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Concentrated Solar Power deployment in emerging economies: The cases of China and Brazil

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ABSTRACT

This paper debates the main reasons why Chinese and Brazilian energy policies have not focused on Concentrating Solar Power (CSP) deployment until now. Like most emerging economies, China and Brazil have registered large increases in energy demand, as well as considerable growth of energy-related greenhouse gas (GHG) emissions. On the other hand, both countries have played an important role on the expansion of renewable energy infrastructure and – considering that large portions of their territories present high levels of "Direct Normal Irradiation" (DNI) – CSP technologies might have figured as an important strategy for the mitigation of atmosphere pollution and global warming. Since large scale deployment of CSP technologies still implies high "Levelized Costs Of Electricity" (LCOE) that could affect the competitiveness of national industry in global markets, we argue that a comprehensive answer for this question must place national energy policies in the context of a "world-system" analysis. CSP has not benefited from the international demand that has boosted wind turbines and photovoltaic cells with their subsequent price reductions. Furthermore, we will discuss the "elective affinities" between thermal solar investments and the development of those regions that present the lowest performances in the Chinese and Brazilian socioeconomic realities.

1. Introduction

Global energy consumption data illustrates a geopolitical shift towards a more decisive role of the Global South in international affairs. According to its "New Policies Scenario", the IEA states that "the center of gravity of global energy demand moves decisively towards emerging economies", which are to be responsible for nothing less than 90% of net energy demand growth to 2035 [1]. China and India will continue to lead this trend, followed to a lesser extent by Southeast Asia and the Middle East. In the Western hemisphere, it is expected that Brazil will reinforce its position as energy producer due to the recently discovered enormous oil sands reserves. In addition, Brazilian internal energy consumption tends to increase from the current 267–480 Mtoe in 2035, while the figures for the electricity market indicate a 80% growth from 520 to 939 TWh in the same period [2,3].

Consequently, emerging economies are also to respond for most of the increase in energy-related CO2 emissions. China already ranks first place in atmosphere pollution and will remain highly dependent on coal and oil for the next decades, in spite of the large-scale efficiency measures implemented since the 11th Five-Year Plan [4]. Even though the Chinese government pledged to cap carbon emissions until 2030 in accordance with the agreement sealed with the USA at the 2014 APEC summit, one coal-fired power plant continues to be inaugurated every ten days [5]. This fact imposes not only a burden upon the country's public health [6], but makes it also hardly doubtful that international

Abbreviations: ANEEL, Brazilian Electricity Regulatory Agency; APEC, Asia-Pacific Economic Cooperation; BRL, Brazilian real; CC, Combined cycle; CO2, Carbon dioxide; CSP, Concentrating Solar Power; DNI, Direct Normal Irradiation; EPC, Engineering, Procurement, and Construction management; EPE, Energy Research Company; GDP, Gross Domestic Product; GHG, Greenhouse gas; GIZ, German Society for International Cooperation; GW, Gigawatt; HDI, Human Development Index; ISCC, Integrated Solar Combined Cycle System; IEA, International Energy Agency; kWh, Kilowatt hour; LCOE, Levelized Costs Of Electricity; LFR, Linear Fresnel Reflectors; MCTI, Ministry of Science, Technology and Innovation; Mtoe, Million Tonnes of Oil Equivalent; MW, Megawatt; PD, Parabolic Dish; PT, Parabolic Troughs; PV, Photovoltaic; R & D, Research and Development; RE, Renewable energy; ST, Solar Towers; STE, Solar Thermal Electricity

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mitigation strategies will succeed in restraining global average temperature increase within the 2 °C limit.

The Brazilian energy mix differs from the Chinese mainly because the shares of renewable energy (RE) in its primary energy supply (43%) and in the generation of electricity (74.6%) are considerably above the world average [7]. However, the planned investments in the gas and oil sector have raised concerns on a "regressive process of carbonization" of the country's electricity supply. Such reversal is associated with the fact that much of the remaining potential for hydropower generation is located in the Amazon basin, and the political and ecological costs of standing for controversial projects like Belo Monte, Jirau and Santo Antônio have led the government to assign natural gas as a strategic resource. Such emphasis on the combination of hydropower and fossil fuels establishes a "vicious circle" in view of current changes in climate patterns: In the Brazilian case, global warming prospects indicate the likely increase in the frequency of drought phenomena similar to the observed in the Midwest and Southeast regions in 2013/2014 and, due to the drop in the level of reservoirs, the decrease in hydroelectric output is already being compensated by coal, oil and gas-fired power plants [8,9].

Nevertheless, the current bases of Chinese and Brazilian energy policies are characterized by a similar paradox: The counterpart of the environment unfriendly axiom "development first" is a major contribution from both countries in what refers to RE deployment – not only in their own territories, but also as key-players of the scaling-up process of renewables worldwide. In 2014, China provided the RE sector with US$ 83.3 billion, which represents an amount 117% higher than the investments made by the USA. Brazilian participation was only a ratio of the Chinese share, though at no means unimportant, for its US$ 7.6 billion input places the country among the ten major supporters of RE deployment, and right after China when solely emerging economies are considered [10].

