Navigating the Political and the Economic Landscape of Responsible Practices in the Chinese Solar Photovoltaic Supply Chain

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Abstract :

Solar energy is an increasingly popular alternative to fossil fuels as it is considered a clean and inexpensive source of energy. The global economy's transition to more sustainable energy sources, such as solar energy, has resulted in China's dominance at all levels of the supply chain. Therefore, understanding the sustainability of the Chinese solar energy industry's supply chain becomes crucial. *How might Chinese dominance in the solar energy industry lead to sustainability issues in the PV manufacturing supply chain?* This study examines the political and economic aspects and their impact on the supply chain practices of Chinese solar energy companies using stakeholder theory, liberalism, and sustainable supply chain management theory as conceptual frameworks. Stakeholder theory emphasizes considering the interests of various stakeholders, including marginalized and vulnerable groups, in supply chain decision-making. Liberalism provides a lens to analyze how Chinese solar panel companies balance economic interests with social and environmental responsibility and its implications for international cooperation on climate change and promotion of liberal principles. Sustainable supply chain management theory focuses on integrating social, financial, and environmental sustainability considerations into supply chain operations. The analysis reveals that while China's Five-Year Plans promote sustainable practices in silicon wafer production and set ambitious targets for solar energy development, challenges remain, such as the industry's growing carbon footprint, resource depletion, and supply chain vulnerabilities. To address these concerns, diversifying the supply chain, encouraging other countries to invest in solar cell production, and exploring sustainable transport options, such as the Belt and Road Initiative's modern railway network, are recommended. This comprehensive approach aims to strike a balance between economic growth and environmental protection, promoting long-term sustainability in the solar cell industry.

Keywords: solar energy, supply chain, sustainability, China, Five-Year Plans, political, economic, stakeholder theory, liberalism, sustainable supply chain management, environment, climate change

Abbreviation & acronyms

AC - Alternating current (electricity)

BRI - Belt and Road Initiative (BRI),

C.C.P. - Chinese Communist Party

IEA - International Energy Agency

DC - Direct current (energy)

FYP(s) - Five-Year Plan(s)

P.R.C. - People's Republic of China

PV(s) - Photovoltaic(s)

SSCM - Sustainable Supply Chain Management

Summary

I. Introduction:

A. Background and context of the study

Introduction :

According to the International Energy Agency (IEA), the People's Republic of China (P.RC.) has invested more than $50 billion since 2011 in expanding its photovoltaic (PV) supply capacity, which is around ten times greater than Europe's investment (IEA, 2022, p. 7). This has resulted in the development of up to 300,000 jobs along the solar PV value chain, with China dominating the PV manufacturing sector with over 80% share in all phases of solar panel manufacture (Ibid.). The top 10 global suppliers of PV manufacturing equipment are all based in China, which accounts for more than twice as much of the world's PV demand as China does (Ibid.). China's efforts in the PV sector have led to a reduction in costs, which has had a significant impact on the global clean energy industry. However, the fact that China is at the center of the world's supply networks also poses potential issues that governments may have to address (Ibid.)

Fossil fuels are becoming scarcer and more volatile as the global economy relies increasingly on energy sources to generate electricity to drive economic growth and distribute wealth. (IEA, 2022b). In light of this scarcity, States are turning towards more sustainable and abundant energy sources, such as hydropower, wind power, and solar power (European Environment Agency, 2022). In recent years, technological advances have enabled the harnessing of solar energy on a large scale, and China has emerged as a leading producer of solar technology (Venditti, 2022). Furthermore, the Five-Year plans (FYPs) have played an important role to shape that. Indeed, the Ministry of Science and Technology of the People's Republic of China (P.R.C.) has been a strong advocate of solar PV (photovoltaics) research and development activities (Powell, 2022). Renewable energy was identified in the 10th five year plan (2000-05) as a key option for optimizing China's energy mix (Ibid.). The 11th five year plan (2006-10), which covered all aspects of the value-chain, allocated $6 million annually for solar PV research and development (Ibid.). This funding was increased to $75,000,000, 12 times more, in the 2012 five-year plans (2011-15). China's 13th 5-year plan (2016-20), which covers the period 2016-20, has set specific targets in terms of solar PV technology innovation (Ibid.). These include the commercialization of silicon

monocrystalline cells with a minimum efficiency of 23 percent and silicon multicrystalline cells with a minimum efficiency of 20 percent (Ibid.). This shows the government's commitment to the advancement of solar PV technology

Although, China's dominance in the production of solar photovoltaics (PVs) could pose a serious problem to the decarbonisation process of the global energy industry. Solar energy's dispersed nature led to expectations that it would decentralize production and consumption of energy and free the world of the geopolitical influence that geographical concentration of traditional forms of energy such as oil or gas brings (Bricout & al., 2022) For instance, the concentration of oil reserves in OPEC member countries has allowed them to exert significant geopolitical influence over global energy markets, while the dependence of European countries on Russian gas imports has given Russia leverage in international relations (Ibid.). However, this view is challenged by China's dominance of the solar PV supply chain and its control of minerals used in the production of solar modules (Oğuz, 2023 ; IEA, 2021). Diversifying the solar PV supply chains could reduce China's dependence, but it would increase the costs of decarbonising the energy sector. In response, large economies such as India and the United States are investing heavily to increase the capacity of their domestic solar PV module manufacturing (Ibid.). The Chinese solar industry's market share is expected to reach 90-95 percent when its expansion plans are complete (Ibid.). China's government support for solar PV research and development activities, as well as its assistance to businesses, along with factors on the supply side such a huge capital investment and strategic foresight have all contributed to this dominance (Ibid.). On the one hand, the concentration of solar PV manufacturing in China can be a major problem for decarbonising the global energy industry. On the other hand, diversification of supply chains may also increase the costs of decarbonisation.

Additionally, it could be necessary to take into account both safety and the amount of copper, silver and other metals required in production for clean energy (IEA, 2021). These elements are widely used in the production of solar panels and other clean energy technologies due to their unique properties, but their availability on earth is limited (Ibid.). Given the rising global demand for clean energy technologies, we may soon face a shortage of essential metals. Recent reports by the IEA (2021, 2022) indicate that supply of certain metals such as copper and silicon may not keep up with demand in the coming decades, potentially impeding progress towards a low-carbon economy. Non-conventionally handled

metals have the potential to be hazardous to both environment and human health (Nkuissi & al., 2020). Furthermore, improper extraction and processing of these metals could harm nearby ecosystems as well as people (Ibid). Thus, companies must adopt responsible sourcing practices and reduce the environmental and social impacts of their supply chains. When considering the amount of other metals required, it is essential to take into account the overall sustainability and resource efficiency of clean energy technologies (IEA, 2022). Solar panels/modules may require a substantial amount of metals for production, but they have an extended life and can generate clean energy over multiple years, potentially offsetting any resource use. Companies may have to consider the full life cycle impacts of their products and strive to minimize resource use and waste generation.

B. Statement of the problem

This study seeks to provide an in-depth examination of the supply chain of the PV in the Chinese solar energy industry, from raw material procurement through final product distribution. When planning the supply chain for solar energy products, it is important to take into account all stages and components involved in their production and distribution. This could include sourcing raw materials, manufacturing and distribution (Hayes, 2022). For example, the procurement of raw materials like silicon and aluminum, production of solar panels and other equipment, distribution and installation at customers' sites, maintenance and repair during their lifetimes are all integral elements within this value chain (Solar Energy Technologies Office, 2022; Walker, 2012). As a matter of fact, Chinese solar energy companies typically collaborate and partner with other businesses, both domestically and abroad, in addition to cultivating relationships with suppliers, customers, and regulatory organizations. Factors such as tariffs and regulatory requirements associated with international trade can negatively impact an industry's competitiveness on the global market. Solar energy companies may address these challenges with strategies like automating their manufacturing process, instituting quality control measures, investing in research and development, as well as prioritizing sustainability. Furthermore, regulatory issues and logistical difficulties could arise during the distribution of solar.

Solar energy is an increasingly popular alternative to fossil fuels due to its lower greenhouse gas emissions. Indeed, it is considered to be a very clean and inexpensive source of energy (DW Planet A, 2021). However, the production of solar panels itself contributes to

emissions, with chemical substances such as silicon tetrachloride and hydrofluoric acid causing negative effects on the environment and human health (DW Planet A, 2021; Thomas, 2019). Moreover, hazardous materials, including lead, cadmium, and arsenic, may end up in solar panels (Thomas, 2019). The industry faces growing pressure to find safer alternatives, and solar panel waste is expected to increase in the coming years (DW Planet A, 2021). While recycling is difficult and expensive, efforts are underway to improve methods and increase the percentage of panels that are recycled. Despite these challenges, solar energy remains an essential component in the fight against climate change. Continued research and development of new technologies and materials, as well as improvements in recycling and production processes, are crucial to making solar energy as sustainable and environmentally friendly as possible.

C. Research question

How might Chinese dominance in the solar energy industry lead to sustainability issues in the PV manufacturing supply chain?

D. Significance of the study

As global energy demands continue to rise, the development of renewable energy technologies is becoming increasingly important in mitigating the negative environmental impacts of traditional energy sources (United Nations, 2023). A promising example of renewable energy technology that can assist in sustainably supplying energy requirements is solar panels (Ibid.). Despite the reputation of solar panels as a green energy source, their production processes often lack adequate attention to sustainability. Therefore, in order to fully maximize the potential of solar energy as a sustainable energy source, it is crucial to focus on the sustainability of the production processes involved in making solar panels."

