Industries of the Future in Perspective

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ABSTRACT

The Office of Energy Efficiency and Renewable Energy in the U.S. Department of Energy is undertaking an intensive program of technology research and planning regarding future energy use and environmental effects. This program, known as the Industries of the Future Program, will be carried out in cooperation with nine energy-intensive industries: aluminum, chemicals, forest products, petroleum, steel, glass, metalcasting, agriculture (biochemicals), and mining. This presentation explains the program's strategy of developing visions and roadmaps for future progress in energy efficiency and emissions reduction in collaboration with industry representatives. Background information regarding industrial energy consumption trends is presented, based on data from the Energy Information Administration (EIA). Discussion ties past data to the program's strategy of developing visions and roadmaps with industry and to information on industrial technologies surveyed in EIA's Manufacturing Energy Consumption Survey (MECS).

Introduction

In this paper, we will be:

- describing how the Industries of the Future program is changing the way the Department of Energy does business with industries;
- examining some of the historic trends in energy efficiency improvement,
- viewing industrial energy intensity projections prepared by the Energy Information Administration (EIA); and
- comparing a sample industry energy efficiency projection with EIA projections.

The Industries of the Future Program

For more than twenty years, the Department of Energy's Office of Industrial Technologies (OIT) has been partnering with energy intensive industries to develop technologies that meet industry's needs. More recently, the "Industries of the Future" concept has been introduced to involve industry partners more explicitly and directly in the process of identifying and prioritizing technology development needs. This customer-driven approach has made it possible for entire industries to work together to define and pursue their top priorities for research, development and demonstration. It has also encouraged an "integrated delivery approach" to energy efficiency,

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from down-to-earth practical ideas for improving everyday energy efficiency right now to futuristic breakthrough technologies with the potential to revolutionize entire industries. There are programs to encourage improvements in motor, compressed air, and steam systems, advanced turbine systems, combined heat and power, and industrial energy auditing in addition to longer-term research and development. The Industries of the Future Program includes nine energy-intensive industries: aluminum, chemicals, forest products, petroleum, steel, glass, metalcasting, agriculture (biochemicals), and mining.

> By giving industry 'ownership' of the process, the strategy also obtains industry commitment to the research and facilitates industry cost-sharing, which averages 50% over the life of a project. Moreover, industry's involvement essentially ensures adoption and use of the successful energy-efficient technologies. (DOE 1999)

The new approach focuses on a government catalyzing industry, through their associations, to establish visions for the year 2020. Industry develops technological roadmaps to reach the vision. The roadmap development includes participation of academia and laboratories. The industry helps DOE implement the programs through competitive solicitations. DOE laboratories entered into a collaboration, with 16 laboratories forming the Laboratory Coordinating Council so that industry can access the capabilities of the laboratories relevant to the Industries of the Future in the performance of projects identified by industry. This process has been praised by industry for allowing them a greater role in the allocation of federal industry energy R&D dollars at the same time that it offers government the opportunity for greater research productivity.

What is unique or important about this approach? Traditionally reticent industry has been open and sometimes dramatic in suggesting the importance of the new approach:

> Aluminum: "To ensure that the DOE OIT response represents the real needs of industry, major elements of US industry have been encouraged to define opportunities for industry/government partnerships that may be useful in enhancing the industry...."(The Aluminum Association, Inc. 1996)
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> Paper: "In many respects, this document represents a bold step forward for the industry. Never before has the industry with such unanimity taken a look at its future, the need for technological development, and ways to leverage its own capabilities with partnerships involving institutions, suppliers and government. Successful efforts to address the major technological issues discussed in [the vision] will ensure the continued success of one of America's most important basic industries." (American Forest and Paper Association 1994)
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> Chemical: "The growth and competitive advantage of our industry depend upon individual and collaborative efforts of industry, government, and academe to improve the nation's R&D enterprise. In this age of reorganization, the synergy of collaboration often has a "multiplier effect" on our nation's pool of talent, equipment, and capital available for R&D." (American Chemical Society et al. 1996)

