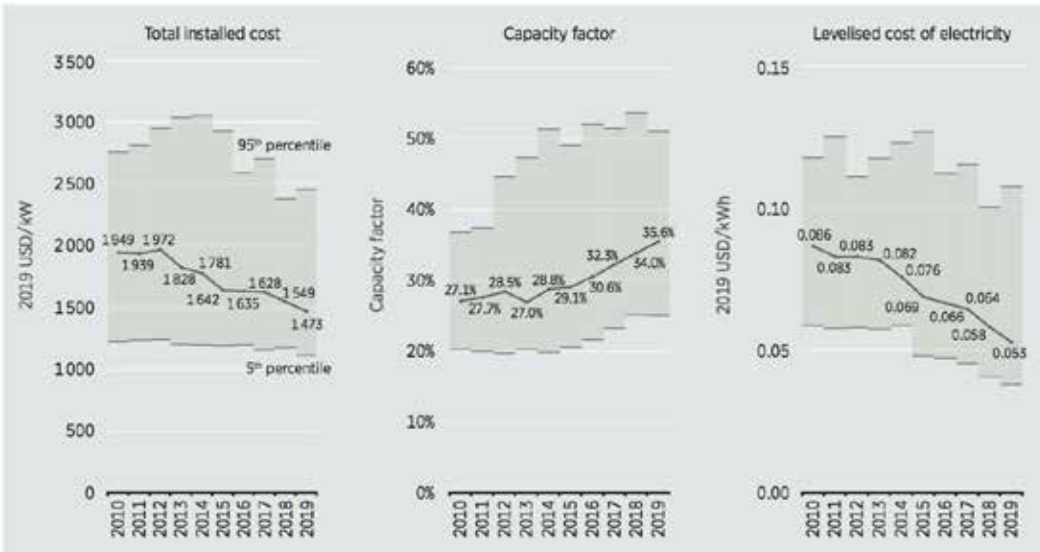
Figure A3.2 Global weighted average total installed cost, capacity factor and levelized cost of electricity for CSP (2010-2019)



Source: IRENA[455]

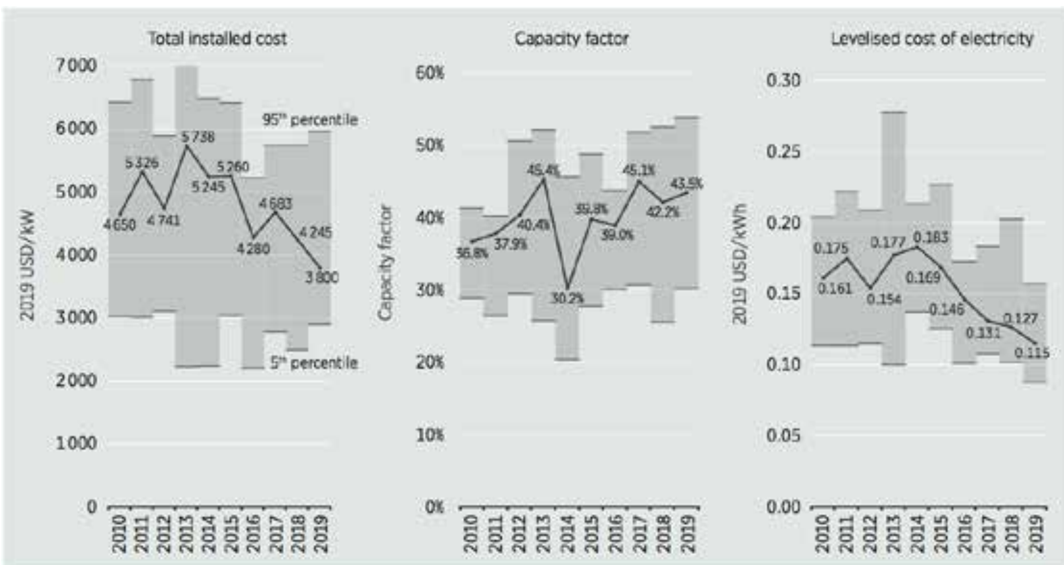
454 International Renewable Energy Agency (2020). Renewable power generation costs in 2019. Retrieved from https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Jun/IRENA_Power_Generation_Costs_2019.pdf.
455 Ibid.

Figure A3.3 Global weighted average total installed cost, capacity factor and levelized cost of electricity for onshore wind (2010-2019)



Source: IRENA[456]

Figure A3.4 Global weighted average total installed costs, capacity factors and levelized cost of electricity for offshore wind (2010-2019)



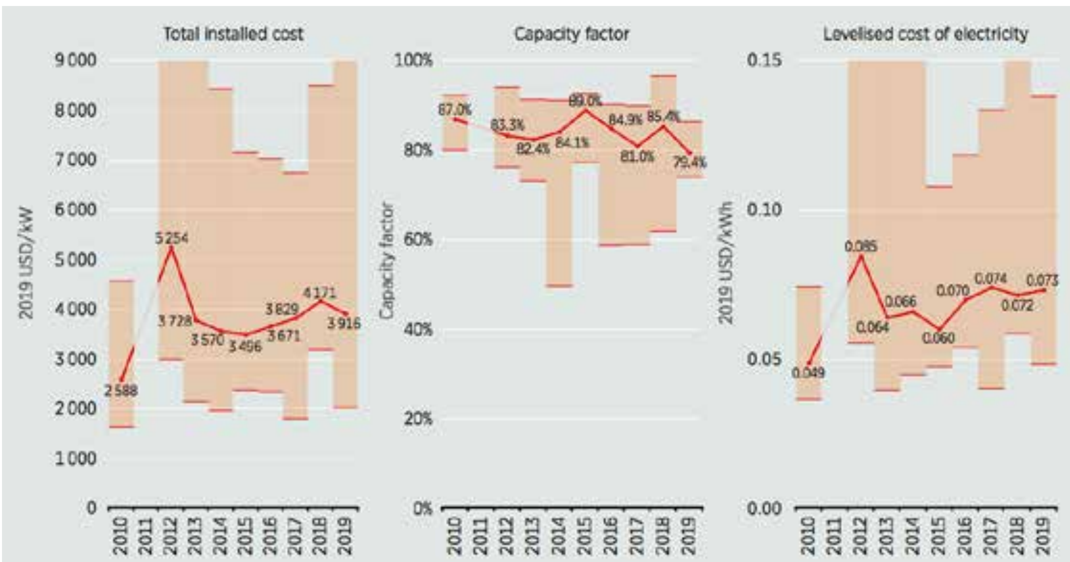
Source: IRENA[457]

456 Ibid.
457 Ibid.

Figure A3.5 Global weighted average total installed costs, capacity factors and levelized cost of electricity for bioenergy (2010-2019)

Source: IRENA[458]

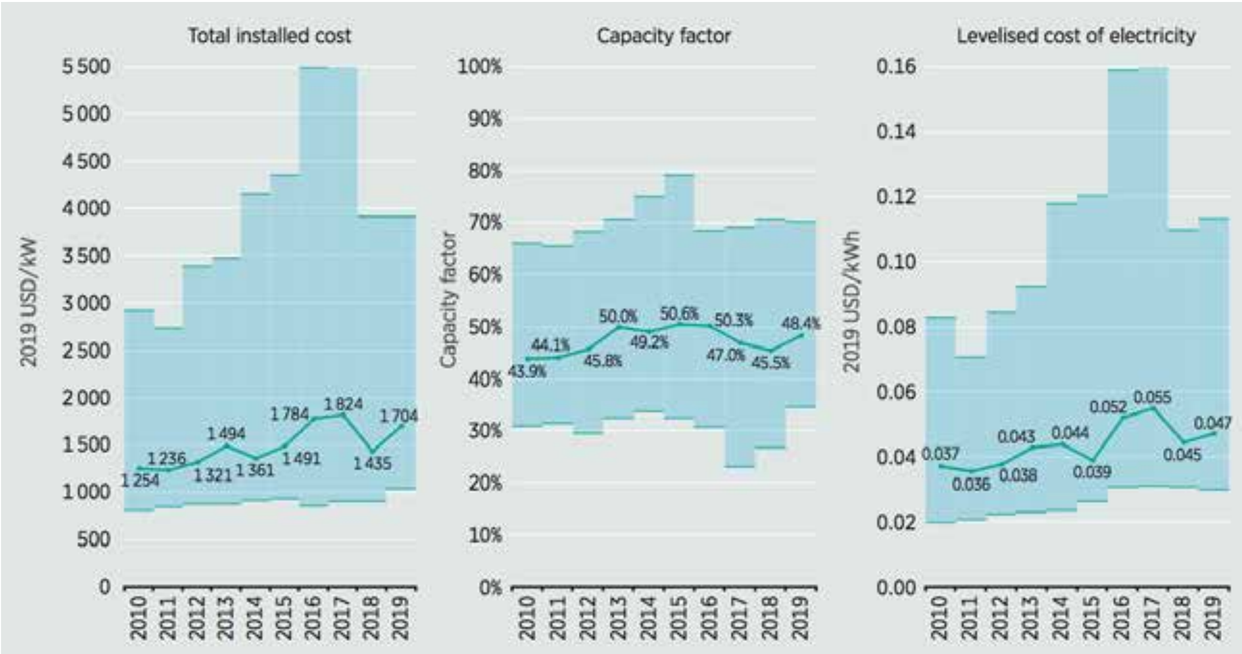
Figure A3.6 Global weighted average total installed cost, capacity factor and levelized cost of electricity for geothermal power (2010-2019)



Source: IRENA[459]

458 Ibid.
459 Ibid.

Figure A3.7 Global weighted average total installed cost, capacity factor and levelized cost of electricity for hydropower (2010-2019)



Source: IRENA[460]

460 Ibid.

Appendix IV Market design considerations

The regulations and market mechanisms that underpin forecasting, scheduling and dispatch are a critical part of the overall energy system framework and are important in supporting efficient integration of variable renewable generation. For vertically integrated utilities operating in a central planning framework, these issues are usually embodied within least cost optimization models run by a single body. However, for competitive electricity markets, it is the administered trading arrangements that establish the incentive framework to drive the behaviour of the various market participants. Given that optimization models generally attempt to mimic the behaviour of a perfect market, it is instructive to understand the design principles of electricity markets and how these might be formulated to promote renewable integration.

