

Bi-regional
economic perspectives



EU-LAC Foundation

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Financing the transition to renewable energy in the European Union, Latin America and the Caribbean



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LIST OF ABBREVIATIONS

| | |
|--|--|
| AC Alternating Current | IADB Inter-American Development Bank |
| AFD Agence Française de Développement | IFC International Finance Corporation |
| BNDES National Development Bank | IPPs Independent Power Producers |
| BoS Balance of System | IRENA International Renewable Energy Agency |
| CaDB The Caribbean Development Bank | KfW KfW Development Bank |
| CAF Development Bank of Latin America | LAC Latin America and Caribbean |
| CCMT Climate Change Mitigation Technologies | LTE “Energy Transition Law”, in Spanish |
| CDB China Development Bank | NER 300 New Entrant Reserve 300 |
| CELAC Community of Latin American and Caribbean States | NREL National Renewable Energy Laboratory |
| CFE Comisión Federal de Electricidad | OECD Organisation for Economic Co-operation and Development |
| CHEXIM China Export-Import Bank | OEM Original Equipment Manufacturers |
| CSP Concentrated Solar Power | PCT Patent Cooperation Treaty |
| DB Development Banks | PPA Power Purchase Agreement |
| DC Direct Current | PV Photovoltaic |
| EBRD European Bank for Reconstruction and Development | R&D Research and Development |
| EC European Commission | RER Renewable Energy Resources |
| ECOFIN Economic and Financial Affairs Council | RES Renewable Energy Sources |
| EEPR European Energy Programme for Recovery | SEI Sustainable Energy Initiative |
| EIB European Investment Bank | SFF Structured Finance Facility |
| ELENA European Local Energy Assistance | SMEs Small and Medium Enterprises |
| ETS Emissions Trading System | SPV Special Purpose Vehicle |
| EU European Union | TFEU Treaty on the Functioning of the European Union |
| FIP Feed-in-Premium | UK United Kingdom |
| FIT Feed-in-Tariff | US United States |
| GEEREF Global Energy Efficiency and Renewable Energy Fund | US EXIM Export-Import Bank of the United States |
| GIB UK Green Investment Bank | WACC Weighted Average Cost of Capital |
| | WB The World Bank Group |

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EXECUTIVE SUMMARY

The transition to more sustainable energy systems has a variety of relevant implications for the European Union (EU) and Latin America and the Caribbean (LAC) countries. These include: ensuring and diversifying electricity supply to an increasing population; the potential for job creation and economic and industrial development; and the fast technology advancements towards cost-effective solutions.

This study is focused on the analysis of financing mechanisms for renewable energy technologies in the EU and LAC countries. The aim is comparing experiences in the introduction of renewable energy in order to draw meaningful lessons, either from LAC countries to the EU or the other way around. This objective is not straightforward. For instance, feed-in-tariffs were a successful instrument for the introduction of renewable energy sources in Germany, but not to the same extent in Brazil. Dedicated auctions for wind power were successful instruments in Brazil, but not in Argentina. The same auctions were used in Brazil to introduce solar PV with limited success.

Most of the research efforts that can be found in the literature have focused on the analysis of different mechanisms to enhance renewable projects' revenue streams (feed-in-tariffs, auctions, etc.) However, in order to understand the whole picture, special attention needs to be paid to the financing challenges that the investment in these new technologies faces. That is especially true in developing countries (as LAC countries), where financial markets are severely constrained. This study aims at complementing the existing literature by an in-depth analysis of the issue.

We show that, in order to develop renewable technologies, we need to take into account that the associated investment needs are significant and markets alone might not be sufficient to coordinate all actions to be taken. Moreover, given the variety of investment conditions across countries, including different characteristics of financial markets, there is no one-size-fits-all solution.

Comparing experiences in the introduction of renewable energy, we find that:

- Two basic market designs can be identified. On the one hand, the “utility business model” is based on a firm that undertakes long-term investments (e.g. power plants) and recovers it by selling power through 1-2 year contracts. On the other hand, the “infrastructure business model” is based on selling power through long-term contracting, e.g. Power Purchase Agreements (PPAs). Long-term contracting can be viewed as mitigating the risks associated with projects' revenue streams so that it facilitates financing.

On the other hand, acting on revenue streams may limit significantly the number of available choices for the electricity market design. We see that, in LAC regions, market designs based on long-term contracts assume there exists a centralised planning effort, which might not be the case, or it may face coordination challenges. On the other hand, the EU choice of relying on more competitive electricity markets requires the existence of a quite efficient access to capital sources, which might not be always the case. In summary, this fundamental trade-off (long-term contracting requires planning, short-term contracting requires liquid capital markets) needs to be recognised. Although there are no silver bullets, the market design needs to be coherent in order to attract private investment for renewable projects.

- Utility business models are based on riskier projects (less available sources of finance) but eliminate the need for planning that characterises infrastructure business models. We observed in LAC countries a preference for mitigating as much as possible risks related to revenue streams to get as much competition as possible from different capital sources. We used solar projects to highlight that not all Renewable Energy Source (RES) project share the same characteristics from an investor's point of view. Policies may be applied equally to all RES projects, considering them as infrastructure, but this decision may be associated with financing solutions that are not efficient. In fact, we identified Yieldcos¹ as an instrument to separate riskier activities in RES projects in a project finance environment. In that sense, market environments that impose the development of RES under the same framework of more traditional infrastructure projects may create undesired constraints. This challenges the adequacy of a convergence to a pure infrastructure-like market design.
- Manufacturers of solar panels are increasing their participation in LAC markets. This may be viewed as a consequence of low risks associated with their revenue stream: as signing a PPA gives them the possibility to find financing sources, they see the opportunity to introduce their technology in LAC countries. At the same time, this mitigated risk implies that investors are not facing technological risk, even if it exists. This risk is absorbed by the counterpart of the long-term contract, who is typically a regulated consumer.
- If the utility business model is discouraged, technological flows channelled through utilities will face difficulties.

This study is structured around three main dimensions of the challenge of introducing renewable technologies in electricity industries, both in the EU and LAC:

- Public instruments to facilitate the participation of private capital in renewable energy projects;
- Technology flows between the EU and LAC;

.....
1. A Yieldco is a dividend growth-oriented public company that bundles long-term contracted operating assets in order to generate predictable cash flows.

- Interaction between flows of capital and flows of technology (e.g. companies may provide financing in order to export technology).

Following the previous scheme, we begin by providing an analytical framework for the analysis. In Chapter 3, we study public policies aimed at facilitating the introduction of RES in electricity industries. We look at both LAC countries and the EU, with the objective of developing a description of the elementary building blocks of each region.

Chapter 4 focuses on the technological flows of renewable energy between both regions (LAC and EU) focusing on Solar Photovoltaic (Solar PV) and wind power. We analyse each technology separately and compare the main results afterwards. We identify the key players of each industry both in the EU and in LAC focusing on the intersections among the regions, i.e. players in both regions (LAC and EU). The analysis shows that the main players in the EU are utilities. Consequently, when considering technological flows from the EU to LAC countries, the main channel will be projects undertaken by utilities. Nonetheless, manufacturers of solar panels are increasing their presence in LAC countries. In that view, market design in LAC may diversify technology sources.

Chapter 5 analyses the interplay between technology and financing. On the one hand, we observe that reinforcing competition among several investors (utility and non-utility investors) is possible and may bring efficiency to financial decisions. This does not mean that choices regarding the generation mix (energy planning) will be efficient as well, because the previous logic considers the choice of generation technology exogenous to the project. On the other hand, the technological trajectory of solar PV is less defined both in LAC countries and in the EU, which means that there is a larger technological risk if compared to wind projects. The comparison between the EU and LAC strategies shows pros and cons of both schemes. The LAC strategy has proved its strength when investments are similar to infrastructure projects (particularly if technological risks are low). However, when the risk is not negligible it may be costly and may hamper innovation.

Finally, in the last chapter, we provide a summary of our findings:

- **Market design crucially affects the available financing mechanisms.** As we have seen, LAC and the EU have chosen different market designs. Both solutions have pros and cons. LAC choice facilitates access to capital markets, although they may face planning challenges. The EU choices enhance competition in the market, although it requires liquid access to capital sources. The design chosen needs to address this trade-off in order to design a solution that is coherent with each country situation.

- **The infrastructure business model implicitly assumes that the role of equity is relatively unimportant.** The EU and LAC are converging to markets designed to facilitate access to capital, reducing the importance of debt. RES projects where equity is important may find difficulties in implementing the efficient financing solution.
- **The infrastructure-like market design might allocate technological risk to consumers.** Developing RES projects through long-term contracts may result in an inefficient technological risk transfer from the investor to consumers.

Based on this evidence, we formulate a series of suggestions for action with the objective of facilitating the decision-making process in electricity industries:

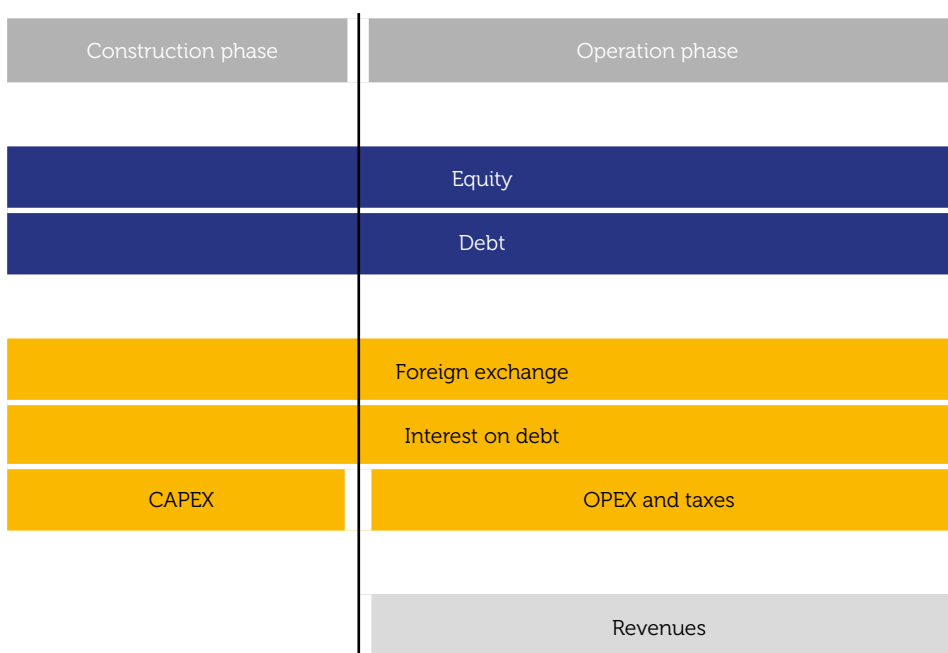
- Formalisation of the decision-making process associated with the definition of a market design. We stress that the complete set of measures implemented in the electricity industry must be coherent.
- When the infrastructure model is chosen, the complexity of electricity projects needs to be tackled also from the financing viewpoint. The design of appropriate contracts is a fundamental element for a well-functioning market, as they allow the existence of long-term financing sources.
- If the choice is a market based on the infrastructure business model, an important role to be played by public and multilateral institutions is the structuring of complex projects for the private sector. Electricity projects are difficult to understand for many investors, and these projects share few characteristics with more liquid instruments for project finance. Hence, the regulatory activity should include in-depth discussions with the financial sector in order to implement a feasible contract.
- The technological aspects cannot be disregarded. In particular, some policies may result in specific contract clauses that complicate financing the projects.
- The effects of market design on industrial dynamics must be considered. The previous recommendations assumed a market model based on long-term contracts. On the other hand, if the utility business model is discouraged, technological flows channelled through utilities will face difficulties.

2. ANALYTICAL FRAMEWORK

Projects to install power production capacity based on RES are often thought of as infrastructure projects. Infrastructure projects have a distinct risk profile, as they are long-term investments with at least two different phases: i) the construction phase, where most capital expenditures are made, and almost no cash flow is generated; and ii) the operation phase, where little capital expenditures are made and cash flows are generated.²

In order to understand how RES are financed, the related policy instruments and their consequences, we begin by describing an elementary infrastructure project. Figure 1 contains this basic representation.

Figure 1. Schematic representation of a generic infrastructure project



Source: Own elaboration

2. While slightly more detailed schemes may be designed (e.g. including phases where part of the infrastructure is built, and some cash is generated), we will consider this schematic representation. For instance, some turbines of a power plant might be ready and able to sell energy before the total completion phase; or part of a subway project might start functioning and generating cash from passengers' tariffs. We will not consider this level of detail except in case studies.

The simplified description of Figure 1 allows us to organise the first part of the study. It will consist of a review of financial instruments devoted to promoting RES projects. We will identify the objectives of such policy instruments and their concrete implementation.

Based on Figure 1, we can also identify other types of measures. A large set of policies aimed at facilitating RES projects are related to “revenue-enhancing” instruments, including dimensions related to contract design, and to “cost-reducing” measures.

When looking at infrastructure as an investment opportunity, one needs to consider the way in which it competes against other opportunities. Some of these conditions are related to the risks of the macroeconomic environment. Changes in taxation and government titles, as rivals in the competition to attract capital, are relevant risks that may have a significant impact on the levels of investment. Moreover, the level of public participation may be affected by the limited liquidity of capital markets. A detailed study of the macroeconomic aspects of financing RES projects in the EU and LAC countries are beyond the scope of this study.

2.1 RES projects financing instruments

Traditionally, energy production projects have often been considered as infrastructure projects. Hence, RES projects are typically associated, from the financing point of view, with infrastructure financing. In this section, we will review the main characteristics of infrastructure projects from an investor’s point of view, and discuss the implicit assumptions behind dealing with RES as infrastructures.

Regardless of whether we consider an equity or debt investor, infrastructure is a special asset. Some of its main characteristics are the following:

- Long-lived assets
- Low technological risk
- High entry barriers (and hence usually strongly regulated assets with predictable and stable revenue streams)

Let us begin by considering RES projects as infrastructure projects. In that view, we will consider two generic categories, project and corporate finance.

Project finance is a relatively recent trend (compared to corporate finance). It builds on the idea that financing does not depend on the creditworthiness of sponsors but only on the ability of the project to repay debt and remunerate capital (Gatti 2013). In that sense, it deals with the financing of a precisely defined economic unit, (Weber, Staub-Bisang, and Alfen 2016). Typically, because cash flows are more stable, project finance tends to allow a higher level of debt.

Corporate finance is the traditional channel for infrastructure projects, especially private ones. Firms in charge of the infrastructure (i.e. building and operating projects) either issue shares or borrow in capital markets to obtain the required funding. Such firms often tend to have a portfolio of projects. In energy markets, utilities typically have a portfolio of energy projects with different risk profiles.

We will observe in this study that one of the main differences between energy financing in LAC countries and the EU is the choice of project finance (in LAC) or corporate finance (EU) as the preferred type of financing strategy. We will discuss the drivers of this choice by policy-makers in the next section.

A schematic representation of financing alternatives is presented in Table 1, which constitutes a summary of the taxonomy developed in (OECD 2015a). More details regarding the possible infrastructure financing instruments can be found there. In it, besides considering the difference between a project and corporate finance, we also consider the differences between debt and equity instruments.

Table 1. Basic financing instruments

| Category | Instrument | Project Finance | Corporate Finance |
|----------|------------|--|--|
| Debt | Bonds | Project Bonds Green Bonds | Corporate Bonds Green Bonds |
| | Loans | Syndicated Loans Direct Lending (to Project) | Direct Lending (to corporate) Syndicated and Securitised Loans |
| | Hybrid | Subordinated Debt Mezzanine Finance | Subordinated Bonds Convertible bonds |
| Equity | Listed | YieldCos | Listed Stocks, etc |
| | Unlisted | Direct Investment Project (SPV) Equity | Direct Investment in Corporate (SPV) Equity |

Source: Own elaboration based on (OECD 2015a) and (OECD 2015b).

The main financing instruments in infrastructure projects are loans and bonds. Debt markets are the deepest markets in the world so they can be structured to form long-maturity products coherent with the long lives of an infrastructure project. Moreover, such debt instruments may benefit from the existence of players in debt markets with a preference for long-term investments. Insurance companies or pension funds tend to prefer long-maturity products to hedge their long-lived liabilities. Consequently, a large part of the project is typically financed through debt instruments (predominantly loans).

A relevant part of debt instruments is subordinated debt and, in general, instruments both for project (as mezzanine) and corporate finance that have characteristics between debt and equity (see OECD 2015a for details). Subordinated debt can be seen as an instrument designed to absorb credit loss before senior debt. Thus, the main effect is that it increases the quality of such senior debt. In that sense, subordinated debt can be designed to have different risk/return ratios, constituting a bridge between traditional debt and equity.

Finally, equity finance may be seen as the risk capital of the project (usually required to begin the project or refinance it). Listed shares would be traded in public markets whereas unlisted shares would provide direct control of the project. Project equity finance may be placed closer to debt instruments in the sense that infrastructure contracts may impose relatively low risk/return ratios. In any case, we understand equity investment as receiving residual claims on cash flows, thus being the highest risk investments.

From the point of view of our research, the relevance of equity in the project will be a central element of analysis. We began by assuming that RES projects are infrastructure projects, which are characterised by low technological risk. This may not be the case for all RES projects. From the financing point of view, this will mean that equity financing plays a more important role than in traditional infrastructure projects. This is also relevant from the policy design standpoint, as we will discuss below.

One instance of a private response to the fact that some RES projects are riskier than others is the increasingly used Yieldcos. A Yieldco is a company that is formed to own projects in the operational phase (hence with a stable revenue stream). In the energy industry, the idea is that utilities place RES projects in the operational phase into a subsidiary and issue shares in public markets (listed). With this, utilities separate the riskier part of a RES project and are able to create companies that are closer to the idea of an infrastructure project. This may be viewed as a response to a weak commitment of the (usually regulated) long-term contract. SunEdison, a large player in the Chilean market (as we will discuss in this study), is one instance of a Yieldco. It shows the importance of this kind of financial structure in the RES market in LAC countries.

2.2 Revenue stream

The restructuring processes of energy industries around the world that took place in the last decades have resulted in the implementation of diverse market designs. In turn, market designs implemented in each jurisdiction differ, among other dimensions, on the mechanisms to commercialise electricity.

Consequently, the diversity of mechanisms to commercialise electricity implies diversity in the ways in which cash is generated, and hence how long-term investments are paid for. From this study's point of view, we will consider two basic electricity market designs: one based on short-term contracting and one based on long-term contracting.

2.2.1 Electricity markets based on short-term contracting

The first basic design is the preferred choice of countries in the EU. This design relies on short-term electricity contracting (typical contract durations do not exceed one or two years). Within this context, the investment in power generation facilities is typically undertaken by a "utility".

A simplified and schematic description of this business model consists of considering a rather specialised firm that makes investments for 20-30 years (a power plant) and pays for the investment selling contracts for 1-2 years (a retail contract). The utility's profit is based on charging a fee for taking that risk.

The risk may be considerable, which justifies the high specialisation of these firms (unless the demand is stable, if there is a low risk of disruptive entry).

The utility business in a liberalised electricity industry is typically associated with corporate finance. Thus, utilities issue shares on the market or borrow funds through capital markets. They tend to own a portfolio of projects and investors may buy its shares and securities.

2.2.2 Electricity markets based on long-term contracting

The second basic market design is preferred in LAC countries. In a simplified view of the second elementary electricity market design, demand is fully contracted in the long run. All generators have contracts with retailers, and retailers have contracts with end consumers, in such a manner that investment risk is fully hedged. This probably does not mean a fixed price for end customers, but would include a number of indexations.

This market design is well suited for financing, based on project finance instead of balance sheet finance. This stems from the fact that long-term regulated contracts reduce significantly the risk associated with cash flows, and hence relying just on cash generated by a single project to recover investment is easier.

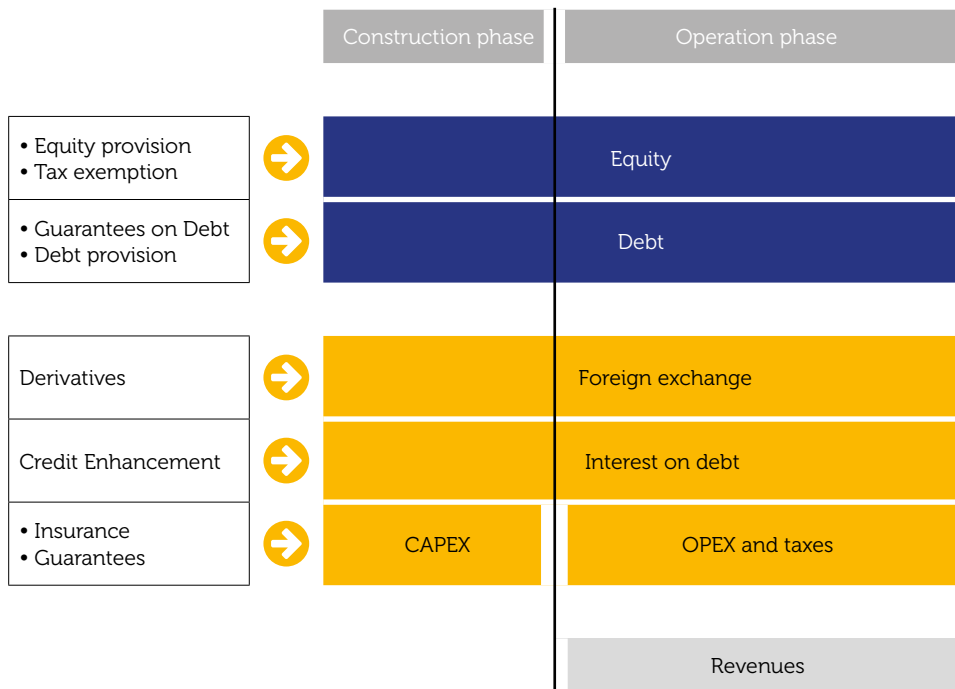
2.3 Policy design

From the previous point of view, policies can be thought of as risk mitigation instruments. We will use two broad categories: i) Financial instruments; and ii) Contract design.

Financial instruments for public participation

Risk mitigation and financing facilitation are the main objectives under this broad header. In order to identify the aim of the particular policy, we represent schematically risks associated with financial challenges in infrastructure projects in Figure 2.

Figure 2. Schematic representation of potential financial instruments to mitigate risks.



Source: Own elaboration.

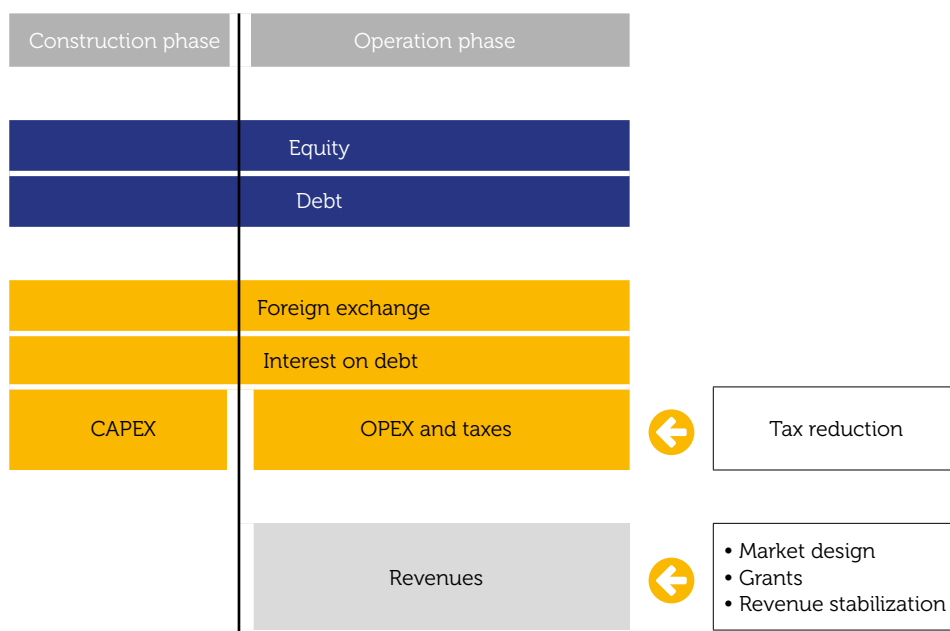
In general, there is a potentially wide range of instruments that can be used by public and private parties to mitigate risks associated with RES projects. In any case, the design of those instruments is related to the identification of the relevant risks. The Organisation for Economic Co-operation and Development (OECD 2015a) provides a taxonomy of infrastructure projects risks, which is similar to the one provided here. Nonetheless, our focus here is to split the mitigation public instruments into those providing financial support and those enhancing revenue streams. For the purpose of this study, this distinction is important in the sense that it may affect technological flows between LAC countries and the EU.

In summary, public participation in financing infrastructure projects can be seen as divided into two main tools: capital provision and guarantee provision. Capital may be provided directly by governments or by national or international development banks. Such capital may be equity or debt (junior or senior), with market or below-the-market interest. There is a wide range of tools that can be used by the public sector with varying amounts of risks absorbed by the public sector. Analogously, guarantees may be provided by governments or development banks. Those guarantees vary from guarantees on debt to guarantees on revenues. As we will see in the case of Argentina, it is possible to establish a guarantee fund to increase the creditworthiness of a long-term contract.

Revenue-enhancing mechanisms

This header contains all possible measures related to mitigating risks associated with revenue streams (see Figure 3).

Figure 3. Schematic representation of revenue-enhancing instruments to mitigate risks.



Source: Own elaboration.

Although one may consider a wide range of instruments with varying degrees of details to perform this function, we highlight the use of long-term contracting. As we will see, tax reductions, grants, and other mechanisms have been relevant for the development of RES projects both in LAC countries and in the EU (see OECD 2015a for details). On the other hand, from this study's point of view, the choice of using long-term contracts to develop RES projects may be seen as the crucial difference between LAC and the EU. These long-term contracts are typically offered in public tenders (in fact, auctions and tenders are often referred to as instruments to promote renewables).

The most discussed instruments within the context of RES projects are among the category of revenue-enhancing mechanisms:

- Feed-in Tariff (FIT) is a mechanism that ensures the payment of energy generated from renewable sources. By identifying costs in the development of renewable energy projects and securing payments throughout the useful life of the technology, FIT significantly reduces the risks of investing in these types of projects. A special type of this support is the so-called feed-in premium (FIP) scheme. Producers receive a premium above the market price.
- Quota obligations refer to minimum shares of RES. These quotas can be defined by national, regional or local governments. Generally, these quotas apply only to RES plants that are owned and operated by the utility. In some cases, utilities have the possibility of using marketable renewable energy certificates.
- Tax incentives are used to facilitate the deployment of RES, either through tax credits or tax reductions.

We use the previous basic scheme to compare strategies in the EU and LAC countries.

- LAC countries have primarily relied on loans from development banks combined with long-term (low-risk) contracts.
- The EU has relied on more sophisticated financial structures and higher levels of risk exposure during the operational phase.

We use the previous framework to compare the solutions adopted in the EU to the ones adopted in LAC countries. The aim of the analysis is to show that the chosen market design strategy may affect considerably the available alternatives for the design of financing measures.

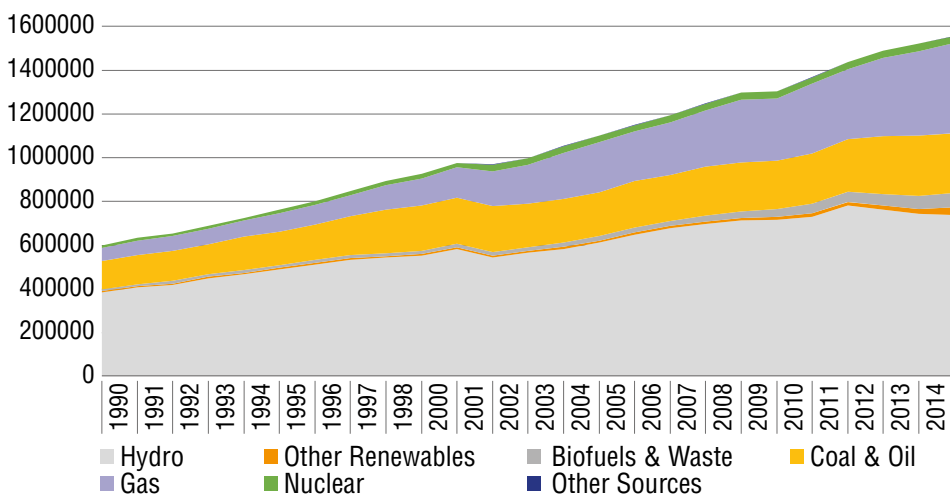
3. PUBLIC POLICIES FOR THE FINANCING OF RES PROJECTS

In this section, we study public policies aimed at facilitating the introduction of RES in electricity industries. We study both LAC countries and the EU, with the objective of developing a description of the elementary building blocks of each region. This description will allow analysing the implications associated with each strategy, paying special attention to the implications regarding technology development. The study of technology flows between the two regions will be the focus of the second part.

3.1 Financing in LAC countries

One of the outstanding facts regarding the power generation market in the Community of Latin American and Caribbean States (CELAC)³ is its great growth of 160% over the past 25 years⁴. A second aspect to highlight is that the matrix is supported by three sources: hydrological projects (which generated half of the power), gas and fossil sources. Even if new renewable technologies have been introduced more recently, this sector is still minimal. A third relevant aspect is the increased proportion of gas generation in the matrix from 10 to 27%.

Figure 4. Gross Electricity Generation in the CELAC



Note: The IEA database does not provide data from Barbuda, Bahamas, Barbados, Belize, Dominica, Granada, Guyana, Santa Lucia, St. Kitts and Nevis and St Vincent and the Grenadines.

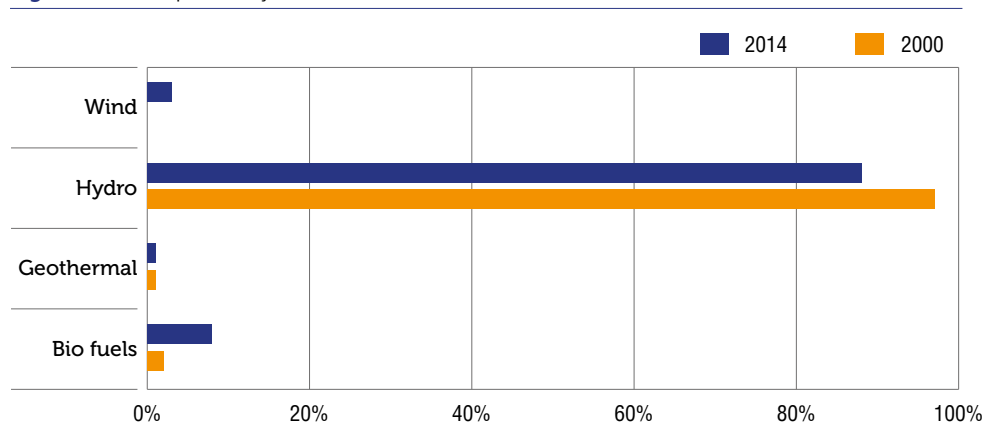
Source: Own elaboration based on IEA 2016a)

3. CELAC consists of 33 sovereign countries: Argentina, Barbuda, Bahamas, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Dominica, Ecuador, El Salvador, Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Paraguay, Panama, Peru, Santa Lucia, St. Kitts and Nevis, St. Vincent and the Grenadines, Suriname, Trinidad and Tobago, Uruguay and Venezuela.

4. For comparative purposes, total electricity production in the EU increased approximately by 30% at an average annual growth rate of 1.3%/year.

The strong increase of generation demands an important amount of investment and funds. Hydroelectricity in countries such as Brazil and Colombia makes the region’s portfolio relatively clean. However, it can be challenged by restrictions to build more hydroelectricity (especially with reservoirs) and the potential to increase the use of fossil fuels in the region. Comparing with other regions (such as Europe) the investment in new renewables (such as solar and wind) in the last two decades was relatively small, and we may observe the predominance of hydroelectricity in the RES portfolio (see Figure 5).

Figure 5. Participation by source of RES in the CELAC



Note: The IEA database does not provide data from Barbuda, Bahamas, Barbados, Belize, Dominica, Granada, Guyana, Santa Lucia, St. Kitts and Nevis and St Vincent and the Grenadines.

Source: Own elaboration based on IEA 2016a

Recently, the challenges to introduce new renewables have lead countries to adopt new policies. However, for effective implementation of this investment is necessary to look also at the financial instruments in the region.

3.1.1 Financial instruments

In Latin America and the Caribbean and developing countries in general, emerging financial markets and cyclical issues make financing more difficult. In this context, development banks have played a unique role in Latin America and the Caribbean. There is an important debate in the literature about the positive and negative effects of Development Banks (DBs) in the region; however, independently of their general impact, their role has been crucial with regards to the investment in new renewables in the region (Mazzucato and Penna 2015; IEA 2015; UNEP and EPO 2014).

To analyse the role of development banks we will separate the scope in two parts. First, we will show the way DBs finance sovereign governments' "green projects". It means the support directed to government's policies or national companies. Second, we will focus on DBs financing renewables projects owned by the private sector.

A. DEVELOPMENT BANKS FINANCING SOVEREIGN GOVERNMENTS

Yuan and Gallagher (2015) examine the extent to which development banks are providing international financing to Latin American governments for environmentally sustainable development projects. They found that eleven development banks provide the majority of international development bank finance to Latin American and Caribbean governments. Between them, four development banks provided the lion's share of sovereign development finance in LAC: the IADB, World Bank, China Development Bank (CDB) and CAF, which contributed roughly 85% of the total loans during the period 2007-2014. The most significant newcomers to the LAC development finance landscape are China's policy banks, the CDB and CHEXIM, which combined have become the largest annual lenders in LAC since 2007.

