



December 16, 2008

## German mechanical engineering steeling economy for the post-oil era

Mechanical engineering is one of the sources of hope for the post-oil era. What counts most in the long run is that action be taken to solve the energy crisis and avoid climate disaster. The mission will only be successful if the global energy mix complies more strictly with the precepts of sustainability going forward. Its success will strongly hinge on the mechanical engineering sector as engineering supplies the crucial technologies for all relevant sectors.

The mechanical engineering and plant construction sectors are modernising power generating plants around the globe. A total of USD 12 trillion is expected to be invested in the expansion and modernisation of power plant structures worldwide up to 2030. Germany's suppliers of power stations will take the lead as their product range is extensive and state of the art. In particular, solutions for coal and gas-fired power stations, large solar thermal power plants, and the development of a hydrogen economy are promising.

Mechanical engineering sector is triggering an efficiency revolution in business. Germany's engineering industry identified energy efficiency as a megatrend a long time ago. All customer groups are now benefiting from its innovative strength. Efficiency is playing an increasingly important role for consumer electronics and is a strong sales argument in power plant construction. Modern laser technology, robotics and automation help car producers develop their technologies and boost efficiency, thus increasing their international competitiveness.

Mechanical engineering is paving the way for a solar future. Only mechanical engineering opens up the opportunity for the industrialisation of new types of energy. For instance, mechanical engineering provides the basis for photovoltaics, which is granted the largest subsidies among renewables, to become gradually competitive. Furthermore, Germany is the world leader in the wind power sector. Mechanical engineering, which accounts for roughly 90% of wind power production value added, makes wind energy attractive even for large companies.

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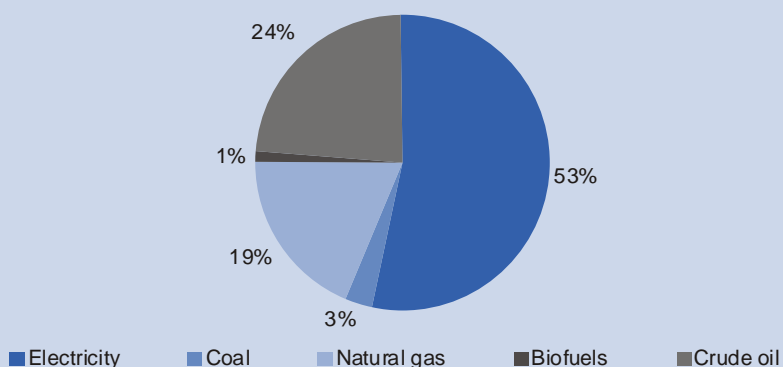
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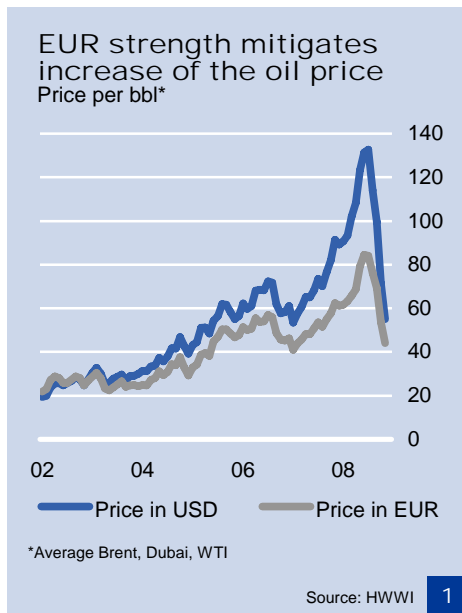
Norbert Walter

### Global high investment requirements for energy infrastructure until 2030

Global high investment requirements for energy infrastructure until 2030 USD 22 trillion



Source: IEA, World Energy Outlook 2007



## End of oil era – one of the greatest challenges of our time

Only a few years ago, our warnings of the looming end of the oil era were criticised as exaggerated pessimism by many observers.<sup>1</sup> In the meantime, most sceptics are aware of the genesis of a new energy age. The reassessment is mainly attributable to the unprecedented rally in crude oil prices over the past ten years; the price of the No. 1 global energy carrier, still at USD 10/bbl in December 1998, soared to price ranges never seen before, peaking at just below USD 150/bbl in the current year. On a euro basis the increase and – following – decrease was less pronounced.

In our view, the period of abundant and secure crude oil supplies at very cheap prices is definitely over. In the logbook of the energy industry, this period will probably be referred to as the “oil era”.

This finding is not out of sync with the current correction of the oil price. The correction was overdue as the booming prices of commodities, including energy, were not consistent with the pronounced slowdown of the world economy. If, however, the world economy picks up in the medium term, especially once the US economy as the world's growth engine recovers, energy prices are likely to reach new peaks. Thus, the current price correction should not be misinterpreted. On the contrary, the time window should be seen as an opportunity to take the right steps and develop reliable alternatives. Here, mechanical engineering has a crucial role to play.

### Crude oil scarcity becomes problem of our time

Of all commodities, energy resources are causing most concern regarding the security of supply in the medium term – initially crude oil, then natural gas, and in the longer term hard coal as well. The leading energy source of our time, crude oil, harbours both demand and supply-side risks.

The demand for oil and other energy sources will continue to rise as long as the world's population grows at the same pace as in the last 100 years. And according to current estimates (UN), the population will grow from currently 6.7 bn to 9 bn by 2050. This means the world's population will grow by 78 m people per year who require energy, e.g. for mobility, communication, housing and the preparation of food. Basically, it is the interplay of two factors: the first factor is rising demand from the emerging markets, not least China and India. The second factor, just as important as the new energy hunger of the emerging markets, is the nearly unlimited energy appetite of the industrial countries. Energy-saving efforts of the industrial countries have so far been negligible. For example, gas-guzzling cars, such as sport utility vehicles, were big sellers for a long time (much too long).

While the medium-term rise in energy demand is predictable, the supply of energy is becoming increasingly scarce. The era of cheap oil production in easily accessible deposits seems to be over. The share of reserves in remote regions of the world, including extremely expensive offshore deposits, is increasing more and more. Furthermore, the rise in the profitability of the oil business has made the oil-producing countries, which did not show much interest in business at previously low oil price levels, increasingly keen to obtain higher yields. Western firms are finding it more difficult to do business, and

## Rising energy demand expected in the medium term

## Scarce energy supply causes concern

<sup>1</sup> See Auer, Josef (2004). Energy prospects after the petroleum age. Deutsche Bank Research. Current Issues. December 2, 2004. Frankfurt am Main.

**Higher energy prices mark the end of the oil era**

expropriations and nationalisations take place more and more often. This leads to a slowdown in investment. On balance, the coincidence of rising energy demand and increasingly unsecure supply leads to higher prices – and the end of the oil era described above.

