MASTER'S THESIS

Stimulating solar energy in the Netherlands: Insights from Chinese solar energy policies and enterprise dynamics

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Abstract

The global shift towards renewable energy is central to addressing climate change, and solar energy plays a key role in this transition. This paper studies how China and the Netherlands' national innovation systems (NIS) affected solar energy development between 2013 and 2023.

The study uses a qualitative research approach using literature analysis, policy document and news analysis, interviews, and a comparative case study design to understand the factors behind the success and limitations of the solar energy sectors in both countries. China's centralized policies, government subsidies, and strong support for state-owned enterprises have fostered rapid innovation, cost reduction, and large-scale solar technology deployment, making China a global leader in solar panel manufacturing. The Netherlands is a more market-oriented economy that has performed well in solar power generation per capita but still relies on imported solar technology, primarily from China. This reliance on imports of solar technologies has impeded its ability to compete with China globally.

The Netherlands could learn from China's integrated solar industry development model, for example, fostering a full value chain and strengthening the central government's power to promote policy. By learning elements of the Chinese approach, such as coordinated government support and the establishment of national banks to invest in domestic solar manufacturing, the Netherlands can strengthen its solar industry's global presence and achieve more sustainable energy independence and national energy security. This research provides insights for Dutch policymakers seeking to adapt NIS to accelerate solar development while achieving long-term climate and energy goals.

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1. Introduction

In the global pursuit of sustainable energy solutions, countries are looking at successful models to deal with the complexities of transitioning to cleaner, more efficient energy sources. One such model that has attracted international attention is China's massive success in advancing its solar energy. China has a more state-led NIS, and in the long-term development process of China's energy industry, the energy industry has been moving in the direction of green and low-carbon transformation while ensuring national energy security (Ren, 2022). In particular, China's new solar energy grid-connected capacity reached 216.3 million kilowatts in 2023, and the cumulative grid-connected capacity by the end of 2023 was 608.918 million kilowatts (China Power, 2024). Meanwhile, the Netherlands, with a more market-led innovation system, has also made significant achievements in solar energy, had approximately 19,600 megawatts of installed solar PV capacity at the end of 2022, and new installed capacity in 2022 was approximately 4,777 megawatts (CBS, 2023). According to data, the per capita solar power generation in the Netherlands (984kWh) was even more than three times that of China (300kWh) in 2022 (Our World in Data, 2023).

Although both the Netherlands and China have considerable achievements in solar energy, compared with China, the Netherlands' solar energy industry has yet to develop along the entire value chain. The Netherlands mainly focuses on investment in research and development and high technologies, but is relatively weak in other aspects of the industrial value chain, such as initial raw materials, mid-term production, and export quotas for finished products. Meanwhile, the Netherlands is known as the country that imports the most solar panels in the world, and according to Statistics Netherlands, Dutch solar panel imports totalled €11.9 billion in 2022, of which €10.5 billion worth of technology came from China (Emily, 2023). However, China has made significant progress in solar energy. Cutting-edge solar technology, such as solar panel efficiency, smart grid technology, and technology to efficiently produce high-quality solar panels give China a significant advantage in the global market (Oleksandra, 2023), which is an instructive case for countries seeking to succeed in solar or even renewable energy.

One possible reason solar energy development in China and the Netherlands varied is the two countries' different national innovation systems. The national innovation system describes the network of institutions, rules and procedures that influence a country's innovation processes. It is a broad and flexible framework for understanding and explaining the factors that affect a country's innovation performance, including the interaction between different actors and institutions involved in innovation processes (Lundvall, 2007). The government plays an important role in China's national innovation system, while the national innovation system of the Netherlands focuses more on the market and industry. NIS can help better understand the differences in solar energy development by focusing on how various actors, such as government, industries, and research institutions, interact within a country to promote innovation. For example, in the case study, in addition to government dominance, state-owned enterprises are also an important influencing factor in solar photovoltaic production in China.

Our research goals are to study how the national innovation system in China and the Netherlands influenced solar energy development, help the Dutch government provide relevant information on solar energy, and suggest policy recommendations. Therefore, the following two questions are raised:

1. How did the national innovation systems of China and the Netherlands influence solar energy development between 2013 and 2023?
2. What policy lessons can be learned from the Chinese solar energy industries, and to what extent could these policies be implemented in the Netherlands?

In order to ensure the coherence of our research, the period the article studies is limited to the last ten years, which is the period from 2013 to 2023. There is a small range of fluctuations of one to three years, and new data for 2024 is also be included to reduce the time constraints when this part is compiled in 2023. The ten-year period could ensure that the policy stay active, and it can also eliminate drastic fluctuations in data caused by the policy.

2. Theory

2.1 National Innovation System

Innovation systems theory is a framework that studies the complex interactions and relationships between various actors, institutions, and elements in a specific geographical or sectoral context to understand the dynamics of innovation (Hekkert et al., 2007). In the real world, some countries have established themselves as technological leaders generally or in specific technological fields, while others tend to lag (Lundvall et al., 1988), which justifies a more detailed analysis of the national innovation system. Just like the topic of our study, why has China's solar energy developed to a higher stage while the Netherlands' solar energy has developed slower than China's? This situation may require analysis from a more systematic and holistic perspective. Regarding the research objective, the national innovation system is a suitable analytical tool. In the national innovation system, in addition to more direct intervention in specific innovations, the government also formulates standards and regulations to make domestic interactions more efficient (Lundvall et al., 1988).

A national innovation system comprises interrelated institutions that create, store, and transfer the knowledge, skills, and artefacts that define new technologies (Metcalfe, 1994). Within this national institution, its incentive structure and capabilities determine a country's pace and direction of technological learning (or the amount and composition of change activities) (Patel, 1994). In past research on China, the national innovation system has been fundamental in shaping the solar energy sector. For example, the central government emphasized the importance of renewable energy, legalized the activities of the photovoltaic industry, and used resources such as cheap capital, land, and institutional advantages to facilitate photovoltaic entrepreneurs, while local governments cooperate with entrepreneurs to lobby for domestic market investment, and the government subsidies and financial support to photovoltaic manufacturers have helped China's solar industry develop rapidly (Huang et al., 2016). The energy industry, notably the transition to clean energy, involves a complex system of actors, policies, technologies, and markets. National innovation systems theory's emphasis on networks and collaborative learning is also well suited to analyzing the dynamics of the energy sector and enterprises.

Figure 1 (Kuhlmann & Arnold, 2001) introduces the elements and possible connections inside a national innovation system. The national innovation system mainly includes three different systems: the industrial, education and research, and political systems. The industrial system mainly comprises different companies, including large companies and small and medium-sized enterprises. The education and research system mainly comprises higher education (universities) and public sector research (research institutes). The political system is mainly about government. In addition to these three systems, a country's infrastructure, overall framework conditions, and supply and demand relationships are also part of the national innovation system. Infrastructure, financial systems, innovation systems, and intellectual information systems are all important factors in promoting national innovation. The relationship between supply and demand provides the impetus for innovation, especially research in enterprises and research systems. In a national innovation system, every part is closely connected, and interactions between these stakeholders jointly promote the development of the system.

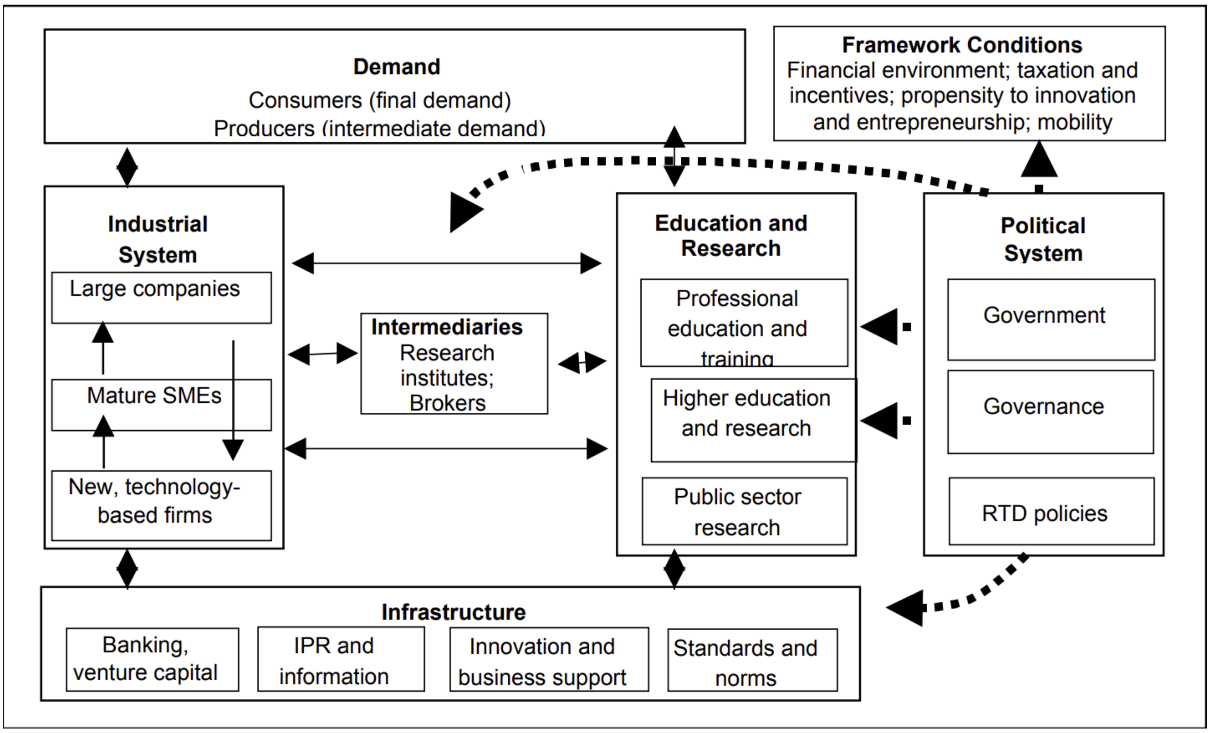

Figure 1: A National Innovation System Model (Kuhlmann & Arnold, 2001)

The NIS elements are discussed in this study only concerning solar, because the entire NIS would be too broad in scope to practically achieve analysis. China's solar industry is a global leader, and its connection with the national innovation system is worth further exploration. The analysis and structure of this article are similar to the combined NIS-TIS analysis in Huang's (2016) article; that is, the article explores the impact of different national institutions on the development of a technology. However, I chose not to adopt a systemic functional perspective on TIS in this paper because I am particularly interested in the impact of national institutions.

The study also considers another element, which is state-owned enterprises (SOEs). Within a national innovation system, producers, consumers, and even banks could be state-owned enterprises, and there are some potential advantages of SOEs for solar energy developments. In this article, to clarify the concept of state-owned enterprises, we identify a company as a state-owned enterprise if it is reported as its controlling shareholder or if the proportion of state-owned capital to registered capital is no less than 50% (Hsieh & Song, 2015). They can implement government policies better and faster, and the government can more conveniently provide more resources to state-owned enterprises to improve environmental performance (Wang et al., 2022). Therefore, with the changes in the national energy structure and the advantages of nationalization, such as overcoming market failures, promoting anti-monopoly and regional development balance, and guaranteeing employment and other factors, these possible benefits can provide a basis and motivation for Dutch solar energy companies to transfer to public ownership.

I use the following factors from Figure 1, to compare the NIS in China and Netherlands. However, in the analysis and the results, I deleted "Banking and venture capital" in the infrastructure part because of the overlap with the financial environment part in framework conditions. Furthermore, I deleted "Propensity to innovation and entrepreneurship", and "Taxations and incentives" in the framework conditions part, because of the overlap with the "Innovation and business support", "IPR and information", and "Standards and norms" parts in infrastructure.

Factors	**Contents or other detailed elements**
Industrial system	Large companies; Mature SMEs; New, technology-based firms; SOEs.
Political system	Government; Governance; RTD policies.
Research and education	Professional education and training; High education and research; Public sector research.
Framework conditions	Financial environment; Mobility; Propensity to innovation and entrepreneurship; taxations and incentives.
Infrastructure	Banking and venture capital; Innovation and business support; IPR and information; Standards and norms.

Later studies have expanded on the view that NIS focuses only on national systems. For example, Fagerberg et al. (2018) consider the importance of focusing on increasing openness and participation in global value chains and building strong national innovation systems for economic development. Binz et al. (2017) emphasize the importance of international cooperation, such as the importance of "acquiring technology from developing countries and innovating" in China's wind and solar PV industries through "technology transfer" and "local manufacturing". Together, these studies extend Kuhlmann & Arnold's NIS framework beyond isolated national systems and provide deeper thinking about the occurrence of cross-industry and cross-border innovation.

Thus, I list these factors below to show more details and expand on their roles in research and innovation:

Factors	Explanation
Value chain coordination	It covers all life cycle stages, from idea or concept, raw material sourcing, production, distribution, and end-customer use, to the return of the product to the biological or technological cycle, thus closing the loop (Franco et al., 2021).
International cooperation	Including but not limited to research and innovation, fundings, strategies, and cooperation agreements (European Commission, n.d.).

The industry and country-level value chain covers all life cycle stages, from idea or concept, raw material sourcing, production, distribution, and end-customer use, to the return of the product to the biological or technological cycle, thus closing the loop (Franco et al., 2021). Moreover, it provides a comprehensive understanding of the solar industry, thus supporting strategic and technological planning for incumbents and new entrants, as well as higher-level policy making (Franco et al., 2021). Kuhlmann & Arnold's NIS model includes the element of Demand (which can be subdivided into consumers and producers). As production and consumption are important elements in the value chain which will be analyzed in this article, therefore, Demand in NIS model is not analyzed separately. Besides, the production and consumption are related to our "Industrial system" and "Infrastructure" in the NIS.

International cooperation refers to the collaboration between countries to address global challenges, share resources, and advance research and innovation. This cooperation takes many forms, including but not limited to research and innovation, funding, strategy and cooperation agreements (European Commission, n.d.). Market cooperation enables companies to enter new markets (such as developing markets in Africa and South America mentioned below), optimize supply chains, and enhance competitiveness in the interconnected global economy. Therefore, this study focuses on technological and market cooperation in international cooperation.

3. Methodology

3.1 Justification research design

This paper only discusses the NIS related to solar energy, which aligns with its research questions and objectives, namely how the NIS affects the development of solar energy and what policy lessons can be learned from the Chinese solar industry. This paper does not provide a comprehensive overview of the entire NIS in China and the Netherlands in all sectors,

<u>Conduct comparative analysis:</u> The solar energy comparison between China and the Netherlands was chosen for the following reasons. As mentioned above, China is a global solar energy production and export leader. Due to its rapid success and influence in the global market,

understanding how China has achieved such outstanding results can provide many experiences for other countries. At the same time, the Netherlands relies on imports of solar photovoltaics, mainly from China, which has established a close cooperation and interdependence between the two countries. This cooperation, coupled with the Netherlands' plans to expand renewable energy capacity and achieve sustainable development, makes this comparative study both timely and convenient for the Netherlands to learn from the cooperation with China.

3.2 Structured document analysis

3.2.1 Data collection

The main research method for this Master's Thesis is qualitative research. The data is collected from grey literature, policy reports publications, and interviews. Analyzing government policy documents and third-party publications can add depth and credibility to the research. A solid foundation for understanding the policy landscape can be developed by drawing on official sources.

Documents and publications (including officially published policy documents, etc.): Policy announcements and publications from the government: This includes energy-related news, policy plans, policy support, industry development reports from the Dutch and Chinese governments, and official statistics (such as national energy consumption proportion). These documents show a more accurate direction of national policy development and the possible impact on private enterprises. For example, China's "National Bureau of Statistics" and the Netherlands' "Statistics Netherlands" can provide more accurate energy information, including the consumption proportion of various energy sources, energy use change trends and other digital icon information. The Dutch government website "Government of the Netherlands" shows relevant energy information, such as the topic "Central government encourages sustainable energy" and the document *Energy Report Transition to sustainable energy*. China's energy policy information can be reflected through annual reports such as *China Energy Big Data Report (2023)*. Meanwhile, according to the introduction, the announcements and publications from the government are limited to the last ten years, which is the period from 2013 to 2023. Considering the policy's consistency, the time range of 2013 can be appropriately advanced to 2010.

Publications and documents from third parties (“grey literature”): This includes documents and publications provided by non-stakeholders such as scholars, researchers, and journalists. For example, papers and journals provided by scholars, policy analysis reports provided by researchers from other fields (industry research analysis provided by researchers in the financial industry), and real-time analysis and comments provided by journalists demonstrate a commitment to a comprehensive understanding of the (solar) energy industry. For example, the article *Opportunities and challenges for renewable energy policy in China* presents policy advice for improving renewable energy development in China, which focuses on enhancing policy effectiveness and completeness and promoting policy innovation in regional contexts

(Peidong et al., 2018). In addition, some industry studies such as *JA Solar Technology Co., Ltd.'s Annual Report on Talent Training in Higher Vocational Education (2023)* introduce how the education system can cooperate with enterprises to jointly promote the development of the solar industry. These third-party documents also help to understand the development of the energy industry more comprehensively and objectively and avoid the bias caused by single data.

<u>Interviews:</u> Since interviews do not involve importing and using a large amount of data, sampling strategies are not applicable here. However, there are still specific grounds for selecting interviewees, which can reduce bias and increase the credibility and general applicability of the research, especially to verify the document analysis and obtain more non-textual insights. I selected Kyle Chan, a postdoctoral researcher and lecturer with in-depth knowledge of China's industrial policy, clean technology, and infrastructure. The research questions mainly focus on the research content of his past papers and related content about China's NIS. The table below shows the examples of the theories and interview questions used.

Theories	**Concepts**	**Example interview questions**
(National) innovation system	➢ Global Perspective	➢ From a global perspective, how do China and the Netherlands' sustainable development policies contribute to the broader solar energy landscape? ➢ China has huge advantages in value chain and exports, while the Netherlands excels in technology and resources. How do these respective strengths influence their global solar energy market positions?
	➢ Nationalization and Policy	➢ What adjustments or innovations do you think the Netherlands might need to make to balance long-term stability, sustainability, and innovation in its solar energy sector? ➢ Do you believe that companies promoting government policy innovation is an effective method for advancing the solar energy sector in the Netherlands?
	➢ Comparative Analysis	➢ What are the key differences between the energy markets in China and the Netherlands? How might these differences affect the potential for nationalization in the Netherlands? ➢ What trends in the global solar energy market do you think might influence the outcome of nationalization in the Dutch context? ➢ Considering China has formed a complete industrial chain and holds a significant advantage in global exports, how might this influence the

		Dutch solar energy sector’s strategic decisions?

To find the documents for the research, I used a combination of targeted keyword searches and systematic browsing of official websites. By searching terms like "renewable energy policy", "solar energy five-year plans", "energy data reports", and "sustainable energy development" I was able to identify a wide range of relevant documents. This keyword approach ensured I could locate policy documents, industry reports, official news updates, and regulatory announcements published by government bodies. Additionally, I accessed government websites directly, like China's National Development and Reform Commission and the Netherlands' Ministry of Economic Affairs, to retrieve policy documents and other key materials posted online.

Regarding document types, I primarily focused on policy documents such as five-year plans, national energy strategies, and development frameworks that lay out government priorities and long-term goals. To complement these, I also included news updates published by government agencies, as they often announce or explain the rationale behind new policies and provide details on their implementation. This approach ensured that my document collection included high-level policy insights, market trends, and practical regulatory updates.

To ensure comprehensive coverage of all main developments, I applied several strategies. Beyond setting a general time range filter for documents published within the last ten years, I took into account the structure of Chinese policy, which often revolves around five-year plans. As such, I specifically sought out the most recent three five-year plans, as this provided a thorough overview of the developments in China's energy policy over the past decade. For the Netherlands, I paid special attention to identifying whether earlier versions of certain policies existed before the most recent publication. This approach allowed me to trace policy evolution and ensure that all significant updates and earlier frameworks related to energy transitions were considered.

Below are the documents I used for coding. These documents were published in the past ten years (sometimes the documents could be published in or after 2010, or in 2024, which also considered as useful and reliable documents), which is consistent with my research time setting.

