Renewable energy and power cooperation between China and six Latin American nations

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Abstract. China has been entitled the biggest supplier and largest market of renewable energy for the past few years. With One Belt and One Road initiative carrying on, the China’s renewable energy industry is looking for opportunities across the world. Latin America, which has rich renewable energy resources and urge demand for a cleaner and more sustainable energy system, may become an important target market for China. The prospect and potential of renewable energy cooperation between China and Latin America are promising. In this paper, six Latin American nations of varied background were selected as study cases. Their nation profile, energy resources, power market, and energy development trends were analysed, and the cooperation prospect and potential between these nations and China in renewable energy sector were discussed. The results indicate that Argentina and Bolivia are most potential cooperation partners, and project development and equipment manufacturing of non-hydro renewable energy, along with power grid upgrading are the prioritized areas. In addition, recommendations and solutions addressing the issues and challenges incurred in the current bilateral energy cooperation between China and Latin American nations were proposed.

1. Introduction

As the largest country of power production and consumption in the world, China has made remarkable achievements in renewable energy industry development in recent years: according to National Energy Administration of China, until 2016, China had total installed capacity of hydropower of 332,000 MW, wind power of 149,000 MW and PV power of 77,420 MW, all ranking No. 1 in the world. Propelled by the exportation of productivity and the One Belt and One Road initiative, China’s renewable energy industry is now looking for new markets across the world.

Latin America has experienced rapid growth in renewable energy over the past decade [1], thanks to the decreased utilization costs and the increasing investment. From 2006 to 2015, the installed capacity of on-shore wind power in the Latin American region climbed up from 512 MW to 15,500 MW, increased by nearly 30 times; the installed capacity of solar energy power generation soared up from 23 MW to 2,200 MW, increased by nearly 100 times; biomass energy also increased by 3.4 times [2, 3].

Given the mushrooming growth of the renewable energy industry in Latin America and urge demand for energy transition from CO\(_2\)-intensive energy technologies across the world, future cooperation on renewable energy between China and Latin America will be mutual beneficial and of great potential, which may also become an impetus to promote the bilateral cooperation in other sectors.

In this paper, six Latin American nations (abbreviated as "SLAN") of varied background in terms of energy resources, economic and social development, power market and renewable energy
development were selected as the study cases namely Uruguay, Chile, Argentina, Peru, Brazil and Bolivia. Their nation profile, status quo of energy and power, and development directions were analyzed. The cooperation potentials and prospects in renewable energy and power between China and the SLAN were discussed. At the end, existing problems and challenges incurred in the cooperation were addressed, and respective recommendations aiming to facilitate the energy cooperation were proposed.

2. Nation profile
The SLAN totally have 316 million people and 1,461 km$^2$ of national territorial areas. In 2016 they registered a total GDP of USD 2.87 trillion and USD 9,088 GDP per capita. The population of each km$^2$ is 21.6 persons. See table 1 for the detailed data.

| Nation  | National territorial area (10,000 km$^2$) | Population (10,000 persons) | GDP (USD 100 million) | GDP per capita (USD/person) | Population per km$^2$ (persons) |
|---------|----------------------------------------|----------------------------|----------------------|----------------------------|--------------------------------|
| Uruguay | 17.6                                   | 344                        | 524                  | 15,233                     | 19.5                           |
| Chile   | 75.7                                   | 1,791                      | 2,470                | 13,791                     | 23.7                           |
| Argentina | 278                                   | 4,385                      | 5,459                | 12,449                     | 15.8                           |
| Peru    | 129                                    | 3,177                      | 1,921                | 6,047                      | 24.6                           |
| Brazil  | 851                                    | 20,765                     | 17,960               | 8,649                      | 24.4                           |
| Bolivia | 110                                    | 1,089                      | 338                  | 3,104                      | 9.9                            |

(Data source: World Bank Database)

3. Status quo of energy resources and power market

3.1. Resources

3.1.1. Fossil energy resources. By 2016, the proved oil reserves of the SLAN totalled around 16.6 billion barrels where Brazil boasted 12.6 billion barrels and a proportion of 76%. The proved natural gas reserves totalled around 1.5 trillion m$^3$, as Peru reported the biggest reserve that reaches 399.3 billion m$^3$. The coal reserves of the SLAN totalled 8.64 billion tons, as Brazil took the lead with 6.6 billion tons and a proportion of 76%. In general, except for Brazil, the SLAN do not have abundant fossil energy resources and in particular are short of coal and oil. Detailed data is show in table 2.

