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Renewable energy statecraft and asymmetric interdependence: how the solar energy industry is wielding China with geopolitical power

Daniel de Oliveira Vasconcelos[1]

This article investigates the geopolitics of the energy transition era, concentrating on China's solar photovoltaic (PV) industry. Authors have noted that the rise of renewables is changing the geopolitical landscape of world energy systems, but these new energy sources carry their own technical characteristics and geopolitical implications. Bearing this in mind, this research answers the questions: What are the structural factors that facilitate China's use of renewable energy to achieve political goals, and what are their implications? In order to analyze the data, I devise an analytical framework based on the energy statecraft literature and contrast rival explanations, particularly the "prosumer theory" and the premise of less geopolitical interdependence in a renewable-centered world. I show that asymmetric interdependence in the solar PV sector is already a reality. China's solar PV industry is a case that suffices all conditions (centrality in industrial capacity, market share, and companies' compliance, but to a lesser extent in critical materials and technological endowments) in the solar PV sector to devise effective strategies aimed at reaping benefits out of its asymmetric interdependence with the rest of the world.

Keywords: China, solar energy, energy statecraft, asymmetric interdependence, renewable energy

1 (Corresponding Author) Master in China Studies (Politics and International Relations) from the Yenching Academy of Peking University. Email: daniel.vas2@gmail.com. Orcid: https://orcid.org/0000-0002-8675-6727.

1. Introduction

The Geopolitics of fossil fuels has often occupied the minds of policymakers preoccupied with their nation's energy needs. Recently, however, due to the climate change agenda, they are turning their attention to renewables as a viable alternative to the risky business of oil politics. To Scholten et al (2020, p. 3), "we are already witnessing a process of creative destruction in global energy markets." This is thus transitioning the world into a "new geopolitical landscape that affects the national security interests of all countries" (Pascual, 2015, p. 6). More importantly, as Scholten et al (2020, p. 4) concluded, "The geographic and technical characteristics of renewable energy systems are fundamentally different from those of coal, oil, and natural gas. In turn, the geopolitics of renewables will look very different from the geopolitics of fossil fuels." For this reason, it is imperative to comprehend how states are adapting their energy policies and foreign policy goals to leverage their position in this new energy transition era, which is set to last for the foreseeable future.

Although the geopolitics of renewable energy is in the spotlight, with a growing interdisciplinary literature surveying the many facets of a world to be dominated by renewables, there are still some major gaps that should be addressed. In a comprehensive review of the literature, Vakulchuk, Overland and Scholten (2020) identified that authors are mainly concerned about the implications for states, such as whether the rise of renewables would bring more peaceful relations and who would be the geopolitical winners. However, they also alerted for the lack of theorization in the field, the absence of differentiation between the energy transition phase and a hypothetical renewable-based world energy system, and that only a few studies "distinguish between different types of renewable energy and their geopolitical consequences" (Vakulchuk, Overland & Scholten, 2020, p. 8). In order to address these gaps and shed some light on the geopolitical importance of renewables to the present world, this article investigates the geopolitics of solar energy in the energy transition era, concentrating on China's solar photovoltaic (PV) industry.

According to the International Renewable Energy Agency (IRENA), solar PV power alone will comprise 25% of the world's total power generation mix by 2050 (IRENA, 2019), elevating at great lengths the geopolitical importance of renewables. Meanwhile, Chinese renewable energy companies are flooding international markets with their energy technology and products. If, on the one hand, it has contributed to plummeting costs, on the other, countries and enterprises must rely on Chinese stakeholders and comply with their strategic interests. There was an astonishing surge in solar energy installed capacity in China over the last decade. Figures show that in 2010 the solar PV installed capacity was less than 1 GW (Wang, 2014). In 2020 alone, China has added over 70 GW, accumulating 253 GW (IRENA, 2021). Now, China's solar enterprises are 8 amongst the 10 biggest companies in the world and Chinese solar manufacturing represents 80% of the world's total (Rapoza, 2021). Notably, the world has become intrinsically dependent on China's solar industry; asymmetric interdependence is the new *status quo* in this renewable energy sector.

What are the domestic and external structural factors that facilitate China's use of renewable energy in creating asymmetric interdependence in the sector? How China is leveraging its renewable energy sector to achieve political goals, and what are their implications? To answer these questions, this paper provides a case study of the solar panel industry in China, deriving from the energy statecraft literature an adapted conceptual framework that takes into account specificities of the geopolitics of renewables. To analyze the data, I contrast it with rival explanations already present in the literature, in special the "prosumer theory" (Scholten & Bosman, 2016; Scholten et al, 2020), the premise about the innate decentralization of renewable energy systems, and key assumptions – or lack thereof – regarding the energy transition period, such as renewables purporting less geopolitical interdependence (Vakulchuck, Overland & Scholten, 2020).

