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Globalization in the wind energy industry: contribution and economic impact of European companies

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ABSTRACT

This paper explores the globalization of the wind energy industry with a focus on the contribution by European companies and their economic impact in the global wind energy sector.

The global wind energy industry is nowadays a tale of two worlds, China and the rest of the world. In the last five years, China installed between 37 and 48% of the annual world market, and it is all but closed to foreign companies. Consequently, Chinese manufacturers captured between 38 and 47% of the world market whereas European reached between 41 and 50%. European manufacturers led in the rest of the world, serving between 73 and 82% of that market. They localise production and supply chain in the main markets (e.g. India, Brazil, US) or in countries where producing for export is cost-efficient (e.g. China, Mexico). Turbine manufacturers enter new markets through joint ventures, technology licensing, establishing wind farm developing subsidiaries, facilitating access to finance, or by acquiring a local company.

Manufacturers help improve the capability of their suppliers and take them to serve new markets. Still, European turbine manufacturers maintain important manufacturing, sales and R&D centres in Europe, where they keep major procurement, supply chain and employment thus significantly contributing to its economy.

European developers also expanded into other markets, sometimes by acquiring and strengthening a local developer (this was generally the case in the US), sometimes by starting a subsidiary from scratch. They have been particularly active in the US and Latin America.

The European wind industry is a success story of worldwide reach that attracts jobs and growth for Europe. In order to support that this will continue to be so in the mid- or long-term future, the industry needs the support of European and national policy makers with consented, well-targeted actions.

1. Introduction

Globalization[1] has involved huge benefits for humankind, from health improvements to culture diffusion and economic growth [1]. In the latter aspect, globalization is to a large extent responsible for the economic growth of entire countries, e.g. Singapore or China [2,3]. However, where local companies could not compete with foreign companies on a level playing field, globalization has caused loss of jobs and a certain impoverishment locally [4].

The most important economic effect of globalization, other than reducing the prices for goods and taking people out of poverty, is probably the increase in trade. For example, between 1970 and 2002 imports as a ratio to world gross domestic product (GDP) increased from around 12% to above 24% [5]. Other economic effects include foreign direct investment (FDI), e.g. where foreign companies either acquire local companies or set up local branches or production facilities, and the financing of local investment with foreign funds as seen e.g. in offshore wind farms in the North Sea [6]. On the other side, a number of negative effects have affected how people see globalization, from changes in land use resulting in the destruction of forests to make room for cash crops [7] to the delocalisation of manufacturing to countries with lower labour costs and less-strict environmental regulations [8].

One interesting aspect of globalization, one that directly affects the object of this research, is the interdependence between innovation and trade. Innovation is a competitive instrument, with

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[1] In this research "global" is considered equivalent to "international", and refers to economic activity distributed across at least two countries.

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producers trying to fight off rivals with the aid of improved products and processes [9]. Innovation, referred to improvements in processes and products, is also a driver behind better quality and lower cost, the two key competitive elements in any established industry.

The scope of this paper is more limited though: because it is focused on an industrial sector, wind energy, this research is centred on globalization of this industry and within it on the contribution by European companies manufacturing turbines and developing wind farms. As part of the research, some of the economic impacts of these companies at home and abroad are analyzed.

Previous research has explored globalization connected to different industrial sectors. Gourevitch et al. explored the effects on the hard disk drive (HDD) industry [10]. This industry had, at the time, worldwide revenues of $30 billion, which is of similar order of magnitude as the turbine manufacture industry at around $53 billion.[2] Although firms from the US dominated the industry in its beginnings, locally manufacturing around 80% of the world's HDD, and thus proved to be the most innovative firms, production moved to Asia by 1995. That year, while "*over 80% of the world's hard disks were made by US firms, less than 5% of drives were actually assembled in the US*". In terms of employment in 1995 "*only 20% of the world's employees in the HDD industry worked in the United States, yet over 60% of the wage bill paid by US firms were earned in the United States.*"

The globalization of the pultrusion technology industry suggests that already some time ago low labour costs stopped being the most significant element behind delocalisation of production to emerging economies. In this case, vicinity to significant markets – as the case of China – was a major reason [11]. Incidentally, the pultrusion industry is indirectly linked to wind energy in that they both use fibreglass, the main material in rotor blades [12]. The globalization of the mechanical industry in Italian industrial clusters shed some additional light on the relationships client company – local suppliers that can help understanding how to promote a local supply chain [13], something that will be reviewed later in this paper.

The analysis of globalization of the energy field can be focused on trade of energy resources and fuels or on means of exploring, transforming and exploiting energy – the latter perhaps linked more to industrial policy that to energy policy. The globalization of conventional energy resources (coal, natural gas, nuclear fuel, and oil and oil products) was explored by Overland (2016) who found that it is growing and accelerating [14]. Renewable energy resources are globally available per nature: solar, wind, water and biomass are present everywhere although to a different extent. Energy products from renewable energy sources (e.g. pellets from biomass) are traded [15] and thus subject to globalization. The energy industrial sector is significantly globalized with multinational corporations operating worldwide. Further, there is evidence of the positive impact of policies in the development of the wind industry [16]. As Kuik et al. found, the competitive advantage of the European wind industry is based on the pioneering character of the related regulation [16], and it is long lasting [17].

This research paper first presents global wind deployment while more weight is put in exploring the key markets. Electricity production from wind turbines is explored in relation to both installed capacity and technical characteristics. Then in Section 3 the globalization of turbine manufacturers is analysed with a focus on key European players, and within it the key enabling factors of home market, financial health, international expansion and the strategies used for it (licensing, joint ventures, taking the role of developer and facilitating access to finance). Mergers and acquisitions are a specific form of globalization with impact on technology transfer between countries, and for this reason it was analysed separately (Section 3.6). Section 4 assesses the impact of globalization in the key aspects of procurement, supply chain, employment, and revenues, based on raw data from a turbine manufacturer and links to more diffuse information from other manufacturers. Section 5 analyses the market for the other key role, the developers of wind farms, and how they have globalized. Finally, Section 6 draws some conclusions.

2. Current situation of the wind energy sector

2.1. World new wind energy capacity installed in 2017 and cumulative

The annual market in 2017 reached 52.6 GW [17], a slight reduction from the 54 GW of 2016 [18]. China installed 37% of global new capacity in 2017 (2016: 43%), followed by the EU with 30% (2016: 23%), the US with 13% (2016: 15%) and India with 8% (2016: 6%) [17,18] (see Fig. 1).

The global annual market reached a record in 2015 with 63 GW installed [19], a highlight in a period (since 2009) when it has remaining at a very high level of around or above 40 GW. In 2017 it dropped to 52.6 GW which is still a very significant figure.

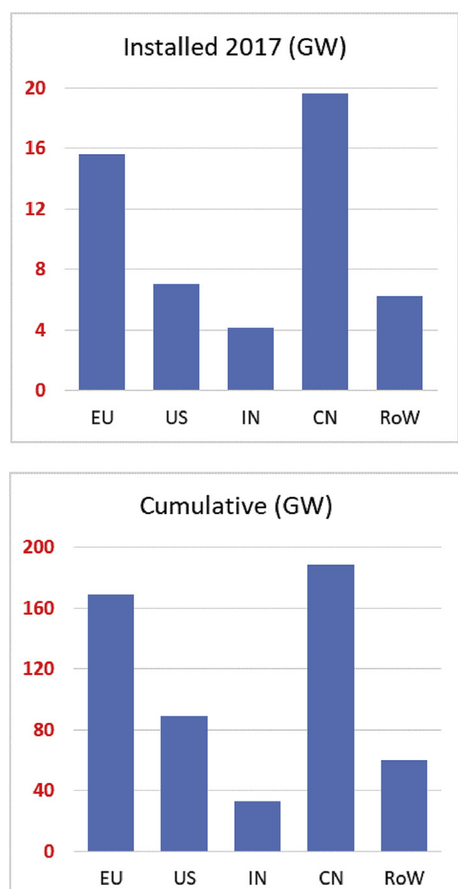

Fig. 1. World wind energy deployment (or market) in gigawatts (GW) of installed capacity, both new installations in 2017 and cumulative at the end of that year [17].

[2] Based on 54 GW installed of which 23 GW in China [18], at an average global turbine cost of 1,13 M$/MW [68] with a 30% discount in China.

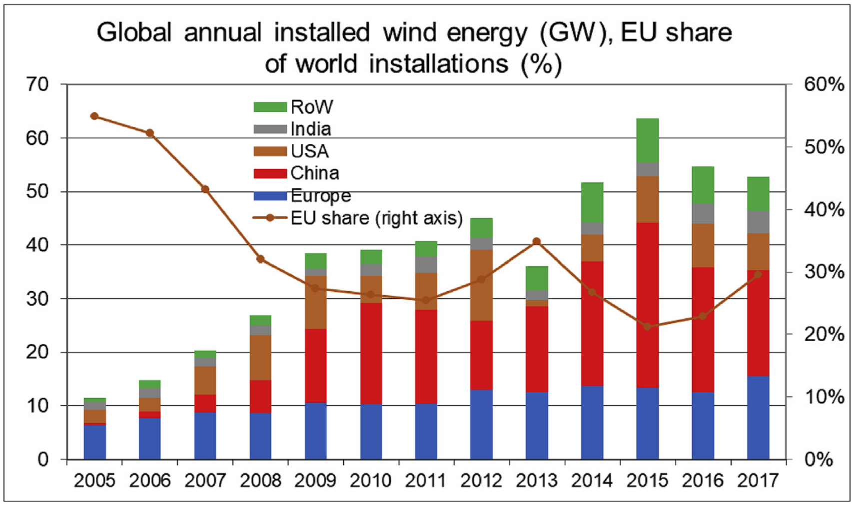

Fig. 2. Global annual installed wind energy generation capacity, and EU share of the annual installations.
Source: GWEC [17], adjusted with Member State data

2.2. World installations evolution and EU share

The European Union, and within it Germany, Spain and Denmark, was the main annual market until 2008 and then it passed on this lead to China (Fig. 2). However, the EU has remained a significant force at 20–30% of annual installations.