| Nation | Oil reserves (100 million B) | Natural gas reserves (100 million m$^3$) | Coal reserves (100 million tons) |
|--------|-----------------------------|---------------------------------------|-------------------------------|
| Uruguay | 0                           | 0                                     | 0                             |
| Chile  | 1.5                         | 979                                   | 13.8                          |
| Argentina | 24                      | 3,511                                 | 5.5                           |
| Peru   | 12                          | 3,993                                 | 1.1                           |
| Brazil | 126                         | 3,710                                 | 66                            |
| Bolivia | 9                          | 2,803                                 | 0                             |

(Data Source: BP Statistical Review of World Energy 2017; EIA Database http://www.eia.gov)

3.1.2. Renewable energy resources. Among the SLAN, Brazil has the richest hydropower resources with technically exploitable capacity of 260,000 MW, which is followed by Peru, Argentina and Bolivia ranging between 40,000-7,0000 MW. The SLAN enjoy outstanding wind power resource endowment, i.e. average wind speed above 6 m/s and high up to 9 m/s in certain areas. The sunlight conditions of Bolivia, Chile and Peru are slightly better than those in the other three nations. Detailed data is shown in Table 3.
3.2. Status quo of power market

3.2.1. Installed capacity and power generation of major energy types. The installed capacity and power generation of major energy types in the SLAN as of 2016 are shown in Table 4 and 5 [4-5], based on which the power market in each country was analysed accordingly.

### Table 4. Installed capacities of power generation types in SLAN (2016).

| Nation | Total installed capacity (MW) | Installed capacity per capita (kW) | Coal-fired power (MW) | Hydropower (MW) | Wind power (MW) | PV power (MW) |
|--------|-----------------------------|----------------------------------|----------------------|----------------|----------------|--------------|
| Uruguay | 5310                        | 1.54                             | 2,050                | 1,540          | 1,210          | 86           |
| Chile   | 22,030                      | 1.23                             | 12,650               | 6,610          | 1,300          | 1,600        |
| Argentina | 33,900                      | 0.77                             | 20,680               | 10,470         | 1,090          |              |
| Peru    | 12,280                      | 0.39                             | 7,050                | 4,710          | 240            | 96           |
| Brazil  | 153,700                     | 0.74                             | 25,930               | 98,010         | 10,740         | 23           |
| Bolivia | 2,160                       | 0.20                             | 1,470                | 500            | 27             | 13           |

(Data source: BP Statistical Review of World Energy 2017; IRENA Renewable Energy Statistics 2017; IEA International Energy Statistics)

### Table 5. Power generation by type in SLAN (2016).

| Nation | Total power generation (TWh) | Gas/oil power generation (%) | Coal-fired power generation (%) | Hydropower generation (%) | Wind power generation (%) | PV power generation (%) |
|--------|-----------------------------|-----------------------------|---------------------------------|--------------------------|---------------------------|-------------------------|
| Uruguay | 14.7                        | 4                           | 63                              | 30                       | 1                         |                         |
| Chile   | 78                          | 58                          | 12                              |                          |                           |                         |
| Argentina | 147                        | 64                          | 27                              |                          |                           |                         |
| Peru    | 52                          | 51                          | 2                               |                          |                           |                         |
| Brazil  | 582                         | 10.6                         | 82                              | 1.2                      | 0                         |                         |
| Bolivia | 9.8                        | 66.2                         | 30.7                            | 3.0                      |                           |                         |

(Data source: BP Statistical Review of World Energy 2017, IRENA Renewable Energy Statistics 2017, IEA International Energy Statistics)

3.2.2. Profile of respective power markets.

A. Uruguay. Although the proportion of coal-fired power exceeds 38% of the total installed capacity in Uruguay, its power generation accounts for less than 4% and is used as the standby capacity only for peak shaving due to environmental consideration. Meanwhile, the proportion of renewable energy power generation is as high as up to 96% including over 60% of hydropower [6]. Uruguay has become the net power export country presently and transmits power mainly to Argentina and Brazil. Nevertheless, the loss rate of power system especially in transmission and dispatch process is up to 12.7% with annual loss of around 2 billion kWh in Uruguay, which is quite serious.