This article first presents a review of the energy statecraft literature, followed by a conceptual framework that analyzes the geopolitical dynamics of the solar PV sector. Subsequently, I delve into the development of renewables in China, focusing on the main characteristics of its solar PV industry. I then explore the main variables that contribute to an asymmetric interdependence between China and the rest of the world. Finally, an analysis of China's tools and strategic goals and the geopolitical implications they entail is laid out, along with some concluding remarks.

2. Renewable Energy Statecraft: an analytical framework

The use of economic instruments by states to pursue strategic goals is deemed by many as a "war by other means" (Blackwill & Harris, 2016; Vasconcelos, 2019). Hirschman (1980), for instance, understood that in a world of asymmetric economic interdependence, countries are capable of exerting influence over their trading partners through direct economic coercion or indirect political influence. Likewise, Drezner (1997) investigated the many occasions that states produced "economic coercion," particularly through economic sanctions. Notwithstanding, the overwhelming emphasis on the negative use of economic instruments missed the complexity of economic interdependencies in a highly globalized world. Baldwin (1985), on the other hand, proposed to define economic statecraft as the deliberate use of economic policies "so as to promote the foreign policy goals of the state – whatever those may be" (Baldwin, 1985, p. 77). In this sense, states devise not only negative but also positive inducements to other international actors (Baldwin, 1985).

Owing to this emphasis on negative sanctions, the literature overlooked long-term strategies that don't entail immediate outputs. Consequently, many conceived that economic statecraft was doomed to fail regardless of what tools were applied, what goals were set, and whether other options were even at the government's disposal. Against this background, Mastanduno (1999) claims that economic instruments are brought into play by states both through short-term and long-term attempts, in which "the assessment of success or failure could only be made convincingly by comparing costs and benefits of economic statecraft to that of other forms of statecraft" (Mastanduno, 1999, p. 290). Furthermore, the intentional attempt of states to use economic instruments also rests on their ability to convey their interests through commercial actors (Norris, 2010). The rate of success to control the economic means would be conditional on the number of commercial actors in the market and how converging they are with the goals of the states, along with the latter's resource endowments and the magnitude of the economic interaction (Norris, 2010; 2016).

In the aftermath of the two "oil shocks" of the 1970s researchers also identified energy resources – at that time, fossil fuels – as instruments of foreign policy. Energy has thus far become an indissociable component of a country's grand strategy (O'Sullivan, 2013). According to Van de Graaf and Sovacool (2020), the strategic nature of energy, coupled with present-day globalization, made it possible to "weaponize interdependence" through energy flows, energy price, and energy infrastructure. But similar to the economic statecraft tradition, the literature on energy statecraft focused on the negative instruments, such as energy interruption and price manipulation (Balmaceda, 2013; Hughes & Gholz, 2016). Balmaceda (2013), nevertheless, shows that asymmetric interdependence hinges on multiple variables beyond the realm of the energy geopolitics, such as national institutions, trade balance, and other geopolitical competition or cooperation.

Asymmetric interdependence is key to understanding energy statecraft (Stulberg, 2007). Distancing from the over-reliance on negative sanctions, Stulberg (2007) contends that the "strategic manipulation" of energy resources may elicit patterns of compliance, defiance, and mutual accommodation in a geopolitical arena where states take advantage of their comparative advantages. In a word, energy resources will be applied according to a nation's strategic goal and may be comprised of negative or positive inducements. The more a state reckons its position is advantageous vis-à-vis others, the more it will leverage their interdependence. Dalgaard's study of Brazil's "ethanol diplomacy" in Africa provides a framework to energy statecraft as a "category of its own" (Dalgaard, 2017), which also widens the scope of the concept, allowing, for example, the historically neglectec analysis of non-fossil sources. According to him, negative sanctions function better when are "short-term, tactical" in nature, whereas positive inducements used "to shore up alliances and to build support for certain ideologies and national security positions" take the long road (Dalgaard, 2017, p. 138).