Market design involves a number of key decisions:

- The extent to which forward physical power trading is organized centrally through pooling arrangements or is de-centralized and left to market participants to decide how and when to trade;
- Timing of gate closure when physical power trading between market participants ceases and trading is restricted to the system operator buying and selling the power necessary to balance supply and demand in real time;
- The procurement processes for non-energy (ancillary) services along with any procurement of system balancing resources outside the short-term balancing market;
- How the costs of energy imbalance are estimated and recovered;
- How system balancing costs (primarily the costs of relieving network congestion but also including other ancillary services such as the costs of scheduling contingency reserves) are estimated and recovered;
- The extent to which "energy only" trading is adjusted to deliver a particular level of system security. This is most commonly done through establishing additional markets to procure capacity or adjusting energy imbalance costs at times of shortage.

Forward trading: The first choice, relating to centralized versus de-centralized physical trading, will largely determine the nature of the forward markets. Centralized markets (or Pools) concentrate liquidity at some point (or points) in time and provide a clear and transparent price signal that can act as a reference price for trading in secondary financial markets. This concentration of liquidity is most extreme where there is a single compulsory Pool. In decentralized markets, trading is driven by the needs of market participants, and various trading platforms may emerge although the extent of liquidity may be compromised by issues related to market structure. Incentives for forward trading are largely driven by the need to manage the financial risks associated with physical supply or demand that is not backed by a contract. These financial risks are determined by the imbalance price calculations described below.

Gate closure: Gate closure defines the point at which market participants cease the physical trading of power (although trading of financial instruments in secondary markets can continue after gate closure). It is now increasingly common practice for gate closure to be as close to real time as possible whilst allowing the system operator time to make the necessary purchases of system balancing services and ensure an optimal real-time dispatch. Short gate closure times are particularly important in allowing generators that have unpredictable output, such as variable renewables, to limit the risks of imbalance penalty (this refinement is not an issue in those markets where renewable generators are not exposed to imbalance risk). However, this benefit can only be captured if short-term, within-day markets are sufficiently liquid to allow positions to be adjusted.

System balancing and ancillary service procurement: De-centralized physical trading will generally give rise to power station scheduling decisions that do not take account of constraints arising from the operation of the power network (e.g., congestion) or the potential for unplanned plant losses or changes in demand. The system operator will therefore have to adjust this schedule ahead of gate closure to take account of these requirements and procure these capabilities through a variety of routes:

- *Regulatory mandate* – in this situation, providing the service is an additional cost for all system users associated with the provision of energy and these costs must be recovered through the energy and capacity prices.
- *Long-term contract* – this is most relevant for those services that are only required from a

sub-set of the market participants and can be procured through targeted auctions.

- *Short-term markets* – this is the most common way that contingency reserves are procured. Short term markets are also the principal route to procure balancing energy after gate closure.

There is a choice as to whether it is the system operator or market participants who take scheduling decisions ahead of gate closures in response to energy balancing issues that arise from predictable changes in supply or demand. This decision depends on the extent to which forecasts of balancing needs require an aggregated view of system conditions or are equally predictable by individual market participants. Where the responsibility lies with the system operator, the full range of procurement routes above are available. Although these services are most commonly bought through short-term markets, there are examples where this capability is procured through long term contracts (e.g., short-term operating reserve contracts in the UK). However, it is important to note that under either system, insufficient volumes of flexible resource will lead to curtailment of renewable generation which can be very costly. It is, therefore, important that the market arrangements bring forward resources that possess the required mix of dynamic capabilities.

All power markets require that a price of last resort is established that can be used to settle un-contracted trades and this is generally derived in some way from the cost of providing balancing energy. In European markets, where gate closure is typically one hour ahead of real time, balancing prices are submitted at gate closure. In the US, the system operators tend to take over the system scheduling process much earlier, typically a day ahead, but allow regular re-submission of balancing energy prices down to five minutes ahead of real time. This regular re-bidding will help ensure that all sources of flexibility services are made available to the system operator at the time when needed and, therefore, when values are the greatest.

The choice of procurement routes involves a series of trade-offs. Although by far the simplest approach, regulatory mandates risk imposing unnecessary costs on market participants. Long-term contracts can ensure sufficient capability is available through directly incentivizing investments that deliver dynamic capability at the point of initial investment in balancing resources or during major refurbishments. However, reliance on long-term contracts can hinder market access for new entrants and prevent the system from taking advantage of technological advances (e.g., energy loss reduction owing to storage technologies).

Energy imbalance: The requirement to continuously balance electricity supply and demand in the absence of large-scale storage means that it is impossible for all purchases and sales to be exactly covered by fixed-volume forward agreements. Electricity markets therefore require a mandatory market of last resort in which a price is calculated for the purchase and sale of un-contracted production or consumption. This price is extremely important since it creates the default value for energy produced and provides incentives for forward trading.

It can be difficult to accurately calculate the costs of energy imbalance, particularly where there are significant constraints on power flows, since the services procured to balance the system will be partly due to energy imbalances and partly due to system requirements arising from the need to maintain stability across the power network. High and volatile imbalance prices can create significant risks for those market participants that find it difficult to predict performance over short timescales. In the case of variable renewable generators, this imbalance settlement risk can create significant earnings risk and feed through to the financing costs. The requirement to help renewable generators manage this imbalance risk has driven the reduction in gate closure times in many markets. The calculation of the energy imbalance cost is, therefore, important in determining the overall risks faced by market participants. The key judgement is to decide whether to allocate energy imbalance costs to market participants or to socialize them across the market as a whole along with system balancing and other ancillary service costs. This decision involves a trade-off between the potential impact on financing costs and maintaining the incentive on all players to balance their own contractual situation. In the US it is generally assumed that variable renewable generators do not have control over their resources and are either exempt from energy imbalance charges or face some limited exposure to encourage the use of forecasting and to update schedules frequently.

System costs: Those system balancing and ancillary service costs that are not allocated to individual users will need to be recovered equitably across all users. These system costs can be significant and generally will be minimized through a combination of investments in both the supply and demand sides of the market as well as in the network infrastructure. The different timescales associated with investments across the value chain make it very difficult for system operators to ensure that cost minimizing approaches are being adopted. Increasing proportions of variable renewable generation will change the nature of system balancing and it is likely that these costs will become a more significant part of overall energy costs for consumers. It is, therefore, important that markets and regulatory arrangements are designed to procure these services efficiently. For example, the system operator will need to work closely with the regulator in determining required network investment in light of the overall balancing needs. This requirement raises questions about the situation that is common across Europe in which system operator and transmission owner are combined within a single organization.

Capacity mechanisms: One of the key functions of the central planning authority in non-liberalized markets has been to ensure that enough supply capacity was built and to plan the appropriate time to retire old capacity. One of the key decisions facing designers of liberalized markets has been to identify who should assume this responsibility and how it should be done.

In energy-only markets, the decision about capacity requirements is entirely devolved to market participants. Revenues for low utilization assets will be strongly affected by the likelihood of shortage (loss of load probability - LOLP) and the price that consumers are prepared to pay at this time (value of lost load - VOLL). These forecasts are extremely difficult to make and, as the proportion of variable renewables on the system increases, this challenge will affect the future economic viability of an increasing proportion of power plants and other balancing resources. In some energy-only markets, the spot/balancing price for power is explicitly capped at a particular level in the expectation that this price will be reached at, or near, times of capacity shortage. Alternatively, the price might automatically be fixed under these conditions. This will tend to reduce, but not eliminate, the forecasting challenge.

Capacity procurement has been incorporated explicitly into the designs of many liberalized power markets to replace the capacity planning function in the traditional centralized structures. The challenge in calculating the economic value of the marginal power plant under energy-only markets has increased calls for capacity markets to be more widely and explicitly adopted, although the issue remains hotly debated. Generally, these markets do not replicate exactly the central planning security standard calculations. Instead, they fall into one of two categories:

- The quantity of capacity is centrally determined, or

- A fixed payment is made to each unit of capacity.

Where the quantity of capacity is determined, there are various approaches to capacity procurement. The main alternatives are:

- Periodic auctions, with prices determined by the marginal accepted bid and paid to all successful bidders.
- Periodic auctions for additional capacity with the marginal accepted bid only paid to additional procured capacity. This is the so-called targeted approach.
- An obligation on suppliers to maintain a margin over their peak load.
- A variable capacity value is calculated in each time period and paid to all capacity available at that time. The calculation ensures that the value is greatest at times when capacity margins are tight.

Where a fixed payment is made, it is usually calculated on the basis that it will just recover the fixed costs of the marginal increment of capacity (often an open cycle gas turbine).

A key feature of many of these administrative approaches is that the fixed payment or quantity does not adjust in light of consumer VOLL (assumed or real). However, enhanced information and communication technology presents the possibility that large proportions of power demand will become controllable – potentially providing large quantities of flexible demand response. Moreover, many end consumers may choose to manage their individual power usage in light of variable short run power prices and would effectively be expressing their individual VOLL. Administered capacity markets will tend to suppress this development by imposing a system-wide security standard on all market participants. It is possible that such practices will become commonplace if supported by easy-to-use artificial intelligence and the proportion of "active" demand might become significant over the coming years.

As the proportion of variable renewable resources increases, it becomes increasingly important that the total available capacity provides the correct mix of dynamic and back-up capability to maintain security of supply. This suggests that traditional capacity markets that purely deliver system peak capacity are likely to be insufficient going forward and it is instead necessary to ensure that market arrangements incentivize the full range of system services that will be required.

In conclusion, there is no single market design that is emerging as the clearly preferred approach for power systems incorporating high volumes of variable renewables. For example, the benefits of a separate capacity market and the particular design to adopt remain hotly debated issues. However, the following issues appear to be extremely important in accommodating high levels of renewable penetration:

- The balancing market and imbalance settlement process must align with the renewable subsidy regime to create an overall environment that will encourage significant investment in renewable generation. In many regimes, renewables are insulated from imbalance penalties and, therefore, the short-term market design is less relevant. However, this is not sustainable with very high levels of renewable penetration given the inefficiencies created. In those markets where renewables are exposed to imbalance costs, it is important that these costs accurately reflect energy imbalances and are not polluted by system costs. In addition, renewable generators should be able to trade in physical markets as near to real time as possible and it is necessary to ensure that these markets are sufficiently liquid. Short term liquid markets and manageable imbalance risks are also important in attracting new players to the market which is likely to play a key role in stimulating the development of the demand side of the market.