An enormous amount of industry effort has gone into establishing consensus on requirements for industrial energy efficiency visions and technology roadmaps. For example, the effort to develop the U.S. Chemical Industry, Technology Vision 2020, involved participation by the American Chemical Society, the American Institute of Chemical Engineers, the Chemical Manufacturers Association, the Council for Chemical Research and the Synthetic Organic Chemical Manufacturers Association in 36 formal working meetings and 20 technical sessions. Development of industry technology roadmaps, a vital step in helping to focus R&D efforts, has involved additional efforts. These documents are initial attempts to link broadly-defined goals in industry visions documents with detailed research portfolios by industry and government that will be needed to reach industry goals.[2] These efforts seek to help coordinate technology direction in industries that have generally not previously come together on research priorities. As an example of an industry's commitment to this on-going process, the Forest Products industry spends an estimated $700,000 annually in staff time and travel to regularly update its vision and roadmaps and participate in the selection and review of projects.

- **Visions are seen as a first step:** Visions and roadmaps will evolve as each industry faces new realities and challenges. Activities relating to energy are only one part of the challenge posed in the visions. A technology vision is the first step of a continuous journey. The *Aluminum Industry: Industry/Government Partnerships for the Future* suggests that "this document should be considered as the initial version of an evolving 'vision' of a growing industry." For the current status of the visions and roadmaps, see Table 1.
- **Economic challenges are intensifying:** All U.S. industries face several common challenges in the future to maintain global competitiveness:
  - maintain technological leadership with increasing competition from abroad
  - government subsidies in countries with low-cost resources and labor
  - more demanding environmental requirements and
  - increasing capital expenditure requirements.

  The Industries of the Future program attempts to address these common challenges at the same time as those specific to each industry.
- **The speed of technology change is increasing:**
  - "The glass industry has always been evolving, with change coming so rapidly that many of the glass products we take for granted today were only developed in the last decade. Rapid change within the industry will continue in future years, as the industry finds fertile new fields to plow .... ." (Glass... 1996)
  - "Imagine how the world has changed over the past 100 years: that's the magnitude of change we can expect in the next 20 to 25 years." (Plant/Crop-Based ... 1998)
- **Co-operative R&D responds to intensifying competitive pressures:**
  "...as economic conditions continue to erode the ability of individual companies to make [investments in the development of advanced manufacturing techniques and new glass uses] unilaterally, alliances within the industry, sharing of technology from other industries, and partnerships with public agencies, universities and laboratories will become increasingly vital." (Plant/Crop-Based ... 1998)

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See Henry Kenchington, Jack Eisenhauer and Richard Green "Implementing the Aluminum Technology Roadmap," paper presented at the 1998 Minerals, Metals and Materials Society Annual Meeting. The Aluminum Association, Inc. has to date produced two roadmap documents, an "Aluminum Industry Technology Roadmap"(May 1997) and more recently an "Inert Anode Roadmap."(February 1998). Development of a non-consumable, or inert, anode has been pursued by the aluminum industry for many years and new technology, if successful could improve energy efficiency by up to 25%, reduce operating costs by up to 10% and increase productivity by up to 5% while at the same time reducing greenhouse gas emissions by 7 million metric tons of carbon equivalent in the United States.

