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European Power Companies' New Business Models

Lessons for Japanese Electric Utilities

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JREF-Japan Renewable Energy Foundation

Japan Renewable Energy Foundation is a non-profit organisation which aims to build a sustainable, rich society based on renewable energy. It was established in August 2011, in the aftermath of the Fukushima Daiichi Nuclear Power Plant accident, by its founder Mr. Masayoshi Son, Chairman & CEO of SoftBank Corp., with his own private resources. The foundation is engaged in activities such as; research-based analyses on renewable energy, policy recommendations, building a platform for discussions among stakeholders, and facilitating knowledge exchange and joint action with international and domestic partners.

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EXECUTIVE SUMMARY

The Japanese electricity system has entered reform phase and renewable energy sources, especially solar photovoltaic, have been significantly deployed since the introduction of a feed-in tariff scheme in the country three years ago. This new reality presents challenges for Japanese electric power companies. Challenges to which their European peers have already been confronted for some years now.

This report proposes exploring how European electric power companies are adapting their business strategies to the energy transition in liberalised electricity markets, and particularly their electricity generation activities, to provide Japanese electric companies relevant information on the possible evolutions of their business model, highlighting potential growth areas and warning against mistakes made in Europe not to be replicated in Japan.

For this purpose 16 of the largest European electric power companies have been selected, including; EDF, Enel, GDF-Suez/ENGIE, E.ON, RWE, Iberdrola, Vattenfall, EDP,… notably, totalling about 640 gigawatts of installed capacity (consolidated).

Expansion for renewables, mixed developments for fossil fuel power, hard times for nuclear

In the last fifteen-twenty years electricity production activities of the major European electric power companies have been significantly impacted by three key factors; electricity markets liberalisation, energy and climate policies, and Fukushima nuclear disaster. Liberalised electricity markets enabled mergers among electric utilities (at the national and international levels), but also with gas utilities, and market entrance of new players. Promotion of renewables has resulted in dramatic cost reductions of wind and solar power through significant deployment, and in a reduction of conventional power plants margins, especially in Europe where demand for electricity decreased in recent years following the economic crisis. And Fukushima nuclear disaster demonstrated that nuclear power is neither safe nor cheap.

The major European electric power companies are increasingly investing to expand their renewables fleet, especially wind (with gigawatts under construction) and hydropower, but also solar progressively. The Groups now recognise the cost competitiveness of renewables and have designated these clean green technologies as their first option in their contribution to tackle climate change. Investments in renewables are, however, usually led outside the Groups' respective domestic markets where renewables would otherwise directly compete with the

Groups' conventional assets often inherited from their past of traditional vertically integrated electric power companies.

Fossil fuel-fired power plants of the major European electric power companies have known various fortunes in recent years. In Europe, a number of plants have been closed because of more stringent environmental standards, new have been constructed to theoretically replace old inefficient power stations shutting down, but with the expansion of renewables, gains in energy efficiency, and a depressed demand for electricity in a context of economic markets these plants are actually not needed resulting in important financial losses for their stakeholders. Gas-fired power plants have been impacted the most, followed by hard coal power plants. And the outlook does not allow optimism. Outside Europe, emerging economies have provided some opportunities for expansion of fossil fuel-power stations.

Saying that the nuclear generation activities of the major European electric power companies have been negatively impacted by Fukushima nuclear accident is a euphemism. Some Groups have been forced to shut down their nuclear power plants and all the ones operating nuclear power plants have to invest more to meet more stringent safety standards, resulting in higher costs. At the same time their new build projects are well over budget and behind schedule. The major European electric power companies now require subsidies to build new nuclear power plants and prefer to invest in renovating their existing plants to get operating lifetime extensions, which may not always be granted. Considering the maturity of the industry these are scaring signs for its future. A future during which methods for decommissioning and storing radioactive waste at a cost that can be afforded by electric power companies will need to be found.

Customers' energy optimisation, electrical networks, more integrated energy systems as growth areas

Even after the liberalisation of European electricity markets, and the unbundling of their generation, transmission, distribution, and supply activities the major European electric power companies are still quite involved in the electrical networks (especially at the distribution level) and electricity retail businesses, usually through subsidiaries. This means that apart from their generation activity, which is facing tough market conditions in Europe, they still have many opportunities in various fields to make profits and they are eager to take advantages of these possibilities.

The Groups studied are increasingly developing customers' energy optimisation solutions; energy efficiency, demand side management, distributed electricity and heating &

cooling production. They notably provide energy advisory services, installation and maintenance of equipment, and possibly financial services as well as pooling (clustering a number of small generators to create a virtual power station thus enabling operators to offer self-generated electricity on the market, e.g. balancing energy market).

Furthermore they are targeting investment in electrical networks, in some cases at the transmission level and in all cases at the distribution level, to integrate renewable energy and develop interconnections. These activities are being pursued with interest because they are regulated and guarantee stable predictable returns.

The major European electric power companies are also interested in participating in the electrification of the transportation sector providing charging stations and their management, notably. Finally, some of them are also developing district heating & cooling networks with a vision of more integrated energy systems.

Energy transition in a context of electricity system reform represents thus both threats & opportunities to the business of Japanese electric power companies. Traditional business as usual is no option. Innovation is critical to adapt to this new paradigm. There is, however, no fatality that this paradigm shift will result in the infamous "utility death spiral." Japanese electric power companies now have the chance to learn from their European peers' experiences, and they will have no excuse not choosing the right path.

INTRODUCTION

The Japanese electricity system is at a crossroads; its electricity system has entered reform phase and evolution of support schemes for renewable energy (RE) is intensively being discussed. In this context, this report proposes exploring how these major changes, and particularly the expansion of RE generation, may impact the businesses activities of the Japanese electric power companies (EPCOs) based on the experiences of their European peers, which have already experienced both liberalisation of electricity markets (See Box 1 on page 10 for information on why the electricity system reform in Europe has rather been about re-regulation than pure liberalisation, and on the variety of forms it has taken at the transmission level) and gone through the first stages of the energy transition in Europe.[a]

This report exhaustively refers to the generation activities of 16 major European EPCOs, as well as their transmission, distribution, and supply activities, illustrated with numerous data, examples, and quotes mainly extracted from over 40 corporate documents, Annual Reports and Strategy Reports, notably, totalling over 6,500 pages (see page 97 for the List of Annual Reports used throughout the report). These Groups are Électricité de France (EDF), Enel, Gaz de France-Suez/ENGIE (GDF-Suez/ENGIE), E.ON, Rheinisch-Westfälisches Elektrizitätswerk (RWE), Iberdrola, Vattenfall, Energias de Portugal (EDP), Statkraft, Fortum, České Energetické Závody (CEZ), Natural Gas Fenosa, Energie Baden-Württemberg (EnBW), Polska Grupa Energetyczna (PGE), Scottish and Southern Energy (SSE), and Verbund (See Table 1 on page 9 for basic information on these Groups).

They have primarily been selected based on their total installed capacity (consolidated); from about 10 to 135 gigawatts (GW), that is to say not smaller than Japanese EPCOs.[b] These Groups are active in their home country and almost everywhere in Europe; Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Italy, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Spain, Sweden, the United Kingdom (UK),… and in all inhabited continents; Africa, Asia, North and South America, and Oceania, i.e. almost everywhere in the world (See Map on page 10 for the locations of the selected major European EPCOs headquarters).

These Groups, once vertically integrated national or regional electricity monopolies

[a] EPCOs are companies engaged in the generation, transmission and/or distribution, and sale of electricity.
[b] In accordance with international financial reporting standards (IFRS) 10, controlled entities (subsidiaries) are fully consolidated. In accordance with IFRS 11, investments in associates and joint ventures are accounted for under the equity method (% of share in the investee's net assets), and in the case of a joint operation, a joint operator accounts for the assets, liabilities, revenues and expenses relating to its interest in a joint operation in accordance with the IFRS applicable to these assets, liabilities, revenues, and expenses.

have thus after electricity markets liberalisation expanded internationally by merging with other EPCOs, but not only. Indeed, some of the former electric monopolies have also merged with gas utilities, becoming integrated energy players and diversifying their activities. This strategy ensured supply of gas for electric utilities' gas-fired power plants, and for gas utilities the sales of their production. Moreover it enabled these two different types of utilities to offer at the supply level bundled packages electricity & gas to their customers (see Box 2 on page 12 for more information about the Major European EPCOs historical mergers).

Although their activities have been unbundled, some of the major European EPCOs are still active in the transmission segment, and all are in the distribution and supply segments, usually through independent subsidiaries, and this is a chance for them in the context of energy transition, in Europe particularly. Indeed, the promotion of RE and energy efficiency (EE) in Europe, in a situation of decreasing electricity demand has had a devastating impact on their generation business especially, but it has also opened new opportunities for investments in innovative solutions (demand side management (DSM), distributed customer-sited generation, electric mobility, district heating & cooling (H&C) networks,…) and electrical networks (transmission and distribution (T&D)), notably.

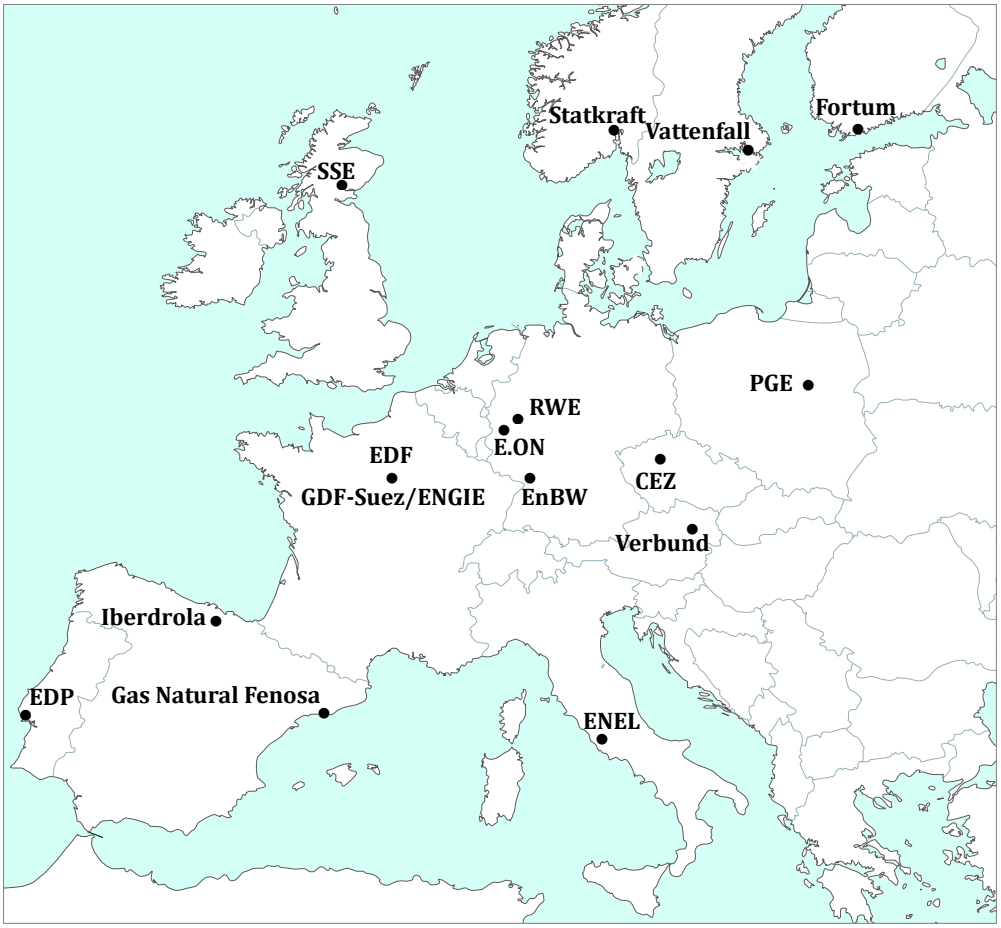
By focusing on how the European EPCOs are adapting to the energy transition in their generation activities (in renewables, fossil fuels and nuclear, and with regard to climate change), as well as in their activities of suppliers of customers' energy optimisation services, electric networks managers, and stakeholders in the electrification of the transportation sector and the development of district H&C networks for more integrated energy systems, this report aims at demonstrating to Japanese EPCOs, Japanese policy-makers, and potential investors in the market that there is no fatality for Japanese EPCOs to enter a death spiral and lose trillions yens by pursuing a nuclear free-low carbon Japanese society.

Table 1: Selected Major European EPCOs Introductory Table

Group	Headquarters, Country	Service Provision				2014 Financial indicators (billion ¥)		
		Generation (installed capacity GW (consolida-ted))	Transmission*	Distribution	Supply	Sales or revenue	EBIT**	Net income***
EDF	Paris, France	136	(ITO)			10,234	1,121	520
Enel	Rome, Italy	96				10,298	434	73
GDF-Suez /ENGIE	Paris la Défense, France	81				10,489	1,006	343
E.ON	Düsseldorf, Germany	60				15,667	655	-444
RWE	Essen, Germany	49	(ITO)			6,481	564	239
Iberdrola	Bilbao, Spain	43	(ISO in UK)			4,218	553	327
Vattenfall	Stockholm, Sweden	40				2,561	-34	-126
EDP	Lisbon, Portugal	24				2,288	308	146
Statkraft	Oslo, Norway	16				810	228	54
Fortum	Espoo, Finland	15				667	481	443
CEZ	Prague, Czech Republic	15				1,023	188	114
Gas Natural Fenosa	Barcelona, Spain	15				3,475	448	205
EnBW	Karlsruhe, Germany	14	(ITO)			2,950	0	-63
PGE	Warsaw, Poland	13				893	171	122
SSE	Perth, United Kingdom	12	(ISO)			5,516	328	95
Verbund	Vienna, Austria	10	(ITO)			398	54	18

*For EPCOs active at the transmission level in Europe the type of TSO is indicated between brackets, as well as the country where it operates if different from the Group's headquarter country. For more information on the different types of TSOs in Europe see Box 1 on next page.
**Earnings before interest and taxes.
***Attributable to shareholders of the Group.
Sources: Groups Annual Reports, and in some cases complementary corporate materials available online.

Map: Selected Major European EPCOs Headquarter Locations



Source: Created by Japan Renewable Energy Foundation

Box 1: Electricity System Reform in Europe; Re-regulation rather than pure liberalisation, and variety of forms at the transmission level

The first European Union (EU) electricity market liberalisation directive was adopted in 1996 and was to be transposed into Member States (MS)' legal systems by 1999 *(Directive 96/92/EC of the European Parliament and of the Council of 19 December 1996 concerning common rules for the internal market in electricity*). [1] The second electricity market liberalisation directive was adopted in 2003 and was to be transposed into national law by MS by 2004, with some provisions entering into force only in 2007 (*Directive 2003/54/EC of the European Parliament and of the Council of 26 June 2003 concerning common rules for the internal market in electricity and repealing Directive 96/92/EC*).[2] A third liberalisation package, including legislative proposals to strengthen competition in the electricity market, notably, was

brought forward in 2007 and adopted in 2009 with transposition by 2011 (*Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC*).[3]

The term of "liberalisation" is often used to qualify this about fifteen year-process of electricity system reform in Europe. That is a misnomer since this electricity system reform has rather been about re-regulation than pure liberalisation. Indeed, new regulations have been implemented in the industry in both the competitive parts, i.e. electricity generation and retail markets, notably by removing gradually any restrictions on customers from changing their supplier in the case of the retail market, and the non-competitive parts, i.e. natural monopolies; operation of the networks (T&D).[4] The EU notably decided to oblige the operators of the non-competitive parts of the industry to allow third parties to have access to the infrastructure (open and non-discriminatory access).[5] In addition, it was also decided to introduce independent regulators (national regulatory authorities) to monitor the sector.[6] This highlights the need for rules to ensure fair and transparent operation for an efficient electricity market.

Another important feature of the electricity system reform in Europe is the variety of forms it has taken at the transmission level across the continent. For instance, when it comes to the separation of electrical grid activities from generation and supply activities in application of EU legislation MS had the choice among three main options; ownership unbundling (OU), independent system operator (ISO), also called functional unbundling, and independent transmission operator (ITO), also called legal unbundling.[7] OU implies the appointment of the network owner as the system operator and its independence from any supply and production interests.[8] An ISO is a fully unbundled system operator without the grid assets (still belonging to an integrated company).[9] In the case of an ITO, a transmission system operator (TSO) owns the assets and belongs to a vertically integrated company, with special rules to guarantee its independence.[10] While the EU recognised OU at transmission level as "the most effective tool to promote investments in infrastructures in a non-discriminatory way, fair access to the grid for new entrants and transparency in the market," not all MS chose this option.[11] For instance, Belgium, Czech Republic, England, Italy, the Netherlands, the Nordic Countries (Denmark, Finland, Norway, and Sweden), Poland, Portugal, and, Spain chose the OU model, France and Austria the ITO model, and Ireland and Scotland the ISO model.[12] In Germany the OU and ITO models are coexisting.[13] This is the reason why some of the Groups studied in this report still have activities in transmission networks (Part 2. 2.A. Activities Related to Transmission Networks).

Box 2: Selected Major European EPCOs Historical Mergers

After electricity market liberalisation the major European EPCOs have sought growth beyond their traditional geographical area (international expansion for former national monopolies, international and/or national expansion(s) for former regional monopolies), and/or in complementary energy markets such as gas for example. The Groups studied in this report are thus the results of electric utility/electric utility mergers, and/or electric utility/gas utility mergers. Less often coal mining was also the object of mergers. This Box introduces some of these most noteworthy mergers.

Among the most important mergers between electric utilities; at the end of the 1990s, the French Group EDF acquired 100% of London Electricity, which was renamed EDF Energy in 2003 after a series of acquisitions and mergers.[14] Some years later, in 2009, EDF energy acquired British Energy, one of the largest energy companies in the UK with eight nuclear power stations notably.[15] In 2009, the Italian Group Enel took full control of Endesa, Spain's largest power company.[16] Endesa also has significant operations in Latin America notably.[17] In 2000, E.ON was formed from the merger of German Groups Vereinigte Elektrizitäts- und Bergwerks- Aktiengesellschaft (VEBA) and Vereinigte Industrie-Unternehmungen Aktiengesellschaft (VIAG).[18] One year later E.ON announced its acquisition of British utility Powergen enabling the German Group to enter the UK and United States (US) energy markets.[19] In 2002, the German Group RWE acquired Innogy, a leading British electricity utility and one of the two parts of former National Power.[20] In 2007, the Spanish Group Iberdrola completed Scottish Power takeover.[21] In Germany in the early 2000s, the Swedish Group Vattenfall acquired Hamburgische Elektrizitätswerke (HEW), Berliner Städtische Elektrizitätswerke Aktiengesellschaft (BEWAG), and Vereinigte Energiewerke Aktiengesellschaft (VEAG), as well as Lausitzer Braunkohle Aktiengesellschaft (LAUBAG) a lignite mining company and became one of the country's largest electricity generators.[22] And SSE is the result of the merger between Southern Electric and Scottish Hydro Electric in 1998.[23]

Among the most important mergers between electric and gas utilities; GDF-Suez/ENGIE is the result of the merger between Gaz de France, France's former national vertically integrated gas monopoly, and the French Group Suez, majority shareholder in Belgian power company Electrabel notably, in 2008.[24] GDF-Suez/ENGIE continued its expansion in the power sector in 2011 by acquiring 70% of International Power, the other part of former National Power (aforementioned).[25] Gas Natural Fenosa was historically a gas utility; Gas Natural, but after the liberalisation of the Spanish energy market, Gas Natural acquired (merger by absorption) the electricity company Unión Fenosa in 2008, and entered into the

electricity sector.[26] It is today an integrated gas and electricity business. In 2010, SSE agreed to buy the natural gas and infrastructure assets of the energy Group Hess in three regions of the North Sea, indicating that gas from the acquired assets will provide fuel to supply its customers and power stations.[27]

Finally, another interesting merger was the takeover of Edison, the oldest Italian electricity company and one of the key players in the Italian electricity market, by EDF in 2012.[28] A transaction carried out as part of the EDF Group's gas strategy, Edison having also expertise at all stages of the gas chain, from hydrocarbon exploration and production to direct sales of natural gas.[29]

Part 1. ELECTRICITY GENERATION

In the last fifteen-twenty years electricity production activities of the major European EPCOs have been significantly impacted by three key factors; electricity markets liberalisation, energy and climate policies, and Fukushima nuclear disaster. Liberalisation of electricity markets has notably enabled international growth of the major European EPCOs' electricity generation businesses, but it has also often meant mergers of conventional power plant fleets and therefore horizontal concentration at the generation level thus limiting competition among producers. Liberalisation of electricity markets has also led to mergers between electric and gas utilities, a "win-win" deal with electric utilities ensuring their fuel supply, and gas utilities their sales (or "loss-loss" if both markets face significant risk exposures, one just reinforcing the other). In terms of electricity generation mix strategies strictly speaking liberalisation of electricity markets has not directly led the major European EPCOs to invest in renewables. It has, however, provided a critical change; a fair access to electrical networks to new entrants. These new entrants had one key advantage over traditional large utilities; they were new entrants, i.e. by investing in RE with close to zero marginal costs they would not hurt the profitability of their own existing power plants.

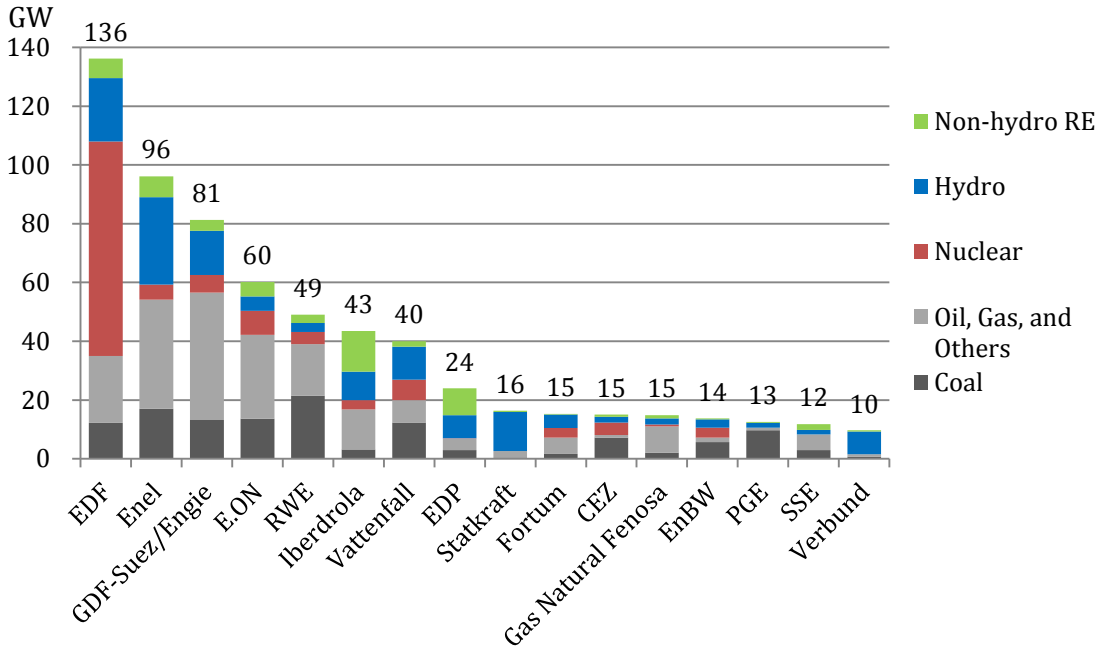
These new entrants could also lead such investments because enabling energy and climate policy frameworks starting to internalise negative externalities of generating electricity from polluting energy sources and rewarding clean energy technologies for their benefits were progressively adopted at the EU level. This set the wheels in motion to dramatic technology cost reductions of wind and solar power and definitively launched their expansion. And Fukushima nuclear disaster significantly accelerated this process by leading some European countries to decide progressive, but relatively rapid nuclear power phase-outs (Germany and Belgium notably) and by increasing the technology costs for operators opting for safety upgrades instead, thus giving more space for renewables to grow and making them more cost competitive.

All these changes occurred in a context of economic crisis resulting in depressed demand for energy. RE have thus increasingly served a decreasing electricity consumption; a double blow for the electricity production activities of the major European EPCOs in Europe: their large conventional power plant fleets have been producing less and selling at lower prices since wholesale electricity prices (resulting from the trade of electricity prior to its supply to the destination grid of the end customer) decreased because of lower demand and the close to zero marginal costs of wind and solar power. For instance average spot prices on power exchanges in 2014 were; €32.8/megawatt hour (MWh) (-13% compared with 2013) in

Germany, €34.6/MWh (-20%) in France, and €29.6/MWh (-22%) in Nord Pool (which notably includes the Nordic countries, and the Baltic countries; Estonia, Latvia, and Lithuania, but not only).[30] Gas power plants, the technology on which the major European EPCOs rely the most, and which has the highest marginal cost (with oil-fired power plants) making them rank last in the merit order, have been the first to be pushed out of the markets. Hard-coal fired power plants have also started to feel the heat. Old inefficient brown coal (lignite) and nuclear will be next victims.

Confronted with this new harsh reality, the major European EPCOs, which power mix are still dominated by conventional power plants (fossil fuels, nuclear, and hydro) (Charts 1 and 2, Chart 2 on next page), have started to change their strategies and are increasingly investing in renewables. And this trend may well be more and more aggressively pursued in the coming years.

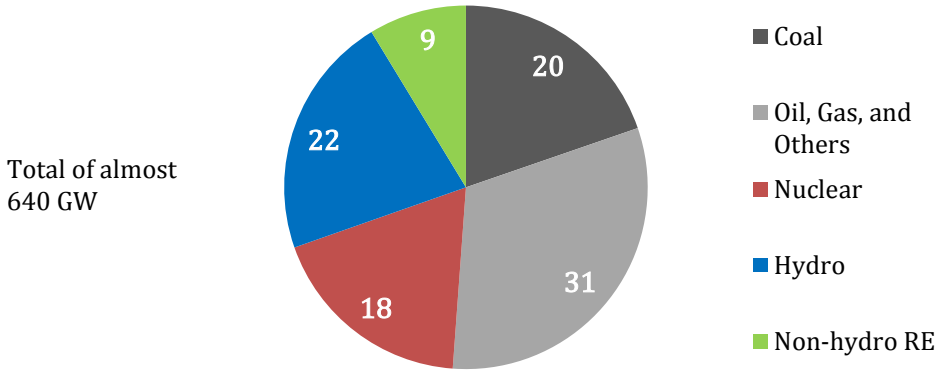
Chart 1: Selected Major European Power Companies Installed Capacity by Group 2014 (Consolidated)



Notes:
- "Oil, Gas, and Others" is mainly gas.
- "Hydro" includes pumped storage and small hydro.
- Groups are not reporting installed capacity information in the same fashion, a great care has been brought to make this chart as consistent as possible, and while some little inaccuracies might remain, it certainly offers a good basis for comparison.

Sources: Companies Annual Reports, and in some cases complementary corporate materials available online.

Chart 2: Selected Major European Power Companies Combined Installed Capacity by Technology 2014 (%) (Consolidated)



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- Groups are not reporting installed capacity information in the same fashion, a great care has been brought to make this chart as consistent as possible, and while some little inaccuracies might remain, it certainly offers a good basis for comparison.

Sources: Companies Annual Reports, and in some cases complementary corporate materials available online.