- **The World Bank Group (WB)**
- **Inter-American Development Bank (IADB)**
- **Development Bank of Latin America (CAF)**
- **The Caribbean Development Bank (CaDB)**
- **European Investment Bank (EIB)**
- **Agence Française de Développement (AFD)**
- **The Brazilian Development Bank (BNDES)**
- **KfW Development Bank (KfW)**
- **China Development Bank (CDB)**
- **China Export-Import Bank (CHEXIM)**
- **Export-Import Bank of the United States (US EXIM)**

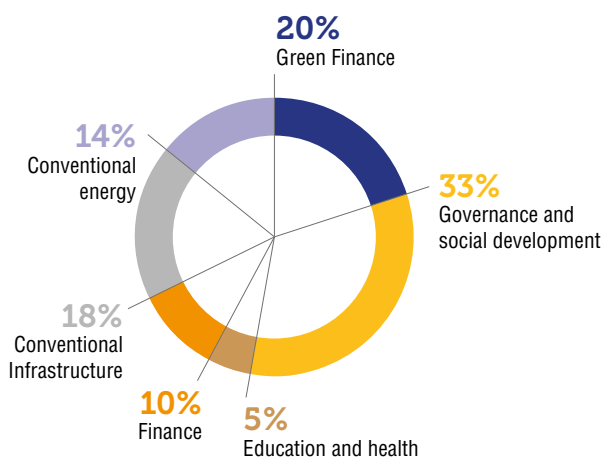
Table 2. Development banks Commitments to Governments in LAC 2003-2014 (USD Millions)

| | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | Total |
|---------|------|------|------|------|------|------|-------|-------|------|------|-------|-------|--------|
| IADB | 6476 | 5564 | 6465 | 5461 | 6870 | 9126 | 14588 | 11370 | 9411 | 9924 | 11799 | 10743 | 107797 |
| CDB | - | - | - | - | 4930 | 4000 | 12050 | 33054 | 7800 | 2700 | 15277 | 2499 | 82310 |
| WB | 5675 | 5003 | 4921 | 5654 | 4331 | 4354 | 13829 | 13679 | 9169 | 6181 | 4769 | 4609 | 82174 |
| CAF | 2166 | 2330 | 2473 | 3791 | 2984 | 3343 | 5590 | 5796 | 4528 | 4586 | 5523 | 5052 | 48162 |
| US EXIM | 972 | 1258 | 1048 | 1247 | 327 | 855 | 1450 | 1016 | 4407 | 2668 | 1589 | 1000 | 17837 |
| CHEXIM | - | - | 30 | - | 45 | - | 178 | 2652 | 2579 | 250 | 2494 | 6094 | 14322 |
| BNDES | 113 | 78 | 239 | 81 | 1165 | 139 | 940 | 1336 | 1480 | 308 | 1172 | 550 | 7601 |
| KfW | 268 | 270 | 216 | 332 | 370 | 649 | 530 | 560 | 745 | 509 | 880 | 1989 | 7318 |
| AFD | - | 20 | - | 12 | 54 | 337 | 398 | 1477 | 1262 | 1289 | 1192 | 1097 | 7138 |
| EIB | 41 | 61 | 106 | 50 | 37 | 138 | 575 | 54 | 980 | 257 | 479 | 573 | 3351 |
| CaDB | 192 | 113 | 138 | 121 | 179 | 298 | 152 | 270 | 145 | 104 | 139 | 244 | 2095 |

Source: Own elaboration based on data retrieved from Yuan and Gallagher 2015

Renewables are part of the Green Finance sector, which has become one of the main focus of Development Bank funds. Figure 6 shows that Green Finance has become the second most important sector of DB investments, after governance and social development.

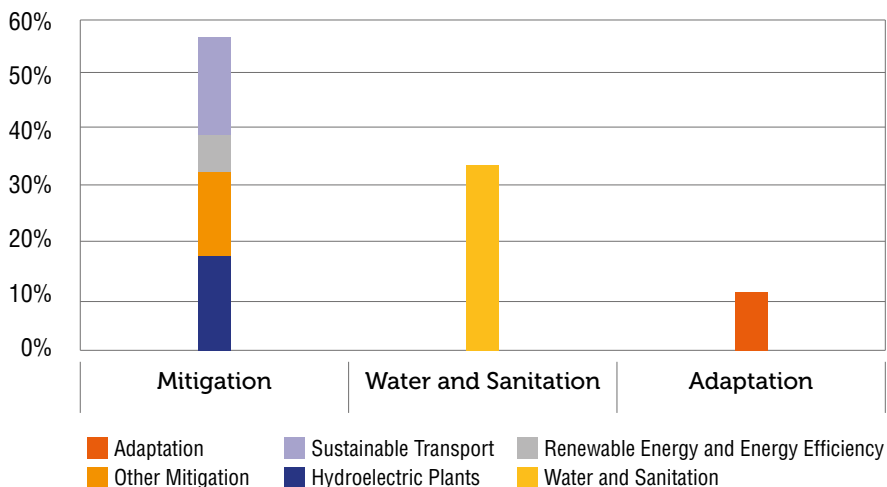
Figure 6. Development Finance Sector Distribution 2007-2014.



Source: Own elaboration based on data retrieved from Yuan and Gallagher 2015

The researchers estimate that development banks provided approximately \$61 billion, or \$8.7 billion per year in green finance between 2007 and 2014, - amounting to 20% of all development bank finance in LAC. The green projects can be divided into three categories 1) clean energy and climate change mitigation (group which includes renewable energy) 2) climate change adaptation and 3) water, sanitation and other environment. The majority of green financial flows in LAC are in the first group (56%), followed by water and sanitation (33%) and climate adaptation (11%). As we can see in the Figure 6, green energy (considering new renewables, energy efficiency, and hydroelectricity) represents more than 20% of the funds directed to clean energy and climate change adaptation. If we compare conventional energy and green energy, the DBs financing government investment in conventional energy was higher between 2007 and 2014, but the importance of renewables showed a tendency to increase (Figure 7).⁵

Figure 7. Composition of Development Banks Green Finance in LAC, 2007-2014

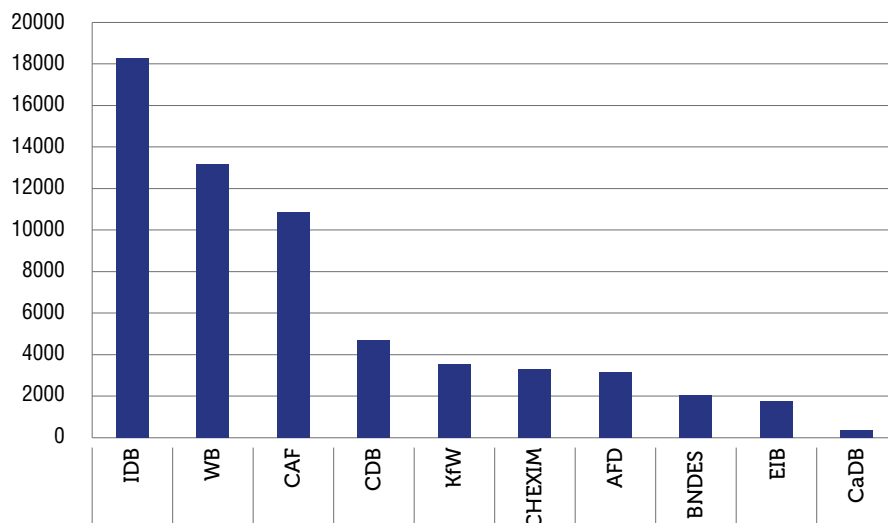


Source: Own elaboration based on data retrieved from Yuan and Gallagher 2015

Considering the importance of Development Banks in Green Finance by volume, we observe in Figure 8 that the **IADB**, the **WORLD BANK**, and the **CAF** stand out as the three largest. The two Chinese development banks and the two European national development banks were at the middle, with approximately \$3 billion during the period. The USEXIM bank provided less green finance to LAC, along with the **EIB**, **BNDES**, and **CaDB**.

.....
 5. While no LAC-wide study has been conducted, a 2008 study of green finance by the MDBs from 1980 to 1999 put global conventional energy finance at three times green finance, down from fourteen times in the early 1980s (Hicks et al, 2010). Thus, comparing with the last decades we can observe a clear tendency to increase green energy funds.

Figure 8. Ranking Development Banks for Green Finance



Source: Own elaboration based on data retrieved from (Yuan and Gallagher 2015)

Cleaner energy finance is significant in the region and is one of the areas where innovative co-financing and ‘green bond’ programs are taking place. Hydropower projects were still the largest category of cleaner energy investment in our sample, which represents 70 % of the total cleaner energy finance during the period under examination. However, there are also significant projects in new renewables such as solar and wind.⁶

We may observe some specific patterns regarding the Chinese Development Banks, they are the largest investors in hydroelectric projects (not only considering the total amount but also in terms of the largest individual projects)⁷, but they also cooperate with national DBs (such as BNDES) and regional institutions (such as CAF) to promote wind power plants among other sustainable projects. Another interesting co-finance partnership has been formed between the IADB and the People’s Bank of China (PBOC), China’s central bank to promote sustainable economic growth (Yuan and Gallagher 2015).

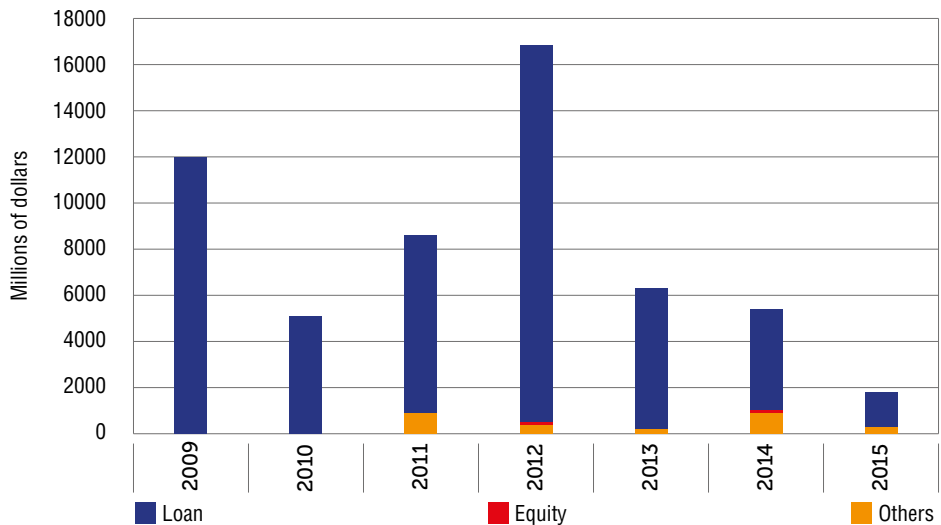
B. DEVELOPMENT BANKS FINANCING PRIVATE PROJECTS

The Development Banks funds in Latin America for private renewable energy projects are channelled through loans as we can observe in Figure 9. Development banks usually fill the in-existent or difficult long-term finance market for infrastructure projects in emergent countries. Regular banks are far less willing to assume long-term risk in those countries, a situation more evident following the global financial crisis. Moreover, the cost of capital in LAC tends to be higher, so the opportunity cost makes the investment in infrastructure projects less attractive and more expensive.

6. We may note that some of these renewable projects also have a social dimension because they aim to give energy access to some isolated areas.

7. The financing agreement signed between China and Argentina for the Néstor Kirchner and Jorge Cepernic hydroelectric dams set a record of \$4.7 billion, the financing was agreed among three Chinese banks.

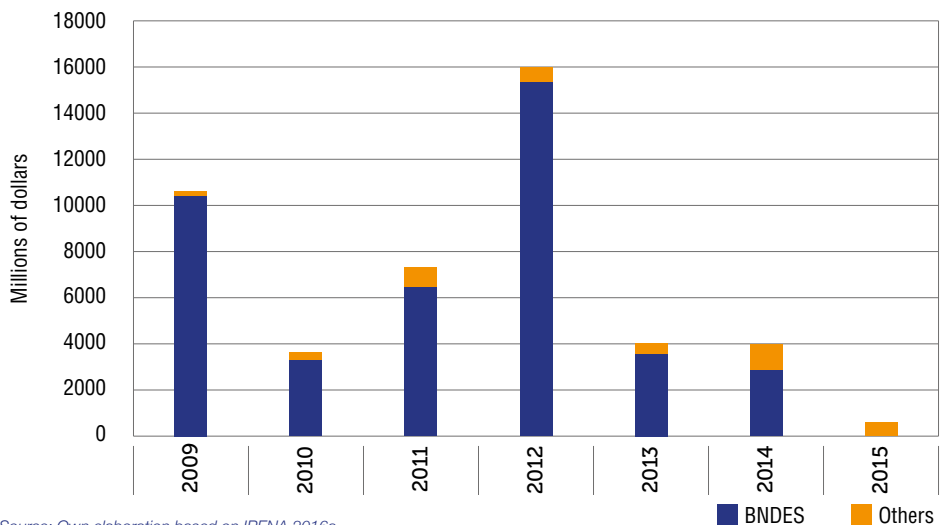
Figure 9. Financing Instrument used in Private RES Projects in LAC



Source: Own elaboration based on (IRENA 2016a)

We can observe in the Figure 10 that **BNDES** has been the most important Development Bank in financing private new Renewable Projects in the region. It can be explained by the successful case of implementation of wind energy policy in Brazil.⁸ The details of **BNDES** financing in the Brazilian case will be enlightened in the following section

Figure 10. Financial Institutions which offers support to Private RES Projects



Source: Own elaboration based on IRENA 2016a

8. We should also relativize Brazilian results as compared against others in the region because of the size of the country economy.

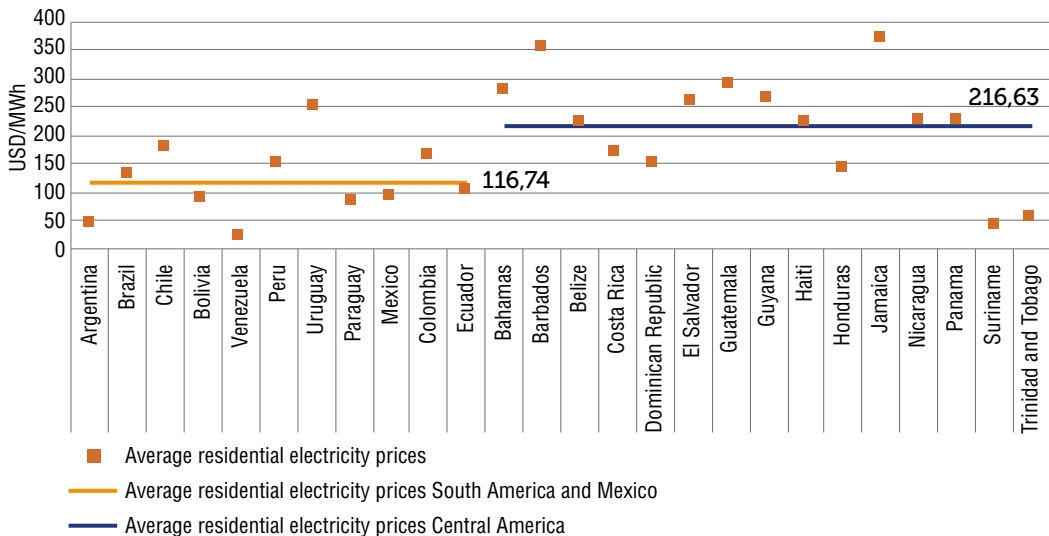
3.1.2 Revenue-enhancing instruments

Latin America and the Caribbean does not have a supra-national order establishing rules and targets for renewable energy. However, the majority of the countries have agreed to participate in the effort established by the Paris Climate Agreement adopted at the Conference of the Parties (COP21). They submitted their national contributions, establishing national priorities, circumstances, and capabilities to reach a global low-carbon and climate-resilient future.

The region already holds a fairly renewable generation matrix through the use of its hydroelectric capacity. Thus, the objectives that drive the countries towards the use of renewable generation would be to keep the energy matrix clean in a context of increasing demand, diversifying sources (in a context of decreasing availability of hydroelectricity potential), energy security and also aspects of industrial policy.

When implementing energy policies, final prices are always a key concern: higher prices can be a social issue (because of low-income groups) and an economic issue (as some LAC energy intensive industry compete internationally). Figure 11 shows the comparison of residential prices in the region. There is an important dispersion of final prices among countries, and there is a tendency to have lower prices in the countries with fossil fuels resources such as Argentina, Bolivia, Venezuela, México and Trinidad and Tobago.

Figure 11. Residential electricity prices in the CELAC zone



Source: Own elaboration.

The region has proposed to increase the share of renewable sources in the long term. Some countries use targets that indicate a strong political commitment hoping to induce greater action by the private sector; in other countries the commitment exists but without an official number as in the case of Brazil. While official targets are an important signalling tool, they are not always sufficient. LAC remains a leader in the use of competitive bidding for projects offering with many auctions. The main principle behind the auctions is to incentivise renewables but also look for the lowest production cost.

In this section, there will be a review of the different support regimes that the countries of Latin America and the Caribbean provide for greater deployment of renewable energy in power generation network divided by countries.

» Argentina

Law N° 27,191 (the "New Promotional Scheme") introduced amendments to the federal promotional scheme for the use of renewable energy for power generation, approved by Law N° 26,190. The law sets different national progressive minimum targets for renewable energy, from 8% of the total power consumption in Argentina by December 31 of 2017, to 20% by December 31 of 2025, respectively. Additionally, the law established that new projects would benefit from an anticipated VAT return for capital goods purchased and accelerated depreciation of applicable assets.

» Brazil

Brazil in its Nationally Determined Contribution (NDC) ratified in September 2016 hopes to expand the use of Renewable Energy source in the power supply to at least 23% by 2030, by raising of the share of wind, biomass and solar. The last feed-in tariff came from the PROINFA plan, created in 2002, which successfully implanted 3300 MW among wind energy, biomass and small hydro.

Brazil is the regional leader in the implementation of wind power, which reached 10 GW in 2016, becoming one of the countries with the highest rate of new wind capacity in the world. The auctions (and Power Purchase Agreements) and the BNDES funds are the main mechanism behind its success.

The Brazilian Development Bank is the largest lender for infrastructure projects in Brazil, in addition to offering financing programmes for conventional energy, it has special programmes for renewable technologies. The conditions of the loans are known before the energy auction occurs and most of the wind projects actually implemented use the BNDES funds (Tomelin 2016).

The auctions for centralised solar energy were also launched and considered a success. However, most of the projects in schedule to be launched were financed by ENEL, the main utility behind these projects. In 2017, BNDES fund was approved for solar energy. The challenge to access BNDES funds are related to the local content clause associated with the financing programme (Andreao, Hallack, and Vazquez 2017).

» Central America

Central American governments have a strong incentive to promote renewable energy as a means to reduce their dependence on imported fossil fuels and hydropower. It is important to take into account that hydropower is a renewable resource quite common in the region. Nonetheless, most of the countries have established guidelines and targets to increase the participation of new renewables technology in the matrix. The instruments adopted to enhance revenue are different among the countries in the region. However, we may find four key instruments: tax reduction, sectorial loans, auctions for long-term PPAs and net-metering for distributed energy.

» Chile

Chile was one of the first nations in South America to set a target for clean generation capacity. Today the mandate called “20/25 law” stands at 20% of renewable energy generation by 2025. However, given the fast development of wind and solar projects, the country is likely to achieve its target much earlier than 2025.

The main support scheme in the country is a quota obligation which applies to all electricity sales and has a noncompliance penalty of approximately USD 32/MWh, which can go up to USD 47/MWh after three years of non-compliance.

According to Norton Rose Fulbright (2017), under the current support regime, parties who are subject to the renewables obligation can comply by collecting green certificates, either issued to them or purchased from the market. The obligation only applies to facilities that contract for the withdrawal of electricity from the transmission system that was entered into, extended or renewed after August 31, 2007. Since this obligation applies only to facilities that were connected as of 2007 the market is quite immature and with a limited number of buyers. However, there is a secondary market where green certificates are traded at a reasonable discount. In the case of wind projects, certificates can represent up to 20% of project revenues.

Through Law 20.018, Chile decided to award long-term energy contracts to supply distribution companies through non-discriminatory, technologically-neutral auctions where the winners correspond to those agents that offer the most economic alternatives. Such auctions must be carried out at least three years in advance, in order to give time to the investors to obtain funding and building a project, providing a 10-year PPA.

Another auction scheme was created in 2013, where the government can deliver annual auctions only for non-conventional renewable energy projects in case that the quota will not be reached. Here, the mechanism has orientations of technologies and the winners are awarded a feed-in-tariff contract. Notwithstanding this scheme has not been used, as the quota has been reached (Marambio and Rudnick 2017).

» Colombia

Through the Indicative Action Plan 2010-2015, Colombia sought to promote the rational and efficient use of energy and to encourage the participation of non-conventional forms of energy in the national grid and non-connected regions. The target for national grid-connected regions was 6.5% and for non-connected regions it was 30% for 2020.

Despite this target, Colombia offers relative weak policy support to renewable energy projects. Among its mechanisms a group of taxable exceptions on renewable energy investment, machinery and ethanol blending can be mentioned (IRENA 2016).

» Ecuador

The National Plan for Good Living 2013–2022 sets a target of reaching 60 % of national capacity from renewable energy sources by 2017.

Since 2000 Ecuador had a feed-in tariff system to support the deployment of renewable energy. In 2013, solar PV was removed from the feed-in tariff and overall technology-specific capacity limits were set for wind, biomass and biogas, CSP, ocean energy and geothermal installations eligible for the tariff. The FIT level, awarded for a period of 15 years, is also differentiated according to the location of the project (mainland Ecuador and Galapagos Islands) and the installations have priority dispatch in the grid access.

» Mexico

Mexico's energy sector is at a turning point. In 2013 several reforms were approved intended to lead to the liberalization of the power generation sector, historically controlled by state-owned Federal Electricity Commission (Comisión Federal de Electricidad, or CFE).

Effective implementation of different instruments such as the clean-energy certificates market aim to incentivise clean generation technologies. The new Energy Transition Law (LTE) mandates to generate 35% of electricity from clean energy by 2024 and 50% by 2050. Confirmation of these targets will provide clarity for new investments in the sector (Landa 2015).

Tax incentives were established since 2004. They included an accelerated depreciation for the Income Tax, allowing a depreciation of 100% of expenses on renewable energy equipment in one fiscal period. In order to make this benefit effective, the equipment must be functional for at least five consecutive years.

» Peru

In 2008, the legal promotion of Renewable Energy Resources (RER) was passed. Briefly, the regulation aimed to produce in 2013, 5% of electricity from biomass, wind, geothermal,

solar, tidal and hydro-power sources. This target was missed by a wide margin. Recently, the government has announced a renewable energy target of 60% of national consumption to be met by renewable energy sources by 2025. In addition, Decree No. 1058 offers income tax reductions to investors (Norton Rose Fulbright 2017).

Peru held on-grid and off-grid auctions. In the on-grid tenders, 882MW were contracted from biomass, solar, wind and small hydro sources. Also, 500,000 off-grid solar PV systems are expected by 2018 (BNEF 2015).

» Uruguay

Uruguay has an extensive regulatory long-term framework governing renewable energy: the National Energy Policy 2005-2030. This plan set a target of 50 % primary energy from renewable sources by 2015. In electricity generation, a target of 15% from wind power, biomass residues and small hydro was set for 2008, which was surpassed.

In 2006, Uruguay instituted an auction mechanism to guarantee stable demand and prices, with contracts awarded for up to 20 years, and the ability to trade surplus power in the spot market. Under this mechanism, the Energy and Mines Minister and the state-owned vertically integrated utility Administración Nacional de Usinas y Trasmisiones Eléctricas (UTE) have auctioned several wind and solar projects. The country expects to secure investments of US\$1.74 billion in renewable energy between 2015 and 2019 under PPAs (IRENA 2015b).

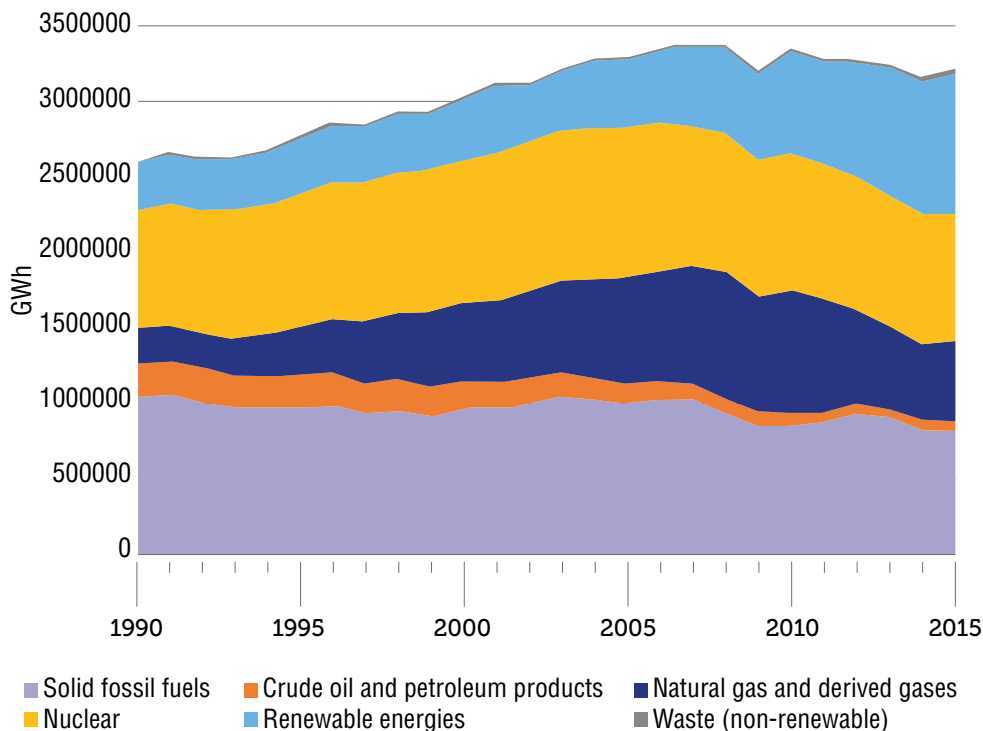
» Dominican Republic

The development of renewable energy projects is a priority for the government of Dominican Republic. The efforts includes tax incentives for investors in the sector in the case there is enough proven interest to purchase the electricity generated, although planned fiscal reforms may reduce these incentives. The implementation of these efforts is done through a legal framework for the renewable energy projects made up of different measures. On the one hand, the Government of the Dominican Republic undertook the partial privatization of generation assets through the reform of the Public Enterprises Law 141-97. The electricity law (General Electricity Law 125-01) establishes tax exemptions for REs projects during 5 years. Besides, in case the renewable energy project is analogous to a non-renewable energy project (in terms of project characteristics, including prices), the renewable energy project is selected first. As a complement, the renewable energy law (Renewable Energy Incentives Law 57-07) specifies additional incentives, as a fixed feed-in price for renewable energy electricity, grants of up to 50 per cent of investment costs (to be decided on a case-by-case basis, for a maximum 5 MW production capacity), tax exemptions for imports on renewable energy components, among others. In addition, the Hydrocarbon Law 112-00 establishes funding to promote renewable energy programs (also for energy saving ones). It started as a 2 per cent hydrocarbon tax credit in 2002, and was increased to 5 per cent in 2005.

3.2 Financing energy transition in the European Union

Between 2000 and 2014, the share of renewable in the EU electricity generation matrix increased from 15% to 29% and now RES is the largest source of electricity generation. Nuclear is the second source with 27% (see Figure 12). The final consumption of electricity was 2740779 GWh in 2015.

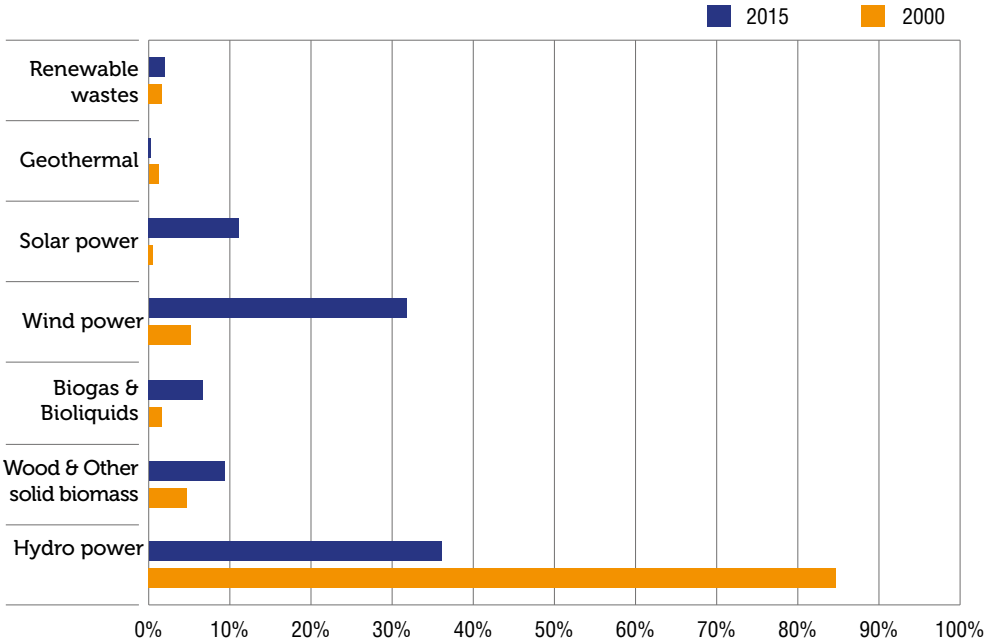
Figure 12. Gross electricity production by fuel in the EU.



Source: Eurostat (2017).

The distribution among renewable energy sources changed substantially. Whilst in 2000 only 5% of the renewable electricity was generated from wind energy, in 2015 this amount rose to 32%. Solar, which was an almost in-existent source in 2000, by 2015 accounted for 12% of renewable sources of energy generation (see Figure 13).

Figure 13. Importance of energy resource in the total of EU RES generation in 2000 and 2015



Source: Own elaboration based on Eurostat (2017).

This evolution in the renewable generation has been influenced by a set of policies, both at the Member State level and at the EU level.

One of the objectives of the EU energy policy is to promote “the development of new and renewable forms of energy”, according to Article 194 of the Treaty on the Functioning of the European Union (TFEU).⁹ Nevertheless, Member States retain the right to choose between different energy sources and decide on the general structure of their energy supply. Consequently, support for RES takes place mostly at the Member State level.

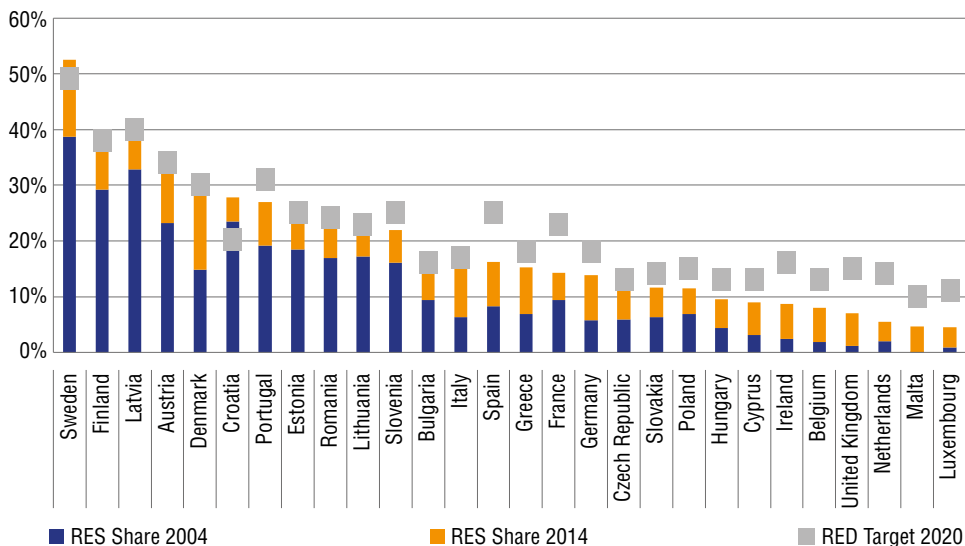
On the other hand, the EU has promoted renewable electricity since 1986, recognising the need for public participation to achieve its targets. The Council Resolution of September 16, 1986, represents the first legislative act that emphasises the need for coordination and harmonization of national energy policies.

The first formal target was defined in the Directive 2001/77/EC and represented a key step in the RES development. The Directive defined a target of 12% of gross energy consumption from renewable energy sources for the EU-15 by 2010. In 2004, as the European Union increased to 24 members, the indicative target for RES was also increased to 21% (Giacomarra and Bono 2015).

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 9.<http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:12012E/TXT&from=EN> Accessed June 1st 2017

Following the 2001 Directive, a second Directive was published in 2009 (2009/28/EC). The proposals contained in this latter Directive are building on the experiences obtained in the implementation of the previous one. This instruction set mandatory national targets, instead of indicative ones: 20% share of energy from renewable sources and 10% share of energy from renewable sources in transport by 2020 (European Parliament and Council of the European Union 2009).

Figure 14. Actual RES shares and 2020 target in the EU-28 Member States.



Source: Own elaboration based on Directive 2009/28/EC (cf. European Parliament and Council of the European Union 2009) and Eurostat (2017).

In order to understand such policies to promote investment in RES, we will pursue the same strategy as in the study of the LAC region. We will successively look at the following characteristics:

- Financing instruments
- Revenue-enhancing instruments

We will summarise these policies at the end of this section in order to facilitate the comparison to LAC policies.

3.2.1 Financing instruments

We will divide the financing instruments in RES in two groups: the first one focused on the technological development (capabilities and innovation), and the second on the implementation of commercial projects.

3.2.1.1 Funding programmes for Research and development

The European Commission offered different funding programmes dedicated to the promotion of renewable energy projects. Most of these programmes are focused on projects in an R&D or pilot plant phase. Besides public funding, regional support also includes partnership between public and private capital and private funds.

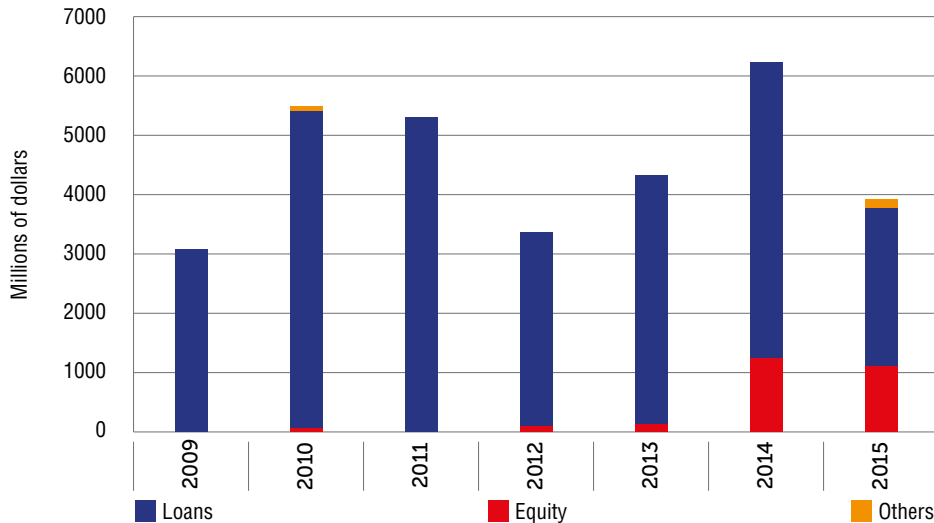
- **Horizon 2020** is the biggest research and innovation programme created by the European Union. It includes almost 80 billion of euros of funding (available over 7 years, from 2014 to 2020). This programme aims also to attract complementary private funds. It aims to push the laboratory ideas to the commercial stage in order to ensure global competitiveness. The main objective of the programme in this area is to provide an acceleration of technology development, necessary to meet EU climate and energy policy goals for 2020 and to prepare the solutions needed to 2030 and beyond. In this context 35% of the Horizon 2020 funds are climate change related. It includes competitive low-carbon energy projects, such as projects for technological innovations in the European electricity grid, alternative fuels, fuel cells, competitive low-carbon electricity generation. The aim of this programme is twofold: on the one hand, to finance clean technology and, on the other, to promote innovation capabilities and competitiveness in Europe.
- The **European Research Framework Programme** is the main research instrument financed at EU level. It is the broader instrument to finance research in the region. From the fifth edition RES research and demonstration measures were included (Giacomarra and Bono 2015). With the specific aim of supporting the Member States during the economic crisis that started in 2008, the EU established this programme in 2009, which had the scope to invest in energy infrastructure. The financial instrument created was a monetary assistance of up to 50% of the eligible costs. Offshore wind energy projects were the only RES funded.
- The **Marguerite Fund** is a pan-European equity fund that acts as a facilitator for key investments in renewable, energy and transport. It is the first fund of its kind launched by Europe's leading public financial institutions, following an initiative endorsed during the second half of 2008 by the Economic and Financial Affairs Council (ECOFIN) and the European Council as part of the European Energy Programme for Recovery (EEPR). The fund has a capital of €710 million (Giacomarra and Bono 2015).

