Cleantech – Is it feasible to bridge the gap of Europe's renewable ambitions?

Point of View by Oskar Almén and Alain Chardon

A European focus on sustainability

The announced targets for increased use of renewable energy in Europe spurs a number of obvious questions for each of the member states in general, and more specifically for the power industry, surrounding the issue of bridging the gap for cleantech[1] capacity. Primarily, the issues include technical feasibility, operational cost, and return on investment. Additionally, issues like competitiveness and reliability of supply need to be addressed, as currently there is a tighter peak capacity margin in Europe. A third issue is the "Guarantee of Origin" (GO). This concerns the function of providing proof that a given quantity of energy was actually produced from a renewable source.

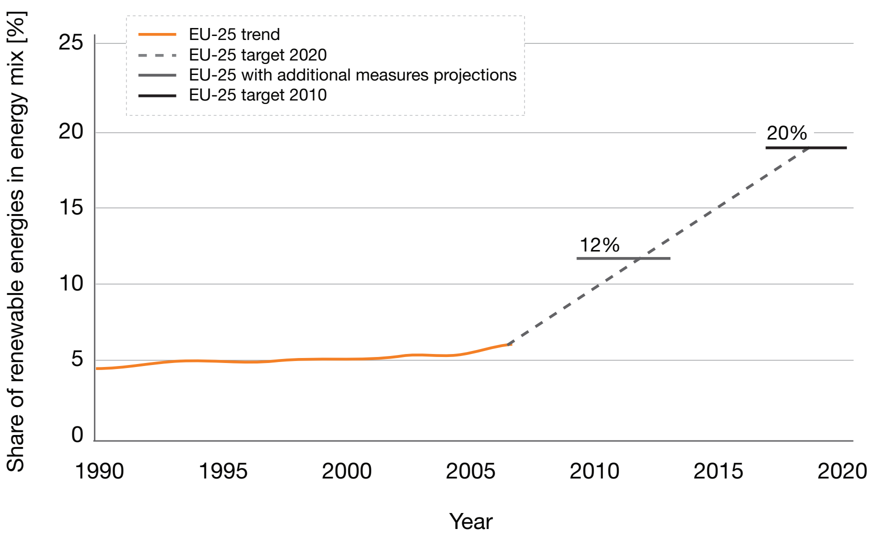
We believe that these questions have not been satisfactorily addressed in the general debate and by European politicians, despite ambitious targets being set for investments. In line with the European Renewable Energy Council, it is our point of view that setting an ambitious target does not automatically deliver the results—although we do agree it is an important start. Hence, we question the feasibility of a mass investment into renewable technologies at a time when bottlenecks are already visible in several parts of the value chain. Further, support mechanisms differ greatly between countries and technologies, causing confusion for private investors and utilities interested in this market. Therefore, with a greater understanding of these variables, we believe that investors will feel more at ease to get involved and committed to reaching the ambitious goal of ensuring that 20% of all energy consumed by 2020 is renewable.

Strong impact on the generation mix

The ambition suggested by the EU includes all forms of energy. We predict, however, that a large share of the announced target will fall on electricity and heat production. Already today a large share of Europe's generated electricity comes from non-carbon sources, and a majority of that is hydro or nuclear power. In fact, with the current kWh price, there is

Figure 1: Target for the 2020 renewable ambition (+20% in the energy mix)

