Alternative Energy for the Chemical Processing Industry

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ABSTRACT

Dow Chemical has a stated goal for sustainable development, and feels that it is part of the companies overall competitiveness. This goal includes the use of raw material for process demands as well as the use of energy to support these process facilities. The goal also includes the manufacture of products that enable sustainable development.

The energy business supplies power and fuel to the production sites. The primary purchased fuel is natural gas, and to a lesser extent fuel oil. The power purchased from local suppliers is based on a variety of sources from hydro to nuclear depending on the region.

Globally there is a continued emphasis on the use of renewable energy sources from solar to bio-gas. Dow is in a unique position as a large user of power to take advantage of these established technologies. The advantage to Dow is lower cost for supply, reduced emissions, and the public exposure resulting from the support of these global initiatives.

Introduction

The Dow Chemical Company is a leading Science and Technology Company with a mission to constantly improve what is essential to human progress. Dow is one of the largest global integrated chemical companies. Dow produces a balanced product mix of performance and basic chemicals.

In 2004 Dow had revenues of over $40 Billion with over 40% in North America, 35% in Europe, and the balance in Asia and Latin America. A little less than 60% of our asset base is in North America, 29% in Europe and the balance in Asia and Latin America.

Energy Demand in Dow

Dow Chemical is the largest industrial consumer of fuel/power. The large number of Olefin and Chlor-alkali production plants, along with the many derivative plants requires a large amount of steam and power, or simply energy. This demand is largely met with internal generation. In the US Dow has over 3000 MW of capacity. Dow has made extensive use of cogeneration or Combined Heat and Power (CHP). This energy integration along with our large production integration provides Dow a competitive advantage.

Worldwide about three percent (3%) of Dow's power is supplied by renewable energy, mostly hydro-electric. Dow's feedstock and energy cost have increased over $6 Billion over the past two years. Since 1994 Dow has reduced its energy intensity (BTU per pound of product) by over 20%. The high energy cost seen today allows Dow to save $35-40 million for each 1% improvement in energy intensity.

Dow began investigating renewable energy in 2002. Renewable energy is seen as an opportunity to reduce the dependence on natural gas, and further diversify the energy mix. Some of the renewable technologies are cost effective now, and with continued development other technologies will become cost effective later. Renewable technologies would allow Dow to meet general environmental and emission requirements in states and countries of operation.

