



Power Generation



Baldor Electric Company - Focus Report Power Generation

Executive Summary:

The Energy Bill signed into law by President Bush lavishes tax breaks on fossil fuel technologies. There is \$1.6 billion in tax credits for new coal technology, \$1 billion for gas distribution lines, another \$1 billion for oil and gas exploration, \$400 million for refineries and more.

The new law also increases tax credits for commercial solar installations and offers individual homeowners a credit for the first time in twenty years. There is very little mention of energy conservation or improved fuel efficiency.

Why was this energy bill so important? The demand for electricity and the cost of fuel to make it drives economic considerations. Electricity consumption will reach 5,467 billion kilowatt-hours by 2025, up a staggering 50% over 2003 demand. Historically, Americans used 17% more energy between 1991 and 2000 than during the previous decade. While during the same period domestic energy production rose only 2.3%. This trend is continuing today.

To meet this expected rise in consumption, experts say that 280,000 megawatts of new generating capacity is needed. Construction costs for coal-fired power plants average \$1300/kW output. For solar power the cost is about \$3,200/kW, geothermal is about \$2,100/kW and for windpower it is about \$900/kW. Nuclear power plants will have the highest total construction costs because of their extraordinary safety requirements and the length of the permitting process. Total future construction costs may reach \$364 billion to meet the expected 2025 demand.



Coal fired power plant

Not only do we have to worry about when and where to build these plants, we need to worry about how to fuel them. Some experts say that we only have about a 10-year supply of inexpensive natural gas available in the U.S., a 20-year supply of oil and a 250-year supply of coal. Although there is an estimated 50-year supply of low cost uranium, lower grade uranium costs more to mine. Ultimately, uranium could provide an unlimited fuel source (a little goes a long way) along with renewable energy sources such as wind, solar, hydro and geothermal. The problem with renewables is that they would not be able to supply the country with a less expensive, reliable base load power (a base load power plant is one that supplies a steady supply of power regardless of total power demand).



Nuclear power plant

According to a recent *Kiplinger Letter*, fifteen new nuclear plants will be built over the next fifteen years. By 2020, one-fourth of our base load electricity will come from nuclear power plants. Nuclear generated electricity is inexpensive, currently at 1.68¢ per kWh and expected to fall to 1¢ per kWh in the near future. Power plants using coal as a fuel source can produce electricity for 1.92¢ kWh, natural gas fired plants at 5.87¢ per kWh and rising rapidly.

Coal is the fuel of choice for 52% of our current electric power plants. Nuclear supplies 20%, natural gas 16%, renewables 9% and oil the other 3% of our power plant fuels. The renewables 9% can be further broken down into biomass (44%), waste-to-energy (26%), geothermal (16%), windpower (13%) and solar (1%).

Today we have a desperate shortage of base load power plants. We have not built a base load coal plant since the 1980s or a nuclear plant since the 1970s. The newer plants that were built took advantage of the peak loading profits that were available during the mid to late 1990s. These newer peaking plants are typically fueled by natural gas.

There has also been a major push for onsite “distributed generation” plants during the last two decades. These plants provide reliable power at a higher cost, but are not a long-term solution to the need for inexpensive power.

Although the energy bill places emphasis on fossil fuels, electricity has met all of our energy growth demands since the 1980s. Today 60% of the national GDP comes from industries and

services that use electricity as a front-end fuel. In 1950 this number was only 20%. This trend is expected to continue, therefore think sales of motors and controls to meet this growing demand.

Power Generation – Types of and Issues:

The remainder of this report will summarize the different power generation technologies and methodologies and look at where motors, controls and gearboxes are used with each.

Distributed Generation:

Distributed generation is a strategy of using local backup generators, peaking power units and “combined cycle heat and power” plants to provide reliable power or reduce peak energy costs. These generation schemes work, but they have limitations on size and fuel types. Most of the engines run on natural gas, a fossil fuel of limited long-term supply, but easy to transport.



Base load and peak shaving at a glass plant

We are currently drilling for natural gas and importing natural gas from Canada and Mexico. Discussions are ongoing about building large seaport facilities to import liquefied natural gas from Africa, South America and Russia. In recent years the cost of natural gas has tripled.

Growth may slow, but emergency power and backup power will remain key markets. Telecommunications is a major growth market. Backup generators are needed for unattended dial offices and cell phone tower backup power.

