Global Energy Interconnection
Development and Cooperation Organization

Volume 1 Number 4 October 2018 (420-427)
DOI: 10.14171/j.2096-5117.gei.2018.04.002

Global Energy Interconnection

Contents lists available at ScienceDirect
journal homepage: http://www.keaipublishing.com/en/journals/global-energy-interconnection

ELSEVIER
Production And Hosting By Elsevier On Behalf Of KeAi

Full-length article

Scientific basis of climate change and its response

Qingchen Chao[1], Aiqing Feng[1,2]

1. National Climate Center, China Meteorological Administration, Beijing 100081, P.R. China
2. Laboratory for Climate Studies, National Climate Center, China Meteorological Administration, Beijing 100081, P.R. China

Scan for more details

Abstract: The scientific understanding of climate change is based on a solid physical-theoretical foundation, and long-term observation and research. By analyzing the accelerated rise of the global climate and its wide-ranging effects on the risk of natural ecosystems and the social economy, and, particularly in view of the stringent targets of 1.5 degrees set by the Paris Agreement to limit global temperature rise, this study contends that climate security has become a new, non-traditional, security issue. The fundamental approach to implementing the objectives of the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement is to develop clean energy vigorously and to accelerate energy transformation. Furthermore, building a global energy interconnection is emphasized as one of the solutions to promoting energy transformation.

Keywords: Climate Change, Scientific basis, Effects and risk, Addressing pathways, Energy transition.

1 Introduction

Climate is a most important part of nature, the basis for human survival and development, a crucial resource, and the basic condition for sustainable economic and social development. Since the industrialization of human society from ca. 1750, coupled with the marked increase in human activities, the already variable climate of the Earth has been influenced significantly by such human actions. The rise in global temperature is accelerating, with the warming climate significantly affecting natural ecosystems and the economic society globally. The progress of humankind has been marked by a relationship with and interactions among people, the economy, society, and nature. In recent years, however, the recognition has grown that climate security has become a new and non-traditional issue. Therefore, actively responding to climate change and accelerating low-carbon development have become the consensus of the international community.

By reviewing the evolution of the idea of development and the progress on the scientific cognition of climate change, this study analyzed the effects of and risk related to climate change. Particularly, in view of the stringent targets set by the Paris Agreement to limit global temperature increases, we pointed out the fundamental approach to implementing the objectives of the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement. These are, namely, to develop clean energy vigorously and to accelerate energy transformation. Accordingly, building a global energy interconnection is one of the solutions to promoting energy transformation.

Received: 17 August 2018/ Accepted: 20 August 2018/ Published: 25 October 2018

Qingchen Chao
chaoqc@cma.gov.cn

Aiqing Feng
fengaq@cma.gov.cn

2 Understanding evolution of the development idea and the scientific basis of climate change

2.1 Evolution of development in a philosophical sense

The development of human beings encompasses evolving from natural beings into self-conscious ones. With the increasing knowledge about the Earth and human evolution, humans have gradually come to embrace the notion that development is global and includes all mankind. The vast progress brought about by the industrial civilization has inspired a human desire to "conquer nature" and, conversely, the damage done by the environmental crisis to human interests has deepened human understanding of industrial development (Fig. 1). Air, water, and soil pollution and the degeneration of the ecology are contrary to the original targets of development and have, therefore, aroused rational thinking. Although using fossil energy has brought about substantial improvements in productivity, the excessive use of this resource has led to a significant burden on the environment and even the occurrence of natural disasters.

In the mid-20th century, people with insight proposed a more in-depth discussion of the relationship between human beings and nature, resources and environment, and development and protection. On this basis, the Norwegian Prime Minister at the time, Gro Harlem Brundtland, first proposed the concept of sustainable development in 1987. In the same year, the World Commission on Environment and Development (WCED) published a report, *Our Common Future*, which clarified further the connotation of sustainable development, i.e., development that meets the needs of the present without compromising the ability of future generations to meet their own needs. "Sustainable development" is an essential improvement in the outlook of human development [1].