B. Chile. In 2016, the power generation in Chile reached 78 billion kWh with 58% from coal-fired power, 30% from conventional hydropower and the remaining from new energy[7]. Chile terminated coal mining in 2013 and has been fully dependent on imported coal since 2014. Currently Chile has reached a balance between power supply and demand, and the power market is mature. Chile is now concentrating on the development of new energy such as solar energy and is gradually reinforcing...
power connectivity construction with other Latin American nations like Argentina. Chile has four power grids but due to its long and narrow topography, they are not interconnected yet, among which the central power grid accounts for 76.4% of the total installed capacity [7].

C. Argentina. Power generation from natural gas accounts for over 60% of the total installed capacity in Argentina, which is followed by hydropower for almost 30% [8]. The proportion of non-hydro renewable energy like wind power is as low as less than 1%. From 2010 to 2016, Argentina maintained stable growth of power consumption with the average annual growth rate at 3.5%. Power grids are highly developed in Argentina with grid coverage close to 100% and interconnected power grids with Uruguay, Brazil and Chile. In 2016, Argentina imported 1,470 GWh power and exported 330 GWh [8], indicating a shortage of domestic power supply.

D. Peru. According to IEA international energy statistics, in 2016 the total installed capacity in Peru reached 12,280 MW as 58% from coal-fired power, 37% hydropower and few from new energy. The total power generation reached 52 billion kWh including 51% from coal-fired power, 48% from hydropower and 1% from solar power and wind power. At present Peru does not have large-scale power export and its domestic power supply is mainly for domestic consumption. However, with the rapid development of mining and manufacturing industry, the shortage of power supply may appear in some regions. Peru is actively working with neighbouring countries including Brazil, Chile and Ecuador on the construction of power grids connectivity.

E. Brazil. Previously Brazil is heavily dependent on hydropower which has accounted for more than 80% of the total power generation for years. Once a drought happens, the capacity of hydropower will be considerably compromised. Therefore, Brazil started optimizing power sources structure since the mid-1990s and focused on the development of non-hydro energy. By the end of 2016, the installed capacity of wind power and biomass power reached 1,040 MW and 1,420 MW respectively [5].

F. Bolivia. Bolivia has relatively low power consumption. Its installed capacity per capita and power consumption per capita are underdeveloped among other Latin American states. According the IEA international energy statistics, Natural gas is the major power source in Bolivia with the proportions of both power generation and installed capacity over 60%. The second major power source is hydropower. Among the non-hydro renewable energy, biomass power accounts for around 90% with installed capacity at 154 MW. The macroeconomic growth in Bolivia in the past few years ensured its steady increase in power consumption. Bolivia’s power demand is growing as the average annual growth rate from 2002 to 2015 is up to 6.3%. However, there are quite a few issues troubling Bolivia’s power system such as aging equipment and power grid, substantial power transmission loss, and lagging development of power sources. Given the abundant resources of renewable energy, Bolivia has huge potentials in the development of non-hydro renewable energy in the future.

4. Energy and power development trends

4.1. Development targets (table 6)

4.2. Development demand and space of power market (table 7)

| Nation   | Development targets                                                                 |
|----------|-------------------------------------------------------------------------------------|
| Chile    | In 2020, the proportion of renewable energy (non-hydro) and hydropower will reach 20% and 45%-48% respectively, with proportional reduction of coal-fired power |
| Argentina| The proportion of Non-hydro renewable energy will reach 20% in 2025                   |
| Peru     | The proportion of renewable energy will exceed 60% in 2025                           |
| Brazil   | In 2021, wind power will reach 22,000 MW, biomass power 13,000 MW and nuclear power 3,000 MW |
| Bolivia  | Developing clean energy such as wind power, hydropower and geothermal energy as the substitution of natural gas. The installed capacity of non-hydro renewable energy will reach 183 MW in 2025 |
Table 7. Development demand and space of power market in SLAN.

| Nation | Market demand and space |
|--------|-------------------------|
| Uruguay | As a net power exporter, Uruguay witnessed rapid development of renewable energy over the past five years and further generation capacity is not currently needed. It will focus more on upgrading the power grid as well as the construction of power connectivity with neighboring countries. |
| Chile | Chile has achieved a balance between power supply and demand domestically. Its target of 20% non-hydro renewable energy in 2025 implies potentials of new energy such as solar power and wind power. |
| Argentina | For the expected power balance, Argentina needs additional installed capacity of 5,350 MW in 2020 and 13,280 MW in 2025. The wide gap of power demand and supply indicates a promising market. |
| Peru | Peru now almost reaches a balance between power supply and demand domestically. From 2020 to 2030, its power shortage will be around 2,000 MW. |
| Brazil | Due to the slow economic growth, Brazil’s need for power development is limited in the near future. Given the demand of power restructuring, the non-hydro renewable energy is relatively more attractive. |
| Bolivia | It is estimated from 2017 to 2025 that Bolivia will face a power shortage of 1,790 MW which indicates great market potentials in the future. |