Studying the economic, political and sustainability landscapes of solar panel production is critical, as if these processes are not sustainable, then their environmental benefits will be diminished in the long run. Therefore, it is essential to assess all stages of production - from raw material extraction through manufacturing, transportation, and end-of-life disposal - in order to guarantee that these panels are produced sustainably (Chowdhury & al., 2020). In fact, studying the sustainability of solar panel production is important for creating a roadmap for future improvements. This could involve developing

alternative manufacturing processes that require fewer resources, reducing the use of toxic chemicals, or finding more sustainable sources for raw materials (Nkuissi & al., 2020). It is then vital to investigate the sustainability of solar panel production to guarantee that the positive environmental outcomes of utilizing solar panels do not get offset by the negative effects of their production. Researchers can play a significant role in creating a sustainable future for renewable energy technologies by recognizing areas that require improvement.

E. Previous studies on the supply chain of Chinese solar energy production

a) *Analysis on the development and policy of solar PV power in China*

Zhang and He's study is an insightful assessment of China's development in renewable energy, particularly solar PV power (Zhang & He, 2013). They comprehensively outline the key policies, regulations, and incentives that have driven this industry in China, underscoring its critical role for government support (Zhang & He, 2013, pp. 395-399). Their evaluation suggests that government financial and regulatory support to domestic solar companies has been instrumental in catapulting China to a global leadership position within renewable energy (Ibid, p. 396).

Furthermore, the research examines the challenges and prospects facing China's solar PV industry, such as technological advancements, manufacturing practices and supply chain management (Ibid). The authors emphasize the need for further research and development in solar energy technologies in order to enhance production efficiency and reduce costs (ibid). This study emphasizes the significance of international collaboration in aiding the growth and development of renewable energy in both China and beyond (Ibid.). Overall, this study offers valuable insight into the current and future prospects of solar PV power in China, with its findings having significant implications for policymakers, industry professionals, and stakeholders in the renewable energy sector (Ibid.).

b) *Sustainability of photovoltaic poverty alleviation in China: An evolutionary game between stakeholders*

The article "Sustainability of Photovoltaic Poverty Alleviation in China: An Evolutionary Game Between Stakeholders" examines the intricate relationships among

various stakeholders engaged in PV poverty alleviation in China, with a goal to identify strategies for sustainable development (Shan & Yang, 2019). Through an evolutionary game framework, the authors examine decision-making and interactions among stakeholders such as government, PV enterprises, rural residents, and financial institutions (Ibid). Results indicate that cooperation and coordination among stakeholders is essential for sustainable development in the PV poverty alleviation program (Ibid). The study also highlights potential barriers to sustainable development, such as insufficient capital investment, inadequate rural electricity infrastructure and limited management and technical capability in PV enterprises (Ibid). To address these issues and achieve sustainable development in the PV poverty alleviation program (Ibid), a coordinated effort involving all stakeholders is necessary (ibid).

The article emphasizes the significance of social and environmental sustainability in China's effort to reduce poverty through photovoltaics (ibid). The authors contend that the program should be created to meet the needs of rural communities, promote local economic development and protect the environment (Ibid.). To meet these goals, the authors suggest that the government should provide policy support to PV enterprises to encourage them to adopt sustainable business practices such as using environmentally friendly materials and creating sustainable supply chains (Ibid). The study suggests the PV poverty alleviation program could benefit from the involvement of financial institutions, who could provide capital investment and technical support to PV enterprises (Ibid.). Overall, this article offers invaluable insights into the intricate relationships among stakeholders involved in this initiative and emphasizes its significance for sustainable development to ensure its long-term success (Ibid.).

c) *Green Innovation Value Chain Analysis of PV Solar Power*

The study "Green Innovation Value Chain Analysis of PV Solar Power" published in Journal of Cleaner Production in February 2014, presents an analysis of photovoltaic (PV) solar power value chains from an environmental innovation viewpoint. The research investigates components within these value chains while also identifying key drivers and barriers related to innovation and sustainability. Olson identifies four drivers of green innovation in the PV solar power industry, such as technological change, market demand, regulatory frameworks and stakeholder engagement (Olson, 2014, p.74). He emphasizes the significance of technological innovations within the PV solar power industry which have resulted in reduced costs of solar panels. The authors identify several key drivers of

innovation within the solar power industry, including development of new materials and processes, advancements in cell efficiency and integration of solar power into buildings or other infrastructure (Ibid., p.77). Moreover, he also explores the role of government policies and regulations in encouraging green innovation within the PV solar power industry (Ibid. p.77). For example, he asserts that government policies such as feed-in tariffs and renewable energy standards have played an essential role in providing an environment conducive to innovation and investment in the industry (Ibid.). The article concludes with several recommendations for policymakers and industry stakeholders to further promote green innovation in the PV solar power industry, including increasing research and development funding, encouraging collaboration between stakeholders, and creating policies supporting solar power adoption (Ibid., p.78)

d) *Navigating the Political and Economic Landscape of Responsible Practices in the Chinese Solar Energy Supply Chain*

Section a) provides the most pertinent information for my research question. It is an analysis of the policy and development of solar PV in China. This paper gives me an overview of the policies, regulations and incentives that have driven China's solar PV industry. It also discusses the challenges and opportunities facing the industry such as technological advances, manufacturing practices and supply chain management. Understanding these factors will help identify sustainability issues within the PV manufacturing supply chains and their impact on long-term sustainability. Section b), which examines relationships between various stakeholders involved in PV poverty reduction in China, may also offer useful insights on the sustainability issues that could arise in the PV manufacturing chain. The final dimension most pertinent to my question of research is the identification and analysis of the key barriers and drivers for sustainability and innovation in the PV solar industry found in section c). This section also discusses the implications on sustainable development. On the first hand, the study demonstrates the value of green innovations in driving the sustainability performance in PV solar power and in creating added value. On the other hand, the study also identifies key barriers and drivers to green innovations in the industry that could impact the sustainability of the PV manufacturing supply chains. Lastly, I would like to add that the "Green Innovation Value Chain Analysis of PV Solar Power" article can help me with my economic liberal theory. In an era where economic liberalism stresses the importance of economic growth and free markets, including sustainability concerns can ensure sustainable economic

development. Adopting an integrated and comprehensive approach to green innovations, PV solar companies can enhance their sustainability performance, create value and contribute to sustainable development. The insights in this article will help me to analyze how economic liberalism can reconcile with the sustainability concerns of the PV manufacturing chain.

As a student of International Development and International Relations with China in a joint master between Aalborg University and the University of International Relations of Beijing, my approach to studying the topic of sustainable and responsible supply chain management in Chinese solar panel companies is different from previous studies. Firstly, it might be the first paper specifically in the field of international relations. While past research has focused on the technical and economic aspects of solar PV development in China, I plan to use stakeholder theories, liberalism, and sustainable supply chain management to analyze the social and political implications of these practices. I aim to shed light on the ways in which these companies balance economic interests with social and environmental responsibility. I will also examine the implications of these practices for international cooperation on climate change and the promotion of liberal principles in the global energy transition. Overall, the goal of my research is to advance knowledge of the potential contribution of solar PV from China to the advancement of sustainable development and global cooperation toward the energy transition.

II. Theoretical Framework

A. Choice of theories

As my first theory, I have chosen the stakeholder theory. Stakeholder theory stresses the importance of considering the views and interests of different stakeholders when making organizational decisions (Freeman, Wicks, & Parmar, 2004). Stakeholder theory can be used to analyze the supply chain practices of Chinese solar panel companies. It can also help identify and analyze the interests and concerns of the different stakeholders. To ensure responsible and sustainable business practices, each stakeholder should be considered. Stakeholder theory raises ethical questions about the responsibilities corporations have in society. These include environmental impacts, treatment employees, and distribution benefits and harms among different stakeholder groups, including marginalized and vulnerable ones.

For my second theory, I have chosen Liberalism. The thesis will use Liberalism as well as a lens to analyze the raw material procurement to final product distribution of Chinese solar panels companies. This analysis will provide an in-depth understanding of how these companies balance economic interests with social and environmental responsibility and examine the implications of these practices for international cooperation on climate change and the promotion of liberal principles in the global energy transition. By examining the role of cooperation and interdependence in the international system, the thesis will provide valuable insights for policymakers, companies, and other stakeholders seeking to navigate the complex political and economic landscape in the Chinese solar energy supply chain.

Finally, my thesis will use the Sustainable Supply Chain Management (SSCM) theory, as a conceptual framework for investigating sustainability in supply chain management. Social, financial and environmental aspects will all be emphasized in SSCM. These perspectives will be used to examine how Chinese organizations can integrate social, financial and environmental sustainability considerations in their supply chain operations to reach long-term sustainability goals. My thesis aims at adding to the existing literature about SSCM and providing practical recommendations to organizations for implementing sustainable practices in their supply chain operations.

B. Theories

Stakeholder theory

The importance of taking into account the interests and viewpoints of different stakeholders in organizational decision-making is emphasized by stakeholder theory (Freeman, Wicks, & Parmar, 2004). In the context of Chinese solar panel companies and their supply chain practices, stakeholder theory can help to identify and analyze the different stakeholders involved in the supply chain, their interests and concerns, and how they are affected by sustainability and responsible practices. Additionally, Freeman & al. (2004) believe that stakeholder theory can provide managers with valuable resources and capabilities to address the challenges of creating sustainable and socially responsible business practices (Freeman, Wicks, & Parmar, 2004, p.365). According to Donaldson and Preston, corporations have a

range of stakeholders who have a legitimate interest in the company's activities, beyond just the shareholders (Donaldson & Preston, 1995).

