ELECTRICAL ENERGY AND THE PETRO-CHEMICAL INDUSTRY: WHERE ARE WE GOING?

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Abstract**—**The petroleum and chemical industries use nearly 26% (≈ 1/4th) of all electricity consumed by industry and nearly 7% of all electrical energy consumed in the US. A segment of the overall energy industry using such a large percentage of the electricity can hardly help but be affected by the future trends in the usage and generation of electricity. Developments in renewable energy systems augmented by the renewable portfolio standards mandated in many states, various energy conservation measures, and the legislative climate all provide cause to reassess the way industry uses and generates electricity. Future taxation, limits on carbon emissions, other environmental and political concerns, high unemployment and overall economic conditions and future growth will also make necessary a paradigm shift on how electricity will be delivered and utilized. This paper examines the present state of energy usage in the petroleum and chemical industry, trends in energy usage and generation, and where these trends may be leading.

Index Terms—Energy Resources, Energy Legislation, Energy Sustainability, Energy Conservation, Renewable Energy, Renewable Portfolio Standards.

I. INTRODUCTION

Overall global energy sustainability, the environmental impact of all energy generation and usage, and the reliance on finite energy resources of fossil fuel will continue to be one of the biggest challenges for engineers and scientists during the 21st century and beyond. Relying heavily on oil and petroleum energy sources located in a handful of politically unstable nations has caused people to reevaluate the importance of energy on world security. Nuclear energy, while becoming increasingly important worldwide, is still controversial in the United States. Recent happening in Japan caused by the earthquake and tsunami has caused further damage to the potential growth of nuclear power. Concerns about climate change and global warming has threatened to result in increased taxes or caps on carbon emission which can only increase the cost of providing electricity using fossil fuels. The challenges of providing the affordable, clean and reliable electricity that industry and mankind will need in the future begs the question: Where will the energy used by industry in the future come from, and at what cost?

In USA, the way electricity is generated, transmitted and utilized has been legislatively driven almost since it was first sold as a commodity. The creation of the Rural Electrification Administration (REA), Tennessee Valley Authority (TVA), the passage of the Public Utility Holding Act of 1935 (PUHCA) and Public Utility Regulatory Policies Act of 1978 (PURPA) as well as the Atomic Energy Act of 1954 (AEC), along with other energy legislation have resulted in the electrical energy climate and structure we see in the U.S. today where most of our electricity is generated using coal, nuclear, natural gas and hydroelectric (70% of renewable energy) sources. Fig. 1 shows the breakdown of how electricity is generated in the U.S. in 2007, the total amount was 4,167 TWh (Tera = 10^{12}).

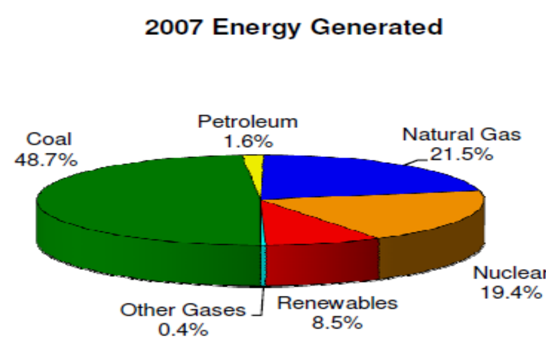

Fig. 1 Electric Energy Production in the USA by Fuel Type.

The recent attempts to modify energy policy includes the passage of the EPACT [1992], the Energy Policy Act of 2005 (EPACT) the Energy Independence and Security Act of 2007 (EISA), the Energy Improvement and Extension Act of 2008 (EIEA) and American Recovery and Reinvestment Act (ARRA) of 2009. EPACT 2005 modified earlier legislation to promote electricity produced by renewables, and provided incentive for research into various forms of renewable energy. The EISA is primarily a conservation bill which also provided incentives for the "smart[er] grid". The EIEA provides tax credits for certain combined heat and power plants (CHP).

A number of States have also produced legislation to promote the future use of electricity from renewable resources. The principal method they have used is the implementation of renewable portfolio standards (RPS) which

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require a certain percentage of the energy used to be produced by renewable sources. Fig. 2 shows the states with Renewable Portfolio Standards as of July 2009. These numbers are also changing with time.