- **Global Energy Efficiency and Renewable Energy Fund (GEEREF)** is a Fund-of-Funds advised by the European Investment Bank Group (EIB), launched in 2008 with funding from the European Union, Germany, and Norway, with a total allocation of €112 million. The Fund is currently seeking to further the amount of private capital from private sector investors, to bring the total funds under management above €200 million. The first private capital commitments were signed towards the end of 2013 and fundraising efforts are still on-going. Priority is given to investment in countries with appropriate policies and regulatory frameworks on energy efficiency and RE. This fund is run by the EIB, and it is capitalised through the European Commission's Horizon 2020 programme.
- **European Local Energy Assistance (ELENA)** helps local and regional authorities that lack the expertise and organisational capacity to implement large energy and renewable energy projects. The aim is to create a solid business and technical plan that can attract outside finance in projects which integrate renewable energy in public and private buildings, energy-efficient district heating and cooling networks or innovative, sustainable and environmentally-friendly transport systems. This fund is a public-private partnership, which acts as a catalyst of funds from institutional investors, professional investors and other well-informed investors within the meaning of the Luxembourg SIF law. It was created through the issue of the Regulation (EU) No. 1233/2010 that explicitly provides for the creation of a financial facility to support energy efficiency and decentralised Renewable Energy investments. 20% of these funds are placed in RES projects, while 70% of the funds are invested in energy saving measures and the rest, 10% support clean urban transport (Giacomarra and Bono 2015).
- **New Entrant Reserve 300 (NER 300)** is an instrument managed jointly by the European Commission, EIB and Member States, established by the revised Emissions Trading Directive 2009/29/EC. This mechanism provided financing capture and geological storage of CO₂ projects, as well as renewable energy technologies demonstration projects. The finance was provided through the sale of 300 million allowances (i.e. rights to emit one tonne of carbon dioxide) in the EU ETS (EU Emissions Trading System).

3.2.1.2 Main investment tools in EU RES

Historically, the implementation of RES mature technologies in commercial stage was mainly based on banks and driven by utilities. More recently, however, an increasing participation of new players and mechanisms has been observed. In the major European economies, the generation is concentrated in a small number of agents (frequently utilities). For these companies, the most used method is the access to commercial banks. These agreements are difficult to analyse because generally the terms of the deals are undisclosed. However, according to International Renewable Energy Agency (IRENA), as we can observe in the Figure 15, RES are mainly financed by loans in Europe. We also observe an increasing participation of equity.

Figure 15. Financing Instrument used to RES Projects in Europe



Source: Own elaboration based on IRENA's Database (cf. IRENA 2016a)

Besides commercial banks, there are a few financial institutions, normally International and Development Finance Institutions, which offered support to renewable commercial projects, such as the European Investment Bank (EIB), the European Bank for Reconstruction and Development (EBRD) and the UK Green Investment Bank (GIB). The main financial instrument is not different from commercial banks, and loans are the main mechanism applied.

The European Investment Bank is the European Union's Bank, and its shareholders are the 28 EU Member States. Within the EU, the EIB provides financing as well as technical and financial assistance to projects that support EU policy objectives across a number of sectors, including energy. Outside the EU, the EIB is active in over 150 countries where it supports projects, which contribute to the EU's external cooperation and development policies.

The traditional financing instruments used by the EIB are medium and long-term loans with fixed or variable interest rates in euro or other currencies. For projects of at least EUR 25 million, the bank provides individual loans covering up to 50% of investment costs. The remaining share and the working capital have to be provided from other sources. For projects under this value, the bank may provide indirect lending through intermediated loans to partner banks (EIB 2013a, 2013b)

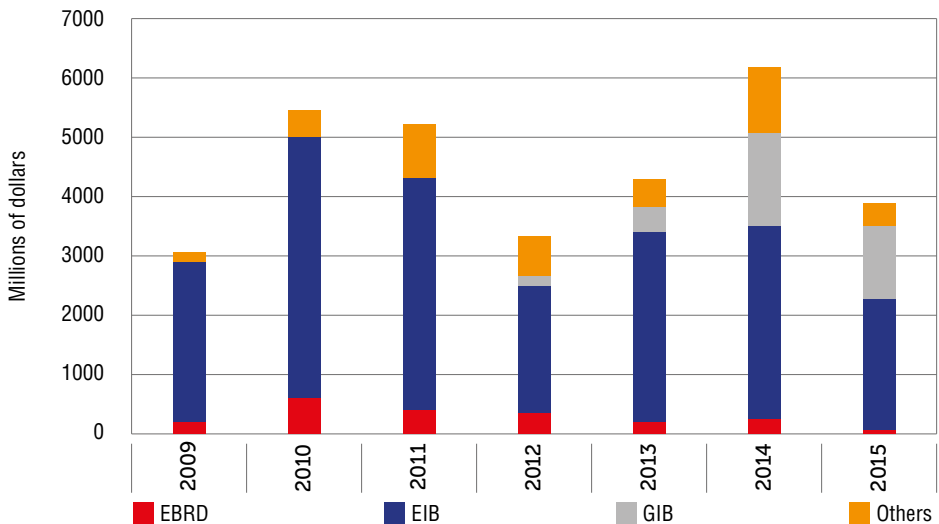
For priority projects with a higher risk profile than those usually accepted, the EIB offers additional support through its Structured Finance Facility (SFF) and uses a mix of the following instruments:

- Senior loans and guarantees incorporating pre-completion and early operational risk;

- Subordinated loans and guarantees ranking ahead of shareholder subordinated debt;
- Mezzanine finance, including high-yield debt for small and medium enterprises (SMEs) experiencing high-growth or which are undergoing restructuring;
- Project-related derivatives.

From the institutions using public funds, the EIB is the leader in financial support to renewable energy projects on the Eurozone as can be seen in Figure 16 below.

Figure 16. Financial Institutions which offers support to RES Projects



Source: Own elaboration based on IRENA 2016a

C. THE EUROPEAN BANK FOR RECONSTRUCTION AND DEVELOPMENT

The European Bank for Reconstruction and Development (EBRD) is a multilateral developmental investment bank. Initially focused on the countries of the former Eastern Bloc, it expanded to support development in 30 countries from Central Europe to Central Asia.

Through its Sustainable Energy Initiative (SEI), the EBRD has developed a model to scale up energy efficiency and renewable energy financing, working closely with governments and the private sector. Based on its practical experience and results, the EBRD continues to expand its investment in energy efficiency and renewable energy with a particular focus on supporting private sector engagement. The SEI, launched in 2006, responds to specific needs of the energy transition in the EBRD countries of operation: regulatory frameworks are not in place in many countries, preferential tariffs are not always adequate, there is problematic grid access, and there are technical and financial skills gaps.

Green Investment Bank (GIB)

The Green Investment Bank (GIB) was established in late 2012 by the UK Government, which provided the initial investment capital. It is owned by the UK Government, but since March 2016 the UK Government launched a process of moving the GIB into the private sector by selling down their shareholding; the transition process concluded in 2017.

The Bank provides flexible capital, investing across the full capital structure, from debt to mezzanine debt and equity. It is especially focused in the UK. GIB typically engages early in the project lifecycle, working with developers to ensure projects are well structured and bankable. Their support is given directly to large projects or programmes and indirectly in smaller projects through funds or developer partnerships. Their core business is investing in UK green infrastructure projects and managing those assets.

GIB has a subsidiary (UK Green Investment Financial Survives Ltd.) that manages private capital in an offshore wind fund. Its objective is to provide long-term institutional investors with the opportunity to invest in unleveraged operating offshore wind farms in the UK. So far, the Fund has raised £818m – with £200m from GIB and £618m from other private investors – making it the UK's largest renewable energy fund. Investors include life insurance companies, pension funds and a sovereign wealth fund.

3.2.1.3 The different financing conditions among EU countries

There are different financing conditions among EU Member States. We will illustrate the difference among Member States by analysing the difference of the weighted average cost of capital (WACC) for RES.

The WACC represents the minimum return that a company must earn on an existing asset base to satisfy its creditors, owners, and other providers of capital, in order to prevent them from investing in another project. Its usual form, the weighted average cost of capital (WACC) is expressed in nominal and after-tax terms, as shown below:

$$WACC = r_E \left(\frac{E}{E + D} \right)^* + r_D (1 - t^*) \left(\frac{D}{E + D} \right)^*$$

where r_E is the cost of equity; r_D is the cost of debt; t^* is the corporate tax rate, D is the total debt and E is the total shareholder's equity.

The authors in Diacore (2016) calculated the WACC for onshore wind project across the 28 Member States of the European Union. They found that Germany has the lowest WACC, with a value between 3.5-4.5%, pointing out a low-risk environment for this kind of investment. On the other hand, Greece and Croatia present a framework for investment less favourable with a WACC nearly three times as high as in Germany. This difference can be explained by the fact that the cost of debt and the cost of equity are relatively low in Germany and a competitive banking system is willing to lend to developers. These results are shown in Table 2.

Table 3. Financial indicators

| Member State | Cost of equity | Cost of debt | Debt/Equity ratio | Debt term | WACC |
|----------------|----------------|--------------|-------------------|-------------|----------|
| Austria | 8-10% | 4.5-5.5% | 80/20 | 10 years | 6.5% |
| Belgium | 10.8% | 5-5.5% | 80/20 | 10-15 years | 5-6% |
| Bulgaria | 12-13% | 7.5-8% | 50/50 | 10 years | 10% |
| Croatia | - | - | 70/30 | - | 12% |
| Cyprus | 15% | 4.5-9% | 70/30 | 10 years | 8-12% |
| Czech Republic | 12% | 6.5-7.5% | 70/30 | 10 years | 8% |
| Denmark | 10-11.2% | 4.5-5.5% | 70/30 | 10 years | 5-6.5% |
| Estonia | 15-20% | 4.5-4.7% | 65/35 | 10 years | 6.4-13% |
| Finland | 12-15% | 3-5% | 70/30 | 10-12 years | 6-7% |
| France | 10.5-11.5% | 5.7% | 80/20 | 15 years | 5.7% |
| Germany | 6-9% | 1.8-3.2% | 80/20 | 10 years | 3.5-4.5% |
| Greece | 14-16% | 8.5-12.5% | 60/40 | 10-15 years | 12% |
| Hungary | 14-15% | 8-10% | 65/35 | 10 years | 11.3% |
| Ireland | 11-12% | 6.8-7.9% | 70/30 | - | 9% |
| Italy | 10-13% | 8-10% | 70/30 | 10 years | 7-9% |
| Latvia | 16.6% | 6% | 70/30 | 10 years | 8-9% |
| Lithuania | 16.1% | 6% | 70/30 | 10 years | 9.3% |
| Luxembourg | 10.2% | 5.9% | - | - | 6% |
| Netherlands | 13.7-14.2% | 4.7-6.3% | 70/30 | 12-15 years | 6-6.7% |
| Poland | 14-14.5% | 6.1-8.1% | 70/30 | 10 years | 8.7-10% |
| Portugal | 12-13% | 6% | 60/40 | 10 years | 7.5-8.5% |
| Romania | 16-18% | 7-10% | 50/50 | 10 years | 11.1% |
| Slovakia | 13.6% | 6-7.3% | 70/30 | 10 years | 8.1% |
| Slovenia | 17.4% | 8.2-9.9% | 75/25 | 10 years | 11% |
| Spain | 13-15% | 9-10% | 70/30 | 10 years | 10% |
| Sweden | 10-12% | 4.5-6% | 60/40 | 10 years | 7.4-9% |
| UK | 7-15% | 5-5.5% | 70/30 | 12 years | 6.5% |

Source: Own elaboration based on Diacore (2016)

3.2.2 Revenue-enhancing instruments

In the European Union approach, each member chooses its policy instrument in order to reach its national renewable energy targets. Moreover, the adoption of the instruments is dynamic, with several members changing or revising their support mechanisms from time to time. It is also a theme of marked differences among EU member states. However, as we can see in Table 4, there are some regional tendencies, such as feed-in tariffs and transportation obligations that have been adopted by many members. Recently, the EU trend moves away from schemes where the government sets the level of support towards auctions in which market participants make competitive bids.¹¹

Table 4. Support schemes at member level

| | Feed-in tariff / premium payment | Electric utility quota obligation / RPS | Net metering / net billing | Transport obligation / mandate | Heat obligation / mandate | Tradeable REC | Tendering |
|----------------|----------------------------------|---|----------------------------|--------------------------------|---------------------------|---------------|-----------|
| Austria | * | | | * | | * | |
| Belgium | | * | * | * | | * | * |
| Bulgaria | * | | | * | | | |
| Croatia | * | | | * | | | |
| Cyprus | * | | * | * | | | * |
| Czech Republic | | | | * | | * | |
| Denmark | * | | * | * | | * | * |
| Estonia | * | | | * | | | |
| Finland | * | | | * | | * | |
| France | * | | | * | * | * | |
| Germany | * | | | * | * | | * |
| Greece | * | | * | * | * | | |
| Hungary | * | | | * | | | |
| Ireland | * | | | * | * | * | * |
| Italy | * | | * | * | * | * | * |
| Latvia | * | | * | * | | | * |
| Lithuania | * | * | | * | | | |
| Luxembourg | * | | | * | | | |
| Malta | * | | * | | | | |
| Netherlands | * | | * | * | | * | |
| Poland | * | * | | * | | * | * |
| Portugal | * | * | * | * | * | | * |
| Romania | | * | | * | | * | |
| Slovakia | * | | | * | | * | |
| Slovenia | * | | | | | * | * |
| Spain | | | * | * | * | * | * |
| Sweden | * | * | | * | | * | |
| United Kingdom | * | * | | * | | * | |

Source: Own elaboration based on REN21 2016

11. In fact, the European Commission (EC) State Aid requires a shift to renewable tenders for many projects by 2017(EC 2014).

The increasing cost and consumers payment of the RES support mechanism is a challenge in Europe, and it has been discussed. In the majority of the Member States, support for RES in electricity is financed by surcharges on consumer electricity bills, so that they do not affect the state budget. Yet, this often results in higher electricity prices for industrial consumers and private households. According to a Commission analysis, the cost of renewable energies constitutes around 6% of the average EU household electricity price and 8% of the price for industrial consumers before taking exemptions into account. The dispersion of support among countries is high, in Spain and Germany reaching 15.5% and 16% of household electricity prices, compared to less than 1% in Ireland, Poland, and Sweden.¹²

The importance of electricity production receiving some RES support is relevant, as we can see in Table 5. In Denmark, more than 50% of total gross electricity produced received renewable support in 2012.

Table 5. Support to electricity

| | Gross electricity produced in 2012 (GWh) | Electricity receiving RES support in 2012 (GWh) | % of gross electricity produced receiving RES support |
|----------------|--|---|---|
| Austria | 72,616 | 6,585 | 9,10% |
| Belgium | 82,874 | 9,58 | 11,60% |
| Croatia | 10,557 | 379 | 3,60% |
| Czech Republic | 87,573 | 5,778 | 6,60% |
| Denmark | 30,727 | 17,182 | 55,90% |
| Estonia | 11,967 | 1,169 | 9,80% |
| Finland | 70,399 | 2,22 | 3,20% |
| France | 564,275 | 29,451 | 5,20% |
| Germany | 629,813 | 114,324 | 18,20% |
| Greece | 60,959 | 6,411 | 10,50% |
| Hungary | 34,59 | 1,862 | 5,40% |
| Ireland | 27,592 | 4,138 | 15,00% |
| Italy | 299,277 | 53,281 | 17,80% |
| Lithuania | 5,043 | 832 | 16,50% |
| Netherlands | 102,505 | 9,75 | 9,50% |
| Norway | 147,845 | 204 | 0,10% |
| Poland | 162,139 | 15,143 | 9,30% |
| Portugal | 46,614 | 13,985 | 30,00% |
| Romania | 59,045 | 3,365 | 5,70% |
| Spain | 297,559 | 68,244 | 22,90% |
| Sweden | 166,562 | 21,511 | 12,90% |
| UK | 363,837 | 35,233 | 9,70% |
| Total | 3334,368 | 420,625 | 12,60% |

Source: Own elaboration based on CEER (2015)

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12. Energy prices and costs in Europe (COM(2014) 21/2).

In order to compare the weight of RES support cost across countries, Table 6 shows the support for RES schemes per unit of total gross electricity produced (i.e. both conventional and renewable electricity). Mostly, the countries with higher penetration of renewables (shown in Table 3) also have the higher RES electricity support per unit of gross electricity produced. The countries receiving highest value of support per unit of gross electricity production are Italy, Germany and Spain (CEER 2015).

Table 6. Support per unit of gross electricity produced (€/MWh)

| | RES electricity support expenditure (€ million) | Gross electricity produced (GWh) | RES electricity support per unit of gross electricity produced (€/MWh) |
|----------------|---|----------------------------------|--|
| Austria | 361 | 72616 | 4,97 |
| Belgium | 1490 | 82874 | 17,97 |
| Croatia | 22 | 10557 | 2,13 |
| Czech Republic | 1268 | 87573 | 14,48 |
| Denmark | 568 | 30727 | 18,48 |
| Estonia | 17 | 11967 | 1,42 |
| Finland | 47 | 70399 | 0,67 |
| France | 2488 | 564275 | 4,41 |
| Germany | 16288 | 629813 | 25,86 |
| Greece | 1165 | 60959 | 19,11 |
| Hungary | 99 | 34590 | 2,86 |
| Ireland | 56 | 27592 | 2,03 |
| Italy | 9585 | 299277 | 32,03 |
| Lithuania | 49 | 5043 | 9,78 |
| Netherlands | 686 | 102505 | 6,7 |
| Norway | 4 | 147845 | 0,03 |
| Poland | 1038 | 162,139 | 6,4 |
| Portugal | 781 | 46614 | 16,76 |
| Romania | 190 | 59045 | 3,21 |
| Spain | 6165 | 297559 | 20,72 |
| Sweden | 495 | 166562 | 2,97 |
| UK | 2743 | 363837 | 7,54 |
| Total | 45605 | 3334368 | 13,68 |

Source: Own elaboration based on CEER (2015)

Support levels vary widely across countries and different technologies. Here we can mention two objectives that can be pursued by countries. The first has to do with what kind of renewable source and in what magnitude they want to encourage. The other takes into account the need for financial support, i.e. the cost of producing energy from different sources varies. In Table 7, of the 21 countries listed, 17 allocated the maximum support per MWh to the solar source.

Table 7. Average support level by technology (€/MWh) 2013

| | Bio-energy | Geo-thermal | Hydro | Other | Solar | Wind - onshore | Wind - offshore | Total |
|-----------------|------------|-------------|-------|-------|--------|----------------|-----------------|--------|
| Austria | 103,4 | | 6,27 | | 205,46 | 43,14 | | 57,32 |
| Belgium | 94,38 | | 24,11 | | 369,07 | 84,19 | 104,89 | 157,41 |
| Croatia | 117,39 | | 58,66 | | 269,88 | 50,29 | | 67,04 |
| Czech Republic | 101,9 | | 57,04 | | 448,04 | 74,95 | | 194,51 |
| Denmark | 26,43 | | | 45,04 | | 24,16 | 57,39 | 36,53 |
| Estonia | 10,56 | | 10,56 | | 10,56 | 10,56 | | 10,56 |
| Finland | 13,19 | | | | | | 64,14 | 22,44 |
| France | 72,62 | | 22,22 | 8,42 | 433,94 | 40,18 | | 91,63 |
| Germany | 147,25 | 201,31 | 56,29 | | 291,54 | 65,63 | 135,5 | 144,15 |
| Greece | 36,63 | | 19,52 | | 341,35 | 20,81 | | 161,52 |
| Hungary | 69,24 | | 32,31 | | 65,85 | 71,17 | | 65,9 |
| Italy | 138,72 | 74,17 | 90,7 | | 306,88 | 79,74 | | 176,66 |
| Lithuania | 69,6 | | 25,97 | | 191,9 | | 44,8 | 56,18 |
| Netherlands | 70,81 | 17,54 | 96,12 | | 220,53 | 60,34 | 99,32 | 68 |
| Norway | | | 23,7 | | | 23,7 | | 23,7 |
| Poland | 70,84 | | 70,84 | 70,84 | 70,84 | | 70,84 | 70,84 |
| Portugal | 65,48 | | 54,89 | 58,69 | 293,69 | 53,49 | 131,4 | 58,94 |
| Romania | 57,71 | | 57,71 | | 57,71 | 57,71 | | 57,71 |
| Spain | 73,34 | | 43,07 | | 327,75 | 43,98 | | 86,62 |
| Sweden | 23,51 | | 23,51 | | 23,51 | | | 23,51 |
| UK | 65,09 | | 67,03 | 113,3 | 256,94 | 59,22 | 95,71 | 78,48 |
| Minimum support | 10,56 | 17,54 | 6,27 | 8,42 | 10,56 | 10,56 | 44,8 | 10,56 |
| Maximum support | 147,25 | 201,31 | 96,12 | 113,3 | 448,04 | 84,19 | 135,5 | 194,51 |

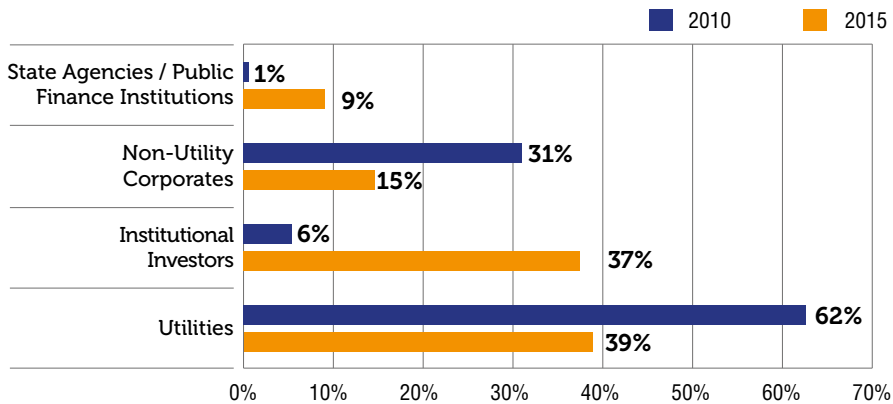
Source: Own elaboration based on CEER (2015)

Most of EU markets are built on the idea of short-term contracting and full retail competition. This implies that the “base case” in the EU, since the beginning of the liberalisation processes in the 1990’s, is a power company undertaking investments in generation and selling energy in short-term contracts (1-2 years).

In this context, Clean Energy Pipeline (2014) analysed the strategies, return requirements and activities of the leading investors’ classes in Europe’s renewable energy sector. The results are summarised in Table 5. In EU the main investors in these projects are: the major utilities, the municipal utilities, the independent power producers (IPPS), the infrastructure funds, the private equity funds and the pension funds. Each of these players prefers to enter at different stage of the projects, and they demand different project features, such as return rate and duration.

In OECD (2016) the authors analysed the equity composition of wind energy deals (onshore and offshore). They found that the equity mix has changed vastly in the last five years as can be seen in Figure 17. The share of equity provided by utilities decreased from 62% in 2010 to almost 40% in 2015 and the respective share of non-utility corporates declined from 31% to 15%. This situation was compensated by an increase of Institutional Investors, making them the second most important equity providers in 2015. The researchers support the trend discussed in the prior table. Institutional investors are more risk-averse than the rest of the agents involved in the renewable energy sector, and they just acquire existing projects.

Figure 17. Equity mix in wind energy projects in Europe



Source: Own elaboration.

Table 8. Characteristic of the European electricity investors.

| | Major Utilities | Municipal Utilities | Independent Power Producers |
|----------------------------|--|---|---|
| Return expectations | In line with market expectations | 7%-9% p.a. after tax | Varied: some have a high-risk strategy others procure mature markets with a FIT or Power Purchase Agreement (PPA) |
| Investment stage | All stages, although many are most active at the development stage | All stages, although many are most active at the development stage | Primarily greenfield projects |
| Holding length | Long-term holders | Long-term holders | |
| Level of engagement | Minority holdings, which allow off balance sheet treatment of the project companies, are preferred | Many will undertake project development in collaboration with an experienced developer; in some cases, municipal utilities will acquire stakes in project developers. | Typically seek controlling stakes; some will divest stakes in projects once operational |
| Ticket size | Often above € 1 billion | € 5-20 million, although many have formed joint investment vehicles enabling them to invest larger sums and compete with major utilities | |
| Geographic focus | Diversified | Prefer to invest where their customer base is located, although are often forced to divert to other countries to meet their targets | |
| Sector focus | Onshore wind, offshore wind & solar PV | Technologies with high capacity factors and low level energy costs are preferred (onshore wind and solar PV) | |
| Use of leverage | | Moderate or no leverage | |

Source: Own elaboration based on Clean Energy Pipeline (2014)

| Infrastructure Funds | Private Equity Funds | Pension Funds and Insurance Companies |
|--|---|--|
| 6%-15% | 15%-25% p.a. after tax | 5%-10% p.a. after tax depending on country and technology |
| Assets at late construction or operational stage | Assets at the development and late construction stage | 1-2 years after commissioning is preferred |
| Hold-to-maturity approach, meaning investments can be held for 20-25 years | Three to seven years | Until the end of assets' lifetime (20-30 years) |
| Passive investors, typically investing in partnerships with experienced operators, such as utilities | Hands-on investors, providing financial, engineering, and contract negotiation expertise | Insurance companies prefer full control of the asset. Pension funds prefer to co-invest alongside experienced strategic or financial partners so will typically make minority investments. |
| €10-€30 million | Prefer investments in assets 50 MW or larger, as these enable funds to scale their management and financial structuring expertise | Pension funds seek to deploy €100-250 million at once while insurance companies seek to invest €20-100 million |
| Mature markets with stable regulatory regimes (Germany, France, Scandinavia, the UK, and Ireland) | Across the EU, including Eastern and Southern Europe | Countries with high credit ratings and stable political environments |
| | Leverage is typically used on a non-recourse basis | Moderate or no leverage |

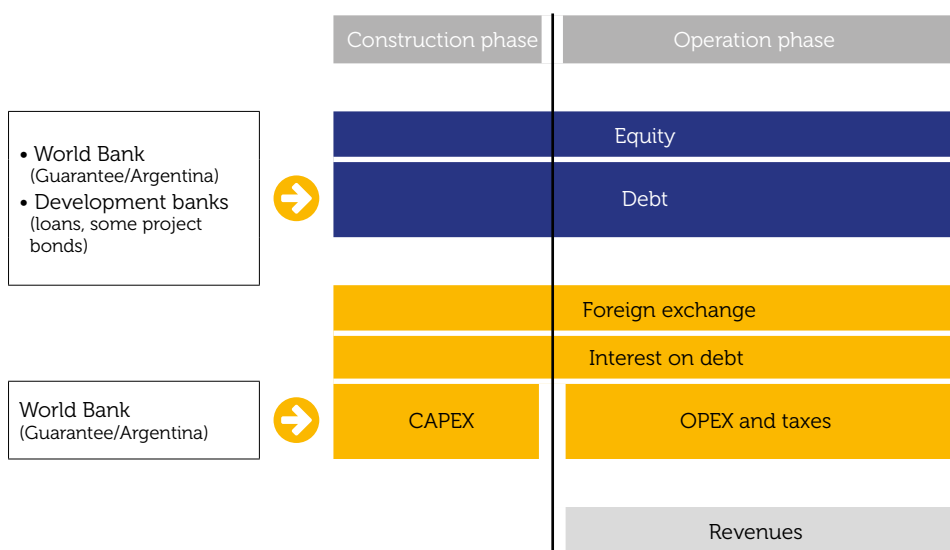
3.3 Analysis of the EU and LAC Policies

There are important differences between EU and LAC policies and financing instruments. The different level of economic and infrastructure development in both regions cannot be forgotten when we analyse both contexts. However, there are some key elements that can be underlined when comparing both regions that may be insightful.

Financing in LAC countries

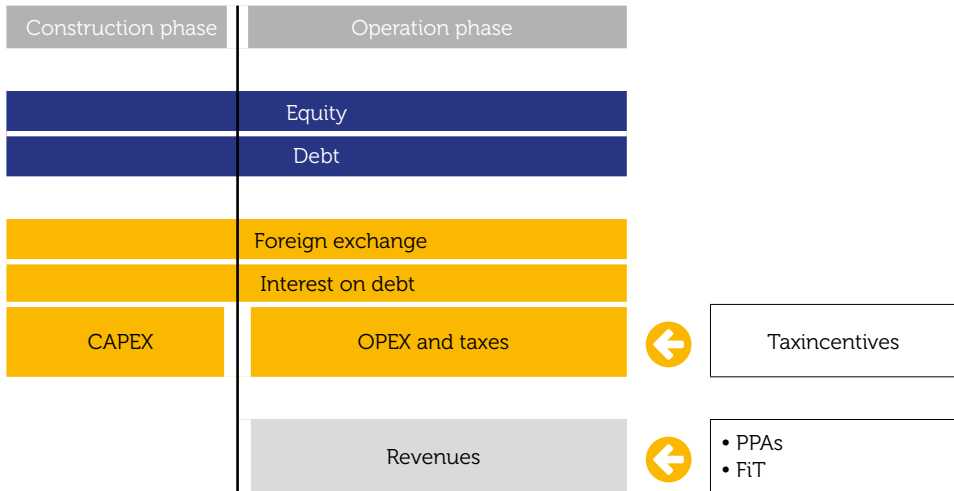
In LAC countries, a large volume of financial resources comes from development banks, typically in the form of long-term loans associated with a special purpose vehicle (SPV). As observed in the Argentinian case, in the early implementation of its renewable programme, when this financing source was not available, little investment was observed. Recently - probably related to a relative reduction of available resources - we observed an increasing importance of public participation through guarantee facilities.

Figure 18. Main financing instruments used in LAC.



Source: Own elaboration

Figure 19. Main Revenue-Enhancing instruments used in LAC.

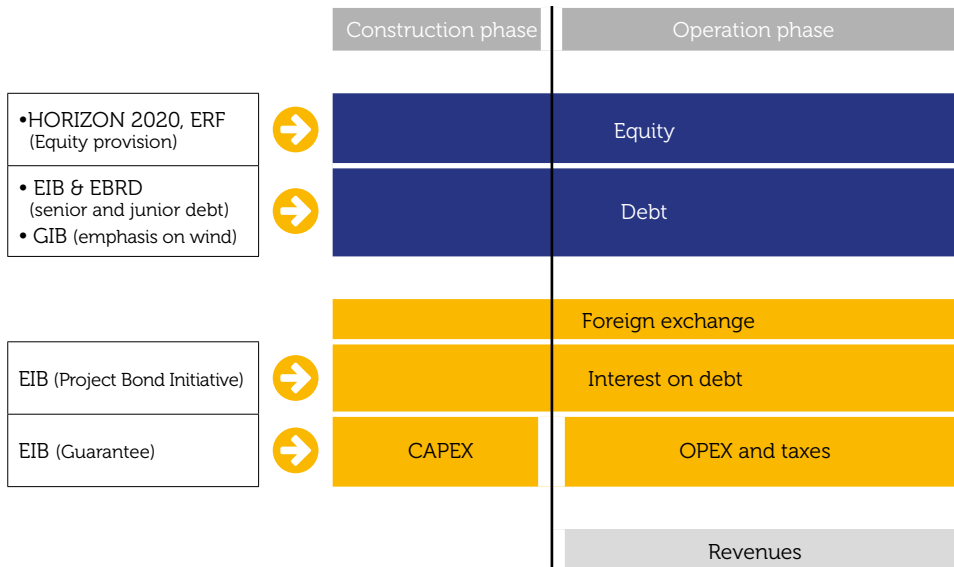


Source: Own elaboration

Besides strong participation of development banks, the regulatory design is central to the LAC strategy to promote RES. Together with several forms of tax incentives, the predominant mechanism to sell energy is the use of a long-term contract tied to a SPV. In principle, this implies the identification of RES projects with an infrastructure asset class.

Financing in the EU

Figure 20. Main financing instruments used by the EU.

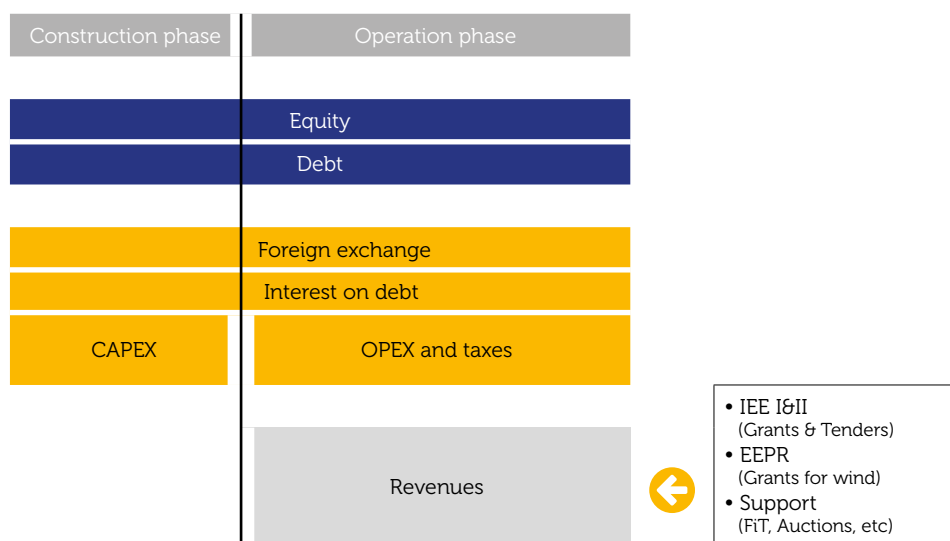


Source: Own elaboration

Two main differences can be observed in the EU strategy: As shown in Figure 20, several instruments based on equity provision were considerably important in the early stages of development of RES in the EU. These instruments were related to innovation policies to develop RES technology.

In addition, the financial instruments used to facilitate RES (and other infrastructure) projects are varied. In particular, we observe a stronger reliance on guarantee facilities and various forms of junior debt. All these measures are targeted at facilitating the participation of the private sector in the financing of long-term investments.