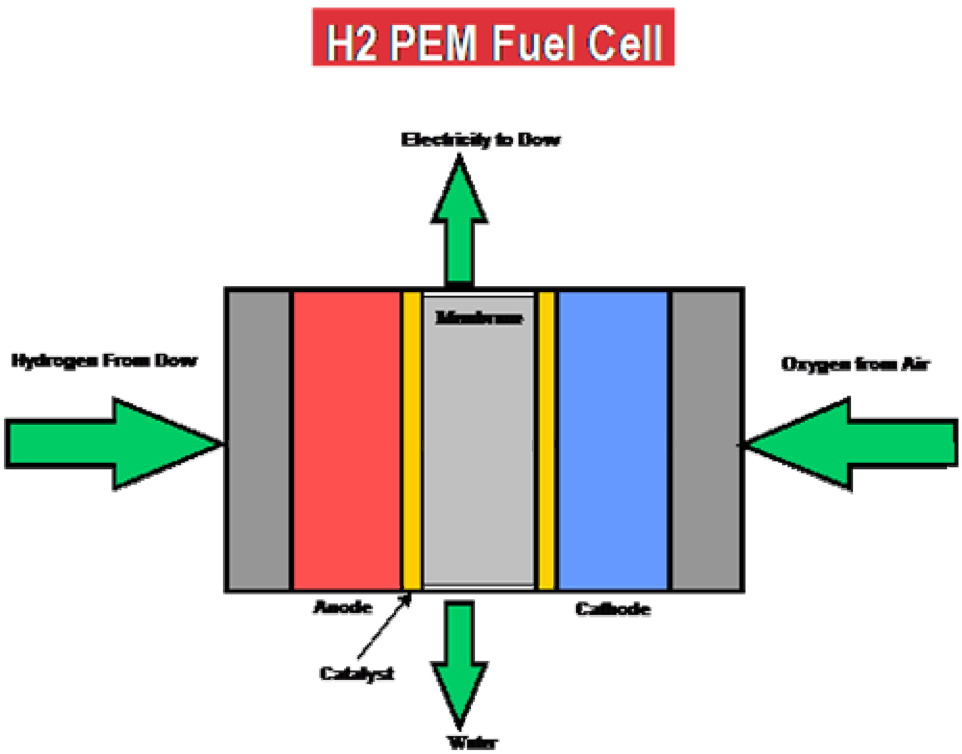
Renewable Energy Opportunities in Dow

Fuel Cells

Dow has a large amount of hydrogen as part of our manufacturing processes. An opportunity exists to use this hydrogen in a fuel cell. Several types of fuel cells are available. Proton Electrolyte Membranes (PEM) appears to be the leading technology. This technology is used in automobiles and will have the largest market share. These units operate at low temperature, 60C as compared to other fuel cell technologies.

Dow and GM developed a project to convert our hydrogen into power for use at one of our sites. This project allows GM to test their fuel cells under varying conditions, and allows Dow to use it's by product hydrogen in a more efficient manner.

Figure 1. A Hydrogen PEM Fuel Cell Element



Source: General Motors 2020 Presentation to Dow

Figure 1 shows a single PEM fuel cell element. The fuel cell consists of two bipolar plates (anode and cathode), a Membrane Electrode Assembly, and Diffusion Media. These elements when connected to an electric load produce DC power.

Hydrogen fuel cells need two elements to generate power, oxygen from the air, and hydrogen. The hydrogen and oxygen react through the membrane assembly to produce the electric power. The only by-product of the fuel cell is pure water. Fuel cells are grouped together in a "fuel cell stack." This stack then becomes the engine in a fuel cell automobile, or the power generator for electricity at our Dow site.

For Dow there are several benefits to the project:

- Continuation of Dow's commitment on our Sustainable Development journey
- Leading edge of emerging technology
- Beginning steps towards a hydrogen economy
- Accelerate fuel cell development for automotive application
- Validation of co-product hydrogen feed sources
- Development of cost effective alternative power generation

Another opportunity is hydrogen. Dow produces a large amount of by-product hydrogen, as much as several large methane reformers. Dow brought expertise for the cleanup of these streams. Fuel cells are picky, requiring "clean" hydrogen. Dow and GM put a lot of effort in the purity issue. Some contaminant levels were in the ppb range, and Dow techniques for measurement allowed these levels to be detected.

Dow investigated several technologies for cleanup including:

- Cryogenic
- PSA
- Membrane
- Ceramic
- Chemical Conversion

Cryogenic separation occurs at low temperatures. The process is commonly practiced by the Air Separation Companies for production of oxygen and nitrogen. It is also used in the separation of syngas from a reforming process producing hydrogen and carbon monoxide for other chemical use. These systems produce high purity componemts and, due to the cryogenic nature of the process are expensive.

PSA or Pressure Swing Absorption is another separation process for gases. A gas mixture is introduced to a vessel with an absorbent that removes one of the components and passes the other component to the process. The absorbed component is later released as a vent stream. These systems are used to separate hydrogen from an Olefins process tails gas stream. The hydrogen is high purity and the methane is fueled.

Chlorine processes produce a hydrogen stream as a result of the electrolysis process. The stream has a small amount of chlorides present that must be removed for a fuel cell application. A proprietary process was developed to convert the chlorides to methane and HCL and then absorb the HCL.

Dow is investigating other fuel cell technologies that can take advantage of the hydrogen from the chemical processes. The PAFC or phosphoric acid fuel cell has potential to use hydrogen directly. These systems may be more robust than PEMs, but will be more expensive. Other higher temperature technologies like solid oxide and molten carbonate use methane or other hydrocarbons as a feedstock integrated with a reformer for the hydrogen production.