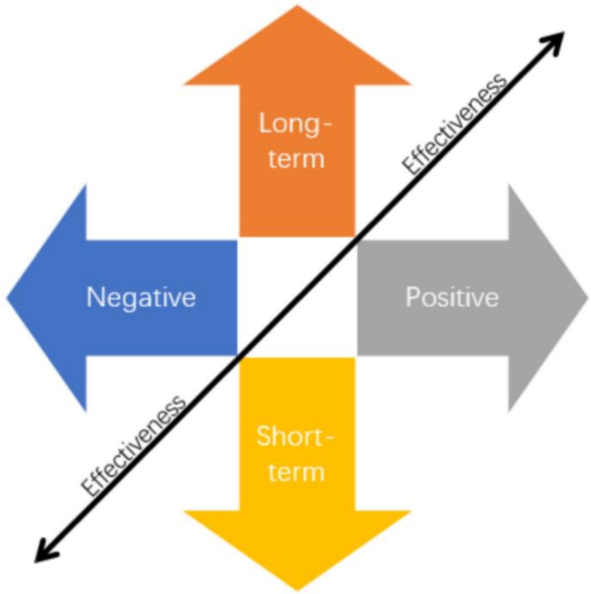

Figure 1. Strategic paths for energy statecraft. Source: Vasconcelos, 2019

Tsakiris (2004) and others only acknowledge fossil fuels as viable tools of energy statecraft. However, as I noticed elsewhere (Vasconcelos, 2019), due to the unreliable, unsustainable international energy security context and emerging environmental issues, it is also conducive for states to regard renewable energy capabilities as sources of energy statecraft. But, as Van de Graaf and Sovacool (2020) contend, "renewable energy has its own geography or trade. Generally speaking, renewables like solar and wind represent a shift from fuel markets to hardware markets." This means that, although we can resort to energy statecraft to analyze the geopolitics of renewables, the theoretical framework should also provide scope for the specificities of different energy sources. Criekemans (2018), for example, argues that "different types of renewable energy create their own specific 'geo-technical ensemble'" and create "new dependencies" in critical materials. Different from fossil fuels, in which geopolitical issues are deeply entwined with energy supply and power struggles that often result in negative influences, renewables are related to trade patterns, long-term investments, and soft power.

In the case of renewables, states employ distinct tools as instruments of energy statecraft. They can manipulate prices, technology transfers, or investment flows. Moreover, they may control transmission lines and the supply of critical materials needed to produce renewable energy equipment. The degree to which a nation can leverage these renewable energy capabilities will depend on sector-specific variables related to 1) the stock of critical materials and the autonomy to supply its industry with them; 2) industrial capacity, measured by the manufacturing capabilities throughout the supply chain; 3) the market share its companies hold in the international market, for trade and investment; 4) technological endowments, such as patents, that secure the country to innovate in the sector; and 5) how companies comply with the country's strategic goals, based on the government's regulatory power and ownership. As shown in Figure 2, the sanctioning state may take advantage of the abovementioned variables to influence other states – through positive inducements or negative sanctions – and create an asymmetric interdependence that is beneficial to its grand strategy.

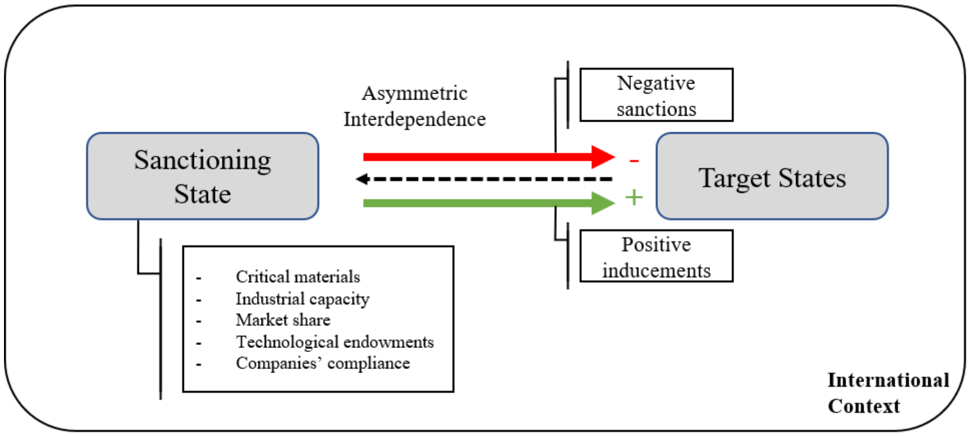

Figure 2. Renewable energy statecraft. Source: author

Some authors (Scholten and Bosman, 2016; Stegen, 2018; Scholten et al, 2020) adhere to the "prosumer" theory to explain the geopolitics of renewables. To them, "the widespread presence of renewable energy sources harbours the possibility of many producers, empowering consumer countries, and enables countries a make or buy decision" (Scholten & Bosman, 2016, p. 281). Consequently, "such trade relations are symmetrical, because the dependence is mutual. Thus, in a renewable energy world, we could expect greater self-sufficiency and/or mutual dependence" (Stegen, 2018). Yet, although they concede that some renewables might "reinforce geopolitical rivalry and fierce geo-economic competition among states" (Scholten et al, 2020, p. 5), these assumptions overlook the power dynamics present in the energy transition phase, which is set to last for the foreseeable future. Conversely, the framework I propose does not set pre-established "truths" for the geopolitics of renewables and is open to empirical validation from the ground up. Resource endowments are unevenly distributed, so technological and trade competition for renewables is fierce. Furthermore, "fossil fuels markets will not wither away overnight and, even if some low-carbon technologies may decentralize the energy system, they are embedded in globally interdependent flows of knowledge, trade, and investment" (Van de Graaf & Sovacool, 2020). As we will see, solar energy is an evident case that the geopolitics of renewables creates challenges of their own.