No	Country	File Type	File Name	Author	Year	Link
1	China	Company or other institutions official website	CAS	CAS	n.d.	https://www.cas.cn/
2			CEIC	CEIC	n.d.	https://www.ceic.com/
3			CNREC	CNREC	n.d.	http://www.cnrec.org.cn
4			Daqo Energy	Daqo Energy	n.d.	https://www.xjdqsolar.com
5			Doctoral Program in Innovation and Leadership Engineering	Tsinghua University	2022	https://www.icon.tsinghua.edu.cn/info/1072/1145.htm
6			Envision	Envision	n.d.	https://www.envision-group.com/
7			Eging PV	Eging PV	n.d.	https://m.egingpv.com/?c=category&id=65
8			Factory Certificates	JinkoSolar	n.d.	https://jinkosolar.eu/downloads/factory-certificates/
9			GCL	GCL	n.d.	https://www.gclsi.com/
10			HuaYang New Energy Investment Group	HuaYang New Energy Investment Group	n.d.	http://www.huayangxinnengyuan.com/
11			JA Solar	JA Solar	n.d.	https://www.jasolar.com/html/en/
12			JinkoSolar	JinkoSolar	n.d.	https://www.jinkosolar.com/en#index1
13			LONGi	LONGi	n.d.	https://www.longi.com/eu/
14			Microquanta	Microquanta	n.d.	https://www.microquanta.com/en/#/pc/home
15			NEA	NEA	n.d.	https://www.nea.gov.cn/
16			Photovoltaic "Practical Technology + Practical Marketing" Training Course	Igreen	n.d.	https://www.igreen.org/index.php?m=content&c=index&a=show&catid=79&id=268
17			SGCC	SGCC	n.d.	http://www.sgcc.com.cn:8000/
18			Sungrow	Sungrow	n.d.	https://cn.sungrowpower.com/
19			Trina Solar	Trina Solar	n.d.	https://static.trinasolar.com/en-glb

20			Why Sule Solar	Sule Solar	n.d.	https://bjsola.com/
21			2021 Wind and solar curtailment rates by province in China	China Energy Transformation Program	2022	https://www.cet.energy/2022/07/14/2021-wind-and-solar-curtailment-rates-by-province-in-china/
22		Industry report	A brief history of China's photovoltaic development	Trendy Finance	2023	https://mp.weixin.qq.com/s?__biz=MzI3MDUwNDU0Ng==&mid=2247653211&idx=2&sn=f94e3b471d95a72d90451e6d4d3f2fe5&chksm=eadcd056ddab5940807707ba9fc11253ec876b88ac7d4ac4170c5dc15bbaa40f2d942c8a3e65&scene=27
23			As patent competition among leading photovoltaic companies intensifies, how can small and medium-sized enterprises cope with patent suppression by leading companies?	Shenzhen Industrial Automation Industry Association	2024	https://mp.weixin.qq.com/s?__biz=MzIyODUyNTg0MA==&mid=2247512385&idx=1&sn=9bffbb24eb7e0f0085910745bfabc1be&chksm=e852633edf25ea288b7f7ed1223a8b8fef1d860f96e5e8cb52b258e6dad1530e2cacad2dd12a&scene=27
24			China Energy Big Data Report (2023): Chapter 1 Overview of Energy Development.	Zhongneng Media Research Institute	2023	https://www.cpnn.com.cn/news/baogao2023/202306/t20230620_1611029.html
25			China's State-Owned Enterprises Hold Keys to Carbon Neutrality	John Lin	2022	https://www.alliancebernstein.com/corporate/en/insights/esg-in-action/esg-in-action-chinas-state-owned-enterprises-hold-keys-to-carbon-neutrality.html
26			Chinese state-owned enterprises are the largest owners of solar assets; The	Juan Monge	2023	https://www.woodmac.com/news/opinion/chinese-state-owned-enterprises-are-the-largest-owners-of-solar-assets/

			largest solar portfolios in the world grew by a staggering 44% in 2022			
27			How China Became the World's Leader on Renewable Energy	Isabel Hilton	2024	https://e360.yale.edu/features/china-renewable-energy
28			Global opportunities for Chinese new energy companies	KPMG	2014	https://assets.kpmg.com/content/dam/kpmg/pdf/2014/08/China-New-Energy-Report-Global-Opportunities-201407-c.pdf
29			Guide to Chinese climate policy 2022	Sandalow, D.	2022	https://chineseclimatepolicy.oxfordenergy.org/
30			JA Solar Technology Co., Ltd.'s Annual Report on Talent Training in Higher Vocational Education (2023)	Jiangsu Tourism Vocational College	2022	https://www.tech.net.cn/upfiles/zlbg2023/qiye/jiangsu/jiangsu%20(168).pdf
31			Making State-Owned Enterprises Work for Climate in China and Beyond	Philippe Benoit	2020	https://www.energypolicy.columbia.edu/publications/making-state-owned-enterprises-work-climate-china-and-beyond/
32			Market status, competition pattern and development trend of China's solar cell industry	Prospective Industry Research Institute	2022	http://www.hfkczx.com/industry_detail.html?id=27423
33			Special Report on Solar PV Global Supply Chains	IEA	2022	https://iea.blob.core.windows.net/assets/d2ee601d-6b1a-4cd2-a0e8-db02dc64332c/SpecialReportonSolarPVGlobalSupplyChains.pdf
34			The Rise of China in the Solar Industry: A Global Revolution	Oleksandra Mamchii	2023	https://bestdiplomats.org/why-china-is-dominating-the-solar-industry/

35			Xinjiang and Polysilicon	Alex Turnbull	2021	https://syncretica.substack.com/p/xinjiang-and-polysilicon
36		News	Analysis: How China's National Emissions Trading Scheme Will Work	Paulson Institute	2021	https://www.paulsoninstitute.org/green-finance/green-scene/analysis-how-chinas-national-emissions-trading-scheme-will-work/
37			Chinese Building Material Group CNBM Acquires AVANCIS's Solar Business	EnergyTrend	2014	https://www.energytrend.com/news/20140425-6615.html
38			China helps Pakistan build world's largest solar farm. Dialogue Earth	Zofeen Ebrahim	2015	https://dialogue.earth/en/energy/8160-china-helps-pakistan-build-world-s-largest-solar-farm/
39			China initiates green loan to finance renewable project boom	Xu Yihe	2021	https://www.upstreamonline.com/energy-transition/china-initiates-green-loan-to-finance-renewable-project-boom/2-1-1025805?zephr_sso_ott=4U8gmW
40			China: Is it burdening poor countries with unsustainable debt	Wang, K	2022	https://www.bbc.com/news/59585507
41			China ranks first in the world in terms of solar cell patent applications	CCTV News	2024	http://www.ce.cn/xwzx/gnsz/gdxw/202401/05/t20240105_38854871.shtml#:~:text=%E5%9B%BD%E5%AE%B6%E7%9F%A5%E8%AF%86%E4%BA%A7%E6%9D%83%E5%B1%80%E6%97%A5%E5%89%8D,%E6%88%91%E5%9B%BD%E4%BC%81%E4%B8%9A%E5%B7%B2%E7%BB%8F%E5%BC%95%E9%A2%86%E4%B8%96%E7%95%8C%E3%80%82

42			China to cut renewable power subsidy to $807 million in 2020	Reuters	2019	https://www.reuters.com/article/business/environment/china-to-cut-renewable-power-subsidy-to-807-million-in-2020-idUSKBN1XU0X7/
43			In 1986, Deng Xiaoping personally decided to launch the "863" plan	People's Daily Online	2014	http://cpc.people.com.cn/n/2014/1231/c69113-26308784.html
44			National Energy Administration: New photovoltaic grid-connected capacity in 2023 was 216.3GW.	China Power	2024	http://www.chinapower.com.cn/tynfd/hyyw/20240229/237058.html
45			On the verge of delisting! Three subsidiaries of this photovoltaic company stopped production	OFweek	2024	https://solar.ofweek.com/2024-06/ART-260006-12000-30637310.html
46			Overview of China's green bond market issuance and trading in September 2024	New Century Ratings	2024	https://finance.sina.com.cn/money/bond/2024-10-24/doc-inctryqx5813538.shtml
47			To resist foreign aggression, we must first stabilize the internal situation" China's photovoltaic industry forms an alliance	China Securities Journal	2010	https://www.chinanews.com.cn/ny/news/2010/05-18/2288614.shtml
48			Zhu Rui, Zhao Lichen, and Gong Qihuang's team made important progress in the study of buried interfaces in perovskite solar cells	Institute of Modern Optics	2024	https://www.phy.pku.edu.cn/info/1031/10405.htm

49		Policy document	China Energy Outlook 2060	Sinopec Group Economic and Technological Research Institute Co., Ltd. & Sinopec Consulting Co., Ltd.	2024	https://www.cpnn.com.cn/news/baogao2023/202401/W020240105322424121296.pdf
50			China Energy Big Data Report 2023	China Energy Media Research Institute	2023	https://13115299.s21i.faiusr.com/61/1/ABUIABA9GAAgreq4pgYomNb_hQc.pdf
51			China Energy Big Data Report 2022	China Energy Media Research Institute	2022	https://www.bj-xinghe.com/wp-content/uploads/2022/07/%E4%B8%AD%E5%9B%BD%E8%83%BD%E6%BA%90%E5%A4%A7%E6%95%B0%E6%8D%AE%E6%8A%A5%E5%91%8A%EF%BC%882022%EF%BC%89-%E4%B8%AD%E8%83%BD%E4%BC%A0%E5%AA%92%E7%A0%94%E7%A9%B6%E9%99%A2.pdf
52			Green Bond Issuance Guidelines	National Development and Reform Commission	2015	https://www.google.com.hk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwir4cqBt66JAxV-hP0HHX-dDbYQFnoECBYQAQ&url=https%3A%2F%2Fzfxxgk.ndrc.gov.cn%2Fweb%2Ffileread.jsp%3Fid%3D1987&usg=AOvVaw1hWBPzQHTEsV0IrOpXit_1&opi=89978449
53			Notice of the National Energy Administration on the Implementation of the Renewable Energy Power	National Development and Reform Commission	2018	https://policy.asiapacificenergy.org/sites/default/files/Draft%20Notice%20on%20the%20Implementation%20of%20the%20Renewable%20Electricity%20Obligation%20%28CH%29.pdf

			Quota System (Draft for Comments)			
54			Photovoltaic power generation project component and support installation quality assessment standard	NEA	2019	https://www.163.com/dy/article/ICP76AN10514DRR7.html
55			The 12th Five-Year Development Plan for Solar Photovoltaic Industry	Planning Department	2012	https://policy.asiapacificenergy.org/sites/default/files/%E5%A4%AA%E9%98%B3%E8%83%BD%E5%85%89%E4%BC%8F%E4%BA%A7%E4%B8%9A%E5%8D%81%E4%BA%8C%E4%BA%94%E5%8F%91%E5%B1%95%E8%A7%84%E5%88%92.pdf
56			The 12th Five-Year Plan for Solar Power Generation Development	National Energy Board	2012	https://zfxxgk.nea.gov.cn/auto87/201209/P020120912536329466033.pdf
57			The 13th Five-Year Plan for Solar Energy Development	National Energy Board	2016	https://policy.asiapacificenergy.org/sites/default/files/IEA_PAMS_China_China13thSolarEnergyDevelopmentFiveYearPlan20162020.pdf
58			The 14th Five-Year Plan for Renewable Energy Development	National Development and Reform Commission, People's Republic of China	2022	https://www.ndrc.gov.cn/xxgk/zcfb/ghwb/202206/P020220602315308557623.pdf
59		Policy website	Implementation Plan on Promoting High-quality Development of New Energy in the New Era	National Development and Reform Commission; National Energy Administration	2022	https://www.gov.cn/zhengce/content/2022-05/30/content_5693013.htm

60			Notice on the implementation of the Golden Sun Demonstration Project	Ministry of Finance of the People's Republic of China	2009	https://www.gov.cn/zwgk/2009-07/21/content_1370811.htm
61			Opinions on improving the institutional mechanisms and policy measures for green and low-carbon energy transformation	National Development and Reform Commission; National Energy Administration	2022	https://www.gov.cn/zhengce/zhengceku/2022-02/11/content_5673015.htm
62	Netherlands	Company or other institutions official website	About ENTSO-E	ENTSO-E	n.d.	https://www.entsoe.eu/about/
63			Claiming back the VAT on your solar panel system	Zonnefabriek	2023	https://www.zonnefabriek.nl/en/our-service/vat-claim-solar-panels/#:~:text=Claiming%20back%20VAT%20on%20your,has%20been%20reduced%20to%200%25
64			Difference Between SDE+ and SDE++ Subsidy	Stephan Marcelis	2020	https://www.indienergie.nl/kennisbank/verschil-sde-en-sde-subsidie/
65			Eneco	Eneco	n.d.	https://www.eneco.nl/duurzame-energie/?utm_source=google&utm_medium=cpc&utm_campaign=werving-corporate&utm_content=&utm_term=eneco&utm_id=google_ads_282875592&utm_landing=search&gad_source=1&gclid=
66			Exasun	ENERGIIQ	n.d.	https://www.energiiq.nl/portfolio-item/exasun/
67			Engineering for Sustainable Energy Systems	TU/e	n.d.	https://www.tue.nl/en/research/institutes/eindhoven-institute-for-renewable-energy-systems/engineering-for-sustainable-energy-systems

68			International cooperation	European Commission	n.d.	https://research-and-innovation.ec.europa.eu/strategy/strategy-2020-2024/europe-world/international-cooperation_en
69			Meyer Burger wins another large contract worth more than CHF 25 million from ReneSola in China for wire and band saws	Meyer Burger	2007	https://www.meyerburger.com/nl/newsroom/artikel/meyer-burger-wins-another-large-contract-worth-more-than-chf-25-million-from-renesola-in-china-for-wire-and-band-saws
70			MSc Sustainable Energy Technology	TUDelft	n.d.	https://www.tudelft.nl/onderwijs/opleidingen/masters/set/msc-sustainable-energy-technology
71			New Energy Academy	New Energy Academy	n.d.	https://newenergyacademy.org/
72			Over Holland Solar	Holland Solar	n.d.	https://hollandsolar.nl/over/
73			Photovoltaic Materials and Devices	TUDelft	n.d.	https://www.tudelft.nl/ewi/over-de-faculteit/afdelingen/electrical-sustainable-energy/photovoltaic-materials-and-devices
74			Products & Services	Rabobank	n.d.	https://www.rabobankwholesalebankingna.com/products-services/
75			Shell	Shell	n.d.	https://www.shell.com/
76			Smart Grids	IEA	n.d.	https://www.iea.org/energy-system/electricity/smart-grids
77			Solarclarity	Solarclarity	n.d.	https://solarclarity.com/en
78			Solar technologies and applications	TNO	n.d.	https://www.tno.nl/en/about-tno/organisation/units/energy-transition/solar-technologies-applications/
79			Themes Greenpeace	Greenpeace	n.d.	https://www.greenpeace.org/nl/oplossingen/

80			The Net-Metering News: A Closer Look at the Dutch Decision	Solar Monkey	2024	https://solarmonkey.io/the-net-metering-news-a-closer-look/#:~:text=What%27s%20net%20metering%2C%20anyway%3F,through%20solar%20or%20wind%20power
81			Techleap.nl (former StartupDelta)	Techleap.nl	n.d.	https://securitydelta.nl/partners/overview-partners/startupdelta
82			Understanding Curtailment and Clipping: Maximizing Your Solar Investment	Sitemark	2023	https://www.sitemark.com/blog/understanding-curtailment-and-clipping-maximizing-your-solar-investment/#:~:text=Curtailment%20occurs%20when%20a%20solar,or%20infrastructure%20can%20effectively%20handle
83			Victron Energy	Victron Energy	n.d.	https://www.victronenergy.com/
84			Vocational education and training in Europe-Netherlands August 2023	Cedefop	2023	https://www.cedefop.europa.eu/en/tools/vet-in-europe/systems/netherlands-u3
85			We have the energy to create a better world	IBC Solar	n.d.	https://www.ibc-solar.com/
86			Who we are	Sustainable Energy for All	n.d.	https://www.seforall.org/who-we-are
87			Zernike Institute for Advanced Materials	Rijksuniversiteit Groningen	n.d.	https://www.rug.nl/research/zernike/?lang=en
88			Zonnepanelen	Zonnepanelen	n.d.	https://www.zonnefabriek.nl/zonnepanelen-van-zonnefabriek/?utm_source=adwords&utm_term=zonnepanelen&utm_medium=ppc&utm_campaign=Best+performing+%7C+NL&hsa_cam=21722110222&hsa_ad=714038000053&hsa_net=adwords&hsa_ver=3&hsa_acc=3307538378&hsa_tgt=

						kwd-183236720&hsa_kw=zonnepanelen&hsa_mt=e&hsa_grp=167307420603&hsa_src=g&gad_source=1&gclid=Cj0KCQjwpvK4BhDUARIsADHt9sSSoKt_aZ1tJPxUq5Na6Xpy4M-GqmSKi3SKKMp7XmSgfkPK7ixmvXIaAnihEALw_wcB
89		Industry report	Analysis of the Technological Innovation System for BIPV in the Netherlands	IEA	2024	https://iea-pvps.org/wp-content/uploads/2024/08/IEA-PVPS-T15-2024-REPORT-Netherlands-TIS-BIPV-.pdf
90			Changes in the net metering law postponed until 2025	Hessel van den Berg	2023	https://www.zonnefabriek.nl/en/news/changes-in-the-net-metering-law-postponed-until-2025/
91			CATL unveils first mass-producible battery storage with zero degradation	Marija Maisch	2024	https://www.pv-magazine.com/2024/04/12/catl-unveils-first-mass-producible-battery-storage-with-zero-degradation/
92			Dutch government shifts policy on solar panels on farmland	Ruben Stokroos	2023	https://www.osborneclarke.com/insights/dutch-government-shifts-policy-solar-panels-farmland#:~:text=To%20minimise%20the%20impact%20on,solar%20parks%20in%20the%20Netherlands.
93			Eneco connects assets to its Virtual Power Plant for the energy system of the future	Eneco	2023	https://news.eneco.com/eneco-connects-assets-to-its-virtual-power-plant-for-the-energy-system-of-the-future/
94			Eneco starts construction of solar farm underneath Kabeljauwbeek wind farm	Eneco	2024	https://news.eneco.com/eneco-starts-construction-of-solar-farm-underneath-kabeljauwbeek-wind-farm/
95			Enterprises by business size	OECD	n.d.	https://www.oecd.org/en/data/indicators/enterprises-by-business-

						size.html#:~:text=SMEs%20are%20further%20subdivided%20into,employ%20250%20or%20more%20people
96			Electricity generation from solar power per person	Our World in Data	2023	https://ourworldindata.org/grapher/solar-electricity-per-capita
97			Europe will struggle to reach its solar PV manufacturing target without subsidies	Edurne zoco & Karl Melkonyan	2023	https://www.spglobal.com/commodityinsights/en/ci/research-analysis/europe-will-struggle-to-reach-its-solar-pv-manufacturing.html
98			European energy market reform | Netherlands	Deloitte	n.d.	https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Energy-and-Resources/gx-er-market-reform-netherlands.pdf
99			Grid Overload: The Impact of the Electricity Grid on the Dutch Energy Transition	Aurora	2024	https://auroraer.com/insight/grid-overload-dutch-energy-transition/
100			Know the Source: The Polysilicon Supply Chain.	Lee Williams	2022	https://www.minespider.com/blog/know-the-source-the-polysilicon-supply-chain
101			Leading energy suppliers in the Netherlands in 2018, by number of clients	Statista	n.d.	https://www.statista.com/statistics/753410/leading-energy-suppliers-in-the-netherlands-by-number-of-clients/#:~:text=Essent%2C%20Vandebron%20and%20Energiedirect.nl,Oxxio%2C%20reached%202.4%20million%20clients
102			LeydenJar silicon anodes increase battery energy by up to 70%	Will Dodds	2024	https://zagdaily.com/people/leydenjar-silicon-anodes-increase-battery-energy-by-up-to-70/
103			Rockstart launches a €21m fund to invest in energy startups	Rockstart	2020	https://rockstart.com/blog/2020/10/07/rockstart-launches-a-e21m-fund-to-invest-in-energy-startups/

104			Solar energy	TNO	n.d.	https://www.tno.nl/en/about-tno/organisation/units/energy-transition/solar-energy/
105			The Netherlands 2020 Energy Policy Review	IEA	2020	https://www.iea.org/reports/the-netherlands-2020
106		News	ABN AMRO makes it easier for businesses to buy solar panels	ABN AMRO	2023	https://www.abnamro.com/en/news/abn-amro-makes-it-easier-for-businesses-to-buy-solar-panels
107			Citizens want to be part of the energy transition	Ellen Hensbergen	2024	https://www.startgreen.nl/en/nieuws/burgers-willen-graag-deel-uitmaken-van-de-energietransitie/#:~:text=Both%20the%20National%20Program%20for,a%20project%20to%20local%20residents
108			Dutch government confirms new restrictions for ASML's exports to China	Giacomo Fracassi	2024	https://www.europeaninterest.eu/dutch-government-confirms-new-restrictions-for-asmls-exports-to-china/#:~:text=The%20Dutch%20government%20started%20to,advanced%20DUV%20tools%20after%202024.
109			EU hits China with big taxes in electric car sales battle	Michael Race	2024	https://www.bbc.com/news/articles/cly20n4d0g9o
110			European Parliament approves legal requirement to install solar on buildings	Patrick Jowett		https://www.pv-magazine.com/2024/03/13/european-parliament-approves-legal-requirement-to-install-solar-on-buildings/
111			Floating solar and trash mountains: How the	Charlotte Elton	2023	https://www.euronews.com/green/2023/03/08/floating-solar-and-trash-mountains-how-the-netherlands-became-europes-solar-power-

			Netherlands became Europe's solar power leader			leader#:~:text=The%20Netherlands%20today%20has%20an,industry%20association%20Solar%20Power%20Europe
112			Nederlandse fabrikant van zonnepanelen Exasun failliet	Edwin van Gastel	2024	https://solarmagazine.nl/nieuws-zonne-energie/i36388/nederlandse-fabrikant-van-zonnepanelen-exasun-failliet
113			Netherlands to phase out net-metering scheme in 2027	Emiliano Bellini	2024	https://www.pv-magazine.com/2024/05/16/netherlands-to-phase-out-net-metering-scheme-in-2027/
114			Solar	Shell	N.d.	https://www.shell.com/what-we-do/renewable-power/solar.html
115			The Netherlands imports the most solar panels - but doesn't use them	Emily Proctor	2023	https://www.iamexpat.nl/expat-info/dutch-expat-news/netherlands-imports-most-solar-panels-doesnt-use-them
116			Transitioning to renewable energy: Challenges and opportunities	Nutifafa Yao Doumon	2024	https://iee.psu.edu/news/blog/transitioning-renewable-energy-challenges-and-opportunities
117			The world needs more diverse solar panel supply chains to ensure a secure transition to net zero emissions	IEA	2022	https://www.iea.org/news/the-world-needs-more-diverse-solar-panel-supply-chains-to-ensure-a-secure-transition-to-net-zero-emissions
118		Policy document	Climate Agreement	Government of the Netherlands	2019	https://www.government.nl/documents/reports/2019/06/28/climate-agreement
119			Climate Agenda: Resilient, Prosperous and Green	Ministry of Infrastructure and the Environment	2014	https://www.government.nl/documents/reports/2014/02/17/climate-agenda-resilient-prosperous-and-green#:~:text=This%20Climate%20Agenda%20o

						utlines%20a,mitigation%20(by%20reducing%20greenhouse%20gas
120			Energy in figures. Energie Beheer Nederland.	Ebn	2022	https://www.ebn.nl/wp-content/uploads/2023/05/26-EBN-Infographic-2022_A4-final_ENGELS.pdf
121			Energy Report Transition to sustainable energy	Ministry of Economic Affairs of the Netherlands	2016	https://www.government.nl/documents/reports/2016/04/28/energy-report-transition-tot-sustainable-energy
122			Next-generation solar power	Netherlands Enterprise Agency RVO	2020	https://www.rvo.nl/sites/default/files/2020/08/NL-Solar-Guide-2020.pdf
123			Subsidies for innovation in energy - Top Sector Energy (TSE)	NEA	n.d.	https://business.gov.nl/finance-and-taxes/subsidies/about-subsidies/subsidies-for-innovation-in-energy-top-sector-energy-tse/
124			The National Technology Strategy	Ministry of Economic Affairs and Climate Policy	2024	https://www.rijksoverheid.nl/documenten/beleidsnotas/2024/01/19/de-nationale-technologiestrategie
125		Policy website	Climate & Energy Programme	Ministry of Education, Culture and Science	n.d.	https://www.government.nl/ministries/ministry-of-education-culture-and-science/climate-and-energy-programme
126			Energy Investment Allowance (EIA) for entrepreneurs	RVO	2024	https://www.rvo.nl/subsidies-financiering/eia/ondernemers
127			Environmental quality of electricity production (MEP)	Eerste Kamer	n.d.	https://www.eerstekamer.nl/wetsvoorstel/28665_milieukwaliteit

