

GLOBAL VALUE CHAINS AS A REGIONAL INTEGRATION TOOL: **THE CASE OF THE RENEWABLES INDUSTRY IN SOUTH AMERICA**



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INTRODUCTION

This study aims at the identification of new paths, starting from concrete productive associations, that could lead to closer production and consumption patterns among South American countries.

The last two decades have put in check the classical approach to regional integrations, raising several doubts on experiments till then considered iconic, particularly that of the European Union.

FGV/IIU has been involved in the creation of new and innovative formats that could foster integration, independently of more encompassing, classic pursuits that, among other things, demand much more negotiating time and red tape, eventually alienating the key actors of integration: producers, consumers, citizens and communities.

Bottom-up, or at least horizontal approaches can be quite effective in establishing bonds that may afterwards facilitate the way to more formal, juridical endeavours. *The establishment of regional production-supply nexus is one of them.*

South American (SA) economies have a lot to gain –so goes the usual rhetoric- if they increase their participation in global value chains, integrating their productive sectors and making use of (and enhancing) their specific competitive advantages. This sounds particularly true in relation to the exploitation of their extremely abundant natural resources, if accompanied by the aggregation of value through use of the new production fragmentation technologies. A process that may also create opportunities to push forward national technological frontiers, something much needed in the continent.

This work sheds a nuanced light on the above narrative. The case here analysed relates to enlarging the use of wind and solar energy sources in their energy matrices: a novel development that should be faced within a regional perspective. We strongly advocate the rationale of incorporating the wind and solar energy activities in a borderless standpoint, encouraging the creation of value chains of providers in the whole galaxy of needed equipment, as well as the potential share of the (green) energy generated.

In terms of both conceptualising and detailing, this is a considerable effort, whose achievement goes beyond this initial attempt. In terms of how the vision matches the present reality and the feasible future paths, a grain of doubt creeps in, calling for a greater role of institutional and public intervention than previously expected.

In order to organise the reasoning, and show how we arrived at the final guidelines, the text begins in section II by outlining a set of simple, ideal methodological steps we eventually have half-successfully pursued. Section III presents a thorough description of the current state of affairs, both along countries and firms.

Those two sections form the background for the proposal. Section IV presents a detailed synthesis of the previous information, including the possible coupling with what can be extracted from the regional input-output matrix –unfortunately not much till now. It draws, in its final subsection (IV.3.4), the basic elements of the value chain for each modality, solar and wind; besides the guidelines in the next section, IV.3.4 has a value in its own.

Policy guidelines, translating what could be extracted and concretely suggested from the core of previous facts and ideas, are detailed in section V. Two Annexes, motivated by the September workshop on the project, organised in Berlin by GIZ, conclude the Report.

CHAPTER ONE

METHODOLOGY

The effort to understand the value chains creation possibilities can evolve through two different levels:

- (1) the analysis of the already existing power units and the main local business developments involved in their construction;
- (2) a more general analysis of the productive sector in South American countries, to see how these new industries will fit in, how they might be integrated across different countries, and what can be their most significant impacts.

In section III, we identify the main current plants and industries already in place, producing an invaluable picture of the present state of affairs in SA. Originally, in section IV, using the regional input-output (I/O) matrix for South America as a tool, we planned to look for the possible consequences of these new players in the SA energy (electricity) matrices, from an integrated viewpoint. However, this has proved not possible to be achieved at present.

Both parts must anyhow, sooner or later, merge, in order to produce a minimally feasible and sensible proposal.

Broadly, in terms of (ideal) methodological steps, the following can be listed:

1. identification of the main generation sites/parks, in terms of country/location and providers;
2. identification of the equipments/technologies used by such providers;
3. decomposition of the equipments into parts & components, and where these parts & components come from: imports or sourced in the region;
4. construction of a map synthesising information from 1-3;
5. analysis of the map in 4, searching for possibilities of further communication and interaction and the existence of novel regional suppliers;
6. combination of the previous (bottom level) information with likely production complementarities of related sectors -

at a fairly broader aggregation level-, as revealed by the Regional IO Matrix for South America;

7. extraction, from the above, of the policy proposal on the regional value-chains for the sector.

Expert knowledge, of specific technical character, must be used for checking the findings, notably as regards items 3-5 and 7 above. Item 6 has been only preliminary developed, with certain nuances, for reasons that will be further explained in section IV.

In spite of all this, it must be kept in mind that the examination of the wind and solar power context here proposed is a screening study, based on the available public information, and looking for the general trends. It prepares the ground for more specific pursuits, requiring the direct involvement of local institutions and individual players.

CHAPTER TWO

THE WIND AND SOLAR POWER SECTORS IN SOUTH **AMERICA AND THEIR INDUSTRIAL BASES**

PRELIMINARIES

The global increase in the use of renewable sources of energy is indeed an imposition, due to the need of reducing the participation of fossil fuels in the world's power sector, responsible for much of the Greenhouse Gases (GHG) emissions nowadays and a likely cause of the climate changes facing the planet. The Fifth Assessment Report of the IPCC proposes that all these GHG emissions should be radically reduced by the year 2100, for which a very large increase in the use of the new renewables is deemed essential.

Historically, most of the clean energy in use in the world is based on hydroelectric power. Although it needs to be further exploited, its availability under reasonable economic and environmental conditions is not large enough to cover most of the pressing needs. Among the new renewable sources with a global availability that seem most promising are wind and solar energy¹. The good news is that their technological development is booming and costs are being reduced every year. Wind power is already competitive in many situations, and also solar photovoltaic may become even more so in the near future. The battery developments in progress seem likely to solve, in less than a decade, the intermittency problem that has been one of the impediments for a larger penetration of solar energy and that of distributed generation.

During the last decade, an enormous increase in the use of wind power as a source for electricity generation took place. Starting in the USA and in Europe - mainly in Denmark, German and

¹ Biomass has not been treated in this work.

Spain -, it spread rapidly along other regions, specially China and India. Solar energy is following behind, and as its costs are being reduced, it seems to be the focus of the next wave.

A 2014 study² made by the financial consulting company Lazard indicates that, in the US, unsubsidised levelled costs of energy for wind (range US\$ 37-81/MWh) is competitive and even cheaper than traditional thermal generation based on fossil fuel costs, including natural gas (US\$ 61-87/MWh) and coal (US\$ 66-151/ MWh). Unsubsidized solar PV (range US\$ 72-265 / MWh) was also at that time reaching commercial ranges.

More recent results confirmed these figures and have shown even a better performance for solar PV. A Chilean tender in 2105 resulted in wind power being contracted at US\$ 79/MWh and solar PV by US\$ 67/MWh. In February 2016, a tender in Peru displayed still lower costs and three wind power plants were contracted at prices close to US\$ 37/MWh and three solar PV plants at around US\$ 48/MWh. In April, 2016 an auction for renewables in Mexico resulted in contracts with solar photovoltaic suppliers at an average price of US\$ 45.2 / MWh, with a surprisingly record low in one case of US\$ 35.5 / MWh. In Brazil, contracted solar PV prices in 2015 averaged at a higher US\$ 78 / MWh, closer to the Chilean figures; in 2016 there are no new solar contracts till now and it is not yet clear whether this downward trend will continue.

For both technologies, South as well as Latin American (LA) participation in the world figures are relatively small but, as the industries are growing, they are reaching the region. In the wind power sector, a large number of projects are currently being implemented and their participation in the power generation nexus is

due to become significant in a few years. Solar is still more in its beginning though its growth had a turning point -actually, a large impulse- in 2014, as it is rapidly getting more competitive.

Both, wind and solar, are extremely abundant in Latin America, and if the new global value chains responsible for their developments could also find segments or niches in the continent, more efficient solutions could be found, with the countries' economies participating in their global benefits. Of course, technical and economic solutions to deal with intermittency are needed, in order to allow larger participation of such energy sources. Hydro reservoirs, pumping storage, and an increased presence of more flexible natural gas generation seem to be able to deal at least partially with the problem in the large systems, till technological advances bring into place cheaper batteries and/or other solutions.

In any case, dealing with renewables in the power sector brings up at the same time two opposite situations. On one hand, distributed generation may grow, affecting the traditional distribution network business model as individual consumers can supply their energy needs themselves with the help of solar PV. On the other hand, larger systems with renewables usually require more system interconnections to make use of complementarities, implying in a higher integration of different regions, what in the SA case means an increased integration of its individual markets.

The next subsection draws a general picture of the current stage of the wind and solar power generation in the SA electricity matrix. The third subsection concentrates in the industrial basis developed to locally supply part of the equipment required by both types of power generation.

² 'Lazard's levelized cost of energy analysis—version 8.0', Lazard, September 2014.

WIND AND SOLAR POWER GENERATION IN SOUTH AMERICA³

A global view

If intensive use of wind and solar sources in the power generation is a new global phenomenon, that is even more true for the region. According to IRENA's data, in 2000 there was around only 18 GW of capacity installed in wind farms in the whole world, with a small 78 MW in Latin America. During the following thirteen years, these figures for the world increased at an impressive 25% a year on the average, reaching a global installed capacity of 419 GW in 2015, of which 15 GW in Latin America. According also to IRENA, in the same period, the installed capacity of solar energy in the world evolved from 1.2 GW to 222 GW, growing from zero to 2.2 GW in Latin America.

As can be seen in Table III.1, the situation at the end of 2015 indicates that wind farms had been implemented in several countries, mainly in Brazil, Chile, Mexico and Uruguay.

Solar energy units, in a smaller number at that date, were mainly in Chile, Mexico, Peru and Honduras. But a large number of in-shore wind projects contracted through Power Purchase Agreements (PPA) in many countries are in the process of implementation and this geographical distribution is changing fast. Although lagging a few years behind, also solar photovoltaic generation is starting to grow and in some cases it is overcoming wind.

Wind Farms

Brazil

The country nowadays with the highest installed capacity of wind farms in Latin America. Growth started in 2002, with the governmental programme Proinfa⁴ that instituted a system of feed-in tariffs (FiT) complemented by long-range power purchase agreements for wind farms that created the initial incentive for the development of the sector and the installation of wind turbines and equipment manufacturers in the country.

TABLE 1 – INSTALLED CAPACITY (MW) OF WIND AND SOLAR POWER GENERATION IN LATIN AMERICA, DECEMBER, 31; 2015.(PRELIMINARY ESTIMATES)

SA COUNTRIES	WIND (ON-SHORE)	SOLAR (PV)
Argentina	279	8.2
Bolivia	3	6.9
Brazil	8,739	22.9
Chile	904	848
Colombia	18	-
Ecuador	21	26,4
French Guyana	-	39.1

³ Though the focus of the study is South America, we shall also address some developments in LA in general, particularly due to the possibility of easily extending the ideas to Central America.

⁴ Programa de Incentivo às Fontes Alternativas de Energia Elétrica - Proinfa' was launched in 2002 as the 'Lei 10,438' legislation was issued.

Guyana	-	2.2
Paraguay	NA	NA
Peru	240	96
Suriname	-	5.4
Uruguay	845	67.7
Venezuela	50	3.4
ADDITIONAL DATA ON MEXICO, CENTRAL AMERICA AND CARIBE		
Aruba	30	4.9
Costa Rica	268	1
Curaçao	30	8
Re. Dominicana	85	15.5
Guatemala	76	85
Honduras	176	455
Jamaica	42	6.3
Mexico	3,073	234
Nicaragua	186	1.4
Panama	270	14,4
Puerto Rico	125	88.4

Source: IRENA International Renewable Energy Agency, 'Renewable Energy Statistics 2016 - Latin America and the Caribbean'.
NA - not available

Before Proinfa, the country had in place only a few plants, starting with an experimental wind farm installed in 1992 at the island of Fernão de Noronha with 75 kW (lately increased in 2001 to 225 kW) built with the support of the Danish Government. Other early experiment was the Eólica do Morro Carmelinho (MG) with 1 MW capacity developed by Cemig with the support of the German Government in 1994.

Through Proinfa, more than 1.4 GW were initially contracted, but only part of these projects overcame the initial difficulties and, in 2011, when Proinfa was formally concluded, there were 41 plants adding up 1,152 MW of installed capacity as result of its efforts, selling

electricity nowadays at an expected average price of US\$ 178 / MWh. Although based on these high energy prices, the programme was successful in developing the sector, attracting investors, and establishing its industrial basis.

In 2004, the institutional model of the Brazilian power sector was changed and the new wind farms were all contracted with long range Power Purchase Agreements (PPA) through a system of auctions as part of the new institutional model that was put in force.

Proinfa was followed by a sequence of tenders, where a degree of competition was introduced, as part of the new general scheme

used to promote new generation in general in Brazil. Some of these auctions were opened only to wind farm projects; others involved also competition with other energy sources.

During 2005-2015, a total capacity of 15,239 MW of wind farms, with an expected Capacity Factor of 44% on the average, was contracted through these auctions. Some were already implemented and part of these projects is in the process of implementation; if successful, they may bring the current total wind capacity of around 9,1 GW (at June 2016) to something close to 15,0 GW by 2020. Considering that the total power capacity installed in Brazil in December 2015 was of 141 GW, it can be seen that wind energy is now playing a significant role in the country.

Some of the auctions were restricted to non-conventional new renewables, but some were also open to standard thermal options and there was always a degree of competition involved. In the process, wind prices fell down and wind became progressively more competitive. In the two 2014 auctions, 551 MW of wind farms projects were successful in their bids and won PPAs. In the first of these auctions, in 06/06/14, open to wind, biomass, small hydro and natural gas thermal generation, to supply energy to the grid in 2017, were contracted 21 wind projects at an average tariff of US\$ 57,91 / MWh. In the second one, now specific for wind power, 31 farms were contracted at an average price of US\$ 58,22 / MWh, almost the same price reached at the first auction. In the following year, 2015, another 1,087 MW of wind parks were contracted in two auctions, reducing still further the average prices to US\$ 51,91 / MWh and US\$ 53,51 / MWh. Even a strong devaluation of Real close to 50% along 2015 did not appear to have affected very much these costs when measured in dollars.

Currently (June, 18; 2016), according to the regulatory agency, ANEEL, there are 369 wind farms in operation, of very different sizes with 9,069 MW; other 132 are being built with a 2,986 MW total capacity and other 256 parks should start construction soon adding 6,115 MW capacity. Two of the largest individual parks are Praia Formosa with 105 MW in the State of Ceara, and Alegria II with 100.7 MW in the State of Rio Grande do Norte, both in the Northeast region of the country but many wind complexes (clusters of wind parks) have higher capacity. This sizeable number of parks has been developed by many different companies, involving a range of investors from traditional power sector ventures to international and local manufacturers, investment funds, and others.

Larger wind complexes, including many individual parks, are the “Complexo Eólico Campos Neutrais” in the Estado do Rio Grande do Sul, belonging to Eletrosul, with three groups of parks, were Geribatu (258 MW) is already built, and Chui (144 MW) and Hermenegildo (181 MW) construction are in progress. Also the “Complexo Alto Sertão”, belonging to Renova, in the Estado da Bahia has 294 MW and is formed by a set of individual parks.

For the sake of illustration of the players' diversity, some of the most recent developments include two wind parks belonging to Copel, a state-owned local company: the wind parks ‘Santa Helena’ e ‘Santa Maria’ with 49,5 MW each, that started operation in May 2015. Also ‘CPFL Renováveis’ a renewable energy branch of CPFL a private group that operates in the Brazilian power sector, inaugurated in April 2015 the ‘Morro dos Ventos II’ wind park with 29,1 MW in the State of Rio Grande do Norte. In March 2015, Queiroz Galvão, a Brazilian construction group, inaugurated its fourth set of wind parks, ‘Complexo Eólico de Ria-

chão' with 145,8 MW constituted by five individual parks in the State of Ceara; other two wind complexes with 208 MW each are also in construction by Queiroz Galvão (QG). It should be noted that some of the QG farms in Brazil have been among the more efficient in the country according to the system operator; for instance, in 2014 its wind farm of 'Colonia' operated with a 67,3% of capacity factor.

Important examples of developers are international players as Enel Green Energy (EGP - subsidiary of the Italian company Enel) that has currently around 400 MW wind parks installed -wind park 'Cristalândia' in the State of Bahia is currently being developed with 90 MW. EGP has also built the first hybrid wind-solar plant in Brazil in Tacaratu (PE): the wind park "Fontes dos Ventos" (80 MW) and two solar PV "Fontes Solar I e II" (11 MW).