3. Renewable Energy in China: the case of the solar PV industry

Due to its investment-led development model and its rapid economic growth, China resorted to fossil fuels – particularly in coal – to meet the domestic energy demand (changing lifestyles, such as increasing reliance on cars and higher incomes converted into consumption) and avoid relying on external energy suppliers. This, however, did not prevent China's dependency on imported oil, which comprises 70% of domestic consumption and may reach 80% by 2030

(Jaffe, 2018). Moreover, the over-reliance on coal, reaching 90% of its energy mix in the 1950s and 75% in the 2000s (Vasconcelos, 2018), entails far-reaching consequences to the Chinese economy, its environment, and public health. China's demand for coal represents half of the world's total (Energy Charter, 2017) and between 80% and 90% of emissions of pollutants among all the energy sources in China (Fan & Hao, 2020). Owing to this hazardous environment, over 1.5 million pollution-related deaths are registered every year (Chiu, 2017). Therefore, energy security and other environmental concerns due to more frequent climate-related natural disasters, along with popular discontent (Dent, 2014), propelled the Chinese government and the private sector to prioritize the development of renewable energy capabilities.

Since the 1980s, after the Environmental Protection Law and the 6th and 7th Five-Year Plans (FYP), renewable energies in China received ample governmental incentive. The Renewable Energy Law, promulgated in 2005 and amended in 2009, established five market interventions to foster deployment, generation, and grid connection (China, 2013; Wang 2014). If before the 10th FYP the Chinese government focused on economies of scale and reducing costs, by 2006 they turned to research and development (R&D) to address the many bottlenecks that were holding back technological breakthroughs in the sector (Ball et al, 2017). Special attention should be given to the 13th FYP, which set ambitious goals for renewable energy technological upgrades, and the "Energy Production and Consumption Revolutionary Strategy (2016-2030)." Furthermore, not only subsidies and industrial policies played a relevant role, but also the "state-led marketization" that granted autonomy and support, apart from control, to corporations (Chen, 2012). In the case of renewables, stakeholders from the industry participated in the policy-making and offered technical support to the government (Shen, 2017).

This state-industry symbiosis unleashed a remarkable growth of renewable energy and infrastructure in China. Since the promulgation of the Renewable Energy Law in 2005, the installed capacity of wind and solar energy surpassed every plan. In 2005, the total installed capacity for wind was 1.26 GW (Mathews & Tan, 2015), whereas for solar was 0.8 GW (Wang, 2014). In 2020, wind energy reached 281.5 GW and solar amassed 253 GW of total installed capacity (Xu & Stanway, 2021). According to BP (2020), renewable energies will be responsible for 34% to 55% of the total energy generation in China by 2050. These figures go beyond any goal previously set by the government. For example, according to the 13th FYP, by 2020 China would have installed 100 GW in solar energy (Ball et al, 2017). Although there are many challenges to further development, such as curtailment, grid connection, residential and industrial adaption, renewables emerged as a successful case of industrial development and technological sophistication – not only replication.

This is particularly true for the solar PV industry. According to Zhao et al (2013), the development of solar energy capabilities can be divided into three stages: the germination (1958-1970s), when a Chinese institute developed and manufactured the first solar cell and a few factories were established in Shanghai, Ningbo, and Kaifeng; the seedling phase (1980s-1990s), comprising the first deployment of a 10 kW PV station in Tibet, the emphasis on monocrystalline and polysilicon solar cells research, and the first export of PV products; and the growth state

(2000s to present), with a rapid increase in PV manufacture, diversification in the supply chain (Zhang & He, 2013), and greater R&D to enhance cell efficiency and equipment technology. Several laws, regulations, and policies were promulgated by the Chinese government throughout these periods (Zhao et al, 2013; Zhang & He, 2013; Hsiao et al, 2021). Among these, the 13th FYP For Solar Energy Development, issued in 2016, set high bars for technological upgrades, large-scale manufacture of "advanced crystalline-silicon" solar cells, and deployment (Ball et al, 2017, p. 92).

Subsidies, such as the Feed-in-Tariffs, had a significant impact on the solar PV industry and even bounced positively to other sectors (Hsiao et al, 2020). In some cases, governmental support via subsidies accounted for 50% of the total invested in PV power generation projects (Zhao et al, 2013, p. 236). However, as Ball et al (2017) found out, solar energy corporations are performing better than before and increasingly detaching from government assistance. They are also supported by an R&D ecosystem (Ball et al, 2017, p. 80) where top Chinese universities and institutes partner with PV companies to produce more sophisticated domestic technology in the sector. Currently forming a world-class industrial complex, the Chinese solar PV companies concentrate their business operation in the Yangtze River Delta (Ball et al, 2017, p. 118). Among them, Jinko Solar, Canadian Solar, JA Solar, Trina Solar, Yingli Solar, and others, top the world's biggest solar manufacturers. Through their "accelerated internationalization" (Mathews & Tan, 2015), the Chinese government is leveraging positive externalities derived from renewables' development overseas to its favor. The domestic infrastructure and policy ecosystem have thus contributed to this major push in the renewable energy sector, especially in the solar PV industry, allowing them to further their operations overseas.