- It is apparent that accurate forecasting of short-term availability of renewable generators requires a system-wide perspective with live data from a geographically disperse fleet of assets being used to support advanced probabilistic forecasting techniques. At present, it appears that the system operator is better placed than individual market participants to make these forecasts and, therefore, is the appropriate body to decide on balancing requirements and schedule reserve resources accordingly. However, in the future, sophisticated artificial intelligence forecasting techniques may eliminate this advantage.

- The role of the system operator in forecasting and scheduling requires that an appropriate regulatory framework and set of market arrangements are in place to minimize the costs of balancing. The same considerations apply to supporting investment in flexible resources such as storage and demand response as in renewable generation assets. It is necessary to strike a balance between signing long-term contracts to procure assets capable of providing the necessary flexibility and procurement through short-term markets.

References

ABB (2010, July 19). ABB commissions world's longest and most powerful transmission link. Retrieved from https://new.abb.com/news/detail/12798/abb-commissions-worlds-longest-and-most-powerful-transmission-link.

African Development Bank. (2013). Energy sector capacity building diagnostic and needs assessment study. Retrieved from https://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/Energy_Sector_Capacity_Building_Diagnostic_and_Needs_Assessment_Study.pdf.

Africa Energy Portal (2019, August 30). Madagascar: 35 MW hydroelectric power plant in project in Antananarivo. Retrieved from https://africa-energy-portal.org/news/madagascar-35-mw-hydroelectric-power-plant-project-antananarivo.

Agora Energiewende (2017). Flexibility in thermal power plants: with a focus on existing coal-fired power plants. Retrieved from https://www.agora-energiewende.de/fileadmin2/Projekte/2017/Flexibility_in_thermal_plants/115_flexibility-report-WEB.pdf.

Alam, F. *et al*. (2017). Regional power trading and energy exchange platforms. *Energy Procedia*, 110, 592-596. Retrieved from https://www.sciencedirect.com/science/article/pii/S1876610217302205.

Arndt, C. *et al*. (2019). Faster than you think: renewable energy and developing countries. *Annual Review of Resources Economics*, 11, 149-168. Retrieved from https://www.annualreviews.org/doi/10.1146/annurev-resource-100518-093759.

ASEAN Capital Markets Forum (2018). ASEAN Green Bond Standards. Retrieved from https://www.theacmf.org/images/downloads/pdf/AGBS2018.pdf.

Association of Southeast Asian Nations (2019, September 23). ASEAN Joint Statement to the United Nations Climate Action Summit 2019. Retrieved from https://asean.org/storage/2019/09/AJSCC-to-UN-Climate-Action-Summit-2019-ADOPTED.pdf.

As You Sow (2020). Carbon clean 200™: investing in a clean energy future. Retrieved from https://www.asyousow.org/report-page/2020-clean200.

Ayaz, H. (2017). Analysis of carbon emission accounting practices of leading carbon emitting European Union companies. *Athens Journal of Business & Economics*, 3 (4), 463-486. Retrieved from https://www.athensjournals.gr/business/2017-3-4-5-Ayaz.pdf.

Ball, J., Reicher D., Sun X., and Pollok C. (2017). The new solar system: China's evolving solar industry and its implications for competitive solar power in the united states and the world. Stanford: Steyer-Taylor Center for Energy Policy and Finance. Retrieved from https://law.stanford.edu/wp-content/uploads/2017/03/2017-03-20-Stanford-China-Report.pdf.

Belt and Road Energy Cooperation (2019). Cooperation principles and concrete actions of the Belt and Road energy partnership (BREP). Retrieved from http://obor.nea.gov.cn/detail/8210.html.

Belt and Road Energy Cooperation (2019). The Belt and Road energy partnership (BREP) was officially established in Beijing. Retrieved from https://bremc.obor.nea.gov.cn/showOneNews?nd=17.

Belt and Road Portal (2019). "图解："一带一路" 倡议六年成绩单" [Illustration: six years' report card for Belt and Road Initiative]. Retrieved from https://www.yidaiyilu.gov.cn/xwzx/gnxw/102792.htm.

Belt and Road Portal (2020). "已同中国签订共建"一带一路"合作文件的国家一览" [List of countries that have signed a BRI cooperation agreement with China]. Retrieved from https://www.yidaiyilu.gov.cn/xwzx/roll/77298.htm.

Bhamidi, L. and Sadhukhan, A. (2017). Multi-objective optimization for demand side management in a smart grid environment. 2017 7th International Conference on Power Systems. Retrieved from https://www.researchgate.net/figure/DSM-load-shape-methods_fig1_325935562.

Bloomberg (2019, October 31). World's biggest solar plant starts in Abu Dhabi, JinkoSolar Says. Retrieved from https://www.bloomberg.com/news/articles/2019-10-31/world-s-biggest-solar-plant-starts-in-abu-dhabi-jinkosolar-says.

Bloomberg New Energy Finance (2017). New energy outlook. Retrieved from https://data.bloomberglp.com/bnef/sites/14/2017/06/NEO-2017_CSIS_2017-06-20.pdf.

Bloomberg New Energy Finance (2020). Clean energy investment trends, 2019. Retrieved from https://data.bloomberglp.com/professional/sites/24/BloombergNEF-Clean-Energy-Investment-Trends-2019.pdf.

Bloomberg New Energy Finance (2020 June). LCOE forecast. Bloomberg data terminal. Retrieved from https://bba.bloomberg.net.

Booth, A., Mohr, N., and Peters, P. (2016). The digital utility: New opportunities and challenges. McKinsey & Company. Retrieved from https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/the-digital-utility-new-opportunities-and-challenges.

Breu, M., Castellano, A., Frankel, D., and Rogers, M. (2019). Exploring an alternative pathway for Vietnam's energy future. McKinsey & Company. Retrieved from https://www.mckinsey.com/featured-insights/asia-pacific/exploring-an-alternative-pathway-for-vietnams-energy-future.

Brite Bridges (2018). How decentralized energy solutions are closing the access gap in Africa. Retrieved from https://briterbridges.com/how-decentralised-energy-solutions-are-closing-the-energy-access-gap-in-africa.

Buchner, B. *et al.* (2019). Global landscape of climate finance 2019. Climate Policy Initiative. Retrieved from https://www.climatepolicyinitiative.org/wp-content/uploads/2019/11/2019-Global-Landscape-of-Climate-Finance.pdf.

Cabré, M., Gallagher, K. P. and Li, Z. (2018). Renewable energy: the trillion dollar opportunity for Chinese overseas investment. *China & World Economy*, 26: 27-49. Retrieved from https://onlinelibrary.wiley.com/doi/abs/10.1111/cwe.12260.

CAF Development Bank of Latin America (2018, December 20). CAF, BICE, and Banco de la Ciudad finance Cafayate solar plant to promote the production of cleaner energy in Argentina. Retrieved from https://www.caf.com/en/currently/news/2018/12/caf-bice-and-banco-de-la-ciudad-finance-cafayate-solar-plant-to-promote-the-production-of-cleaner-energy-in-argentina/.

Carbon Brief (2018, October 15). The Carbon Brief profile: South Africa. Retrieved from https://www.carbonbrief.org/the-carbon-brief-profile-south-africa.

Central Electricity Regulatory Commission (2016, April 6). Notification No. L-1/18/2010-CERC. Retrieved from http://www.cercind.gov.in/2016/regulation/124_1.pdf.

Climate Home News (2020, September 17). Which countries have a net zero carbon goal? Retrieved from https://www.climatechangenews.com/2020/09/17/countries-net-zero-climate-goal/.

CGTN (2020, September 23). Full text: Xi Jinping's speech at the general debate of the 75th session of the United Nations General Assembly. Retrieved from https://news.cgtn.com/news/2020-09-23/Full-text-Xi-Jinping-s-speech-at-General-Debate-of-UNGA-U07X2dn8Ag/index.html.

Charles River Associates (2005). Primer on demand-side management: with an emphasis on price-responsive programs. World Bank. Retrieved from https://openknowledge.worldbank.org/handle/10986/8252.

Chen, Y. (2018). “推动绿色金融标准体系建设” [Promoting the construction of green finance standards system]. China Finance. Retrieved from https://www.cnki.com.cn/Article/CJFDTotal-ZGJR201820003.htm.

China Banking Association (eds.) (2018). “绿色信贷” [Green bonds and loans]. China Financial Publishing House. Not available online.

China Council for International Cooperation on Environment and Development (2009). China’s pathway towards a low carbon economy. Retrieved from http://www.cciced.net/ccicedPhoneEN/Events/AGMeeting/2009_3973/meetingplace_3974/201609/P020160922381047979521.pdf.

China Daily (2019, April 27). Xi's full remarks at the leaders' roundtable meeting of the Second Belt and Road Forum for International Cooperation. Retrieved from https://www.chinadaily.com.cn/a/201904/27/WS5d9c5982a310cf3e3556f389.html.

China Energy Storage Alliance (2019). “储能产业研究白皮书” [Energy Storage white paper]. Not available online.

China’s Government Portal (2014). “李克强：要像对贫困宣战一样 坚决向污染宣战” [Li Keqiang: We will resolutely declare war against pollution as we declared war against poverty] . Retrieved from http://www.gov.cn/zhuanti/2014-03/06/content_2631811.htm.

China Green Finance Committee (2018). “湖州制定全国首批绿色金融地方标准” [Huzhou formulates the first batch of local standards for green finance]. Retrieved from http://www.greenfinance.org.cn/displaynews.php?id=2236.

China Green Finance Committee (2018). “绿色金融动态” [Latest news of green finance] . Retrieved from http://www.greenfinance.org.cn/displaynews.php?id=2368.