**Mechanical engineering: A source of hope for the post-oil era**

Germany's mechanical engineering and plant construction sectors gained international reputation in the 20th century, outperforming virtually all German industrial sectors. Problem solutions around the value chain in the provision, production and distribution of energy have traditionally been an important domain of the Germans. In the more and more important technologies for energy generation and the energy-saving and environmentally friendly use of fuel and materials, German companies compete in the champions league.

**Green technologies increasingly sought after worldwide**

Since the early 1970s at the latest, a contribution has also been made by an extremely controversial debate on energy and environmental issues in Germany which led to ambitious legislation and regulations. Energy and environmental legislation – initially regarded as a burden by the affected industrial sectors – proved to be a fortunate development more and more often in the last few years as they were major drivers for the development of new green technologies in Germany. These are now increasingly sought after worldwide.

Against the backdrop of the outlined global scarcity of fossil energy sources and rising environmental risks – especially the anthropogenic climate change – Germany's mechanical engineering and plant construction can make valuable contributions to solving the energy problem.

***Mechanical engineering is key***

The crucial global long-term challenge to solve the energy crisis and avoid the climate disaster can only be tackled successfully if the global energy mix complies more strongly with the precepts of sustainability. Here, hopes are pinned on mechanical engineering and plant construction as they can offer solutions going forward which are better able to secure our energy supplies, weigh less on the world's climate and bring the cost explosion of energy supply to a halt.

**Mechanical engineering supplies enabling technologies**

Mechanical engineering and plant construction, as developers and suppliers of revolutionary enabling technologies, will play a large role in all three segments shaping the future:

- The modernisation of global power plant facilities which are currently still dominated by power plant technology with mostly large power plants;
- The efficiency revolution in all areas of energy use in the industrial sector and on the part of consumers;
- The development and commercialisation of new technologies that use renewable energies.

**Mechanical engineering modernises global power plant facilities**

In earlier decades, trends in power plant construction were relatively clear: for instance, the first oil price shock led to a genuine nuclear power boom in the 1970s. It was triggered by the first energy price crisis which raised general doubts about the security of the very high proportion of fossil energies as a result of the dependence on the



### Important parameters changing

OPEC cartel, but also confidence in the new nuclear technology. The US gas turbine boom in 2000 and 2001 was due to other factors. Gas turbine technology benefited from the oil price weakness of the 1990s which made prices of natural gas very favourable. They improved the competitiveness of gas versus coal. Besides the low fuel costs, the relatively low investment costs were an advantage of gas turbines.<sup>2</sup>

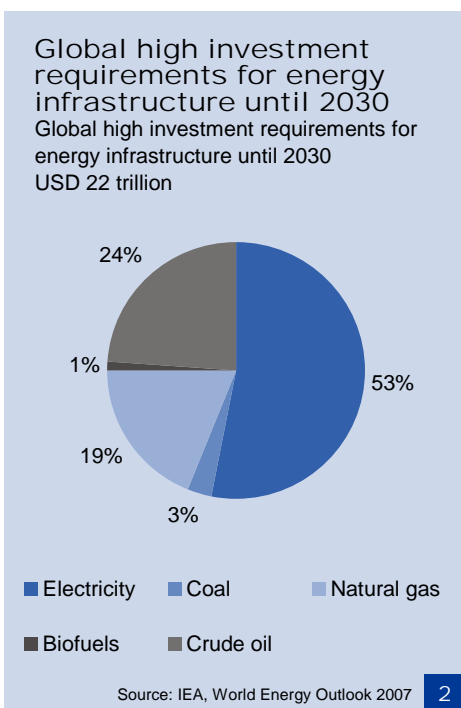
With the end of the oil era, many important parameters are changing. What is new is the parallel occurrence of great trends and events which was unknown so far. The expected rise in energy needs of the emerging markets as a result of the dynamic pace of population growth requires the extension of existing power plant structures, as well as additional projects. In Eastern Europe, the modernisation of electricity infrastructure remains a perennial issue. For example, Russia is still facing the risk of serious power bottlenecks. In industrial countries where population figures grow only slightly, tasks such as replacement, modernisation, emission reduction and decentralisation are more pressing issues. Furthermore, increasing urbanisation, with more and more new and bigger cities up to megacities, requires innovative solutions for energy infrastructure.<sup>3</sup>

### German mechanical engineering predestined for leadership

German mechanical engineering and plant construction are predestined to play a leading role when it comes to the modernisation of global power plants. German suppliers win points with complete, client-driven solutions, low lifetime costs, a broad availability of plants, energy and material efficiency, as well as above-average environmental and security standards. Other advantages worth noting are the international presence and the reputation built up over decades to strictly comply with contracts – i.a. with regard to price and budget, quality and deadline. One advantage in global power business is not least the variety and modernity of the German product range. To cover the international growth in energy demand all available energy sources are required, including fossil energy. This suggests that the traditional large power plants for fossil and nuclear fuels will continue to be sought after worldwide, and that new decentralised solutions – not least surrounding renewables – also have to be developed.

According to calculations by the International Energy Agency (IEA), the extension and modernisation of the global energy supply infrastructure will require an investment volume of USD 22 tr until 2030.<sup>4</sup> At nearly USD 12 tr, the lion's share of investment will be accounted for by global power plant construction, while investment on primary energy – oil, natural gas and coal – will be considerably lower. The high share of investments in power plants is due to the expected doubling of electricity demand until 2030, i.e. an expected increase of nearly 3% per year. While growth in energy demand in the OECD countries and the East European transformation countries will be weaker, much stronger growth dynamics are likely in the Asian emerging markets. Electricity consumption is set to rise by 5% in China and 6% in India. Thus, China will have to invest USD 2.7 tr and India nearly USD 1 tr in the electricity sector. Therefore, the two

### German suppliers have a lot to offer in power plant business



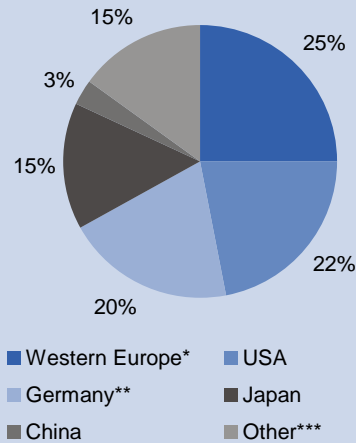
<sup>2</sup> See AG Großanlagenbau (2008). Weltweite Erfolge – Ressourcen schonende Technologien für den globalen Markt. Frankfurt, p. 18.

<sup>3</sup> See Just, Tobias (2008). Megacities: Boundless growth? Deutsche Bank Research. Current Issues. March 12, 2008. Frankfurt am Main.

<sup>4</sup> See IEA (2007). International Energy Outlook. Paris.



In large plant construction,  
one out of five plants  
comes from Germany  
Global market volume 2007: EUR 250 bn



\*excl. Germany

\*\*including foreign subsidiaries

\*\*\*includes South Korea, India

Source: Arbeitsgemeinschaft Großanlagenbau

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### German companies leaders in state-of-the-art coal technology

### GTL increasingly sought after

countries together account for almost one-third of required global power plant investments.