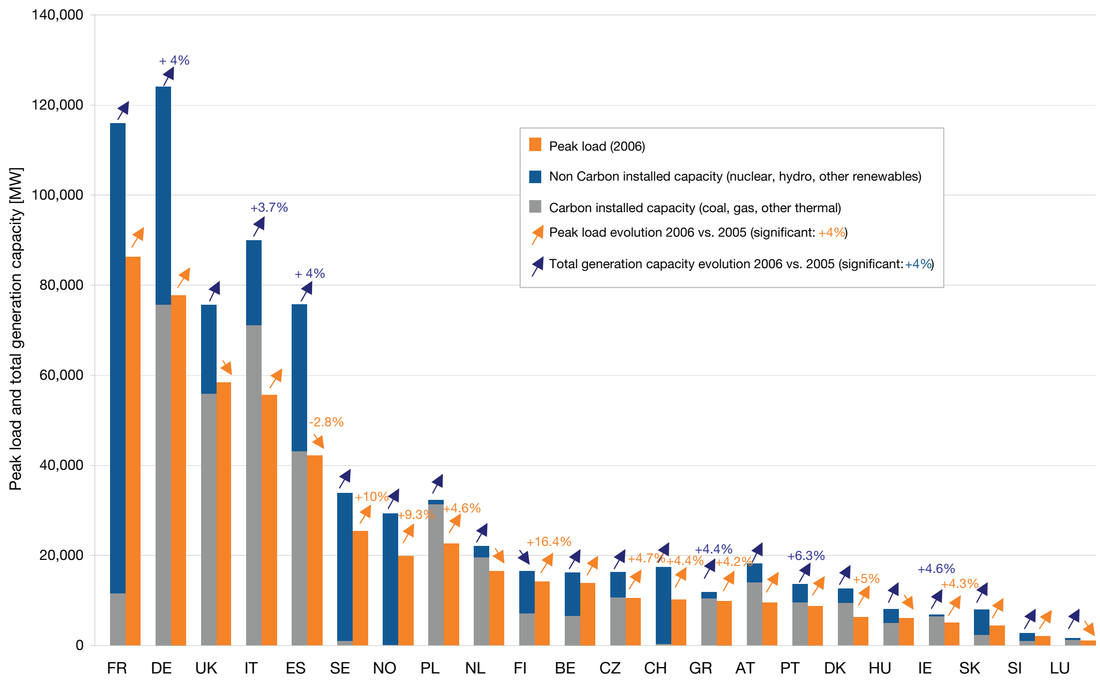
	Share Renewables in the final energy demand by 2020
AT	34%
BE	13%
BG	16%
CY	13%
CZ	13%
DK	30%
EE	25%
FI	38%
FR	23%
DE	18%
EL	18%
HU	13%
IE	16%
IT	17%
LV	42%
LT	23%
LU	11%
MT	10%
NL	14%
PL	15%
PT	31%
RO	24%
SK	14%
SI	25%
ES	20%
SE	49%
UK	15%



Source: European Commission, Capgemini Analysis

[1] There is no one single definition for cleantech. Common to all definitions regarding electricity generation, is that it is a means to create electricity with a limited environmental footprint. The notion of renewable sources and cleantech is generally used simultaneously.

Figure 2: Generation capacity and electricity mix (2006)

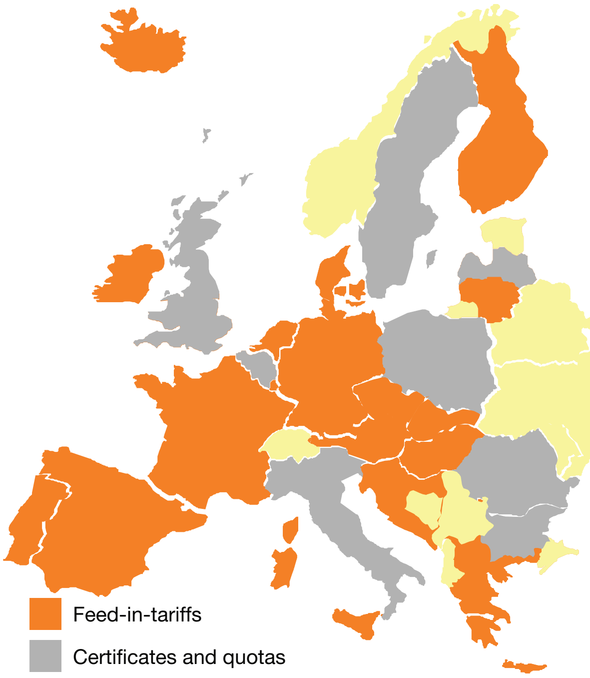


Sources: UCTE, Nordel, EirGrid, National Grid—Capgemini EEM09

limited potential left for an additional cost efficient extension of hydro power. This already existing high share of hydro power, in combination with a strong local opposition against further exploitation of rivers and the areas they run through, makes hydro a marginal source of the future additional capacity. The effort will hence need to primarily be on developing and expanding other clean technologies for power production in order to reach the targets. Inevitably, this means that a large share of the growth of renewable energy will focus on non-base load capacity, and capacity that is off the main grid. Further, these technologies and energy sources will have to compete with existing sources for where substantial infrastructure investments have already been made, making them relatively cheap in comparison today.