In terms of cumulative installed capacity, in 2016 China overtook the EU, 169 GW vs. 154 GW. However, 12% of Chinese installations (20 GW) were not connected to the grid at the end of the year [20]. One year later, China reached 188 GW, the EU had 169 GW and the US was placed third with 89 GW (Fig. 1). They were followed at long distance by India with 33 GW [17,18].

It is perhaps interesting to mention that the three dips in annual growth, in 2013, 2016 and 2017, were due to significant contractions in a key market: the US in 2013 and China in 2016 and 2017. This shows that the sector is heavily dependent on major markets.

Fig. 2 shows the evolution of the main markets in the global market. It shows that China became the major market in 2009 and since then it has remained as such: it has consistently installed between 40 and 50% of global capacity since [18]. The other large market, the US, until 2017 was subject to much instability due to the situation of its support framework in the midst of political battles. This instability seems now over with legislation that disposed an orderly and gradual (20% per year) phase out of the main support measure, the Production Tax Credit (PTC) [21].

Due to strong support policies, China will continue leading the world market for the foreseeable future. The EU will probably increase installations towards 12–14 GW per year thanks to the offshore sector. The US could install between 8 and 12 GW per year up to 2022.

China is therefore the main player. However, it is important to explore how would the market look like without China. Fig. 3 is based on Fig. 2 but removes the effect of Chinese installations, showing what a less concentrated market could be.

The figure shows a smaller global market where the effect of the US instable support scheme is more profound e.g. in 2013 only 62% of the 2012 installation took place, a reduction of 38% year-on-year. Without China, the world wind power deployment clearly depends on two pillars, the US and the EU.

A key factor determining future trends is the level at which the cost of generating wind energy will continue to fall [22]. However, the analysis of this factor is beyond the scope of this research.

With that limitation in mind, prospects are that, in the medium term, China, the US and India will accelerate deployment. In the first two countries a main driver is the forthcoming radical changes to their support systems, feed-in tariffs (FiT) and production tax credits (PTC) respectively, which will reduce the revenue for future wind farms and thus trigger a flux of new projects trying to get the current levels of remuneration. In the case of India, the main driver is government push towards carbon-free, indigenous electricity generation, coupled with lowest-ever costs achieved through auctions. Both China and India have set ambitious wind deployment targets: China's Strategic Energy Action Plan 2014–2020 set a target of 200 GW by 2020, although recent reports point out towards an increase to 210–250 GW [23], and India's 60 GW by 2022 [24].

In the EU, offshore wind is currently receiving a significant push (see Fig. 8 in Ref. [25]), but the long-term perspectives are less clear, as a new low-cost paradigm makes governments re-consider how to fit new projects and to absorb large amounts of offshore wind electricity in the respective electricity systems.

2.3. Wind electricity generation in 2017 vs. installed capacity

Wind electricity production in 2017 was in the EU (346 TWh), higher than in China (306 TWh [26]) or the US (254 TWh [27]), see Fig. 4. However, it is in the US where the average turbine produced more electricity: US capacity factors in 2017 reached 33.9% compared to 22.3% in China,[3] and 24.5% in the EU.[4]

Main reasons for these differences include wind resources and electricity system limitations. The wind resource in the US is significantly higher than in Europe, in particular in their mid-West states which is where most wind deployment has taken place: in 2016 64% of new capacity was installed in 10 states, according to the

[3] Capacity factor considered over grid-connected capacity only. If CF was calculated on the (larger) installed capacity the figure for China would be significantly lower.

[4] Calculations based on the respective country and industry sources, see Fig. 4.

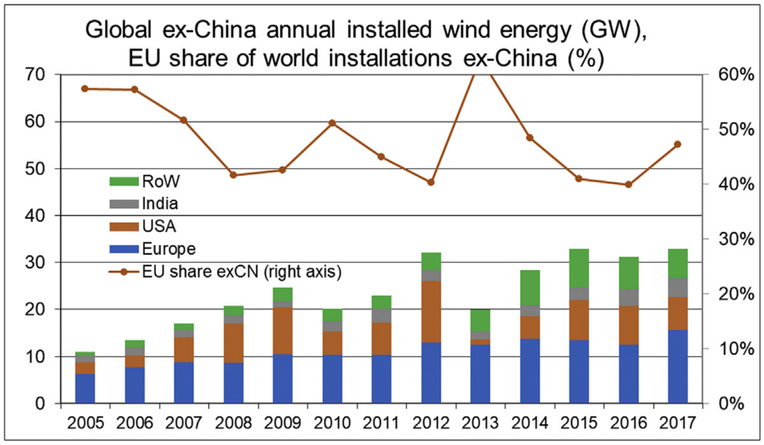

Fig. 3. Global excluding China annual installed wind energy generation capacity, and EU share of the installations.
Source: GWEC [17], adjusted with EU Member State data

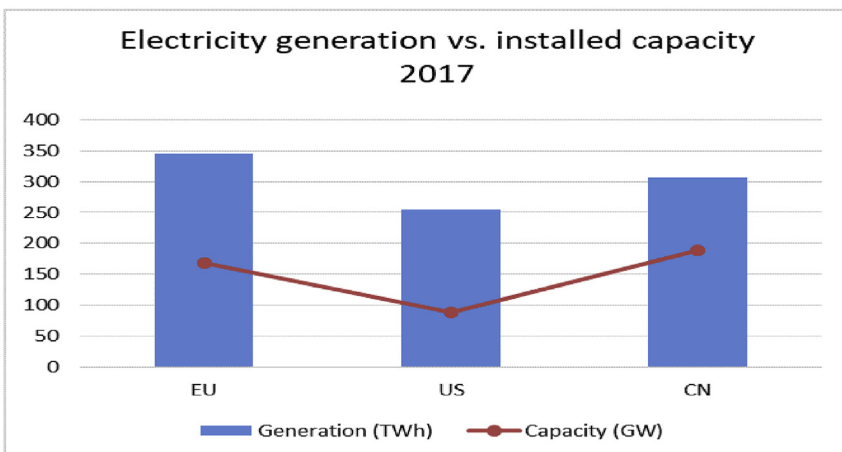

Fig. 4. Electricity generated in the three main markets in 2017 compared to their respective installed capacity at the end of 2017.
Sources: US Energy Information Administration [27], ENTSO-E [69], GWEC [17], China National Energy Administration [26], CWEA [70].

American Wind Energy Association[5] [28]. In Europe, only the North Sea area (including both onshore and offshore) reaches high average wind speeds. Rather than to its wind resource, the problem causing very low capacity factors in China relates to limitations in its electricity grid which obliges to curtail production: wind resource-rich areas, in the north of the country, are heavily affected by grid constraints to export electricity to the demand areas in the south and the east.

Wind electricity production naturally increases with increased deployment. Interestingly, on a turbine-by-turbine basis, electricity production from new wind turbines is increasing as well because new technologies (essentially larger rotors and taller towers) boost production and capacity factors, all other factors remaining equal.

Specific power is the ratio of the size of the electricity generator of the turbine (in Watts) to the size of its rotor (in m^2). Specific power downwards evolution (Fig. 5) involves that rotors are getting larger related to the electricity generator of the turbine. In addition, the swept area of larger rotors is larger, and thus more energy is extracted by a single turbine.

3. The global turbine manufacture market

3.1. Wind turbine manufacture market in 2017

The group of the top ten wind turbine manufacturers in 2017 includes the presence of five European companies: Vestas, SGRE,[6] Enercon, Nordex-Acciona and Senvion [29,30]. Based on FTI , the share of European OEMs in this top ten has increased from 50% in 2015 to 61% in 2017. This was partly due to their increased installations (from 22 to 25GW) but mostly due to the reduction in home market for Chinese manufacturers (down from 30 to 20 GW) which naturally resulted in a higher relative share of the rest of the world market.

Three of the other top ten manufacturers per installed capacity (MW) are Chinese. GE of the US and Suzlon of India complete the top ten. The former company could partly be considered European after it acquired in 2015 FR/ES manufacturer Alstom Wind.

In addition to showing this ranking, Fig. 6 shows that concentration in the turbine manufacture market was significantly higher in 2017 than in 2015: in 2015 the top 10 gathered 70% of global installations ("others" was the remaining 30%) whereas in 2017

[5] In the states of ND, MN, WY, SD, IA, CO, KS, NM, OK and TX a total 52.54 GW were installed at the end of 2016, over 82.18 GW in total. Source: AWEA's US Wind Industry Fourth Quarter 2016 Market Report.

[6] Note that the merger Siemens – Gamesa was finalised in early 2017.

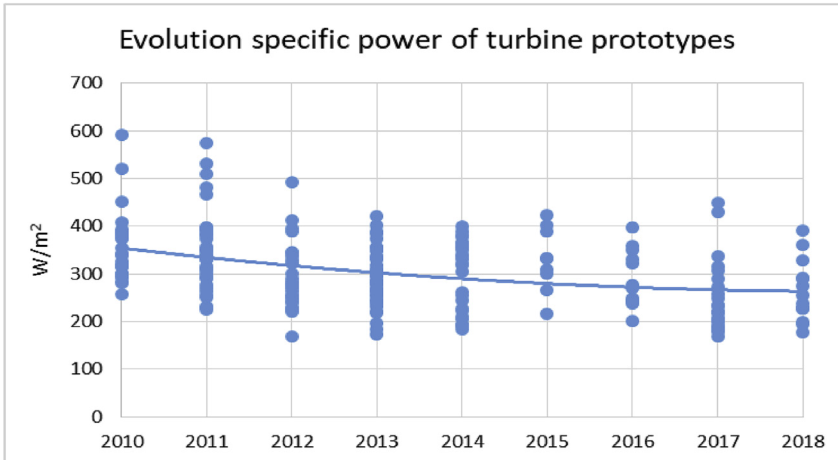

Fig. 5. Evolution of the specific power factor in 215 prototype wind turbine models introduced between 2010 and 2018. Note: not all turbines were eventually commercialised. Source: own database.

