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Trend Report: Finding a reliable supply of clean energy - the worldwide challenge

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- Economic crisis only causes brief pause in the energy race
- New generation and distribution strategies needed to achieve climate goals
- Increasing demand for renewable energy and smart networks worldwide

The energy industry has reached a crossroad. An enormous effort will be needed in the coming years worldwide to ensure security of supply. China and the US, the two largest emitters of CO₂, will have a special role to play. Fossil resources are currently used as power station fuel and as raw materials in the chemical industry, creating a conflict which needs to be resolved. Visitors to AchemAsia 2010, which will take place on June 1st - 4th in Beijing, will have the opportunity to learn more about the latest advances in energy utilization and other technologies in the industry.

The current energy debate seems to contain a paradox. Politicians and the car industry want to take us into a world where electric vehicles are king of the road. However, the general population (at least in Europe) is increasingly reluctant to accept construction of new power stations. A simple calculation illustrates the extent of the divergence. The electrical efficiency of a state-of-the-art coal-fired power station is around 50% (as a percentage of chemical energy consumed). Electric motors in cars have an efficiency of 80% - 90% (as a percentage of electrical energy consumed). Electrical power transmission loss also needs to be added into the equation. Thus the best-case overall efficiency is in the 40% - 45% range, which is equivalent to efficiency levels achieved by today's combustion engine in terms of primary energy utilization. Is the discussion about electric cars nothing more than hype to pacify the masses?

The answer is no. Power distribution networks offer genuine opportunities. Tomorrow's electric cars could help solve one of the most pressing problems in the power generation industry, namely how to store electrical energy. In February 2009, the EDISON ("Electric vehicles in a distributed and integrated market using sustainable energy and open networks") research project got underway in Denmark, where scientists are looking at ways of storing excess energy from renewable sources in vehicle batteries and feeding it back

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into the grid as needed. It is no coincidence that the project is being carried out on the Danish island of Bornholm. The country is the world's leading producer of wind energy which is available even at times when there is no demand for the electricity, e.g. at night, during the weekend or on holidays. Car owners could take advantage of the situation by charging their batteries with cheap electricity during off-peak hours and selling it during the day at a higher price when demand increases. The chemical industry is a key player in this scenario. The industry has joined forces with car manufacturers to develop long-life batteries. Lithium-ion cells appear to be the most promising technology. However, cost and power density are still major issues. 1 kW currently costs at least 200 - 300 €. The car industry is looking for prices between 200 and 400 € for the complete battery including the electronics and cooling. The Electro Smart is currently expected to have a 31 kW system.

The electric car debate highlights another issue which affects industrialized nations and emerging countries alike. Demand for electricity and energy will increase enormously in the years to come. The current economic crisis has only caused the energy race to pause briefly. According to estimates published by the International Energy Agency (World Energy Outlook, November 2009), worldwide energy consumption will increase by 2.5% a year between 2010 and 2015. Oil consumption could reach 105 million barrels a day in 2030, an increase of 20 million barrels compared to the 2008 level.

China: an additional 100 GW a year

4800 gigawatts of power generation capacity is expected to go online during the next 25 years, which is five times the current installed capacity of the US. According to IEA, 80% of power station construction will take place in countries that are not currently members of OECD. China alone will account for 28% of the volume. China produced around 800 GW of electricity in 2008. Plans are in place to add another 100 GW annually during the coming years, which is equivalent to the annual capacity of all German electricity suppliers. China will continue to rely to a large extent on traditional sources of energy, namely coal, oil and nuclear.

There are provisions, however, in the 11th Five Year Plan for the utility sector which was published in 2007 to reduce the proportion of coal in the energy mix from 69.1% in 2007 to 66.1% in 2010. The proportion of oil will also decrease. To compensate for the decline, China is pressing ahead with gas and other sources of energy. In addition, the contribution from nuclear power will increase from 1.2% to 4% (36 GW). Another aspect has gone largely unnoticed in the wake of the debate which has ensued after the failure of the Climate Conference in Copenhagen: China has its own Renewable Energy Act, and only Germany remains ahead of China in its efforts to promote alternative sources of energy. The Chinese added 10 GW of wind generation capacity in 2008 alone. The country is not

only a supplier of low-cost solar modules in the world market, it is also making increasing use of solar energy to meet domestic energy demand.

However, plans are also in place to construct large power stations elsewhere. The United Arab Emirates attracted considerable attention at the end of December 2009 by awarding a contract for the construction of four nuclear power plants to a consortium led by Korea Electric Power Corporation. 16 nuclear plants are now under construction or are at the planning stage in the Middle East. To meet rising energy demand in the sun-drenched Emirates, 24 GW of additional power generation capacity will be put in place in the 7 desert sheikdoms by the year 2020. The UK currently has Europe's most ambitious nuclear power expansion program. Approval was recently granted for 10 new nuclear power stations. The German government plans to extend the lifespan of existing nuclear power stations.