To identify stakeholders in the supply chain of Chinese solar panel companies, it's important to consider the various parties involved in the production process (Donaldson & Preston, 1995). These may include raw material suppliers, manufacturers, distributors, customers, regulatory authorities, and local communities and ecosystems (Ibid.). Each of these stakeholders plays a crucial role in the production and distribution of solar panels, and their interests and concerns should be taken into account to ensure sustainable and responsible business practices. Firstly, the raw material suppliers are responsible for providing the necessary raw materials for the production of solar panels (Ibid.). They may include companies that mine silicon, aluminum, and other materials used in solar panel production (Hoffs, 2022). These stakeholders are interested in ensuring a steady supply of raw materials at a reasonable cost (Ibid.). Secondly, the manufacturers who are responsible for producing the solar panels and other equipment used in solar energy production. They are interested in maximizing profits while minimizing costs, including those associated with sustainability and responsible sourcing practices. Thirdly, the distributors are responsible for transporting solar panels and other equipment to customers. They are interested in ensuring timely and cost-effective delivery of products (Donaldson & Preston, 1995). Fourthly, the customers who are interested in purchasing high-quality, reliable solar panels at a reasonable price. They may also be interested in the environmental and social impact of their purchasing decisions (Donaldson & Preston, 1995). Fifthly, the CCP, other regional and local authorities, as regulatory authorities who are responsible for setting standards and regulations for the production, distribution, and use of solar panels (Donaldson & Preston, 1995). They may be interested in promoting sustainability through policies and implement ethical sourcing practices to stand out on the international scene. Finally, the local communities and ecosystems may be affected by the mining and processing of raw materials used in solar panel production, as well as by the disposal of solar panels at the end of their life (Curtin & al., 2020). They are interested in minimizing negative impacts on their environment and their health.

According to the researcher (Olsen, 2016) we can determine that by recognizing the legitimate interests of multiple stakeholders, the stakeholder theory of the corporation raises important ethical questions about the responsibilities of corporations in society (Olsen, 2016).

Indeed, the stakeholder theory raises important ethical questions about the responsibilities of corporations in society. These questions include inquiries into the environmental impact of business activities, such as the use of natural resources and the generation of waste and pollution (Donaldson & Preston, 1995). The theory also prompts discussions about how corporations treat their employees, including their wages, benefits, and working conditions (Ibid.). Furthermore, the stakeholder theory highlights the importance of considering the distribution of benefits and harms among different stakeholder groups, including those that are historically marginalized or vulnerable (Donaldson & Preston, 1995).

Liberalism

In examining the supply chain of a Chinese solar energy company, the present thesis will use the theoretical framework of Liberalism to provide a deeper understanding of the political and economic landscape of sustainable practices. Liberalism is a theoretical framework that emphasizes the importance of cooperation and interdependence in international relations (Dunne, 2020 ; Mcglinchey & al., 2017). This perspective suggests that states and firms can benefit from working together to achieve shared goals. Additionally, Liberalism recognizes the significance of economic competitiveness and technological advancement in the global arena (Conway, 2012).

Liberalism's core principles are the belief in economic liberty and free market principles (Cowen, 2021). According to Smith or Rawls, global politics and economics are driven by economic competitiveness (Ibid.). Liberalism stresses the importance of market-oriented policies to promote innovation and competition (Ibid.). Economic competitiveness is crucial in the success and sustainability of a company's supply chains, especially in the solar energy sector.

Another important aspect of Liberalism is technological advancement (Mohamed Alsebai, Liu and Nie, 2022). According to the theory, technological advancement and innovation are crucial for economic growth (Ibid.). Technological advancement in the solar industry is crucial for increasing efficiency and effectiveness of solar panel production, reducing costs and increasing companies' competitiveness on the global market (Ibid.). Technological advancements also contribute to the overall sustainability of the solar energy

supply chain by enabling more environmentally friendly manufacturing processes and reducing the environmental impact of production (Ibid.).

Global competition is fierce and companies need to constantly strive to stay ahead of technological developments and to remain competitive in order to succeed (Mohamed Alsebai, Liu and Nie, 2022). The context of the solar industry is one where sustainability is an important concern. Liberalism emphasizes the importance for companies to invest technologically in research and development, adopt market-oriented policy, and promote economic compatibility to stay globally competitive (Mohamed Alsebai, Liu & Nie, 2022).

From a liberal perspective, China's success in the solar industry can be attributed to economic factors such as its large and growing economy, investments in the domestic solar industry, and exports of solar panels and technology (Reuters, 2012). The Chinese government has actively supported the growth of its domestic solar industry through policies, subsidies, and investment (Ibid.). This has led to the development of a strong and competitive solar industry, with Chinese companies dominating the global market (Fialka, 2016 ; Venditti, 2022).

It is noteworthy that both state and non-state actors, especially multinational organizations, are important in world politics in the liberal view of international affairs (Viotti & Kauppi, 2012, p. 129). For instance, non-governmental organizations like multinational businesses, environmental and human rights organizations, and even individuals, can have a substantial impact on the global stage. Then, liberalism also highlights the role of international institutions and mechanisms such as trade, investment, and the exchange of ideas and information in promoting cooperation and stability in the international system (Mcglinchey & al., 2017 ; Viotti & Kauppi, 2012, p. 129) . The thesis will explore how these mechanisms have contributed to China's success in the solar industry by promoting cooperation among firms and governments, fostering innovation, and encouraging the exchange of best practices.

Overall, applying liberalism as a theoretical framework can offer valuable insights into ethical considerations and promote cooperation to reach shared objectives - such as the promotion of sustainable and responsible business practices (Moore & Farrands, 2010, p. 63 ; International Labour Office, 2007). By examining the role of cooperation, interdependence, and ethical considerations, the thesis can contribute to a better understanding of the

challenges and opportunities for sustainable and responsible business practices in the global solar energy industry (Fialka, 2016) .

Sustainable Supply Chain Management theory

The Sustainable Supply Chain Management (SSCM) theory places great emphasis on the strategic importance of supply and purchase decisions in achieving an organization's long-term performance while simultaneously tackling sustainability challenges (Carter & Rogers, 2008). According to Carter and Rogers (2008), the lack of conceptual underpinning for SSCM could prevent it from becoming a widely recognized management discipline (Panigrahi & al., 2019, p. 1006). Although, recent SSCM research has largely been descriptive, without making a substantial contribution to theories on the topic. Therefore, the area remains conceptually underdeveloped and requires further investigation (Panigrahi & al., 2019, p. 1006). Researchers have examined the environmental, social, and economic implications of SSCM; performance measurement and governance have also been considered as additional perspectives. The theory emphasized three elements: "[p]rofit--As a financial performance measure; [p]eople--As an indication of the company's commitment to socially and ethically responsible business practices; and [p]lanet--As an indicator of environmental commitment and performance" (Min, 2015, p.3990).

Firstly for the social - people - perspective of SSCM emphasizes the importance of corporate social responsibility, public awareness, fair working conditions, and employee welfare (Min, 2015, p. 390 ; Panigrahi & al., 2019, p. 1007). This perspective recognizes the necessity of supplier support and fair trade, effective resource management, profitability, and financial performance for achieving competitive advantage (Panigrahi & al., 2019, p. 1007). In addition, governance views in SSCM highlight the significance of governance structures, procedures, and interactions in achieving these goals (Ibid.). Furthermore, perspectives on performance measurement in SSCM place a strong emphasis on the importance of well-defined procedures, effective governance structures, and reliable audit and assessment methods to ensure that sustainability goals are achieved (Ibid.).

Thirdly, the environmental - Planet - perspective of Sustainable Supply Chain Management (SSCM) places emphasis on the conservation of the environment within which

the supply chain operates (Min, 2015, p. 390). It recognizes the need for sustainable practices, such as responsible use of natural resources, ethical labor practices, and reduction of greenhouse gas emissions, to minimize the ecological impact of industrialization and other supply chain operations on the environment (Panigrahi & al., 2019, p. 1007). Essential components of a sustainable supply chain include reverse logistics, eco-friendly technologies, and green procurement techniques, which aid in reducing environmental degradation (Ibid.)

Finally, the financial – Profit - perspective can be realized when incorporating sustainable practices into business strategies for a sustainable future (Min, 2015, p. 390 . Panigrahi & al., 2019, p. 1007). This includes developing and implementing sustainable sourcing strategies, promoting responsible production and consumption, reducing waste, improving working conditions, and engaging stakeholders in the supply chain (Villena & Gioia, 2020). Not only do these initiatives contribute to environmental conservation but they also have positive economic and social effects which enhance overall supply chain sustainability (Panigrahi & al., 2019, p. 1007). Therefore, a "Profit" perspective emphasizes the significance of integrating sustainable practices into supply chain operations to reduce negative environmental impact while promoting long-term viability (Ibid.).

In conclusion, SSCM is a theory that promotes eco-friendly technologies and fosters greater environmental responsibility throughout the supply chain. Implementing SSCM activities into business plans can help ensure a sustainable future, with strategies such as green procurement, eco-friendly technologies, reverse logistics and waste control helping to reduce pollution in the environment. The social perspective of SSCM emphasizes employee welfare, working conditions, equity, public awareness, ethics and corporate social responsibility; governance perspectives focus on supplier support, fair trade practices, efficient resource utilization profitability and financial performance for competitive advantage; finally performance measurement emphasizes audit & assessment as well as governance structures & mechanisms to guarantee sustainability goals are achieved (Panigrahi & al., 2019, pp. 1006-108)

II. Methodology

A. Research design and approach

This qualitative case study employs multiple theoretical frameworks in order to gain a comprehensive understanding of solar panel energy supply chain management in China. I am using stakeholder theory, liberalism and sustainable supply chain management as my guiding frameworks in conducting my analysis. My research design involves an in-depth exploration of the complex relationships and interdependencies among various stakeholders involved in supply chains including suppliers, manufacturers, distributors and consumers. Utilizing theoretical frameworks I will explore how these stakeholders interact and how their actions impact sustainability and efficiency of solar panel energy supply chains in China.It also considers key considerations like ethical and environmental concerns, transparency in supply chains, stakeholder engagement, and transparency in supply chain. The research also aims to examine the impact of the clean tech industry on the global energy transition. The theoretical framework is designed to understand international cooperation in climate change mitigation and promote liberal principles in the energy transition. The theories will then examine the integration of responsible supply chain management by Chinese solar panel manufacturers. The study approach will be used to collect and analyze qualitative data from various sources such as whitepapers, books, and newspapers. This will help evaluate the overall sustainability of the supply chain for solar panels. This includes ethical and environmental concerns, supply chain transparency, stakeholder engagement in clean energy production (Villena & Gioia, 2020).