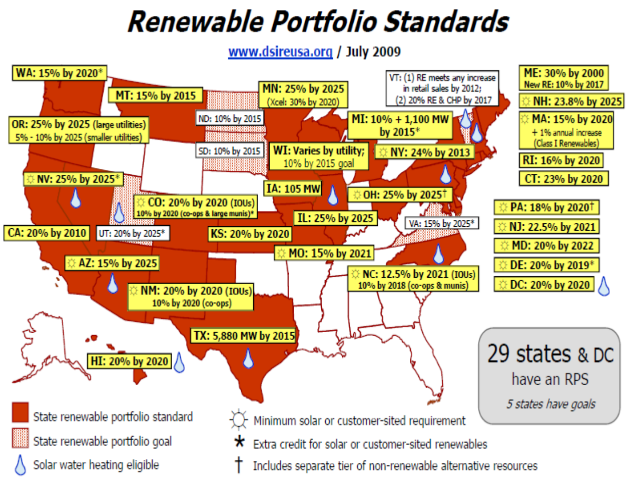

Fig. 2 States with Renewable Energy Portfolios. [1]

TABLE 1 shows the amount of electrical energy (or *electricity*) each state is required to produce from renewables and the year this must be achieved. Thirty-two states and the District of Columbia have set either mandatory and/or voluntary goals for the amount of energy they will get from renewable sources. The legislation producing this Renewable Portfolio Standards RPS) also provides both financial and tax incentives for the use of renewable energy. Some of these incentives will be applicable for industrial customers.

TABLE 1
Renewable energy portfolio requirements by state [1].

Arizona	15%	2025
California	33%	2030
Colorado	20%	2020
Connecticut	23%	2020
District of Columbia	20%	2020
Delaware	20%	2019
Hawaii	20%	2020
Iowa	105 MW	
Illinois	25%	2025
Massachusetts	15%	2020
Maryland	20%	2022
Maine	40%	2017
Michigan	10%	2015
Minnesota	25%	2025
Missouri	15%	2021
Montana	15%	2015
New Hampshire	23.8%	2025
New Jersey	22.5%	2021
New Mexico	20%	2020
Nevada	20%	2015
New York	24%	2013
North Carolina	12.5%	2021
North Dakota*	10%	2015
Oregon	25%	2025
Pennsylvania	8%	2020
Rhode Island	16%	2019
South Dakota*	10%	2015
Texas	5,880 MW	2015
Utah*	20%	2025
Vermont*	10%	2013
Virginia*	12%	2022
Washington	15%	2020
Wisconsin	10%	2015

*Five states, North Dakota, South Dakota, Utah, Virginia, and Vermont, have set voluntary goals for adopting renewable energy instead of portfolio standards with binding targets

A cursory look at these numbers suggests that approximately 20-25% (some higher and some lower) of total electricity will be produced by renewables by the year 2020, which is less than 10 years from now.

II. ELECTRICITY USAGE IN THE PETROCHEMICAL INDUSTRY

In 2002 (most recent information available) the petroleum and chemical industry in USA used approximately 252TWh of electricity [2]. This is approx. 26% of all the electrical energy used by industry and about 7% (252/3,858 = 0.066) of the total amount of electricity used in the U.S. in that year. Fig. 3 shows the percentage used by the petroleum and chemical industry broken down among five general industry categories.

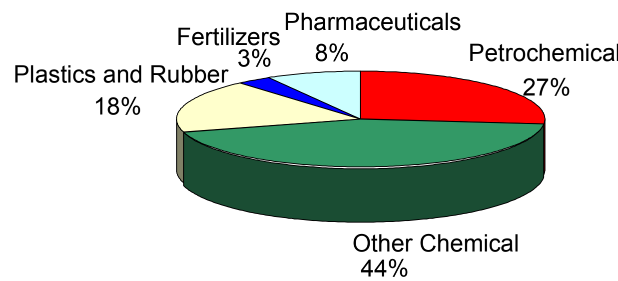

Fig. 3 Electrical Energy Usage by Industry Category

It is clear that the petrochemical and chemical industries are the largest users of electricity, and the petrochemical industry alone accounted for more than one quarter of all electricity used by the petroleum and chemical industries.