2.2 Theoretical basis of climate change

Climate change has existed since ancient times but the science of "modern climate change" has come into being two hundred years ago and has been developing up to now. Several milestones in the progress of the new science include the following. In 1824, a French scientist, J. Fourier, proposed that the atmosphere of the Earth acts like a blanket or the glass of a greenhouse to increase the temperature (compared with there being no such envelope of gases), i.e., the "greenhouse effect" [2]. In 1867, the British scientist, J. Tyndall, measured the radiation characteristics of CO_2, CH_4, and other molecules, and clarified the effect of the greenhouse gases in the atmosphere on the temperature change of the earth [3]. This study on molecular physics is the core of the contemporary climate change theory. In 1896, the Swedish scientist, Svante August Arrhenius, calculated the greenhouse effect of carbon dioxide in the atmosphere [4]. In 1938, a study by British scientist, G. Callendar, linked the increase in fossil fuel combustion and the rise in the carbon dioxide concentration with the greenhouse effect. He pointed out that human actions could cause significant climate change [5]. Later, the Japanese scientist, Syukuru Manabe, and the American scientist, Jule Charney, established a relatively complete theory and

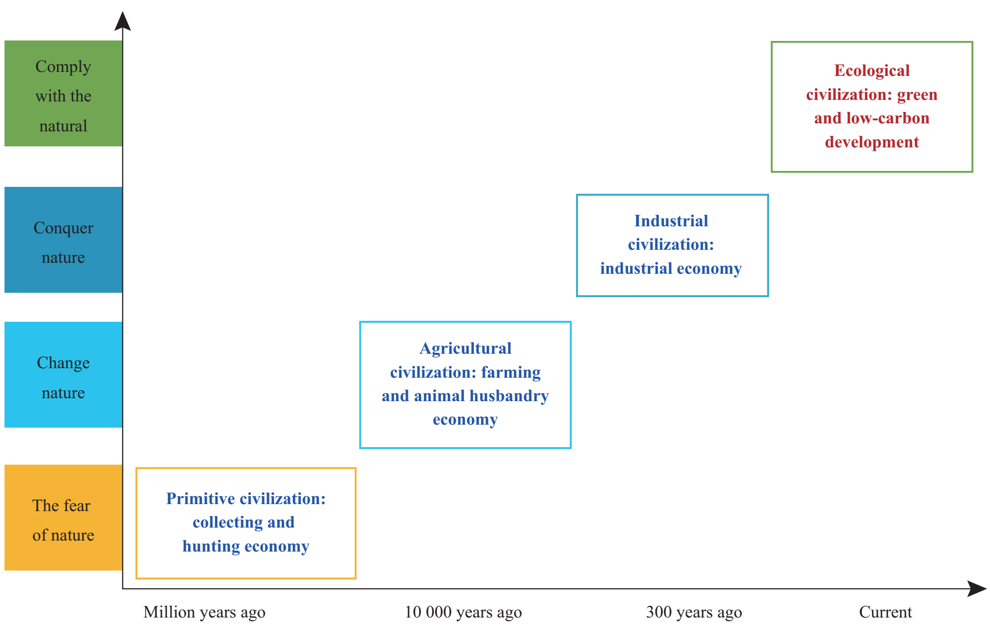

Fig. 1 Harmonious relationship between socioeconomic development and evolution of nature under different civilizations

