Arnoud van der Slot and Ward van den Berg

Study

Clean Economy, Living Planet

The Race to the Top of Global Clean Energy Technology Manufacturing

2012

Roland Berger
Strategy Consultants

Commissioned by:

WWF


FSC
www.fsc.org
MIX
Paper from
responsible sources
FSC® C003314

Arnoud van der Slot and Ward van den Berg Study

Clean Economy, Living Planet

The Race to the Top of Global Clean Energy Technology Manufacturing

2012

This report was commissioned by WWF-Netherlands (Wereld Natuur Fonds)

WWF

Executive summary

For four years, WWF[1] and Roland Berger have tracked developments in the global clean energy technology (cleantech) sector and ranked countries according to their cleantech sales. This third CLEAN ECONOMY, LIVING PLANET report compares regions and countries on the basis of their sales value in the cleantech manufacturing chain, covering manufacturing inputs such as silicon and specialized machinery, intermediate products such as solar cells, and final products such as wind turbines, heat pumps and biofuels. Individual technology sales are aggregated to produce country rankings, market share analysis and growth rates.

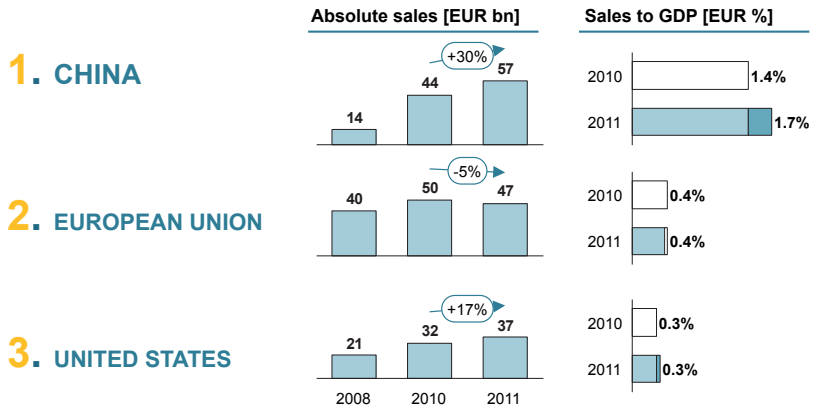
Cleantech offers attractive market opportunities for countries and companies alike. Today, clean energy technology manufacturing is a fast-growing global industry, similar in size to the consumer electronics industry. In 2011, the value of cleantech manufacturing almost doubled over 2008, reaching EUR 198 billion. While the period between 2008 and 2010 saw growth of 31% per year, the sector is maturing, and growth became more stable at 10% in 2011. This is still well above global GDP growth. The pace of growth has slowed in part because of lower economic growth in key regions, and also because of significant cost declines in both solar and wind that reduced sales value.[2] The strongest growth was observed in the energy efficiency market (+22%) and the solar PV market (+11%).

Although growth has slowed, the cleantech sector will continue to outgrow other sectors. By 2015, it will rival the oil and gas equipment market, when the market size is forecast to be between EUR 240 and 290 billion. WWF advocates a 100% renewable energy future by 2050.[3] Countries, companies and consumers working on this goal will adopt cleantech on a large scale and over a prolonged period. This warrants long-term growth and further raises the attractiveness of the market.

Countries and companies are already benefiting from the shift to renewable energy and increased energy efficiency. China, the European Union and the United States are the main cleantech regions. China is the cleantech winner, and its sales grew EUR 13 billion to EUR 57 billion in 2011, as shown in figure 1. The US was also able to grow its sales, though its sales as a share of its national economy are still significantly lower than those of China and the EU. In contrast to the other two regions, sales in the EU actually declined.

1 *WWF is known as World Wildlife Fund in North America and World Wide Fund for Nature elsewhere*
2 *The WWF/Cleantech Group report "Coming Clean: The Global Cleantech Innovation Index 2012" addresses the importance of cleantech innovation and its opportunities for countries. The report benchmarks countries' potential to produce cleantech innovation in entrepreneurial start-up companies over the coming years*
3 *WWF/Ecofys, The Energy Report, 2011*

Figure 1. Cleantech sales in three regions



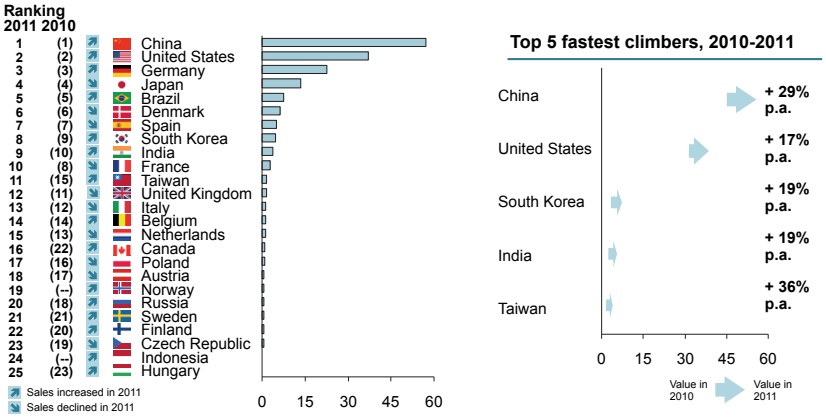
China is the largest cleantech country in absolute terms. China is successful not only because of its lower labor and capital costs, but also because of its stable government policies, strong applied R&D and well-developed supply chain. As a result, China overtook the EU as the number one cleantech manufacturing region in absolute terms.

Other major cleantech regions have not been able to capture these opportunities in the same way as China did. Despite growing at 17%, the US is still far behind China and the EU. It has a strong position mainly in biofuels and does not seem to be interested in advancing in other segments. While the US has a good federal policy for biofuels, it lacks similar incentives for other cleantech segments, and incentives at the state level differ from one state to the next.

European countries were not able to benefit from the growth, either, and their cleantech sales even declined. The Netherlands saw a decline of 14%, cleantech sales in France fell 30%, and in Spain, sales dropped 9%. Denmark and Germany are exceptions, with steadier sales. Because of these two countries, the EU still has a strong position in wind. The financial crisis that continues to affect Europe has monopolized the attention of governments, made all investors more risk averse than in past years, and has directly impacted on cleantech investment levels. We expect European countries thus affected to refocus their attention on the strategic growth opportunities in the cleantech sector as they recover from the financial crisis.

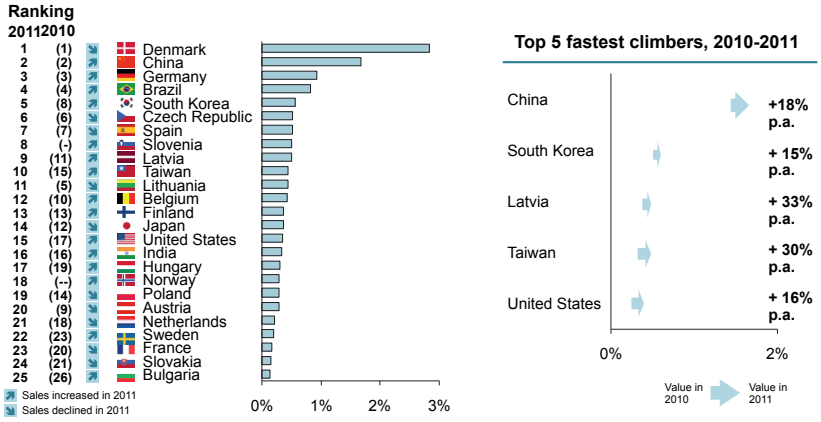
Figure 2A shows the performance of all countries in the absolute country ranking, which measures the sales from manufacturing cleantech. China is the clear leader, showing remarkable growth of 29% per year. The US holds second place in the absolute ranking, with sales of EUR 37 billion. Germany is number three, and South Korea, Taiwan and India are runners-up.

Figure 2A. Absolute cleantech ranking



Our country ranking in figure 2B shows which economies focus most strongly on cleantech manufacturing. This ranking measures sales as a proportion of the countries' total economies. In these terms, Denmark remains the global cleantech leader. Though a comparatively small country, Denmark is home to large companies in this sector. China holds second place and is closing in on Denmark.

Figure 2B. Relative cleantech ranking



With substantial market growth expectations, our new 2011 ranking by no means illustrates a settled cleantech manufacturing race. The race is just beginning. All countries can learn from the best practices of successful countries. Successful countries share a coherent, long-term and comprehensive approach that includes all stakeholders. The best practices of Denmark, China, Germany, the US and South Korea demonstrate a strong approach on three levels. First, on a foundational level, government, R&D institutes and financial institutions shape the right conditions for the cleantech industry to develop and grow. On the second level, cleantech adopters (customers) create market demand for cleantech products. Finally, on the third level, the cleantech industry must develop into an efficient, innovative industry and optimize its supply chain:

Foundation:

- **A coherent and stable policy environment has to include both energy and industry policy –** A good example is runner-up South Korea, which has identified cleantech as the next engine for growth by focusing on R&D and manufacturing incentives, as well as targets for renewable energy use and energy efficiency
- **A focus on R&D from basic research to applied demonstration projects results in better cleantech products –** Since the 1970s, Denmark and Germany have invested substantial amounts in and put a strong focus on demonstration projects, thereby creating a leading position in the wind industry

- **Availability of sufficient capital fosters the development and use of cleantech –** For example, Chinese companies have good access to capital, and in the US, a thriving venture capital industry supports cleantech companies

Cleantech adopters

- **Cleantech adopters create a domestic market for cleantech companies –** In Denmark and Germany, local communities invested in wind turbines, and in the US, large companies purchased cleantech products, thereby creating a domestic market

Supply chain

- **Large companies and a strong supply chain drive cleantech sales growth –** Chinese companies have grown their operations substantially and benefit from their economies of scale. A focus on vertical integration enables Chinese companies to manufacture more efficiently.

To assess the strengths and weaknesses of each major region in developing and accelerating the growth of the cleantech sector, Roland Berger surveyed more than 60 cleantech companies worldwide. Based on company responses and additional analysis of regional developments, we developed recommendations for the EU and the US on improving the business climate for cleantech manufacturers, as well as the additional steps China can take to stay ahead:

The **European Union** member states can

- **Develop a strategic vision for the cleantech sector that provides a stable basis for long-term policies –** Ending frequent changes in policies and sticking to a clear and strategic vision will give market participants the security to invest
- **Make more capital available to cleantech companies and cleantech adopters –** More venture capital would enable European startup companies to bring their innovations to the market. In addition, expanding the financing options of cleantech adopters would support the growth of cleantech companies

The **United States** can

- **Develop a stable policy support system for cleantech products at the national level and align policies across states –** Replacing short-term programs with a more comprehensive, long-term approach would create more stable demand and offer companies greater investment security

- **Create a more stable cleantech R&D budget to increase innovation and drive down costs –** Long-term R&D roadmaps should be matched with long-term R&D budgets that enable research institutes to conduct their research and achieve their objectives

And finally **China** can

- **Increase funding of basic R&D –** The Chinese government should allocate more resources to basic research, as well as raise the attractiveness of basic research jobs to attract the brightest talent
- **Build awareness and cleantech acceptance among companies and consumers –** An increase in local demand for cleantech products will help grow the cleantech sector. Current business practices may be need to be adjusted to enable the inclusion of cleantech products

Each country has the opportunity to increase its cleantech sales value and capture a share of the 21st century industries. The global cleantech market is predicted to grow between EUR 40 and 90 billion by 2015. We have calculated the stakes of each region. These stakes are based on the differences between the 2015 sales value in the base case and best case. In the base case, countries do not implement the recommendations, and in the best case, they do implement these recommendations. The difference in value between the base and best cases for the EU, or the European stake in the cleantech market, is between EUR 19 and 31 billion. The US stake in the cleantech market is between EUR 23 and 28 billion. China has the highest stake, between EUR 30 and 80 billion. These stakes show the great economic opportunities of the cleantech sector. Long-term opportunities are even greater, when the 100% renewable energy future is made a reality.

Contents

1. Introduction, scope and methodology

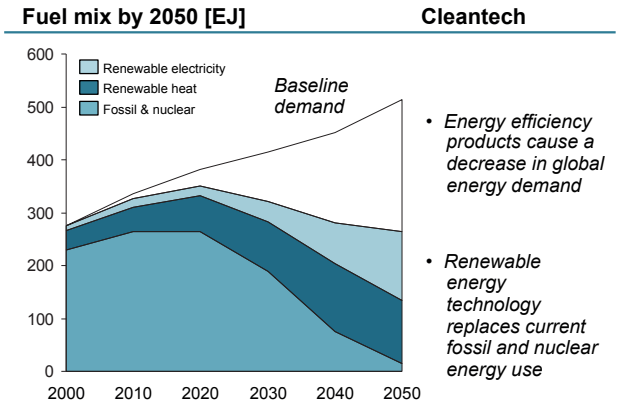
Temperature increases due to global warming can be limited to 2°C if clean energy technologies (cleantech) are deployed rapidly and worldwide. The 2009, 2011 and this 2012 report for WWF[4] reveal the economic opportunities that the cleantech sector presents to national economies. The reports rank countries according to their cleantech manufacturing bases, and comparing countries' performance over time shows which countries have been able to capture the sector's growth opportunities. WWF advocates the rapid growth of the cleantech manufacturing industry as one of the most important ways to reduce climate change.

1.1 Clean energy technology cuts CO_2 emissions worldwide and creates social and economic opportunities

WWF advocates a 100% renewable energy future by 2050. This requires a substantial increase in the use of renewable energy and energy-efficient technologies. The Energy Report[5] and the Energy Scenario included therein would see CO_2 emissions from the world's energy supply sector reduced by over 80% by 2050 – providing a high level of confidence that the average global temperature rise will be limited to less than the 2°C threshold identified as presenting unacceptable risks of catastrophic climate change.

The Energy Scenario achieves this primarily through the aggressive rollout of the most energy-efficient technologies and fast growth of renewable energy supplies, including bioenergy. If this path is followed, energy demand can be stabilized and the overall energy system can be 95% sustainably sourced by 2050 (see figure 1).

Figure 1. Fuel mix scenario put forward in WWF's Energy Report 2011



4 *WWF is known as World Wildlife Fund in North America and World Wide Fund for Nature elsewhere*

5 *WWF/Ecofys, The Energy Report, 2011*

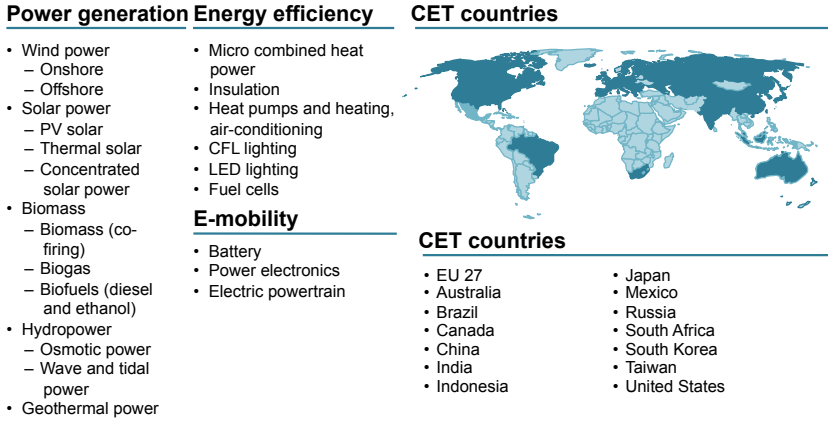
It is the manufacturing industry that develops and supplies the market with energy-efficient and renewable energy technologies. Today, clean energy technology manufacturing is a fast-growing global industry, similar to the size of the consumer electronics industry.

The growth of this sector illustrates how climate solutions can generate revenue, create jobs, reduce pollution, create better health conditions and add value to economies. Countries that attain a good position in the clean energy tech manufacturing race today have the best prospects for a strong position in a much bigger (near-) future market.

1.2 Clean energy technologies include most renewable energy and energy efficiency products

Figure 2 defines the scope of clean energy technologies as used in this report. A large part of our inventory involves the manufacturing of renewable energy technologies, such as solar, wind, biomass and geothermal. The inventory also includes manufacturing of dedicated energy efficiency products, such as low-energy lighting, better insulation and electric car components.

Figure 2. Scope for cleantech market assessment



The scope of technologies used in the report represents the renewable energy and energy efficiency market well. Three assumptions on the inclusion of technologies may require further clarification.

First, products where incremental energy efficiency advances have been made, such as household appliances and cars with energy-efficient engines, have not been included. The value of these products would measure not only the enhanced efficiency, but also the normal benefits of using the product. These two features often cannot be separated. Nevertheless, the dedicated energy efficiency products included are good indicators of progress in the energy efficiency market.

Second, although hydropower is the biggest renewable power source to date, we have not included hydropower technology sales in our inventory. WWF advocates restricted future growth of hydropower to limit ecological and social side effects.

