Alternative Energy Choices, Conservation, and Management: A Primer for Advanced Manufacturing Managers

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Abstract

Manufacturing managers need to understand the interrelated links between advanced manufacturing technology, primary and alternative energy choices, energy output values and costs, and energy conservation over the life of a project. Through an overview of these topics and the manager's energy conservation processing optimization model developed in this paper, manufacturing managers, engineering technologists, and academics gain greater insight to the impacts of energy technologies upon manufacturing activities.

Introduction

Alternative energy is the rage in today's ongoing pursuit to lower energy costs. Whether the energy technology is ethanol, biomass, solar, or wind, consumers of energy are consistently seeking new and better ways to save on their bottom line and meet energy needs [1]. Advanced manufacturing managers are no less driven to lower energy costs for their employers. Through properly applied management techniques of planning, organizing, actuating, and control (POAC), managers need to be equipped to not only understand but also be willing and able to practice energy conservation. Likewise, managers need to be change agents promoting alternative energy in their respective geographic regions to become more environmentally and cost friendly. Justification for this paper consists of the following major points:

- Advanced manufacturing technologies support higher quality and greater productivity.
- Alternative energy is undergoing increased interest.
- Different primary and alternative energy methods have varying levels of energy output and costs.
- Managers need to understand conservation methods currently available to them.
- A synopsis of the best process configuration in advanced manufacturing technology, energy usage, and conservation methods are presented in terms of energy output and related costs.

Through this paper, the reader is exposed to what constitutes "advanced manufacturing," currently available primary and alternative energy technologies (and their energy output values and costs), energy conversation methods, and an optimal energy configuration for a selected manufacturing industry process.

Innovation and Advanced Manufacturing

John Kao states, "Innovation means anticipating opportunities and responding with appropriate resources and talent" [2]. Opportunities for innovation have made significant strides in the area of advanced manufacturing over the last 50 years. Chiang supports a new economy "characterized by innovation, knowledge, and collaboration," transforming manufacturing into informational services and mechanization into digitization [3]. Information management and computerized digitization of part and product characteristics are a vital part of advanced manufacturing technologies.

Many companies have adopted advanced manufacturing technologies to remain globally competitive through the use of high technology components and manufacturing systems. The Society of Manufacturing Engineers (SME) has recognized advanced manufacturing as the automation technologies of robotics, programmable logic controllers, computer-integrated machining equipment, quality assurance measurement components, automatic storage and retrieval systems, barcode readers, and assembly equipment [4]. SME made this assertion through the funding of a two-year $204,021 grant to the University of Central Missouri in Warrensburg, Missouri, from 2007-2009. In this case, advanced manufacturing makes it possible to manufacture finished products in an automated environment with little human intervention or maintenance [4]. The advanced manufacturing term may also be utilized for subcomponents within this defined set of components (e.g., robots, computer numerical control equipment, and so on).

Today's manager and engineering technologist should have a firm grasp of available advanced manufacturing technologies to sufficiently serve their respective company and domestic economy. Jim Lorincz, senior editor for manufacturing engineering [5], relates how oil companies utilize advanced manufacturing technology to retrieve oil and natural gas to meet global demand. In the article, "Technology Chases Production: Productivity Flows from CNC Machining," Lorenz highlights the following capabilities required by oil conglomerates in their computer numerical control (CNC) equipment:

- CNC turning with precision threading capability.
- Multitasking machines that can machine difficult-to-machine metals and substantially reduce setup time.
- Automation that can dramatically reduce cycle times and increase throughput.

This example briefly illustrates that the advanced manufacturing equipment used must be capable of operating at optimal output levels in an effective and efficient method for selected tasks. Innovation helps to make this possible. Likewise, as alternative energy technologies are developed and exploited, innovation will play a key role in meeting energy needs for advanced manufacturing components and systems.

Alternative Energy Choices, Costs, and Power Output Levels

Global energy demand is predominately met by oil (petroleum), natural gas, and coal, although other alternative sources of energy are available such as ethanol (also called biofuel), biomass, solar, ocean waves and tides, nuclear power, wind, and hydropower [6]. Biomass, solar, ocean waves and tides, ethanol, wind, and hydropower are renewable; but oil, natural gas, coal, and nuclear power are not. All of these energy sources is used to meet the energy needs of the world's commercial and industrial power base. In this paper, current and projected needs for these types of energy for the United States are listed in terms of supply, consumption, and price, over the next 22 years (from 2008 to 2030).