Considering the factors mentioned above, we believe that the increase of electricity from renewable sources will be a challenging target to meet, as the investment in this area is not clear at present. It will be both an economical and technological challenge to generate large scale cost efficient energy. Having said that, there is also a big potential in several of the technologies, and with the right incentives from governments, the ambitions could become reality. The aim of this publication is to address these issues and explore the feasibility of a large scale shift into cleantech electricity and heat generating capacity. Our focus in this discussion, surrounding cleantech capacity, comprises renewable energy sources including wind, hydro, solar, and biomass/biogas.

Figure 3: A comparison of mechanisms to support the development of renewable energies



	Description of mechanism	Benefits and Concerns
Feed-in-tariffs (FIT)	▪ RES producers are paid a fixed tariff guaranteed by the government. ▪ FIT suggests a shift to a small scale way of doing things (local grids, local generation, local suppliers and manufacturers) ▪ A variant of the FIT scheme is the fixed-premium mechanism currently implemented in Denmark and partially in Spain. Under this system, the government sets a fixed premium or an environmental bonus, paid above the normal or spot electricity price to RES generators.	▪ Feed-in tariffs have the advantages of investment security, the possibility of fine tuning and the promotion of mid- and long-term technologies. ▪ Political risk when uncertain cost is transferred to customers
Certificates (tradable) and quotas	▪ Electricity produced by RES is sold at conventional power-market prices, but the quota for this is set by the government. ▪ Consumers (or suppliers) are obliged to purchase a certain number of green certificates from producers according to a fixed percentage of their total electricity consumption (supply). There are penalties for non-compliance.	▪ Market based system ▪ Green certificates pose a higher risk for investors and make it less attractive to invest in developing high cost technologies with long term perspective ▪ Favours the incumbent utilities

Source: European Commission, European Renewable Energies Federation, Capgemini Analysis

Artificial investment climate

Almost €100bn was invested in renewable energy in the world in 2007 (+ 21% compared to 2006)[2]. The mandatory trade in carbon credits had reached €45bn ($60bn) in 2007, which is three times more than the previous year.

The level of investments indicates that overall it has been financially quite appealing to invest. This is primarily true in geographies where favorable subsidies and incentive mechanisms exist; however, it is our point of view—framed after developing an overview of the European power production situation—that this statement is not befitting to all countries and technologies. Further, so far the scale of investment into renewable energies (not including hydro) has been rather small compared to what is required in future to reach the set targets.

Already we can see major differences in attitudes and action. One example is the UK, where, despite announcements about enthusiastic ambitions to increase the share of electricity generated by renewable sources, only 270 households were awarded grants to help meet the cost of installing solar photovoltaic systems in 2007. This can be compared with 130,000 grants awarded in Germany.

[2] Worldwatch Institute, "State of the World 2008: Innovation for a Sustainable Economy"

Which technologies could bridge the gap?

The industry and the general public have been discussing alternative energy sources for quite some time; however, there are reasons why non-traditional sources have not yet become a significant share in electricity production. The cost of renewable energy has been falling steadily for the last 20 years, but remains higher than that of conventional energy sources. The average additional cost of meeting the announced targets is estimated at between €10 billion and €18 billion per year, depending on energy prices and research efforts made[3].

Both wind and solar power are by definition uncertain sources of energy, as we cannot predict and control the weather in the long run. For example, only 25% of the total hours in a year have favorable conditions to generate wind power. Further, solar power is—to a large extent—a decentralized source of energy (wind to some degree). This enables customers to save transmission and distribution costs (roughly 2/3 of the final electricity price). However, the uncertainty and detachment from the grid creates difficulties for the operation and balancing of the complete electrical grid. As a consequence, there is a necessity to build reserve energy sources to be used when there is no output from wind farms and solar cells. Usually, operators are forced to have CO_2 emitting reserve sources! Hence the power is not entirely CO_2 free.

Moreover, there are currently bottlenecks in the production of needed equipment, due to the high demand and limited number of suppliers of technology[4]. This increases the cost for potential new projects and the cost to maintain existing ones.

Hydro power

Conventional hydro power is a mature technology (wave and tidal technologies are still in a developmental stage). Norway, France, Sweden and Italy have the largest total installed capacity in MW. There is an estimated additional 300 TWh/year of economically viable hydro power still not in use in Europe. However, growth of the total capacity, which is economically beneficial, is limited in Western Europe and there is major environmental opposition to use the few remaining untouched rivers[5].