Third, in this study, bioenergy includes the value of biomass inputs as well as products, such as biofuels and biogas. Like wind turbines and PV systems, we regard biofuels and biogas as products that are ready to produce sustainable heat or power. Bioenergy is included because sustainably sourced bioenergy plays a key role in the 100% renewable energy future. Note, however, that in this study we did not assess the sustainability of the bioenergy value chain.[6]

We adopted modular approach to calculating the manufacturing value of cleantech. For each technology in the 40 countries, Roland Berger listed the important steps in the value chain and assessed the total production volume and the value added to the intermediate product at each step in the production process. For instance, a solar PV cell may be produced in a factory in China and used as an intermediate product in a panel factory in the USA.[7] Here, the sales value of the PV cell is attributed to China, and only the remaining incremental sales value of the module is attributed to the US. This value chain approach prevents products from being double-counted and assures proper attribution of sales to countries.

Only the capital and operational expenditures on tradable goods was counted.[8] So, we do include the value of biomass for biofuel production, and the value of silicon and solar cell manufacturing equipment for solar PV, but we exclude the value of installing and maintaining wind turbines and solar modules. While these installation and maintenance activities do create substantial value and employment, their inclusion would measure the deployment of renewable energy, not the production of cleantech.

6 *WWF only supports bioenergy that is environmentally, socially and economically sustainable. WWF is working with partners around the world to influence bioenergy policies, as well as with private sectors and their supply chains – from producers, manufacturers and processors to buyers, retailers and investors – to transform and drive entire commodity markets including bioenergy, towards greater sustainability. See: http://wwf.panda.org/what_we_do/footprint/climate_carbon_energy/energy_solutions/renewable_energy/bioenergy/*

7 *For details, see Appendix A*

8 *Tradable goods are those that have export or import potential. Their prices are set in international markets*

A comprehensive overview of clean energy tech sales did not exist previously. This makes our inventory unique. The sales value calculation therefore draws from a broad range of sources, including industry trade organizations, broker and industry reports, and the companies themselves. A complete list can be found in Appendix A.

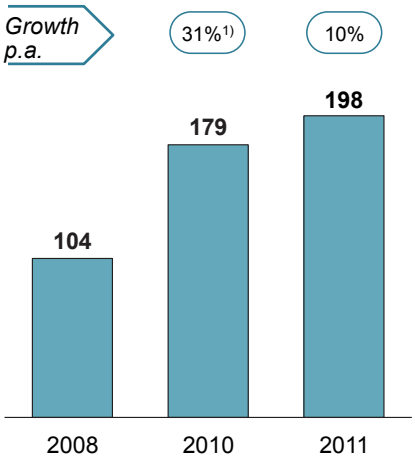
2. The global cleantech market

This section presents the attractiveness of the global cleantech market. It first shows the global market size and analyzes the growth from 2008 to 2011. A comparison with other industries, and the average growth of the global economy, reveals that cleantech is a highly attractive market. Secondly, the section explores the various cleantech segments, like wind, solar PV and biofuels. It gives further insight into the recent developments in the global cleantech market and confirms this attractiveness. Thirdly, our forecast based on the future deployment of cleantech and projected cleantech costs shows that the market will continue to grow and rival the oil and gas equipment market by 2015.

2.1 The global cleantech market grew faster than the global economy in 2011

In the 2011 report, Roland Berger estimated the growth of the global cleantech market at 31% per year, with a market size in 2010 of EUR 179 billion, up from EUR 104 billion in 2008. In 2011, the global cleantech market grew to EUR 198 billion, an increase of 10%.

Figure 3. Global cleantech market



1) From 2008 to 2010, per annum figure

The cleantech market is becoming more mature, with growth rates slowing from 30% to a more sustainable level, at 10% per year. Nevertheless, growth of 10% still implies an annual increase of EUR 20 billion. The cleantech sector's growth still significantly exceeds that of the global economy, at 2.7%, and the fastest growing economies, like China, India, Russia and Brazil, whose economies grew between 2.7% and 9.2% in 2011. It is also notable that the cleantech sector grew faster than the global telecom, software and pharmaceuticals sectors, which are seeing growth of between 5.1% and 9.9%.[9]

There are two main reasons why the growth of cleantech has come down. First, the price of cleantech products and technologies dropped substantially in 2011. Annual additions of renewable energy worldwide rose by 21%[10] in 2011 compared to 2010, although the value of these products increased by just 10%. This is essentially good news. Lower prices are needed for renewable energy to compete with fossil alternatives and for investments in energy efficiency to pay off. The price drop also reflects the high levels of innovation in the cleantech sector.[11] For companies and countries to be able to continue to compete, they need to invest in R&D.

Continued price drops seen in cleantech products is a feature that fossil fuels do not share. Oil and coal prices have risen in the past few years and are expected to increase further due to increased demand. While new resources may be discovered, they will also come with higher exploration costs.

A second reason for the slower growth in 2011 is the financial crisis. Governments, especially in Europe, have reduced incentives for renewable energy generation. For instance, the annual growth in new wind turbine installations flattened by 2009. New installations of wind turbines in Europe remained stable at 9.6 GW in 2010 and 2011, below the all-time high of 10.5 GW in 2009.[12]

2.2 Wind and solar together make up 50% of cleantech sales

With its 26% share of the total cleantech market, wind energy is still the most important technology. Solar PV has almost closed the gap with wind energy, holding a market share of 25%. Biomass is the third largest segment, with a market share of around 20%.

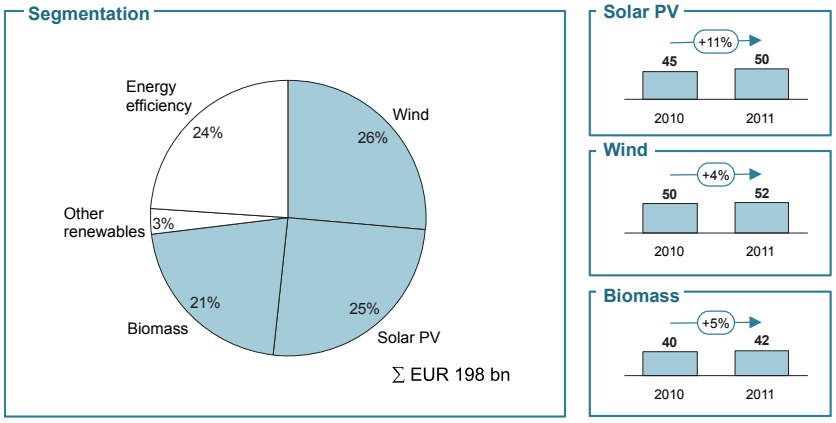
9 *Global Data*

10 *Based on wind, solar PV, biogas installations and geothermal energy*

11 *The WWF/Cleantech Group report "Coming Clean: The Global Cleantech Innovation Index 2012" addresses the importance of cleantech innovation and its opportunities for countries. The report benchmarks countries' potential to produce cleantech innovation in entrepreneurial start-up companies over the coming years*

12 *EWEA, Wind in power – 2011 European statistics, 2012*

Figure 4. Segmentation of the global cleantech market [EUR bn]



Demand for wind energy is spread across the globe. Large companies from Europe and China dominate the sector. Vestas remains the largest player in the field, with a market share of 13% and manufacturing locations around the world, and Siemens and Gamesa are also strong competitors with a global manufacturing footprint. Goldwind, Sinovel and United Power are the largest manufacturers from China, but they produce predominantly in China.[13] Wind turbine prices have come down from around EUR 1.2 million per MW in 2008 to EUR 0.9 million per MW in 2011.[14]

While solar PV sales in 2008 totaled just EUR 11 billion, in the two years since, it grew by 100% per year, to EUR 45 billion. Growth slowed to 11% in 2011, and sales now total EUR 50 billion. The rapid decline in costs in the solar PV supply chain caused this slowdown. While total market volume rose by 65% between 2010 and 2011,[15] sales went up by only 5%. Within a year, the average price of solar wafers fell 70%.[16] Similarly, the price of modules dropped by 50% in a single year.[17] The solar PV market continues to be the fastest growing of the three largest cleantech segments.

Chinese companies like Suntech Power, LDK Solar and Trina Solar have fueled the growth in solar cell and module manufacturing. Equipment for solar PV manufacturing is delivered by American and European companies like Applied Materials and Centrotherm. Meyer Burger quickly consolidated the market by buying Roth und Rau in Germany and OTB Solar in the Netherlands. Finally, balance of systems parts, such as inverters, are also part of the solar market.

13 *IHS Emerging Energy Research, Global Wind Turbine Supply Market Share Evolution, 2012*
14 *BernsteinResearch*
15 *EPIA, global market outlook 2012, 2012*
16 *IMS Research, PV Modules, Cells, Wafers & Polysilicon – Supply & Demand Quarterly - Q1'12*
17 *GTM research, Polysilicon 2012-2016: Supply, Demand & Implications for the Global PV Industry, 2012*

The biogas and biofuels segment showed growth of 5% between 2010 and 2011. While the US and Brazil are the major suppliers of bioethanol and biodiesel worldwide, the European Union has a strong position in biogas. The bioethanol market grew a modest 3%, to 89 billion liters. A bad crop in Brazil was partially compensated by an increase in bioethanol production in the US. Globally, production of biodiesel has grown by 20%, from 20 billion to 24 billion liters.

Other renewable energy technologies include geothermal power, concentrated solar power, solar thermal and ocean power. Despite the huge potential of geothermal power, new installations have declined in the past few years. In 2009, a total of 400 MW came online, while in 2011, new installations totaled just 99 MW.[18] Suppliers to these installations are largely based in the United States, Iceland, Italy and the Philippines. Concentrated solar power is applied primarily in Spain and the United States. Solar thermal is a widely applied technology in China, leading to China's 70% market share.

The energy efficiency segment as a whole has grown by 22%. The financial crisis and decline in new construction of houses and office buildings led to lower growth in insulation material. The number of CFLs, mainly produced in China, and LED lighting have risen. Legislation in the EU and other countries to ban incandescent light bulbs is fostering this growth. Electric vehicles have now entered the marketplace, with the Nissan Leaf and the Chevrolet Volt being introduced in 2011. But with total sales of around 60,000 electric vehicles worldwide in 2011, the market is still in its infancy.

2.3 In the coming years, the cleantech sector will remain an attractive market, rivaling the oil and gas equipment market by 2015

The cleantech sector has developed into an important economic sector for many countries. Global market size is comparable to other large industry sectors, such as the machinery, consumer electronics and oil and gas equipment markets, as shown in figure 4. The global cleantech market is expected to continue its growth at an above-GDP growth rate. Volume growth, however, will be higher than growth in sales revenue. Based on the market predictions of industry trade organizations[19] and the IEA and WWF scenarios for global energy demand,[20] the market will grow in volume terms by 10-15% per year through 2015. However, due to the expected declines in costs, the market will

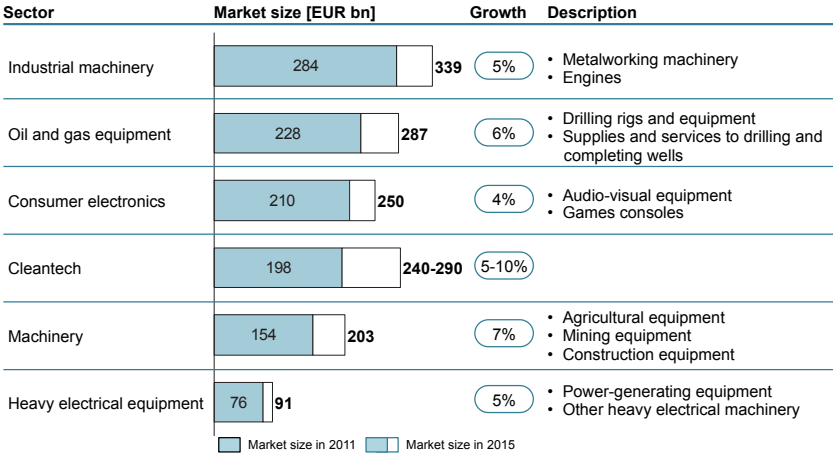
[18] *International Geothermal Association, Global Geothermal Energy Database*

[19] *EPIA, GWEC, IGSHPA and RFA*

[20] *Forecast based on the growth in the capacity of renewable energy in the IEA 450 ppm scenario and the WWF/Ecofys Energy Report. It is important to note that, in both scenarios, renewable energy capacity will increase through 2020, and accelerate thereafter*

grow in value terms by just 5-10% per year, falling between EUR 240 and 290 billion in 2015. With this growth, the cleantech market will reach about the same size as the global oil and gas equipment market.[21] Forecasts of other market researchers[22] for the cleantech sector's growth range between 5% and 12%. However, each has included a different scope of the technologies in its forecast.

Figure 5. Market size of cleantech and other sectors in 2011 and forecast for 2015 [EUR bn]



The cleantech sector is already becoming more mature, and is an attractive market with above-average growth. To realize the WWF ambition of a 100% renewable energy future in 2050, cleantech must be applied on a large scale, creating a high-growth market for the coming decades. Countries and companies must position themselves to capture a part of this attractive market. Besides its economic advantages, cleantech also offers social benefits. The cleantech sector creates many high-level, green collar jobs, and deployment of cleantech not only reduces CO_2 emissions, but also other pollutants.

21 *Global Data*
22 *HSBC, BCC, Global markets and EBI*

3. Cleantech in China, the European Union and the United States

The cleantech market has become more mature, and with its size of EUR 198 billion in 2011, it is about as large as the electronics market. Previous versions of this report showed that countries were successfully growing their cleantech sectors, but that some countries were not able to capture the economic opportunities. An analysis of the current state of the cleantech sector in China, the countries of the European Union and the United States shows how the major economic regions have been able to develop this sector during the financial crisis. The following provides an overview and greater details of their performance.

3.1 While China shows high growth in cleantech manufacturing, the European Union and the United States have yet to realize their full potential

The combined sales for the major regions China, the European Union and the United States total EUR 150 billion, or almost 75% of the global cleantech market. China has become the world's most successful cleantech region in terms of growth and in terms of the size of its sector relative to its total economy. While sales there totaled just EUR 14 billion in 2008, this figure has expanded to EUR 57 billion in the three years since. The majority of this growth (77%) took place between 2008 and 2010, but even in 2011, it outpaced average global cleantech sector growth by a factor of three.

While the European Union also grew rapidly, at 12% between 2008 and 2010, sales figures for cleantech products manufactured in the 27 EU countries fell 5% in 2011. Nevertheless, in terms of sales value relative to its economy, the European Union remains the second largest cleantech region.

Finally, though the United States has the smallest cleantech sector relative to its GDP, it is catching up to the European Union, with 17% growth in sales. This growth has slowed somewhat compared to the 24% seen between 2008 and 2010, but the US continues to outpace average global cleantech sector growth.

Figure 6. Cleantech sales in three regions

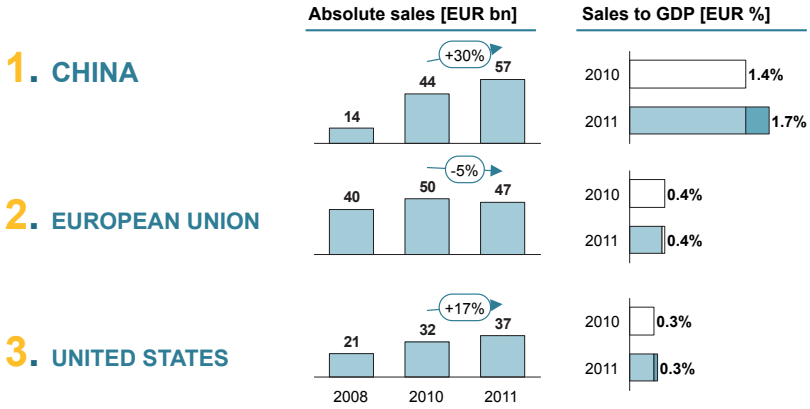
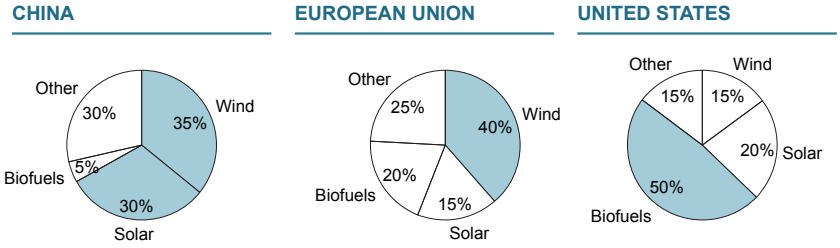


Figure 7 outlines cleantech sales by segment for each of the three regions. Each region has specialized in one or two segments. In China, the wind and solar markets account for 35% and 30%, respectively, of China's total cleantech sales. The European Union dominates wind energy, while the United States generates 50% of its cleantech sales from biofuel production.

Figure 7. Regional cleantech sales per segment



3.2 China excels in wind and solar

China shows high growth in wind and solar. Its growth in wind turbine manufacturing, including blades, gearboxes and other components, totaled 22% in 2011, and total sales now amount to EUR 20 billion. While China imported most of the wind turbines installed in the early 2000s, it has since developed its own industry under the "equipment first" policy.[23] Now Chinese companies produce for both the domestic and foreign markets. Four Chinese players already rank among the top 10 global wind turbine manufacturers. Chinese production is 30% cheaper than in other regions, and Chinese companies could overtake Vestas as the number one manufacturer if the quality of their products further improves.[24]

In solar PV, China has managed to become the global manufacturer for the world. This reflects China's current manufacturing stronghold on both cleantech and non-cleantech products, such as consumer electronics, mobile phones and computers. Total sales for solar PV have risen by 19%, to EUR 17 billion, and the value of solar thermal applications rose 21% in 2011, to EUR 3.5 billion. China now produces more than half of the world's solar cells. China has also recently expanded its solar scope, and has begun building the manufacturing equipment for solar PV, as well. Interestingly, when the Chinese solar PV sector began, it targeted production for the export market, but China has recently increased installation of solar PV domestically. China has also expanded its presence in batteries, heat pumps and energy-efficient lighting. The Chinese government has put a strong focus on the development of its cleantech sector as part of its overall economic objectives. The current performance of the cleantech sector demonstrates the success of its strategy.