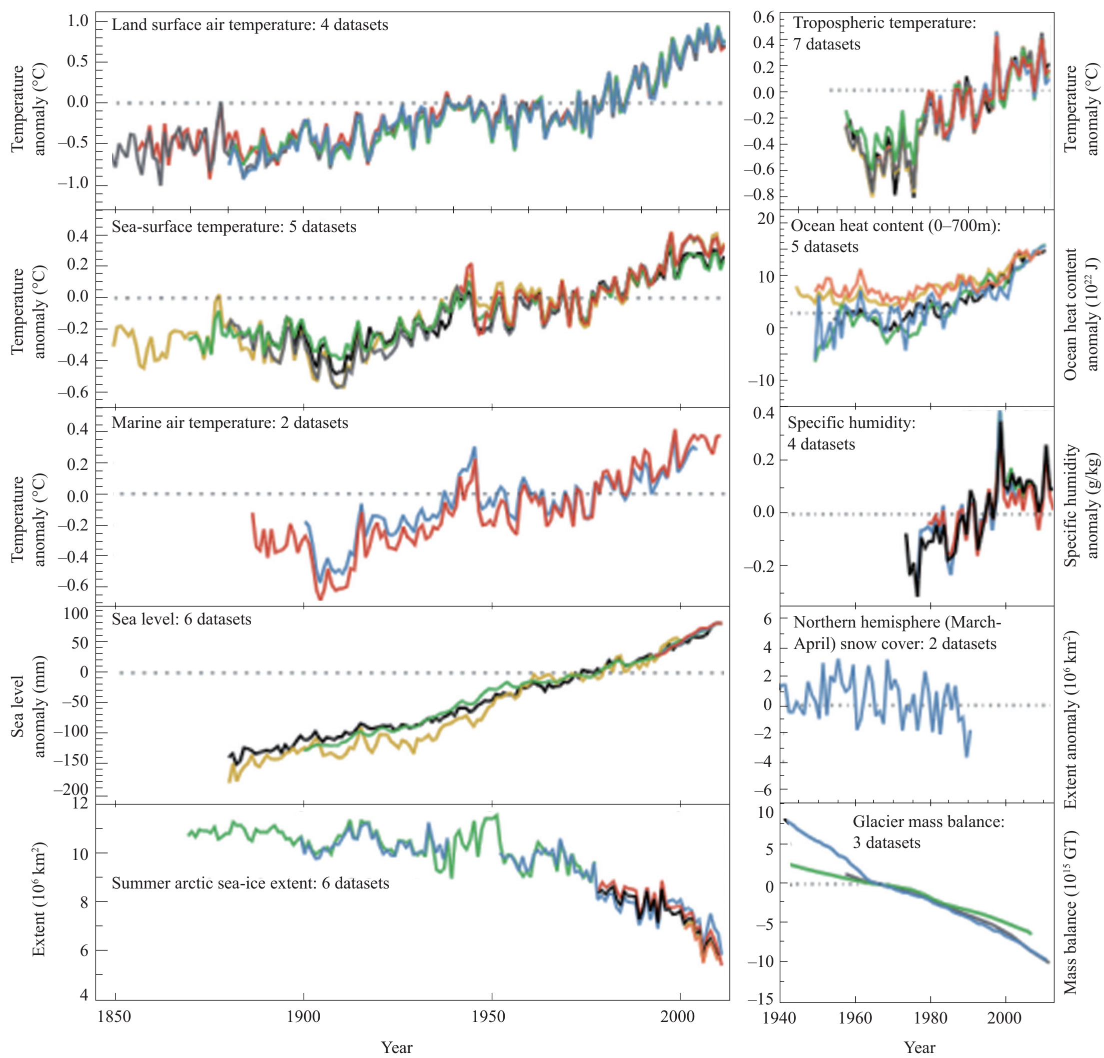

Fig. 2 Multiple independent indicators of a changing global climate. Each line represents an independently derived estimate of change in the climate element. In each panel, all data sets have been normalized to a common record period (Cited from the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, IPCC AR5, WGI FAQ 2.1 Fig. 2)

evaluated the relationship (i.e., sensitivity) between the carbon dioxide concentration and climate change [6-7]. In 1958, the Mauna Loa Observatory in Hawaii, USA, started to observe the CO_2 concentration, officially unveiling the prelude to research on climate change.

2.3 Changes in the climate system

A series of actual observations of and the substantial number of studies on global climate change from the 20th century to the present [8-10] have been augmenting the scientific understanding of modern climate change. A comprehensive analysis of the latest global climate observation data confirmed that in 2017 the global surface average temperature was approximately 1.1 °C higher than was the pre-industrial level (1850–1900 annual mean). This was the second warmest year and the warmest non-El Niño year since the start of complete meteorological observation records. From 1870 to 2017, the global mean sea surface temperature (SST) showed a significant upward trend and a continued high level after 2000. In 2017, the SST in most of the global seas was higher than normal and the global average SST was the third highest since 1870. From 1958 to 2017, the global ocean heat content (upper 2000m) increased significantly, and ocean warming accelerated significantly after the 1990s. In 2017, the value of global ocean heat content was the highest since the start of modern ocean observation.