Fig. 4 shows how electrical energy is utilized in the chemical and petrochemical industry. More than half of the total energy used (154TWh), is consumed by electric motors.

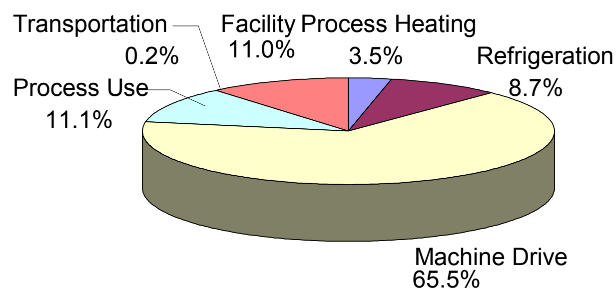

Fig. 4 Energy Use by Utilization Type.

Of the nearly 26TWh being used in facilities, 53% is used for heating, ventilation, and air conditioning (HVAC) and 38% is being used for lighting.

In the year 2002, the petroleum and chemical industries generated nearly 67TWh using on-site generation, 64TWh of which was by combined heat and power (CHP) plants, cogeneration facilities. None of this electricity was generated using non-biomass renewable energy sources. The amount of energy generated on-site was nearly equal to the total of all energy purchased by utilities in the U.S. from CHP plants [3].

Combined heat and power plants use part of their energy for generating electricity and some for producing heat for industrial or other processes. Very high overall efficiencies (60-80%) can be attained in this type of generation and these types of plants were encouraged by the passage of PURPA. On-site generation, including combined heat and power plants, have long been a part of providing power at petroleum and chemical facilities and the chemical industry is the largest user of CHP in the United States [4].

III. EFFECTS OF FEDERAL LEGISLATION

The EIEA [2008] provides an investment tax credit for qualifying CHP systems placed in service before January 1, 2017. A facility up to 15MW would qualify for an investment tax credit of up to 10% of the installed cost. For plants between 15-50MW the tax credit declines linearly from 10% to 3%. To qualify a facility must have an overall fuel efficiency of at least 60% with a minimum of 20% each of useful electrical and thermal energy produced. Although CHP plants are widely used in the petrochemical industry these incentives could encourage the future installation of new CHP systems.

The EISA [2007] is principally an energy conservation and efficiency bill and the provisions contained therein encourage research and the installation of more efficient systems. One aspect of the bill important to the petrochemical industry is the motor efficiency standards. With the exception of fire pumps, this bill raises the efficiency standards for induction motors and creates minimum efficiency standards for newly manufactured general purpose motors [5]. The bill requires that all motors between 200-500HP meet the NEMA (National Electrical Manufacturer's Association) standards which were formerly reserved for high efficiency motors. Since motors make up the single largest component of energy use by the petrochemical industry this increase in motor efficiency can be expected reduce future energy use.

Another aspect of conservation that will affect the petroleum and chemical industry are the new efficiency standards for incandescent and fluorescent lamps. While not making up a large percentage of the energy used by the industry, lighting accounts for nearly 10TWh of energy used/year. Switching to more efficient lighting in some industries has led to saving from 20% to 50% in the energy used for lighting, depending upon whether standard lighting was replaced with high frequency fluorescent or LED fixtures [6].

EISA [2007] authorizes $300 million for the promotion of the use of waste heat for the generation of electricity. It authorizes a grant of up to $10/MWh of electricity produced by waste heat for the first three years of operation. This grant may be of interest to petroleum or chemical plants planning the instillation of CHP power plants that can make use of underutilized heat that might already be available at the facility. The bill also requires that electrical utilities be required to purchase any excess electricity being produced by a plant of this type at utility's retail rate minus distribution costs. Furthermore, the bill allows the construction and operation of a distribution system owned by the power plant owner. This system could be used to sell electricity to the customers within a radius of three miles of the power plant. This sale of electricity would not be subject to regulation as a public utility. Both of these provisions make the construction and sale of CHP plants using waste heat more attractive.