For this study, I plan to employ an in-depth research method which draws heavily from secondary sources, including academic articles and industry reports. Analyzing the data gathered, I will use various analytical techniques, such as content analysis to examine how well data support my theoretical assumptions and thematic analysis to identify key themes and patterns related to responsible solar power procurement (Delve & al. 2023). Overall, this case study will contribute towards better understanding the complex issues involved with responsibly procuring renewable energy as well as provide insight and recommendations to companies and policymakers looking for ethical and sustainable practices. Finally, this study seeks to explore the key challenges and opportunities associated with promoting responsible and sustainable practices in China, and how this can contribute to a more sustainable global

clean energy transition by taking account of principles such as liberalism and sustainable supply chain management theory. More specifically, I will look into how Chinese solar panel companies integrate sustainable practices with responsible supply chain management theory, along with any implications this has for international climate cooperation as well as liberal principles promoted in global energy transition (Nkuissi & al. 2020).

This study's importance lies in its ability to contribute towards a more sustainable future for renewable energy technologies. By highlighting areas where improvements could be made in terms of material sourcing and processing, this research can assist Chinese solar panel companies and policymakers in creating more responsible supply chains - ultimately contributing towards an enhanced global clean energy transition and furthering liberalism and sustainable supply chain management in international relations fields.

Initial plans included conducting a case study of the supply chain of one or several Chinese companies. Instead, I have changed to focus on the overall economic and political aspects of the supply chain being more relevant to my field of research in International Development and International Relations with China. My study will be promoting responsible solar power sourcing and practice in the manufacture since it is often coined as a clean energy and I just wanted to see if in the long term it was really environmentally-friendly and ethical. This study will investigate both challenges and opportunities associated with responsibly practicing solar power; such as ethical considerations, supply chain transparency issues and stakeholder engagement opportunities.

B. Data Collection and Analysis:

The study uses a deductive approach, which involves the search for patterns from observation and the development of explanations or theories for those patterns through a series of hypotheses (Dudovskiy, 2011). The data will be collected through an extensive review of academic journals (Zhang & He, 2013 ; Huang & al., 2021 ; Shan & Yang, 2019), a report from the International Energy Agency (IEA, 2022) and whitepapers from China (Ministry of Industry and Information Technology of the P.R.C, 2012; National Energy Administration, 2016), to comprehensively cover the theoretical framework. By adopting this methodology, this research aims to provide a comprehensive and objective understanding of the integration of sustainable and responsible supply chain management practices by the Chinese solar power industry.

The research biases were mitigated by adopting a rigorous selection process for sources. Only well-documented, legitimate sources were used, few or no newspapers were used to avoid accusations of fake news. By using a range of reputable sources, the research aimed to reduce the risk of biases and ensure objectivity in the analysis. One such document is from the IEA, an intergovernmental organization that works to promote reliable, clean, and affordable energy for its member countries and beyond (IEA, 2023). The IEA releases the "World Energy Outlook" report annually, which provides a comprehensive analysis and projections of global energy trends and their potential impact on energy security, environment, and economy. I chose the "Special Report on Solar PV Global Supply Chains" of 2022 as it is the latest at the moment (IEA, 2022). I am writing my thesis in 2023. Then, I chose to use the 11th (2006-2010), 12th (2011-2015) and 13th (2016-2020) Five-Year Plans. The C.C.P. 's Five-Year Plans (FYPs) have served as a reliable and accurate benchmark for analysis for over sixty years (National Energy Administration, 2016), serving as an overall policy framework that guides China's economic and social progress. The FYP provides China's national goals, strategies, and targets for various sectors such as energy, environment, and climate change (National Energy Administration, 2016). The plan outlines specific policies and measures designed to address climate change challenges, such as reducing carbon emissions, improving energy efficiency, and encouraging renewable energy (Ibid). Additionally, FYP is the result of extensive research, analysis, and consultations with various stakeholders such as government agencies, academic institutions, and industry associations (OECD, n.d.). This plan incorporates the most up-to-date scientific knowledge and international best practices on climate change mitigation and adaptation, giving China an authoritative perspective on their policies regarding climate change impacts and potential solutions. The FYPs provide an insightful view into China's solar industry development, since they contain comprehensive policies and measures designed to promote solar energy, such as tax incentives, research funding, and grid integration measures. Furthermore, these plans offer a framework for monitoring and assessing progress with deployment of solar energy assets; this helps guarantee targets are met and the industry grows sustainably.

Due to limited access to relevant data sources and time/resource constraints, this study could not have reached its full potential without using mixed methods research methods. Primary sources could have included interviews with experts in the field, surveys, and other data collection methods from relevant stakeholders (Taylor & al., 2015).

IV. Analysis

Understanding the entire production process for solar panels from raw material purchase through final product distribution is vital in order to understand its opportunities and challenges in terms of ethical and environmental considerations. This in-depth analysis will give us a comprehensive view of the political and economic forces that shape the supply chain, as well as identify any key issues. Thus, we can create plans to encourage ethical behavior by comprehending China's solar energy supply chains. This includes an examination of raw material procurement, manufacturing and distribution. I will use three theoretical lenses: stakeholder theory, sustainable supply chain management theory and liberalism to examine this process. These theories will allow us to analyze the supply chain and understand the role played by government and market forces. I can also evaluate the potential for socially responsible and sustainable practices in the solar industry.

A. Overview From Polysilicon to Module: A Comprehensive Analysis of the Solar Panel Manufacturing Process

The procedure of making solar panels involves several steps. Firstly, the production of polysilicon is essential, as it serves as the raw material for making solar cells, which are the building blocks of solar panels (Tech Vision, 2021). This involves melting high-purity silicon at high temperatures and forming it into solid cylindrical rods known as ingots (Zhang & He, 2013, p. 394). Secondly, a wire saw is used to split the ingots into tiny, circular wafers, a step known as "ingot slicing" (Tech Vision, 2021; Zhang & He, 2013, p. 394). The resulting wafers are polished to remove any imperfections and to make them shiny and smooth (Tech Vision, 2021). Thirdly, the wafers are processed into solar cells, starting with cleaning and then doping, a chemical treatment that creates a surface capable of converting sunlight into electricity (Tech Vision, 2021 ; Zhang & He, 2013, p. 394). The wafers are then coated with an antireflective material to enhance their efficiency in capturing sunlight (Tech Vision, 2021). High-temperature baking follows to create a protective layer (Ibid.). Fourthly, to create panels, the cells are connected together and covered in a glass or plastic shell for protection. (Ibid.). They are tested to ensure compliance with the required electrical standards before installation (Ibid.). Finally, the panels are installed on a roof or other surface, mounted on

racks or frames, and wired together to create a system that can generate electricity (Zhang & He, 2013, p. 394). The inverter transforms the direct current (DC) energy produced by the panels into alternating current (AC) electricity (Solar Energy Technologies Office, n.d.). The AC electricity is then utilized to power homes, businesses, and other electrical devices (Ibid.).

The Party's 13th FYP sets ambitious objectives for solar panel manufacturing and energy development. By 2020, the plan aims to install 110 million kilowatt of solar electricity - of which 105 million kilowatt will come from PV power and the remaining 5 million kilowatt from solar thermal energy (National Energy Administration, 2016, p.12). When reviewing China's 13th FYP solar energy plan from a sustainability perspective, we can take into account its economic dimension - profit. The SSCM framework emphasizes the significance of creating economic value not only for businesses, but also society and the environment (Min, 2015, p. 390 ; Panigrahi & al., 2019, p. 1007). Thus, the country's ambitious targets for solar energy development and deployment provide significant economic advantages for businesses in the country. For instance, the plan's emphasis on distributed PV applications and private investment in large-scale solar projects can encourage innovation and competition within the sector, leading to cost reductions and improved efficiency (National Energy Administration, 2016, p. 25). These cost reductions will benefit consumers, while also increasing profits for businesses involved in the solar energy supply chain. Additionally, the plan's emphasis on building large heating stations in appropriate areas illustrates that solar thermal energy could become a viable alternative to traditional fossil fuel-based heating systems (National Energy Administration, 2016, p. 12). Businesses involved in the solar thermal energy supply chain could find new markets and revenue streams from this development, creating additional economic opportunities and profits for them.

In the economic landscape of solar panel manufacturing, China's 13th FYP stresses the values of free markets, competition, and individual rights from a liberalist viewpoint. Solar energy development is in line with these values, as it encourages market competition and individual rights through distributed PV application demonstrations. For example, the strategy seeks to establish 100 demonstration zones for this purpose, guaranteeing that 50% of existing buildings and 80% of newly constructed industrial park buildings have PV power generation installed on their rooftops (National Energy Administration, 2016, p. 13). This approach promotes competition and market development, leading to economic development.

Furthermore, the plan encourages private investment in large-scale solar projects by constructing 1.5 million kilowatt solar power model projects during the first half of the "13th Five-Year Plan" period (Ibid). This strategy aligns with the liberalist philosophy of reducing government intervention in the economy, encouraging market competition and economic growth. Finally, the plan calls for the construction of more than 200 substantial heating stations by 2020 with a combined collector area of more than 4 million square meters (Ibid). This demonstrates the government's dedication to promoting renewable energy sources and decreasing dependence on traditional fossil fuels.