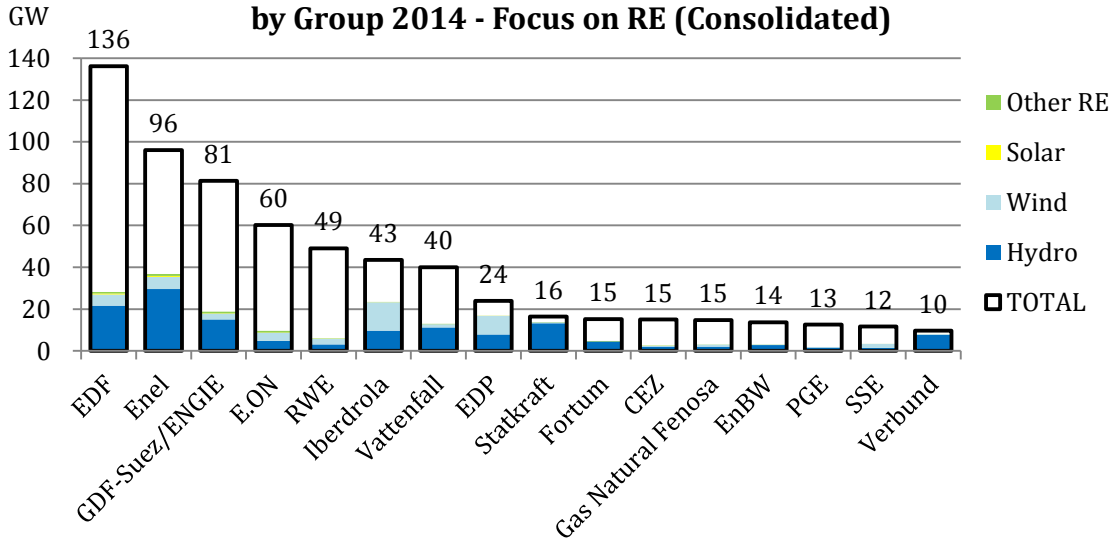
1. Renewables Expansion

The major European EPCOs have historically not been leaders in terms of RE technology deployment, especially when it comes to developing non-hydro renewables in their home country. In Chart 3 (on next page), the part of the bars which is white shows the amount of non-renewables installed capacity the Groups considered had in their portfolio at the end of 2014. It clearly appears that most of the EPCOs represented in this Chart had a majority of their power capacity coming from fossil fuel and nuclear technologies.

Another way of representing the current situation is by aggregating the various power installed capacity of the 16 Groups represented in Chart 3; combined they had approximately 640 GW of installed capacity at the end of 2014, out of which almost 140 GW of hydropower (22%), about 50 GW of wind power (8%), more than 1.5 GW of solar power (0%), and roughly 5 GW of other renewables (1%) (Chart 4 on next page).[c] Renewables thus accounted for just over 30% of these EPCOs' total installed capacity.[31]

[c] All hydropower capacities referred to in this report include pumped storage and small hydropower capacities as it was not always possible to distinguish among the different type of hydropower technologies in the Groups' corporate documents.

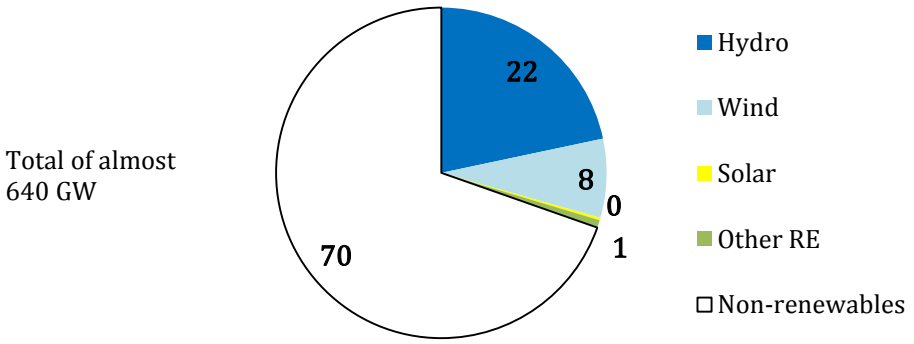
Chart 3: Selected Major European EPCOs Installed Capacity by Group 2014 - Focus on RE (Consolidated)



Notes:
- "Hydro" includes; pumped storage and small hydro.
- "Other RE" includes; bio, geothermal, and marine energies.
- Groups are not reporting installed capacity information in the same fashion, a great care has been brought to make this chart as consistent as possible, and while some little inaccuracies might remain, it certainly offers a good basis for comparison.

Sources: Groups Annual Reports, and in some cases complementary corporate materials available online.

Chart 4: Selected Major European EPCOs Combined Installed Capacity by Technology 2014 - Focus on RE (%) (Consolidated)



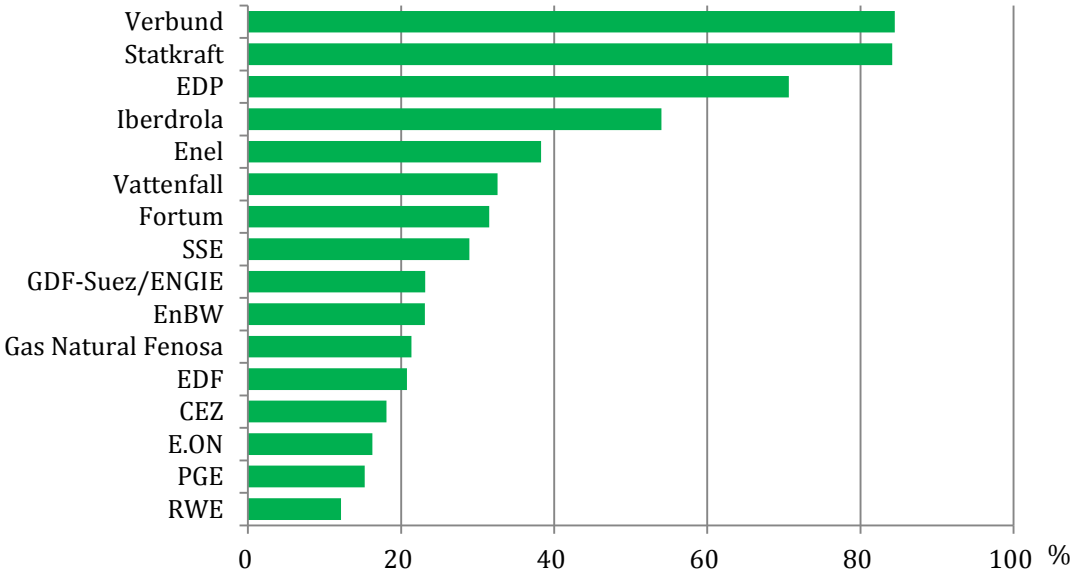
Notes:
- "Hydro" includes; pumped storage and small hydro.
- "Other RE" includes; bio, geothermal, and marine energies.

Sources: Groups Annual Reports, and in some cases complementary corporate materials available online.

Charts 5 and 6 (on next page) essentially complement Chart 3; thanks to Chart 5 we can notice that only one-fourth of the Groups considered had more than 40% of their installed capacity coming from renewables – half of which essentially thanks to hydropower (Verbund and Statkraft) (see Chart 3), and thanks to Chart 6 that only two of them (EDP and Iberdrola)

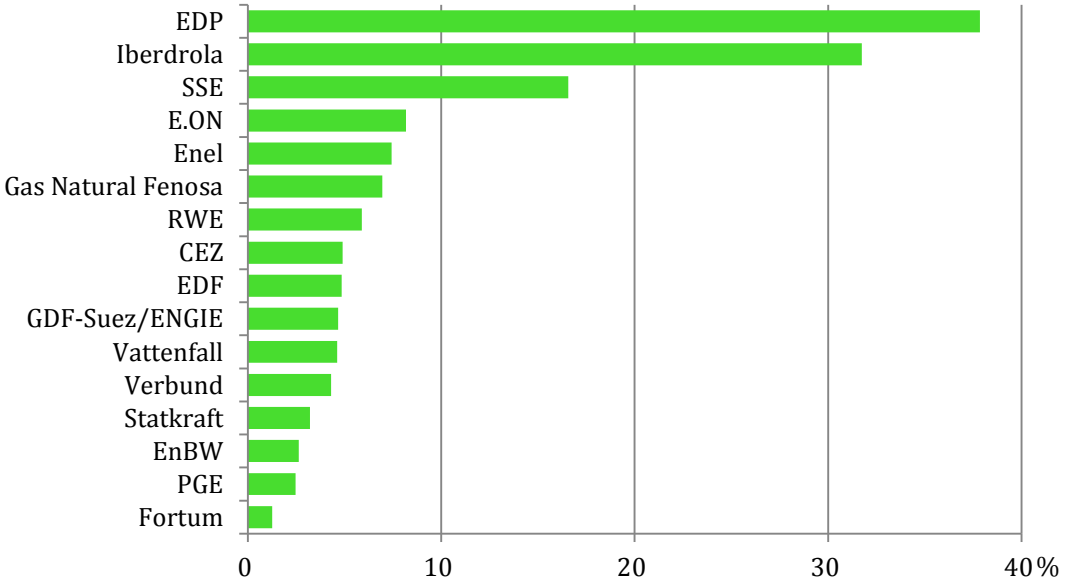
had more than 30% of their installed capacity coming from non-hydro renewables, essentially thanks to wind power (See Chart 3).

Chart 5: Share of RE Installed Capacity in the Group's Total Installed Capacity 2014 (Consolidated)



Sources: Groups Annual Reports, and in some cases complementary corporate materials available online.

Chart 6: Share of Non-hydro RE Installed Capacity in the Group's Total Installed Capacity 2014 (Consolidated)



Sources: Groups Annual Reports, and in some cases complementary corporate materials available online.

These results are relatively unsurprising insofar as hydropower like the other main conventional technologies (fossil fuels and nuclear) is mature and cost effective, and as non-hydro renewables have either been introduced more recently (wind and solar power) or may face resource constraints/lack of potential slowing down their development (biomass and geothermal) in addition of historically generally higher costs.

A very interesting point which deserves to be highlighted is that the major European EPCOs have often been relatively reluctant to invest in non-hydro renewables (particularly wind and solar power) in their home country, but much less abroad (See Table 2 on next page). Indeed, for the thirteen Groups for which data were available, the share of non-hydro renewables in their home country portfolio power plants fleet was only about 5% (thirteen Groups aggregated), this share increases by almost 3 times in their abroad portfolio's fleet (14%). Also worth noting, roughly 70% (thirteen Groups aggregated) of these Groups' non-hydro renewables capacity were located abroad, and approximately 55% (thirteen Groups aggregated) of their conventional capacity in their respective home country. And these are mainstream trends among the Groups specifically considered here; for a large majority (10/13) the share of non-hydro renewables in their abroad portfolio as opposed to their home country portfolio was about 2 or more times higher, a large majority (10/13) had over 50% of their non-hydro renewables installed capacity abroad, and a majority (8/13) had more than 50% of their conventional installed capacity in their home country. Some facts are particularly revealing of the figures presented in Table 2. At the end of 2014, E.ON's wind power installed capacity was essentially outside Germany.[32] Iberdrola is very dynamic in wind power in the US where the Group had about 5.5 GW of wind power installed capacity at the end of 2014; that is over 40% of the Group's total wind power capacity and more than 85% of the Group's total installed capacity in the US.[33] At the end of 2014 also, Vattenfall had over 40% of its total wind power installed capacity in the UK, where the Swedish Group did not have any conventional capacity, and CEZ had almost all its wind power installed capacity in Romania, where the Czech Group only had renewables capacity.[34] This can be explained by the fact that these Groups, which have historically often been national or regional monopolies, have thus first developed in their home market. And that for decades at a time when wind and solar power were if not existing, in their infancy, i.e. investments in generating capacity were thus essentially made in conventional power plants. After electricity markets liberalisation the major European EPCOs, and especially the largest ones, have demonstrated appetite for international growth. Simultaneously support for renewables was taking off, and their expansion started. An expansion in which the Groups considered in this report have been willing to take part in (to an extent that has differed from a Group to another) as long as they could receive some financial incentives to invest in technologies which were more expensive at the beginning, and as long as

these new capacities with close to zero marginal cost were not directly competing with their conventional assets. For instance, since wind and solar power have close to zero marginal cost they should be dispatched first from an economic point of view. As a result, conventional assets are pushed back in the merit order, meaning they are operating less hours and are rewarded less for their services. No reasonable business would risk hurting the profitability of its own assets by cutting their margins unless for dissuading new potential competitors from entering the market.

Table 2: Selected Major European EPCOs Non-Hydro RE and Conventional Installed Capacity Locations "Home Country VS. Abroad" (only Groups for which almost exact data were available are included)

Group (home country)	Group's non-hydro RE capacity located in home country/Group's total capacity in home country (%) [A]	Group's non-hydro RE capacity located abroad/Group's total capacity abroad (%) [B]	Group's non-hydro RE capacity abroad/Group's total non-hydro RE capacity (%) [C]	Group's conventional capacity in home country/Group's total conventional capacity (%) [D]
EDF (France)	<2.0%	<15%	>75%	>75%
Enel (Italy)	4.5	9.3	76.8	39.5
GDF-Suez/ENGIE (Europe)	7.0	2.3	24.6	49.2
E.ON (Germany)	<2.0%	>10%	>90%	<35%
RWE (Germany)	2.2	10.6	79.1	58.1
Iberdrola (Spain)	22.5	43.9	59.7	64.5
Vattenfall (Sweden)	2.7	6.0	75.1	42.9
EDP (Portugal)	12.0	56.0	86.9	58.4
Statkraft (Norway)	2.1	6.2	53.6	72.9
Fortum (Finland)	1.2	1.3	71.4	29.9
CEZ (Czech Republic)	1.0	38.3	81.9	93.2
Gas Natural Fenosa (Spain)	6.6	8.8	22.7	82.3
SSE (Great Britain)	13.8	33.7	28.0	89.1
TOTAL (estimate)	**~5%**	**~14%**	**~70%**	**~55%**
TOTAL /13	**N/A**	**10**	**10**	**8**
[B] > 2*[A] (roughly)				
[C] > 50%				
[D] > 50%				

Sources: Groups Annual Reports, and in some cases complementary corporate materials available online.

If renewables, and particularly non-hydro renewables, have not been the most deployed technologies by the major European EPCOs so far this picture may, however, well change in the years to come as onshore wind and solar photovoltaic (PV) power, which have in recent years significantly taken-off worldwide thanks to policy support and dramatic cost reductions, are more and more regarded by the major European EPCOs as technologies to increasingly invest in. This key trend can be captured in the strategies of the considered Groups, which are largely aiming at expanding in renewables.

The EDF Group, the world leader in nuclear energy production, has a target of achieving a 25% share of RE in its energy mix by 2020 (installed capacity) against 21% in 2014 and 20% in 2013, and it recently announced, in September 2015, that it is aiming for more than 50 GW of renewable energy capacity in Europe by 2030 compared with 28 GW today.[35d] The 2020 goal will notably be reached thanks to new wind and solar power capacity developed by EDF Énergies Nouvelles (EDF EN), which capital is 99.9% owned by the EDF Group.[36] EDF EN targets to reach 12 GW net (or 20 GW gross) of renewables installed capacity by 2020, against 5.1 GW net (or 7.5 GW gross) at the end of 2014.[37] For the past four years, EDF has devoted the largest portion of its gross operating investments for development into new RE, even more than for the development of the nuclear segment.[38] In 2014, the percentage of RE in the Group's gross operating investments for development totalled 37% (~€1.7 billion).[39]

The second largest European EPCOs Enel notes "that despite the very challenging macroeconomic context, the crisis in consumption and changes in regulatory frameworks that marked some geographical areas, renewables have a great track record and strong growth prospects globally," notably thanks to their cost competitiveness.[40] And the Group certainly wants to take part in this growth as it now plans to increase its non-hydro renewables capacity by over 7 GW by 2019.[41]

Among the seven largest European EPCOs (all with over 40 GW of total installed capacity): GDF-Suez/ENGIE also recently sets itself a new target; doubling its renewables capacity from 8 GW to 16 GW in Europe by 2025.[42e] E.ON intends for renewables to account for more than 20% of its owned generation by 2020 (against 18% at the end of 2014).[43] And Vattenfall targets to grow faster than the market in RE capacity.[44]

Other initiatives worth to be highlighted include: EDP's goal to reach 75% of renewable installed capacity by 2017, from 71% in 2014.[45] Statkraft's decision to make new investments only within RE.[46] EnBW's targets to more than double its share of RE in its generation portfolio (installed capacity), raising it from a current level of 19% (based on the reference year of 2012) to more than 40% in 2020, and to multiply the operating results of its

[d] In addition in September 2015, EDF also announced a further expansion of wind and solar power outside Europe.
[e] At 100%. 8 GW installed at the end of first half 2014 in Europe, excluding Energy Services business line.

RE segment by 250% from €0.2 billion (reference year 2012) to €0.7 billion in 2020, the segment would thus contribute to around 30% of the Group's operational results.[47] And Verbund, which is aiming for 100% of its own generation to come from RE by 2020.[48]

The following quotes illustrate and summarise relatively well the directions the major European EPCOs are taking with regards to renewables and what they state in terms of renewables cost competitiveness today:

"Its (the EDF Group's) aim is to develop all forms of renewables, focusing primarily on wind and solar power."

EDF – Annual Financial Report 2014, page 115 –

"The new path to industrial growth will be sustained by major investment in promising markets and businesses, beginning with renewables [...]."

Enel – Annual Report 2014, page 11 –

"*Renewables like wind and solar have achieved a cost level that is competitive relative to that of conventional generation technologies.*"

E.ON – Annual Report 2014, page 12 –

"*The evolution of renewable energy over the past decade has surpassed all expectations. Global installed capacity from all renewable technologies have increased significantly; costs for most technologies have decreased considerably.*"

EDPR – Annual Report 2014, page 29 –

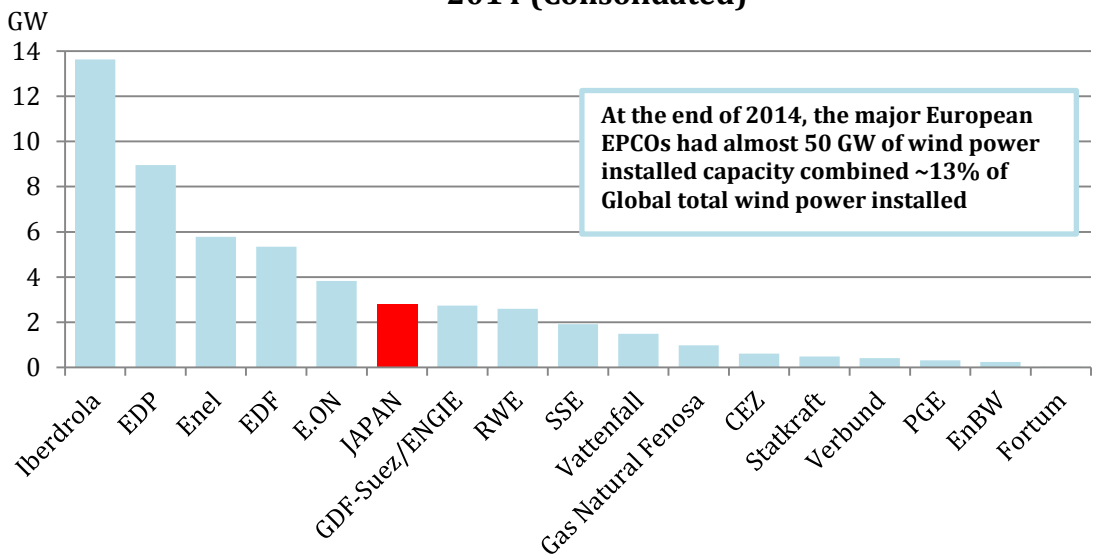
In light of the last two quotes recognition of renewables cost competitiveness by European EPCOs appears to have become mainstream today, which is surprisingly still not the case in Japan – one of the most powerful manufacturing countries in the world. This is notably due to inadequate regulations creating unnecessary high "homemade" costs.

The major European EPCOs are thus aiming to expand cost competitive renewables, but the growth of each technology will be different. The following subsections investigate the outlook for each RE technology.

A. Wind Power

Wind power is by far the first non-large hydro RE technology European EPCOs invested in over the last decade. Today the Spanish and Portuguese Groups Iberdrola and EDP are the leading European EPCOs in terms of wind power cumulative installed capacity (Chart 7) and share of wind power capacity installed in the Group's total installed capacity (Chart 8 on next page). Together these two Groups of the Iberian Peninsula cumulated about 22.6 GW of wind power capacity worldwide (mainly in Spain and the US) at the end of 2014; 13.6 GW for Iberdrola and 9.0 GW for EDP, respectively. In comparison, Japan had only less than 2.8 GW of wind power installed capacity at the end of 2014 – more than 8 times less than the Iberdrola and EDP Groups combined.

Chart 7: European EPCOs Wind Power Installed Capacity 2014 (Consolidated)

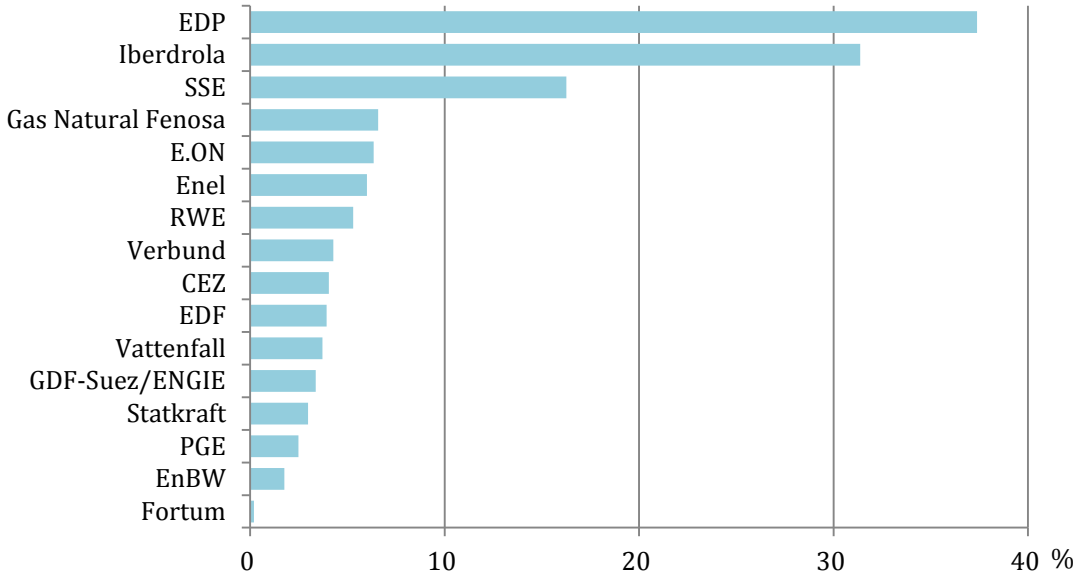


Sources: Groups Annual Reports, and in some cases complementary corporate materials available online for EPCOs. And Global Wind Energy Council, Global Wind Report Annual Market Update 2014 (2015) for Japan and Global.

While Chart 7 seems to show three of the four largest EPCOs; Enel, EDF and E.ON being among the leaders in terms of wind power cumulative installed capacity, with respectively 5.8 GW, 5.3 GW, and 3.8 GW, Chart 8 indicates that there is room for improvement for these big companies as the share of wind power in the total installed capacity of these

Groups were only between almost 4% and a little more than 6% in 2014. At the opposite, when looking at Chart 7 SSE does not appear to be a leader in wind power developments but this is due to the relative small size of the Group compared with the largest European EPCOs. Chart 8 corrects that.

Chart 8: Share of Wind Power Installed Capacity in the Group's Total Installed Capacity 2014 (Consolidated)



Sources: Groups Annual Reports, and in some cases complementary corporate materials available online.