3.3 The European Union is still strong in wind

In the European Union, sales in the wind energy industry have remained stable, at EUR 18 billion. Production in the wind industry increased in Germany, but was reduced in Denmark and Spain. The onshore European market has plateaued in recent years, and given the current financial situation, is likely to remain flat in the years to come. In export markets, such as the US, India, and Brazil, European manufacturers face competition from Chinese players. However, only European manufacturers are active in the offshore wind market.

[23] *Before China set out to deploy wind energy on a large scale, it first aimed to develop a local manufacturing industry. Local content requirements were useful in developing the industry in the early 2000s*

[24] *Roland Berger, Wind turbine manufacturing – A case for consolidation, 2011*

For instance, Siemens had an 80% market share in offshore wind turbines in 2011. As a result, offshore will become the main growth market for the European industry. Across the board, European wind companies are reducing costs to remain competitive with their Chinese rivals and to enable grid parity for wind turbines, thus reducing their dependence on government support.

Sales figures across the solar PV manufacturing value chain in the European Union declined 15%. This is largely because the European Union is losing its presence in manufacturing cells and modules. The value of cell manufacturing in the EU dropped 40% in 2011. European companies have trouble competing with Asian companies, particularly Chinese companies, and unlike their Chinese counterparts, have not yet reduced the costs of the cells and modules as quickly as necessary. Also unlike the wind market, the efficiency and quality of Chinese solar products is at least at the same level as those from European suppliers. As a result, solar PV companies in many countries are facing bankruptcy.

The European Union still holds a strong position in solar PV manufacturing equipment, which it sells mainly to China and other Asian countries, and it is strong in the inverter industry. For example, the German company SMA is still the market leader in inverters, with a global market share of 31%. Solar PV manufacturing equipment sales grew 46%, to EUR 2.2 billion. The European Union also grew in the energy efficiency segment by 5%, to EUR 9.2 billion.

There are large differences between countries within the European Union. While Denmark and Germany combined contribute the most to cleantech sales, at EUR 29 billion, large countries like the UK and France combined contribute only EUR 4.5 billion to total cleantech sales. The relative decline in sales is also greater in smaller countries. While German sales remained stable, sales in France fell 30%. Modest growth, though starting from a lower level of sales, is found primarily in eastern and central EU countries, where biofuel production and insulation manufacturing increased.

The diverging performance reflects the differences in the governments' approaches to cleantech. In Germany and Denmark, renewable energy is part of their long-term energy vision. In other European countries, the governments may have created incentives to boost the sector, but then abolished or amended these incentives when those countries put higher priority on other national issues.

3.4 The United States has a dominant position in biofuels

The United States has the largest share in biofuels, at around 40%. The value of activities in the bioethanol sector rose 9%, to EUR 16 billion. The US bioethanol sector has profited from a poor 2011 sugar cane harvest in Brazil, raising its exports to 9% of total US production in 2011.[25] Biodiesel is showing higher growth, as well, as sales doubled to EUR 2 billion. In 2011, a federal tax credit of USD 1 per gallon was reinstated, and production subsequently exceeded the 2008 record.

The wind industry in the US continued to grow but did not keep pace with global growth. Sales rose by 17% to EUR 5.5 billion, while annual installations in the US rose by 30%. Some European and Asian manufacturers continue to supply part of the US demand from their manufacturing facilities in their home countries. Uncertainty over policies and incentives like the PTC has prevented companies from opening large-scale manufacturing facilities in the US.[26]

Sales in the solar industry grew 14%, to EUR 8 billion. Similar to European Union counterparts, the US solar cell and module manufacturing industry is struggling to compete with Chinese production, but the US still has a strong position in silicon production. The largest thin film manufacturing company, First Solar, has part of its operations in the US. Finally, companies like Applied Materials and GT Solar, which make solar PV manufacturing equipment, are strong contributors to the American solar industry.

On the federal level, the US government has created long-term incentives only for biofuels. Other technologies are supported by legislation primarily on the state level, and federal support is volatile. The performance of the different US cleantech reflects the relative stability of policy support.

3.5 Large differences between regions exist

The high growth and innovative nature of the cleantech sector offers countries and regions many economic and social opportunities. China is the global cleantech leader, with its large and growing manufacturing base. The United States and the European Union have considerable potential that is yet to be realized. Although sales are increasing in the United States, its total sales volume relative to the size of its economy is still low, as can be seen in figure 6.

[25] *Renewable Fuels Association*

[26] *Japan's Mitsubishi Heavy Industries (MHI) is scrapping plans to open a wind turbine manufacturing plant in the US because of the stagnating market there. Vestas announced of a 2,335 job cuts across its operations and threatened to cut 1,600 more in the US if the PTC is not extended*

In the European Union, many countries are seeing declining sales, and sales volume is low relative to their economies. The cleantech sector is centered in Germany and Denmark.

China's performance is in line with the government's clear choice to develop the cleantech sector. In the United States, the development of the biofuels sector is supported by stable long-term incentives and policies. Other cleantech segments benefited to a lesser extent from stable federal support. In Denmark and Germany, the government has also developed the sector with long-term and stable policies. Other countries in the EU have not been able to develop similarly stable policies. The country ranking will go into further details of these countries' performance.

4. Cleantech country ranking

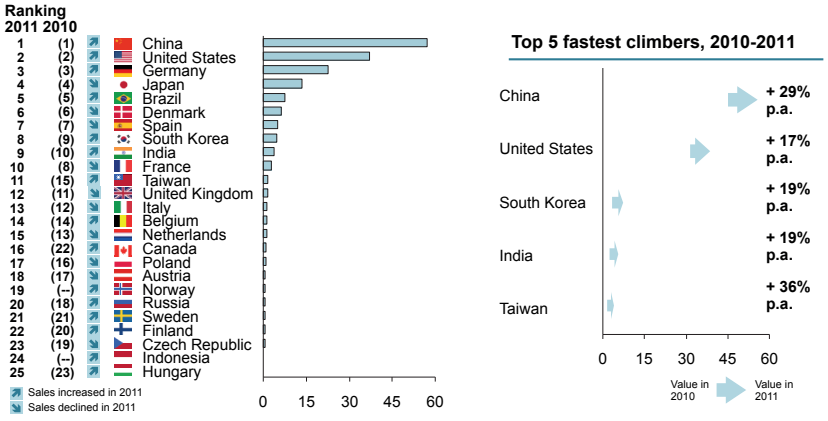
In this section we present the prominent key indicators that we have been using in the cleantech reports to compare countries on their cleantech manufacturing performance. One indicator ranks countries on their absolute cleantech sales figures, while the other ranks the contribution of the cleantech sector to a nation's economy. A ranking of the performance of individual countries in manufacturing did not exist previously. Unlike other rankings, which focus on deployment or investment potential, this ranking reveals which countries are manufacturing attractive products at favorable prices and quality.

4.1 Denmark, China and Germany are the three cleantech leaders

The ranking includes the 27 EU member states, the G7 countries, the BRIC countries, and South Africa, South Korea, Taiwan, Mexico, Indonesia and Australia. The ranking includes only the countries' contributions to each individual step in the value chain for each cleantech segment. Hence, when China assembles a solar module using a solar cell made in Taiwan, only the incremental sale value of the panel is measured. More details on the methodology and the included technologies can be found in section 1 and Appendix A.

Figure 8 shows the outcome of the 2011 manufacturing sales value of the individual countries.[27] This ranking does not take into account the overall size of the countries' economies.

Figure 8. Absolute global clean energy technology sales [EUR bn]

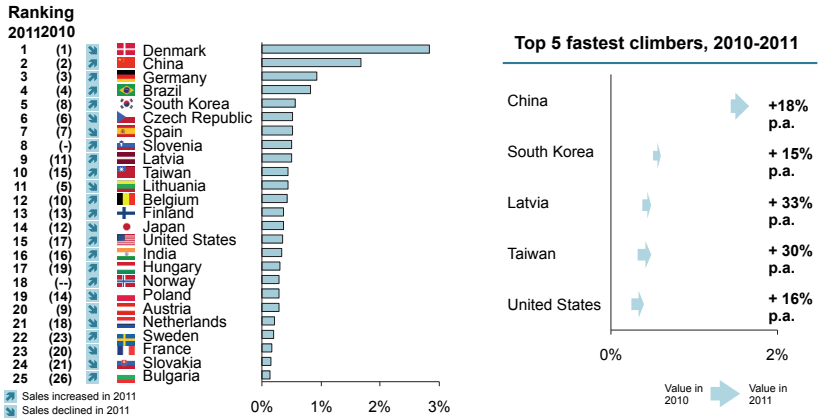


[27] *Sales of 15 countries were too low to be included inranking. Together, they share last (26th) place*

China is a clear growth leader, showing remarkable growth at 29% per year. With close to a 25% global market share, it tops the absolute cleantech sales ranking. The United States holds second place in the absolute ranking and has a market share of close to 20% in the global cleantech sector, with sales of EUR 37 billion. From the European continent, Germany is the absolute number three. South Korea, Taiwan and India are the runners-up in our ranking.

The relative ranking shows how important the cleantech sector is for the national economies and how well countries are positioned to take advantage of the economic opportunities of the high-growth cleantech sector. Figure 9 presents the outcome of the relative country ranking for 2011.

Figure 9. Relative clean energy technology sales weighted by GDP [EUR]



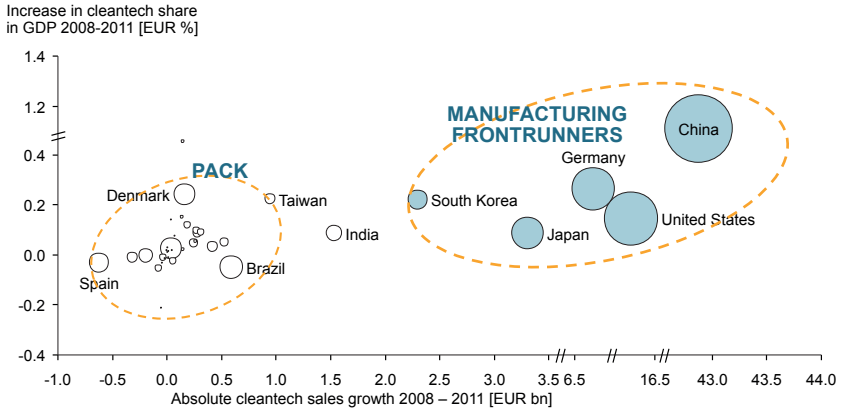
In this relative ranking, Denmark remains the global cleantech leader. Though a comparatively small country, Denmark is home to large companies in this sector. Vestas, for instance, holds a 13% share of the global market for wind turbines, Siemens has based most of its operations in Denmark, and Rockwool is a world leader in insulation material. However, Denmark's sales volume declined by 4% in 2011, along with the European market.

China still holds second place in the relative ranking and is closing in on Denmark. The Chinese cleantech sector is growing faster than the global cleantech market. China has a strong position in wind and solar PV, but is also a leader in energy-efficient lighting, batteries and solar thermal. It has the highest absolute cleantech sales in the world.

Germany is present in most cleantech segments, a fact that is reflected in its top-3 position in both rankings. Companies like Siemens, Repower and Enercon develop and manufacture wind turbines, and the country is a major producer of manufacturing equipment for the solar PV segment. It also manufactures solar PV cells and modules and is a leading supplier of CSP equipment. The largest inverter company, SMA, is also based in Germany. Germany was able to keep its sales figures steady and has benefited from a larger market share in wind and the increase in its biogas manufacturing.

The most successful cleantech manufacturing countries are those that expand the size of their cleantech manufacturing industries and increase the share of the cleantech sector in their nations' economies. They are shown as manufacturing frontrunners in figure 10, which illustrates trends over the 2008-2011 period. Countries that perform well on both axes seem to be best prepared for a future in which cleantech is a key driver behind the global economy.

Figure 10. Absolute cleantech growth and relative cleantech growth in size of national economy of countries from 2008 to 2011



Clearly, China is the manufacturing frontrunner, given its high and above-average growth in cleantech and the strongest increase in the share of the cleantech sector in its economy. South Korea shows that also countries with a smaller economy[28] can quickly expand the cleantech sector through targeted industry and energy policies. Germany, the US and Japan show a steadily growing cleantech sector. Although Denmark still has the highest share of cleantech manufacturing in its economy, its sales have grown only moderately since 2008.

[28] *The GDP of South Korea totaled EUR 847 billion in 2011*

France, Italy, Spain and the Netherlands have shown a strong decline in sales since 2008 and in 2011. The reasons behind the drop in cleantech sales vary. France and Italy are affected by the drop in their biofuels production and are having difficulties competing with the US and Argentina. In Spain, the CSP sector is still flourishing, but the financial crisis has had a negative impact on its wind sector. In the Netherlands, the large solar PV manufacturing companies are in financial distress. Also, the offshore wind sector, which is highly volatile due to its project-driven nature, did not perform as well as its German and Danish counterparts.

The country pages detail the characteristics of the cleantech sectors in the five top-performing countries in the relative ranking, plus the United States with the second-largest cleantech sales, and the Netherlands as an example of a country showing a decline in sales.

DENMARK

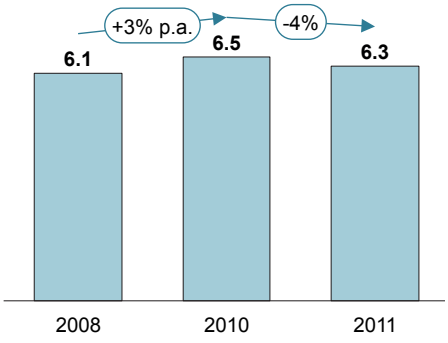
Danish cleantech showed a decline of 4% in 2011. Total sales of the Danish industry amounted to EUR 6.3 billion, or 3% of the GDP of Denmark – the highest in the world.

The Danish cleantech industry is highly dependent on wind energy, with Vestas and Siemens as its main players. In the global market, Denmark has a market share of 11%, well above the share of its economy in global GDP. Growth of Danish wind energy, however, is below the global market average. Even though Vestas and Siemens gained market share in 2011, a larger part of their production takes place in other countries. Denmark is expanding its presence in offshore wind, with Dong taking the lead in setting up strong partnerships between companies, like Bladt and MT Højgaard, across the entire supply chain.

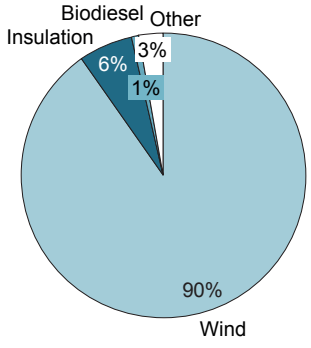
The biodiesel industry in Denmark is experiencing a large decline, as seen in other countries in the EU that have difficulties competing with the US and Argentina.

With companies like Rockwool, Denmark has a strong position in insulation material. However, insulation material is often manufactured close to the end market, which explains the relatively low share of this segment within the Danish sector.

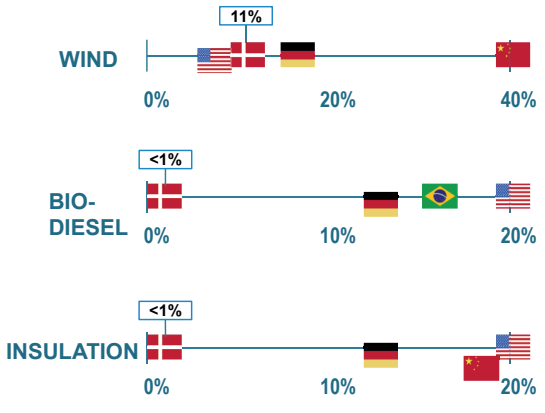
Danish cleantech sales [EUR bn]



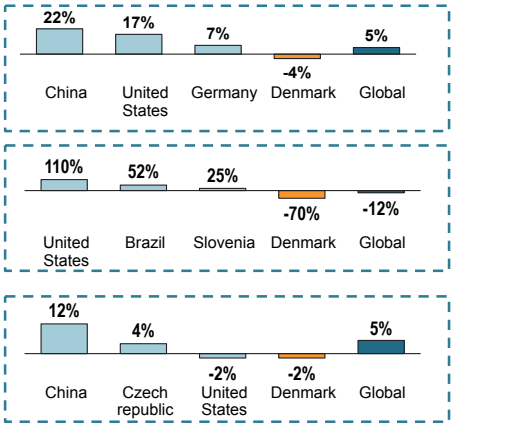
Danish cleantech sales by segment, 2011



Danish global market share



Danish growth in an international comparison



CHINA

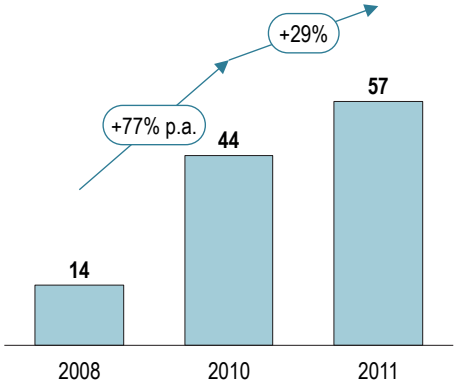
Growth in the Chinese cleantech sector slowed down, from 77% per year between 2008 and 2010 to 29% in 2011, though it remained three times higher than global growth of cleantech sales. Chinese cleantech production caters to more than 25% of global demand.