From 1979 to 2017, the extent of the Arctic sea ice decreased significantly, whereas that of the Antarctic sea ice generally showed an upward trend. However, the range of the Antarctic sea ice was abnormally small in 2017, with a minimum value in March and the second smallest value in September since the start of satellite observation records. In addition, the global sea level has been rising consecutively for six years. In 2016, the global average sea level reached a new height, approximately 82 mm higher than when satellite recording began in 1993. Over the past 20 years, the sea level has risen at an average rate of approximately 3.4 mm per year, with the highest increases being observed in the Western Pacific and Indian oceans.

Greenhouse gas emissions continue to set new records. In 2016, the annual average global atmospheric concentration of major greenhouse gases reached a new high level, with 403.3 ppm carbon dioxide, 1853 ppb methane, and 328.9 ppb nitrous oxide, which were 145%, 257%, and 122%, respectively, of the pre-industrial (before 1750) levels. It was the first time since 800 000 years that the concentration of carbon dioxide in the atmosphere exceeded 400 ppm, an increase of 3.5 ppm compared with 2015, and the sharpest increase in 58 years. The carbon dioxide concentration of 404.4 ppm, at the Waliguan Global Almosphere Watch (GAW) station in China released by China Meteonological Administration (CMA), was slightly higher than the global average value.

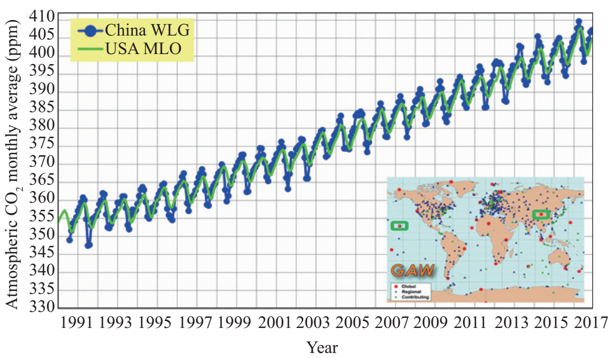

Fig. 3 The monthly CO_2 mole fractions observed at the Waliguan GAW station in Qinghai Province, China, and the Mauna Loa Observatory in Hawaii, USA

With the rise in the global temperature, extreme weather and climate events have also been increasing significantly worldwide, leading to frequently occurring disasters that have caused fatalities and substantial economic losses. Indeed, the frequency of high-temperature red alerts is rising. The extremely active hurricanes in the North Atlantic Ocean, the severe monsoon floods on the Indian subcontinent, and the continued severe droughts in Eastern Africa have contributed to economic losses totaling $320 billion in 2017, the highest annual climate-related losses since the start of records.

Studies have shown that [8] the trend of global warming is set to continue in this century. Compared with the period 1986–2005, the global average surface temperature would likely increase by 0.3–0.7 °C during the period 2016–2035, and to 0.3–4.8 °C by the end of this century. At the end of the 21st century, the sea level would have risen by 0.26–0.82 m. The Arctic Sea ice area in September would be reduced probably by 43%–94%, and the global glacial volume could probably shrink by 15%–85%. Two emission scenarios (RCP 2.6 and RCP 8.5), based on more than 20 CMIP5 (Coupled Model Intercomparison Project Phase 5) models, were used to analyze the changes in the frequency of five-consecutive-day maximum temperatures higher than 35 °C in China. The results showed that the frequency of heatwaves could increase threefold by the end of the 21st century compared with 1986–2005, if maintaining the current energy policies placed the world on the high emission pathway consistent with RCP 8.5 (Fig. 4). Overall, the uncertainty related to the high emission scenario was larger compared with the uncertainty related to the low emission scenario. Furthermore, the uncertainty was more substantial in regions with more significant warming trends compared with regions with weaker trends. Among three periods (2016–2035, 2046–2065, and 2080–2099), the projected uncertainty would be the smallest during 2016–2035.