Increasing the efficiency of coal-fired power stations

Renewed interest in nuclear power is primarily the result of the climate debate and widespread use of power generation techniques which release CO₂, causing climate change. In actual fact, replacement or modernization of old coal-fired power plants would be far more effective in reducing the impact on the climate. Around 70% of electricity worldwide is produced in fossil-fueled steam power generation plants. The average efficiency of the plants is currently 30%. Anthracite powered steam generation plants could operate at 46% efficiency, and the figure is 44% for lignite. The efficiency of combined cycle power stations can exceed 58%. The German Environment Minister is backing plans to replace existing power stations that have a total capacity of around 21 gigawatts with 12 state-of-the-art stations. The opportunities for improvement are greater in China, partially because power is still produced there in less efficient small and medium-sized power stations. More than 250 of these power stations were shut down in 2007 alone.

Process technology can boost energy efficiency

Process engineering can provide solutions to boost energy efficiency. Every incremental increase in efficiency reduces greenhouse gas emissions and investment costs. In a policy document entitled "The Contribution of the Chemical Industry to Our Future Energy Supply"¹, which was published by a group of industry organizations (DBG, DECHEMA, DGMK, GDCh, VCI and VCI-GVC) last October, the avoidance of CO₂ emissions is one of the main factors driving further development of power generation technology. Simply by pre-drying lignite in fluidized-bed systems, efficiency can be improved by 4%. High-temperature combustion, which requires the use of nickel-based alloys, could raise the efficiency of coal-fired power stations to above 50%. Economy-of-scale effects offer additional opportunities for boosting energy efficiency at combined cycle power plants. Siemens estimates that a turbine retrofit at a medium-size power station can increase output by 30 – 40 MW. The company claims that the ROI period is only a few years. The

chemical industry also plays a crucial role in carbon capture. The most promising techniques are:

- Pre-Combustion Capture
- Post-Combustion Capture and
- Oxy-fuel technologies

Pre-combustion carbon capture involves conversion of the fuel to carbon monoxide and water using a gasification or reforming process. CO shift conversion, which creates a hydrogen/carbon dioxide gas mixture, is the next step in the sequence. Finally, the carbon dioxide is separated out using physical absorption. Post-combustion techniques involve chemical absorption to remove the CO₂ from the flue gas at the end of the power generation process. This approach is attractive, because it only involves a relatively simple retrofit at existing power stations. BASF and Linde have jointly developed a process for removing CO₂ from flue gas with the aid of an amine-based solvent. The two companies plan to jointly market the technology. Oxy-fuel combustion is another carbon capture technology. When the fuel is burned in pure oxygen, the flue gas contains only CO₂ and water which are separated by condensation.

All of these techniques have the disadvantage that efficiency decreases by 9% - 13%, and more fuel needs to be burned to produce the same amount of electricity. A number of pilot and demonstration plants are currently under construction, but chemical industry organizations are not expecting wide-scale introduction of carbon capture at power plants before 2020. A lot of development work remains to be done.

Where to put the CO₂

Whatever technique is used, one problem remains, namely where to put the carbon dioxide after it has been captured. A number of options are currently under investigation including storage on the seafloor and sequestration in disused mines. Despite the fact that no one at the moment can accurately assess the long-term risks, several billion dollars in funding has already been made available for carbon capture and storage (CCS) in the US where the coal industry has a very powerful lobby. Around half of the electricity produced in the US comes from coal-fired power stations, and the country has enough coal to meet demand for the next 250 years.

Biotechnology may be able to help solve the CO₂ problem. The energy supplier RWE working in conjunction with the biotech company Brain is looking at ways of using specially cultivated microorganisms to remove carbon dioxide from flue gas. The basic idea is not new, as plants absorb CO₂ to sustain growth. Compared to plants and algae, microorganisms grow more quickly, and their metabolism and production rate can be accelerated with fermentation systems. This approach may appear to be very promising,

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but researchers agree that the learning curve will be a long one, even if massive resources are invested in research. Large-scale solutions are probably 20 to 30 years away. Climate researchers tell us that we do not have that much time.

To address these issues, the German Chemical Industry Association and the DECHEMA Society for Chemical Engineering and Biotechnology defined a clear priority list in a policy document on the use and storage of CO₂ which was published in 2009ⁱⁱ. Saving energy has top priority. State-of-the-art building and insulation materials, for example, can help reduce energy consumption. The Chinese are aware of the potential energy savings. 24.4 kg of coal equivalent is burned to heat one square meter of living space in Beijing, whereas the figure is only 9 kg/m² on average in Germany. One of the goals of the Chinese government is to save 350 million metric tons of coal by reducing energy consumption in buildings.

The proportion of renewable energy is increasing worldwide

The climate issue and efforts to reduce dependency on foreign oil and gas have given extra impetus to the continued development of renewable energy in recent years. Research subsidies and laws regulating feed-in tariffs have made a huge contribution to the use of wind, hydro and solar power to meet increasing demand for energy. According to figures published by the German Energy and Hydroelectric Association, around 16% of the electricity which was supplied to customers in Germany in 2009 was generated from renewable resources. It would appear that the country is well ahead of the game in its efforts to meet the EU goal of generating 18% of its energy from renewable resources by 2020. The Association believes that 28 % is achievable.