When reviewing China's solar PV manufacturing through the SSCM framework, there are numerous environmental considerations to take into account. First, the P.R.C.'s solar PV manufacturing has seen an exponential increase in production capacity and emissions (IEA, 2022, p. 41). As a result, their operations are now having an increasingly substantial carbon footprint (Ibid.). In 2011, China produced 59% of the emissions associated with solar PV materials like polysilicon, ingots, wafers, cells and modules (Ibid.). As of today that number has skyrocketed to 87% (IEA, 2022, p. 47). Due to its possible impact on climate change and global warming, this poses a risk to the environment. In fact, China's production capacity has grown faster than any other sector of the industry in the last ten years (IEA, 2022, p. 41). Thus, China's production and CO2 emissions shares have outpaced global expansion, suggesting that its solar PV manufacturing is a significant contributor to global emissions. Furthermore, resource depletion is becoming an issue. Solar PV products require a significant amount of raw materials, such as silicon, which if not managed sustainably could lead to resource depletion. Indeed, according to the IEA (2022, p. 59), solar PV systems require raw materials like silver, tellurium, copper and antimony that are concentrated in a few countries (Ibid). Yet, the top three producers of each mineral are in China and account for more than half of the global supply (Ibid.). This raises a potential jeopardy to the sustainable availability of these essential elements. Finally, waste management must also be addressed. The manufacturing process generates large amounts of waste that, if not properly managed, can have detrimental environmental effects. This includes disposing of hazardous materials used in production like lead, cadmium or arsenic (Thomas, 2019).

Now that we have an overview of the overall production process of solar PVs modules and its challenges, let's move on to a more detailed analysis of each stage of the supply chain. I will examine the manufacturing of solar PVs panels, assembly of solar

modules, and distribution of the final product. Through this analysis, we will gain a comprehensive understanding of the Chinese solar energy supply chain and the political and economic landscape surrounding it. Additionally, I will use three theoretical lenses - stakeholder theory, liberalism, and sustainable supply chain management - to critically evaluate the issues and challenges associated with sustainable practices (i.e., social and environmental impact) in the Chinese solar energy supply chain.

B. Breaking Down the Economic and Political Landscapes of PV Solar Panel Supply Chain: An Inside Look at Each Step

Step 1 Polysilicon

Looking at the political landscape, ten years ago, the CCP openly acknowledged the country's shortcomings in PV production and distribution. Indeed, the Party's 12th FYP recognized that despite increasing pressure from international competition, the domestic PV industry still had much work to do (Ministry of Industry and Information Technology of the P.R.C, 2012, p. 5). According to this plan, China had yet to catch up to international polysilicon key technology levels (Ministry of Industry and Information Technology of the P.R.C, 2012, p. 6). Furthermore, Chinese enterprises were still dependent on imports to manufacture crystalline silicon cells using advanced equipment, and their thin-film cell processes and capabilities lagged behind significantly (Ministry of Industry and Information Technology of the P.R.C, p. 6). From a liberalist perspective, this policy statement emphasizes the significance of economic competition and technological progress in today's global marketplace. Additionally, it illustrates how governments can assist and regulate domestic industry growth through policy measures. Furthermore, the CCP's acknowledgement of shortcomings in PVs indicates a recognition of the significance of technology and innovation for economic growth and global influence. Generally, the Party's 12th FYP emphasizes the need for China to catch up with advanced technological levels and overcome domestic production constraints by importing equipment from other countries. This approach takes a liberal view, emphasizing the significance of free trade and competition on the global market. Finally, the Chinese government recognizes that their domestic PVs industry is still developing slowly and they are actively taking measures to enhance

capabilities in this field by investing in research and development, streamlining manufacturing processes, and encouraging innovation (Ibid.).

Additionally, China's 12th FYP sought to promote the production of high-quality polysilicon by providing aid for essential production equipment (Ministry of Industry and Information Technology of the P.R.C, 2012, p.11). The supported equipment included machinery for reducing or hydrogenating polysilicon, large-scale monocrystal furnaces with low energy consumption, casting furnaces for metric ton-grade polysilicon ingots, ultra-thin silicon wafer multi-wire cutting machines and automatic sorting machines (Ministry of Industry and Information Technology of the P.R.C, 2012, p.11). This support had significant implications from the perspective of SSCM - planet, as it promoted the incorporation of production methods with PV production equipment that uses less energy, is more efficient, and is automated. It also aligned with the goal of reducing greenhouse gas emissions by utilizing low-energy consumption monocrystal furnaces and ultra-thin silicon wafer multi-wire cutting machines. On the other hand, China's encouragement of high-quality polysilicon production can be seen as an act of economic liberalism (Conway, 2012). Indeed, by encouraging the expansion of the solar panel market through aid for high-quality polysilicon production, the government promoted free trade and an international marketplace for clean energy. Furthermore, providing assistance with essential equipment production encouraged international collaboration in creating sustainable supply chains, reinforcing the liberal principles of economic cooperation. Moreover, the Chinese 12th FYP recognized the country’s dependence on imports for high-end equipment and lagging behind in thin-film cell processes and equipment reveal potential supply chain issues that may impact the sustainability of the industry (Ministry of Industry and Information Technology of the P.R.C., 2012). Indeed, the dependence on imports may create issues around the availability, reliability, and cost of equipment, which can have significant economic impacts. But to address these questions, I believe that sustainable supply chain management practices need to be implemented. This includes developing and implementing sustainable sourcing strategies, promoting responsible production and consumption, reducing waste, improving working conditions, and engaging stakeholders in the supply chain (Villena, 2020). From an SSCM point of view, this strategy would balance economic growth with social and environmental responsibility in the development of the PVs industry. It also underscores the need for collaboration and transparency among stakeholders to promote sustainable and responsible supply chain practices .

Anyhow, according to experts from the IEA, polysilicon production is the most carbon dioxide-intensive segment of the solar PV supply chain. However, its share in overall PV manufacturing emissions has steadily decreased from over two-thirds in 2011 to just above 39% last year worldwide (IEA, 2022, p. 40). From a sustainability standpoint, polysilicon manufacture is the most energy-intensive component of the solar PV supply chain and poses an acute environmental risk due to its high energy consumption and carbon emissions (Ibid.). As a matter of fact, CdTe, a material commonly used in solar panels, can have negative consequences for both environmental health and human wellbeing if contaminated drinking water directly affects local communities (Curtin & al., 2020). Therefore, the industry, with the P.R.C being the leader of it, must adopt sustainable practices that minimize its carbon footprint, such as using renewable energy sources and implementing carbon capture and storage technology (IEA, 2020). To address this problem, there are a variety of interventions that can be implemented: regulating recycling and disposal practices, using bioreactors, and installing dye-sensitized solar cells (Curtin & al., 2020, p. 1). Business leaders and politicians can use a framework called multiple criteria decision analysis (MCDA) to decide which interventions are most successful (Ibid.). By safeguarding water supplies and increasing access to reliable electricity through low-cost solar, the industry can achieve the UN Sustainable Development Goals (Curtin & al., 2020 ; United Nations, 2023).

Looking at the economical landscape, in 2022, for the production of polysilicon the P.R.C. dominates with around 79% of the overall production (Conte, 2022 ; IEA, 2022, p.58). Although this has not always been the case. Experts in polysilicon production, such as the Bernreuter Researchers (2020), claim that China used to have the smallest market share along the value chain. Due to their familiarity with the Siemens process[1], non-Chinese polysilicon producers had an edge in this area (Bernreuter Research, 2020 ; Jäger-Waldau, 2012). Well, now, Chinese companies have focused on this and have since caught up to their rivals. In fact, Chinese businesses have seen their market share in polysilicon for solar energy grow steadily over time, spurred on by high tariffs placed on imports from the United States as reported in 2020 by Bernreuter Research (Bernreuter Research, 2020 ; Alan Reinsch & Arrieta-Kenna, 2021). As a result, Xinjiang province is particularly significant, accounting for 42% of China's polysilicon capacity and hosting the largest polysilicon plant in the country - contributing 14% of global production capacity (IEA, 2022, p.58). However, the

[1] The Siemens process entails depositing silicon onto high-purity filaments using an inert mixture composed of pure silane or TCS gas and excess hydrogen gas, in an insulated reaction chamber known as 'bell-jar.' Here, silicon growth takes place within this reaction chamber containing these gases. (Jäger-Waldau, 2012)

concentration of polysilicon production in Xinjiang raises concerns for local stakeholders such as workers, communities and the environment. Reports of human rights abuses, including forced labor in Xinjiang have prompted businesses to examine their supply chains and ensure they are not complicit in such practices (OHCHR, 2021 ; Alan Reinsch & Arrieta-Kenna, 2021). Though new polysilicon plants are being planned for China, it is encouraging that they won't be located in Xinjiang (IEA, 2022, p.58). This could help reduce production concentration and associated risks in that province. Nonetheless, companies must be aware of how their business activities could affect stakeholders and take measures to ensure they act ethically and responsibly (Alan Reinsch & Arrieta-Kenna, 2021).

Next up in the manufacturing process is "melting and extracting of doped silicon into a crystalline ingot". (Svarc, 2018) This step is essential for creating high-purity silicon material which will form the basis of PVs panels. Let's take a closer look at how this step is carried out.

Step 2 Ingot

"Ingot" is the term most often used to refer to the polycrystalline silicon ingot produced in a special furnace (IEA, 2022 ; Tech Vision, 2021). The ingot squaring machine is used to square off the edges of an ingot, making it easier to handle during subsequent processing steps (Tech Vision, 2021). The 11th FYP of China, established in 2006 and covering the period from 2006 to 2010, sought to increase domestic production while decreasing dependence on foreign technology (Ministry of Industry and Information Technology of the P.R.C., 2012, p. 6). Indeed, since the 2008 financial crisis, Chinese PV manufacturers have struggled due to a shrinking foreign market worldwide (Zhang & He, 2013, p. 394). Germany and other European countries cut incentives, while the US and EU began investigations against Chinese PV products (Ibid.). As a result, the C.C.P. seeked to stimulate domestic demand to reduce dependency on overseas markets and support the growth of its PV industry (Ibid.). As a result of this plan, domestically manufactured equipment such as polycrystalline silicon ingot casting furnaces and ingot squaring machines underwent significant industrialization (Ibid.) This led to an incremental growth in their market share within China, decreasing the country's dependence on imported equipment (Ibid.). Liberally speaking, the gradual industrialization of domestically produced equipment such as polycrystalline silicon ingot casting furnaces and ingot squaring machines is a positive development. This is because it signifies an improvement in economic efficiency and productivity, which could ultimately

result in greater wealth creation as well as overall economic expansion. Thus, China's increasing domestically manufactured equipment market share can be seen as evidence of its economic efficiency, since it reduces costs associated with importing equipment. This can lead to increased productivity and innovation, as companies have more resources for research and development. However, it is essential to note that this fast industrialization has resulted in China dominating the production of ingot today (Conte, 2022). Though this could be seen as a positive development from a liberal perspective, it could also pose potential threats to international economic stability. In fact, dominance by one country in an industry can lead to unfair trade practices, such as dumping or anti-competitive behavior, that harm other nations and undermine the liberal principles of free and fair trade (Qaqaya & Lipimile, 2008). Therefore, while China's industrialization of domestically manufactured equipment may be beneficial to their economy, it is essential to consider potential consequences on other economies and respect fair trade practices (Ibid.). A liberal approach to international relations emphasizes the significance of free and fair trade; making sure one country's growth does not come at the expense of others.