The cost of power produced by fuel cells today is high relative to other means of producing electricity for use within a manufacturing complex. The cost to manufacture a fuel cell is $1500 to $2500 per KW. The cost to produce hydrogen from conventional means is higher than other hydrocarbon fuels. Even in a chemical plant where hydrogen is produced as a co-product the cost for clean-up versus the use of the hydrogen as a fuel needs to be offset by the efficiency gain. The projects at Dow allow this early development and improvement in the cost performance of fuel cells.

Landfill Gas

Landfill gas (LFG) emitted from decomposing refuse is a reliable and renewable fuel option that remains largely untapped at many landfills across the United States, despite its many benefits. LFG is created when organic waste in a landfill naturally decomposes. This gas consists of about 50 percent methane (CH4), the primary component of natural gas, about 50 percent carbon dioxide (CO2), and a small amount of non-methane organic compounds. Instead of allowing LFG to escape into the air, it can be captured, converted, and used as an energy source. Using LFG helps to reduce odors and other hazards associated with LFG emissions, and it helps prevent methane from migrating into the atmosphere and contributing to local smog and global climate change.

Dow is investigating projects to use landfill gas in areas where a landfill is located close to a site that requires steam for process heat. The economics of these projects is greatly affected by the distance between the landfill and the site for use, but can compete with natural gas. Many landfills are now required to install gathering and destruction systems which can enhance a project. Many landfills are owned by a city or county, and can use the income from the use of landfill gas to offset operating and capital cost. Another benefit to these projects is the environmental credits generated by using the gas to offset purchased fuels.

Wind Power

The use of wind turbines has increased around the world. These turbines are getting larger and the cost is continuing to drop. Wind Turbines are organized in large areas hundreds or thousands of acres often referred to as wind farms producing hundreds of Megawatts.

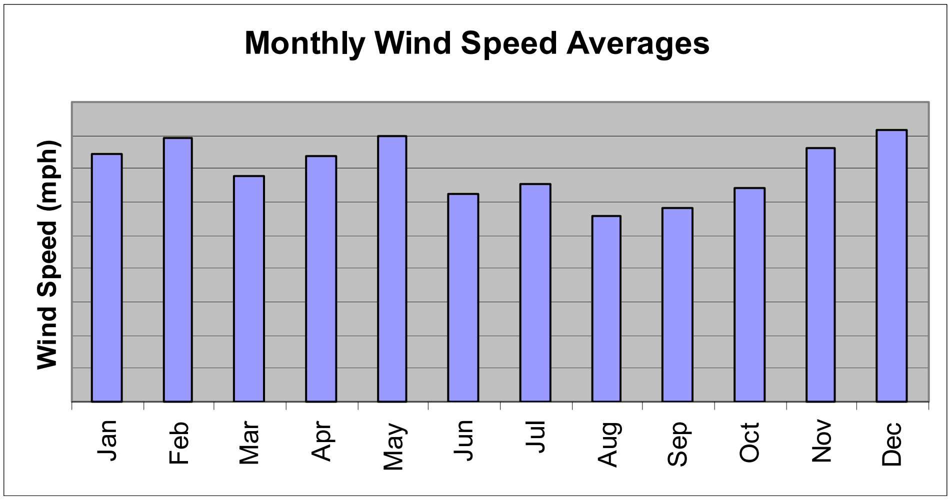
Some Dow sites cover large land areas. These sites have buffer areas and large land areas for raw material storage. These available lands can be developed into Wind Parks that would produce 25 to 75 MW. The ability to utilize these sites is dependent on the wind intensity and wind strength.

The initial steps involve gathering any local wind information. Airports and other federal agencies are typical resources. This data can provide an initial screening step for the potential of wind at any given site.