128			Green Bonds	Ministry of Finance	n.d.	https://english.dsta.nl/subjects/green-bonds#:~:text=In%202019%2C%20the%20State%20of,%2Drelated%2C%20expenditures%20and%20investments
129			ISO and NEN certification for your business	Netherlands Chamber of Commerce	n.d.	https://business.gov.nl/running-your-business/growth/iso-and-nen-certification-for-your-business/
130			Make your company more sustainable with solar energy	Netherlands Enterprise Agency RVO; Statistics Netherlands, CBS	n.d.	https://business.gov.nl/running-your-business/environmental-impact/energy/make-your-company-more-sustainable-with-solar-energy/
131			MEP grant. Renewable electricity production stable	CBS	n.d.	https://www.cbs.nl/nl-nl/nieuws/2012/09/productie-hernieuwbare-elektriciteit-stabiel/mep-subsidie
132			Support for small and medium-sized enterprises (SMEs)	Ministry of Economic Affairs	n.d.	https://www.government.nl/topics/enterprise-and-innovation/support-for-small-and-medium-sized-enterprises-smes
133			The Netherlands largest importer of Chinese solar panels	CBS	2023	https://www.cbs.nl/en-gb/news/2023/36/the-netherlands-largest-importer-of-chinese-solar-panels#:~:text=The%20total%20value%20of%20Dutch,panels%20are%20highest%20as%20well
134			Renewable electricity; Production and power	CBS	2023	https://opendata.cbs.nl/#/CBS/nl/dataset/82610NED/table
135			Working with the environment plan	RVO	2024	https://business.gov.nl/regulation/environment-plan/
136			46 percent more solar energy production in 2022	CBS	2023	https://www.cbs.nl/en-gb/news/2023/24/46-percent-more-solar-energy-production-in-2022

3.2.2 Data analysis

Considering the qualitative research design, the analysis method involves qualitative rather than quantitative methods such as regression analysis. Depending on the type of data collected, the following qualitative analysis methods are used:

Thematic Analysis: After collecting and transcribing the interviews and documents, I systematically identified and analyzed recurring themes related to national innovation system perspectives. Then I identified the key features of data by generating initial codes. For example, some interview content was categorized under the "Political system", which involves how the policies and governance act on solar research and development, solar panels (production), and connecting solar power to the grid. This topic can be used to analyze all aspects of the current situation of solar energy and then conduct a more detailed analysis. Here are some examples of how I made for the coding according to the NIS factors mentioned above:

Code	**Text**
Financial environment	*"Improve the supervision and management mechanism. Build a coordinated supervision mechanism that is conducive to the development of renewable energy, strengthen supervision of renewable energy planning, industrial policies, development and construction, grid access, dispatching and trading, and consumption and utilization, and ensure the effective implementation of national planning policies. Implement inclusive and prudent supervision of new industries and new formats of renewable energy. Promote the construction of a credit system for the renewable energy industry, vigorously promote credit supervision, establish a credit rating system for market entities, and improve the incentive mechanism for keeping promises and the punishment mechanism for breaking promises (Kyle, 2024)."*
Standards and norms	*Improve the industrial standard certification system. Improve the standards, testing, certification and quality supervision organization system for renewable energy technology and equipment, and improve the production, project construction and operation management of renewable energy equipment. Encourage domestic enterprises to actively participate in the formulation of international renewable energy standards, promote the alignment of the standard system and conformity assessment system with international standards, and promote international mutual recognition of certification results (The 14th Five-Year Plan for Renewable Energy Development,*

	2022).
Innovation and business support	*In conjunction with the reform of the power system, market-based transactions of distributed photovoltaic power generation will be carried out, and photovoltaic power generation projects will be encouraged to be built close to power loads and connected to medium and low voltage distribution networks to realize nearby power consumption. All types of distribution network companies should provide services for the access of distributed photovoltaic power generation to the grid, give priority to consuming distributed photovoltaic power generation, build a technical support system for the grid-connected operation of distributed power generation, and organize distributed power transactions. The market-based electricity sales model of distributed photovoltaic power generation projects to power users will be promoted, and the transmission and distribution prices paid to power grid companies will be reasonably determined in accordance with the principle of promoting the nearby consumption of distributed photovoltaic power generation (The 14th Five-Year Plan for Renewable Energy Development, 2022).*

By aggregating lower-level codes such as “Standards and norms” and “Innovation and business support” into higher-level categories such as “Infrastructure”, and aggregating codes such as “Financial Environment” into “Framework Conditions”, the results were able to be structured into more explicit and easier to compare sections. The aggregate codes are used to structure the Results section, with higher-level codes showing a clear framework, presented in a table at the beginning of each result part, and clearly showing how the two countries are similar or different. For example, “Infrastructure” analyzed both countries by comparing China’s comprehensive approach to national standards and regulations for solar and the Netherlands’ focus on business support programs such as solar installation standards. Lower-level codes provide detailed analysis and interpretation of the results. For example, the high-level code “Infrastructure” focuses on sub-themes such as “Standards and Regulations” and “Innovation and Business Support”, which was able to show how these factors contributed to solar development in both countries.

Comparative analysis: The figure 2 below shows all the groups used in the code, including themes in the NIS framework, such as infrastructure. In addition, I introduced new themes in the system using open coding, namely value chains and international cooperation. The results present these themes related to solar policy in more detail.

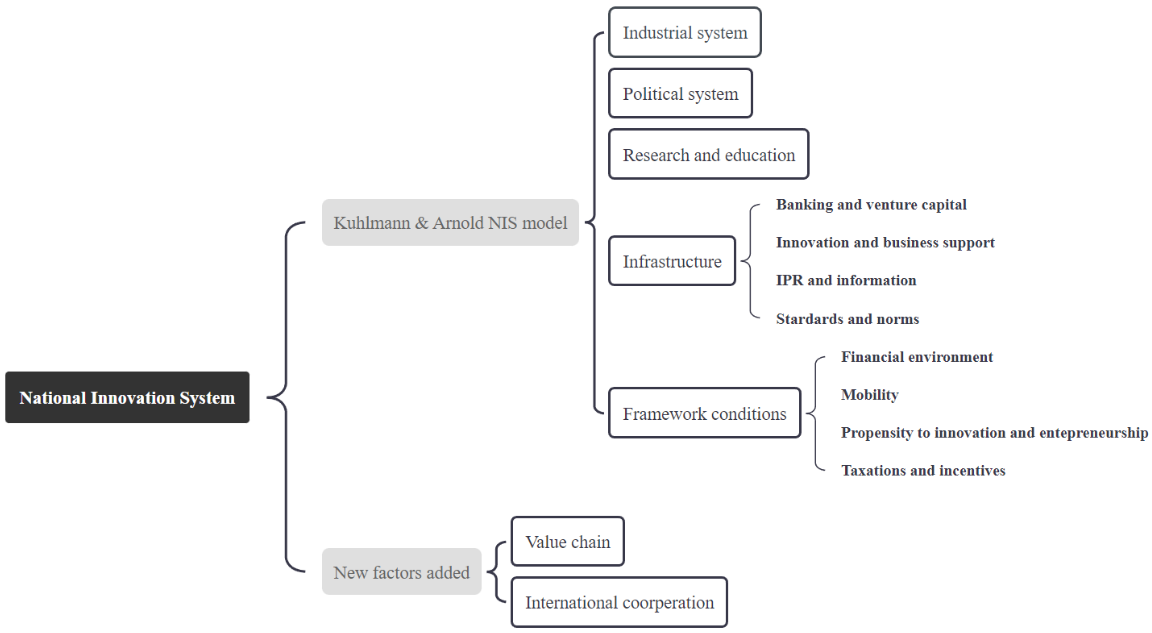

Figure 2: All the groups used in the code

3.3 The reliability and validity of the methods

Reliability: Government policy documents may still face issues with data accuracy and completeness (Piotrowski, 2012). Thus, based on the criteria for available government information, including accuracy, accessibility, completeness, understandability, timeliness, and low cost (Piotrowski, 2012), it is still necessary to consider whether the transparency and accuracy of government reports are subject to bias. The reliability of third-party publications depends on the credibility of the source. For example, peer-reviewed academic journals and reports from reputable researchers or institutions may increase reliability. The reliability of interviews and questionnaires must be fully considered when designing questionnaires and interview questions. Thus, structured questions are used to ensure comprehensive coverage of the questions and invite the supervisor to review them before using the questionnaire or interview to ensure no significant errors or biases. Finally, after obtaining the interview results, the study can use the interviews to confirm the results of the document and policy analysis to reduce possible errors.

Validity: Document and publication analysis is required to ensure that data extracted from policy documents and publications accurately represent the intended information. Thus, cross-referencing from multiple sources can enhance effectiveness. Third-party publications require that the reported findings are valid within the corresponding period. Interviews and questionnaires need to be considered as to whether the results from interviews with specific companies can be generalized to the wider Dutch (and also Chinese) solar energy industry.

Result detection: A combination of methods is used when examining the data to increase reliability and validity. For example, comparing interview data with information in policy documents and third-party publications can enhance the overall credibility of findings. Besides, having other researchers such as the supervisor to evaluate the reliability and validity of the methods and findings could add to the study's credibility.

4.Results

The Results section analyzes the impact of the NIS in China and the Netherlands on the solar industry. The Industrial System chapter assesses the role of large companies, mature SMEs, new technology-based enterprises, and state-owned enterprises in both countries and identifies their dynamics. The Political System chapter discusses government policies, governance structures, and RTD policies, highlighting the different approaches governments take to promote growth in the solar industry. The Research and Education chapter explores the role of professional education and training, high education and research, and public sector research. The Framework Conditions chapter assesses the financial environment and mobility that support solar innovation and examines how these structural conditions differ between the two countries. The Infrastructure chapter discusses important aspects that promote the development of solar technology, such as innovation and business support, IPR and information, and standards and norms. The Value Chain chapter analyzes each country’s approach to solar technology life cycle stages from production and consumption. Finally, the International Cooperation chapter explores technical and market cooperation, promoting the solar industry's development in both countries. The article shows what the Netherlands could learn from China and possible future policy directions by comparing these various factors between the two countries.

4.1 Industrial system

Aspect	China	The Netherlands
Large companies	Large companies in different aspects such as manufacturers of monocrystalline solar panels and solar module manufacturer.	Some large energy companies have solar or other renewable divisions, such as Royal Dutch Shell and Eneco.
Mature SMEs	A lot of startups including different sectors such as manufacturer of inverters and solar product manufacturer.	A lot of startups including different sectors such as consultancy firm and solar energy solutions firms.
New, technology-based firms	A lot of firms including different sectors such as producer of polysilicon and wafers and solar cell production firms.	A lot of firms including different sectors such as solar-powered electric vehicle firms and solar roads solutions firms.
State-Owned Enterprises (SOEs)	State-owned are often responsible for implementing strategic initiatives, such as expanding renewable energy capacity or exporting Chinese	N/A

	solar technology abroad.	

China and the Netherlands show distinct profiles of their industrial systems, reflected in their solar activities. China has significant players such as LONGi Solar, Jinko Solar, and Trina Solar, which lead in solar panel manufacturing. At the same time, China also has innovative startups like GCL-Poly Energy and Tongwei Solar. Additionally, China's State Power Investment Corporation, a state-owned enterprise, has a dominant presence, surpassing the combined solar asset holdings of the top 15 non-Chinese owners in 2022 (Juan, 2023).

In contrast, the Netherlands features large energy companies like Royal Dutch Shell and Eneco, which have solar and renewable energy divisions. At the same time, its mature SMEs include firms such as Solarplaza and Sunrock. New technology-based firms in the Netherlands include Lightyear, which develops solar-powered vehicles, and SolaRoad, focusing on solar road technologies. Unlike China, the Netherlands does not have prominent state-owned enterprises in the solar sector.

4.1.1 China

China has become a global leader in renewable energy, especially solar energy. Its dominance results from coordinated government policies, large-scale manufacturing, and technological innovation (Bian, et al., 2024). China's solar industry system is a dynamic ecosystem with several key players, including large multinational companies, established small and medium-sized enterprises (SMEs), new technology companies, and state-owned enterprises (SOEs). Together, these entities have transformed the solar industry from an emerging market to a globally competitive industry that influences the global energy landscape. This industry ecosystem is characterized by each type of company playing a unique role. In particular, SOEs play a guiding role by ensuring strong backing and stability through state support and are led by the government. Large companies (especially competing subsidiaries of SOEs) drive large-scale production and global market penetration, SMEs contribute niche innovations and specialized components, and technology-based startups push the cutting edge of solar technology.

Large companies

Enterprises are often categorized by size, with the number of employees serving as the most common criterion. Large companies are defined as those employing 250 or more people (OECD, n.d.). Large companies in China's national innovation system promote technological progress through vertical integration and economies of scale, and integrate global knowledge to enhance China's competitive advantage in the high-tech industry market.

Large companies in China are unique in their active presence across the entire green value chain and their global reach. These companies are involved in everything from manufacturing key solar components, like photovoltaic modules and inverters, to downstream sales and services (IEA, 2022). These large companies dominate the global market with their ability to exploit economies of scale, invest heavily in research and development (R&D), and create advanced manufacturing facilities (IEA, 2022). For example, JinkoSolar, one of the world's largest solar module manufacturers, operates in multiple countries. It has a vertically integrated business model covering silicon ingot manufacturing, solar cell production, and module assembly, which makes it a dominant player in the global market (JinkoSolar, n.d.). Trina Solar, another Chinese solar giant, produces high-efficiency modules and expands its business to downstream solar storage and intelligent energy solutions (Trina Solar, n.d.). Other large companies, such as LONGi Green Energy Technology, are leading producers of monocrystalline silicon wafers and solar modules (LONGi, n.d.). JA Solar is well-known globally for its high-efficiency solar cells and modules (JA Solar, n.d.). With vertically integrated business models, these companies control multiple stages of production, ensuring cost efficiency and quality across the supply chain.

This dominance is vital for the solar industry because it allows for economies of scale, making solar products more affordable and accessible globally. First, large companies can achieve economies of scale. Through scale and capital resources, large companies can bring vertical integration to the industry and complete the production of the entire supply chain at a lower cost, from raw materials (such as polysilicon) to finished products (solar modules) (IEA, 2022). Large companies can maintain cost control and quality assurance, allowing them to provide high-quality and cheap solar products at competitive prices worldwide (Kyle, 2024). They try to promote global development by producing so-called green products, such as solar panels, wind turbines, and, more recently, electric vehicles and batteries. These are very important all over the world in the transition from high-emission energy production to more sustainable production (Kyle, 2024). In addition, through joint ventures and foreign subsidiaries, international cooperation promotes the transfer of technological capabilities and expertise, innovation, and improvement of technological capabilities (Shubbak, 2019). For example, these companies expand their business to other parts of the world, helping Chinese solar products to establish a global influence. Their global influence extends from Europe to the United States and increasingly to developing markets in Asia, Africa, and Latin America (The 14th Five-Year Plan for Renewable Energy Development, 2022). At the same time, it provides continuous cross-border interaction, facilitating the transfer of crucial tacit knowledge, which is essential for acquiring product- and process-related expertise (Quitzow, 2017).

Mature SMEs

Smaller businesses are classified into medium-sized enterprises, which employ between 50 and 249 people; small enterprises, which employ between 10 and 49 people; and micro enterprises, which employ fewer than 10 people (OECD, n.d.). Mature SMEs means the state of an SME, in which it reaches the fully development state (Pham, 2010).

While large companies dominate the mass production of solar products, small and medium-sized enterprises (SMEs) in China's solar industry often operate in niche areas or focus on providing specialized products and services, especially those that large companies cannot serve or cannot reach (Shenzhen Industrial Automation Industry Association, 2024). These SMEs may have little capital or resources but are essential for technological innovation, component supply, and system integration. Mature SMEs in China's solar industry often have expertise in specific technologies or value chain links. For example, Sungrow is a leading solar inverter and energy storage systems supplier (Sungrow, n.d.). Eging PV specializes in monocrystalline and multicrystalline solar cells and modules (Eging PV, n.d.). Daqo Energy specializes in high-purity polycrystalline silicon. Although smaller than large companies, Daqo New Energy is integral to the large companies' supply chain (Daqo Energy, n.d.). This flexibility allows them to adapt to changing market demands or technology trends, such as advances in perovskite solar cells or bifacial modules. They help to build a more diversified and resilient supply chain within China's solar industry (Shenzhen Industrial Automation Industry Association, 2024).

New, technology-based firms

China's solar industry has seen the emergence of many new tech-based firms, though large companies still dominate the market. Microquanta Semiconductor is a startup focused on improving solar cell efficiency and developing next-generation photovoltaic technologies such as perovskite solar cells (Microquanta, n.d.). GCL System Integration Technology focuses on research in integrated solar solutions and advanced solar technologies (GCL, n.d.). Envision Energy is a technology-based company focused on intelligent energy systems, including solar energy storage (Envision, n.d.).

These new companies typically invest heavily in research and development. Many new companies, including Chinese and foreign investors, receive funding from venture capital firms. This capital enables them to take risks on emerging technologies. The Chinese photovoltaic industry has significantly benefited from foreign direct investment (FDI) and international collaboration, which has driven technological advancement and innovation (Shubbak, 2019). However, venture capital in the solar industry is less widespread in China than in markets like Silicon Valley. Much of China's solar sector investment still comes from government support, state-owned enterprises, and large private companies. The Chinese government has played a crucial role in fostering solar industry growth through subsidies, favorable policies, and infrastructure investment, which reduces reliance on venture capital (KPMG, 2014). These new, technology-based companies push the limits of solar energy and ensure that China will continue to be at the forefront of solar innovation on the road of new technologies and innovation. However, with high returns come high risks. Many technologies being developed have yet to be proven in the commercial market. These companies often operate on thin margins and face a high risk of failure if their technologies cannot be successfully scaled. For example, due to the current difficulties in the solar cell and module product market, the three subsidiaries of ST Aikon, a photovoltaic listed company, temporarily suspended operations at their main holding subsidiaries to reduce operating pressure (OFweek, 2024).

State-Owned Enterprises (SOEs)

State-owned enterprises (SOEs) are enterprises that the state owns and operates. Before the reform and opening up in 1978, China's state-owned enterprises were state-owned and stateoperated. After the reform, state-owned enterprises were restructured and a modern enterprise system was established, with shareholders' meetings, boards of directors and supervisory boards becoming the three main governance bodies. However, the state still maintains control over state-owned enterprises (Lin, et al., 2020).

In China, state-owned enterprises are critical to solar strategy. These entities are often both producers and consumers of solar energy, forming a closed-loop system that can benefit from state subsidies, policy support, and large-scale contracts (Lin et al., 2020). China Energy Investment Corporation is one of the largest energy companies in China and has invested heavily in solar development, especially in solar farms and grid integration projects (CEIC, n.d.). State Grid Corporation of China (SGCC) As the world's largest utility company, SGCC is responsible for integrating renewable energy, including solar, into China's national grid system (SGCC, n.d.). Another interesting thing related to this is that China's oil and gas and traditional energy industries are dominated by state-owned enterprises. However, these oil and gas companies and some oil and gas companies in the West are starting to diversify and enter the renewable energy sector. Thus, whether it is Sinopec in China or BP in the West, they are looking at the renewable energy industry (Kyle, 2024).

State-owned enterprises benefit from substantial financial and policy support from the Chinese government (Philippe, 2020). They are often responsible for implementing strategic initiatives, such as expanding renewable energy capacity or exporting Chinese solar technology abroad. China's goal of achieving carbon neutrality by 2060 relies heavily on state-owned enterprises to promote the use of renewable energy (Philippe, 2020). State-owned enterprises are often involved in large solar farm projects or serve as the leading supplier of solar energy to the national grid, especially in remote areas such as deserts or rural areas, which are often rich in natural resources, but difficult for non-state-owned enterprises to invest and develop in these areas due to long development cycles and slow cost recovery (The 14th Five-Year Plan for Renewable Energy Development, 2022). At the same time, state-owned enterprises are involved in integrating solar energy into the national grid, who are important in ensuring that the increasing share of renewable energy does not destabilize the grid (SGCC, n.d.).

4.1.2 The Netherlands

Traditionally known for its reliance on fossil fuels and strong position in the oil and gas industry, the Netherlands has undergone a significant energy transition in recent years (IEA, 2020). The Netherlands’ commitment to reducing greenhouse gas emissions and meeting European Union (EU) climate goals has accelerated the adoption of renewable energy technologies, with solar energy playing a central role. The Dutch solar industry has proliferated with the participation of large multinational corporations, established small and medium-sized enterprises (SMEs), and innovative technology-based companies.