4. Asymmetric Interdependence in the Solar PV Sector: China at the core

Renewables are set to increase their share in the world energy generation dramatically by 2050. But conceptualization, production, and deployment of renewable energy sources are unequally distributed among nations. Only a few countries master the technology to produce highly efficient solar PV modules and windmills. Likewise, China's industrial capacity overpasses any other country. Therefore, it is not yet a *fait accompli* the argument from proponents of a green political theory that a renewable energy-based world will be friction-free, or will be a "shift towards less oligopolistic global markets" (Scholten et al, 2020). Compared to fossil fuels, the geopolitics of renewables is no longer a race for resources as much as they are for access to technology and supply chains (Bazilian, Sovacool & Moss, 2017). Today, the distribution of renewable energy endowments is very asymmetric, which creates hierarchies in the global energy interdependence.

This is certainly the case with solar PV energy. The cost of electricity from solar PV plummeted 77% from 2010 to 2018 (Van de Graaf & Sovacool, 2020). Average LCOE (Leveled Cost of Energy) for solar PV fell from 0.37 USD/kWh in 2010 to 0.06 USD/kWh in 2019, and this is very close to the cost of hydropower, 0.04 USD/kWh in 2019 (IRENA, 2020a). According to IRENA (2020a), this was driven by the reduction in PV modules price, improvements in capacity and efficiency (technological upgrades), which allowed more countries to deploy solar

PV at an affordable price. Solar PV installed capacity worldwide then hit 707 GW in 2020 (IRENA, 2021). However, the Solar PV industry is a technology-intensive sector, depending on high levels of R&D and industrial capacity. Although it is not the absolute leader in the solar energy sector, China drives the global market with its total installed capacity, production throughout the supply chain, and control of critical materials, but lags behind in sophistication. Below, I analyze the five factors that impact China's Solar energy statecraft.

In order for a country to foster a domestic industrial solar PV complex, firstly, it must secure a reliable, uninterrupted supply of critical materials that compose the solar modules. Solar power depends on Bauxite and Aluminum, Cadmium, Copper, Gallium, Germanium, Indium, Iron, Lead, Nickel, Selenium, Silicon, Silver, Tellurium, Tin, and Zinc (Vakulchuk, Overland & Scholten, 2020). These critical materials are found sparsely worldwide, but only a few countries detain large reserves and produce at an industrial level to supply global markets. Unsurprisingly, China tops the world producers and, in some cases, such as the so-called rare-earths, over 90% of global total production are located there (Stegen, 2018; Klement, 2021). Some authors reckon that, due to the capital intensity and high cost of mining and processing of these critical materials, China will further monopolize this sector in the coming years (Vakulchuck, Overland & Scholten, 2020). However, data collected from the U.S. Geological Survey (see table 1) suggests that China is far from monopolizing this market. Expect for Gallium, and perhaps to a lesser extend Germanium, Silicon, and Tellurium, China depends more on the world supply than is able to export to other countries. Moreover, since China is by far the largest producer of solar PV modules (see below), it relies on imports of these materials from multiple partners, such as Australia, Brazil, and Indonesia, which creates a rather fragmented, interdependent supply chain. This doesn't mean, however, that China is not trying to upscale its preeminence in critical materials' markets. To reduce its dependence abroad and prevent shortages at home due to its "high burn rate," China is pressing for broader Chinese-owned mining and mineral processing assets worldwide (Malkawi, 2020).

Table 1

Production of Critical Materials for Solar Modules and China's Share in the World Market.

Production (2019)	*China*	*World (excluding the U.S.)*	*China's share in the world market*
Aluminum	36,000	64,000	56.2%
Alumina	73,000	130,000	56.1%
Bauxite	75,000	370,000	20.2%
Cadmium	8,200	25,000	32.8%
Copper	1,600	20,000	8%
Galium	310,000	320,000	96.8%
Germanium	85,000	130,000	65.3%
Indium	300	760	39.4%
Iron ore (usable)	350,000	2,500,000	14%
Lead	2,100	4,500	46.6%
Nickel	110,000	2,700,000	4%
Selenium	930	2,800	33.2%
Silicon	4,500	7,000	64.2%
Silver	3,600	27,000	13.3%
Tellurium	290	470	61.7%
Tin	85,000	310,000	27.4%
Zinc	4,300	13,000	33%

Source: USGS, 2020.