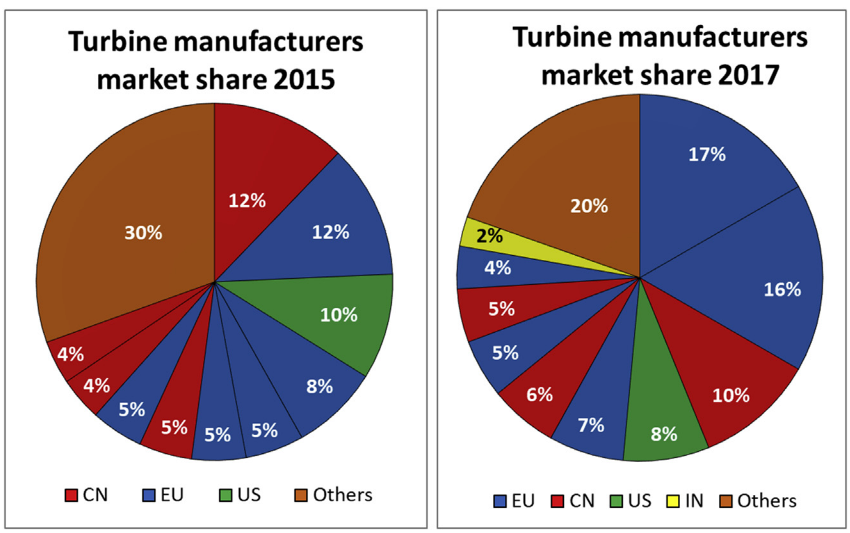

Fig. 6. Turbine manufacturers market share in 2015 and 2017, per country or region. Note: For comparison purposes, Nordex includes its acquisition Acciona in both 2015 and 2017, even when in 2015 Acciona was not yet part of Nordex. European companies in blue and Chinese in red.
Source: Global Wind Market Update 2016 & 2017 [29,30], adjusted with own data. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

they reached 80%.

In the medium term it is possible that Suzlon (IN) and Goldwind (CN) take market share from EU manufacturers. Suzlon has a past international footprint and it has stated a strategy to recover in those markets. Goldwind's turbines are reaching bankability outside China, a difficult task [31]. This is less likely to happen with other Chinese manufacturers as they are only starting to expand outside China – this is the case of Envision, Ming Yang and United Power.

In the long term Envision and perhaps SEwind from China might also take a significant international market share.

3.2. Evolution of the global market and role of European companies

There are two figures whose comparison is probably the simplest way to measure how successful European turbine manufacturers actually are. As shown in Fig. 7 these two figures correspond to:

- Share of installations in the EU within global installations (EU share of deployment)
- Market share of EU manufacturers (OEM) within the annual global market.

In the last five years (2013-2017) European manufacturers consistently held between 41 and 50% (average 45.2%) of the world market, whereas the EU market was only between 20 and 32% (average 25.5%) of the world market. Therefore European turbine manufacturers capture an average 19.7% world market share above the EU market.

If installations in China are discounted ("ex-China"), European manufacturers enjoy an even greater success, as they have held between 73% and 82% of ex-China world installations since 2013. They have the enormous merit of having withstood the threat of low-cost Chinese turbines exporting to world markets, something not achieved by other related industrial sectors such as photovoltaic solar panels.

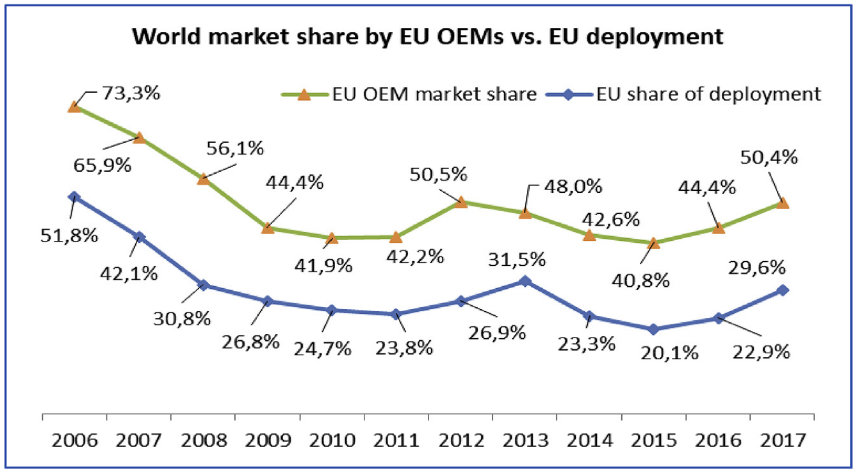

Fig. 7. Whereas the share of EU deployment is relatively low, the share of European turbine manufacturers (OEM) in the global market is much higher. Notes: Percentages vary slightly depending on the exact milestone (installation, commissioning …) and source (GWEC, FTI, own data) used.

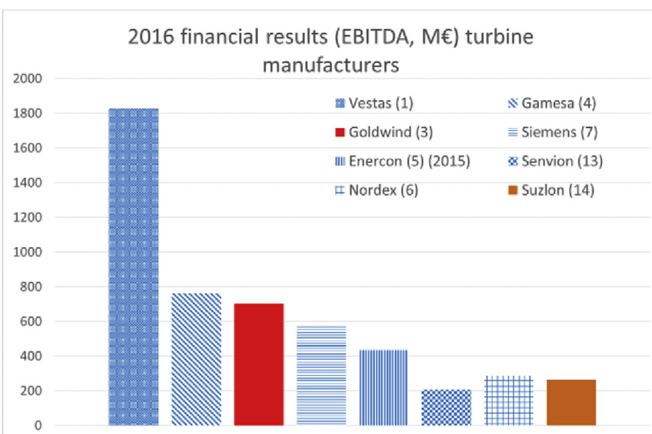

Fig. 8. Profit of turbine manufacturers, as reflected by EBITDA figures, 2016. European companies in blueish. The numbers between brackets correspond to the company market ranking in 2016 installed capacity. Sources: [32,33,55,56,62,70–74]. Note: Enercon EBITDA corresponds to 2015.

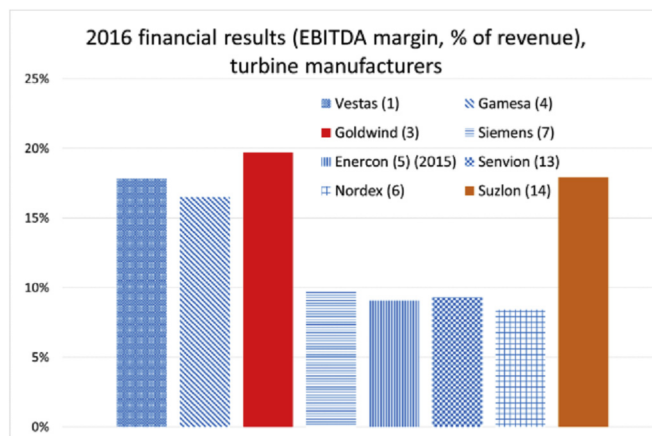

Fig. 9. 2016 EBITDA margin as percentage of revenue, selected turbine manufacturers. Sources: [32,33,55,56,62,71–74]. Note: Enercon figure corresponds to 2015.

3.3. *Turbine manufacturer financial health*

In general wind turbine manufacturers presented a very healthy financial situation in 2016.

Fig. 8 shows the financial health of a group of wind turbine manufacturers including six European companies. Companies part of the top ten that are missing here include General Electric because it is a big industrial conglomerate that does not present a breakdown per business areas; and Chinese companies Envision and Ming Yang because of lack of data. Enercon (DE) is privately owned and thus it does not present annual results in public, still Enercon made public some figures in interviews with sector magazines [32,33].

Vestas, the market leader, presented the highest EBITDA. European manufacturers Gamesa, Siemens (in 2016 they still were separate companies) and Enercon present significant EBITDAs, along with Goldwind of China. A third group could include Nordex and Senvion (DE) and Suzlon (IN), with lower margins.

However, if we look at another financial indicator (Fig. 9), the profit margin (EBITDA margin) or margin of EBITDA on total revenues, Asian companies showed higher figures at 19.7% (Goldwind) and 17.9% (Suzlon). This suggests that those Asian competitors would be in a stronger position to face price competition, i.e. they can reduce prices —and still make a profit- further than European companies.

Profits have greatly improved across the board since the 2012/3 crisis.

3.4. *Manufacturers going global*

In a sector undergoing global expansion such as wind energy is, most players have expanded to new markets. Fig. 10 shows this global trend: in general all manufacturers (represented by coloured bubbles) between 2008 and 2016 have increased the number of markets where they have made annual sales totalling more than 50 MW of turbines.

European companies Vestas, Enercon, Siemens, Gamesa and Nordex have increased the number of markets served, as so has General Electric. The data shows as well that Suzlon retreated into its home market in 2013 (even when it had some exports in 2014/2015). Chinese companies show very limited expansion to other markets, with only Goldwind showing a certain presence abroad.

Several reasons lie behind this situation. First, EU markets are generally small and sometimes subject to political negative policy changes (e.g. Spain, Italy), thus European manufacturers have to

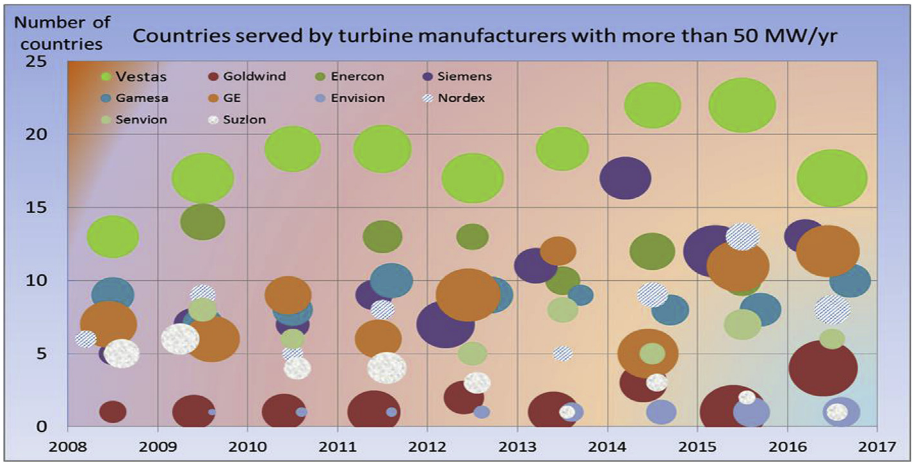

Fig. 10. Number of countries served by turbine manufacturers 2008–2016. Notes: The vertical axis represents the number of countries for which each turbine manufacturer installed, in the given year, at least 50 MW of wind turbines. The area of the bubble represents total installed capacity by the given manufacturer in those countries. Source: Bloomberg New Energy Finance database of wind farms.