Large companies

In terms of NIS in the Netherlands, Large companies are able to mobilize large amounts of capital, operate extensive supply chains, and participate in domestic and global large-scale solar projects. These large Dutch companies play an essential role in the solar sector by driving large-scale production, innovation, and international market expansion (Next-generation solar power, 2020). Shell Renewable Energy is investing heavily in solar as part of its broader strategy to transition to renewable energy (Shell, n.d.). Eneco, one of the largest energy companies in the Netherlands, is making a big push into renewable energy, including solar (Eneco, n.d.). Eneco operates solar farms, provides solar solutions to residential and commercial customers, and has a growing portfolio of projects that combine solar energy with other renewable energy sources, such as wind and battery storage (Eneco, 2024).

Large companies have significantly contributed to the Netherlands' renewable energy capabilities by making the construction of large-scale solar farms possible through investments. These multinationals have expanded their solar business to other markets, especially in Europe and beyond. For example, Shell has invested in solar projects in the United States, India, and Africa, helping to export Dutch solar expertise to other regions (Shell, n.d.). Eneco integrates solar with other renewable energy sources such as wind and storage, which helps stabilize the grid and ensure a more reliable renewable energy supply (Eneco, 2023). Despite their significant contributions, these energy companies still face the challenge of maintaining profitability during the transition from fossil fuels to renewable energy, managing public perception, and navigating a regulatory framework that is still adapting to the rapid growth of solar energy (Nutifafa, 2024).

Mature SMEs

Mature SMEs in the Netherlands typically specialize in a specific aspect of the solar value chain. They invest in developing new products or improving existing technologies to increase the efficiency and affordability of solar energy. For example, Solarclarity is a leading distributor of solar products in the Netherlands, focusing on providing high-quality PV modules, inverters, and energy storage systems for residential and commercial customers (Solarclarity, n.d.). Victron Energy specializes in power conversion and energy storage technologies, and the company's products are widely used in off-grid and hybrid solar systems, essential to making solar energy more viable in areas with unstable grid access (Victron Energy, n.d.). Zonnepanelen specializes in rooftop solar installations, particularly for commercial and industrial buildings (Zonnepanelen, n.d.). However, similar to the challenges SMEs face in China, many SMEs often face fierce competition from large multinational companies and need help from the government to obtain financing to expand their business or invest in research and development (Ministry of Economic Affairs, n.d.).

New Technology-Based Firms

A new crop of tech companies has emerged in the Dutch solar industry, driving innovation in solar materials, smart grid technology, and energy storage. These companies are often spin-offs of startups or academic institutions focused on developing next-generation technologies that could change the solar landscape. TNO is actively developing cutting-edge solar technologies and is committed to improving the efficiency and reducing the cost of photovoltaic modules through material innovation and advanced manufacturing techniques (TNO, n.d.). LeydenJar Technologies, a spin-off of Leiden University, is developing silicon anodes for lithium-ion batteries, significantly improving energy storage capabilities. This technology could make solar energy storage more efficient and cost-effective (Will, 2024). These new tech companies are often at the forefront of advances in solar technology, and could have a transformative impact on the industry. However, as mentioned in the SME part, many of these emerging companies need help to get the funding they need to scale their innovations from pilot projects to commercial viability, which can limit the impact of promising technologies. Especially when their products are more expensive or require significant infrastructure changes, it is more difficult to determine whether the technology will be able to enter the mature market to compete.

State-Owned Enterprises (SOEs)

SOEs in the Netherlands have historically been more involved in traditional energy sectors such as oil, gas, and coal. However, the Dutch energy market has been privatized since 2004 (Deloitte, n.d.). SOEs do not play a significant role in the Netherlands.

4.2 Political system

Aspect	**China**	**The Netherlands**
Government	The Chinese government is highly involved in the solar energy sector, setting national goals, providing financial support, and enacting regulations that shape the industry.	The Dutch government plays a central role in shaping the solar landscape through policy development, regulation, and financial support.
Governance	China's solar industry governance is highly centralized, with SOEs, regulators, and local governments all involved.	Characterized by a collaborative, and multi-stakeholder approach, which includes the involvement of different shareholders
Research and technological development (RTD) policies	The Chinese government has invested in research to improve the solar technology according to RTD strategies.	RTD drives innovation in the solar industry, supported by leading research institutions and government funding.

These policy frameworks and support mechanisms have played crucial roles in the growth and development of the solar PV industries in both countries. The Netherlands has focused on incremental policy evolution and integration with energy management technologies, while China has leveraged aggressive state support and comprehensive policy measures to establish itself as a global leader in solar PV manufacturing and deployment.

4.2.1 China

This analysis explores the key components of China's political system that influence the development and expansion of solar energy, including the role of government, governance structures, and RTD policies. These elements have played a significant role in making China a global leader in solar energy, with massive production capacities and technological advancements that shape the global solar market.

Government

A high level of central government influence on the solar system characterizes the Chinese NIS. The Chinese government is highly involved in the solar energy sector, setting national goals, providing financial support, and enacting regulations that shape the industry.

China’s solar energy policy is guided by its broader energy and environmental goals in several key national strategies. For example, The Five-Year Plans are central planning documents that outline China's economic and social development goals for specific periods. Solar energy has been a priority in recent FYPs, especially in the 13th FYP (2016-2020) and the 14th FYP (2021-2025). For example, the 14th Five-Year Plan emphasizes strategies tailored to local conditions. China's renewable energy development strategy focuses on optimizing large-scale wind, solar, and other renewable energy sources in different regions based on ecological and geographical conditions. In the "Three Norths" region, efforts are focused on expanding wind and solar power bases, while the southwest integrates hydropower, wind, and solar. The central and eastern regions focus on local renewable energy development, and coastal areas promote offshore wind power clusters. In addition, desert and arid regions in the west and north will accelerate ecologically and economically sustainable wind and solar projects. Enhanced grids and transmission systems will support the integration of renewable energy to ensure that 50% of new transmission capacity comes from renewable energy by the end of the 14th Five-Year Plan. China has invested in the development of sustainable energy throughout the country, with a particular focus on solar energy in the western region. These plans set targets for renewable energy production, encourage investment in solar energy, and promote the development of new solar technologies.

Moreover, in 2020, President Xi Jinping announced that China aims to peak its carbon emissions by 2030 and achieve carbon neutrality by 2060. Solar energy plays an important role in this strategy as the country moves away from coal and other fossil fuels. Under the Paris Agreement, China’s Nationally Determined Contributions (NDCs) emphasize renewable energy, prioritizing solar for reducing carbon emissions. At the same time, China’s overarching energy strategy is laid out in the Energy Development Strategy Action Plan (2014-2020), and more recent strategies are aimed at achieving carbon neutrality by 2060. Solar energy is a critical part of China’s energy mix, and the government seeks to increase its share significantly as part of the country's efforts to reduce reliance on fossil fuels.

In China, multiple government agencies are responsible for developing, implementing, and regulating solar energy policies, such as the National Development and Reform Commission (NDRC). The NDRC is an important decision-making body overseeing China's economic and social development. In the 2022 "Opinions on Improving the Institutional Mechanisms and Policy Measures for the Green and Low-Carbon Transformation of Energy," the NDRC proposed ten macro-level guidelines, including improving the coordinated promotion mechanism for the implementation of national energy strategies and plans, improving the institutional and policy system for guiding green energy consumption, establishing a new mechanism for energy development and utilization oriented towards green and low-carbon, and improving the construction and operation mechanism of new power systems. The National Energy Administration (NEA) is a specialized agency under the NDRC that oversees the energy sector, including developing and deploying solar energy. The NEA sets renewable energy targets, issues solar development guidelines, and manages the grid integration of renewable energy. In 2022, the NEA proposed more detailed guidance and requirements, such as innovating new energy development and utilization models, promoting the integrated development of new energy development and utilization and rural revitalization, accelerating the construction of a new power system that adapts to the increasing proportion of new energy, improving the responsibility weight system for renewable energy power consumption, and improving fiscal and financial policies to support the development of new energy and enriching green financial products and services (NEA, 2022).

In addition to the two major departments above, the Ministry of Ecology and Environment (MEE) oversees China's environmental protection and climate change mitigation efforts. It works closely with other government agencies to ensure solar energy helps achieve China's climate goals, especially reducing carbon emissions (MEE, n.d.).

The Chinese government has implemented a series of financial policies to support solar energy development. These policies include subsidies, tax incentives, and financial mechanisms that have promoted the rapid expansion of the solar industry.

Distributed solar power generation subsidies: A significant milestone in China's solar energy development came in 2013 with the introduction of a comprehensive solar PV policy. This policy included initiatives such as promoting distributed PV power generation, ensuring the full-price purchase of photovoltaic power, and establishing feed-in tariffs based on national zoning (Huang, 2016). China provides subsidies for distributed solar systems (such as rooftop solar installations). The 14th Five-Year Plan mentions actively promoting the distributed development of wind power and photovoltaic power generation. It proposes distributed development programs such as "urban rooftop photovoltaic action," "'photovoltaic +' comprehensive utilization action," and "new energy power station upgrade and transformation action." These subsidies help reduce the upfront costs of residential and commercial solar systems, enhance the ability of rural local green power supply, and encourage wider adoption.

Green finance and renewable energy bonds: The government promotes green financial mechanisms to support solar development. These include financial institutions issuing green and renewable energy bonds, enabling solar companies to raise funds for new projects. The

14th Five-Year Plan puts forward requirements for improving the green finance system for renewable energy, such as improving the green finance standard system, implementing special policies for financial support for green and low-carbon development, and further increasing the support of green bonds and green credit for eligible new energy projects.

Grid parity policy: As solar energy costs decrease, China is entering a new era of unsubsidized parity or even low-price market-oriented development (The 14th Five-Year Plan for Renewable Energy Development, 2022). Grid parity means that the cost of solar power generation is equal to or lower than the cost of fossil fuel power generation. The government has implemented policies to encourage solar producers to participate in market competition without relying on subsidies, that is, to shift from subsidy-supported development to parity and low-price development and from policy-driven development to market-driven development (The 14th Five-Year Plan for Renewable Energy Development). At present, the 14th Five-Year Plan has mentioned that one or two parity offshore wind farm projects will be built by 2025, and the green electricity certificate mechanism also mentions encouraging parity projects to carry out green certificate transactions actively, which marks a major shift in the solar industry.

Governance

In line with the NIS, demonstrating the strong role of the national government, China's solar industry governance is highly centralized, with state-owned enterprises (SOEs), regulators, and local governments all involved. The governance framework aims to coordinate the interests of the central government, local authorities, and private sector players to ensure solar projects' efficient development and deployment.

China's solar governance is based on centralized planning, with the central government playing a key role in setting national solar industry priorities and targets. The government's top-down approach ensures that the development of the solar industry is in line with national energy and environmental policies. The NEA and the NDRC are responsible for issuing policies related to solar development, including capacity targets, grid integration rules, and environmental standards. As a result, the government will make more efforts to push some of the companies under its control to invest in sustainable energy, such as solar and wind power, which also allows China to shift and push its companies to invest more in renewable energy (Kyle, 2024). This is a different situation from the Western countries, where there is some grassroots pressure from civil society groups and consumer protection organizations to shift to low carbon and reduce investment in oil and gas companies. However, China is more government-led, with the central government setting national solar targets and ensuring that these targets are implemented through regulations, guidelines, and financial support (Kyle, 2024).

While the central government sets national solar targets, local governments play a role in implementing policies at the regional level. The Chinese government has implemented renewable energy quotas and renewable portfolio standards (RPS) for provincial governments and grid operators (Xu et al., 2022). These policies require a certain percentage of energy from renewable energy, including solar, which encourages local governments to support solar projects. Provinces that fail to meet renewable energy targets may face penalties, which provides a strong incentive for local governments to promote solar energy. For example, the 2020 indicators are guiding indicators, which will be adjusted dynamically according to the renewable energy resources and the transmission of renewable energy through inter-provincial and inter-regional channels; the Inner Mongolia Autonomous Region can be assessed separately according to the western and eastern regions of Inner Mongolia, and the specific regional quota indicators will be determined by the energy department of the Inner Mongolia Autonomous Region (NDRC, n.d.).

Research and Technological Development (RTD) Policies

Research and technology development (RTD) is important to China's solar strategy. The Chinese government has invested in research to improve the efficiency of solar technology, reduce costs, and develop new applications for solar energy.

Improving solar cell efficiency: A major focus of China's RTD work is to improve the efficiency of solar cells. Chinese research institutions and companies are working to develop new materials and manufacturing technologies to improve the efficiency and reduce the costs of solar panels. For example, new high-efficiency crystalline silicon cells, perovskite cells, and other advanced high-efficiency battery technology application demonstrations master the preparation and industrial production technology of new generation high-efficiency and low-cost photovoltaic cells such as perovskite, break through the key technology of water electrolysis hydrogen production equipment suitable for flexible hydrogen production from renewable energy, research and development of sodium-ion batteries, liquid metal batteries, solid-state lithium-ion batteries, metal-air batteries, lithium-sulfur batteries, and other high energy density energy storage technologies, promote the development of cutting-edge technologies with a large-scale market, and continue to advance photovoltaic power generation technology progress (14th Five-Year Plan).

Solar photovoltaic manufacturing: China is the world's largest solar panel manufacturer, and maintaining this leadership is one of the top priorities for the government. The RTD strategy focuses on improving the manufacturing process of solar photovoltaic panels to make them more efficient, durable, and cost-effective. This includes research on new materials, automation technology, and innovations in solar panel design. For example, it focuses on the industrial production technology of high-concentration compound solar cells, with a concentration multiple of more than 500 times, and the efficiency of industrially produced cells exceeds 35% under non-concentrated conditions and more than 40% under concentrated conditions (14th Five-Year Plan, 2022).

Energy storage and grid integration: As solar energy becomes a more important component of China's energy structure, the need for efficient energy storage solutions and improved grid integration has become more urgent. In particular, support research on smart grid technologies to better manage the intermittency of solar energy. In resource-rich regions such as Qinghai, Gansu, Xinjiang, Inner Mongolia, and Jilin, give full play to the energy storage regulation capacity and system support capacity of solar thermal power generation, build long-term thermal storage solar thermal power generation projects, promote the integrated construction and operation of solar thermal power generation with wind power and photovoltaic power generation bases, and improve the stability and reliability of new energy power generation (14th Five-Year Plan, 2022).

In addition, China has many research institutions and universities at the forefront of solar energy research. These institutions work closely with industry and government to develop new technologies and promote innovation in the solar energy field, such as the Chinese Academy of Sciences (CAS), China National Renewable Energy Center (CNREC), etc. We will introduce these research institutes and universities in more detail in the Education and Research section.

4.2.2 The Netherlands

The Netherlands has become a leader in renewable energy. The shift to renewable energy sources such as solar is driven by a strong political commitment to achieving national and international climate goals, particularly those set by the European Union (EU) and the Paris Agreement. The Netherlands has developed a comprehensive political system covering government engagement, governance structures, and research and technological development (RTD) policies to ensure it is in line with sustainability and climate goals.

Government

The Dutch government shapes the solar energy landscape through comprehensive policy development, regulation, and financial support. Recognizing solar energy as a crucial element of the Netherlands' energy transition, the government has set targets to reduce carbon emissions by 49% by 2030 compared to 1990 levels, aiming to achieve a climate-neutral economy by 2050 (Next-generation solar power, 2020).

To facilitate this transition, the government has signed several key agreements. The Dutch Climate Agreement (Klimaatakkoord), signed in 2019, establishes specific targets for reducing carbon emissions and increasing the share of renewable energy in the national energy mix. This framework highlights explicit goals to expand solar power capacity by 2030. The Energy Agreement for Sustainable Growth laid the groundwork for the current renewable energy strategy, including a target to increase the share of renewable energy. The National Energy and Climate Plan (NECP) is another document that outlines how the Netherlands intends to meet the 2030 climate and energy targets set by the European Union.

Moreover, several government departments and agencies are involved in developing solar policy in the Netherlands. The Ministry of Economic Affairs and Climate Policy oversees national energy policy, including renewable energy. The ministry also manages financial support mechanisms for renewable energy projects, such as subsidies and grants. The Netherlands Enterprise Agency (RVO), operating under the Ministry of Economic Affairs and Climate Policy, manages renewable energy subsidies, including the Stimulating Sustainable

Energy Production and Climate Transition (SDE++) program, which provides financial support for solar projects. Furthermore, the Netherlands Environmental Assessment Agency (PBL) monitors and assesses the environmental impact of energy policies, including solar energy expansion, providing data and analysis to inform policy decisions.

The Dutch government has established a set of financial incentives to promote renewable energy development, particularly in solar photovoltaic systems. Central to this framework are subsidy programs including the Milieukwaliteit van de Elektriciteitsproductie (MEP), Stimulering Duurzame Energieproductie (SDE), SDE+, and the latest SDE++ scheme.

The MEP grant, introduced through an amendment to the Electricity Act in 1998 to encourage sustainable and environmentally sound electricity production through the national high-voltage grid operator, TenneT. This grant subsidized the production of renewable electricity, including that generated by combined heat and power (CHP) systems, for a period of ten years, with provisions to prevent subsidy leakage abroad. The MEP was active from July 2003 to August 2006, ensuring financial support directly benefited the domestic renewable energy sector (CBS, n.d.). Following the MEP, the SDE scheme was launched in 2013 to incentivize companies to generate renewable energy, focusing on electricity, heat, and gas. The SDE++ scheme began in autumn 2020 and broadened its scope to include technologies that reduce CO2 emissions, covering low-CO2 heat and production methods (Stephan, 2020). Under SDE++, subsidies are awarded based on the amount of CO2 avoided, with only one application round per year, thereby increasing competition for limited budget resources and necessitating strategic planning for successful applications (Stephan, 2020). In addition to these subsidy schemes, net metering has been crucial in promoting residential solar PV adoption since its introduction in 2004. This policy allows households to offset their electricity bills with the energy they generate, making solar investments more financially attractive (Solar Monkey, 2024).

The Dutch government targets for renewable electricity, which is 42 terawatt-hours (TWh) by 2030, with 7 TWh coming from small-scale solar installations. Additionally, there is an aim for a 30% reduction in solar electricity costs by 2025, with a focus on fostering innovation through partnerships between companies and research institutions (Ministry of Economic Affairs, 2016). Acting as a "launching customer" for floating solar farms, the government is actively developing the domestic market with supportive policies, permits, and subsidies. This transition to renewable energy is expected to significantly transform the Dutch housing landscape, business parks, and rural areas, integrating sustainable heat supply decisions with infrastructure planning (Ministry of Economic Affairs, 2016). Strong political networks and industry support have consistently advocated for solar PV, keeping it at the forefront of the political agenda (Vasseur, 2013).

Governance

The Dutch solar regulatory framework creates a stable and predictable environment for investors while ensuring that solar energy projects align with national and regional energy goals. For example, a key component of this framework is the permitting and zoning process, which mandates that solar projects, especially large-scale solar farms, comply with both national and local zoning regulations. These rules are established to manage land use effectively and to balance the need for renewable energy development with other priorities, such as agriculture, nature conservation, and housing (RVO, 2024). While this approach helps maintain a harmonious balance among various land uses, it can also introduce complexities that may slow down project approvals, particularly when solar initiatives compete with high-priority land uses. Another critical aspect of the regulatory framework involves grid access and tariff structures. The Dutch government has implemented policies to ensure that solar energy can be effectively integrated into the national grid, addressing challenges related to connection fees, grid reinforcement, and shared costs associated with grid integration (Mastenbroek, 2024). Besides, as decentralized solar generation continues to grow, the government has introduced policies to promote the development of smart grids. These smart grids are designed to handle the intermittent nature of solar energy, facilitating efficient distribution of electricity to where it is needed most (IEA, n.d.).

In addition, a notable feature of the Dutch solar governance system is its collaborative approach. The development of solar energy policies and projects is often the result of dialogue and collaboration between various stakeholders such as government, industry, civil society, and academia. This collaborative approach helps ensure that solar energy policies are well-designed, widely supported, and effectively implemented. Several industry associations play an essential role in shaping the solar energy industry. For example, Holland Solar is the Dutch solar energy industry association representing companies producing, installing, and distributing solar energy systems. Holland Solar advocates provide industry data and insights and help shape government policies related to solar energy (Holland Solar, n.d.). Organizations such as Greenpeace Netherlands advocate for more robust renewable energy policies and hold governments accountable for meeting their climate goals (Greenpeace, n.d.). These non-governmental organizations often work with the solar energy industry to promote the adoption of solar energy as part of the environmental movement. Dutch research institutions such as TNO (Netherlands Organization for Applied Scientific Research) and Delft University of Technology (TU Delft) are participating in solar energy governance. These institutions conduct cutting-edge research on solar energy technologies, energy efficiency, and grid integration, providing a scientific basis for policy development. Finally, public participation and citizen involvement is another aspect of solar governance in the Netherlands. The government actively encourages citizen participation in the energy transition, primarily through programs that support community solar projects (Hensbergen, 2024). Public consultations are often held during the planning and licensing process for large-scale solar projects, ensuring local communities have a say in developing renewable energy infrastructure (Hensbergen, 2024).

However, one significant downside of this collaborative approach is the slower decision-making process. For instance, the government may focus on long-term sustainability, the industry may prioritize short-term profitability, and civil society might push for stricter environmental and social standards, which means the need to reach a consensus among various stakeholders often leads to lengthy discussions and negotiations.

Research and Technology Development (RTD) Policy

The Netherlands' Research and Technological Development (RTD) policy is driving innovation and ensuring the continued success of the Dutch solar industry. The policy focuses on several areas, such as improving the efficiency of solar cells. TNO is working to improve solar cell performance and develop new materials for solar panels (TNO, n.d.), while TU Delft is working to create the next generation of solar cell technology (TUDelft, n.d.). Energy storage is another key focus of the Netherlands' RTD policy, particularly in exploring advanced battery technologies such as lithium-ion and flow batteries. Institutions such as Eindhoven University of Technology (TU/e) have contributed to efficient energy storage areas by advancing materials science and integrating energy systems (TU/e, n.d.). In addition, RTD policies support innovative projects such as floating solar and hybrid renewable energy systems, which including installing solar panels on water bodies and combining solar energy with other renewable energy sources such as wind or hydropower. This approach optimizes land use and increases energy production (Next-generation solar power, 2020).