According to the Clean Energy Review, many prominent solar panel manufacturers are “vertically integrated”, meaning they manufacture all primary components needed for making solar PV cells within their company (Svarc, 2018). By the 11th FYP of 2006, many leading solar panel manufacturers in China were vertically integrated and produced all primary components - indicative of China's development of an extensive supply chain for producing solar panels (Ministry of Industry and Information Technology of the P.R.C, p. 4). This supply chain likely involves the production of high-quality silicon ingots “utilizing regional resource advantages and industrial bases. Jiangsu, Hebei, Zhejiang, Jiangxi, Henan, Sichuan and Inner Mongolia have become regional industrial centers” (Ministry of Industry and Information Technology of the P.R.C, p. 4). Thus, it could be argued that China's vertically integrated PV industry has enabled it to maintain control over the quality of the ingots used for solar panel production. By having this control over raw materials used for production of solar panels, China could guarantee its solar panels meet international standards from a Liberal perspective.

However, since China's PV industry has a high concentration of ingot production which restricts competition and any decrease in quality could negatively affect the entire global value chain. Indeed, the liberal perspective emphasizes the role of market competition

in upholding quality standards. In a liberal world order, competition is seen as the primary catalyst for economic growth and innovation - leading to higher-quality products at lower costs. From a stakeholder perspective, China's concentration of ingot production may grant some suppliers significant bargaining power which could influence raw material prices and quality (Talerico, 2022). Therefore, it is critical for these manufacturers to source only top quality ingots in order to guarantee their solar panels remain efficient and long lasting (Svarc, 2018). Further, still from a stakeholder perspective, the quality of solar panels manufactured using ingots affects customers who purchase and use them. If these ingots become less reliable, this would lead to decreased efficiency and durability in production - ultimately impacting customers' experiences negatively.

Let now turn our attention to the third step of the process, which involves diamond wire-cutting round ingots into thin square wafers (Svarc, 2018). This step is essential for creating wafers of desired thickness that will be utilized for microchips and other electronic components (Svarc, 2018).

Step 3 Wafer

From a political perspective, the C.C.P. 's 12th FYP from a decade ago stressed the significance of adopting sustainable practices in silicon wafer production. The objective was to reduce any negative environmental effects associated with this process (Ministry of Industry and Information Technology of the P.R.C., 2012). Implementing sustainable practices is essential to meet this objective and promote long-term sustainability throughout the supply chain. According to the plan, sustainability in wafer production could be achieved by optimizing the cutting process of silicon wafers (Ibid.). One solution proposed was the use of new technologies, such as cutting technology for silicon carbide and steel wires, to improve wafer quality, increase yield from same amount material, and minimize silicon waste during cutting (Ministry of Industry and Information Technology of the P.R.C., 2012, p. 10). Furthermore, supporting high-efficiency, low-cost large-size ingot technology with a special focus on developing quasi-single crystal ingot technology contributed towards sustainable practices in silicon wafer production (Ibid.). Adopting sustainable practices not only benefits the environment, but they have positive economic and social repercussions as well. Therefore, it was essential to integrate sustainable practices into supply chain operations like China in order to promote environmental conservation and long-term viability in the production of silicon wafers. Therefore, governments and industries around the world must

prioritize sustainable practices in the production of silicon wafers and other materials to minimize their environmental effects and guarantee our planet's long-term viability.

From the economic perspective, China's dominance in the wafer manufacturing industry has grown significantly over time, with its global manufacturing capacity increasing from 80% in 2010 to 97% currently (IEA, 2022, pp.22-24). This has been accomplished through economies of scale, supply chain integration, innovation and government support (Bernreuter Research, 2020). Therefore, other market participants have been unable to compete, leaving China as the sole major player in this industry (Ibid.). Furthermore, much of the remaining capacity for cell production is concentrated in Asia-Pacific, leaving much of the rest of the world heavily reliant on imports. (IEA, 2022, p. 24). In a liberal framework, encouraging economic interdependence and cooperation among states is essential for maintaining peace and stability (Barbieri, 1996). Although, the concentration of wafer production in one country and a few provinces could create vulnerabilities in global supply chains, potentially leading to trade disputes or tensions between states (Barbieri, 1996 ; IEA, 2022, p. 24). Encouraging other countries to invest in solar cell production and diversifying the supply chain could promote economic interdependence and reduce conflict over resources (Ibid.). Furthermore, encouraging free trade and open markets helps guarantee fair competition and prevent monopolies - both of which benefit all countries (China's Foreign Trade, 2012)

As we progress through the production of photovoltaics, we now reach an essential stage: turning a thin base wafer into a functional solar cell (Svarc, 2018). In analyzing this stage of the supply chain, I will consider political, economic and environmental consequences associated with certain materials and production methods; ultimately aiming to ensure that resulting solar cells are both sustainable and economically viable.

Step 4 Cell

Analyzing the economic and political implications, the 11th FYP states that China's special equipment for crystalline solar cells was self-sufficient between 2006 and 2010, except for automatic printing machines and cutting machinery (Ministry of Industry and Information Technology of the P.R.C, 2012, p. 3). Since the plan, China has made significant technological strides, reducing its reliance on imported technology and enabling local firms to run fully integrated production lines. It shows that Chinese enterprises possess the

infrastructure and expertise to sustain the industry's development and meet its production demands. This is an indication that China has emerged as a major force in the global solar cell market. Chinese companies have also developed full-line production facilities for products utilizing silicon-based thin film cells. The country has made significant strides in the development of technologies for producing thin-film solar cells, which offer certain advantages over traditional crystalline silicon in certain applications (Ibid.). The potential of this industry to grow and progress can be seen through its small-scale products made with thin-film technology.

Thus, the P.RC. has been of course a major force in global solar cell manufacturing for almost ten years, now accounting for 85% of total capacity (Conte, 2022). Most of this capacity is located in three provinces: Sichuan, Zhejiang and Jiangsu (IEA, 2022, p. 58). Cell production may not be as concentrated as wafer or polysilicon manufacturing, but it still accounts for 8% of the industry (Ibid.) Though, liberalists worry that the concentration of solar cell production in one country and a few other provinces could raise questions about market power and its effects on global supply chain disruptions. To guarantee efficient functioning in the marketplace, liberal economic systems must promote competition and prevent monopolies (China's Foreign Trade, 2012). This could include encouraging other countries to invest in solar cell production to diversify their supply chains and reduce reliance on one country. Nonetheless, the C.C.P still has ambitious plans for their 13th Five Year Plan (FYP), including creating micro-grids for renewable energy in areas with high distributed penetration rates or favorable building conditions (National Energy Administration, 2016, p. 31). Additionally, the plan seeks to enhance PV system efficiency and thermal power generation using solar energy, as well as construct a renewable energy smart grid to replace diesel generators and reduce power costs while protecting the environment and enhancing regional energy structure (National Energy Administration, 2016, pp.18-19).

After studying the various steps involved in producing solar cells in China, it's time to move on and evaluate its final stages: exportation and distribution of modules. While China has made great strides toward developing its solar cell industry, shipping these products overseas for global distribution can have an adverse effect on the environment, contributing significantly to climate change. Hence, consideration should be given to how growth in this sector and China's role as a major player on the global market has an environmental effect.

Step 5 Module

According to the IEA report, most transport-related emissions in photovoltaic (PV), come from the assembled module (IEA, 2022, p. 43). This is the heaviest part and is usually shipped from China to markets around the world (Ibid.). This component accounted specifically for 95% of PV transport-related emissions in 2021 (Ibid.). Climate change is largely influenced by the transportation of goods. Indeed, China's coast shipping sector emitted approximately 45 million tonnes of CO2 in 2019, or 4.5% of China's total CO2 emissions (Mao & Meng, 2022, p.2). These transportations are mainly done by large cargo ships and trucks, which are both major contributors of greenhouse gas emissions (Transport & Environment, 2022). Furthermore, China's substantial increase in solar PV module demand has contributed to an increase in greenhouse gas emissions. China's share of total annual installations increased from 12% in 2012, to nearly 45% in 2016, (IEA, 2022, p. 43). Trade routes for solar PV modules are now shifted towards Australia, India, and Japan (Ibid.). This has resulted in shorter travel distances for Chinese imports and lower transport-related emissions (Ibid.). From a stakeholder theory framework, it is clear that China's significant increase in solar PV module demand has benefited some stakeholders (China and solar PV manufacturers), while endangering others (the global community affected by climate change). The increase in demand has contributed to an uptick in greenhouse gas emissions, contrary to the global community's desire to reduce these emissions. However, the shift in trade routes towards Australia, India, and Japan has resulted in shorter travel distances for Chinese imports as well as lower transport-related emissions. This development is beneficial to both China and the global community at large. The stakeholder theory framework suggests that China and solar PV manufacturers should take into account the interests of all parties involved, including those affected by climate change around the world. To address this concern, stakeholders could look into ways of reducing greenhouse gas emissions associated with the production and transportation of solar PV modules, such as using renewable energy sources during production or optimizing transport routes (OECD, 2018, p.27). Other countries that import these panels could also take similar steps to reduce emissions. By working together towards a sustainable future that balances economic growth with environmental protection, stakeholders can work towards an equitable future.