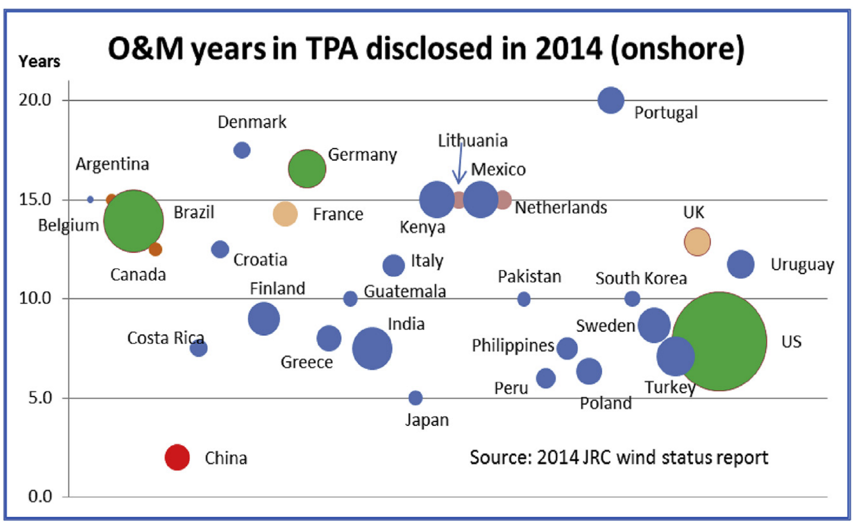

Fig. 11. Length of O&M contracts included as part of turbine purchase agreements (TPA). The thickness of the bubbles represents the country volume in MW. *Source:* [35].

focus growth on international expansion. In addition, they enjoy the first-mover advantage [34] and recognised technological quality which are enablers for this expansion.

Chinese companies' difficulties to expand abroad could be caused by a certain lack of trust in the long-time performance of Chinese-made turbines. This view is probably supported by anecdotal evidence: Chinese wind turbine contracts traditionally do not include any maintenance beyond the two years of customary guarantee (see Fig. 11 borrowed from reference [35]), which suggests that maintenance after the second year of operation is not carried out by the turbine manufacturer, who is (in theory at least) well placed to do proper maintenance.

3.5. *Strategies for entering new markets*

As in any other industrial sector, wind turbine manufacturers have expanded abroad by following different strategies. These include licensing, joint ventures, acquisitions, developing wind farms, or contributing to financing the wind farm projects.

3.5.1. *Licensing*

Licensing turbine designs is an approach followed by engineering, non-manufacturing companies focusing on a "design and license" business model as well as by wind turbine manufacturers.

Among the former the most successful are Aerodyn (DE) who licensed to BARD (DE), Ming Yang (CN), SEwind (CN), United Power (CN), Hyosung (KR) and HEAG (CN)[7] and Dongfang [36]; MECAL NV (NL) who licensed to HEAG and CSIC Haizhuang (CN) and in particular Windtec (AT) which, under its parent company American Superconductors (AMSC) licensed to more than 10 manufacturers worldwide.

A few turbine manufacturers have resourced to licensing as a way to enter new market and increase the profitability of their intellectual property investment. The following could be highlighted:

[7] Until here data from our own database.

- Vensys (DE), 70% property of Goldwind, has licensed as well to Regen (IN), IMPSA (AR), GenesYs (DE) and Eozen (ES). The last three are no longer in business, whereas Vensys continues to develop and sell turbines.
- Senvion (DE) licensed (as REpower, its name to 2013) to Goldwind, Windey and DEC, all Chinese.
- Lagerwey (NL) licensed to CASC (CN) and EWT (NL).
- Fuhrländer (DE) licensed to A-Power, Huide and Sinovel (all Chinese).

A variation of licensing is an activity that is called "joint development", or "joint R&D" in China. This activity is an extension of licensing where the technology company is a turbine design company (e.g. Aerodyn, MECAL, AMSC). The activity was analysed by Zhou et al. [36] who concluded that "*joint R&D has improved Chinese companies' technical capacity, human resources and financial growth. However, the effect on Chinese companies' innovation capacity is still limited because of unequal technical capacities of the two sides in collaboration, as well as their preference for augmenting profits rather than technical capacity. Current joint R&D mode is only the extension of licensing mode in wind-turbine manufacturing industry.*"

3.5.2. Joint ventures

Joint ventures have used to enter new markets as different as Spain and China – but they have not proven successful in the long time, they have been rather problematic. One key difference with licences is that licences commonly give licensees more control but it is thought that "*the most accessible technology is usually somewhat outdated*". Cooperative development as joint ventures, by contrast, "grants *domestic turbine manufacturers access to newer designs and the right to manufacture turbines locally, albeit with greater foreign involvement*" [37].

In joint ventures (JV) foreign corporations contribute technology and knowhow, sometimes capital and marketing, whereas the local partner contributes manufacturing capacity, relationships with the national government and/or understanding of the local context.

Gamesa Corporación Tecnológica ("Gamesa") wind turbine manufacturer, now part of Siemens Gamesa Renewable Energy, was created as "Gamesa Eólica" in 1994. Gamesa Eólica was a joint venture between Gamesa's local owners (51%) and Vestas (40%) with a focus on manufacturing and selling turbines in Spain, Latin America and Northern Africa [38]. In 2001 Vestas sold its share to its partner and Gamesa became free to enter other markets in direct competition with Vestas [39]. Part of the agreement included technology transfer for turbines G52, G58, G66 and G80.

Joint ventures have been a key strategy for the expansion of European manufacturers to enter the Indian and Chinese markets, although with very different results. In India, Vestas joined RBB Consultants and Engineers Private Ltd in 1987 to form Vestas RBB India on a 49/51% share, where Vestas contributed the V27-225 kW, V39-500 kW and V47 technologies. The JV was dissolved in 2006, changed named (now RRB Energy Ltd) and claims to continue manufacturing V27, V39 and two new models (600 and 1800 kW). Since then Vestas did not enjoy any significant success in the country judging by their own orders announcements: only 99 MW in 2009, 129 MW in 2010, 78 MW in 2011, 51.8 MW in 2013, and 86 MW in 2015.

In 1995 Enercon joined the Mehra family of Mumbai in a 56/44% JV called Enercon India Ltd, with negative results as it finished in a series of court cases. In effect, after a dispute arose in 2008 on the terms and royalty payments due after the linked technology licence agreement [40], Enercon became unable to sell in the Indian market while the court case lasted. It was only in 2017 that the case finished and Enercon could enter the Indian market again [41].

In China nine joint ventures started in the 2000s and all of them have been dissolved [42]. For example, Harakosan of Japan and state-owned XEMC (CN) formed Hara XEMC Windpower in 2006 and by the end of 2008 Harakosan had sold all shares to XEMC [43]. It is perhaps interesting to see some the arguments given by Harakosan when in 2007 it sold to XEMC 23% of its initial 50% in their joint venture: "*1) Since most wind-power generation projects in China are for electric utilities, the operation of these businesses is closely associated with policies of the Chinese government. Consequently, using a majority-owned Chinese company results in a more advantageous position for negotiations of all types*" [44]. This is consistent with the situation for Chinese state-owned enterprises (SOE) as described in the analysis of the developers market in section 5.3.

The following lists all wind turbine manufacturers joint ventures in China:

- Yituo-MADE (Luoyang) Wind Turbine Co. Formed by China YiTuo Group and MADE (ES) [37].
- Xi'an Nordex Wind Turbine Co. Ltd. Formed by Xi'an Aero-Engine Group and Nordex (DE)
- Nordex (Yinchuan) Wind Power Equipment Manufacturing Co. Ltd. Formed by two Chinese partners (Ningxia Electric Power Group and the Ningxia Tianjing Electric Energy Development Group) and Nordex [37].
- Hara XEMC Windpower: XEMC, Harakosan (JP)
- Nantong CASC Wanyuan Acciona Wind Turbine Manufacture Co., Ltd.: CASC and Acciona (ES)
- REpower North. Formed by North Heavy Industry Corp. and two Western partners, developer Honiton Energy Ltd. (UK) and REpower (DE)
- Harbin Hafei-Winwind Wind Power Equipment Co. Ltd. (also called Hafei in Harbin) Formed by Harbin Power Equipment Group and WinWinD (FI)
- Guangxi Yinhe Avantis Wind Power Co., Ltd., Formed by Yinhe group and Avantis Group (DE)
- Shandong Swiss Electric Co., Formed by Weifang Zhongyun Machinery Co., Ltd. And unidentified Swiss and German partners.

Licensing and joint ventures sometimes occur successively. In 2011 Siemens constituted two JVs with Shanghai Electric to build blades and assemble nacelles in China [45]. Later these JVs were terminated and then Siemens licensed to Shanghai Electric the construction of all models of blades, and the entire rotor-nacelle assembly of the 4 MW offshore machines in China. The licensing agreement was later extended to the 6 MW direct-drive machine [46]. With that, all the business of Siemens Wind Power (SWP) in China was reduced to the licensing of its technology (previously the licensing agreement was focused only in the smaller onshore G2, and D3 turbines whereas blades were supplied directly by SWP, who had set blade manufacturing facilities in the country).

3.5.3. Manufacturers taking the role of developers

Several turbine manufacturers including Vestas and Gamesa resourced to developing wind farms as a way to sell their turbines abroad as well as at home (section 5.3 includes some details on how OEMs inroads into the developer market). Suzlon since the 2000s, and several Chinese companies more recently, have adopted this strategy with which they are supporting their foreign expansion.

Envision and Goldwind in particular have pursued the strategy of developing wind farms. Goldwind has been particularly active in

Australia and the US, and Envision in Chile and Mexico.

Given that the competitive advantage of Chinese manufacturers is the lower cost of manufacture in China, they have enjoyed most success in markets where a local content is not required. On the contrary, in countries like India and Brazil[8], Chinese manufacturers have hardly had any deployment. One exception, from the period before local content rules existed in Brazil, is Sinovel's 34.5 MW Barra dos Coqueiros wind farm (2012).