Figure 21. Main Revenue-Enhancing instruments used in the EU.



Source: Own elaboration

By contrast, the EU has relied to a lower degree than LAC countries on revenue-enhancing mechanisms. Although it is true that auctions and feed-in mechanisms (mechanisms aimed at securing revenue streams) have played an important role in the development of RES projects, the reference market design in the EU has been one based on short-term contracting and hence relatively riskier.

Implications

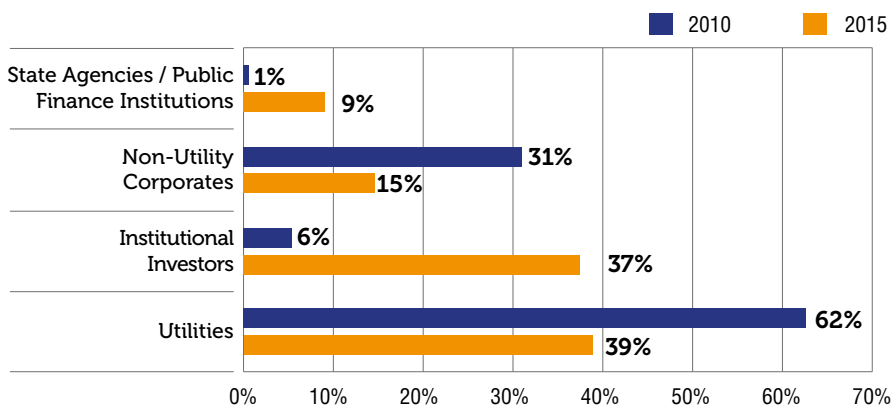
We point at several implications of these differences:

- The EU the industry configuration is more adapted to the “utility business model”. That is, more exposed projects are financed primarily through corporate vehicles. On the contrary, the industry configuration in LAC countries prefers the “project finance model”, i.e. very stable revenue streams combined with project finance.

- From that point of view, the LAC strategy seems more adapted to technologies that share characteristics with infrastructure projects: long-lived assets with low technological risk and low risk in revenue streams.

However, the EU market design is increasingly relying on revenue-enhancing mechanisms. This is especially true for wind projects (also other RES). A first indication of the convergence in both the EU and LAC to the infrastructure business model may be observed by looking at the equity structure of wind projects in the EU.

Figure 22. Equity in wind energy projects in Europe.



Source: Own elaboration.

The share corresponding to utilities has decreased significantly since 2010, and it has been substituted by institutional investors. Besides, auctions of long-term contracts for wind projects have increased in this period. Combined, the two observations suggest that wind power is becoming closer to “infrastructure projects”, in the sense that they are attracting investors interested in long-term contracts. It is also important to note that, up to 2010 (when the technological risk was larger) corporate finance channelled through utilities together with equity provision by R&D programmes were instrumental in the development of wind technology.

With the introduction of solar technologies, the hypothesis that RES projects are subject to low technological risk may become less realistic. The above convergence to the infrastructure business model implicitly assumes low technological risk. Hence, the role of equity is relatively unimportant. However, if technological risk is higher, as in some RES technologies, equity financing plays a more important role than in traditional infrastructure projects. Therefore, market environments that impose the development of RES under the same framework of more traditional infrastructure projects may create undesired constraints. One instance of a private response to the fact that some RES projects are riskier than others is the increasingly used Yieldcos. With this, utilities separate the riskier part of a RES project and are able to create companies that are closer to the idea of an infrastructure project.

4. TECHNOLOGICAL FLOWS BETWEEN EU AND LAC IN THE DEVELOPMENT OF RENEWABLE ENERGY

This second part focuses on the technological flows of renewable energy between both regions (LAC and EU) focusing on solar PV and wind power. We will analyse each technology separately and compare the main results afterwards. For that, we will closely examine some key elements of the technology that affect the understanding of the industry. We will identify the key players of each industry, both in EU and in LAC focusing on the intersections among the regions, i.e. players in both regions.

4.1 Photovoltaic solar power

The sunlight as a direct source for electricity production was only developed consistently from the 20th century onwards. Regarding the availability of energy resources in the world, compared to the world's electric energy needs (around 16 TW-year), solar power is by far the most abundant energy resource available (with around 23 thousand TW of gross potential), even more than most traditional energy sources reserves (petroleum with 240; natural gas with 215 and coal 900 TW) (Perez and Perez 2015). However, approximately half of all solar energy that goes to the Earth reaches the surface. According to IEA (2016), in its 450 scenario (safe climate scenario) for 2040, solar PV could provide up to 9% of the global electricity.¹³

It is possible to distinguish two main types of technologies of electric power production:

- **Photovoltaic power (PV):** consisting on the direct conversion of light into electricity;
- **Concentrated Solar Power (CSP):** a form of thermoelectric generation, in which a fluid is heated from the solar energy to produce steam.

For the purpose of this study, we will focus on PV technologies because of their larger market share. In recent years, PV has been gaining market momentum rapidly, representing around 98% of installed capacity of solar technologies in 2015 (REN21 2016).¹⁴

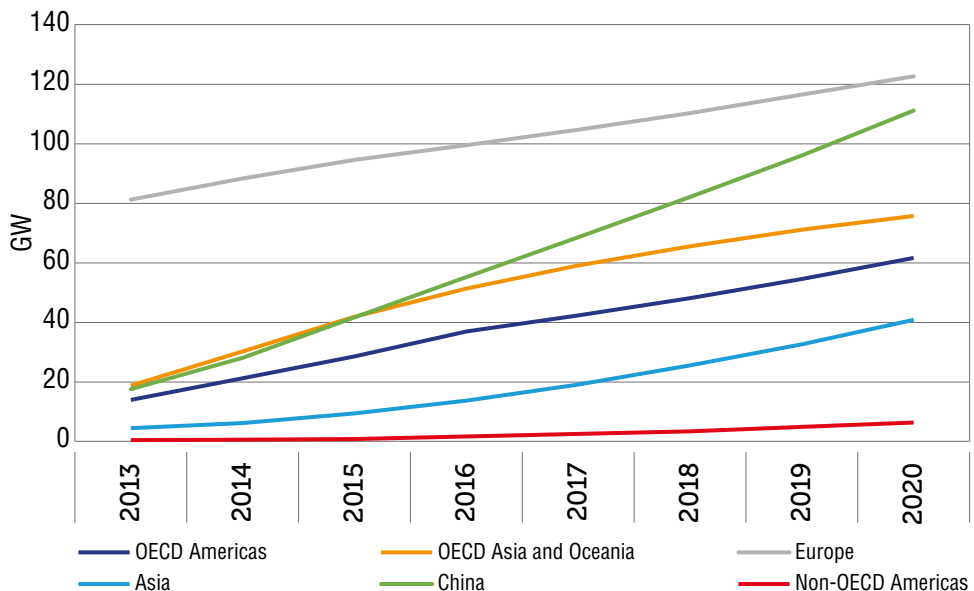
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13. In 2014, fossil fuels represented 67% of the electricity generation in the world, while hydro and nuclear accounted for 16% and 11% respectively. Solar PV accounted for 1%, wind 3% and other renewable energies 2% in the total power generation (IEA 2016a).

14. China and Taiwan are currently leading in the production of solar PV capacity (Fraunhofer ISE 2016).

In 2015, solar PV accounted for just 1,2% of the global electricity demand, but its adoption is quickly growing in recent years (IEA 2016b). From a nominal installed capacity of 5.1GW in 2005 to 227 GW in 2015, the solar PV annual market grew rapidly compared with a decade ago (REN21 2016). This expansion can be explained by the recognition of the large technical potential, strong cost reduction, and its carbon-free operation. The perception of solar potential has driven several countries (such as Germany, France, Spain, Chile, etc.) to promote support mechanisms to incentivise the introduction of PV. China, Japan, North America, Germany and Italy are major players in terms of cumulative installed solar PV capacity (Fraunhofer ISE 2016).

According to IEA (2015), solar PV capacity in the world is expected to grow almost threefold in seven years: from 136 GW of total installed capacity to over 400 GW between 2013 and 2020. OECD countries are expected to have over half of the installed capacity in 2020, with most of it in Europe. However, OECD Americas (which encompasses Chile and Mexico) is expected to have ten times the solar PV capacity of non-OECD American Countries: 60 GW and 6 GW respectively. In the non-OECD world, China appears as a leading country, with over 100 GW out of the total 174 GW of planned installed solar PV capacity. Europe is the region with higher PV capacity installed, while Latin America, except for projects in Mexico and Chile, is struggling to include this technology in its energy matrix.

Figure 23. Solar PV capacity and forecast by region.



Source: Own elaboration based on data from IEA (2015)

On the other hand, we know that there are many European companies investing in LAC. It raises the question if they could be the kind of players willing to transfer PV technology to LAC. As the solar resource is free, the investment in technology is the main cost in this business. Moreover, given the current technological development of the industry, the main elements that gives impetus to PV industry development are: (1) innovation to decrease commercial technologies costs; (2) R&D focusing on new technologies; and (3) the increasing introductions of newer markets.¹⁵

This section aims to discuss the solar technology adoption from the perspective from both regions (LAC and EU) and look at the interaction among them. For that, first we define the key elements of solar technology that must be considered to understand the industry dynamic. Second, we briefly present the main players in both regions. We aim to identify the key players placed in the interaction between the industries in both regions. Third, we examine certain representative case studies, aiming to illustrate the LAC-EU PV industry interaction through the analysis of selected projects.

4.1.1 Technology

PV systems vary in components, materials, and dimensions. The efficiency and the cost of PV technologies will depend on their technical features (such as if they are crystalline cells or thin film cells, single-junction or multi-junction, etc.). The differences between technologies' efficiencies and costs are relevant and may determine the market selection of each type. This section includes a brief description of the innovation diversity. We show that even if the current commercial PV has a well-defined structure, the industries' innovation points toward potential path changes.

The commercial technology

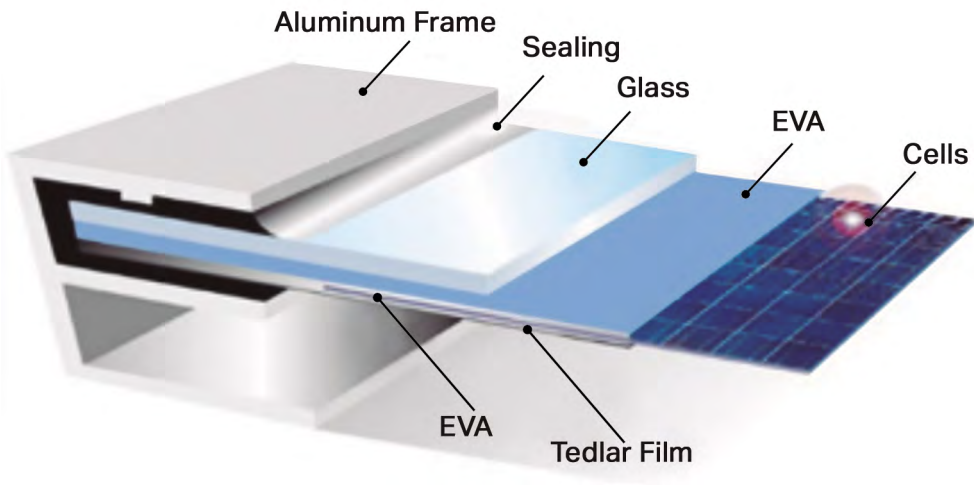
Solar PV energy is obtained through the conversion of light into electricity and is based on the photovoltaic effect. The photovoltaic effect, reported by Edmond Becquerel in 1839, is the result of a potential difference between extremes of a semiconductor, produced by the exposure and absorption of light. Light conversion (photon) into electricity (voltage) is the basic process of the photovoltaic effect. Semiconductors are characterised by energy bands where, on one side electrons are allowed to move, and the other side is empty (band gap or gap). The most used semiconductor is silicon, which is abundant, meaning there are little restrictions on the raw material.¹⁶ (EPE 2012; Tolmasquim 2016)

Besides the photovoltaic cells (the conductors), PV modules have several other components (Tolmasquim 2016), see Figure 24.

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15. Regarding invocation trends, MITEI (2015, 21–45) points out three broad evolutions in the near future: marginal innovation towards higher efficiency (smaller modules); lower usage of materials; and more streamlined and innovative manufacturing processes.

16. Thin film panels are cheaper, however they have an inferior output to silicon based PV panels, which means that those need a larger area for a similar output to a silicon panel (EPE 2012)

Figure 24. Typical photovoltaic module layers.



Source: Ritek Green (2017, 3)

- **Frame:** the structural part of the module, usually made of aluminium. It is through the frame that the module is fixed.
- **Sealing:** an adhesive compound used to join the inner layers of the module with the frame. It prevents the entry of gases and moisture, besides protecting the interior from vibrations and mechanical shocks.
- **Glass:** an outer rigid layer that protects cells and conductors from the environment, while allowing light to enter to be converted into electricity. It is a special glass, with low iron content, with an anti-reflective layer, and with a textured surface, which avoids reflection of light reaching the glass.
- **Encapsulant:** a film that surrounds cells, protecting them from moisture and external materials, and optimising electrical conduction (e.g. ethylene vinyl acetate - EVA).
- **Photovoltaic cells:** an electronic component responsible for the direct conversion of electromagnetic energy into electrical energy.
- **Backsheet:** The lower part of the module prevents moisture from entering and protects cells from external elements. It also offers additional electrical insulation (e.g. Tedlar film).

The modules are then serialised and associated in parallel to compose the entire generation facility. As the generation is produced in direct current (DC), in a grid-connected system, a transformation is required to feed the grid with alternating current (AC). Combiners, inverters, and transformers convert the low-voltage DC output of the group of PV modules into high-voltage AC power. For isolated systems (off-grid systems), batteries and load controllers are often required (EPE 2012; Tolmasquim 2016)¹⁷.

Diversity of photovoltaic technologies and potential routes

The photovoltaic modules is a developing technology and, even if the crystalline silicon (c-Si) cells are the most commercially available (representing around 90% of total PV cell production by 2015), it is not the only technological route for PV (Fraunhofer ISE 2016). There are other technologies that have been developed, and some of them have already been used in some market niches such as Gallium Arsenide (GaAs) cells¹⁸ and thin film cells (based on cadmium telluride, indium-gallium diselenide or hydrogenated amorphous silicon)¹⁹. Moreover, another technological path for PVs is to integrate different types of cell (in this context, instead of competing cells technology we could have complementarity). Considering that each photovoltaic cell absorbs light more efficiently over some wavelength ranges, then multi-junction cells, i.e. two or more types of photovoltaic cells stacked, can cover a larger range of the solar radiation spectrum, which increases energy absorption. Multi-junction cells can reach the highest efficiency levels. However, nowadays, multi-junction cells are very expensive due to their complex manufacturing process and high costs of materials used.

In this context, IRENA (2016a) categorise solar PV technologies into three generations:

- First Generation – Fully commercial technologies, such as wafer-based cells of c-Si and GaAs;
- Second Generation – Technologies that have been deployed on a commercial scale, but some at low volumes such as thin-film cells and multi-junction cells such as CIGS;
- Third Generation – Technologies that are still in a demonstration phase or have not yet been widely commercialised such as thin-film devices, organic cells and other concepts.

However, this division incurs into certain problems because it cannot fully take into account the dynamics of the industry's innovation (because that includes technologies that are not restricted to one generation). There are several lines of R&D looking for new concepts and seeking higher efficiency in the commercial technologies (MITEI 2015)

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17. Regarding its efficiency, commercial solar cells have a transformation rate between 10% and 20% (Fraunhofer ISE 2016). According to the authors' analyses, high concentration multi-junction solar cells can achieve an efficiency of 46%.

18. It can be more efficient but is more costly than c-Si cells.

19. Some of the key advantages of thin film cells are: (1) higher light absorption (if compared with silicon), (2) lower temperature coefficient and (3) higher flexibility (which increases the range of usage possibilities). The disadvantages of this technologies are: (1) lower efficiency (compared to crystalline silicon), (2) higher annual degradation rate and challenges related to toxicity (e.g., cadmium) and rarity (e.g., tellurium and indium) of materials applied; see (EPE 2012).

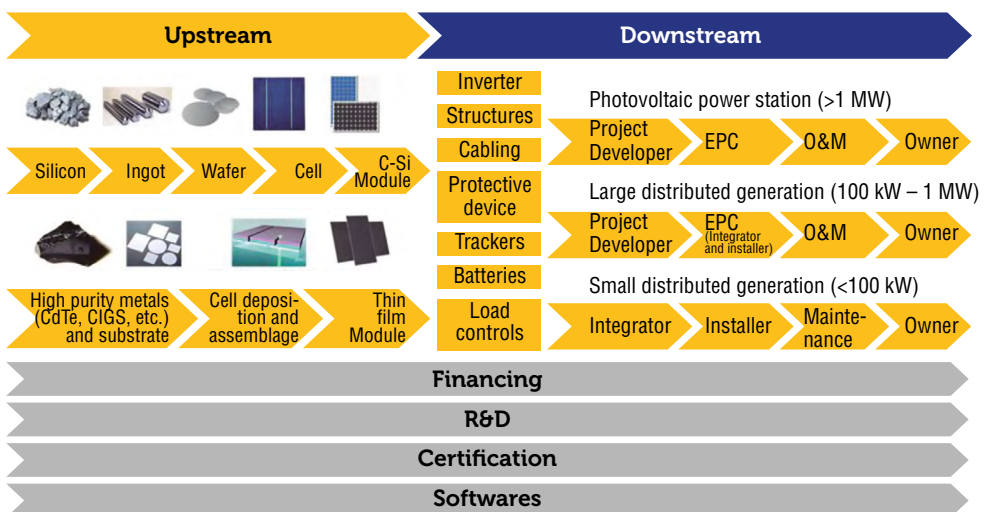
The challenges and complexity of the different technologies are in the core of the actual dynamic of PVs. Currently it is possible to identify trade-offs regarding the complexity in two different dimensions: material and manufacturing process. For instance, silicon is simpler than nano-materials in terms of material; however, to obtain silicon is harder than nano-materials. Moreover, technological maturity and complexity of material have an inverse relation, with more complex materials we expect to have more mature technological processes. The increase in the complexity of materials permits the emergence of attributes such as less materials, efficiency, flexibility; transparency; durability (MITEI 2015, 36).

As the latest PV technologies currently deployed in large scale, crystalline silicon (c-Si), had a long maturing period. Currently, it is considered the most competitive technology considering cost and efficiency. However, it is not clear if the path for solar PV will continue on silicon-based panels or move away to thin-film and nano-materials panels, or if there will be a combination (or a coexistence) of both. Something that is clear, however, is that solar PV is a rapidly evolving industry where R&D is an integral part of it. The potential technological paths open room for investment of different players and different countries, even if they do not produce the most commercially competitive technology.

Industry value chain

The photovoltaic value chain can be divided in upstream (the industrial chain up to PV module), downstream (including project development, integrator, installer, operation and maintenance) and complementary activities (such as R&D, certification and software development). Figure 25 aims to illustrate this scheme.

Figure 25. Photovoltaic Value Chain.



Source: Adapted from Tolmasquim (2016, 349).

» Upstream

The PV upstream chain is characterised by the production of overall components that compose the PV system such as modules, equipment, and accessories required for the installation of the systems. The production chain of crystalline silicon (c-Si) photovoltaic systems initiates with the phase of obtaining the metallurgical silicon, followed by its transformation into solar grade silicon (crystalline). After that, ingots and wafers as well as the silicon cells are manufactured. Finally, support industries provide other products (glass, aluminium frames, electronic devices, etc.) for the manufacture of photovoltaic modules (EPE 2012).

Nowadays, crystalline silicon production is a market with only very few players. Production comes mostly from China²⁰ but Germany, South Korea, USA, Japan, Malaysia, and Norway are also countries with polysilicon production (IEA 2016b).

Module manufacturers often carry out the production of silicon ingots, which involves cutting those ingots into bricks or blocks that are then sawn into thin wafers. In 2015, an estimate of over 60 GW of crystalline silicon wafers were produced, with a share of 80% from China²¹ (IEA 2016b). Large companies such as Yingli (China), ReneSola (China), Trina Solar (China), SolarWorld (Germany), Panasonic (Japan) and Kyocera (South Korea) can be highlighted. Due to cost pressures, some of the largest module manufacturers started to buy wafers from specialised producers, due to cost advantages and their quality. In this phase, economies of scale are very important to reduce costs.

Modules and cells manufacturing have a slightly lower market concentration than silicon ingots. Modules manufacturing allows higher entry possibilities for new and small industries, due to its lower technical requirements for production, as well as the reduced investment required. China's module production volume accounts for 69 % of the world total. It strongly increased after 2005 with China acquiring important parts of Japanese and European market shares, - countries which were previously the market leaders (see IEA 2016b). The entry of China in this market was a result of strategic cost reduction, economies of scale and capacity surplus leading to a strong price reduction.²² We observe persistent excess in production (see Figure 26), which contributed to the fall in prices²³ of the PV modules²⁴ and caused the closure of many manufacturers, which helps to explain the change of countries' production market-share.

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20. China is the largest producer and consumer of polysilicon in the world, reporting in 2015 165.000 tons of production (almost 50% of global production) and 260.000 tons of consumption.

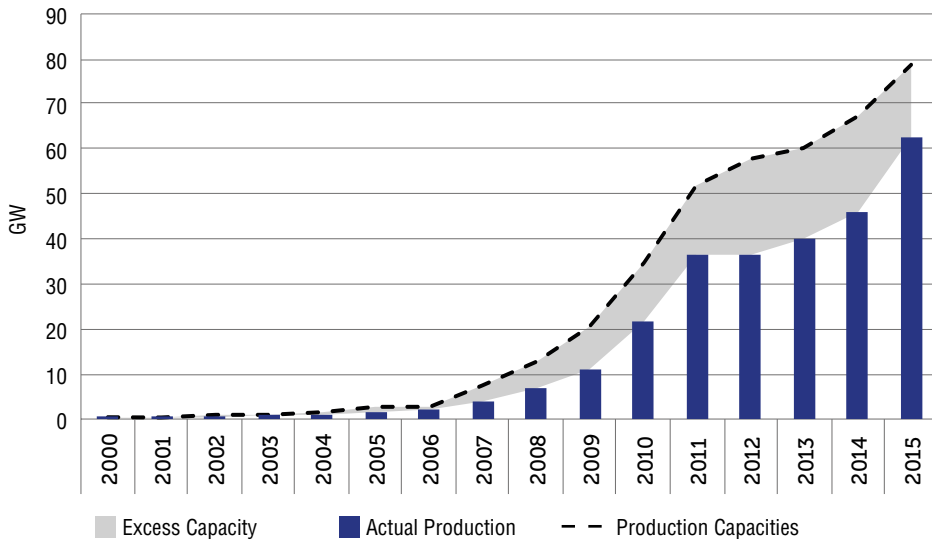
21. According to (EPE 2012, 18), Europe - a major market for solar power generation - imported from China about half of its solar panels in 2012 and China provided until that year at least 50% of all solar PV panels used in the world.

22. The PV module price per Watt cost of 2015 is around 15% of 2005 price. According to IHS (2016), the cost of PV commercial module in China was more than 20% cheaper than in its competitor, <https://technology.ihs.com/577318/the-price-of-solar-april-2016> accessed June 1st 2017.

23. Alongside technological advances.

24. For index of module prices see IRENA 2016a: http://www.irena.org/DocumentDownloads/Publications/IRENA_Power_to_Change_2016.pdf accessed June 1st 2017.

Figure 26. World PV Modules Production Capacity and Production.



Source: Own elaboration based on IEA 2016b

Table 9 displays the countries with higher participation in the PV production chain of crystalline silicon. The focus of the table takes into account the manufacturing of solar components. China holds the highest market share in all parts of the industrial chain. Looking at Europe and LAC, only Germany contributes substantially to this part of the industry.

Table 9. Summary of the upstream key producers.

| | Main producing countries | Leader | Leaders' market share ²⁵ |
|----------------------------------|---|--------|-------------------------------------|
| Crystalline silicon | China, Germany, South Korea, USA, Japan, Malaysia, Norway | China | 50% |
| Silicon ingots and wafers | China, Germany, Japan, South Korea | China | 80% |
| Modules and cells | China, Japan, Germany, S. Korea, Malaysia, Canada, US | China | 69% |

Source: Own elaboration

There is a strong tendency toward concentration in the PV industrial chain, however, and the growth in PV generates conflicts in trade policies, especially regarding taxes and duties. To avoid the duties imposed in several regions, some PV module manufacturers have announced new production expansion plans of parts of the industrial chain in countries such as Thailand, India, Singapore and Portugal.

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25. The value of market share is not precise, it based on IEA (2016b) report. It aims to give an idea of the level of concentration.

The Balance of System (BoS) components are another important part of the PV value chain. It refers to the components and equipment that move DC energy produced by solar panels through the conversion system, which in turn produces AC electricity.²⁶ While PV modules costs fall, BoS products are becoming an important share of project cost (especially in decentralised projects). Since the grid's connected systems became predominant, inverters are pivotal for PV deployment. Inverters are produced in countries such as China, Japan, South Korea, Australia, the USA, Canada, Germany, Spain, Austria, Switzerland, Denmark, France, and Italy. As inverters may follow grid codes and regulation, they are often produced and applied domestically in those countries.

Specific components from BoS, such as tracking systems, connectors, DC switchgear and monitoring systems, are commonly produced by large electric equipment manufacturers. Almost half of utility-scale PV power plants now adopt trackers, while small-distributed generation is becoming more reliable with battery use.

Some of the key PV costs are country-specific. However, the various components tend to be more similar, especially the cells industrial chain. Even if there are costs' differences among the regions, the modules costs curves are correlated and they tend to converge. The BoS cost presents larger differences from country to country. BoS costs deal not only with technical components (which can be a commodity in the absence of local content policies), but rely on local services and financial resources which vary significantly among countries.²⁷

» **Downstream**

The photovoltaic downstream chain is characterised by the services associated with the implementation of photovoltaic projects. They are the mostly soft costs, depending on the type of project, services and components. For large projects (such as utilities), it usually includes project development, engineering, procurement and construction, operation and maintenance. For small projects (such as residential and commercial) it also includes an integrating agent (project and design), an installer, and maintenance (Tolmasquim 2016). Regarding operation and maintenance, Table 10 shows that maintenance remains one of the highest cost factors (41%-52%). Another important component is related to land rent. This is the component that may be avoided (or reduced) if it is installed in areas being used for other purposes (i.e. together with wind farms). Residential/commercial/parking building areas may also avoid this kind of costs.

Table 10. Operation & Maintenance of PV power plant.

| Component | USD/MW/year | % of total O&M Cost |
|--------------------------------------|-----------------|---------------------|
| Maintenance | 10,000 - 22,000 | 41% - 52% |
| Land Rental | 8,000 - 12,000 | 28% - 33% |
| Insurance | 4,000 - 6,400 | 15% - 16% |
| Management and administration | 2,500 - 3,000 | 7% - 10% |
| Total | 24,500 - 43,400 | 100% |

Source: IRENA (2016a)

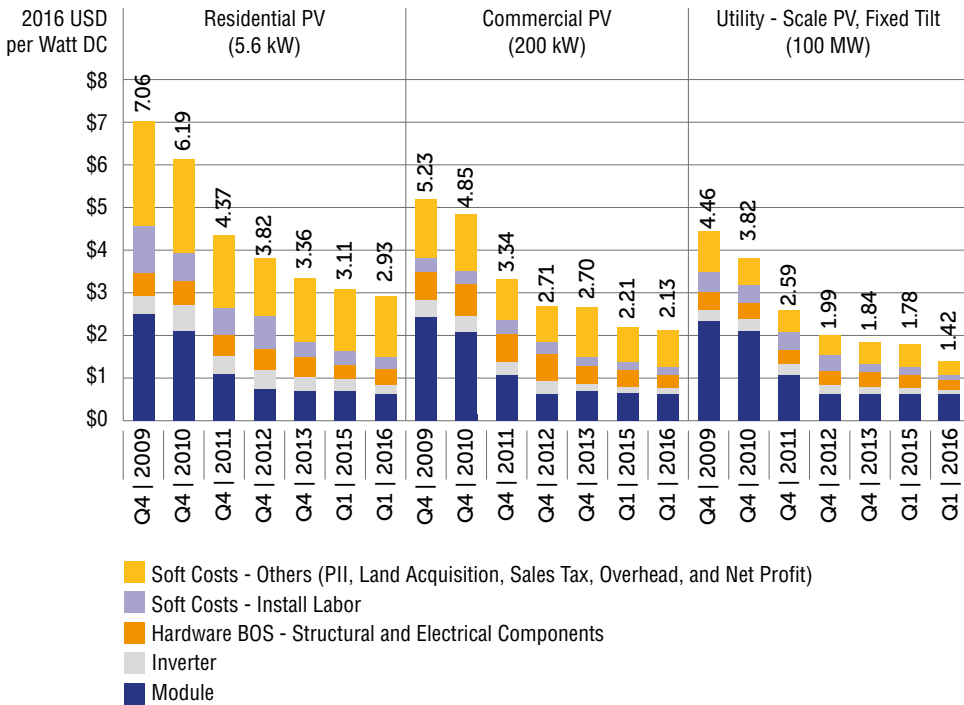
26. Most often, BOS refers to all components of a PV system other than the modules such as inverters (the main component), racking, cables/wires, switches, enclosures, fuses, ground fault detectors, etc. BOS are required for all types of solar applications (i.e. commercial, residential, agricultural, public facilities, and solar parks).

27. IRENA (2016a) expects that the major part (about 70%) of future cost reductions should come from lowering BoS costs.

Currently the soft cost in the downstream can be even higher than the upstream costs in some countries and projects. The drop of manufacturing cost has been higher than the implementation costs. The installation and other soft costs, however, strongly depends on local variables such as the institutional framework (as regulation) as well as national capabilities. Irena (2016c) shows a strong heterogeneity among costs breakdowns of solar PV by country; for instance, Germany has comparably lower soft cost, whereas Chile faces one of the highest (the latter being more than twice than the former).

Another important element within the costs breakdown is the size (and the user) of the project. Considering the United States, Figure 27 shows an estimation of NREL (2016) for the costs breakdown between 2009 and 2016. While modules costs are quite similar in the respective projects size; inverter, BoS and soft costs are much higher from Residential PV.

Figure 27. Costs reduction in United States.²⁸



Source: NREL (2016).²⁹

28. Values are inflation adjusted using the Consumer Price Index. Thus, historical values from our models are adjusted and presented as real USD instead of nominal USD. Moreover, Cost categories are aggregated for comparison purposes. For instance, "Soft Costs – Others" represents PII, land acquisition, sales tax, and EPC/developer overhead and net profit.

29. See: <http://www.nrel.gov/docs/fy16osti/67142.pdf> accessed June 1st 2017.

» Complementary activities

Among the complementary services, we will focus on the R&D because it is one of the key elements of solar PV and it is key to understand the flow of technologies in this industry.³⁰

Patenting encourages technological development and deployment, especially in the field of renewable sources and climate change mitigation technologies. Protecting its intellectual property, basic and applied R&D are therefore ensured, because the returns of the innovative technology process are then granted solely for the innovative company or licensed corporations. Among the most relevant patent offices are the: United States Patent and Trademark Office; the Japan Patent Office; as well as the European Patent Office. The State Intellectual Property Office of the People's Republic of China (SIPO) faces quality issues and other problems even though it has a higher number of patents filed.³¹ Therefore, patents are a useful (and very often used) way of planning, monitoring and securing innovation. However, Patent Offices in the EU, Japan and the US are the most used indicators for monitoring innovation (IRENA 2013; UNEP and EPO 2014).

Solar PV has one of the highest volume of patent filings in energy-related technologies, having still only a few established players as well as a significant potential for innovative players (Helm, Tannock, and Iliev 2014). Since the 1990's there has been a rise in patent filings related to renewable technologies (biofuels, solar thermal, solar PV and wind energy). However, PV has emerged as the top researched technology since the late 2000's, increasing from a 10% annual average growth from the 1975-2005 period to 22% in the 2006-2011 period. Moreover, solar PV is responsible for 41% of all renewable technologies patent filings with more than 80,000 patent applications, and, alongside solar thermal, holding about 60% of the total (Helm, Tannock, and Iliev 2014, 4–5, 9–10, 25–28).

According to the authors, out of the top 20 renewables technology owners, 15 are allocated in solar PV, with the remaining five researching wind energy technologies. All 15 solar PV companies were Asian. However, only one technology owner was Chinese: the Industrial Technology Research Institute, ranking 17th among the total and 13th among solar PV technology owners³², with 199 patent families in the 2006-2011 period (Helm, Tannock, and Iliev 2014).

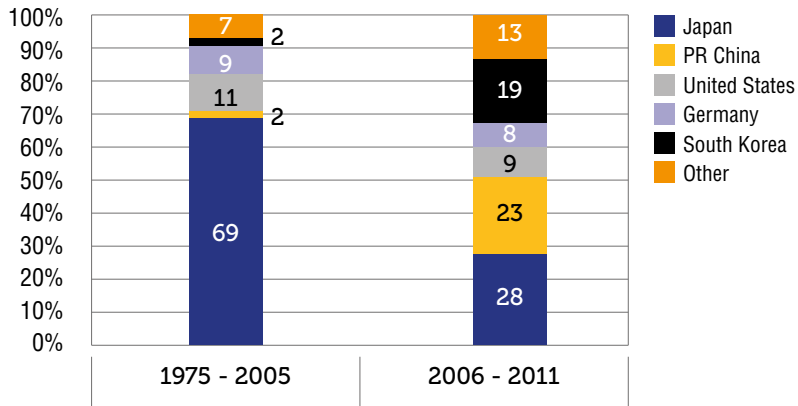
Considering the countries separately and the patent filled in different offices around the world, the major solar PV players are still Japan-based (see Figure 28), however, Korean and Chinese players are rising in importance. In Europe, Germany remains the main country filing the most patents in solar PV.

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30. Moreover, we do not include the financing in this section because we will dedicate the next chapter of this study to financing services.

31. For more information on the matter we suggest the reading of Reuters (2016).

32. There are three Chinese organisations in the top 20 solar PV technology owners, being Trina Solar Co Ltd and Oceans King Lighting Science the other two, both with 174 and 161 patent families in the period respectively.

Figure 28. Office of first filing in solar PV from 1975-2011.



Source: Helm, Tannock and Iliev (2014, 27).

This database considers patents in different offices, so it needs to be carefully considered, because some countries as China and South Korea have patent policies over-incentivising patents applications in their offices. As consequence, the use of this data as proxies for innovation must be pondered.³³ It is frequently associated with technological transfer and manufacturing process.