One limitation in EISA [2007] which may preclude the widespread addition of new power plants, no utility is required to purchase power from a CHP if the additional power exceeds the capacity of the utility's lines. This lack of transmission capacity is becoming a major constraint in the construction of new renewable energy power plants (in particular large scale wind farms), and will likely limit the number of new CHP plants installed that produce excess power. This may limit industrial producers to producing only the amount of power they can use, and not produce excess that the electric utility would purchase. This limitation may mean a CHP plant must curtail its output of power during low production conditions. Limiting the power output from the CHP during some periods of time will extend the payback period of the plant and may make these types of plants less attractive than they otherwise would be if excess power could be sold to the utility at the retail rate.

Of particular interest to the petroleum and chemical industries is the research mandated by EISA [2007] into the use of geothermal energy from oil and gas fields for the generation of electricity and the smart[er] grid activities. The bill authorizes grants for demonstration projects in the 1MW size range for the generation of electricity from geo-pressurized oil and gas production facilities. The bill also contains grants for the development of the use of advanced organic Rankin cycle systems to produce electricity from marginal or unproductive oil and gas wells. If this technology can be successfully developed it may become useful as a source of distributed generation for producing some of the electricity used for oil production. It may also be useful for extracting electrical energy from depleted oil and gas fields.

EISA [2007] promotes research into the development of methods of producing energy from wave, tides, ocean currents and other marine and hydrokinetic energy sources. Fig. 5 shows one such device currently under development to generate electricity from wave action [7]. If the government's incentives along with research already being done on hydrokinetic devices succeed in producing reliable and economic sources of this type, the production of electrical power using wave and ocean current energy could be useful for isolated power systems such as oil platforms and remote production and processing sites with access to the ocean.

One principal drawback of nearly any type of renewable energy source is its intermittency and non-dispatchability. The problems due to this intermittency issue can be mitigated if cost effective energy storage systems can be found. EISA [2007] includes funding for research into energy storage systems including flywheels, batteries, compressed air systems, and hydrogen storage. If effective energy storage systems can be developed, renewables will be much easier to integrate into industrial distribution systems and the utility grid.

Fig. 5 Hydrokinetic Electrical Generator [7].

IV. RENEWABLE ENERGY AND THE PETRO-CHEMICAL INDUSTRY

The petrochemical industry has not yet widely implemented the use of renewable energy in processing and manufacturing facilities, although they have historically been leaders in using CHP. The forthcoming regulation of carbon emissions is causing oil companies to begin to look at alternatives for the generation of power [8]. While many oil companies have directed the bulk of their renewable energy research investment into bio-fuel, they have also made substantial commitments to solar (both Photovoltaic or PV and Concentrated Solar Power or CSP) and wind energy. One company recently broke ground on a 29MW solar steam plant in California. This solar installation will displace the use of natural gas for the production of steam for injection into oil wells to enhance production by heating thick petroleum so it will flow freely [9]. It is claimed that generating steam using the solar powered process planned at this site will be as cost effective as burning natural gas when natural gas prices exceed $8.50 per million BTUs [10]. While not cost effective at today's prices, it may become so quickly if climate change legislation adds to the cost of burning natural gas.

While not yet cost effective compared with burning fossil fuels, the use of renewable energy in petrochemical plants can be a viable option if used in place of energy generated by fossil fuels or purchased from the utility. The two major types of renewable sources have gained momentum and readily available at the present time are wind and solar. Solar photovoltaic installations in the 1MW (or higher, some up to 20MW range) size range are becoming common, and wind farms are becoming common in all sizes up to nearly 300MW. Large CSP plants may also become a viable choice for both power generation and steam production in the future.

Production tax credits for electricity production using wind and the additional subsidies by states and utilities have caused the large growth in the number of wind farms throughout the country. Recently, a 24MW wind farm was installed to supply electricity to a cement plant [11]. Installations of this type could become common in all large industries, and give plant owners the ability to supply a substantial amount of power from sources which do not produce carbon emissions.