3.5.4. Facilitating access to finance

Under certain conditions access to finance is a limiting factor in the development of new wind farm projects. One example is when the country risk[9] is high or very high whereas in other cases it is the specificities of the project that create the risk. Under these conditions, turbine manufacturers that can facilitate access to finance as part of a turbine supply package are better positioned to get the contract and thus to expand internationally. This is a strategy used generally in countries like Pakistan, but lately exploited widely by Chinese turbine manufacturers and GE.

The Sapphire wind farm in Pakistan is an example. Mr Nadeem Abdullah, owner of the wind farm, declared "*we chose GE wind turbines because (…). GE has been instrumental in* supporting *Sapphire to achieve financial closure with OPIC.*" "*OPIC is the U.S. Government's Development Finance Institution, which mobilizes to provide capital to global development in order to assist U.S. foreign policy efforts, including helping develop renewable energy as a mutual American-Pakistani goal. OPIC's funding will help assist in the development of the wind farm*" [47].

Chinese manufacturers are backed by significant financial possibilities stemming from the internationalisation policies of their government. China's Belt and Road initiative [48], or OBOR (One Belt One Road), supports financing of infrastructure projects including wind farms, and this has had an impact already e.g. in Pakistan, as shown in Table 1.

Irrespectively of whether the funding is coming from the state, multi-lateral or private banks, well-funded turbine manufacturers can offer the developer some kind of financial package: as St. James puts it "his is perhaps why we see them more successful in markets with difficult access to capital" [49].

The strategy of partial financing or facilitating access to finance is not limited to countries with a high risk profile. For example in the US, GE Energy Financial Services (the financing business unit of GE) invests in wind farms partly because the synergy to do the financing and the equipment allows the turbine manufacturer "to sit with project developers at an earlier stage than we otherwise might" [50].

3.6. Merger and acquisition processes[10]

One of the most typical and more critical aspects of globalization is that it normally comes with merger and acquisition (M&A) of companies. This has severe consequences for the industry and the economy of countries that lose ownership of decision-making in their companies when they are acquired by foreign ones.

In the wind sector, very often foreign companies have bought European companies with the objective of absorbing their technology. In most of those cases small European companies are incorporated into a big industrial conglomerate.

Table 2 shows some examples of M&A −focusing in those having the most important industrial or technology impact-since 2000, highlighting in bold the cases in which foreign companies have acquired European technology.

There were 42 large transactions completed in the wind industry between 2001 and 2017.

The table shows that M&A activity of significant market players has accelerated, with annual transactions peaking at 12 in 2016. Seventeen among those transactions have been between European companies. This could be due to the large European history in wind industry, the financial crisis and the subsequent consolidation happening among a broad number of agents in Europe.

Seventeen is also the number of operations in which European technology was acquired by foreign companies, in most cases American (7 cases) or Chinese (4[11]) but also from Japan (3), South Korea (2) and India (1). The consolidation of the wind industry is taking place, and companies of the largest world economies are acquiring European technology in order to accelerate, improve and expand their business.

It is significant that no acquisition of American or Asian technology companies by a European company was identified.

Fig. 12 shows that there has been a recent increase in M&A activity, concretely since 2014. This activity has affected the sector with higher impact that it has targeted European technology.

M&A activity has demonstrated that consolidation can help turbine OEMs achieve greater economies of scale, for example through geographic expansion and the exploitation of a larger resource capacity to create synergies and diversify product offering. Moreover, it also offers the opportunity for large industry conglomerates to enter the wind industry (e.g. Daewoo, General Electric) or to set up joint ventures reaching global leadership as demonstrated by those in the offshore wind industry (e.g. Vestas and Mitsubishi). This might contribute to increasing the competitiveness of the entire wind sector against other renewable or conventional energy industries.

This consolidation of the wind industry very often comes naturally accompanied by restructuration plans that benefit from all synergies of merging two companies, or of acquisition of a small company by a large industrial conglomerate. In the case of foreign companies acquiring European technology companies, the result is that the EU risks to lose (a) highly-paid industrial jobs, (b) the corresponding industrial fabric (c) long-term investment in the projects that supported these companies, and (d) intellectual property rights of innovations. Another concern is that the capital or R&D investment lost to foreign owners was in part or in all publicly funded -through universities, EU or national public research programmes and/or company R&D tax relief.

With the wind turbine technology sector becoming more mature, European turbine manufacturers are facing increased pressure mostly from GE and Chinese turbine manufacturers. In addition, competition from solar photovoltaic (PV) technology is becoming increasingly intense [51] due to the faster cost-reduction pace of solar PV.

In order to gain a strong or dominant position in the markets which are seeing fast growth while being competitive in cost of

[8] Brazil, like Russia and previously China, has local content rules which forces the establishing of local manufacture plant and/or the purchase of local components, both sourcing strategies not favoured by Chinese OEMs.

[9] Country risk is "the risk of investing or lending in a country, arising from possible changes in the business environment that may adversely affect operating profits or the value of assets in the country. For example, financial factors such as currency controls, devaluation or regulatory changes, or stability factors". Source: Wikipedia.

[10] The author would like to warmly thank Mr Daniel Román Barriopedro for his significant contribution to this subchapter.

[11] Two more Chinese acquisitions focused on developers, not considered technology companies here, even when it is acknowledged that the acquisition gave foreign companies access to the technology in the European turbines installed in their wind farms.

Table 1
Projects financed by the Chinese OBOR initiative in Pakistan, financial information. Note: RoE means return on equity. Sources: [75–81]; own database; financial information from Reynolds et al. [82].

Project	Capacity (MW)	Cost (M$)	Debt/Equity	RoE (%)	Developer	Equipment manufacturer	Status
Hydrochina Dawood	50	125	–	–	HydroChina (CN)	Ming Yang (CN)	Operational (2016)
United Energy Pakistan	99	250	–	30.14	UEP (PK)	Goldwind (CN)	Operational (2017)
Sachal	49.5	134	80/20	18	Arif Habib (PK)	Goldwind (CN)	Operational (2017)
Three Gorges 2 & 3	99	260	75/25	28.85	Three Gorges (CN)	Goldwind (CN)	Operational (2018)
Cacho	50			24.6			Announced
Western Energy	50						Announced

Table 2
Mergers, joint ventures and acquisitions in the XXI century. Notes: bold highlight denotes that European technology is acquired by foreign companies; Enron Wind's (US) technology was European after its acquisition of German Tacke in 1997, and Harakosan of Japan is considered to have European technology when it was acquired by STX in 2009; OEM denotes wind turbine manufacturer.

Buyer	Buyer sector	Target company; merge with; JV name	Target sector	Announced
Gamesa (ES)	OEM	Gamesa JV (ES) (buy 40% Vestas share)	OEM	2001
GE (US)	**Industrial conglomerate**	**Enrond Wind (US)**	**OEM**	**2002**
Gamesa (ES)	OEM	MADE (ES)	OEM	2003
Vestas (DK)	OEM	NEG Micon (merge) (DK)	OEM	2004
Siemens (DE)	Industrial conglomerate	Bonus (DK)	OEM	2004
Harakosan Co Ltd (JP)	**Building developer**	**Zephyros (NL)**	**OEM**	**2005**
Suzlon (IN)	**OEM**	**86,5% REpower (DE)**	**OEM**	**2007**
Alstom (FR)	Industrial conglomerate	Ecotecnia (ES)	OEM	2007
Goldwind (CN)	**OEM**	**Vensys (DE), 70%**	**OEM**	**2008**
XEMC (CN)	**OEM**	**Darwind (NL)**	**OEM**	**2009**
GE Wind (US)	**OEM**	**ScanWind (SE)**	**OEM**	**2009**
STX Heavy Industry (KR)	**Industrial conglomerate**	**Harakosan (JP)**	**OEM**	**2009**
Daewoo (KR)	**OEM**	**DeWind (DE)**	**OEM**	**2009**
AREVA (FR)	Industrial conglomerate	Multibrid (DE)	OEM	2010
TOSHIBA (JP)	OEM	Unison (KR) 40%	OEM	2011
GE Power Conversion (US)	**Industrial conglomerate**	**Converteam (UK)**	**Generator & converter manufacturer**	**2011**
Hitachi (JP)	OEM	Fuji HI Wind (JP)	OEM	2012
MingYang (CN)	OEM	GWPL (IN)	OEM	2012
Titan Wind Power (CN)	**Tower manufacturer**	**Vestas' tower business (except US)**	**Tower manufacturer**	**2012**
MHI (JP) & Vestas (DK)	OEM	JV Offshore (DK)	OEM	2013
Gamesa & Areva	OEM	JV in Offshore	OEM	2014
Yaskawa (JP)	**Industrial conglomerate**	**The Switch (FI)**	**Generator manufacturer**	**2014**
GE Renewable Energy (US)	**OEM**	**Alstom Wind (FR)**	**OEM**	**2015**
GE Renewable Energy (US)	**OEM**	**Blade Dynamics (UK)**	**Blade Manufacturer**	**2015**
Cheung Kong Infrastructure (CN)	**Developer/Operator**	**Iberwind (PT)**	**Developer/Operator**	**2015**
CSR (CN)	**Industrial conglomerate**	**Soil Machine Dynamics (SMD, UK)**	**Subsea vehicles**	**2015**
Centerbridge (US)	**Investment house**	**Senvion (DE)**	**OEM**	**2015**
GE Renewable Energy (US)	**OEM**	**LM Wind Power (DK)**	**Blade manufacturer**	**2016**
Three Gorges (CN)	**Developer/Operator**	**WindMW (DE)**	**Developer**	**2016**
Envision Energy (CN)	OEM	Portfolio of 600 MW of projects by Vive Energia (MX)	Developer	2016
Siemens & DONG	OEM/developer	A2Sea (DK)	Offshore installation	2016
Nordex (DE)	OEM	Acciona (ES)	OEM	2016
Vestas (DK)	OEM	Upwind (US)	Independent Service Provider	2016
Vestas (DK)	OEM	Availon (DE)	Independent Service Provider	2016
Nordex (DE)	OEM	SSP (DK)	Blade manufacturer	2016
Senvion (DE)	OEM	Euros (DE)	Blade manufacturer	2016
Senvion (DE)	OEM	Kenersys (IN/DE)	OEM	2016
State Grid (CN)	**Developer/Operator**	**CPFL Energia (BR)**	**Developer**	**2017**
Gamesa (ES)	OEM	Adwen, 50% Areva stake	OEM	2016
Siemens (DE)	OEM	Gamesa (Merge)	OEM	2016
Nidec (JP)	**Generator manufacturer**	**Leroy-Somer (FR)**	**Generator manufacturer**	**2017**
DEME (BE)	Offshore installation	A2Sea (DK)	Offshore installation	2017

energy terms, in the past three years European turbine manufacturers streamlined production and significantly reduced costs. In this context, those M&A deals have had a significant impact on turbine OEMs' competitive landscape both in the short and in the medium term. The main impact that M&A activity is introducing to the competitive landscape of EU OEMs are, in the short term:

1. GE-Alstom, Nordex-Acciona and Siemens-Gamesa are three major operations that have a significant impact on the competitive landscape of the turbine manufacturing sector. For example, although the acquisition of Alstom's power business did not boost GE's global wind market share dramatically, it brought GE back to the offshore wind sector with nearly 2 GW offshore wind pipelines in the European waters. The other two cases had an impact mostly in providing de acquiror access to additional markets.
2. Nordex returned to the top 10 OEMs after its acquisition of Acciona's turbine business, approved by the European Commission in 2016.