Among the SLAN, both Uruguay and Chile have installed capacity per capita over 1.2 kW/person, which indicate limited space for power sources construction in the future. Brazil has a large yet unbalanced power market with hydropower dominating. Although the installed capacity per capita of 0.74 kW/person implies ample room for development, Brazil’s power investment and construction slowed down due to a sluggish economy, nonetheless structural opportunities are still available. Argentina has the second largest power market in Latin America following Brazil with installed capacity per capita of 0.77 kW/person, and its continuously growing demand for energy ensures a promising market. Peru and Bolivia have lower installed capacity per capita of 0.39 and 0.20 respectively. Once their economy booms, huge demand for power development is expected. What is more, most of the SLAN suffer from aging power grids and higher loss rates, which call for grid upgrade. To solve the problem of regional power imbalance caused by geographic factors, the construction of transnational and interregional power grid should also be promoted.

4.3. Prioritized sectors
In accordance with the national resource endowment, current profile of power market, market space and development targets, the prioritized sectors of each nation regarding power development in the future were sorted out in table 8.

Table 8. Prioritized areas of power development in the SLAN.

| Nation | Prioritized sectors of power development |
|--------|------------------------------------------|
| Uruguay | Small hydropower, pumped storage power, power grid upgrade, smart grid, power connectivity |
| Chile | Wind power, solar power, hydropower (pumped storage power), connectivity |
| Argentina | Wind power, solar power, hydropower, nuclear power, gas power generation |
| Peru | Hydropower, wind power, solar power |
| Brazil | Wind power, solar power and other non-hydro energy |
| Bolivia | Wind power, solar power, natural gas power generation, power grid upgrade |
5. Prospects of power cooperation between China and the SLAN

5.1. Foundation of cooperation

In the past decade China and the SLAN have reached diversified cooperation such as investment, acquisition, EPC, equipment and operation in quite a few sectors including hydropower, coal-fired power, wind power and power transmission and distribution networks, which had laid solid foundations for future cooperation.

Examples of cooperation range from equity acquisition, project development to joint studies and governmental agreement. In 2016, for instance, the State Grid Corporation of China acquired 23.6% shares of CPFL, the third largest power transmission enterprise in Brazil and planned to build the power transmission grid connecting Belo Monte hydropower station and the southwestern power consumption centre in Brazil. In October 2016, China and Uruguay had signed an MOU on renewable energy cooperation. In April 2017, the third China-Argentina economy cooperation and coordination strategy dialogue was held in Beijing in which both sides reached common understanding of further cooperation which involves two nuclear power stations and four power projects in the list of prioritized projects of China-Argentina Five-year Overall Cooperation Planning in Infrastructure Sector (2017-2021).

5.2. Cooperation prospects

As the international community increasingly focuses on the issues such as energy security, climate change and environmental protection, most countries across the world have reached common understanding and taken concerted action to accelerate the development and utilization of renewable energy. The SLAN have rich resources of renewable energy. Under the pressure of energy restructuring, the development of renewable energy (especially non-hydro renewable energy) will be strongly supported to enrich the types of power sources and reduce dependency upon conventional energy sources. On the other hand, China has witnessed remarkable development of the renewable energy industry and accumulated technical and practical experience regarding project engineering, equipment manufacturing, operation management, etc. For example, China’s share in global solar PV manufacturing has been over 40% for the last five years [9]. Therefore, a promising cooperation prospect is expected between China and the SLAN in renewable energy industry.