Moreover, this issue can be analyzed through the SSCM framework since it is clear that goods transportation has a major impact on the environment (Transport & Environment,

2022). Companies should reduce the carbon footprint of their supply chains by adopting more sustainable transport options and eco-friendly practices (Ibid.). The PV industry can help contribute to global efforts to fight climate change by doing this (United Nations, 2023). For instance, the Belt and Road Initiative (BRI), which is a global initiative to reduce carbon emissions, offers an opportunity for the industry to explore other modes of transport (OECD, 2018, p.27). Trains are a viable alternative to trucks and cargo ships, as they produce less carbon than other modes of transportation (European Environment Agency, 2021). The BRI includes plans for a modern railway network that would connect China with Europe, potentially reducing transportation-related emissions while also improving the speed and efficiency of trade between the two regions (cfd the *New Eurasia Land Bridge* (OECD, 2018, p. 11). The BRI can significantly reduce the environmental impact on trade between China, Europe, and other parts of the world by shifting to more sustainable transport modes, such as trains (OECD, 2018 ; European Environment Agency, 2021). It is crucial to ensure that these transport modes are implemented in a sustainable manner and sustainably responsible, considering the entire lifecycle impact on infrastructure and transportation systems.

V. Discussion

In this subsection, I discuss the research findings and their relevance to the research question, which examines the sustainability issues arising from Chinese dominance in the solar energy industry, particularly in the PV manufacturing supply chain. My analysis highlights the challenges posed by increased emissions, resource depletion, and waste management, as well as the necessity for a diversified supply chain, international collaboration, and sustainable practices. As we move forward, I will further explore these concerns and discuss potential solutions to ensure the long-term viability and positive environmental impact of solar energy.

A Research findings and their relevance to the research question

In relation to the research question, "*How might Chinese dominance in the solar energy industry lead to sustainability issues in the PV manufacturing supply chain?*", it is evident that Chinese dominance in the solar energy industry has led to both positive and negative implications for the sustainability of the PV manufacturing supply chain. On the positive side, China's 12th FYP has promoted the production of high-quality polysilicon, which has implications for environmental sustainability. The plan supports the adoption of production

methods and PV production equipment that are energy-efficient and environmentally friendly. Additionally, China's vertically integrated PV industry has allowed it to maintain control over the quality of the ingots used for solar panel production, which has ensured the quality of solar panels meets international standards. This approach aligns with the liberal perspective that emphasizes the importance of free trade and competition on the global market. However, there are sustainability issues arising from China's dominance in the solar energy industry. For example, the concentration of polysilicon production in Xinjiang raises concerns for local stakeholders, such as workers, communities, and the environment, due to reports of human rights abuses and forced labor. Also, the industry's dependence on imports for high-end equipment and lagging behind in thin-film cell processes and equipment may impact the sustainability of the supply chain, leading to potential environmental, social, and economic consequences. The high concentration of ingot production in China may restrict competition and affect the global value chain, leading to potential unfair trade practices and undermining the liberal principles of free and fair trade. To address these sustainability issues, Chinese companies need to implement sustainable supply chain management practices, which include developing and implementing sustainable sourcing strategies, promoting responsible production and consumption, reducing waste, improving working conditions, and engaging stakeholders in the supply chain. Furthermore, they should consider diversifying its production locations and upholding fair trade practices to minimize any negative consequences on other economies.

Additionally, based on my research findings China's dominance has resulted in several sustainability challenges. These include increased emissions, resource depletion, and waste management issues. To ensure the long-term viability and favorable environmental effects of solar energy, several issues must be addressed. In fact, first, China's dominance in the solar energy industry has resulted in a significant increase in production capacity and emissions. As mentioned in the analysis, China produced 59% of the emissions associated with solar PV materials in 2011, and this number has increased to 87% as of today (IEA, 2022, pp. 41, 47). The rapid expansion of China's solar PV manufacturing has contributed to global warming and climate change. Secondly, resource depletion poses a potential threat to the sustainability of the solar PV manufacturing supply chain. China's dominance in the industry has led to an increased demand for raw materials such as silicon, silver, tellurium, copper, and antimony. As China accounts for 50% or more of the global supply for these minerals, the sustainability of their availability is a cause for concern (IEA, 2022, p. 59).

Lastly, waste management is another sustainability issue in the Chinese solar energy supply chain. The manufacturing process generates large amounts of waste, including hazardous materials such as lead, cadmium, and arsenic. Proper waste management and disposal are crucial to prevent detrimental environmental effects (Thomas, 2019).

Furthermore, my research findings indicate that Chinese absolute dominance, in the first two steps of the value chain, in the solar energy industry has led to significant advancements in technology and production capacity in polysilicon and ingot. This dominance poses sustainability issues, however, because it makes the solar industry more vulnerable to disruptions, and also stifles worldwide innovation. The solar industry's heavy reliance on China's dominance, which accounts for nearly 85% of global solar component production, exposes the sector to potential risks and hinders innovation worldwide (Holleyman, 2022). For example, if China were to block or threaten to block solar exports in response to geopolitical conflicts, countries like the United States would face significant challenges in meeting their low-carbon goals and ensuring energy security (Ibid). Moreover, this situation prevents the growth of a diverse and resilient global solar manufacturing sector, limiting job opportunities and stifling technological advancements in renewable energy. The PV sector must diversify its supply chains, promote international cooperation, and keep putting effort into R&D for environmentally friendly PV manufacturing technology in order to meet these problems. For China's PV sector to continue to thrive and be resilient over the long term, it must also achieve a balance between industrial growth and commitments to economic, social, and environmental sustainability. Similarly, in wafer production, China's 12th FYP aimed to reduce negative environmental effects by adopting sustainable practices, which have had positive environmental, economic, and social impacts. However, the concentration of wafer production in China has created vulnerabilities in global supply chains and could lead to trade disputes or tensions between states. Encouraging other countries to invest in solar cell production and diversifying the supply chain could promote economic interdependence and reduce conflict over resources. Likewise, in cell production, China's dominance has raised concerns about market power and potential supply chain disruptions. Promoting competition and preventing monopolies can help address these issues.

Moreover, the CCP’s 13th FYP aims to create micro-grids for renewable energy and enhance photovoltaic system efficiency, but the country's role as a major player in the global market has environmental consequences, especially in terms of transport-related emissions. In

fact, in panel/module transportation, the assembled module is responsible for 95% of PV transport-related emissions. China's coastal shipping sector emitted about 4.5% of the country's total CO2 emissions in 2019. Reducing greenhouse gas emissions associated with the production and transportation of solar PV modules can help address this issue. Trade route shifts towards Australia, India, and Japan have resulted in shorter travel distances and lower transport-related emissions. From a stakeholder theory perspective, China's increase in solar PV module demand has benefited some stakeholders while endangering others, such as the global community affected by climate change. China and solar PV manufacturers should take into account the interests of all parties involved and work together to reduce emissions. The SSCM framework for the planet suggests that companies should reduce the carbon footprint of their supply chains by adopting more sustainable transport options and eco-friendly practices. The Belt and Road Initiative (BRI) offers an opportunity to explore alternative modes of transport, such as trains, which produce less carbon than trucks and cargo ships.

B. Implications of the findings for the sustainability of the solar energy industry

Political Implications:

China's efforts to develop its PV industry and reduce dependence on foreign technology and markets demonstrate a strategic approach to strengthening its economic and political influence globally. By fostering domestic production, China aims to become more self-reliant and resilient in the face of global market fluctuations and geopolitical tensions. However, the concentration of solar cell production in China raises questions about market power and the potential for global supply chain disruptions. To ensure efficient functioning in the marketplace, liberal economic systems must promote competition and prevent monopolies, encouraging other countries to invest in solar cell production to diversify supply chains and reduce reliance on one country.

The dominance of China in the solar energy industry, particularly regarding raw material supply, raises concerns about geopolitical risks and dependencies. Ensuring a stable and diversified global supply chain for solar PV materials requires international cooperation and

strategic alliances between countries. This can reduce the risk of supply disruptions and promote a more equitable distribution of benefits from the solar energy industry among nations. The research findings suggest the need for international cooperation and collaboration in addressing sustainability challenges in the PV manufacturing supply chain. By sharing best practices, fostering dialogue, and encouraging transparency among stakeholders, countries can work together to promote a sustainable and responsible global PV industry.

Economic implications:

China's solar energy industry has brought many economic advantages, such as cost reductions, innovation and enhanced efficiency that have contributed significantly to its rapid expansion. Unfortunately, due to China's dominance in PV manufacturing and sales, participation from other countries may be limited and this necessitates international collaboration and investment to build production capacities and innovation capability in other countries and create a more diverse and competitive global solar energy market. Indeed, China's dominance in the PV manufacturing supply chain has implications for global trade and economic stability. The concentration of production in one country can lead to potential unfair trade practices and risks to international economic stability. For example, China's dominance in the solar energy industry, particularly in wafer and cell manufacturing, has led to an imbalance in global market competition. The research findings indicate that other countries should be encouraged to invest in solar cell production and diversify their supply chains to promote economic interdependence and reduce conflict over resources. Furthermore, promoting free trade and open markets will ensure fair competition and prevent monopolies, benefiting all countries involved.

Policy implications:

The research findings emphasize the role of government policies and market forces in shaping the solar energy industry in China. The liberalist values embedded in China's 13th Five-Year Plan have promoted market competition and private investment, leading to economic growth. However, striking a balance between economic development and environmental and social sustainability requires a comprehensive policy framework that integrates stakeholder theory and sustainable supply chain management principles. International cooperation in developing such policies can facilitate a more sustainable growth trajectory for the solar energy industry.