Both Chinese and Brazilian public banks have been financing RE industry with low interest rates in order to enable the accomplishment of their respective goals on the expansion of alternative energy technologies. China's State Council announced the purpose of meeting 20% of the country's energy needs by 2030 from non-fossil fuel. On the Brazilian side, the US-Brazil Joint Statement on Climate Change affirms that 28–33% of its energy matrix (excluding hydropower) must derive from renewables by 2030 [11,12]. In this sense, the interactions between climate change mitigation goals and economic incentives for the RE industry has contributed for the highlighted position of these countries in the global value chain of alternative energy technologies. One in two wind turbines deployed worldwide in 2010 were produced in China, as well as 60% of the photovoltaic panels manufactured in the following year. Brazil has also become an exporter of wind turbines, supplying RE markets in the United States, Europe and Argentina [13–15].

In the light of such facts, the question that this article approaches focuses more specifically on the perspectives of Concentrating Solar Power (CSP) technologies in the Chinese and Brazilian energy markets: Why have these countries presented so meagre CSP deployment results until now, especially when compared to the evolution registered by them in other RE technology fields? Considering the escalation in Chinese electricity demand and the environmental pressures associated to it, a CSP roadmap that assigns merely 1 GW by 2015 and 3 GW until 2020 seems astonishingly modest.[1] This situation becomes even more puzzling when one remarks that—differently from its usual performance in the energy infrastructure sector, in which the targets are either achieved or surpassed—China is very distant from reaching the established goal for CSP expansion. The current operational capacity is limited to 2.18 MW, and even if all the projects under construction, development or planned are added, the total figure is still restrained to 567.5 MW [16].

Except for some progress in Research and Development (R & D) conducted by scientists associated to public universities and electricity agencies, CSP evolvement in Brazil is almost inexistent. Cooperation ties between the Ministry of Science, Technology and Innovation (MCTI) and the German Society for International Cooperation (GIZ) have provided Brazilian scientists and policy-makers with German expertise in thermo solar energy and contributed to further research on the requisites for the deployment of CSP in Brazil. However, there is currently only 1 MW pilot plant under construction in Petrolina (PE) and other four commercial projects that amount to 130 MW, which find themselves in a very initial phase of development [17]. Furthermore, while in China the backward situation of thermal solar power does not apply to other branches of the solar industry (photovoltaic panels or solar water heaters), the abundant solar resources in the Brazilian territory are decidedly underused from the perspective of energy supply [18,19].

Rational energy planning might be defined as the development of the energy infrastructure that makes use of technological innovations to improve efficiency gains and explore renewable resources in order to meet the energy demands of a society in accordance to sustainability criteria. Following this definition, the adoption of specific technological innovations must be endorsed by their social acceptance and employed in a complementary perspective that explores different renewable energy resources conform to their geographical availability. Nevertheless, several barriers interfere as constraints for the accomplishment of rational energy planning, both within and beyond the limits of national sovereignty. Therefore, the next section is dedicated to a brief presentation of the theoretical framework and the methodological tools that oriented the assembly of original data for the analysis of our research problem. We will argue that the "World-Systems Theory", such as developed by Immanuel Wallerstein (2002, 2004), offers a comprehensive perspective that enables us to highlight the commonly neglected importance of electricity prices for determining the position of each country in a competitive world-economy [20,21].

In Section 3, we will give an overview of CSP technologies and emphasize their particular advantages in terms of energy conversion, storage and hybridization possibilities, as well as their life cycle assessment. In Section 4, the analysis of Direct Normal Irradiance (DNI) data will confirm that China, as well as Brazil, have large portions of their territories registering DNI values above the minimum necessary for an effective CSP performance. An important similarity between these countries will emerge from the analysis of solar resources data, for in both cases the places with higher DNI coincide to a great extent with the regions where the socioeconomic conditions are most critical. In this sense, it will be argued in Section 5 that, besides its environmental benefits, the large-scale deployment of CSP power plants in China and Brazil might also contribute for diminishing regional inequalities.

More attention will be paid to the economic viability aspects of Chinese and Brazilian CSP markets in Sections 6 and 7. We will provide an overview of the CSP value chain and demonstrate that thermal solar power plants demand regular industrial materials—e.g. steel, mirrors, steam turbines, electronic components—in which the Chinese manufacturing sector excels. Brazil also possesses a mature range of industries in the production of components and equipment for electrothermal conversion so that an important part of the value chain could be added locally [17,22].

The concluding remarks are intended to clarify the significance of the financial obstacles interposed by the high Levelized Costs of Electricity (LCOE) for CSP deployment in China and Brazil. From a sociological perspective, we criticize the limits of current explanations that point out solely the higher electricity prices imposed on consumers and the ensuing inflationary pressures. Beyond that, we indicate how

[1] Our analysis refers to the time frame of the 12th FYP. The 13th FYP was published when this article was being reviewed and we decided to write an appendix at the end with some further considerations and updated data regarding the 13th FYP.