Coal-fired Power Plants:

Despite the fact that we have over 100 years of history in the production of electricity from coal, no new coal-fired plants have been built in two decades. Coal-fired plants are the backbone of our electric power system. Today over 50% of our electricity is generated by coal.

The U.S. is estimated to have a 250-year supply of coal. Twenty-six producers mining fifty-eight mines, produce 1,072,000 thousand tons of coal annually. We have the fuel for base loading and we know how to remove the harmful emission that once held up the construction of new plants. We can remove the sulfur, fly ash, heavy metals and a host of harmful gases that deplete the ozone layer, contribute to acid rain and smog and pollute the environment with heavy metals such as mercury.

New plants will be equipped with the latest air pollution technology. Older plants are adding technology to clean up the air as resources and the addition of compatible air pollution technologies permit. Coal will therefore continue to be a key element in our future power generation needs.

These plants offer a wealth of opportunity to provide motors, drives, gearboxes and control systems. A large plant can have thousands of motors, drives and gearboxes to power conveyers, crushers, washers, pumps and blowers of all types.

One major upgrade opportunity often overlooked is the replacement of these motors with premium efficient motors and adding drives where applicable. The less electricity the power plant consumes means more electricity available to sell.



Nuclear Power Plants:

Nuclear power will play a major role in future power generation. Except for hydro, nuclear power is the least expensive method of producing electricity. Currently at 1.68¢ per kWh and falling, this is very attractive power.

We have 104 nuclear plants operating today that provide about 20% of our electricity. By 2020, nuclear power is expected to generate 25% of our base power needs. Although these plants are old, thirty-five of them have been upgraded to use the latest digital technologies and incorporate the latest safety features.

Constructing a new nuclear plant takes only five years, but the current regulation and permitting can triple this time span. But, because of new power plant designs, digital controls and safety features, the time needed to obtain operational permits should decrease substantially and is currently being reviewed.

The one drawback of nuclear power, as seen by many, is the disposal of spent nuclear fuel. In reality, nuclear power plant waste is a fraction of the total radioactive waste created in this country and should not be a major deterrent.

Hundreds of millions of dollars will be invested in peripherals that will use thousands of pumps, valves, condensers, compressors, evaporators and controls. Nuclear plants can even use standby generators.

Municipal Waste to Power Plants:

With today's high gasoline and diesel prices, how far are we willing to ship municipal trash? Our cities accumulate mountains of trash daily not to mention sewage sludge that must also be placed in landfills. We are running out of economical sites to bury this material.

One solution is to convert this material to energy at a local facility. After recyclables are removed there is still plenty of combustible fabric, plastic, wood, organics and paper to burn. Some estimates range as high as 50% of the volume. Combine this material with dried sludge from the sewage treatment plant and there is plenty to burn.

High temperature fluidized bed combustors seem to work best with this type of fuel. The result is an economical source of power that is also clean burning with minimum emissions.

St. Paul, MN, has converted an old coal burning power station to burn urban wood waste such as dead trees, prunings, crates, pallets and furniture parts. The wood, chipped offsite, is delivered at a rate of 70 tractor-trailer truckloads per day. Emissions are easier to control and the cost of generation is competitive at 4¢ to 5¢ per kilowatt-hour.

This is one example of an innovative process to produce electricity which uses motor driven equipment such as: choppers, chippers, shredders, augers, conveyers, dryers, blowers, pumps, and still captures the fly ash for disposal.

Biomass Power Plants:

Waste products are also produced in rural areas. In our food supply production, we concentrate production processes, which makes it harder to remove the large quantities of waste. This is a problem for us, but one which has been solved all over Europe.

Modern biomass power plants combine agricultural waste, coal tailing (the leftovers of coal production) and a bit of limestone into a combustible mixture that burns cleanly. The University of Illinois estimates that Illinois produces nearly a half million tons per year of animal waste and over two million tons per year of coal tailings. Here is a potential and consistent supply of fuel that can be converted into electricity.

Anaerobic digestion, besides being used to process waste at a sewage plant can be used to make electricity. A demonstration project in Menomonee, WI, collects waste from cows and pigs in a 775,000-gallon holding tank, 40 feet in diameter and 60 feet tall.