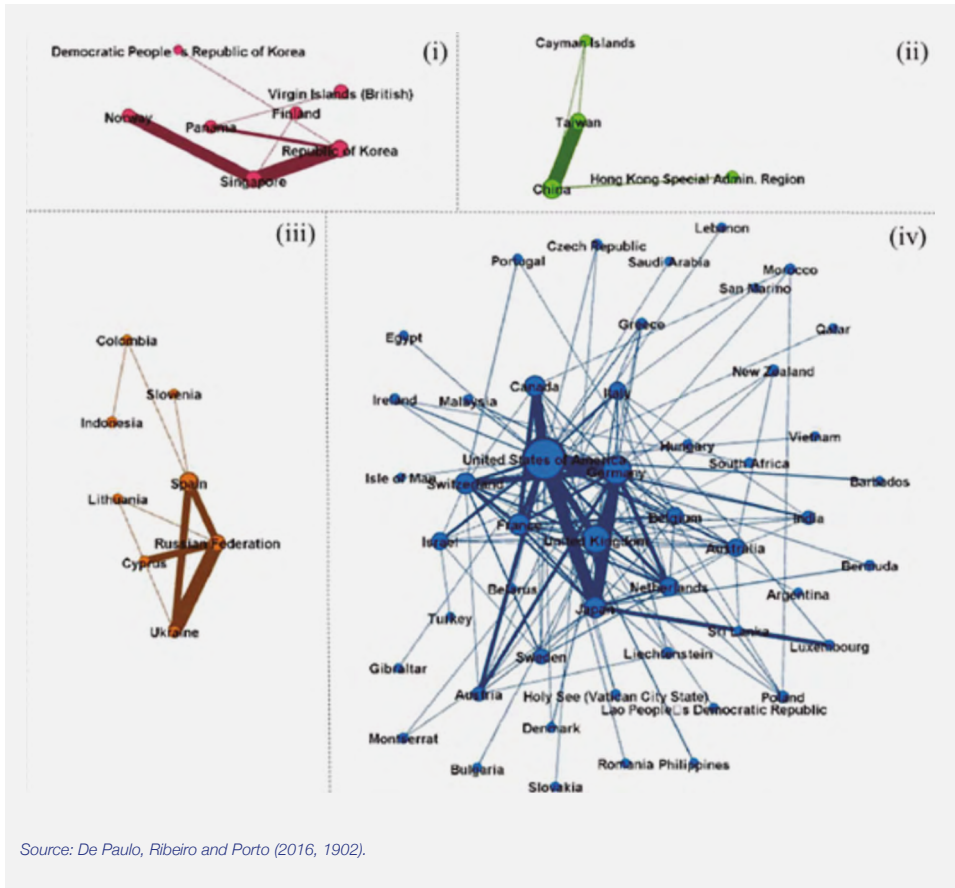
Regarding the concentration of intellectual property, it has grown substantially from about 25,000 patent families to 34,849 patent families (Helm, Tannock, and Iliev 2014). According to the authors, the new patents focused on PV systems and concentrators; organic silicon solar cells and dye sensitised solar cells. Recently, (Cleantech Group 2016) analysed the evolution of patents in the United States, showing a consistent growth of solar PV over all other renewable technologies. Moreover, solar PV ranks highest in the number of entities granted patents. After 2009, it exceeded wind patents and after 2013 it exceeded fuel cells.

According to De Paulo et al. (2016), cooperation in terms of patents for solar PV R&D has increased since 2011. The cooperation on patents is key (even though imprecise) to measure technological relations and flows. The authors separate four clusters of cooperation networks along patent-filing countries in terms of solar PV (see Figure 29). The first cluster shows South Korea as its major player, with Finland and Norway as important

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 33. In the next section we will use the European Patent Office database; it is used as a proxy for innovation by different authors, and we observe different results.

European countries and Panama as the only Latin American country in this cluster. The second cluster has China and Taiwan as major players, with some participation of the Cayman Islands in LAC. In the third cluster, Spain is a major player from the EU and it is directly linked to Colombia. We may observe that the first three clusters in Figure 29 are relatively isolated. Moreover, we observe very little interaction between them and the fourth and most important cluster.

Figure 29. Cooperation clusters for PV technologies.



Source: De Paulo, Ribeiro and Porto (2016, 1902).

The fourth cluster encompasses most countries and most patents. The United States is a major player, however, Germany, the United Kingdom, France, Italy, Netherlands and Belgium are important European countries in terms of patent cooperation. Argentina and Barbados are the most important LAC countries. Japan, like the United States, is a major non-European player. Given the sheer size of the cluster, it is possible to separate it into two cooperation subnets: the first one with participation of the major players (United States, United Kingdom, Japan, Netherlands); and one with smaller players (France, Belgium, Canada, Sweden, Portugal). The Latin American and Caribbean countries are part of the United States subnet. Spain cooperates with most major players of the fourth cluster, in a similar manner as China. The United States, Germany, United Kingdom and France are the major countries regarding technological (R&D) cooperation in terms of patent filings co-assignments:

“The USA, Germany and the UK were the most relevant countries in collaboration network for the photovoltaic technologies because they were the ones with more cooperation with other countries and with the most collaborative countries. Although they are key countries in their communities, China and Spain showed little influence on the overall network. Thus, USA, Germany and UK are the largest holders and influencers in the development of photovoltaic technologies” (De Paulo, Ribeiro, and Porto 2016: 16).

Therefore, out of the most important countries in the development of solar PV, two of them are European Union Countries. Latin American and Caribbean countries are still less important according to the authors, regarding cooperation toward R&D in solar PV³⁴, even though it starts to appear in the cooperation clusters.

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34. The study of Lei et al. (2013) is in line with De Paulo et al. (2016). International collaborations are increasingly important in terms of innovation and patent filings. Again, European countries figure amongst the top major players in terms of international collaboration (Germany, France, United Kingdom) alongside the United States and some Asian countries (China and Taiwan). However, no Latin American or Caribbean country was of major importance until 2010.

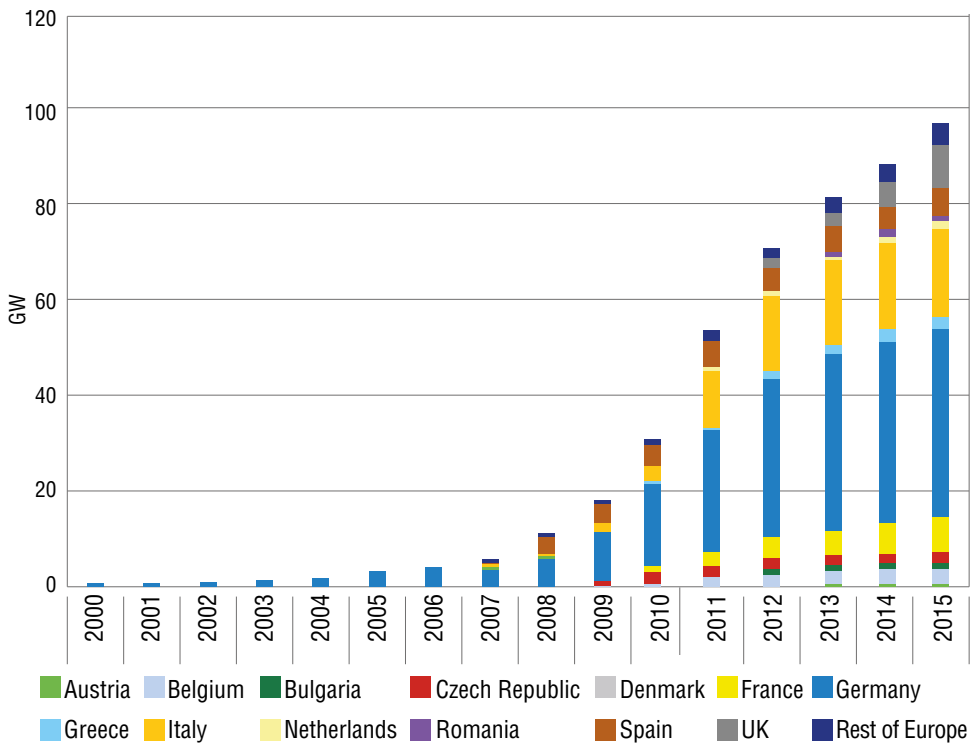
4.1.2 Key players in the EU and LAC

Europe is a key region considering the solar PV market. Latin America and the Caribbean have experienced a rise in its solar capacity, which is expected to have a sustained growth throughout the 2010's and 2020's. In this section, we analyse major players in both regions, highlighting overlapping companies that are relevant in both continents. In the end, we will analyse briefly a collection of case studies in Europe and Latin America.

A. KEY PLAYERS IN THE EUROPEAN UNION

Europe is an important market for PV. It was the first major market for the technology to emerge in the mid 2000's, it maintained its importance through the 2010's, and is expected to have a sustained growth until 2020 and beyond (IEA 2015; Solar Power Europe 2016). Figure 30 shows the installed capacity in European countries with Germany as the country with the highest PV capacity, followed by Italy, UK and France.

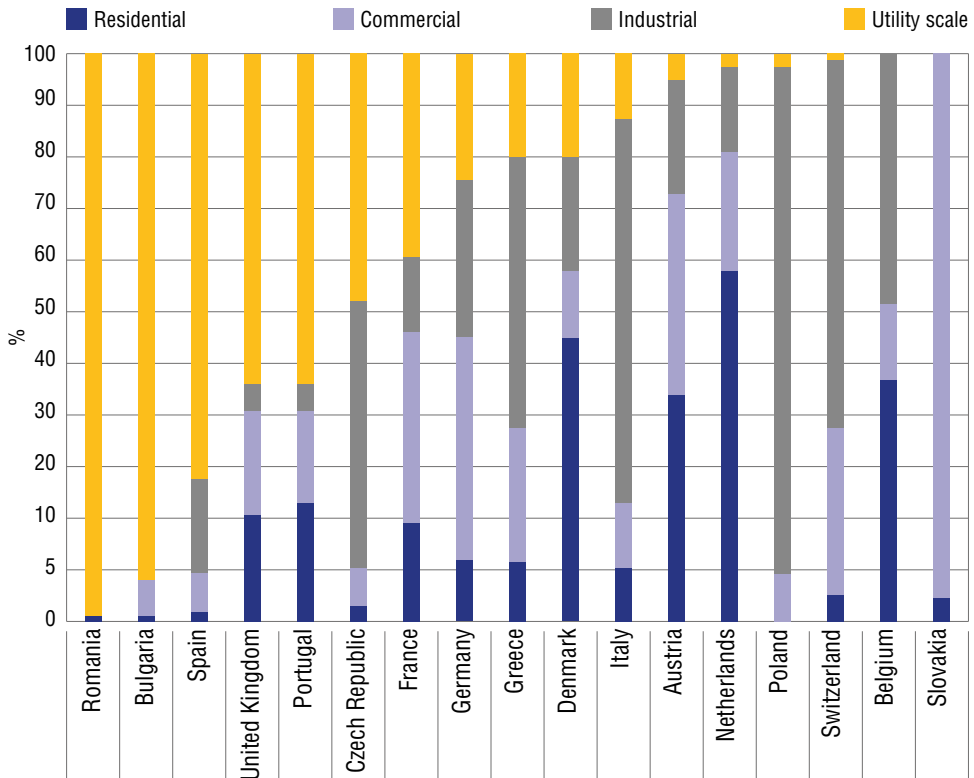
Figure 30. Evolution of European solar PV installed capacity 2000-2015 for selected countries.



Source: Solar Power Europe (2016, 27).

The introduction of PV solar varies among European countries; the heterogeneity can be explained by the amount, the timing and by the power plants' scale as well as business model. As illustrated in Figure 31, in Germany and Italy most of PV capacity comes from distributed power plants. On the other hand, the new investments in Romania and Bulgaria area mainly on utility-scale level solar PV (IEA 2016b). Even if utility-scale solar PV participation may increase, it will not eliminate the importance of distributed solar PV in Europe, especially in countries like the Netherlands, Austria, Italy, Germany³⁵ and France as they are not only top markets for PV but also currently important countries regarding distributed power generation (IEA 2015, 2016b; Solar Power Europe 2016).

Figure 31. European solar PV total installed capacity until 2015 for selected markets.

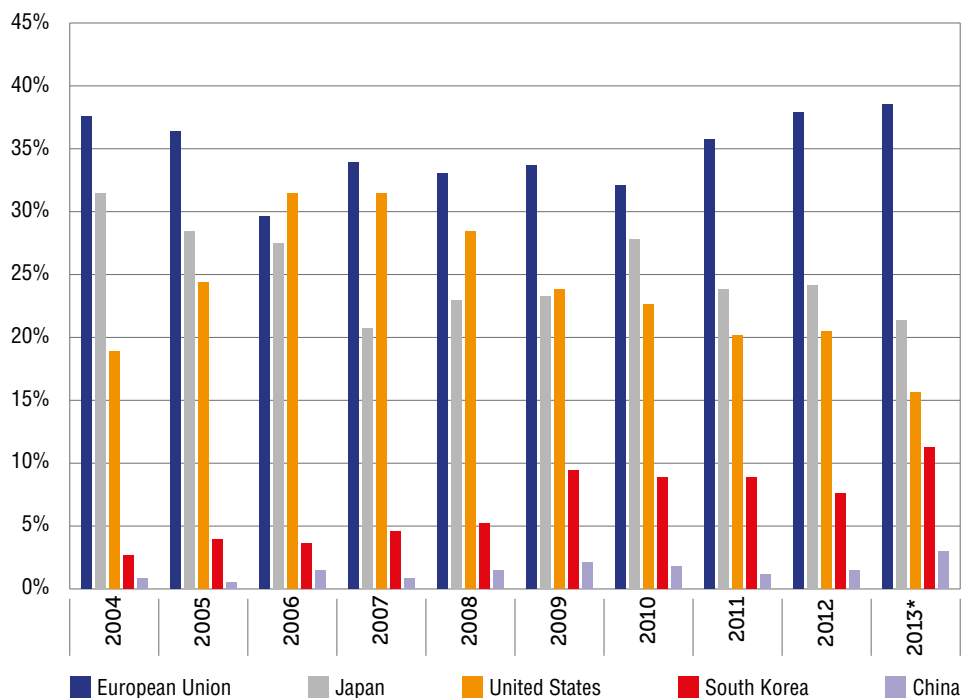


Source: Solar Power Europe (2016, 28)

.....
 35. Fraunhofer ISE (2016) details the evolution of German Solar PV installed capacity.

There are no European companies among the top ten PV modules manufacturers, with most of these companies being based in China or in the United States (PV Tech 2015b). Analysing the results of Cleantech Group (Cleantech Group 2016), North-American, Japanese and Korean companies comprise the top ten solar energy patent assignees at the United States Patent and Trademark Office. When analysing the patent applications for solar PV to the European Patent Office, Japan remains the most important country, followed by U.S, Germany and South Korea. However, comparing patents of the different regions, the European Union has a higher rate of patent applications to the European Patent Office if compared to Japan, as we can see in Figure 32.

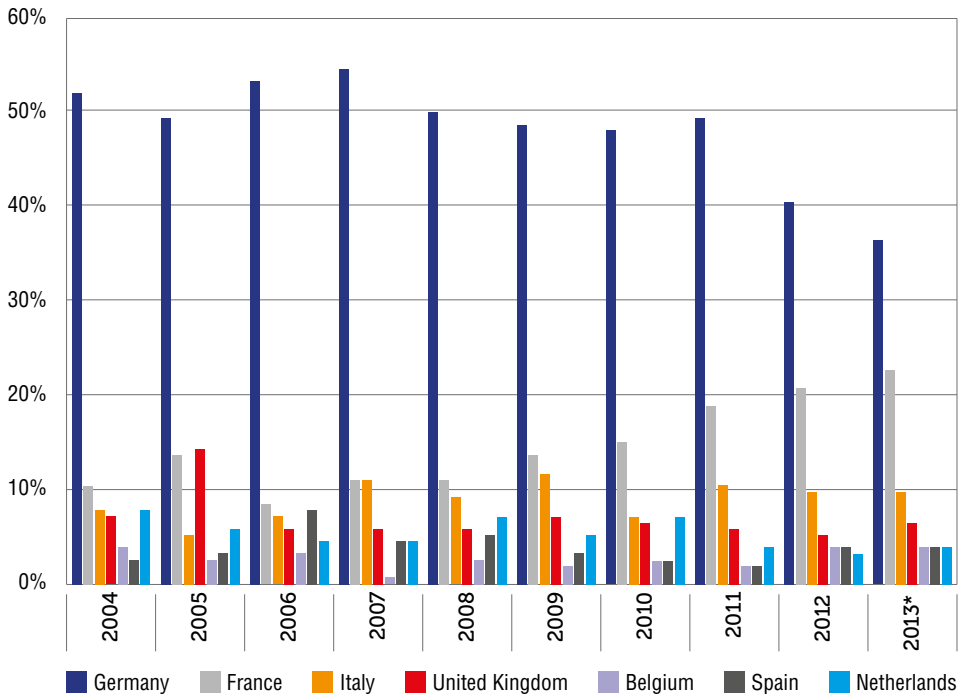
Figure 32. Solar PV patent applications to the European Patent Office - 2004-2013 (% of patent application per region/total application).



Source: (Eurostat 2017). *Preliminary data.

In Figure 33, we observe that Germany is by far the country with the highest amount of PV patent applications to the European Patent Office among European countries. Nevertheless, increased R&D efforts in other countries have increased the number of patent applications by France, Italy and Spain.

Figure 33. Solar PV patent applications to the European Patent Office - 2004-2013 (% European countries patent/total European Union patents).



Source: Eurostat 2017. *Preliminary data.

Thus, considering the installed capacity and the filings of patents (in the EPO), we assume that the most important countries in the solar PV industry in Europe are Germany, France, Italy, UK and Spain.

From a national perspective, we understand that national regulations, policies and the domestic market have an important role to explain the companies' success. Taking advantage of the incentives offered by national governments, these companies were able to thrive and expand beyond the national territory and sometimes beyond Europe. The fact that European companies are no longer among the largest panel manufacturers did not stop them from operating and expanding, although some had to focus on other objectives, such as changing the technology of its panels or outsource production lines while keeping the R&D sectors in Europe. Following this, we will have a look at some of the key European companies.

» Utilities

Among European Utilities, the companies with higher solar PV portfolio are **EDF** and **ENEL** (Solar Asset Management 2016).

- **ENEL** is clearly the most relevant Italian company in the solar PV market, especially in the Italian market, starting as a public utility in 1962. ENEL Green Power, the renewables division of **ENEL**, has a strong presence in Italy, other parts of Europe and various other regions in the world, especially in the Latin American and Caribbean region. The renewables division develops, operates and manages solar PV, as well as hydro, wind and biomass power plants in Italy, Mexico, Chile, Brazil and other European and Latin American countries (i.e. France, Peru, etc.). Internationally, the solar PV capacity owned and operated by **ENEL Green Power** (and its national subsidiaries) is quite relevant and is continuously increasing (BN Americas 2017a; ENF 2017).

The company also owns the brand of thin-film PV modules **3SUN**, a joint-venture with the Swiss-based company **STMicroelectronics** and the Japanese firm **Sharp** (which is one of the most important companies producing thin-film panels). The company focuses on a technology well suited for hot temperatures and that is currently being deployed in some small-scale PV power plants in Chile. As of 2014, the factory, located in the Italian region of Catania, could produce up to 200 MW of thin-film panels per year (Enel Green Power 2014, 2015b).

Starting in 2010, **ENEL** started to install small solar PV modules on the roofs of Italian Embassies around the world. The Italian embassy in Brasilia, Brazil was the first to be equipped with a 50 kWp solar system. The embassies in London, Tehran, Dhaka, Casablanca and Rio de Janeiro were also equipped with solar power generation systems over the years, all provided by ENEL Green Power. This was part of the “Green Embassy project” that included ENEL Green Power, the Italian Ministry of Foreign Affairs and International Cooperation, and embassies. Abu Dhabi was the last Italian embassy to be equipped by ENEL, with all the 27 kWp capacity being composed of 3SUN’s thin-film PV modules. Before the program, in 2009, ENEL only owned and operated four solar farms, all located in Italy. Out of the pre-2010 power plants, Serre Pisano, comprised almost all the solar PV capacity of the company at the time (3.3 MW of 4 MW total). Since the program, the company grew its capacity internationally, especially regarding solar PV (Enel Green Power 2010, 2017a).

- **Endesa** is a former public utility currently with majority ownership by the Italian group **ENEL**. In Spain and Portugal, the company is known as **Endesa S.A.**, whereas in operations in Latin America it uses its subsidiary **Endesa Américas**. Following the same strategic lines of the holding, **Endesa** is also involved in distributed solar power generation (BN Americas 2017a; Endesa 2016; PV Tech 2016a).
- **EDF** is a public utility; it has a key importance in providing long-term PPAs for solar farms and net metering for decentralised solar power generation. The company also owns solar capacity in France and other countries, with a total of 1 GW capacity of solar PV. **EDF** is also relevant in the wind power generation segment (BN Americas 2017a; EDF 2017b,

2017a). Besides wind, solar photovoltaic is a second axis of development for **EDF Energies Nouvelles**. In Europe **EDF** invests in solar power in France, Spain, Italy and Greece and in LAC countries, **EDF** has solar projects in Chile, México, Brazil and French Guiana. In the similar line of **Enel**, **EDF** also has a subsidiary producing photovoltaic modules. Following a different approach than the former, the company designs and produces photovoltaic modules based on crystalline silicon technology. **Photowatt** has been a French manufacturing pioneer in the solar industry for over 35 years, it has been one of the leaders in developing PV technologies in Europe in the 2000s. In 2012 it was taken over by **EDF Energies Nouvelles**. It aims to achieve different types of application, from residential rooftop equipment to solar power plant (BN Americas 2017a; EDF 2017a, 2017b; Renewables Now 2016; PV Magazine 2016b; EDF Energies Nouvelles Mexico 2016).

- **Solairedirect** produces, maintains and installs PV systems and modules. Founded in 2006, the company was bought by **Engie** (another French Utility) in 2015. With 500 MW of PV capacity in France, the company is responsible for nine times more capacity outside of France: 4.5 GW of capacity owned by **Solairedirect** are located (or are under construction) in Chile, India, Mexico, Brazil, and other countries (including EU countries) (BN Americas 2017a; ENERDATA 2015; PV TECH, 2015b; Reuters 2014).

» PV modules manufacturer

Q-Cells is part of the South Korean Group **Hanwha**, which is one of the six main companies of PV modules. Germany was the location of manufacturing of solar panels until 2015, when production was shifted to Malaysia. However, the German headquarters are still operating as the company heavily relies on its German R&D headquarters for innovation (ENF 2017; Hanwha Q-Cells 2017; PV Tech 2015a).

Schott is a solar cell producer and PV panel manufacturer, one of the oldest companies in the solar PV business. In 2012, it withdrew from manufacturing of silicon panels (c-Si), especially due to Chinese competition, shutting down production in German, Czech and North American facilities. The company then focused on amorphous silicon, monocrystalline and thin-film panels (ENF 2017; GTM Research 2015; PV Tech 2012b). There is a change of strategy of the industry investing in PV technologies.

» PV solar downstream

Besides the companies in modules manufacturing, Germany also has important companies in the downstream of the solar PV industrial chain. **Conergy** is a German company engaged primarily in services (financing and engineering especially) related to the deployment of solar PV facilities. In Europe, the company also has projects in the UK and Italy. In LAC countries, it has dependencies in Brazil, Chile and Mexico. All main projects in Germany from **Conergy** have an installed capacity of less than 1 MW, which is different for most of its projects abroad.

It is globally recognised in terms of solar PV downstream (Conergy 2017; ENF 2017). The company also works with PV leasing (GTM Research 2014).

The Gehrlicher Group owns three subsidiaries related to solar PV: **Gehrlicher Solar**; **Gehrlicher Solar Business GmbH**; and the **Gehrlicher Solar Management GmbH**. Through its subsidiaries, the group funds, develops, plans, builds and operates PV plants and decentralised generation, using its own line components (provided by the sister company **GerTech**) and imported PV panels. The company filed for insolvency in the early 2010's (like various other German companies³⁸, including **Conergy**) (Gehrlicher Solar 2017).

Ingenostrum mostly provides engineering and consulting services. It owns, operates and provides power plants, having solar power plants in Spain, Italy and Chile (BN Americas 2017a).

Grupo Cobra constructs, operates, perform installations and maintenance of energy (and industrial) installations in Europe, Latin America and other parts of the world. The group is owned by **Actividades de Construcción y Servicios, S.A. (ACS)**. In Spain, the group mostly owns geothermal solar power plants (BN Americas 2017a).

Key players in Latin America and the Caribbean

According to GTM Research (2017) and Solar Asset Management (2016), Chile, Honduras and Uruguay are the most important countries in terms of current installed solar capacity in LAC. However, Brazil and Mexico are countries that are expected to become key in PV solar energy. Mexico has 713 MW of PV solar capacity, if we include operational and under construction capacity. It is expected that the country will achieve 4 GW of total solar capacity in the mid-term.³⁹ Brazil has great potential; however, the installed capacity (including under construction) is just 590 MW and the mid-term expected capacity is 2690 MW.

Chile is expected to enhance its importance in terms of solar PV on the continent. It should remain the Latin American country with the largest installed capacity of solar PV (more than 6 GW of total capacity, with 4 GW of capacity being already operational or at least under construction). This means an increase by a factor of seven regarding its 736 MW of the current installed capacity. Chile also has one of the largest power plants in operation in Latin America and the Caribbean: the Finis Terrae solar PV power plant.

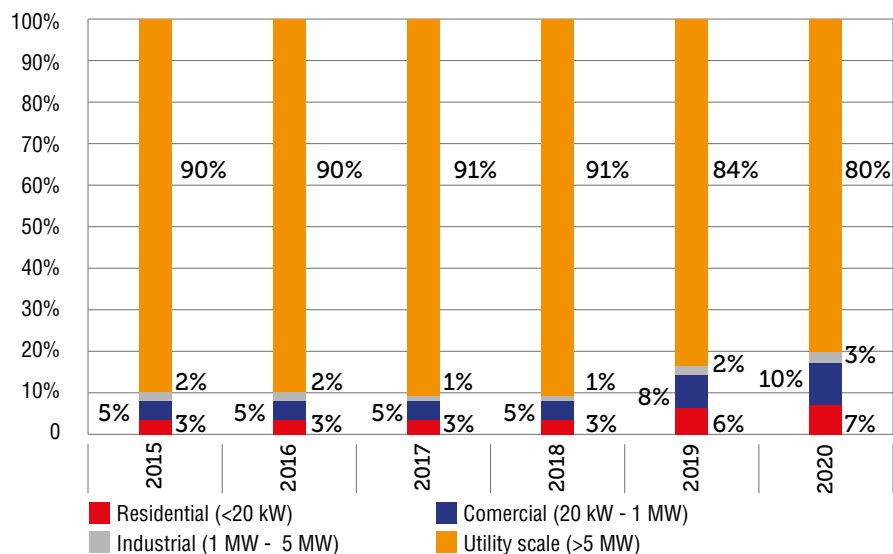
A characteristic of the Latin American solar PV sector is the fact that it focuses on utility-level solar PV: regarding the market division, residential (<20 kW of capacity), commercial (20 kW – 1 MW) and industrial (1 MW – 5 MW) are much less relevant than utility-level solar PV, which currently covers 90% of the market as we can see in Figure 34. This can be explained by the focus on auction-led demand, in which governments prefer the rapid competitiveness of the economies of scale rather than the possibilities of a greater share of distributed generation (GTM Research 2017).

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38. For more information on the matter, we recommend Energy Transition (2013) and Inhabitat (2013).

39. Here, total capacity is comprised of the installed capacity, the capacity under construction and the announced or scheduled capacity. GTM Research (2017) analyses data up to 2020, regarding the year of commercial operation of announced capacity.

Figure 34. Latin America Market Segmentation 2015-2020e.



Source: GTM Research (2017).

European companies related to solar PV have a major importance in the development of Latin America solar PV markets. French, German and Spanish utilities, developers and panel manufacturers are major players in these countries and pivotal for the success of their domestic solar markets. Despite the prominent use of imported Chinese panels, European companies still thrive in the Latin American solar markets. Generally, these companies were well established in the country before attempting a solar expansion, normally having multiple assets in energy and infrastructure. They also engaged in joint-ventures, agreements and consortium with other European companies, for example, in Chile, the Italian ENEL Green Power has a PPA with the Spanish Endesa. It is not unlikely however, to observe domestic companies cooperating with these European subsidiaries. We will now analyse the major players in the following countries: Mexico, Brazil and Chile.

» Mexico

Hanwha Q-cells, Solairedirect, EDF (also through subsidiary **Citelium**), **Acciona** and **Enel** are important companies in a growing Mexican solar market (BN Americas 2017a; Hanwha Q-Cells 2014). The Mexican solar capacity is expected to increase 20-fold by 2019, reaching almost 6 GW (BN Americas 2017b).

The South Korean-German company **Hanwha Q-Cells** manufactured, financed and provided 3 MWp of solar panels to the Mexican retail company **Tiendas Sorianas S.A.** (the second largest retail company in the country). However, this is just the first phase of the project, which has planned to build 31 MW of distributed capacity for the retail stores of the company. This operation was planned and done without subsidies, possessing a 20-year PPA between the panel provider and the retail company headquarters. For example, the fact that the 31 MW of solar capacity are to be put on different sites did not largely affect the transaction: it was done between the two

companies, and not between **Hanwha** and each store. Besides, according to Mexican regulation, most projects with less than 500 kW do not need regulatory approval, lowering the costs significantly. The Mexican solar resource and the specificities of the transaction (long-term PPA) were cited as determinant factors for the success of this particular case.⁴⁰

The **French Solairedirect** (part of Engie group) has almost 200 MW of Mexican solar PV capacity under backlog in the country. The company has won an auction for 23 MW of solar capacity in the northern region of Mexico (Baja California), being a competitive project in terms of tender located in a region expected to concentrate more than half of all Mexican solar capacity. The company already had projects in Chile and Panama when the auction took place. The group **Engie S.A.** is active in the country since 1989, although focusing on gas pipelines and other utilities (BN Americas 2017a; Engie 2016; Solairedirect 2016).

The French public utility **EDF** owns, contracts and provides for power generation through its Mexican subsidiary **EDF EN Mexico**. With a clear focus on wind power generation, the company installed its first wind project in Mexico in 2009 and has put into service almost 400 MW of wind power capacity. However, regarding solar PV, the company is still incipient in the country, winning a 90 MW solar power plant in its second auction in Mexico: the Bluemex Power solar project, located in the Guymas, Sonora. This however is considered as a pivotal step toward a larger number of operations and a larger capacity in the country, because EDF aims to diversify its portfolio toward solar energy (BN Americas 2017a; EDF Energies Nouvelles Mexico 2016; PV Magazine 2016b; Renewables Now 2016). EDF is also present in the country through its subsidiary **Citelum**, specialised on street lightning (Citelum S.A 2017)

Acciona has a 227 MW Project contracted by Mexico's second auction, at the same time the largest contracted at the auction (PV Magazine 2016b). The company, through its subsidiary **Acciona México**, was incorporated in 1978. Its energy portfolio focuses on wind power generation, with almost 600 MW of capacity in operation (almost 20% of the Mexican wind capacity). In regards to its solar PV portfolio, the Puerto Libertad solar power plant, located in Sonora, will have a 50% increase to 270 MW. The prior 180 MW are part of a PPA signed with the Comisión Federal de Electricidad (CFE) (in regards to output), while the output generated by the 90 MW of new capacity will be used by an industrial facility, also through a long term PPA. Construction is scheduled for the end of 2017 (Acciona 2016, 2017b; BN Americas 2017a; PV Tech 2017a; Renewables Now 2015a).

ENEL Green Power Mexico, a subsidiary of the Italian company **ENEL**, entered the Mexican energy market in 2008, becoming the main clean energy operator with almost 800 MW of capacity in operation and over 1200 MW of capacity under construction. With its project portfolio, it is the largest Mexican company in terms of renewable capacity in operation.⁴¹

ENEL Mexico started to develop the largest solar project envisioned by the company in LAC, the Villanueva solar project, with a planned installed capacity of over 700 MW – larger

40. Construction company ILIOSS (property of SolarCity, a North-American solar services provider) were responsible for some of installations of rooftops system modules and carport solar systems (CLEAN TECHNICA, 2014; GTM RESEARCH, 2014a; PV MAGAZINE, 2014b; PV TECH, 2014; SOLAR CITY, 2017).

41. The company develops and manages renewable power generation projects in Mexico. This is a key market for the company in Latin America, covering a quarter of all capacity owned by the Multinational ENEL in the region, followed by Chile. Regarding its worldwide capacity, Latin America accounts for 20% of the total for ENEL capacity.

than all current capacity owned by the firm in the country. This power plant is also the largest under construction in the Americas. The company also benefits from various long-term PPAs with CFE (Bloomberg 2016a; BN Americas 2017c, 2017b, 2017a, Enel Green Power 2016a, 2017b, PV Tech 2016b, 2017b, 238).

» Brazil

Conergy, Gehrlicher Solar, Solairedirect, EDF (also through its subsidiary **Citelum**), Grupo Cobra, Acciona, ENEL are relevant companies in the still incipient Brazilian solar PV market.

Conergy do Brasil is the Brazilian subsidiary of the German company **Conergy**. Present in the country since 2015, it focuses on distributed and centralised solar PV power generation. The company acquired solar power plants in auctions, however, none of its plants are currently operating or under construction. The company expects to focus its operations on distributed solar PV, however, the success of the 60 MW of contracted utility-level solar is considered pivotal for the success of the company in the country with regards to solar power generation (ANEEL 2016a, 2017; BN Americas 2017a; Revista Exame 2015; Solar Power World 2015).

Gehrlicher Solar AG is a company founded in Germany that started its activities in Brazil in 2010, planning and realising ground-mounted and rooftop distributed panel installations. The joint venture **Gehrlicher Ecoluz Solar**, with the Brazilian company **Ecoluz participações**, completed and connected the installation of 408 kW of solar PV capacity in the Pituáçu Soccer Stadium, using North-American and Chinese PV panels. The State of Bahia and the Brazilian utility **Coelba** were the developers of this project (PV Tech 2012a; Renewables Now 2012).

Solairedirect and its sister company **Engie Ineo Brasil** (formerly known as **Tractebel**) are companies operating and providing services related to solar PV. Its portfolio consists of 7 MW divided into fossil-fuel plants (coal, biomass, gas), hydro plants, wind farms and one solar farm: The 3 MW Nova Aurora Solar plant, connected to the grid in 2014. The companies have auction-contracted solar PV plants and are also focusing on developing a distributed solar PV market in the country (ANEEL, 2016b, 2017; BN AMERICAS, 2017a; ENGIE ENERGIA, 2016; G1, 2015; RENEWABLES NOW, 2015b).

The French utility **EDF** (in Brazil **EDF Norte Fluminense**) and EDF Energies Nouvelles own wind farms, solar PV projects (contracted by auctions) and a fossil-fuel power plant in Brazil. It started working alongside **Canadian Solar Inc.** in a solar PV power plant in the Minas Gerais State. In October 2016 EDF bought 80% **Canadian Solar Inc.'s shares** of the power plant. The Pirapora I solar power plant will have a capacity of 191 MW, and has an expected investment volume of over 1 billion reais (over 300 million dollars). It is the first project to receive the BNDES funds as they invested in the panel assembly manufacturing in Brazil in order to comply with local content requirement to access **BNDES** subsidised funds.