### High power plant investments beneficial to Germany

Germany benefits from globally high investment needs, for German large plant construction (including petrochemicals, cement, paper and iron and steel plant construction, as well as steel rolling mill construction) accounts for a world market share of 20%. The share in the power plant construction market is also about 20%, with installations of hydropower stations reaching a higher share and the share of the world market for crude oil processing being lower. The export share, at 80%, is very high.

Major competitors come from other industrial countries. Currently, US system builders are less active on an international scale as they are still busy coping with the damage of hurricane Katrina, have to refurbish plants and build refineries. Japanese suppliers continue to play a big role but Germany will maintain its good position. China's plant construction is on a growth path but still largely concentrated on South and South East Asia. Chinese suppliers currently mainly rely on low-cost manufacturing and thus competitive prices; however, they will not be a real challenge to West European plant construction until they catch up in terms of technological capabilities.

### Germany has largest product spectrum worldwide

German mechanical engineering and plant construction offer innovative solutions for the improvement of power generation plants worldwide, for the transport of energy carriers, such as natural gas, but also for renewable energies. The product range includes the following technologies:

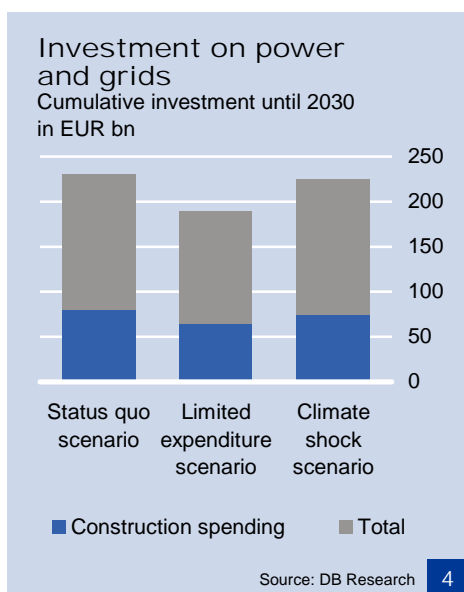
- German companies have unique know-how around coal mining and firing. Coal does have great potential as a substitute for oil and gas in the medium term to change from pariah to paragon of virtue, assuming that the CO<sub>2</sub>-problems are solved. The multi-talent coal can in general be used in all three major energy segments: in power generation, the heating market and transportation. Liquefaction becomes increasingly attractive in view of rising oil prices ("synthetic fuel" being the buzzword here). It is of major importance that technological solutions secure "clean coal". German producers of power plants are a flagship on technologies which reduce CO<sub>2</sub>-emissions and may eliminate them completely in the longer term. Important fields of activity are sequestration, the storage of carbon dioxide in underground reservoirs, but also the injection of CO<sub>2</sub> in oil deposits to increase oil extraction.<sup>5</sup>
- For the worldwide consumption and marketing of natural gas, so-called Gas-to-Liquids (GTL) play an increasingly important role. Only by transporting liquefied natural gas will it be possible to cover the demand for natural gas in the USA and Japan and in a variety of regions in Europe without access to pipelines. Thus, it does not come as a surprise that even the largest Russian natural gas company and market leader for pipeline gas targets global GTL business. Besides Qatar and North Africa, the Gulf of Guinea is becoming increasingly important. No wonder that Russian and also German players have staked their claims.

<sup>5</sup> See Auer, Josef, 2007. Technology to clean up coal for the post-oil era. Deutsche Bank Research. Current Issues. February 6, 2007. Frankfurt am Main.



### Modernisation of biofuels possible

### Good prospects for solar thermal large-scale power plants



There is much to suggest that the technology urgently required will come not least from Germany.

- A Frankfurt-based company, Lurgi, is world leader in the development of plants for the production of biofuels. For instance, a pilot plant targeting the production of so-called designer fuels could gain global significance. The synthetic fuel would produce fewer noxious emissions, would be sulphur-free and could be mixed with petroleum-based fuel. As all biomass available (i.e. not only corn and grain) can be used, competition with basic foods could also be reduced.
- Plant construction has become increasingly important for solar energy in the last few years. It allows the production of large-scale solar thermal power stations (with a capacity of 30 to 200 MW) which are consistent with the requirements of centralised electricity generation. Such large power stations are currently the only option for renewable power generation which may substitute for nuclear and fossil-fired power plants in terms of generation capacity. Solar technology has very good prospects in the world's Sun Belt, i.a. Northern Africa, the Iberian Peninsula, Australia, as well as the American Southwest.<sup>6</sup>
- Hydrogen is an interesting alternative energy source. German power plant construction is the global force in the production of hydrogen, and hydrogen is becoming increasingly important for the production of clean conventional fuels. The on-site power plants at already existing refinery locations offer opportunities to purify and desulphurise crude oil – and thus make it consistent with environmental requirements.

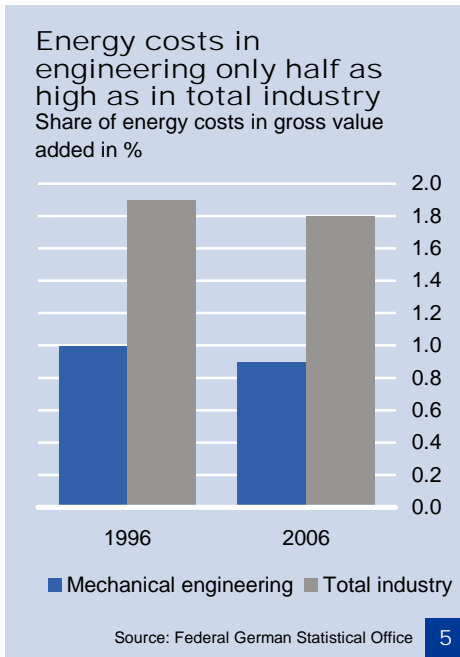
The investments required in the global power plant facilities are huge but, in Germany as well, very large sums will have to be invested. According to our calculations – depending on the scenario (e.g. excluding or including the lengthening of lifetimes of nuclear power plants) – investment requirements in German power plants will probably be EUR 190 bn - 230 bn<sup>7</sup> up to 2030.

### Mechanical engineering increases economic efficiency

It is a law of rationality to economise as much as possible on scarce resources. However, in times of high energy prices, much more attention is paid to the issue than in times of cheap energy. Germany's mechanical engineering industry identified energy efficiency as a megatrend a long time ago. Against this background the sector can benefit from the current trends in the energy market in various respects.

<sup>6</sup> According to estimates, the global installed capacity of solar thermal power plants will total 2,000-8,000 MW by 2010 and reach 20,000-45,000 MW by 2020. See AG Großanlagenbau (2008). p. 55/56. As of the end of 2007, there were 29 solar thermal power plant projects generating 1,800 MW worldwide, one-third of which in Spain. See BINE. Solarthermische Kraftwerke werden Praxis. Projektinfo 07/08. Karlsruhe, p. 4.