There are also many local players developing wind parks, as is the case of 'Casa dos Ventos' that has around 5,5 GW of projects with PPAs obtained in the auctions, including the recently built cluster 'Ventos de S. Clemente' (216 MW) in the state of Pernambuco. 'Casa dos Ventos' has a 'partnership with GE and its service branch; GE gave support to 'Casa dos Ventos' in the construction of 'Ventos de S. Clemente' as in two other wind farms clusters: 'Tinguá' in the State of Cará that has GE has 77 GE 1.6-100 wind turbines, and 'Santa Brígida' in the State of Pernambuco using 107 GE 1.7-100 wind turbines.

Another important local player is Renova, but it recently lost market participation as its negotiations with TerraForm, a SunEdison affiliate, were affected by the Sun Edison financial problems, and as such it gave up of a contract with the distribution company Cemig to build a 676 MW wind complex in Jacobina, Estate

of Bahia. Even so Renova has a portfolio of wind parks with 1,4 GW of installed capacity, including the complexes of Alto Sertão I (293 MW) and Alto Sertão II (386 MW), both in Umbirana, the State of Bahia.

Chile

Following Brazil (and Mexico), Chile and Uruguay have also developed its wind generation. Chile is in fact a pioneer country in the developing of wind and solar plants in LA, as its energy matrix is highly dependent on imported fuels and it is a very convenient place for these new renewables.

At the end of 2015, the country had 904 MW of wind parks installed, most of it in the Coquimbo region connected to the 'Sistema Integrado Central (SIC)'. Although it still has a hydro potential to exploit, there is also a huge environmental contentieux related to these large hydro projects; some are in Patagonia (as is the case of the paradigmatic project of UHE HydroAysen), in a well cared natural environment, and it is extremely difficult to build the long transmission lines needed to carry their energy to the main loads, located in Central and North Chile. The country thus depends for its electricity on imported fossil fuels and energy prices are used to be very high, with generation costs of the diesel thermal plants above US\$ 100 / MWh. At current levels, with the lower oil prices in the global market, Liquefied Natural Gas has been imported at the price range of US\$ 8-11 / millions of BTU what brings the electricity generation to prices around US\$ 60-80 / MWh, though remaining very sensitive to the oil-gas market fluctuations.

The wind farms were initially developed, as in Mexico⁵, to supply directly large industrial consumers, as it was not usual a consistent offer

⁵ See coming Note on Mexico.

of long-range contracts with guaranteed prices, what helps investors in obtaining the necessary support from the financial institutions. One of the largest Chilean wind farms was developed to answer the needs of Antofagasta Minerals, a mining company that, in partnership with the North American developer Pattern Energy, inaugurated in August 2014 the wind farm 'El Arrayan' with 115 MW close to its 'Los Pelambres' mine. At that time, it was the largest wind farm in operation in Chile.

In Coquimbo, a particularly windy region, is also located the wind farm Punta Palmeras of 45 MW completed by Acciona Energia Chile in 2015 that has a 12-years Power Purchase Agreement (PPA) in order to supply local company Colbun. Although the Region of Coquimbo concentrates most of the Chilean wind parks, other regions started to be exploited as is the case of the Chiloé island, where the wind conditions are very stable and the local company Ecopower is building a 101 MW park even with the opposition of environmental local groups. Also in Chiloé, Viento Austral, belonging to the Hungarian group Callis, is developing the wind park Ancud (120 MW) and Trans Antarctic Energia, subsidiary of the Spanish Jealsa, owner of the local wind park San Pedro I (36MW), has signed a contract with Gamesa to build another one, San Pedro II (65 MW).

With the introduction of auctions and long-range contracts for supplying the regulated consumers after 2005, and with a new legislation imposing quotas of renewable energy in 2008, the availability of long term contracts increased stimulating the growth of individual energy producers.

In 2015, another significant change happened as the government through the 'Comisión Nacional de Energia (CNE)', with the participa-

tion of the distribution companies, promoted a major tender to supply electricity to the regulated customers, breaking the daily demand in blocks in such a way that wind and solar projects could compete for supplying only at determinate periods of the day. As a result, around 11 TWh were awarded under 20-year contracts, of which almost 20% were won by the new renewables, divided between solar and wind projects.

Among these new projects, Alea Energy (joint venture between the developer Irish Mainstream and the investment fund Actis) is going to build four wind farms totalizing 343 MW at an average price of US\$ 79 / MWh. Other contracts at this auction were won by Ibereolica Cabo Leones and by PV solar projects of Abengoa.

At the beginning of 2016 the largest wind park being built is 'San Juan de Chañaral' (186 MW) in Freirina, Atacama Region, that is going to be connected through an 84 km line to Punta Colorada in the central system, SIC, supplied by Vestas and developed by Latin American Power, with presence in Brazil, Peru and Chile.

A new large tender is expected by July 2016 and with long-range power purchase agreements available, the high costs of imported energy in Chile, and the availability of wind resources, it can be expected that the growth of the wind participation in the electric matrix of Chile will continue in the years ahead.

Uruguay

Another country that has been aggressively promoting the implementation of wind farms is Uruguay. Considering its population, it was the one with the highest proportion between wind capacity and population among the LA countries. At the end of 2014, Uruguay had 136 MW installed in wind farms for each million habitants, seconded by Chile with 47 and

Costa Rica with 42. At that date, Brazil had only 24 and Mexico 21 MW of wind farms per million habitants. Its total wind installed capacity by the end of 2015 reached the impressive 805 MW.

The above figure was the result of a concentrated effort to reduce dependence on imported energy and at the same time to increase the participation of renewables. Thanks to the expressive availability of wind, '*Administración Nacional de Usinas y Trasmisiones Eléctricas (UTE)*', a vertical (state) monopoly responsible for the supply of electricity in the country, started its own wind parks (Caracoles I and II, with 10 MW each, and Juan Pablo Terra with 67 MW) while promoting tenders offering long-range contracts for buying wind energy from independent developers.

Since 2007, based on a governmental decree, UTE has organized a sequence of competitive tenders offering 20-year contracts at pre-defined prices that resulted in this strong growth. Between 2006 and 2012, UTE managed six tenders: two for biomass and four for wind plants. As a result, around 1 GW of wind parks installed capacity was contracted.

The last tender for wind parks in 2012 considered 50 MW as a maximum size for the parks, at a fixed price of US\$ 65 / MWh. In this tender, 11 projects were selected with a global capacity of 538 MW. Many are being implemented and Uruguay and UTE is now developing itself three wind parks - 'Pampa' (140 MW) in Tacuarembó, 'Arias' (70 MW) in Flores and 'Valentine' (70 MW) in Treinta y Tres.

Argentina, Peru, and Colombia

With ever-increasing cost reductions, it is likely that most countries with a wind poten-

tial will implement wind farms in the near future, and many others that have been less involved in the wind power promotion until now, as the three above, will start to move in this direction.

Since October 2009 the Peruvian government has promoted four tenders for non conventional renewables (Wind, solar, biomass, small hydro, geothermal) after the edition of new legislation in 2008. All together they have resulted in contacts for a total of 1,262 MW of installed capacity of such plants. In the last tender Enel Green Power (EGP) won contacts for the wind park of Nazca (126 MW) at US\$ 38 / MWh, while Greenenergy Peru won 20-years contracts for the wind parks of Huambos (18 MW) and Duna (18 MW) at US\$ 36,84 and US\$ 37,79 dollars/MWh, respectively, probably the lowest prices for wind generation in all LA⁶. Analysis⁷ of these surprising low prices points to the possibility of the use of green bonus to finance these projects.

While in February 2015 EGP received the governmental licenses needed to start building the wind complex of Nazca in the Region of Ica in Peru, with 126 MW, it has also many other wind farms with "concesiones temporales" to study. It seems to be one of the most aggressive players in the renewable businesses in Peru.

Argentina, that had 279 MW already installed at the end of 2015, the State of La Rioja is discussing with the Chinese company Hydro China an agreement to increase in another 104 MW the existing wind farm 'Parque Arauco' in what seems to one of be the first moves in this field in Latin America of Chinese companies. In 2016 it was announced that the local company 'Parque Eolico Arauco', a joint venture between the State of La Rioja and the federal

6 In this same auction, the prices paid to solar PV were also very low, in the range of US\$ 48 / MWh.

7 <https://www.linkedin.com/pulse/4th-renewable-energy-auction-peru-life-below-50mwh-mart%C3%ADnez-fanals>

state company Enarsa, received a green light for a Chinese financing to expand its capacity to 200 MW.

With the change in the federal government, the new authorities are indicating that they intend to push the penetration of these non conventional renewables in the country (a 1GW tender for renewables is being expected), however they are still recovering the general electricity tariffs that were artificially compressed for many years, and it is not clear how long it will take to bring the power sector back to normality in order to stimulate properly new inversions in power generation. In any case a strong growth of wind and solar PV can be expected in the next few years.

In Colombia, in the region of La Guajira, one important wind energy potential has been identified, with a possible capacity factor of 50% that could make the wind energy competitive even without any subsidies, and some projects are being already analysed, but till now the penetration of wind generation has been very small. The development in La Guajira still depends on the availability of transmission lines to carry the electricity to the demand centres.

Note on Mexico and Central America

Mexico

Second only to Brazil in LA, Mexico has more than 3.0 GW of wind generation already in operation that has been continuously growing since 2009-2010. According to the 'Asociación Mexicana de Energía Eólica (AMDEE)' at the end of 2015 Mexico had an installed capacity in wind turbines of 3,073 MW with 37 farms in operation in the Sates of Oaxaca, Baja California, Chiapas, Jalisco, Tamaulipas, San Luis Potosí y Nuevo León.

One of the largest Mexican wind complexes was Oaxaca I-IV with 350 MW capacity, built

and operated by Acciona. The firm also owns in Mexico the 'Eurus' wind park, with 250 MW, situated in the Oaxaca region and considered one of the largest in LA, that has been in service since 2009 and supplies electricity to the cement local company Cemex.

At the end of 2015, also based on information published by AMDEE, Mexico had to that date 2,360 MW (77% of the total) wind parks concentrated in the Oaxaca region. Most of these farms, around 69% of the total capacity, were built in order to supply large consumers that were the initial main motivation of these developments.

More recently Mexico started to change its power sector institutional model and instituted the use of tenders to contract both new supply (15-years contracts) and 'Certificados de Energía Limpia" (20-years contracts) that the distribution companies are obliged by law to acquire in order to comply with the new legal obligations (Mexico is supposed to have in 2018, 25% of its electricity coming from renewable sources). The first of these tenders was concluded in March, 30 2016, resulted in of contracts for 11 solar plants and 5 wind parks, corresponding to 5,385 GWh/year that roughly corresponds to 1,810 MW new installed capacity (using an average capacity factor of 33.6%), with 74% of solar PV and 26% of wind parks. The wind prices in this auction averaged US\$ 55 / MWh. It has shown also a solar industry growing stronger than the wind, that can be partially explained by the larger availability of solar than wind resources in Mexico, and the solar prices were lower in the range of US\$ 45 / MWh.

Central American countries

Many other countries in LA are also promoting the advance of new renewables, particularly some Central American states. Although

with relatively small power markets, they have been implementing wind parks, as can be seen from the 2015 figures in Table II.1, mainly in the case of Costa Rica, Honduras, Panama and Nicaragua. In addition, Guatemala has started to build its wind farms. It should be noted that all these countries have recently completed the major part of a set of transmission lines interconnecting Central America, and establishing a common institution to regulate its flows, SIEPAC.

Costa Rica is expecting to increase by 2017 its wind farms capacity to 393MW bringing its participation from the current 7% to 10,5% of the power generation in the country, as eight new projects are being implemented. Honduras in 2012 installed a 102 MW wind farm -‘Cerro de Hula’ - one of the largest projects in Central America and at the beginning of 2015 a second wind farm became operational - ‘San Marcos de Colón’ with 50 MW. Nicaragua installed its first project at the ‘Parque Eólico Amayo’, ‘Amayo I’ with 40 MW and posteriorly ‘Amayo II’ with 23 MW; other wind projects followed bringing its wind generation capacity to 186 MW at the end of 2015.

Other Central American countries are following the example of these pioneers and Panama, the fastest growing economy in the region, is involved in the construction of the wind complex ‘Laudato Si’ in Penomé with 215 MW. Also Guatemala, a country with the tradition of an energy exporter, is reported to be building three new wind farms - ‘Viento Blanco’ with 21 MW, ‘Tresca’ with 30MW and ‘Eólico San Antonio del Sitio’ with other 52,8 MW.

At a company level, it is interesting to notice that in the wind power sector it was possible to identify only two experiences of internationalization and partnership among Latin American companies in the power sector. The wind park ‘Artilleros’ with 65 MW was inaugu-

rated in 2015 and was developed through a partnership among UTE and Eletrobras, a Brazilian state-owned company. EPM, the state-owned company from the city of Medellin, Colombia, developed a wind farm in Chile, the ‘Parquet Eólico Los Cururos’ with 110 MW. Curiously, a declaration to the press of an executive of EPM, when questioned about why to build wind farms in Chile rather than in Colombia, he said that in Chile the conditions and the costs were lower.

One interesting possibility that was vented, of a partnership of UTE and the Brazilian company Eletrobras in order to jointly exploit the wind potential in Uruguay and in the South of Brazil, did not move forward at least till now.

In the power sector as a whole, apart from the above mentioned, considering the LA companies, only the Colombian ISA and EDM have significant investments outside their country of origin; and in a smaller scale the Chilean Colbún has a coal generation plant in Peru. As such, the power companies with a more global presence in Latin America are basically multinationals from abroad. In the specific case of the wind and solar developers, many international players are presents in LA, including, Enel Green, Acciona, Abengoa, SunEdison (although now filing for bankruptcy protection), and among the companies controlled by Chinese capital, Canadian Solar, as the Chinese companies Goldwind and Jynko Solar are just beginning to grow in the region.

Solar plants

Following the wind power wave, the other new non-conventional renewable that is showing a fast development is solar energy, whose costs are decreasing rapidly, making it already competitive in some cases, and most likely globally in the next decade.

Two main technologies have been considered – the photovoltaic (PV) generation and the thermal solar, this last one usually based on the concentration of solar energy (CSP). Currently the most developed technology is PV and most Latin American plants that sell energy to distribution companies or to large consumers are included in this category with just a few exceptions. The CSP⁸ plants are still very expensive and generation is not competitive.

PV generation, apart from its large units here discussed, has also the capability of directly supplying small individual customers, *what will possibly have a strong disruptive effect over the current business model absolute since Edison's times*. As the complementary installation of batteries for electricity storage is still expensive, the distributed generation with PV modules may take a few more years to develop properly and will not be addressed in this report. Though we are more concerned with the existing power systems, it should be noted that distributed solar generation must be closely followed and can be the root of one of the most important transformations of the power sector in these initial decades of the 21st Century.

The biggest problem with solar generation is clearly the fact that solar energy is not available at night-time; moreover, its conditions can vary considerably along the days. Some of the CSP have been implemented with the capacity of storing energy for a few hours, using melted salts heated during the day, and can give back energy for some hours at night-time, but this is still a very expensive solution. One option adopted by some is to have also another kind of generation available (through property or contract) that can be used at night, and sell the energy considering both plants.

⁸ The first CSP commercial unit in the world was built in the State of California in the 1980s. The US and Spain were the pioneers in this type of generation. Recently, a large plan -the largest in the world-, was developed through a public-private partnership and started its operation in 2014, the 'Ivanpah Solar Electric Generation System', in the Mojave desert also in the State of California, with 392 MW of installed capacity. Recent news (according to the Wall Street Journal) indicates that it is generating only 40% of the energy originally expected.

In the long-range energy outlook published by the International Energy Agency (IEA) it is expected that the solar energy installed capacity in the world will reach the 400 GW figure by 2020, as PV costs will keep falling.

In Latin America, solar energy is still in its infancy but the situation has been changing, and after the success of wind power, most countries are looking seriously at their solar potential. According to GTM Research (Greentech), a provider of market analyses, at the beginning of 2015, the top 10 developers of solar projects in LA, in operational capacity, were: Sun Edison (236 MW), Enel Green Power (136 MW), Solventus/Sun Power (90 MW), Solarpack (88 MW), T Solar (40 MW), Gestamp (40 MW), Gauss (39 MW), EOSOL (15 MW), CFE (6 MW) and Greenergyze (7 MW), adding up to 697 MW, compatible with the IRENA figures. But the recent changes in the rhythm of expansion were so impressive that the same GTM Research estimates that another 1,416 MW of solar PV capacity were added in the region through 2015.