- **Environmental considerations are increasingly recognized:**
  - "Increased use of recycled metal as the primary source of aluminum for product manufacturing will yield substantial energy savings, compared to producing aluminum from ore." (The Aluminum Association, Inc. 1996)
  - The Forest Products industry vision Agenda 2020: A Technology Vision and Research Agenda for America's Forest, Wood and Paper Industry, sets an industry goal of increasing recycling from 40% in 1994 to 50% in the year 2000. New environmental requirements for the paper industry are seen an a "burden that the U.S. industry must bear over the next decade and beyond," which will require at least for some industries like forest products "unprecedented increases in capital expenditures, operating costs and energy use." (American Forest and Paper Association 1994)
  - "Recycling will play a larger role in the industry." Greater attention to life cycle analysis and an understanding of the total environmental impact of products will increase steel's value versus other materials...." (Steel... 1995)
  - "Once these [advanced] technologies are developed and in place, they will allow the industry to use its energy, land, capital and labor resources even more efficiently during all stages of the mining cycle which will in turn, create a safer, less environmentally disruptive industry with high quality output at lower cost." (The National Mining Association 1998)
- **Future capital requirements will challenge industry:**

The speed of new technology uptake will be determined by the capital investment decisions of industry. It will also be determined by the economic health of the industry and its ability to raise needed capital and to achieve adequate returns on its investments. For example, the Mining industry's The Future Begins with Mining: A Vision of the Mining Industry of the Future, acknowledges that "[d]espite the significant economic contributions of the U.S. mining industry, returns on investment have not kept pace with competing industries. Capital inflows are the lifeblood of the mining industry and the industry must become more attractive to investors by using technologies to increase returns to investors ...."

The ability of these industries to raise needed capital to introduce new technologies cannot be assumed and the magnitude of industry capital requirements implicit in the development of industry roadmaps is substantially greater than past capital investment in most Industries of the Future. Capital availability at reasonable cost is thus a key concern to these industries.

- **Specific numerical targets have been set in several industry visions but not in all:**

The Forest Products industry established one approach "recognizing the inability of humans to accurately predict the future, the focus is on direction and broad, general goals rather than specific endpoints and solutions. Trying to predict the future with specificity always results in a presentation of the authors' biases and preconceived solutions to current problems." (American Forest and Paper Association 1994)

Several industries have included clear and precise goals. One example, the glass industry, has set several quantitative goals. By the year 2020, the glass industry will:

1) Operate with production costs at least 20% below 1995 levels;

2) Recycle 100% of all glass products in the manufacturing process, where consumption is greater than 5 lb/capita;

3) Reduce process energy use from present facility levels by 50% toward

Table 1 **Industries of the Future**

Industry	Vision Doc. Completion	Technology Roadmap	Quantitative Goals (Examples)	Revision Planned?
Forest Products	November 1994	revised annually	increase recycling from 40 to 50%	Implementation Plan for Vision February 1999
Steel	May 1995	March 1998	see Steel Industry Technology Roadmap for detailed technology goals	Currently under discussion
Metalcasting	September 1995	January 1998	increase productivity by 15% ; reduce average lead times by 50% ; reduce energy consumption 3-5% ; achieve 100% pre- and post-consumer recycling; 75% beneficial re-use of foundry by-products and complete (100%) elimination of waste streams	None planned at this time
Glass	January 1996	in process	see text below	None planned at this time
Aluminum	March 1996	May 1997	roadmaps contain specific targets	None planned at this time
Chemicals	December 1996	4 roadmaps completed	some (50) roadmaps are under development and will contain specific targets	None planned at this time
Agriculture (Biochemicals)	January 1998	February 1999	achieve at least 10% of basic chemical building blocks from plant-derived renewables by 2020	no
Mining	September 1998	January 1998	some general goals are provided	no
Petroleum	under development			

theoretical energy use limits;

4) Reduce air/water emissions by a minimum of 20% through environmentally sound practices;

5) Recover, recycle and minimize 100% of available post consumer glass (Glass...1996)

In the next section, using the glass industry as an example, we will look at how the projected energy efficiency improvements for the glass industry compare to all-industry, all-manufacturing, or industry specific energy efficiency improvements in the past.

Historic Trends

What have been the trends in industrial energy efficiency and what factors appear to have influenced the rates of efficiency improvement in the past?