Environmental implications:

The increased manufacturing capacity and emissions in China's solar PV industry have raised environmental concerns. The rise in CO2 emissions due to the manufacturing process contributes to global warming and climate change, highlighting the need for further international collaboration to promote sustainable practices in solar PV manufacturing. Additionally, the potential depletion of essential raw materials, such as silicon, silver, tellurium, copper, and antimony, calls for international cooperation in developing alternative materials and promoting recycling practices to ensure the sustainable availability of these resources.

The research results also highlight the need for promoting sustainable practices in the solar energy industry's supply chain, particularly in the production of silicon wafers and transportation of solar modules. The CCP's FYPs have emphasized the adoption of sustainable practices, such as optimizing cutting technology and supporting high-efficiency ingot technology. These practices contribute positively to environmental conservation and long-term sustainability throughout the supply chain. Additionally, the findings suggest that stakeholders should explore ways to reduce greenhouse gas emissions associated with solar PV modules' production and transportation, such as using renewable energy sources during production or optimizing transport routes.

Social implications:

China's dominance in the solar PV manufacturing supply chain raises concerns about the working conditions, labor rights, and health and safety of the workforce involved. Ensuring that the solar energy industry adheres to international labor standards and human rights principles will contribute to the social sustainability of the industry. This highlights the need for a collaborative effort from governments, businesses, and non-governmental organizations to monitor and improve labor practices throughout the supply chain.

Sustainability Issues:

The thesis highlights the sustainability challenges associated with China's dominance in the solar energy industry, particularly in the PV manufacturing supply chain. China's focus on polysilicon production and vertically integrated PV industry has led to concerns about the environmental and social impacts of the industry. In fact, the research emphasizes the

importance of SSCM practices in addressing potential sustainability issues in the PV manufacturing supply chain. Simply adopting sustainable sourcing methods, supporting responsible manufacturing and consumption, decreasing waste, improving working conditions, and involving stakeholders, the sector may balance economic growth with social and environmental responsibility. On the one hand, the industry must address issues such as carbon emissions, energy consumption, and potential contamination of drinking water to minimize negative consequences for local communities and the environment. On the other hand, companies must act ethically and responsibly by considering the interests of various stakeholders, including workers, communities, and the environment, in the PV manufacturing supply chain and ensuring that they do not contribute to human rights abuses or negative environmental impacts.

C. Limitations of the study and suggestions for future research

In this master dissertation, I explored the sustainability challenges that arise within China's solar energy sector, with a particular emphasis on the PV manufacturing supply chain. It is important to note that I am not an engineer, but rather a researcher with a background in economics and international relations. As such, I have navigated into a complex, technical subject that lies outside my primary area of expertise. Nonetheless, I have made every effort to ensure the study is comprehensive, while recognizing that there are certain limitations that may affect the findings and conclusions.

First and foremost, the research relies heavily on secondary data sources, such as existing literature and reports. This approach may limit the study's capacity to provide the most current and in-depth insights into the PV manufacturing supply chain and its sustainability issues. Gathering primary data from industry stakeholders or conducting on-site assessments could offer more precise perspectives on the matter. On the other hand, the analysis is based on stakeholder theory, liberalism, and sustainable supply chain management as its guiding frameworks. While these theories provide valuable insights, incorporating additional approaches or perspectives could enrich the understanding of sustainability challenges within the solar energy industry. For instance, incorporating global supply chain theory into the analysis could have shed light on the interconnectedness of the solar energy industry and highlighted China's dominant role in a more balanced manner. This perspective would allow for a better understanding of how the intricate relationships among various

stakeholders influence the industry's sustainability challenges. By examining the interdependence of different countries and their roles within the global PV manufacturing supply chain, we can gain a more comprehensive view of the factors contributing to the industry's sustainability issues and potential solutions. I may get a more complete understanding of the elements behind the industry's sustainability problems and potential remedies by looking at the interconnectedness of various nations and their roles within the global PV manufacturing supply chain but also with a background in engineering.

VI. Conclusion

In conclusion, the analysis first showed the evolution of the 11th Five-Year Plan, and how the Chinese Communist Party acknowledged shortcomings in photovoltaics. This shows a recognition of technology and innovation as important for economic growth and global impact that led to China's dominant position in the sector. The 11th Five-Year Plan of China, established in 2006 aimed to increase domestic production and decrease dependence on foreign technology. This led to a gradual growth in their market shares within China. Although, it is important to consider the potential consequences for other economies and to uphold fair trading practices. Dominance by a country in an industry may lead to unfair practices such as dumping and anti-competitive behaviors that harm other countries and undermine liberal principles of fair and free trade. Though, many prominent solar panel producers are "vertically-integrated", meaning that they manufacture all the primary components required for making solar PV cells within their company. This strategy will likely continue to accelerate with continued investment from both domestic and foreign firms alike.

The analysis included insights on China's 13th Five-Year Plan to develop and deploy solar energy. We learned that the plan was designed to encourage competition and innovation within the solar energy sector, resulting in cost reductions and increased efficiency. It also sought to reduce China's dependence on coal, which can have serious environmental and medical consequences. This plan is more in line with the liberal philosophy of reducing government interference in the economy and encouraging market competition and economic growth. Nonetheless, China's photovoltaic manufacturing must take into consideration a number of environmental factors. In fact, China has experienced a sharp rise in solar-PV output and emissions, which could be hazardous to the environment because they contribute to the greenhouse effect. Solar PV products also require a large amount of raw materials such

as silicon. If not managed sustainably, this could lead to resource depletion. The management of waste is also important, including the disposal of hazardous materials like lead, arsenic, or cadmium.

The analysis further examined the manufacturing of solar panels, assembly of solar modules, and distribution of the final product, and uses three theoretical lenses - stakeholder theory, liberalism, and sustainable supply chain management - to critically evaluate the issues and challenges associated with sustainable practices in the Chinese solar energy supply chain. The paper discussed the key steps related to the solar photovoltaic (PV) supply chain, its carbon footprint, and the sustainability issues associated with it. It is observed that polysilicon production is the most carbon dioxide-intensive segment of the solar PV supply chain, and the industry must adopt sustainable practices that minimize its carbon footprint. Some of these sustainable practices include using renewable energy sources and implementing carbon capture and storage technology. CdTe, a material commonly used in solar panels, can have negative consequences for environmental health and human wellbeing if contaminated drinking water affects local communities. Therefore, it is suggested that the industry should adopt sustainable practices such as regulating recycling and disposal practices, using bioreactors, and installing dye-sensitized solar cells to address this problem.

Step 1 : China has experienced significant industrialization, which has resulted in the country dominating the production of silicon ingot today. Although this development could be viewed positively, it could pose potential threats to international economic stability, such as unfair trade practices that harm other nations and undermine free and fair trade principles. It is important to consider the potential consequences of China's industrialization on other economies and uphold fair trade practices to ensure that one country's growth does not come at the expense of others.

Step 2: Many solar panel manufacturers in China are vertically integrated, producing all primary components necessary for making solar PV cells within their company. China has developed an extensive supply chain for producing solar panels, likely involving the production of high-quality silicon ingots. However, China's concentration of ingot production may restrict competition, and any decrease in quality could negatively affect the entire global value chain. Moreover, it is critical for manufacturers to source only top-quality ingots to ensure that their solar panels remain efficient and long-lasting.

Step 3: Adopting sustainable practices in the production of silicon wafers not only benefits the environment but also has positive economic and social impacts, promoting long-term sustainability throughout the supply chain. Governments and industries worldwide must prioritize sustainable practices in silicon wafer production and other materials to minimize their environmental effects and ensure the planet's long-term viability. Encouraging economic interdependence and cooperation among states is also essential for maintaining peace and stability, and diversifying the supply chain could reduce conflict over resources.

Step 4: China's technological strides in reducing reliance on imported technology and enabling local firms to run fully integrated production lines have reduced its reliance on other countries. However, the concentration of solar cell production in one country and a few other provinces could raise questions about market power and its effects on global supply chain disruptions. Liberal economic systems must promote competition and prevent monopolies to ensure efficient functioning in the marketplace. Encouraging other countries to invest in solar cell production to diversify their supply chains and reduce reliance on one country could help achieve this goal.

Step 5: Transport-related emissions in photovoltaic (PV) panels come mainly from the assembled module, which accounts for 95% of PV transport-related emissions in 2021. Climate change is largely influenced by the transportation of goods, and China's coast shipping sector emitted approximately 45 million tonnes of CO2 in 2019. Large cargo ships and trucks are the main transportation means for these products, highlighting the need to reduce transport-related emissions to achieve sustainable production and consumption.

Finally, my research findings on the supply chain for the Chinese solar energy industry offer important new perspectives on the effects of Chinese dominance in the fields of international relations and development. I drew multiple implications for the field of international development by investigating the manufacturing of solar panels and the economic and political landscape that surrounds it. Understanding the political, social, economic, and environmental aspects of the solar supply chain will help policymakers, businesses and international organizations work together to promote sustainable practices and responsible sourcing. This collaborative approach could contribute to a more environmentally friendly and equitable growth trajectory for global solar energy.

This research has revealed critical insights into the dynamics of the Chinese Solar Energy Industry's supply chain, which have far-reaching implications on international relations, environmental sustainability, and development. This is only the tip of a very large iceberg. It is important to do more research in order to understand the complex dynamics of this growing industry. Given the dominance by China, what are the challenges and opportunities for greater international collaboration within the solar industry? What are the implications of China's dominance within the solar energy industry for the global economic and political landscape, especially in terms of renewable energy policies and trade deals? Can lessons from the Chinese solar industry's supply-chain be used to guide other renewable energy sectors in the future? Future research can help to gain a better understanding of solar energy by addressing these questions. These investigations may also help to develop innovative policies and strategies that will promote a sustainable and equitable future for global energy.

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