Most of the renewable energy sources mentioned above are well-known, with ethanol and biomass taking on revived national interest. Ethanol is a product of food grain extraction of alcohol or vegetable oil from corn, soybean, sunflowers, and other organic matter. [7, 8, 9]. Ethanol is a biofuel requiring one Btu of oil to produce 1.3 Btu of energy; this equates to "450 pounds of corn to yield enough ethanol to fill the tank of an average SUV" [7, 9]. Biomass is technically "lignocellulose biomass" that is burned to create thermal energy for electrical power generation [8]. Biomass may be produced from citrus, switchgrass, or wood waste [10].

Solar, ocean waves and tides, wind, and hydropower are all renewable energy sources that may help consumers (both individuals and large corporations) reduce energy bills. Solar is probably the most well-known through the use of thin-film photovoltaic cells or thermal liquid technology. Solar is expected to continually grow as additional silicon-producing capacity is increased by more than a dozen new manufacturing facilities in Europe, China, Japan, and the United States [11].

Ocean waves and tidal forces are another promising contender for energy generation. In one example, a Pelamis converter was able to generate 293 kilowatt hours (kWh), which is comparable to a large wind turbine; payback of materials and servicing of equipment is within 20 months [12]. Potential impediments to ocean energy usage are dependent upon location of energy converters and electrical transmission lines.

Wind power generation also holds promise as more turbines are constructed to capture fluctuating wind energy that can be transferred to a national power grid – provided that locations selected have ample wind velocity. Per Archer and Jacobson [13], the world's electric power demand is at 1.6 – 1.8 terrawatts (tW) and could be met entirely through the construction of five 890,000 (5) megawatt (mW) turbines with 126-meter diameter rotors [13]. Smaller turbines exist and could help this meet energy demand in local municipalities.

Hydropower is yet another widely used method to generate electricity. While hydropower is efficient and clean, growth is restricted based upon available water supplies that can be pooled and released for power generation. "Run-of-River" small power generation units exist and as of 2002, 19 percent of United Kingdom power needs were met with 100 megawatt (mW) of capacity with another 400 megawatts (mW) of potential capacity [14]. Current literature for the state of small-scale "Run-of-river", or other types, of hydropower generation could not be found later than 2002.

Hydrogen is not listed in the above literature review because of its apparent limitation to only meet the energy needs of transportation. In an article by Heiman and Solomon [15], "transportation is responsible for one-fourth of global greenhouse gas emissions and consumes 75 percent of world oil production" [15]. Based on these facts, it should be understood that hydrogen fuel is a product of other materials. Currently, 95 percent of all hydrogen is extracted from natural gas or coal. Because hydrogen is primarily an intermediary for energy transference, it is not an actual alternative energy source. While hydrogen can be generated from electrolysis of water, oil refining, or gasification of biomass, the authors state that hydrogen production is not "geologically, economically, or thermodynamically on a scale large enough to support commercial production" [15].

The United States' current and projected 2008 to 2030 primary energy supplies are listed in Table 1 and Figure 1, Table 2 and Figure 2 list information for alternative energy supplies [16]. Data from the United States was chosen for all tables and figures due to availability and potential country-to-country comparison difficulties.

Table 1: U.S. Projected Primary Energy Supplies

Primary Energy Supplies in Quadrillion Btu (Production / Imports)						
Energy Type / Year	2008	2010	2015	2020	2025	2030
Oil	33.34	33.90	35.05	34.98	35.37	36.45
Natural Gas	26.75	26.92	27.49	27.23	26.97	26.65
Coal[(A)]	23.74	23.97	24.48	25.20	26.85	28.63
Nuclear[(A)]	8.34	8.31	8.41	9.05	9.50	9.57
Hydropower[(A)]	2.70	2.92	2.99	3.00	3.00	3.00