■ **Industrial Sector**

Looking first at the industrial sector in general, which includes manufacturing as well as mining, construction, agriculture, fisheries, and forestry, we see in Figure 1 that the total for industrial energy consumption in 1973, 31.5 quads including electricity system energy losses, is not dramatically different from the 1997 total of 33 quads. But what happened in the interim?

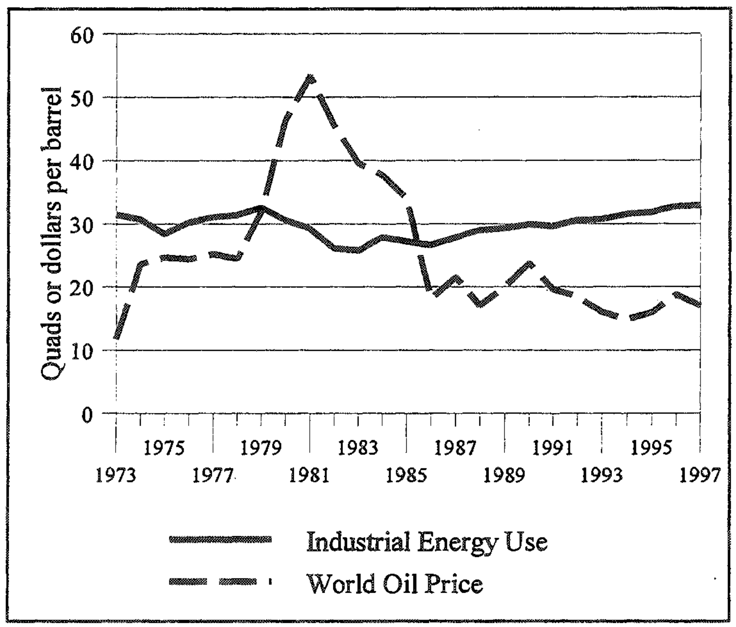

Figure 1. Industrial Energy Use and World Oil Price

The composite refiner acquisition cost of crude oil which was $11.76 in inflation-adjusted 1992 dollars in 1973 climbed to a fairly steady mid-twenties inflation-adjusted price through the mid seventies. A second more dramatic climb resulted in a high of $53.39 (inflation-adjusted annual average) for 1981, decreasing to $14.83 by 1994. (EIA 1998)

The level of economic activity increased markedly. During that time, the inflation-adjusted measure of Gross Domestic Product increased from 3.9 trillion dollars to almost 7.3 trillion dollars. So while roughly the same amount of energy was being used in industry, almost twice the output was being produced in the economy. The ratio of energy used in the industrial sector to GDP fell from 8.1 thousand BTUs per dollar of output in 1973 to 4.5 in 1997, a decrease of almost 44 percent. While Figure 2 shows that the efficiency improvements were larger in the earlier years, when dramatic energy price increases encouraged industry to pick the low-hanging energy efficiency fruit quickly, on an annualized basis energy efficiency was improving by 2.4 percent per year in the industrial sector.

Manufacturing

Next we will examine the changes in efficiency in the manufacturing portion of the industrial sector. The Energy Information Administration surveyed manufacturing establishments at 3-year intervals from 1985 to 1994, through the Manufacturing Energy Consumption Surveys (EIA 1985, 1988, 1991, 1994). Total manufacturing energy use was 13.6 quads in 1985, increasing to 20.5 in 1988, decreasing to 15 in 1991, and increasing again to 16.5 in 1994. Starting with the 1998 MECS, the survey is being conducted every 4 years.

