DKK to U.S. dollars are based on the exchange rate in effect on Jan. 22, 2013, 1 DKK = US$0.178.

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Beginning on a modest scale in the 1920s, two Copenhagen-based companies — Nordisk Insulinlaboratorium and Novo Terapeutisk Laboratorium — started to manufacture insulin from bovine pancreas, which was readily available from the meat industry’s slaughterhouses. Over the years, competition between the two companies spurred an impressive series of innovations and growth, as each developed and refined new insulin products. Nordisk produced insulin with protamine in 1935, crystalline protamine insulin in 1944, and highly purified porcine insulin in 1977, while Novo marketed zinc-protamine-insulin (ZIP) in 1936, Lente products in 1953, and highly purified insulin (MC insulin) in 1977, and converted porcine insulin into human insulin in 1982. During the 1960s, Novo branched out to produce new pharmaceutical chemicals for hormone replacement therapy, as well as industrial enzymes such as Alcalase, which is used in detergents. In the 1980s, the companies pioneered new insulin-delivery systems, such as Nordisk’s Infuser insulin pump in 1983 and Insuject insulin pen in 1986, and Novo’s NovoPen in 1985 and Novolet — the world’s first disposable syringe — in 1989 (3).

After decades of individual development, in 1989 the two companies merged to form Novo Nordisk, which became a global leader in diabetes care and industrial enzymes. In 2000, Novo Nordisk split into a healthcare business (the company name remained Novo Nordisk) and an enzyme business (Novozymes). Since then, both companies have continued to grow by investing in research and development in their niche markets, including growth hormone therapy, and expanding into new areas such as hemophilia care. Today, Novo Nordisk has the highest market capitalization among all the companies traded on the Copenhagen Stock Exchange, and both Novo Nordisk and Novozymes receive high rankings in the Dow Jones Sustainability Index, in recognition of their economic, environmental, and socially responsible sustainability practices.

The development of such strong companies within the pharmaceuticals and biotechnology sectors has attracted other companies that supply complementary technologies and solutions. For example, NNE Pharmaplan A/S (founded in 1989 and owned by Novo Nordisk) has for decades served as a consultant to Denmark’s pharmaceuticals industry, and has expanded globally with international offices that provide a wide range of services, including design, construction, optimization, and startup of pilot-scale and production processes. It is now one of the world’s largest engineering and consulting companies specializing in pharmaceutical and biotechnological industries.

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Energy challenges and progress

Until the 1970s, Denmark had no significant domestic reserves of oil and natural gas, which posed an obvious barrier to the development of petroleum-based industries.

This changed with the technology development that allowed the exploitation of oil and gas in the North Sea that began in 1972 and 1984, respectively. These efforts were led by the Dansk Undergrunds Consortium (DUC) — an alliance between A.P. Møller (today known as AP Møller-Mærsk), Shell, and Chevron — which in 1962 had been awarded concessions by the Danish government for the development of oil and gas. Since 1984, oil and gas exploration has been open to other companies, among them DONG Energy, Denmark’s national energy company, whose operations include power generation and distribution, as well as oil and gas exploration and production.

Thanks to these North Sea activities, Denmark’s industries were not only able to fulfill their own fossil energy needs, but Denmark has since become a net exporter of energy through companies that include Mærsk Oil and DONG Energy — albeit on a modest scale compared to neighbors such as Norway. In 2011, Denmark’s oil and natural gas exports were 48.3 billion DKK (US$8.6 billion) and 9.9 billion DKK (US$1.76 billion), respectively.

Denmark’s early lack of domestic fossil resources established a long tradition of industries using other forms of energy, notably wind power. The wind power industry was supported by such home-grown companies as Vestas, established in 1898, which began developing windmills in the 1970s and today is a global technology leader in the field of wind turbine manufacturing and related energy services.

Today, in the arena of biomass-based renewable energy production, Inbicon (a subsidiary of DONG Energy) has developed a technology for cellulosic ethanol production that employs an enzymatic hydrolysis and fermentation route. Inbicon has tested the technology on a demonstration scale at the Asnæs Power Station in Kalundborg, Denmark — where the biomass refinery is integrated into the coal-fired power plant by using the steam from the power plant to pretreat the biomass. This technology is being used in first- and second-generation ethanol production, power plants, and other combined heat and power (CHP) plants.

Danish power plants have long been market leaders in clean-coal technologies, boasting fuel-energy-to-electricity power efficiencies of close to 50%. With CHP production, overall efficiencies have exceeded 80% (10). This success has been the result of collaborations between industry and academia, including fundamental chemical engineering research in process technology and high-temperature materials. Such collaboration has also led to breakthroughs in the application of biomass and waste to power and heat production. For example, during the 1990s, technologies for grate firing of biomass and waste were developed in cooperation with companies such as Babcock & Wilcox Vølund, and Burmeister and Wain Energy A/S. These technologies have been installed in many plants worldwide.

Science and technology clusters

Following the emergence and success of the industrial-park concept, which pools together a critical mass of specialized competences in a certain geographical area (see CEP, Oct. 2011, pp. 44–47), Denmark has established chemical clusters of its own. These include the Medicon Valley, Agro Food Park, and Welfare Tech regions, as well as an important collaboration devoted to renewable energy.