Today most of the wind power installed capacity has been onshore, but in recent years some Groups, especially the largest ones but not only, have also started to develop offshore wind power projects. With 0.8 GW of offshore wind power capacity owned at the end of 2014 Vattenfall appeared to be one of the leading European EPCOs in offshore wind power, but quite behind the Danish EPCO DONG Energy, which owned 1.4 GW of offshore wind capacity in comparison.[49] Among the Groups considered in this report, German Groups RWE and E.ON followed with both approximately 0.5 GW.[50] Other companies participating in offshore wind farm projects at the end of 2014 notably included: SSE that had 355 megawatts (MW) of offshore wind power installed capacity at the end of September 2014, Statkraft, which commissioned, in partnership with the Norwegian multinational oil and gas company Statoil, the 317 MW Sheringham Shoal offshore wind farm in England in 2012 (Statkraft's share in this project is 50%), Iberdrola that had 194 MW of offshore wind power installed capacity at the end of 2014, as well as EDF and EnBW.[51] EDP, one of the leaders in onshore wind power, has so far been less dynamic in the offshore area, but still distinguished itself a few years ago with the

launch of an innovative 2 MW floating offshore wind turbine research and development (R&D) project in the Atlantic Ocean.[52]

Having depicted the current situation, the next big question is: what is the outlook for a further expansion of wind power in the portfolio of the major European EPCOs? Without being over optimistic, we can say that this future is relatively bright for both onshore and offshore wind as suggested by the numbers communicated by the considered companies. EDF EN had over 1.6 GW of wind power capacity under construction at the end of 2014, which once commissioned will increase the Group's RE subsidiary wind power capacity by more than 37%.[53f] In addition, EDF EN also reports a 13.7 GW wind pipeline (including capacity under construction) with projects in Europe (France and the UK mainly), North America, and emerging economies (Morocco, South Africa, Brazil, Mexico, Turkey, notably).[54g] At the end of 2014, Enel Green Power (EGP), the Enel Group company entirely devoted to the development and management of the Group's renewables generation operations around the world, had over 0.6 GW of wind power plants under construction (a number that increased to over 0.9 GW as of July 2015) and 19.4 GW gross pipeline (a number that decreased to 16.1 GW as of July 2015).[55] Still at the end of 2014 among the other major European EPCOs: GDF-Suez/ENGIE had over 0.7 GW of wind power capacity under construction, mainly in Brazil and France, an increase of about 27% from the Group's existing capacity, RWE Innogy, which pools the RE expertise and power plants of the RWE Group, over 0.6 GW (mainly offshore wind interestingly, in Germany and the UK), E.ON was making good progresses in the construction of the Amrumbank West (Germany) and Humber Gateway (UK) offshore wind farms, with capacity of 288 MW and 219 MW respectively which are expected to supply electricity by the end of 2015, and Vattenfall was about to formally complete the 288 MW DanTysk offshore wind farm in Germany and had decided to proceed with construction of the €1.3 billion 288 MW Sandbank offshore wind farm (in these two projects Vattenfall owns 51% and Stadtwerke München 49%).[56h] Iberdrola and EDP, the leaders in wind power deployment, also had hundreds of megawatts under construction.[57] The rest of the pack was led by SSE, which had almost 0.6 GW of onshore wind power under construction or pre-construction at the end of September 2014, PGE, which had over 0.2 GW to be commissioned in the last two quarters of 2015, Statkraft, which completed 144 MW of the total 270 MW for the onshore wind farm Björkhöjden in Sweden in 2014, and EnBW, which is expanding in the wind offshore area, with the erection of the Baltic II offshore wind farm, which 80 wind turbines will be fully operational in the summer of 2015 with a total output of 288 MW (a contract for the sale of approximately half the shares in this wind farm

[f] Net capacity corresponding to EDF EN's share.
[g] Projects in the "pipeline" means projects under development, without guarantee of concrete realisation for all projects though.
[h] Consolidated capacity indicated for GDF-Suez/ENGIE and RWE Innogy. RWE Innogy's 295 MW Nordsee Ost offshore wind farm went online in the first half of 2015.

was signed in January 2015).[58]

Whereas the initial growth of wind power has been enabled by favourable policy frameworks, today's growth is rather driven by the economics, particularly for onshore wind, which cost has substantially decreased over the years to the extent that the major European EPCOs have recently made the following statements:

"*This (onshore wind power) is a mature sector which is now close to competing with, if not matching, traditional sectors [...]. It benefits from economic incentives in various countries, although an increasing number of projects are developed without a financial support mechanism.*"

EDF – Annual Financial Report 2014, page 115 –

"*We will continue to invest in expanding renewable energy, particularly in wind farms. These investments are paying off increasingly.*"

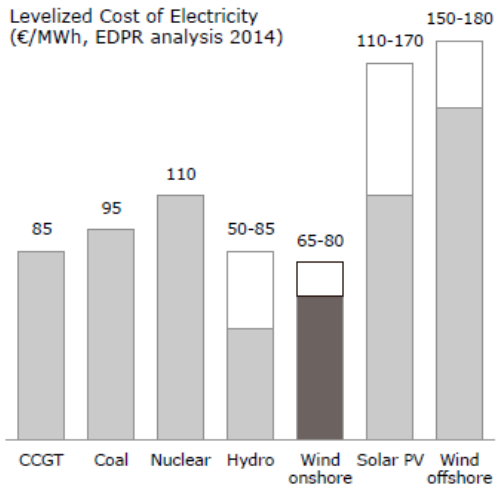
RWE – Annual Report 2014, page 5 –

"*[...] wind power is the cheapest source of energy production, even if taking into account the oil price fall [...].*"

EDP – Annual Report 2014, page 6 –

"*Wind onshore is the most competitive source of energy, with the only exception of large hydro in some cases.*"

EDPR – Annual Report 2014, page 5 –



EDPR, Annual Report 2014, page 32

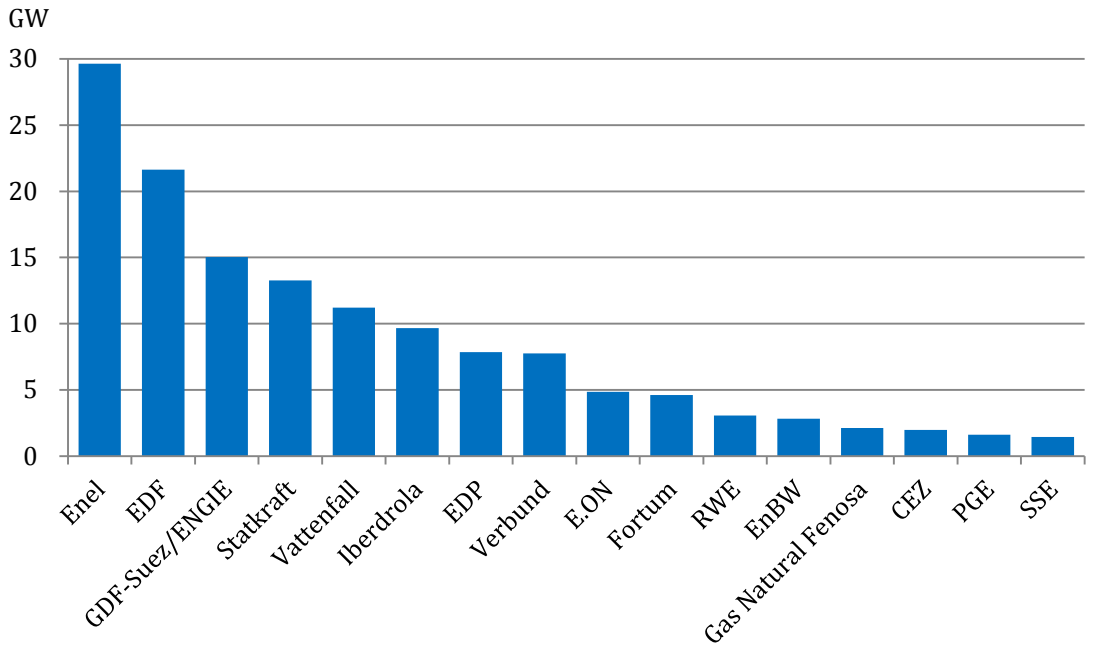
This new reality, which is the result of technology improvements, has – as we could have notice it - started to change the stand of the major European EPCOs towards wind power enabling increasing investments and further expansion of the technology.

B. Hydropower

Hydropower is a mature technology which potential has already been largely tapped in, especially in developed economies. This, however, does not mean that there are no opportunities anymore to be pursued by the EPCOs for a further expansion of hydropower. Charts 9 and 10 (Chart 9 on next page, Chart 10 on page 29) illustrate the state of the market. The market outlook is described afterwards.

In terms of installed capacity the three largest European EPCOs had the most hydropower capacity at the end of 2014: Enel was the first with about 30 GW, EDF and GDF-Suez/ENGIE followed with about 22 GW and 15 GW, respectively. Statkraft and Vattenfall had well over 10 GW of hydropower capacity and Iberdrola just below. In the 5-10 GW range, EDP and Verbund had both about 8 GW. All the other Groups, including German large EPCOs E.ON and RWE had less than 5 GW.

Chart 9: European EPCOs Installed Hydropower Capacity 2014 (Consolidated)

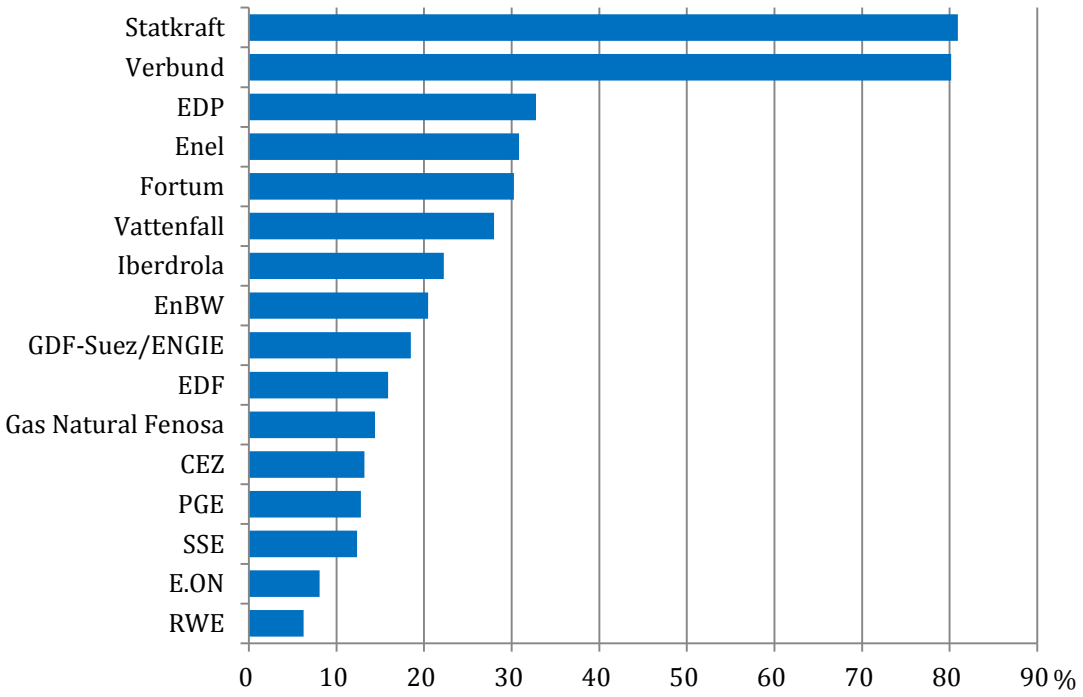


Note: including pumped storage and small hydro.

Sources: Groups Annual Reports, and in some cases complementary corporate materials available online.

When looking at the share of hydropower installed capacity in the Group's total installed capacity, the story is a little different. Statkraft and Verbund, respectively ranking #4 and #8 in terms of hydropower installed capacity, now clearly lead with both having over 80% of their total capacity being hydropower. Follows a Group of four, led by wind power leader EDP, and also including Enel, Fortum and Vattenfall, which all had approximately 30% of their total capacity being hydropower. Large EPCOs Iberdrola, GDF-Suez/ENGIE, and EDF had more than 15% of their total installed capacity from hydropower, but less than 25%. Gas Natural Fenosa, PGE, CEZ, and SSE, which were the four Groups with the less hydropower installed capacity are also at the bottom of this ranking, but not the last ones this time. Indeed, German large EPCOs E.ON and RWE with less than 10% of their total capacity from hydropower brought up the rear.

Chart 10: Share of Hydropower Installed Capacity in the Group's Total Installed Capacity 2014 (Consolidated)



Note: including pumped storage and small hydro.

Sources: Groups Annual Reports, and in some cases complementary corporate materials available online.

The outlook for the developments of hydropower by the major European EPCOs consists in: a relatively significant expansion in emerging economies, refurbishment and upgrades in developed countries, where some limited expansions will however still also take place, and a little growth in small-scale hydro.

Some of the major European EPCOs are focusing to expand their hydropower capacity in emerging economies; Latin America and Southeast Asia, in particular, and Southeast Europe, Russia and Africa to a less extent. Among them: the EDF Group, which commissioned, under a "turnkey" contract, the 1,070 MW hydropower complex Nam Theun 2 in Laos 2010, is now quite active in Brazil.[59] In December 2014, EDF, through its subsidiary EDF Norte Fluminense, acquired a 51% stake in Compagnie Énergétique de Sinop, which is in charge of building and operating a 400 MW hydroelectric dam, which commercial operation is scheduled to start in the second half-year of 2017.[60] The Enel Group is constructing the 400 MW El Quimbo hydroelectric plant in Columbia, as well as the new 102 MW hydroelectric complex Apiacás in Brazil, and the 50 MW hydroelectric plant Chucas in Costa Rica, notably.[61] At the end of 2014, GDF-Suez/ENGIE had close to 1 GW consolidated of hydropower capacity under construction,

essentially in Latin America (Brazil and Peru), but also in North America.[62] Statkraft, one of the major European companies in hydropower generation, is also quite dynamic in emerging economies where the Group has four hydropower plants totaling 1,030 MW under construction.[63] EDP has launched a joint venture with China Three Gorges, Hydro Global JV, which aims to capture the hydro investment potential in emerging markets, with a strong geographic focus in South America, Africa and Southeast Asia, and is notably taking part in the construction works of the hydroelectric power plants of Cachoeira Caldeirão (219 MW, 50% EDP) and São Manoel (700 MW, 33% EDP), with entry into service estimated to 2017 and 2018, respectively, in Brazil.[64] Spanish Groups, Iberdrola and Gas Natural Fenosa are also active in new hydropower projects in Latin America: in Brazil and Costa Rica, notably.[65] E.ON developed 439 MW of hydropower capacity in Turkey in 2014.[66] And Fortum announced in December 2014 its intention to increase the Group's hydropower production capacity by 60% through the restructuring of TGC-1, a Russian territorial generating company.[67]

The second key trend in hydropower developments by the major European EPCOs is the refurbishment and upgrade of existing hydropower facilities in developed countries in order to notably improve their efficiency, flexibility, and increase their capacity thus increasing their capability to respond to the needs of the electrical system (balancing the variability of wind and solar power for example) and to economic opportunities arising on the electricity market. In this regard, interesting activities that can be referred to include: EDF, which for some years has been initiating programmes involving automation, remote control of hydropower plants and centralised management of the valleys.[68] In France, the largest plants in the Group's fleet are remote-controlled from four control centres able to make adjustments to the plants' operating programmes at any time in order to respond to the system needs and market opportunities.[69] In France still, the Group is also seeking to optimise the potential of its pumped storage facilities: notably, it has begun a project to transform one of the turbine-generator sets at the Le Cheylas pumped-storage power plant so that it can work at variable speed, and back in 2010 it took the opportunity during a major renovation of the Revin pumped-storage power plant to improve the facility's performance.[70] From the other side of the Pyrenees the Spanish Group Iberdrola developed a major pumped-storage project a couple of years ago: La Muela (over 2 GW).[71] At the end of 2014, Verbund was planning to begin the operation of its new pumped storage power plant Reißeck II in Carinthia at the end of the second quarter of 2015 that will increase the turbine capacity of the Malta/Reißeck power plant group by 430 MW to 1,459 MW and the pumping capacity by 430 MW to 855 MW.[72] In parallel the Austrian Group is also leading a programme to increase efficiency at a number of existing hydropower plants (notably including the Kaprun-Hauptstufe power plant, which output, after completion of the ongoing modernisation project by the end of 2016, will

be increased by 40 MW).[73] In addition, Vattenfall is leading its largest hydropower project in 20 years with the refurbishment and expansion of the Akkats hydropower plant in Sweden.[74] The goals of the project, which is scheduled for completion in 2016, are to decrease sensitivity to operational disruptions and increase electricity generation.[75] In the Nordic countries, Statkraft and Fortum are also leading refurbishment and upgrades of their existing hydropower plants.[76] And whilst current policy and market signals do not favour SSE's investment in new pumped storage, the Group continues to explore conditions for a 600 MW project in Scotland.[77] In this context of moderate growth and of optimisation of existing assets, EDP's current hydropower domestic expansion appears ambitious: at the end of 2014, the Group had five new hydro plants under construction in Portugal for a total of almost 1.5 GW.[78] Two new hydro plants; Baixo Sabor (173 MW) and Ribeiradio/Ermida (81 MW), and two new repowerings; Venda Nova III (756 MW) and Salamonde II (207 MW) are due to start operations during 2015, and the last plant; Foz Tua (263 MW) in 2016.[79]

Finally, the last trend, which is rather minor compared with the two previous ones, when it comes to the activities of the European EPCOs in the hydropower area is the existing, but limited interest in new small-scale hydropower. For instance, in France the EDF Group completed the construction of the 2.2 MW Le Rondeau power plant in 2014, and is now building the 2.6 MW Palisse plant.[80] In the UK, RWE Innogy had 3 MW of small-scale hydropower projects under construction at the end of 2014.[81]

C. Solar Power

While the major European EPCOs have substantially developed their wind power activities in recent years, solar power has known a much more modest growth in their portfolio. And while some of the Groups considered have made some interesting inroads in 2014, the outlook for further developments of solar technologies by the European EPCOs is overall not extremely bright yet. Interestingly, though, the largest Groups have recently started becoming more ambitious.

At the end of 2014, only one Group had over 0.5 GW of solar power capacity installed: EDF (536 MW, mainly in France, Italy, and the US).[82] "Worse," only a handful had over 100 MW of solar power installed capacity, namely: Enel (433 MW net installed capacity for EGP, mainly in Italy, Greece, and Chile), GDF-Suez/ENGIE (over 160 MW), E.ON (130 MW), CEZ (130 MW), and Iberdrola (106 MW).[83][i] Other Groups including EDP, Fortum, RWE, and Verbund reported 82 MW, 15 MW, 3 MW, and 3 MW of solar power installed capacity, notably.[84][j] In total, the major European EPCOs would thus have about 1.6 GW of solar power – 30 times less than their

[i] For GDF-Suez/ENGIE the figure reported here is either not as of the end of 2014 (, but as of the beginning of 2015) or not the consolidated figure.

[j] Update: as of July 2015, EGP had 464 MW of net solar power installed capacity.

wind power installed capacity, or less than 1% of the world's solar power capacity![85]

While the current status of solar power in the existing portfolio of the considered Groups is rather poor, some recent progresses deserve to be highlighted: In 2014, EGP increased its solar net installed capacity by 184 MW (almost +75%).[86] Last year too, EDF EN commissioned seven solar power plants in Israel (for a total of 54 MW), three in the US (39 MW), one in India (30 MW), and one in Guyana (5 MW with a battery energy storage system (BESS)) making a total of 128 MW gross capacity going into service.[87] In 2014 as well, E.ON more than doubled its portfolio of PV and concentrating solar thermal power (CSP) plants: from 62 MW in 2013 to 130 MW at the end of the year, notably with the completion of the jointly constructed and operated (with Tucson Electric Power) largest ever solar project built on a U.S. military base (18 MW) in southern Arizona.[88] GDF-Suez/ENGIE, was also active last year adding new capacity in France (45 MW) and Canada (10 MW), notably.[89k] Finally, still in 2014, EDP Renováveis (EDPR), which EDP is the majority shareholder of, installed 32 MW of solar capacity with its first projects in California and Portugal, and Fortum commissioned the 10 MW Kapeli solar power plant in India.[90]

Nevertheless, these encouraging signs must not hide the overall relative lack of ambition of the major European EPCOs' solar power expansion plans. With the exceptions of the four largest Groups, no other Group is clearly communicating about expanding its solar power capacity by hundreds of megawatts, at least in their respective Annual Report, as this is generally the case for wind power. EDF EN had 231 MW net solar power capacity under construction in the US, India, and Israel at the end of 2014 (compared with 516 MW net solar power installed capacity at the end of 2014), and a PV pipeline of 3.1 GW (including capacity under construction) with projects in India and the US mainly, but also in Chile, Mexico, Saudi Arabia, and France.[91] EGP had 180 MW solar power capacity under construction mainly in South Africa, but also in Latin America (Chile and Panama) and the US at the end of 2014 (compared with 433 MW net solar power installed capacity at the end of 2014), and a solar gross pipeline of 5.2 GW.[92l] GDF-Suez/ENGIE has recently acquired (in July 2015) a 95% stake in Solairedirect (with 100% voting rights), a global leader in solar power, which developed 486 MW of solar power capacity on four continents, and which has a portfolio of projects at the pre-construction phase amounting to more than 4.5 GW, 434 MW of which are set to be built within the next 6 to 18 months.[93] And E.ON has just announced having a pipeline of around 1 GW of solar in the US.[94]

This is relatively surprising as solar power cost has dramatically fallen in recent years, making it a credible alternative to conventional power plants in an increasing number of places

[k] At 100%.
[l] Update: as of July 2015, EGP had 661 MW of solar power capacity under construction, and a solar gross pipeline of 5.3 GW.

across the world. Today, further technology cost reduction seems, however, a prerequisite for a real acceleration of solar power deployment by the major European EPCOs. This may take some time as Fortum notably describes it in its solar economy vision, but this may well happen.[95] The two following quotes may best illustrate the current position of the considered Groups towards solar power:

> "*The cost of generating solar power has fallen considerably in recent years. Solar power is now a competitive energy in an increasing number of regions of the world (Chile or California, for example). However, there is still considerable room for improvement. Innovative, disruptive technology is essential if costs are to come down even further, particularly for regions that have less sunshine.*"

EDF – Annual Financial Report 2014, page 116 –

> "*[…] investments (in solar PV) are something more to be judged on a case-by-case opportunistic approach […]. Yet with the expectable further reduction in the levelized cost of energy of this technology, we are reviewing options to reinforce in this area.*"

EDPR – Annual Report 2014, page 11 –

D. Other Renewable Energy

In the past, the major European EPCOs have not heavily invested in bio, geothermal, and marine energies and this is not really about to change in the coming years.

Among these other RE technologies bio-power and geothermal power are considered as mature technologies, which the Groups considered in this report have unevenly developed to some extent. Marine energy rather represents a technology of the future, which potential remains largely untapped.

D-i. Bio-power

Of these three technologies, the major European EPCOs have mostly developed bio-power. At the end of 2014, GDF-Suez/ENGIE had 930 MW of biomass and biogas power installed capacity (of which 41 MW of cogeneration), Vattenfall 362 MW of biomass and waste, RWE 252 MW of biomass, Fortum 147 MW of biomass and bioliquids (in recent years the company has been relatively dynamic and built a number of new-biomass- and waste-based

combined heat and power (CHP) capacity in Finland, Poland, and the Baltic countries notably), EDF EN had 127 MW of biogas and biomass, Iberdrola at least 55 MW of biomass, Statkraft 40 MW of biofuel, EGP 39 MW of biomass, and SSE 38 MW of dedicated biomass, notably.[96m] In these figures are included some projects completed last year as for example RWE's 46 MW biomass-fired CHP station near the Scottish town of Markinch commissioned in March 2014.[97]

Interesting trends observable in recent years concerning bio-power have been the co-combustion of biomass with coal and the conversion of coal-fired units to dedicated biomass in order to reduce greenhouse gases emissions. For examples, German Groups, RWE, through RWE Generation, currently operates 183 MW co-firing capacity in Dutch coal plants notably, and E.ON is converting unit IV of its Provence power station in France to burn biomass instead of coal and petroleum coke (start of operation expected for 2016).[98] CEZ, PGE, and SSE are also using biomass co-firing with coal.[99] Vattenfall is investing to replace coal with biomass where commercially feasible.[100] EDP is targeting co-combustion of coal and biomass to minimise its carbon dioxide (CO2) emissions in Spain.[101] But the most symbolic and impressive coal to biomass conversation project certainly remains Drax, one of Europe's largest power stations with almost 4 GW of capacity: out of its six units (each of 660 MW), two have already been converted to biomass, and a third one is expected to be converted in 2015/16.[102]

The outlook for a further expansion of bio-power by the major European EPCOs is, however, not very promising. Though there are existing projects of some significance such as the ones of the joint venture Fortum Värme, which is constructing a new biomass-fired CHP plant in Stockholm (scheduled to be completed in 2016) with 130 MW electricity capacity and 280 MW heat capacity to replace an old coal-fired capacity, EDF, which is developing a project for a biomass electricity power plant with two 23 MW units in Ivory Coast, EGP, which has about 20 MW of biomass power projects under construction in Italy (Finale Emilia 15 MW and Cornia II 5 MW), and RWE, which has been awarded with a Contract for Difference (CfD) for the biomass conversion of the 395 MW coal station in Lynemouth in 2014 (European state-aid approval pending), the overall picture is not really bright.[103] Sustainability of the feedstock and the cost of the technology (either for dedicated biomass or co-firing) are the two key hurdles for a further deployment of bio-power. The two most striking quotes of the considered Groups may be:

[m] For EDF EN "net" capacity.

"We do not plan to construct new biomass-fired power stations [...]."

RWE – Annual Report 2014, page 20 –

"The use of biomass as fuel as a replacement for coal requires support systems in order to be profitable."

Vattenfall – Annual and Sustainability Report 2014, page 35 –

D-ii. Geothermal Power

The major European EPCOs have historically invested in geothermal power only a little, and no significant growth is expected in the years to come as there are only few projects under developments.

Enel is by far the leader in terms of geothermal power installed capacity with 833 MW, including the 38 MW of the new Bagnore IV geothermal power plant which entered into service in late December 2014.[104] EGP has a geothermal gross pipeline of 0.7 GW.[105]

Today, GDF-Suez/ENGIE appears to be the Group with the most ambitious development program concretely ongoing for geothermal power. In cooperation with PT Supreme Energy the company is developing three geothermal projects in Sumatra: Muara Laboh, Rantau Dedap, and Rajabasa.[106] At the end of 2014, the commencement of the first stage of construction of the 220 MW Muara Laboh project was expected as early as 2015.[107] Regarding the Rantau Dedap project, which targeted capacity is 240 MW, the exploration drilling program is expected to be completed in 2015.[108] The 220 MW Rajabasa project has been delayed by opposition from local residents.[109] Sumitomo Corporation is participating in the Muara Laboh and Rajabasa projects.[110]

In addition, it can also be noted that EDF and EnBW have joined forces with partners (including Électricité de Strasbourg and German energy companies) to develop and operate a prototype geothermal power plant in the hot, naturally fractured crystalline rock around Soultz in France.[111]

D-iii. Marine Power

Marine energy is by far the least developed renewable technology by the major European EPCOs. The most significant tidal power plant operated by one of the considered Groups today is still EDF's 240 MW Rance power station, which dates back from 1966.[112] Other than that, Iberdrola distinguishes itself with 1 MW of marine capacity in the UK.[113]

Marine power not being a mature technology, and its costs being still too high for commercial operation it is no surprise that the major European EPCOs have not deployed it at a large-scale, that, however, does not mean that they are not leading some activities related to this technology, notably:

In its last annual financial report EDF indicates that it is leading a demonstration project on the Paimpol-Bréhat site in France where the Group is testing the principle of power generation from tidal currents under real conditions. A prototype was launched during the summer of 2012 and will soon enter a second test phase, when it will generate electricity for the first time. The project will ultimately include four turbines with a total capacity of 2 MW.[114]

In 2014, Enel, through a partnership with 40 South Energy, was able to place a marine wave energy converter into operation off the Italian coast of Punta Righini, and was selected, along with the French firm DCNS, by the Chilean government's economic development organisation to set up a groundbreaking global centre for marine energy R&D excellence in the country, named Marine Energy Research and Innovation Centre.[115]

In December 2014, GDF-Suez/ENGIE's Raz Blanchard project won the call for expressions of interest in "Pilot Tidal Energy Farms" from the French agency for the environment and the control of energy, with its partner Alstom.[116]

In 2014 also, Fortum continued its involvement in wave power technology development by cooperating with Seabased AB in Sweden and Wave Hub in the UK, and by acquiring a minority share of 13.6% in the Finnish wave energy developer Wello Oy.[117]

While these are encouraging signs, according to the major European EPCOs the prospects for marine power remain modest for the next decade.

"The use of ocean energy is in the test phase; its advancement into a commercial technology may be more than a decade out."

Fortum – Annual Report 2014, page 27 –

2. Fossil Fuel Power Mixed Developments

The major European EPCOs had between 320 GW and 330 GW of fossil fuel-fired power installed capacity worldwide at the end of 2014, this represented about half of their total installed capacity.[118n] Of this 320-330 GW, over 155 GW was gas power, approximately a

[n] Inconsistencies in reporting do not allow to be more precise than this given range. For instance, fossil-fuel

quarter of the Groups' total installed capacity making it the main technology they exploited. Coal power with about 125 GW, or almost 20% of the major European EPCOs' installed capacity, was the second fossil fuel technology they relied the most on, but not the second of all technologies since the Groups considered had almost 140 GW of hydropower capacity. Oil-fired power plants accounted for at least 15 GW and were essentially used as extreme peak capacity because of their excellent responsive capabilities and high fuel cost.[o] The developments for fossil-fired power stations have been very mixed in recent years, from both geographical and technological perspectives.

In a context of low electricity demand (due to the continued effects of the economic crisis, EE gains, and most recently relatively warm winters), significant expansion of subsidised non-hydro renewables, some of which (wind and solar power) with close to zero marginal cost, massive overcapacity, low coal and CO2 prices (between €3-7/tonne of CO2 in most of 2013 and 2014) wholesale electricity prices have substantially decreased in Europe.[119] Fossil fuel power plants have thus not only been operated fewer hours, but they have also been remunerated less, which has obviously seriously hurt their profitability contributing to a number of power plant closures, either definitive or temporary. In the last couple of years (2013-2014), fossil fuel power capacity in the EU decreased by almost 17 GW notably.[120] Outside Europe, emerging economies with growing electricity demand have provided some opportunities for the major European EPCOs to expand their fossil fuel power fleet in order to meet these additional needs. Japanese businesses which are currently aiming at exporting their fossil fuel power technologies, and especially their so called "clean coal," in emerging economies should, however, take good note that this window of export opportunities might be closing as these countries are increasingly investing in renewables – and already almost as much as developed countries (in 2014 at least) because renewables are more and more cost competitive, can be installed faster than any other technologies, and help tackle air pollution, which all are very important concerns shared by countries which want to develop quickly and compete in the global economy while mitigating the impact of their activities on the environment.[121] For instance, China is already a leader in RE today; number one in hydropower and wind power installed capacity (280 GW and 115 GW, respectively), and number two in solar PV installed capacity (28 GW) (all as of the end of 2014).[122] And China may be joined by India tomorrow. Indeed, India has recently set an impressive target to significantly expand non-hydro renewables in the country; from about 30 GW in 2014 to 175 GW by 2022, of which 100 GW of solar and 60 GW of wind power, notably (compared with 3

power capacities are sometimes mixed with other technologies in the categories "others," "cogeneration/CHP," or "thermal" (the latter two may also include bioenergies).