Apart from critical materials, the solar PV supply chain is composed upstream by the polycrystalline silicon, ingots, and wafers, downstream by solar cells and modules, and the installation segment, in which modules are installed and connected to the electricity system (Zhang & He, 2013). In every aspect, Chinese companies are the top producers, with large industrial capabilities. According to the IEA (2019), China's share in global PV manufacturing and demand reached almost 50% in 2017. In 2016, "China accounted for 52% of polysilicon manufacturing capacity, 81% of silicon-solar-wafer manufacturing capacity, 59% of silicon-solar-cell manufacturing capacity, and 70% of crystallinesolar-module manufacturing capacity in the world" (Ball et al, 2017, p. 110). Some estimate that Chinese production of polysilicon now reaches 64%, ingots and wafers correspond to 99%, solar cells at 80%, and modules at 75% (Ferry, 2021). The US' only representative business is in polysilicon production with 11%, whereas the rest of the world combined meagerly produce and advance their industrial capabilities upstream and downstream relative to China.

Different from wind and hydropower market dynamics, the solar PV industry relies on trade, rather than investment, as the dominant mode of global economic integration (Tan et al 2013). This means that investment plays only a minor role in the solar PV sector, but it is still of great importance, especially when countries impose trade barriers. China's solar PV industry was export-oriented since its inception (Dunford et al, 2012), and it is only recently that domestic deployment has been catching up. On the other hand, in Germany and the US, for instance, the production is domestic-oriented. Worldwide Solar PV module shipments – which corresponds to exports – in 2019 was equivalent to 124 GW of installed capacity, of which China amassed 78 GW (62.9%), followed by Malaysia (15 GW), Vietnam (10 GW), Taiwan (7 GW), and the Republic of Korea (5GW), with the remaining 9 GW corresponding to the rest of the world combined (IEA, 2020). Nonetheless, an important caveat is that a considerable part of shipments from Malaysia and Vietnam also comprised exports from Chinese companies that invested locally.

The Solar PV industry is a technology-intensive sector. It has been the leading technology among all energy sources in patent applications since 2009 (Nurton, 2020). The cumulative patents in the solar PV were 59,963 in 2009, whereas in 2019 it reached 212,590 (IRENA, 2020b). Japan takes the top position between 2010 and 2019 in patents for solar, but China witnessed a surge in patent applications in the last years. Japan accumulated 5,360 patents, followed by the U.S. (3,876), China (1,892), Republic of Korea (1,803), and Germany (1,534). However, when we compare the patent families in solar energy, China has three times the number of Japan (Nurton, 2020). Although China concentrates the new patent applications, this doesn't mean that the technological sophistication of Chinese solar PV products equals those of Japan or Germany. Recent studies show that China is still inefficient in clean-tech innovation compared to other countries (Klement, 2021, p. 17). Cao, Rajarshi and Tong (2018), for instance, found out that China's renewable energy products exported between 2007 and 2016 were mainly composed of medium and medium-high technical complexity.

Finally, a defining characteristic of the solar PV industry is that the largest producers are private companies. Even in China, where the State-owned enterprises (SOEs) dominate the energy sector – State Grid and China Three Gorges as prime examples –, the main PV manufacturers and operators of solar PV stations are private entities. The Chinese government upholds relatively high control over foreign direct investments (FDIs) with the oversight of SASAC (State-owned Assets Supervision and Administration Commission) of the State Council. Conversely, the export-oriented economy is relatively autonomous in their overseas sales. Due to the level of government subsidies to private companies and R&D investments, along with converging interests (Vasconcelos, 2019), Chinese companies comply with the government's policies. This is not unique to China, however. Because it is still considered a nascent industry, major countries in the sector also resort to governmental subsidies and proximate state-company relationships, creating symbiosis among national stakeholders.

Evidently, the relations in the solar energy sector between China and the rest of the world stem from asymmetric interdependencies throughout the industry's supply chain and international trade. A few countries still produce better PV modules, but don't have China's manufacturing capabilities. Overall, however, most nations resort to trade with China due to low prices and relatively high efficiency. China also depends on this trade in order to clear up its companies' over-capacity and financial burdens, along with critical materials that it is short of production. As more countries seek investments in renewable energy to address environmental issues and boost their energy security, solar energy will increase in importance in global energy geopolitics. China stands out as the key player in the sector, withholding enough capabilities to rack up geopolitical gains, but other countries are still central in technology (Japan and Germany) and the supply of critical materials (Australia, Brazil, Indonesia, etc.). In this geopolitical context, how does China use these capabilities, and with what goals in mind?

5. China's Use of Renewable Energy Statecraft

In a world that is still dependent on fossil fuels, where renewable energy is but a nascent industry (though a strategic sector in the long-term), there are systemic constraints against the use of renewables as negative influence attempts of energy statecraft. In this case, the strategic manipulation of renewables, although susceptible to occasional short-term, negative sanctions, is often used to foster win-win cooperation among states. Investments and trade in the solar PV industry, for instance, facilitate the recipient country's transition to a greener energy mix, and alleviate its dependence on fossil fuels. In the energy transition era, states don't have incentives to use solar energy as "sticks" but rather as "carrots." That is the case of China. Since the "accelerated internationalization" of its solar PV enterprises, the overall behavior is positive in nature. China is playing a long-term, positive engagement with other nations, leveraging the current asymmetric interdependence in the sector to accumulate soft power, enlarge its market share, and uphold its energy security.