Other developers than the above are also working in new projects and the above ranking is likely to change in the next few years. In any case, it can give us an indication of the degree of activity currently in the field.

Chile

Now the most advanced country in solar generation in LA is Chile, where its energy situation and high degree of insolation have been extremely favourable to a competitive development of PV units. At the end of 2014, 368 MW of PV were reported installed in Chile; at the end of 2015 these figures changed to 848 MW.

According to the *'Centro Nacional para la Innovación y Fomento de las Energías Sustentables'* (CIFES), a Chilean governmental agency, 2014 was the year of the take-off for the solar energy in the country, when many solar PV plants and also a CSP plant entered in construction. The CIFES report of May 2015 indicated an installed capacity of 548 MW (with an increase of 180 MW over the December 2014 figure) and the existence of 1,647 MW of PV projects and a 110 MW of CSP in construction.

In just one year, in May 2016, according to the *'Ministerio de Energía'* the installed capacity in solar plants increased to 852 MW, as the wind farms capacity was 910 MW at the same time, while other 814 MW of solar plants and 383 MW of wind parks were being built. These figures show that by the end of the current year the installed capacity of solar plants will likely be higher than the total capacity of wind parks.

Many different developers are present in Chile, both local and international companies, usually in partnership. Among the Chilean plants, SunEdison built one of the largest PV plants in LA - the *'Amanecer Solar'* with 100 MW in the Atacama Desert region, selling part of its energy to the mining group CAP. SunEdison has also there *'San Andres'*, a 50 MW plant selling to the Interconnected Central System (SIC), and is concluding a merchant plant *'Santa Elena'* with 72,8 MW in partnership with Pacific Solar (with local and Spanish owners) in Antofagasta. As SunEdison filed for bankruptcy its assets in Chile are being sold, and two of its solar PV plants connected to the SIC and with PPAs in force were already bought by the local generator Colbun that is entering the solar business.

The other leading developer in Latin America, Enel Green Power is also present in Chile

with four solar plants already built, the *'Diego de Almagro'* (36 MW), *'Lalackama'* (60 MW) *'Chañares'* (40 MW), and *'Finis Terrae'* (160) MW. EGP has invested approximately 270 million US dollars in Finis Terrae, situated in Maria Elena at the Atacama region, is now the largest PV plant in Chile; it started production in May 2015 and has a PPA signed to deliver energy in the North at the SING. EGP has also started production at the first 20 MW of *'Carrera Pinto'* (97MW), located in the Atacama region, close to the city of Coiapó, and has signed a long-term power purchase agreement (PPA) with Endesa Chile, and its energy is to be delivered to SIC Region.

Other developers are also working in Chile.

Another large plant, in the Atacama region, in the city of Coiapó, is under construction by First Solar, *'Luz del Norte'*, with 141 MW, expected to be finished by the end of 2016. The Chinese Sky Solar, based on Hong Kong, is finishing the financing⁹ for the construction of the solar plant *'Arica I'* with 44 MW in *'Pampa Dos Cruces'* also in the Atacama region.

Also Acciona, a Spanish company, is present in Chile and has started in October 2015 the construction of what will be the largest PV plant in Chile, *'El Romero Solar'* (246 MW) in the municipality of Vallenar in the Atacama Region.

The largest CSP plant in LA is also being built in Chile. In the supply auction at the end of 2014, contracts were awarded to Abengoa, to supply electricity from 2019 to 2033, on a 24-hour basis, from two 110 MW CSP with a thermal storage system and a solar PV plant with 100 MW. The US\$ 115/ MWh tariff has beaten in the auction other bids from conventional thermal projects. The recent financial trouble with the company may however change this whole design.

9 The IDB has approved a syndicate loan.

Currently the development of new solar plants in the north of the Atacama region, where there are excellent conditions for this technology, is facing some problems for the lack of the needed transmission lines to take this energy to central Chile whose construction is being slowed by difficulties in getting the proper permissions. Chilean transmission lines legislation is presently being discussed by the Congress, and positive changes are expected giving more rights to the government to force the construction of these lines.

Peru

Peru has an installed capacity of 90 MW in solar plants, expected to keep growing. Solarpack a Spanish company focused in solar energy with offices in many countries, including Chile and Peru, has in partnership with T-Solar (group Isolux) currently three operating PV power plants in Southern Peru, with a total capacity of 62 MW ('Tacna' 22 MW, 'Panamericana' 21 and 'Moquegua' 19 MW). T-Solar has also another two other PV solar plants adding 44 MW capacity: 'Repartición' e 'Majes' in the 'Departamento de La Joya'.

Enel Green Power (EGP) is also very active in Peru and won some contracts in 2015 in the fourth auction promoted by the Peruvian government apart from the wind plants, EGP was awarded a 20-years PPA for the large PV solar plant 'Ruby' (189 MW) to be built in the Moquegua region.

Brazil

Moving a bit later than Chile and Mexico, by December 2014 Brazil had only 15 MW installed of PV plants, all of them very small, the largest one a 3 MW pilot project of Tratctebel, the 'Nova Aurora' plant. However, the situation has been radically changing and there is a huge increase of power projects in development, as 890 MW

of PV plants were contracted in a specific tender still in August 2014 at an average price of US\$ 88 / MWh, the first tender exclusively oriented to solar energy. In 2015 there were another two auctions for solar PV, and other 834 MW were contracted in August 2015 at US\$ 84 / MWh and 929 MW in November 2015 at US\$ 78 / MWh. According to ANEEL, the regulatory agency, in June 2016 there was 95 plants with permissions to start construction adding up 2,707 MW of peak capacity.

In the near future, it is expected to promote a series of tenders of at least 500 MW per year, focussed on solar, what may create a stable market for solar generation equipments and services.

In order to satisfy these new contracts, many developers are building new PV plants, mainly Enel Green Power, SunEdison/Renova and Solatio/ Canadian Solar. The Spanish Solatio won a big stake of the PPAs offered in the last first tender representing a combined 360 MW capacity, and is examining the unregulated market of big consumers. In partnership with the Spanish engineering company Cobra, it is developing seven projects with 270MW in the state of São Paulo.

Solatio also established a partnership with the Canadian Solar (a Canadian company with Chinese capital and manufacturing units in China) for four projects with total capacity of 650 MW in the state of Minas Gerais, where the largest project 'Pirapora' (297 MW) has already obtained permissions for 8 individual parks adding up to 240 MW.

Enel Green is the main player in solar energy in Brazil and won contracts for a large number of solar PV plants in the first two solar auctions; among them is the PV complex with 210 MW 'Ituverava' at Tabocas do Brejo Velho, in the state of Bahia, and, at the same municipal-

ity, the solar 'Horizonte MP' with 103 MW. The company is also building in the State of Bahia, another solar complex with a total capacity of 158 MW, divided in two groups 'Bom Jesus da Lapa' (80 MW) and 'Lapa' (78 MW). In other northeast state, it is building 'Nova Olinda' with 210 MW at Ribeira do Piaui, in the State of Piaui. In September 2015 EGP started also the operation of the first hybrid wind and solar park 'Fontes' as pointed above.

SunEdison was starting its operations in Brazil and, in partnership with the local company Renova that successfully bid in the last tender, was planning to install around 107 MW of solar PV, and it is still not clear what will happen with these projects. Renova itself had a portfolio large portfolio of renewable projects and sold earlier 14 wind parks to SunEdison, where around two thirds of the sale were paid in SunEdison shares. Affected by the SunEdison downfall, Renova is also trying to restructure, and, as such, it may not develop its planned solar and wind plants.

Apart from the larger plants Brazil is experimenting with the possibility of floating solar PV units at some Hydro dams. It is the case of the 'UHE Porto Primavera' in the Estado de S. Paulo where CESP the proprietary of the hydro plant is installing 180 flexible floating panels and 100 rigid floating on land, adding a small capacity of 26 kW. Also Eletronorte in partnership with Sunlution and WEG installing a larger 5 MW in two stages at the 'UHE Balbina'; a similar project is also being developed by CHESF with Sunlution and WEG in the 'UHE Sobradinho'.

Also distributed generation (DG) is expected to start growing in the country as more flexible regulations were issued. As an example, both AES and CPFL Energia are expanding

their distribution businesses to operate directly in the DG segment and had already signed their first contracts with local consumers. Among the top companies the US FirstSolar has an office in Brazil and is prospecting also its GD market. Currently, many other smaller local developers are also looking for opportunities in that market. As Brazil already has an important network of companies working in the field of solar energy for water heating¹⁰, it may be possible that also some of these companies may come to operate also in DG.

Uruguay

Similarly to what is happening in Brazil, other countries are also moving into the solar generation although in a smaller scale. Uruguay, a country that has been aggressively promoting new renewables, has launched a tender in 2013 in order to contract 200 MW of solar plants at a maximum price of US\$ 91.50 / MWh.

In July 2014, the first contract was signed between UTE and the Spanish Fotowatio Renewable Ventures, for a 64 MW plant - 'La Jacinta' in the region of Salto - with a PPA for 30 years with UTE. La Jacinta was completed in January 2016 and is the largest PV plant in Uruguay to date.

In 2015 Uruguay has commissioned 58 MW solar PV plants, and plans to commission other 167 MW in PV plants in 2016.

Argentina

With the changes in the Federal Government, it started to recover the power sector tariffs, though it may take some time to become again attractive to potential investors. In the case of solar energy, the provincial governments are pushing forward a few actions.

¹⁰ According to the German consulting firm Solrico in May 2016 Brazil was the third country in the world in solar heating panels; also the International Energy ranks Brazil as fifth in the world in the use of solar for water heating, after China, US, Germany and Turkey.

In the State of Jujuy it was signed in 2016 an agreement between local companies and the Chinese Shanghai Electric Power (Power China affiliate), in order to develop a two phases solar plant, each with 300 MW.

There was also announced that the State of La Rioja has signed two agreements to develop the solar generation in that region. One with the Chinese company CSIC (China Shipbuilding Industry Corporation), and the other with the German company Photovoltaic Park.

Note on Mexico and Central America

Mexico

Another LA country that is advancing in the solar power is Mexico, with installed PV plants that at the end of 2014 were adding 131 MW installed capacity. In 2014 started operations the 'Aura Solar I' photovoltaic power plant by Gauss Energia and Martifer Solar, an international engineering company. Recently Energy Partners Latin America (EPLA) announced the construction of a 150 MW PV plant in the State of Baja California.

As the institutional model of the power sector in Mexico underwent expressive changes in 2014, favouring the introduction of private players, new solar projects are in the pipeline. The first governmental auction for renewables that took place in April 2016, has shown a large advance of the solar PV in the country, as solar projects won 74% of the PPA contracts, for 4,108 GWh / Year, an estimated 1,808 MW of installed capacity.

Among the solar contracts, 56.7% were won by Enel Green Power (EGP) becoming the largest solar player in Mexico, 18.6% by the Indian Vega Solar, 11.4% by the Chinese JinkoSolar, 6.8% by the US company Sun Pow-

er, 3.6% by Canadian Solar (through its subsidiary Recurrent Energy), and the remaining contracts by local companies, 1.4% by Photenergy and 1.5% by Sol de Insurgente.

The average price of solar PV in that auction was also a surprisingly low US\$ 45.2 / MWh, with a record low in one case of US\$ 35.5 / MWh (for one of the EGP contracts), confirming the trends pointed by the 2015 Peruvian auction.

Central America

Also in Central America, solar energy is booming.

Honduras inaugurated in 2015 a large 100 MW PV plant, the 'Nacaome-Valle' and have others in the pipeline. SunEdison is building a PV complex in Honduras with three individual plants: Pacífico (23,3MW), Choluteca I (23,3MW) y Choluteca II (35,1MW), under a 20 years PPA to sell this energy to the state-owned company ENEE. Guatemala has inaugurated in 2015 a 58 MW PV plant Horus Energy, whose development was contracted with the Spanish group Ortiz. Panama, through his first tender, has offered 20-year contracts, won by different investors, with tariffs in the range US\$ 80-105 / MWh with the obligation of starting supply in 2017. As a result the following projects are being developed: Scott Solar (77MW), Pocrí (16MW), Boquerón (19,8MW), Progreso (49,5MW) and Pacora II (10MW).

THE INDUSTRIAL STRUCTURE FOR WIND AND SOLAR GENERATION

Overview

The main players in both wind and solar industries are large international companies. In 2013, in the wind power sector according to the International Energy Agency (IEA)¹¹ six

¹¹ 'Technology Roadmap, Wind Energy', International Energy Agency 2013.

countries dominated the turbine manufacture sector in 2013 (the United States, Denmark, Germany, Spain, India and China), but although this group has not changed in 2015, there is currently a much larger participation of China, with a large part of the turbines production moving from Europe to Asia. In 2015 North American Windpower¹² indicates that the top onshore wind turbine maker was the Chinese Goldwind and if one considers that also in the top-10 rank there were also many other Chinese companies, the growth of China in this industry can be clearly seen.

The European and North American companies were responsible for the initial efforts in the wind industry, but, in Asia, India and China have been increasing very quickly their participation in the global market and Chinese companies are currently finding their space in the top 10. Outside this group of nations, emerging manufactures can also be found in the United Kingdom, France, Korea and Brazil.

In Latin America (LA), Brazil became the main hub for wind turbines assemblage, and most of the complementary industrial activities. No other countries have had a similar industrial development in this field with the partial exception of Mexico, but in that case oriented to the US market. Very recently however, in Argentine, Impsa inaugurated a wind turbines assembly plant with an initial production capacity of 150 2.0 MW turbines a year in the Mendoza province.

In the solar industry the global picture is not very different, although competing with European and North American multinationals, the global dominance nowadays is clearly Chinese. For instance, in the purification of silicon, the first step in the solar industrial value chain, the

Chinese dominate 80% of the market. Again, after initial efforts in German and US, the Chinese grew, possibly gaining scale from its huge internal market, and assumed the lead.

Although the list of the top manufacturers has been changing year after year as many of these companies are changing its place in the rank many simply leave the list and others leave and also declared bankruptcy, most of the time the Chinese companies dominated the rank. In 2015 according to the Renewable Energy World Magazine, only one of them had no manufacture established in China, although some of them have also plants in Europe and in US; topping that list were the Chinese China Tina Solar (with manufacture in China/ Netherlands), JA Solar (in China and Malaysia), Hanwa Q-Cells (in China, Germany, Malaysia and South Korea), and Canadian Solar (China), and only in the fifth position came the US company First Solar but with manufacture also in the Orient (in US and Malaysia).

In LA, these top solar manufacturers, European, North American and Chinese companies, are also already present but basically only by selling units and there is only an incipient degree of industrialization in the region, although but this picture may change in the next few years as solar energy is just starting to play a more expressive role in the electricity matrix of many LA countries and an industrial base can be built as the market is growing fast. With solar energy pushing forward, this could be an important process and a chance to be well exploited in the technological arena in the next years to come.

In what follows, the SA industrial context for these two energy forms, wind and solar, is discussed.

12 "Top10 Wind Turbine Makers for 2015: The Year of China", in <http://nawindpower.com/top-10-wind-turbine-makers-for-2015-the-year-of-china>.

Wind power manufacture

The main parts of a wind farm unit are the tower (that may be made of steel or concrete, the higher ones being usually of concrete), the nacelle, that sits over the tower and where the components are enclosed (including the controller, brake, gear box, generator, etc.) and the rotor, made up of blades attached to the hub. The wind turbine is also integrated to the grid, through sub-stations and transmission lines. Usually, different companies manufacture different parts that are aggregated through a value chain by the turbine assembler.

In 2014, according to MAKE, a Danish renewable energy consultancy, the main wind turbine world market shares were around 10% each and belong, in this order, to Siemens (Germany), GE (US) and Vestas (Denmark). The other seven largest producers are Goldwind (China), Enercon (German), United Power (China), Gamesa (Spain), Ming Yang (China), Envision (China) and XEMC (China). As the scenario changed in 2015 according¹³ to both FTI Consulting and Bloomberg New Energy Finance, the new rank was, first Goldwind, and following, in this order, Vestas, GE (that bought Alston), Siemens, Gamesa, Enercon, Guodian (China), Ming Yang and Envision tied for eighth place, and CSIC (China).