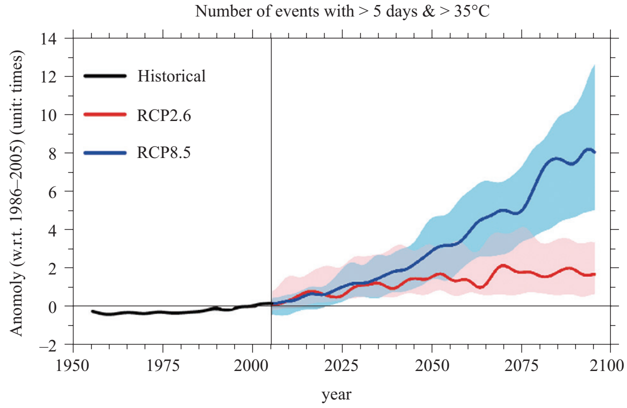

Fig. 4 Change in the number of events lasting at least five days with the daily maximum temperature exceeding 35 °C

3 Effects and Risk of Climate Change

Because of differences in natural geographical conditions and socioeconomic situations, the effects of and risk related to climate change on a global scale are heterogeneous; therefore, the responses vary as well. Furthermore, as regards the risk of future climate change to sectors, research results differ because of the difference in climate models, scenarios, data, and the like. However, the trend of the long-term climate risk is certain.

3.1 Effects on global important sectors

It indicated that adverse effects of climate change on food production are more pronounced than the beneficial effects. Globally, the average biophysical production could be reduced by 17% by 2050 compared with that under a constant climate condition [11]. By the end of this century, food production would have decreased by 0%–2% per decade, whereas the projected food demand would have increased by approximately 14% per decade by 2050. The cropland area and cropping frequency are more sensitive to climate change than crop yield [12].

Climate warming has caused precipitation changes and snowmelt in many regions, particularly in the permafrost regions of high-latitude and high-altitude mountains. Warming also affects downstream runoff and water resources. At the same time, it promotes the potential evaporation of most land areas and accelerates the hydrological cycle. Currently, approximately one billion people live in watersheds with water shortages. By 2050, there would be more than 50 million to 3.1 billion people suffering water shortages because of climate change [13]. With a global warming of 2 °C, the population at risk of serious water shortages would increase by 15% [14].

During the 21st century, ecosystems would face a substantial risk of regional-scale mutations and irreversible changes, such as the Arctic tundra and Amazon forests. The geographical distribution, seasonal activities, migration patterns, and abundance of some biological species have changed already [8]. Climate change directly affects plant physiology and ecosystem functioning, resulting in changes in global productivity and generating indirect effects on ecosystems through changes in plant composition and diversity [15]. In the 21st century and beyond, combined with other pressures, most terrestrial and freshwater species would be at a higher risk of extinction. Studies have shown that [16] between 1979 and 2013, climate change has caused an increase of 25.3% in wild forest fires worldwide, and the average length of the fire season has increased by 18.7%. This situation could worsen, thereby significantly affecting global ecosystems.

Coastal areas could be affected adversely by submergence, flooding, and erosion, caused by the rise in sea level. By 2030, the global urban area of high-frequency coastal floods would have increased from 30% in 2000 to 40% [17]. By 2100, more than half of the global delta regions would be inundated, considering the predicted sea-level rise [18]. In the absence of adaptation measures, the population of the global coastal zones at risk of flooding would reach 0.2%–4.6%, and the average GDP loss would be 0.3%–9.3% [19]. In addition, climate change would affect human health and the socioeconomic system. Moreover, it threatens the process of global sustainable development.

3.2 Climate risk under different rates in temperature rise

Generally, the global risk is medium to high compared the pre-industrial temperature with 1 °C or 2 °C rise, whereas a temperature rise of more than 4 °C or higher would indicate a high or very-high risk level. Key risks in Asia are embodied mainly in the increased flooding of rivers, oceans, and cities, where extensive damage would be caused to the infrastructure, livelihoods, and settlements.