[o] Because it is not possible to split Enel's 21.0 GW of fuel oil/gas installed capacity these capacities are neither included in gas power nor in oil power. They are, however, included in fossil fuel-fired total capacity.

GW and 22 GW respectively in 2014).[123] In India mega-solar is already cost competitive with new coal power plants using imported coal, and will be with new coal power plants using domestic coal in a few years.[124] In addition, if this RE expansion happens in a context of slower economic growth, which is not to be excluded as some signs are hinting to a slowdown of the Chinese economy that could negatively impact other emerging economies' financial markets notably, a strategy based on exporting fossil power technologies should be seriously reconsidered. Certainly in favour of a strategy that would rather seek to export RE technologies; manufacturing opportunities representing potential very large profits are at stake. The heavy industry parts of Mitsubishi, Japan Steel Works, Hitachi and other Japanese businesses have most of the prerequisites to be profitable actors in the global development of wind power for example.[125]

In terms of technologies, in Europe, gas power plants, which generation cost is high due to relatively higher fuel cost have been impacted the most by negative market conditions (see Box 3 on page 42 for more information on differences and similarities between coal and natural gas prices and supply conditions in Europe and Japan). Coal power plants, especially hard coal ones, have also seen their profitability be harmed, but to a lesser extent thanks to both low fuel and CO2 costs. For instance, since August 2013, RWE made several decisions to take 6.3 GW of gas and coal (combined) power capacity off the system either temporarily or permanently.[126] In the last two years, GDF-Suez/ENGIE closed or sold 4.5 GW of gas and coal (combined) power capacity.[127] And the future will probably not be brighter for fossil fuel power generation in Europe as renewables will keep being expanded and further EE gains pursued. As a result, Enel's target to reduce its fossil fuel power plant portfolio by about 13 GW from 2014 and 2019, and Vattenfall's strategy that seeks to divest the Group's entire lignite operation in Germany, where the Group had notably 7.8 GW of lignite power capacity in 2014, seem quite relevant.[128][p]

One of the options, which remains opened for the major European EPCOs regarding fossil fuel power plants in Europe is to modernise their fleet, which certainly does not necessarily mean to replace old plants with new ones since there is overcapacity; maybe best illustrated by RWE's statement that new coal plants are not profitable (See Part 1. 2.A Coal Power), the symbolic closure announcements of E.ON's new Irsching IV and V, and the fact that only one of the three units of Vattenfall's new Magnum could start commercial operation at the start of 2014 (See Part 1 .2.B. Gas Power), but rather to upgrade, update, renovate their existing assets, to make them more efficient, more flexible, less polluting (emitting less greenhouse gases (GHG); CO2, sulfur dioxide, nitrogen oxides, dust,…), and less resources consuming (fuel,

[p] While Enel does not indicate where this reduction will take place, figures provided show that oil & gas (excluding CCGT) and coal power capacities will be decreased, yet these capacities of the Group are very largely located in Europe.

water,…). A particular attention to limit the increase in wear and tear due to more frequent and faster ramping up and down of fossil fuel power stations is notably a key area to invest in since more and more electricity generation from fluctuating variable renewables will need to be accommodated; E.ON, RWE, and SSE – among others – are making efforts in this specific area, notably.[129] Overall, the various types of actions described above are being taken by the major European EPCOs.

The other option is to fight and seek new revenue streams for these assets. This path is also being explored by the major European EPCOs, which insist on the essential capabilities of fossil fuel-fired power plants; responsiveness and flexibility, critical advantages to reliably ensure balance of production and consumption and cope with fluctuations in electricity supply and demand.[q] Regarding the integration of variable renewables, particularly, it must however be complementary noted that improving wind and solar power production forecasts and curtailing their output only when really necessary, optimising networks and storage uses, as well as improving markets and trading conditions, and tapping into the potential of demand side resources are all valuable options to also reach the objective of ensuring balance of production and consumption.[r] A number of Groups considered in this report are warning/threatening that security of supply may be jeopardised if these power stations keep being pushed out of the market. To restore the profitability of their fossil fuel power plants some of the major European EPCOs are strongly supporting the establishment of capacity markets to reward the services these plants can provide. This is the stance of the Magritte Group, which is an initiative bringing together 11 of the biggest energy Groups in Europe, among which Enel, GDF-Suez/ENGIE, E.ON, RWE, Iberdrola, Fortum, CEZ, and Gas Natural Fenosa, notably.[130] So far, while France and the UK, among others, have recently introduced capacity mechanisms, Germany has instead opted for a market-based approach on the grounds that a capacity mechanism would lead to overcapacities and be too costly.[131]

The situation of fossil fuel power stations in Europe is certainly of great relevance to Japanese EPCOs at a time when significant new build capacities (both renewables, especially solar, and non-renewable thermal, particularly coal-fired power plants) are being announced and some nuclear power plants may be restarted. If Japan is really serious about promoting renewables and tackling climate change, further expanding fossil fuel power capacity in Japan is a financial and environmental non-sense. The situation after the Fukushima nuclear disaster has demonstrated that Japan already has enough power capacity to meet its electricity needs,

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[q] While the flexibility of fossil fuel power plants, and especially natural gas-fired ones, is often advanced, it is also worth noting that nuclear power plants can also be operated flexibly – to some extent – has demonstrated in France.

[r] Curtailment is used in Europe, especially for wind power, but curtailment rates are quite low overall in countries with significant penetration of wind and/or solar power (Denmark, Germany, Ireland, Italy, Spain, and the UK, notably).

and these needs should reasonably at least not increase since the country's population is decreasing and major EE gains are still very achievable (the insulation of buildings is very poor notably). If renewables are to be expanded they will probably contribute to a bigger part of a smaller cake, meaning less operating hours for fossil fuel fired power plants, and at lower wholesale electricity prices because, once again, solar and wind power have close to zero marginal cost and thus should be given economic priority dispatch. Japanese EPCOs would be well inspired to learn this lesson from their European peers to not repeat the same avoidable mistakes made in Europe. If not, they will also ending up recognising impairment losses for their fossil fuel-fired power plants, which cannot be an objective for reasonable businesses seeking profits.

Below is a sample of the most striking statements recently made by the major European EPCOs about the current situation of and near-term outlook for fossil fuel power stations in Europe:

Regarding the difficulties faced by fossil fuel-fired power plants in recent years;

"As regards electricity production, the market fundamentals of the (European) countries in which the Group operates are characterized by contracting demand, the rise of renewable energies, and overcapacity which – coupled with competition from renewables – has triggered a drop in the running hours of the thermal power plants and electricity prices, which remain at very low levels."

GDF-Suez/ENGIE – Registration Document 2014, page 257 –

"From the combination of falling demand with the increase of renewables, consumption fueled by conventional thermal production has been decreasing, with strong impacts on the operating systems of thermal power plants and, consequently, on the economic viability of some of those plants."

EDP – Annual Report 2014, page 38 –

"Due to the continued weakness in the economy, demand for electricity declined in most European countries. Subsidies for new renewable energy, low prices for coal and CO2 and overcapacities led to wholesale electricity prices falling even further and put pressure on the entire arena of conventional, unsubsidised electricity generation."

Verbund – Annual Report 2014, page 6 –

Regarding the need of fossil fuel-fired power plants to ensure a reliable security of supply in a context of renewables expansion;

"Even if renewable energy continues to be expanded, these (conventional power) stations will remain indispensable. Without them, there would regularly be interruptions in supply, because electricity from wind turbines and solar panels is not available at the push of a button."

RWE – Annual Report 2014, page 5 –

"[…] gas combined-cycle plants, and, to a lesser degree, thermal coal-fired plants, can be used as backup for non-manageable renewable energies, so providing security in the supply to the national grid."

Gas Natural Fenosa – Integrated Annual Report 2014, page 34 –

Regarding the need to change regulations to reward fossil-fuel fired capabilities;

"In power generation, the Group continues to optimize its fleet of thermal power plants in response to the crisis in thermal generation, and is campaigning for improvements in European regulations, mainly through the Magritte Group , which is calling for measures to preserve the energy future of Europe."

GDF-Suez/ENGIE– Registration Document 2014, page 6 –

"[…] because conventional generating capacity will remain indispensable for ensuring a reliable power supply, European markets will need to establish mechanisms that provide appropriate compensation for maintaining this capacity."

E.ON – Annual Report 2014, page 12 –

Regarding the outlook for fossil fuel-fired power plants;

"In view of the price trend on electricity and fuel forward markets, there is little hope of an easing of the crisis in conventional electricity production in the years ahead. Although numerous unprofitable power plants are being closed in Germany, removing excess capacity, the consolidation process may persist until the price of electricity starts showing signs of a potential shortage. In addition, the effects of the reforms to the design of the electricity market announced by the German government will be visible in the medium term at best."

RWE – Annual Report 2014, page 87 –

"The electricity market will continue to be highly influenced by the development of renewable energy production. [...] This will mean less space for conventional energy [...]."

CEZ – Annual Report 2014, page 93 –

"Without certainty around SBR (Supplemental Balancing Reserve) and the outcome of the Capacity Market auction process investment decisions in new and existing thermal generation plant will continue to be difficult."

SSE – Annual Report 2014, page 35 –

Box 3: Coal and Natural Gas for Electricity Generation in Europe and Japan; Prices and supply

Steam coal prices for electricity generation are low both in Europe and Japan; about $3/million British thermal units (MBtu) and $4/MBtu in 2014, respectively.[132] And natural gas prices (liquefied natural gas (LNG) prices in the case of Japan) rather high, especially in Japan; $16/MBtu in 2014 against $8-9/MBtu in Europe.[133] While recent falling crude oil prices, to which natural gas prices are more or less indexed to (for instance, whereas the majority of LNG imports in Japan is still based on long-term contracts indexed on oil prices, a more important shift towards more gas-to-gas based prices is ongoing in Europe), have tightened the gap between coal and natural gas prices and between natural gas prices in Europe and Japan; in September 2015 natural gas prices were "only" $7/MBtu in Europe and $9/MBtu in Japan, fuel

cost for generating electricity from natural gas is still about 2-3 times higher than from coal (note that coal prices also decreased in the meantime, notably the prices of Australian coal, which accounts for the majority of Japan's coal imports).[134] In both Europe and Japan coal prices are thus relatively much lower than natural gas prices and, despite their lower capital and operations and maintenance (O&M) costs gas-fired power plants will keep being outcompeted by coal-fired ones, unless negative externalities of generating electricity from coal are (better) taken into account (carbon price on CO2 emissions for example) or (more) stringent standards set on the maximum amount of CO2 emissions power plants can emit. In this regard, the current situation is relatively similar in Europe and Japan. Generally, however, the position of natural gas is weaker in Japan than in Europe because of natural gas prices indexation on oil, which makes natural gas prices higher and more volatile, and because of the extra costs of liquefaction, shipping, and regasification that are incompressible (most of the gas trade in Europe is done through pipelines).[135] Switching durably from coal to gas in Japan will thus require on the one hand strong political will and the other hand other price setting mechanisms.

In terms of supply, while Japan is a resource rich country when it comes to renewable energy (biomass, geothermal, hydro, solar, and wind), it is a resource poor country when it comes to fossil fuels (coal, natural gas, and oil) and uranium. With regards to the two fossil fuels specifically studied in this Box, Japan, the world's largest natural gas importer and one of the largest coal importers, imported all the natural gas (mainly from Asia-Pacific and the Middle East), and almost all the coal it consumed in 2014.[136] The situation is quite different in Europe where over 60% and 55% of natural gas and coal consumptions, respectively, could be covered by domestic productions (mainly Norway, the Netherlands and the UK for natural gas, and Poland, Germany, and Czech Republic for coal) in 2014.[137] This has deep various implications. In the case of Japan, dependency on fossil fuel imports means jeopardising the country's security of supply because of exposures to geopolitical risks and volatility of commodity prices. Furthermore, it results in an an outflow of the national wealth. In the case of Europe, fossil fuel production and especially coal mining has historical and politico-social dimensions with jobs at stake. That is particularly true in Germany and Poland notably, making the energy transition sometimes more difficult to be accepted within a fringe of the labour force, which is backed by powerful trade unions. Taking all these facts into account, and even without raising any environmental concerns, one may wonder why Japan has not made yet its much needed energy turnaround.

A. Coal Power

The major European EPCOs altogether had about 125 GW of coal-fired power capacity installed – almost 20% of their total installed capacity – worldwide at the end of 2014.[138] By far the most dependent Group on the dirtiest energy source was PGE with 93% of the electricity it produced from coal.[139] Other companies heavily relying on coal were CEZ, RWE, and EnBW, which with respectively 7.2 GW, 21.5 GW, and 5.7 GW of coal power capacity had coal-fired plants accounting for 40-50% of their total installed capacity.[140] With the exception of Iberdrola, all the seven largest EPCOs had over 12 GW of coal power capacity.[141]

In recent years environmental regulations, EU's policies particularly (the Large Combustion Plants Directive (LCPD) and Industrial Emissions Directive (IED)), have impacted the portfolio of coal-fired power plants of the major European EPCOs.[142] Tighter emissions standards for pollutants have resulted in a number of closures and upgrades, but also of new builds. It is thus important to note that in Germany for example the decisions to construct the coal-fired power plants, which have been recently commissioned, were made in a – at that time (some years before the *Energiewende* started) – favourable framework for building new plants to replace old inefficient ones.[143] However, the fleet of coal-fired power plants of the major European companies has not only been impacted by regulatory texts, but also market developments such as the fuel cost competition between coal and gas and the dramatic expansion of subsidised non-hydro renewables (particularly wind and solar), which with their close-to zero marginal cost have started to push coal-fired power plants back in the merit order, a fatal blow also for many hard coal plants in a context of low electricity demand and overcapacity.

Among the considered Groups, the following interesting actions recently taken can be highlighted: since August 2013 RWE has made decisions resulting in 1.6 GW of coal-fired generation capacity (especially old hard coal-fired stations) being taken off the system either temporarily or permanently in Germany and the Netherlands because they are no longer profitable due a significant drop in wholesale electricity prices.[144] In parallel, in 2014, as a part of its new build power plant program launched in 2006, the German Group also began commercial operation of the first unit (net installed capacity of 764 MW) of its new hard coal-fired power station in Hamm, Germany, and was leading a test run of the two units of its new hard coal-fired power plant in Eemshaven, Netherlands (total capacity 1,554 MW).[145s] These three units with a 46% efficiency are considered as "state-of-the-art" units by the Group thanks to their high efficiency and low emissions (when compared with other stations of their type).[146] These new power plants may, however, face some hard times from a financial point of

[s] At the Hamm power station, the commissioning of the second unit has not yet been scheduled. It experienced major delays caused in part by a defective steam generator. The power station in Eemshaven was expected to take up commercial operation in May 2015.

view, as Graham Weale, Chief Economist at RWE indicated it in at least one of his presentations in 2014 "new coal plants not earning a return on capital."[147] In recent years, the other large German EPCO, E.ON, also closed a number of coal-fired power plants, but was, at the beginning of 2015, working on the construction of a new one as well.[148] For instance, in 2014, E.ON closed the coal-fired power plants units I to III in Datteln, Germany, Lucy III, and Emile Huchet IV and V in France.[149] This was followed on January 1, 2015, by units D, E, and F in Schloven and C in Knepper, Germany.[150] These represent a combined 2.8 GW.[151] The main reasons for these closures were that these plants had reached the end of their technical and economic lifetime.[152] At the same time, E.ON is also building a hard coal-fired power plant in Datteln, Germany ("Datteln IV"), which is designed to have a net electricity capacity of about 1,055 MW. However, it must be noted that the construction of this plant, in which E.ON has invested more than €1 billion so far, was stopped by a state court in… 2009 because it was challenged by environmental Groups, farmers, and local citizens (the plant was already 90% completed).[153] In its last Annual Report the German Group was still anticipating that Datteln IV will become operational, but was also expecting additional delays to its originally planned date of commissioning (beginning of the 2010 decade).[154] Other activities worth presenting include: the EDF Group has been updating its most recent and efficient coal-fired generating units and closed its low performance ones in France.[155] In particular, EDF's most recent 600 MW coal-fired units are now equipped with flue gas desulphurisation and denitrification systems, and are undergoing a renovation program with the aim of improving their reliability and extending their operating life by 2035.[156] At the same time, due to environmental regulation constraints, EDF already closed four of its nine 250 MW coal units (two in 2013 and two in 2014), and the five remaining will also be shut down in a near future.[157] By 2016, EDF will have closed over 2 GW of coal-fired power plants within a few years.[158] GDF-Suez/ENGIE recently made significant progresses with two ultra-supercritical coal-fired power plants projects in Rotterdam, Netherlands, and in Wilhelmshaven, Germany.[159] The coal-fired power plant in Rotterdam (731 MW) has taken up commercial operation at the end of January 2015.[160] The one at Wilhelmshaven (731 MW also), in which the Group has a 57% stake, was connected to the grid for the first time in 2014.[161] GDF-Suez/ENGIE, however, also closed 252 MW and 333 MW of coal power capacity in Belgium in 2012 and 2013, respectively.[162] Iberdrola is optimising the efficiency of its coal-fired power plants in Spain and the UK.[163] Vattenfall started commercial operation of one of the units of its new (2*827 MW) hard-coal fired Moorburg power plant in Hamburg, Germany in the first half of 2015, and is increasing its coal units efficiency through the replacement or upgrades of turbines at Jänschwalde and Boxberg lignite-fired plants in Germany.[164] Regarding the new Moorburg power station, it must be noted that it was decided on back in 2006 when "the market situation and outlook

were entirely different than they are today" as stressed out by the Group itself.[165] Technical problems in the construction of the plant and today's lower price forecasts have significantly negatively impacted its anticipated profitability, leading Vattenfall to recognise substantial impairment losses.[166] EDP plans to have its coal-fired power stations Aboño II and Soto III in Spain fully equipped with desulphurisation and denitrification systems by 2017.[167] CEZ is advancing toward the completion of the renovation of lignite-fired power plants to enable them to meet future requirements: flexibility, low emissions, and high efficiency.[168] In 2015, the Group expects to complete environmental upgrades at the Počerady I and Dětmarovice power plants, the renovation of Prunéřov II power plant, and the commissioning of a new 660 MW coal-fired unit at the Ledvice power plant, notably.[169] In 2014, EnBW commissioned the new hard coal unit RDK VIII (gross electrical rated capacity of 912 MW and an efficiency of over 46%) in Karlsruhe, Germany and submitted application to decommission the hard coal units V and VI (connected to the grid in the mid-1960s with a capacity of 125 MW each) in Heilbronn, Germany.[170] PGE is currently restoring and modernising its existing coal-fired power plants, including Belchatów, Europe's largest coal power plant with over 5 GW of installed capacity, Turów, Opole, and Dolna Odra, notably.[171] SSE coal capacity was recently reduced by 1.4 GW with the closures of Uskmouth and Ferrybridge Units I and II in March 2014.[172] And Verbund is currently implementing decommissioning measures for its Dürnrohr hard coal power plant in Austria.[173]

All the activities aforementioned concern the actions taken by the major European EPCOs with regard to coal-fired power plants in recent years. When it comes to the future, the outlook for this technology varies relatively significantly from a company to another. While some companies are planning to build new coal units in the years to come, especially in emerging economies, others are rather aiming at decreasing their reliance on coal power. Among the companies which are constructing new plants are GDF-Suez/ENGIE, PGE, and EDF, notably. GDF-Suez/ENGIE had 1.2 GW consolidated of coal-fired capacity under construction essentially in India and Morocco at the end of 2014.[174] Regarding the Group's project in Morocco, project in which Mitsui is also notably involved, construction of the two 693 MW ultra-super-critical coal-fired power units started in October of 2014, and are expected to be completed in 2018.[175] It must, however, be highlighted that GDF-Suez/ENGIE has recently not only abandonned important large-scale projects in Turkey and South Africa, but also announced that the Group will not invest in new coal projects anymore, with the exceptions of projects that already are subject of a firm commitment, for economic and environmental reasons .[176] PGE is building new coal-fired power units in Poland: Opole II (2*900 MW) and Turów (490 MW), which should be commissioned by 2019.[177] And EDF, in April 2014, signed an agreement with the electricity operator China Datang Corporation to take a 49% stake in

Jiangxi Datang International Fuzhou Power Generation Company Ltd.[178] This joint venture is constructing an ultra-supercritical coal-fired power plant consisting of two 1,000 MW units in Fuzhou, China, which is scheduled for commissioning in 2016.[179] It may also be noted here that among the major European EPCOs which have recently expanded or sought to expand their coal-fired power plant fleet in emerging economies stand E.ON and EDP, both in Brazil.[180] In 2014, E.ON acquired a 50% stake in Pecém II, and EDP has agreed to purchase 50% stake in Pecém I.[181] At the opposite, Enel is targeting to reduce its coal power capacity by about 2 GW by 2019.[182] Vattenfall, in autumn 2014, began looking into the prospects for divesting its entire lignite operation in Germany where the Group had 7.8 GW of lignite coal-fired power plants – almost one-fifths of the Group's total installed capacity.[183] And CEZ expects its installed coal power capacity to decrease by about 2.4 GW between 2014 and 2025.[184]

In recent years, the major European EPCOs have thus closed a number of coal-fired power plants, especially the oldest least efficient ones for regulatory and economic reasons, upgraded more recent ones to meet new standards and evolving market conditions, and build new efficient and relatively low emission ones. Today some of them keep investing in new units whereas others are decreasing their reliance on this technology. The main reasons advanced by the considered Groups to pursue coal power generation are: the output stability of coal-fired power plants – as opposed to the variability of wind and solar power – and its cost, which is discussable insofar as coal power generation is responsible for negative externalities on the people and the environment. These harmful damages are today still difficult to monetise and internalise making the cost of coal power generation potentially artificially low. The following quote may best summarise/illustrate the current position of most of the major European EPCOs, particularly the most conservative ones, towards coal:

"*Hard coal will continue to play an important role in future at EnBW in ensuring a reliable and economic supply of electricity.*"

EnBW – Integrated Report 2014, page 37 –

This type of statement should, however, be balanced in light of long term trends in electricity generation from coal in developed economies. In 1990, with 1,050 terawatt hours, coal accounted for 41% of the EU's electricity generation.[185] From 1990 to 2012 electricity generation from coal decreased by 11% in the EU, and coal's share in the EU's electricity generation mix decreased to 29%.[186] And according to the International Energy Agency (IEA), this decline will continue; in its World Energy Outlook 2014 "New Policies Scenario" (central

scenario) the IEA forecasts that electricity generation from coal will decrease much further, and that coal's share in the EU' electricity generation mix will be only 15% in 2030 and 9% in 2040.[187] In the US as well both electricity generation from coal and the share of coal in the country's electricity generation mix decreased from 1990 to 2012.[188] Still according to the IEA scenario mentioned above, with the implementation of the Clean Power Plan, from 2012 to 2030 electricity generation from coal should decrease by almost 25% in the US, and the share of coal in the country's electricity generation mix be reduced from 38% to 25%.[189] Leading developed economies have thus clearly started to move away from coal and this shift towards a cleaner energy future is expected to accelerate. In this regard, backwards plans to build over 23 GW of coal fired power plants in Japan appear to ridiculously run against the course of history.[190]

B. Gas Power

From a market to another, gas power has known various fortunes in recent years. While the major European EPCOs have brought some new builds online in and out their domestic market, many plants have also been shut down either definitely or temporarily, essentially in Europe. If hard coal-fired power plants have started to feel the heat related to the situation in European electricity markets: low energy demand (slowdown of the European economies following the financial crisis, EE improvements…) and significant expansion of renewables, which combined have led to an overcapacity of power capacity, gas power stations which have higher fuel cost and which lower GHG emissions are not rewarded by a strong carbon price have already taken a huge blow. Outside Europe, under different market conditions, the Groups considered have invested in and keep invest in gas-fired power plants to some extent.

As of the end of 2014, the major European EPCOs had certainly well over 155 GW of gas power installed capacity worldwide, approximately a quarter of their installed capacity.[t] With over 40 GW consolidated of gas power installed capacity (of which 1.2 GW of natural gas cogeneration) – almost half of its total installed capacity – GDF-Suez/ENGIE was one of the Groups relying the most on gas power (with Gas Natural Fenosa, another important gas market player).[191] With the exceptions of EDF and Vattenfall, which still respectively had 12.9 GW and 5.8 GW of gas power capacity, respectively, all the other largest European EPCOs; Enel, E.ON, RWE, and Iberdrola, were quite dependent on gas power with all of them having at least 12 GW of gas power capacity installed representing very roughly between 30 and 40% of their total

[t] Estimating gas power installed capacity is a quite difficult exercise insofar as the Groups considered in this report sometimes mix gas power with oil power and/or do not always precise fuels used in cogeneration plants when reporting installed capacity data. The estimate presented here deals with this inconsistency in reporting and while being an approximation still gives a relatively good order of magnitude of the gas power installed capacity of the major European EPCOs, especially for comparison purpose with other technologies.

installed capacity.[192u] Among the other Groups considered, Gas Natural Fenosa 8.6 GW and SSE 4.3 GW, representing 58% and 37% of their total installed capacity, respectively, were also quite dependent on gas, but for different reasons (see Box 2 on page 12 about Major European EPCOs' Historical Mergers).[193]

In the EU in the last couple of years (2013-2014), some new gas-fired power plants were installed and more closed (decommissioned or mothballed).[194] For instance in this period, 9.8 GW of new gas power capacity was installed, 13.1 GW decommissioned, and at least several gigawatts mothballed.[195] The story has not been exactly the same in all markets because the need to replace fossil fuel-fired power plants, the expansion of renewables, and the decrease in energy demand have differed a little from a country to another (or from an area to another), but overall the picture has been quite gloomy for gas power. On the side of the new builds, we can notably refer to EDF, which has commissioned three combined-cycle gas turbines (CCGT) in France since 2011, at the Blénod site (430 MW) in 2011 and at the Martigues site in 2012 and 2013 (Martigues V and VI, 465 MW each).[196v] In France also, the Group is now constructing a new CCGT in Bouchain (510 MW) with commissioning scheduled in 2016.[197] EDF has also been active in the UK where the three new units, of the new combined cycle gas power plant in West Burton B (total capacity of 1.3 GW) have been operating since 2013.[198] In France, these investments were notably made to replace coal-fired power plants, which have been shut down to respect EU's directives (See Part 1. 2.A. Coal Power).[199] In the UK, West Burton B is expected to contribute to lower the Group's CO2 emissions in order to reach its 2020 CO2 emissions reduction goal (see Part 1 .4. Adapting Power Plant Fleets to Climate Change).[200] One might also advance that investing in new gas-fired power plants in the UK was appearing relevant taking into account the need to replace the numerous coal-fired power plants which have been shut down due to EU's directives aforementioned.[w] Vattenfall is currently building a new gas-fired CHP plant, which commissioning is expected in 2016, to replace an older power plant in Lichterfelde in southern Berlin.[201] The plant will have an electricity generation capacity of approximately 300 MW and heat capacity of 230 MW, more than 85% of the fuel's energy will be used.[202] EnBW, also, is constructing a new gas power station; the Lausward CCGT power plant in Düsseldorf, which is due to enter service in 2016.[203] The plant, which is aiming for three world records: it will have an electrical output of 595 MW, the highest ever for a single combined cycle unit, its net energy conversion efficiency will add

[u] The 30-40% range given here is based on the assumption that half or more of the 21.0 GW of fuel oil/gas installed capacity reported by Enel are gas power capacity. If these 21.0 GW were only fuel oil, the range would be ~20-40%

[v] The Martigues site was hit by a fire in February 2015. Since then Units V and VI are shut down. Unit V was expected to return at the latest in June 2015, and unit 6 by winter 2015-2016.