In LA, many of these top international companies are present, both developing the farms themselves and supplying other wind farm developers; in many cases they assume also the operation and maintenance of the equipment. The global industrial energy sector however is not static and many transformations are going on all the time. In 2015 and 2016 there were many major important corporate changes in the wind turbines fabrication business whose practical consequences for LA region are still not clear.

One of most important was certainly the acquisition of Alston energy businesses, including renewables, nuclear and transmission segments, by GE, both companies with presence in the wind sector in Brazil. The operation involving regulatory approvals in more than 20 countries was concluded in October 2015.

More recently, in June 2016 Siemens and Gamesa have signed binding agreements to merge Siemens' wind power business with Gamesa. Siemens will control the new combined wind company and will hold 59 percent of the share capital. With this new movement Siemens will most likely move up in the next list of the top 10.

Many other large players outside the top 10 list, have being through global corporate changes that could affect their performance. Indian Suzlon, with presence in LA where it supplied among others the 'Artilleros' wind park in Uruguay, lost global market share in 2015 as it sold its German subsidiary Senvion to reduce its debt.

Acciona, another important player with a large market share in LA, announced in April 2016 the fusion between Acciona Windpower (Spain) and Nordex (German), where the later will be in control of the resulting company but Acciona will have a stake of 29,9% of the Nordex shares becoming the major shareholding of that company. The resulting company starts operations with a portfolio of more than 2,800 MW contracts for wind turbines in the world.

It is still not clear how these changes will affect their LA' strategy but till now Latin America seems to be seen by those companies only as an important market in expansion and does not have any role in their industrial plans, ex-

¹³ As previously pointed by North American Windpower.

cept may be for the case of Brazil. The examination of the industrial plants in LA brings out the striking observation, that all the main industrial wind turbines plants in the region are located in Brazil, where not only the size of the market but also the requirements of local contents by the development bank BNDES have attracted the installation of many industries, requiring for the purposes of this document a closer look at the evolution of the Brazilian turbines factories.

In Brazil, the initial feed-in tariff programme, Proinfa¹⁴, was devised to stimulate the introduction of wind parks, and BNDES, the Brazilian development bank that lends money at preferred rates to local industries, offered a special credit line to wind turbines industries that complied with its specific rules of local content.

Initially BNDES asked for 60% as the minimum representative of local content. Later on, when the PPA were offered through regular tenders by the government to supply electricity to the regulated consumers, the local content parameters to finance new projects progressively asked for higher levels of nationalization. As of 2012, these rules included a progressive increase in local production, requiring as starting point that at least three out of four conditions should be observed:

- (1) domestic production of at least 70% of the steel or of the concrete used;
- (2) domestic production of the blades (could be by third parties);
- (3) assembling of the nacelles in Brazil;
- (4) Production (could be by third parties) and assembling of the cube (hub) in Brazil.

Many companies nowadays fulfil these conditions, in order to obtain the BNDES financial support. Sometimes they were obliged to adjust their production to them, as their obsolescence is essential to keep them competitive in Brazil. Initial difficulties were responsible for the failure of many projects under the Proinfa, but the main players eventually established manufacturing units in the country.

Some of the initial efforts were developed by Wobben, a subsidiary of Enercon GmbH that was the first industry of the sector to be installed in Brazil. In 1999, Enercon supplied in S. Gonçalo do Amarante (CE) the wind park of 'Eólica de Taiba' - the first independent producer of wind energy in Brazil -, with ten turbines of 500 MW each, and the 'Eolica de Prainha' in Aquiraz (CE) with 10 MW, the largest wind park in Brazil at the time.

Currently, the wind energy support-industry installed in the country includes a large number of plants, not only of turbine assemblers; a myriad of different businesses provides products and services to the industry. According to a very detailed mapping made by the 'Agência Brasileira de Desenvolvimento Industrial - ABDI'¹⁵, there are in the country ten companies assembling large wind turbines; four building blades, eight building steel towers, eight building concrete towers, and also a large number of other manufactures and service providers in 2014.

The larger turbine assemblers in Brazil according to ABDI are, Acciona, Alston, Impsa, Gamesa, GE Energy, Siemens, Suzlon, Vestas, WEG and Wobben. Impsa recently asked for bankruptcy while involved in a restructuring process.

14 See the previous subsection.

15 "Mapeamento da Cadeia Produtiva da Indústria Eólica no Brasil", Agência Brasileira de Desenvolvimento Industrial -ABDI, Ministério do Desenvolvimento, Indústria e Comércio Exterior, Brasília, 2014.

Following Lage and Processi¹⁶, the production capacity of wind turbines in Brazil in 2013 was of 2,950 MW per year and distributed as follows: Alstom (300 MW), Gamesa (200 MW), GE (750 MW), Impsa (450 MW), Siemens (250 MW), Vestas (400), WEG (100 MW), Wobben (500 MW). Also by the same authors, considering the expansion plans in place at 2013 this total capacity was likely to increase to 4,680 MW in the near future, and three new producers should be added, Acciona (432 MW), Fuhrlander (360 MW) and Suzlon (388 MW). Alstom was expected to increase its production capacity to 450 MW and Vestas to 800 MW.

The above figures have to be slightly revised now, as both Impsa and Fuhrlander signed for insolvency. Fuhrlander, still in 2012, signed for insolvency in Germany, hurt both by financial problems and by the reduction of wind turbines prices in Europe, due to Chinese competition. As such, it gave up its Brazilian plans and broke an initial contract with Furnas (from the Eletrobras group) to supply turbines for two parks in the Ceara State, where it was also going to build its Brazilian plant.

Wind Power Energy, the Brazilian unit of the Impsa group facing serious cash problems, has filed also for bankruptcy protection at the end of 2014 and is considering to sell some of its assets. Its holding, Impsa, has also filed for bankruptcy protection in Argentina. It is not clear yet what will happen with Wind Power Energy itself. In July 2015 it was announced that both Chinese companies Goldwind and Sandy were examining the possibility of buying Impsa factories.

It should be pointed also that the major corporate changes in the last year above mentioned are modifying the global field but it is still not clear how they will affect the local context al-

though some kind of restructuring could be expected. In any case, both combined GE/Alston and Siemens/Gamesa tend to increase their market share and may have to increase also their production capacity in the next few years. Also the industrial presence of Nordex in the country through Acciona may increase its competitiveness. It has to be seen how the other players will react, but at least Vestas, inaugurated in January 2016 its first local factory. The current economic and political crises in Brazil may postpone some of the expected industrial growth, but the energy demand most likely will grow again, and as the potentiality of these clean energy forms is great its industry growth should follow.

A more detailed look at the presence of these major players in the wind turbines in Brazil, can give us a better view of their operations and of the possibilities of evolution of their participation in these global value chains in Brazil and in the region as a whole:

Wobben, a subsidiary of **Enercon**, as told before, was the first to be installed in Brazil and in the LA region as a whole. It has currently three units operating in the country. The main assembly unit in Sorocaba (SP) was installed in 1995, another unit concentrated in making blades was installed in 2011 in the port of Pecem (CE), and the unit of Parazinho (PA) inaugurated in 2010 builds concrete towers.

Its local production complemented the imports from Enercon, constituted the main provider of turbines for the Proinfa projects, and was responsible for half of the initial wind farms, existing in 2012, adding up to 1,0 GW of the total 2,0 GW installed capacity at that time. Wobben also exported its turbines to two plants In Argentina, one in Costa Rica and one in Bonaire, in the Dutch Caribbean islands.

16 "Panorama do setor de energia eólica", Elisa Salomão Lage and Lucas Duarte Processi, Revista do BNDES 39, junho de 2013.

In spite of its early presence in the country, it has been losing market share with time as the competition became more intense. Even so, in 2015 Wobben signed an agreement with Rio Energy to supply its wind park 'Serra da Babilonia' (216 MW) in the State of Bahia.

WEG is a local company founded in 1961 producing motors and electrical equipment, which has also expanded also abroad in the 1990,s and, in 2011, started the production of wind turbines in Brazil.

It is the only local company, controlled by local investors, operating in this field. It had initially the support of a Spanish company, MTOI, but since 2013 is under a technological agreement with the US company Northern Power Systems. Apart from buying the technology, it developed a local network of suppliers, as 14 local companies have started to supply some wind plant items, and another 23 are investing in order to do the same, according to WEG.

Its first sales were to the wind park 'Bons Ventos da Serra' in the State of Ceara, involving 11 turbines of 2,1 MW. Another early sell contract was to supply 46 turbines of 2.1 MW each to 'Energia dos Ventos I" park in Arati, Ceara, where WEG will also be responsible for its O&M for ten years. Its success in the wind sector in 2015 resulted in its turbines manufacture division being responsible for 29% of the total income of the company. At December 2015, WEG has signed an agreement with Copel, a State of Paraná owned distribution and generation company, to supply 13 new wind parks with 149 turbines; 86 turbines are for the wind complex of Cutia and the other 63 for the complex of Bento Miguel, both at the State of Rio Grande do Norte.

In partnership with Tratctebel, WEG is developing a proprietary technology for producing 3,3 MW turbines, using the P&D recourses in-

stituted by law and regulated by the Brazilian power sector regulatory agency, ANEEL. The project is under way, but with the Real strong devaluation in 2015 the project budget suffered and they are looking for other partners to bring additional recourses.

WEG is also under an internationalization process and it bought in 2015 a Spanish production unit for electric panels for industrial installations situated in the city of Valencia, Autrial, as part of that effort. The company is also starting operations in the solar photovoltaic field, producing all its components, except the solar panels.

Vestas, after Siemens and GE, the third largest world player in 2014, owns a plant in Maracanaú (CE). However, as BNDES rules changed, its production scheme was not able to comply with the new local content conditions. As such, in 2014 Vestas had a contract to supply 254 MW to 'CPFL Renovaveis' cancelled, what reduced its presence in the country as in that year it supplied only 87 MW in Brazil out of a total of 767 MW deliveries in Latin America.

In consequence, to protect its market position it invested 32 million euros to adjust its production to the BNDES rules, and since the end of 2015 it has been able to comply with these conditions. In January 2016 it inaugurated officially a new wind turbine plant in Aquiraz, Estate of Ceara to produce its V110-2.0 MW turbines, one selected in 2015 by the English magazine Windpower as the best in the world in the under 2.9 MW category. Its development included the formation of a network of local suppliers in order to reach the BNDES conditions of local content. Among others this network includes Atis, that produces blades and the Brazilian division of ABB that produces the generators.

Currently, Vestas operates 13 wind parks in the country and announced many new contracts for selling their equipment, including to a consortium formed by the French EDF and by the German Sowitec that is developing four wind parks in the State of Bahia with a total 117 MW capacity that have won PPAs in a 2015 tender. According to Vestas the company has orders for another 286 MW in wind turbines and is negotiating more 420 MW.

The Aquiraz plant was built considering also the possibility of exporting its production to other LA countries, and it should also be pointed that Enel Green Power (EGP) has a traditional relationship with Vestas and is one of its more frequent clients and its strong presence in LA may facilitate Vestas exports to some of these countries from the Brazilian factories.

Siemens, a subsidiary of the German Siemens, with headquarters in Berlin and Munich, produces capital goods in the fields of electrical engineering and electronics. The company develops and manufactures products, designs and installs complex systems and projects. Founded in 1847, just at the beginning of the second industrial revolution, it currently has one of the largest share of the competitive world market of wind turbines. Its Brazilian subsidiary was founded in 1905. Currently it has 13 factories in the country and its production for the energy sector as a whole has an index of more than 70% of local content.

In 2011 it signed a contract to supply the companies Ersa, Enel and Tractebel with 300MW, entering in the Brazilian wind power market. Since then, it has been involved in 18 wind parks already installed with 205 turbines and a total capacity of 450 MW in the Northeast region in the states of Bahia, Pernambuco, Ceara and Rio Grande do Norte.

Siemens executes the entire project, from siting to engineering and project management. It currently produces in Brazil some of the components utilized in the projects, including long blades, hubs and 80 meters high towers. Although otherwise expected, it still did not increase directly the range of its production, but through the global acquisition of Gamesa (see below) it has now a much strong position in the wind sector, including a production sector that complies with BNDES rules.

With the fusion of its wind businesses with the Gamesa ones, the resulting Siemens / Gamesa has now more than 21% of the production capacity of wind turbines in Brazil, coming behind only of the combined GE / Alston. In 2015 Siemens sold only 386 MW in turbines, but Gamesa sold 1,496 MW bring their combined Brazilian market share to 1,882 MW.

As Siemens is the world leader in the offshore wind equipment production, now with a strong position in the wind sector in the country it can be expected that it will start prospecting this market segment also in Brazil, till now unexplored.

Gamesa, a Spanish company working in the wind power sector has inaugurated its plant in Brazil in the 8th of July 2011, in the state of Bahia, with a BR\$ 50 million investment, besides the Petrochemical Complex of Camaçari, in Salvador. It can produce around 300 wind turbines adding up to 300 MW a year. In December 2014, its annual report indicated that Gamesa had already installed 868 MW in Brazil, and 2,970 MW in the whole of Latin America. In December 2015 its production of the 2.0 and 2.1 MW turbines was certified by BNDES and declared apt to receive its financing.

At the end of 2014 it replaced Vestas as supplier of 'CPFL Renováveis' for its new wind

parks, and will sell them 220 MW. More recently, it also won two contracts to supply wind turbines. One to Serveng Energia at Rio Grande do Norte including 54 turbines of 2.0 MW each. The other of 21 turbines of 2.0 MW each was for Chesf, an Eletrobras subsidiary. Both new contracts included the services of operation and maintenance.

Gamesa has more than 700 MW of wind turbines installed in Brazil and announces that have more than other 2,000 MW already signed. It has also an important presence in other LA countries as a wind turbines supplier. It has recently furnished 51 2.0 MW turbines for the “Cerro de Hula’ plant in Honduras among others. It supplied till now more than 3.0 GW in LA (Mexico, Brazil, Uruguay, Honduras, Argentine and Costa Rica).

GE, the largest wind turbines producer in the world in 2014, is present in Brazil since 1919 but only started to operate in the wind power market in 2011. In a short period, it has gained market share and in 2014 GE celebrated its first 1.0 GW of wind turbines capacity installed in the country. Among these, 0,6 GW were connected in that year (2014), corresponding to 281 individual turbines.

In 2014, it also produced its first 1000 hubs in its plant in Campinas (SP) and is producing the hubs and starting to produce also the nacelles. To assist its clients, GE has created two service centres, one in Campinas (SP), another in the State of Rio Grande do Norte. In the same year, the 184 turbines supplied to the wind farm ‘Alto Sertão I’ to Renova the 1.0 GW of local sales was reached.

In February 2015, GE delivered its first nacelle produced in Brazil, in Campinas, Estate of S. Paulo, to Eletrosul for its wind park Hermenegildo (RGS) with 181 MW. In this process, GE invested in the formation of its supply chain

and brought to Brazil some of its suppliers from abroad increasing its number from 5 to 25. In March, it announced it was going to build two new service centres to support its products for Casa dos Ventos, as they have three wind farms being built in partnership – Tianguá (CE) with 77 turbines of 1.6 MW, Santa Brigida (PE) with 107 turbines of 1.7 MW and São Clemente (PE) with 126 turbines also of 1.7 MW. Later in August 2015, the company announced that has increased its production capacity from 400 to 500 units a year. Trying to increase its production chain, GE brought also to Brazil one unit of the Swedish SKF that is now producing ball bearings to be used in the wind turbines (connecting the blades to the hub and the nacelle to the tower) whose production was one of the bottlenecks of the local wind industry.

In 2015 GE concluded also the nationalization of its generators used to integrate their larger 3.0 MW turbines, in order to comply with the BNDES conditions. These generators are being built in the GE plant at Campinas, together with other turbine components. Also, more than 100 local and foreign suppliers were attracted to complement its production chain. The company is also working in the nationalization of the manufacture of inversors both for wind and solar industries.

In January 2016 it started production of its 2.0 MW turbines in Brazil, and the first set is going to supply the wind park Omega in the State of Piauí. According to GE these turbines follows an approach that intends to optimize the park as a whole, more than the individual turbines, that has been called Digital Wind Farm.

As GE bought the Alston turbines manufacture plants in Brazil, it is expected to increase even more its participation in the country. However, as part of the restructuring GE is closing an Alston plant in Canoas, Estate of

Rio Grande do Sul, that used to produce steel towers for the wind plants; about 100 workers may be affected.