Hydro has low volatility of power output and high initial investment costs. From an economic point of view, the most promising option is upgrading or refurbishing existing plants; however, the span of cost for refurbishment is wide (800-3600 €/kW). Equipment with improved performance can be retrofitted, often to accommodate market demands for more flexible, peaking modes of operation. The investment cost (and cost span) for small (900-6050 €/kW) versus large hydro (1450-5950 €/kW) is fairly similar and the level depends to a great extent on the physical conditions on site. Most hydro equipment in operation today will need to be modernized before 2030.

[3] A Renewable Energy Roadmap: paving the way towards a 20% share of renewables in the EU's energy mix by 2020
[4] One indication is the results made by VESTAS in 2007.
[5] The Water Framework Directive 2000/60/EC

Additionally, hydro development is driven by the increasing need for water management. Multi-purpose hydro reservoirs can bring security of water supply as well as power.

Current and future R&D priorities are on allowing manufacturers to propose simple, reliable and efficient turbines with guaranteed performances covering the high cost of development.

Leading markets and where to invest in hydro

Norway, France, Italy and Sweden are mature markets. These markets have the largest current shares of the total capacity in Europe. There is, however, limited economically beneficial expansion potential, and currently the focus lies on updating existing facilities. In addition to updates, development of wave and tidal technologies has started, and France has one installation for tidal energy in commercial operation. This is an area where mature hydro countries may be going in the near future. The main current concern is the cost of maintenance of the equipment, which has a big impact on the total cost.

Central and Eastern Europe are the hot markets to pursue. Only one-third of Bulgaria's technically feasible water potential has been developed so far. Many of the existing plants are over 30 years of age and are in need of rehabilitation. The forecast for 2015 is a total capacity of 2,850 MW. This means a 10 TWh annual potential by 2020 (including small, medium and large plants), investments which are highly encouraged by the Bulgarian government.

Development of hydro power is further encouraged in Romania. Romania has an installed capacity of 5,964 MW (29.2% of generation capacity) and the build out is forecasted to be 7,044 MW in 2015. Currently the total annual generation is 19.5 TWh (2006).

Figure 4: Large hydro characteristics (LHP > 10MW)

Typical plant size (MW)	Investment costs (€/kW)	Operation & Maintenance costs (€/KWh)	Lifetime (years)
>250	850–3,650	35	50
75	1,125–4,875		
20	1,450–5,950		
Upgrading	800–3,600		

Source: OPTRES, European Renewable Energies Federation, Frost and Sullivan, Capgemini Analysis

Figure 5: Small hydro characteristics (SHP < 10MW)

Typical plant size	Investment costs (€/kW)	Operation & Maintenance costs (€/KWh)	Lifetime (years)
9,5	800–1,600	40	50
2	1,275–5,025		
0,25	1,550–6,050		
<0,25	900–3,700		

Source: OPTRES, European Renewable Energies Federation, Frost and Sullivan, Capgemini Analysis

Wind power

Wind power is a standardized and proven power conversion technology with an incremental mid-term potential. Most machines start to generate at a similar speed—around 3 to 5 m/s—and shut down in very high winds, generally around 20 to 25 m/s. Energy yields do not increase with the cube of the wind speed, mainly because energy is discarded once the rated wind speed is reached. For that sake, it does not make economic sense to build turbines with very high ratings that will only be reached on rare occasions.

Technological solutions differ in detail by manufacturer, but in general, the overall concepts are proven and well established. The various components are standardized and manufacturing is characterized by increasing competition. The typical turbine size grew rapidly during the 1980s and 1990s. Currently, the average size of typical on-shore turbines is around 2 MW, with even 5 MW being installed. Off-shore, the development is for larger scale and already Enercon and REpower are testing 6 MW turbines. We predict that the 10 MW turbine will be ready for full-scale tests by 2010.