The Medicon Valley, which spans the region between eastern Denmark (including the greater Copenhagen area) and southern Sweden (Figure 1), has established itself as one of Europe’s strongest life-sciences clusters in pharmaceuticals, biotechnology, and medical technology. Medicon Valley brings together more than 300 companies (among them Novo Nordisk, Lundbeck, and AstraZeneca) with academic research
Not all of Denmark’s chemicals-industry success stories are in the pharmaceuticals and biotech sectors. The following chemical industry sectors are among Denmark’s largest, and among the country’s largest employers of chemical engineers.

**Catalysts and catalytic processes** — Founded in 1940, Haldor Topsoe is a major applied-research company in the field of catalysts and catalytic process technology. Applications of its R&D range from oil refining, to air pollution/emission control in motor vehicles and power plants, to the production of bulk chemicals such as sulfuric acid, methanol, and ammonia.

**Building materials** — Originating as an equipment supplier in the 1880s, FLSmidth remains a significant player in the heavy process industries. It is among the world’s largest companies in the cement industry, providing engineering, equipment, and plant design and operation support services. The company recently expanded its business to include the capability to provide full flow-sheet solutions for the mineral industry, e.g., for the production of copper, gold, coal and iron.

**Coatings** — Hempel began in 1915 as a supplier of paints for maritime applications, and has grown into a global developer of heavy-duty protective coatings for the marine industry (coatings for ships, oil platforms, and sea-based wind farms), and for land-based industry and infrastructure. Hempel has focused on its specialized niche, combining technology development with global business development.

**Crop protection** — Cheminova offers customized chemical crop-protection products that help farmers to increase the yield and quality of foods, animal feed, and biofuel crops. The company has innovated environmentally friendlier products with lower organic-solvent content.

**Equipment** — Established in 1883, Alfa Laval is a leader in heat transfer, separations, and fluid handling, and its products are used in industries that include food, water, energy, environmental protection, and pharmaceuticals. Two other Danish companies in the equipment sector are GEA Niro, a supplier of process equipment for spray drying, fluid-bed drying, and freeze drying; and Anhydro, which designs and develops innovative liquid-concentration and powder-processing equipment.

More and better scientists and engineers

Danish chemical companies have demonstrated that they have the resources to innovate, compete, and expand on a global scale in highly specialized niche markets. This has required an interdisciplinary array of business, scientific, and technical abilities — from product development and production technologies, to distribution, marketing, and supply chain logistics. To sustain a leadership position in today’s market, these industries must rely on a highly qualified workforce with a broad range of skills and knowledge in science and engineering, including chemical engineering. This places an emphasis on higher education, and in particular on PhD education — to supply more (and higher quality) graduates with the skills and knowledge needed to support these knowledge-intensive industries.

Denmark’s higher-education system has responded well to the demand for trained workers. Denmark’s official bureau of statistics (Danmarks Statistik) has charted a steady increase in the number of students receiving BS, MS, and PhD degrees in engineering and the sciences for the period 2001–2009 ([1]). In fact, Denmark saw an average 10% annual increase in the number of PhD graduates between 1998 and 2006, placing Denmark third in the world on this measure, behind only China and Mexico ([2]).

Figure 1. Medicon Valley is one of Europe’s largest industrial clusters, home to many life sciences companies. The complex straddles the Øresund strait, which lies between Malmö in Sweden and the greater Copenhagen area in Denmark — joined by the iconic Øresund Bridge.
The quality of Denmark’s PhD education is high, comparing favorably with other developed countries (14). And, while the recent increases in the number of PhD graduates has created an oversupply problem in some countries (including Japan and the U.S.), Denmark’s biotechnology, chemicals, and processing industries have been able to absorb the increased supply of PhD graduates. However, analyses indicate that Denmark will soon face a workforce shortage, and must expand the capacity and international reach of its PhD education system.

The Danish Society for Engineers (IDA) has carried out a supply and demand analysis of Denmark’s engineering graduates (13). The study has revealed that by 2020, at the economy’s current growth rate, Denmark will have a shortage of nearly 30,000 engineers and scientists: 13,574 trained in technical sciences (chemical and biochemical engineers, as well as other technical specializations relevant to the chemical and processing industries), and 16,088 graduates trained in natural sciences such as bioinformatics, biology, physics, chemistry, mathematics, and statistics (Table 2). Even under a low-growth scenario, the IDA projects that there will be a combined shortage of 18,000 engineers and scientists in 2020.

Danish universities are collaborating with stakeholders in industry, government, and engineering societies to educate a new generation of engineers to keep up with current and future demands for a high-quality workforce. Among these efforts, the Technical Univ. of Denmark’s (DTU) department of chemical and biochemical engineering is training researchers at the PhD and postdoctoral levels. DTU also offers an International Elite Master Education program in cooperation with companies such as Hempel and Haldor Topsøe, through which students are connecting with companies that take a global approach to research, innovation, and design.

### In closing

Denmark’s chemicals industry includes an array of innovative world-class companies. Among its successes, Denmark has co-established an important industrial cluster, Medicon Valley, to attract pharmaceuticals, biotechnology, and medical technology companies, leveraging the multidisciplinary competences and skills of the participants to spur further innovation and growth.

The Danish higher-education system, in collaboration with industry and government, is well positioned to meet the challenge of educating the next generation of engineers and scientists, contributing to the nation’s research and knowledge base, and keeping Denmark competitive.

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