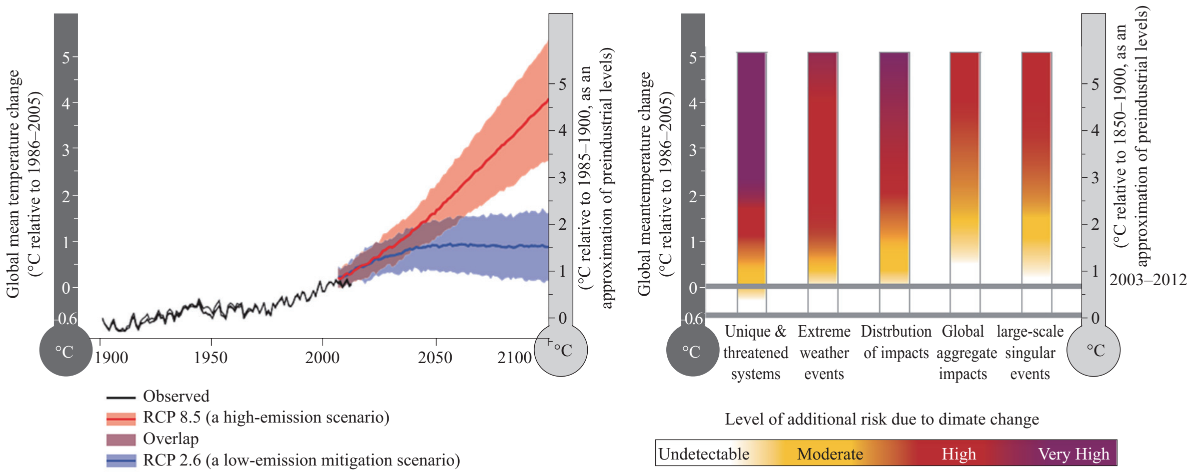

Fig. 5 Global perspective on temperature change (left) and climate-related risk (right). The color shading indicates the additional risk related to climate change when a certain temperature level is reached and subsequently sustained or exceeded

(Cited from IPCC AR5 WGII Assessment Box SPM 1 Fig. 1)

The risk of death associated with a high temperature and the risk of malnutrition resulting from drought-related water and food shortages would also rise [8].

4 Pathway to Addressing Climate Change

4.1 Evolution of long-term goals of mitigation and adaptation on climate change

The ultimate objective determined by the UNFCCC was to achieve "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner". The UNFCCC has not elaborated on which changes were deemed dangerous, what level of human interference could lead to dangerous climate change, or how to avoid such dangerous climate changes. Starting in 1995, with the *Second Assessment* Report of the Intergovernmental Panel on Climate Change (IPCC), the international scientific community has continued to conduct research on this issue. Under the patronage of leading countries, such as the member states of the European Union, a temperature rise limit of 2 °C was put forward in the *Copenhagen Accord* in 2009 and was reconfirmed in the *Cancun Agreement* adopted in 2010. Since then, global political consensus has been reached on the 2 °C temperature rise target.

The Alliance of Small Island States (AOSIS) has appealed for a long-term goal lower than the 2 °C limit. In 2007, AOSIS submitted a detailed proposal to the UNFCCC on this long-term goal. Both the *Copenhagen Accord* in 2009 and the *Cancun Agreement* in 2010 mentioned considering the 1.5 °C target. In the final phase of the 2015 Climate Change Conference in Paris, the "High Ambition Coalition", composed of the European Union, Switzerland, the United States, Africa, the Caribbean, and the Pacific Group of States strongly promoted the global temperature rise to be controlled within the 1.5 °C limit (*Paris Agreement*). Present studies indicated that the risk to the ecosystem or the human socioeconomic system related to a temperature rise of 2 °C, compared with 1.5 °C, would obviously be higher, despite the substantial regional differences [20].

4.2 Pathway to achieving 2 °C or 1.5 °C limits

Effectively coping with the adverse effects of climate warming can only be done through adaptation and mitigation measures. Disaster risk management and enhancing the resilience of the human social systems are effective ways to adapt to climate change and reduce vulnerability and exposure, and are the only way to achieve active adaptation under sustainable development [21]. Controlling or reducing greenhouse gas emissions through climate change mitigation policies and measures is a fundamental way to address climate change, including increasing carbon sinks and employing geoengineering. The most important measures [8] to reduce greenhouse gas emissions include the reformation of the energy supply sectors and the early implementation of systematic and cross-sectoral emission reduction strategies.