The demand utilization is an industry measure for the ratio of the average annual hourly production to the installed capacity. The wind industry sometimes refers to this as the wind efficiency. Typical economic demand utilization needs to be 35 % or higher to justify the capital and provide a reasonable return.

Dow picked Texas as a base for an initial study for wind. Texas is a deregulated power market, and has identified renewable energy as a state goal. The western areas of Texas have a high average wind speed with demand utilization to 45%. The Texas Gulf Coast also shows potential for wind development, but the wind speeds are lower than west Texas. Working with turbine suppliers and project developers we found the available data had some variation, some months have a higher average wind speed than others. This seems to occur at any location. Figure 2 is an example of this effect.

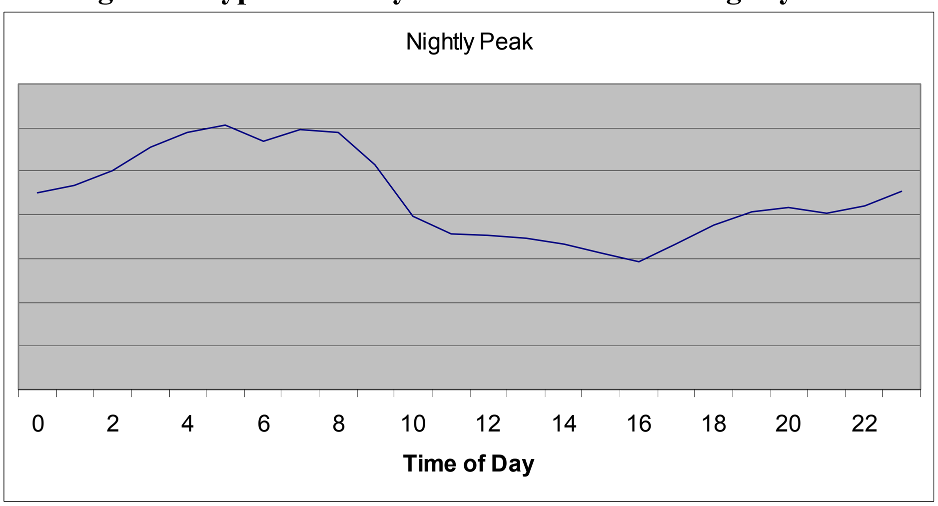
Figure 2. Typical Nominal Wind Speeds Over a Year



Source: Wind Turbine Supplier in Review to Dow

Another variation in the measure of wind that is important is wind velocity as a function of time-of-day, a nightly peak vs a daytime peak. These peaks are important relative to the time-of-day pricing for deregulated markets like Texas. The winds in west Texas have a nightly peak as seen in Figure 3.

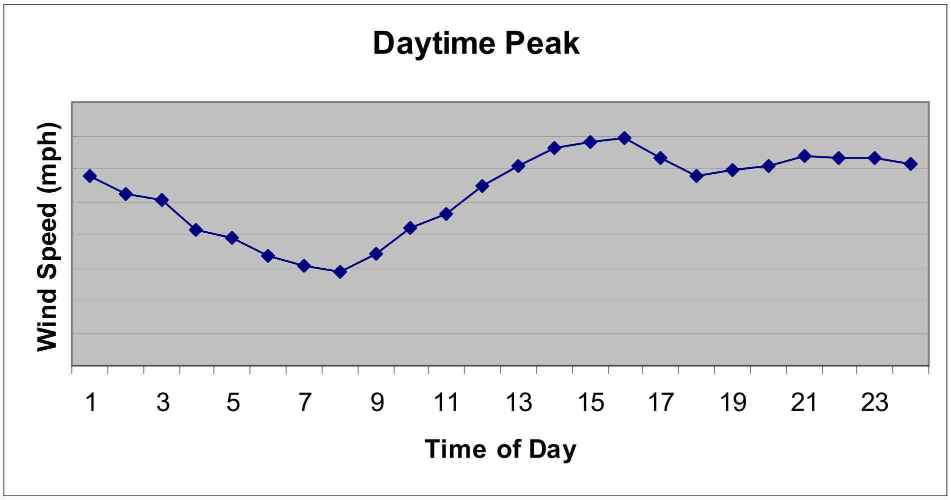
Figure 3. Typical Hourly Wind Profile with a Nightly Peak



Source: Project Developer for a Wind Project in West Texas

The winds along the Texas Coast showed a daytime peak as seen in Figure 4.