Notes:
A/ Not imported

Figure 1: U.S. Projected Primary Energy Supplies

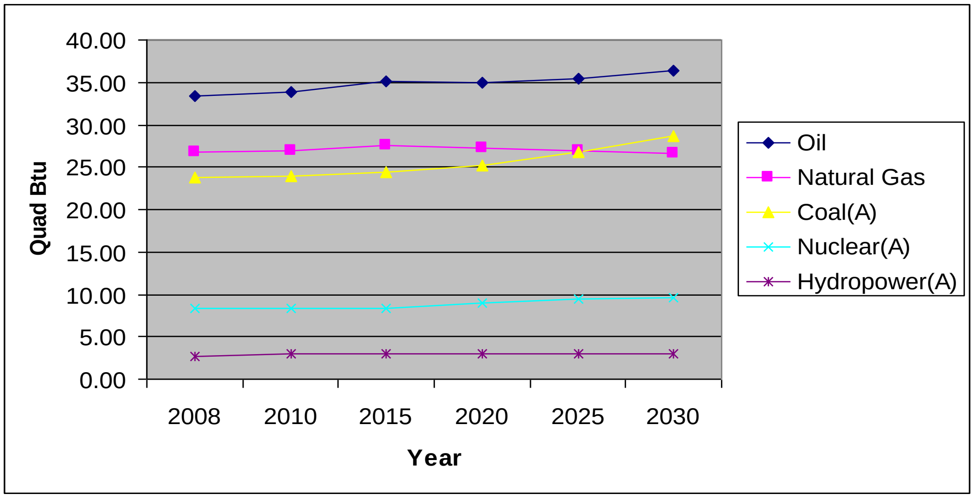


Table 2: U.S. Projected Alternative Energy Supplies

Alternative Energy Supplies in Quadrillion Btu (Production / Imports)						
Energy Type / Year	2008	2010	2015	2020	2025	2030
Biomass(A,B)	3.83	4.05	5.12	6.42	8.00	8.12
Other Renewable(A,C)	1.18	1.51	1.75	2.00	2.25	2.45
Ocean Waves/Tides(A,D)	0.00	0.00	0.00	0.00	0.00	0.00

Notes:

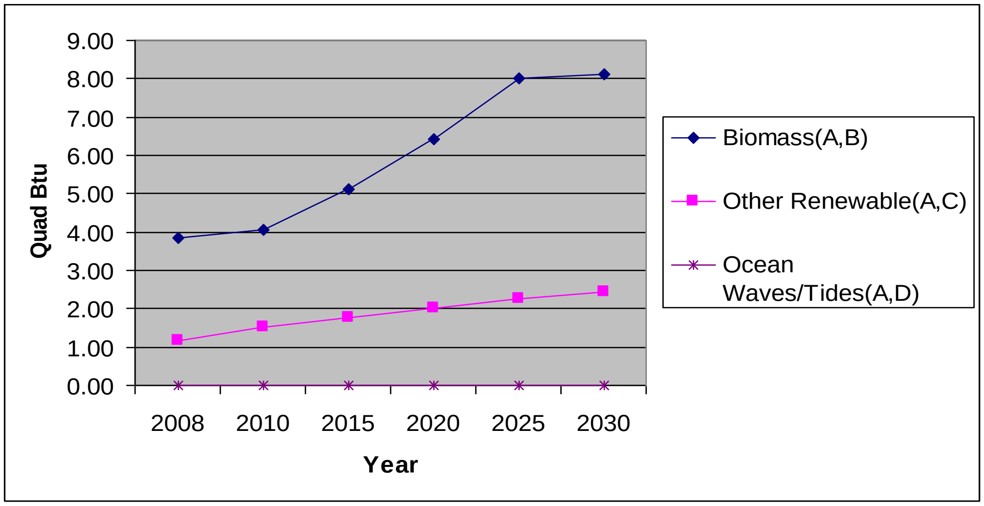
A/ Not imported

B/ Includes wood waste, Ethanol (from corn)

C/ Includes landfill gas, wind, photovoltaic, and solar thermal sources

D/ Not listed

Figure 2: U.S. Projected Alternative Energy Supplies



The United States' current and projected 2008 to 2030 primary energy consumption is listed in Table 3 and Figure 3, Table 4 and Figure 4 list information for alternative energy consumption [16].