Study has shown that if all the current Nationally Determined Contribution (NDC) targets were achieved punctually, global greenhouse gas emissions could be expected to reach 550 (514–573) Gt CO_2 by 2025, and 562 (520–593) Gt CO_2 [22] by 2030. As a result, the global temperature rise would be 2.2–3.4 °C by the end of 2100. To achieve the 2 °C goal, it would be necessary to reduce an additional 30%, on the basis of the current NDC targets, by 2030 [23]. The remaining carbon budget for limiting global warming to 1.5 °C is complicated because of the uncertainties in the climate response to emissions, the different sets of multi-gas and aerosol scenarios, and the use of different concepts of carbon budgets. New research has shown that the remaining carbon budget for a one-in-two chance of limiting global warming to 1.5 °C was approximately 770 Gt CO_2, and approximately 570 Gt CO_2 for a two-in-three chance using Global mean surface temperature estimation. This implies rapid reductions in the net global anthropogenic CO_2 emissions to reach net-zero around mid-century, together with the rapid reduction of other anthropogenic emissions. Limiting global warming to 1.5 °C would require rapid and far-reaching systems transitions during the coming one to two decades, in energy, land, urban, and industrial systems [24].

Currently, global energy development is showing three major trends [25, 26]. The first is to transform to clean, low-carbon, and efficient energy. In 2015, low-carbon energy (non-fossil energy and natural gas) accounted for more than 40% of the global primary energy structure and showed a growth momentum. Coal combustion accounted for 28.6% of the global energy; however, excluding China, coal combustion accounted for only 19% of the energy of the rest of the world. Second, the growth in the total global energy demand is slowing down, with growth points being mainly in emerging economies. In 2016, the total global energy consumption increased by 1%, whereas that of China increased by 1.3%, and the energy intensity decreased by 2.1%. This trend is resulted from the global economic situation and energy efficiency progress. Third, energy technology innovation is most active and many countries are actively seizing the strategic high point of energy technology. Some of the highlights include energy storage technology, distributed energy, and intelligent technology. The fundamental way to respond actively to climate change is to accelerate the development of clean energy and to implement “two alternatives”. These are developing and implementing clean energy alternatives to fossil fuels, and electricity for coal, electricity for oil, electricity from afar. Clean energy is expected to dominate in the future. The global energy interconnection would be one of the significant ways to contribute to regional or even global energy transformation in the future.

5 Conclusion

The international community has been working hard to address climate change. The *Paris Agreement* fully demonstrates the consensus of countries to cope with climate change and to promote green and low-carbon development. Advancing low-carbon development together with the energy transformation is a historical process. The nature of such change might be long-term and arduous but the direction and path are clear. Governments, enterprises, and the public need to work together to practice the concept of “innovation, coordination, green, openness, and sharing”, create a new sustainable development path in China, and make a greater contribution to the progress of human civilization. The global energy interconnection can build a new pattern of energy development, stimulate new activities for economic growth, and become a new approach to addressing climate change.

Acknowledgements

This research was supported by the major project of the Ministry of Education (15JZD035), the MOST project of the 4th National Climate Change Assessment Report, and the Laboratory of Climate Studies Open Funds for Young Scholars of China Meteorological Administration in 2018.

References

[1] UNDP (2005) Human Development Report 2005. United Nations Development Programme, United University Press. Oxford

[2] Fourier J (1824) Remarques générals surles températures du globe terrestre et des espaces planétaires. Annales de Chimie et de Physique, Vol. XXVII, pp:136-167//Archer D, Pierrehumbert R (2011) The Warming Papers: The Scientific Foundation for the Climate Change Forecast. Oxford. UK: Wiley Blackwell, pp: 3-20

[3] Tyndall J (1861) On the absorption and radiation heat by gases and vapors, and on the physical connection of radiation, absorption and conduction. Philosophical Magazine Series 4, Vol. 22, pp:169-194, 273-285

[4] Arrhenius S (1896) On the influence of carbonic acid in the air upon the temperature of the ground. The London Edinburgh, and Dublin Philosophical Magazine and Journal of Science 5th Series, 465(251)//Archer D, Pierrehumbert R (2011) The Warming Papers: The Scientific Foundation for the Climate Change Forecast. Oxford. UK: Wiley Blackwell, pp: 45-77