Alston has operated in Brazil for more than 60 years (originally as Schneider) producing different types of products, including for the power sector. Among others it supplied equipment for the 2,800 km transmission line that brings the energy produced by the large hydroelectric plants at the Madeira River to the consumer centres in the Estate of S. Paulo in the Southeast. In wind generation it has around 6,227 MW of wind turbines installed or under construction in the world, of that 3,078 are in Brazil its biggest market for wind turbines.

It has a plant in the Petrochemical Complex of Camaçari, in Salvador (BA), where nacelles are produced, and a tower-manufacturing unit in Canoas¹⁷ (RGS) in the South Region. In January 2015, a third industrial plant in partnership with Andrade Gutierrez was inaugurated to build steel towers in Jacobina (BA) with the production capacity of 200 towers per year.

Nevertheless, while expanding its productions in Brazil, the energy world branch of Alstom was bought by GE by US\$ 17 million, beating Siemens in the process, and had obtained the agreement of the French government that is also going to buy a stake of 20% in the company. In Brazil, the anti-trust agency Cade approved in April 2015 the acquisition of the Brazilian branches of Alstom Energy by GE. The operation as a whole was concluded after the exam of the European authorities.

One of the global consequences of this operation is that GE now owns the Alston' wind turbines Haliade that are going to supply the first off-shore park in the American continent in Rhode Islands, US. As such it may now

compete for supplying this type of wind parks with Siemens, that dominates the segment in the European market, if these parks start growing in LA.

Acciona Energy, the energy division of the Acciona Group, a Spanish company, opened in 1993 its first plant in Brazil, initially a hub assembly plant that represents the first step of the wind turbine subsidiary in the country, located in Simões Filho (BA) with a production initial capacity of 135 hubs a year for its 3.0 MW turbine. In 2014, this plant started also to assemble nacelles, with a capacity of 150 units a year, reaching the basic conditions established by Bndes in terms of local contents. It has also a concrete wind tower manufacturing plant in Rio Grande do Norte to supply the facilities being built in that state. In July 2015, BNDES formally announced that Acciona has completed all the necessary changes and its turbines are now attending all the local content conditions, six months in advanced of the time previously scheduled.

In December 2014, Acciona had a record of 825 MW of wind turbines already sold in Brazil. At the beginning of 2015 this number was surpassed reaching the 1.0 MW mark, as it won a contract to sell 65 3 MW turbines, adding another 195 MW of capacity to its local sales. These turbines will supply a wind power complex located in the State of Piauí (northeast region) being developed by 'Atlantic Energias Renováveis' and the British private equity firm Actis consisting of eight wind farms: Lagoa do Barro I-VII and Queimada Nova. The turbines will be mounted on 120-meter-high concrete towers that will be produced in a company site nearby.

Acciona production in Brazil suffered with the economic recession. In 2015, it sold only 79 turbines, representing a demand reduc-

17 That is being closed by GE as part of the restructuring process, as pointed above.

tion close to 50% in relation to 2014 but it is expecting to have a new increase in 2016. As the German company Nordex took over Acciona Windpower, the new company intends to increase its market share in Brazil but it still considers that the Brazilian costs make it uncompetitive to export wind equipment to other countries. For instance, recently Nordex supplied a new wind park in Uruguay with turbines produced by its European units.

Acciona is present in many LA countries and is one of the main players in Mexico where it operates 557 MW of wind farms, representing more than 23% of the wind parks in that country in 2014. In 2015 it will add another 239 MW with the Mexican wind farms of 'Ventika I and II' in the region of Nova Leon and 'Ingenio' in Oaxaca. It is also starting the operation of a concrete tower manufacture unit in Nuevo Leon, Mexico, one of the few wind farms sector manufacture installations in LA identified outside Brazil.

Suzlon, an Indian company, has installed more than 14.5 GW of wind turbines in 17 different countries, with R&D units in Germany, Netherlands, Denmark and India. It has initiated its operations in Brazil in 2006 being responsible now for around 740 MW of installed capacity. Its head offices in Brazil as a monitoring centre are installed in Fortaleza (CE), in which State is also located the biggest wind park supplied by Suzlon in Brazil, that is the wind park of Praia Formosa, in Camocim (CE) with 105 MW.

In June 2012, Suzlon started the production of electrical panels and the assembly of hubs in a plant in Maracanaú (CE) with a capacity of production of 400 MW in turbines per year. Suzlon was expected to start building an industrial plant in Brazil in 2015, in the state of Ceara, but as its holdings in India suffered some financial problems in 2014, it is not clear whether plans will move forward.

Some of the Suzlon's parks in Brazil have been among the most efficient in the country. In 2012, for instance, according to the Operador Nacional do Sistema (ONS), the four better results in terms of performance were the wind parks of Icaraizinho, Canoa Quebrada, Bons Ventos e Enacel, in the State of Ceará, which O&M are under the responsibility of Suzlon that supplied its turbines.

Wind Power Energy (WTE) - created by the Argentinian **Impsa** -now both are under the holding Venti- is a wind turbines industry based in Brazil. Currently WTE has filed for bankruptcy and is selling its wind parks in order to sort out its financial situation and restructure its debt. It has been announced that it is currently selling a stake in five of its wind parks to 'Ventos de Sao Jorge', a wind-power developer owned. At the same time, Impsa is asking for a bailout from the Argentinian government as some of its clients in Brazil and Venezuela delayed payments. With these problems at least 300 turbines were not delivered by WTE, causing serious difficulties for many wind parks that were to be operating in the States of Ceara and Rio Grande do Norte, affecting an estimate total capacity of 1,580 MW, according to the regulatory agency ANEEL.

Impsa has five production centres, two in Mendoza (Argentine), one in Lumut (Malaysia) and two in Brazil through WTE, both in the port of Suape (PE): one plant for wind turbines since 2009 and another also in Suape for hydro-electrical equipment. WTE wind plant has a capacity of production of 450 MW a year. It owns also wind parks in operation with 330 MW and has close to 480 MW under construction. It is not clear at the moment how its financial situation will evolve in the near future. In any case, recently, in July 2016, Impsa announced that it was going to start as-

sembling turbines in its Mendonza plant with a 300 MW a year capacity.

Apart from the global players above mentioned, and the two locals WEG and Impsa, with manufacturing plants in Brazil, other suppliers are reported selling imported equipment to wind farms in LA, as for instance Clipper Windpower, a US manufacturing company with an expressive participation in the Mexican market.

Chinese companies are also present, although not in the manufacturing business, and only supplying wind farms (imports), many of them associated to loans provided by Chinese Banks.

In Brazil, the China Development Bank (CDB) agreed to loan \$55 million to Brazil's Desenvix for the 34.5 MW wind farm 'Barra dos Coqueiros' in the State of Sergipe with turbines purchased from the Chinese supplier Sinovel. In Chile, the 17.8 MW wind plant 'Ucuquer' was supplied by the Chinese company Envision; also Hidro China is signing an agreement to increase in other 50 MW the wind park 'Arauco' in Valle de La Puerta. Goldwind supplied 34,5 MW to the 'Negrete Cuel' wind park in Chile and is building, in partnership with the Dublin headquartered Mainstream, the 70,5 MW 'Ckani' wind farm also in Chile, while supplying the state-owned Equatorian company CELEC with turbines for its 16.5 MW first wind farm.

In Argentina, Chinese companies are also selling wind turbines with the support of CDB loans. The Loma Blanca wind farm, a 200 MW project, being built by the Spanish Isolux-Corsán has inaugurated its first 50 MW in 2013 with Alston turbines, but CDB is offering a loan that may open another 50 MW step to the Chi-

nese XMEC (Xiangtan) turbines. Also a US\$ 3 billion loan from CDB may be used for the development of a Generadora Eolica Argentina del Sur SA, Geassa, 1,350-megawatt wind project in the Gastre plains in southern Argentina's that could be the continent's largest.

Solar power manufacture

Two main technologies are considered for solar generation: the photovoltaic and the thermal concentrated solar power, the former dominates the field, being responsible for more than 90% of the capacity already installed or in process of installation.

Photovoltaic (PV) generation is based on semiconductors properties to generate electricity (direct current, DC) from the incident solar energy structured in photovoltaic cells, the basic component of a PV generation plant. There are two types of PV cells: the bulk ones that can be made of monocrystalline (Mono-Si) or of polycrystalline (Poli-Si) silicon material, and the thin-film types. They usually differ in terms of efficiency and costs. Mono-Si uses the purest silicon, and as such is the most efficient and also the more expensive. All these types are currently being in use by different manufacturers.

The production chain of a solar PV plant includes many stages: (1) the purification of silicon, (2) production of ingots, (3) production of wafers, (4) production of PV cells, (5) production of solar panels and (6) assembling the PV system.

The PV cells require pure silicon, a field dominated by the Chinese and German companies¹⁸, followed by North American companies. The silicon is melted in ingots to reach a

¹⁸ Market Realist, a market analysis consulting, indicates that in 2014 Chinese GCL Solar had 22%, German Wacker Chemie 21% and North American Hemlock 14% of the polysilicon global market. High capital cost and small margins made polysilicon a commodity and work as an entry barrier that reduces the interest of competitors in this field.

proper format; these ingots are then cut into wafers, used to manufacture a solar cell that includes glass covers, layers of wafers and electrical circuits. The cells are then organised in panels that will form the basic equipment of the PV generation systems.

The set of equipment that complements a PV system is known as 'Balance-of-System (BoS)'. It includes wirings, the mounting system, inverters that transform direct current (DC) into alternate (AC), batteries, controls, and other devices that 'balance' the direct current generated in the PV cells with the AC grid distribution, or directly to the household appliances belonging to the consumer, as BoS applies to all types of solar applications.

PV generation can be used in two general modes; it can either give origin to large generation plants that only sell to the grid or to large consumers, or it can be used in smaller units directly to small and medium residential, rural or commercial consumers, that may be also connected to the grid, or be isolated. The latter is one of the most important forms of what is being called *distributed generation*. Although the solar panels are showing large cost reductions, this smaller scale PV generation is quite sensitive to BoS costs that are not falling at the same rates and are becoming relatively more important.

The expansion of distributed generation is still pending on further cost reductions on not only the solar panels and BoS in general, but also on the batteries that will make it fairly independent of the unavailability of solar generation at night; and as such quite independent of the grid itself. Cost reductions that lay a bit more in the future. Thus, as pointed above, here we are more concerned with the large PV units.

Although originally developed mainly in Europe and the US, the industry nowadays is being overcome by the Chinese players that seem to dominate the field. The ranking of the top 10 solar panel makers in 2014, as indicated by the consulting company HIS¹⁹, includes five Chinese companies, even six if one considers that Canadian Solar has its manufacturing base installed in China, and is led by the Chinese Trina Solar and Yingli Green Energy. In 2015 as pointed above this list suffered some changes as this industry is very dynamic, but the dominance of the Chinese companies remains, and according to Renewables Energy Magazine its current complete top ten list is: Tina Solar (China/ Netherlands), JA Solar (China/ Malaysia), Hanwa Q-Cells (China/ Germany/ Malaysia/ South Korea), Canadian Solar (China), First Solar (US/ Malaysia), Yingli Solar (China), Motech Solar (Taiwan/ China), NeoSolar (Taiwan/ China) and Shunfeng-Suntech (China/ US).

According also to HIS, 2014 may be seen as an inflection point for the solar industry market that, after a period when it suffered a downturn -thanks to an oversupply of solar panels²⁰ that forced smaller companies out of the business-, started to grow again at higher rates.

Many countries are entering into the solar generation business in 2015, as prices became more competitive and climate change considerations more urgent, favouring renewables. This seems to be the case of Latin America, where many PV generation plants are being commissioned.

Differently of the wind power industry that has many manufactures installed and concentrated in Brazil, the solar power industry in LA is still incipient, though conditions are indeed very adequate for a solar expansion in the whole region.

19 HIS is a business consulting firm; its 2014 solar panel ranking is: (1) Trina Solar, (2) Yingli Green Energy, (3) Canadian Solar, (4) Jinko Solar, (5) JA Solar, (6) Sharp Solar, (7) Renesolar, (8) First Solar, (9) Hanwha SolarOne, (10) SunPower and Kyocera.

20 A large increase of production from China and South Korea was followed by cuts in incentives in Spain and other countries facing financial difficulties.

Large PV plants are relatively new in the region, with a pioneer presence in Chile, a country with exceptionally good conditions (solar incidence and dependence on imported fossil fuels) in favour of solar power penetration.

Most of the PV generation in LA until 2013 was of small scale, mainly in order to supply electricity off-grid in isolated and small communities and/or individual residences. A small solar industry, spread through many countries, grew in order to give some support to these distributed initiatives.

With large PV units being commissioned, the situation is starting to change very sharply. Even if Chile seems not interested in developing an indigenous industry, relying in the competitive imports market, other countries are engaged in promoting an industrial park, in many cases through solar local content conditions, as in the wind manufactures case in Brazil, and, in a smaller scale, Uruguay. Argentina, even without a solar market, is promoting the implementation of manufactures in its territory.

As the PV solar panel assemblage has less entry barriers and does not involve any complex technological processes, it is more fragmented around the world. As such, many of the initial LA plants installed manufacture smaller solar modules for off-grid usage.

Mexico

An exception to the general LA picture is Mexico with six solar module manufactures already in 2014, though with their production oriented towards exports to the US. Among these, three were subsidiaries of international companies: Jabil Circuit, in Chihuahua; Japan's Kyocera, in Tijuana; and US firm SunPower, with a 400 MW factory in Mexicali. The other local ones are: ERDM in Veracruz with an installed capacity of 15MW a year,

buying its solar cell from the German; Solarvatio, with a 12 MW a year production capacity, and Solartec in the state of Guanajuato. Solartec was the only company in LA at that time that was producing also solar cells, and is integrating vertically as it bought the German's Bosch wafers production line, is looking to integrate also in the ingot production, and has a planned production goal of 250 MW a year.

More recently, also Chinese companies, as for instance, JA Solar, Chint and Hareon are showing the intention of building solar modules in Mexico, to take advantage of the special conditions of the Mexico-US agreements and avoid possible new import tariffs in the US.

Outside Mexico there were only small manufacturing units but there are a very large number of projects in different stages of maturity, indicating that a very different picture is under construction to fructify in a few years from now, mainly in Brazil, Argentina and Uruguay.

Brazil

Brazil had its first solar panel factory built in 2012 by Tecnometal with a 25 MW/year capacity whose machinery was provided by US manufacturer Spire Co. The local manufacturer LC Eletronica is building a solar module plant in the state of Minas Gerais. Since the country promoted its first regular solar tender in 2014, many other players are announcing new and larger facilities.

BNDES, similarly to what it has made in the wind sector, is offering special financial conditions coupled with local content requirements, forcing the companies to build manufacturing facilities in the country in order to be competitive. Currently five companies are producing solar modules in accordance to the BNDES initial requirements, Globo Bra-

sil, Tecnometal, Premier, Minas Sol and CSEM Brasil, that all together represent a production capacity of 300 MW a year, of which 180 MW are from Globo Brasil and the other 120 MW distributed among the other four smaller companies. Globo Brasil inaugurated its plant in Valinho, Estate of S. Paulo, in August, 2015, using German, French and Swiss equipment.

Since the country started promoting larger auctions, however top world players start also planning to build factories in Brazil. Although there were no requirements of local contents in the auctions themselves, the special financing facilities for solar plants with local content offered by BNDES is, as in the wind industrial sector, working as a strong stimulus to the implementation of these plants. Adding the perspective of a growing market, the Chinese JA Solar, Canadian Solar and BYD, as the Brazilian WEG are analysing this possibility. In fact, Canadian Solar has already announced that it will make a partnership with the local Flextronics and will use Flextronics fabric in Sorocaba, Estate of S. Paulo, to produce solar modules, starting in September 2016 and with a production capacity of 350 MW a year, that will supply not only the Canadian Solar PV plants that are being built but also to other clients. The Chinese BYD also, that has been examining the local market for many years, has announced that it will start production of solar modules till the end of 2016 in a factory in Campinas, Estate of S. Paulo with a production capacity of 400 MW a year.

Among other local companies planning start production, in 2014, the Brazilian S4 Solar do Brasil announced that it would start manufacturing crystalline modules with an annual capacity of 100 MW in the State of Goiás; in June 2016 it was granted a tax exemption

and the company indicated that it was the last step of its preparation and it is going to start production by the end of 2016 in a factory at the State of Pernambuco, but now with an increased capacity of 200 MW a year, using a innovative glass-glass technology.