Figure 4. Hourly Wind Profile with a Day Time Peak

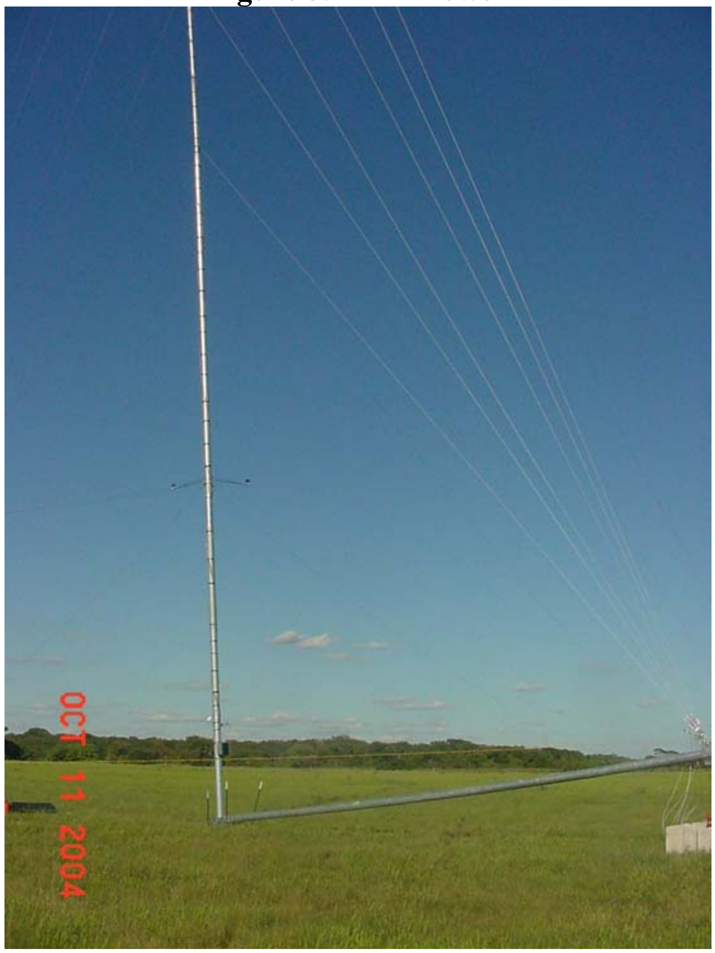


Source: Developer for a Wind Project on the Texas Coast

We choose to focus the study at a site along the coast. Even with a lower wind speed, Dow could use its land resource as well as keep the power behind the fence.

Once the potential wind data was identified, a base case economics scenario was developed. Typical capital cost for a project is $1100 to 1200 per KW. The initial economic review including tax and emission credits was favorable as compared to the market. Since estimated wind resource was acceptable we decided to install wind measuring towers (MET towers) at a few locations within the planned development. MET towers measure wind information at several vertical levels typically speed, direction and temperature. These towers are fairly self sufficient, gathering, storing and transmitting the data over a several month period. Many times the data can be correlated to historical data that enables the analysis of the wind resource to extrapolate to cover a period of a few years accurately. Figure 5 shows a typical field erected MET tower.

Figure 5. MET Tower



Source: The Dow Chemical Company Photo

Other factors that must be considered are birds and neighbors. Wind Turbines have suffered over bird issues. Older wind farms with smaller wind turbines have caused bird deaths in some parts of the country particularly California. Today avian studies can be performed to estimate a bird population in a proposed turbine project location.