<sup>7</sup> See Auer, Josef, Eric Heymann and Tobias Just (2008). Building a cleaner planet. Deutsche Bank Research. Current Issues. November 14, 2008. Frankfurt am Main.



### **Mechanical engineering ensures fuel-efficient mobility**

### **State-of-the-art machine tools and automation make car industry competitive**

### **Laser technology revolutionises car production**

### **Higher efficiency reduces costs and vulnerability**

German mechanical engineers recognised at an early stage of rising energy prices that they have to come to grips with their energy costs to remain internationally competitive. True, the share of energy costs in total costs in mechanical engineering is limited. However, in fierce international competition, each cost factor is relevant. For this reason domestic engineers have excelled at reinventing efficiency. Thus, the share of energy costs in the total costs of engineering accounts for only 1%, i.e. only half as much as in the other industrial sectors on average. Thanks to the rise in cost consciousness the vulnerability of domestic mechanical engineering companies to soaring energy prices was reduced considerably. In the last few years, the rise in energy prices was more pronounced than the economies on consumption; thus, the share of energy costs in total costs recently picked up again slightly (e.g. from 0.8% in 2004 to 0.9% in 2006). Without energy-saving, the increase would have been much stronger, though.

### **Mechanical engineering generates efficiency gains for clients**

German mechanical engineering companies recognised very early that rising energy prices also offer opportunities – not least for diversification and for gaining ground on foreign competitors: due to the rise in energy prices, customer industries – e.g. the international car industry – have higher demands on energy efficiency to be met by suppliers. Given the higher sensitivity of potential car buyers, car producers can only sell their product successfully if they are able to offer fuel-efficient mobility at favourable prices. This has also been recognised by US automotive companies by now as for a long time they were blind to the trend of energy efficiency. Due to the change in consumer behaviour, customers such as the multinational car companies meanwhile place high demands on mechanical engineers for ambitious energy efficiency targets. It has paid off for German mechanical engineering that it gave priority to environmental standards and energy efficiency at an early stage.

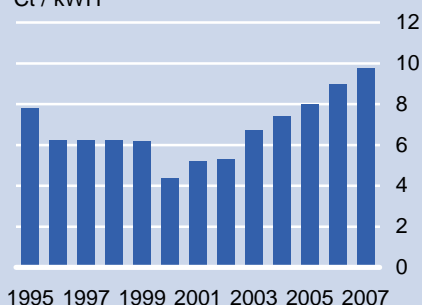
A broad range of mechanical engineering products have helped the car industry to increase the fuel efficiency and thus attractiveness of their vehicles. For instance, high-performance machine tools enable the production of particularly thin, energy-saving metal sheets. Modern production technologies such as the automated complete processing of workpieces on 5-axis machining centres increase productivity as increasingly complex products can be manufactured with highest precision in a minimum of time. The workpiece is benefiting from the high precision of the machinery. Without large-scale automation, car manufacturing in the high-wage countries of Western Europe and Northern America would no doubt have come to a halt.

Modern laser technology, in which German companies take the lead, has led to a soft revolution in car production, so to speak. The technology is flexible in its application: it ranges from the production of catalytic converters and the production of exhaust systems to the welding of gear and motor parts. The application of lasers allows the manufacturing of tailored blanks – also from aluminium – which, while maintaining the stability of metal sheets, offer significant weight and thus cost savings to car producers. Furthermore, thanks to lightweight building, the energy consumption of cars declines.

Last but not least, the potential for weight reduction is a major factor for the future market success of hybrid cars and the market entry of



### Electricity prices for industrial customers in Germany Ct / kWh\*

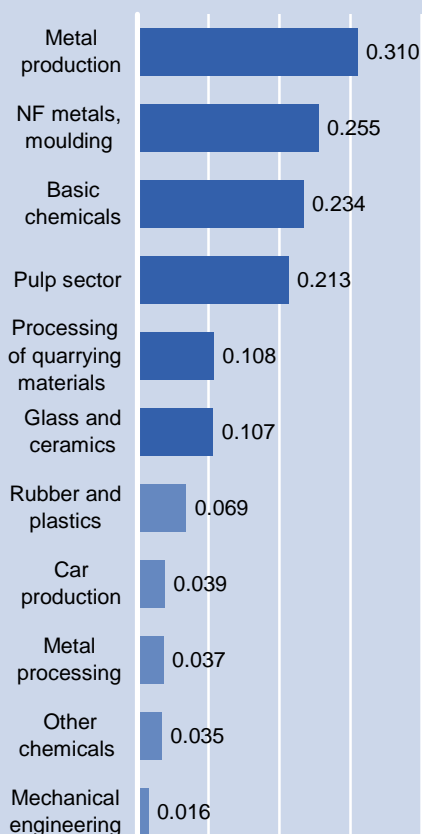


\* Consumption scenario: 4 MW \* 6,000h/a = 24 m kWh, excl. VAT

Source: Eurostat

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### Electricity-intensive sectors Germany Electricity intensity kWh/m EUR\*



\*Quotient of power consumption and gross-value added

Source: HWWI

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electric cars. The lower weight of cars with hybrid-driven engines helps to meet the technically demanding challenge to realise an energy-saving concept for urban traffic, while enabling dynamic driving on roads and motorways. Especially for electric cars weight plays a key role as the issue of electricity storage units and batteries still harbours great challenges.

#### **All customers are keen on efficiency**

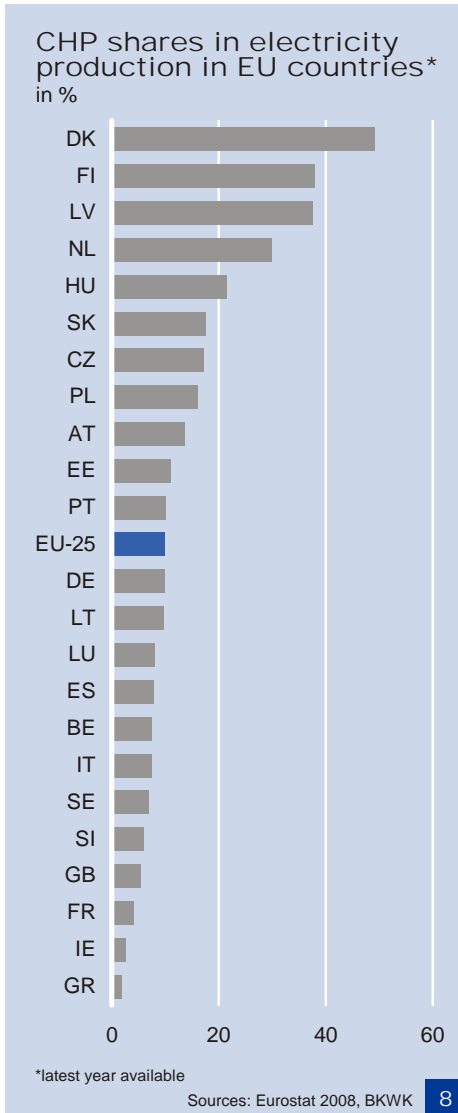
Of course, all other industrial sectors also place higher demands on increasingly high-performance technologies for improved energy efficiency and higher environmental standards, and mechanical engineering has to deliver. Robotics and automation offer potential for more favourable cost structures. Furthermore, the automation of companies' manufacturing processes reduces energy consumption. The variety of customer industries can be illustrated by some examples:

- In aviation, weight and energy consumption play an even larger role than in the car sector. Thus, demand for laser technology – a cross-sector technology – rises in this sector as well. While jet fuel costs accounted for close above one-tenth of airlines' total expenditure at the end of the 1990s, they have increased to one-third by now. Airlines with aging fleets and thus above-average fuel consumption cannot keep pace with the fierce international competition. European airlines and suppliers will benefit from the trend towards energy-saving aircraft.
- In particular, the energy-intensive basic industries in Europe continue to rely on affordable energy prices. And given the auctioning of emissions certificates from 2013, energy-efficient manufacturing could achieve even greater relevance. For if no exemptions from the auctioning obligations are made for the electricity-intensive sectors of basic industries, e.g. building materials, non-ferrous metals, chemical processing, the steel and pulp industries, the affected production facilities in European industry would have a lower chance of survival.<sup>8</sup> In essence, companies can use only two adjustment strategies: first, the use of modern, energy and environmentally efficient technologies to cut costs further; second, if this is not possible any more, the shift of production facilities to countries with lower environmental standards.
- The manufacturers of consumer electronics in Europe positioned themselves in low energy consumption and high energy efficiency at an early stage. As a result, the European manufacturers of state-of-the-art electric cookers, washing machines and fridges are currently benefiting from the trend towards globally rising electricity prices. Consumers' purchase decisions consider more and more often that the purchase price of a new electric appliance is only a fraction of the lifecycle cost. State-of-the-art machinery allows the manufacturing of electricity-saving electric appliances.

#### **Efficiency has become top priority in power plant construction**

Fossil fuels for power generation continue to be sought after. An important approach for more energy efficiency and better climate protection could therefore be provided by more powerful technologies – used last but not least at conventional coal-fired plants.

<sup>8</sup> See also McKinsey (2008). Änderungen der europäischen Richtlinie zum Emissionshandel: Auswirkungen auf die deutsche Zementindustrie. Düsseldorf. June.



German engineers have developed promising solutions in this field. New filter technology features have been available in Germany and other west European countries for a long time. The example of China where only 5-10% of coal-fired plants are fitted with desulphurisation equipment reflects the high market potential for European technological leaders.

Demand for decentralised energy services has been rising in the industrial countries as well. This is also due to the fact that parts of the population oppose large-scale power plants. The Energy and Climate Programme which has just been adopted targets a doubling of the share of the high-efficiency combined heat and power plants (CHP) in German electricity production to 25% by 2030. State-of-the-art CHP plants utilise 90% of the input energy (e.g. biofuels) for the combined generation of heat and power. CHP's exceptionally high efficiency saves primary energy such as natural gas and coal and eases the burden on the global climate.<sup>9</sup> The market potential of innovative technologies where German engineers have considerable know-how by now is enormous, not least in the emerging markets.

Thus, VDMA (industry association) president Manfred Wittenstein is right when he says that energy-efficient products are a huge growth market.<sup>10</sup> If even greater attention is paid to the domestic market as a technological showroom for foreign clients, German mechanical engineering and plant construction will continue to be successful on the world market.

### Mechanical engineering paving the way for a solar future

The dream of a solar future on planet Earth is not a discovery of modern man. But since the first oil crisis of the early 1970s, the fascination with it has increased strongly as it is promising a sufficient supply for all at relatively favourable prices and without environmental damage. However, the modern industrial and service societies are still a far cry from this ideal.

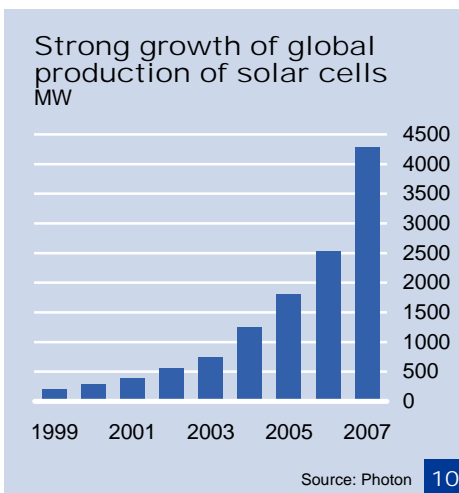
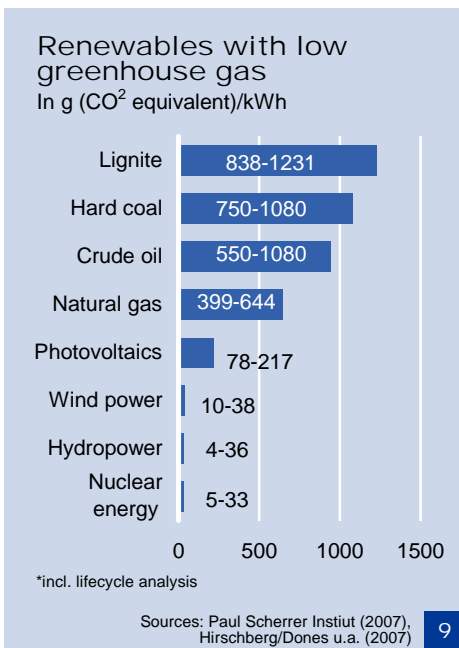
It was recognised long ago that only a concerted effort between politics, environmental commitment and economics can bring the progress desired. True, a fierce debate is going on on the way forward and the strategies to take. However, after several energy price crises, a certain basic consensus has emerged with regard to the expected increasing scarcity of fossil-based hydrocarbons: the demand-supply gap can only be filled with intelligent innovative solutions. Observers also seem to agree that the sooner new technologies will be developed and become marketable, the more sensitive and successful the transition will be.

No doubt, the greatest sources of hope in the post-oil era will be the renewables. Not only the already used energy carriers hydropower and biofuels but also the new renewable energies, such as solar energy, windpower and geothermal power, offer considerable potential.

The public debate on renewable energies is in most cases among politicians and, in single cases, representatives of research institutions. Usually, little attention is paid to the views of mechanical

<sup>9</sup> See Auer, Josef (2008). Combined heat and power generation. A pillar of Germany's integrated energy and climate programme. Deutsche Bank Research. Current Issues. May 14, 2008. Frankfurt am Main.