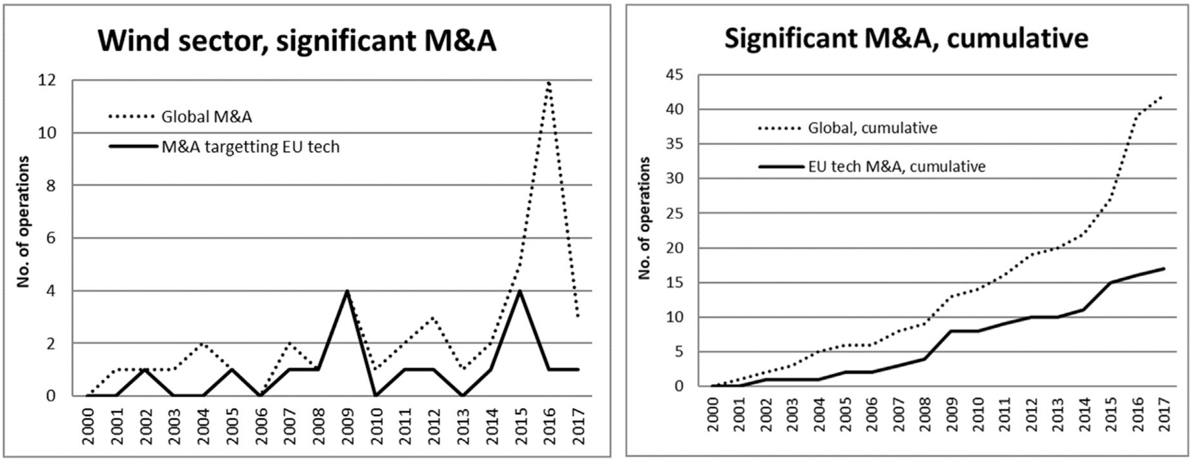

Fig. 12. Mergers and acquisitions (M&A) in the wind sector, no of operations per year and cumulative since 2000.
Source: Daniel Román Barriopedro, own data, press releases and news.

3. The merger between Siemens Wind Power and Gamesa makes a global leader in the wind market. According to FTI Consulting [29], the combined entity accounted for more than 13% of global wind turbine installation in 2016 and 16.6% in 2017 [52], making it the second largest OEM in the world.

In conclusion, the global market will favour larger players in the medium term, especially in onshore wind. Offshore, the limited number of markets will play a role but it is unlikely to support consolidation in the OEM market. As a consequence during this process of consolidation Europe is losing some of its core technology industrial fabric, and with it a relevant piece of its economic activity.

4. Impact of globalization of turbine manufacturers

From a policy point of view probably the most important economic impacts of globalization are related to "***where***": where companies create employment, both direct and indirect in their supply chain, and where they pay taxes. It is perhaps worth noting in this respect that in its recent *Reflection paper on harnessing globalization* [53], the EC suggested that every billion euro of exports supports 14 000 jobs.

Information on where OEMs pay taxes is essentially non available for this research, perhaps it is not publicly available at all. Information on where companies create employment is available in a patchy way as some manufacturers are more transparent than others.

Gamesa's corporate social responsibility (CSR) reports detail elements that can be used to answer the first question above. Other manufacturers give less details, but the information they give is key to confirm -and at times modulate- the trends shown in [54]. Therefore, the approach followed in this part of the research is to use Gamesa's data to define a trend and then to contrast that trend with the available data and information by other turbine manufacturers.

European turbine manufacturers have access to a limited market at home (see section 3.1), and thus in general most of their revenues come from third countries. Fig. 13 shows that this OEM obtained only 16% of its global income in the EU in 2016, but it spent 34% of its procurement there [54]. EU countries specifically accounted for by Gamesa are Germany (2.61% of total procurement), France (0.82%), Spain (25.14%), Italy (1.04%), the UK (1.14%) and Denmark (0.59%).

Another European manufacturer, Vestas, installed 37% of its turbines in the EU [55], Nordex 53% in the EU [56] and Enercon 48% in Germany [57]. They all show higher dependency on the EU (or any of their Member States) as home market.

The weight of EU purchases in total procurement can be considered a partial proxy for competitiveness of European sub-suppliers (or supply chain). Fig. 14 shows that in the particular case of this OEM the weight of the EU in procurement has eroded during the last few years, while the weight of China and India —and, to a lesser extent, Brazil-has increased. The increases in the case of India and Brazil can be understood as a need to localise production in these large markets.

Whereas the latter localisation argument also applies to China, however, in the Chinese case procurement share (17% in 2016) largely exceeds revenue (4% in 2016). It can be concluded that a significant part of the goods procured in China are actually used in other markets.

Vestas expresses as well the need for localisation in target markets Brazil, China and India: "local presence and local sourcing is of great importance in these countries, be it for reasons of proximity to customers, cost-effectiveness, or fulfilling local content requirements in manufacturing" [55].

Furthermore, Vestas has a strategy to have closer ties with large suppliers because "*involving these in the development of products and processes, as the suppliers often possess many years of knowledge and experience that can be utilised to the benefit of both parties*" [55]. This kind of strategies could be a threat for Vestas' European suppliers even when it offers them an opportunity to expand abroad because of the required supplier size: some foreign suppliers, most commonly Chinese ones,[12] do have the required size, and thanks to this strategy they may conquer part of the market share currently in the hands of European suppliers.

The decision of where to set up components manufacture comes therefore hand-by-hand with supply chain decisions, and they both are partly the result of the size of the focus market.

Data on number and location of suppliers corresponding to both tier 1 and tier 2 suppliers are shown in Fig. 15. Gamesa kept in the EU the largest share of world suppliers (48%) despite having only 16% of revenue from EU markets. A comparison with Fig. 13, which

[12] Gamesa's figures show that procurement from the average Asian supplier reaches significantly higher unit value tan procurement from the average European supplier. In a loose average, the ratio would be 3.3 to 1. Source: own calculations based on [54].

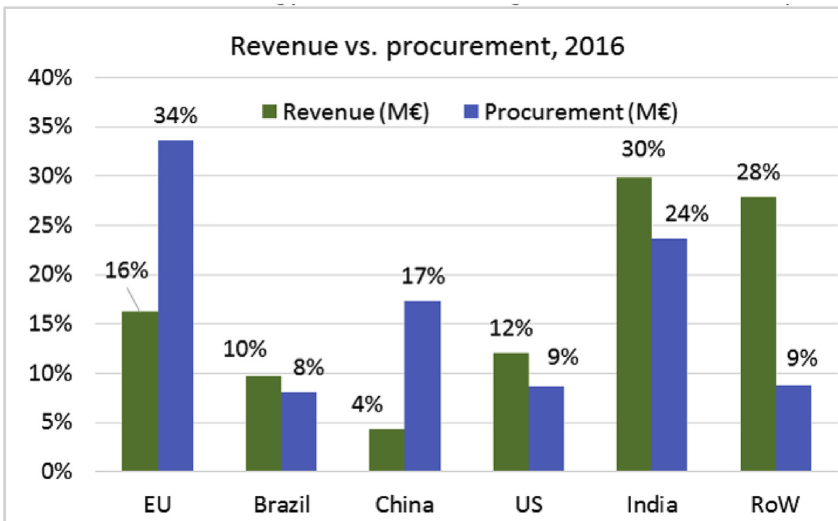

Fig. 13. Revenue vs. procurement split, Gamesa. Note: 4.43% of procurement in the original data set is unassigned. Following a principle of proportionality, here these have been allocated to the EU and RoW on a 50/50 basis.
Source: [54].

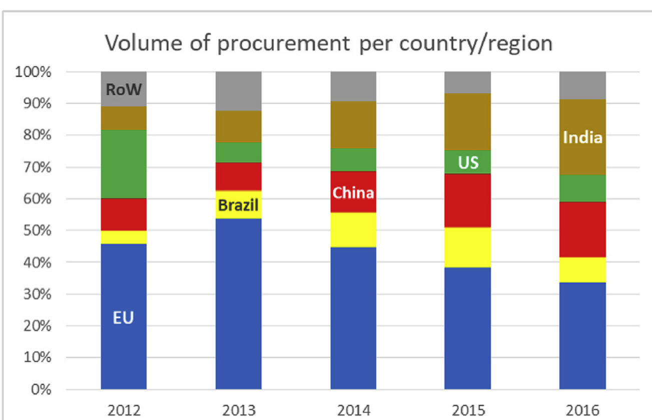

Fig. 14. Evolution of procurement per region, Gamesa. Note: Between 4.5% and 9% of procurement is not allocated to a country in the original. Here it has been added to the EU and to the rest of the world (RoW) on a 50/50 basis.
Source: [54].