4.3 Research and education

Aspect	China	The Netherlands
Professional education and training	Professional education and training programs are designed to provide practical hands-on skills and technical knowledge related to solar energy systems, equipment, and operating procedures.	Vocational education and training (VET) institutions in the Netherlands are essential to developing a skilled workforce that meets the needs of the renewable energy industry.
High education and research	Universities and research institutes across the country are actively involved in developing new solar technologies related to energy storage and grid integration.	Universities and research institutes across the country are actively involved in developing new solar technologies, improving efficiency, and addressing energy storage and grid integration challenges.
Public sector research	The Chinese government has invested in research and development to improve solar technology, increase solar power generation efficiency, and reduce the cost of solar deployment.	Government agencies and public research organizations conduct extensive research on solar technologies, support pilot projects, and provide funding for innovative research programs.

China and the Netherlands both prioritize solar energy development. In China, rapid industry growth has created high demand for skilled professionals in solar technology. The government invested in research and development to improve efficiency and reduce costs. Meanwhile, the Netherlands emphasizes vocational education and training (VET) to build a skilled workforce, with universities and public sector organizations conducting research to improve solar efficiency and address energy storage challenges.

4.3.1 China

China's solar energy research and education system can be divided into three key elements: professional education and training, higher education and research, and public sector research. Government policies have supported these initiatives, ensuring Chinese firms possess the skills necessary to innovate and maintain a competitive edge in the global market (Zhang, 2016).

Professional Education and Training

The rapid development of China's solar industry has created a huge demand for skilled professionals with expertise in solar technology, installation, and maintenance techniques. Thus, professional education and training programs are designed to provide practical hands-on skills and technical knowledge related to solar energy systems, equipment, and operating procedures.

Solar Vocational Education and Solar PV Installation: Many vocational schools and technical colleges offer courses that specialize in installing solar photovoltaic systems. These courses cover everything from the design and layout of solar photovoltaic systems to wiring, testing, and commissioning, aiming at students who want to enter the labor market directly after completing their studies and are tailored to the actual needs of the solar industry (Igreen, n.d.). Graduates of these courses have the skills required to work as solar installers or technicians in the rapidly growing distributed solar energy market. For example, in some vocational course outlines, students are required to be able to engage in distributed photovoltaic site surveys, low-voltage grid-connected photovoltaic system design, etc. after completing the course (Igreen, n.d.).

Industry training partnerships: To bridge the gap between education and industry, vocational schools and training institutions in China often work with solar companies to develop tailored training programs. Many solar companies also offer internships, apprenticeships, and on-the-job training to students in vocational courses, providing them with practical experience and improving their employability after graduation. For example, JA Solar Technology Co., Ltd. has partnered with Jiangsu Tourism Vocational College to improve the industry's professionalism through institutions that implement employee education and training. The company connects with vocational colleges to arrange for full-time staff to teach, and the vocational college leads the company to participate in the school's talent training program formulation (Jiangsu Tourism Vocational College, 2022).

Higher Education and Research

The NIS in terms of education is a system with a small group of elite universities leading in research and education, a large number of universities and colleges with more specialized or applied programs, and a vast network of research institutions that operate independently or in conjunction with universities (I will introduce these institutions at the “Public sector research” part). Several Chinese universities have been recognized globally for their contributions to solar research. These universities have established specialized research centers and laboratories that focus on various aspects of solar technology, from basic research in materials science to applied research in solar power generation and system integration.

Tsinghua University, for example, is a global leader in renewable energy research. Its Institute of Energy, Environment, and Economics conducts solar technology research focusing on improving solar cells' efficiency and developing strategies to integrate solar energy into China’s energy grid. Tsinghua University also offers an advanced degree program in renewable energy engineering to prepare students for careers in the solar industry (Tsinghua University, 2022). Peking University has a strong research program in solar energy, particularly in photovoltaic materials and technologies. Peking University researchers are developing new materials for high-efficiency solar cells, such as perovskite solar cells (Institute of Modern Optics, 2024). Besides, many Chinese universities have established exchange programs with international institutions to allow students to study abroad and learn about global research trends in solar energy. Thus, in the 21st century, China has enough skilled engineers to meet the challenges of new energy sources. These engineers have received doctoral training in independent technical fields. Many Chinese students are studying in Germany and Australia, and they return to help develop the Chinese solar industry, such as Jenko, who are developing cutting-edge solar energy. Looking forward, the new generation of tandem solar cells has the potential to increase efficiency, which is crucial to the future development of global solar energy (Kyle, 2024). The focus on solar energy research at top universities and research institutes has driven rapid technological advancement and rapid innovation.

Public Sector Research

The Chinese government has implemented several national research programs to strengthen forward-looking research, accelerate the research and development of cutting-edge and disruptive development and utilization technologies for renewable energy to support solar research and development (The 14th Five-Year Plan for Renewable Energy Development, 2022). These programs provide funding for research projects, promote cooperation between academia and industry, and promote the commercialization of new solar technologies, such as the National High-Tech Research and Development Program (863 Program). Among 15 thematic projects belonging to 7 fields, solar research was the program's focus, and a large amount of funds were allocated to projects focusing on improving the efficiency of solar cells, developing energy storage solutions, and integrating solar energy into the grid. Strong support was provided for projects that advance solar cell technology, develop new materials for solar panels, and improve the performance of solar energy systems (People's Daily Online, 2014). 863-funded research has driven advances in energy research and manufacturing technology. Solar photovoltaics and battery manufacturing are areas where Chinese innovators are particularly strong, as measured by patent citations. China had 8% of the world's low-carbon energy intellectual property patents from 2010 to 2019, with increasing patent activity over the decade (Sandalow, 2022). Since 2000, China's energy patents have doubled every five years, and low-carbon energy patents have grown rapidly, especially in the fields of batteries, electric vehicles, and solar energy (Sandalow, 2022).

In addition, China has several public research institutions dedicated to advancing solar technology. These institutions conduct research on a wide range of topics, from basic science to applied engineering, and play a key role in supporting the development of the solar industry. For example, the Chinese Academy of Sciences (CAS) is one of China's leading research institutions central to solar energy research. CAS researchers are developing new materials for solar cells, such as perovskites and organic solar cells, and improving the efficiency of solar power generation (CAS, n.d.). The China National Renewable Energy Center (CNREC) is a government-affiliated research center focused on renewable energy policy and technology. The center researches solar technology, including large-scale solar power generation, distributed solar systems, and energy storage (CNREC, n.d.). The National Energy Administration Solar Energy Research Center oversees several research centers that advance solar technology. These centers research topics such as solar cell efficiency, grid integration, and energy storage and work closely with industry partners to commercialize new technologies (NEA, n.d.).

4.3.2 The Netherlands

This system includes professional education and training programs, higher education institutions conducting cutting-edge solar energy research, and public sector research initiatives. Dutch companies and research institutes are making significant strides in solar energy technology by focusing on sustainable and recyclable solar components, achieving record-breaking efficiencies in tandem solar cells, and pioneering advanced production techniques like spatial atomic layer deposition (ALD) to enhance industrial solar cell manufacturing (Next-generation solar power, 2020). They are also developing innovative materials, such as anti-reflective and anti-soiling coatings, to boost panel efficiency and integrate solar technology into buildings, infrastructure, and agricultural settings through building-integrated photovoltaics (BIPV) (Next-generation solar power, 2020).

Professional education and training

Vocational education and training (VET) institutions in the Netherlands are essential to developing a skilled workforce that meets the needs of the renewable energy industry. The VET system in the Netherlands is well-established, which also influences solar with many schools offering professional training in installing, maintaining, and operating solar photovoltaic systems (CEDEFOP, 2023). These programs are designed for students who want to enter the workforce directly as solar technicians, installers, and maintenance professionals. Students learn electrical wiring, system configuration, panel installation, and troubleshooting skills, ensuring they are prepared for residential and commercial solar projects.

The Dutch government also supports professional training in the renewable energy sector through various programs and initiatives (Ministry of Education, Culture and Science, n.d.). For example, Energy Academy Europe in Groningen offers training and certification programs for professionals who want to upgrade their skills or switch to a career in renewable energy, including solar (New Energy Academy, n.d.).

High education and research

Universities and research institutes nationwide are actively participating in developing new solar technologies, improving efficiency, and addressing energy storage and grid integration challenges. They also provide higher education and training for engineers, researchers, and policymakers.

Several Dutch universities promote innovation and produce graduates with the technical expertise needed to advance the future of renewable energy in the Netherlands and beyond. For example, TU Delft is one of the world's leading engineering universities and a global center for solar research. Its Photovoltaic Materials and Devices (PVMD) group focuses on developing high-efficiency solar cells, solar integrated systems, and new photovoltaic materials such as perovskites (TUDelft, n.d.). TU Delft also offers specialized degree programs in sustainable energy technology and electrical engineering, preparing students for solar research and development careers (TUDelft, n.d.). TU/e focuses on solar energy. The Department of Applied Physics and Institute for Renewable Energy Research conduct research in advanced photovoltaic technologies, energy storage systems, and smart grid integration (TU/e, n.d.). TU/e also offers undergraduate and postgraduate courses in energy engineering, renewable energy systems, and physics, equipping students with the knowledge and skills to contribute to the solar industry (TU/e, n.d.). The University of Groningen has the Zernike Institute for Advanced Materials, where researchers work on developing innovative materials for solar cells, including organic and hybrid solar technologies (Rijksuniversiteit Groningen, n.d.). The university also offers a degree program in energy science and technology, preparing students for careers in the renewable energy sector (Rijksuniversiteit Groningen, n.d.).

Public sector research

Government agencies and public research organizations conduct extensive research on solar technologies, support pilot projects, and provide funding for innovative research programs. For example, The Dutch government's Top Sector Energy (TSE) is a platform for supporting innovation in renewable energy, including solar. The program brings together stakeholders from the public and private sectors to collaborate on R&D projects to improve energy efficiency, reduce carbon emissions, and increase renewable energy use. Solar research under the Top Sector Energy program focuses on photovoltaic innovation, energy storage, and integrating solar energy into smart grids (NEA, n.d.). TNO mentioned above conducts applied research on various solar technologies, from high-efficiency photovoltaic systems to energy storage and smart grid solutions. It’s solar research also includes collaboration with industry and academia to ensure solar innovations are quickly commercialized (TNO, n.d.). The Netherlands Enterprise Agency (RVO) is the government agency responsible for promoting sustainable economic growth in the Netherlands, including developing renewable energy. RVO manages various funding programs that support solar research and development, such as the SDE++ program mentioned above.

4.4 Framework conditions

Aspect	China	The Netherlands
Financial environment	Various financial institutions, including state-owned banks, venture capital firms and international investors, have played an important role in financing solar projects.	Public and private investment, favorable financial policies, and a variety of financing mechanisms have enabled the rapid deployment of solar technology across the country.
Mobility	Due to China's heavy investment in renewable energy research and education, the mobility of skilled workers and researchers in China's solar industry is relatively high.	The Netherlands benefits from an innovation system that heavily emphasizes collaboration between universities, research institutions and the private sector and creates a dynamic environment where knowledge flows easily between academia and industry.

4.4.1 China

A range of framework conditions have created a favorable environment for growth, supporting the solar industry's rapid development. These conditions encompass financial structures, mobility and logistics networks, innovation and entrepreneurship support, and taxation and incentive policies. Each element has positioned China as a global leader in the solar energy industry, driving its transition toward a clean energy future.

Financial environment

China's state-owned banks, a feature of China's national innovation system, are a major source of financing for solar projects. China's solar industry has benefited from many public and private investments, including state-owned banks, venture capital firms, and international investors. State-owned banks such as the China Development Bank (CDB) and the Industrial and Commercial Bank of China (ICBC) are the main sources of financing for solar projects (Xu, 2021). These banks offer favorable loan terms, low interest rates, and long repayment periods, making it easier for companies to obtain funds for large-scale solar installations. For example, in 2021, the CDB proposed to allocate RMB 500 billion in loans over the next five years to finance green energy projects (Xu, 2021).

The rise of green finance in China has also provided another mechanism for financing solar projects based on the 14th Five-Year Plan. Green bonds refer to corporate bonds whose raised funds are mainly used to support technological transformation for energy conservation and emission reduction, clean and efficient use of energy, and other green, circular and low-carbon development projects (NDRC, 2015). It encourages social capital to raise funds through multiple channels by market principles and establish investment funds to support the development of the renewable energy industry and increase the support of green bonds and green credit for eligible new energy projects (The 14th Five-Year Plan for Renewable Energy Development, 2022). Therefore, As of September 2024, among the green bonds with public fundraising purposes, funds are concentrated in the clean energy field, accounting for 85.97%, including projects on wind power generation, photovoltaic power generation, etc. (New Century Rating, 2024)

China's central government has generously subsidized solar manufacturers and developers for years through programs such as the Golden Sun Program and the Renewable Energy Law. These programs use fiscal subsidy funds to support building user-side photovoltaic power generation systems (The 14th Five-Year Plan for Renewable Energy Development, 2022). For example, in principle, grid-connected photovoltaic power generation projects in the Golden Sun Plan would be subsidized at 50% of the total investment in the photovoltaic power generation system and its supporting transmission and distribution projects, and independent photovoltaic power generation systems in remote areas without electricity would be subsidized at 70% of the total investment (Ministry of Finance of the People's Republic of China, 2009). These subsidies help offset the costs of solar panel production and installation, making solar energy more competitive with traditional fossil fuels.

Mobility

In China's solar industry, talent mobility is also important in promoting innovation and maintaining China's leadership in the global solar market. In particular, the large enterprises and professional colleges mentioned above maintain close cooperation, which leads to the high mobility of skilled workers and researchers in China's solar industry. However, although China has adopted open cooperation in many fields, intellectual property issues and protecting proprietary technologies sometimes hinder the free flow of information (Muehlfeld et al., 2022).

4.4.2 The Netherlands

Financial environment

The Netherlands has a strong financial environment in the national innovation system, offering various banking and venture capital options to support the solar industry. Traditional banking and venture capital are predominantly used to support the solar photovoltaic industry. These financial mechanisms enable photovoltaic companies to innovate and compete effectively in the international market (Verhees, 2013).

As one of the largest banks in the Netherlands, ABN AMRO offers loans and other financial products tailored to the needs of the renewable energy industry, helping companies invest in solar installations and infrastructure (ABN AMRO, 2023). Rabobank is another major financial institution in the Netherlands that strongly emphasizes sustainability and renewable energy projects, which offers green loans and investment opportunities specifically targeted at solar development. The bank works closely with the agricultural sector to provide tailored solutions for solar installations on farms and rural areas (Rabobank, n.d.). Rockstart is one of Europe's leading startup accelerators, focusing on energy and sustainability. Through its Smart Energy Accelerator program, Rockstart supports startups to support startups in emerging technologies and vertical industry sectors, from early stages to scale-up (Rockstart, 2020).

In addition to private investment, the Dutch government provides several grant programs and low-interest loans to support solar projects. For example, the Netherlands Enterprise Agency (RVO) manages the Energy Investment Allowance (EIA), which provides tax breaks to companies that invest in renewable energy projects, including solar installations (Next-generation solar power, 2020). In addition, the SDE++ program and the net metering system (salderingsregeling) mentioned above are among the main financial tools supporting solar energy in the Netherlands, which could reduce electricity costs, making solar installations more affordable for individuals and small businesses.

Mobility

The Netherlands' NIS benefits from collaboration between universities, research institutions and the private sector. As mentioned above, TNO works closely with industry to develop new solar technologies, and universities such as TU Delft are actively involved in collaborations, creating a dynamic environment where knowledge flows freely between academia and industry. In addition, the Netherlands has an environment that highly supports the development of entrepreneurial and technology-based companies, especially in the renewable energy sector. Non-profit publicly funded organization initiatives such as Techleap.nl provide resources, funding and networking opportunities to help entrepreneurs start and grow solar companies (Techleap.nl, n.d.). The Netherlands also benefits from a strong venture capital ecosystem, such as YES!Delft mentioned above, which helps startups in the clean technology sector. These different research institutions work together to facilitate the flow of ideas and talent and drive innovation and the creative system in the Netherlands.

4.5 Infrastructure

Aspect	**China**	**The Netherlands**
Innovation and business support	Chinese government policies place great emphasis on technological innovation, with a focus on the renewable energy sector.	In addition to financial support, the Netherlands places a strong emphasis on promoting innovation and supporting small and medium-sized enterprises.
IPR and information	China has become a global leader in patent applications for solar technology.	The Netherlands has a strong legal system for intellectual property protection, providing an attractive environment for companies developing new solar technologies.

Standards and norms	China has developed a comprehensive set of standards for the solar industry, covering everything from photovoltaic panel manufacturing to installation and maintenance.	The Netherlands has developed comprehensive standards to guide solar technologies' production, installation, and maintenance, ensuring they meet national and international requirements.

4.5.1 China

Innovation and business support

Chinese government policies support innovation, with a focus on the renewable energy sector is one of the characteristics of NIS. For example, CNREC is an important platform for developing solar technology in China. It promotes collaboration between research institutions, government agencies, and industry players to advance the country's renewable energy goals. Chinese universities play a vital role in advancing solar technology. Universities such as Tsinghua University, Peking University, and Shanghai Jiao Tong University are leading research in solar panel efficiency, energy storage, and innovative photovoltaic materials such as perovskites. These universities often work with industry players to ensure that academic research is translated into commercial applications. In recent years, China has also launched China’s national emission trading scheme (ETS), which allows companies to trade emission reduction credits. Clean energy producers (including solar) can benefit from this system by selling credits generated by their renewable energy projects, creating an additional source of revenue and further incentivizing the development of solar projects (Jia & Tang, 2021).

In addition to government-supported R&D centers, many incubators and science parks help solar startups grow and develop. Zhongguancun Science Park is a high-tech innovation center, including renewable energy, which is home to several solar startups working on advanced photovoltaic technologies. For example, Sule Solar focuses on non-powered solar water heating systems (Sule Solar, n.d.), and Huayang New Energy Investment Group focuses on solar power generation, energy storage, and other technologies (HuaYang, n.d.). Besides, to help China achieve its carbon peak and carbon neutrality goals, the park has formulated a five-year action plan for green development and established special funds for constructing ecological parks, smart parks, and the demonstration and application of new technologies and products (Hao, 2022).

Chinese solar companies benefit from government programs that promote market expansion, especially into international markets. Export assistance, trade missions, and government-backed overseas project financing all help Chinese solar companies compete globally. China is trying to keep up with international developments in the renewable energy sector. In the past, the German and even the Dutch governments helped develop electrification and solar plans in terms of technology. However, the technological focus has shifted to China, and China is no longer behind in these areas. Some of them may even be ahead (Kyle, 2024).

IPR and information

China has recently strengthened its intellectual property (IPR) protection framework significantly. China's global solar cell patent applications are more than 126 thousand, ranking first globally (CCTV News, 2024). Leading companies such as Longi Green Energy and JinkoSolar regularly could apply for patents for new photovoltaic technologies, solar cell designs, and energy storage solutions. A strong IP system enables these companies to protect their innovations and ensure that they can exploit their research and development results.

Standards and norms

Improving the industrial standard certification system is necessary to promote the solar energy according to the requirements of the 14th Five-Year Plan. Besides, it encourages domestic enterprises to participate actively in formulating international renewable energy standards, promotes the alignment of standards system and conformity assessment system with international standards, and promotes international mutual recognition of certification results.

Therefore, China has developed a comprehensive set of standards for the solar industry, covering everything from photovoltaic panel manufacturing to installation and maintenance. The National Energy Administration (NEA) has launched the "Photovoltaic Power Generation Project Component and Support Installation Quality Assessment Standard". These standards suit photovoltaic component and bracket installation projects of newly built, rebuilt, and expanded ground photovoltaic power generation systems and building-attached photovoltaic power generation systems to ensure solar products meet strict quality and safety requirements (NEA, 2019). Besides, Chinese solar companies also comply with international standards developed by organizations such as the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC). Chinese manufacturers meet these international standards to ensure their products are competitive in global markets. For example, JinkoSolar has certificates such as IEC TS 62941 All series and ISO 14001 2015 EN 2023 for designing and manufacturing solar cell modules (JinkoSolar, n.d.).

4.5.2 The Netherlands

Innovation and business support

The Netherlands has a strong culture of innovation and entrepreneurship in NIS. In addition to financial support, the Netherlands strongly emphasizes promoting innovation and supporting small and medium-sized enterprises (SMEs). Through local networks and targeted policies, the Netherlands has strengthened the capabilities of these companies, promoted technological progress, and maintained the competitiveness of the photovoltaic industry (Vasseur, 2013).

The government has introduced several fiscal measures to encourage investment in solar projects and make solar more affordable for consumers and businesses. The Energy Investment Allowance (EIA) is the main tax incentive for companies that invest in renewable energy projects, including solar installations. Companies can deduct a significant portion (up to 45%) of their investment in energy-saving technologies, such as solar panels, from their taxable profits (RVO, 2024). This incentive reduces the overall cost for companies to install a solar system, making solar a more attractive option. In addition, homeowners in the Netherlands who install solar panels are eligible for a VAT rebate on the installation costs. This rebate effectively reduces the price of a solar panel system by 21%. In particular, the VAT on solar systems has been reduced to 0% from January 1, 2023, making it easier for homeowners to invest in solar energy (Zonnefabriek, 2023). In addition to tax incentives, the Dutch government also provides direct subsidies to support solar system deployment, including the SDE++ subsidy program mentioned above and local governments and community organizations applying for subsidies to support solar projects. These subsidies help finance solar installations on public buildings, schools, and other community-owned properties, spurring wider adoption of solar energy across the country.

TNO, TU Delft and Yes!Delft are organizations and companies that develop innovative technologies and provide guidance, funding and technical expertise for solar startups. The details have already covered in the Mobility and other sections above, so it is not repeated here.