China Industrial Bank Guangzhou Branch (2020). “粤港澳大湾区绿色债券市场国际化及其发展路径研究” [Research of internationalization and development path of green bond market of Guangdong-Hong Kong-Macau Greater Bay Area]. South China Finance. Retrieved from https://kns.cnki.net/KCMS/detail/detail.aspx?dbcode=CJFQ&dbname=CJFDLAST2020&filename=GDJR202001009&v=MTIxMjRmTEc0SE5ITXJvOUZiWVI4ZVgxTHV4WVM3RGgxVDNxVHJXTTFGckNVUjdxZlllUm9GeUhsVjd2TUlpbkI=.

China.org (2012). Report of Hu Jintao to the 18th CPC National Congress. Retrieved from http://www.china.org.cn/china/18th_cpc_congress/2012-11/16/content_27137540_8.htm.

Citizens Climate Lobby (2020). Jobs: fossil fuels vs clean energy. Retrieved from https://citizensclimatelobby.org/laser-talks/jobs-fossil-fuels-vs-renewables/.

Climate Bond Initiative (n.d.). Climate bond standard and certification. Retrieved from https://www.climatebonds.net/standard.

Climate Bonds Initiative and Syntao Green Finance (2017). Study of China’s local government policy instruments for green bonds. Retrieved from https://cn.climatebonds.net/files/files/ChinaLocalGovt_02_13_04_final_A4.pdf.

Cochran J. *et al*. (2015). Grid interaction and the carrying capacity of the US Grid to incorporate Variable Renewable Energy. National Renewable Energy Laboratory. Retrieved from https://www.nrel.gov/docs/fy15osti/62607.pdf.

Danish Energy Agency (n.d.). The Danish energy model: innovative, efficient and sustainable. Retrieved from https://ens.dk/en/our-responsibilities/global-cooperation/danish-energy-model.

Du Xiangwan (2016). “低碳发展总论” [Low-carbon Development Introduction]. China Environmental Publishing Group. Not available online.

Eberle, A. *et al.* (2017). Systematic review of life cycle GHG for geothermal electricity. National Renewable Energy Laboratory. Retrieved from https://www.nrel.gov/docs/fy17osti/68474.pdf.

Ehlers, T., and Packer, F. (2017). Green bond finance and certification. *BIS Quarterly Review*, September. Retrieved from https://www.bis.org/publ/qtrpdf/r_qt1709h.htm.

ENERGIA, World Bank and UN Women (2018). Policy brief: global progress of SDG 7 – energy and gender. Sustainable Development Goals Knowledge Platform. Retrieved from https://sustainabledevelopment.un.org/content/documents/17489PB12.pdf.

Environmental Research Center at Duke Kunshan University (2019). “中国碳定价顶层设计的经济学分析” [Economic analysis of top-level design of China’s carbon pricing]. Retrieved from http://www.efchina.org/Reports-zh/report-lceg-20190804-zh.

European Commission (2011). A roadmap for moving to a competitive low carbon economy in 2050. Retrieved from https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0112:FIN:EN:PDF.

European Commission (2018). Communication from the Commission to the European Parliament, the European Council, the Council, the European Central Bank, the European Economic and Social Committee and the Committee of the Regions. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018DC0097&from=EN.

European Commission (2020). European neighbourhood policies and enlargement negotiations: twinning. Retrieved from https://ec.europa.eu/neighbourhood-enlargement/tenders/twinning_en.

European Commission (n.d.). Market stability reserve. Retrieved from https://ec.europa.eu/clima/policies/ets/reform_en.

European Commission (n.d.). Monitoring, reporting and verification of EU ETS emissions. Retrieved from https://ec.europa.eu/clima/policies/ets/monitoring_en.

European Commission (n.d.). Phases 1 and 2 (2005-2012). Retrieved from https://ec.europa.eu/clima/policies/ets/pre2013_en.

European Emissions Trading System (n.d.). EU ETS product benchmarks. Retrieved from https://www.emissions-euets.com/product-benchmarks.

European Wind Energy Technology Platform (2013). Workers wanted: the EU wind energy sector skills gap. Retrieved from http://www.windplatform.eu/fileadmin/ewetp_docs/Documents/reports/Workers_Wanted_TPwind.pdf.

Executive Office of the President of the United States (2013). The President's Climate Action Plan. Retrieved from https://obamawhitehouse.archives.gov/sites/default/files/image/president27sclimateactionplan.pdf.

Executive Office of the President of the United States (2014). The all-of-the-above energy strategy as a path to sustainable economic growth. Retrieved from https://scholar.harvard.edu/files/stock/files/all_of_the_above_energy_strategy.pdf.

Fine, S. *et al*. (2017). Penetration of Variable Energy Resources (VERs) – US Outlook and Perspectives. In: Jones, L. (ed) *Renewable Energy Integration: Practical management of variability, uncertainty and flexibility in power grids*. Academic Press, 15-26. Retrieved from https://www.sciencedirect.com/science/article/pii/B9780128095928000020.

Gallego-Alvarez, I. Martínez-Ferrero, J. & Cuadrado-Ballesteros. B. (2016). Accounting treatment for carbon emission rights. Systems 4, 12. Retrieved from https://www.mdpi.com/2079-8954/4/1/12/xml.

Garrett-Peltier, H. (2017). Green versus brown: comparing the employment impacts of energy efficiency, renewable energy, and fossil fuels using an input-output model. *Economic Modelling*, 61, February, 439-447. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S026499931630709X.

Global Carbon Capture Storage Institute (2019). Is CCS expensive? Decarbonization costs in the net-zero context. Retrieved from https://www.globalccsinstitute.com/wp-content/uploads/2020/05/Cost_Brief_Final_May_2020.pdf.

Global Carbon Capture and Storage Institute (2020). Global CCS 2019 report. Retrieved from https://www.globalccsinstitute.com/resources/global-status-report/.

Global Energy Interconnection Development and Cooperation Organization (2019). Development report on global energy interconnection for promoting the Belt and Road. Retrieved from https://www.geidco.org/html/ydyl/ydyl.html.

Global Energy Interconnection Development and Cooperation Organization (2019). Six agreements signed and Plan for Belt and Road energy interconnection released. Retrieved from https://m.geidco.org/article/633.

Goldwind (2019, April 12). Goldwind’s overseas service solution factories completed and put into operation. Retrieved from http://www.goldwindglobal.com/news/focus-article.html?id=2279.

Greater Bay Area (2020). Environmental protection and sustainable development. Retrieved from https://www.bayarea.gov.hk/en/opportunities/mainpoints-environmental.html.

Greenpeace and Sichuan Province Cyclic Economy Center (2019). “ ‘一带一路’后中国企业风电、光伏海外股权投资趋势分析” [Analysis on the trend of Chinese enterprises’ overseas equity investment in wind power and solar PV after the Belt and Road Initiative]. Retrieved from https://www.greenpeace.org.cn/china-overseas-re-investment/.

Greenovation Hub (2020). Investment and financing models, challenges and recommendations of renewable energy projects by Chinese companies in the Belt and Road countries. Retrieved from http://www.ghub.org/en/bri-re-report/.

Guterres, A. (2019). Report of the Secretary-General on SDG progress 2019. Special Edition. United Nations. Retrieved from https://sustainabledevelopment.un.org/content/documents/24978Report_of_the_SG_on_SDG_Progress_2019.pdf.

Ha, T. (2019, November 19). Gusty growth: Vietnam's remarkable wind energy story. *Eco-business*. Retrieved from https://www.eco-business.com/news/gusty-growth-vietnams-remarkable-wind-energy-story/.

Heiligtag, S. *et al*. (2019). Fueling the energy transition: opportunities for financial institutions. McKinsey & Company. Retrieved from https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/fueling-the-energy-transition-opportunities-for-financial-institutions.

Helman, C. (2017, January 11). Ambitious Texas carbon capture project turns rocky for NRG at USD 50 oil. Forbes. Retrieved from https://www.forbes.com/sites/christopherhelman/2017/01/11/nrg-energy-ceo-carbon-capture-is-very-challenging-at-50-oil/#364fc1ac5b22.

Hepburn C. *et al*. (forthcoming 2020). Will COVID-19 fiscal recovery packages accelerate or retard progress on climate change? Forthcoming in the *Oxford Review of Economic Policy* 36 (S1). Retrieved from https://www.smithschool.ox.ac.uk/publications/wpapers/workingpaper20-02.pdf.

Hesser T., *et al*. (2012). Renewables Integration through Direct Load Control and Demand Response. In Sioshansi, Fereidoon P. (ed.) *Smart Grid*. Academic Press: 209-233. Retrieved from https://www.sciencedirect.com/science/article/pii/B9780123864529000097.

Huang, J. *et al*. (2018). The effect of technological factors on China's carbon intensity: new evidence from a panel threshold model. *Energy Policy*, 115, 32-42. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S0301421517308248.

Independent Group of Scientists appointed by the Secretary-General (2019). Global sustainable development report 2019: the future is now–science for achieving sustainable development. Retrieved from https://sustainabledevelopment.un.org/content/documents/24797GSDR_report_2019.pdf.

Inter-American Development Bank (2018). IDB invest finances the construction of an 80 MW solar plant in Argentina. Retrieved from https://www.iadb.org/en/news/idb-invest-finances-construction-80-mw-solar-plant-argentina.

Intergovernmental Panel on Climate Change (2018). Global warming of 1.5°C. Retrieved from https://www.ipcc.ch/sr15/.

International Accounting Standards Board (2005). IASB withdraws IFRIC interpretation on emission rights. Retrieved from https://www.iasplus.com/en/binary/pressrel/0507withdrawifric3.pdf.

International Development Association (2016). Further details on the proposed IFC-MIGA private sector window in IDA18. Retrieved from http://documents.worldbank.org/curated/en/947651474898912390/pdf/Further-Details-on-the-Proposed-IFC-MIGA-Private-Sector-Window-in-IDA18.pdf.

International Energy (2015). 5th anniversary of Xiangjiaba-Shanghai ±800kV UHV-DC project. Retrieved from https://www.in-en.com/article/html/energy-2234725.shtml.

International Energy Agency (2017). Denmark 2017 review. Energy Policies of IEA Countries. Retrieved from https://webstore.iea.org/download/direct/266?fileName=EnergyPoliciesofIEACountriesDenmark2017Review.pdf.

International Energy Agency (2017). Energy access outlook 2017. Retrieved from https://www.iea.org/access2017/.