The material is next fed through a mixing tank with a shredder and the resultant slurry is pumped to a covered 8,000,000 gallon covered holding lagoon. Here the slurry “cooks” deprived of oxygen. The resultant methane gas is fed through a scrubber before being fed to a 775-kilowatt turbine generator. Excess heat is used to warm barns in the winter. The dried residual is now a clean fertilizer to be spread on local crop fields.

The farmers own the tanks and holding ponds and the power company owns the turbine generator. This is a small-scale demonstration power plant, but in Denmark a 25 megawatt plant is in the works. Rural farming in America now has access to efficient three-phase power thanks to cows and pigs. *This system uses motor and gearbox driven equipment such as: shredders, emulsifiers, mixers, pumps and controls.*

The 1,500 cow heard Blue Spruce farm in Vermont has begun supplying power to the grid from its anaerobic digester. The farm is expected to produce 1.7 million kilowatt hours per year.

Gasification Power Plants:

Today there are 117 gasification plants worldwide generating 45 gigawatts of power. The fuel for a gasification plant is very flexible. They can burn slag coal, waste oil, tires, plastic medical waste, tar sand or anything else combustible. Materials are ground up and burned in a pressurized oxygen-free tank that reaches 2200° F in which even methane breaks down into pure carbon dioxide and hydrogen. About half of the fuel is typically coal tailings, one-third waste oil and the balance trash. The high temperature breaks down even hazardous medical and chemical waste.

If the waste were taken directly to a landfill, typical landfill fees to dispose of this waste can be expensive in comparison to burning it. Typical truckload fees are \$5 for sewage solids, \$50 for

municipal trash, \$100 for tires, \$1000 for medical waste and \$2500 for HAZMAT waste. The gasification process reduces total solids by 95% volume, which make disposal much easier.

The captured gas is separated. The carbon dioxide is recycled for industrial processes like dry ice and the hydrogen can run turbine generators. In the future, this may be a source for hydrogen for fuel cells. *The entire process uses motor and gearbox driven equipment such as: choppers, grinders, conveyors and air handlers.*

Wind Power Plants:

As the sun heats up the earth unevenly, winds are formed. The kinetic energy in the wind can be used to turn wind turbines with capabilities currently at 5 megawatts each. The power output is a function of the cube of the wind speed, therefore turbines generally require a wind in the range of 5.5 meters/second or (12.4 miles/hour). By some estimates one third of our energy needs could be met by wind power.

Certain regions of the world have prevailing surface winds of this speed, but offshore or at higher altitudes, the winds are constant and favorable at the height achieved by modern turbines. Today hub heights reach 240 feet in order to take advantage of the favorable winds.

The downside of this technology is that a lot of turbines would be needed to handle our base load of electricity needs. The typical turbine operates only 25% of the time on average with higher operation times in the winter.



Wind Farm, Baldor motors are often used to control blade pitch and yaw

In the past other countries, especially the Europeans, embraced wind technology much faster than the U.S. Although today's designs have overcome many of the early speed, vibration and reliability problems, there is still the perception that they are noisy and contribute to visual pollution.

Worldwide there are now 65 gigawatts of installed wind power and the race is on to build more. Some turbine builders are experiencing a growth rate of 30% per year.

The U.S. is quickly following Europe's lead in placing wind turbines. We have moved from sites only in California (during the early years) to placing wind farms wherever wind blows on a near consistent basis. We see sites going up in the upper mid-west and the northeast and even offshore. The best sites are located where the winds blow nearly perpetually along the eastern side of the Rocky Mountains coming out of Canada toward the Dakotas, Wyoming and Montana. The American Wind Energy Association forecasts that the U.S. will install 2,500 megawatts of new wind capacity during 2005. A megawatt of electricity can power 250-300 average homes. The new capacity can power up to 700,000 homes.

The Global Wind Energy Council says that in 2004, the global wind power industry installed nearly 8,000 megawatts of new turbine capacity.

The opportunities to sell motors and gearboxes include the pitch and yaw control devices and the use of induction motors as the generator on smaller wind turbines. Electronic inverter control panels may also provide a sales opportunity.

Solar Power:

For decades the number of installed solar power generated megawatts has been stagnant at 350. Although the technology has improved and the cost for each kilowatt of solar installation has decreased, it still has not been cost effective without tax incentives. Other countries such as Egypt, Israel, Italy, Mexico, Spain and Morocco have very strong programs for solar power.