Chinese growth in wind is well above the global average of 12%. Production in China is from both domestic and international companies. In addition, Chinese wind turbines are shipped worldwide, enabled by low transportation costs that are around just 2% of the total cost of a turbine.

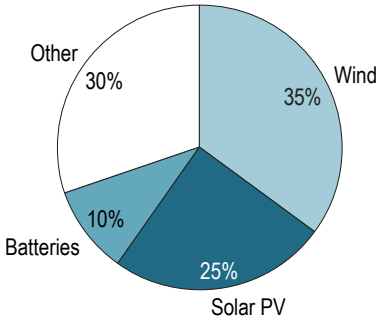
China's growth in manufacturing value in solar PV is well above the global average. Chinese companies are expanding their presence across the value chain and are now present in solar manufacturing equipment, as well. Their overall market share in solar PV is now around 35%, but exceeds 50% in, for instance, solar cells.

China is expanding its presence in other segments, as well. In batteries, for example, China is almost entirely responsible for global growth, and now holds a market share of 32% after doubling its sales figures.

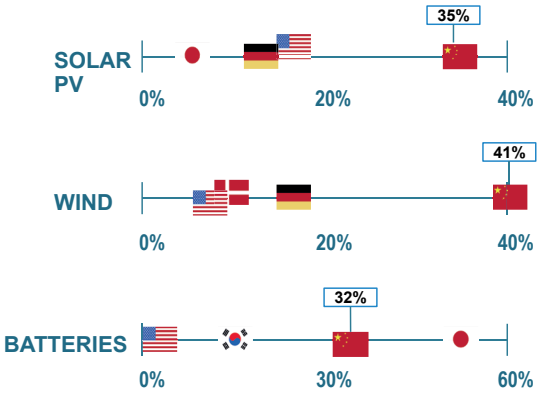
Chinese cleantech sales [EUR bn]



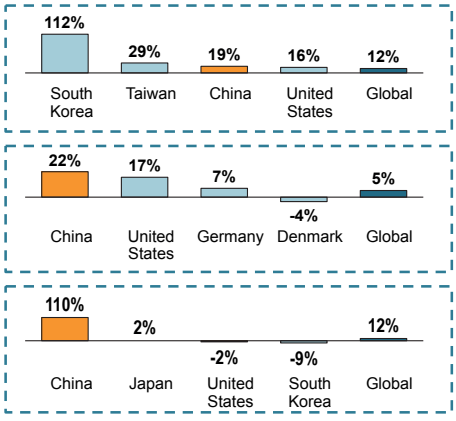
Chinese cleantech sales by segment, 2011



Chinese global market share



Chinese growth in an international comparison



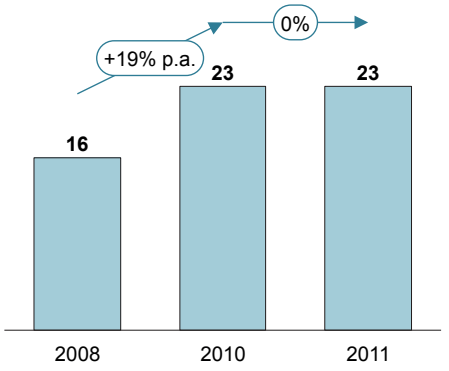
GERMANY

Growth in the German cleantech industry came to a halt in 2011, after having grown 19% between 2008 and 2010. With total sales of EUR 23 billion in 2011, it still comes in third in both the absolute and relative global cleantech ranking. Wind and solar PV account for 65% of Germany's sales.

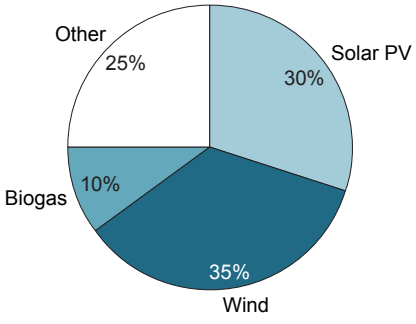
In Germany, the solar PV market has declined by around 15%. A shift in the global production of solar PV cells and modules to Asian-Pacific countries is being seen. German companies must now compete with lower-priced but equally high-quality products from Asia. Germany has expanded its sales in other steps of the value chain, such as manufacturing equipment and balance of system components (like inverters) by 16% and 40%, respectively.

The German wind energy industry is growing faster than the global market. German companies are able to benefit from the increase in US demand and produce part of the sales at home. Siemens, for instance, has increased its market share. Furthermore, the German industry is developing new turbines for offshore deployment. Complex partnerships with utility companies, foundation manufacturers and project financiers are evolving to bring these large offshore projects to fruition, like the offshore wind farms Alpha Ventus and EnBW Baltic 1.

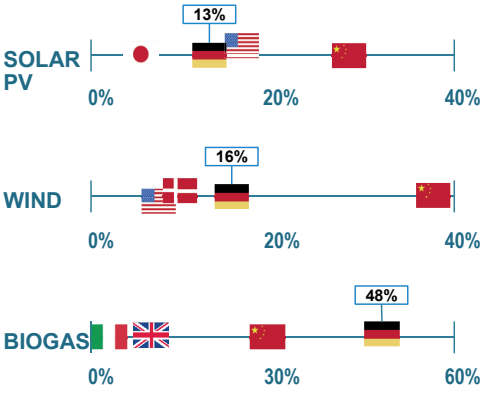
German growth cleantech sales [EUR bn]



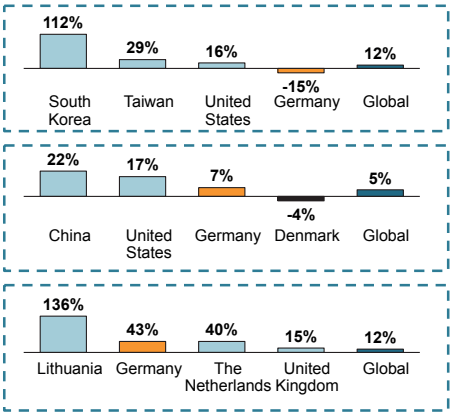
German cleantech sales by segment, 2011



German global market share



German growth in an international comparison



BRAZIL

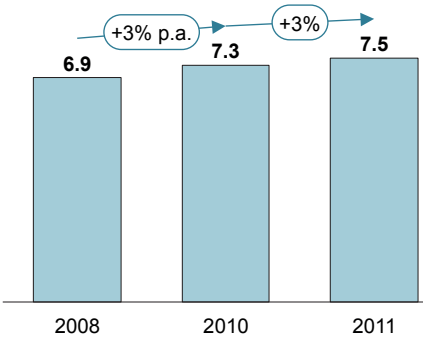
Brazil continues the 3% per year growth of its cleantech sector, with total sales amounting to EUR 7.5 billion in 2011. Brazil holds fourth place in the cleantech ranking. The majority of Brazilian cleantech sales are in bioethanol and biodiesel. Brazil has had a strong focus on biofuels since the 1970s, when the oil crisis pushed the country to replace foreign oil with domestic production.

Bioethanol declined slightly, caused by a bad sugar cane crop in Brazil. The 26% drop in production volume was partially compensated by higher prices, and total value declined just 5%. US imports of bioethanol and lower fuel blending requirements partially relieved the bioethanol shortage in Brazil.

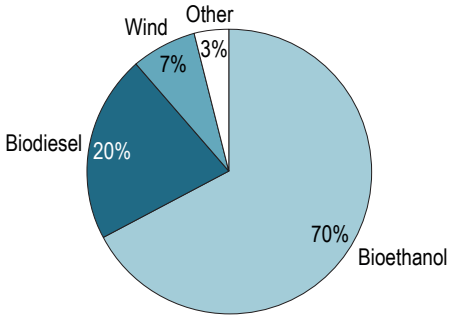
In contrast, biodiesel production in Brazil showed a strong increase of 52%. The Brazilian government sees biodiesel as an important means to increase family income in rural areas. The government thus raised fuel blending requirements to 5%, and this requirement will continue to rise.

Brazil is mainly active in producing wind turbine blades, though Brazilian production is highly volatile, showing a decline of 21% in 2011 due to financial problems at Tecsis.

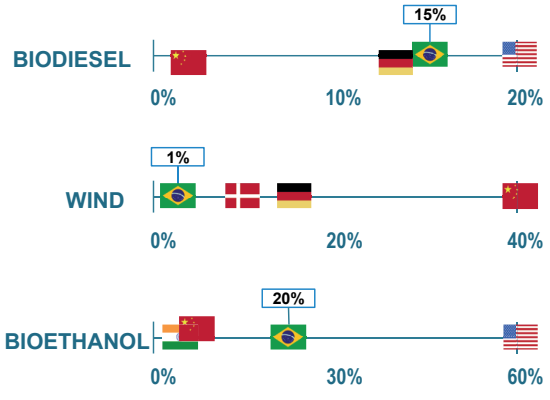
Brazilian cleantech sales [EUR bn]



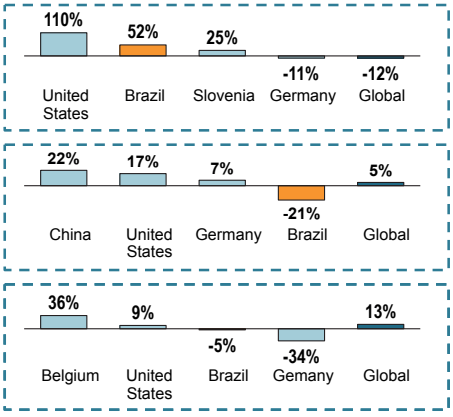
Brazilian cleantech sales by segment, 2011



Brazilian global market share



Brazilian growth in an international comparison



SOUTH KOREA

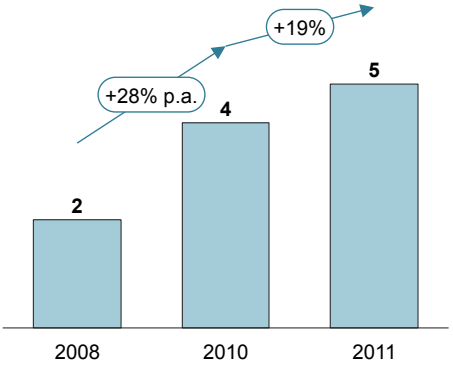
The South Korean cleantech sector grew 19% to a total of EUR 5 billion in 2011. Compared to the period 2008-2010, when the sector grew in line with the global sector, South Korea accelerated its pace and is now growing almost twice as fast as the global sector. As a result, South Korea now ranks 5th, jumping from its 8th place position in 2010.

South Korea has a strong position in ES batteries, solar PV and LED lighting. These sectors have been defined by the government as key to the country's cleantech growth objectives.

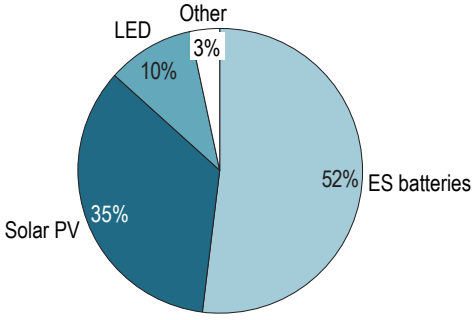
South Korea showed high growth in solar PV, mainly due to its strong position in silicon. New OCI manufacturing plants and others raised production capacity from practically nonexistent in 2007 to among the top 3 worldwide in 2011. Production of silicon is helped by relatively low and stable electricity prices in South Korea, which accounts for 30% of the cost of silicon. The production value of solar cells declined, mainly due to the lower price, since volume rose 10%.

In LED lighting, South Korea saw a 20% increase. This is mostly due to the production of high-brightness LEDs. Manufacturing equipment still originates from the US, the UK and Germany.

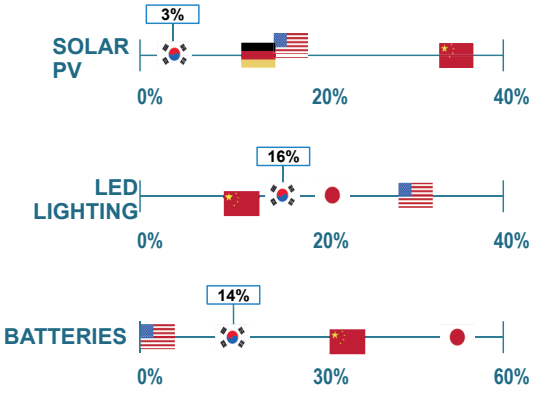
South Korean cleantech sales [EUR bn]



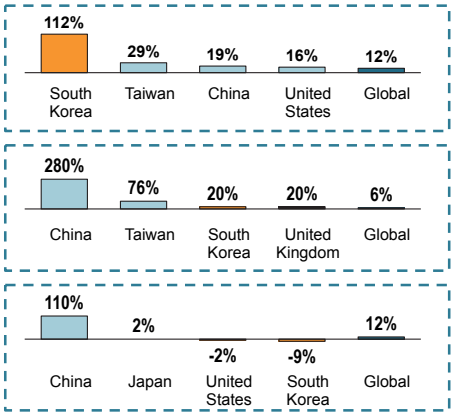
South Korean cleantech sales by segment, 2011



South Korean global market share



S. Korean growth in an international comparison



UNITED STATES

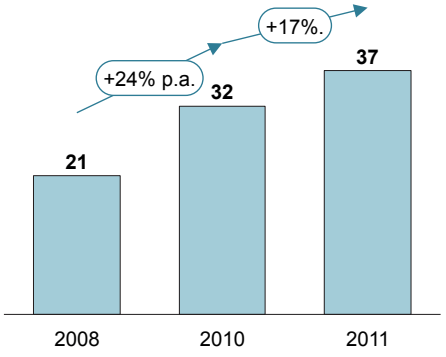
The cleantech sector in the United States grew 17% between 2010 and 2011, to EUR 37 billion. While growth slowed from an average of 24% per year between 2008 and 2010, it still exceeds average global cleantech sector growth. The United States has advanced two positions and now comes in 15th in the relative ranking.

The US is the global leader in bioethanol, with a market share of close to 60%. US bioethanol has increased 9% and partly made up for the decline in Brazilian production due to a poor sugar cane harvest. Biodiesel is the highest-growth biofuels segment, growing at 110% due to the 2011 reinstatement of a USD 1 per gallon tax credit for producers.

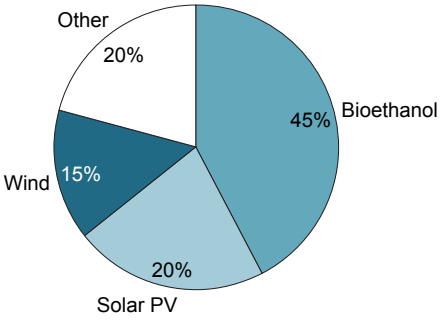
Despite 30% growth in US demand for wind turbines, wind turbine manufacturing in the United States grew just 17% in 2011. GE has lost market share worldwide, and other multinational companies have produced only part of their wind turbines in the United States. Uncertainty around US policies caused Mitsubishi to defer investing in a US manufacturing plant, as has been the case for other manufacturers looking to expand in the US market.

Even though the US faces tough competition from Chinese PV solar players, total US production has risen by 16% due to an increase in sales of solar PV manufacturing equipment and in silicon production.

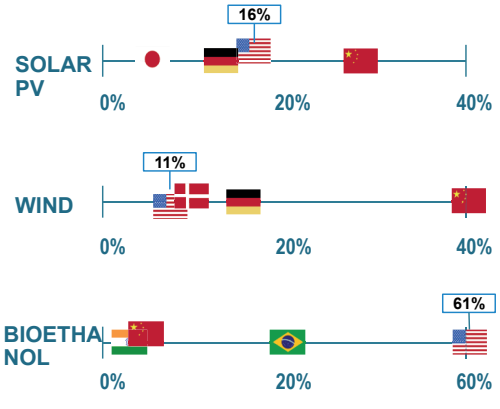
US cleantech sales [EUR bn]



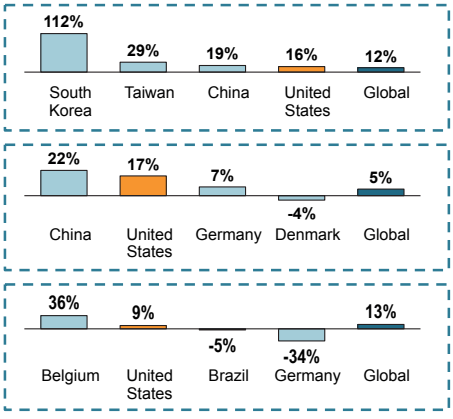
US cleantech sales by segment, 2011



US global market share



US growth in an international comparison



THE NETHERLANDS

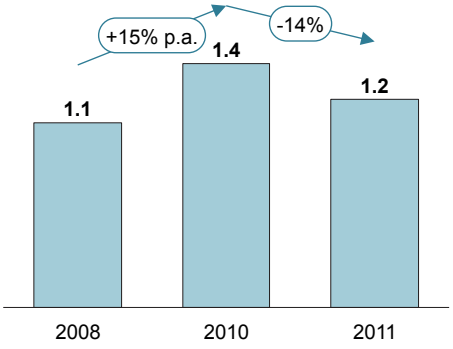
In a market that is growing globally, the Dutch cleantech market showed a significant decline of 14% in 2011, bringing the country down to 21st place in the global ranking. The Dutch market share in all of its stronger segments is less than 1%.