[w] The impact of the LCPD has been quite significant in Great Britain where about 8 GW of coal-fired capacity – over a quarter of the island's coal-fired capacity – will be closed by the end of 2015.

up to more than 61%, and for the first time it will be possible to extract 300 MW of thermal energy from a single power plant unit in combined cycle operation (in this way the overall efficiency of natural gas as a fuel rises to 85%), is expected to meet the future energy needs of Düsseldorf's region where, contrarily to many other regions in Germany, the population is continuing to grow.[204] However, the most important fact concerning gas-fired power plants in Europe in recent years has been the significant reduction of their contribution to the electricity mix.

Ranking last (with oil-fired power plants) in the merit order due to their fairly high fuel cost, and in a context of low electricity demand and renewables expansion gas power stations have been pushed out of the market. For instance, since the summer 2013, RWE made decisions to take off the system either temporarily or permanently gas-fired power plants with combined installed capacity of 4.7 GW in Germany and the Netherlands.[205] In the Netherlands in July 2014, the Group's Claus C CCGT power station, with a capacity of 1,304 MW and commissioned in 2012 was mothballed, notably.[206] In 2014 alone, GDF-Suez/ENGIE closed or sold gas power plants with combined installed capacity of 1.7 GW in Europe.[207x] In previous years, the Group had also already closed significant gas power capacity in Europe: in 2013, gas power plants with combined capacity of over 2.4 GW were closed, including Teesside power plant, which was the largest CCGT in Europe with 1,875 MW (started operation in 1993), and in 2012 over 1.7 GW.[208y] In addition, E.ON reported that its attributable gas-fired capacity declined by over 900 MW in 2014 owing to the closures of three gas turbines, one each in Germany, Slovakia, and the Netherlands.[209z] In March 2015, the Group announced its plan to close from April 2016 Irsching IV (550 MW) and V (846 MW) in Germany, two of the most efficient gas-fired power stations in the world, which entered service in 2011 and 2010, respectively, because the two CCGTs have no prospect of operating profitably.[210] In Spain in 2014, Iberdrola requested authorisation for the closing of the Castellón III (800 MW) CCGT plant to "optimise the generating facilities of the Group."[211] In the Netherlands, Vattenfall decided to put only one of three units at its new gas-fired Magnum power plant (1,311 MW) in Eemshaven into full commercial operation at the start of 2014 because of "deteriorated market conditions."[212] In Norway, based on continued low operational utilisation, Statkraft's Kårstø gas-fired power plant operational mode was changed to preservation with a one-year start-up time.[213] This 430 MW plant was completed in the autumn of 2007.[214] In England, at the end of 2014, SSE's Keadby 735 MW gas-fired power plant was also mothballed for example.[215aa]

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[x] At 100%.
[y] The 2012 figure does not include the 826 MW of the gas/light fuel oil of Dunamenti F 9-12 power station, which has been closed by GDF-Suez/ENGIE in Hungary in 2012.
[z] Attributable capacity; the capacity that reflects the percentage of the Group's ownership stake in an asset.
[aa] It might also be worth noting that at the same time SSE was about to commission a 460 MW gas-fired power plant, but in Ireland.

Finally, Verbund, which new Mellach CCGT plant is facing unfavourable market conditions notably, recently congratulated itself for selling its gas power plants in France, as well as in Italy.[216]

While the situation for gas power plants has been disastrous in Europe in recent years, emerging economies have provided some opportunities for the major European EPCOs to expand their gas power portfolio. In April 2014, GDF-Suez/ENGIE started commercial operation of its new 381 MW gas-fired unit Uch II in Pakistan.[217] At the end of 2014, the Group also had over 1 GW consolidated of gas power stations under construction in Thailand, Peru, Mexico, Kuwait, Saudi Arabia, and the United Arab Emirates.[218] In recent years, E.ON commissioned new CCGT power plants in Brazil and Russia.[219] In the middle of 2013, RWE commissioned commercially a new gas-fired power station near the town of Denizli in Turkey.[220] In Mexico in 2014, Iberdrola began the construction of the Baja California III (300 MW) and of Monterrey V (300 MW) CCGT plants.[221] In Russia in 2013, Fortum started commercial operation of two of the three units of Nyagan (over 1,270 MW) CCGT power plant, and the third unit followed in early 2015.[222] In its last Annual Report, Fortum was also reporting the construction of two natural gas-fired CHP plant units in Russia in 2014, which upon completion in 2015, will increase the Group's electricity capacity by 496 MW and its heat capacity by 350 MW.[223] In the Czech Republic in October 2014, CEZ completed the construction of Počerady II (845 MW) CCGT plant.[224] Finally, in 2013, EDF signed a joint development agreement with the project developer Australis Power, with the aim of notably constructing a CCGT power plant consisting of two 600 MW units in Chile.[225]

The major European EPCOs may thus keep seeking to expand their gas power portfolio outside of Europe where these assets could help meet growing electricity demand. In Europe, however, the outlook for gas-fired power stations remains rather dark at least for the short to medium term. The Groups considered in this report are now rather working on improving the flexibility and efficiency of their gas power plants, this is the case – among others – of E.ON and SSE, in order to enable them to react better to fluctuations in variable renewables generation, notably, than planning to build not-needed new ones.[226] In the longer term, the situation may potentially improve for gas power plants driven by their relatively low capital costs, flexibility to help integrate increasing amounts of variable renewables electricity, high thermal efficiency, and status as the cleanest of the fossil fuel technologies. This will, however, require more incentives to switch over coal-fired based power to gas-fired production. SSE anticipates that this may happen in Great Britain, where a carbon price floor exists (about £18/tonne of CO2 since April 2015) and where the Group will continue to pursue development options for CCGT including Abernedd, Keadby II, and Seabank III.[227] EnBW rather points out that further expansion of renewables may rather induce a lower structural demand for gas in

Europe, since such expansion will primarily reduce the periods when gas power plants are utilised.[228]

On the one hand the difficulties faced by gas power plants may be seen as a bad sign since gas as often been recognised as a "bridge fuel" to enable a smooth energy transition, in the electricity sector in particular thanks to the flexibility of gas power stations, on the other hand the situation in Europe also tends to prove that integrating moderate shares of variable renewables (~10-45% of annual gross electricity production) can be realised without relying excessively on this option. That might be a lesson for Japan.

Below is a compilation of the most clarifying statements of the major European EPCOs regarding their related gas power activities in Europe:

"*Even the latest environmentally friendly combined-cycle gas turbine (CCGT) power plants are not economically viable to operate. This is due to the low wholesale price for electricity, over-capacity leading to under-utilization, and the persistently low price of carbon certificates.*"

E.ON – Group's Website, "Portfolio Development" (viewed 26 June 2015) –

"*[…] it is these […] stations (gas-fired power plants) that are forced off the market by renewable energy, as their fuel costs are relatively high.*"

RWE – Annual Report 2014, page 20 –

"*The situation of gas power plants is a particularly precarious one. Due to high gas prices and low electricity prices, the ongoing operating costs of gas power plants cannot be covered.*"

Verbund – Annual Report 2014, page 58 –

"*There is currently a lack of economic incentive to switch over from coal-fired base power to gas-fired production with lower CO2 emissions.*"

Vattenfall – Annual and Sustainability Report 2014, page 13 –

"The CO2 low price, combined with coal and natural gas prices, allow coal-powered production to remain more competitive than the combined cycle and natural gas plants in most European markets [...]."

EDP – Annual Report 2014, page 38 –

"Despite currently experiencing short term market challenges, gas-fired plant will play an increasingly important role in electricity generation [...]."

SSE – Annual Report 2014, page 36

"Moreover, further expansion in renewable energies will also induce a lower structural demand for gas in Europe, since such expansion will primarily reduce the periods when gas power plants are utilised."

EnBW – Integrated Report 2014, page 42

C. Oil Power

Besides coal and gas, the major European EPCOs are also using oil to generate electricity, but to a much lesser extent compared with the first two fossil fuels mentioned. This is due to the fact that oil-fired power plants are highly responsive facilities, but with quite high fuel cost. They are therefore rather used as extreme peak capacity (extreme end of the merit order).

While still being essential to the well-functioning of the electricity system today, oil-fired power stations are thus used at its margin most often, which also means they are not accounting for a large part of the EPCOs generating assets portfolio. This, however, does not mean either that oil power capacity was completely negligible. For instance, EDF, E.ON, Vattenfall, SSE, and Gas Natural Fenosa notably reported 9.9 GW, 2.8 GW, 1.8 GW, 1.1 GW, and 0.3 GW of oil power capacity at the end of 2014, respectively.[229bb]

In recent years, the oil-fired power plants fleet of the major European EPCOs has been impacted by EU's regulations and economic conditions, notably: on the one hand some power stations have been upgraded to meet more stringent environmental standards on the other hand some have been closed and possibly replaced. In this regard, EDF notably recently

[bb] In addition, Enel reported 21.0 GW of fuel oil/gas installed capacity.

equipped some of its oil-fired units with low nitrogen oxides burners and repowered an oil unit into gas combined cycles.[230] In 2014, E.ON closed 313 MW of oil capacity owing to the closure of two units in Italy.[231] In November 2014, SSE was planning to decommission a 240 MW heavy fuel oil plant in Ireland after completing a new CCGT in the same area.[232]

From a broader perspective, it is also interesting to note that (1) from 2000 to 2014 fuel oil power installed capacity decreased by 25.3 GW in the EU; the highest reduction of all technologies, just ahead of coal power 24.7 GW.[233] In the meantime wind and solar PV increased by 116.8 GW and 87.9 GW, respectively.[234] In addition, (2) Japan's historical reliance on expensive non-domestic polluting oil imports to generate electricity – even before Fukushima nuclear accident (9% of electricity generation in 2010 against only 3% in the EU and 1% in the US) – is an absurd isolated anomaly(/aberration?) at all levels; economical, geopolitical, and environmental, which means oil power should be drastically reduced as soon as possible.[235]

3. Nuclear Power Facing Hard Times

The major European EPCOs had almost 120 GW of nuclear power installed capacity essentially in Europe at the end of 2014, making it the fourth most important technology they relied on, just behind coal power and at a respectable distance of gas and hydro power, but very well ahead of wind power.[236] The undisputed leader, we can even talk here of "giant" in terms of nuclear power deployment was EDF, which had about 73 GW of nuclear installed capacity at the end of 2014, mostly in its home country, accounting for over half of the Group's total installed capacity (54%) or over 20% of the world's total nuclear power installed capacity in operation.[237] In comparison, no other Group had more than 10 GW of nuclear power installed capacity. This, however, does not mean that they had few nuclear power installed capacity and/or that it was accounting for a minor part of their portfolio. Indeed, Enel, GDF-Suez/ENGIE, E.ON, RWE, Iberdrola, and Vattenfall all had between 3 and 9 GW of nuclear power installed capacity.[238] In addition, nuclear power accounted for roughly between 20% and 30% of Fortum, EnBW, and CEZ's total installed capacity.[239]

Nuclear electricity production activities of the major European EPCOs have known various fortunes in recent years, but overall the picture has been rather gloomy. The prevailing optimism before the Fukushima nuclear disaster ("Nuclear Renaissance") and continuous difficulties in the building of new power plants has given way to a new harsh reality.

The Fukushima nuclear disaster has strongly impacted the nuclear related activities of the major European EPCOs, not to the same extent though. If all the Groups considered in this report with nuclear installed capacity and/or expansion plans (this excludes Statkraft, SSE,

and Verbund) have had to deal with more stringent safety standards for existing and future facilities, some of them simply had to shut down some of their power stations (rapidly) and/or will have to do/keep doing so within the decade to come. At the forefront of this huge blow, EPCOs with nuclear power plants in Germany: E.ON, RWE, Vattenfall, and EnBW, where the national government decided, in the aftermath of the Fukushima disaster, that all nuclear power in the country is to be shut down by 2022 at the latest. As of early July 2015, nine out of Germany's seventeen nuclear reactors – all operated by one of the four Groups aforementioned – had already been closed: E.ON had closed three facilities; Isar I, Unterweser and Grafenrheinfeld, and RWE, Vattenfall, and EnBW two each; Biblis A and B for RWE, Brunsbüttel and Krümmel for Vattenfall, and Neckarwestheim I and Phillipsburg I for EnBW.[240] Out of the eight reactors still remaining in operation in Germany today, three are operated by E.ON (Grohnde, Brokdorf, and Isar II), three by RWE (Gundremmingen B and C, and Emsland), and two by EnBW (Neckarwestheim II and Phillipsburg II).[241] Upgraded safety standards certainly do not mean safe nuclear power plants, but rather additional costs, which for a technology are never welcome especially when wholesale electricity prices are decreasing as well as the cost of competing technologies (wind and solar power especially). The timing of the Fukushima nuclear disaster was particularly terrible for investors in the nuclear power "revival" since it came at a time when it became very clear that major new build projects in Europe were facing multiple delays and major cost overruns.

European pressurised reactors (EPRs) Flamanville III (1,630 MW) in France and Olkiluoto III (1,600 MW) in Finland being constructed for EDF and Teollisuuden Voima Oyj, respectively, are the most symbolic examples of the complete debacle of nuclear new builds in which some of the major European EPCOs got involved in in recent years.[cc] Flamanville reactor construction started in December 2007 with commercial operation expected in 2012, and a cost initially estimated at €3.3 billion (2005 prices or about €4 billion in 2015 prices).[242] In February 2015, the French Nuclear Safety Authority (Autorité de Sûreté Nucléaire (ASN)) was informed by AREVA of reactor vessel manufacturing anomalies, which AREVA apparently knew since 2006, and which the French nuclear watchdog finally qualified of "serious or very serious" two months later.[243] In June 2015, it was also revealed that the French Institute for Radiological Protection and Nuclear Safety (Institut de Radioprotection et de Sûreté Nucléaire (IRSN)) found malfunctioning safety valves in the Flamanville EPR that could cause its meltdown, in a similar scenario to the 1979 Three Mile Island nuclear accident in the US.[244] Today, the plant is already three years behind schedule and will not be in operation before the end of 2018 at the earliest (in October 2015, EDF asked the French government to extend the

[cc] Enel originally had a 12.5% share in the Flamanville project, but pulled out of the project in December 2012. Fortum has a 25% share in the Olkiluoto project.

deadline for launching the reactor to 2020, originally set to 2017, so as to allow "room for manoeuvre" in case of new developments without asking to request further changes to a state decree authorising the reactor construction), and its cost has risen to €10.5 billion (2015 prices), i.e. over +150%![245] Olkiluoto construction, in which AREVA is also involved, as well as Siemens, started in 2005 with commercial operation expected in 2009, and a cost originally estimated at €3.2 billion.[246] Today the plant is six years behind schedule, and according to the Areva-Siemens consortium it will start commercial operation in 2018, a nine year delay.[247] In addition, AREVA indicated in late 2012 that the project cost would end up closer to €8.5 billion (over +165%!).[248] While less often referred to, at least another relatively important project led by one of the major European EPCOs, Enel, is facing significant delays and cost overruns. In 2009, the Italian Group started construction of Mochovce III and IV in Slovakia, with initial expectations of completing the two units by 2013 at a cost below €2 billion.[249] Today, the reactors are two years behind schedule, and will not provide power before 2017-2018.[250] Budget for the plant was revised upward to €3.8 billion – more than a doubling – in April 2014.[251] And the worst may actually be to come; concerns have been raised about the state of the power market and electricity demand due to sluggish economy, and it is expected that if and when these units are completed their capacity will primarily be used for export, so given the low wholesale electricity prices in the European market, the chance of Enel recovering its ever-increasing investment seems slim.[252] It thus comes with no surprise that Enel announced in July 2014 that it is seeking to sell its share in SE (Slovenské Elektrárne, the Slovakian State electric utility, which is leading the considered project, and in which Enel has a 66% stake).[253] These facts tend to demonstrate that nuclear new builds are real complicated technological challenges, which costs are everything, but negligible. Myths surrounding nuclear appear thus to be falling one after another like dominos, "safe," "cheap,"… a list to which "reliable" can also be added as multiple unplanned outages struck EDF and GDF-Suez/ENGIE's nuclear facilities in Belgium and the UK in 2014.[254dd]

Other evidences that cost competitiveness of nuclear new builds is still to be proved are: the strike price of £89.50-92.50/MWh (2012 prices) fully indexed to the consumer price index for 35 years, compared to a current wholesale price of £40/MWh, agreed on by EDF and the UK to build Hinkley Point C (HPC) two EPRs (combined capacity of 3.2 GW) (total cost is expected to be £16 billion in 2012 prices, the final investment decision, which has been pushed back from the initial forecasts is finally expected to be made by mid-November 2015 after EDF and China General Nuclear Power Group (CGN) agreed a deal on building the project in October 2015), and the decision of CEZ to cancel the award procedure for the construction of two new

[dd] Unplanned nuclear outages occurred at Doel III and IV, and Tihange II in Belgium, and Heysham I and Hartlepool in the UK.

units at the Temelín nuclear power plant on 10 April 2014 because the Czech government announced the day before that it will not provide any guarantee or stabilisation mechanism for the construction of low carbon facilities notably.[255ee] Since building new nuclear power plants increasingly appears to be a quite risky technological and financial business bet – without talking of difficulties in terms of social acceptance, the major European EPCOs are usually rather investing to extend the lifetime of their existing assets, enhancing their safety, and increasing their capacity, efficiency, and availability, instead of replacing old units with new ones, and/or pursuing growth opportunities for their nuclear activities.

At the forefront of this trend, EDF, which Board of Directors approved in principle the major overhaul program called "Grand carénage" in January 2015.[256] This massive investment program for the nuclear fleet in France (58 reactors in operation with an average age of 29 years, spread over 19 sites owned by EDF, and totaling 63.1 GW at the end of 2014), aiming at refurbishing the country's nuclear fleet, enhancing reactor safety, improving technical performance, and if conditions allow, extending their operating lives (beyond 40 years), is estimated to reach a maximum of €55 billion (2013 prices) by 2025.[257ff] In addition, the French Group has also made the decision to extend the lives of five of its nuclear power plants in the UK: Hartlepool and Heysham I by five years (to 2019), Hinkley Point B and Hunterston B by seven years (to 2023), and Dungeness B by ten years (to 2028).[258] Enel, which has nuclear power station operations in Spain and Slovakia with a total combined capacity of 5.1 GW is also seeking extension of the useful life of these plants.[259] In 2014, the agreement governing the extended lifetime of GDF-Suez/ENGIE's Tihange I nuclear power plant to 2025 was signed, and the Belgian federal government made the decision to extend the lifetime of the Group's Doel I and II units by ten years.[260] This does, however, not jeopardise the country's legal nuclear phase-out goal for 2025.[261] Oskarshamns Kraftgrupp, of which E.ON is the major shareholder, initially planned to extend the lifetime of its three reactors at Oskarshamn, Sweden to 50 years for Oskarshamn I, and to 60 years for Oskarshamn II and III, but due to low wholesale

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[ee] Price benefits from upfront reduction of £3/MWh built in on assumption that EDF will be able to share first of a kind costs of EPR reactors across HPC and Sizewell C sites. If the final investment decision is not taken on Sizewell C, strike price for HPC will be £92.50/MWh. EDF reached an agreement in principle with the UK government on the price to be paid for the output of HPC via a CfD in October 2013 and agreed key terms of the government-backed guarantee for which HPC pre-qualified under the government's Infrastructure Guarantee scheme. The main terms of the agreement were confirmed to be compatible with EU State Aid rules by the European Commission on 8 October 2014.
The plant was originally scheduled to open in 2017. EDF has announced that it would be constructed by 2025. The subsidy agreement with the British government contains a clause allowing the plant to be completed no later than 2033.
Difficulties in the building of nuclear reactor at Flamanville might bring the HPC project down as the UK's finance guarantees for HPC will collapse if Flamanville is not working by 2020.
In addition, regarding the Temelín project, CEZ noted that it "became economically unreasonable under the existing conditions," citing also "increasing uncertainty in energy markets and a further drop in wholesale electricity prices."
[ff] Indicative figure, will be confirmed later and gradually.

electricity prices combined with increased output tax on nuclear power and additional requirements on extensive investments, decision has recently been made to shut down permanently unit I between 2017 and 2019, and unit II by 2020 – that is at least 3 years and 14 years, respectively, earlier than originally expected.[262gg] In Sweden as well, Vattenfall initially envisaged extending the lifetime of its seven reactors at Ringhals (I to IV) and Forsmark (I to III); to 50 years for Ringhals I and II, and to 60 years for the five others.[263] However, in April 2015, the Group announced that Ringhals I and II may be closed down between 2018 and 2020, instead of previously decided around 2025 – that is after 44 to 46 years of operation "only."[264] Continued low wholesale electricity prices and increasing production costs were the reasons given.[265] CEZ is investing with the aim of production upgrading, stabilising, safety, and efficiency in relation to the planned extension of operation of its Dukovany nuclear power plant beyond 2015.[266hh] At its Temelín nuclear power plant CEZ also continues to implement projects fulfilling requirements from the Czech Republic National Action Plan for Safety Enhancement, based on the results of nuclear plant stress tests that were carried out following the adverse events at the nuclear power plant at Fukushima.[267] For instance in 2014, new independent alternative backup power supplies (diesel generators) for the two units of the plant were handed over and subjected to operating tests.[268] In addition, CEZ recently increased the capacity of Temelín nuclear power plant unit I from 1,056 MW to 1,078 MW, and is expecting to increase the capacity of unit II by 24 MW in 2015.[269] Fortum is also modernising its Loviisa nuclear power plant in Finland and targets to increase the plant's nominal output by a total of about 29 MW.[270]

In light of these developments, and in particular the lifetime extension of nuclear power plants, it must be noted that getting approval from national nuclear safety authorities is not a foregone conclusion. There is no guarantee that despite their significant efforts, financial ones notably, the major European EPCOs' nuclear power stations will pass in-depth examinations. EDF has already been warned by the ASN on that point.[271] Economics also plays an important role in extending the lifetime of nuclear power plants as demonstrated by E.ON's Oskarshamn I and II, and Vattenfall's Ringhals I and II. In Japan, seismic issues should theoretically require higher safety standards and drive costs for compliance even higher. And the economic mechanisms aforementioned may well start affecting the profitability of conventional power plants with the expansion of renewables and a lower electricity demand. As a result, heavily investing in the lifetime extension of nuclear power plants without the guarantee of getting the approval of the Nuclear Regulation Authority might not be the wisest choice Japanese EPCOs could make.[272] While the major European EPCOs are focusing on

gg Minority owner Fortum was opposed to the early shut down of these units.
hh The operating license for unit I will expire at the end of 2015, for unit II at the end of 2016, and for units III and IV at the end of 2017.

improving their existing nuclear facilities to be allowed to operate them longer, notably, this does not, however, mean that they are not pursuing a further expansion of their nuclear electricity generation activities at all. Indeed, some of the Groups considered in this report are eyeing opportunities in emerging economies, as well as some European countries.

Among the emerging economies the major European EPCOs are interested in developing nuclear power plants are China, Turkey, and Saudi Arabia, notably. EDF's nuclear activities are already quite active in China where the Group owns a 30% shareholding in Taishan Nuclear Power Joint Venture Company, which started construction of two EPRs Taishan I and II (1,660 MW each) in 2009-2010 with expectations for the project to be completed in 2014-2015 at a cost of €8 billion. Expectations which will not be met because of delays plaguing the project; the reactors are now expected to be in operation in 2016-2017 (cost overruns appear to be unknown).[273] In 2014, Enel signed a memorandum of understanding (MoU) with China National Nuclear Corporation (the state-owned company responsible for all aspects of nuclear programs in China) establishing a framework for the exchange of information and best practices related to the development, design, construction, O&M of nuclear power plants.[274] GDF-Suez/ENGIE, which had nearly 6 GW of nuclear power installed capacity, but no nuclear power plant under construction at the end of 2014, has, in cooperation with its Japanese partners Mitsubishi Heavy Industries (MHI) and Itochu, launched a feasibility study for a nuclear power station to be built near the city of Sinop in Turkey, based on the ATMEA1 technology developed by MHI and Areva (around 4.5 GW).[275] In its last Annual Report GDF-Suez/ENGIE also indicated that the intergovernmental agreement between the Turkish and Japanese governments and the agreement between the project operators and the Turkish government have been approved by the respective authorities and should be ratified by the Turkish parliament in 2015.[276] Finally, regarding nuclear power opportunities in emerging economies, it is also worth to point out that EDF opened a joint office with AREVA in Riyadh, Saudi Arabia in 2012 with a view to working with the Saudi government, which is planning to develop an energy policy that focuses on replacing fossil fuels with nuclear power and RE sources (mainly solar power, but also wind power).[277] Together, the two companies are leading work to evaluate the local industrial fabric and the educational system, in order to prepare for the launch of a nuclear program.[278] In this regard, EDF signed a cooperation partnership agreement with the Saudi Electricity Company (the country's leading electricity sector operator) in 2014.[279]

In Europe, EDF, apart from building the Flamanville EPR, which commissioning will trigger the closure of an equivalent nuclear generating capacity in France according to the country's Energy Transition Law for the Green Growth, aims to build four new EPRs in the UK including the two aforementioned at Hinkley Point in Somerset, and possibly a further twin at

Sizewell in Suffolk.[280] At the opposite, Iberdrola completed the sale of its 50% shareholding interest in NNB Development Company (NNB) to Advance Energy UK Limited, a subsidiary of Toshiba Corporation, in 2014. NNB owns 100% of the share capital of British company NuGeneration Limited which Moorside project aims to develop a new generation nuclear power station of up to 3.6 GW in West Cumbria in the UK.[281] CEZ is supporting the initiative of developing new units at Temelín and Dukovany nuclear power plants in Czech Republic.[282] CEZ is also involved in the construction of a new nuclear power plant at Jaslovské Bohunice in Slovakia, but wants to sell its stake in the joint venture leading the project (Jadrová Energetická Spoločnosť Slovenska) to concentrate on its Temelín expansion project.[283] As a result of these activities, the Group does not expect an increase in its nuclear power installed capacity by 2025.[284] Fortum is ready to participate with a minority stake (maximum 15%) in the Finish Fennovoima nuclear power project on the same terms and conditions as the other domestic companies currently participating in the project, provided that the Group obtains more than 75% ownership in Russian TGC-1 hydro assets (See Part 1. 1.B. Hydropower).[285] Finally, PGE is planning to begin construction of its first nuclear power unit in Poland in 2020.[286]

This section entitled "Nuclear Power Facing Hard Times" has so far pointed out the main difficulties currently met by the major European EPCOs regarding their nuclear power activities, without treating the future major challenges nuclear power plant operators will start to have to cope with sometime soon such as numerous facilities decommissioning, storage of radioactive waste (notably; will provisions for decommissioning and waste disposal be enough?), or generation renewal (how to maintain critical knowledge as the first generation of senior nuclear experts starts to retire?). As a nuclear power house, this rocky road is also clearly ahead for Japan:

Regarding radioactive waste storage facilities, three main concerns need to be addressed: their technical feasibility and safety, their cost, and gaining social acceptance of local population. Finding suitable geological repository such as large clay deposits for example is a first challenge. Handling the industrial process of storing waste and ensuring the long term safety of the sites are next on line. The costs of these operations are still very largely unknown today because of the lack of experience and because each country's geography is different. And public discussion becomes heated when suggestions for this type of facilities are advanced. In Europe, little progresses have been made overall on all these issues so far. In Germany, a study of the Deutsches Institut für Wirtschaftsforschung released in June 2015 pointed out that a repository in which the highly radioactive fuel elements could be safely stored for thousands of years is not yet in sight; the final location for a repository is expected to be selected by 2031 at the very earliest.[287] And that the not-very-reliable cost estimates for decommissioning and disposal stand at least to €50 billion to €70 billion, much more than the provisions set up by

the power plant operators, which currently amount to €38 billion.[288] More recently, in October 2015, Germany Economy Ministry said that the operators of the country's nuclear power plants have set aside enough funds to pay for decommissioning reactors, even though stress tests showed the potential cost could far exceed their provisions (by almost €40 billion in a worst case scenario, which operators would still be in a position to meet their combined assets being worth around €83 billion).[289] Moreover local population is quite hostile to this type of facilities; the name of Gorleben, a municipality where a controversial nuclear waste disposal facility (currently used as an intermediate storage facility, but intended to become permanent) is located, brings up negative images in the minds of many Germans.[290] In France reprocessing of spent nuclear fuel, originally introduced to obtain plutonium for fast breeder reactors, is now established as the national policy for spent-fuel management.[291][ii] Reduction of the quantity and toxicity of radioactive waste is sought notably by processing spent fuel and by processing and conditioning radioactive waste.[292][jj] High level wastes from reprocessing spent fuel are vitrified and stored at La Hague reprocessing plant, which spent fuel storage capacity is to be significantly increased because of waste accumulation while waiting for the start of operations at the deep-storage facility for high-level and long-lived intermediate-level radioactive wastes Cigéo that could enter industrial pilot phase in 2025.[293] Both projects, La Hague's extension and Cigéo, are facing public opposition.[294] In 2014, the cost of the Cigéo project was estimated between €14 billion to €28 billion, excluding insurance costs notably.[295] EDF's nuclear provisions for its nuclear activity in France amounted over €34 billion at the end of 2014, that is less than the provisions of the nuclear power plants operators in Germany, while the French Groups operates more than 3 times the number of reactors in operation in Germany before the beginning of the *Energiewende* (58 reactors against 17).[296][kk] Elsewhere; Belgium is a small country with few possibilities for permanent nuclear waste storage (in this regard, the clay deposits at the research facility in the town of Mol are too small for a storage site).[297] In Czech Republic, the situation is not transparent and there is opposition in the country towards the government's plans to create nuclear storage facilities.[298] Only the Nordic

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[ii] Today plutonium is burnt as mixed oxide fuel (MOX) at "ordinary" nuclear reactors. Most of the fast breeder reactor programs in western countries have been either abandonned (Germany, UK, and US) or put on hold (France) because of their high building and operating costs, safety and reliability problems, and because their fuel cycle provides easy access to plutonium for weapons increasing geopolitical tensions among countries.
In Europe, the UK is also promoting reprocessing.