Another Brazilian company, Solar Par, announced plans in 2014 to build three integrated solar factories (in the States of Mato Grosso do Sul, Espírito Santo e Minas Gerais) to produce wafers, cells and modules, adding up to 295 MW a year, but there has been no news of any progress.

Others companies are planning new industrial operations. Among many others:

- the Spanish Soltec started in December 2015 to produce trackers in its factory in the State of Bahia; its production capacity corresponds to 600 MW a year, and it pretends also export part of its production to other countries in LA;
- Sunew (Centre Suisse d'Electronique et de Microtechnique - CSEM) started in November 2015 to produce photovoltaic films in Belo Horizonte, Estate of Minas Gerais;
- Sunlition, a local company, intends to start production in 2016 of floating solar panels with a initial capacity of 30 MW a year;
- Local company Grameyer entered in partnership with the Spanish GPTech in order to produce large scale inverters in the State of Santa Catarina;
- the bi-national Brazil-Paraguay hydro company Itaipu has a research centre and is analysing with the State of Parana Industry Federation the possibility to produce solar modules; in this process it has also had talks with the Fraunhofer Institute²¹;

²¹ According to a private communication, these talks included the silicon purification process, as Brazil is one of the greater silicon producers in the world but lacks the purification technology required by the solar cells.

- the Chinese big player Yingli is examining how to comply with BNDES conditions to have a presence in the country;
- Pure Energy, owned by the Italian MGH Systems, is planning a 40 MW solar panels plant in the State of Alagoas;
- SunEdison, before it filed for bankruptcy, was going to build solar modules and tracking systems.

Uruguay

Not only Brazil is using the local content conditions to promote local manufactures, Uruguay is doing the same, requiring however lower levels of nationalization than Brazil (20% of the project). It has promoted a 200 MW tender PPA for solar energy, with a 20% quota stipulated for local content. The Spanish firm Fotowatio agreed with these conditions and is building 65 MW 'La Jacinta' solar PV, using local facilities in such a way to respect the quota. The solar modules for 'La Jacinta' are going to be supplied by the Chinese company BID, which is also announcing the construction of a factory in Brazil. In Uruguay, other solar generation projects are in construction.

A 50 MW a year solar module factory to sell locally and to export to other countries, where mounting structures will be produced, is being developed with the involvement of the Chinese Sky Solar in partnership with the Uruguayan Tecnogroup.

Argentina

Argentina ranks among the countries developing industrial infrastructure for the sector, even if its market is still very small for the solar generation companies. It is stimulating the construction of a solar industry and has several industrial projects in the pipeline. Construction of an integrated 71 MW/year factory has recently started with the support of the German manufacturer

Schmid in the province of San Juan. The plant will supply the local agriculture, with the support of the government of San Juan, and the excedent exported to other markets. Possibly the Chilean market will be exploited. This factory is said to be verticalised including also the ingot/wafer stages of production.

LV-Energy Lumins, recently built another Argentinian solar PV module factory with a 12 MW / year capacity, in the province of San Luis. The Mexican Solartec is going to produce solar modules in the province of La Rioja.

Other Latin American Countries

Other LA countries have also small industrial facilities for the solar power industry and may develop new ones in the future. Differently of the wind power sector, the possibility of small residential rooftop units may be a positive factor helping the spread of more industrial facilities in the region. Larger integrated factories are being planned, and will be located mainly in Mexico, Brazil and Argentina, but it is still too early to have an idea of how competitive they may be. In any case, in terms of regional production chains, there seems to be more room in the solar field than in the wind power sector, following an energy integration process that is also in its early stages.

Small solar modules production units can already be found in many countries in the region as is the case of Central America and Caribe: El Salvador, Saint Vicent and Granadines, Cuba, all with 15 MW a year of production capacity.

CHAPTER THREE

COMBINING THE APPROACHES

A SOUTH AMERICA MAP OF RENEWABLES

From the information in the previous section, it is possible to draw a first map of the renew-

ables industry in SA. Tables IV.1 and IV.2 synthesise (as of September 2015) the situation, respectively, of the wind and solar industries.

The Tables describe the companies active nowadays, taking the country dimension as guideline. In the case of wind, most manufacturers are located in Brazil; as for solar, they are relatively spread along quite a few countries -a situation revealed in the tables.

TABLE 1 - WIND POWER INDUSTRIES IN SOUTH (LATIN) AMERICA

COMPANY	BRIEF DESCRIPTION OF ACTIVITIES
BRAZIL	
ACCIONA	<p>(1) Hubs & nacelles assembly plant located in Simões Filho, Bahia State, with a capacity of 150 units a year for its 3.0 MW turbine (AW3000) that can be expanded to 200 units (In July 2015 it has completed the necessary changes to attend the BNDES conditions).</p> <p>(2) Concrete wind tower manufacturing plant in the State of Rio Grande do Norte</p> <p>[Acciona Windpower was bought by Nordex; it still not clear how this global operation will impact Brazil and LA.]</p>

ALSTON	<p>(1) Nacelles assembly plant in the Petrochemical Complex of Camaçari, in Salvador, in the State of Bahia.</p> <p>(2) Tower-manufacturing unit in Canoas, in the Rio Grande do Sul State.</p> <p>(3) Steel towers plant in partnership with Andrade Gutierrez in Jacobina, State of Bahia, with the production capacity of 200 towers per year.</p> <p>[In spite of expanding its productions in Brazil, the energy world branch of Alstom was bought by GE.]</p>
GAMESA	<p>(1) Nacelles & hub assembly plant for 2.0-2.5 MW wind turbines located besides the Petrochemical Complex of Camaçari, in Salvador in the State of Bahia. It can produce around 300 units (its expansion being built expects to increase these figures to 640 turbines a year) adding up to 300 MW a year (its production of the 2.0 and 2,1 MW turbines was certified by BNDES in December 2015).</p> <p>[Gamesa was integrated to the Siemens energy businesses at a world level; strengthening Siemens position]</p>
GE	<p>(1) Hubs & nacelles assembly plant in Campinas, State of S. Paulo, with a production capacity of 500 MW a year (as of 08/15); also 3.15 MW induction generators were nationalised in November 2015.</p> <p>GE invested also in the formation of its supply chain and brought to Brazil some of its suppliers from abroad increasing its number from 5 to 25. For instance, the Swedish SKF produces 'ball bearings' for wind turbines installed a plant in Cajamar, State of S. Paulo, brought by GE.</p> <p>[As a consequence of the incorporation of Alston energy divisions, GE closed an Alston plant in Canoas that used to produce steel towers.]</p>
IMPISA (WTE)	<p>(1) Wind turbines plant at the port of Suape, in the State of Pernambuco, with a capacity of production of 450 MW a year.</p> <p>(owned by Wind Power Energy (WTE) an Impisa subsidiary)</p> <p>Currently WTE has filed for bankruptcy and is selling its wind parks in order to sort out its financial situation and restructure its debt.</p>
SIEMENS	<p>Siemens executes the entire project, from siting to engineering and project management. It currently produces in Brazil some of the components utilized in the projects, including long blades, hubs and 80 meters high towers. Although otherwise expected, it still did not increase the range of its production. Instead by buying the Alston energy divisions, it secured a strong position in the wind sector in Brazil.</p>

SUZLON	<p>(1) Hubs & electric panels assembly plant in Maracanaú, State of Ceara, with a capacity of supplying 400 MW in turbines per year.</p> <p>[does not comply with the BNDES requirements of local contents. It is expected to start building an industrial plant in Brazil but as its holding in India suffered some financial problems in 2014 it is not clear if these plans will move forward as originally intended.]</p>
VESTAS	<p>(1) Industrial plant in Aquiraz Maracanaú, in the State of Ceará, (CE) with a production capacity of 400 MW a year. Originally, Vestas had an assembling plant in Maracanaú at the same State, but the need to increase and adjust to comply with the BNDES local content conditions, required a larger unit and it has invested in a production unit in Aquiraz, that was concluded in January, 2016, and now produces its V110-2.0 turbines.</p> <p>It has developed a complementary chain of suppliers to the Aquiraz plant, including the local Atis that produces blades, and the Brazilian ABB division that produces generators.</p>
WEG	<p>(1) Assembler unit of wind turbines of 2,3 MW at Jaragua do Sul, in the State of Santa Catarina, with a production capacity of 200 MW a year.</p> <p>It is the only company controlled by local investors operating in this field. Since 2013 is under a technological agreement with Northern Power Systems, from the US.</p> <p>It developed a local network of suppliers, as 14 local companies have started to supply some wind plant items, and another 23 are investing in order to do the same.</p>
WOBLEN	<p>(1) The main assembly unit in Sorocaba, state of São Paulo with a production capacity of 500 MW a year.</p> <p>(2) Blades production unit installed in 2011 in the port of Pecem, state of Ceara.</p> <p>(3) Concrete towers production plant in Parazinho, State of Pará.</p> <p>Wobben also exported its turbines to Argentina, Costa Rica and Bonaire, in the Dutch Caribbean islands.</p>
OTHER LATIN AMERICAN COUNTRIES	
ARGENTINA	
IMPESA	Assembler unit of 2.0 MW wind turbines, in Mendoza Province, with a capacity of 300 MW a year, recently inaugurated in July 2016.
Others	Two steel towers producers: Metalurgica Calvino and SICA Metalurgica Argentina.
MEXICO	
ACCIONA	Concrete tower manufacture unit in Nuevo Leon, Mexico. Has the only wind farms sector manufacture installations in LA identified outside Brazil and Argentina.

TABLE 2 – SOLAR POWER INDUSTRIES IN SOUTH (LATIN) AMERICA

COUNTRY	BRIEF DESCRIPTION OF ACTIVITIES
Argentina	<p>(1) The construction of an integrated 71 MW/year PV turnkey factory has been recently started with the support of the German manufacturer Schmid in the province of San Juan. This factory is said to be verticalised, including also the ingot/wafer stages of production. It will equip the state-owned energy provider Energía Provincial Sociedad del Estado (EPSE). Its production is due to start in October.</p> <p>(2) Led Lar has a 10 MW factory a year in La Rioja and plans to double its capacity.</p> <p>(3) LV-Energy operates a module factory, capable of producing 12 MW per year, in San Luis.</p>
Brazil	<p>(1) Tecnometal has a solar panel factory built in 2012 with a 25 MW/year capacity whose machinery was provided by US manufacturer Spire Co.</p> <p>(2) Globo Brasil started in Valinhos, State of S. Paulo the production of solar panels with a production capacity of 580 thousand panels a year (180 MW/year).</p> <p>(3) A Canadian Solar (founded in Canada by a Chinese) in partnership with the Brazilian company Flextronics is investing in a solar panels assembly line in Sorocaba (SP) with capacity to produce 350 MW in panels yearly, starting September 2016; Canadian Solar intends also to develop new projects adding up 400 MW in PV plants that won contracts in the tenders of 2014 and 2015.</p> <p>(4) Chinese BYD intends to build till the end of 2016 a solar panels plant in Campinas, State of S. Paulo, to produce 400 MW panels a year, using a 'double glass' technology.</p> <p>(5) Brazilian S4 Solar will start assembling crystalline modules with an annual capacity of 200 MW in the State of Goiás, with technology provided by Switzerland's Meyer Burger and China's Confirmware and Jinchen Machinery.</p> <p>(6) WEG is also starting to operate in the solar photovoltaic field in the production of all its components, except the solar panels.</p> <p>(7) LC Eletronica is building their first solar module plant in the State of Minas Gerais.</p> <p>(8) Grameyer & GPTech signed the State of Sata Catarina in agreement to produce 250 MW a year solar inverters.</p> <p>(9) Spanish Soltec is producing solar trackers since December, 2015 in the State of Bahia.</p> <p>(10) Sunew (Centre Suisse d'Electronique et de Microtechnique - CSEM) started in November 2015 to produce photovoltaic films in Belo Horizonte, Estate of Minas Gerais.</p> <p>(11) Sunlition a local company, intends to start production in 2016 of floating solar panels with a initial capacity of 30 MW a year.</p>

	<p>(12) the bi-national Brazil-Paraguay hydro company Itaipu has a research centre and is analysing with the State of Parana Industry Federation the possibility to produce solar modules; the southwestern German industry association Solar Cluster and three research institutes in Baden-Württemberg were involved in feasibility studies, including the Fraunhofer Institute.</p> <p>(13) Chinese Yingli is examining how to comply with BNDES conditions to have a presence in the country.</p> <p>(14) Pure Energy, owned by the Italian MGH Systems, is planning a 40 MW solar panels plant in the State of Alagoas.</p> <p>(15) German manufacturer J.v.G. Thomas, stated that it would deliver a 70 MW turnkey line to Brazilian company Renovasol.</p> <p>(16) Solar Par, announced plans to build three integrated solar factories to produce wafers, cells and modules.</p>
Uruguay	<p>(1) Fotowatio a Spanish firm is building a 65 MW 'La Jacinta' solar PV using local facilities in such a way to respect the 20% quota Uruguay stipulated for local content; the solar modules are going to be supplied by the Chinese company BID.</p> <p>(2) the Chinese Sky Solar in partnership with the Uruguayan Tecnogroup are planning a 50 MW a year solar module and mounting structures factory in Paysandu to sell locally and to export to other countries.</p>
Venezuela	
ADDITIONAL DATA ON MEXICO AND CENTRAL AMERICA	
Caribbean	<p>(1) A 15 MW factory in Saint Vincent.</p> <p>(2) A 15 MW factory in El Salvador.</p> <p>(3) A 15 MW factory in Cuba.</p> <p>(4) An integrated solar factory is expected to be built in Trinidad and Tobago to supply the Caribbean market.</p>
Mexico	<p>Six solar module manufactures installed already in 2014, but with their production oriented towards exports to the US.</p> <p>(1) Jabil Circuit, a US company with a production capacity of 45 MW a year in Chihuahua.</p> <p>(2) Japan's Kyocera, with a 150 MW facility in Tijuana.</p> <p>(3) US firm SunPower, with a 400 MW factory in Mexicali.</p> <p>(4) ERDM in Veracruz with an installed capacity of 15MW a year, buying its solar cell from the German Schmid, that may build a 110 MW solar module plants.</p> <p>(5) Solarvatio, with a 12 MW a year production capacity in Oaxaca.</p> <p>(6) Solartec in the state of Guanajuato producing also solar cells, and is integrating vertically as it bought the German's Bosch wafers production line, is looking to integrate also in the ingot production, and has a planned production goal of 250 MW a year.</p>

Beyond the local manufacturers, imports must not be forgotten, as well as activities – both in wind and solar- by foreign developers not necessarily with a juridical presence in a given country.

MOVING TO A HIGHER AGGREGATION LEVEL WITH THE REGIONAL IO MATRIX

The Regional IO Matrix for South America, a long range project involving IPEA -the official Brazilian socio-economic think tank-, CEPAL/ECLAC -the UN agency for Latin America and the Caribbean-, the technical co-ordination of FGV/NPll and the work of country experts in ten different SA countries –all SA nations but Guiana and Suriname-, is a huge effort still under way.

Funded by different international organisms and Brazilian agencies, the project is due to produce the first regional IO matrix for the region. As of the date of this report, a final version has just been delivered, open to testing and generalised checks.

Not only a few conclusions seem robust already, as some issues that put a little grain of salt on our original plans became evident.

The first is the unavoidable high aggregation level of the sectoral classification used to describe each economy. It comprises 40 sectors, energy itself figuring in three: mining and quarrying (energy) –s4; coke, refined petroleum and nuclear fuel –s16; electricity and gas –s34. The manufactures sectors do not allow an easy identification of elements that could be important for either the wind or solar complexes. Though not impossible, this will demand further work, nearly making for a new, separate endeavour.

Moreover, the reference date of the Matrix is 2005, a moment, as seen from the previous section, when both new energy developments were still in an initial phase.

This does not mean that the Matrix is useless. Beyond the further technical pursuit just mentioned, the picture it provides on the channels through which the ten economies interact, and on the whole global pattern of these very interactions, are potentially useful for calibrating proposals ensuing from this project.

VALUE CHAINS: FIRST APPRAISAL

Wind and solar PV generation

The observation of the status of non-conventional renewables in South America shows a huge increase in the participation of wind and solar PV generation in most countries, in the last ten years. Wind farms were responsible for the first growth wave and are present mainly in Chile, Brazil and Uruguay (and Mexico). Peru and Argentina -as its economic situation is improving- are also following these leading countries; Colombia and the rest of South America will probably join them soon (while wind farms are already found in Central America).