According to Joseph Nye, soft power is the ability that a country has to co-opt other actors to emulate or desire the same outcomes rather than coerce them (Nye, 2004). In this sense, it is different from hard power in terms of its tangibility: soft power attracts through values, policies, and culture. The idea to use renewables as sources of soft power is also present in China's energy geopolitics. The Chinese government aspires to become the champion of green development and lead by example on the transition toward a low-carbon energy system. Xi Jinping, for instance, announced at the 2020 United Nations General Assembly that China would have installed 1,200 GW of wind and solar energy capacity by 2030, and would reach "carbon neutrality" by 2060 (Meidan, Andrews-Speed & Qin, 2021; Xi, 2020). This pledge can be conceived under Xi Jinping's "ecological civilization" framework (Xiang-chao, 2018), which is intended to guide China – and the world – toward a more sustainable future. Accordingly, in the latest Energy Policy White Paper published by the State Council, from December 2020, China vows to "guide global cooperation in climate change," lead the South-South cooperation to promote and "improve low-carbon energy access in developing countries" (State Council, 2020).

The White Paper provides examples of investments in solar energy that go according to these goals, such as the Kaposvar PV power station project in Hungary, the PV solar power project, Noor Energy 1, in Dubai, and the solar PV power project in the Quaid-e-Azam Solar Park in Pakistan. It also refers to some other instruments of energy statecraft that bear close relation to soft power. Among them, China was the Co-host of the International Forum on Energy Transitions in cooperation with the IRENA and other international organizations, the proponent of the Shanghai Cooperation Organization Energy Club, the Host of the APEC Sustainable Energy Center in China, the proponent of the BRICS Energy Research Cooperation Platform, and a founding member of the IEA's new Energy Efficiency Hub (State Council, 2020). Moreover, China's energy giants, such as State Grid, China Three Gorges, and China General Nuclear (CGN), are diversifying their portfolios with overseas investments in the renewable energy sector (Springer, 2020). In another study (Vasconcelos, 2019), I noticed that these companies were also conveying a better image of China as a green investor. This diplomatic thrust in the global energy governance feeds on the development of solar capabilities in China, investments and trade, but also reinforces Chinese companies' outreach in the international market. Due to China's industrial capacity and growing engagement, exports of solar PV modules are also carrying the government's soft power goals as the leader in green development.

However, when it comes to the world of economic competition, China's stance in the solar PV sector is deemed ambiguous by other nations. Zhao et al (2019), for instance, found out that energy cooperation along the BRI was very asymmetric, with 24 countries out of 25 surveyed engaging passively with China. China oversupplied the market with solar PV modules (Jordan, 2014). Some countries accused China of blocking access from overseas manufacturers to rare earths in 2010 and 2011. Likewise, the United States imposed anti-dumping tariffs on solar cells in 2012, which were followed by Europe (Ball et al, 2017). Recently, however, a trade agreement between China and the US tried to soothe these tensions by setting import targets, which so far haven't been met (Meidan, Andrews-Speed & Qin, 2021). Stulberg (in Dalgaard, 2017, p. 284) contends that a sanctioning state wields "significant market power in energy if it controls roughly 30% of supply and exports to foreign markets." As we have seen, China has surpassed this to a large extent, prompting backlash from other countries.

With Europe and the US on the defensive, China's market power will be felt in the developing world, where countries are struggling to clean their energy mixes. In particular, for countries whose territories provide great potential for solar energy (see map in Klement, 2021, p. 35), Chinese companies may supply them with PV modules and energy infrastructure. Because of this, China's ambitions of upholding market power in the solar PV industry also entwines with grid connection and electrification of energy systems. This dependence puts other nations' energy security at China's will. If countries intend to meet the targets for energy generation to curb climate change, experts estimate that solar and wind energy will require investments at $4.2 trillion and $5.3 trillion, respectively, by 2050 (Klement, 2021, p 20). By being able to use various instruments of renewable energy statecraft, such as trading PV modules at diminishing prices, controlling the supply of critical materials and the energy transmission through Chinese grid operators, and investing in solar PV farms, China can leverage its market share to bolster its own energy security.

Energy security is indeed China's primary goal with the development of its solar PV industry. As stated in the Energy Policy in 2012 and further updated in 2020, China's energy security strategy is based on "Four reforms and one cooperation," which includes reforms to improve energy consumption, build a diversified energy supply system, upgrade the innovation in the industry, and optimize the energy market, along with "comprehensive cooperation with other countries to realize energy security in an open environment" (State Council, 2020). Consequently, it remains "committed to an energy revolution, and move faster to build a clean, low-carbon, safe and efficient energy system, to lay a solid foundation for basically achieving socialist modernization in 2035 and becoming a great modern socialist country by the middle of the 21st century" (State Council, 2020). Intensive development in the solar PV industry is crucial to fulfilling these goals, as China's gargantuan energy needs won't stall in the foreseeable future. In the current energy transition phase, dependence on fossil fuels is still China's Achilles' heel and the biggest threat to its energy security. Coal and oil imports are still needed to supply the domestic market, but produce notorious effects on the environment and public health.