When highly variable, low capacity factor sources like wind and solar are installed to offset energy usage at an industrial installation, one of two things must be done when planning the size of the plant. Either the power plant must be sized so its peak load never exceeds the minimum plant load, or else there must be a plan in place for handling the excess electricity when the power plant is generating more than can be used on the site. For small installations net metering is a common solution. In this arrangement the power plant is installed on the plant side of the meter, and simply turns the meter backwards when delivering excess power out of the plant, and forwards again when the power plant is not generating all the electricity needed, and some energy is being used from the utility. This arrangement is typically meant for smaller industrial and commercial sized plants and normally is not used on industrial scale power plants.

If net metering is not possible then there must be a plan in place to sell the power to the utility or some other entity. Whether net metering is possible or not, it is likely that power must be transmitted over the utility's transmission system during high generation and low load conditions. In many areas of the United States, the transmission system is already fully committed by existing power plants, power purchase agreements and those already being planned. This fact has constrained the construction of wind farms in many parts of the country. If a wind farm is to be placed at a location where the existing transmission system is already 100% committed, then either the transmission system must be upgraded (a very costly undertaking) or the output of the power plant may have to be curtailed during times when the load is light. Either option will extend the pay-off period of the power plant, and may make the construction of the plant uneconomical.

Another problem limiting the usage of wind and solar energy for industrial production is the large amount of land that both sources require. A wind farm can produce 1.2W/m^2 of land area and may not be an acceptable choice for use at an industrial facility located in an urban area [12]. Solar sources are somewhat better and generate a peak output of approximately 20-60W/m^2 [13]. The use of building roofs is a possibility with solar photovoltaic panels, but a power plant in the MW size range or a wind farm will require the dedication of considerable amounts of land area.

The most important impediment to the installation of renewable sources remains their high initial cost. However, considering the present political and economic environment, an industrial facility choosing to generate a portion of its own electricity can be an attractive option if the site has a good quality solar or wind source, sufficient land area is available for installing the necessary equipment, and a plan can be formulated for the use of excess power. In installations which are not connected to a utility, and all power is self-generated, the use of a renewable energy source can cut the cost of providing fossil fuels for existing generation. The high initial cost of renewable energy may be offset in the future by the results of climate change legislation. If carbon emission becomes regulated, the generation of some energy using renewable sources instead of traditional fuels may become cost effective and desirable.

The U.S. Department of Energy (DOE) concluded that within the 20 years it is unlikely that renewable energy can compete economically with fossil fuel generation. They concluded: "*failing a strong worldwide commitment to* *environmental considerations, such as the limitations and reductions of CO_2 emissions outlined in the Kyoto Climate Change Protocol, it is difficult to foresee significant widespread increases in renewable energy use*" in the near term [13]. Exactly the type of CO_2 regulation anticipated by the DOE has been enacted by a few European countries and regulatory pressure is mounting in the U.S. to enact some type of legislation to limit CO_2. Passage of any of the types of legislation now being proposed in the U.S. to limit or tax CO_2 emissions could raise the cost of fossil fuel generated electricity to the point where some renewable sources could compete economically. This would make the installation of generation using renewable sources a desirable addition to petrochemical facilities where a renewable energy source was available.

V. CLIMATE CHANGE LEGISLATION

Global climate change issue has become a much debated topic in the U.S. and around the world in recent years. There are several types of legislation which is being proposed or has already been enacted in an effort to mitigate future climate change. Among the types of climate change legislation being proposed and/or already enacted (but not limited to) include:

1. Renewable [energy] Portfolio Standards [RPS]
2. Cap-and-trade legislation
3. Carbon taxation
4. Demand side efficiency standards
5. Use of Plug-in-Hybrid-Electric-Vehicle (PHEV)

Two of these, cap-and-trade and carbon taxation, are proposed to directly control the amount of greenhouse gasses (GHG) being produced. A number of countries have already acted to curb gasses which are considered to be responsible for much of the climate change seen in recent decades.

The two most important greenhouse gases, and the two usually considered to be responsible for most of greenhouse warming, are water vapor and CO_2 [14]. CO_2 and a handful of less common industrially produced gasses have received the most attention from environmentalists and legislators. While federal legislation has not yet been enacted, a mandatory cap-and-trade program is currently being discussed and debated. Several states have already implemented cap-and-trade policies for CO_2. In 2009 ten New England and Mid-Atlantic states enacted mandatory limits under the Regional Greenhouse Gas Initiative (RGGI). Under this plan a cap-and-trade program is used to control CO_2 emissions in power plants 25MW and larger which burn fossil fuels [14].