The Singaporean multinational company **Flex** (with facilities in Sorocaba, São Paulo) is also cooperating with **Canadian Solar Inc.** on the panels of the Pirapora I project. The panels are expected to be manufactured in Brazil as part of the companies' strategy to use BNDES pub-

lic financing tools (Ambiente Energia 2017; ANEEL 2016a, 2017; BN Americas 2017a; Guiar Investimento 2017; PV Tech 2016c; Reuters Brasil 2016).⁴²

The Spanish company **Grupo Cobra** operates in Brazil through its subsidiary **Lintran do Brasil participações**, operating primarily on transmission lines.⁴³ The company was a successful bidder at the solar auctions promoted by the government, becoming the third largest company regarding expected capacity, with over 300 MW of contracted capacity. However, there is currently no solar capacity owned by the group that is under construction or already in operation (ANEEL 2016b, 2017; BN AMERICAS 2017a).

Acciona operates in Brazil since the 1990's, however, only recently has the company decided to enter the PV market in the country. It operated and constructed infrastructure projects as well as energy projects, especially wind power plants in the North-eastern region of the country (Acciona Energia 2017; Valor Econômico 2016).

ENEL Green Power Brasil is the most important company in the solar PV market in Brazil. As owner of the largest solar capacity in operation (more than 10 MW), capacity in construction (more than 500 MW), and planned capacity (almost a quarter of all contracted solar PV capacity), ENEL is active in the country since the late 2000s. The company has an extensive portfolio of assets, comprised of wind power plants, hydro power plants, transmission lines, distribution lines and distribution companies. The Nova Olinda solar park, located in the North-eastern state of Piauí is expected to be the new largest solar power plant in Brazil, with almost 300 MW of capacity (ANEEL 2016a, 2016b, 2017; BN Americas 2017a). Until the moment of writing, ENEL's funding strategy has not been based on the use of BNDES funds (differing from EDF and Canadian Solar Inc.).

» Chile

The leading country in solar PV since the mid-2010's⁴⁴, the main companies in the Chilean solar PV market are: **ENEL**, **Solaredirect**, **EDF** (also through its subsidiary **Citelium**), **Grupo Cobra**, **Ingenostrum**, **Acciona Energia** and **SunEdison** (GTM Research 2015).

Chile is a focus of the international operations of **ENEL**, being one of the company's largest installed capacity, alongside prospects of a sustained and steady growth in the future. This follows the analysis and prospects for the country. **ENEL Green Power Chile** owns the largest Latin American and Chilean solar PV power plant, Finis Terrae, but is also responsible for innovative projects in the Country, such as the Diego de Almagro solar power plant, made up of multi-junction thin-film solar PV panels manufactured by ENEL's subsidiary 3SUN. The technology is expected to be better suited for high temperatures. The company develops, operates and owns

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42. EDF is also present in the country through its subsidiary Citelum (formerly known as Citeluz), providing street lighting to 35 Brazilian Cities, including Salvador, Bahia (CITELUM S.A, 2017).

43. The company develops and manages renewable power generation projects in Mexico. This is a key market for Grupo Cobra operates also in Chile, however there it owns a Coal Power plant in Mejillones alongside transmission and distribution networks for power, gas and water (BN AMERICAS, 2017a).

44. Several reports and newspapers have pointed out the importance of Chile in the PV solar in LAC, see for instance IRENA (2017), BLOOMBERG (2016a); FORBES (2015); PV TECH (2017b) and THE GUARDIAN (2014).

solar projects (and also, wind farms, hydro power plants, and geothermal plants) in Chile, with a capacity of almost 700 MW, out of which almost 500 MW were comprised of solar PV capacity (BN Americas 2017a; Enel Green Power 2015a; IEA 2014; PV Magazine 2014).

Solairedirect Chile is active in the country since 2010, with 55 MW of solar PV capacity under construction or in operation: the power plants of Los Loros and Andacollo. The panels used in the power plants were provided by the Chinese panel manufacturer JinkoSolar. The Los Loros power plant has no PPA, being called a “merchant plant”, selling all output in the spot market. According to PV Magazine (2016a), this particular type of power plant is generally financed by export and development banks. Los Loros was financed by the Inter-American Development Bank; the Canadian Climate Fund and the China Co-financing Fund (Cleantechies 2016; Renewables Now 2013a; Solairedirect 2016).⁴⁵

EDF through its subsidiary (**EDF Energies Nouvelles**) constructed its first plant in the country in 2015: the 146 MWp Laberinto⁴⁶ Solar Power Plant in the Atacama Desert. A considerable number of companies involved in the project were also owned by **EDF**, with the exception of the Japanese general trading company **Marubeni**. The merchant plant is connected to the Northern Grid of Chile, and was at the time of completion one of the largest solar projects of the world. The company also planned a 115 MW solar power plant north of the city of Santiago, with a 15-year long PPA signed with 20 distributors (with the possibility of excess electricity being sold on the spot market). The plant is also owned partially by the Chilean company Andes **Mining & Energy**, and the Spanish company **Elecnor** was hired for construction, being its first turnkey contract in the Chilean renewables market, worth 117.2 million dollars. The Santiago solar photovoltaic park entered into operation in 2018. EDF is also present in Chile through its subsidiary Citelum, which is involved with street lighting (including the city of Santiago in its portfolio) (BN Americas 2017a; Citelum S.A 2017).

Ingenostrum Chile S.p.A. is the Chilean subsidiary of **Ingenostrum S. L.** - a Spanish company whose core business is solar project implementation and equipment supply. It is currently developing eight large-scale projects in the north of the country. The company works alongside the Portuguese PV modules manufacturer **Martifer** in some cases. Most of its assets are owned by other subsidiaries of Ingenostrum, and some plants were sold to other companies as **EDF's** Boléro plant and **Enel's** Finis Terrae (BN Americas 2017a; PV Magazine 2012).

Acciona Energia is a Spanish energy and infrastructure company active in Chile since 1993. Through its subsidiaries, it owns, operates and contracts projects in Chile's solar market. Its El Romero solar plant surpassed the prior **ENEL** Finis Terrae project as the largest in Chile and Latin America, with its 246 MWp of installed capacity. It was awarded at a 2014 tender. It represents an investment of over 500 million dollars. Former solar projects of the company in Chile included the Pampa-Camarones PV power plant (built for a third-party); the company also developed wind projects and other infrastructure projects (hospitals, highways, etc.) The company has a long-term PPA of 15 years to distributors connected to the central grid. It also owns and operates other PV plants as well as wind power plants in the country and develops

45. Engie Energia Chile, subsidiary of the same group as Solairedirect (Engie) has a fossil-fuel dominated portfolio of plants.

46. Its name was later changed to Boléro solar plant (BN Americas 2017a; EDF Energies Nouvelles 2016)

power plants for third parties (Acciona Energia 2015; BN Americas 2017a).⁴⁷

Inversiones y Servicios SunEdison Chile Ltda., a subsidiary of the North American company SunEdison, owns, operates, contracts and provides for solar projects in Chile. It took advantage of a 15 years long PPA for companies in the central Chilean grid. Its portfolio includes the Amanecer Solar power plant, with 100 MW of capacity. In 2016 the company filed for bankruptcy and some assets were sold. The British private equity company **Actis** bought 1500 MW of solar PV assets in Latin America that were formerly owned by **SunEdison**. Two solar assets, a total of 202 MW of capacity under construction⁴⁷, were sold to the Chilean utility **Colbún S.A.**, which already owned and operated power plants in the country (mostly comprised of thermoelectric plants and hydro power plants), as well as transmission lines (Bloomberg 2016b; BN Americas 2017a; Renewables Now 2017; Reuters 2016).

The main solar companies in Mexico, Brazil and Chile are part of the investment strategy of European companies, including utilities, companies specialised in the development of renewable energy projects and a solar panel developer. Even though these European companies are not the key manufacturers of solar PV panels, in LAC they are the main companies developing, implementing and also financing solar PV. We show that there is a substantial financial and technological link within the region in solar business implementation as it includes not only panel, project and direct financing, but also the use of companies' portfolio and know-how in developing PV solar. It is also interesting to note that most of the European companies with strategies concerning PV solar in the region have previously been present in the energy market (frequently in wind generation but also in other parts of energy business). The German companies more adapted to the distributed energy business and not related with traditional utility business may find it challenging to adapt to the LAC market, where projects are mainly awarded through auctions.

B. PLAYERS IN BOTH REGIONS

The analysis of the most relevant solar PV markets show that the European companies are either the leading companies in both Europe and Latin America, or are at least important in relation to Latin America and the Caribbean. The widespread use of Chinese panels has impacted the European manufacturers as well as the North American producers; however, the case of 3SUN and Q-cells shows how companies can bypass these issues through innovative strategies, either through R&D per se or by focusing on another technology path.

When we consider the trade balance between regions EU-28⁴⁹ and CELAC, Europe is a net export origin for PV related components to LAC, reaching around 0.47 billion dollars, in 2015, while the PV global market amounted to around 109 billion dollars that year. LAC exports to Europe in this sector, in turn, account for only 10% of EU exports.

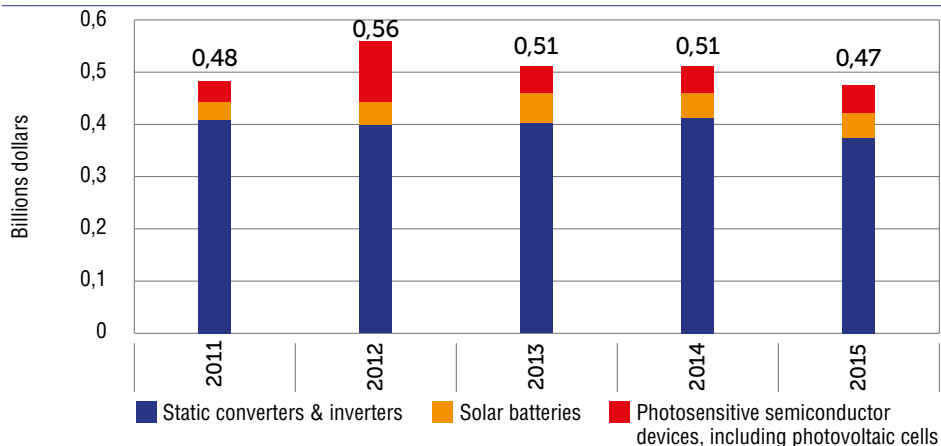
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47. Acciona is the biggest shareholder of the German Nacelle company Nordex (Acciona 2017a).

48. The plant in the Valparaiso region has 145 MW of capacity, whereas the capacity of the power plant located in the metropolitan region amounts to 57 MW.

49. The EU-28 include: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, The Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom.

Figure 35. EU-28 exports to LAC by group of goods.



Note: HS Code Solar Photovoltaic (PV) components (Cao and Groba 2013):

850440 – Static converters (Inverters for converting DC power to AC power)

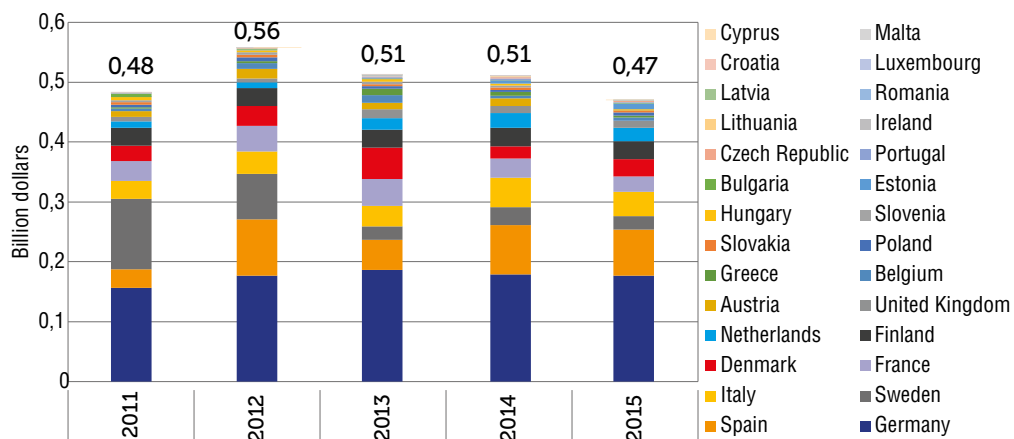
850720 – Other lead-acid accumulators (solar batteries)

8541040 – Photosensitive semiconductor devices, including photovoltaic cells whether or not assembled in modules or made up into panels; light emitting diodes

Source: Elaborated with data retrieved from UN (2017)

The EU's exports are concentrated on inverters, representing around 80% of total amount of PV related exports to LAC countries, while PV cells and batteries related components represented 10% each. Germany and Spain were the European leaders in such field totalling over half of exports in 2015. Brazil, Chile and Mexico were the main importers from European PV components. Figure 35 and Figure 36 present the evolution of exports flows from Europe to LAC respectively by goods and by country.

Figure 36. EU-28 PV related exports to LAC by European Country.



Note: HS Code Solar Photovoltaic (PV) components (Cao and Groba 2013):

850440 – Static converters (Inverters for converting DC power to AC power)

850720 – Other lead-acid accumulators (solar batteries)

8541040 – Photosensitive semiconductor devices, including photovoltaic cells whether or not assembled in modules or made up into panels; light emitting diodes

Source: Own elaboration based on data available in UN (2017).

The following table (Table 11) summarises the differences between the analysed major players.

Table 11. Specificities of selected companies

| | Home country or current location of HQ | Company | Primarily European | Primarily an energy company |
|----------|--|-------------------------------|--------------------|-----------------------------|
| Europe | Italy | ENEL | yes | yes |
| | Italy, Switzerland, Japan | 3SUN ¹ | yes | yes |
| | Germany, South Korea | Q-Cells ³ | no | yes |
| | Germany | Conergy ⁴ | yes | yes |
| | | Schott Solar | yes | yes |
| | | Gehrlicher Group ⁴ | yes | yes |
| | France | Solairedirect ² | yes | yes |
| | | EDF | yes | yes |
| | Spain | Endesa ¹ | yes | yes |
| | | Ingenostrum | yes | no |
| | | Grupo Cobra | yes | no |
| Acciona | | yes | yes | |
| Elecnor | | yes | yes (utility) | |
| Portugal | Martifer | yes | yes | |
| America | United States | SunEdison ⁴ | no | yes |
| | | SolaCity ⁴ | no | yes |
| | Canada | Canadian Solar Inc. | no | yes |
| | Brazil | Coelba | no | yes (utility) |
| | Chile | Andes Mining & Energy | no | yes |
| | Mexico | Tiendas Sorianas | no | no |

Notes: ¹: Owned by ENEL | ²: Owned by Engie | ³: Owned by the South Korean Group Hanwha with R&D headquarters located in Germany

⁴: Filed for Bankruptcy

Source: Own elaboration

| Is the company owned or headquartered with relevancy in Europe | Active in EU | Active in LAC | PV manufacturer | Examples of relevant markets |
|--|--------------|---------------|-----------------|---|
| yes | yes | yes | no | Italy, France, Chile, Brazil, Mexico |
| yes | yes | yes | yes | Italy, Chile |
| yes | yes | yes | yes | Germany, Mexico |
| yes | yes | yes | no | Germany |
| yes | no | no | yes | Germany |
| yes | yes | yes | no | Germany, Brazil |
| yes | yes | yes | no | France, Chile, Mexico, Brazil |
| yes | yes | yes | no | France, Chile, Mexico, United Kingdom |
| yes | yes | yes | no | Spain, Chile |
| yes | yes | yes | no | Spain, Italy, Chile |
| yes | yes | yes | no | Spain, Brazil |
| yes | yes | yes | no | Spain, Chile, Mexico |
| yes | yes | yes | no | Spain, Chile, Mexico, Brazil |
| yes | yes | yes | yes | Portugal, Spain, Chile |
| yes | yes | yes | yes | United States, Mexico, Chile |
| no | yes | yes | no | United States, Mexico |
| yes | yes | yes | yes | United States, Mexico, Brazil, Chile, France, Germany |
| no | no | yes | no | Brazil |
| no | no | yes | no | Chile |
| no | no | yes | no | Mexico |

4.1.3 Case studies

For the purpose of illustration, in this section we summarise some projects considered successful case studies of solar PV implementation both in LAC and in EU.

Chile – the case of Finis Terrae

At the time of completion it was the largest PV power plant in Latin America⁵⁰, and Chile is the country with the largest solar PV capacity out of all Latin America and the Caribbean. According to IRENA (2017) one may consider Chile as a Latin American leader in terms of investment in solar PV. On the national level it has renewable energy laws, targets related to renewables as well as quotas or renewable portfolio standards. Its economic support toward renewables consists of the following: capital grants and subsidies, tax reliefs, net metering, tradable green certificates, carbon pricing, and the recently introduced auction schemes (IEA 2015).

Regarding its drivers toward renewable energy deployment, Chile has excellent renewable resources as well as high wholesale and retail electricity prices. Also, the country has a rapidly growing project transmission line for utility-scale plants. There are projects developed to sell energy (or at least part of it) in the short-term market and, on the other hand, there are bilateral contracts (PPAs) with distributors and final consumers. We also can see some funding from regional and international development banks. However, the country currently has only little national financial incentives and long-term PPAs as well as grid bottlenecks and a relatively high volatility of spot market prices (IEA 2015).

The project of Finis Terrae was built by the **ENEL Green Power Chile**, a subsidiary of the Italian energy group **ENEL**. It is located in the Northern part of Chile (Antofagasta Region) and it is connected to the Northern Grid of the country. According to ENEL Green Power (2015c, 2016b), construction began in 2015 and was completed a year later, with an investment of 270 million US dollars, being financed through ENEL's own resources (Enel Green Power 2016b). There is a long-term PPA to the **Empresa Nacional de Electricidad SA (Endesa Chile)**, the largest electric utility in the country, and the project benefited from the fact that **ENEL** had already 154 MW of solar PV installed capacity, rising to 430 MW of installed capacity in the following year, being more than half of all Chilean capacity owned by the company. This means that the company was already familiar with the country's circumstances and that it benefited from its prior experiences with planning, constructing and financing solar PV projects in Chile. The power plant has an estimated output of 400 GWh per year.

The Spanish company **Grupo Cobra** was also present in the construction of the power plant, providing the electrical equipment for the project. The environmental license was acquired four years prior (2012) to the conclusion of the project (Electricidad 2016). According to BN Americas (2017a), **Ingenostrum** Chile was another company involved in the project. **Ingenostrum**, through its Chilean subsidiary, performed measurements of solar irradiation, basic engineering services and the execution of the processing of sector and administrative permits (Ingenostrum 2014).

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50. The El Romero PV plant is currently the largest PV Project in the region. Finis Terrae remains the largest at the Northern Grid of Chile, as the El Romero Plant is connected to the central grid (MercoPress 2016).

Brazil – the case of Fontes Solar I

As the first ground-mounted solar farm to be concluded in Brazil (ANEEL 2017), this PV power plant originated not from a federal auction (as usual in the country), but from a state promoted auction, in the northeast region of Brazil (Governo de Pernambuco 2013). This means that the auction mechanism remained a driver in this case, albeit with little changes.

Brazil has national-level targets and also has national-level economic support policies for renewables, such as capital grants and subsidies, soft loans, tax relief, net metering as well as auction schemes. The Brazilian auction mechanism is considered a main driver for a larger deployment of renewable electricity. Through this mechanism, Brazil saw the rise of its most important wind power plants. The inclusion of utility-scale solar PV in some energy auctions is considered a policy highlight (EPE 2014; IEA 2015).

Brazil has its sponsored power auctions aligned with long-term PPAs, which, combined with the low-cost financing available from **BNDES**, are its main drivers regarding the deployment of renewable energy, especially the new renewable (solar PV in particular). However, its local content policy and the slow deployment of distributed solar PV are challenges for the country. Currently it is also encountering difficulties to deliver its solar power plants already contracted through the auction mechanism: few plants are currently in construction; and fewer are expected to be actually finished on schedule (ANEEL 2016b; IEA 2015; SITAWI and CEBDS 2016).

ENEL Green Power Brazil is one of the subsidiaries of the Italian group **ENEL** in the country, owning a number of wind power plants, hydro power plants, and distribution and transmission lines. Fontes Solar I and II were built on already used land for power generation: in the northeast region of Brazil, near the City of Tacaratu of the Pernambuco State, **ENEL** already operated an 80 MW wind power plant called Fontes dos Ventos. The hybrid power plant is expected to have an additional capacity of 11 MW from the addition of solar PV, becoming the largest PV power plant in Brazil in terms of capacity⁵¹ (Ambiente Energia 2015; Investimentos e Notícias 2015). Fonte dos Ventos was also the first wind power plant operated by ENEL in Brazil (Consumidor moderno 2015).

The north-eastern Brazilian State of Pernambuco promoted a special capacity auction in December 2013, from which the two power plants were contracted (Governo de Pernambuco 2013). This deviated from the traditional auction mechanism because such auction was promoted by a specific state and not by the Federal Government. It is important to notice that out of the contracted power plants, the only two that are operating were the smallest bids (in terms of capacity); the other four winning projects had at least over 20 MW of installed capacity. Another important factor in the success of the first PV power plants of Brazil is the fact that they were constructed near an already utilised (and operational) site (sharing the same are with wind farms). This brought down the costs related to connecting the power plants to the grid. The Fontes Solar I and II PV power plants are expected to produce about 17 GWh per year, with the whole hybrid power plants producing about 340 GWh per year (Ambiente Energia 2015; Investimentos e Notícias 2015). This investment was expected to reach almost

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51. As of March 2017, ANEEL (2017) listed 44 PV power plants. However, few of them have an installed capacity of over 1 MW - the total average is only 327 kW without including Fontes Solar I and II.

20 billion USD or R\$ 72 million, being cheaper than the Fonte dos Ventos wind power plant (R\$ 130 Millions) (Consumidor moderno 2015). According to **ENEL**, hybrid solar and wind farms are strategic not only because of the lower costs (through the sharing of large parts of the infrastructure), but also because of better usage of natural resources (Enel Green Power 2015d). Moreover, still according to the company the financing of the power plants followed the same mechanism utilised in its Chilean PV plants, deviating from the traditional financing mechanism in Brazil that is **BNDES** (Enel Green Power 2015d).

France – The case of Cestas Solar Farm

Cestas Solar Farm is the largest PV power plant in Europe and was developed by the French company **Neoen**. Like the United Kingdom, French power plants are retiring, and there's an increasing peak demand in the country (IEA 2015). Alongside tenders for offshore wind and solar PV, those are the main drivers appointed for a larger deployment of renewable energy in the French territory. Nevertheless, the country needs to reduce non-economic barriers for this to become a possibility, and should clarify the future possibilities of its energy transition policy.

The French regulatory support policies are national-level renewable energy laws and recently updated targets. This target is "... a 32% renewable energy target in gross final energy consumption to be reached by 2030, and a 40% target for renewable electricity by 2030" (IEA 2015, 59), which, alongside the renewal of its feed-in tariff for onshore wind are the policy highlights of the country. Other economic support policies are: capital grants and subsidies, soft loans, tax reliefs and auction schemes. According to the author, all are national-level policies.

The Cestas Solar Farm is located in south-western France, near the city of Bordeaux (PV Tech 2015b). With an installed capacity of 300 MW, it is Europe's largest PV power plant. It was connected to the grid in mid-2015, taking 10 months for completion and costing about US\$ 400 million (360 million euros). The plant is expected to sell power at 105 euros per MWh, below the cost of some new nuclear projects.⁵² The plant has benefited from a 20-year PPA with the French utility EDF. Unlike traditional PV power plants, Cestas solar farm's PV panels face east and west alternately, aiming to improve the output during the early hours of the morning and the late hours of the afternoon, and producing up to three or four times more energy than the traditional (for the north hemisphere) south-orientation of panels.

The PV panels came from three manufacturers: **Trina Solar**, **Yingli Solar** (both Chinese) and Canadian Solar. The plant is expected to produce about 350 GWh per year. The companies **Eiffage**, **Clemessy**, **Schneider Electric** and **Krinner** were also part of the winning consortium chosen to construct and operate the plant (PV Tech 2015b). **Eiffage**, Clemessy, Schneider Electric and Krinner are respectively: a French construction company responsible for

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52. According to Reuters (2015), EDF planned the construction of two nuclear reactors in the United Kingdom, selling energy at about 130 euros per MWh, 25 euros more expensive than the electricity produced by Cestas Solar Farm.

earthworks and connection work; a subsidiary of Eiffage, responsible for engineering studies; a French energy corporation responsible for the electrical conversion chain; and a French company specialised in the assembly of PV modules, responsible for screw-in foundations and PV structures (Eiffage group 2013). Most of the investment was not spent on the PV modules, instead being used for construction services, engineering services, cabling, and other electrical equipment (mostly comprised of French suppliers) (Reuters 2015).⁵³

Germany – the case of Senftenberg Solarpark

The Senftenberg Solarpark is the largest PV power plant in Germany and Europe's largest PV installed capacity. The Senftenberg Solarpark I and II⁵⁴ is located near the city of the same name in the southern part of the federal state of Brandenburg. It has a total capacity of 248 MW (SolarServer 2011b)

Regarding the regulatory support for a larger deployment of renewables, Germany has national-level policies on targets and laws related to renewable energy. The country also uses feed-in tariffs, capital grants and subsidies, soft loans and tax relief as national-level economic support policies for renewables. A current policy highlight for the country is that Germany is trying to improve control over its renewable expansion (in terms of prices and tariffs) (IEA 2015).

According to IEA (2015, 57–60), Germany has effective environmental policies, decarbonisation aims and a small-scale solar PV attractiveness for self-consumption. Nevertheless, a balance between affordability and market design (especially related to prices) is still a challenge for this country.

The ground-based PV power plant was constructed over a former open-pit mining area. The first part of the plant (78 MW of installed capacity) was finished in September 2011 after three months of construction. Like former case studies, there were already two completed power plants in the area, encompassing almost 90 MW of installed capacity already connected to the grid. The Solarpark Senftenberg I was built in 2010, encompassing only 18 MWp of capacity, and not directly related to the Solarpark Senftenberg II and III. This means that the PV plant shared a connection with those power plants. It was financed by three German Banks (including the **HSH Nordbank**) and the total investment amounted to 150 million euros (SolarServer 2011b, 2011a).

Canadian Solar Inc. supplied the PV panels used in the German PV plant. GP Joule was the German company responsible for the assembly. The two companies have cooperated since 2009. **Unlimited Energy GmbH and Luxcara** are two other German companies involved in the Senftenberg PV plant with regards to project finance and the management of the plant (SolarServer 2011a). **Saferay GmbH** is another German company involved with the project, possessing an active role in the financing of the plant (Canadian Solar Inc 2011).

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53. This corroborates the statement of EPE (2012) that most of the added value of PV Power plants is added in the site of construction and mainly through services.

54. The Solarpark Senftenberg I was built in 2010, encompassing only 18 MWp of capacity, and is not directly related to the Solarpark Senftenberg II and III (SolarServer 2011b).

4.2 Wind power

Through significant technological advancement, manufacturers' emergence and concerns about national energy security and from Greenhouse Gas (GHG) emissions, wind power is one pivotal technology for energy transitions. In recent years, the use of wind power for electricity generation has grown rapidly in many countries. The wind is caused by differences in the air pressure due to sunlight, and is influenced by the Earth's rotation and physical characteristics of geography (especially landscape and roughness of terrain).

Most wind farms are installed onshore, but offshore wind has been a new frontier of deployment. Despite the significant growth in installed capacity, wind power share is still small in the world's electricity supply, representing around 3% of the total power generation in 2014 (IEA 2016a).

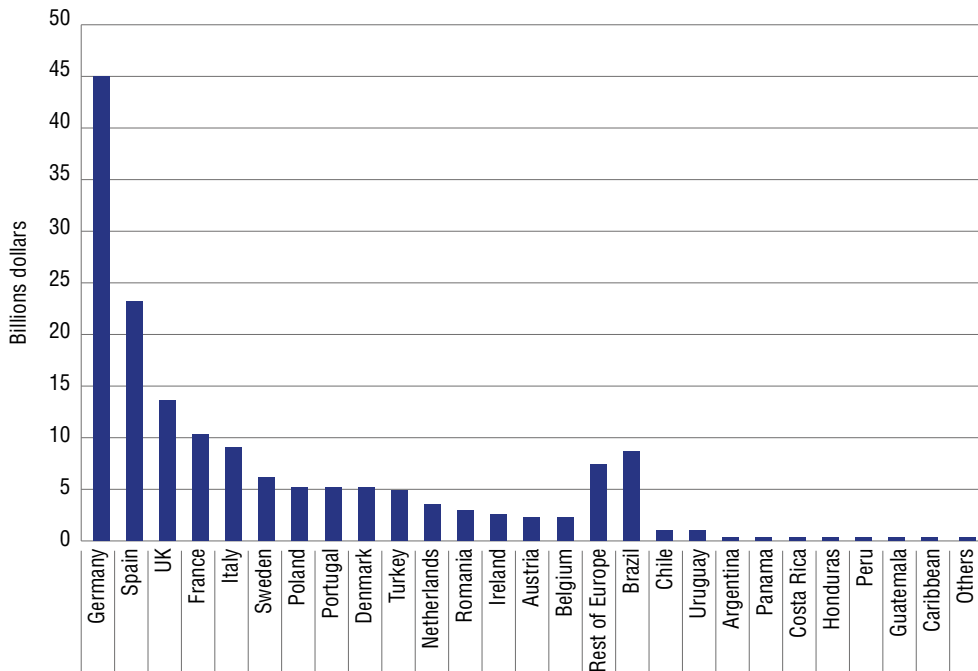
About 84% of wind installed capacity is located in 10 countries, the three largest being China (34%), the United States (17%) and Germany (10%). This group of countries forms the largest market both in the production of wind turbines and related services, and in the acquisition and installation of new wind farms. At the end of 2015, total wind power installed capacity amounted to 432.9 GW around the world, with China installing almost half of the 63,4 GW installed that year (GWEC 2016). Offshore installed capacity reached 12,1 GW in 2015, while most of the global capacity is land-based.

Wind capacity has been developed in different places and extensions in several countries. Europe is a region where wind has been deployed in a widespread fashion, meaning that despite the total capacity, several countries decided to adopt wind sources to diversify energy portfolios and to comply with energy and climate targets. As shown in Figure 37, with a much lower total capacity, LAC countries have just started to add wind sources into their energy mix, and there is still a considerable concentration in a few countries, particularly in Brazil.

The installed wind capacity in Europe is more than ten times higher than in LAC. Germany's capacity is one of the biggest in the world; at the same time this country has a leading role in Europe, followed by Spain, the UK, France and Italy. Germany and Spain's capacity together account for around 45% of the EU's overall wind capacity. The UK, in turn, is Europe's leader in offshore wind capacity.

In LAC, the amount of capacity is lower, but it is also more concentrated. Brazil comes 9th regarding the wind installed capacity in the world and 5th regarding the amount of new capacity installed in 2016 (GWEC 2016). Brazil accounts for around 75% of the total wind capacity in LAC. Chile and Uruguay are the other two countries with higher amounts of installed wind power plant capacity in the region.

Figure 37. Total wind installed capacity in EU-28 and LAC in 2015 in GW.



Source: Elaborated with data retrieved from (GWEC 2016).

Wind technology is already considered a competitive option compared with traditional generating technologies, even without a specific support scheme. Moreover, the technology is still evolving as it is lowering costs and increasing scale. As a consequence, the wind-installed capacity is expected to increase. In Europe, the main countries with wind power plants are Germany, Spain and the UK while in LAC we will examine Brazil, Chile and Uruguay.

4.2.1 Technology

The commercial technology

Wind power conversion is done through windmill's blade movements which capture wind kinetic energy. Air, like any other fluid, has energy that can be harnessed when in motion. This conversion is based on the amount of axial movement of a rotor, which has a theoretical limit estimated at 59% of maximum power (known as the Lanchester-Betz limit).

The wind power generation potential can be defined by three fundamental influences: the wind speed, the area covered by the turbine's blades and the specific mass of the air. Speed

is the most important variable and will depend on the region's wind regime being influenced by topological conditions. This influence decreases as a function of the height above the ground, with higher velocities observed at higher heights. The area covered by wind power plants is also an important factor as it increases and stabilises the efficiency of power conversion. Spreading turbines across a considerable area (dependent upon factors such as roughness of terrain, altitude, etc.) leads to less variability of output in time. Therefore, wind farms are more able to present a reasonably stable power output than a single turbine. The specific air density is influenced by pressure, humidity, and temperature. While pressure influences proportionally the wind energy potential, humidity and temperature are inversely proportional. Thus, the best use of wind resources is found at higher heights and larger areas swept by the blades of wind turbines (Tolmasquim 2016).

Wind power generation can be categorised as onshore or offshore. The onshore can also be divided into subcategories: centralised and distributed. The former refers to large wind turbines groups (>100 kW) most often used by utilities to provide power to a grid. Utility-scale turbines are grouped in wind farms producing large amounts of power. The latter subcategory refers to distributed sources used directly at the load location (e.g. buildings, farms and industrial facilities) and with this feature they can operate independently, especially when they are off-grid installations. Small turbines, when associated with diesel generators, batteries, and/or solar PV systems encompass hybrid systems. Those systems are typically used in remote, off-grid locations.

Onshore wind power generation is currently the market standard for electricity generation based on this source. It is a mature technology, with a clear technology path and established players.⁵⁵ Offshore wind power generation is currently pushing forward a serial production of large-scale turbines in Europe, the main market for offshore wind. Offshore wind projects are a trend in countries with little territorial extension, with little space available for onshore installations or with substantially better offshore resources at sea, such as some European countries.⁵⁶

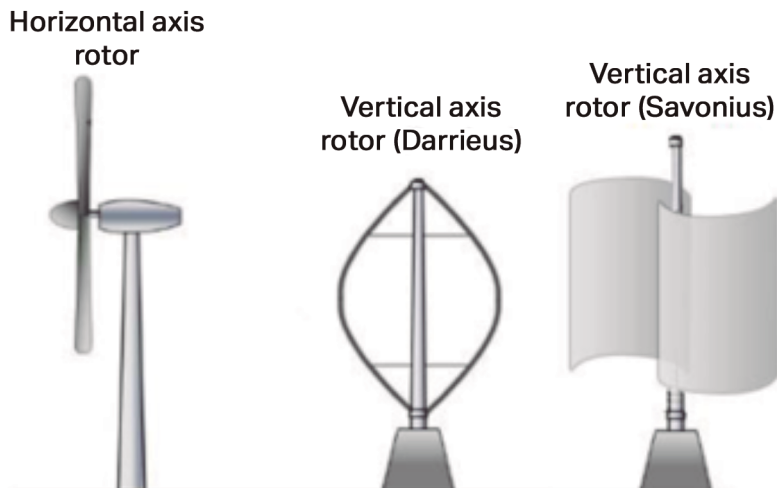
There are two basic types of rotors, the vertical axis and the horizontal axis (Figure 38). The most common, however, are wind turbines with a three-bladed horizontal axis. Horizontal axis turbines are either upwind (the wind hits the blades before the tower) or downwind (the wind hits the tower before the blades). The blades for a vertical axis wind turbine can cost significantly more than the equivalent blades of a horizontal axis. Vertical axis wind turbines have not penetrated the utility scale market (>100 kW) in the way horizontal turbines did.⁵⁷ Vertical axis turbines can be categorised by two main designs: (i) drag-based, or Savonius, turbines have rotors with solid vanes that rotate about a vertical axis; or (ii) lift-based, or Darrieus, turbines have a tall, vertical air foil style (some appear to have an eggbeater shape; see (ABDI 2014; US DOE 2014)).