5.3. Most potential nations and prioritized areas

Table 9. Ratings of cooperation potential on renewable energy between China and the SLAN\textsuperscript{a}

| Nation    | Resource endowment | Market space | Credit rating | Cooperation potential |
|-----------|--------------------|--------------|---------------|-----------------------|
| Uruguay  | ☆\textsuperscript{b} | ☆            | ★★           | ★                     |
| Chile    | ★                  | ☆            | ★★           | ★                     |
| Argentina | ★★☆               | ★★          | ★☆           | ★★☆                  |
| Peru     | ★★                 | ★            | ★☆           | ★☆                   |
| Brazil   | ★★★                | ★☆           | ★☆           | ★☆                   |
| Bolivia  | ★☆★                | ★★☆         | ★☆☆          | ★☆☆                  |

\textsuperscript{a} credit rating is based on the sovereignty credit rating data of Moody’s, S&P and Fitch Ratings in 2017

\textsuperscript{b} ☆ indicates half value of ★

As shown in Table 9, on the basis of each nation’s resource endowment, power market space, and political environment, in line with China’s advantages, the potentials of cooperation between China and the SLAN on renewable energy and power are graded: Argentina and
Bolivia have greater potentials, Peru and Brazil are on the secondary tier, while the cooperation prospect for Uruguay and Chile are less promising.

The prioritized areas of cooperation between China and the SLAN on renewable energy and power include project development and equipment manufacturing of non-hydro renewable energy (wind power, solar power, etc.), power grid upgrading, energy conservation and storage technology (including pumped storage energy), integrated energy development projects, etc.

6. Issues and recommendations

6.1. Issues and challenges

6.1.1. Political, economic, social and other impediments. The indicator of political stability and absence of violence/terrorism for the SLAN issued by World Bank in 2016 was listed in table 10. As shown, some of the SLAN are troubled by an unstable political environment. This political risk of policy uncertainty might be a big threat to international investors. In the meantime, the changing political situation is also a negative factor for economy growth and currency stability. Apart from that, in some countries social, technical, economic and political barriers tends to stymie the development of renewable energy according to Scott Valentine [10].

|                | Uruguay | Chile  | Argentina | Peru    | Brazil  | Bolivia |
|----------------|---------|--------|-----------|---------|---------|---------|
| Political stability and absence of violence/terrorism | 1.1     | 0.51   | 0.22      | -0.16   | -0.45   | -0.21   |

6.1.2. Disparity of languages and culture. The SLAN are mainly using Spanish and Portuguese as the official languages. English penetration rate is still low. External enterprises may encounter more or less language barriers in marketing and project development. What is more, the discrepancy in engineering standards and specifications, working tradition and enterprise culture may also have negative impact on the project implementation.

6.1.3. Lack of overall planning. The energy and power development involves different sectors and requires overall planning and coordinated development. However, some countries pay insufficient attention on the overall planning of the national power system. If the development enterprises only focus on the specific project and does not comprehend the overall picture of the entire power market, it may result in a waste of resources and possibly unfortunate consequences.

6.2. Cooperation recommendations

6.2.1. Planning ahead. Bilateral or multilateral cooperation on energy and power shall go beyond the projects but be planned ahead considering regional economic, social development and power market status. In-depth joint studies and planning shall be carried out by both sides beforehand, with time sequence of projects development designed, interests of all stakeholders coordinated, risks managed within controllable scope, protective mechanism established and finally win-win cooperation achieved.

6.2.2. Policy support. On the one hand, the intergovernmental agreements and cooperation mechanisms should be established to facilitate exchange of project information, promote project cooperation, provide policy support, in order to smooth the implementation of projects, reduce investment risks and protect the legitimate rights and interest of enterprises from both sides [11].
6.2.3. **Resource integration.** Chinese enterprises are encouraged to form consortia with local enterprises or the entities from the third-party nations for joint investment and development, and explore for more financial channels to attract international capital. Such consortium on one hand can avoid conflict of language, culture, customs, etc. and on the other hand can assist Chinese-funded enterprises in breaking the local commercial or industrial barriers and getting better understanding of local policies, regulations, technical standards and best practice.

6.2.4. **Power connectivity development.** Cross-border trade in electricity is rapidly expanding because of technical innovations, economic and geopolitical developments and the ongoing decarbonisation of the electricity sector in response to climate change. The expansion of electricity networks and the integration of increasing shares of electricity produced from renewable energy sources into the grid have made long-distance electricity flows both feasible and desirable [12]. Although electricity transmission lines on a small scale have existed among most of the Latin American countries for some time, the development of large-scale and long distance transmission lines built with the idea of exporting electricity has only occurred for about 10 years [13]. Therefore, power integration and connectivity development among the SLAN will become an important and effective approach in bridging the gap between domestic power demand and supply due to the geographic discrepancy in the layout of power sources and power consumption centres, as well as transmitting electricity from one country to another in pursuit of maximum benefits of the SLAN.

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