International Energy Agency (2017). World energy outlook 2017. Retrieved from https://www.iea.org/reports/world-energy-outlook-2017.

International Energy Agency (2018). Renewables 2018: analysis and forecasts to 2023. Retrieved from https://www.iea.org/reports/renewables-2018.

International Energy Agency (2019). China power system transformation: assessing the benefit of optimized operations and advanced flexibility options. Retrieved from https://webstore.iea.org/download/direct/2440?fileName=China_Power_System_Transformation.pdf.

International Energy Agency (2019). Data and statistics. Retrieved from https://www.iea.org/data-and-statistics?country=CHINAREG&fuel=Energy%20supply&indicator=Total%20primary%20energy%20supply%20(TPES)%20by%20source.

International Energy Agency (2019). Energy policies of IEA countries: Sweden 2019 review. Retrieved from https://www.iea.org/reports/energy-policies-of-iea-countries-sweden-2019-review.

International Energy Agency (2019). Offshore wind outlook 2019. Retrieved from https://www.iea.org/reports/offshore-wind-outlook-2019.

International Energy Agency (2019). Onshore wind. Tracking Report. https://www.iea.org/reports/onshore-wind.

International Energy Agency (2019). Solar photovoltaics: an analysis. Retrieved from https://www.iea.org/reports/solar-pv.

International Energy Agency (2019). South Africa energy outlook: analysis from Africa energy outlook 2019. Retrieved from https://www.iea.org/articles/south-africa-energy-outlook.

International Energy Agency (2019). Status of power system transformation. Retrieved from https://www.iea.org/reports/status-of-power-system-transformation-2019.

International Energy Agency (2019). World energy outlook. Retrieved from https://webstore.iea.org/download/summary/2467?fileName=Arabic-Summary-WEO2019.pdf.

International Energy Agency (2020). Electricity generation by source in the world and in China. Data and Statistics. Retrieved from https://www.iea.org/data-and-statistics?country=WORLD&fuel=Energy%20supply&indicator=Electricity%20generation%20by%20source.

International Energy Agency (2020). Global CO_2 emissions in 2019. Retrieved from https://www.iea.org/articles/global-co2-emissions-in-2019.

International Energy Agency (2020). Data and statistics: Denmark, power generation. International Energy Agency Database. Retrieved from https://www.iea.org/data-and-statistics?country=DENMARK&fuel=Energy%20supply&indicator=Electricity%20generation%20by%20source

International Energy Agency (2020). Renewable energy market update. Outlook for 2020 and 2021. Retrieved from https://www.iea.org/reports/renewable-energy-market-update.

International Energy Agency (2020). Sustainable recovery. World Energy Outlook Special Report. Retrieved from https://www.iea.org/reports/sustainable-recovery.

International Energy Agency (2020). TPES by source in the world and in China. Data and Statistics. Retrieved from https://www.iea.org/data-and-statistics?country=WORLD&fuel=Energy%20supply&indicator=Total%20primary%20energy%20supply%20(TPES)%20by%20source.

International Energy Agency. (2020). World energy investment. Retrieved from https://www.iea.org/reports/world-energy-investment-2020.

International Energy Agency. (2020). World energy outlook. Retrieved from https://www.iea.org/reports/world-energy-outlook-2020.

International Energy Agency (n.d.). Solar. Retrieved from https://www.iea.org/fuels-and-technologies/solar.

International Energy Agency and International Renewable Energy Agency (2013). Solar photovoltaics technology brief. Retrieved from https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2015/IRENA-ETSAP-Tech-Brief-E11-Solar-PV.ashx?la=en&hash=229A7B44B1FD2456A671462327F089C5AA847689.

International Energy Agency and International Renewable Energy Agency (2016). Wind power technology brief. Retrieved from https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA-ETSAP_Tech_Brief_Wind_Power_E07.pdf.

International Energy Agency and Organization for Economic Cooperation and Development (2010). Low Emission Development Strategies (LEDS). Retrieved from https://sustainabledevelopment.un.org/index.php?page=view&type=400&nr=708&menu=1515.

International Finance Corporation (2017). Partnering with IFC syndications. Retrieved from http://ifcglobaldebtconference.lightdigital.cloud/attachments/model-2-syndications-brochure-september-2017-final-9-8-2017_1505390592.pdf.

International Finance Corporation (n.d.). Managed Co-Lending Portfolio Program (MCPP). Retrieved from https://www.ifc.org/wps/wcm/connect/corp_ext_content/ifc_external_corporate_site/solutions/products+and+services/syndications/mcpp.

International Finance Corporation (n.d.). MCPP infrastructure. Retrieved from https://www.ifc.org/wps/wcm/connect/4c9e0868-1232-4212-b4f2-a5c39d177afa/MCPP+Infrastructure+Flyer+2018.pdf?MOD=AJPERES&CVID=mcoa4bt.

International Financial Reporting Standards (2010). IASB update. Retrieved from http://media.ifrs.org/IASBUpdateNov2010.html.

International Financial Reporting Standards (n.d.). Pollutant pricing mechanisms. Retrieved from https://www.ifrs.org/projects/work-plan/pollutant-pricing-mechanisms/#project-history.

International Labour Organization (2011). Skills and occupational needs in renewable energy. Retrieved from https://www.ilo.org/wcmsp5/groups/public/---ed_emp/---ifp_skills/documents/publication/wcms_166823.pdf.

International Labour Organization (2016). Green jobs: progress report 2014-15. Retrieved from https://www.ilo.org/wcmsp5/groups/public/---ed_emp/---emp_ent/documents/publication/wcms_502730.pdf.

International Monetary Fund (n.d.). IMF DataMapper. Retrieved from https://www.imf.org/external/datamapper/NGDP_RPCH@WEO/OEMDC.

International Renewable Energy Agency (2012). Capacity-building strategic framework for IRENA (2012 – 2015). Retrieved from https://www.irena.org/publications/2012/Nov/Capacity-Building-Strategic-Framework-for-IRENA-2012--2015.

International Renewable Energy Agency (2014). Tidal energy. Technology Brief. Retrieved from https://www.irena.org/publications/2014/Jun/Tidal-Energy.

International Renewable Energy Agency (2017). Renewable energy and jobs: annual review. Retrieved from https://www.irena.org/publications/2017/May/Renewable-Energy-and-Jobs--Annual-Review-2017.

International Renewable Energy Agency (2018). Renewable energy and jobs: annual review 2018. Retrieved from https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/May/IRENA_RE_Jobs_Annual_Review_2018.pdf.

International Renewable Energy Agency (2019). Flexibility in conventional power plants. Innovation Landscape Brief. Retrieved from https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_Flexibility_in_CPPs_2019.pdf?la=en&hash=AF60106EA083E492638D8FA9ADF7FD099259F5A1.

International Renewable Energy Agency (2019). Hydrogen: a renewable energy perspective. Retrieved May 2020, from https://irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_Hydrogen_2019.pdf.

International Renewable Energy Agency (2019). Innovation landscape for a renewable-powered future. Retrieved from https://www.irena.org/publications/2019/Feb/Innovation-landscape-for-a-renewable-powered-future.

International Renewable Energy Agency (2019). Renewable energy: a gender perspective. Retrieved from https://www.irena.org/publications/2019/Jan/Renewable-Energy-A-Gender-Perspective.

International Renewable Energy Agency. (2019). Renewable energy and jobs – annual review 2019. Retrieved from https://www.irena.org/publications/2019/Jun/Renewable-Energy-and-Jobs-Annual-Review-2019.

International Renewable Energy Agency (2019). Renewable power generation costs in 2018. Retrieved from https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Jun/IRENA_Power_Generation_Costs_2019.pdf.

International Renewable Energy Agency (2019). Supergrids. Innovation Landscape Brief. Retrieved from https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_Supergrids_2019.pdf?la=en&hash=4C6639C08B1BEC582B700609C6D3C3B2E126AE70.

International Renewable Energy Agency (2019). Transforming the energy system and holding the line on rising global temperature. Retrieved from https://www.irena.org/publications/2019/Sep/Transforming-the-energy-system.

International Renewable Energy Agency (2020). Global renewables outlook: energy transformation 2050. Retrieved from https://www.irena.org/publications/2020/Apr/Global-Renewables-Outlook-2020.

International Renewable Energy Agency (2020). Renewable energy finance: green bonds. Retrieved from https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Jan/IRENA_RE_finance_Green_bonds_2020.pdf.

International Renewable Energy Agency (2020). Renewable power generation costs in 2019. Retrieved https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Jun/IRENA_Power_Generation_Costs_2019.pdf.

International Renewable Energy Agency (n.d.). Hydropower. Retrieved from https://www.irena.org/hydropower.

International Renewable Energy Agency (n.d.). Geothermal energy. Retrieved from https://www.irena.org/geothermal.

International Renewable Energy Agency (n.d.). Renewable Readiness Assessment (RRA). Retrieved from https://www.irena.org/rra.

International Renewable Energy Agency (n.d.). Solar energy. Retrieved from https://www.irena.org/solar.

International Renewable Energy Agency *et al*. (2020). Tracking SDG 7. The Energy Progress Report. Retrieved from https://www.irena.org/publications/2020/May/Tracking-SDG7-The-Energy-Progress-Report-2020.

Ji, J. and Liang, H. (2018). Annual report on investment security of China's "the Belt and Road" construction. Blue Book of Investment Security of "the Belt and Road" Construction. No. 2. Beijing: Social Sciences Academic Press (China).

JinkoSolar (2019, March 22). JinkoSolar announces fourth quarter and full year 2018 financial results. Retrieved from http://ir.jinkosolar.com/news-releases/news-release-details/jinkosolar-announces-fourth-quarter-and-full-year-2018-financial.

JinkoSolar (2020). About JinkoSolar Holding Co., Ltd. Retrieved from https://www.jinkosolar.com/en/site/aboutus.

Kittner, N. *et al*. (2020). Grid-scale Energy Storage. In: Junginger M., and Atse L. (eds.) *Technological Learning in The Transition to a Low-Carbon Energy System: conceptual issues, empirical findings, and use in energy modelling*. Academic University Press, 1st edition., 119-143. Retrieved from https://www.sciencedirect.com/science/article/pii/B978012818762300008X.