[jj] It must, however, be noted that these processes also produce high-level wastes that contain much of the radioactive content of the spent fuel as well as other streams of radioactive waste, including plutonium waste from the manufacture of plutonium-containing fuel. Irradiated MOX fuel, which is not being reprocessed, contains six times the percentage of plutonium as spent low-enriched uranium fuel.
In addition, the continuation of reprocessing policies may contribute to make the question of waste treatment an invisible issue and encourage postponing key decisions on the choice of final disposal sites for spent nuclear fuel.

[kk] EDF's France nuclear provisions: €10.1 billion for management of spent fuel, €7.7 billion for long-term management of radioactive waste, €13.9 billion for dismantling power stations, and €2.4 billion for last cores.

region has made progress in the search for permanent storage sites.[299] In Finland, a first facility is under construction on the island of Olkiluoto, but it is facing some hurdles; several investigations are being conducted that could potentially halt the process and it is therefore unclear at this stage when it could realistically begin operations.[300]

Finally, in terms of generation renewal, a publication of the Joint Research Centre of the European Commission released in 2014 pointed out that younger generations' interest in nuclear studies decreased dramatically and nuclear education was abandoned by many engineering faculties.[301] Meanwhile the first generation of senior nuclear experts started to retire, resulting in a gap between incoming and outgoing flows of experts.[302] It will not be possible to keep exploiting nuclear power at large-scale without the required scientific skills of much needed human resources.

Nuclear power exploitation is thus more and more surrounded by serious uncertainties at all levels, some of the drawbacks of relying on this energy source seem increasingly complicated to solve, and the last arguments still standing in its favour today are that it can provide a stable electricity output, strenghtens energy security, and helps mitigate climate change. But we already know that what is needed to accommodate fluctuations in variable renewables output is flexible capacity, that uranium reserves while being considerable are not-domestic resources for most of the countries relying on nuclear power this means relying on uranium imports, which always entails dealing with geopolitical risks, and that nuclear power helps mitigate climate change only when (1) it replaces fossil fuel power plants, which renewables can do faster and at a lower cost without bringing negative uncertainties in terms of long-term cost, safety, and sustainability, or (2) a decrease in nuclear power production is not completely offset by an increase in RE electricity generation in combination with energy savings (ESs) enabled by EE gains and/or optimisation of energy consumption (this has so far been the case in Japan after Fukushima nuclear disaster, not in Germany). On top of next page is a positive quote from EDF's last annual financial report on nuclear power, it will be interesting to see how long such statement will hold true for the Group (note: the claim that nuclear power is an "economically efficient response to future energy needs" is already if not controversial at least highly questionable when observing the cost of new builds projects, particularly the ones in which the Group is involved and for which cost information are available, i.e. Flamanville and HPC EPRs, and taking into account the uncertainties surrounding decommissioning and waste storage costs):

"EDF believes that nuclear power constitutes a sustainable and economically efficient response to future energy needs: it allows relative energy independence due to considerable uranium reserves worldwide, that are more than adequate to meet global demand forecasts [...]; in addition, nuclear energy does not emit CO2, an essential asset in the context of climate change."

EDF – Annual Financial Report 2014, page 57 –

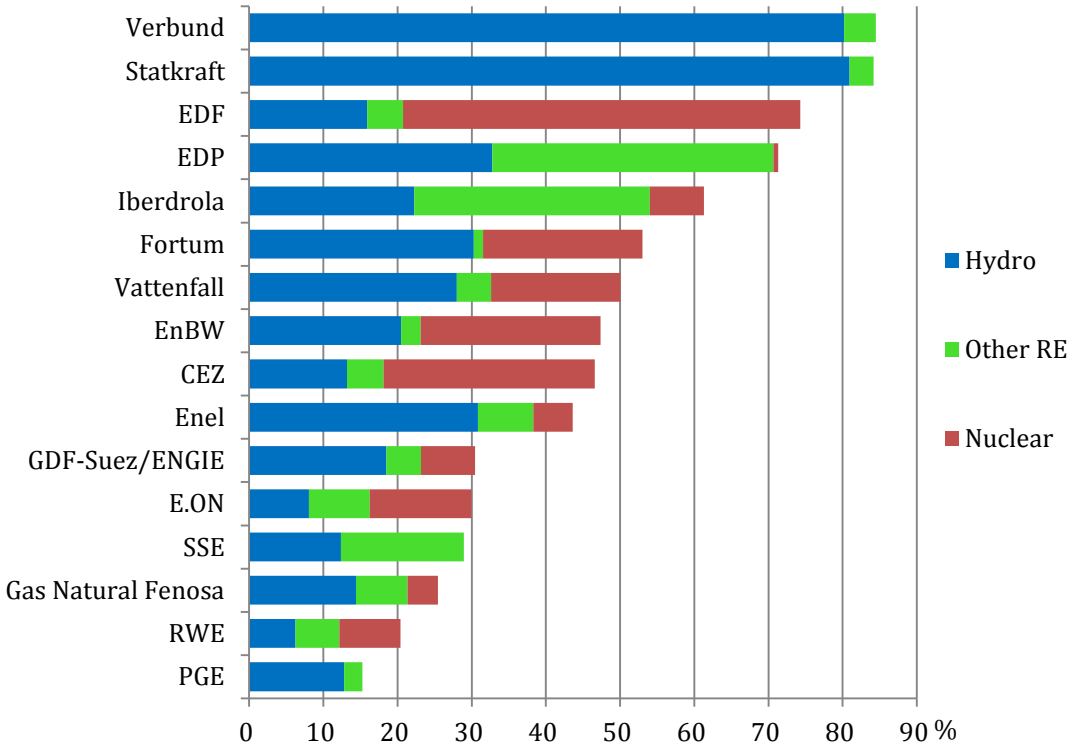
4. Adapting Power Plant Fleets to Climate Change

By setting ambitious targets and developing enabling policies the EU has established itself as one of the leaders in the fight against climate change. The EU has notably set the following targets for GHG emissions reduction (all compared with 1990): -20% by 2020, at least -40% by 2030, and -80% to -95% by 2050.[303] To progressively reach these targets policies have been implemented, in particular: the EU's emissions trading system (ETS), and the LCPD, and IED. So far, their outcomes, and especially the ones of the ETS, have been relatively contrasted.[ll] However, it is still important to note that they offer a regulatory framework the major European EPCOs have to comply with regarding their activities in Europe, i.e. the considered Groups do not face these types of regulations in all countries where they are active.

Seven of the sixteen EPCOs studied in this report had low carbon technologies accounting for half or more of their total installed capacity worldwide at the end of 2014 (Chart 11 on next page): Verbund and Statkraft both 84% (essentially hydropower), followed by EDF almost 75% (largely nuclear, but also hydro), EDP just above 70% (essentially other renewables and hydropower), Iberdrola just above 60% (renewables and nuclear), Fortum 53% (essentially hydropower and nuclear), and Vattenfall 50% (essentially hydropower and nuclear as well). Among the other Groups: EnBW and CEZ had both 47% of their total installed capacity being low carbon technologies mainly thanks to nuclear, large companies Enel, GDF-Suez/ENGIE, and E.ON between 30 and 45%, notably. RWE and PGE came last with 15-20%.

[ll] The price of European emission allowances has been consistently too low in recent years, notably.

Chart 11: Share of Low Carbon Technologies Installed Capacity in the Group's Total Installed Capacity 2014 (Consolidated)

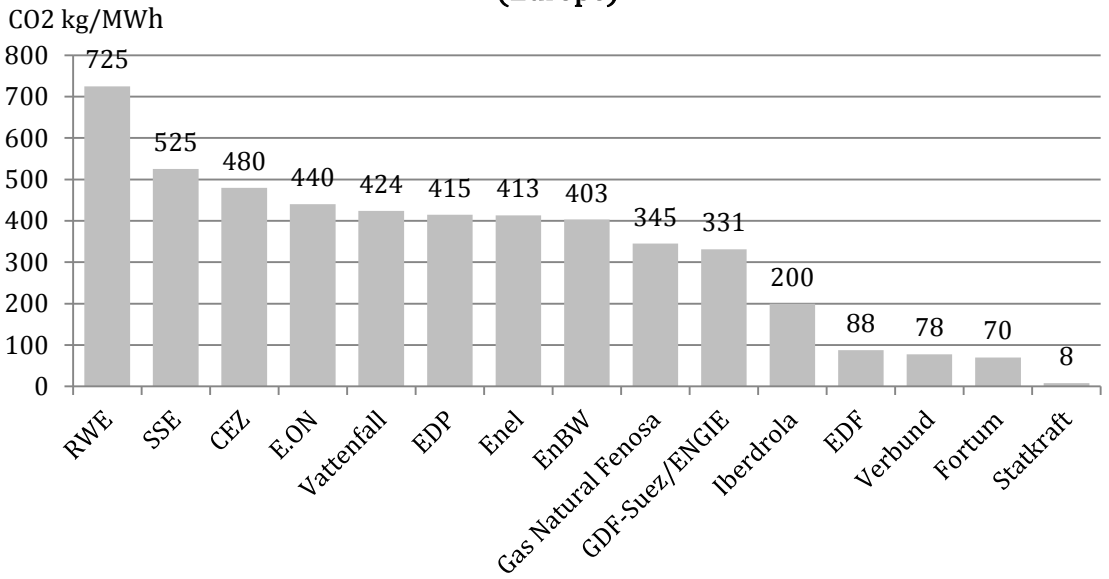


Sources: Groups Annual Reports, and in some cases complementary corporate materials available online.

Unsurprisingly, EPCOs with the largest share of low carbon technologies in their generation portfolio are also the ones with the lowest emissions per unit of energy generated (Chart 12 on next page). Charts 11 and 12 do not provide the exact same picture because Chart 11 takes into account installed capacity worldwide whereas Chart 12 focuses on energy generated in Europe only. The following explanations and Chart 13 (on page 66 – data not available for all Groups) will, however, fill that gap in.[mm]

[mm] Unfortunately, reporting inconsistencies and availability of data do not allow for a clearer and more up-to-date analysis.

Chart 12: Selected Major European EPCOs Carbon Factor 2013 (Europe)



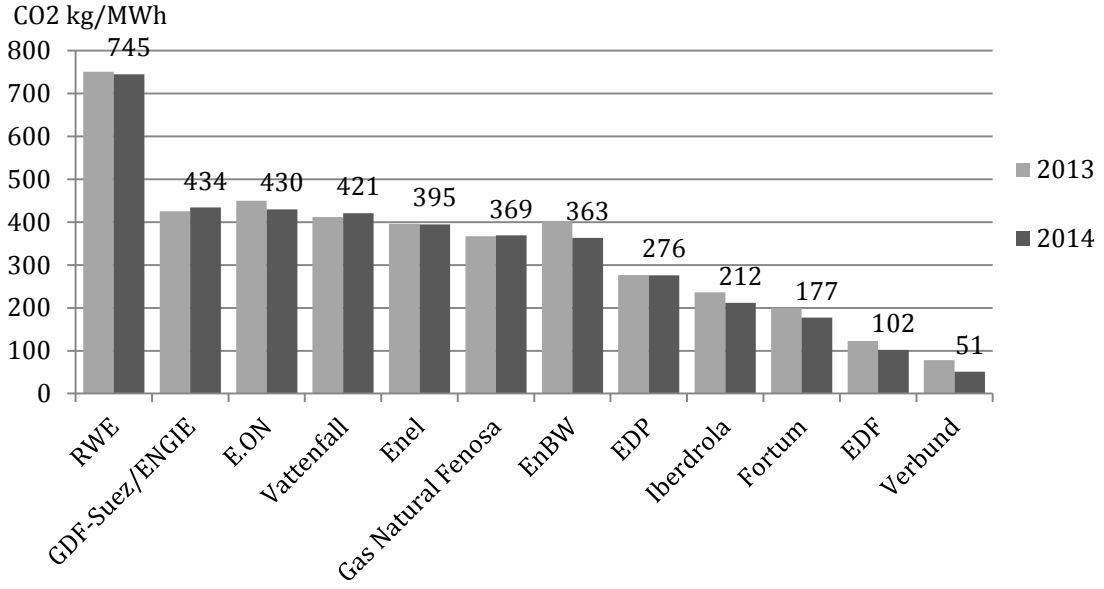
Note: PGE does not appear on this chart because the Group is not included in PWC's report. If it would, it would apparently rank last with a little less than 1,000 CO2 kg/MWh according to PGE's 2014-2020 Strategy.

Source: PricewaterhouseCoopers, Changement Climatique et Electricite

The reason why Fortum ranks 2nd in terms of CO2 emissions per unit of energy in Europe, while ranking only 6th in terms of share of low carbon technologies installed capacity worldwide is because over 30% of the Group's total installed capacity is located in Russia and consists essentially in gas and coal power. When the emissions of these facilities are included, Fortum's CO2 emissions raise to about 200 kg/MWh for 2013 making the Group virtually rank 4-5th in Chart 12.[304] EDP drops from 4th in terms of share of low carbon technologies installed capacity worldwide to 10th in terms of CO2 emissions per unit of energy in Europe because the Group has over 6 GW of renewables installed capacity outside Europe (mainly wind power in the US and hydropower in Brazil), this is 36% of the company's renewables capacity or about a quarter of all its installed capacity. Including the emissions of these facilities EDP's CO2 emissions decrease to about 280 kg/MWh for 2013 making the Group virtually rank 6th in the Chart above.[305] From share of low carbon technologies installed capacity worldwide to CO2 emissions per unit of energy in Europe, GDF-Suez/ENGIE climbs the ladder because the Group has a higher share of low carbon technologies in Europe than it has outside. Worldwide emissions from the Group's generation fleet evaluated in 2013 were 425 kg/MWh in comparison (11th place in Chart 12 virtually).[306] Gas Natural Fenosa's ranking improves from share of low carbon technologies worldwide to CO2 emissions per unit of energy in Europe because the Group is largely relying on gas (over 54% of its installed capacity in Europe are

CCGTs), compared with companies relying more on coal power, Vattenfall notably.[307] Finally, if CEZ slides to the bottom of the ranking in terms of CO2 emissions per unit of energy in Europe while ranking 9th in terms of share of low carbon technologies in total installed capacity worldwide this is because the Group is heavily relying on coal power, which accounts for roughly the other half of its generation portfolio.[308]

Chart 13: Selected Major European EPCOs Carbon Factor 2013-2014 (World)



Sources: Groups Annual Reports, and in some cases complementary corporate materials available online.

Interestingly, all the major European EPCOs considered in this report, but Statkraft which carbon factor is already extremely low, have set themselves some types of – more or less ambitious – GHG emissions reduction targets (Table 3 on pages 67-68). As described in the table below a quite wide range of options exists to meet these goals. All these possibilities neither reduce GHG emissions to the same extent nor have the same cost. Each EPCO thus elaborates its own decarbonisation strategy based on many variables including obviously its existing power plant fleet. While all of the Groups presented in this report are different in many regards (size, generation mix…), they all recognise the expansion of non-hydro renewables as one of the main – and very often the main – options to reduce their carbon footprint. More important they all invest to expand their non-hydro RE portfolio (essentially wind power, but also solar power increasingly). No other option is unanimously pursued. The two other solutions implemented by the major European EPCOs to reduce their GHG emissions are; to

Table 3: Selected Major European EPCOs Strategies to Lower GHG Emissions

GROUP	GHG EMISSIONS REDUCTION TARGET		IMPLEMENTED OR TARGETED ACTIONS TO REDUCE GHG EMISSIONS								
	Goal(s)*	Status 2014**	Expand Renewables		Expand Nuclear	Changes in Fossil Fuels Uses					
			Hydro	Other RE		Reduce coal	More efficient new coal	Coal to gas	Coal-biomass co-firing	Improve efficiency of existing plants	CCS interest
EDF	Keep CO2 specific emissions ≤150 kg/MWh (carbon neutral in Europe by 2050)	102 kg/MWh	■	■	■		■	■		■	■
Enel	Reduce CO2 specific emissions to <380 kg/MWh by 2020 (carbon neutral in Europe by 2050)	395 kg/MWh (618 in 1990)	■	■		■				■	■
GDF-Suez /ENGIE	Reduce CO2 specific emissions to ~400 kg/MWh by 2020 (Electrabel, the Group's Belgian subsidiary, carbon neutral in Europe by 2050)	434 kg/MWh (443 in 2012)	■	■	■			■		■	■
E.ON	Reduce CO2 specific emissions in Europe to 315 kg/MWh by 2025 (carbon neutral in Europe by 2050)	410 kg/MWh (630 in 1990)	■	■			■		■	■	■
RWE	Reduce CO2 specific emissions to 620 kg/MWh by 2020 (carbon neutral in Europe by 2050)	745 kg/MWh (792 in 2012)		■			■		■	■	■
Iberdrola	Reduce CO2 specific emissions to <150 kg/MWh by 2030 (carbon neutral in Europe by 2050)	212 kg/MWh (~300 in 2007)	■	■						■	
Vattenfall	Reduce CO2 emissions to 65 million tonnes by 2020. (carbon neutral in Europe by 2050)	82.3 million tonnes (93.7 in 2010)		■		■	■		■	■	■
EDP	Reduce CO2 specific emissions to 120 kg/MWh by 2020 (carbon neutral in Europe by 2050)	276 kg/MWh	■	■					■	■	
Statkraft	No goal – CO2 specific emissions close to 0 kg/MWh in 2013 (8 kg/MWh) (carbon neutral in Europe by 2050)	N/A	■	■							■

Fortum	Electricity in the EU: CO2 emissions <80 kg/MWh (5-year average), and energy in all countries: CO2 emissions <200 kg/MWh (5-year average) (carbon neutral in Europe by 2050)	60 kg/MWh (EU), and 198 kg/MWh (all countries)									
CEZ	Reduce CO2 emission intensity of energy to 420 kg/MWh by 2025 (carbon neutral in Europe by 2050)	500 kg/MWh			(?)						
Gas Natural Fenosa	Keep specific average CO2 emissions from electricity <390 kg/MWh for the period 2013-2030	368 kg/MWh (average 2013-2014)									
EnBW	Reduce CO2 emission intensity of electricity to <450 kg/MWh by 2020 (carbon neutral in Europe by 2050)	363 kg/MWh									
PGE	Reduce CO2 emission intensity of energy to ~750 kg/MWh by 2030	~985 kg/MWh									
SSE	Reduce CO2 emission intensity of electricity to ~300 kg/MWh by 2020 (carbon neutral in Europe by 2050)	474 kg/MWh (1 April 2013-31 March 2015) (~600 in 2006)									
Verbund	Reduce CO2 specific emissions to <10 kg/MWh by 2020 (carbon neutral in Europe by 2050)	89 kg/MWh									
TOTAL /16	**15 (Statkraft's CO2 emission intensity is already close to 0)**		**11**	**16**	**4**	**6**	**7**	**3**	**7**	**14**	**9**

*Group (global) target unless otherwise noted.
**2014 unless otherwise noted. Between brackets is indicated the baseline year.
(?) According to CEZ's investment program released in May 2015, the Group, which is supporting the initiative to develop new nuclear power plants in Czech Republic, does not expect an increase in nuclear power capacity in the next ten years to reduce its carbon emission factor.
Sources: Groups Annual Reports, and in some cases complementary corporate materials available online.

improve the efficiency of their existing fossil-fuel power plants, which while being necessary does not result in significant emissions reduction, and the expansion of hydropower (renewables expansion again). Compared with the expansion of renewables, the expansion plans for the last low carbon technology, nuclear, seem quite bleak, maybe because it appears more and more clearly that climate change can be fought faster and with much less various uncertainties by investing in renewables. Nuclear power expansion might help tackle climate change but the large majority of the major European EPCOs do not recognise it as a key option. Reducing coal power would be of great help to reduce GHG emissions, however, less than half of the Groups considered in this report (six out of sixteen) are planning to decrease or have decreased their reliance on this technology. That is less than the number of companies replacing old coal-fired power plants by new ones (seven). Interestingly, slightly more Groups are interested in carbon capture and storage (CCS), though this interest does not go further than an experimental stage in almost all cases, than in co-firing biomass with coal. Finally, replacing coal with gas power is the least pursued option, which painfully reveals how far gas power is to compete with coal power without a much higher carbon price.

A brief focus on CCS, which has not been discussed in details so far: the major European EPCOs and especially the largest ones have demonstrated some interest in CCS technology; EDF commissioned a demonstrator in Le Havre, France in 2013.[309] The project, with 25% of its financing provided through a research fund, has now been disabled.[310] In 2009, Enel began a joint work with China Huaneng Group in the field of CCS.[311] In 2011, Italy's top court stopped Enel's key CCS project in Porto Tolle, and due to permitting and legislation issues the final investment decision has been delayed until 2016.[312] GDF-Suez/ENGIE is also leading some research activities to develop CCS.[313] E.ON, which defines CCS as "a vital tool to help tackle climate change," focuses part of its R&D activities on post-combustion capture because it could be suitable for retrofitting onto existing power plants.[314] RWE is also supportive of CCS, and in particular integrated gasification combined cycle (IGCC) with CCS.[315] The Group, however, had to defer its IGCC-CCS project in Hürth, Germany because the project requires that the Carbon Storage Law (KSpG) be passed and that policy-makers promote acceptance of the technology.[316] In 2008, Vattenfall inaugurated the world's first pilot plant for separating CO2 in connection with coal combustion using oxyfuel technology at the Schwarze Pumpe power plant in eastern Germany.[317] However, a lack of political support and acceptance by the general public prompted the Swedish Group to abandon its CCS-projects in 2011.[318] Statkraft is involved in a project which has been delayed in 2009 with no update on when it will start.[319] In addition, EnBW also developed a CCS pilot project in Heilbronn, Germany.[320] And SSE is continuing to work in partnership with Shell UK on a CCS project at SSE's gas-fired power station in Peterhead, Great Britain.[321] The project aims to create the first commercial-scale

application of CCS technology at a gas-fired power station anywhere in the world by capturing up to 1 million tonnes of CO2 annually.[322] In February 2014, the UK government announced that it would fund the next stage in the development of the project.[323]

Until January 2015, three of these nine Groups, three; EDF, RWE, and Vattenfall, were belonging to the Zero Emission Platform (ZEP) which advises the European Commission about CCS technologies.[324] They pulled out of ZEP arguing the technology is too expensive.[325nn] This is symptomatic of a technology, which has accumulated failures at the early stage of its development. While the companies aforementioned are facing difficulties in their CCS activities, they keep communicating more or less their interest in this technology, which does not some seem to be the case anymore of Iberdrola, Fortum, and PGE, which all abandonned CCS projects in recent years.[326] As a result, it is fair to summarise the position of the major European EPCOs towards CCS as follows; a slight decreasing majority of them still believe in the potential of CCS to mitigate climate change, they however all recognise that significant hurdles remain to be cleared in terms of technology economics and maturity, social acceptance, and establishment of enabling legal framework before CCS starts fulfilling its promises. Today, it is clearly not a mainstream solution to tackle climate change as renewables have become.

Other interesting facts regarding the major European EPCOs activities on climate change include: in 2009, almost all of them signed a declaration in which they commit to become carbon neutral in Europe by 2050.[327] In 2014, a very large majority of them supported the initiative "Put a Price on Carbon."[328] In this regard, it is important to note that carbon pricing is gaining momentum, especially with the countdown on to the 21st Conference of Parties, which will be held in Paris at the end of 2015.[329] Currently, carbon pricing instruments cover about 12% of global emissions.[330] Since January 2012, the number of carbon pricing instruments already implemented or scheduled for implementation has almost doubled; from 20 to 38.[331] This year, particularly, a major structural reform in the EU ETS has been approved for implementation starting in 2019, and a proposal to revise the system after 2020 has been put forward, China has announced its plan to launch the world's largest emissions trading program in 2017, creating a carbon market for electric power generation, and Korea has launched an ETS.[332] In addition, some of the major European EPCOs are also proposing visions of future integrated energy systems in which electricity plays a central role in decarbonisation, and in which utilities' activities grow and expand beyond their traditional activities of electricity generators (See Part 2. 3. Electrification of the Transportation Sector and Part 2. 4. Developments in Heating & Cooling).

Finally, below are quotes illustrating the stance of the major European EPCOs on how they plan to reduce their GHG emissions and the importance of a strong price signal to

[nn] Gas Natural Fenosa also quit the the ZEP at the same time.

accelerate the shift of their investments towards clean technologies:

Regarding the Groups' strategies to reduce their GHG emissions;

"[…] the fight against climate change was sub-divided into several issues, corresponding to EDF's levers for action: low-carbon nuclear and hydro mix, development of new renewable energies, energy efficiency of generation and distribution, control of energy demand."

EDF – Annual Financial Report 2014, page 243 –

"Renewable energy is one of Enel's key strategies for reducing CO2 emissions and, at the same time, for making our production portfolio more competitive."