Dutch sales in wind, and especially offshore wind, declined by 60%. While Dutch players were involved in many new offshore wind farms between 2008 and 2010, their involvement dropped drastically in 2011, and Danish and German competitors increased their market shares in offshore wind in 2011.

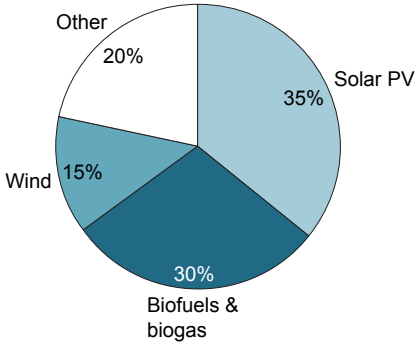
In solar PV, solar cell and module manufacturing suffered from a large drop in prices and production volume. Compared with 2010, the segment lost EUR 150 m. The Netherlands kept its relatively strong position in solar manufacturing equipment, showing a total increase of EUR 195 m. Therefore, overall sales increased by a modest 7%.

Though claimed as one of the Dutch strengths, the biofuels and biogas sector remained stable in 2011. While biogas production and installation manufacturing went up 37%, total production of biodiesel declined by 55%.

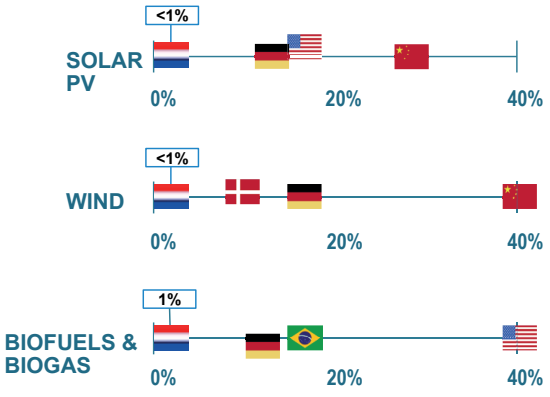
Dutch cleantech sales [EUR bn]



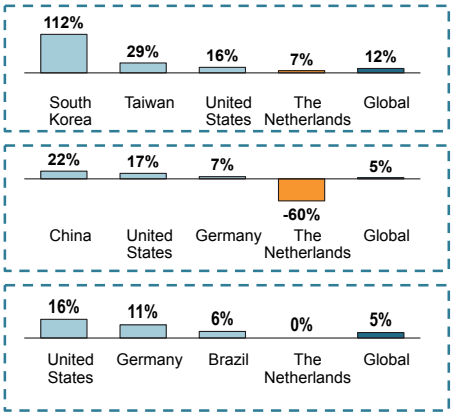
Dutch cleantech sales by segment, 2011



Dutch global market share



Dutch growth in an international comparison



4.2 Successful countries can guide other countries to grow their cleantech sector

The global cleantech market has grown significantly since WWF started monitoring the sector's development in 2008. The sector is now becoming more mature and some segments, such as wind, solar PV and biofuels, have become important sources of economic activity for some countries and regions. China, Germany and Denmark have gained large market shares in these sectors.

The country rankings for cleantech sales in 2011 clearly demonstrate the uneven growth of the global cleantech market worldwide. Many countries in Asia and the Americas have taken huge steps forward, although many European countries have kept their sales stable or even seen a decline in sales. This is in contrast to the previous sales ranking in 2010, where all countries saw growth.

In some countries of the European Union, governments do not give priority to cleantech sector development. The financial crisis immediately caused most countries to reduce their incentives to the sector, and these countries seem to lack a strategic vision for cleantech. Denmark and Germany, being exceptions in the EU, account for more than 60% of all European sales. The strong focus of the Chinese government on the cleantech sector as part of its economic development objectives and the consistent policy for the use of biofuels in the US have also created strong cleantech sectors in these countries.

Given the continued growth of the sector and the rise of new cleantech segments, such as electric vehicles, LED lighting and marine power, there are still sufficient opportunities available to all countries to play a large role in the growing cleantech sector. Looking at successful countries shows the best practices for developing a strong position in the current or upcoming cleantech segments.

The historical developments in China, the US, Denmark and Germany provide examples of how various regions have successfully fostered the growth of a cleantech segment. Also South Korea has also developed its cleantech sector favorably since the government made it one of its priorities. Based on these country experiences, we have developed five lessons from which other countries can benefit:

4.2.1 Stable long-term government policy provides the right conditions for the cleantech sector to flourish

The United States (biofuels), China (wind and solar) and European countries such as Denmark and Germany (wind), share clear and coherent policies for the development of their cleantech sectors or specific segments thereof. Each country has made the choice that cleantech will play an important role in its economy and industry structure. Each one has a comprehensive policy for the segments in which they excel. Cleantech is an important part of both their energy policies and their economic policies.

Since the oil crisis of the 1970s, the United States has undertaken various efforts to reduce its dependence on foreign oil. The US government introduced various policies to create a strong market pull for bioethanol use. Starting with a partial exemption for ethanol from the motor fuels excise tax, the US government continued the financial support of bioethanol until December 31, 2011. The renewable fuel standard (RFS) introduced in 2006 will take over the role of the financial support to create a domestic market. Under the latest RFS standard, 36 billion gallons of biofuel must be used each year by 2022.

In China, the conditions for the cleantech sector are well developed to accelerate the growth of the industry. Government policy for the cleantech sector is stable and the government sees the cleantech industry as one of its strategic industries. In its five-year plan, the government puts a joint focus on the development of the cleantech industry, the deployment of renewable energy, and taking energy-efficiency measures. The government has also set ambitious targets for renewable energy deployment by 2015: 100 GW of wind and 15 GW of solar by 2015. The energy intensity of the economy should be reduced by 16%. In the recent 12th five-year plan, the Chinese government has pledged to increase the domestic market for solar PV, enabling a shift from an export-driven to a domestic-demand-driven industry. Fluctuations in export demand due to changes in foreign subsidy regimes can then be absorbed by the domestic market.

In Denmark and Germany, the governments committed to developing the renewable energy sector in the aftermath of the 1970s oil crisis. Stable regulation with feed-in tariffs and preferred grid access created domestic markets in these two countries. Also Spain has developed its local wind energy industry with a combination of energy and industrial policies, fostering the use of local content

in its wind parks. In turn, the domestic markets gave the European wind industry the opportunity to improve on the technologies.

Of the fast-growing countries, the South Korean government has made a clear choice for renewable energy in its Green Korea Plan. While cleantech does provide great economic opportunities for South Korea, the government also sees it as a necessity, since more than 80% of its energy use has to be imported. The country has set mandatory targets on renewable energy use and energy efficiency. For instance, 30% of lamps must be in the form of led lighting by 2015, enabling the development of the local industry.

4.2.2 Focus on R&D from basic research to applied demonstration projects results in better cleantech products

Often, the government's cleantech policy coincides with a focus on renewable energy R&D. Some countries, especially smaller ones, focus on doing R&D in only in a few cleantech segments. The focus helps them build substantial skills in those segments that matter most to them and prevent spreading funds too thinly.

Once the United States made the choice to use more biofuels in the 1970s, investments in renewable fuels R&D were initiated. The government established a national research lab, which would later become the National Renewable Energy Laboratory. The US has been developing technology that can produce bioethanol more efficiently, and the US government sponsors many second-generation biorefinery demonstration projects, enabling the objectives of increasing advanced biofuel use in its RFS standards.

The Chinese solar industry has a strong focus on applied research, for which extensive government support is available. The Chinese government also promotes international collaboration on cleantech and collaboration between industry and academia. The quality and efficiency of Chinese solar PV cells are highly competitive with those from other countries.

Denmark has spent the majority of its renewable R&D budget on wind energy. With this focus on a single segment, Denmark was able to out-spend many other countries.[29] Denmark focused its R&D on "learning by doing".

[29] *Denmark is also the number 1 country in the WWF/Cleantech Group Global innovation index 2012*

Denmark's long history in learning by doing throughout the 1980s and 1990s has developed a competitive wind industry. Large test centers enable wind turbine manufacturers to cooperate with research institutes and other private partners to improve their products. In the 1980s, Germany developed large-scale demonstration projects.

4.2.3 Availability of sufficient capital fosters the development and use of cleantech

Companies need capital to develop new and better products and to scale up their production. Companies in their early stages have high capital requirements in order to bring their products from prototype to commercial product. However, uncertainty is also high in these development stages. Venture capital funds, in particular, have the ability to support these innovative companies in their development and cater to the combination of high capital needs and high uncertainty. Only companies in later stages of their development can rely on bank financing or list their equity on the stock exchange.

Also the adopters of cleantech need capital to buy these products. A distinguishing feature of cleantech is that the products are usually expensive to buy, but require little expenditure once installed. This is in contrast to fossil energy, which, besides the equipment, requires ongoing purchases of coal, gas and oil. This high capital outlay may deter adopters from adoption. Banks can provide loans and project financing to renewable energy project developers or companies investing in adopting cleantech.

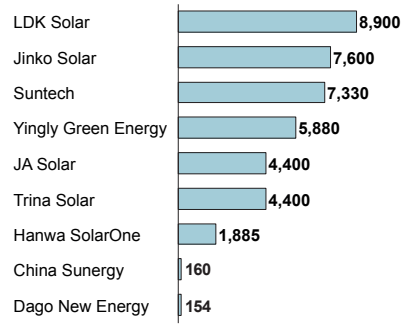
The United States has developed a thriving venture capital industry in California, Texas, Massachusetts and other states. The US venture capital industry is characterized not only by the large number of funds that target the cleantech sector, but many funds are also large enough to support companies throughout their development.

Chinese banks provide solar companies with capital at favorable terms to invest in production capacity and innovation. Being a strategic industry, cleantech companies and adopters have obtained easy access to capital compared with companies in the EU and the US, which have been facing difficulties since the financial crisis. Since 2010, Chinese PV Solar companies have obtained more than USD 40 billion in loan guarantees. Also the IPO market is functioning well. Of the ten largest public market deals, seven were from Chinese companies.

Figure 11. Chinese companies have easy access to capital

Easy access to debt financing

Loan transactions of Chinese banks to Chinese Solar PV companies [USD m]



Well-functioning IPO market

Top 10 public market deals

Company	Deal value [USD m]
Sinovel	1429
GD Power	862
Huaneng Renewables	799
OCI	692
Guodian	648
SDIC	507
Beijing Jingyuntong	394
Adecoagro	314
Darling International	307
SPC Environment Protection	282

In the European Union, the financial crisis made banks reluctant to provide loans and project financing. Countries in the European Union have already acted and anticipated this financing gap. The German government, for instance, created a fund at the Kreditanstalt für Wiederaufbau to participate in funding the first ten offshore windparks in the North Sea. Besides supporting the German offshore wind objectives, the fund also enables the German offshore wind industry to develop experience in this new market and later sell this abroad. The Danish Export Credit Agency (EKF) actively supports Danish companies through cleantech guarantees that provide insurance against loss and allow Danish companies to offer long-term credit to their customers. This credit sometimes determines the continuation of projects and certainly gives Danish companies a competitive edge. Also the European Investment Bank participates in financing cleantech projects. Finally, the UK is currently setting up a Green Investment Bank, and similar plans exist in the Netherlands.

The South Korean government has developed a set of policy measures to stimulate financial support of the cleantech sector. The Korean Financing Corporation will provide indirect debt and equity financing to cleantech companies and act as a loan guarantor to cleantech companies.

4.2.4 Cleantech adopters create a domestic market for cleantech companies

Often, governments have set targets for the use of renewable energy and energy efficiency and foster use with tax breaks or other incentives. However, the targeted users also need to act on these incentives and include cleantech in their normal course of business. Consumers and companies also have a responsibility to create a market for cleantech products. Countries where consumers and companies have created a market have contributed to the sector's development.

In the United States, fuel blenders are increasingly using bioethanol not only to benefit from tax incentives, but also to replace MTBE as a fuel oxygenator. Demand for ethanol has further increased thanks to the introduction of flexible fuel automobiles that can run on fuels with up to 85% ethanol content. In the United States, companies are replacing some of the cars in their fleets with electric vehicles and other green cars. AT&T, PepsiCo and Johnson & Johnson have more than 1,000 hybrid or electric vehicles in their fleets.[30]

Large corporations in the US are taking further action to reduce their CO_2 emissions. Google, for instance, invested USD 915 m in renewable energy plants (mainly wind and solar) and became carbon neutral by the end of 2007. Also Walmart has developed a viable store prototype that is up to 25% to 30% more efficient and produces up to 30% fewer greenhouse gas emissions, providing a great incentive to the cleantech sector.[31]

In the European Union, adopters of wind energy have been varied. In Denmark, local communities invested in wind turbines for their local communities. In Germany, citizens themselves invested in wind turbines. Project developers, utilities and even private equity funds have now built their wind farms, both onshore and offshore. Consumers in the European Union have also adopted green energy, fostering the deployment of renewable energy equipment. In the German state of Hamburg, 15.7% of consumers adopted green power in 2011.[32] In the Netherlands, even 54% of consumers had adopted green power by the end of 2011.[33]

[30] *Automotive fleet, top 50 green fleets, 2011*
[31] *Walmart CSR report, 2011*
[32] *Statista, 2012*
[33] *NMa,Rapport energiemarkt voor consumenten tweede helft 2011, 2012*

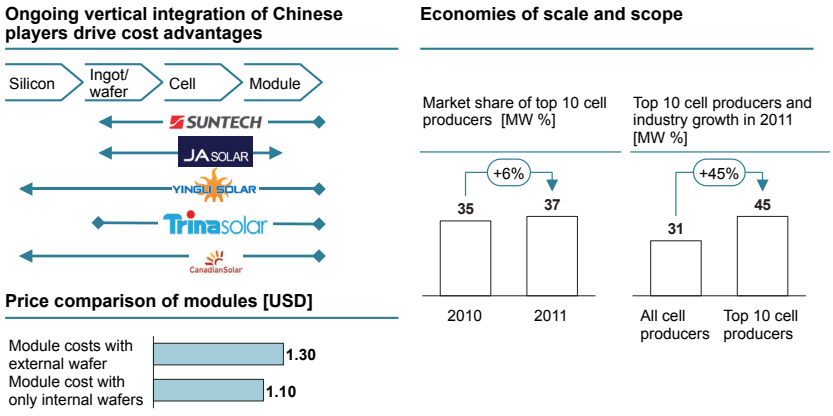
4.2.5 Large companies and a strong supply chain drive cleantech sales growth

Top-performing cleantech countries have established large companies in the sector and have built a cleantech cluster of supportive companies, including suppliers and clients, financial institutions and research institutes. Large companies can bring the sector to the next level. Producing on a large scale brings many efficiencies in the production process. Large-scale companies have the skills and resources to improve their products and expand their sales across the globe. A strong supply chain brings further operational efficiencies to the sector due to specialization of the cleantech players and the cooperation between companies in developing new or better products. Growth in the Solar PV industry has come from large companies. In wind energy, most players are part of large conglomerates, leveraging their experience in other fields and applying it to the wind energy business units.

Chinese companies benefit from their effective scale of operations. In solar PV, for instance, Chinese companies are pursuing a strategy to become active in several steps of the supply chain. Suntech claimed that it can reduce the price of its modules by 15% by manufacturing the wafers in-house. At the same time, Chinese companies maintain the flexibility to source some of the intermediate products from other suppliers to be able to adapt to price fluctuations. The larger players in the solar PV sector are able to grow faster. The top 10 players have grown 45%, at a faster pace than the average cell producers. As a consequence, the market share of the top 10 is expanding.

The Chinese government has defined the growth of large companies as a top priority. It wants the leading polysilicon suppliers to achieve a capacity of 50,000 tons a year, and the top cell manufacturers a capacity of 5 GW.

Figure 12. Chinese companies pursue a strategy of vertical integration and obtaining economies of scale



The wind energy industry in Europe consolidated in the first decade of the 2000s. Vestas acquired NEG Micon in 2004. Siemens bought Bonus and brought its large-scale experience into the energy business. India's Suzlon acquired a stake in REPower in 2007 and took complete ownership in 2009.