So far, the focus has been on onshore wind farms (55.5 GW of total 56.6 GW wind capacity in EU-27). As markets are getting mature, offshore development is considered. Strong steady coastal winds, as well as bigger mills will ensure higher and steadier production of electricity. On the other hand, deep waters, grid connection and distance from the coast will require higher investments and top technological skills from developers. Currently, the cost is typically 50-100% higher for offshore capacity compared to onshore; however, over the coming 10-15 years this spread is forecasted to shrink substantially. The major difference at present is the cost of grid connection, as attempts are made to locate the fields further out to sea—for example the deepwater Moray Firth project in Scotland which is 25 km offshore.

The costs of turbines represent 50-70% of the total investment cost of an onshore wind farm, making it the crucial part of an investment (and a bottleneck). The global equipment market is highly concentrated and dominated by a handful of companies, including the world leader Vestas. Additional new players are entering this booming industry, albeit with a limited market share (notably Asian companies). However, since a wind turbine contains more than 8,000 components, it is a highly complex structure, making the ramp up time for a new player quite long.

The growing demand brings about higher prices and ever longer delays to get wind farms running. Currently, there is an estimated 24-36 months ordering backlog for turbines, which is expected to last until the year 2011. Due to that, utilities are diversifying and investing vertically to cope with future demand. Iberdrola's approach to this challenge was a bold bet in 2006 to lock up most of the order book of Gamesa through 2009. Additionally, Iberdrola holds a 24 percent equity stake in Gamesa.

Figure 6: Predicted evolution of turbine capacity 1985-2010

	1985	1990	1995	2000	2005	2010
Nominal capacity (kW)	80	250	600	1,500	5,000	8–10,000
Output per year (MWh)	95	400	1,250	3,500	17,000	

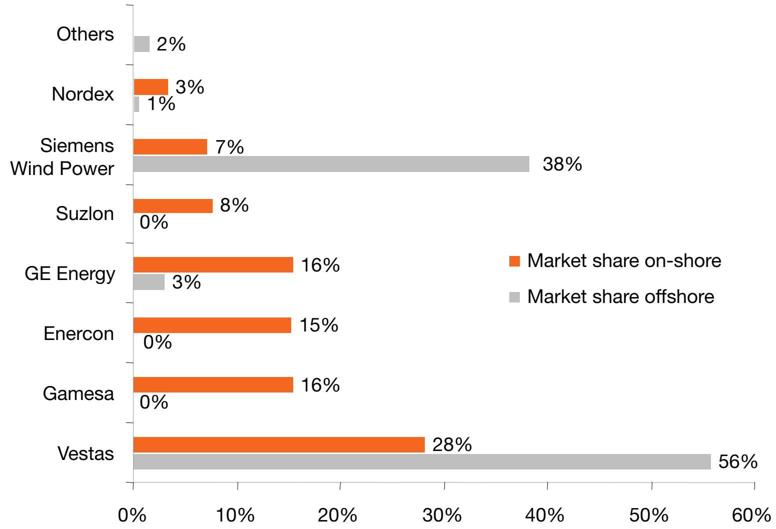
Source: European Renewable Energies Federation, European Wind Energy Association, Capgemini Analysis

Figure 7: Predicted evolution and share of wind capacity 2007-2020

Capacity	2007	2007	2010	20120
Onshore	55.5(GW)	98%	93%	33%
Offshore	1.1(GW)	2%	7%	67%

Source: European Renewable Energies Federation, European Wind Energy Association, Capgemini Analysis

Figure 8: Wind equipment market (share of the market at year end 2006)



Source: Company annual reports, Capgemini Analysis

Figure 9: Wind characteristics

Type	Invest. Cost (€/KWh)	Operation & Maintenance costs (€/KWh)[6]	Lifetime	Typical farm size (MW)
Onshore	890–1,100	33–40	25	2–50
Offshore/Near Shore	1,590	55	25	50–100
Offshore 5-30km	1,770	60	25	50–100
Offshore 30-50km	1,930	64	25	50–100
Offshore >50km	2,070	68	25	50–100

Source: European Wind Energy Association, OPTRES, European Renewable Energies Federation, Capgemini Analysis

Leading markets and where to invest in wind

Germany and Spain are the largest onshore markets in Europe. Germany dominates the wind market in Europe with 40% of the installed capacity in 2007[7] (22,247 MW). A government objective is to increase onshore wind capacity with an additional 10,000 MW by 2020. Total long-term government targets for offshore wind were identified at 1,500 MW until 2011.

