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Introduction and background

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This report highlights research from the Sino-Danish Center (SDC), the fruit of a consolidated and strong bilateral partnership for collaboration in science, technology and innovation between universities in China and Denmark. In 2020, SDC celebrates its ten-year anniversary, making it a perfect moment to present some of the academic outcomes of this partnership. This volume constitutes a collection of research that brings to the fore one of the most important global challenges facing the world today: the energy transition. Addressing this challenge and achieving the sustainable development goals calls for international collaboration, and as the chapters in this report illustrate, bringing together scholars from different disciplines, backgrounds and geographies offers a holistic perspective for a sustainable transition. Moreover, the report simultaneously addresses the development, context, implementation and dissemination of energy transition solutions.

We intend to draw attention to the work of two SDC research clusters: Sustainable Energy and Social Science. A prerequisite for understanding how a sustainable energy transition can materialize is an analysis of how these two areas interrelate. Indeed, the transition 1) may be facilitated by policies, drivers and strategies at different levels (international, national and regional), 2) can be organized in ways that ensure common goods are safeguarded across generations, and 3) is subject to technological development, selection and integration. Technology and societal change are two sides of the coin when addressing the challenge of climate change.

The Covid-19 virus, which has been changing the world as we write, is a current and germane example of the relevance of interdisciplinary and international collaboration. Workshops and conferences have moved online along with our teaching programmes, and we were unable to make visits throughout 2020. Covid-19 has become an international crisis, with an enormous impact on people's welfare, health and economic activities. In terms of the energy transition, Covid-19 is also a reminder of the indispensable role of electricity in modern life. With entire countries locked down, system operators faced new challenges in balancing supply and demand. Covid-19 can be considered a testing ground for international governance and collaboration, and a beacon to future demands for a sustainable and reliable energy system that is based on generating electricity from renewables and is underpinned by flexible, smart and resilient networks.

The energy sector is in the midst of unprecedented global change driven by rapidly evolving technologies, changing customer demands and new business opportunities. China and Denmark are at the forefront of this development, both in terms of research and implementation. Since the 1980s, Denmark has been a bona fide pioneer in energy transition, and over the past two decades, China has become a global leader in the large-scale deployment of renewable energy technologies and new grid concepts. Both China and Denmark have committed to the Paris Agreement and its central goal to keep global warming well below 2°C. Though their roadmaps differ, both countries have set ambitious targets to increase renewable energy as a percentage of total energy consumption by 2030.

With high annual economic growth rates and a constant rise in energy consumption, China faces a substantial challenge to maintain the balance between energy supply and demand in a sustainable and affordable way. In 2016, China introduced policies to promote a cleaner and greener economy. These policies established specific targets for environmental management and protection, clean energy and emissions control, and the development of green industries. With the Nationally Determined Contributions (NDC), China has committed to a CO_2 emissions peak and a reduction in carbon intensity of 60-65% by 2030 (compared to 2005). The government also introduced the 'New Normal', marking a shift in national policy towards an economy with moderate but higher quality growth. It is expected that the next Five-Year plan, and the medium and long-term plans, all of which will be launched in 2021, will reaffirm this direction and set even higher national targets.

In June 2018, the Danish government signed an energy agreement setting the goal of reaching 55% renewables in total energy consumption and 100% renewable electricity by 2030. This will be mainly generated by new offshore wind parks. In 2019, Denmark introduced a binding de-carbonization target and consequently the 2030 benchmark was updated to a target of reducing emissions by 70% below the 1990 level (excluding international shipping and air travel). Danish policies also

encompass energy efficiency improvements, a broad electrification strategy, a ban on the sale of all new diesel and petrol cars from 2030, and cooperation with other North Sea countries to further exploit offshore wind energy potential.

Future energy systems in Denmark and China will be smart, efficient and integrated. New technology will play a significant role in achieving national energy consumption targets and providing a smooth transition to a low-carbon energy system. Research, development and education across the fields of Energy and Social Science are crucial in addressing challenges related to the planning, development, integration, operation and optimisation of energy systems; these systems should be accessible, reliable and resilient, and steadily increase the share of renewable energy sources. SDC researchers from China and Denmark across the Energy and Social Science research fields have taken on the task of closely monitoring and contributing to this development. The following chapters show how the dual perspectives of technical and societal transformations complement each other, constituting the Yin and the Yang in the transition of the two countries' energy systems.

Chapter 2 provides an overview of Sino-Danish research collaboration in relation to energy transition. The remaining chapters are organised into two main sections. Part II, 'Sino-Danish energy outlook for technologies and systems' focuses on technical and engineering aspects of energy transitions from a systems perspective. Chapter 3 examines the development and deployment of energy scenarios in Denmark and China. Chapters 4 to 9 focus on specific technologies: Wind mapping (Chapter 4), smart energy solutions (Chapter 5), integration of renewables into the grid (Chapter 6), solar thermal power (Chapter 7), district heating (Chapter 8) and digitalisation (Chapter 9). All these technologies benefit from a substantial level of collaboration across the two countries and a high level of complementarity in the knowledge base. Part III, 'Transforming the Chinese energy system through policy and innovation' addresses changes related to energy transition at multiple levels, including business, consumers, national and international governance, policy and socio-economic transformation. Chapter 10 analyses the industrial development of Chinese manufacturers and their role in the deployment of renewable energy in the Chinese market. Chapter 11 looks at urban development and the construction of new satellite housing areas, while Chapter 12 explores the upgrading of urban energy and mobility. This is followed by an examination of China's new role, both internally (Chapter 13) and as a financial actor in the region (Chapter 14). Finally, Chapter 15 assesses sustainability of small hydropower.

The chapters are written by teams of leading international researchers responsible for projects embedded in the SDC research themes of Sustainable Energy and Social Science. Each chapter is founded on internationally recognized research and is fully referenced. Indeed, the chapters have been subject to a peer review process involving leading international experts in line with the highest standards of academic quality. The four editors are the Principal Coordinators of SDC in China and Denmark.

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