<sup>10</sup> See Wittenstein, Manfred (2008). Die Welt liebt deutsche Maschinen! VDMA press conference at the Hannover fair. April 21, 2008.



engineers. This does not appear logical as mechanical engineering, more than other sectors, is paving the way to the solar future even though its key role is in general not perceived as such.<sup>11</sup> This is all the more surprising from a German angle as in particular German engineers have a global reputation in solar energy and are deemed likely to offer even more successful solutions in future. Two examples illustrate the key significance of mechanical engineering for the shift to an economy tapping the resources of the sun:

### ***Mechanical engineering makes photovoltaics competitive***

When Albert Einstein explained the photoelectric effect in 1905, which was discovered by Becquerel in 1839, that won him the Nobel prize for physics in 1921 it was not apparent yet that the topic “electricity from sunlight” would one day electrify an entire generation. However, until the basic technical innovation matured into the boom sector solar energy<sup>12</sup>, the sector underwent several conversions. In a rough description, three stages can be distinguished: the pioneers of the start-up phase (stage 1) until the mid-1980s in Germany were large companies such as AEG, Siemens, Nukem and MBB but also university institutions. (Basic) research was dominant. The subsequent period of stagnation (stage 2) until the mid-1990s was marked by consolidations at company level, the shift of production to foreign locations but also the establishment of extra-university research institutes. Furthermore, initial state promotion schemes for the uptake in the grid were launched (e.g. the “1,000 solar roof programme” of 1990).<sup>13</sup>

The beginning of the actual industrialisation phase (stage 3) goes back to the mid-1990s. Germany was the international trendsetter with ambitious political initiatives such as the “Solar energy from 100,000 roofs” programme of 1999 and – even more importantly – the Renewable Energies Act (EEG) introduced in 2000, which, in essence, is meanwhile applied by roughly 50 other countries as well, albeit in some cases with modifications. At company level, a large number of small and medium-sized companies were set up or outsourced.

### ***Only mechanical engineering makes industrialisation possible***

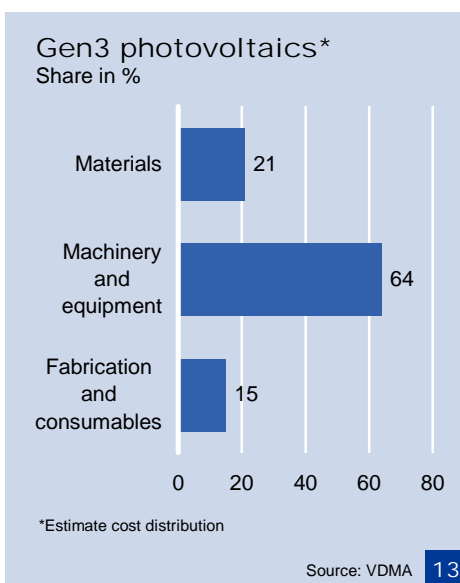
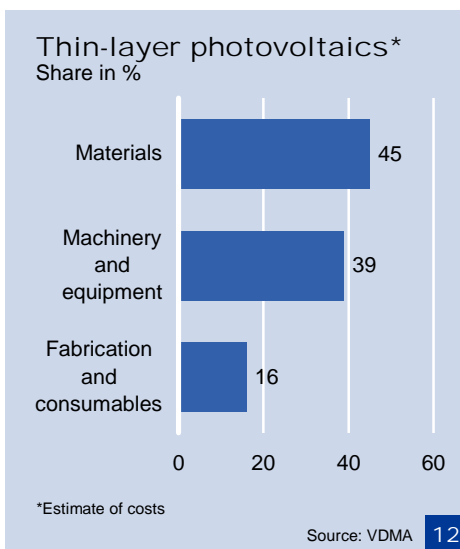
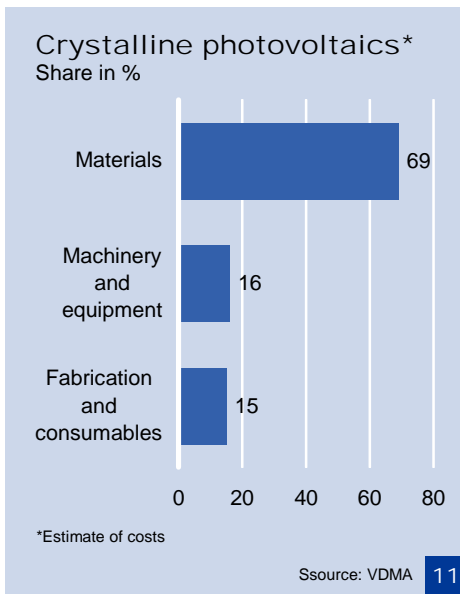
On the cost side, the move of mechanical engineering into niches made the difference. The most important stimulus surely came from the EEG, in particular its amendment in 2004 for it guaranteed stable markets and very high compensation for alternative energy sources. This created the basis for the quantum leap in production from manufacturing to industrial automated production. This ensured economies of scale at all levels of the PV value chain.

In future, mechanical engineering will gain even further significance for the photovoltaic sector. True, photovoltaic technology is no longer in its infancy. However, out of all energy alternatives it is still the least competitive from an economic standpoint. Standardisation and mass production thus continue to gain importance.

<sup>11</sup> For this reason polarisations with regard to the alleged contradiction between environmental protection and mechanical engineering sometimes put forward seem to be quite artificial. See e.g. BMU (2007). GreenTech made in Germany. Munich, p. 13. Modern mechanical engineering – be it new procedures or products, process optimisation or resource-saving aimed at the use of materials – is ultimately also environmental protection; what else?

<sup>12</sup> See also Auer, Josef (2005). Boom Industry Solar Energy. Deutsche Bank Research. Current Issues. May 24, 2005. Frankfurt am Main.

<sup>13</sup> See Dewald, Ulrich (2008). Innovationssystem Photovoltaik in Deutschland. In ForschungsVerbund Sonnenenergie (FVS). Produktionstechnologien für die Solarenergie, pp. 130-135.



Empirical evidence shows that for photovoltaic panels a doubling of output, i.e. installed capacity, has led to cost savings of 20%.<sup>14</sup> In comparable industries, such as electronics and flat panel displays, such effects have been known for a long time. In the short term the PV value chain offers much potential so that a similar learning effect in the next few years seems achievable.<sup>15</sup> In the longer term, however, an extrapolation is subject to risk as limits with regard to technology, material and technological advances could cloud the picture.