IPR and information

The Netherlands has a strong legal system for intellectual property protection, providing an attractive environment for companies developing new solar technologies. In terms of technological innovation, the Netherlands ranks second in the world in terms of patent applications per capita, with a large part of its innovative strength concentrated in the photovoltaic technology chain (Next-generation solar power, 2020). Dutch companies and research institutions can apply for patents to protect their innovations in solar technology. Patents are administered by the Netherlands Patent Office, part of the European Patent Office (EPO) system. This enables Dutch companies to protect their inventions throughout the EU and beyond, ensuring they can compete in global markets.

Standards and norms

The Netherlands Institute for Standardization (NEN) is responsible for developing national standards in the Netherlands, including standards for renewable energy technologies. NEN works with international bodies such as the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) to ensure that Dutch solar products meet global quality and safety standards (Netherlands Chamber of Commerce, n.d.). In addition, as part of the European Union, compliance with EU standards ensures that Dutch solar products are competitive in the European market. For example, the European Building Performance Directive stipulates that EU member states will have to gradually deploy solar installations based on the size of public and non-residential buildings if it is technically and economically appropriate (Patrick, 2024). For the Netherlands, which ranks first in per capita solar energy installation, this regulation will further promote the internal and external development of solar energy in the Netherlands.

4.6 Value chain

Aspect	China	The Netherlands
Production	Chinese factories have the world's largest and most automated production lines, from raw material mining to production to terminal installation and after-sales service, and are able to produce large quantities of solar modules at extremely low costs.	Rather than focusing on mass production, the Dutch solar manufacturing system focuses on niche markets and high-value components.
Consumption	Scale of utility-scale solar farms and distributed solar power generation systems have developed rapidly.	Dutch solar value chain has been the widespread adoption of distributed solar, especially rooftop installations for homes and businesses. And the development of utility-scale solar farms has also seen steady growth in the Netherlands.

China has become the world leader in solar power due to its integrated value chain, which spans from raw material production to final solar energy consumption. It dominates global solar panel manufacturing, benefiting from large-scale production, government support, and vertical integration. However, there are challenges include reliance on coal-based electricity and concerns over labor practices. On the consumption side, China faces grid issues that waste energy. The Netherlands, in contrast, focuses on niche solar markets and distributed generation, with strong policies supporting rooftop solar installations. However, it relies heavily on imports for solar components and struggles with grid congestion.

4.6.1 China

The value chain complements the NIS model by covering two important parts - production and consumption. China's solar value chain characteristics cover all links from the production of raw materials and components to the final consumption of solar energy. The production stage includes the manufacture of polysilicon, ingots, wafers, photovoltaic cells, and modules. In contrast, the consumption stage covers installing and using solar energy systems for residential, commercial, and industrial applications. This integrated system has enabled China to dominate global solar energy production and domestic consumption, with far-reaching impacts on the global renewable energy market.

Production

China produces over 80% of the world’s solar panels (Chadly, 2024). Chinese factories have the world’s largest and most automated production lines, capable of producing large quantities of solar modules at very low costs (Chadly, 2024). This scale advantage is key to China’s ability to offer solar modules at prices that are difficult for competitors in other regions to match. In addition, the Chinese government supports this large-scale production capacity through policies such as subsidies and tax incentives, encouraging manufacturers to invest in advanced equipment and expand their operations (Kyle, 2024). As a result, Chinese manufacturers have become very efficient, driving the cost per watt of solar energy to an all-time low.

Polycrystalline silicon is the basic material used to make solar panels. China has entered the global photovoltaic value chain by focusing on manufacturing and exporting photovoltaic modules, adopting a vertical integration approach across multiple value chain links. This strategy reduces costs, integrates technology and market knowledge, and accelerates innovation in the global PV value chain (Zhang, 2016). Polysilicon manufacturing in China is concentrated among a few major companies, including GCL-Poly, Tongwei and Daqo New Energy. These companies have invested heavily in large production facilities, achieving significant economies of scale that allow them to produce cheap polysilicon. This vertical integration is a hallmark of China's solar manufacturing system and ensures Chinese manufacturers have a reliable and cost-effective supply of raw materials, which eliminates the need to import key inputs and protects the industry from global market fluctuations. By controlling the entire manufacturing process from silicon to solar panels, Chinese companies can minimize transportation costs, optimize manufacturing processes, and further drive down prices (IEA, 2022).

However, China's polysilicon manufacturing system faces challenges. Regions such as Xinjiang are the main areas for polysilicon production in China, and coal remains the main source of electricity (Williams, 2022). Reliance on coal for power generation creates a paradox in that key inputs to renewable energy are carbon-intensive, undermining the environmental benefits of solar technology. Additionally, allegations of forced labor in the polysilicon supply chain have sparked calls for greater transparency and ethical standards in the industry (Turnbull, 2021), which pressures Chinese manufacturers to ensure their production practices comply with global labor and environmental standards.

Consumption

Consumption plays an important feedback mechanism in China's national innovation system, influencing future R&D work and shaping market trends through demand for innovative products and services. China's utility-scale solar farms are the largest in the world, and projects such as the Tengger Desert Solar Farm and the Longyangxia Dam Solar Farm demonstrate China's ability to produce large amounts of clean energy (The 14th Five-Year Plan for Renewable Energy Development, 2022) and make solar an important part of China's energy mix. Despite the impressive scale of utility-scale solar farms, China faces a serious curtailment problem, especially in western regions. For example, in Qinghai, the curtailment problem worsened in 2021, and the line operation conditions could no longer meet the requirements for power transmission (CET, 2022). Curtailment refers to the situation where solar power cannot be used or transmitted due to grid constraints after generation (Sitemark, 2023). China's rapid expansion of solar farms has outstripped its ability to upgrade and expand transmission infrastructure. This has resulted in energy waste and weakened the economic viability of many solar projects.

Distributed solar power generation systems (including residential and commercial facilities) mentioned above have developed rapidly in China. Government incentives (such as subsidies and preferential policies for rooftop solar facilities) have driven large-scale adoption. The 14th Five-Year Plan also mentions "accelerating the promotion of distributed grid-connected photovoltaic power generation systems on the user side, and encouraging the installation of photovoltaic power generation systems on the roofs of urban public facilities, commercial buildings and industrial parks where conditions permit, and supporting the connection of photovoltaic power generation systems to the internal grids of large industrial enterprises." However, one of the main challenges is policy uncertainty. China has scaled back many subsidies for distributed solar power generation, leading to slower growth in recent years (Reuters, 2019).

In addition, China has made great progress in solar energy storage, with companies such as CATL and BYD developing advanced battery technology. Integrating energy storage systems with solar installations is essential to managing intermittency and ensuring a stable power supply. Although China has made significant progress in reducing the cost of solar cell modules, such as CATL's launch of the first mass-producible battery energy storage system (Maisch, 2024), the high cost of energy storage remains a barrier to widespread adoption, limiting their use in residential and commercial applications.

4.6.2 The Netherlands

The Netherlands has become an important player in the global solar market, particularly in adopting solar energy and integrating it into the national grid. While the Netherlands has made significant progress in solar energy consumption, its role in solar production (specially manufacturing sector) is less prominent compared to countries such as China or Germany. The research breaks down the key elements of the Dutch solar value chain, focusing on the strengths and weaknesses of the production and consumption stages.

Production

Rather than focusing on mass production, the Dutch solar manufacturing system focuses on niche markets and high-value components in terms of NIS. Companies like Exasun are at the forefront of producing premium high-performance solar panels, focusing on product durability and aesthetics, such as integrating urban rooftops (ENERGIIQ, n.d.). Dutch companies also work closely with research institutions to develop new solar technologies using the country's strong R&D infrastructure. For example, TNO, mentioned above, researches advanced photovoltaic technologies such as bifacial solar panels and perovskite cells. These innovative technologies enable the Netherlands to capture niche markets in the global solar market.

In addition, the Netherlands has a competitive advantage in solar system assembly and its integration with smart energy solutions. While most photovoltaic cells and modules are imported (CBS, 2023), Dutch companies excel in adding value through system design, customization and integration. Companies such as IBC Solar specialize in designing complete solar systems for residential, commercial and utility-scale applications (IBC Solar, 2023). These companies provide end-to-end solutions, including panel installation, energy storage integration and smart grid connection.

The Netherlands does not have the manufacturing capacity to produce polysilicon, ingots, or wafers and, therefore, relies on global supply chains for these materials (Edurne, 2023). The Netherlands' limited production capacity makes it dependent on imports and vulnerable to supply chain disruptions or geopolitical trade issues.

Consumption

Consumer preferences and demands influence the design and production processes in the Netherlands' NIS. One of the greatest successes in the Dutch solar value chain has been the widespread adoption of distributed solar, especially rooftop installations for homes and businesses. The Dutch government has implemented favorable policies, including net metering, encouraging homeowners to install solar panels. The Netherlands has more than 1 kilowatt (KW) per capita installed capacity, ranking first in Europe for per capita solar power generation (Elton, 2023). The rapid adoption of rooftop solar systems has been supported by strong financial incentives, such as subsidies and tax exemptions, as well as the decline in the cost of solar panels. Dutch consumers increasingly turn to solar energy to reduce electricity bills and achieve national sustainable development goals. In 2022, the energy production of residential solar panels in the Netherlands was slightly higher than commercial building panels (CBS, 2023). These installations' decentralized nature also helps diversify energy production and make the energy system more resilient.

The development of utility-scale solar farms has also seen steady growth in the Netherlands. The government supports these projects through various incentives, including the SDE++ mentioned above, which provides subsidies for large-scale renewable energy projects. These large solar farms are often built on unused agricultural or industrial land and have significantly contributed to the country's renewable energy goals.

While distributed solar power is growing rapidly, the Dutch grid needs help to keep pace. The existing grid infrastructure is not fully equipped to handle the growing influx of decentralized renewable energy, leading to grid congestion and power outages (Aurora, 2024). In addition, the reduction of net metering and other financial incentives may slow the future growth of distributed solar systems. The Netherlands is moving to a new policy framework focusing more on self-consumption rather than delivering excess power to the grid (Jäger-Waldau et al., 2020), which may reduce the economic attractiveness of solar installations for some consumers.

As with distributed solar, grid congestion remains a significant problem for utility-scale solar farms (Aurora, 2024). The Dutch grid was not originally designed to accommodate large amounts of intermittent renewable energy, and upgrades to the grid infrastructure have not kept pace with the rapid expansion of solar generation capacity. This results in solar farms being unable to transmit all the power they generate, reducing the system's overall efficiency (Blijswijk et al., 2012). In addition, the Netherlands' small land area and high population density limit the space available for large solar farms. Therefore, the Netherlands need to rely on more than just utility-scale solar projects to achieve its renewable energy goals, and emphasize distributed generation and system efficiency.

4.7 International cooperation

Aspect	China	The Netherlands
Technology cooperation	In the early stages, China benefited greatly from technology transfer and cooperation with leading solar manufacturers in Europe, the United States and Japan. However, now foreign companies are trying to take advantage of some Chinese companies and their industry leadership, especially in terms of technology and scaling up production.	The Netherlands' participation in international testing and standardization of solar PV technology, and is known for its strong R&D ecosystem.
Market cooperation	Chinese companies are consolidating their investment in traditional solar energy markets such as Europe and North America through initiatives such as the Belt and Road Initiative, while focusing on emerging markets such as Latin America and Africa, where governments and private sector players rely on Chinese technology to build large-scale solar projects.	The Netherlands has leveraged its expertise in solar technology development and deployment by participating in the European and global solar markets, and has established strong ties with developing markets, especially in Africa, through partnership.

The two countries also differ in how they approach international coordination regarding industry development regarding technology and markets. China initially benefited from technology transfer from global leaders, but it now leads in scaling up production, attracting foreign companies seeking collaboration. In contrast, the Netherlands focuses on solar technology R&D and international standardization. In market cooperation, China consolidates its position in Europe and North America while expanding into emerging markets through initiatives like the Belt and Road. The Netherlands leverages its expertise to strengthen ties in European and African markets, emphasizing partnerships for solar technology deployment.

4.7.1 China

Technology cooperation

China's international cooperation model is "in the past highly dependent on technology transfer from other countries, but now transferring science and technology to other countries and expanding production". Technology cooperation in the national innovation system has enabled China's technology to develop rapidly, and has promoted global technological cooperation and expanded production scale. In the early stages of China's solar development, China benefited greatly from technology transfer and collaboration with leading solar manufacturers in Europe, the United States, and Japan. European companies, for example, Meyer Burger were important in sharing manufacturing expertise and advanced solar cell technology with Chinese companies, enabling them to rapidly scale up production while incorporating state-of-the-art technologies into their processes such as the production of recycled silicon, and extended to the processing of single crystal silicon wafers and multi-crystalline silicon wafers (Meyer Burger, 2007). Besides, Chinese companies have increasingly focused on international acquisitions to acquire advanced technologies. For example, China National Building Materials Group (CNBM) acquired German solar equipment manufacturer Avancis to acquire its thin-film technology, enabling it to diversify its products beyond traditional silicon-based solar cells (EnergyTrend, 2014). This approach has enabled Chinese companies to innovate faster by leveraging global expertise. However, these partnerships are now going in almost the opposite direction than they were in the past. Foreign companies are trying to take advantage of some Chinese companies and their industry leadership, especially regarding technology and scaling up production (Kyle, 2024). For example, in the battery field, China has a much larger scale of battery production than the United States or Europe. So American and European automakers want to take advantage of that, and they may want to buy batteries from CATL, which is driving new cooperation areas (Kyle, 2024).

However, rising geopolitical tensions and concerns about intellectual property protection have begun to complicate international technology collaboration. Western countries have become more cautious about sharing advanced technology with Chinese companies, especially in sensitive sectors such as energy and telecommunications. Tighter import and export controls such as EV imports (Michael, 2024) and DUV export (Giacomo, 2024), and increased scrutiny of technology transfers could limit China's ability to continue to benefit from global technology partnerships.

Market cooperation

China uses large policy project, like Belt and Road to create markets for new industries. At the same time, through initiatives such as the Belt and Road Initiative, China has also promoted the financing and development of renewable energy projects in developing countries, often bundling infrastructure investment with technology exports (The 14th Five-Year Plan for Renewable Energy Development, 2022). Chinese companies have strengthened international market planning and research for the solar industry in key regions such as the China-Pakistan Economic Corridor and the Bangladesh-China-India-Myanmar Economic Corridor, guided the development and construction of major international projects, consolidated traditional solar industry investment markets such as Europe, North America and parts of Asia, and focused on developing emerging markets such as Southeast Asia, West Asia, Latin America and Africa (The 14th Five-Year Plan for Renewable Energy Development, 2022). These regions ' governments and private sector players rely on Chinese technology to build large-scale solar projects.

In addition to domestic funds, foreign venture capital and private equity firms have also shown interest in China's solar market. Thanks to the large amount of financial support from the CDB and a large amount of foreign direct investment, China's solar photovoltaic industry has achieved substantial growth. This financial support has helped promote technological innovation and strengthen China's leading position in the renewable energy sector. National policies and global market opportunities have created a favorable environment for research and development, leveraging global trade infrastructure to support the rapid expansion of the PV industry (Huang, 2016). In addition to financial support, foreign direct investment has played a vital role in China's PV industry by promoting technology transfer, establishing joint ventures, and increasing production capacity. These investments are crucial to improving the technological capabilities and global competitiveness of Chinese companies, promoting the rapid growth of the PV industry (Shubbak, 2019).

Despite China's success in global market expansion, it faces increasing resistance, such as trade barriers and protectionism. The European Union and the United States have imposed tariffs and anti-dumping measures on Chinese solar products, accusing Chinese manufacturers of unfair trade practices, such as accepting state subsidies to undercut foreign competitors (Bickenbach et al., 2024). These trade restrictions have limited China's access to key markets and forced Chinese companies to focus on emerging markets such as the African market that the Belt and Road Initiative focuses on, where competition is less intense, but profit margins are lower. In addition, many countries that have received Chinese solar project financing are developing countries with limited financial resources. As a result, critics say China's investment strategy could leave these countries with unsustainable debt, especially if solar projects do not bring the expected returns or economic conditions deteriorate (Wang, 2022).

4.7.2 The Netherlands

The Netherlands has established a strong international cooperation framework in the solar energy sector. Through technical cooperation and market collaboration, the Dutch solar industry has made significant progress in developing innovative solutions, deploying solar energy on a large scale, and integrating renewable energy into the national grid.

Technology cooperation

International technological cooperation within the Netherlands' NIS promotes knowledge exchange, resource sharing, and joint research initiatives. As mentioned above, the Netherlands is known for its strong R&D ecosystem, with institutions like TNO and Dutch research institutions regularly collaborating with counterparts in other European countries, such as the EU's Horizon Europe program. Another area of strength is the Netherlands' participation in international testing and standardization of solar PV technology, such as IEA PVPS Task 15 (IEA, 2024), which helps Dutch solar technology integrate more smoothly into the global market and promotes knowledge sharing with foreign partners.

The Netherlands still faces limitations in scaling up certain technological innovations to commercial applications. Much of the cutting-edge research developed in Dutch laboratories does not always translate into large-scale production or widespread deployment domestically or globally (Ministry of Economic Affairs and Climate Policy, 2024). This limits the scale of domestic innovation commercialization, and stronger international partnerships are needed before the Netherlands realizes the full potential of its technological advances. In addition, as mentioned above, while Dutch research institutions are leading the way in solar PV innovation, they face strong competition from international institutions, especially China, where solar R&D is often supported by large-scale government investment. As competition intensifies, the Netherlands needs to consider further increasing investment in solar R&D to remain at the forefront of innovation.

Market cooperation

The Netherlands is very well-connected in terms of international networks, technological and market networks are often related. Market cooperation in international cooperation within the Netherlands national innovation system promotes strategic partnerships in the domestic market while enabling Dutch companies to enter new markets internationally. The Netherlands has leveraged its expertise in solar technology development and deployment by participating in the European and global solar markets. For example, the Netherlands has a strong presence in niche markets such as solar building-integrated photovoltaics and solar energy management solutions (Vroon et al., 2022). Dutch companies such as Solarclarity providing customized solar solutions that meet specific needs, such as urban solar installations and small rooftop systems (Solarclarity, n.d.).

The Netherlands has established strong ties with developing markets, especially in Africa, through initiatives such as the Sustainable Energy for All partnership (Sustainable Energy for All, n.d.). These initiatives support the development of renewable energy projects in emerging economies, allowing Dutch companies to expand their influence and contribute to global solar deployment. In addition, the Netherlands is actively promoting the integration of the European solar market, which aims to create a unified EU energy market. As an EU member state, through organizations such as ENTSO-E (European Network of Transmission System Operators for Electricity), the Netherlands works with its European neighbors to create an interconnected grid to manage better the supply and demand of renewable energy, including solar (ENTSO-E, n.d.).

Although Dutch companies are competitive in certain market segments, they need to improve when competing with large solar manufacturers in countries such as China. In addition, regulatory coordination between EU member states has been slow. While the EU is working to create a unified energy market, regulations, subsidies, and incentives for solar energy still differ from country to country (Pablo-Romero, 2013). This can create barriers to cross-border solar projects and complicate the integration of solar energy into national grids.

5. Discussion

5.1 Theoretical implications

This paper mainly illustrates the multifaceted role played by national innovation systems in shaping the development of the solar industry, helping to expand the current literature on NIS and implications for the NIS in the Netherlands for solar energy.

The study adds to the literature by illustrating how the structure of NISs, whether government-led or market-driven, can produce different outcomes for the solar industry. For example, in China, where SOEs dominate the energy sector, strategic government interventions such as subsidies, grid upgrades, and fiscal incentives have made China a global leader in solar technology manufacturing and deployment, which illustrates that in addition to promoting innovation and innovation systems, a strong state-led NIS also plays a vital role in building the entire industry value chain. In contrast, the Netherlands focuses more on market forces, and innovation concentrates on specific aspects of solar technology. However, the entire industry's expansion and the industry chain's development face challenges due to policy fragmentation and the need for cohesive state-led initiatives. The study also incorporates the concepts of value chain and international cooperation into the framework, expanding Arnold and Kuhlmann's theoretical insights on NIS, especially extending the "demand" part into the "value chain" by emphasizing production and consumption. Furthermore, this study complements Huang’s 2016 study’s findings by highlighting the importance of both technical and market cooperation, with factors such as technology transfer and the large European market making China a leader in solar PV. In China, the state intervenes in all stages of the value chain through fiscal incentives, subsidies, and direct participation in production, making China a dominant player in the global solar market. This situation contrasts with the Netherlands, where low-value chain integration has led to major challenges in scaling solar production and establishing a complete industry ecosystem.

The other important extension of NIS theory is international cooperation. This article shows that China's success in solar energy is due not only to its domestic policies and a strong government but also to its strategy for global partnerships, such as technology transfers from Europe, the United States, and Japan, to aid China's early success and help China rapidly scale up production and improve efficiency. Despite its smaller size, the Netherlands could benefit greatly from international collaboration to compensate for its limited manufacturing capabilities, which is particularly important for a country like the Netherlands. International cooperation also enables Dutch companies to enter developing markets such as Africa, where they contribute to solar deployment through strategic partnerships, expanding their influence while reverse-driving the entire value chain. NIS can be considered internal ecosystems and part of a broader global network that promotes technology exchange, standardization, and market access (Binz & Truffer, 2017).

Future research could analyze deeper into comparative studies of NIS influence across different energy sectors, not just solar but also wind and other renewable energy technologies. For example, as mentioned in Quitzow's (2017) article, in terms of competitiveness in foreign markets, the achievements of Chinese solar photovoltaic companies far exceed those of their counterparts in the wind energy field. Therefore, it is worth studying the relative influence of NIS factors as compared to other technology specific or external factors. In addition, research focusing on the evolving role of public ownership and state-owned enterprises in the renewable energy sector could further deepen the existing innovation ecosystem literature. For example, the roles of the government and state-owned enterprises are different in different industries, and in wind energy SOEs are even more important (Zhu et al., 2022). This is important for understanding how state intervention balances market competition with large-scale infrastructure development in transition economies and to explore how innovation systems adapt to technological and market changes over time.