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55. This is clear not only because of the behaviour of its patent filings, but also because of the rise in equity order's regarding onshore companies: Gamesa's, Nordex, GE and Vestas orders were increased by over 120%, 40%, 26% and 12% in 2014 (IEA 2015).

56. Those turbines can range from 7 to 10 MW each of installed capacity (IEA 2015).

57. They are largely used for research purposes or to small off-grid operations, such as boats (Podcameni 2014).

Figure 38. Types of Wind Rotors.

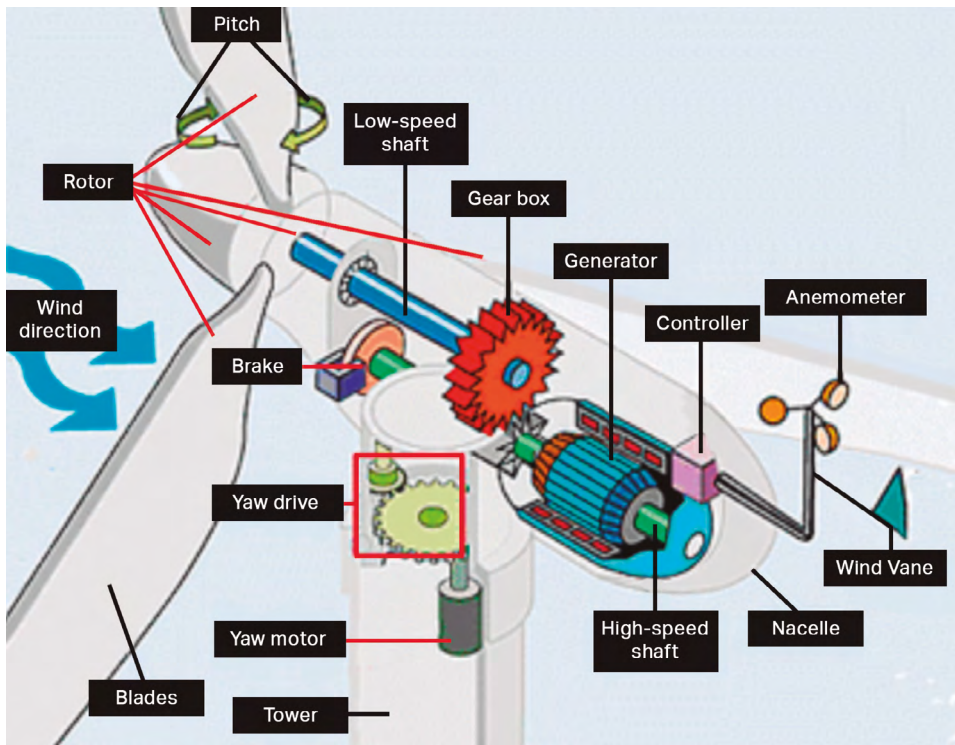


Source: Adapted from (Tolmasquim 2016, 262).

Horizontal axis wind units are composed basically of the following components, see Figure 39 (US DOE 2014; USITC 2009):

- **Blades:** responsible for capturing the wind and converting its power to the centre of the rotor; most wind turbines have three blades.
- **Controller:** monitors the condition of the turbine and controls the turbine movement. There is a controller in the nacelle and one at the base of the turbine.
- **Gearbox:** increases the rotational speed of the wind turbine shaft. A low-speed shaft feeds into the gearbox, and a high-speed shaft feeds from the gearbox into the generator; some turbines use direct drive generators that are capable of producing electricity at a lower rotational speed; such turbines do not require a gearbox.
- **Generators:** the component that converts the mechanical energy of the axis into electricity. Wind turbines typically have a single AC generator.
- **Nacelles:** houses the main components of the wind turbine, such as the controller, gearbox, generator, and shafts.
- **Rotor:** promotes the conversion of the kinetic energy of the winds into mechanical energy of rotation; the rotor includes both the blades and the hub (the component to which the blades are attached).
- **Towers:** supports the rotor and the nacelle at the height suitable for the operation of the wind turbine; this is a large structural item and represents a significant portion of the initial cost of the system.

Figure 39. Illustration of a horizontal axis wind unit components.



Source: (US DOE 2014).

The growth of the wind power market has been boosted by strong cost reductions, increasing efficiency levels and reliability. Blades, control mechanisms, the use or absence of a gearbox and the type of generator were some of the components that have evolved throughout the years. This evolution was based on the development of wind turbines with a horizontal axis with three blades and an upwind rotor seen as the best option to capture wind energy defined by the market.

C. DIVERSITY OF WIND TECHNOLOGIES AND POTENTIAL ROUTES

Wind resources are variable by nature. The turbine must be designed in such a way that it will withstand diverse climates. Turbines convert wind energy with their propeller-like blades. As the wind blows, a low-pressure air pocket pulls the blade toward it, turning the rotor (lift). The force of the lift is stronger than the wind's force against the front side of the blade (drag). Therefore, the spin movement is due to this lift and drag combination. Gears increase the rotation of the rotor from about 18 revolutions a minute to roughly 1,800 revolutions per minute, allowing the generator to produce AC electricity. The controller maintains the rotor speeds to avoid damage through high winds. A continuous wind speed measurement is required for this purpose. In emergencies, a brake stops the rotor mechanically, electrically or hydraulically (US DOE 2014). The adaptation of the technologies to local conditions is currently one of the main elements driving innovation.

The adaptation of wind technology to local conditions increases productivity for several reasons. One of them is due to increasing capacity factors. The annual capacity factor is the amount of energy a plant produces over the year divided by the amount of energy that would have been produced at full capacity. For wind turbines, capacity factor is dependent on the wind resources, its technical availability and the size of the generator in comparison to the length of the rotor blades. Long blades improve the capacity factors, while curtailments reduce it. Most wind power plants operate at a capacity factor of 25-40%.⁵⁸

Other incentives for innovation in wind technology are offshore turbines as they often have higher capacity factors, however, costly adaptations to the system are necessary (such as the interconnection to the transmission system).

D. INDUSTRIAL VALUE CHAINS

We can divide the wind energy chain into three groups: upstream (the production side chain of equipment), downstream (the chain of deployment and related services of wind farms) and complementary activities (important activities that are not in the main line of the value chain). The upstream comprises the raw materials, manufacturing of equipment, components and subcomponents (blades, towers, generator, etc.). The downstream activities comprise the project planning, procurement, equipment transportation, installation, service provision (logistics and operations), grid connection, O&M and dismantling at the end of its lifetime. The complementary services comprise R&D, certification and software development.

» Upstream

The upstream comprises raw materials, manufacturing of equipment, components and sub-components (blades, towers, generator, etc.).

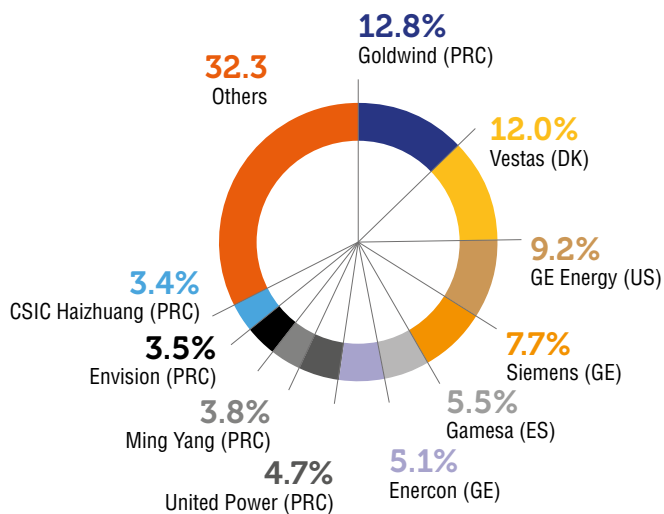
On the other hand, the manufacturing branch comprises manufacturers of wind turbines and their main suppliers. Wind turbine manufacturers often outsource a large number of components to assemble them.⁵⁹ The production of wind turbines is dominated by large OEM (Original Equipment Manufacturers) companies (Podcameni 2014). Despite the similarity between wind turbine models produced, differences in some essential components significantly alter the performance of the machines. OEMs can produce much of the equipment – or outsource some components such as shovel and tower – but they are always responsible for wind turbine projects and design, component integration and software.

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58. In 2014, Brazil presented a stunning average capacity factor of above 45% for onshore wind, while Germany and Denmark have around 25% and near 30% respectively (IRENA 2016b).

59. Wind turbines can be built in various sizes and configurations. They use a variety of materials, where the most relevant materials are steel, glass and carbon fibres, resins, core materials for blades, permanent magnets, copper, and aluminium. Steel is the most used component in wind turbines, being present at the tower (over 90% of its weight), nacelle (around 90%) and blades (over 10%). Fiberglass and other resins are used in blades of the wind turbines (over 80% of its weight). Copper is used in the generator, transformer, nacelle machinery, gearbox, and cables; while aluminium is used in rotor hubs, gearboxes, transformers, housings, cables, etc. (Podcameni 2014; Tolmasquim 2016; Narbel, Hansen, and Lien 2014)

The top wind turbines suppliers (see Figure 40) show the importance of Chinese firms, the biggest producer of wind turbines, but also show a dispersion of wind producers. More than 32% of suppliers' produce less than 3% of the turbines. The share of smaller suppliers has increased in recent years as it was around 28% in 2014. This can be explained by several reasons: the technology is mature; the costs of transport are relevant; the adaptation to local specificities plays an important role; and the industrial policies in some countries may offer relevant advantages to national production.⁶⁰

Figure 40. Top 10 wind turbine suppliers' market share in 2015.

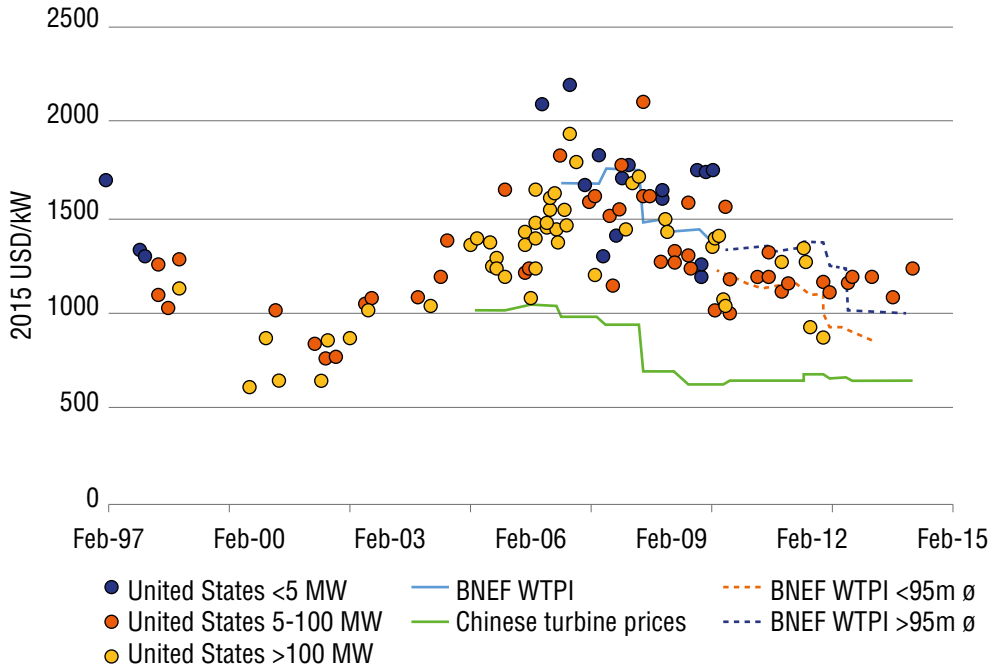


Source: Navigant Research (2016).

The main cost components for a wind project are the wind turbines (including towers and installation). The turbines costs may vary between 64-85% of total costs of onshore wind projects if it includes the installation cost (IRENA 2016b). However, excluding installation it reaches around 45%. Manufacturing costs of wind turbines and associated costs dropped substantially, while increasing the quality and size of wind turbines, it captured potential economies of scale. Wind turbine prices declined until 2004, when the downward trend was interrupted, and it rose again until 2008, due to significant increases in commodity prices (used to manufacture wind turbines) and a shortage of wind turbines. However, in recent years, wind turbine costs have stabilised, and they are currently decreasing again (as we observe in Figure 41).

60. Some countries adopt local content rules for wind power projects. Local content policies can vary widely, from considering labour and number or weight of domestic materials and equipment to domestic value added measures. Brazil has its wind local content regulation, which is linked with facilitating financial conditions through its development bank (Podcameni 2014; Ferreira 2017; Johnson 2016)

Figure 41. Wind turbine prices (1997-2016).



Source: Wisser and Bollinger, 2015; CWEA, 2013; BNEF, 2016a; GlobalData, 2014

For offshore wind, the cost breakdown does not differ very much, even taking into account the fact that the total cost is much higher per installed capacity. Europe has promoted offshore units consistently, and is expected to achieve further cost reductions by gaining experience from adoption. Technological innovation will continue to improve energy conversion, reduce the cost of components; lower O&M needs and extend turbine lifespan. Manufacturing automation and standardisation can improve efficiency, while the search for larger markets and preserving high and constant wind speed sites will enjoy further economies of scale.

Offshore costs vary in accordance to: distance from shores, depth, geological and geographical specificities as well as weather conditions. It is expected that in the following years the industry will go beyond its current averages of 22.4 m of depth and 32.9 km distance from shores (Europe). The base represent between 20-25% of most offshore European wind projects. With the development of larger turbines cost-reductions are expected for the near future.

» Downstream

Owners of wind projects are commonly utilities, corporations, independent power producers (IPPs), private companies (for self-consumption), income funds, and communities. The trend towards non-utility entities investing in wind energy continues.

When considering the service related activities, at the initial stages of a project, engineering services companies are responsible for developing the project and planning the wind farm. These companies carry out initial surveys of wind data and measurements at a selected site, define the layout of wind turbines, and prepare technical-economic feasibility studies as well as the basic design. The engineering companies also participate in the implementation of a wind farm (soil survey, foundations project, wind farm access project, substation project, environmental monitoring and studies to integrate the system into the power grid). There are also companies engaged in the transportation, installation, maintenance, repair of machines and equipment. The transportation and assembly of the equipment are usually the responsibility of the manufacturers, who can outsource these services through specialised firms (Podcameni 2014).

Components transportation is often a big challenge to manufacturers and entrepreneurs. The main concern is to move increasingly bigger components to their destinations, with existing transport infrastructures. Curves, tunnels, slopes and legal transport circulation restrictions are challenges faced by wind projects. Solutions such as local factories and inclusion of these constraints in the equipment designs and deployment are becoming more and more common.

When compared with other energy technologies (such as fossil fuel, nuclear or hydroelectricity), wind farms construction can be classified as relatively quick and with low interference with the environment and local communities.⁶¹

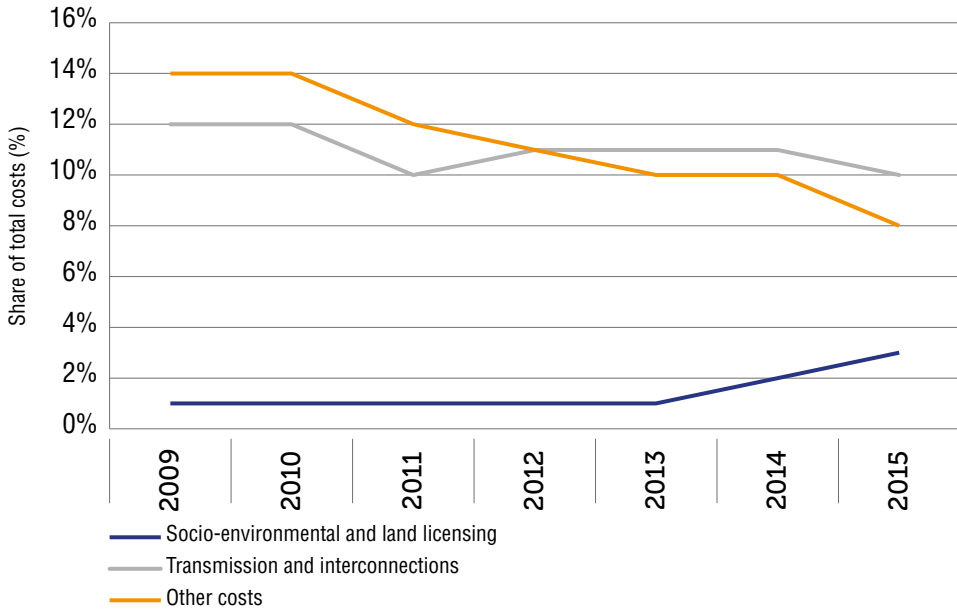
In addition to the wind turbine costs, there are other relevant costs to be taken into account, such as the socio-environmental and land licensing actions, transmission and interconnections costs, as well as other direct and indirect costs.

In Brazil, these costs can account for 21% to 27% of total cost of the project. The fall in equipment costs has been accompanied by a similar drop in the major portion of project items. However, socio-environmental constraints began to increase costs given the increasing complexity of socio-environmental studies and programmes related to the environmental licensing process.

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61. Its construction does not require a massive labour mobilisation as in the civil work of other generating units.

Figure 42. Evolution of the share of onshore wind costs in Brazil.



Source: Tolmasquim (2016).

According to IEA, 2015, country-specific policies are a major part of BoS costs. Construction costs and the specific topography (or geographical and maritime) are also country-specific and are a major part of the project costs.

» Complementary activities

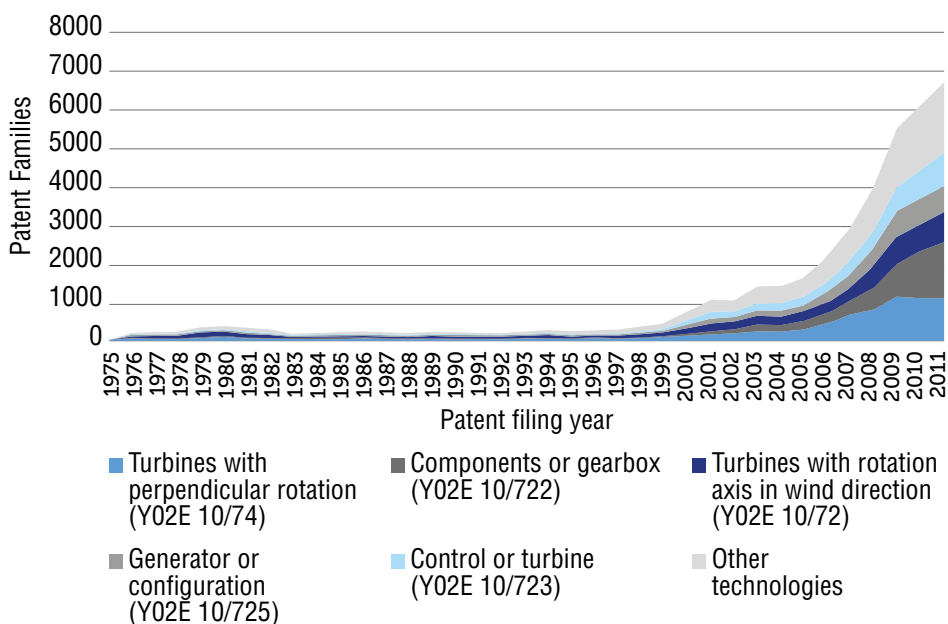
Renewable energy sources (excluding hydro power) were essentially developed since the 1970's. This puts emphasis on innovation and therefore on patents. There is a strong correlation between the growth of patent filings and a larger deployment of renewables, especially relating to wind and solar PV (IRENA 2013; UNEP 2015). Nevertheless, even though the patent filings for climate change mitigation technologies are dominated by renewables, solar PV accounts for only 1% of patent filings of renewables, whereas wind accounts for 30% (UNEP and EPO 2014). Brazil appears as the most important country in terms of patents in Latin America and the Caribbean, with over 50% of all climate change mitigation technologies patents filings (over 0,5% of the global patent filings in this category). Mexico finishes as a close second.

According to Helm, Tannock, and Iliev 2014, out of the four areas analysed (biofuels, solar thermal, solar PV and wind), wind energy is currently the most mature, with a 27% average

annual growth rate in global patent filings in the period 2006-2011, and 23% in all patent families filed from 1975 to 2011, with almost 70,000 patent applications. An indicator of the maturity of this sector is the fact that, among the top 20 technology owners, there are no universities or public sector research institutions. The patent offices of the United States, Europe⁶², Korea and Japan account for 40% of all patent filings, whereas China accounts for 30% of the total. According to the authors, "... the multinational composition of the top technology owners suggests that a number of international corporations likely use China as a manufacturing base and therefore find it useful to file patents in China." (Helm, Tannock and Iliev 2014, 7). However, Chinese players are starting to gain more market shares. This indicates that China is an important manufacturer of wind energy related technology, although Europe and the United States remain key players regarding innovation and the number of projects.

Unlike all other renewable technologies, wind increased the concentration of its intellectual property among the top 20 companies from 1975 to 2011, being "...likely indicative of the relative maturity of wind technologies compared to technologies in the other spaces" (Helm, Tannock, and Iliev 2014, 8). Its major focus of innovation is on incremental innovation, solving turbine-related, software and control issues. A large portion of R&D is allocated to offshore wind; however, it largely uses technology reminiscent of onshore wind projects adapted to offshore purposes. Probable frontiers are micro-wind solutions for urban environments (especially using vertical axis turbines), floating and underwater turbines.

Figure 43. Technology trends in wind patent by component.

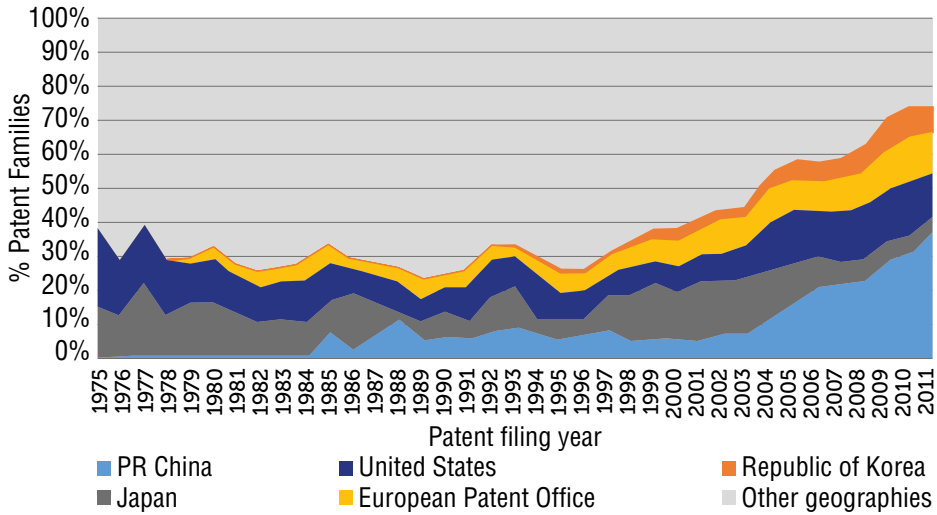


Source: (Helm, Tannock, and Iliev 2014, 29)

62. Germany alone accounts for 9% of the total, being the highest-ranking European country in this technology.

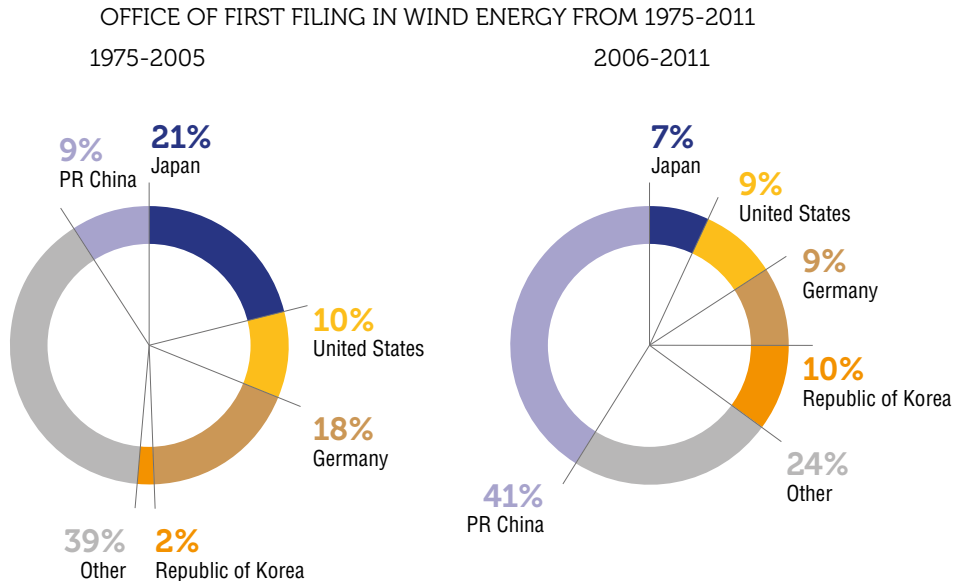
The high relative numbers of European patent filings indicates that Europe remains a major market and a base of operations for the top companies in the industry (Helm, Tannock, and Iliev 2014). This confirms the statement given by (Podcameni 2014) that large (European and North-American) multinationals in this field still see their home market (Europe and United States) as an important revenue source with strategic importance attributed to them.

Figure 44. Technology trends in wind patent by region



Source: (Helm, Tannock, and Iliev 2014, 29)

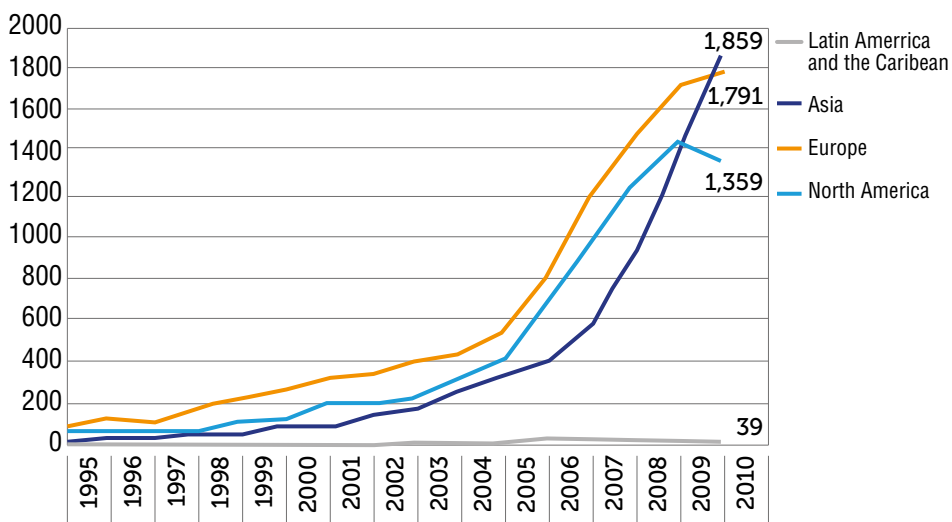
Figure 45. Technology trends in wind patent office



Source: (Helm, Tannock, and Iliev 2014, 29).

According to Cleantech Group (2016), wind energy patents in the United States patent office saw a steady rise from the early 2010's to the mid of the decade, after which it remained relatively constant. In turn, Latin American countries still face obstacles in developing clean energy technologies, despite possessing unique natural endowments that usually challenge and stimulate innovation driven research efforts. According to Miller and Viscidi (2016), clean energy innovation in this region faces a lack of access to capital, inadequate government incentives as well as a lack of industry-academia ties. Moreover, most of the researchers file patents just in their countries, reducing the range of opportunities to protect and market their inventions abroad. From 1995 to 2011, the region has 245 patent applications for renewable energy generation technologies within the Patent Cooperation Treaty (PCT); from which 59% came from Brazil, 19% from Mexico, 6% from Chile, 5% from Argentina and other 9% from Colombia, Costa Rica, Peru, Ecuador, Venezuela and Guatemala.

Figure 46. Patent application for RES



Source: MILLER & VISCIDI, 2016

Considering the funding for renewables in EU and LAC discussed in the first part of this study, we observe that, contrary to the EU, LAC has no structured funding scheme or programs dedicated to RES research and development. The role of Brazil as the regional leader in wind patents can be explained (at least partially) by industrial policy associated to BNDES funds. The local content restrictions to access the subsidized BNDES oblige firms to install at least parts of the manufacturing process in Brazil, meaning both costs and benefits for the respective companies. Unfortunately, there is no clear evaluation of the policy costs and benefits for RES; however, until now it seems that they have been adapted more toward wind energy features than to solar. This can be explained by several factors, among them the difference of technology maturity, the highest concentration of the commercial solar PV technology, and the higher transportation cost of wind generator (especially towers and blades). (Podcameni 2014; Ferreira 2017; Hochstetler and Kostka 2015)

4.2.2 Key players in the EU and LAC

The wind industry has evolved overtime guided by technology and policy stimulus. Since the 1980's, government incentives and the consequent technological development of wind turbines allowed a consolidation of the industrial activity of wind turbine production. Large manufactures such as Vestas, Enercon and Nordex emerged in Germany and Denmark. One decade later, Gamesa and Suzlon were created in Spain and India. In the 2000s, General Electric (GE) and Siemens as a move towards diversification, started to produce wind turbines, and new companies emerged, supported by public policies and growth of markets. It is the case of Chinese companies such as Sinovel, Goldwind and Dongfang and the Argentine Impsa (Podcameni 2014).

Besides manufacturers, developers are increasingly important in wind projects. Large utilities and generators also play a role integrating wind energy into the system. They realised that wind power is an option for diversification and portfolio expansion, which led to them becoming the main investors in wind farms. Table 12 shows the largest wind asset owners globally. It is remarkable that several European companies in this rank lead the world's wind industry together with Chinese and North American companies.

Table 12. Top 25 global asset ownership ranking by cumulative wind capacity 2015.

| Rank | Companies | Country* | Type |
|------|-----------------|----------|----------------------------------|
| 1st | Guodian | China | Power Producer |
| 2nd | Iberdrola | Spain | Utility power |
| 3th | Huaneng | China | Utility power and gas |
| 4th | NextEra | USA | Utility power |
| 5th | Datang | China | Power Producer |
| 6th | Huadian | China | Power Producer |
| 7th | CGN | China | Power Producer |
| 8th | EDPR | Portugal | Power Producer |
| 9th | SPIC | China | Power Producer |
| 10th | Shenhua | China | Power Producer |
| 11th | Acciona Energia | Spain | Power Producer |
| 12th | EDF | France | Utility power |
| 13th | Enel | Italy | Utility power |
| 14th | BHE | USA | Power Producer |
| 15th | E. ON | Germany | Utility power and gas |
| 16th | CR Power | USA | Power Producer |
| 17th | Three Gorges | China | Power Producer |
| 18th | Invenergy | USA | Power Producer |
| 19th | SunEdison | USA | Power Producer/solar manufacture |
| 20th | NRG | USA | Utility power |
| 21th | Tianrun | China | Power Producer |
| 22th | RWE | Germany | Utility power and gas |
| 23th | Engie | France | Utility power and gas |
| 24th | Pattern | USA | Power Producer |
| 25th | Duke | USA | Utility power and gas |

*European companies in grey
Source: Own elaboration.

Key players in the European Union

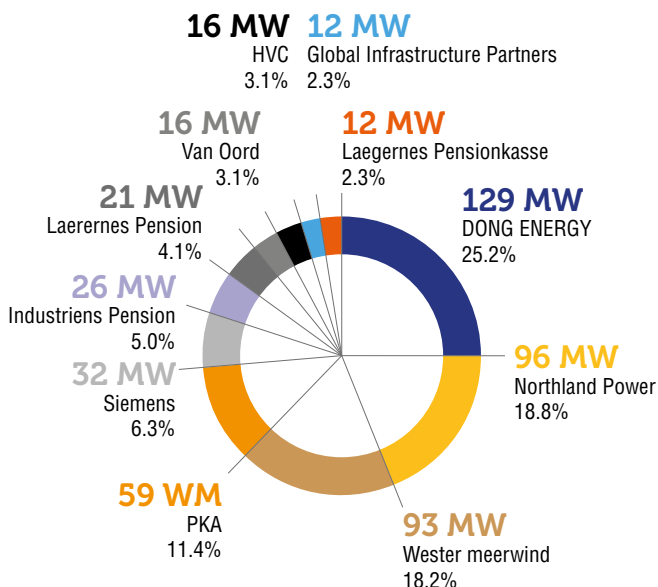
During its formation phase, the wind industry was concentrated to a few companies, - mostly European turbine manufactures. As the industry evolved and globalised, there was a shift of asset ownership toward other players, either European or multinational companies.

As indicated in Figure 47, European manufacturing pioneers and leaders are currently competing with Chinese and North American companies, and as volumes increase, technology and cost competitiveness will remain critical factors to stay in the market. European turbine manufacturers currently leading in the region include **Vestas, Enercon, Gamesa, Siemens, Nordex** (acquired by **Acciona**), **Alstom** (energy business acquired by **GE**).

Regarding ownership, the European wind market can be divided into manufacturers, utilities, independent power producers (IPPs) as well as institutional and private investors. Figure 47 shows the diversity of players participating in new offshore projects. Power producers are the major developers; however, infrastructure and pension funds account for 25.2%.

The - mostly pan-European - utilities are increasing their participation in this market and they operate mainly in their home countries, but also expand investments around the region. Examples are companies such as **Iberdrola, E.ON, EDF, ENEL, RWE** and **Engie**.