Table 3: U.S. 2008 -to- 2030 Projected Primary Energy Consumption

Primary Energy Consumption[A] in Quadrillion Btu						
Energy Type / Year	2008	2010	2015	2020	2025	2030
Oil	40.29	40.46	41.62	41.27	41.36	42.65
Natural Gas	23.79	23.93	24.35	24.01	23.66	23.39
Coal	22.73	23.03	24.19	25.87	27.75	29.90
Nuclear	8.34	8.31	8.41	9.05	9.50	9.57
Notes:						
A/ All sectors (residential, commercial, industrial, transportation) - hydropower not available						

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Figure 3: U.S. 2008 -to- 2030 Projected Primary Energy Consumption

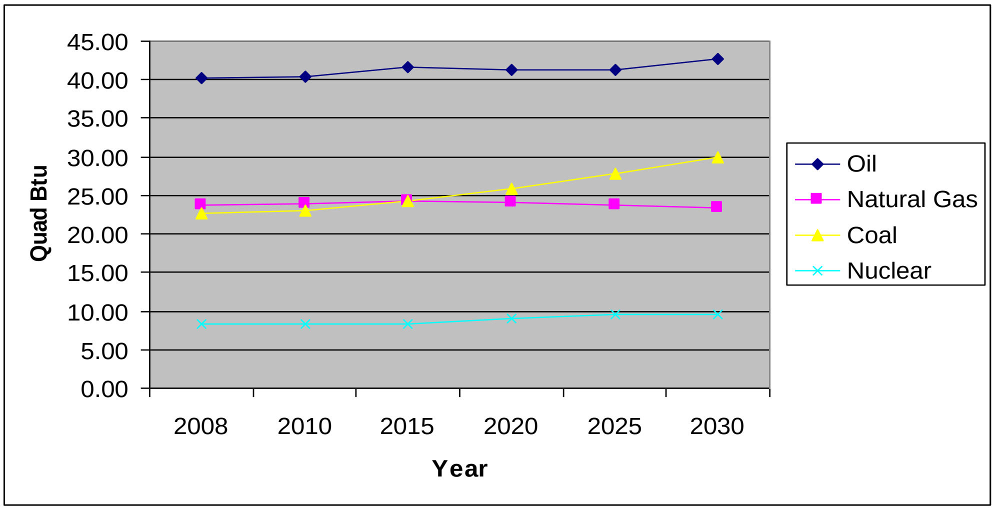


Table 4: U.S. 2008 -to- 2030 Projected Alternative Energy Consumption

Alternative Energy Consumption in Quadrillion Btu						
Energy Type / Year	2008	2010	2015	2020	2025	2030
Hydropower[(A)]	2.70	2.92	2.99	3.00	3.00	3.00
Ethanol[(B)]	0.77	1.05	1.34	1.82	2.06	2.01
Biomass[(C)]	1.90	1.89	2.18	2.60	2.75	2.82
Solar[(D)]	0.05	0.05	0.05	0.06	0.08	0.10
Wind[(E)]	0.50	0.74	0.87	1.02	1.13	1.24
Ocean Waves/Tides[(F)]	0.00	0.00	0.00	0.00	0.00	0.00

Notes:

A/ Sectors: industrial, electric power

B/ Sectors: transportation

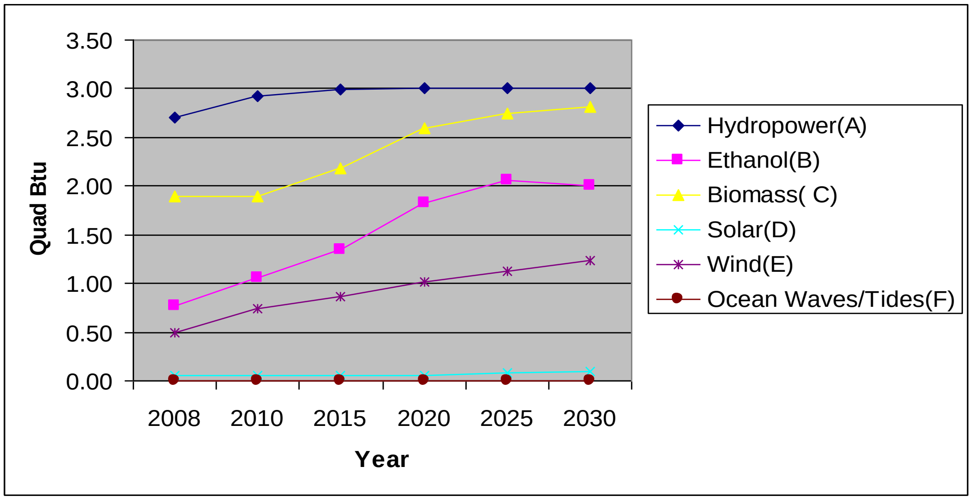
C/ Sectors: commercial, industrial, electric power

