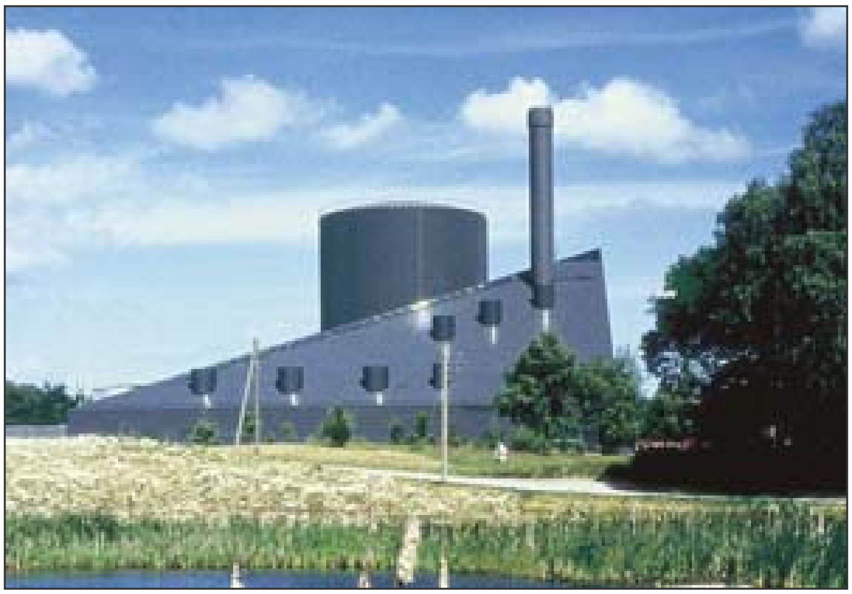
Solutions at a Glance: COMBINED HEAT AND POWER PLANTS

"Engineering is the science of economy, of conserving the energy, kinetic and potential, provided and stored up by nature for the use of man. It is the business of engineering to utilize this energy to the best advantage, so that there may be the least possible waste." - William A. Smith, 1908



50 MW Combined Heat and Power Plant in Helsingør, Denmark

The Challenge

In 2002 only 31% of the primary energy consumed for electricity production in the United States was ultimately delivered to end users (Energy Information Administration, Annual Review 2002). The remaining 69% was lost during the conversion process or transmission/distribution, equivalent to the energy of 4,700 million barrels of crude oil. This waste dwarfs the 9 to 16 million barrels of oil estimated to be recoverable from the Arctic National Wildlife Refuge, often described as America's best opportunity for new energy reserves. The reality is that our greatest energy reserves lie in changing the basic processes that we use for energy production in our country.

The Solution

In 1975, with the Arab oil embargo, Denmark faced its own energy crisis, as 93% of its energy was dependent on imported oil. The government embarked on an aggressive program of reforms, including promoting higher building efficiencies and the development of Combined Heat and Power (CHP) plants. Today 53% of the electricity in Denmark is produced in tandem with heat production. The impact of these changes has been remarkable – since 1990 adjusted gross energy consumption has increased by only 1%, despite a 30% increase in GDP during the same period. In addition, adjusted CO_2 emissions have fallen almost 14%. This means that each unit of gross domestic product required 22.6% less energy and resulted in 34% less emissions of CO_2 than in 1990.

Background

In a traditional thermal power plant 40% to 60% of the energy contained in the fuel is dispersed into the atmosphere or cooling water as "waste" heat; in CHP plants this "waste" heat is captured and used for different purposes: district heating, industrial processes, and other production processes. As a result the overall plant efficiency can be increased to 90% or more. For example Helsingør, a 57 MW natural gas-fired combined-cycle plant feeding a small town north of Copenhagen, utilizes 88% per cent of the fuel energy to produce electricity and heat.

Larger plants, such as the Avedøre 2 plant serving Copenhagen, operate at an efficiency of up to 94%, the highest level in the world. Though Avedøre 2 is capable of burning oil and natural gas, it primarily uses straw and wood pellets, and is equipped with a range of cutting-edge technology to reduce harmful emissions into the environment and meet Kyoto protocol targets to limit climate change. The efficient utilization of these fuels through cogeneration benefits the environment by considerably reducing emissions of CO_2, SO_2 and Nox. Avedøre 2 generates 570 MW of electricity, meeting the needs of some 800,000 households, while providing the heat for approximately 110,000 homes.

In 2000 there were more than 678 CHP plants in Denmark, with a combined capacity of 10,231 MW. Of these, 15 were large-scale centralized CHP plants, 576 were small-scale decentralized plants, and 87 were industrial plants. The small-scale plants are on average about 3.5 MW, and are typically designed to meet the electricity and heating needs of a neighborhood or small town. The number of these plants has exploded over the past 20 years, largely due to government policies requiring all district heating systems to convert their gas boilers to cogeneration, in order to increase the overall efficiency of the energy systems and decrease CO_2 production.

The plants are highly automated, normally running with a staff of only three to four people during the day shift, and can be easily operated from a centralized utility control center. They are architecturally designed to merge unobtrusively into a mixed use or even a residential setting, and the sound of these plants is practically inaudible – far quieter than the traffic noise from adjacent streets. In fact, were it not for the presence of an exhaust stack many of these plants would simply appear to be typical commercial buildings.

Although the technologies behind CHP plants are well proven in Scandinavia and elsewhere, they do require some fundamental changes in thinking for traditional power plant designers. First, for reasons of basic thermodynamic efficiency, the goal of power system engineers has historically been to maximize combustion temperatures, while releasing exhausts at the lowest possible temperature. For a CHP plant to produce useful heat as an intentional, marketable product, the output temperature must be elevated, making the electrical generation process slightly less efficient. However, this reduction in the efficiency of electricity generation is more than offset by the overall increase in plant efficiency gained by capturing and reusing the waste heat.

Secondly, the heating or cooling output of a CCHP plant has economic value only if there is a readily accessible market for the output. In the United States this has been primarily restricted to heat intensive industrial processes or space heating of individual buildings, which greatly limits the potential opportunities. It is the widespread adoption of district energy systems, now providing heat for almost 60 percent of the heated floor space in Denmark, that has created a ready-made market for the output of these plants, allowing adoption of these more efficient designs to become much more widespread.

Because CHP plants are designed to deliver both hot water and electricity, even the larger, centralized facilities are located close to urban load centers. This runs counter to the common approach in the United States, where large generating plants are typically sited far from population centers. However, by reducing the losses due to long distance transmission and distribution this philosophy further increases overall energy system efficiencies.

The 2004 Urban Sustainability Study Group to Sweden and Denmark

In March 2004, a group of architects, engineers, developers and others from Washington and Oregon went to Sweden and Denmark to look at advanced urban sustainability projects. A key component of this trip was a visit to a CHP plant in Helsingør, Denmark.

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