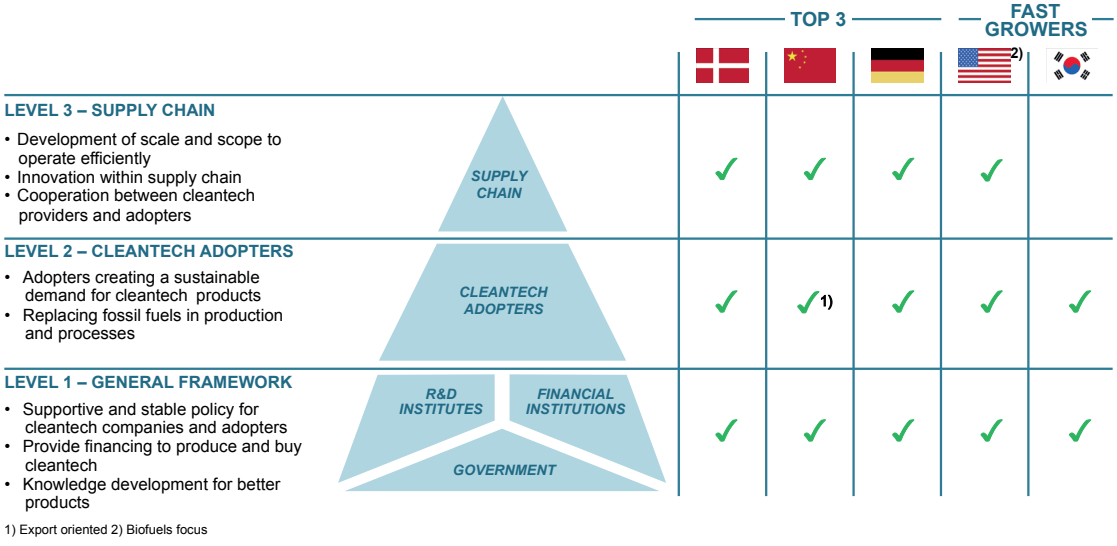
The European industry is currently redefining itself for the offshore wind market. Large and complex projects require extensive cooperation models between project developer, foundation, transition piece and turbine supplier, and installer. Due to the scale and complex nature of offshore wind, risks in the construction phase are high and players are devising ways to mitigate those with new collaboration approaches. New setups for these partnerships are being explored. RWE, for instance, has invested in installation vessels and will be involved in actual construction. DONG Energy has initiated long-term contracts and will develop several offshore wind farms with preferred suppliers.

4.3 Successful countries share a coherent, long-term and comprehensive approach that includes all stakeholders

The best-practice examples in the previous section share a comprehensive and coherent approach to the development of their cleantech sectors. This comprehensive approach is visualized in figure 13 by three levels of conditions.

At the first, foundational level, government, R&D institutes and financial institutions shape the right conditions for the cleantech industry to develop and grow. At the second level, the cleantech adopters (customers) create a market for cleantech products. The successful adoption of these products critically depends on the enabling conditions created by government, financial institutions and R&D institutes. Finally, at the third level, the cleantech industry must develop into an effective industry that can exploit economies of scale and cooperate along the supply chain to improve products and production processes. Figure 13 illustrates the connection between these three key stages in the cleantech "growth pyramid". It also shows which country example led to these insights.

Figure 13. Best-practice conditions for growth of cleantech manufacturing



1) Export oriented 2) Biofuels focus

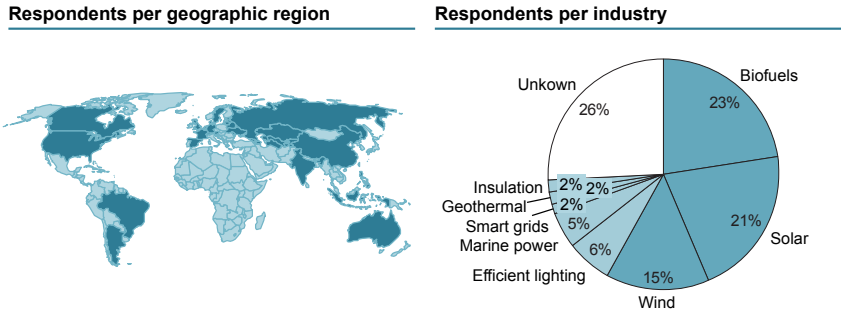
5. Recommendations

The previous section provided an overview of best practices from Denmark, China, Germany, the United States and South Korea. Fostering the sector's growth on three levels has been the basis of these countries' success. In many countries, including the countries that are already successful, companies may still face barriers to growing their business. Central in this section is a survey among 62 cleantech companies in the US, China and the EU that provides the most recent look at how cleantech companies today view barriers to and conditions for increased cleantech sales growth. The responses from these 62 companies guided our assessment of the performance on the three levels of the cleantech "growth pyramid" as presented in the previous section. Based on these outcomes, we have developed recommendations to accelerate the growth of the cleantech sector in the United States and the European Union. We also made recommendations for China to stay ahead of competition and become the number one cleantech country.

5.1. Barriers inhibit the countries from capturing the full potential of the cleantech sector

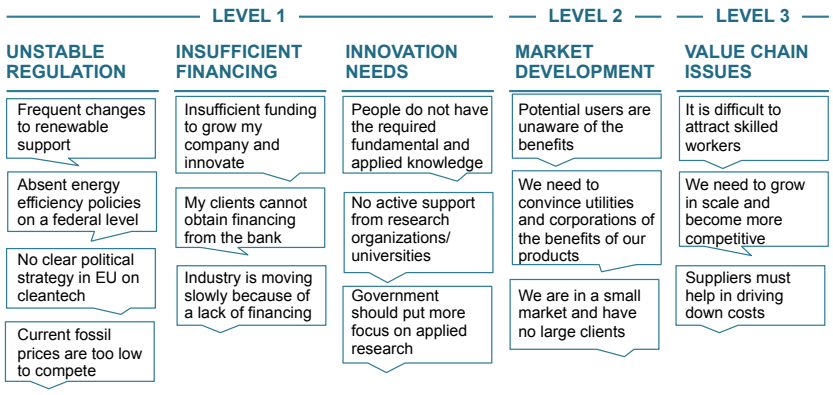
To understand why regions and countries are not capturing the full potential of the cleantech sector, we conducted a survey among cleantech companies. Companies in each region were asked to name the barriers that most severely hamper their growth, how they would prioritize these barriers, what actions are needed to overcome the barriers, and how they would compare the different regions. Sixty-two companies representing a range of cleantech segments from all over the world responded to the questionnaire.

Figure 14. 62 cleantech companies participated in the survey



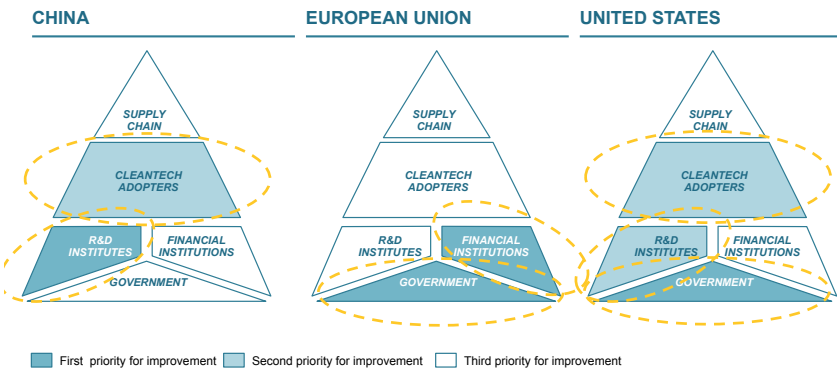
Responses were classified in five categories corresponding to the three levels of the cleantech growth pyramid.

Figure 15. Grouped selection of responses



While barriers are present in all regions, the degree to which they affect the business of cleantech companies differs from one region to the next. The cleantech survey revealed differences between the effects the barriers may have on cleantech companies in China, the European Union and the United States. The outcome of the survey led us to investigate further to identify the mechanisms behind these barriers. Figure 16 shows the areas on which each region should focus its efforts to improve its cleantech business climate.

Figure 16. Prioritization of levers to be improved in China, the European Union and the United States



China can improve its R&D and the adoption of cleantech to stay ahead. The governments of European Union countries can work on both the energy and industry policies for cleantech and the European financial sector can contribute more to cleantech. The government of the United States should focus on creating more comprehensive, long-term policies for cleantech and R&D and enable better adoption of cleantech.

5.2 To stay ahead, China can invest more in basic R&D and let consumers and companies adopt more cleantech

To stay ahead, China should prioritize two levers. First, it should increase funding of basic R&D. Second, it should build awareness and cleantech acceptance among companies and consumers. These two recommendations will strengthen the Chinese cleantech sector, enabling it to sell more and better products at home and abroad.

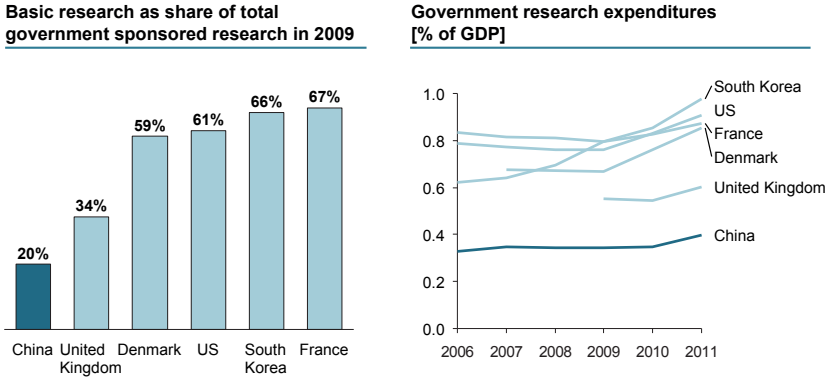
R&D institutes: Increase funding of basic R&D

Cleantech is a highly innovative sector. The efficiency of solar cells has risen to over 20%, wind turbines have grown to a size of 6 MW and the color of LED lighting is approaching that of natural light. The costs of most technologies have come down and the costs of some renewable energy technologies are nearing grid parity. The sector's innovation is a direct result of the basic research being conducted at universities, applied research institutes and corporate labs.

While the Chinese government fosters applied research, the quality of its basic research is behind that in other regions. The leadership in terms of developing innovative low-carbon technologies remains in Western countries.[34] This trend is being seen in other fields, as well. A study conducted by the World Bank and China's cabinet concluded that the quality of Chinese research falls short. The report noted that the country produces relatively few high-impact articles, and that the majority of Chinese patents constitute minor novelties rather than genuine innovations. Also, the IEA has set in its wind energy roadmap that China should carry out basic energy research and common technology research to solve some technical difficulties faced by Chinese manufacturers.[35]

[34] *CIEP, China and the Future of New Energy Technologies, 2012*
[35] *IEA, Technology Roadmap – China Wind Energy Development Roadmap 2050, 2011*

Figure 17. R&D in China compared with other countries



The Chinese government should allocate more resources to basic research in renewable energy and energy efficiency. It should also raise the attractiveness of basic research jobs to attract the brightest talent. In addition, the government should continue to promote all types of research, including applied research and pilot and demonstration projects.

Cleantech adopters: Build awareness and cleantech acceptance among companies and consumers

Since the Chinese government has set highly ambitious targets for renewable energy adoption, it must ensure that companies can connect new generation capacity to the grid. Energy efficiency improvements in China are largely being implemented by large companies rather than small companies. The Chinese construction sector can use more green building materials. Though initial costs may be higher, the total costs will be lower in the end. An increase in local demand for cleantech products will help grow cleantech, improve the products and secure a return on the investment. Cleantech adopters need to adapt their current business practices to enable the inclusion of cleantech in their businesses and to create stable demand, as well as a stable market.

Before they can make a well-informed decision on cleantech, Chinese companies and consumers should be made aware of its economic and technological benefits. Company management can then include the long-term advantages of cleantech in their targets, even though, in the short term, higher capital expenditures may cause temporary deviation from financial boundaries.

Company management must also invest in adapting certain business processes to use cleantech technologies.

Chinese consumers can also foster cleantech market development by choosing products that have a lower carbon footprint. When choosing an apartment, for example, preference should be given to those that have better insulation and use renewable energy supply (heat pumps, solar thermal, BIPV). Consumer demand for such products will bolster company supply.

5.3 Countries in the European Union should develop a strategic vision for cleantech and make more capital available to cleantech companies and cleantech adopters

The European Union is losing ground in the cleantech sector. Cleantech sales declined in 2011, and the European countries should take action to create growth again. Its first priority should be for the European government to develop a strategic vision and stick to it. Second, it should provide more capital to cleantech companies and cleantech adopters.

Government: Develop a strategic vision for the cleantech sector that provides a stable basis for long-term policies

The European Union has developed a coherent renewables vision for 2020, including a target of 20% renewable energy by 2020. EU law has divided this target among member states into legally binding national targets. EU member states have the flexibility to use their own policy instruments to achieve these targets. EU policy has played a major role in motivating renewables growth in the EU over the past decade.

While the European Union has developed its vision for renewable energy, the EU member states have often not set a coherent and stable long-term vision. As a consequence, the member states' policies and incentives have seen frequent changes. The surveyed companies in the European Union confirmed the fact that the European Union is a patchwork of countries with different and changing systems. While Germany and Denmark are often seen as examples for the world, other countries in the EU, are not. In Spain, the financial crisis prompted the Spanish government to abandon its support of renewable energy. In France, the government has frequently changed the solar PV tariffs, and only recently seems to have developed a sound framework for the development of offshore wind.

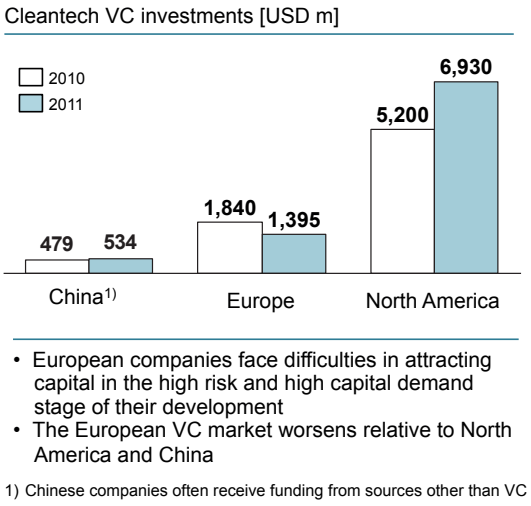
The EU target approach and vision should be matched by a similar approach on the national level. The countries of the European Union should develop a clear and coherent vision for cleantech development and for their renewable energy and energy efficiency objectives. Only then can countries develop a stable policy that can provide long-term incentives to the market and provide market participants with sufficient security to invest.

The European Union can also provide more stability to the market. Extending targets to 2030 will give the market long-term investment certainty. In the meantime, a strategic EU vision on renewable and energy-efficient technologies should not focus solely on realizing energy targets; it could also benefit from a stronger focus on the economic potential of the cleantech manufacturing industry. By doing so, the EU can include the cleantech sector in its plans to stimulate economic growth.

Financial institutions: Make more capital available to cleantech companies and cleantech adopters

Providing capital is the main responsibility of the financial sector, which includes asset managers, pension funds, banks and regulators. There is a major need for cleantech venture capital to provide equity financing to entrepreneurs and firms in their development and expansion stages. While research institutes are developing sound knowledge, turning this knowledge into new products is difficult because of a lack of capital. The supply of venture capital is scarce in Europe, and even declined further in 2011. This is in strong contrast to the United States.

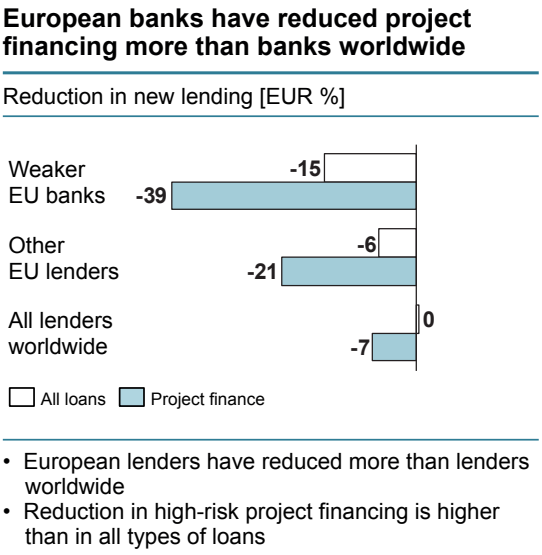
Figure 18. European cleantech companies do not receive sufficient venture capital



More funds dedicated to cleantech venture capital would enable European companies to bring their innovations to the market and advance their position in the global marketplace. European investors should acknowledge the financial opportunities of cleantech in their investment portfolio and, in turn, the European venture capital community should raise more funds dedicated to cleantech. By looking at US experiences and working with US VC funds investing in cleantech, the European venture capital community can improve the funding available to entrepreneurial cleantech companies. European governments can assist by contributing a minority share in a VC's fund, thus expanding the amount of capital available to cleantech and, at the same time, developing a thriving venture capital community.

The second financing issue in the European Union concerns the decline in available project financing, and thus also the decline in cleantech investments. While cleantech typically involves high capital expenditures and low operational expenditures, the adoption of cleantech is hindered by the absence of sufficient loans and project financing. In Europe, finance capital for renewable energy was severely restricted by two factors: a lack of long-term funding available in the market and the impact of financial legislation. Compared with lenders worldwide, European banks have reduced new lending by 6% and 39%.