NIMBY (not in my back yard) issues also arise with projects, but for a large manufacturing site with few neighbors an inside-the-fence project may not have these issues.

The economics of wind depend largely on the cost of the turbines and towers, and the wind resource. Large turbines are available approaching 3 MW, with 100 meter diameter rotors. These are typical for high wind speed areas mainly off shore. Low wind speed turbines are available at 1.5 to 2 MW and rotor diameters of 60 -70 meters. About 65% of the project cost is in the turbines and towers.

Solar

Solar cells seem to have limited use within Dow. The technology is expensive and requires a large amount of land for any significant output. Dow has limited application today mainly along pipelines to power metering units and perhaps for buildings in specific markets.

Conclusion

Renewable energy is a viable alternative for energy production within an industrial environment. Wind Power can provide larger amounts of power that industry requires. Landfill gas projects also fit particularly for use as process heat. Fuel cells show promise in an industrial environment particularly if co-product hydrogen is available.

References

Dow mission: To constantly improve what is essential to human progress by mastering science and technology. **www.dowpublicreport.com**

Personal discussions that Dow and General Motors had in 2003 and information from their website. http://www.gm.com/company/gmability/adv_tech/400_fcv/fact_sheets.html

Praxair introduced commercial cryogenic air separation technology to North America in the early 1900s, and, ever since, the company has led the development of new air separation, process and application technologies. The company currently holds almost 3,000 patents. http://www.praxair.com/praxair.nsf/AllContent/9F19624ECB53908785256A93005DAEC6?OpenDocument.

In 1895, Carl von Linde perfected a new process for producing large quantities of oxygen, which Air Products and all other industrial gas manufacturers still use over a century later. There are three steps to the process: the extreme cooling of air until it becomes liquid; purification of the liquefied air; separating the various components of the liquid by using the different boiling points of each gas. By controlling temperature and pressure, the gases can be separated. http://www.airproducts.com/Products/LiquidBulkGases/Oxygen/History/production.htm

The Pressure Swing Adsorption (PSA) process is based on the principle that adsorbents are capable of selectively adsorbing impurities. The impurities are adsorbed in a fixed-bed adsorber at high pressure and desorbed by "swinging" the absorber from the feed to the tail gas pressure and by using a high-purity purge. Typically the desired component is not adsorbed and is recovered at high purity http://www.uop.com/objects/108PolybPSAGasExtPur.pdf

Pressure Swing Adsorption (PSA) uses selective adsorption for the recovery and purification of hydrogen from synthesis gas and refinery and petrochemical streams. http://www.airproducts.com/CPI/product_offering.asp?intRegionalMarketSegment=127&intProductTypeCategoryId=45&intTab=45&intApplicationGroup=&pc=&reg=USC

.Because hydrogen is not readily availably, fuel cell systems often include another system called a fuel reformer or fuel processor that extracts hydrogen from hydrocarbons such as natural gas.http://www.utcpower.com/

Private Discussions with a PAFC supplier

All across the country, landfills release gas containing methane and carbon dioxide, two well-known greenhouse gases, along with other compounds identified as pollutants by the US Environmental Protection Agency (EPA). While landfill gas poses many hazards to safety, health, and the environment, it also presents a unique opportunity to create value from a waste stream through the generation of electricity, heat, or steam. http://www.thegreenpowergroup.org/landfillgas.html

As of December 2004, approximately 380 landfill gas (LFG) energy projects were operational in the United States. These 380 projects generate approximately 9 billion kilowatt-hours of electricity per year and deliver 200 million cubic feet per day of LFG to direct-use applications. EPA estimates that more than 600 other landfills present attractive opportunities for project development. http://www.epa.gov/lmop/proj/index.htm

http://www.awea.org/financing/cost.html

EnXco presentation to the Green Power Market Development Group http://www.enxco.com/

Private Discussions between Dow and GE Wind and Vestas

Private Discussions with a large wind developer

On-Going Avian Study at the Texas Dow site