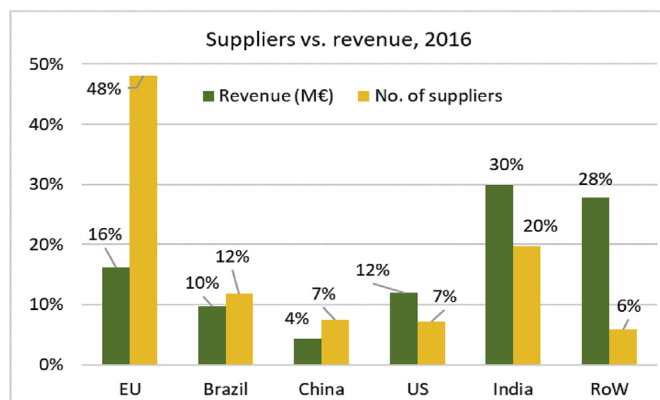

Fig. 15. Location of suppliers vs. origin of revenue. Most suppliers are EU-based, whereas most revenue is created abroad. Remarks: comparison is only loose because suppliers statistics show "EMEA" figures (vs. "EU" in revenue statistics), and "LATAM" (vs. "RoW").
Source: [54].

shows similar breakdown for procurement amounts, suggests that a lower number of Chinese suppliers obtain a higher share of procurement, thus reaching higher average individual share of procurement. Similarly to Chinese suppliers, US, Indian and RoW suppliers are larger than EU or Brazilian ones.

Some EU OEMs follow a strategy to "develop" foreign suppliers in an effort to localise the supply chain [58]. In these cases, OEMs assign their own materials and quality development engineers to suppliers' facilities in order to ensure their technological development and competitiveness. During this process foreign firms learn and improve, thus increasing the quality of their products while maintaining the price-based competitive advantage of lower-cost countries and social systems. When a third-country supplier proves to be of outstanding quality and price, the OEM uses its products beyond the host country, actually integrating the supplier as a new member of its global supply chain. Whereas this process helps the OEM become more competitive globally and reduce the cost of energy, there are two drawbacks for the EU economy: first, European jobs are lost as they are transferred to the third country; second, there is a risk that the supplier offers its newly-acquired knowhow to competitors of the OEM who would eventually better compete with the European OEM, thus eroding the latter's competitive advantage.

Therefore, one strategy to create additional added value in Europe would be to implement programmes that promote OEMs to develop their European supply chain in the same way as they develop suppliers elsewhere. Initial exploration of this option suggests that a crucial enabler of this process is the attitude of the local workforce, as perhaps measured by productivity ratios. Indeed, the relationship between productivity and competitiveness is strong: competitiveness has been defined as "the set of institutions, policies, and factors that determine the level of productivity of a country" [59].

Emerging (Latin America, South Africa) and open (Australia, US) markets are first in the list of non-localisation-required markets: "entry barriers are lower, local financing is hard to obtain, and, perhaps more importantly, manufacturers can compete on price" [60].

Some European manufacturers have the strategy to internationalise without creating a local supply chain. This is the example of Senvion (DE) who, with this approach, is entering Australia, Chile, Argentina, Japan and the US among others. The advantages that are claimed for this strategy include: no expenditure in building up local facilities (unless economically feasible); faster product time to market; and benefits of scale in manufacturing via consolidation of existing factories [61].

Finally we will explore figures comparing the creation or maintaining of employment at home to where revenue is earned, as the amount of jobs being kept in Europe is the key benefit of European wind energy companies' success in globalization.

Vestas, with more than 22 000 employees in over 34 countries, had at the end of 2016 54.3% of them based in the EMEA region (Europe, Middle East and Africa), an area where it earns just 45% of its revenues [55]. However, despite maintaining the majority of employment in Europe, Vestas also shows that European companies are subject to the pressures of globalization: in 2016 the blade factory in Lem (DK) had to reduce 300 staff due to "*its high manufacturing costs compared to the market level as well as the need to strengthen Vestas' overall manufacturing and supply chain competitiveness in response to evolving market conditions*".

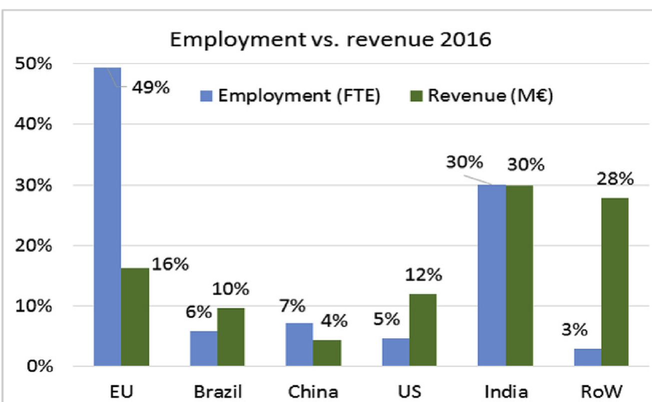

Fig. 16. Location of jobs in full-time equivalent (FTE) vs. origin of revenue. Most of the employment is maintained in the EU, whereas most of the revenue is raised abroad. Source: [54].

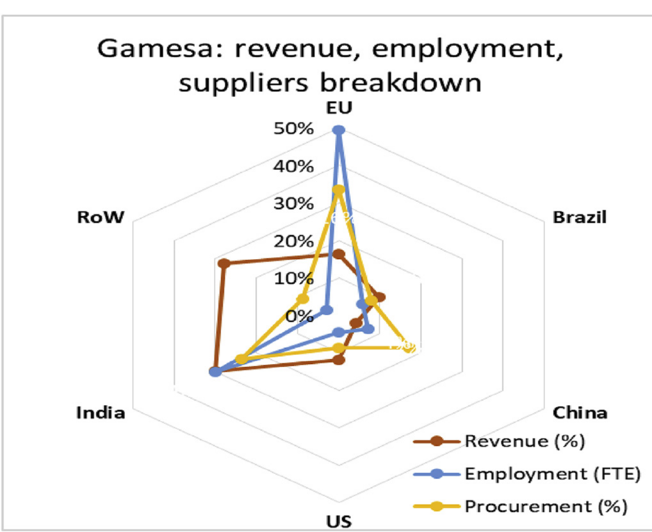

Fig. 17. Comparison of where revenue is earned, where procurement takes place and where employment is maintained, 2016

Fig. 16 shows data for Gamesa which could be the extreme case save, perhaps, Enercon, whose data are not public. The former concentrates in the EU 49% of their workforce whereas only 16% of its global revenue originates in the EU. Further, Fig. 17 compares the percentages of revenue (€), employment (no. of jobs) and procurement from suppliers (first and second tier) for the company, and reinforces the conclusion that this company maintains a very significant base at home even when most of its revenue (84%) originates outside the EU.

With regards other European OEMs in the top-15 ranking of manufacturers in 2016, data for Enercon and Siemens were not available. Nordex-Acciona maintained in Europe, at the end of 2016, 83% of its employees, whereas 61% of orders came from Europe [56]. Senvion, whose 2016 revenue in the EU was 80% of total revenue (the remaining being Canada and the US) [62], does not provide a breakdown of its workforce per country/area in its annual report.

5. Global wind farm developer market

The role of the developer is crucial for the success of a project, and it has certain characteristics that are interesting to highlight in the context of this research.

Wind energy projects normally consists of two major elements: the turbines, which are generally supplied from towers to blades by the turbine OEM, and the balance-of-plant (BoP) which includes civil works, electrical connections among turbines and to the grid, and an electricity substation if necessary. Transport and installation of the turbines could be part of either element. In China, a dual system of contracts makes that it is not the turbine OEM that supplies the tower nor the turbine transformer, but the BoP contractor.

BoP is provided by very varied companies including legal consultants, builders, cable manufacturers, etc. Therefore, the developer has to have deep knowledge of the local market, legal, economic and social context. This knowledge is naturally held by local companies and thus the developer market is highly localised.

5.1. Methodology

This part of the research is based on data from Bloomberg New Energy Finance (BNEF) wind farm database received in May 2017.

This database contained both onshore and offshore projects commissioned between 2007 and 2016 or that were under construction by the end of 2016. Projects below 5MW were removed as they were considered local projects. This resulted in a total capacity in the database was 401 662 MW.

5.2. Details of the developers market

Based in the need to be local, the developers market is much more diversified than the turbine manufacturer market. The 20 largest developers only sum 35% of wind energy commissioned in the years 2007–2016 (see Figure 18), which can be compared with 97% of the wind turbine market held by the 20 largest manufacturers, according to the same database.

Most large developers are business units of either Chinese state-owned enterprises (SOEs) including Guodian/Longyuan, Huaneng, Datang, Huadian, China General Nuclear (CGN), or of traditional European utilities such as Iberdrola, EDP, EDF, E. ON, Enel, Dong, SSE Renewables. Two American developers, owned by utilities, are among the leading developers by volume installed: NextEra and Invenergy.

The five largest Chinese developers are active essentially only in

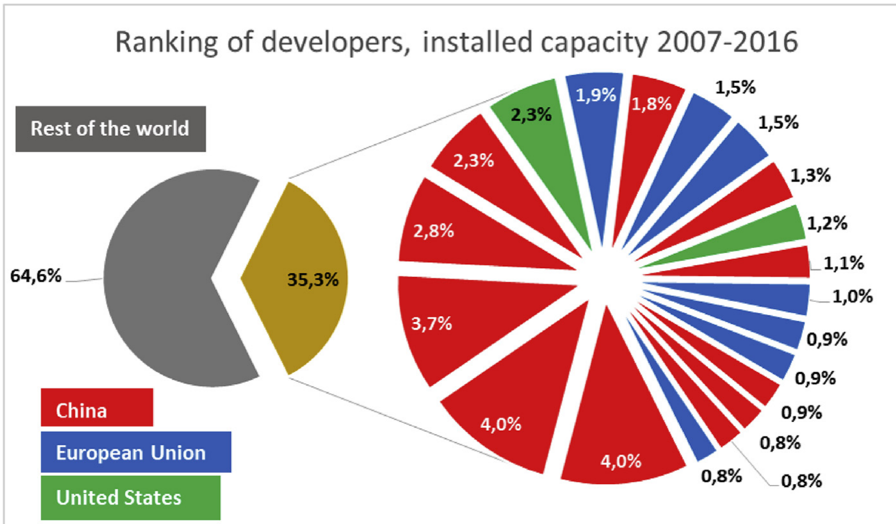

Fig. 18. Developers market per installed capacity, last 10 years. Based on 402 GW of onshore and offshore projects deployed between 2007 and 2016 or under construction at the end of that year. Source: BNEF database of wind farms adapted with own market knowledge.