D/ Sectors: residential, commercial

E/ Sector: electric power

F/ Not listed

Figure 4: U.S. 2008 -to- 2030 Projected Alternative Energy Consumption



The United States' current and projected 2008 to 2030 primary and alternative energy prices are listed in Table 5 and Figure 5 [16].

Table 5: U.S. 2008 -to- 2030 Projected Primary and Alternative Energy Prices

Primary and Alternative Energy Avg. Prices in Dollars per million Btu						
Energy Type / Year	2008	2010	2015	2020	2025	2030
Oil(A)	20.92	16.96	14.69	15.09	15.67	16.52
Natural Gas(B)	11.25	10.89	11.17	9.92	10.31	10.96
Coal(C)	3.32	3.25	2.92	2.85	2.91	2.95
Ethanol(D)	24.88	23.58	17.61	18.15	18.50	19.58
Gasoline(E)	24.51	21.23	18.80	19.64	19.67	20.24
Alternative Energy(F)	---	---	---	---	---	---

Notes:

A/ Residential, Commercial, Industrial, Transportation (Distillate Fuel Oil)

B/ Residential, Commercial, Industrial, Transportation

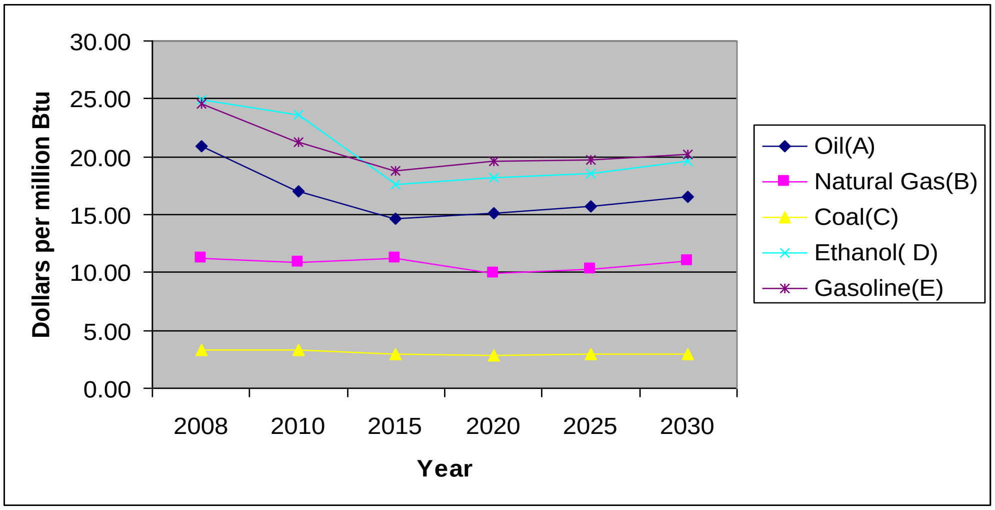
C/ Industrial (Metallurgical and Other Coal)

D/ Transportation (E85)

E/ Transportation (Gasoline)

F/ Primary and alternative energy sources of nuclear, hydropower, biomass, solar, wind, and ocean waves/tides are not listed

Figure 5: U.S. 2008 -to- 2030 Projected Primary and Alternative Energy Prices



While supplies and consumption may be accurate for energy usage in the United States, prices may not be accurate for oil price changes to be experienced in upcoming years. Table 6 and Figure 6 [17] indicate oil price changes for 2008, whereas Table 5 and Figure 5 [16] indicate a price decrease. The disparity may substantially affect future Department of Energy projections and have considerable effect on other primary and alternative energy usage.