Figure 19. European banks have reduced lending more than banks worldwide



Adopting cleantech products often involves a large capital investment. Large wind projects, or investments in energy efficiency or geothermal energy, are often delayed or deferred due to difficulties in obtaining financing. Even though the project itself can be profitable, the project developer may not get the required financing from banks or other financial institutions. Due to the large capital and low operational expenditures of cleantech, the risk and return characteristics of these investments differ from other projects. The unique characteristics of cleantech projects require a different financing approach.

European asset managers and other financial institutions should incorporate the different characteristics of cleantech investment in their credit and risk management policies. The financial sector should also take their corporate social responsibility and scale up investments in renewable energy and energy efficiency projects. The financial sector can develop specific financing solutions for cleantech investments that allocate and share risks and returns in accordance with the investors' ability to assume those. Furthermore, European banks should actively seek funds from the government or government-sponsored financial institutes to close financing deals, or actively contribute to deals sponsored by these government players.

5.4 The United States should develop a more stable policy support system and create a more stable R&D budget

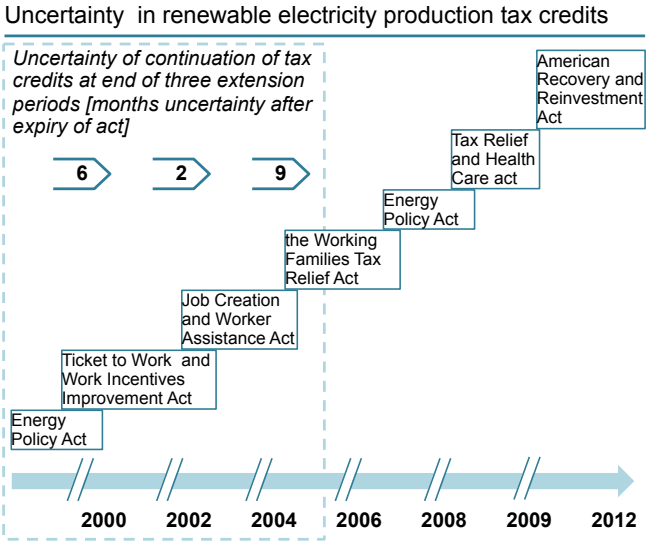
The United States has a strong position in biofuels, but it has not yet developed a similar position in other cleantech segments. The United States should develop a more stable policy support system at the national level and create a more stable R&D budget.

Government: Develop a stable policy support system for cleantech products at the national level and align policies across states

The biggest challenge in the United States is the development of sufficient, stable government policies that will foster the cleantech industry. While the US has successfully advanced the bioethanol industry with a federal excise tax exemption and federal renewable fuel standard, the US does not have such standards for the electricity sector at the federal level. Some states have independently developed their own renewable portfolio standards, though the details and ambitions of these standards varies considerably. In the survey, companies mentioned the absence of federal standards as a barrier to conducting sales.

At the federal level, investment in wind energy is driven substantially by a production tax credit (PTC). While these credits have existed since the early 1990s, the duration has often been only a few years, creating a boom and bust cycle in the installation of wind energy. The PTC for wind will expire again at the end of 2012, and the American Wind Energy Association says that 37,000 jobs could be lost if the PTC is not extended before the end of the year. As a consequence of this uncertainty, the US has invested less in R&D and relied more on foreign manufacturing due to insecurity regarding long-term profitability.

Figure 20. Succession of US acts providing production tax credits



The US federal government should develop a more comprehensive, long-term approach to supporting renewable energy generation that replaces short-term programs like the production tax credit. Longer-term support is crucial to create more stable demand for cleantech and provide companies with greater investment security.

The most important aspect of cleantech policies is that they provide long-term stability and predictability, allowing cleantech companies and adopters to make long-term investment plans. Favorable, predictable and long-term tax policies, sufficient manufacturing incentives, and streamlined transmission and siting processes (e.g. priority grid access and accelerated permitting) are some of the most important national-level policies that need to be strengthened. Policy frameworks should also be designed to stimulate innovation to precipitate cost declines and further improvements in technology.

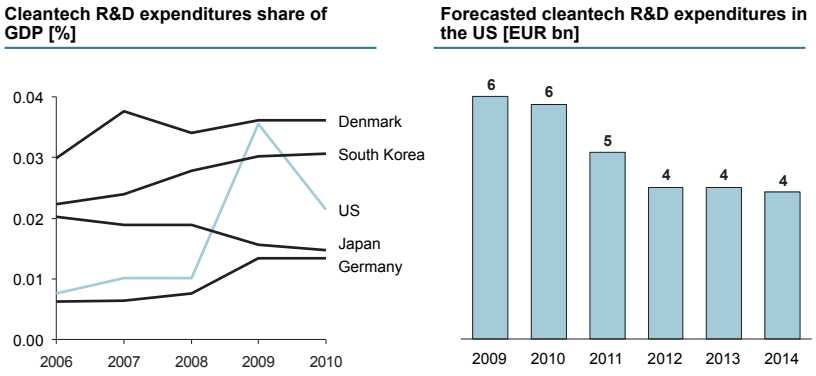
Furthermore, to provide more policy continuity and reduce challenges associated with the state patchwork of often conflicting policies, state and federal policy should better align to accelerate deployment of cleantech. While differences among the 29 states with renewable portfolio standards reflect local energy circumstances, different implementation policies create an unclear climate for investors. States should do what they can to work together to

harmonize rules and processes, but ultimately, what is needed are coherent national policies, a national clean energy standard and a carbon price.

R&D institutes: Create a more stable cleantech R&D budget to increase innovation and drive down costs

Similar to creating more certainty to support the cleantech market, stable funding for cleantech R&D is important to maintaining quality research institutions and hence research outcomes. Public investments in R&D are critical to developing new, improved technologies in which the private sector might not otherwise invest. Stable and sufficient cleantech R&D also provides opportunities for more extended, productive public-private research partnerships to test and deploy new technologies and reduce costs. While funding through the American Recovery and Reinvestment Act boosted cleantech R&D in recent years, the phase-out of funding perpetuates an unstable cycle that compromises cleantech research objectives and impedes prospects of bringing new, better technologies to the marketplace.

Figure 21. US R&D expenditures for cleantech

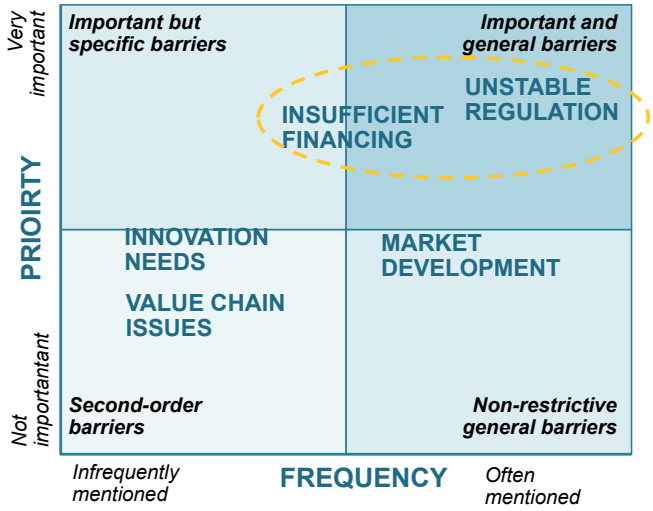


The US government should provide more stability in funding cleantech R&D. Long-term R&D roadmaps should be matched with long-term R&D budgets that enable research institutes to conduct their research and achieve their objectives. These budgets should also include funds for pilot and demonstration projects, with a strong role for research and demonstration partnerships with the private sector. The United States should further assess its optimum spending on cleantech R&D, which, even at an all-time high in 2009, was below Danish R&D expenditures relative to its GDP.

5.5 Worldwide, countries should improve government policies and financing of cleantech

The recommendations for the US and the EU show that government policy is the main barrier to cleantech sector growth. This is also confirmed by the 62 companies in the survey. Figure 22 charts their category responses according to the number of times they were mentioned, as well as the priority level respondents assigned to them. The survey clearly reveals that unstable regulation and insufficient financing are seen as major obstacles to sector growth worldwide.

Figure 22. Importance of barriers to global cleantech growth



A global priority for cleantech sector development is therefore that governments develop a clear strategic vision for cleantech. This vision must be supported by stable long-term policies that provide incentives for companies and adopters to sell and purchase cleantech. Setting targets, providing financial incentives and solving non-financial bottlenecks to deployment supports cleantech in competing with fossil alternatives. Government stability will also give financial institutions the stability to provide more capital to cleantech.

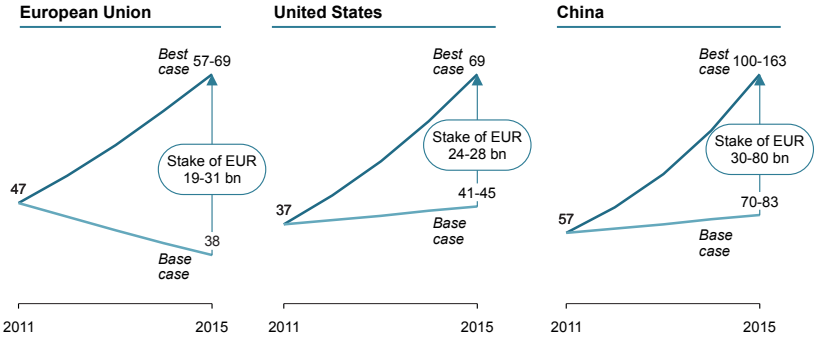
The second global priority is enabling sufficient financing for the cleantech sector. It concerns capital for both the development of cleantech companies and the deployment of cleantech. Financial institutions should incorporate the benefits of low carbon in managing the risks of their portfolio. Acknowledgement of the specific characteristics of cleantech, with its high capital expenditures and low operational expenditures, should lead to financing solutions that cater to the needs of capital providers and cleantech adopters.

5.6 Implementing the recommendations enables countries to seize large economic opportunities

The question is not whether the cleantech market will continue its growth. By 2015, it may have added another EUR 40 to 90 billion to its 2011 market value. The true question is which region will capture this growth. The race is on. To win that race and capture their share of the cleantech market's growth, countries and regions should implement the recommendations in the section above.

We have calculated the stakes of the three major cleantech regions in the race. These stakes are based on the difference between the sales value in 2015 in the base case and in the best case. In the base case, countries do not implement the recommendations and therefore continue on their current trajectory. In the best case, they take steps, like the ones outlined in the recommendations of this report, to increase their cleantech sales.

Figure 23. Stakes in the cleantech race of the three major regions



In 2011, sales in the European Union declined by 5%. If this decline continues, total European sales in 2015 will stop at EUR 38 billion. We defined this as the base case. Our proposed recommendations suggest that the countries of the European Union can return to the same growth rates as the overall cleantech market of between 5% and 10%. In this best case, European countries will achieve a 2015 sales value of EUR 57 to 69 billion. Hence, in the European Union, EUR 19 to 31 billion is at stake.

The United States has a strong position only in biofuels. In the base case, the United States is able to grow only this biofuels segment in line with the market, at 5-10%, while its other cleantech segment sales remain stable. In this base case, sales in 2015 will be between EUR 41 and 46 billion. There are a number of recommendations that the US can follow to improve the development of its other cleantech segments. In the best case, the US will remain a cleantech frontrunner, and sales in each of its segments will continue to grow at the same rate as today's average rate of 17%. In this best case, its cleantech sales could then total EUR 69 billion by 2015. Hence, in the United States, EUR 24 to 28 billion is at stake.

China was responsible for the majority of the cleantech sector's growth in 2011. If it can stay ahead and continue to grow three times faster than the global cleantech market, its sales will end up between EUR 100 and 163 billion by 2015 in the best case. If China were to lose its competitive edge, it would end up in the base case, and growth could slow to the global average of 5-10%. For China, that puts EUR 30 to 80 billion at stake.

These stakes are only the beginning. The road toward a 100% renewable energy future will provide many opportunities in the cleantech sector. Countries that gain a strong position in cleantech in the coming years have the best prospects to capitalize on the enormous growth expected for the decades thereafter. Furthermore, cleantech improves the competitive position of a country at a time when the secure supply of fossil fuels is becoming increasingly scarce. The ability to produce alternatives will become increasingly valuable.

Appendix A - Methodology

The cleantech country ranking measures cleantech sales per country – how much is earned through the manufacturing of cleantech products and technology. The ranking includes the 27 EU member states, the G7 countries, the BRIC countries, and South Africa, South Korea, Taiwan, Mexico, Indonesia and Australia.

To measure the status of each country, we analyzed the sales value of the major renewable energy and energy efficiency technologies in 2011. Renewable energy is defined here as the technologies for generating heat, electricity or transportation fuels. Energy efficiency comprises those technologies that are dedicated only to increasing efficiency or replacing less efficient technologies. Insulation and lighting solutions are considered in the study, for example, because they are dedicated solely to increasing efficiency. Products where incremental advances have been made, such as household appliances or cars with energy-efficient engines, have not been included. Although we recognize that the contribution of these products can be significant, they are not dedicated solely to reducing CO_2 emissions. It is important to note that we have excluded hydropower in this ranking. The environmental damage caused by hydropower and hydrodams contributes to global warming. Furthermore, hydropower has been used for more than a century and thus does not represent a new or innovative application of cleantech. We acknowledge that this is an important industrial sector in countries like Austria, Germany, France and China, but exclude it from our definition of cleantech for the purposes of this report.

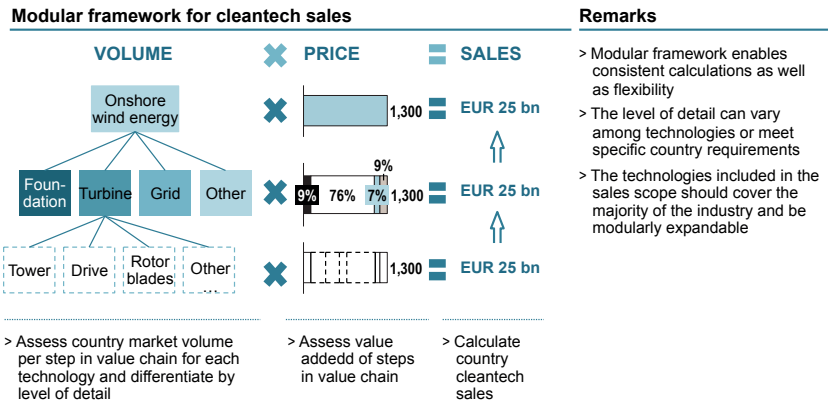
The sales value of manufacturing cleantech products in each country has been calculated. We attributed this value to the country where the products were manufactured. For instance, if a Japanese company manufactured a solar cell in China and sold it in the US, the value of the solar cell was attributed to China. To show the economic potential of cleantech, we only counted the manufacturing of tradable goods.[36] This means that we counted capital expenditures on cleantech goods, but we did not count operational expenditures or local installation costs.[37] Counting operational expenditures or local installation costs would imply that we implicitly measure adoption as well, rather than just the manufacturing part of cleantech. Although adoption of cleantech also adds economic value to a country, other rankings already show which countries have already deployed cleantech on a large scale.

[36] *Tradable goods are those that have export or import potential. Their prices are set in international markets*

[37] *Except for those technologies where installation has the characteristics of a tradable good, and foreign companies and laborers are specialized in the installation, for instance in offshore wind or geothermal energy*

The methodology is based on a modular framework to include a country's manufacturing contribution at each step of the value chain of each cleantech segment. This modular approach enables the allocation of manufacturing value to countries for separate value chain steps, and avoids the allocation of all manufacturing volume to the country that makes the final product. For instance, a Danish wind energy turbine may include a Belgian gear box. While the wind turbine could be sold by a Danish company, the value of the transmission in this wind turbine was allocated to Belgian sales, and the other parts of the turbine to Danish sales.

Figure A. Modular approach to sales calculation



The sales value was calculated in three stages. In the first stage, the manufacturing volume at each step of the value chain was totaled for each country. The second stage determined the cost share per step in the value chain. The total costs of a cleantech product were allocated to the various production steps in the value chain. In the third stage, the value per country now equals the manufacturing volume at each step in the value chain, multiplied by the cost share per step in the value chain.

The ranking is based on the following cleantech segments:

- Wind energy (onshore and offshore)
- Solar PV
- Solar thermal
- CSP
- Geothermal
- Biodiesel
- Bioethanol

- Biogas
- Heat pumps
- Insulation
- LED lighting
- Compact fluorescent lighting
- Electric vehicles
- Fuel cells
- Micro CHP
- Batteries

There is, as yet, no single source available with comprehensive data on the cleantech manufacturing industry. Therefore, the ranking is based on a broad range of sources, including industry trade organizations, broker and industry reports, and the annual reports and investor presentations from the cleantech companies themselves. A complete list can be found below.