[5] Callendar GS (1938) The artificial production of carbon dioxide and its influence on climate. Quarterly Journal of the Royal Meteorological Society, 64(275):223-240

[6] Manabe S, Wetherald R (1967) Thermal equilibrium of the atmosphere with a given distribution of relative humidity. Journal of the Atmospheric Sciences, 24(3): 242-259

[7] Charney J, Coauthors G (1979) Carbon dioxide and climate: A scientific assessment. Washington, DC: National Academy of Sciences

[8] IPCC (2014) Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds)]. IPCC, Geneva, Switzerland, pp: 151

[9] WMO (2018) WMO Statement on the state of the global climate in 2017

[10] Climate Change Center of China Meteorological Administration (2018) Blue Book on China Climate Change. Beijing, China

[11] Nelson GC, Valin H, Sands RD et al (2014) Climate change effects on agriculture: Economic responses to biophysical shocks. Proceedings of the National Academy of Sciences, 111(9): 3274

[12] Cohn A, VanWey LK, Spera S et al (2016) Cropping frequency and area response to climate variability can exceed yield response. Nature Climate Change, 6(1): 601-604

[13] Gosling SN, Arnell NW (2016) A global assessment of the impact of climate change on water scarcity. Climatic Change, 134(3): 371-385

[14] Schewe J, Heinke J, Gerten D et al (2014) Multimodel assessment of water scarcity under climate change. Proceedings of the National Academy of Sciences, 111(9): 3245-3250

[15] Morin X, Fahse L, Jactel H et al (2018) Long-term response of forest productivity to climate change is mostly driven by change in tree species composition. Scientific Reports, 8(1): 5627

[16] Jolly WM, Cochrane MA, Freeborn PH et al (2015) Climate-induced variations in global wildfire danger from 1979 to 2013. Nature Communications, Vol. 6, pp: 7537-7547

[17] Güneralp B, Güneralp İ, Liu Y (2015) Changing global patterns of urban exposure to flood and drought hazards. Global Environmental Change, Vol. 31, pp: 217-225

[18] Syvitski J, Kettner AJ, Overeem I et al (2009) Sinking deltas due to human activities. Nature Geoscience, 2(10): 681-686

[19] Hinkel J, Lincke D, Vafeidis AT et al (2014) Coastal flood damage and adaptation costs under 21st century sea-level rise. Proceedings of the National Academy of Sciences, 111(9): 3292-3297

[20] Schleussner C, Lissner TK, Fischer EM et al (2016) Differential climate impacts for policy-relevant limits to global warming: The case of 1.5 °C and 2 °C. Earth System Dynamics, 7(2): 327-351
[21] IPCC (2014) Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp: 1-32
[22] UNFCCC (2016) Updated synthesis report on the aggregate effect of INDCs. FCCC/CP/2016/2
[23] Energy Transitions Commission (2016) Pathways from Paris: Assessing the INDC opportunity. http://www.energy-transitions.org/
[24] IPCC (2018) Summary for Policymakers of the IPCC "Special Report on Global Warming of 1.5 °C, an IPCC special report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty". http://cache2.nmic.cn/files/304700000094E6A8/report.ipcc.ch/sr15/pdf/sr51_spm_final.pdf
[25] IEA (2017) Outlook on Energy Technology, http://www.escn.com.cn/news/show-430389.html, 13 June
[26] BP (2017) Outlook on World Energy, https://www.bp.com/zh_cn/china/reports-and-publications/_bp_2017_.html, 30 March

Biographies

Qingchen Chao received her bachelor degree in Beijing Institute of Meteorology. She received her master and Ph.D. degrees from Institute of Atmospheric Physics, Chinese Academy of Sciences. Her research areas are climate system analysis and interactions, climate risk and climate policy. She serves as the member of Global Climate Observing System Steering Committee. She currently is the deputy director general of National Climate Center of China Meteorological Administration.

Aiqing Feng received her Ph.D. degree from Institute of Geographic Sciences and Natural Resources Research (IGSNRR), Chinese Academy of Sciences (CAS). She is currently working at Meteorological Disaster Risk Management Division of National Climate Center. Her research focuses on the risk of meteorological disasters under climate change.

(Editor Chenyang Liu)