Khan, I. (2019). Energy-saving behaviour as a demand-side management strategy in the developing world: the case of Bangladesh. *International Journal of Energy and Environmental Engineering*, 10, 493–51. Retrieved from https://link.springer.com/article/10.1007/s40095-019-0302-3.

Li, J. (2019). "低碳经济视角下中国绿色金融发展研究" [Research on China's green finance development in the perspective of low-carbon economy]. Retrieved from https://www.cnki.com.cn/Article/CJFDTotal-CKTX201929009.htm.

Li, Q. *et al*. (2020). "分布式能源规模化发展前景及关键问题" [Outlook and critical issues of large-scale development on distributed energy resources]. *Distributed Energy*, 5(2), 1-7. Retrieved from http://der.tsinghuajournals.com/CN/Y2020/V5/I2/1.

Liu, L. and Zhang, Y. (2018). "基于碳排放权交易市场的碳税制度研究" [Research on carbon tax system based on market of carbon emissions trading]. *Taxation Research*. Retrieved from http://www.tanpaifang.com/tanshui/2019/0509/63900.html.

Liu, M., Feng, X., Wang, S., & Qiu, H. (2020). China's poverty alleviation over the last 40 years: successes and challenges. *Australian Journal of Agricultural and Resource Economics*, 64 (1), 209-228. Retrieved from https://onlinelibrary.wiley.com/doi/abs/10.1111/1467-8489.12353.

Long, W. (2019). “第三代分布式能源系统及其应用” [The third generation of distributed energy system and application]. *Journal of HV & AC*. Retrieved from http://www.cnki.com.cn/Article/CJFDTotal-NTKT201907001.htm.

LONGi Solar. (2019, November 11). JBM Group exclusively selected LONGi high efficiency monocrystalline modules for their 135MW Maharashtra project in India. Retrieved from https://en.longi-solar.com/home/events/press_detail/id/168_JBM_Group_exclusively_selected_LONGi_high_efficiency_monocrystalline_modules_for_their_135MW_Maharashtra_project_in_India.html.

Lou, S., Lu, S., Wu, Y., and Yin, X. (2013). “低碳电力系统规划与运行优化研究综述” [An overview on low-carbon power system planning and operation optimization]. *Power System Technology*.

Ma, J. and Sun, T. (2020). “气候变化对金融稳定的影响” [The impact of climate change on financial stability]. *Modern Finance Guide*. Retrieved from http://www.tanpaifang.com/tanjinrong/2020/0602/71210.html.

Madagascar’s Ministry of Water, Energy and Hydrocarbons (2018). Investment plan for renewable energy in Madagascar. Retrieved from https://www.climateinvestmentfunds.org/sites/cif_enc/files/srepinvestment_plan_for_madagascar_final.pdf.

McKinsey & Company. (2020). How a post-pandemic stimulus can both create jobs and help the climate. Retrieved from https://www.mckinsey.com/business-functions/sustainability/our-insights/how-a-post-pandemic-stimulus-can-both-create-jobs-and-help-the-climate#.

Mercure, J.-F. *et al*. (2018). Macroeconomic impact of stranded fossil fuel assets. *Nature Climate Change*, 8, 588-593. Retrieved from https://www.nature.com/articles/s41558-018-0182-1.

Ministry of Commerce of the People’s Republic of China (2020). “商务部：去年与“一带一路”沿线国家货物贸易额增长 6%” [Ministry of Commerce: trade volume with countries along the Belt and Road increased by 6% last year]. Retrieved from http://tradeinservices.mofcom.gov.cn/article/tongji/guonei/buweitj/swbtj/202001/97482.html.

Ministry of Commerce of the People’s Republic of China(2020). “6 年时间中国与“一带一路”沿线国家货物贸易总额超 7.8 万亿美元” [China's trade volume with countries along the Belt and Road exceeded 7.8 trillion U.S. dollars in six years]. Retrieved from http://www.mofcom.gov.cn/article/i/jyjl/e/202005/20200502966315.shtml.

Ministry of Ecology and Environment of the People’s Republic of China (2017). “一带一路生态环境保护合作规划” [Cooperation Plan of Ecological and Environmental Protection along the Belt and Road]. Retrieved from http://www.mee.gov.cn/gkml/hbb/bwj/201705/W020170516330272025970.pdf.

Ministry of Ecology and Environment of the People’s Republic of China (2019). “中国应对气候变化的政策与行动 2019 年度报告” [Annual report on policies and actions to address climate change (2019)]. Retrieved from http://www.mee.gov.cn/ywdt/hjnews/201911/W020191127531889208842.pdf.

Ministry of Finance of the People’s Republic of China (2019). Notice on issuing interim provisions of accounting standards for carbon emissions trading. Retrieved from http://kjs.mof.gov.cn/zhengcefabu/201912/t20191223_3448268.htm.

Ministry of Industry and Information Technology of the People’s Republic of China (2018). “工业和信息化部关于印发坚决打好工业和通信业污染防治攻坚战三年行动计划的通知” [Notice of the Ministry of Industry and Information Technology on printing and distributing the Three-year Action Plan for Resolutely Fighting the Pollution of the Industry and Communication Industry]. Retrieved from http://www.miit.gov.cn/n1146285/n1146352/n3054355/n3057542/n3057545/c6273874/content.html.

Ministry of Science and Technology of the People’s Republic of China (2019). Roadmap for Carbon Capture, Utilization and Storage Technology Development in China. Not available online.

Mundaca, L., Ürge-Vorsatz, D. & Wilson, C. (2019). Demand-side approaches for limiting global warming to 1.5 °C. *Energy Efficiency*, 12, 343–362 Retrieved from https://link.springer.com/article/10.1007/s12053-018-9722-9.

National Aeronautics and Space Administration (n.d.). Global climate change: vital signs of the planet. Retrieved from https://climate.nasa.gov/vital-signs/sea-level/.

National Business Daily (2009, November 27). "中国承诺：到 2020 年碳减排 40%~45%" [Commitment from China: reducing carbon intensity by 40% - 45% by 2020] . Retrieved from http://www.nbd.com.cn/articles/2009-11-27/255297.html.

National Development and Reform Commission (2017). "国家发展改革委办公厅关于做好 2016、2017 年度碳排放报告与核查及排放监测计划制定工作的通知" [Notice on promoting annual emissions reporting and verifying (2016 & 2017) and making emissions monitoring work plan]. Retrieved from https://www.ndrc.gov.cn/xxgk/zcfb/tz/201712/t20171215_962618.html.

National Development and Reform Commission, Ministry of Foreign Affairs of the People's Republic of China, Ministry of Commerce of the People's Republic of China, and State Council (2015). Vision and actions on jointly building Belt and Road. Retrieved from http://2017.beltandroadforum.org/english/n100/2017/0410/c22-45.html.

National Renewable Energy Laboratory. (2017). Greening the grid: pathways to integrate 175 GW of renewable energy into India's electric grid. Retrieved from https://www.nrel.gov/docs/fy17osti/68720.pdf.

National Energy Agency (2016, July 7). "国家发展改革委 国家能源局关于推进多能互补集成优化示范工程建设的实施意见" [National Development and Reform Commission and National Energy Administration's Opinions on promoting the construction of multi-energy complementary integration and optimization demonstration projects]. Retrieved from http://www.nea.gov.cn/2016-07/07/c_135496039.htm.

National Energy Administration (2017). "2017 年全国电力工业统计数据" [2017 China national power industry statistics]. Retrieved from http://www.nea.gov.cn/2018-01/22/c_136914154.htm.

National Energy Administration (2020). “国家能源局发布 2019 年全国电力工业统计数据” [National Energy Administration releases 2019 national power industry statistics] . Retrieved from http://www.nea.gov.cn/2020-01/20/c_138720881.htm.

National Renewable Energy Laboratory (2016). Forecasting wind and solar generation: improving system operations. Retrieved from https://www.nrel.gov/docs/fy16osti/65728.pdf.

Network for Greening the Financial System (2019). A call for action: climate change as a source of financial risk. Retrieved from https://www.ngfs.net/sites/default/files/medias/documents/ngfs_first_comprehensive_report_-_17042019_0.pdf.

Nie, Y. (2018). “低碳经济视角下企业财务风险预警研究” [Research on the early warning of the financial risks from a perspective of low-carbon economy]. Communication of Finance and Accounting. Retrieved from https://new.oversea.cnki.net/kcms/detail/detail.aspx?filename=CKTX201814026&dbcode=CJFQ&dbname=CJFD2018&v=.

North American Solar Stores (2019). Solar works nearly as well in Idaho as it does in Florida. Retrieved from https://www.northamericansolarstores.com/solar-pv-everywhere/.

Organization for Economic Cooperation and Development (2019). ODF for infrastructure at a glance by donor. Retrieved from https://public.tableau.com/views/Infrastructure_6/bydonor?:embed=y&:display_count=yes&publish=yes&:toolbar=no?&:showVizHome=no#1.

Osborne, M. (2019, February 25). LONGi to build new 1GW mono solar cell plant in Malaysia. *PV-Tech*. Retrieved from https://www.pv-tech.org/news/longi-to-build-new-1gw-mono-solar-cell-plant-in-malaysia.

Overseas Development Institute (2018). Private infrastructure financing in developing countries. Retrieved from https://www.odi.org/sites/odi.org.uk/files/resource-documents/12366.pdf.

Partnership for Market Readiness (2016). Greenhouse gas data management. World Bank. Retrieved from https://openknowledge.worldbank.org/bitstream/handle/10986/23741/K8658.pdf?sequence=5&isAllowed=y.

Pehl, M. et al. (2017). Understanding future emissions from low-carbon power systems by integration of lifecycle assessment and integrated energy modelling. *Nature Energy*, 2, 939–945. Retrieved from https://www.nature.com/articles/s41560-017-0032-9.

People Online (2017, April 7). "贵安新区建设国内首座"1+3"多能互补分布式智慧能源站" [Gui'an New District builds the first "1+3" multi-energy complementary distributed smart energy station in China]. Retrieved from http://gz.people.com.cn/GB/n2/2017/0407/c194827-29981997.html.