Table 6: U.S. 2000-to-2008 Crude Oil Usage

U.S.A. Actual Crude Oil Statistics

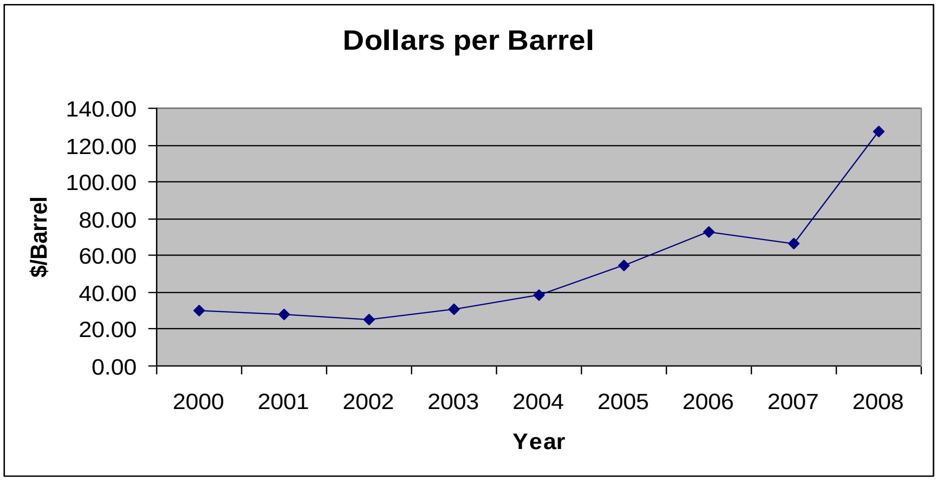
Year[(A)]	$/Barrel	$/Gallon[(B)]	% Increase / Year
2000	29.87	0.71	-
2001	28.14	0.67	-0.06
2002	25.10	0.60	-0.12
2003	30.72	0.73	0.18
2004	38.72	0.92	0.21
2005	54.46	1.30	0.29
2006	72.50	1.73	0.25
2007	66.17	1.58	-0.10
2008	127.75	3.04	0.48

Notes:

A/ 1st Week of June each year

B/ Base cost per gallon; not including processing & tax costs

Figure 6: U.S. 2000 -to- 2008 Crude Oil Usage



As seen in the previous tables and figures, U.S. energy supplies, consumption, and prices are predicted to substantially increase during the next 22 years. Also, alternative energy (ethanol, solar, wind, ocean wave / tide) supplies, consumption, and prices were too low to merit listing individual values. This may change as oil prices continue to escalate.

Btu energy outputs for the various primary and alternative energy sources are listed in Table 7 [19]. Electricity is the primary power medium generated by the energy referenced in the chart. Electricity will be used as the baseline for advanced manufacturing energy conservation in the rest of the paper.

Table 7: Primary and Alternative Energy Btu Output Levels

Btu Output Levels				**Table 5 Ref. Info.**
Energy Type	Amount	Btu	kWh	2008 Dollars / Million Btu[(A)]
Oil (#2 Fuel Grade)	1 Gallon	139,000	40.73	20.92
Natural Gas	1 Cu. Ft.	1,030	0.30	11.25
Coal	1 Pound	12,000	3.52	3.32
Ethanol	1 Gallon	76,000	22.27	24.88
Gasoline	1 Gallon	125,000	36.62	24.51
Biomass (Wood)	1 Pound	3,500	- - -	- - -
Conversions				**Abbreviations**
Energy Type	From	To		
Oil (#2 Fuel Grade)	42 Gallons	1 Barrel		
Electricity	1 kWh	3,413 Btu/hr		kWh = kilowatt-hour

Notes:

A/ U.S. Dept. of Energy / Energy Information Administration [16]

B/ Primary and alternative energy sources of nuclear, hydropower, biomass, solar, wind, and ocean waves/tides are not listed [16]