Spain has the second largest capacity in Europe and the highest growth ambitions in absolute terms. The target is an additional 18,000 MW by 2015, which will be very difficult to achieve with current bottlenecks in supply. With over 4,500 MW installed, Iberdrola is the leading player in Spain (and the world). Acciona Energia and Endesa are additional players among the top 5 in the world based on installed capacity.

Current small and medium size markets in Europe are hot markets because of their faster growth. Italy is for several reasons one of the most interesting markets for investment in Europe. The government objective is a further 4,000 MW in capacity during the period of 2006-2015. To reach the target, Italy offers the highest incentives for wind power in Europe with its green certificates system. In addition, Southern Italy is a recipient of EU structural funds (for heavy investments).

Poland has a modest installed current capacity, but is predicted to have one of the highest relative annual growth rates over the next 10 years within EU-27[8]. Further, Poland has fairly good geographical conditions for offshore wind farms.

[6] OPTRES
[7] European Wind Energy Association
[8] European Wind Energy Association

Biomass and biogas

The European biomass market is dominated by Finland, Sweden and Germany. There has been a spectacular growth of electricity and heat production from biomass, and it is a viable option in comparison to wind to reach the renewable targets. It is however a CO_2 emitting technology, which is controversial (although the CO_2 is equalized by cultivation of replacement trees).

Electricity generation from biomass is characterized by non-volatility of the power output, high variable costs (up to 165 €/kWh), and various energy conversion concepts. It is difficult to precisely determine the cost of producing electricity from bio sources, and to estimate the price evolution due to the great diversity and complexity of combinations of technologies, conversion processes, fuel types, system designs, industrial patterns and local climate. Also, as it is a small scale (typically 1-25 MW) and often local form of generation, the conditions vary greatly including aspects of infrastructure and supply of feedstock. The development of these technologies has reached a second generation and is becoming increasingly efficient with decreasing cost.

Figure 10: Biomass characteristics

Technology	Invest. Cost (€/KWh)	Operation & Maintenance costs (€/KWh)	Efficiency	Lifetime (years)	Typical size (MW)
Biomass Pl.	225–2,530	75–135	0.26–0.3	30	1–25
Co-firing	550	60	0.37	30	
Biomass Pl CHP	2,600–4,230	80–165	0.22–0.27	30	1–25
Co-firing CHP	550	60	0.2	30	

Source: OPTRES, European Renewable Energies Federation, Capgemini Analysis

Figure 11: Biogas characteristics

Type	Invest. Cost (€/KWh)	Operation & Maintenance costs (€/KWh)	Efficiency	Lifetime	Typical size (MW)
Agricultural biogas plant	2,550–4,290	115–140	0.28–0.34	25	0.1–0.5
Agri. CHP	2,760–4,500	120–145	0.27–0.33	25	0.1–0.5
Landfill gas	1,280–1,840	50–80	0.32–0.36	25	0.75–8
Landfill gas CHP	1,430–1,990	55–85	0.31–0.35	25	0.75–8
Sewage gas plant	2,300–3,400	115–165	0.28–0.32	25	0.1–0.6
Sewage gas plant CHP	2,400–3,550	125–175	0.26–0.3	25	0.1–0.6

Source: OPTRES, European Renewable Energies Federation, Capgemini Analysis

Germany is a dominant force in biogas with almost 70% of the volume; however, the market consists of a high number of very small units (0,1-0,6 MW capacity) with a low efficiency (0,26-0,36). The market is growing fast, and volumes are expected to double in the next 10 years. Due to the often lacking demand for heat, it can be used for (pure) power generation. Hence, if possible, CHP (Combined Heat and Power) would be the preferable option.