Under a cap-and-trade program limits, or caps, are placed on the amount of CO_2 that can be produced. Permits are sold allowing a facility to produce a specified amount of the controlled pollutant. A market is then created which allows the trading of these permits. This type of a system has been used for many years to control other pollutants such as SO_2. However, the production of CO_2 is a different matter than the production of substances such as SO_2 which occur due to undesirable constituents existing with the primary fuel being used. CO_2 is a fundamental byproduct of combustion for nearly any type of commonly available fuel. Moreover, many natural processes such those resulting in human respiration and natural decay result in the release of CO_2. As such, CO_2 will be much more difficult to control than are pollutants resulting from fuel byproducts. The question becomes: What will the result be on the cost of electricity to an industry such as the petrochemical industry, of a cap-and-trade policy, rigidly enforced?

The economic cost of a cap-and-trade policy is much debated with little agreement [16]. Estimates range from very little affect to more than doubling the cost of electricity. The actual cost will be difficult to assess until the final form of legislation is known. However, the long term cost could be substantial. The concern voiced by some economists is that, while the effects of cap-and-trade policies are well known, the success of these policies hinges on the availability of viable and low cost methods of controlling the substance regulated by the cap-and-trade program. This type of program may have some initial success as the easiest sources of CO_2 are controlled, but long term the costs will rapidly rise and the program will become less viable [17]. Most recently high unemployment, lack of economic growth and the oil spill incident in the Gulf of Mexico have caused a reevaluation of the entire process.

Some industrial customers are already planning for the results of cap-and-trade legislation, no matter its final form. Several large companies from a variety of industries including the petroleum and chemical industries have united to form the United States Climate Action Partnership (USCAP). This group has the stated purpose of calling on the federal government to quickly enact strong legislation requiring reductions in greenhouse gas emissions [18].

In addition to working to affect the final form of climate change legislation, industries have also formulated greenhouse gas reduction strategies. A number of these strategies will be fundamental in the efforts of petrochemical facilities to reduce their greenhouse gas emissions. Among the strategies that may become common are [19]:

1. Construction high performance energy efficient buildings
2. Using electricity generated by renewable or nuclear sources (debatable now), whenever possible
3. Providing on-site generation using CHP or renewable sources
4. Reclaiming waste gases produced by industrial process such as methane or hydrogen for use in on-site electrical generation
5. Switching boiler fuels to higher efficiency and lower CO_2 production fuels or to renewable sources
6. Reduce electrical demand through efficiency upgrades
7. Participating in the carbon cap-and-trade schemes
8. Implementing carbon sequestration projects if carbon sequestration methods become available

No matter what the final form of climate change legislation takes in the US, the likely result will be increased electricity costs and a better environment for the construction of renewable and nuclear (if any, after the recent incident in Japan) power plants. Needless to say, the petroleum and chemical industries should begin planning now for their strategy to limit the use of fossil fuels in their production and delivery processes.

VI. SMART METERING AND THE SMART[ER] GRID

Another widely touted technology for which legislators have appropriated significant funding is the development of "*smart* *metering and the smart[er] grid*." The terms smart meter and smart[er] grid have no exact definition and can refer to a number of technologies varying in complexity. The smart[er] grid technology of most interest to the petrochemical industry will likely be those technologies facilitating demand side management and the use of real-time tariffs.

Smart[er] grid technology makes possible two-way communication between power producers and users via the customer's meter. Among the information that can be communicated to the meter is the tariff structure being used by the utility at a particular time during the day.

Energy used during peak times, such as noon, may cost the utility many times more than the same amount of energy would cost at off-peak times, such as midnight. A smart meter which can accept a time-based cost profile can pass the costs the utility sees directly to the customer.

Presently, most electrical tariffs are constant from day-to-day and hour-to-hour and only change when the utility gets permission from the Public Utilities Commission (PUC) to change them. The end user may pay higher costs due to high demand but generally pays the same rate no matter when energy is used or when their highest electrical demand occurs. If electricity tariffs can be communicated to each meter every day or several times a day it makes possible the use of several types of tariff structures that can be advantageous to industrial customers like the petroleum and chemical industries.