People Online (2019, December 13). China's first virtual power plant put into operation. Retrieved from http://en.people.cn/n3/2019/1213/c90000-9640526.html.

Permanent Mission to the United Nations Industrial Development Organization (2017). MOFCOM issues the Guidance on Promoting Green Belt and Road with three line ministries. Ministry of Commerce of the People's Republic of China. Retrieved from http://vienna2.mofcom.gov.cn/article/headnews/201705/20170502571393.shtml.

Pinto, H. (2017). Closing the infrastructure gap by building country capacity. The Global Infrastructure Facility. Retrieved from https://blogs.worldbank.org/ppps/global-infrastructure-facility-closing-infrastructure-gap-building-country-capacity.

Pollitt, M., Yang, C. H., & Chen, H. (2017). Reforming the Chinese electricity supply sector: lessons from international experience. Energy Policy Research Group Working Paper 1704. Retrieved from https://www.eprg.group.cam.ac.uk/wp-content/uploads/2017/03/1704-Text.pdf.

Power For All (2019). Powering jobs census 2019: the energy access workforce. Retrieved from https://www.powerforall.org/resources/reports/powering-jobs-census-2019-energy-access-workforce.

Proano, M. (2018, November 16). What's next for the energy transition in Uruguay? *Energy Transition*. Retrieved from https://energytransition.org/2018/11/whats-next-for-the-energy-transition-in-uruguay/.

Regional Electricity Regulators' Associate and Word Bank (2009). International experience with cross-border power trading. Retrieved from https://openknowledge.worldbank.org/handle/10986/12716.

Renewable Energy Policy Network for the 21st Century (2019). Renewables 2019. Global Status Report. Retrieved from https://www.ren21.net/gsr-2019/.

Renner M. (2017). Rural renewable energy investments and their impact on employment. International Labour Organization working paper. Retrieved from https://www.ilo.org/wcmsp5/groups/public/---ed_emp/documents/publication/wcms_562269.pdf.

Rogers, M. (2019). Vietnam's renewable energy future. McKinsey & Company. Retrieved from https://www.mckinsey.com/business-functions/sustainability/our-insights/sustainability-blog/vietnams-renewable-energy-future.

Roig-Ramos, C. (2018). Blooming price on the European Emission Trading System. Institut Français des Relations Internationales. Retrieved from https://www.ifri.org/sites/default/files/atoms/files/roig_carbon_prices_eu_2018.pdf.

Sachs, J. *et al*. (2020). The Sustainable Development Goals and COVID-19. Sustainable Development Report 2020. Cambridge: Cambridge University Press.

Shi, Y., Zuo Y., and Meng, Y. (2017). "中国火电产业的历史轨迹与发展展望" [Historical track and prospect of China's thermal power industry]. *Science and Technology Management Research*. Retrieved from https://www.cnki.com.cn/Article/CJFDTotal-KJGL201716020.htm.

South Africa's Energy Department (2019). Integrated resource plan. Retrieved from http://www.energy.gov.za/IRP/2019/IRP-2019.pdf.

Standardization Administration of China (2018). "标准联通共建'一带一路'行动计划(2018-2020 年)" [Action plan to build the Belt and Road through Standard Unicom]. Retrieved from http://www.scio.gov.cn/xwfbh/xwbfbh/wqfbh/37601/39274/xgzc39280/Document/1641459/1641459.htm.

State Grid Corporation of China (n.d.). Homepage. Retrieved from http://www.sgcc.com.cn/ywlm/index.shtml.

State Council Information Office of China (2020), National Development and Reform Commission's response to the electricity price setting. Retrieved from http://www.scio.gov.cn/xwfbh/gbwxwfbh/xwfbh/fzggw/Document/1538542/1538542.htm.

State Grid Corporation of China (2019). "中国特高压直流输电技术现状和发展方向" [Current situation and development direction on China's UHV-DC transmission technology]. Retrieved from http://www.csee.org.cn/pic/u/cms/www/201912/04100423vh6e.pdf.

State of Green (2013). Denmark and South Africa have joined forces to reduce greenhouse gas emission. Retrieved from https://stateofgreen.com/en/partners/state-of-green/news/denmark-to-share-wind-power-expertise-with-south-africa/.

Steffen B. (2020). Estimating the cost of capital for renewable energy projects. *Energy Economics*, 88, May. Retrieved from https://www.sciencedirect.com/science/article/pii/S0140988320301237.

Sustainable Development Solutions Network (2020). Sustainable Development Report dashboards: transformations to achieve the Sustainable Development Goals. Retrieved from https://dashboards.sdgindex.org/map .

Swedish Smart Grid (2019). Smart grid market analysis: China. Retrieved from http://swedishsmartgrid.se/globalassets/publikationer/china_marketanalysis21mars.pdf.

Tahira, M. F., Chen, H. *et al*. (2020). Significance of demand response in light of current pilot projects in China and devising a problem solution for future advancements. *Technology in Society*, 63, November. Retrieved from https://www.sciencedirect.com/science/article/pii/S0160791X19306700.

Taylor Hopkinson (2017). Tackling skills shortage in the renewable energy sector by 2020. Retrieved from https://www.taylorhopkinson.com/wp-content/uploads/Skills-shortage-Report-Taylor-Hopkinson.pdf.

Teske, S., Morris, T., Nagrath, K., Dominish, E. (2019). Renewable energy for Viet Nam. University of Technology Sydney. Retrieved from https://www.uts.edu.au/sites/default/files/article/downloads/Teske-Morris-Nagrath-2019-Renewable-Energy-for-Viet-Nam-report.pdf.

The American Enterprise Institute and the Heritage Foundation (n.d.). China global investment tracker. Retrieved from https://www.aei.org/china-global-investment-tracker/.

The Economist (2020, January 25). Vietnam grapples with an unexpected surge in solar power. Retrieved from https://www.economist.com/asia/2020/01/25/vietnam-grapples-with-an-unexpected-surge-in-solar-power.

The Economist (2020, May 23rd). Not-so-slow-burn: once more with renewables. Retrieved from https://www.economist.com/schools-brief/2020/05/23/the-worlds-energy-system-must-be-transformed-completely.

The People's Government of Zhejiang Province (2019). "湖州绿贷通助推高质量发展" [Huzhou Lvdaitong promotes high quality development of green finance] . Retrieved from http://www.zj.gov.cn/art/2019/3/27/art_1554469_31680462.html.

Tian, C. and Xu, C. (2019). "我国碳交易试点的成效分析与政策建议" [Effectiveness analysis and policy recommendations for the carbon trading pilot of China]. *Journal of North China University of Technology*. Retrieved from http://www.tanpaifang.com/tanguwen/2020/0511/70669.html.

Tiseo, I. (2020). Global smart grid market size by region 2017-2023. Statista. Retrieved from https://www.statista.com/statistics/246154/global-smart-grid-market-size-by-region/.

Tu K. (2020). COVID-19 post-pandemic impact on China's energy sector: a preliminary analysis. Columbia University: Center on Global Energy Policy. Retrieved from https://energypolicy.columbia.edu/research/commentary/covid-19-pandemic-s-impacts-china-s-energy-sector-preliminary-analysis?utm_source=Center+on+Global+Energy+Policy+Mailing+List&utm_campaign=1a88b172af-EMAIL_CAMPAIGN_2019_09_24_06_19_COPY_01&utm_medium=email&utm_term=0_0773077aac-1a88b172af-102313325.

United Kingdom Department of Trade and Industry (2003). Our energy future - creating a low carbon economy. Retrieved from https://fire.pppl.gov/uk_energy_whitepaper_feb03.pdf.

United Kingdom Energy Research Centre (2017). The costs and impacts of intermittency. Retrieved from http://www.ukerc.ac.uk/publications/the-costs-and-impacts-of-intermittency-2016-update.html.

United Nations (2015). About the Sustainable Development Goals. Retrieved from https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf.

United Nations (2015). Sustainable Development Goals. Sustainable Development Goals Knowledge Platform. Retrieved from https://sustainabledevelopment.un.org/?menu=1300.

United Nations (2015). Transforming our world: the 2030 Agenda For Sustainable Development. Retrieved from https://sustainabledevelopment.un.org/post2015/transformingourworld.

United Nations (2020). End poverty in all forms everywhere. Retrieved from https://sdgs.un.org/goals/goal1.

United Nations (2020). The Sustainable Development Goals report. Retrieved from https://unstats.un.org/sdgs/report/2020/The-Sustainable-Development-Goals-Report-2020.pdf.

United Nations Department of Economic and Social Affairs (2019), Accelerating SDG 7 achievement: SDG 7 policy briefs in support of the High-Level Political Forum 2019. Retrieved from https://sustainabledevelopment.un.org/content/documents/22877UN_FINAL_ONLINE_20190523.pdf.

United Nations Department of Economic and Social Affairs. (2020). Energy statistics pocketbook 2020. Retrieved from https://unstats.un.org/unsd/energystats/pubs/documents/2020pb-web.pdf.

United Nations Development Programme (2008). Capacity development practice note. Retrieved from http://content-ext.undp.org/aplaws_publications/1449053/PN_Capacity_Development.pdf.

United Nations Development Programme (2018). Human development report indices and indicators. Retrieved from http://report2017.archive.s3-website-us-east-1.amazonaws.com/#one.

United Nations Development Programme (2019). Human development indicators: Madagascar. Retrieved from http://hdr.undp.org/en/countries/profiles/MDG.

United Nations Development Programme (2020). COVID-19 and human development: assessing the crisis, envisioning the recovery. 2020 Human Development Perspectives. Retrieved from http://hdr.undp.org/sites/default/files/covid-19_and_human_development_0.pdf.

United Nations Development Programme (n.d.). China-Ghana south-south cooperation on renewable technology transfer description. Retrieved from https://www.gh.undp.org/content/ghana/en/home/operations/projects/environment_and_energy/china-ghana-south-south-cooperation-on-renewable-energy-technolo.html.

United Nations Development Programme and China Development Bank (2019). Harmonizing investment and financing standards towards sustainable development along the Belt and Road. Retrieved from https://www.cn.undp.org/content/china/zh/home/library/south-south-cooperation/harmonizing-investment-and-financing-standards-.html.