Our greatest potential geographically for solar voltaics (conversion of one energy form to another) is in the south and particularly the southwest where is nearly always sunny. Four state governors (CA, AZ, NM, NV) have formed a consortium to promote the expansion of the installed base to 1,000 megawatts by 2010 using both regulatory and investment incentives. Estimates put the potential at 2,800 megawatts by 2020 with a cost of 3¢ per kilowatt-hour compared to 11¢ today.

Solar power could be a boom to help reduce the cost of peak power purchased from the utility. Electricity would be available during the daylight hours, which see the most demand and has the highest peak load costs. Peaking power already costs more than solar power. The initial capital is expensive, but maintenance costs are low. Solar voltaics can be placed on rooftops and undesirable pieces of real estate such as deserts.

Photovoltaics (convert radiant energy to electrical voltage) – These large arrays of rooftop units are common in California and other sun states. The panels are connected together to a DC-to-DC converter that replaces the rectifier section of a regular AC inverter. Power is sent to the lines at a constant voltage and frequency. *Some smaller units use gearmotors and controls to track the sun and maximize generation capability.*

Solar Thermal – These systems focus the sun’s energy on a target that heats water to temperatures as high as 700 to 1000° F. This super heated steam then turns a conventional steam turbine to produce electricity.

The “trough type” design uses a single axis gearmotor attached to the parabolic reflectors (called heliostats) that track the sun throughout the day. The reflectors focus the sun on a central pipe of flowing water that feed the turbine generator.

Two square miles of area can generate 100 megawatts. Six square miles could generate 500 megawatts. This is equivalent to the typical coal-fired power plant in output and without the emissions.

The “tower” design has a large field of individual reflectors controlled by two axis gearmotors. The reflectors follow the sun and project its energy to the top of a collection tower. Temperatures often exceed 1000° F. This technology often uses molten salt as a heat transfer medium to prevent the potential of explosive boiling of the water. This high temperature technology has the potential of better efficiency and kilowatt-hour cost of 5.7¢ by 2020.



This 1996 photo shows the solar tower and surrounding field of mirrors for Solar Two, a demonstration project located near Bartow, California.

Credit: Warren Gretz

Geothermal Power Plants:

The word geothermal is defined as thermal energy taken from the core of the earth. The heat contained in the earth’s core is used to create geothermal electricity. First a fluid (oil or water) is pumped into the earth and allowed to evaporate. The returning hot gasses then turn a turbine, which is connected to electrical generators.

There are three ways to use this heat found at the earth’s core.

- Generate electricity using steam turbines.
- Geothermal heating through pipes sunk deep into the earth.
- Geothermal heating through a heat pump commonly found in residential homes.

Hot underground steam or water can be brought to the surface easily in such places as Iceland, New Zealand, the U.S., the Philippines and Italy for power generation and heating. The two most prominent areas in the U.S. are in Yellowstone National Park and in northern California. A major success story is Iceland. Iceland produced 70 megawatts of geothermal power and heated 86% of all houses in 2000. In total there are 8,000 megawatts of geothermal power globally.

Motors and controls are often used with the pumps and air handlers installed in these facilities.

Water Power:

The energy in water can be used in the form of motive energy or by manipulating the temperature differences. Even slow moving water is a good energy source because water is about 1000 times heavier than air. There are many methods of extracting energy from water. These are:

- Hydroelectric energy - power obtained from hydroelectric dams as water is released over turbines that spin electric generators. The Hoover dam and the Three Rivers Gorge on the Yangtze River projects are good examples of hydroelectric power.
- Tidal power - which captures power from the tides in a horizontal direction. Tides will come in and raise the water levels in a basin then go out again. The moving water is passed through a turbine to generate electricity.
- Wave power - waves use energy to move large pontoons up and down thus hydraulically turning generators.
- Ocean thermal energy conversion (OTEC) – this technology takes advantage of the difference in temperature between warm surface water and colder deeper water. A cyclic heat engine is used to capture and convert this energy into electricity.

Motors are used to control water flow through the sluice (an artificial channel for conducting water or regulate water flow) gates on dams and the control of peripheral processes.

Power Generation News during 2005:

- BP, Conoco Phillips and Shell in the UK have announced development plans for an industrial scale “carbon free” power plant fueled by hydrogen. Under the plan 70 million cubic feet of natural gas will be converted to hydrogen daily to fuel a 350-megawatt power plant. The hydrogen production process will produce carbon dioxide, which will be pumped to the North Sea oil fields and used to extract more oil then store there. The proposed plant will reduce overall emission by 90% and store 1.3 million tons of carbon dioxide annually.
- The Southern Company and the Georgia Institute of Technology announced the Southeast’s first offshore wind farm. The project is will consist of three to five wind turbines with a total generating capacity of 10-megawatts.