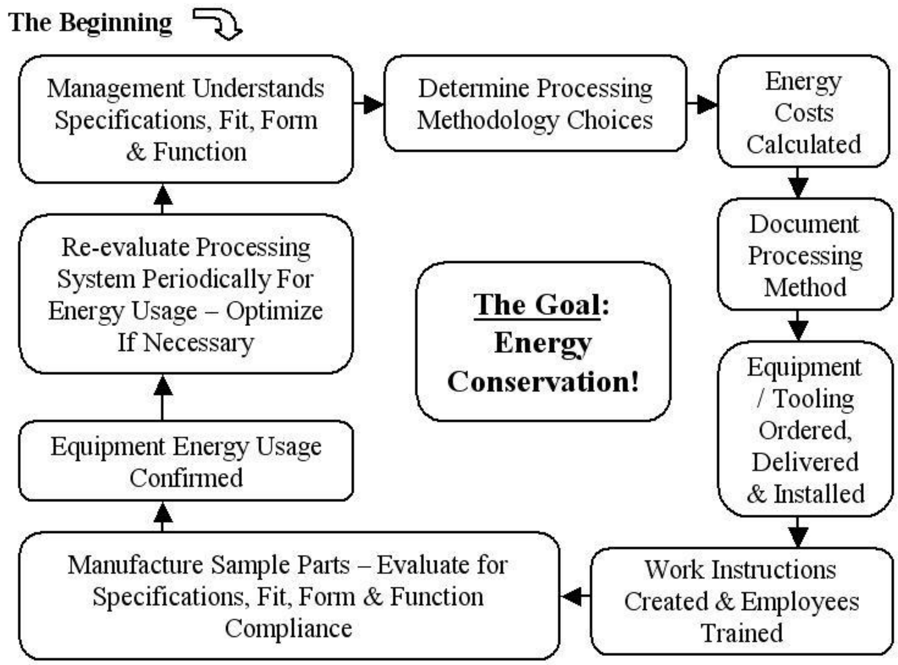
Based upon the Btu and kWh output levels listed in Table 7, it is readily apparent that power generation is much higher for oil and gasoline than the other energy choices. At the same time cost per million Btu is also at a higher level. The exception is ethanol; the only alternative energy choice listed that has equivalent costs to oil and gasoline. However, ethanol is significantly lower in Btu output per gallon. As oil and gasoline continue to increase in cost (see Table 6 and Figure 6), one would surmise that alternative energy choices of biomass, solar, wind and ocean waves/tides will be added to future U.S. Department of Energy/Energy Information Administration charts for power-grid distribution and usage.

Energy Conservation Management Techniques

Energy conservation at the simplest level is using the minimal amount of energy required to perform a task. This methodology could be termed strategic asset management. Smid and Nieboer [18] provide such a model in relation to estate management for properties, although the same can be utilized for the management of energy resources. The model used by Smid and Nieboer essentially defines the business mission and considers internal and external analysis, goal formulation, strategy formulation, program formulation, implementation, and feedback and control [18].

In relation to conservation of energy resources for the advanced manufacturing manager, the goal is similar to Smid and Nieboer's model although with a different slant. Advanced manufacturing managers must first have a firm grasp on specifications, fit, form, and function of a component or product. Next, component or product processing methodology choices need to be analyzed. Energy use and resulting costs of each processing method are considered. The processing method is documented for use in manufacturing. Equipment and tooling are ordered, delivered, and installed. Work instructions are created, employees trained, and manufacturing of the component or product may begin. Once this manufacturing system is set up, a sample run of parts are made and the process methodology is analyzed to evaluate if manufactured components and products are meeting specifications, fit, form, and function. If the components and products are compliant to these parameters, energy usage should be confirmed to stated equipment manufacturer specifications. Provided that energy usage is within anticipated values, periodic evaluation of the system should be conducted to ensure continued compliance. See Figure 7 for an abbreviated diagram of this processing optimization model for optimal energy conservation.

Figure 7: A Manager's Energy Conservation Processing Optimization Model



Key to any continuously improving value-added system is the element of resource conservation and optimal utilization. The advanced manufacturing manager must be cognizant of this fact and properly use equipment, energy, and human power to the highest extent possible. Managers, and the employees who work for them, who practice conservation of these vital resources not only provide value to their companies but also to the global community as well.