In time of use pricing (TOU) every month or every week a tariff would be sent to the meter reflecting the cost to generate electricity that is expected by the utility for that season of the year. The day may be divided up into several timeslots in each of which a different electricity price may apply. The price differences between time slots are the incentive for the customer to move load from peak expensive times to off-peak cheaper times, requiring some type of a peak shaving effort [20][21]. Some of the concepts are easily understood, but implementation strategy and cost effectiveness is still not proven and accepted by the public and the industry.

Real-time tariffs or real time pricing (RTP) reflect the actual cost of generation and transmission costs for any given half-hour of trading. In commercial energy markets power plants bid for energy on an hourly or semi-hourly basis. After this bidding is completed the utility would know the actual energy generation costs for the following 24 hours. The utility would then transmit this information to each meter and the cost of electricity for the customer would vary accordingly. In this tariff method the retail and wholesale rate of power would perfectly mirror each other. The customer would have sufficient information to shift loads from more to less expensive energy usage hours.

The third tariff type is critical peak pricing (CPP). This type of pricing may be combined with either TOU or RTP. It sets out times of each day or each year when energy usage may be critical and sets higher tariffs during these periods of time. The hope is that this will motivate customers to move their loads away from critical times, perhaps the time of day or time of year when the utility experiences its peak load.

The hope in implementing the smart[er] grid is that in the future, sales of electricity to retail customers would go something like this:

1. Each utility would project a day in advance the amount of energy it will need the next day. This projection will include projections of wind and solar energy available which the utility must purchase and which will depend upon weather projections made 24 hours in advance.
2. The utility will take bids for the energy it needs from generation providers in blocks of 30 minutes.
3. After accepting the low bid for each 30 minute block the utility will prepare a tariff profile that will be downloaded to each of its customers meters and this same tariff profile will be available at the customer's home using a display on the meter or a computer display via the customers automated energy conservation system.
4. The customer or their automated energy conservation system will decide which systems will run during each part of the day to minimize their energy costs.

Those advocating the smart[er] grid also anticipate the invention and inclusion of devices which will automatically control when devices operate to use electricity. The smart meter would communicate to an energy automation system that would automatically control electric usage in the plant on some schedule decided upon by the owner. It is the hope that automatic control of energy usage will make it possible for the utility to control their demand. For example, if the utilities projections of wind or solar energy were too low, and the utility did not purchase enough energy in advance, instead of purchasing additional energy on the spot market which will be very expensive, the utility may remotely cause loads to turn off lowering its demand and reducing the energy need.

Some proponents of the smart grid believe that demand management will make possible the reduction in total electricity usage and a reduction in total demand. It is estimated that by giving customers detailed information about their energy usage and the price of electricity at all times they may decrease their energy consumption by 10-15%, and it is also estimated that implementing the smart grid could reduce energy consumption in the US by 7-11% [22]. It is hoped that the utilities may benefit from purchasing smaller amounts of power at peak demand times.

Fig. 6 shows a typical utility load duration curve [23]. It illustrates how much hourly power is needed by the utility. The part of the curve labeled "peak load" typically will cost more for the utility to purchase or produce than the power contained in the base or intermediate loads. Since the generation used for the peak load operates for such a short length of time it becomes more costly. Also, the whole power system must be large enough to deliver this peak energy when needed even though it may occur for only a few hours to few hundred hours every year. This makes the energy delivery system more costly. It is the hope that with the installation of the smart[er] grid and smart metering that loads can be controlled by the owner or the utility to reduce the size and duration of the peak load. This will save both the utility and customer money in energy production and delivery costs.

Smart grid proponents also hope that controlling demand will allow large amounts of unpredictable yet available sources such as wind and solar energy to be used. The basic idea is that if wind energy varies, instead of requiring other types of generation such as natural gas to come on-line and vary in concert with the wind generation (if wind goes up natural gas generated electricity goes down) the utility will be able to vary the amount of load as the available energy from renewable sources varies. This will require many customers to be willing to allow utilities to control their demand when needed.