- Biofuels Platform - statistics
- Bosch Thermotechnik - The market for thermotechnology
- BSRIA - UK market Update 2011
- BTM Consult - World Market Update
- Bundesverband Solarwirtschaft - Statistische Zahlen der deutschen Solarstrombranche (Photovoltaik)
- Center for Agricultural and Rural Development, Ethanol Price 2005-2010
- Central Bureau of Statistics - Statline database
- Chi-Hsun Lin and Mong-Chiao Huang, LED Lighting Industry, ITIS Program, 2010
- China Association of Lighting Industry, several publications, 2011-2012
- Citibank, Asia Solar View, 2011
- Clean Edge – Clean Energy Trends 2008-2012
- Comext - External trade database
- Commerzbank, Inverter market, 2012
- CRISI Research, Independent Equity Research, 2011
- Delta Energy & Environment Ltd, several publications on Micro CHP, 2009, 2010 and 2011
- Deutsch Energie-Agentur, Biogaspartner - gemeinsam einspeisen, May 2010
- Ecoprog & Fraunhofer Umsicht, The Market for Biogas Plants in Europe, June 2010

- Emerging Markets Online - Biodiesel 2020: Global Market Survey, Feedstock Trends and Forecasts
- Energy Information Administration, several publications, 2010-2012
- ePure, European Production Capacity Installed, August 2010
- EurObserv'ER - Barometer (various versions)
- European Biodiesel Board - statistics
- European Commission, Strategic energy technologies information system, Geothermal Energy, 2011
- European Heat Pump Association, Outlook 2010, 2011
- European Photovolatics Industry Association - Global Market Outlook for Photovoltaics until 2013
- European Photovolatics Industry Association - Solar generation V 2008
- European Solar Thermal Industry Association - Concentrated Solar Thermal Power - Now!
- Eurostat - Statistics database
- Fachverband Biogas e.V., Biogas Branchenzahlen 2010
- Farms.com, 2010 Annual Ethanol Production = 13.23 billion gallons
- Freedonia Group, World Insulation, 2011
- FuelcellToday, The Fuel Cell Today Industry Review 2011, 2011
- GCL-Poly Energy Holdings Limited, 2010 Full Year Results, March 2011
- Geothermal Energy Association - Geothermal Industry Employment: Survey Results & Analysis
- Geothermal Energy Association, Geothermal Energy: International Market Update, May 2010
- Global Wind Energy Council - Global Wind Report 2008, 2009, 2010 and 2011
- GTM Research, several publications, 2009,2011 and 2012
- Hong Kong Exchanges and Clearing Limited, NVC Lighting Holding Limited
- IAL Consultants, The Chinese Market forThermal Insulation, 2011
- IHS Emerging Energy Research, several publications, 2010-2012
- IMS Research, several publications, 2010-2012
- International Geothermal Association - statistics database
- International Institute of Refrigeration, Newsletter no. 45, January 2011
- Islandsbanki, U.S. Geothermal Industry Overview, February 2011
- IPVEA, Knowledge increases innovation - 2011 report, 2011
- Jefferies - CleanTech Primer

- Jefferies International Ltd., Energy Storage - Battery Technology, 2011
- JRC Scientific and Technical Reports, Renewable Energy Snapshots
- 2009, 2010 and 2011
- JRC Scientific and Technical Reports, PV status report, 2011
- KPMG, World Geothermal Market & Outlook, 2010
- LEDinside, HB-LED market to grow, 2011
- LEDsmagazine, LED market grew, 2012
- Lux Research - several publications, 2011 and 2012
- Marketsandmarkets, Micro Combined Heat & Power (CHP) (Microgeneration) Market by Technology, Geography, Application, Regulation and Market Trends (Forecast to 2016), 2011
- MAKE Consulting, Wind Energy Market Share 2010, March 2011
- Marketbuzz, Solarbuzz Annual World Photovoltaic Market Review, March 2011
- Müll und Abfall, Der Biogasmarkt in Europa kommt bis 2020 in Fahrt - Deutschland bleibt Vorreiter, 2011
- Navigant Consulting Europe, Ltd., Review of Sales and Inventory Estimates, 2011
- NREL, Concentrating Solar Power Projects, June 2010
- Photon Magazine, several publications, 2011
- Photon International, several publications, 2010, 2011 and 2012
- Pike research, various market reports, 2010-2012
- Prodcom - statistics database
- Renewable Energy World, Can Europe Solar Thermal Compete?, March 2011
- Renewable Fuels Association - statistics
- Renewable Fuels Foundation, 2012 Ethanol Industry Outlook
- Roland Berger - various reports
- Ruggero Bertani, Geothermal Power Generation in the World 2005-2010 Update Report, April 2010
- SEIA, several publications, 2011 and 2012
- SEMI Industry Research & Statistics, several publications, 2010-2012
- SolarServer, several publications 2010, 2011 and 2012
- Sonne Wind & Wärme - several publications, 2009-2011
- U.S. Commercial Service China, HVAC Industry Overview, 2011
- U.S. Energy Information Administration, Geothermal Heat Pump Manufacturing Activities 2009
- USDA Foreign Agricultural Service, several reports, 2009 - 2012
- VLSI Research, several publications, 2010-2012

- Vrinda Bhandarkar, World Status of SSL Manufacturing, Strategies Unlimited, April 2010
- Werner B. Koldehoff, Climate Change and Renewable Energies, February 2011
- Worldwatch Institute - Strong Growth in Compact Fluorescent Bulbs Reduces Electricity Demand
- Yano research, several publications, 2011-2012
- Zia Eftekhar, The Transformation of the Lighting Industry, March 2011

Investor presentations, annual reports, press releases, websites of and broker reports on various companies:

- Abener
- Alstom
- AIXTRON
- AMG Advanced Metallurgical Group N.V.
- Amtech Systems
- Ballard
- Bosch
- BMW
- Chery International
- CHSTE Group
- CRH
- Danfoss
- Enel
- Flabeg
- GE
- GM
- Hansen Transmissions
- Kingspan
- LM Wind Power
- MeyerBurger
- National Renewable Energy Laboratory
- NEM
- Nissan
- NPC
- Ormat Technologies
- Osram
- Owens Corning
- Philips

- Philips Lighting
- Power-one
- Recticel
- Renault
- ReneSola Ltd.
- Rockwool
- Saint Gobain
- Satcon
- Schott Solar
- Sener
- Siemens
- SMA Solar Technology
- Solel
- Synbra
- Veeco
- Vestas

Appendix B - Literature

- Aki, Helen, Zachary Arnold, Genevieve Bennett, Jesse Jenkins, Chris Knight, Ashley Lin, Taj Walton and Adam Zemel, Case Studies in American Innovation – A New Look at Government Involvement in Technological Development, The Breakthrough Institute, 2009
- Amos, J., Proceedings of the ICE – Engineering Sustainability: Denmark's sustainable energy future, 156(9), 2009
- Andersen, Per Dannemand, Review of Historical and Modern Utilization of Wind Power, 1999
- Andersen, Per Dannemand, Mads Borup and Michael Holm Olesen, Innovation in energy technologies, Risø Energy Report 5, 2006
- Arvizu, Dan E., Biofuels Research and Development to Reduce Reliance on Imported Petroleum, written statement presented to the Senate Energy and Natural Resources Committee, 2007
- Automotive fleet, top 50 green fleets, 2011
- Bartlett, David, Clean Technology in Europe, 2011
- Beintema, N. M., A. F. D. Avila, and P. G. Pardey. Agricultural R&D in Brazil: Policy, Investments, and Institutional Profile. Washington, D.C.: IFPRI, Embrapa, and FONTAGRO, August 2001
- Bank of International Settlements, Quarterly review, March 2012
- Bernstein Research
- The Breakthrough Institute, "Rising tigers, sleeping giants", 2009
- The Breakthrough Institute, Brookings Institution, World Resources Institute, Beyond Boom and Bust - Putting clean tech on a path to subsidy independence, 2012
- Bundesministerium für Bildung und Forschung, die Hightech Strategie zum Klimaschutz, 2007
- Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, Greentech made in Germany 2.0, Verlag Franz Vahlen München, 2009
- China IPR SME Helpdesk, IP Strategies for EU Cleantech SMEs in China, 2012
- China Greentech Initiative, China's Solar PV Value Chain, 2011
- CIEP, China and the Future of New Energy Technologies, 2012
- Clean Edge, Clean Energy Trends, 2009-2012
- Clean Fuels Development Coalition, The Ethanol Fact Book, 2007
- Cleantech Group, Global Investment Trends and the Rise of Cleantech in South Korea, 2011
- Climate Policy Initiative, Survey of Photovoltaic Industry and Policy in Germany and China, 2011

- The Climate Group/HSBC, Delivering Low Carbon Growth, 2011
- Colares, Juscelino F., A Brief History of Brazilian Biofuels Legislation (June 25, 2008). Syracuse Journal of Law & Commerce, Vol. 35, No. 2
- Deutsche Bank, The German Feed-in Tariff for PV, 2011
- EPIA, global market outlook 2012, 2012
- European Biodiesel Board, 2009-2010: EU biodiesel industry restrained growth in challenging times
- European Commission, Investing in the Development of Low Carbon Technologies, SET plan, 2009
- European Union, Directive 2009/28/EC of the European Parliament and of the Council, 2009
- European Investment Bank, Wind Energy – Meeting the Climate and Energy Challenges in the EU, 2011
- European Renewable Energy Council, Rethinking 2050, A 100% Renewable Energy Vision for the European Union, 2010
- EWEA, Wind in power – 2011 European statistics, 2012
- Fabre, Guilhem, S. Grumbach, The World upside down, China's R&D and innovation strategy, working paper, 2012
- Fulley, Laura, State Renewable Portfolio Standards and Energy Efficiency Resource Standards, presentation of American Council for an Energy-Efficient Economy
- Garnaut, R., The Garnaut Climate Change Review, Cambridge University Press, Cambridge, 2008
- Global data, several publications, 2011-2012
- Green Giraffe Energy Bankers, Project Finance in offshore wind – what route will the market take, 2011
- GTM research, Polysilicon 2012-2016: Supply, Demand & Implications for the Global PV Industry, 2012
- Humphries, Marc, Rare Earth Elements:The Global Supply Chain, Congressional Research Service, 2011
- HSBC, "Climate investment update", 2012
- Huang,C., et.al., Government funded renewable energy innovation in China, Energy Policy, 2011
- IHS Emerging Energy Research, Global Wind Turbine Supply Market Share Evolution, 2012
- IMS Research, PV Modules, Cells, Wafers & Polysilicon – Supply & Demand Quarterly – Q1'12
- IPPC, Fourth assessment report: Climate change, 2007

- Jacobson, S., and V. Lauber, The Politics and policy of energy system transformation – explaining the German diffusion of renewable energy technology, Energy Policy, 34, pp. 256-276, 2004
- Kamp, L.N., Learning in wind turbine development: a comparison between the Netherlands and Denmark, University of Utrecht, 2002
- Karplus, V.J., Innovation in China's Energy Sector, Working paper #61, Stanford University, 2007
- Kemfert, Claudia (2005). "Global Climate Protection: Immediate Action Will Avert High Costs". DIW Weekly Report 1(12): 135-141.
- Korea Capital Market Institute, System Architecture for Effective Green Finance – Korea's Case, 2011
- Korea Energy Management Corporation, IEA DSM Task 22 Presentation, 2010
- Kristinsson, Kari and Rekha Rao, Learning to Grow: A Comparative Analysis of the Wind Energy Sector in Denmark and India, DRUID Working Paper No. 07-18, 2007
- Krohn, S. Wind Energy Policy in Denmark Status 2002, Danish Wind Energy Association, 2002
- Krohn, S. Wind Energy Policy in Denmark: 25 years of Success – What now? Danish Wind Energy Association, 2002
- Lauber, V., L. Metz, Three Decades of Renewable Electricity Policies in Germany, Energy and Environment, 15(4), pp 599-623, 2004
- Lewis, J.l. and Ryan H. Wiser, "Fostering a Renewable Energy Technology Industry: An International Comparison of Wind Industry Policy Support Mechanisms", Energy Policy 35, no. 3 (March 2007): 1844–1857
- Lewis, J.L., Technology Acquisition and Innovation in the Developing World: Wind Turbine Development in China and India, St Comp Int Dev, 2007
- Lewis, J.I., Building a national wind turbine industry: experiences from China, India and South Korea, Int. J. Technology and Globalisation, 2011
- Lipp, J., Energy Policy, Lessons for effective renewable electricity policy from Denmark, Germany and the United Kingdom, 2007
- Lohse, Ulf, Developments in the German PV sector technology advances and cluster building, Eclareon GmbH, 2009
- Martinot, E., and L. Junfeng, Powering China's Development: The Role of Renewable Energy, Worldwatch Institute, 2007

- Mathiesen, Brian Vad, Henrik Lund, Kenneth Karlsson, 100% Renewable energy systems, climate mitigation and economic growth, Applied Energy, Pages 488-501, 2011
- Mercom Capital Inc, Loans and Credit Agreements involving Chinese Banks to Chinese Solar Companies since Jan 2010, 2011
- Nielsen, Jens Buurgaard and Donald Pols et al., Investing in climate change: Dutch banks compared 2007, Profundo, 2007
- OECD, The Role of Pension Funds in Financing Green Growth Initiatives, 2011
- OECD/IEA, presentation on "Accelerating Technology Transitions project", 2010
- OECD/IEA, CO_2 emissions from fossil fuel combustion – highlights, 2010
- OECD/IEA, Global gaps in clean energy R&D, 2010
- OECD/IEA, Integration of Renewables - Status and challenges in China, 2011
- OECD/IEA, Technology Roadmap – China Wind Energy Development Roadmap 2050, 2011
- OECD/IEA, World Energy Outlook 2008-2011
- Qiu, Jane, China's budget backs science, Nature, 483, 2012
- RE-Shaping, several reports, 2009-2012
- Roland Berger, Wind turbine manufacturing – A case for consolidation, 2011
- Schmalensee, Richard, Renewable Electricity Generation in the United States, MIT CEEPR working paper, 2009
- Schnepf, Randy, Agricultural-Based Biofuels: Overview and Emerging Issues, Congressional Research Service, 2012
- Skidmore, Mark, C. Cotti, J, Alm, The Political Economy of State Government Subsidy Adoption: The Case of Ethanol, Michigan State University working paper, 2011
- Sorda, Giovanni, M. Banse, C. Kemfert, An overview of biofuel policies across the world, Energy Policy, 2010
- Stern, Nicholas. 2006: The Stern Review on the Economics of Climate Change
- Tyner, Wallace E., M. Caffe, US and French Biofuels Policy – Possibilities for the Future, Purdue University working paper, 2006
- UNEP, Towards a Green Economy, 2011
- U.S.-China Economic & Security Review Commission, Backgrounder: China's 12th Five-Year Plan, 2011

- Vaekstfonden, The Energy Industry in Denmark – perspectives on entrepreneurship and venture capital, 2006
- Vestas, How to finance Renewables projects – Market reality and needs for support from a business perspective, presentation at 11th Inter-Parliamentary Meeting on Renewable Energy and Energy Efficiency, 2011
- Watkiss, Paul, Tom Downing, Claire Handley and Ruth Butterfield (2005). The Impacts and Costs of Climate Change. Brussels, European Commission DG Environment.
- Watts, Jonathan, China makes renewable power play to be world's first green superpower, The Guardian, 2009
- Wiser, Ryan, M. Bollinger, G. Barbose, Using the Federal Production Tax Credit to Build a Durable Market for Wind Power in theUnited States, Ernest Orlando Lawrence Berkely National Laboratory working paper, 2009
- World Bank, China 2030: Building a Modern, Harmonious, and Creative High-Income Society, 2012
- Wrobel, Paul, Clean Energy: The Brazilian Ethanol experience, 2007: Embassy of Brazil, London
- Wüstenhagen, R. and M. Bilharz, Green Energy Market Development in Germany, working paper, University of St. Gallen, 2004
- WWF/Cleantech Group, Coming Clean: The Global Cleantech Innovation Index 2012, 2012
- WWF/Ecofys, The Energy report, 2011

Appendix C - Contributors

Expert committee

Bryn Baker	WWF-US
Charlie Droste	FME-CWM
Clara van der Elst	Rabobank
Harm Jeeninga	Energy Centre Netherlands
Rob Retèl	De Lage Landen
Bart Wesselink	WWF-NL

Sounding Board

Gerard van Baar	Holland Financial Centre
Arjan ten Elshof	Eneco
Thom Emmons	Rabobank US
Richard Holland	WWF
Mark McGovern	De Lagen Landen US
Joel Posters	De Lage Landen
Justin Sherrard	Rabobank
Marty Spitzer	WWF US
Kees Stap	Ecofys

Contact information:

Roland Berger Strategy Consultants
World Trade Center, Strawinskylaan 581
1077 XX Amsterdam, The Netherlands

Telephone: +31 20 7960 600
Internet: http://www.rolandberger.nl

Amsterdam
Barcelona
Beijing
Beirut
Berlin
Brussels
Bucharest
Budapest
Casablanca
Chicago
Detroit
Doha
Dubai
Düsseldorf
Frankfurt
Gothenburg
Guangzhou
Hamburg
Hong Kong
Istanbul
Jakarta
Kuala Lumpur
Kyiv
Lagos
Lisbon
London
Madrid
Manama
Milan
Moscow
Mumbai
Munich
New York
Paris
Prague
Riga
Rome
São Paulo
Seoul
Shanghai
Singapore
Stockholm
Stuttgart
Taipei
Tokyo
Vienna
Warsaw
Zagreb
Zurich

supported by
WWF partners:

Eneco

Rabobank

de lage landen
partners in finance