An Optimally Managed Industrial Process

Electricity generated by primary and renewable energy sources is used to power the majority of advanced manufacturing equipment. The latest United States industrial average electricity cost, as of December 2007, is $0.0625 per kWh [20]. This rate takes into account all types of primary and alternative energy sources used to generate electricity within the United States.

The simple advanced manufacturing process under consideration is a computer numerical controlled (CNC) milling operation requiring three, eight-hour shift operations for five days per week (plus one, six-hour shift each Saturday) for 50 weeks per year. The manager needs to purchase three high-speed vertical machining center (VMC) CNC mills that will operate at less than $20,000 per year, for three years, in energy costs (Increasing costs of energy, repairs, upgrades, or other costs are not evaluated in this study.) For this manufacturing process, the manager has identified three mill models for procurement consideration. All three mill models have the same performance (spindle speed, table feed rates, accuracy, accessories, etc.), except the power requirements for each model are different. Through rated

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load testing, the manager has learned that mill model one operates at 15.8 kWh; mill model two operates at 16.3 kWh; and mill model three operates at 17.1 kWh. At first glance, it is easy to pick the lowest cost mill; mill model one meets the requirements for lowest operational cost. The following equation confirms that mill models one and two meet the requirements for year one:

Mill Model One: 16.4kWh * [5(8*3)+6]hrs * 50wks * 3mills * $0.0625/kWh = $19,373

Mill Model Two: 16.6kWh * [5(8*3)+6]hrs * 50wks * 3mills * $0.0625/kWh = $19,609

Mill Model Three: 17.0kWh * [5(8*3)+6]hrs * 50wks * 3mills * $0.0625/kWh = $20,081

However, the manager has a maximum energy cost requirement for a total of three years and must consider total energy costs. Since it is not usually possible to project future equipment energy costs, the manager must typically pick one of the mill models for the manufacturing facility and use the "Manager's Energy Conservation Processing Optimization Model" (see Figure 7) to evaluate each mill's operational performance on a yearly basis. Through the use of this technique, the manager is able to evaluate the current methodology choice, review energy costs on each machine, optimize processing documentation, evaluate the mechanical and electrical condition of the equipment and tooling, review work instructions, analyze a set of machined samples, and confirm mill energy usage. If there are any weaknesses discovered, these issues should be addressed to ensure that parts are being manufactured correctly and that energy conservation goals are being met.

In this hypothetical case, the advanced manufacturing manager purchased one of each of the three mill models initially evaluated. Table 8 documents electricity usage and energy costs that were accrued over three years for all three models.

Table 8: Mill Electricity Usage and Energy Costs

	Year 1		Year 2		Year 3		Year 1-3
Mill Model No.	kWh	Dollars	kWh	Dollars	kWh	Dollars	Total Energy Costs
One	16.4	$19,373	17.2	$20,318	18.0	$21,263	$60,953
Two	16.6	$19,609	17.3	$20,436	18.1	$21,381	$61,425
Three	17.0	$20,081	17.1	$20,199	17.3	$20,436	$60,716

Based upon total energy costs listed in Table 8, attributable to power consumption variance over time (due to equipment wear, tooling wear, etc.), mill model one or two would not have been the best choice for conservation of energy costs for all three years. While mill model three would have been eliminated in the initial evaluation, due to the $20,000 maximum energy cost constraint, this model has proven to be the lowest cost machine over the life of the project. Likewise, this illustrates that while electric usage is important at some point in time, energy costs need to be evaluated over the duration of equipment utilization to maximize investment dollars and energy conservation. A proactive action as a consequence to this study may be to sign a binding contract with the potential equipment vendor, stating that energy costs will not increase beyond a certain level or the vendor will compensate for the additional costs incurred.

Conclusion

Innovative and efficient management of energy resources cannot be avoided in the value-added processing activities performed in manufacturing. Due to rising costs in petroleum-based energy technologies, alternative energy sources are undergoing considerable research and development to supplement the future energy needs of manufacturers. Through understanding of the current primary and alternative energy technologies, energy output values / costs, and the energy conservation evaluation model presented in this paper, advanced manufacturing managers are better equipped to understand and handle future energy-related technological challenges.

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