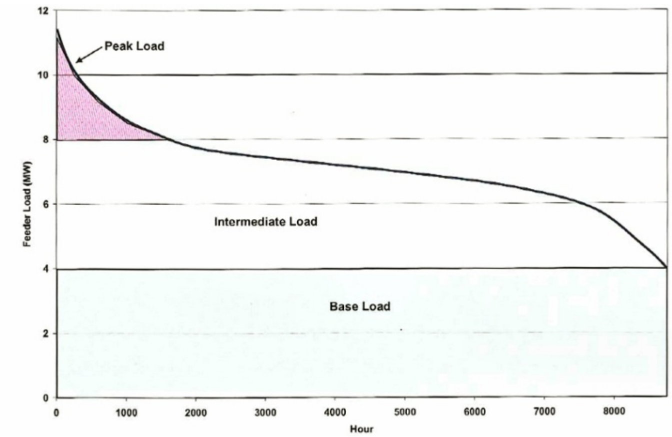

Fig. 6 Typical Annual Load Duration Curve.

If fully implemented the smart grid may have mixed results for customers such as the petrochemical industry. On the plus side if a plant uses processes which are not constant and can be shifted to times of when the electrical tariff is less expensive, a plant can save money by taking advantage of the lower electrical rate. However, if processes cannot be shifted then the smart[er] grid and smart metering will have little effect or may increase costs.

If a plant installs a renewable energy source which is normally non-dispatchable such as wind or solar, smart metering may reduce the value of the electricity generated and extend pay-back periods for their power plants since these plants produce a substantial amount of their electricity during off-peak and therefore cheaper periods. The electricity produced by the renewable power plant will be less valuable under a continually varying tariff than under a flat rate tariff as exists today. This is probably of more concern for wind sources which produce much of their energy during off-peak hours than it is for solar installations which produce at least a portion of their energy during utility peaks. The result of smart metering and the smart[er] grid will be to extend the payback periods for any non-dispatchable renewable source.

VII. THE FUTURE OF ELECTRIC ENERGY IN THE PETROCHEMICAL INDUSTRY

It is clear and evident that the way electricity is currently generated and utilized will change considerably in the foreseeable future as a result of changes in the political and legislative climate in the U.S. and globally. This change in the market for electricity will affect considerably all large users such as the petroleum and chemical industries. In the short term petrochemical industries should plan for the results of climate change legislation and use of plug-in-hybrid-electric-vehicles (PHEV), not addressed in this paper. They should begin with increasing the overall energy efficiency of energy use while considering the likely increase in future electricity costs. They should also contemplate increased CHP plants and the use of waste heat and fuels not yet being used. Planning for the installation of renewable sources of energy such as wind and solar should be part of the industry's strategic planning for the near future.

Smart[er] grid technology along with the advancement of the PHEV technology is another short-term innovation that will become a part of the petrochemical industry. Future plants and processes used in the industry should be planned for using electricity at the cheapest time available whenever possible. Planning should also begin to determine if existing processes can be modified to take advantage of the time varying cost of electricity which will exist if the smart[er] grid becomes a reality. Reliability and security of electricity production and availability must also be considered.

In the long term a number of technologies may be produced by the research and development money being spent by the federal government and industry today. This research may result in methods to use geothermal energy from depleted oil fields that can be used by the petrochemical industry to offset power usage. Hydrokinetic technologies may also produce devices that will be valuable in offshore power production for facilities such as oil platforms and off-shore oil production. Future research may produce energy sources which are completely unknown today. PHEV and other electric vehicle related research activities will present challenges and opportunities that the petroleum and chemical industries must face.

If carbon sequestration technology becomes viable or if the present concern for climate change dissipates, the use of coal, petroleum, and natural gas for electricity generation may continue far into the future. Ultimately, however, as future energy needs grow, nuclear energy of some form will likely be called upon to fill the long-term needs of the petrochemical industry, and the world, for carbon free electricity.

It is hoped that this paper will provide an impetus to the petroleum and chemical industries to take a fresh look at the energy industry today. Modern strategies for energy conservation, research and development efforts targeted at energy and electrical production, and the present business climate should be re-evaluated with the objectives of minimizing the cost of production and maximizing the efficient generation and use of electrical energy in the petroleum and chemical industries.

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IX. VITA

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