Leading markets and where to invest in biomass/biogas

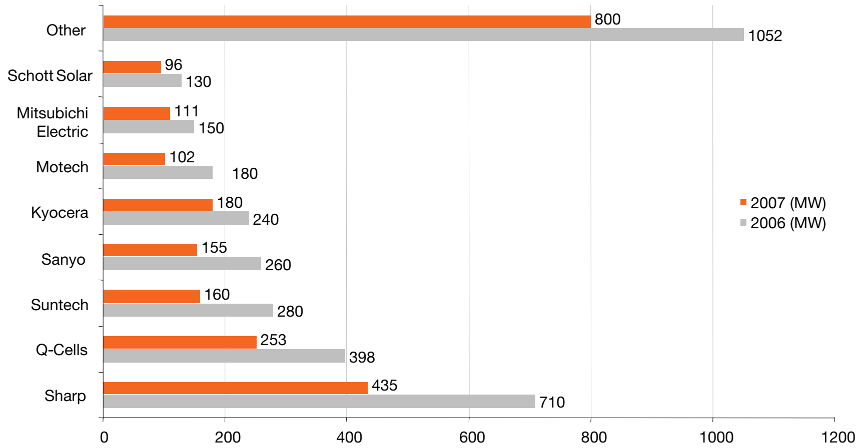
There is considerable potential for growth of both biomass and biogas in Germany. This is due to high and long-term guaranteed feed-in tariffs under the EEG Act and other supporting measures. At the end of 2006, proximately 3,500 biogas units were in service in Germany. These units are small, however, and a majority is for household use, which then makes the total capacity rather small.

Co-generation of heat and power onsite in biogas is the most prominent way of utilizing biogas in Germany. In addition to farm-scale plants, there exist currently around 100 bio waste fermentation plants and 700 sewage sludge fermentation plants.

Solar energy: photovoltaic and solar thermal

Although using the sun as a source for energy is an ancient idea, electric power generated from the sun is still a developing area. Photovoltaic (PV) technology has advanced the most, showing potential for large scale capacity in the long-term perspective. Solar thermal is far from being mature and very much a developmental technology. One area of sun energy already in full blossom is roof top water heating for residential houses, and this is an important part of several governments' future legislations to increase energy efficiency. The photovoltaic market is growing very fast—thanks to incremental developments in cell technologies, which are substantially lowering the cost of electricity generation. Currently the market is fragmented with a few large players (Sharp, Q-Cells and Kyocera), and a consolidation and acquisition wave of the smaller players could be expected in the near future as the market matures. The growth in production has been extreme over the last couple of years, with market leaders Sharp and Q-Cells almost doubling their output between 2006 and 2007 (Figure 12).

Figure 12: Global PV cell makers' market shares 2007 (Cell production in Mw)



Source: Company annul reports, Capgemini Analysis

Figure 13: Photovoltaic characteristics

Plant Specificities	Invest. Cost (€/KWh)	Operation & Maintenance costs (€/KWh)	Load Factor (hours)	Lifetime (years)	Typical size (MW)	GWh/ year
PV plants	5,080–5,930	38–47	500–1,300	25	5–50	4

Source: OPTRES, European Renewable Energies Federation, Capgemini Analysis

Germany dominates the global and European PV market as far as installed capacity and investment into R&D (with leading company Q-Cells) is concerned. There is a major interest outside Europe with Japanese and Chinese companies leading the way. PV development is still highly dependent on support schemes. ROI is closely correlated with commitment from national governments, and cannot currently be justified on its own merits, as the current investment cost is beyond 5000 €/kW.

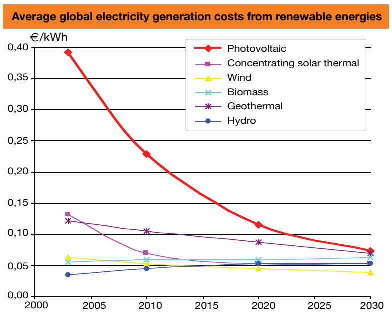
The main driver for the high cost is the increasing price on silicon due to the current deficit of production. There are doubts whether silicon capacity will be increased quickly enough to sufficiently lower development cost, which hampers the growth pace of generation capacity till 2010.

Leading markets and where to invest in photovoltaic

Germany is the primary European market for investment and R&D, with a high public awareness and acceptance for the technology. Although Germany is not the most obvious geography for solar-based energy, the industry has developed fast due to strong backing by the government. This support has led to German companies being world leaders in the development of solar technology as well as building capacity. In 2006, Germany accounted for more than 89% of the installed European capacity. Additionally, Italy and Spain are increasingly attractive markets with strong current initiatives and a beneficial climate for PV; however, we note that tariffs in Spain are expected to decline at the end of 2008.