### ***Mechanical engineering smoothes growth of PV in three ways***

Currently, three development paths are particularly promising:

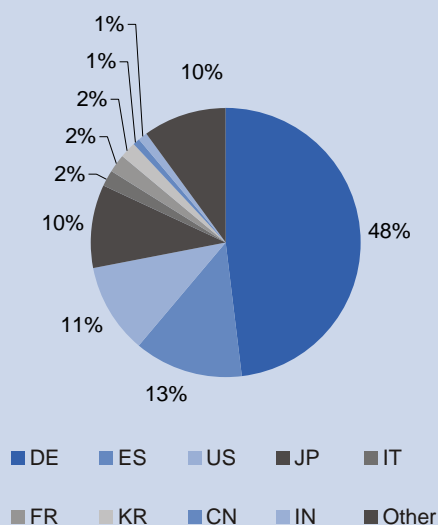
- First, the manufacturers of crystalline cells which dominate the market; here, the availability and the price of silicium play a large role. The share of material costs alone (excluding consumables) accounts for close to 70%. By contrast, machinery and plant account for a cost share of only one-sixth.
- Second, thin-layer solar photovoltaic systems have meanwhile made it to the marketplace. In this technology, materials play a minor role; machinery is thus a more significant factor than in the area of crystalline photovoltaics.
- Third, third-generation technologies (Gen3). This is photovoltaic technology e.g. on the basis of printed, semi-conducting plastics (organic PV), tandem cells or concentrator cells. In Gen3, the share of machinery may account for as much as two-thirds. By means of complex procedures, mechanical engineering thus has increasing potential to contribute Intellectual Property (IP) and thus create added value. True, the manufacturing of thin films is still in its infancy but like the two other PV technologies, it has considerable growth potential.

Mechanical engineering will contribute to significant cost reductions in the photovoltaics sector and thus higher acceptance by the public who has to bear the costs of the high subsidies over many years. Advances in technology mostly take place in close cooperation with innovative research institutes and ambitious solar companies. Photovoltaics is benefiting from mechanical engineering even more strongly than other sectors which have already been treated in the chapter on efficiency (see above). Mechanical engineering leads to cost reductions on three levels. First, the costs are lowered due to the continuing improvement of solar products. Especially mechanical engineering holds potential with regard to lower material usage, higher efficiency and simpler manufacturing methods. Second, mechanical engineering plays the key role with regard to the optimisation of production technology. Here, the targets are stronger automation, more rapid throughput times, higher output as a result of less fractures (the main cost driver is the fracture rate of the thin silicon wafers, not of the glass!), higher efficiency and quality, lower processing costs as well as lower investment on machinery in general. Third, mechanical engineering creates the prerequisites for mass production which brings economies of scale in manufacturing

<sup>14</sup> See Brendel, Rolf (2008). Entwicklung neuer Produktionstechnologien für die Solarenergienutzung im FVS. In FVS, pp. 10-17.

<sup>15</sup> See also Weber on the price learning curve for Si PV modules, who says that in general total costs are reduced by 20%, based on double the production volume. This applies from 1980 and can be extrapolated until 2020. Weber, Eicke (2008). Solarstrom wird billiger. In VDI nachrichten. No. 34, August 22.

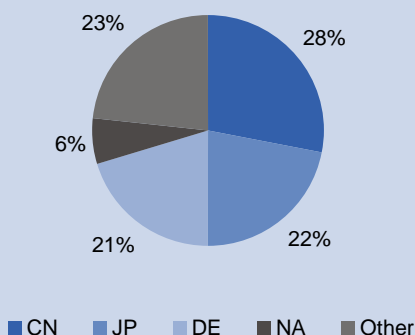
Germany takes the lead in global installed PV capacities 2007



Source: European Photovoltaic Industry Association

14

China: World leader in production of solar cells 2007



Source: Photon

15

and lower unit costs. Finally, the larger volumes of the PV sector ensure better purchase prices and financing conditions.<sup>16</sup>

### ***Thanks to mechanical engineering: cost parity no longer an illusion***

The PV sector expects solar electricity to reach cost parity around the middle of the coming decade.<sup>17</sup> True, reaching cost parity means that solar electricity can in principle be offered to residential consumers at the same price as conventional electricity. But as solar radiation intensity is not always high in all parts of the world, global infrastructure grids ("The sun always shines somewhere") and localised grid networks (e.g. batteries of hybrid cars) are targeted in the long term. Until this target has been reached, the grid connection has to be used to meet electricity demand; it is thus indispensable for the interim period.

From an economic point of view, cost parity with other power generation options, such as wind power, should be of even higher interest than grid parity for residential consumers. To reach this competitiveness, the "magical triangle" research, solar industry and mechanical engineering has to achieve even more leaps in technology.

### ***Mechanical engineering can do the trick with regard to the cost issue***

Industry representatives hold the view that global PV manufacturing should reach an average growth rate of 20% p.a. As the market volume at the end of the forecast horizon will thus account for 31,000 MWp/a (currently: roughly 5,000 MWp/a), competitiveness without subsidisation is crucial – not only in peak times and applications independent of the grid.<sup>18</sup> Making PV cost competitive is thus essential for the future of the sector. This cannot be achieved without the help of innovative know-how of engineers.

This also applies to the solar thermal segment<sup>19</sup> which has very high growth potential as well. In contrast to photovoltaics, solar thermal technology utilises sun radiation for the generation of heat. Concentrating Solar Power (CSP) plants are thus a lot like conventional power plants.

### ***Mechanical engineering makes wind power attractive for large companies***

In the initial years of wind exploitation, the technology pioneers got laughed at mildly at best by the traditional electricity companies. Meanwhile, the tide has turned. More and more often, the start-up small and medium-sized companies become appealing to established large companies. The dawning of the new age has much to do with the innovative strength of mechanical engineering and plant

<sup>16</sup> See Stryi-Hipp, Gerhard (2008). Die Solarindustrie in Deutschland. In FVS, pp. 18-23.

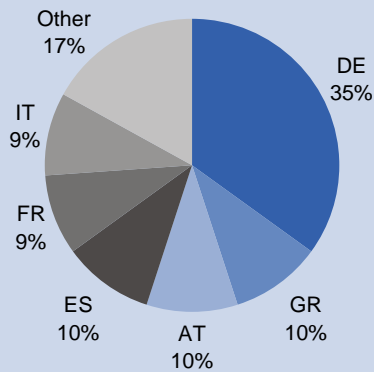
<sup>17</sup> See Aulich, Hubert (2008). Von der Manufaktur zu Giga-Watt-Anlagen. In FVS, pp. 36-44. According to Aulich, the total cost of the installation of a solar power plant can be lowered by roughly 40% to EUR 3/W<sub>p</sub> by 2015. Considerable savings potential is calculated for the silicon share, ingots, wafers, solar cells, module and system. See also Weber, Eicke (2008).

<sup>18</sup> See Staiß, Frithjof (2008). Wertschöpfung und Arbeitsplatzeffekte durch die Nutzung erneuerbarer Energien in Deutschland. In FVS, pp. 24-35. Nitsch, Joachim (2007). BMU-Leitstudie 2007. Ausbaustrategie erneuerbare Energien. Stuttgart.

<sup>19</sup> On solar thermal energy see, for example, also various contributions in FVS, 2008, and Nitsch (2007).