In general, a few particular regions in each country tend to concentrate the initial development – Coquimbo in Chile, Oaxaca in Mexico, the Northeast and Rio Grande do Sul in Brazil –, use being afterwards spread along many other regions.

Solar PV seems to represent a second wave that can even overcome the wind one, as many of the latest auctions indicate. Chile, strongly dependent on imported energy, is the pioneer in this field, favoured by excellent solar conditions, mainly in the Atacama desert. Brazil and Mexico started later but are also growing sharply and will soon lead the Latin American installed capacity. Other countries have developed solar plants or are in the process of, as, for instance, Peru, Uruguay, and Honduras. Growth is based on the construction of relatively large

plants selling electricity to either big or regulated consumers. Notwithstanding, until now, distributed generation (DG) is not booming.

Both wind and solar PV are becoming very competitive, *although it is difficult to evaluate their total system costs, considering the need of transmission lines and of complementary generation to deal with their natural intermittency.*

In the last auctions in 2015, wind generation in Brazil was contracted at US\$ 53/MWh and solar at US\$ 78/MWh. In Chile, wind and solar generation were contracted lately at US\$ 79/MWh on average. Surprisingly, the last auctions in Peru and Mexico reached lower prices: US\$ 38/MWh and US\$ 55/MWh, respectively, for wind and, for solar PV, US\$ 48/MWh and US\$ 45/MWh, also respectively. It is still not clear whether this reflected specific market situations or lower prices will be standard in the near future.

Growth of renewables is expected to continue in the next years. Temporary limitations can happen and have been imposed by fluctuations in the electricity demand (Brazil), or by lack of transmission lines (some other countries). The North of Chile, in particular, has been facing limits in the expansion of renewables, due to lack of transmission capacity to take the energy to the main demand centres; legislation currently discussed in the Congress can facilitate the development of new lines. Brazil, that has added around 1-2 GW from renewables a year, is going through an electricity demand fall, as a consequence of economic crises, that may reduce the amount of energy to be contracted in its next auctions.

In a longer timeframe, the participation of these new renewables in the electricity matrix of each country may also face technical limits around 30% depending on the availability of storage and on the operators' abilities in dealing with

intermittency. Higher renewables participation and the increase of distributed generation that may follow will need new solutions from the power system planners and regulators.

Wind structure integration

A striking conclusion from the observation of this industry in South America is that only Brazil has created a wind equipment complex with a large number of turbines factories, complemented by diverse suppliers of towers and other components as blades, generators, invertors, etc. Argentina seems to be taking also the industrialisation route, what may bring some interesting future possibilities, with currently one wind turbines plant and two suppliers of steel towers. Apart from this, a concrete towers manufacture located in Mexico was one of the few wind sector manufacturers identified outside Brazil.

The reason for the particular Brazilian development seems to be the existence of a large potential internal market, together with the industrial policy supported by BNDES special financial conditions, dependent on increasing levels of local content. Uruguay has also required some degree of participation of local companies, but with a smaller market it was not able to achieve a higher degree of domestic industrialization.

Chile, with one of the most advanced clusters of wind and solar generation, seems to support a more competitive positioning, avoiding any protective measures. Individual opinions in Chile, through private communications, seem to indicate that the size of its internal market was one of the main barriers to a more aggressive industrial posture.

Exports of wind equipment from Brazil to other LA countries do not play a important role. Wobben announced in the past a few

turbine exports to Argentina and the Caribbean; facing a possible gap in its future sales, WEG is currently also examining this possibility. Only Tecsis, a local company established in the State of S. Paulo, reports larger exports of wind blades, but mainly to the US and Mexico.

With the recent corporate rearrangements (GE-Alston, Siemens-Gamesa), the strategy of the top players may change and one may see in the future more exports from their Brazilian units. Vestas, that just inaugurated its factory in Brazil and seems to have a good supplier-client relationship with Enel Green Power, becoming the dominant renewables developer in LA, may increase its exports. Nothing however points, up to now, to a cross-country integration through a global chain.

Solar structure integration

Differently of the wind power one, the solar energy industrial sector is still incipient in the whole region, as the large PV units are relatively new, but small industrial units have been established in many countries to supply solar panels to individual consumers in isolated regions.

An exception of the general picture is Mexico with six solar module manufacturers already in place in 2014, though their production is oriented to the US. In Brazil, in 2015, one first relatively larger solar panel factory (180 MW a year) was built by a local company, Globo Brasil, and, in 2016, Canadian Solar announced a partnership with local Flextronics to produce 350 MW a year of solar panels. Larger integrated factories are being planned in the region, and Brazil, Mexico and Argentina may be the chosen locations.

Considering the future of the local solar industry, it is not clear whether it may be feasible to move to the region the upstream parts of the solar (and storage) production chain.

Chile is one of the largest Lithium producers in the world, essential to batteries, and Brazil has a huge availability of Silicon, whose purification is economically dominated by the Chinese nowadays. Ventures in these areas depend on technological advances and require a large production scale and significant amounts of capital not easy to be found. In any case, there are rumours of informal talks about silicon purification between the Fraunhofer Institute, Germany, and Itaipu, a Brazilian-Paraguayan bi-national company.

Downstream, the production of solar equipment involves many individual parts under permanent evolution and, as solar generation becomes more competitive, industrial plants may easily be built in many countries, to supply a growing market. Looking to the future growth of distributed generation and the large number of small companies involved in countries where DG is flourishing -as the US, in what is called the Balance-of-System to install and control the DG units-, industrial moves in this direction should also be feasible.

SA value chains in wind and solar industries

Considering both industries, wind and solar, the development of global value chains in SA looks still far away. Even in the more developed wind industry, there is no sign of any integration.

As the solar industry is beginning, things can evolve differently, although the current trend does not signal positively, unless new measures take place. Solar equipment comprises many individual parts, always in dynamic change, opening opportunities to new specialized firms to settle in different countries, creating regional flows of parts and components. As distributed generation may also grow and create a larger market for small plants in many countries,

the possibility of the industry to spread along more regions, with a higher degree of integration, should be further examined.

In any case, production of solar equipment and the supply of very technical services will require mastering new technologies and the formation of specifically trained personnel. Advances in technology may be grounded on the acquisition of foreign companies, as the Chinese are doing; buying high-tech companies in Germany to have access to their technology. However, this approach is not akin to the region, and building partnerships may be a better way to arrive at these goals.

The development of global chains, sharing different products and components among different countries, may be favoured if the countries themselves are relatively homogeneous. As countries in the Southern Cone are moving along similar and roughly simultaneous paths, one may see this kind of integration in the solar segment emerging between Brazil and Argentina -that already have experience in production arrangements in the car industry-, including also Chile and Uruguay, which clearly promote the new renewables.

Growth of value chains requires co-ordination and does not evolve as a natural process if left by itself. In terms of policy measures, a multi-country co-ordination is considered essential to stimulate building them, though the availability of a growing market -something already identified- may not be enough to the desired industrialization level to take place. Financial measures related to local content, as Brazil and Uruguay have been doing, may be needed as an additional incentive. As technological developments are involved, the promotion of partnerships and transfers between local and foreign companies is surely helpful.

CHAPTER FOUR

POLICY GUIDELINES

PRELIMINARY CONSIDERATIONS

Two, not necessarily contradictory, stylised facts can be highlighted.

First, evidence gathered so far seems to point out that our original assumption has been somewhat optimistic. There undoubtedly is a positive and irreversible trend of ever increasing use of renewables in SA, with each semester new ventures, regions and (still) countries engaging further in this pursuit. Notwithstanding, awareness of -and, consequently, interest on- the benefits of implementing this broad endeavour within an integrated, value-chain approach in the equipment-production side is still very low.

Even the building of a local complex to provide capital goods and services to these industries seems to be almost absent, in practical terms, in most countries of the region, as

Chile illustrates. Only Brazil and, in a smaller scale, Uruguay, and more recently Argentina, have clearly moved towards local industrialisation experiences.

Second, due to the situation above, a project like this one has oftentimes to rely on guesses or heroic hypotheses to grasp a finer view of the sense and profits from a regional value chain approach. Though we did not either gather or identify obstacles to the idea, no defined route to boost it has been fully conceived. If further systematisation is needed and welcome, it is hard to imagine that an unexpected solution will emerge from it.

We still believe that the (new) renewables capital goods suppliers and services providers may have a place on SA integration and technological advances, but it remains something to be built in a hopefully not too distant future.

In spite of lack of concrete steps in most countries in the region, it is worthwhile to create institutional conditions that could help such

potential future developments, as they are in the forefront of a wave of innovations in the world power sector.

Renewables growth means that a new type of electricity generation, less concentrated -with smaller units including a large number of new players both in the regulated sector as in the distributed generation realm-, is creating novel technological opportunities. In South America, where natural conditions - winds and sunshine levels - are very favourable to this kind of generation, there is a lot of room for developing the associated industries throughout the region: they may represent an important step in adding technology to the mere natural resources exploitation.

There are indeed few examples of production chains integrating South American countries, in spite of the reduced trade flows among them, mainly if one compares with the industrial relationships that were built during the last decades among the Asian countries, and their role in the Global Value Chains. In SA, one can find some degree of integration between Brazil and Argentina -as the car industries optimize their production, sharing plants and transferring parts among the two countries- and only a few other examples.

Even in the power sector, integration is still incipient.

Lack of trust and the prevalence of self-supply energy policies have helped to keep electricity trade to a minimum, mostly to answer specific demand periods, usually under spot market conditions. This situation may be gradually changing, as power systems expansion across borders seems to be the logical solution in most cases. The existence of several hydro plants, even with their growth limited by environmental pressures, reinforces the possibilities of building new bi-national dams

as well as of other plants close to specific borders that will help to push the integration of the related systems.

The exploitation of renewables, including both the pending hydro projects as the new modalities, with their seasonal and/or intermittent characteristics, located in regions often isolated and far away from the demand centres, asks initially for integration that could be mainly fulfilled inside the countries themselves, but also opens the way for feasible crossboard options.

Wind and solar PV plants installations have been growing in most SA countries lately, and the prices of these energy forms have accordingly been falling. Nevertheless, their participation in the regional electricity matrix is still relatively small. The difficulties nowadays faced by developers of large hydro plants indicate that if one wishes to reduce the current use of fossil fuels, and at least avoid a huge increase of the participation of natural gas and coal, as it may happen in the current situation, it will be necessary to exert a stronger effort for the penetration of wind, solar, and also other new renewables as, for example, the different types of biomass already present in many countries.

In the current conditions it is quite sensible to assume that the growth of wind and solar plants in SA will continue in the next decade, and it is also likely that it will be followed by a parallel growth of industrial facilities producing its capital goods. Sophisticated new services may be added as distributed generation being spurred by the PV costs reduction will find more room for supplying electricity. In this context, if the institutional conditions are favourable, new production chains in these industries, although not existent yet, may be formed, helping the development of SA industrial integration, and also fostering technology developments and innovation, typical of these new forms of energy production.

GUIDELINES

Considering the many factors that lead to the formation of GVCs -different costs of labour, scale, financial conditions, possibilities of technology specialization, presence of industrial bases, etc- it can be guessed that a potential starting point for the promotion of ties in the renewables industries may involve Brazil and Argentina, maybe Uruguay and Paraguay, and, through a co-ordinated process, Chile²².

In any case, the development of relevant chains will depend of the effective interest of the private companies. As a counter example, it should be noted that not all leading companies are producing through chains, as it is the case of the German company Enercon. Be it in Germany, or in its Brazilian subsidiary Wobben, it opts to produce most of its wind turbines at home²³.

Attractiveness to private investors of the regional/global production schemes is a central determinant of their eventual creation.

Based on all the above considerations we are finally led to propose the following policy lines:

a) development of an integrated planning view for the electricity market in South America, *incorporating in it the future of the production of goods and services for the power sector*. UNASUL²⁴ should be the locus where to lodge this initiative, backing also attempts like the ones with the help of CAN and MERCOSUL, as well as those from existing regional energy

organizations as CIER²⁵ and OLADE²⁶.

In this vein, foster the creation, under MERCOSUL, of similar institutional mechanisms for electricity integration as those already existing and functioning within CAN, *with a view to a greater integration of both power systems*;

b) establish a loosely co-ordinated action -ideally coupled with guideline a)-, involving all SA countries, as regards planning for greener energy sources in the continent. This rejoins the argument in Section I, of using simpler, horizontal approaches to progressively foster regional integration;

c) develop further and more detailed studies -as a sequence to this project- of the local industries producing equipments for the SA energy sectors, in order to promote a broad debate on the possibilities of creating regional value chains for them, mainly in the renewables segment. Incorporate the leading world firms of these sectors in the effort;

d) in conjunction with the above, enhance awareness of concrete, specific gains in productive integration, by highlighting groups of parts and components whose manufacturing could be regionalised, *and calling attention to its role as an important way to circumvent the market size constraint*; surely one of the factors against local production initiatives by smaller countries, even those as Colombia.

22 Although Chile may be considered the SA pioneer in both wind and solar plants developments, till now its strategy has been to rely on the market without any special steps to promote local involvement in the renewables industry. Private communications during a visit to Chilean organisations and companies indicate that the main reasons for this positioning were the limited size of the Chilean market and the lack of institutional support and co-ordination.

23 In a visit to the Enercon industrial facilities in Germany, promoted by GIZ, it was clearly pointed out that they produce around 85% of its wind equipment at home.

24 União de Nações Sul Americanas - UNASUL

25 Comissão de Integração Energética Regional - CIER

26 Organización Latinoamericana de Energía - OLADE

Given the speed of technological change, great care must be exerted when selecting the parts and components;

e) create, at the same time, more incentives to foreign participation in the renewables sector, combining greater and easier market access with wise measures on local content and (always) a minimum amount of technology transfer. In a regional level, the Brazilian approach, and, in a global one, the Chinese policies could inspire, though not determine, how to fashion *a set of rules to be regionally adopted*. Market size, again, may act either for or against such policy (see also the above guideline);

f) devise ways and incentives, internally and externally, for spreading technological information on the production methods and steps of the main equipment for wind and solar generation. The same should be done as regards the techno-administrative processes for introducing renewables, giving -in both cases- equal emphases on transfers from the outside and knowledge-sharing in an intra-regional mode. Chile, Brazil and, perhaps, Uruguay are well-positioned to help other SA countries in specific instances of renewables promotion, use and manufacturing; from the successful recourse to auctions in Brazil, to solar and wind technologies tested and adopted in these three countries;

g) develop complementary analyses of other possibilities of participation of renewables in the SA electricity matrix, and the creation of related goods and services production chains; the various types of biomass are an example. Also, the new **distributed generation sector** and its multiple suppliers should be

considered, as they may grow sharply in the next decade. The experience of other countries and regions, as that of the German *Energiewende*, should be examined in order to help or inspire drawing new policies for the promotion of clean energy forms.

ANNEXES

ANNEX I

THE BERLIN ROUNDTABLE

In order to shed light over the project questions, and discuss the preliminary version of the results, an interesting roundtable²⁷ was promoted by GIZ in Berlin, last September. It reinforced the importance of creating institutional conditions that could help to simultaneously push the renewables advances and the integration -energy included- efforts. Many suggestions were put forward in this direction.

The workshop has also drawn our attention more closely to (1) the still incipient energy (and electricity) integration and to (2) the more general industrial integration of South America, where the incipient global value chains can be seen as one of the tools for reaching this goal. A few considerations about these two topics are presented in Annex 2, in

order to better frame and complement the discussion of policy measures in this report.

Among the many points raised in the workshop, the need of regional planning and co-operation was stressed, although national goals should precede the formulation of regional ones. To drive and organize the regional efforts, multilateral institutions as Mercosul may be helpful.

Also, it was remembered that most global chains usually have individual company leaders that create and organize the chain, and such companies demand favourable institutional conditions. Clear goals and regulations at national and regional levels provide to the private industrial players the necessary incentives to push forward the production chains.

Preliminary in-depth feasibility studies may help, even if, as in the case of Desertec²⁸, they could indicate the lack of a business case to move forward. Intra-regional global chains require specific local advantages to give them

27 'The Potential of Global Value Chains of Renewable Energies as Regional Integration Tool', Economic Policy Forum EPF/GIZ, Berlin, 22 September 2016.