China: Guodian/Longyuan (5.3% of the global market), Huaneng (4%), Datang (3.7%), Huadian (2.8%) and CGN (2.3%). Next is US company NextEra (2.3%, 95% of which in US and the rest in Canada), followed by Spanish developer Iberdrola (1.9%). Chinese Guohua follows and EDP Renovaveis and EDF Energies Nouvelles from the EU complete the top ten in this database.

5.3. Globalization of developers

European developers, although overall not the largest in size, have expanded operations through several markets whereas Chinese and US ones only marginally or moderately expanded abroad. For example, US developers have expanded, e.g. to 1–3 countries in the case of NextEra and Invenergy, whereas Chinese developers have only recently started to expand into Canada, Pakistan, Australia, South Africa, the US and other countries.

At first sight it feels surprising that Chinese developers, with plenty of financial muscle, have not expanded abroad significantly. Cui and Jiang [63] argue that state ownership is a problem for those developers to invest abroad as it "*creates the political affiliation of a firm with its home-country government, which increases the firm's resource dependence on home-country institutions, while at the same time influencing its image as perceived by host-country institutional constituents*." This point is reinforced by Huang et al. [64] who, based on resource dependence theory, suggest that SOE's dependence from state resources "*may also reduce these firms' willingness to expand internationally*".

Part of developers' international expansion took place through acquisitions, in particular into the US market. Iberdrola acquired local developers MREC Partners and Midwest Renewable Energy Projects and utility Energy East. EDP and EDF acquired Horizon Wind Energy and enXco respectively. In other cases, developers expanded with organic growth, setting up country subsidiaries. This was most common in markets with closer cultural ties, e.g. Gestamp from Spain into Brazil.

Another form of expansion to new markets is the acquisition of projects. For example, Acciona (ES) in 2016 acquired the San Roman wind farm (93 MW) in Texas, US, from American developer Pioneer Wind Energy [65].

European developers lead in terms of number of countries present. This ranking is led by Spanish Gamesa Development and Acciona Energía who are present in 14 countries each. They are followed by Iberdrola (ES) and ENEL (IT), who are present in 13 countries, EDF (FR) in 11, E. ON (DE) in 10, Engie (FR) in 9, and EDP (PT) in 8 countries. Present in 7 countries are RES (UK), Vestas (DK), and four more European companies follow with presence in 6 countries: Innogy, ABO and Nordex from Germany and Gestamp from Spain.

It's only in position 16 of this ranking of countries present that the first non-EU developer present in 5 countries is found, AES from the US. AES is accompanied by yet more European developers: juwi, WKN and BayWa (DE), Vattenfall (SE) and Global Wind Power A/S (DK), all of which are present in 5 countries.

Purchases of EU assets by non-EU firms.

Recently, a consortium of three Japanese entities (investment trading company Sojitz Corporation, Mitsubishi UFJ Lease & Finance and utility company Kansai Electric Power) bought 60% of a portfolio of five Irish wind farms (four of which already in operation and one under development), with a total 223 MW capacity, for 300 M€ [83]. This involves a valuation of the assets of 2242 €/kW, significantly higher than the estimated CapEx of 1200–1400 €/kW.

Within the EU, Irish assets have been particularly attractive for non-EU investors, with China General Nuclear Power Group buying 230 MW of wind farm assets from Gaelectric in December 2016.

The analysis of the global number of installations (in MW) per year shows the companies that have become more active or successful than others. Chinese developers, focused only on their domestic market, have been subjected to the ups and downs of that market, and generally show peaks in 2010 and 2015 and drops in 2011–2014 and 2016.

Large developers from the European Union have reduced their investment and thus show a negative trend in the period studied: Iberdrola, E. ON, Gamesa Development, Acciona, and BP. EDP and EDF, although generally having less new installations recently than at the beginning of the period, have picked up slightly in 2016.

American developers show strong growth lately, led by NextEra and Invenergy, as have European Enel, Renewable Energy Systems and wpd.

The description, based on BNEF data, shows how selected European developers internationalised.

- Iberdrola. Based on its home country (ES) and on the home country of its acquisitions (see above, mostly UK and US), Iberdrola expanded into other EU countries (to FR, DE, PL) at the beginning of the period but new onshore EU projects became rarer, and something similar occurred in the US. In 2015 Iberdrola entered the Asian market (TR). Overall, Iberdrola has reduced investment in wind farm deployment over the years.
- EDP (*Energias de Portugal*) Renovaveis has expanded mostly in the US, significantly more than in ES, RO, PT, PL, and FR. Originally EDP was present in the US, Spain and France, and over the 10 years under study it diversified to a total 8 countries.
- EDF (*Electricité de France*) Nouvelles Energies had diversified prior to 2007 with presence in FR, IT, PT, GR, US. After 2007 EDF further diversified to CA, MX, PL and the UK. Significant markets for EDF are the US, PT, IT, FR and CA.
- E. ON (DE) somehow surprisingly did not start developing wind farms in its home country but in the US, and it still has a very low basis in Germany. E. ON expanded to DK, PL, PT, ES and SE, although the bulk of its assets during this period (68%) are in the US.

Chinese developers have as well made attempts to go global, with mixed results. For example, China Longyuan Power Group Corporation Limited, a minority stock market-listed subsidiary of Chinese state-owned utility China Guodian Corporation with 58% of capital, has as main business the development and operation of wind farms. By mid-2017, Longyuan had a consolidated wind capacity of 17.4 GW [66].

In 2011 Longyuan and Gamesa signed a memorandum of understanding (MoU) for Gamesa to support Longyuan's internationalisation [67]. Shortly afterwards Longyuan acquired its first operational foreign project, the 99 MW Dufferin wind farm in Canada, which was developed … with GE turbines. The other Longyuan overseas project, the 245 MW Mulilo De Aar in South Africa, is being built with Guodian wind turbines.

The MoU was therefore never put in operation.

Internationalisation of the development activity of turbine manufacturers

European turbine manufacturers have traditionally included a wind farm development business unit or activity focused on the onshore subsector that developed as well projects outside the EU. These projects often took place in partnership with local companies, e.g. offering turnkey installations.

Table 3 shows the countries where the wind farm development businesses of European turbine manufacturers are or have been active. It is perhaps interesting to mention some details:

- Gamesa was originally present in some EU countries (ES, PT, IT, DE) and expanded within the EU, then the US, China and Mexico. However, similarly to Iberdrola, towards 2013 it reduced very significantly its developing business.
- Acciona Energía concentrated most activity in its home market (ES) but already at the beginning of the period it had some activity in other EU countries and beyond. After the crisis in the Spanish renewable energy sector, Acciona expanded to other American markets although its development activity was significantly less.

Table 3
Wind farm development activity of European wind turbine manufacturers outside Europe. Source: BNEF database of wind farms.

	Acciona	Gamesa	Nordex	Vestas	Enercon
Argentina					X
Australia	X	X			
Brazil					X
Canada	X				
Chile	X			X	
China		X	X		
Costa Rica	X				
Egypt		X			
India	X	X		X	X
Jordan				X	
Mexico	X	X			
Morocco	X				
New Zealand					X
Philippines		X			
South Korea	X				
Turkey			X		X
Uruguay					X
US	X	X	X		
Venezuela		X			

6. Conclusions

Globalization goes hand-by-hand with localisation. In order to compete in large markets (India, China, US, Brazil), EU companies have had to grow local manufacture and a supply chain. The US is somehow the exception and this could be due to its openness as a market. Smaller markets are supplied from the main production centres (whether the EU or factories in China) and do not require localisation.

Vestas, Gamesa, and other European companies to a lesser extent have been successful at localisation whereas Suzlon and Chinese companies are generally less able to localise supplies, perhaps due to the low-cost production achieved in their home countries.

OEMs in the EU contribute to the economy significantly thanks to their exports, but China is emerging as a manufacturing hub for them. Eventually, this could result in Chinese suppliers offering products of higher quality which risks increasing competition from Chinese OEMs using this modality of technology transfer.

Whereas seven acquisitions of EU technology firms by US companies, and four acquisitions by Chinese companies were identified, no European company acquired a US or Chinese technology firm. This can be the result of the longer history of EU companies in the business, of the quality of their technology, of the successive crisis affecting the sector in Europe, of the availability of funding on the side of the American and Chinese, or a combination of these. Significantly as well, General Electric of the US has been the acquirer of all but one European technology companies bought by US firms.

The European wind industry is a success story of worldwide reach that attracts jobs and growth for Europe. In order to ensure that this will continue to be so in the mid- or long-term future, the industry may need the help of European and national policy makers with consented, well-targeted actions. Support programmes could help maintaining technological leadership through research, development and innovation programmes feeding on cross-industry knowledge and knowhow. They could support industrial leadership also in the manufacture of components. Instruments to financially and politically back the expansion of the industry to new and existing foreign markets may also be required.

Further reflection of policy makers with developers, turbine manufacturers and other key players may be needed so as to increase the impact of the sometimes already existing programmes (e.g. Horizon 2020) and make their implementation more comprehensive.

Disclaimer

"The views expressed in this paper are purely those of the author and may not in any circumstances be regarded as stating an official position of the European Commission. The author declares not to have any significant competing financial, professional or personal interests that might have influenced the performance or presentation of the work described in this manuscript."

Declarations of interest

None.

This research uses ISO 3166 2-letter countries codes, always written in capital letters. ISO codes are available at https://www.iso.org/iso-3166-country-codes.html.

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List of abbreviations and definitions

BNEF: Bloomberg New Energy Finance, a Bloomberg company
BoP: Balance of plant of a wind farm
HDD: Hard disk drive
FTE: Full-time equivalent (jobs)
LATAM: Latin America
M&A: Merger and acquisition
O&M: Operations and maintenance
OEM: Original equipment manufacturer, in this report OEM refers to the turbine manufacturer
PV: Photovoltaics
RoE: Return on Equity
RoW: Rest of the World
SGRE: Siemens Gamesa Renewable Energy
SOE: state-owned enterprise
SWP: Siemens Wind Power