Our point of view on bridging the cleantech gap

Figure 14: Forecasted average global generation cost based on a 2006 cost baselinetechnology maturity/size of capacity)



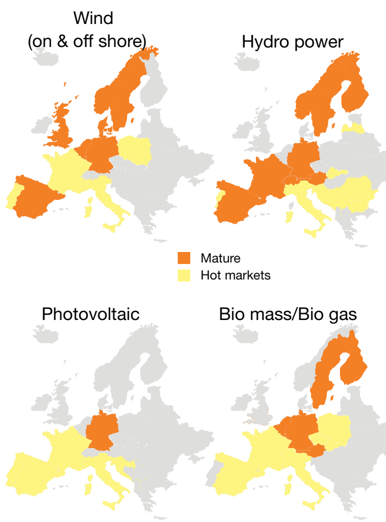
Source: OPTRES, European Renewable Energies Federation, Capgemini Analysis

It is our point of view that hydropower can contribute significantly to reach the objective of gaining increased share of the total renewable energy capacity mix in 2020. There is potential to increase the cleantech capacity through build outs and refurbishment. However, this will simultaneously lead to strong opposition from environmentalists (hydro and wind) as well as the local population with NIMBY[9] objections.

Further, we are convinced that wind can—to a large extent—contribute to the ambitious plan of increased share of renewable energy. However, with an already existing capacity of over 56,000 MW in Europe, it will be highly complex and costly to increase the capacity. The existing wind farms are utilizing the most favorable areas for wind energy, and hence new installations will incur higher cost and more opposition from local communities. Offshore wind power is a solution, but it lies 10-15 years away in the future before the costs are low enough to make this economically sound as investments. In addition to this, as wind cannot be counted as base load, balancing capacity needs to be built as well. The other technologies are still not mature enough to be counted on a large scale.

We strongly emphasize that governments all around Europe have to assume greater responsibilities, by introducing favorable incentive schemes to

Figure 15: Summary of clean technologies' Benefits and Concerns (in order of technology maturity/size of capacity)



Technology	Characteristics	Conclusions	Timing of commercial maturity
Hydro	• High exploitation • Proven technology • Low volatility of the power output • High initial investment costs	Realisable potential for large-scale hydro power is hard to predict. Despite high current exploitation in Europe, the technical as well as the economic potential is still quite high – compared to other renewable options.	Mature technology. Wave and tidal within the next 10-20 years.
Wind	• High volatility of the power output • Standardised and proven power conversion technology	The technical potential for wind energy is high, but several barriers have to be overcome, e.g. public acceptance, power grid constraints. High R&D and operational cost for off shore	Onshore : Already Offshore : Within the next 10 years
Biomass/ Biogas	• Non-volatility of the power output • High variable costs • Biomass represents a 'competitive resource' • Various fuel fractions occur • Long distance transportation should be avoided	An energy source with a limited potential – depending on country-specific conditions. The energetic use of biomass stands in competition to the material use. Bio gas potential in semi-urban or agricultural areas where waste and sewage can easily be accessed. CO2 emitting and hence not a good green solution.	Both tech, small scale already in place. Biomass: Large scale within the next 10-20 years. Biogas: Large scale 10-15 years
PV	• High volatility of the power output • High initial investment costs • Technology in early development stage • Fragmented supplier market	PV has a potential which can be realised from a technical point-of-view in most countries but the time scale is uncertain. Small scale residential applications have high acceptance and feasibility.	Within the next 15-20 years.

Source: European Renewable Energies Federation, American Wind Energy Association, Capgemini Analysis

[9] Not In My Back Yard (NIMBY)

promote more investment to reach the renewable ambitions. But the focus cannot only be on direct subsidies for building capacity. Governments and the EU must also focus on the development of companies who in turn drive the development of maturing technologies and to focus on next generation technologies. In the 1990s, the Danish government handed out vast subsidies to develop a domestic renewable energy industry. As a result, Vestas is now the world's largest wind turbine manufacturer. Germany and Japan are leading the development of photovoltaic technology and generation of solar power for the same reason. We believe that in order to reach the targets, similar approaches must be made so that the cost of each of the developing technologies (and the ones still in the laboratories) can be lowered, and hence the technology can become both a technically and economically viable option for a secured and green energy supply in Europe.

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Philippe David
Philippe Coquet
Sopha Ang
Emmanuel Gourbesville

Contacts:

Oskar Almén
+46 8 5368 4249
oskar.almen@capgemini.com

Alain Chardon
+ 33 (0)6 1902 4382
alain.chardon@capgemini.com

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