Enel – Annual Report 2014, page 118 –

"*By shifting our electricity production to modern power stations and renewable energy sources, we want to reduce our carbon emissions considerably."*

RWE – Annual Report 2014, page 109 –

"*Reducing Vattenfall's emissions will require that the production portfolio be transformed away from fossil-based energy and towards more renewables-based production."*

Vattenfall – Annual and Sustainability Report 2014, page 35 –

"*[…] gas combined cycles are the most efficient technology for producing electricity based on fossil fuels and with lower associated CO2 emissions, making it one of the best solutions for reducing greenhouse gases."*

Gas Natural Fenosa – Integrated Annual Report 2014, page 81 –

"[…] EnBW believes that increasing the electrification of heating and mobility, in combination with strong incentives for energy conservation, is key to achieving Germany's climate protection goals."

EnBW – Integrated Report 2014, page 45 –

Regarding the need the importance of carbon pricing;

"We support carbon pricing because we believe there is a need to address risks linked to climate change, and we support action to address emissions reductions cost effectively. We are in favor of market-based approaches and emissions trading which allow business the flexibility to reduce when and where it makes the most business sense."

GDF-Suez/ENGIE – 2014 Annual Results Appendices, page 99 –

"Emissions must be reduced cost-efficiently, e.g. through carbon emissions pricing and a functioning carbon market. It is important that the upcoming international climate agreement would enable wide use of the carbon market so that climate change mitigation costs and their impact on energy prices would remain lower than with other climate policy instruments."

Fortum – Annual Report 2014, page 36 –

Part 2. CUSTOMERS' ENERGY OPTIMISATION, ELECTRICAL GRIDS, AND INTEGRATED ENERGY SYSTEMS

Even after the liberalisation of European electricity markets, and the unbundling of their generation, transmission, distribution, and supply activities the major European EPCOs are still quite involved in the networks and retail businesses. Indeed, some of the Groups studied in this report are still active at the transmission level, and all of them are at the distribution and supply levels, usually through subsidiaries.

This means that apart from their conventional generation activity, which is facing tough market conditions in Europe, and apart from investing in renewables, they still have many opportunities in various fields to make profits. And they are definitely eager to take advantages of these possibilities. This may be best illustrated by E.ON's spin off; from 2016 the new E.ON will, in addition of renewables, focus on energy networks and customers solutions, and Uniper (the new independent company resulting from the spin off) on conventional generation, notably.[333oo]

Today, the major European EPCOs are thus particularly interested in providing innovative customers' energy optimisation services to their customers and, when they are allowed to do so, strengthen and expand electric networks as more and more renewables are connected to the grids and the integration of the electricity market is being pursued in Europe or as networks need to be developed to meet growing demand for electricity in emerging economies. In addition, the electrification of the transportation sector also increasingly appears to create new markets to invest in for EPCOs. Finally, some utilities see growth opportunities in H&C networks, and particularly district heating at a time when the efficiency of more integrated energy systems is being pursued.

1. Customers' Energy Optimisation

In light of higher retail electricity prices (including energy and supply costs, as well as network costs and taxes and levies) and the existence of support schemes to adopt clean technologies more and more electricity consumers have been willing to optimise their energy

[oo] In early September 2015, E.ON scrapped German nuclear spin off because of government proposals for legal changes that would make utilities permanently liable for the costs of nuclear waste and plant decommissioning. E.ON's German nuclear operations are now planned to be bundled into an independent unit within E.ON (PreussenElektra). And E.ON's Swedish nuclear operations will be spun off into Uniper as planned (see endnote 333 for references on this recent update).

usages in recent years (see Box 4 for more information about the difference between retail and wholesale electricity prices).[pp][qq] This trend is particularly notable in European countries where customers are always getting more interested in reducing their energy consumption, becoming electricity and/or H&C producers – when they can either make a profit from selling green electricity to the grid (e.g. feed-in tariffs (FITs)…) or saving money from not purchasing electricity from the grid at a higher cost (when retail electricity prices are higher than the cost of own generation, which is more and more frequent as the cost of solar PV continues to decrease while FITs are steadily declining) –, and optimising both their energy consumption and production.

EE and distributed electricity and heating & cooling (DE) production are significant threats to EPCOs' traditional business models since they not only directly decrease electricity demand from their large power plants and the volume of electricity they can sell as suppliers, but also lower the prices of wholesale electricity (law of supply and demand in combination of merit order effect). However, these "threats" also definitely represent great opportunities for EPCOs, if instead of resisting the tide they decide to surf it. Indeed, this new "decentralised" energy system offers multiple opportunities in; energy consulting, design, installation, O&M of EE and DE generation solutions, financing, and system management. The major European utilities have started to understand it and are now increasingly offering various types of solutions to meet the new needs of their customers.

Box 4: Difference Between Retail and Wholesale Electricity Prices

While wholesale electricity prices result from the trade of electricity prior to its supply to the destination grid of the end customer, i.e. the prices of electricity traded at the point of production, retail electricity prices reflect the prices paid by end customers and include the costs of electricity generated, supply, and T&D (roughly 15-50% of retail electricity prices in Europe for households, and 10-60% for industrial customers), as well as taxes and

[pp] Green electricity, independence from the grid may be other motivations, but the stronger driver for the widespread adoption of clean technologies is the economics; either by realising savings or making profits (depending on the type of financial support mechanism, if any).

[qq] "Support schemes to adopt clean technologies" refer to schemes promoting either clean DE production or EE. The later ones are often less referred to though they can also be of great significance. For instance, in the framework of Energy Savings Certificates in France, EDF has an obligation to achieve ESs for customers. This policy driven approach has pushed, and keep pushing, EDF to expand its activities in the field of energy demand optimisation, which are described in Part 2. 1.A. Optimisation of Energy Demand. In 2014, as a part of this programme, EDF notably carried out 14,300 building energy performance improvement operations with regional authorities and corporate customers, and handed out 165,000 financial incentives to residential customers to carry out energy renovation work, in addition to 168,000 incentives for social housing. Since the creation of the programme in 2006, the French Group helped bringing about 1.6 million energy renovations with residential customers and almost 1 million in social housing.

levies (about 5-55% of retail electricity prices in Europe for household customers, and 0-45% for industrial customers).[334]

In the case of Germany, on the one hand wholesale electricity prices are low; about €0.03/kilowatt hour (kWh) in 2014, notably thanks to significant penetration of non-hydro renewables with close to zero marginal costs, on the other hand retail electricity prices are relatively high; €0.30/kWh and €0.15/kWh for household and industrial consumers (second semester of 2014 for both types of consumers), respectively.[335] This is essentially due to higher taxes and levies, partly resulting from the surcharge for subsidising non-hydro RE.[336]

This, however, does not mean that promoting non-hydro renewables, and particularly wind and solar power is costly, but rather that it should be done cost-efficiently with well elaborated energy policies and fine-tuned financial support schemes. The experience in Sweden, where the share of wind and solar power in the country's gross electricity generation has increased from 2% to 7% between 2010 and 2014, and retail electricity prices have decreased for both household and industrial consumers by 4% and 22% (from the first semester of 2010 to the second semester of 2014), respectively, has demonstrated that it is possible.[337]

Lower retail electricity prices may, however, not be in the interest of EPCOs. This issue is to be addressed by policy makers, who have to decide who should benefit from lower retail electricity prices; the very large majority of customers (both residential and industrial) or EPCOs, including the future former ex-monopolies which businesses have been protected for decades? This battle of interests may be particularly interesting in Japan where the ten regional monopolies have historically thrown their weight around to protect their vested interests. A change of energy paradigm may offer audacious and forward-looking Japanese politicians a chance to step in and promote the social welfare optimum.

A. Optimisation of Energy Demand

The Groups considered in this report are more and more offering a relatively wide range of energy consumption optimisation solutions to their customers: residential, commercial and industrial businesses, local authorities…

In this field, three types of services are mainly offered: EE and consumption improvement diagnostics, implementation of equipment optimising energy demand, e.g. more efficient machines/materials/devices and DSM tools, and financing services enabling customers to implement identified solutions.

Among the major European EPCOs at least EDF, GDF-Suez/ENGIE, RWE, Vattenfall, EDP, SSE, and Verbund could have been identified as energy advisory services providers. EDF

offers EE and consumption improvement diagnostics to its customers in all market segments.[338] For residential customers the French Group offers advice concerning different heating systems or insulation solutions and personalised accompaniment on renovation work projects.[339] In 2014, it sold 8,000 "Diagnostic Habitat Bleu Ciel," a product consisting in diagnostics tests conducted in the home by an ES expert, including: a heating assessment, a simulation of potential ESs, recommendations, estimation of work required and advice on financing.[340] For corporate and business customers, EDF advises customers on the reduction of energy expenses by analysing their key uses, such as the production of cold, heat, compressed air and motorisation, and assists them in the implementation of identified solutions for reduction of energy consumption.[341] For instance, in 2014, EDF provided audits and solutions to the Jaguar, Land Rover and Total Groups for their English sites.[342] For communities and social-housing lessors, the Group offers in-depth energy diagnostics to construct personalised EE programmes classifying and prioritising actions for ESs to carry out on their properties.[343] In the home EE value chain GDF-Suez/ENGIE holds positions in energy audits and advice notably.[344] RWE markets its EE expertise to commercial and medium-sized industrial enterprises.[345] Vattenfall offers energy advisory services to business and private customers, EDP to residential, business and large customers.[346] SSE offers EE advice to households, and similar services to commercial, industrial and public sector customers.[347] Verbund offers energy consulting services.[348] And PGE sees energy advisory services as one of its growth directions.[349]

In terms of equipment, the major European EPCOs offer two big types of solutions to optimise EE and consumption: more efficient machines/materials/devices and "smart" tools enabling energy consumption management. A few Groups are present in the first segment aforementioned. The largest growth is probably set to happen in the second segment.

Regarding the implementation of more efficient machines/materials/devices, EDF is assisting its corporate and business customers by delivering, installing, operating and maintaining new efficient equipment.[350] In addition, in 2014, EDF teamed up with the Dutch Group Philips to market 600,000 light-emitting diode (LED) light bulbs at competitive prices (less than €5) in several large retailers in order to encourage and help residential customers renovate their household lighting.[351] The partnership was renewed for 2015 and 2016 and extended to other manufacturers.[352] In 2014, Enel launched the offering of LEDs in Italy to promote the replacement of existing light bulbs in the homes.[353] GDF-Suez/ENGIE designs, installs and maintains energy efficient equipment.[354] The Group notably has 1.4 million maintenance contracts.[355] For residential customers' heat pumps, EDP is providing a more efficient water heating solution, which includes economisers for reducing water consumption.[356] For public buildings, the Portuguese Group is leading initiatives to improve

lighting and cooling systems through the substitution of low EE equipment.[357] And SSE, under the Energy Company Obligation in Britain, which mandates energy suppliers with more than 250,000 customer accounts to install EE measures in customer' homes, had promoted at the end of March 2015 the installation of almost 250,000 EE measures, including loft, cavity and solid wall insulation and boiler replacements.[358]

Regarding the deployment of "smart" (-meters, -thermostats,...) tools enabling energy consumption management the interest of the major European EPCOs is pretty high. In 2014, Enel had already deployed 37 million smart meters.[359] The Italian Group is now targeting to increase this number to 48 million by 2019.[360] Électricité Réseau Distribution France (ERDF) – 100% owned subsidiary of the EDF Group, and France's main distribution system operator (DSO) is now in the deployment phase of its Linky smart meter which will allow an easier consumption control.[361] A target of 35 million meters installed by 2021 (90% deployment rate) is being pursued.[362] This large-scale deployment project represents a €5 billion investment between 2014 and 2021.[363] It follows a successful 300,000-meter scheme conducted in the cities of Lyon and Touraine in 2010 and 2011.[364] According to the deployment of smart meters, EDF will progressively extend its range of electricity supply offers, which notably provide incentives to manage demand and smooth out peak consumption. The EDF Group is also actively deploying smart meters in the UK where energy suppliers are mandated to deliver the government's Smart Metering Programme, which requires all reasonable steps to be taken to deploy smart electricity and gas meters to 100% of residential and small business customers by the end of 2020.[365] Under this programme EDF Energy's supply business will be required to install an estimated 6.2 million meters, including communications hubs and in-home displays, to all of its domestic and small business customers.[366] Still in the UK, SSE will have to install around 9 million smart meters.[367] As of 31 March 2015, the Group had installed over 40,000 smart meters in customers' homes.[368] In the coming year ending 31 March 2016, the Group expects to install a further 210,000 smart meters.[369] At the end of 2014, Iberdrola had completed the installation of 4.2 million smart meters in Spain.[370] In 2014, E.ON conducted its bigger-ever product launch in Sweden, giving away 120,000 smart meters.[371] In the framework of the Inovcity Évora programme extension, EDP installed about 100,000 smart meters in Portugal.[372] And EnBW notably signed an agreement with Landis+Gyr to test smart metering system functionalities.[373]

Apart from these smart meters roll-out activities multiple projects related to the use of smart technologies to optimise energy consumption have also recently taken place or are currently ongoing. For instance, EDF's new subsidiary Dalkia runs seven Energy Savings Centres in France, monitoring the energy consumption of 20,000 Dalkia-managed sites.[374] Using a digital network to collect real-time data it is possible to trigger corrective actions as

soon as anomalies are detected.[375] Another EDF's new subsidiary, Citelum developed a remote lighting management system enabling lighting to be switched on and off and adjusted remotely, and provides data for monitoring energy consumption.[376] Other activities of EDF related to energy consumption control include the launches in 2014 of "Heatsmart" in the UK, a device which studies the behaviour of customers in their home then offers them advice to better manage their heating consumption, and of "Energy Control" in Italy, an energy consumption management system coupled with a discussion forum and a place to submit feedback online (1,000 offers sold), as well as the promotion of energy consumption telemonitoring solutions for business customers, such as the service "Load curve telemonitoring" which allows thousands of customers to graphically visualise their electricity consumption load curves on the Internet.[377] Enel led the "Enel Info+ Isernia" or "*Come Consumo*" (How I Consume) projects, notably, featuring the deployment of devices giving customers information about their energy consumption.[378] The Italian Group is now leading the "Multi-Service Platform" project, which goal is to give customers easy access to energy-consumption information, specifying the various uses, and information as to how to optimise consumption, in addition to receiving other services to help them in the-day-to-day management of the home or office.[379] In 2014, E.ON developed a smart tool that can be operated using a mobile phone application and that empowers customers to reduce their energy consumption.[380] In 2014 also, the German Group expanded its partnership with U.S.-based GreenWave Reality to improve its ability to offer customers secure, individually tailored solutions combining energy management and smart home infrastructure, and became an investor and partner in Leeo, a U.S.-based company that develops and provides smart home solutions consisting of simple and intelligent plug-and-play devices and related data services.[381] And a few months ago, the distributed energy subsidiary of E.ON acquired 25% of U.K.-based Intelligent Maintenance Systems Ltd, giving the EPCO exclusive access to a technology that enables primarily business customers to remotely control terminal devices such as air conditioning and lighting units.[382] RWE is now advancing its "SmartHome" solution; a system for automatically managing domestic consumption by enabling users to control their heating, blinds, lights and household appliances using a computer or mobile device, even when they are not at home.[383] In addition, since 2014 the German Group is selling intelligent thermostats manufactured by its partner Nest in the UK, and on an exclusive basis in the Netherlands and Belgium.[384] In 2014, in cooperation with the organisation Quivicon, led by Deutsche Telecom, Vattenfall launched the "Vattenfall Smart Home" service, which gives customers an opportunity to actively manage their energy use.[385] In 2014 also, the Swedish Group launched the MijnNuon app, which gives customers an overview of their energy consumption, enables them to set savings targets and offers customised tips for EE.[386] EDP offers a system that manages, monitors and measures energy

usage "Re:dy."[387] In recent years, Fortum has introduced new services such as the "Fortum Valpas" or the "Fortum Kotinäyttö" (Home Display), enabling its customers to monitor their energy consumption and optimise their home heating notably.[388] In Czech Republic, CEZ introduced "EnergoManager," a system that seeks opportunities for savings and helps cut down businesses' and industrial plants' costs.[389] Gas Natural Fenosa continues working on several pilot energy management systems in the residential and small and medium-sized enterprises sectors to expand commercial services that help the Group's customers control and reduce their energy consumption.[390] This includes the DC4Cities European project, which aims to optimise energy management at data centres, by notably minimising consumption.[391] Finally, Verbund offers domestic companies the Verbund's "Power Pool" solution; Austria's first virtual large-scale power plant.[392] Initiated in December 2014, the pool combines individual consumption and generation flexibility and markets it on the balancing energy market.[393] By flexibly managing their energy consumption if needed the companies taking part in the pool can achieve reductions in their energy costs and generate additional revenue.[394]

Willingness to invest in measures optimising energy demand may be constrained by access to capital because of relatively important upfront costs. Some of the major European EPCOs have also entered the market of financial services. This is notably the case of EDF through its subsidiary Domofinance, which meets the financing needs of EDF's residential customers and building management companies who wish to integrate energy-efficient solutions into their renovation projects.[395] In 2014, Domofinance granted more than 51,000 loans.[396] GDF-Suez/ENGIE also provides financing of EE works.[397] EDP promotes the funding of EE projects through the savings generated.[398] An approach also shared by EnBW, which offers to finance investments in efficiency enhancement measures through energy cost-savings.[399]

B. Distributed Electricity and Heating & Cooling Production

The major European EPCOs are increasingly offering a wide range of DE production solutions to their customers. This range of solutions includes products such as solar PV (possibly with battery storage) panels, small/medium-scale CHP plants, or heat pumps for examples. And in some cases not only are these technologies available, but also tools to optimise their output.

Among the Groups considered in this report at least EDF, Enel, GDF-Suez/ENGIE, E.ON, RWE, Iberdrola, Vattenfall, EDP, Fortum, CEZ, EnBW, SSE, and Verbund, that is to say a very large majority including all the largest Groups, offer solar PV solutions to their customers today.[400] For instance, EDF Énergies Nouvelles Réparties (EDF ENR), wholly owned by EDF EN,

is an integrated player in decentralised PV solar power generation, involved in the design, build, O&M of rooftop installations.[401] The wholly owned subsidiary EDF ENR Solaire markets and installs PV solar power solutions in France.[402] It has more than 14,000 residential customers and over 700 projects delivered to business customers and local authorities.[403] In 2014, E.ON partnered with Sungevity, a global provider of solar-energy solutions, as the German Group wants to offer the best customer-centric residential solar solutions to its customers.[404] In addition, E.ON is now offering to handle solar projects on behalf of municipal utilities, which wish to offer their retail and commercial customers PV arrays.[405] The Group is offering to set up websites in the design of each utility, handle procurement, all of installation, and follow-ups for the solar arrays in collaboration with tradespeople.[406] RWE's offering also includes PV panels, which the Group's customers can combine with other RWE products such as RWE's "SmartHome" (See Part 2. 1.A. Optimisation of Energy Demand) or battery storage units to create a system for optimising the use of their self-generated solar power.[407] In this regard, RWE already launched its "HomePower Storage" system in 2013, which maximises the usage of decentralised solar PV to cover customers' own needs.[408] Iberdrola has just launched "Smart Solar Iberdrola," an initiative aimed at offering PV solutions for self-consumption to Spain's residential, commercial, and industrial customers (the company will provide services for the installation and maintenance of turnkey PV systems, along with financial packages).[409] Vattenfall offers sales and installation of solar panels.[410] EDP offers solar energy solutions for self-consumption to its residential customers.[411] Fortum offers turnkey solar panel systems to its private and business customers in Finland and Sweden, and buys surplus solar electricity at a market price.[412] And Verbund offers its private customers the "Eco packages" product, which notably combines a PV installation plus storage system enabling households to use their self-generated energy efficiently and cost-effectively.[413]

In terms of small/medium cogeneration plants, Groups including at least EDF, E.ON, RWE, Vattenfall, and CEZ offer solutions to their customers.[414] For instance, in 2014, E.ON's Germany regional unit installed 111 new cogeneration units (more than a doubling compared with 2013 (51 units)), and replaced 10 existing units (against 7 in 2013).[415] Altogether, it added 24 MW of new electric capacity in 2014, up from 18 MW in 2013.[416] RWE offers to plan, build, operate, and finance new CHP systems for large electricity and heat consumers.[417] In addition, in Germany, the Netherlands and Belgium, RWE offers customers with CHP plants the opportunity to actively trade energy using the Group's IT platforms called "RWE WebMarket" and "Powerhouse."[418] This enables them to optimise their production behaviour notably.[419] Finally, RWE is also advancing mini and micro-CHP units applications for households, which are mainly used whenever heat is required to operate radiators or to heat water (independently of demand for demand of electricity).[420] RWE Effizienz developed an

intelligent control technique called "RWE easyOptimize," which enables the operation of generation assets to be brought more in line with peak power consumption by households without trade-offs in heat supply, and to use more of the electricity which households generate themselves.[421] Moreover this tool also makes it possible to pool several micro-CHP units, which when clustered create a virtual power station with a much bigger capacity that can offer self-generated electricity on the market.[422rr] In 2014, in Germany – mainly in Berlin and Hamburg – Vattenfall's venture into decentralised small-scale CHP spurred a growing number of customers to switch from oil-fired heating boilers to gas-fired (CHP) notably.[423] In 2014 also, 24 of the almost 90 CHP units (combined electrical capacity of 52 MW) operated by CEZ's subsidiary CEZ Energo were installed.[424] The Czech Group is now planning to increase its share in the market of small cogeneration plants.[425]

In addition of solar PV (possibly with battery storage) and small/medium-scale CHP plants, the major European EPCOs are also offering solutions around the following distributed energy technologies: heat pumps (at least EDF, Enel, Iberdrola, Gas Natural Fenosa, SSE, and Verbund), solar water heaters (EDF, SSE), small-scale wind turbines (SSE), and woodburners (EDF).

To conclude this section, three quotes have been selected to illustrate the threats that represent customers' energy optimisation solutions for the major European EPCOs, but also the multiple opportunities they offer:

"Although the increasing efforts to enhance energy efficiency in all European energy markets create sales-volume risks for E.ON, they also create new sales opportunities by enlarging the market for energy-service businesses."

E.ON – Annual Report 2014, page 65 –

"Solar energy costs continue to decrease and, in many countries, solar electricity production is already profitable for consumers without any subsidies."

Fortum – Annual Report 2014, page 48 –

[rr] In October 2014, RWE Effizienz and RWE Vertrieb formed a pool initially consisting of 22 micro-CHP units with a total installed electric capacity of 100 kilowatts. RWE sells the electricity on the balancing market and controls plant operation notably.

"[…] we believe that business with households and small commercial enterprises will see entirely new types of customer relationships develop. These relationships will be based on holistic support in all energy-related matters, from consulting to financing to the installation and maintenance of decentralised generation assets and from electricity storage facilities to the unification of several small power producers to form a virtual power plant."

RWE – Annual Report 2014, page 22 –

2. Transformation of the Electrical Grid

When it comes to non-electricity generation related businesses, electrical grid activities is, with the supply of customers' energy optimisation services, the other key business in which the major European EPCOs are quite active in. Electrical grid activities describe here include actions taken both at the T&D levels and exclude smart meters roll-out activities described in Part 2. 1.A. Optimisation of Energy Demand, which are sometimes led as DSO, but not always. As noted in introduction of Part 2. Customers' Energy Optimisation, Electrical Grids, and Integrated Energy Systems, even after liberalisation of electricity markets and the unbundling of their generation, transmission, distribution, and supply activities some European EPCOs have remained active in the transmission business and all of them have in the distribution business usually through subsidiaries. These subsidiaries are independent to ensure transparency and fair operation of markets (including non-discriminatory access to all users).

Beyond the need of maintaining and gradually renewing existing infrastructures the European electrical grid is facing two major transformation challenges today: the integration of always increasing electricity production from variable renewables and the development of new interconnection capacities with neighbouring countries. While the need to expand grids to transport electricity from variable renewable resources that is produced in remote areas to load centres is usually referred to, the need to develop new interconnections capacities is often undermined. Besides ensuring operational safety of the transmission networks these capacities yet critically improve the efficiency of electricity markets by allowing the sale of energy to customers in another country and better pooling of the means of generation at the European level by playing on the time differences of peak loads on either side of borders.

When allowed to, almost all Groups considered in this report are eager to take part in these strengthening and modernisation developments, which can take various forms; from automation and digitalisation to grid connection and expansion. The reason behind this

enthusiasm is because network activities are regulated and thus ensure stable predictable returns for years, which help companies to hedge against future uncertainty and compensate for the decrease in their conventional generation activity earnings.

This subsection essentially deals with the European electrical grid, but not only as some of the major European EPCOs have also demonstrated some appetite to invest in the grid of a number of emerging economies where they can value their experience in planning, designing or operating networks. This is notably the case of Enel in Latin America for example.

Below are some quotes well summarising the position of the major European EPCOs towards electrical grid activities:

> "*The power grid plays a key role in the transformation of the German energy system. The steady increase in electricity from renewable energy sources that depend on the weather and time of day and the rising number of small decentralised generation units present us with huge challenges, but also offer us opportunities for growth.*"

RWE – Annual Report 2014, page 21 –

> "*We will further expand our grid business at all voltage levels [...].*"

EnBW– Integrated Report 2014, page 17 –

> "*[...] well-managed economically-regulated networks provide a relatively stable revenue flow [...].*"

SSE – Annual Report 2015, page 19 –

A. Activities Related to Transmission Networks

Among the Groups considered in this report, EDF, Iberdrola, Gas Natural Fenosa, EnBW, SSE, and Verbund are quite involved in activities related to the transmission of electricity (see Box 1 on page 10 for more information on the different TSO models in Europe).[426ss] Some of them are notably leading projects of great significance, and not always in

[ss] In 2012, RWE sold the majority interest it had in the German electricity ITO Amprion. RWE remains a shareholder (minority shareholder) though.

their domestic market.

For instance, in 2014, Réseau de Transport d'Électricité (RTE), France's ITO, and wholly owned subsidiary of EDF, invested about €1.4 billion, including €1.2 billion for network facilities.[427] This relates to investments in projects such as the construction of direct current (DC) lines that aim to strengthen the interconnection between France and Spain through the East of the Pyrenees, securing power lines and power supply to some regions, as well as restoration work.[428] Regarding the project of new interconnection between France and Spain, its first objective is to double the electricity exchange capacity between the Iberian Peninsula and the rest of Europe from 1,400 MW to 2,800 MW.[429] The project total budget is €700 million.[430] For 2015, RTE's investment programme amounts to €1.5 billion and notably concerns the construction of a DC link between France and Italy passing through the Fréjus safety tunnel and the commissioning of the France-Spain interconnection.[431] Outside Europe, EDF is also active in transmission works in the Middle East where the Group is present through its subsidiary EDF Abu Dhabi.[432] Iberdrola is involved in significant projects in Europe and the US.[433] In the UK, the Group is investing in the transmission network to improve the reliability and quality of supply.[434] In this regards, the "Western Link," a subsea cable linking the networks of Scotland and England, is especially noteworthy.[435] In the US, the Spanish Group is notably making progress with the Maine Power Reliability Programme transmission project (700 kilometres (km) of network, 5 new substations, and 6 expanded substations).[436] In 2014, Gas Natural Fenosa acquired the Chilean Group Compañía General de Electricidad (CGE), a leading utilities company in Latin America, number one in transmission of electricity in Chile notably.[437] EnBW , through its subsidiary TransnetBW (one of Germany's four TSOs), is planning under the projects ULTRANET and SüdLink to massively invest to set up new high-voltage DC (HVDC) transmission lines to make the transport of RE from the north to the south of Germany possible.[438] SSE, through its 100% owned subsidiary Scottish Hydro Electric Transmission (one of the UK's four TSOs), is investing in a number of transmission network projects in the North of Scotland, notably including the Beauly-Denny replacement line and the Caithness-Moray project, which includes a HVDC subsea cable.[439] The Caithness-Moray transmission line represents the largest ever investment by SSE (the Office of Gas and Electricity Markets announced its approval of capital funding of £1.1 billion in December 2014).[440] And in 2014, the majority of Verbund's investments flows into expanding Austria's regulated HV grid.[441] Austrian Power Grid (APG), one of Austria's two ITOs, and subsidiary of Verbund notably invested in grid expansion (including the new Schwarzenbach substation) and in renovation works.[442] APG is now advancing two major line construction projects the 380-kilovolt (kV) Salzburg line and the 380-kV "Germany line" from St. Peter to the Isar River.[443]

B. Activities Related to Distribution Networks

While some of the major European EPCOs are still involved in transmission network activities all of them still are in distribution network activities. And there are a lot of opportunities to exploit for them in this area. When referring to the concept of RE integration transmission networks are often considered as key assets to optimise. They certainly are, but so are also distribution grids since the large majority of decentralised renewables are connected to these grids. In the context of the energy transition the critical role of distribution networks must thus not be undermined. Confronted with technical challenges at this level, the very large majority of the Groups in this report are however eager to take advantage of the opportunities that making smarter distribution grids represents. This can be illustrated by the numerous activities led by the major European EPCOs in that field.