United Nations Economic and Social Commission for Asia and the Pacific (2010). Low-carbon development path for Asia-Pacific: challenges and opportunities for the energy sector. Retrieved from https://www.unescap.org/sites/default/files/Energy%20Resources%20Development%20Series%2041.pdf.

United Nations Economic and Social Council (1997). Overall progress achieved since the United Nations Conference on Environment and Development. Report of the Secretary-General, addendum: combating poverty. Commission on Sustainable Development (CSD). Fifth session, 7-25. Retrieved from https://digitallibrary.un.org/record/231333.

United Nations Environment Programme (2019). Emissions gap report 2019. Retrieved from https://www.unenvironment.org/resources/emissions-gap-report-2019.

United Nations Environment Programme (2019). Global environmental outlook 6. Retrieved from https://www.unenvironment.org/resources/global-environment-outlook-6.

United Nations Environment Programme (n.d.). About us: United Nations Environment Programme finance initiative. Retrieved from https://www.unepfi.org/about.

United Nations General Assembly (2015). Transforming our world: the 2030 Agenda for Sustainable Development, resolution adopted by the General Assembly. A/70/L. 1. New York: United Nations General Assembly.

United Nations Global Compact (n.d.). What is the UN Global Compact? Retrieved from https://www.unglobalcompact.org/what-is-gc.

United Nations News (2020, April 8). COVID-19: impact could cause equivalent of 195 million job losses, says ILO chief. Retrieved from https://news.un.org/en/story/2020/04/1061322.

United Nations Principles for Responsible Investment (n.d.). 2018/19 in numbers. Retrieved from https://www.unpri.org/annual-report-2019/2018/19-in-numbers.

United Nations World Commission on Environment and Development (1987). Our common future. Retrieved from https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf.

United States Energy Information Administration (2020). US Crude oil first purchase price. United States Energy Information Administration. Retrieved from https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=f000000__3&f=m.

United States Environmental Protection Agency (n.d.). Electricity storage. Retrieved from https://www.epa.gov/energy/electricity-storage.

University of Cambridge Institute for Sustainable Leadership (2016). Environmental risk analysis by financial institutions: a review of global practice. Retrieved from https://www.cisl.cam.ac.uk/resources/publication-pdfs/environmental-risk-analysis.pdf.

Vu, K. (2019, July 31). Vietnam will face severe power shortages from 2021: Ministry. Reuters. Retrieved from https://www.reuters.com/article/us-vietnam-energy/vietnam-will-face-severe-power-shortages-from-2021-ministry-idUSKCN1UQ11M.

Worldatlas (n.d.). What are the biggest industries in Zambia. Retrieved from https://www.worldatlas.com/articles/what-are-the-biggest-industries-in-zambia.html.

World Bank Databank (n.d.). Retrieved from https://databank.worldbank.org/home.aspx.

World Bank (n.d.). Electricity access. Databank. Retrieved from https://data.worldbank.org/indicator/eg.elc.accs.zs.

World Bank (n.d.). Fossil-fuel energy consumption (% of total consumption). Databank. Retrieved from https://data.worldbank.org/indicator/EG.USE.COMM.FO.ZS.

World Bank (n.d.). Renewable energy output (% of total power generation). Databank. Retrieved from https://data.worldbank.org/indicator/EG.ELC.RNEW.ZS.

World Bank (2016). Financial viability of the electricity sector in developing countries: recent trends and effectiveness of World Bank interventions. Retrieved from https://ieg.worldbankgroup.org/sites/default/files/Data/reports/lp_financial_viability_electricity_sector_0.pdf.

Word Bank (2018). Harmonization of energy support schemes to enable regional electricity trade – case of MENA. Retrieved from https://www.financeministersforclimate.org/sites/cape/files/inline-files/Session%203-4.%20Waleed%20Alsuraih_CMI_PAEM%20support%20schemes%20harminzation%20and%20trade%20FNL.pdf.

World Bank (2018). Poverty and shared prosperity 2018: piecing together the poverty puzzle. Retrieved from https://www.worldbank.org/en/publication/poverty-and-shared-prosperity.

World Bank (2018). The force of the sun: Madagascar embarks on renewable energy production. Retrieved from https://www.worldbank.org/en/news/feature/2018/10/10/the-force-of-the-sun-madagascar-embarks-on-renewable-energy-production.

World Bank (2020). COVID 19: Debt Service Suspension Initiative. Retrieved from https://www.worldbank.org/en/topic/debt/brief/covid-19-debt-service-suspension-initiative.

World Bank (2020). Debt report 2020 edition I. Retrieved from https://blogs.worldbank.org/opendata/debt-report-2020-edition-i.

World Bank (2020). Global Photovoltaic Power Potential by Country. Retrieved from https://www.worldbank.org/en/topic/energy/publication/solar-photovoltaic-power-potential-by-country.

World Bank (2020). Global Solar Atlas. Retrieved from https://globalsolaratlas.info/map.World Bank (2020). Projected poverty impacts of COVID-19. Retrieved from http://pubdocs.worldbank.org/en/461601591649316722/Projected-poverty-impacts-of-COVID-19.pdf.

World Bank (2020). World Bank Group and IMF mobilize partners in the fight against COVID-19 in Africa. Retrieved from https://www.worldbank.org/en/news/press-release/2020/04/17/world-bank-group-and-imf-mobilize-partners-in-the-fight-against-covid-19-in-africa.

World Bank (n.d.). Baikonur solar power plant. Retrieved from https://ppi.worldbank.org/en/snapshots/project/Baikonur-solar-power-plant-9529.

World Bank (n.d.). Carbon pricing dashboard. Retrieved from https://carbonpricingdashboard.worldbank.org/.

World Bank (n.d.). External debt stocks (% of GNI). Retrieved from https://data.worldbank.org/indicator/DT.DOD.DECT.GN.ZS.

World Bank and the International Finance Corporation (2020). Global solar atlas. Retrieved from https://globalsolaratlas.info.

World Bank Solar Atlas (n.d.). Retrieved from https://globalsolaratlas.info.

World Coal Association (2020). High efficiency low emissions coal. Retrieved from https://www.worldcoal.org/file_validate.php?file=Hele%20Factsheet.pdf.

World Nuclear Association (2017). Nuclear power economics and project structuring. Retrieved from https://www.world-nuclear.org/information-library/current-and-future-generation/nuclear-power-in-the-world-today.aspx.

World Nuclear Association (2020). Storage and disposal of radioactive waste. Retrieved from https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-waste/storage-and-disposal-of-radioactive-waste.aspx.

World Wildlife Fund (2019). Sustainable banking in ASEAN. Retrieved from https://d2ouvy59p0dg6k.cloudfront.net/downloads/wwf_sustainable_finance_report_2019.pdf.

Wynn, G. (2018, November 13). Uruguay nears world record wind and solar market share. *Energy and Carbon*. Retrieved from https://energyandcarbon.com/uruguay-poised-overtake-denmark-wind-solar-leader-market-share/.

Xinhua. (2015, August 4). China's State Grid builds "electricity super highway" in Brazil. Retrieved from http://en.people.cn/business/n/2015/0804/c90778-8931240.html.

Xinhua (2017, October 18). Secure a decisive victory in building a moderately prosperous society in all respects and strive for the great success of socialism with Chinese characteristics for a new era. Retrieved from http://www.xinhuanet.com/english/download/Xi_Jinping's_report_at_19th_CPC_National_Congress.pdf.

Xinhua (2017, May 14). Full text of President Xi's speech at opening of Belt and Road forum. Retrieved from http://www.xinhuanet.com/english/2017-05/14/c_136282982.htm.

Xinhua (2018, May 30). "我国特高压有望成'走出去'新名片" [UHV-DC will become another business card in China]. Retrieved from http://www.xinhuanet.com/fortune/2018-05/30/c_1122908102.htm.

Xinhua (2020, January 10). "2019年中国绿色债券市场发展回顾" [Review of development of China green bond market 2019]. Retrieved from http://greenfinance.xinhua08.com/a/20200110/1907055.shtml?f=topnav.

Yin, F., Wu, M., Xiao. J., and Niu, Z. (2019). Datasets of China's overseas hydropower stations (2002-2019). Science Data Bank. Retrieved from http://www.scidb.cn/journalDetail?dataSetId=633694461364273152&version=V1&dataSetType=journal&tag=2&language=zh_CN.

Zeng, X. *et al*. (2017). Data-related challenges and solutions in building China's national carbon emissions trading scheme. *Climate Policy*, 18 (1), 90-105. Retrieved from https://www.tandfonline.com/doi/pdf/10.1080/14693062.2018.1473239.

Zhang, H., Zhou, Y., and Ma, J. (2016). Impact of environmental factors on credit risk of commercial banks: research and application by ICBC based on stress test. ICBC and Green Finance Committee. Retrieved from http://www.greenfinance.org.cn/upfile/upfile/filet/ICBC%E7%8E%AF%E5%A2%83%E5%8E%8B%E5%8A%9B%E6%B5%8B%E8%AF%95%E8%AE%BA%E6%96%87_2016-03-19_08-49-24.pdf.

Zhong, D., Li, Q. *et al*. (2018). "多能互补能源综合利用关键技术研究现状及发展趋势" [Research status and development trends for key technologies of multi-energy complementary and comprehensive utilization system]. Thermal Power Generation. Retrieved from https://tow.cnki.net/kcms/detail/detail.aspx?filename=RLFD201802001&dbcode=CRJT_CJFD&dbname=CRJT_CJFDTOTAL&v=.

Zhou, Y., Jiang, H., Xiao, J., and Liang, C. (2020). "清洁低碳发展背景下跨国互联电力系统规划方法" [Planning methods for transnationally interconnected power systems under the background of clean low-carbon development]. *Electric Power*.

111th US Congress (2009). H.R.2454 - American Clean Energy and Security Act of 2009. Retrieved from https://www.congress.gov/bill/111th-congress/house-bill/2454.

"2050 Japan Low-Carbon Society" scenario team (2008). Japan scenarios and actions towards low-carbon societies (LCSs). Retrieved from http://2050.nies.go.jp/report/file/lcs_japan/2050_LCS_Scenarios_Actions_English_080715.pdf.

Logos from IRENA are used in Table 3.2 and Table 3.3.