5.2 Limitations

Despite the valuable insights gained from this study, some limitations should be acknowledged. These limitations may be, but are not limited to, methodological choices, data availability, and scope of the study.

Although both government-led and market-oriented NIS can drive innovation, the first limitation of this study is that it focuses only on solar energy and does not consider how solar technology integrates with other technologies, such as the broader energy grid or other complementary renewable energy technologies such as wind power (Yap, 2022). System approaches such as technology innovation systems can provide deeper insights into how solar innovation spreads and is integrated into social structures, rather than just in the development of NIS related elements.

The second limitation of this study is the reliance on qualitative data from literature analysis, especially data from government policy documents, which may be inherently biased. To address this issue, I used multi-party verification to improve the reliability of the data, which was done by using industry reports and expert interviews from a range of independent sources. However, using only one interview also limits the generalizability of the conclusions. Subsequent research could conduct multiple interviews with different stakeholders, such as company management teams, research scholars, and government personnel, to gather more information.

The third limitation lies in the validity of the comparison between China and the Netherlands. Although both countries have made significant progress in solar energy, the huge differences in the two countries' political, economic, and social environments make direct comparisons difficult. For example, significant geographic, demographic, and cultural differences between China and the Netherlands may limit the comparative validity of this study. China's solar industry benefits from its vast land area and the ability to build solar farms on a large scale in remote areas. On the other hand, the Netherlands is geographically limited and has fewer locations suitable for such large-scale projects. Therefore, large-scale land-based solar farm construction is unsuitable for the Netherlands. In addition, regarding scientific research and education, both China and the Netherlands have relatively good vocational education systems, higher education systems, and public scientific research systems. However, since China has a larger population labor force advantage and can cultivate more solar-related talents, it can only be indirectly concluded that China's education system is more advantageous than the Netherlands.

This study focuses on developments from 2013 to 2023, which provides a coherent window for understanding the long-term trends in solar development. The study uses China's 12th, 13th and 14th Five-Year Plans as basic materials to expand the time and events. Because these two plans almost cover the development and changes in China's solar energy policies in the past decade, especially how the government gradually shifted from a leading role to guiding opinions. However, the rapid and dynamic development of technology and policies in the field of renewable energy means that the results of this decade may soon become updated or even outdated. For example, the Netherlands' Net metering will be phased out in 2025, and the previous Parliament had rejected a proposal to cancel the scheme by the end of 2025 (Emiliano, 2024). Meanwhile, many of the technologies mentioned in this paper may also make breakthroughs in the future, which could greatly change the situation and affect the relevance of the research results. Therefore, the conclusions may be limited regarding whether they are still useful for future development, and a certain advantage may gradually disappear or even become a disadvantage.

5.3 Recommendations

Based on the findings in the Results section, several targeted recommendations can be made for policymakers and managers in the Dutch solar industry.

5.3.1 Industrial System

Dutch companies could collaborate with global solar manufacturers to gain access to advanced manufacturing technologies and economies of scale, just like what China did the at the beginning. Then large companies can benefit from economies of scale by vertically integrating solar and other sustainable energy industries. As it is difficult for large companies to quickly complete vertical integration in a short period, close collaboration within Europe as the first step would be a viable and superior alternative. Such collaboration and integration would also enable Dutch companies to access advanced manufacturing technologies and benefit from economies of scale, allowing them to compete more effectively in domestic and international markets while focusing on niche innovation.

Meanwhile, in the short term, policymakers could incentivize vertical integration through tax breaks or subsidies aimed at companies that expand into multiple areas of the solar energy ecosystem. Investing in future options could encourage investment in high-value markets where the Netherlands has demonstrated strength while reducing the Netherlands' future reliance on solar modules that may need to be imported. In the long term, more SOEs are feasible in areas that affect national energy security, such as solar energy. Based on China’s experience, these SOEs can make up for the lack of resources and other problems that large enterprises may encounter in vertical integration, to rapidly promote the country's solar energy development.

5.3.2 Political system

To improve the political environment surrounding solar development, the Netherlands should consider simplifying solar facilities' licensing and regulatory processes to reduce bureaucratic delays. More central guidance is beneficial, and we can learn from the Chinese model because it is impossible to fully consider all stakeholders' interests when implementing policies. At the same time, if there is no strong government to enforce it, policies that are hindered by many aspects will be very difficult to implement. And clearer, long-term policies will help drive investment in large-scale solar infrastructure. Simplifying the licensing process and reducing bureaucratic obstacles at the local and national levels will greatly speed up the project's progress, thereby promoting the wider application of solar technology. A more coordinated approach between governments at all levels can also promote the rapid implementation of solar projects, especially in utility-scale projects. However, the government still needs to pay attention to broad consultation to prevent the emergence of authoritarian or biased policies.

In addition, enterprises can work with local and national governments to develop public-private partnerships. This does not lead to the emergence or increase of "state-owned enterprises" in the future. Nevertheless, enterprises can advocate for clearer and faster regulations to meet business needs through closer public-private cooperation, especially regarding grid integration and large-scale solar projects.

5.3.3 Framework Conditions

The financial environment for solar projects is a key factor in the industry's growth. Fiscal incentives, such as R&D grants and tax breaks for solar projects, should be expanded to cover a wider range of solar technologies and businesses, especially those focused on grid integration and energy storage.

In addition, in the early stages of China's solar development, financial investment mainly came from state-owned banks, such as the Industrial and Commercial Bank of China. Since non-public banks are less likely to lend when profits or returns are unpredictable, like state-owned banks, Chinese companies can obtain investment and loans faster or more conveniently than Dutch SMEs and start-ups, thus completing the development from niche markets to mainstream markets. Therefore, the Dutch government can support and assist the solar industry to a certain extent through alternative financing mechanisms, including green bonds (Ministry of Finance, n.d.). In the longer term, the Dutch government can create state-owned banks, similar to China. In a banking system backed by national credibility, start-ups and small and medium-sized enterprises can obtain stronger economic support and complete the development and transformation from niche markets to mainstream markets. By diversifying funding sources, companies can enhance their financial resilience and growth capabilities.

5.3.4 Value chain

Policymakers could consider building a comprehensive domestic solar value chain, from research and development to production and installation of solar technology. Fiscal incentives could be extended to companies involved in all stages of the value chain, from resource extraction to installation. This investment would increase local manufacturing capacity and reduce dependence on imports from foreign markets while improving the country's strategic energy security. Dutch companies have some options. The Netherlands can continue to focus on its strengths in high-value solar technologies, such as advanced solar panels and innovative energy storage solutions. As the solar market is currently dominated by China, focusing on innovation and high-tech areas where the Netherlands excels can enable it to maintain a relatively advantageous position in the global solar value chain. This situation can be seen from the fact that ASML focuses on high-tech chip technology, which enables it to maintain its leading position in the global chip value chain. However, vertical integration of the entire solar industry is still a wise move in the long run. The Netherlands has the full EU market access, and there are many small and medium-sized enterprises engaged in manufacturing solar-related materials and solar panels, which provides certain resources for the downstream of the industrial chain. For large Dutch companies, vertical integration in the long term, while the government conducts government-enterprise cooperation to support related corporate mergers and acquisitions, is still greatly beneficial to developing the Dutch solar industry.

5.3.5 International cooperation

Finally, international cooperation is equally important for the continued growth and competitiveness of the Dutch solar industry. China is characterized by technology transfer (either from other countries to China in the early stage or from China to other countries in the later stage) and the use of existing projects, such as the Belt and Road Initiative, to promote the construction of solar energy markets and technologies. Therefore, Dutch policymakers can directly learn from China and Chinese companies about their technology and maintain a long-term partnership. Cooperation with China can promote technology transfer, knowledge sharing and market expansion opportunities for Dutch companies more quickly, especially by leveraging the Netherlands' advantages in niche markets and innovation. In addition, it is also important for the long-term development of Dutch solar energy to gradually open up developing markets in Africa and Latin America using existing partnerships, which is learning from China's Belt and Road approach, and expanding the Dutch solar market through existing projects, such as the Sustainable Energy for All mentioned above, and possible future projects.

6. Conclusion

This study explores how the NIS of China and the Netherlands affect solar energy development between 2013 and 2023. The comparative analysis examines the role of seven NIS aspects, including governance structures, industrial systems, and cooperation frameworks, in shaping solar innovation in the two countries. An analysis of policy documents highlights the differences in state involvement, ownership patterns, and innovation structures that shape solar development in the two countries.

China’s solar development has been marked by a highly centralized, state-driven approach, with the government playing a major role in setting national targets and providing financial support. This strong state involvement has enabled rapid resource mobilization, large-scale deployment, and full control over the solar value chain. State-owned enterprises dominated the industry early stages development, enabling China to excel in solar panel manufacturing and effectively meet domestic and global demand. Non-state-owned enterprises then rapidly scaled up production and reduced costs, consolidating China’s position as a global solar leader.

In contrast, the Netherlands has taken a more market-oriented approach to solar, focusing on innovation at the technological level. The Netherlands has made significant progress in improving solar panel efficiency and integrating solar technology with smart grids. Its decentralized system has fostered innovation and technological breakthroughs, with government subsidies and large renewable energy budget, making the Netherlands a global leader in per capita solar power generation. However, the Netherlands is heavily dependent on imports for solar energy, especially from China, and scaling up solar production across the value chain. This dependence limits the Netherlands’ ability to build a self-sufficient solar industry. While the market-oriented system has driven innovation, the lack of comprehensive domestic production capabilities remains a weakness in achieving energy independence.

The Netherlands can learn important policy lessons from China’s experience, particularly the importance of an integrated value chain in the solar industry. Vertically integrating domestic solar production and building stronger public-private partnerships could help the Netherlands achieve greater autonomy in solar and expand global markets. The Netherlands can learn from the Chinese model, where more central guidance is beneficial. Clearer, long-term policies, on the one hand, can help drive investment in solar energy while streamlining the licensing process, on the other hand, will greatly accelerate the progress of projects. In addition, more targeted government support, such as establishing a state-owned bank to provide more complete financial support, especially in expanding commercial deployment, can enhance the competitiveness of the Netherlands. The Netherlands can benefit from a hybrid approach by combining its market-oriented advantages with China's centralized policy coordination and maintaining its innovation advantage.

This study contributes to the theory of national innovation systems by extending the framework to include value chains and international cooperation, particularly in relevant in the solar sector. China's state-led model successfully integrates the value chain from production to consumption, while the Netherlands faces challenges due to limited value chain integration and fragmented policies. However, the limitations of this study are that it focuses only on solar energy, excluding integration with other renewable energy technologies and other system models, Future research could explore comparative studies of NIS influences in different energy sectors and deeper into the role of state intervention in scaling up the renewable energy industry.

In summary, the paper shows that different NIS frameworks have different advantages and challenges in solar energy development. By learning from each other's strengths, countries such as the Netherlands can adjust their policies to build a more resilient and competitive solar industry.

7. Acknowledgement

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Lastly, I wish to acknowledge my family for their unwavering encouragement and support during my studies abroad. Their belief in me has always been a source of strength throughout this journey.

Appendix

1. Timetable for research process

Activity	Start Date	End Date	Duration/weeks
Proposal	8 Jan 2024	8 Mar 2024	8
Write thesis	11 Mar 2024	16 Aug 2024	23
Publications information collection	11 Mar 2024	3 May 2024	8
Interviews	11 Mar 2024	7 Jun 2024	13
Analyze collected data	22 Apr 2024	7 Jun 2024	7
Discussion and detailed analyze	3 Jun 2024	26 Jul 2024	8
Get preliminary conclusions	29 Jul 2024	9 Aug 2024	2
Researching	12 Aug 2024	18 Oct 2024	11
Final thesis submission	21 Oct 2024	27 Oct 2024	1
Final presentation	28 Oct 2024	1 Nov 2024	1

2. Invitation email for the interview

Title: Appreciate Your Advice - Invitation to an Interview_Qiaochu Chen_Utrecht University

Dear Mr./Ms. XXX,

My name is Qiaochu Chen. I'm a master's student majoring in innovation science at Utrecht University. My master's thesis topic is Stimulating solar energy in the Netherlands. This proposal investigates how the national innovation systems of China and the Netherlands influenced solar energy development between 2013 and 2023, aiming to derive policy recommendations by comparing and analyzing the solar energy strategies of the two countries. I will conduct interviews to get more specialized expertise on the topic. Thus, I'm reaching out to you, and I would appreciate it if you could spend a bit of your time to help me learn more about solar-related topics such as sustainability and policies, because you are specialized XXX.

In the interview you can share your views on a topic that you are passionate about. I also aim to create policy recommendations based on the thesis, which I will send to you when the project is done.

I believe you are busy, but thirty minutes is good enough for me. If you can communicate with me in the next XXX weeks, could we have this chat in person or, depending on your convenience, using the most convenient online method, such as Teams?

Thank you very much for your kind help, and I am looking forward to hearing from you soon!

Yours sincerely,
Qiaochu CHEN

3. Initial interview person list

If one company has one more contact person, I chose at most two people in one company as the interviewee.

Type	Company name	Contact person	Position or Title
Manufacturer	Elsun	Jakob Jan Dijksterhuis	Productie- en verkoopmanager
Manufacturer	Van Der Valk Solar Systems	Enrico Molegraaf Roderick Wubben Erik Janse	Project Specialist Project Manager Projectmanager
Manufacturer	ZigZagSolar	Wim van de Wall Frank Bartelen Archana Sakharwade Renu George	CEO / Scientist Sales Manager Expert Research & Development Research & Development
Manufacturer	Blubase	Albert Assen Remco W. Michael Dieterman Christel de Winter	Managing Director Inside Sales B2B Marketing & Communication Manager Demand en Supply Planner
Distributors, Manufacturers, OEM, Wholesalers	Autarco BV	Shiwankar Garg Christiaan Vroemen Lau van der Kaa	Product Manager Marketing Manager Demand Planner
Scholars and experts	Princeton University	Kyle Chan	Postdoctoral Research Associate
Scholars and experts	The Chinese University of Hong Kong, Shenzhen	Ping Huang	Associate Research Fellow
Scholars and experts	North China Electric Power University	Sufang Zhang	Professor

Scholars and experts	Technische Universiteit Eindhoven	Bram Verhees	
Scholars and experts	Technische Universiteit Eindhoven	Frank Veraart	Assistant professor
Scholars and experts	Universiteit Maastricht	Véronique Vasseur	Post-doctoral research fellow
Scholars and experts	University of Bremen	Mahmood H. Shubbak	Senior Researcher / Lecturer
Policymaker	Ministry of Economic Affairs and Climate Policy	Micky Adriaansens	Minister of Economic Affairs and Climate Policy
Policymaker	Ministry of Economic Affairs and Climate Policy	Rob Jetten	Minister for Climate and Energy Policy
Policymaker	Ministry of Economic Affairs and Climate Policy	Hans Vijlbrief	State Secretary for the Extractive Industries

4. Interview questions

Theory	Category	Concepts	For Dutch energy company questions
	Overall question		What is your company's recent overall sustainable development strategy, especially in the area of solar energy?
(National) innovation system	Market	Demand	How would you describe the current demand for solar energy in the Netherlands, and how has this demand influenced the development of solar energy within your firm?
		Organization	To what extent does the market organization in the Netherlands, such as the unbundling of vertical integration, influence the development of solar energy in your firm?
		Consumer Behavior	How do consumer awareness and behavior in the Netherlands impact the adoption and growth of solar energy solutions offered by your firm?

		Intermediate Behavior	How do relevant supplier awareness and behavior impact the adoption and growth of solar solutions your company offers? Do you think the current Dutch solar market is competitive or not? Any reasons do you think is the cause? Any solutions, will the government management help?
		Overall questions	What challenges and opportunities do you foresee in the solar industries in the Netherlands for your company according to the questions above, such as market demand, policies, incentives, or supplies?
	Education and Research	Education System	To what extent does the Dutch education system influence your firm's solar energy development? Are specific educational programs or institutions significantly contributing to your workforce?
		R&D	How has the research landscape in the Netherlands, including collaborations with academic institutions and research funding, influenced your firm's solar energy development?
	Political System	Government Policies	To what extent do current government policies, including subsidies and regulations, influence the development of solar energy in your firm? Are there specific policies that have had a major impact?
		Subsidies and Finance	How significant is the role of government subsidies and financial incentives in supporting your firm's solar energy projects? Can you provide examples of how these have influenced your operations?
		Regulatory Environment	How does the regulatory environment in the Netherlands impact your firm's ability to innovate and expand in the solar energy sector? What do you think of the current regulatory environment (tight or loose)?
	Infrastructure and Industry	Supply Chain	What are the key challenges and opportunities related to the solar energy supply chain in the Netherlands, and how do they affect your firm's development efforts? For example, What is the situation like for the Dutch solar industry (production of solar panels) or the adoption of solar panels in the Netherlands?
		Production Capacity	To what extent does the existing industrial infrastructure in the Netherlands support or hinder your firm's ability to scale up solar energy production?
		Ownership	At present, China's solar industry is developing rapidly, and one important reason is the nationalization first and then privatization later in the industry. How do you view the role of state-owned enterprises in the clean energy sector, especially solar energy?
		International Policies	What policy lessons from the Chinese solar energy industry (if any) do you believe could be effectively implemented in the Netherlands? How might these lessons influence your firm's strategy?

		Technology Transfer	How does the availability and transfer of technology within the Netherlands impact the development of solar energy in your firm?
		Partnership	Could you elaborate on any collaborations or partnerships your company has engaged in to foster research and development in solar energy?
	Overall Strategy and Future Outlook	Ownership	Around 1980, most Dutch energy companies were mainly owned by the government, and later, they were slowly converted into privately owned companies. Now that we are facing new global sustainable development challenges, do you think it is feasible to nationalize solar energy again?
Linkage to other theories and strategies		Strategic Evolution	How has your firm's strategy evolved in response to the Netherlands' national innovation system and its commitment to clean energy targets such as SDG 7?
		Future Prospects 1	Looking ahead, what are your firm's long-term goals and strategies for contributing to the solar energy sector both domestically and internationally?
		Future Prospects 2	Does your company have any ideas about expanding into the international market and cooperating with Chinese companies? Such as through greenfield investments or mergers and acquisitions, to build a complete supply chain in partner countries and increase production capacity? Or do you think this will be a good idea in the future?
			Any other question you would like to ask?

Theory	**Category**	**Concepts**	**For policy makers questions**
(National) innovation system	Market	Demand	How does the Ministry assess the current demand for solar energy in the Netherlands, and what measures are being taken to stimulate this demand further?
		Organization	How has the market organization (except Ministry and other organization from the governmeny) in the Netherlands, such as the unbundling of vertical integration, influenced the development and competitiveness of the solar energy sector?
		Consumer Behavior	What initiatives are in place to increase consumer awareness and influence behavior towards adopting solar energy solutions? Are there any relevant initiatives or regulations in the past or in the future that may promote consumer awareness of consuming solar products?
		Intermediate Behavior	Are there any past or future initiatives or regulations that may promote awareness among manufacturers or other businesses selling or consuming solar products?

	Overall questions	What challenges and opportunities do you foresee in the solar industries in the Netherlands from the government perspective according to the questions above, such as market demand, policies, incentives, or supplies?
Education and Research	Education System	To what extent does the Dutch education system influence your firm's solar energy development? Are specific educational programs or institutions (or financial support) significantly contributing to your workforce?
	R&D	What is the role of government funding and support in fostering research and development in solar energy? Can you highlight any successful collaborations between the government, academic institutions, and the private sector?
Political System	Government Policies	What are the key policies implemented by the Ministry in the recent ten years to support the development of solar energy in the Netherlands? How effective have these policies been in achieving their goals?
	Subsidies and Finance	Has the government provided any relevant financial subsidies or financial incentive programs in the past decade? How significant are government subsidies and financial incentives in promoting solar energy projects? Are there any plans to adjust these subsidies to better meet industry needs?
	Regulatory Environment	How does the regulatory environment in the Netherlands facilitate or hinder innovation and expansion in the solar energy sector? Are there any upcoming regulatory changes that the industry should be aware of? What do you think of the current regulatory environment (tight or loose)?
	Production Capacity	How is the Ministry supporting the expansion of production capacity for solar energy in the Netherlands? Are there any specific initiatives aimed at boosting local manufacturing capabilities?
	Ownership	At present, China's solar industry is developing rapidly, and one important reason is the nationalization first and then privatization later in the industry. How do you view the role of state-owned enterprises in the clean energy sector, especially solar energy?
	International Policies	what are strengths and weaknesses of the Dutch policy towards solar energy? What policy lessons in the solar energy industry (if any) from other countries, such as China, could be effectively implemented in the Netherlands?

		Technology Transfer	How does the Ministry facilitate the transfer of technology within the solar energy sector (if any)? Are there programs to promote the adoption of innovative technologies developed domestically or internationally?
		Partnership	Could you elaborate on any collaborations or partnerships the government or ministry has engaged in to foster research and development in solar energy? How does the Ministry encourage collaboration and networking within the solar energy industry? Are there specific frameworks or platforms to foster partnerships between different stakeholders?
	Overall Strategy and Future Outlook	Ownership	Around 1980, most Dutch energy companies were mainly owned by the government, and later, they were slowly converted into privately owned companies. Now that we are facing new global sustainable development challenges, do you think it is feasible to nationalize solar energy again?
Linkage to other theories and strategies		Strategic Evolution	How has the Ministry's strategy for promoting solar energy evolved in response to the Netherlands' commitment to clean energy targets such as SDG 7?
		Future Prospects	What are the Ministry's long-term goals and strategies for supporting the solar energy sector in the Netherlands? How do you envision the future of solar energy in the national energy mix?
			Any other question you would like to ask?

Category	Concepts	For researchers questions
Global Perspective	Global Contributions	From a global perspective, how do China and the Netherlands' sustainable development policies contribute to the broader solar energy landscape?
	Advantages and Challenges	China has huge advantages in industrial chain and exports, while the Netherlands excels in technology and resources. How do these respective strengths influence their global solar energy market positions?