For instance, ERDF, France's main DSO, and wholly owned subsidiary of EDF, is conducting large-scale testing of a number of solutions to provide a deeply modernised distribution network to consumers and companies.[444] This R&D work covers the operation of low- and medium-voltage networks, for instance; the integration of RE and electric vehicles (EVs), storage management, voltage stability.[445] ERDF is notably steering and/or supporting around 15 demonstrators in France and Europe.[446] Priorities of the Group include the automation of distribution networks to optimise the quality of service and reduce operating costs and preparation of the transition to smart grids which will help future local energy balancing (for information about specific smart grid projects of the major European EPCOs see Box 5 on next page).[447] Still regarding EDF, it is also noteworthy to add that the French Group, through EDF International Networks, has recently signed technical support contracts in China concerning the planning and performance improvement of distribution networks in the Shanxi and Shaanxi provinces.[448] Enel sees new smart distribution grids as one of its key growth areas.[449] E.ON, which Sweden unit notably invests in the expansion and upgrade of the distribution network (including new connections), intends to operate technologically advanced smart distribution networks.[450] RWE, which is active in the electricity distribution system business (in Germany, Hungary, and Poland), is planning to invest €2.5 billion in the period from 2015 to 2017 to maintain and expand its German distribution network infrastructure in order to ensure a reliable supply of electricity as renewables keep growing.[451] The German Group is notably working on increasing the efficiency and flexibility of its networks by developing new control technologies and subjecting them to field trials.[452] Iberdrola is not only investing in transmission projects, but also in distribution projects, In Spain notably.[453] Vattenfall owns and operates electricity distribution networks in Sweden and Germany, and despite the sale of electricity distribution operations in Hamburg, Germany in 2014, is aiming for modernising and expanding its existing distribution networks.[454] EDP is leading various

projects in Portugal, Spain, and Brazil to improve distribution grids.[455] CEZ is making preparations for distribution grid operation under the conditions of growing share of DE generation.[456] By acquiring CGE, Gas Natural Fenosa not only took control of Chile's main electricity transmission utility, but also of the country's leading electricity distribution utility.[457] EnBW is advancing its "smart" expansion, retrofitting and upgrading of distribution grids.[458] This will notably include partnerships with municipalities by opening up distribution grids.[459] By 2020, PGE plans to dedicate a quarter of its investments to develop and modernise its distribution networks, about 8 times more than the Polish Group plans to invest in new RE capacity.[460] SSE is also leading different investments in distribution grids (e.g. replacement of cables, installation of new underground and subsea cables,…).[461] At the opposite, few companies have recently divested or are planning to divest from their electricity distribution business. In 2014, GDF-Suez/ENGIE, through its subsidiary Electrabel, and public partners in Flanders signed and executed an agreement to end their collaboration in mixed DSOs notably, with Electrabel selling its stake in the DSOs to the public partners.[462] And in 2014 also, Fortum divested from the electricity distribution business in Finland and Norway, and continued the preparation and assessment of divestment opportunities for Sweden's electricity distribution business.[463]

As a part of their efforts to integrate RE a number of Groups are also starting to deploy BESS, as DSO notably (See Box 6: Implementing New Utility Scale Energy Storage Solutions on next page).

Box 5: Participation in Smart Grid Projects

A smart grid can be defined as an "electrical grid that uses information and communications technology to co-ordinate the needs and capabilities of the generators, grid operators, end-users, and electricity market stakeholders in a system, with the aim of operating all parts as efficiently as possible, minimising costs and environmental impacts, and maximising system reliability, resilience, and stability."[464]

The very large majority of the major European EPCOs are concretely involved in smart grid projects throughout Europe, but not only.

In Europe, the "GRID4EU" programme which started in 2011 is the largest smart grid project to be co-financed by the EU (€25 million, with an overall cost of €54 million).[465] The project is being carried by six European DSOs covering more than 50% of the metered electricity customers in Europe; ERDF, Enel, RWE, Iberdrola, Vattenfall, and CEZ, and aims at

testing the potential of smart grids in areas such as RE integration, EV development, grid automation, energy storage, EE, and load reduction.[466] The six smart grid projects are taking place in France, Italy, Germany, Spain, Sweden, and Czech Republic and will last until January 2016.[467]

Outside the scope of this programme, these Groups are also active in other smart grid related projects, notably: EDF Group is involved in over 10 research programmes on smart grids, in France (e.g. "Smart Electric Lyon") and elsewhere in Europe, to test different protocols, standards, technologies and business models.[468] Enel is leading various smart grid projects in Spain and Latin America, including the "ICONO" project.[469] Iberdrola is advancing several smart grids projects in Europe (Spain and Scotland), but also in America (Brazil and the US), and it now has a smart grid R&D and innovation centre in Qatar.[470] And, Vattenfall has recently concluded the first stage of its "Smart Grid Gotland" project, in which customers are given an opportunity to monitor and steer their energy use to hours of the day in which the electricity price is the lowest.[471]

Other notable smart grid projects from other Groups include: a smart grid in an industrial park to connect facilities that consume energy with those that generate it and those that store it in Toulouse, France designed and installed by Cofely Ineo, a subsidiary of GDF-Suez/ENGIE.[472] EDP's "Inovcity Évora" programme, which has now been extended to 6 other towns in Portugal.[473] The Portuguese Group has also been developing Brazil's largest integrated smart grid project, which began in the city of Aparecida in São Paulo state and was extended to the municipalities of Domingos Martins and Marchal Floriano in 2013.[474] And SSE's "Orkney Smart Grid" project, UK's first smart grid which has started in 2009 and has enabled the connection of renewable generation to the distribution network at a fraction of the cost as would have been made possible by conventional network reinforcement.[475]

The E.ON, Fortum, Gas Natural Fenosa, EnBW, and Verbund Groups, notably, are also leading activities to develop smart grids.

Box 6: Implementing New Utility Scale Energy Storage Solutions

At the end of 2014, the major European EPCOs had certainly over 30 GW of hydroelectric pumped storage capacity.[476] Of these, Enel had 9.6 GW, GDF-Suez/ENGIE at least 4.4 GW, and EDF 4.2 GW (mainland France only), notably.[477] And at least E.ON, RWE, Iberdrola, Vattenfall, CEZ, EnBW, PGE, and Verbund had over 1 GW of pumped storage capacity.[478] Pumped storage was by far the most developed energy storage solutions in the Groups' portfolio. And while this is a mature technology further developments are still taking place

(See Part 1. 1.B. Hydropower). Regarding new energy storage solutions some activities are also being led, very largely limited to BESS. Indeed, few progresses have been made by the Groups studied in this report with regards to other energy storage technologies such as power-to-gas, compressed air energy storage, or flywheels.

In recent years, Enel Distribuzione, Italy's primary DSO and subsidiary of Enel, has demonstrated interest for BESS to ease the integration of variable renewables within its electricity distribution network, in Southern Italy particularly. In 2013, ABB thus announced that it will provide a BESS that can provide 2 MW of power for up 30 minutes to Enel Distribuzione to help integrating variable renewables in Sicily.[479] And in 2014, NEC Corporation commissioned a 2 MWh lithium-ion BESS designed to ease the integration of RE into the DSO's network in Calabria.[480] In addition, still regarding the Italian Group, it is also worth to highlight that EGP has just installed a 1 MW/2 MWh storage system at a 10 MW PV power plant in Catania, Italy, which is the country's first facility to store electricity generated from variable renewables, and that EGP and Tesla finalised, a few months ago, an agreement for the testing of the integration of Tesla's stationary energy storage systems with EGP's solar and wind plants.[481] The collaboration will begin with the selection of an initial pilot site, where a BESS, which has a power output capacity of 1.5 MW and energy storage capacity of 3 MWh, will be installed.[482]

Other BESS related activities of other Groups notably include: the commissioning by Vattenfall and Younicos of a 1 MW battery in Berlin, Germany in 2012.[483] The installation of a large-scale BESS at a large PV farm by Vattenfall and Belectric in Germany as well in 2014.[484] The start of construction work for a 3 MW battery project by Statkraft in Germany in 2015.[485] A partnership between SSE and MHI for a BESS with a maximum power output capacity of 2 MW in Orkney Islands, Scotland.[486] The commissioning of a 1 MW BESS by EDF in Reunion Island, France.[487] The testing of a transportable lithium-ion 0.5 MW BESS by Gas Natural Fenosa and Toshiba in Spain.[488] The upcoming commissioning by RWE of an innovative battery storage facility near the city of Wettringen, Germany in autumn 2015.[489] And the participation of E.ON in a project to plan and build a large-scale modular battery storage system called M5BAT in Aachen, Germany.[490]

3. Electrification of the Transportation Sector

The major European EPCOs are quite supportive of the electrification of the transportation sector, and not only because this would help increase their electricity sales. Indeed, the electrification of the transportation system has much more to offer; on-board

batteries and charging stations as well as all related services to these innovative solutions are new markets with significant growth potential. The Groups studied in this report are definitely willing to help developing these markets and serve them. Below are introduced the various activities they have started to lead in the area of electric mobility.

EDF's offering ranges from consulting services for local authorities and businesses on the positioning and scale of EV charging infrastructure, installation of charging infrastructure for all customers segments (residential, businesses, local authorities, car parks, and supermarkets), and remote management and supervision of charging stations, to small-scale car-sharing solutions in urban areas and rental and maintenance with performance guarantees for batteries for heavy vehicles (electric buses, trucks and river shuttles) based on lithium batteries.[491] In addition, through ELease, 70% owned by Sodetrel (a wholly owned subsidiary of EDF), the French Group has developed a medium-term EV leasing scheme to allow companies and local authorities to use EV without having to buy the vehicle first.[492] EDF has also developed full scale trials with car manufacturers such as Renault, BMW, Toyota…[493] For instance, in Grenoble, France a car-sharing service comprising 70 EVs and 30 charging stations was opened in 2014, as a part of a partnership between the city council, EDF, and Toyota notably.[494] Significant projects of the Group include: a partnership agreement with Vinci Park to provide, install and maintain infrastructure for self-service charging terminals.[495] By the end of 2014, 50% of Vinci car parks in major cities had been fitted out.[496] A project launched in 2014 which will see 200 rapid charging stations installed along major roads and motorways in 2015, and a partnership agreement for testing electric driveline systems, batteries, charging systems and their impact on power grids for the Régie Autonome des Transports Parisiens, which operates 4,500 buses in Paris area and aims to have a 100% green bus network by 2025 (using electric and natural gas buses).[497]

In early 2013, Enel inaugurated the first public charging station for EVs in Bari and in all of southern Italy.[498] The first in a distribution network that will be comprised of 50 Enel charging points.[499] Way more impressive: over the last four years, Enel's Spanish subsidiary Endesa has installed 958 standard charging stations for EVs across Spain, thus tripling the number of facilities installed since 2011.[500] In the meantime Endesa has also installed 37 "charge-and-go" stations, which can charge 80% of an EV battery in 15 minutes.[501] Also noteworthy, Endesa launched the sale initiative "All-in-one Charging Point Solution," a package including a standard charging station, a professional installation service and a three-year warranty, emergency repair service and a breakdown service within three hours priced at €1.85/day.[502] Finally, in 2014, Enel signed a MoU with Hubject under which the parties will work together for the development of an Europe-wide eRoaming platform.[503] Through eRoaming, EV drivers can recharge their vehicles at facilities that are not owned or operated by

the utility of which they are customers.[504] The goal is to enable EV recharging at around 5,000 stations across an area spanning from Sicily to Lapland, with automatic debiting of the charge to customer's ordinary utility bills.[505]

E.ON set up over 100 charging stations all over Europe.[506] The German Group's aim is not to establish its own charging infrastructure so much as to develop practical charging solutions that suit the different needs that customers have.[507] Particularly, E.ON expects that parking space operators (parking lot operators as well as retailers and municipalities which public transport systems include large park and ride parking lots) will also start offering recharging facilities, and it is therefore testing integrated payments for these target groups so that users can pay for parking and recharging costs in one.[508]

In conjunction with German local utilities, RWE is operating today the largest network of public charging stations in Europe with a network comprising some 2,800 charging points (a figure which is on the rise).[509] The Group offers different types of charging stations ranging from charging technology suitable for the mass market and for installation in private garages to public charging networks with load management and roaming.[510] In addition, RWE provides support to customers, such as local utilities, municipalities, car-sharing companies and firms in the management of their charging stations networks.[511] Finally, the German Group is currently actively involved in nine different projects at the same time to foster electricity mobility. These includes the metropol-E project, which supports the city of Dortmund, Germany in its objective of becoming a centre of electric mobility, and the eMERGE project, which notably features the testing of up to 175 EVs in the regions of Rhine-Ruhr and Berlin-Potsdam.[512]

Vattenfall offers comprehensive solutions for building and operating public charging stations with normal charging in the Netherlands and Germany.[513] The Swedish Group also offers simple and smart charging boxes for electric car owners, businesses and tenant-owner associations interested in offering EV charging to employees, tenants and visitors.[514] At the end of 2014, Vattenfall operated more than 1,000 public EV charging stations, mainly in Amsterdam, Berlin and Hamburg.[515] The Group had also installed several thousand charging boxes at homes and workplaces.[516] In 2014, Vattenfall established its first fast charging stations for EVs.[517] At the end of the year the Group had installed seven fast charging stations in Sweden (Stockholm and Uppsala) and two in Germany (in the framework of the Schnell-Laden Berlin project).[518] At these stations, an EV battery can be charged from 0% to 80% in 20-30 minutes.[519] In addition, Vattenfall is currently participating in a project to establish an electric bus route in central Stockholm.[520] Eight plug-in hybrid buses will be put in service in the country's capital's mass transit system.[521] Finally, the Group is also participating in electric car R&D projects.[522] In partnership with BMW, Vattenfall is notably

studying methods to reuse batteries from EVs in electricity networks in which a large share of wind and solar energy is fed in.[523]

EDP is also active in the electric mobility market. The Portuguese Group notably offers installation of home charging point from €750 plus value added tax (payment in installments on the energy invoice during one year).[524] The charging time is between 2 and 8 hours, depending on the characteristics of domestic electrical installation and EV.[525] Other services include technical visit to advice customers what is the most appropriate charger for each case.[526] Also noteworthy, EDP created a launch offer for its customers who purchase an EV from of the Group's partners (notably including Mitsubishi, Nissan and Toyota) and sign-up for a specific tariff: 1 year of free electricity (this offer has a maximum value of €400 for a maximum period of 1 year and is valid for the first 500 clients of specific tariffs who buy their EV with 2015 plates from one of the Group's partners in electric mobility).[527]

Verbund, through the electric mobility provider SMATRICS (founded in 2012 together with Siemens) has been operating 170 charging stations in Austria since mid-2014.[528] In addition, the Group coordinates the Central European Green Corridors project, which acts to speed up implementation of the charging infrastructure.[529] By the end of 2015, 115 quick charging stations will be set up in Central Europe (Austria, Croatia, Germany, Slovakia and Slovenia) as part of the project.[530] Nissan is one of the partners of this project notably.[531] Finally, Verbund is also working together with Green eMotion, Europe's largest R&D project for electricity mobility which is notably focusing on standardisation.[532]

Fortum has some 50 charging stations in Finland, 90 in Sweden, and almost 200 in Norway.[533] Of these more than 100 are fast charging stations.[534] At the end of 2014, CEZ had installed 39 charging stations for EVs, including 5 fast charging stations.[535] And the Czech Group recently added 2 more fast charging stations to its portfolio.[536] In early October 2015, over 300 charging points operated by EnBW were referenced by the website ChargeMap.com.[537] SSE has recently installed a number of different charging stations in the Isle of Wight, England and offers to use those for about £4-6 per charge (depending on the type of stations) and free parking.[538]

Finally, all the other Groups; GDF-Suez/ENGIE, Iberdrola, Statkraft, Gas Natural Fenosa, and PGE, have also demonstrated some interest in participating in the electrification of the transportation sector.

4. Developments in Heating & Cooling

The last area in which the major European EPCOs are demonstrating some interest for further developments is the H&C sector, especially at the district level. While transformational changes are not really advancing at full speed, projects of some significance are still being led by some of the Groups studied in this report.

For EDF's subsidiary Dalkia, the increase in district H&C networks is a growth engine and a major factor in its development.[539] Dalkia is one of Europe's leading operators in the management of district H&C networks.[540] It notably operates 328 district and local H&C networks providing heating, hot water, and air conditioning to a wide range of public and private buildings (schools, medical facilities, offices and apartment buildings) in France.[541] In 2014, Dalkia's wood-fired heating plant for the Greater Dijon, France district heating network (3*30 MW) was inaugurated.[542] The facility's three biomass boilers will consume 50,000 tonnes of wood per year, mostly sourced from the local region.[543] The heating network will at the end cover a distance of 30 km.[544] And in 2014 also, Dalkia notably commenced drilling operations for a geothermal heating network in Bagneux a city located in Paris area.[545] This is only one of Dalkia's projects linking geothermal and district heating in Paris area; others have also taken place in Issy-les-Moulineaux and Créteil notably.[546]

GDF-Suez/ENGIE, which has strong positions in Germany, Switzerland, Austria, Spain, and the UK in heating networks, is also active in Paris area where it will notably construct and operate a new geothermal heating network for the cities of Rosny-sous-Bois and Noisy-le-Sec.[547] Still in France, but outside of Paris area, the Group also signed a contract with the city of Pont-à-Mousson to build and operate an urban heating network mainly fuelled by biogas.[548]

Vattenfall is a leading player in district heating in Germany and one of the foremost in Sweden and the Netherlands. The Group's district heating networks in these three countries span some 5,500 km.[549]

At the end of 2014, Statkraft had 760 MW consolidated of district heating capacity from 29 plants in Norway and Sweden.[550] In Norway in 2014, Statkraft started operations of a new district heating plant (23 MW) in Sandefjord, started constructing a district heating plant and grid in Moss/Rygge, and also decided to continue developing the district heating system in Namsos.[551] Within district heating, the Group is seeking to continue to develop the profitability of its existing portfolio and generate organic growth in connection with existing plants in Norway and Sweden.[552]

At the end of 2014, Fortum had district heat networks in Finland, Poland, the Baltic countries and Russia.[553] The Finnish Group is continuously developing district heat solutions

in all the countries where it produces and sells heat.[554] For instance, Fortum has advanced the open district heat network solution, a new solution that enables buildings producing heat to sell their surplus heat to the Group's district heat network at a market price.[555] In Finland, two information technology (IT)-sector data centres and the Espoo hospital under construction have made an agreement with Fortum to sell surplus electricity to the open district heat network.[556] Towards the end of 2014, the Group also launched an open district heat network in Sweden.[557] In addition, in Chelyabinsk, Russia, the district heat networks of Fortum's CHP-I and CHP-II power plants were integrated to notably optimise power plant operations.[558]

Finally, CEZ is aiming at operating and developing promising district heating systems, and SSE to expand its district heating schemes in the UK.[559]

CONCLUSION

If the Japanese government becomes really serious about advancing a transparent, efficient, and fair electricity market and aggressively promoting RE for the sake of the country's economy and social welfare, the Japanese EPCOs will be well inspired to learn from their European peers' experiences in terms of energy transition in liberalised electricity markets.

Doing so they will learn that energy transition in a context of electricity system reform definitely represents both threats and opportunities to their business. They will learn that fighting will only result in defeats, and that business as usual is no option to remain profitable, i.e. it could only lead to the infamous "utility death spiral." They will also learn that being innovative, daring, and adapting to the new reality is not only a prerequisite to survive, but also the right path to profits.

Besides expanding internationally, not by exporting "clean coal" technologies, which might be an increasingly risky business, four key areas of growth exist for the Japanese EPCOs in their domestic market:

At the electricity generation level, (1) when it comes to new capacity: invest in renewables with close to zero marginal cost, and avoid all investment in new fossil fuel and nuclear power capacity unless a critical need for these types of plants arises. At first sight, and particularly in a context of stagnating or decreasing electricity demand, investing in new renewables capacity may look like cutting the branch the Japanese EPCOs are sitting on since these facilities will reduce the margins of their existing conventional power plants. However, if they not do so it will leave more space for new entrants to invest in new renewables capacity displacing even more the power plants of the Japanese EPCOs in the merit order. In addition, Japan has demonstrated in the years following Fukushima nuclear accident that it already has enough capacity to meet its electricity needs at all times. With continuous expansion of renewables and further EE gains investing in new conventional capacity will just be like throwing money out the window. Growth in both renewables and conventional capacity is not needed, will only result in overcapacity and must therefore not be pursued. A conservative mind may, however, raise the question "but why should new capacity necessarily be renewables?" The answer lies in the economics, trends are crystal clear; renewables costs have come down dramatically and keep decreasing, conventional power plants ones increasing. As a result, current plans to significantly expand coal-fired power plants in Japan should thus be abandonned. (2) When it comes to existing capacity: invest in efficiency, flexibility, and technologies to reduce GHG emissions (in the case of fossil fuel-fired power stations).

Conventional power plants will remain in Japan's electricity generation mix for decades, and they have valuable capabilities to offer to the country's future electricity system, these investments for upgrades will on the one hand increase their costs, but on the other hand also increase the added value of the services they can provide, which they will be able to showcase and get rewarded for by responding to market signals. Implementing these recommendations is the only solution to keep the generation business segment of the Japanese EPCOs relatively healthy.

Customers' energy optimisation services is the second growth area. EE, DSM, DE production solutions constitute multiple opportunities in various ways for Japanese EPCOs as it does for their European peers. And Japanese customers may increasingly be willing to reduce their increasing electricity bills by taking control of their energy uses, especially since solar PV has recently reached socket parity.[560] Why not being the ones meeting their expectations?

Electrical networks; integrating variable renewables and DE solutions into the grid presents opportunities at both T&D levels. These opportunities will notably depend on how business activities of the Japanese EPCOs will be unbundled. What can be said today, is that even if large-scale transmission lines expansion projects are often referred to when it comes to help transporting electricity generated from utility scale wind and solar power plants located in remote areas far away from load centres, distribution networks are certainly as much important if not more. Most decentralised renewables are actually connected to the distribution grids and it is likely that large-scale transmission lines expansion projects will face social acceptance challenges. A special attention should thus be brought to distribution grids.

Finally, the development of more integrated energy systems through the electrification of the transportation sector and the construction of district H&C networks also offer business growth opportunities. Particularly, the electrification of the transportation sector is very intriguing and has big potential. Not only will it help increasing the electricity sales of the Japanese EPCOs, but also create new various markets ranging from infrastructures to customers services and system management expertise. Japan has a powerful car industry, already quite involved in electric mobility (Honda, Mitsubishi, Nissan, Toyota…). Partnerships between Japanese EPCOs and automobile manufacturers may be very promising.

Hence Japanese EPCOs have more to lose than to win not embracing the energy transition. There is no fatality in this paradigm shift. Losers will only be the ones who keep resisting the inevitable. Others, if they demonstrate adaptive skills will not extinct like dinosaurs. EDF, Enel, GDF-Suez/ENGIE, E.ON, RWE, and Vattenfall – that is to say all the largest European EPCOs, with the exception of Iberdrola, which is already a leader in non-hydro renewables – have well understood that business as usual was no longer an option and have

started to react more or less aggressively. The most striking examples of business approach changes are certainly; E.ON's spinoff, EDF's goal to double the Group's renewable energy capacity in Europe to over 50 GW by 2030, GDF-Suez/ENGIE's announcement that it will not invest in new coal projects anymore, Enel's plan to decrease its fossil fuel power plant portfolio by 13 GW by 2019, and Vattenfall's decision to divest its entire lignite operation in Germany.

It is now only up to the Japanese EPCOs to decide their path, and they will have no excuse to not chose the right one since their European peers start to draw the way for them.

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LIST OF ABBREVIATIONS

APG: Austrian Power Grid
ASN: Autorité de Sûreté Nucléaire
BESS: battery energy storage system
BEWAG: Berliner Städtische Elektrizitätswerke Aktiengesellschaft
CCGT: combined-cycle gas turbine
CCS: carbon capture and storage
CEZ: České Energetické Závody
CfD: contract for difference
CGE: Compañía General de Electricidad
CGN: China General Nuclear Power Group
CHP: combined heat and power
CO2: carbon dioxide
CSP: concentrating solar thermal power
DC: direct current
DE: distributed electricity and heating & cooling
DSM: demand side management
DSO: distribution system operator
EDF: Électricité de France
EDF EN: EDF Énergies Nouvelles
EDF ENR: EDF EN Réparties
EDP: Energias de Portugal
EDPR: EDP Renováveis
EE: energy efficiency
EGP: Enel Green Power
EnBW: Energie Baden-Württemberg
EPCO: electric power company
EPR: European pressurised reactor
ERDF: Électricité Réseau Distribution France
ES: energy saving
ETS: emissions trading system
EU: European Union
EV: electric vehicle
FIT: feed-in tariff
GDF: Gaz de France
GHG: greenhouse gases
GW: gigawatt
H&C: heating & cooling
HDVC: high-voltage direct current
HEW: Hamburgische Elektrizitätswerke
HPC: Hinkley Point C
IEA: International Energy Agency
IED: Industrial Emissions Directive
IFRS: international financial reporting standards
IGCC: integrated gasification combined cycle
IRSN: Institut de Radioprotection et de Sûreté Nucléaire
ISO: independent system operator
IT: information technology
ITO: independent transmission operator
km: kilometre
kV: kilovolt
kWh: kilowatt hour
LAUBAG: Lausitzer Braunkohle Aktiengesellschaft
LCPD: Large Combustion Plants Directive
LED: light-emitting diode
LNG: liquefied natural gas
MBtu: million British thermal units
MHI: Mitsubishi Heavy Industries
MoU: memorandum of understanding
MOX: mixed oxide fuel
MS: Member States
MW: megawatt
MWh: megawatt hour
NNB: NNB Development Company
O&M: operations and maintenance
OU: ownership unbundling
PGE: Polska Grupa Energetyczna
PV: photovoltaic
RE: renewable energy
RTE: Réseau de Transport d'Électricité
RWE: Rheinisch-Westfälisches Elektrizitätswerk
SSE: Scottish and Southern Energy
T&D: transmission and distribution
TSO: transmission system operator
UK: United Kingdom
US: United States
VEAG: Vereinigte Energiewerke Aktiengesellschaft
VEBA: Vereinigte Elektrizitäts- und Bergwerks- Aktiengesellschaft
VIAG: Vereinigte Industrie-Unternehmungen Aktiengesellschaft

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