Figure 47. Offshore wind developers' share of new grid connected capacity in Europe - first half 2016 (MW)



Source: <https://windeurope.org/wp-content/uploads/files/about-wind/statistics/WindEurope-mid-year-offshore-statistics-2016.pdf>
 Accessed June 1st 2017

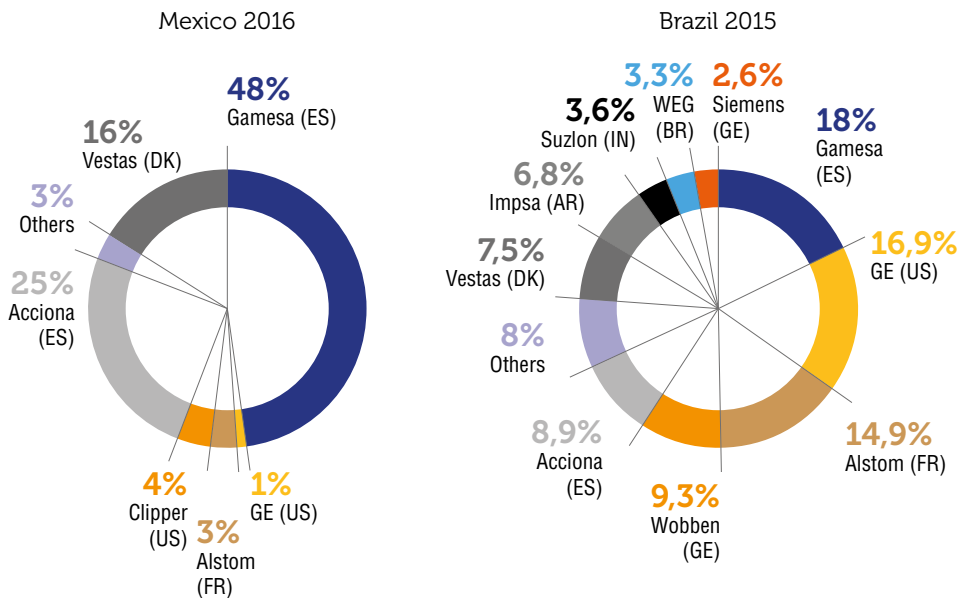
Key players in Latin America and the Caribbean

Most of these multinational players are also active in Latin America and the Caribbean. European companies participate in renewable development in the region by creating local subsidiaries and/or through Special Purpose Vehicles (SPV). European companies and manufacturers that are present in the region are: the Spanish **Acciona, Gamesa, Iberdrola, Iberolica, Elecnor, Aldesa**; the Danish **Vestas**; the Italian **ENEL**; the German **ABO Wind, SOWITEC, Siemens, Wobben Enercon, Wpd AG**; the French **Engie, Voltalia**; the Portuguese **EDP**; and the Hungarian **Callis**.

According to ECLAC (2007), major Iberian companies have invested in the power sector throughout the LAC region. For instance, companies such as **Endesa, Iberdrola** and **EDP** have a long-standing history in Argentina, Colombia, Peru and Brazil. Particularly in the wind sector, other European companies can seize opportunities to interact and invest in the region.

In Mexico, as Figure 48 shows, Europeans such as Acciona, Vestas, Gamesa and Alstom (now acquired by the American GE) compose the bulk of the wind-installed capacity in the country. In turn, in Brazil, the largest wind market in the LAC region, there is a more diverse pool of manufacturers participating. However, the Europeans have a leading role in the country with over 60% of the wind-installed capacity.

Figure 48. Wind Energy Installed Capacity in Mexico and Brazil by Manufacturer

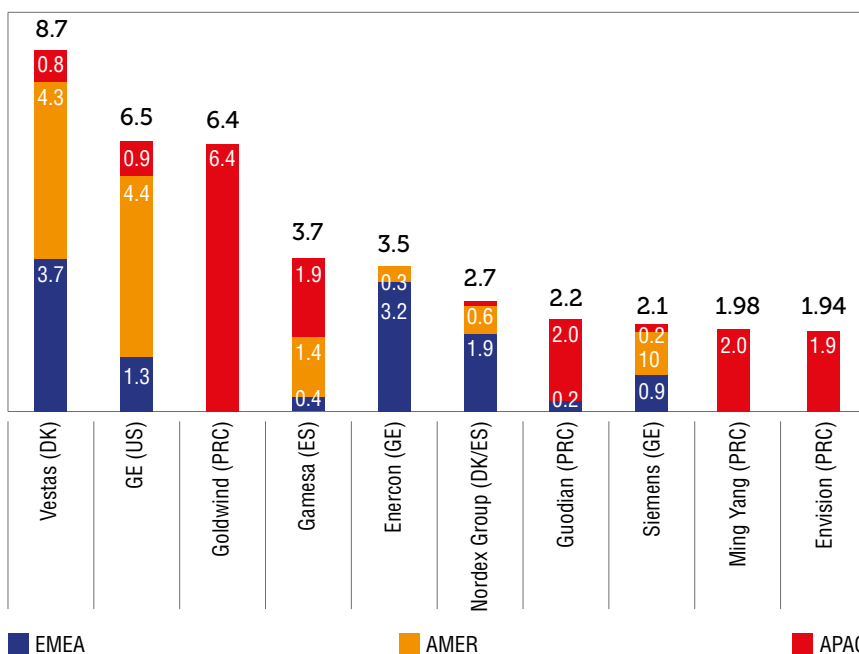


Source: Elaborated by the authors, data retrieved from Brasil Energia e Santiago & Sinclair, LLC Cf. <https://public.tableau.com/profile/gustavo.gaudarde#!/vizhome/EnergiaelicanoBrasil/ParquesElicosnoBrasilv2> Accessed June 1st 2017 And: <http://carlosstjames.com/renewable-energy/why-three-european-turbine-manufacturers-dominate-mexicos-wind-energy-sector/> Accessed June 1st 2017

Players in both regions

When looking at the manufacturer side in both regions, one can see a fairly concentrated global market, where European pioneers have been challenged by Chinese newcomers, especially if they aim to participate at the Asia Pacific markets. However, we observe the importance of America for Europeans companies such as **Vestas**, **Gamesa** and **Siemens** are still important (see Figure 49).⁶³

Figure 49. Top 10 onshore wind turbine manufacturers by selling region 2016 (GW)



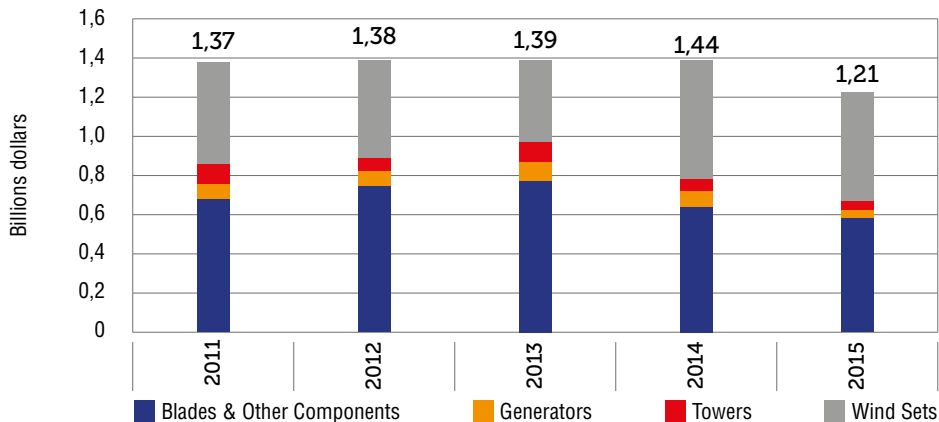
Note: AMER – Americas; EMEA – the Middle East and Africa; APAC – Asia Pacific and Japan. PRC – People's Republic of China, GE – Germany, DK – Denmark; US – The United States; ES – Spain. Source: Bloomberg NEF 2016 Cf. <https://about.bnef.com/blog/vestas-reclaims-top-spot-annual-ranking-wind-turbine-makers/> Accessed June 1st 2017

As far as trade flows between Europe (EU-28) and LAC countries are concerned (Figure 50), we find that Europeans exported about 1.2 billion dollars in 2015 to LAC, which accounts for 3.4% of global wind components trade. European exports focused on blades, components and wind electric generating sets. In 2015, Spain led the European exports to LAC with 49% of the amount traded, followed by Germany (21%) and Denmark (11%). Mexico was the main importer with 40% of total amount traded, followed by Uruguay (22%) and Brazil (19%). The relatively low Brazilian import rate can be explained by the local wind industry promotion policy. On the other hand, in the case of installation of wind components in Brazil, there are several indications that flow of knowledge happened besides the trade in components, as shown by the case studies of Podcameni (2014).

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63. Unfortunately, we do not have the data to identify the LAC participation.

Figure 50. EU-28 exports to LAC by Wind Components



Note: HS Code Wind Power Industry components (USITC 2009)

730820 - Towers and lattice masts (Towers)

841290 - Other parts of engines and motors (Blades & Other Components)

850164 - AC generators of an output exceeding 750 kVA but not exceeding 10,000 kVA 2.4% (Generators)

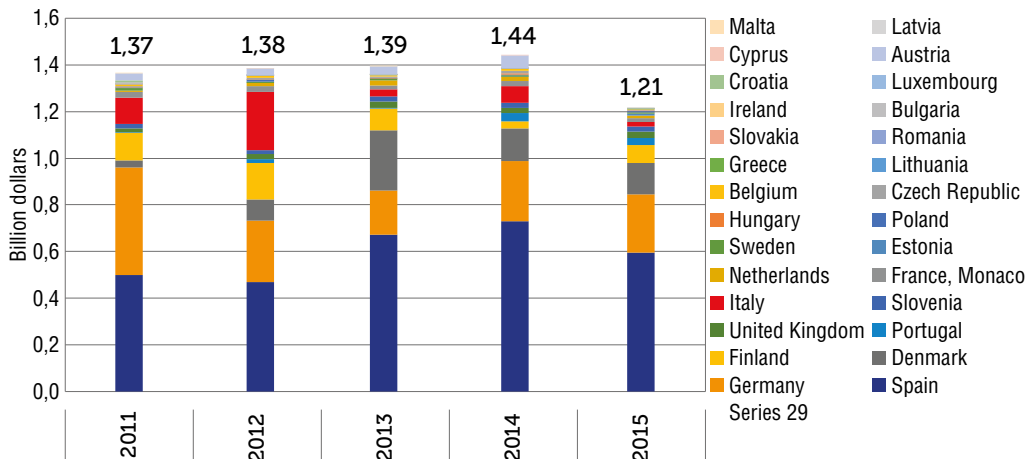
850231 - Wind-powered electric generating sets (Wind Sets)

850300 - Other parts of generators (Blades & Other Components)

Source: Elaborated with data retrieved from (UN 2017)

Regarding the LAC exports to EU-28, Brazil is the leading exporter with 95% of the total amount exported in 2015, which totalled almost 100 million dollars (0.3% of wind components traded internationally). LAC's main export components were blades (99%), imported mostly by Germany (78%) and Portugal (12%), as we can see in Figure 51. The Brazilian export and interaction with EU countries is probably also a result of the interaction of EU and Brazilian companies in the process to implement national manufactures to comply with the local content policy of BNDES in Brazil.

Figure 51. EU-28 exports to LAC by Country



Note: HS Code Wind Power Industry components (USITC 2009):

730820 - Towers and lattice masts (Towers)

841290 - Other parts of engines and motors (Blades & Other Components)

850164 - AC generators of an output exceeding 750 kVA but not exceeding 10,000 kVA 2.4% (Generators)

850231 - Wind-powered electric generating sets (Wind Sets)

850300 - Other parts of generators (Blades & Other Components)

Source: Elaborated with data retrieved from (UN 2017)

4.2.3 Case studies

Brazil – the case of Osório

According to IRENA (2017), Brazil is the Latin American leader in terms of investments in on-shore wind power generation. At the time of completion (2007), the Osório wind farm complex was the biggest wind farm in Latin America and the second in the world. The project is owned by **Enerfin** (subsidiary of the Spanish company **Elecnor**) with a share of 90%, the turbine manufacturer **Wobben Windpower** (subsidiary of German company **ENERCO GmbH**) with a share of 9%, and the Brazilian **Consultores Internacionais Brasil** (CIP Brasil) with 1%. For this project, a special purpose entity (SPE)⁶⁴ called Ventos do Sul Energia was created, which is in charge of developing the Osório wind farm.

This big wind farm complex has the same name as the city of Osório where it was built. The city of Osório already disposed of the necessary infrastructure and power connections to develop the project. The project was quite a complex operation, as it required the construction of significant logistical infrastructure (e.g. 24 kilometres of roads) to transport large wind equipment. This wind farm has a total installed capacity of 150 MW, with 75 wind turbines, 70 meters of diameter and turbines with 2 MW capacity each. The blades were produced in the city of Sorocaba (São Paulo state) and turbines were imported by **Wobben WindPower**. It was built within 15 months, with a total cost of around R\$670 million (~ US\$344 million considering 2007 exchange rates) and R\$800 thousand (~US\$410 thousand) as environmental obligations. The average capacity factor reached 34%.

The **BNDES** structured a financing scheme of 69% of the total investment, with R\$105 million directly disbursed by the bank and the other R\$360 million transferred through a consortium of banks (**Banco do Brasil, Santander, ABN Amro Real, BRDE Caixa do Rio Grande do Sul** and **Banrisul**). It was carried out within the PROINFA program.

Regarding the companies involved, in 2015, the Spanish group **Elecnor** established the subsidiary **Enerfin** in the city of Porto Alegre (Rio Grande do Sul state). However, **Elecnor** is active in Brazil since 1999.

In turn, **Wobben Windpower** was created in 1995 by the German company **ENERCON**. The subsidiary was the first producer of wind turbines in Brazil, both in order to provide for local supply and for export. **Wobben** has three manufacturing plants, one in the city of Sorocaba/São Paulo (for blades and generators), one in the city of Pecém/Ceará (blades) and another one in Juazeiro/Bahia (towers). These projects are a consequence of the **BNDES** local content policy, and they explain the current exportation of blades from Brazil to Germany. The investment involved in these projects is an illustration of the kind of technological and financial flows established in the interaction between both regions. The projects are also an illustration of a joint organisation of wind projects based on the construction of SPE to isolate the risk of projects, and they were also adapted to the existing financing instruments offered by **BNDES** to RES.

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64. SPE is a legal entity created to fulfil narrow, specific or temporary objectives. SPEs are typically used by companies to isolate the firm from financial risk.

Panama – the case of Penonomé

As the largest wind farm in Central America, Penonomé possesses almost all the wind capacity in Panama. The project was organised by several agents such as: the UEP Penonomé I S.A. (UEP is an acronym for Unión Eólica Panameña, which was created by the Spanish **Unión Eólica Española**), UEP Penonomé II S.A. (a SPV which became subsidiary of the Dominican Republic **InterEnergy Holdings**), the Chinese wind turbine manufacturer **Goldwind Global** and the **International Finance Corporation** (IFC – a member of the World Bank Group).

The Penonomé Wind Farms were developed in four phases. The first phase (called Rosa de los Vientos) cost around US\$140 million and was financed and built by **Goldwind**, with a 55 MW capacity and started operating in 2014. The construction and operation of the second phase (Marañón) and third phase (Portobello) reached costs of about US\$430 million, being carried out by UEP Penonomé II and financed through green bonds managed by the **IFC**, adding 215 MW (IFC, 2016). They are 106 wind turbines with 2,5 MW capacity each, 52.2 meters long blades, and towers of 90 meter high. The fourth and final phase is estimated to cost US\$120 million, giving the Penonomé Wind Complex a total installed capacity up to 337.5 MW⁶⁵. This case is also an illustration of the relation between technological choices and funding: the first phase of the project was financed by the wind turbine manufacturer. It can be seen as a strategy, and it is an illustration of different projects pushed by manufacturers. After that, the **IFC** joined as a key player because the project required a significant amount of capital, which could be an obstacle if it depended on the local commercial banks. On the other hand, the support of the **IFC** enabled and demanded “a comprehensive environmental and social evaluation which guided it in following internationally-recognised standards and adhering to high levels of environmental and social performance”⁶⁶. It also illustrates the role of multilateral financial organisations in LAC, and how they are related to specific projects and financial structures.

According to Moody (2015) **InterEnergy Holdings** acquired (for US\$425mn) the 215MW Penonomé wind project in the late stages of development, and prior to construction. To finance the project, **InterEnergy** raised US\$100mn in bridge financing from **Banco Espirito Santo de Inversión**; and subsequent to the acquisition, **InterEnergy** secured US\$284m in senior secured and US\$16mn in subordinated 17-year project debt financing from the **International Finance Corporation** and a syndicate of development banks and commercial lenders. The long-term lenders, led by the IFC, focused on four key risks: **Goldwind's** direct drive turbine technology (this was the first international financing by development banks for this wind turbine technology), the wind resource in Panama, the interface risks among the commercial contracts (there was no wrapped EPC contract; **InterEnergy** managed the sequencing between turbine supply, transportation, and civil works contracts), and the debt

65. Source: Molen Services <https://molenservices.com/penonome-windfarm>
http://www.ifc.org/wps/wcm/connect/30378942-042b-4744-b794-4cd448a331ff/2StoriesOfImpact-wind-Penonome_Panama+%28revised+7-27%29.pdf?MOD=AJPERES

<http://laestrella.com.pa/economia/parque-eolico-penonome-generara-270-2015/23847924> (All accessed June 1st 2017)

66. See: http://www.ifc.org/wps/wcm/connect/30378942-042b-4744-b794-4cd448a331ff/2StoriesOfImpact-wind-Penonome_Panama+%28revised+7-27%29.pdf?MOD=AJPERES Accessed June 1st 2017

service coverage given the project's power supply agreements (PPAs for 165MW for 15 and 20 years, and 50MW on a merchant basis).

However, according to Moody (2015), there are clear differences between commercial and development bank lending. A first difference is related to the period: DBs provide longer tenor financing – up to 17-18 years – whereas commercial bank lenders only grant around 10-12 years. Secondly, development banks will selectively provide mezzanine debt at the project level, in order to enhance the amount of the project's contingency; the combination of longer tenor and higher amounts of debt financing mobilised by the development banks was sufficient to make this a viable project for **InterEnergy**.

United Kingdom – the case of London Array

As the largest wind farm in the world, this offshore wind farm is an example for the innovation frontier associated with offshore power generation. It was developed and owned by the Danish company **Dong Energy**, the German **EON** and **Masdar** company from the United Arab Emirates, and is operated by **Dong** and **E.ON**, using Siemens turbines. The owners are E.ON with 30%, the **Caisse de Dépôt et Placement du Québec** (Canada) with 25%, **Dong Energy** with 25% and **Masdar** with 20%.

The project is located 22 kilometres (km) from British shores and it has 175 wind turbines with 3.6 MW each, with a diameter of 107 metres and towers of 87 metres height. It has a capacity factor of 45% due to great wind resources offshore. The total installed capacity is 630 MW and it started operating by 2013. The total investment was £1.8 billion and was partially financed through the **European Investment Bank** (EIB) and the **Danish Export Credit Fund** with £250 million. We can also observe the relation between the funds' source and the companies' nationality as well as the importance of the EIB in these European projects.

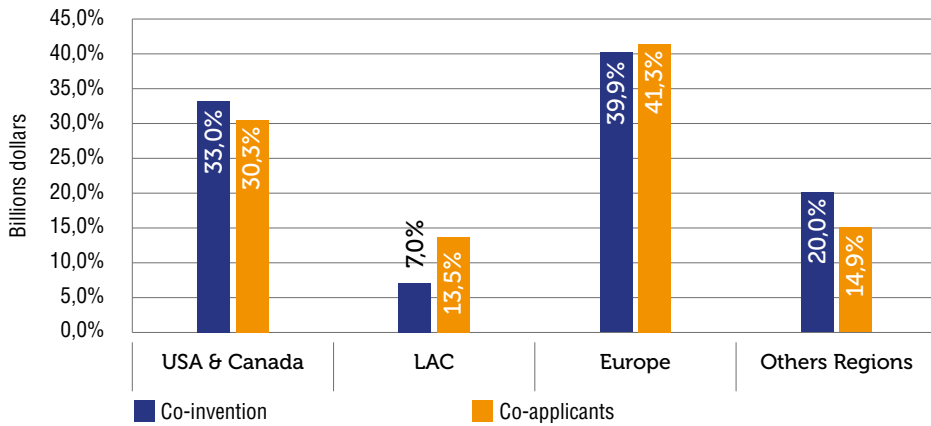
4.3 Analysis of patents flows between regions

According to UNEP & EPO (2014), from 1995 and 2010, patent filings related to Climate Change Mitigation Technologies (CCMT)⁶⁷ in LAC countries increased considerably, especially regarding patents from clean energy technologies (includes renewables and energy storage). However, they represented only 2.8% of the world's global patent filings in this area.

LAC and EU countries present levels of co-invention, indicating international cooperation in R&D, and co-application, that are indications for technology transfer. From the sample analysed in UNEP and EPO (2014), see Figure 52, one can observe that Europe as a region had a closer relationship in CCMTs' R&D with LAC countries (representing around 40% of all patent filings in the period) than among LAC itself and North America (representing respectively around 13% and 33%).

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67. Climate Change Mitigation Technologies (CCMT) include: (i) greenhouse gas capture and storage; (ii) energy generation, storage and distribution; (iii) CCMTs relating to buildings; (iv) CCMTs relating to transport; (v) smart grids.

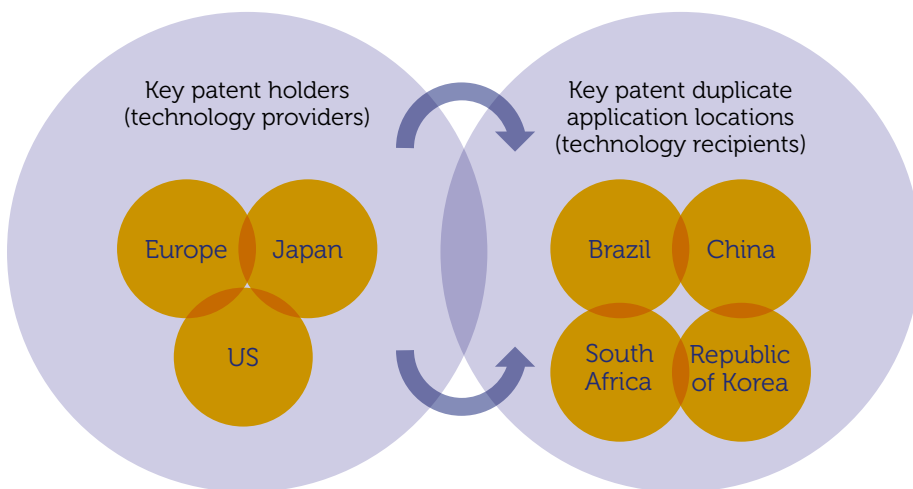
Figure 52. Share of Co-invention and Co-application Partners of CCMT's patent filings with LAC countries from 1995 to 2010.



Source: Elaborated from CCMT patent filing sample of (UNEP and EPO 2014)

The relation between LAC and Europe, however, is not balanced as IRENA (2013) explains, because the key patent holders in RES technologies are the US, EU, and Japan (see Figure 53). On the other hand, there is a movement pushed by local content policies to patent duplicating application locations in developing countries, such as Brazil, South Africa, South Korea and China (especially the last one).

Figure 53. Trends of technology transfer of solar PV and wind energy from OCDE to developing countries.



Source: IRENA 2013

5. INTERACTION BETWEEN FINANCING AND TECHNOLOGY FLOWS

Two different technologies have been selected for a closer examination. On the one hand, wind power was introduced in LAC countries several years after its deployment in the EU. This may suggest that wind power was relatively developed when it began entering the LAC market. On the other hand, the technological trajectory of solar PV is thus far less established both in LAC countries and in the EU.

5.1 Solar photovoltaic power

We consider solar PV as a candidate for a counterexample of the idea that RES are infrastructure projects. LAC countries are good examples of market designs where technological risk is considered non-existent. However, if the technological risk does exist, the risk is allocated by market design, and the allocation may not be efficient.

In principle, the projects are not far from the ones involving wind power. They have revenue streams with low risk, together with several other instruments to facilitate investment.

We should consider that the solar PV chain consists of three abstract stages:

- Project design – it tends to be a specialised activity, which is often adapted to the activities of a utility. There is an increasing number of companies helping prepare solar projects in order to facilitate their financing.
- The solar panels – the stage where most innovation activity takes place. As shown in Figure 53, most technological activity takes place in Asia, having recently increased in the EU. Technological activity in LAC countries is still marginal, but it begins to appear in cooperation clusters.
- Installation – relatively less sophisticated in terms of technology, installation is often performed locally.

Both in the EU and in LAC countries, we find two types of players:

- Utilities (e.g. **EdF** or **Enel**).
- Solar panel developers (e.g. **ACS**).

In addition, the main players in the EU are utilities. Consequently, when considering technological flows from the EU to LAC countries, the main channel will be projects undertaken by utilities. The question is whether financing instruments found within the market affect technological flows.

Manufacturers of solar panels are increasing their presence in LAC countries. This may be viewed as a consequence of a secured revenue stream: as signing a PPA gives them the possibility to find financing sources, they see the opportunity to introduce their technology in LAC countries.

We observe utilities in the EU beginning to invest in solar panels, changing from an initial tendency of distributed PV to an increasing importance of centralised PV in countries in the East Europe, Spain and UK. However, considering technologies and R&D, EU investors focus on new solar panel technologies. As consequence, we observe (in some projects promoted by these companies) the use of less traditional PV solar technologies (e.g. **ENEL** investment in new technologies in a Chilean project). This may constitute a signal of a potential technological risk.

Bringing together both arguments, we may point to the consideration that the LAC market design is bearing a technological risk. The reasoning for this would be as follows: in order to facilitate investment, LAC countries eliminate risk associated with revenue streams; but as the technological risk does exist, consumers ultimately absorb such risk.

In summary, the comparison between the EU and LAC strategies shows pros and cons of both schemes. The LAC strategy has proved its strength when investments are similar to infrastructure projects (particularly if technological risks are low). However, when the risk is not negligible, and assuming that investments are similar to infrastructure projects, this may be very costly.

5.2 Wind power

Several features place wind power projects in the EU close to the concept of an “infrastructure project”. For instance, they tend to enjoy several revenue-enhancing instruments put in place either by Member States or by the European Commission. In the EU case studies we have analysed the use that these projects make of grants coming from European programmes, such as the EEPR. Besides, they tend to benefit from EIB loans. Simultaneously, in the LAC case studies in LAC, we observed strong reliance on project finance (in some cases projects are financed through special purpose vehicles). Furthermore, some of these projects benefitted from development banks financing.

Therefore, even if initially projects in the EU (based on utilities corporate financing) and in LAC (based on project finance) were supposed to use different logics, they are in practice closer than expected. Because energy policies in place in the EU largely reduce technological risks, the characteristics of wind projects are similar to other infrastructure projects, hence they tend to use similar financing mechanisms.

In that sense, we can observe that reinforcing competition among several investors (utility and non-utility investors) is possible and may bring efficiency to financial decisions. This does not mean that choices regarding to the generation mix (energy planning) will be efficient as well, because the previous logic considers the choice of generation technology exogenous to the project.

6. CONCLUSION AND POLICY IMPLICATIONS

The transition to more sustainable energy systems has a variety of relevant implications for the EU and LAC countries. We have shown that, in order to develop renewable technologies, we need to take into account that the associated investment needs are significant and markets alone might not be sufficient to coordinate all actions to be taken. That is, special attention needs to be paid to the financing challenges faced by investment in these new technologies. This is especially true in developing countries, where financial markets are constrained.

Given the variety of investment conditions across countries, including different characteristics of financial markets, there is no one-size-fits-all solution. Nonetheless, this study aimed at drawing lessons from the experiences already implemented and identify fundamental elements of the way forward. In this context, we aimed at exploring the relationship between Latin America, the Caribbean and the European Union along two basic dimensions: (1) Studying the financing instruments that have been used in the European countries to promote renewable technology that could also be used in Latin American and Caribbean countries; (2) Studying mechanisms of cooperation between European and Latin American and Caribbean institutions (multilateral agencies and private companies), facilitating technological and financial flows.

The considerable needs for investment in the coming years will require attracting private capital to renewable energy projects. The European Union has been active in this field through the European Investment Bank. Its role has included special conditions for loans, and mechanisms to decrease the risks in traditional private financing instruments. Besides, several Member States have developed national financing instruments to promote renewable energy, as Feed-in-Tariffs, Quotas or Green Certificates. In that view, the design of adequate financing instruments to deal with the specific features of new renewable technologies have been key to the inclusion of renewables in Europe.

Experiences in LAC countries are less abundant. Most countries do not have specific financing mechanisms to help attract private capital, being multilateral institutions (such as the World Bank) the ones offering special funds. A notable exception is Brazil, where, historically, the main financing source has been its National Development Bank's (BNDES) special loans. However, recent constraints on the available funds have led to develop several tools based on using more private-oriented financing instruments (as infrastructures debentures).

This study focused on comparing experiences associated with the introduction of renewable energy and drawing meaningful lessons, either from LAC countries to the EU or the other way around. We find that:

- **Market design crucially affects the available financing mechanisms.** Two basic market designs can be identified. On the one hand, the “utility business model” is based on a firm that undertakes long-term investments (e.g. power plants) and recovers it by selling power through 1-2 year contracts. On the other hand, the “infrastructure business model” is based on selling power through long-term contracting (e.g. PPAs). In the last decade, policies to facilitate investment in RES projects have been converging to markets designs that implement the infrastructure business model. One important conclusion that can be drawn from the comparison between LAC countries and the EU is that the identification of required measures to develop RES is not the same. The initial market failure identified by the EU was the inefficiency in R&D efforts. To that end, measures were based on equity provision to aid in the R&D efforts. The need to complement incomplete capital markets is also a common view both in the EU and LAC countries. Nonetheless, risk mitigation can be achieved through several channels. We have identified two broad groups of targets: mitigating the risks of available financing instruments and mitigating the risks associated with projects’ revenue streams. Acting on revenue streams may limit significantly the number of available choices for the electricity market design. We have seen that, in LAC regions, market designs based on long-term contracts assume there exists a centralised planning effort, which might not be the case, or it may face coordination challenges. On the other hand, the EU choice of relying on more competitive electricity markets requires the existence of a quite efficient access to capital sources, which might not be always the case. In summary, this fundamental trade-off (long-term contracting requires planning, short-term contracting requires liquid capital markets) needs to be recognised. Although there are no silver bullets, the market design needs to be coherent in order to attract private investment for renewable projects.

- **The infrastructure business model implicitly assumes that the role of equity is relatively unimportant.** Utility business models are based on riskier projects (less available sources of finance) but eliminate the need for planning that characterises infrastructure business models. We observed in LAC countries a preference for mitigating as much as possible risks related to revenue streams to get as much competition as possible from different capital sources. Initially, the EU preferred to leave a less regulated market in order to benefit from competition among different suppliers, even if the diversity of capital sources was limited (not necessarily the volume associated with those sources). However, the EU is converging to the infrastructure-like market design for wind power. In both the EU and LAC, policies to facilitate investment in renewable technology projects are converging to the infrastructure business model. Nonetheless, not all RES technologies share the same characteristics. Policies may tend to translate wind power policies to all RES projects (considering them as infrastructure), but this decision may be associated with financing solutions that are not efficient. This challenges the adequacy of a convergence to a pure infrastructure-like market design.

- **The infrastructure-like market design might allocate technological risk to consumers.** Manufacturers of solar panels are increasing their participation in LAC markets. This may be viewed as a consequence of low risks associated with their revenue stream: as signing a PPA gives them the possibility to find financing sources, they see

the opportunity to introduce their technology in LAC countries. At the same time, this mitigated risk implies that investors are not facing technological risk, even if it exists. This risk is absorbed by the counterpart of the long-term contract, who is typically a regulated consumer.

- **If the technological risk does exist but it cannot be managed by equity investments** (from utilities and other business models), **it may create barriers for innovation.** Differently put, if the utility business model is discouraged, technological flows channelled through utilities will face difficulties.

Based on this evidence, we formulate a series of suggestions for action with the objective of facilitating the decision-making process in electricity industries.

- Formalisation of the decision-making process associated with the definition of a market design. This formalisation aims at increasing the efficiency of stakeholders' participation and the cost-benefit analysis of fundamental trade-offs. The EU has developed successful experiences in this regard, especially with the implementation of the measures associated with the Internal Energy Market. LAC countries, on the other hand, would benefit for an increased focus on discussing market design issues. This process should deal with a fundamental trade-off. When the infrastructure model is implemented, there is an implicit reliance on a "central planner", i.e. an authority in charge of determining the appropriate investment needs. The logic for this is that an infrastructure-based market design assumes competition in the procurement of electricity generation projects. However, the choice of the projects that the system needs is done exogenously by a planning authority. Correspondingly, from consumers' point of view, planning risks are typically absorbed by them when the infrastructure business model is implemented, so they need to understand whether it is worth absorbing planning risks in exchange for lower capital costs.
- Related to the previous point, we stress that the complete set of measures implemented in the electricity industry must be coherent. For instance, implementing a utility business model when the available financing sources are scarce will probably result in lack of investment, even if the electricity market is well designed. Analogously, implementing an infrastructure business model without proper planning institutions will also result in lack of investment.
- When the infrastructure model is chosen, the complexity of electricity projects needs to be tackled also from the financing viewpoint. The design of appropriate contracts is a fundamental element for a well-functioning market, as they allow the existence of long-term financing sources. The evidence presented in this study shows that difficulties in financing mechanisms can hamper the development of RES projects. In this context,

one of the main lessons is that securing cash flows is not necessarily the easiest way to de-risk electricity projects. Providing, for instance, guarantees and financial insurance is typically crucial in the creation of an infrastructure asset class. However, these financial instruments are difficult to find in illiquid capital markets. This suggests that the role of public administrations and multilateral institutions should be oriented to provide these kinds of products, and to reduce their role as lenders for electricity projects. These measures facilitate attracting private capital, avoiding the effect that cheap public funds compete against private sources of capital.

- If the choice is a market based on the infrastructure business model, an important role to be played by public and multilateral institutions is the structuring of complex projects for the private sector. Electricity projects are difficult to understand for many investors, and these projects share few characteristics with more liquid instruments for project finance. Hence, the regulatory activity should include in-depth discussions with the financial sector in order to implement a feasible contract. But, perhaps more importantly, there is a need for an expert in electricity projects. Consequently, with the aim of facilitating the participation of the private financial sector, one important role to be played by multilaterals is the structuring of these contracts. This means, on the other hand, that multilaterals need to be included in the decision-making process associated with the electricity market design.
- As shown in this study, the technological aspects cannot be disregarded. In particular, some policies may result in specific contract clauses that complicate financing the projects. For instance, Brazilian contracts include local content requirements, which are part of a local content policy towards RES technologies. These policies were developed for wind projects, and then translated directly into solar PV projects. We showed that the direct application of the wind's support framework led to unfeasible local content requirements that did not succeed in promoting PV solar technologies. Consequently, and along the lines of previous recommendations, industrial policies must be part of a wide cost-benefit analysis that involves all stakeholders.
- Moreover, the effects of market design on industrial dynamics must be considered. The previous recommendations assumed a market model based on long-term contracts. On the other hand, if the utility business model is discouraged, technological flows channelled through utilities will face difficulties. A more elementary question: is the infrastructure business model the preferred option for the electricity industry? Although the model facilitates financing, it also represents long-term commitments to technologies that may be obsolete before the contracts expire. Therefore, the planning activity plays a key role in the selection of the projects that should be financed. So, one basic question to be answered in the market design process is whether central planning deals with these issues efficiently, or the costs associated with central planning exceeds its advantages.

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