Nationalization and Policy	Potential Challenges of Nationalization	What potential challenges might arise if the Dutch solar energy industries were nationalized? Please refer to your article XXX for context.
	Potential Challenges of Nationalization	What adjustments or innovations do you think the Netherlands might need to make to balance long-term stability, sustainability, and innovation in its solar energy sector?
	Innovation	Do you believe that companies promoting government policy innovation is an effective method for advancing the solar energy sector in the Netherlands?
Comparative Analysis	Differences in Energy Markets	What are the key differences between the energy markets in China and the Netherlands? How might these differences affect the potential for nationalization in the Netherlands?
	Nationalization	Are there nationalization methods used in China that you believe could be adapted to the Dutch context, or are they unique to China?
	Global Market Trends	What trends in the global solar energy market do you think might influence the outcome of nationalization in the Dutch context?
	International Industrial Chain	Considering China has formed a complete industrial chain and holds a significant advantage in global exports, how might this influence the Dutch solar energy sector's strategic decisions?
	International Cooperation	How can the Netherlands use international cooperation to strengthen its solar energy landscape?
	Lessons from China	Does China's solar energy policy or development situation have any lessons that could benefit the Netherlands?

Lessons and Future Directions	Sustainable Goals	How can policymakers ensure that nationalization is consistent with long-term sustainable development goals and promotes innovation while minimizing biases and excessive opposition?

5. Interview transcripts

5.1 Interview transcript with Kyle Chan

Q means questions raised by Qiaochu Chen
A means response answered by Kyle Chan

Q: Thank you very much. And yeah, it's really exciting to know all of the information. So let's start. I'll start recording. Okay, thank you for participate in this interview. And then we have a very quick interview questions. Okay, so about the 1st question is related to the global perspective. How do China contribute to sustainable and policies, just focusing on the solar to my topic, or for all the different sectors, for different aspects, what do you think China contribute to sustainable development to the whole world?

A: Yeah. So this is a good question to start. So one of the largest contributions: They're trying to make to global development is in producing so-called green goods. Things like solar panels. Wind turbines. And more recently, electric vehicles and batteries. These are all going to be very important. All over the world in terms of moving away from high emissions energy in production to a more sustainable production. So even if, you know, even if we're talking about the develop of Europe and the US. For example. but also, if we're talking about developing countries in the global south. You can see that they can all benefit from, from these, you know, green goods. And. Not only is China producing a lot of these at low cost, but they are also producing relatively high quality. So these are very useful again, for a whole range of applications.

A: And that's one big area. And the other big area is within China itself. Because China has such a large share of global manufacturing and production. Also, and also has a a rising middle class. The amount of its share of global emissions has gone. Significantly as a as China itself has developed. And it is now. I believe the largest sorts of car missions. So within China, though there's a lot of efforts to reduce China's own carbon footprint. And that includes, of course, using some of these same goods that China is exporting to the rest of the world, to build out China's own, you know, renewable energy.   But also other policies domestically to try to promote. For example, more sustainable consumption patterns. Even very sort of narrow policies, like about plastic waste can have a large impact. Especially given China's population size and China's economic scale. So. I would probably start with pointing out these 2 main areas where Chinese you know, critical to sort of global so inspiring points. For adding these questions.

Q: Yeah. And I remember that when I doing the research, I know that for the solar panels, but only for Netherlands from China, and there are more than 60% solar panels they import from the China. And then after that, they only keep only 40% of those 60%, and then another 60% they sell to other countries like to Germany, to Belgium, something. It's really, really interesting to know that support. And also in my research, I noticed that, okay. For the Netherlands. they produce only a little bit solar panels in their country they are important, but they have their advantages, for the neighborhood is, they have budget policies. They have better advantages in the marketing system, instead of producing systems. This is what I found in my, in my research.

A: Yeah, yeah, I think that's right. Also I wrote a piece earlier, too, about how countries like the Netherlands, that have been successful in quickly deploying solar. They often are able to do it because they have access to relatively affordable Chinese solar panels imports. You see it? Not just the Netherlands, but Australia is another example. There are other countries in Europe. 16:40:52 You know that that are examples of this. So you don't have to necessarily manufacture all of it on your own. You can take advantage of the lower cost production and relatively high-quality production in China.

Q: Yeah. Of course, the word is the big factory. Okay, so about the next questions about the advantages and challenges. So for this topic, I will ask. So China has a huge advantages in the industry value chains, and also such as the exports, to export solar PVs. So what potential or what's challenges during this system for the for those policies facing for China.

A: Yeah, so 1st is the technology which is, can be very difficult to develop. I think. If you look at, say, solar panels. There are a number of different research institutes. And then fund, and then investment from the private sector as well. That has gone into research and development. For solar technology you know, China began looking at solar technology very early. In the 60 s. Even maybe 50s. ith looking at. Also, satellite technology. So that was the early time. But even then it's very difficult. And then in the 2000s trying to face challenges with having enough skilled engineers. In who were trained as PhDs in in solo technology. And so there was actually many Chinese students studying in Germany, Australia, who came back and helped develop the Chinese solar industry. So still to this day you see a lot of investment in research. And you have Chinese solar companies like Jenko who are developing cutting edge solar. So the new generations, looking ahead you know, like tandem, solar cells. Those have the potential to increase efficiency which is critical, for the future development of solar around the world. And so you do see a lot of Chinese companies at their cutting edge here.

A: Another area that has been challenging that I think Chinese Solar Firms seem to do very well at is scaling up production. Especially when it comes to buying and working with very expensive capital goods, like a high end, solar manufacturing equipment. So a lot of especially solar cells and wait for production is highly automated, and Polycom, as well means that you need to make a very large investment. And in acquiring, acquiring the right machinery and equipment and now increasingly that machinery is built by other Chinese companies. So so all of that will help you reach a degree of scale. And with scale, you get efficiencies in production. And so part of the low cost of Chinese solar panels is because of this large investment in in in the scale. In addition to, of course, support from from the government.

Q: So. Do you think the you you mentioned that those high talents in China. Do you think it's still a problem after so many, so many years? Because you mentioned. I think it's around 2,000 or something you mentioned there's a lot of people going abroad study abroad, and they are not come back. And then those talents were lost. So do you think it's still a problem? This problem still happens?

A: Alright, so I think the A lot of the talent now is within China and educated within China. So again, a lot of universities and research institutions within China are now some of the leading research centers for solar technology. At the same time, of course, China continues to benefit from exchanges with other countries. To the extent that that's still attractive for the students. You know, it's getting tougher in places like the US. For example. But you see that where in the 2000 s. It was very hard to find Chinese PhDs within China with the right skill set. Now I think that probably the majority of technical expertise in this. In this field, or a large, a large portion is is probably in China now.

Q: Okay, yeah. It's really important for the research and also education systems. In China. This is a really important perspective. Yeah. And also, I have another question related to the national. As you can see, there is a still the so ease, and those nationalized company still controls the key sectors and the key resources in China, such as the energy and even the the oils the gasoline something else. So compared to the other countries like in Europe, Americans. There's a lot of countries are focusing on the market. Do you think there are adjustments of innovation for China to change in the long term. To track, to transfer from the national system to a market domain, systems.

A: So in in general. I don't see China becoming like exactly like the market systems in the west. Because I think there will always be a role in the training system for the state-owned enterprises. And also for the State intervention in certain industries like energy. So at the same time of course there are some practices that have spread. Like the use of competition has definitely grown a lot more, you know since obviously the beginning of reform. But even more recently you have some interesting competition across, say, the wind sector. In China you have many firms producing wind turbines, including some of them, are state owned, and some of them are private. And they compete actively for contracts to build wind projects on onshore, especially offshore wind. So you see that that's one area where China is trying to use some of the advantages of a market system like competition. But still keep some control over the direction of some of these areas.

A: Another interesting thing related to this is the you know you mentioned the oil and gas and sort of the traditional energy sector in China, and a lot of that is dominated by state owned enterprises, especially. And it's interesting, because there's a trend for those oil and gas companies in China. And for some of the oil and gas companies outside of China in in the west. to both, to start to diversify and enter into the renewable sector. So you know whether you're talking about Sino in China. Or you're talking about BP, you know in the west. They are also looking at the renewal sector. The difference is that in China, obviously the pressure comes more directly from the government. So you have a lot more effort from the Government to to push some of these companies under its control, to invest in wind for example. And then I, yeah, I would highlight this interesting dynamic where maybe you know, China still always worries about energy security. And so the energy sector is very state controlled in many ways. But also that allows China to shift and push its own companies to invest more heavily in renewable energy. In a way that's different than in in the West. There's some maybe grassroots pressure by civil society groups and consumer advocacy groups to you know. Shift to low carbon, maybe reduce investment in oil and gas companies. But you see that China is more government directed, that's that's my understanding.

Q: Yeah, as I know that it's like in the 2,010 or something that at that time that's so is the government control as they. They provide the directions, and also they provide some the basic functions to those so and then those. So you have a different subsidies, could do their what they're they're like and find advantages in the competitive marketing markets. How do you think, China, in energy, landscape, and the energy policies not only related to the solar energies, but for all the energies, and more and maybe broader sectors.

A: Well. Definitely in terms of in terms of deploying and selling their renewable energy goods to the rest of the world. You have a lot of cooperation between international companies and governments and Chinese firms that are providing these things. And you also have some technical cooperation, as well. Even trying to organize standards. For example. For Energy, industry standards at the international level is another example of this. So but is your question more about within China itself or globally.

Q: Only China is a good enough. But if you have some more international or globally thinkings, yeah, you can. You can also talk about.

A: Yeah. I mean I think one thing to note, though, is that in the past. I think China was more open to accepting foreign cooperation and investment domestically. So in the renewable energy area, because China was trying to catch up more in this. In the technology. So in the past. You have like a German Government helping to find rule electrification and rule solar programs. You have I think maybe even the Netherlands was also helping China with this sort of technical cooperation. But now because the center of gravity has shifted now more to China and China's not catching up so much in these areas anymore. But maybe even leading some of them. That now you have maybe less interest, at least in trying to work with foreign companies acquire new technology. And now actually with electric vehicles, for example, the foreign auto companies are trying to learn from some of the Chinese electric vehicle companies. So. You see partnerships between maybe some Chinese startups even Volkswagen or the big European carmakers. Or say Ford and GM. In the US. Maybe they wanna buy batteries from CATL. So you see that the partnerships are working almost in the opposite direction than in the past, where now the foreign companies are trying to take advantage of some of the Chinese firms and their industry leadership, especially when it comes to both technology but also again, scaling up production. So. Batteries, for example, is one area, where the scale of Chinese battery production is much greater than what exists in the US or Europe. And so US and European carmakers want to take advantage of that, and that's driving new areas of of cooperation.

Q: Yeah, because I think for the for the EVs and even for the batteries in China, and that's if you have an idea, you can directly put the idea into the productions, and you can sell it. I think that's why China succeeds in the electric vehicles, but for I think, in reasoning. In Europe, especially in the Netherlands. They do have a lot of ideas. They do have a lot of, but because they are lacking of the production systems, or even they have some different advantages in their value chain. So sometimes it's hard for them to directly produce a car during these sections. And also, yeah, this is hard for them to achieve this, to transfer the idea into the productions. So one last question, let's go on quickly. Yeah, I know you are leaving very soon. So what trends in the global energy markets maybe related to solar energy markets or maybe not, do you think might influence the outcome of the nationalizations or the market. Compared to the Chinese solar policies or the ultimate situation. Or maybe have any lessons to learn for the Netherlands to study from the China energy policies.

A: Yeah. So in general the biggest trend is that solar deployment is continuing to grow significantly. Not just in China, China is the biggest by far, driver of solar growth. But all across the world in the US. There is a large-scale investment program called Inflation Reduction Act to incentivize greater renewable energy, including solar. You have different policies across Europe countries. Like India are deploying solar at very high rates and southeast Asia, as well. And even regions of the world that are lower income, like parts of suberect Africa. And parts in the Middle East. They have a chance to develop with renewable energy and not have to to switch later. So that's one big trend. The demand for solar is continuing to grow. But the other trend is the international trade situation right now, which is changing a lot. So there's greater pressure to produce domestically. So, especially for the US. And for the Netherlands. I think. I'm not sure the what the lessons could be for the Netherlands, because, to me that.

Q: Maybe not. Maybe not only focusing on the Netherland, for those market domain countries like the West and the maybe the Europe, the US. Or some other countries.

A: Yeah. Yeah. Okay. So in general, for the sort of market oriented economies. They have to deal with the problem of market volatility and long-term investment. And these are areas where it helps to have industrial policy that can offer, for example, patient capital in long term, investment. And also subsidize demand when you have still a large amount of especially in the US cheap oil and gas. So they reaching economic equivalence for the renewable energy sector is still is still a problem. And this also applies for the auto industry. Where say electric vehicles in the US are still much more expensive actually, than gas powered vehicles. So the problem is in these market orientated economies that many of the market forces are still pushing against the renewable energy adoption. And the question is whether they can put in the right government policies to incentivize the market actors to invest in scale and technology. So eventually they will be cost competitive with the non-renewable energy sources.

Q: Maybe we might give some examples for you mentioned that those kind, those companies who produce the sustainable products or sustainable vehicles and traditional energy companies and new companies that produce a ceremony, and any cases Traditional counties to prevent for the new company.

A: Oh, oh, I see! You mean like lobbying from the traditional energy companies.

Q: Yeah, yeah, yeah.

A: Yeah, yeah, this is a big problem. Yeah, yeah, so and this is a political issue. In market economies. Because, yeah, there's a for example, in the US. There's still a lot of pressure to develop, continue to develop oil and gas industry. And to keep the jobs that are tied to those industries. So there's a lot of pressure for the politicians to retain this and continue to support these sectors. Is that what you're talking about?

Q: Yes, yes. This's a good good reasons and good points. And yeah, and I think this is all about my questions. Maybe, do you have any questions to ask for me. Ask me.

A: I don't have any questions.

Q: Okay, so that is all for the interviews. And really thank you for participate for this interview, since I know it's a really hard to find people's waiting to know this topics, especially some people. That's okay. I'm not familiar with this topic. So sorry about that. Or maybe my, my research is out of time. Maybe you can find somebody else to help you. So yeah. I'm always facing this problem for the interviews.

A: Yeah, I understand. Well, I'm I'm I'm glad to help. I hope you wish you good luck with your project.

Q: Okay. And finally, and if you are still interested when I finish all my master cities, I can send it to you.

A: Yes, thank you. That that'll be. That'll be great. I would love to read it.

Q: Okay, I'll let you keep in touch. And yeah, have a good day. Thank you very much.

A: Thank you. You too. Bye, bye.

Q: Bye.

Reference

Bian, L., Dikau, S., Miller, H., Pierfederici, R., Stern, N., & Ward, B. (2024). China's Role in Accelerating the Global Energy Transition Through Green Supply Chains and Trade. London School of Economics and Political Science, Grantham Research Institute on Climate Change and the Environment, and Energy Foundation China, Policy Insight.

Binz, C., Gosens, J., Hansen, T., & Hansen, U. E. (2017). Toward technology-sensitive catching-up policies: insights from renewable energy in China. World Development, 96, 418-437.

Binz, C., & Truffer, B. (2017). Global Innovation Systems—A conceptual framework for innovation dynamics in transnational contexts. *Research policy*, *46*(7), 1284-1298.

Bickenbach, F., Dohse, D., Langhammer, R. J., & Liu, W. H. (2024). EU Concerns About Chinese Subsidies: What the Evidence Suggests. Intereconomics, 59(4), 214-221.

Chadly, A., Moawad, K., Salah, K., Omar, M., & Mayyas, A. (2024). State of global solar energy market: Overview, China's role, Challenges, and Opportunities. Sustainable Horizons, 11, 100108.

Chung, S. (2002). Building a national innovation system through regional innovation systems. Technovation, 22(8), 485-491.

Fagerberg, J., Lundvall, B. Å., & Srholec, M. (2018). Global value chains, national innovation systems and economic development. The European Journal of Development Research, 30, 533-556.

Franco, M. A., & Groesser, S. N. (2021). A systematic literature review of the solar photovoltaic value chain for a circular economy. Sustainability, 13(17), 9615.

Hekkert, M. P., Suurs, R. A., Negro, S. O., Kuhlmann, S., & Smits, R. E. (2007). Functions of innovation systems: A new approach for analysing technological change. Technological forecasting and social change, 74(4), 413-432.

Hsieh, C. T., & Song, Z. M. (2015). Grasp the large, let go of the small: The transformation of the state sector in China (No. w21006). National Bureau of Economic Research.

Huang, P., Negro, S. O., Hekkert, M. P., & Bi, K. (2016). How China became a leader in solar PV: An innovation system analysis. Renewable and Sustainable Energy Reviews, 64, 777-789.

Jackson, M. M., Lewis, J. I., & Zhang, X. (2021). A green expansion: China's role in the global deployment and transfer of solar photovoltaic technology. Energy for Sustainable

Development, 60, 90-101.

Jäger-Waldau, A., Adinolfi, G., Batlle, A., Braun, M., Bucher, C., Detollenaere, A., ... & Ueda, Y. (2020, June). Self-consumption of electricity produced with photovoltaic systems in apartment buildings-Update of the situation in various IEA PVPS countries. In 2020 47th IEEE Photovoltaic Specialists Conference (PVSC) (pp. 0938-0950). IEEE.

Kuhlmann, S., & Arnold, E. (2001). RCN in the Norwegian research and innovation system. Fraunhofer.

Lin, K. J., Lu, X., Zhang, J., & Zheng, Y. (2020). State-owned enterprises in China: A review of 40 years of research and practice. China Journal of accounting research, 13(1), 31-55.

Lundvall, B. A., Dosi, G., & Freeman, C. (1988). Innovation as an interactive process: from user-producer interaction to the national system of innovation. 1988, 349, 369.

Lundvall, B. Å. (2007). National innovation systems—analytical concept and development tool. *Industry and innovation*, *14*(1), 95-119.

Metcalfe, J. S. (1994). Evolutionary economics and technology policy. The economic journal, 104(425), 931-944.

Muehlfeld, K., & Wang, M. (2022). Intellectual Property Rights in China—A Literature Review on the Public's Perspective. Frontiers in Sociology, 7, 793165.

Pablo-Romero, M. D. P. (2013). Solar energy: Incentives to promote PV in EU27. AIMS Energy, 1(1), 28-47.

Patel, P. (1994). The nature and economic importance of national innovation systems. STI review, 14, 9-32.

Peidong, Z., Yanli, Y., Jin, S., Yonghong, Z., Lisheng, W., & Xinrong, L. (2018). Opportunities and challenges for renewable energy policy in China. Renewable Energy, Vol4_486-Vol4_503.

Pham, Q. T. (2010). Measuring the ICT maturity of SMEs. *Journal of Knowledge Management Practice*.

Piotrowski, S., & Liao, Y. (2012). The usability of government information: The necessary link between transparency and participation. The state of citizen participation in America, 163-194.

Quitzow, R., Huenteler, J., & Asmussen, H. (2017). Development trajectories in China's wind and solar energy industries: How technology-related differences shape the dynamics of industry localization and catching up. Journal of Cleaner production, 158, 122-133.

Ren Ping. (2022). The energy sector must be in our own hands - On promoting the high-quality development of China's energy in the new era. People's Daily, 01-07.

Shubbak, M. H. (2019). The technological system of production and innovation: The case of photovoltaic technology in China. Research Policy, 48(4), 993-1015.

van Blijswijk, M. J., & de Vries, L. J. (2012). Evaluating congestion management in the Dutch electricity transmission grid. *Energy policy*, *51*, 916-926.

Vasseur, V., Kamp, L. M., & Negro, S. O. (2013). A comparative analysis of Photovoltaic Technological Innovation Systems including international dimensions: the cases of Japan and The Netherlands. Journal of cleaner production, 48, 200-210.

Verhees, B., Raven, R., Veraart, F., Smith, A., & Kern, F. (2013). The development of solar PV in The Netherlands: A case of survival in unfriendly contexts. Renewable and sustainable energy reviews, 19, 275-289.

Vroon, T., Teunissen, E., Drent, M., Negro, S. O., & van Sark, W. G. (2022). Escaping the niche market: An innovation system analysis of the Dutch building integrated photovoltaics (BIPV) sector. Renewable and Sustainable Energy Reviews, 155, 111912.

Wang, Q., Liu, M., & Zhang, B. (2022). Do state-owned enterprises really have better environmental performance in China? Environmental regulation and corporate environmental strategies. Resources, Conservation and Recycling, 185, 106500.

WBCSD. (2011). Collaboration, innovation, transformation: Ideas and inspiration to accelerate sustainable growth - A value chain approach, p.3 & 5, emphasis added (Accessed 19.05.23).

Xu, J., Yang, G., Wang, F., & Shu, K. (2022). A provincial renewable portfolio standards-based distribution strategy for both power plant and user: A case study from Guangdong, China. Energy Policy, 165, 112935.

Yap, X. S., Truffer, B., Li, D., & Heimeriks, G. (2022). Towards transformative leapfrogging. Environmental Innovation and Societal Transitions, 44, 226-244.

Zhang, F., & Gallagher, K. S. (2016). Innovation and technology transfer through global value chains: Evidence from China's PV industry. Energy policy, 94, 191-203.

Zhang, S., Andrews-Speed, P., & Ji, M. (2014). The erratic path of the low-carbon transition in China: Evolution of solar PV policy. Energy Policy, 67, 903-912.

Zou, C., Pan, S., & Z, Q. (2020). On the connotation, challenges and significance of China's "energy independence" strategy. PETROLEUM EXPLORATION AND DEVELOPMENT, 47(2).

Zou, H., Du, H., Ren, J., Sovacool, B. K., Zhang, Y., & Mao, G. (2017). Market dynamics, innovation, and transition in China's solar photovoltaic (PV) industry: A critical review. Renewable and Sustainable Energy Reviews, 69, 197-206.

Zhu, M., Qi, Y., & Hultman, N. (2022). Low-carbon energy transition from the commanding heights: How state-owned enterprises drive China’s wind power “miracle”. Energy Research & Social Science, 85, 102392.