Furthermore, this dependence ensues China's more pro-active stance in the Middle East in order to secure reliable partners to supply the domestic market. Conversely, solar energy reduces air pollution, is locally supplied, and admits decentralized capital inversions, as the cost of the infrastructure is reduced compared to coal, hydropower, or even wind (Criekemans, 2018). Despite solar's energy generation intermittence, China's world-class grid infrastructure, comprising 31 UHV (ultra-high voltage) transmission lines (Ye & Yuan, 2021), and guaranteed supply of critical materials facilitate solar PV's penetration in the energy mix, which reduces external dependence in the entire energy sector, from raw materials to generation and distribution of electricity.

What are the geopolitical implications that stem from China's search for soft power, market share, and energy security? Scholten et al (2020, p. 4) contended that "Great power relations will become less underpinned by access to and availability of energy sources and asymmetric trade and infrastructure interdependencies." But this assumption may not hold true in the energy transition period. Indeed, as countries turn to the domestic generation of electricity from renewable energy sources, they will depend less on the "fossil-fuels based energy system [which] is fundamentally asymmetric and a driver of tension" (Scholten et al, 2020, p. 4). On the other hand, as shown above, China not only is cementing its ambitions in the solar PV industry to safeguard its energy security, it's also causing seismic moves on the epicenter of energy geopolitics, which was once located in Europe (coal), relocated to the Middle East (oil), and now is lured to China. Asymmetric trade is already a reality throughout the solar PV supply chain, whereas grid infrastructure won't be free from interdependencies. Bottlenecks in grid electricity are ubiquitous, where another US$ 11.4 trillion of investments are needed to support renewable energy's ascension (Klement, 2021, p. 21-22). In this regard, State Grid has also set up a plan in 2016 to build a Global Energy Interconnection, devised to cover all continents and integrate "distributed power generation from renewable sources" (Klement, 2021, p. 22). In sum, as the world became dependent on the Middle East's oil in the past, a sustainable future might be equally dependent on China.

6. Conclusion

Perhaps prophetically, Deng Xiaoping asserted in his 1992's Southern Tour that "the Middle East has oil, China has rare earths" (Criekemans, 2018). Similarly, though in a somewhat alarmist tone, Rapoza (2021) wrote to Forbes that China was turning into the "green OPEC." What these remarks have in common is the assumption of China's centrality in the renewable energy sector. As we've seen above, China suffices all conditions (centrality in industrial capacity, market share, and companies' compliance, but to a lesser extent in critical materials and technological endowments) in the solar PV sector to devise effective strategies aimed at reaping benefits out of its asymmetric interdependence with the rest of the world. These strategies are best designed if positive and long-term vis-à-vis other countries. But even if China only engages positively in the solar energy sector, the geopolitical implications of its renewable energy statecraft might be beyond its control. For developed countries, growing suspicion might lead to more trade and investment barriers, whereas for developing nations China's renewable energy revolution could be seen as a successful case to be emulated.

Authors often regard geopolitics as permeated by conflict and zero-sum games; but the geopolitics of renewables also entails other dimensions of inter-state relations, such as competition, cooperation, and soft power. In this article, through a theoretical framework that adapts to the looming geopolitics of renewables, I showed that asymmetric interdependence in the solar PV sector is already a reality. Far from the idea that renewables produce mutual dependence (Stegen, 2018) or decentralize the supply of raw materials, equipment, and technology (Scholten & Bosman, 2016), China's solar PV industry is a case that asymmetric interdependence also exists in green politics. However, as I've argued, this doesn't necessarily mean that China will use its solar energy capabilities as weapons. Systemic constraints force China to promote energy cooperation and foster mutual energy security through trade and investment in the solar PV sector, even if occasional demonstrations of hard power occur.

The exact degree of this asymmetric interdependence, and the effectiveness of China's use of solar PV as an instrument of renewable energy statecraft to pursue its strategic goals, would be better understood in bilateral relations, which transcends the scope of this study. Further research, therefore, should bear in mind the implications of such asymmetric interdependence on a case-by-case basis. Blanchard and Ripsman (2008), for instance, offer a "conditionalist model" that helps to investigate the target state's level of "stateness" and its ability to resist the sanctioning state's policies. This, with the framework I laid out in this article, may offer a basis to further analysis about the effectiveness of renewable energy statecraft. Nevertheless, for this energy transition period, we already witness irrevocable trends in the geopolitics of renewable energy: China's predominance in the solar PV sector may be beneficial to other nations which dream to clean their energy mixes, but the former amasses most of the geopolitical gains for being in the center of the energy revolution that will define the future of the planet.

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