The Obama Administration has initiated a number of projects in the US. The goal is to increase the proportion of renewables to 10% by 2012 and to 25% by 2025. China is striving to increase the share of renewables in the energy mix to 10% in 2010 and 15% in 2020 (including hydroelectric power). The Chinese plan to increase solar power output from a current level of 90 megawatts to between 10 and 20 gigawatts by 2020. News that a gigantic solar park is to be built in the Gobi Desert by 2019 with a capacity of 2 GW attracted considerable attention last year. Construction is scheduled to begin in June 2010.

Wind power is currently the largest source of climate-neutral electricity. A number of gigawatt-scale offshore wind parks are currently planned or already under construction in Europe. Plans are in place to build nine huge wind parks off the British coast in the North Sea. The contract for the largest park (9 GW) was awarded to RWE Innogy, Statoil of Norway and Scottish & Southern Energy. Around 12 billion euros will be invested in the wind parks.

Solar thermal: electricity from the desert

PV systems are not the only option for generating electricity from solar energy. Solar thermal technology can also harness the sun's energy. Solar thermal power stations are basically similar to combined cycle and coal-fired stations. The difference is that the steam generator is powered by the sun's heat rather than combustion of coal, oil or gas. Parabolic mirrors focus the rays to heat thermal oil or brine to a temperature of several hundred degrees Celsius. Steam to drive the turbine is generated in heat exchangers. The first thermal power stations of this type were built in the Mojave Desert in California in the 1980s. Europe's first solar thermal power station was recently completed in La Calahorra, Spain. Andasol I has been generating electricity from the sun's heat on a regular basis since the middle of 2009.

Solar thermal could become a major source of energy for Europe in the future. The aim of the Desertec project is to cover 15 - 20% of European electricity needs by the year 2050 using parabolic trough power stations. The power stations will be located in Africa and the Middle East. A dozen European companies formed the Desertec Industrial Initiative in July 2009 to provide the resources needed for the 400 billion euro project. 50 billion euros will have to be invested in electric power transmission technology alone.

New power grid technology

As renewables begin to play a bigger role in the energy mix, researchers, engineers and the general public are turning their attention to another problem. The distance between the point of generation (desert, ocean, etc) and the point of use continues to increase. Power grids will have to be expanded, and there is also a need for new power transmission technology. The largest next-generation grid will go into operation in Southeast China this year. A dozen hydroelectric plants on the Jinsha River, a tributary of the Yangtze, will supply electricity to five million households in the megacities Guangzhou, Honkong and Shenzhen, which are 1,400 kilometers away. The engineers are making use of Ohm's Law to minimize the unavoidable power losses. Resistance and power loss decrease as the voltage increases while power output remains the same. The electrical energy will be stepped up to no less than 800,000 VDC in Jinsha to supply 5,000 MW which is equivalent to the output of 5 large power stations. The power line loss over the one and a half thousand kilometer stretch is only 5%. The same principle could be exploited on power transmission lines from the Sahara to Europe.

However regardless of whether electricity is supplied from large remote power stations or distributed CHP stations which are linked together to form a virtual large power station, grid management is another issue that needs to be addressed. Tomorrow's smart grids will be based on automation technology including electronic electricity meters. Because output from wind and solar sources is not constant, there will be a greater need to temporarily

store electricity in the future. The chemical industry is currently looking for new strategies and solutions. In addition to the car batteries mentioned above, researchers are investigating compressed air systems and hydrogen extraction using electrolysis. Compressed Air Energy Storage systems use excess electricity to compress air up to pressures of 100 bar. The compressed air is stored in underground caverns such as salt domes. The compressed air drives gas turbines to generate electricity at peak times.

Summary

Increasing demand for energy and the need to supply energy with minimal impact on the climate have created a huge worldwide challenge. The chemical industry is making a contribution to the development of secure sources of energy in a number of areas including solar cells, semiconductors, efficient insulation materials and new energy storage technology. Chemical and process engineering also play a major role in carbon capture systems. The latest solutions will be on display at AchemAsia.

www.achemasia.de

(The trend reports are compiled by international trade journalists. DECHEMA does not accept any responsibility for incomplete or incorrect information.)

ⁱ Energieversorgung der Chemie – der Beitrag der Chemie: Eine quantitative Potentialanalyse. Published by the Chemical Energy Research Coordination Group (DBG, DECHEMA, DGMK, GDCh, VCI and VDI-GVC), October 2009. http://www.energie-und-chemie.de/pdf/psp_energie09.pdf

ⁱⁱ Policy document “Verwertung und Speicherung von CO₂”. Published by DECHEMA and VCI, 2009. http://www.dechema.de/dechema_media/Positionspapier_CO2.pdf