28 Desertec Initiative is a consortium of private companies that studied unsuccessfully the development of Wind and Solar plants in the North Africa and Middle East (MENA) region in order to supply electricity to Europe through DC high voltage lines.

competitive advantages. If these advantages cannot be found in the case of the renewables, focus on separated individual national developments can be a more sensible option.

Though the main subject of our project was the solar and wind industries, the Roundtable suggested that other renewable technologies should be examined in the future. Biomass generation stands as an important candidate as it already has an initial presence in many SA countries. Off-shore wind and concentrated solar, not studied here, may play a role in the future and should be the subject of further exam.

In the photovoltaic solar case, the strong dominance of the Chinese companies in the silicon purification and production of solar panels can be a limit to the development of local industries.

Specific locational and technological aspects should be further investigated, as they will probably differ throughout the region. As the development of global chains requires the leadership of individual companies, it may be useful to exploit all the necessary conditions for their internationalization in the region. Dunning's OLI Eclectic Paradigm²⁹, that stresses the importance of *ownership, location and internalization* factors in the companies' decisions about what to do at home and what to do (or buy) abroad, may be of help here.

Building new technology industries related to renewables may require a dream, or a vision³⁰, as it was the case with the ethanol production and usage by the car industry in Brazil -something clearly pointed out in the work-

shop. It may start at national level, as in the Brazilian case -where wind power is already in motion-, but if one looks for some degree of regional integration, a broader international view should also be included, as a multilateral goal. In both national and regional industrial developments, as pointed in the roundtable, the study of experiences as the German Energy Transition ('Energiewende') can help, and should be taken into consideration³¹.

29 See, for instance, Dunning, J. H., The eclectic paradigm of international production: A restatement and some possible extensions, *Journal of International Business Studies* 19(1), 1988, or *The Multinational Enterprise Revisited*, The Essential Buckley and Casson, edited by P.J. Buckley and M. Casson, Palgrave Mac Millan, 2010.

30 As said in the workshop by Dr. Alexander C. Kauer, '... about building a vision - I would like to quote Kennedy here: we don't do it because it is easy, we do it because it is hard'.

31 FGV/IIU is working in a project, in partnership with the Konrad Adenauer Foundation, to discuss the pros and cons of introducing the new renewables in Brazil and Germany, which includes comparisons with the Energiewende experience.

ANNEX II

BACKGROUND - GLOBAL CHAINS IN SOUTH AMERICA: INDUSTRIAL AND ENERGY INTEGRATION

The Trade Dimension

Latin America's share in international trade is relatively low. UNCTAD³² data for 2015 show that the gross domestic product (GDP) of the region represented 3.5% of the world GDP, while the volume of exports, around 406.7 billion US dollars, was close to 2.8% of the world total. Although 24.7% of global exports was of primary products, in South America this participation was of 75.3%, indicating a much smaller trade of industrial products.

Looking to the intra-trade export figures for the SA economies, that would proxy some degree of productive integration, they represented only 18.4% of the total exports in 2015; by comparison, the intra-trade of the developing economies of Asia, in the same year, measured 53.8% of its total exports.

Although modest in scale and less interconnected, the regional export market is still very important for the South American countries as the region is the principal destination of their (reciprocal) manufactures exports. In a detailed study of industrial integration and value chains in Latin America, CEPAL³³, in many LA countries more than 70% of their exports of manufactures is oriented towards the region itself. Although small, the volume of intra-trade is quite differentiated. In 2013, SA exported

2,312 different products to other countries inside the region, 1,149 to the United States, 1,204 to Europe and 308 to China. Even so, the participation of South America in global chains is very limited and most of its current opportunities are related to the regional market.

The growth of production chains in the world is mainly explained by the industrial fragmentation process that has progressively replaced the successful multidivisional³⁴ structures of the 20th Century by new forms of organization, as for instance production networks.

For products involving more sophisticated technology and innovations, as in the case of the wind and solar industries, the production chains, local or global, *are usually established under the leadership of a multinational and sometimes, but not often, under a leading local company with a technological agreement with a multinational*. Scale, labour costs, logistics and access to local development funds play a role in the creation and the regional location of most of these chains, where products on the higher technological echelons tend to be imported and small and medium size companies are locally constituted to supply specific parts. When those production chains are extended across other countries' frontiers, they may become important tools of industrial integration.

Looking to South America, as clearly pointed in the aforesaid CEPAL study, only a few large production chains could be identified, most with international connections. Outside the focus of the present study, considering all Latin America, some involvement in a larger number of global chains could be found in

32 United Nations Conference on Trade and Development (UNCTAD), Data Centre.

33 Barcena, A., A. Prado, O. Rosales e R. Perez - Comisión Económica para América Latina y el Caribe, Panorama de la Inserción Internacional de América Latina y el Caribe, 2014, Chile, 2014.

34 See Chandler, A.D., Jr., The Visible Hand, The Managerial Revolution in American Business", The Belknap Press of Harvard University Press, Cambridge, (1st. Edition 1977) 14a. ed., 1997, or Williamson, O.E., Markets and Hierarchies; Analysis and Antitrust Implications, The Free Press, MacMillan, New York, 1975.

Mexico and Central America, under the leading influence of United States companies. But, even looking at LA as a whole, the CEPAL studies concluded that the countries in the region have not advanced in creating regional value chains and have only a marginal involvement in the global production chains, considering both the production and exporting of basic goods to be used in them, and the importing of intermediate products to be processed locally.

The Southern Cone industrial relations show some degree of interrelation in a few sectors, as in the case of the automobile industry in Brazil and Argentina, that may constitute one of the few examples to help the formulation of policies to promote other chains and support more regional integration. In a study of the GVC in Latin America conducted under the Mercosul³⁵, a few basic chains were identified in South America, in agricultural production and textiles, as well as some degree of interrelations in more technologically advanced sectors, mainly in the aforesaid car industries.

In spite of a few empirical regional studies indicating the local industries participation in global chains of SA companies -as CEPAL points out-, and even if the industrial inter-trade in the region has a relatively small participation in their production, global fragmentation is changing the organizational models of corporations and world companies are becoming more and more international. Such global changes are likely to push the participation of local SA companies in GVCs, if institutional conditions help.

Considering the wind and solar industries in South America, the continuous increase in the power sector interconnections and trade that has been taking course may be one of the forces that will simultaneously strengthen the power sector industrial interrelations.

The main local policy goals should not only look for positions in the GVCs, but also in obtaining technological upgrades in the few existing participations and in the new global chains; what will probably require special care with the governance³⁶ of these chains -encompassing the role of the leading companies and the regulatory environment-, to improve the very design of appropriate industrial policies.

Adding technology and innovation to their natural resources base seems the most adequate strategic option to be pursued by SA countries in the near future, as stated by Perez (2010)³⁷. In the power sector, new renewables industrial developments are a sensible focus for this strategy.

The Energy Dimension

The SA sub-continent could be reasonably independent in terms of energy if its oil, gas, hydro and other resources were continuously developed and if energy integration -and inter regional energy trade- could be pushed forward.

SA energy demand levels are smaller than the world averages; in 2015 SA consumed 1.4 tons of oil equivalent (toe) per capita versus 1.9 for the world, while SA electricity per capita was of 2,350 KWh versus 3,028 KWh for the world. With a relatively large participation of renewables, its CO2 emissions by the energy sector

35 Prochnik, V., J.A. de Negri, C. Garrido, V.R. Peçanha and L.E. Sanley, in *La Inserción de América Latina en las Cadenas Globales de Valor*, Coordinated by V. Prochnik, Serie Red Mercosur de Investigaciones Economicas, Montevideo, 2010.

36 Cepal developed a specific methodology to analyse the GVC and its governance, with the support of German Federal Ministry for Economic Cooperation and Development (BMZ) and of the 'Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)'.

37 It is worth while to read C. Perez, *Technological dynamism and social inclusion in Latin America: a resource-based production development strategy*, Cepal Review 100, April, 2010.

are smaller than the world average, with 1.9 tons/toe for SA and 2.3 tons/toe for the world.

The SA electricity matrix is still a very clean one. In 2015³⁸ hydro generation was responsible for 58% of the total regional generation, while other renewables added more 8% reaching a regional 66% of renewable generation sources (a much higher level than the 23.8% participation of these sources in the world electricity generation as a whole) complemented by natural gas (20%), oil (7%), coal (5%) and nuclear (2%).

There however will be crescent difficulties to keep the same past degree of cleanness in the SA matrix. In this context the growth of the new renewables may be one of the few options available to compensate for the reduction in the expansion of hydro plants. If one thinks in terms of climate problems in SA the expansion of wind and solar generation should clearly be one of the most important goals. Also, as the integration of these intermittent and seasonal sources requires system' complementation, building more integration among the SA countries may be one of the important policy tools available to favour the efficient penetration of these clean sources.

The presence of renewables in general is usually a strong argument in favour of building large transmission networks to move this energy and promoting systems integration to compensate its irregularities. Internally, in most countries, as typically in the Brazilian case, large transmission lines were built and specific operation rules are used to optimize the generation system. For instance, the Brazilian System Operator estimates a 20% energy production gain originated from integration and coordination of its operation.

However, this systems integration is usually limited to be developed only inside each country frontier. The need of having a guaranteed supply able to respond to each country' needs, and a lack of trust in receiving energy from abroad in case of a difficult supply period, are the main reasons that imposes to most SA countries a strict self-supply policy that goes against any major integrations.

Electricity is more generally considered a kind of non-tradable good, as it cannot be easily imported/exported. In order to trade electricity heavy investments in infrastructure are needed and once built they cannot be moved (without heavy costs), with a typical asset specificity that generates huge moral hazard contractual risks. Its trade requires some institutional stability among the partners and tends to be limited to marginal situations.

Looking for signs of electricity integration among SA countries, means looking for specific infrastructure investments more commonly, with a bilateral character, joining two countries by transmission lines and sub-stations, or through the construction of binational hydro plants in frontier rivers.

A detailed view of the physical interconnections among the SA power systems can be found in a FGV/IIU study³⁹ showing that the main physical investments are included in two main groups: under the Mercosur region and under the Andean Community (CAN), complemented in both cases by connections with Chile. Also another important transmission line crossing Guyana, French Guyana and Suriname, and connecting them to the Brazilian system in the Amazon region - the so-called North Arch - is being planned and may be built in the future.

38 Energy in South America, year of reference 2015, SPE/MME, Brazil, April, 2016.

39 Crespo, F., Furthering South American Integration Through Energy Integration, NP/II/FGV, July 2014.

CAN is nowadays constituted by Bolivia, Colombia, Ecuador and Peru. In 2002 they signed an agreement defining initial rules for promoting electricity integration, and created a committee that should be responsible for its implementation, closely followed by Chile. Difficulties in its implementation and conflicting interests are still keeping further integration more as a proposition for the future than a close reality. However, in any case, bilateral trade has been growing as electrical interconnections among these countries have been operating answering local needs, and power trade has taken place under transitional bilateral short term agreements. In particular Colombia has been importing electricity from Ecuador. Interconnection of Colombia with Panama in Central America, where a regional market⁴⁰ was already built, can in time enlarge this integration.

With a serious energy deficit in Chile, an important interconnection between Chile (importer) and Peru (potential net exporter) is being planned in order to operate in 2022, overcoming old political problems among these two countries that till now have blocked this initiative. It should be pointed that one obvious very interesting trade involves producing electricity in Peru, that has large reserves of natural gas and also an expressive hydro potential unexplored, in order to sell to Chile, and mainly to the North of Chile where are situated most of its mining capacity and has a huge demand of electricity, only partially supplied by the renewable plants available in the Atacama Desert, and depending on very expensive imported oil generation.

Also Bolivia, that in the earlier 2006 took measures that have scared away internation-

al investors, is now planning to attract capital and become an important energy exporter; a bi-national hydro power in the frontier with Brazil is being studied by both countries, Guajara-Mirim (2,000 MW) in the Madeira River upstream the large existing Brazilian plants of Jirau (3,450 MW) and Santo Antonio (3,150 MW), and also another project Cachuela Esperanza (990 MW) in the Beni River, also in the Madeira Basin, inside Bolivia, may be included. Brazil has also had an agreement with Peru to develop about six hydro projects inside that country, but all of these projects shown to be unfeasible facing environmental problems; one of them the Inambari (2,000 MW) project close to the Brazilian frontier has advanced, but many opposition groups, including local influence of illegal mining and terrorist groups, resulted in the closing of the project because lack of security in order to conduct the required local popular consultations.

In the Mercosul area, there were developed a few bi-national projects starting with the large Itaipu (14,000 MW) between Brazil and Paraguay, Yacireta (3,200 MW) between Argentina e Paraguay, and Salto Grande (1,800 MW) between Argentina and Uruguay. Two other projects are being discussed, Garabi (1,150 MW) and Panabi (1,050 MW) between Brazil and Argentina and also Corpus (3,800 MW) between Argentina and Paraguay, although the later project faced strong popular opposition. All those hydro projects imply also in the existence of electrical interconnections among these countries.

The construction of many transmission lines and sub-stations has resulted in temporary flows of electricity among them. Among them, two interconnections join the Brazilian and

40 Possibly the most ambitious interconnection with regional market rules established in Latin America is the Central America Electricity Market SIEPAC, fruit of a regional agreement signed in 1986, that involves a large transmission line through the region, and includes the presence of a regional operator (EOR) and of a regional regulator (CRIE).

Argentine systems, one at Garabi and another connecting Passos de los Libres (Ar) to Uruguayana (Br); Brazil and Paraguay also have interconnections joining the adjacent cities of Ponta Porã (Br) and Pedro Caballero (Py); Paraguay and Argentina are interconnected also at El Dorado (Ar) to Mal. A. Lopez Py) and at Clorinda (Ar) to Guarambaré (Py); Argentina and Uruguay are also joined through Colonia Elia (Ar) to San Javier (Ur). Between Brazil and Uruguay, two interconnections were built, the smaller Livramento-Rivera and the recently concluded 500 MW line connecting Presidente Medici (Br) to San Carlos (Ur).

Towards the North, Brazil and Venezuela (also in the Mercosul) have a transmission line joining the hydroelectric plant of Guri (10,200 MW) in Venezuela to the Brazilian city of Boa Vista. Also, in the south cone, Chile is interconnected with Argentina through a transmission line from the thermal plant Termo Andes (Ar.) to Salto (Ch).

There are already many electric interconnections between SA countries, but they have mainly been the place of spot market operations used in an intermittent basis and attending more often to specific supply problems in individual countries, under specific rules designed for these particular short range situations. In a few cases, energy (natural gas and/or electricity) contracts have been discarded as originally unpredictable supply difficulties affected the planned supplier and reinforced the local opposition on future energy transactions.

As production and demand of electricity grows in the region (one can expect between 3-5% of yearly growth in most of the region, during the next decade) and as more renewable plants are added it, is reasonable to foresee that more pressures will be exerted on systems integration, and as such more stable forms of electricity trade will have to be devised.

One clear example of such move is in the Brazil-Uruguay relationship, where a more unified energy market is under construction.

Growth of the power sectors and the recent past events indicate that the SA electricity integration will keep on moving. It is likely that governance of the most promising integration advances will take place within the two main regional organizations, CAN and MERCOSUL. As concern for the climate problems takes hold of local communities and governments, more renewable sources must be developed, even if the big hydros grow at their full physical possibilities. More renewables means that more integration trends, creating a better framework to industrial integration and the formation of new regional GVCs in the wind and solar sectors, as here analysed.

For the integration of both the power sectors and their supporting industries -as in the case of the wind and solar modes-, some basic planning and co-ordination among the SA countries is clearly needed. The best option for the industrial development is to have its promotion considered *together with the power sector regional expansion planning*. In order to move ahead of bilateral agreements this may be supported by the existing multilateral organizations, including the countries' associations and financial actors.

One of the crucial steps in the power sectors integration is the creation of electricity markets across countries based on clear and sustainable rules. They may start by the formation of bilateral markets and, ideally, should evolve towards regional markets as integration deepens. This evolutionary process is already happening, more or less independently, in two regions: the Andean countries and the Southern Cone. In institutional terms, CAN is already promoting this market creation. Mercosul will have to get involved into this process, and probably

both institutions will extend their agreements to include Chile, which may work as a link between the two blocks. As these movements grow they may create a strong basis also to the promotion of production integration and the proper institutional conditions to stimulate industrial players to lead the formation of regional production chains, in the wind, solar and other sectors as well.



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