- A new global wind energy map produced by the American Geophysical Union says that wind can easily supply the world's power needs. The Stanford University researchers took wind speed measurements from 7,500 surface stations and 500 balloon-launch stations to determine global wind speeds at 300 feet above the surface, which is the hub height of modern wind turbines. In a surprise conclusion North America was found to have the greatest wind power potential.
- A Portuguese consortium has ordered the world's first commercial wave power plant to be installed five kilometers off the Portuguese shore. The initial phase of the project will consist of three to five wave converters each capable of producing 750 kilowatts of power. The power plant will be expanded to 25 megawatts capacity. The wave converters are four semi-submerged hinged cylinders anchored to the ocean floor. As waves move the cylinders, hydraulic fluid is pumped through hydraulic motors that turn generators.
- The Long Island Power Authority and FPL Energy are moving ahead with their plans to install 140-megawatts of capacity off the south shore of Long Island.
- Methane rich landfill gas is a growing source of power as landfills seek to reduce their greenhouse gasses and the odors associated with the emissions. Santa Cruz County is California is working on a 3.2-megawatt methane power plant at their Watsonville landfill.
- In Colorado one coal-fired power plant is replacing part of its coal supply with biomass from tree thinning operations in the state.
- A Minnesota company is building a power plant that will burn turkey dung. The turkey litter will create clean power for 55,000 homes. Three poultry litter plants have already been built in England, but this is the first such plant in the U.S. The 55-megawatt plant will burn 700,000 tons of turkey dung a year and produce fertilizer as a byproduct with no net gain in greenhouse gases.
- Spain is building an 11-megawatt solar power tower near Seville. Called PS10, the power plant will be the largest solar power system in Europe and the first tower-based solar power system to generate electricity commercially. The system will consist of a field of 624 large mirrors mounted on computer-controlled pedestals to focus sunlight onto the top of a 330-foot tower, generating steam to turn a turbine and produce electricity.

Conclusion:

Our electrical power needs are expected to increase by 50% over the next two decades. Yet there is no single source of power that will satisfy this need. All power segments will grow. Coal and nuclear will again carry the base load at the lowest costs.

Wind, solar and biomass will grow even faster, but they have a low share to start with. One major thing we can all do now is conserve energy. Take a serious look at our electric powered motor systems and use high efficiency motors wherever possible.

The Department of Energy (DOE) estimated that electric motor-driven systems consume 679 billion kilowatt hours annually or 23% of all of the electricity used in the U.S. The DOE went on to say that if we used premium efficient motors wherever possible, we could save between 62 and 104 billion-kilowatt hours annually. We can all reduce this consumption by using premium efficient motors! We can add a variable speed drive on variable loads to save even more energy!

We need to embrace all options to secure a future with plenty of inexpensive electrical power.

References for additional reading:

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- *National Energy Policy*, a Report of the National Energy Policy Development Group, May 2001
- The Kiplinger Letter, Volume 82, No. 30, July 29, 2005
- The EIA, Energy Information Administration a department of the Department of Energy
- Wikipedia (<http://en.wikipedia.org>), articles on renewable energy and future energy development

Definitions:

- Watt – an electrical energy unit of measure. In our business a watt is defined as a unit of power and is calculated as the product of volts and amps. Therefore 100-watt bulb used on a 110-volt electrical circuit would use 0.91 amps of electricity. ($110V \times 0.91A = 100W$)

But, technically one watt is the flow of electricity at a rate of 1 joule per second. A 100-watt light bulb uses 100 joules of electricity per second or 360,000 joules per hour.

- Kilowatt (kW) – 1000 watts (In the motor business the power rating of a one horsepower electric motor could be rated at 0.746 kilowatts.)
- Kilowatt Hour (kWh)– A unit of electric energy equal to the work done by one thousand watts acting for one hour.
- Megawatt Hour (MWh)- A unit of electric energy equal to the work done by one million watts acting for one hour.
- Gigawatt Hour (GWh)- A unit of electric energy equal to the work done by one billion watts acting for one hour