### European solar thermal market

Newly installed capacity 2007  
EU-27: 2.7 m m<sup>2</sup> with 1.9 GW<sub>th</sub>

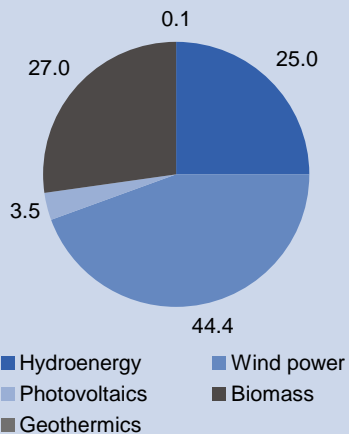


Source: European Solar Thermal Industry Foundation. Solar Thermal Markets in Europe, p. 6

16

### Wind power No. 1 in regenerative electricity generation

Share in regenerative electricity generation in Germany, 2007, %



Sources: BEE, BBE

17

### Mechanical engineering paves the way for export success of wind technologies

construction. The quantum leap of the sector has ensured that, even if strict financial controls are in place, wind power pays off.

The share of mechanical engineering and plant construction in wind power accounts for roughly 90%. This includes the producers of wind turbine towers, driving gears and the establishment of wind systems, while generators are in general a category of electrical engineering.<sup>20</sup> Among the new regenerative energies, the share of mechanical engineering in the wind sector is thus particularly high.

The successful business development of the segment in the last few years made it possible for Germany to take the global lead in wind energy. As the EEG amendment, which will take effect in 2009, stipulates further shifts of the legal environment in favour of wind power, the German wind sector is on course to further success. For traditional wind farms on land, standardisation and series production – i.e. industrial production – began a long time ago.

#### Growth potential from several sectors

First, repowering holds potential. Repowering is a technical term in the wind industry and stands for the replacement of several small wind farms by much more powerful modern large-scale plants. In principle, it is possible to “repower” wind farms both on land and at sea. In actual fact, though, the onshore segment will remain the future market of repowering for many years, as offshore wind power has so far scarcely achieved relevance. In essence, repowering means being able to increase the efficiency of plants on the basis of modern, powerful turbines, bigger rotor blades and more height. The rule of thumb for repowering is: half of the existing facilities with twice the power. The technological advances in mechanical engineering and plant construction thus allow a better wind harvest at lower cost, i.e. an improvement in the profitability of plants.

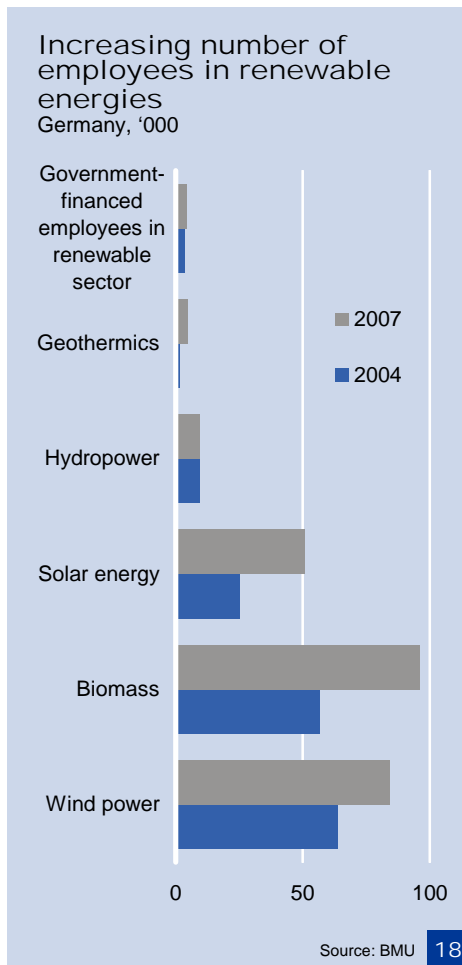
Second, besides repowering, the innovative offshoring area ought to become a new domain of the German wind industry. The installation of exemplary reference systems at sea will encourage other countries to follow suit and stimulate the business of the German suppliers of wind technology. The fascination with offshoring is based on the fact that the wind is more constant and stronger over the ocean than on land. Only technological leaps in mechanical engineering and plant construction will allow professional wind exploitation at sea.

Naturally, a modern electricity network is an important prerequisite for the expansion of wind power. If network capacities are insufficient wind power has to be taken off-line especially when the wind blows strongly. As the deciding factor for offshoring is to generate much higher quantities of electricity, higher-capacity networks for transmitting electricity are vital. As politicians have meanwhile recognised the challenge, chances are good for a near-term improvement. This requires relatively high investment.

#### Germany world leader in wind business

The still relatively young sector can look back to only a few years of practical experience. Engineers have made the interesting discovery that generators, gearboxes, rotor blades and even the technologically rather unsophisticated concrete bases are more vulnerable to permanent loads than originally calculated. For this reason, tech-

<sup>20</sup> This is also suggested by the structure of the working group “Windenergie” in the VDMA. See Power Systems (2008). Annual report 2007/08. Frankfurt am Main, p. 16/17.



nical solutions are required. The gearboxes of windmills, a problem area, are just a case in point. Here, the competition for innovation and development has brought considerable technological progress. On the one hand, much more powerful gearboxes on the basis of conventional technology have been made available. On the other, innovative driving systems have been developed which do not require any gearboxes. Hydrodynamic driving technologies (e.g. Voith) are particularly innovative.

### ***Export business on the way to third growth driver***

Thanks to the advances in technology, the wind industry, besides repowering and offshoring, has a third growth path: export business. By the end of the next decade, wind energy is likely to expand by roughly one-fifth p.a. globally. Not least the above-average economic expansion of China, India and the US offers favourable sales opportunities for the global champion in wind business.<sup>21</sup> If the sector wants to benefit from all opportunities on the world markets, not least in the offshore segment, production facilities on the coast of the mainland will also be required. The huge wind plants – e.g. the huge rotor blades – cannot simply be transported by train or heavy load trucks any more. In this context, it may be beneficial if the required cooperation between the large power producers with their wealth of experience and logistic know-how join forces with the small and medium-sized companies of the wind industry.

### **Mechanical engineering kickstarts solar age**

German engineering and artistic genius even made their way to the beautiful island of Capri where the spectacular winding route of Via Krupp was commissioned by Friedrich Alfred Krupp, the son of the German steelworks founder, and where the Gardens of Augustus belonged to his villa. Currently, German industry is marked by a lack of young talent. If, however, Germany's global leadership in state-of-the-art energy and environmental technologies finds greater public awareness, mechanical engineering holds great potential. What could be more tempting for young people than to do their part in solving the energy crisis and avoiding the climate disaster? Fuelled by the passion for research and enthusiasm of young tinkerers and technology freaks, mechanical engineering will do the trick: the age of "Here comes the sun" is only a question of time.

Josef Auer (+49 69 910-31878, josef.auer@db.com)

<sup>21</sup> See Auer, Josef (2007). Germany – the global force in wind energy. Deutsche Bank Research. Current Issues. December 5. Frankfurt am Main, p. 11.

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