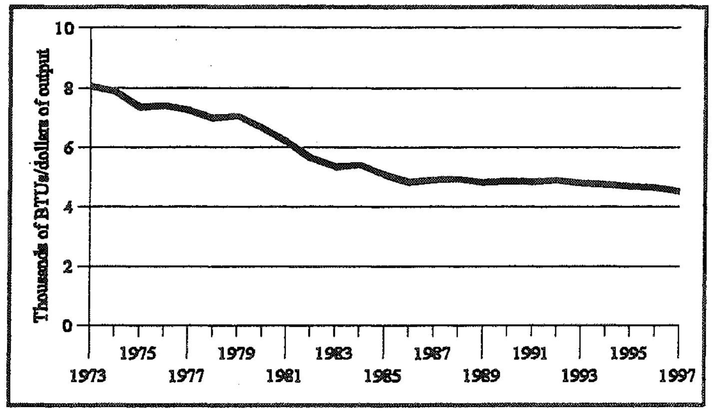

Figure 2. Industrial Energy/GDP

Comparing real GDP from manufacturing in 1985 and 1994, one sees that they were virtually the same. While total real GDP increased from 5.3 trillion 1992 dollars to 7.3 trillion, manufacturing's share fell from almost 22 percent to almost 18 percent. A general downward trend in energy prices during this period was dampening some of the previous incentives to save energy. The low-hanging fruit had already been picked, and the energy savings available at lower prices did not justify buying a ladder. And the composition of GDP was moving toward more energy-intensive goods. For example, the energy-intensive chemical industry contributed only 7.6 percent of manufacturing's total in 1985, but had grown to 10.7 percent by 1994. Paper, another energy-intensive industry, was 3.9 percent of manufacturing GDP in 1985 but had grown to 4.3 percent in 1994 (Statistical Abstract of the United States 1992 and 1997).

Industries of the Future

According to MECS 1994, the most energy-intensive industries in terms of energy consumption for heat, power, and electricity generation per dollar of value of shipments are petroleum and coal products, paper and allied products, primary metals, stone, clay, and glass products, and chemicals and allied products. We'll begin with a brief analysis of some of the components of that list that match the Industries of the Future:

- The paper industry consumed 2,198 trillion BTUs of energy in 1985 for heat, power, and electricity generation, increasing to 2,634 trillion BTUs in 1994. This 19.8 percent increase in energy use was associated with a 11.5 percent increase in industry product measured in real dollars, for an energy intensity increase of 7.5 percent.
- Primary metals saw a 22.8 percent increase in energy intensity between 1985 and 1994.
- The chemical industry, however, saw a 4.7 percent energy intensity decrease in the period, an energy efficiency improvement.

Glass

Using the glass industry (Standard Industrial Classification (SIC) codes 3211, 3221, and 3229) as an example of an Industries of the Future forecast, their vision statement sets a goal of "reduc(ing) process energy use from present facility levels by 50% toward theoretical energy use limits" (Glass... 1996) by the year 2020. Energy use in the glass industry in 1997 was 194.7 trillion BTUs for 19.52 billion 1987 dollars worth of industry output, for an energy intensity ratio of 9.98 thousand BTUs per 1987 dollar of output (EIA Web site).

This energy use included more than melting. According to MECS 1994, almost 83 percent of the 198 trillion BTUs of energy used in glass production in 1994 was used for process heating. The theoretical minimum is 2.5 million BTUs to melt a ton of glass.

To estimate the energy used for melting in 1997, we first found that 14.6 million tons of glass were produced in the U.S. in these SIC codes, and 194.7 trillion BTUs were used for all purposes. If we assume that the process heating percentage was the same in 1997 as in 1994, the estimated 1997 process heating use would be 161 trillion BTUs. An estimated process heat intensity would then be 11.0 million BTUs per ton of glass (161 trillion BTUs/14.6 million tons of glass).

Halfway from the 1997 11.0 million BTUs per ton of glass to the theoretical minimum of 2.5 million BTUs per ton would be 6.75 million BTUs per ton. Reaching that goal by 2020 would imply an annualized improvement rate of **2.1** percent for the glass industry.

Comparing An Industry of the Future Projection to EIA's Annual Energy Outlook

To put the energy efficiency improvement estimates presented above in perspective, we examined the Annual Energy Outlook 1999 forecasts prepared by the Energy Information Administration. In the Reference Case Forecast (EIA 1999), delivered energy intensity in the industrial sector, as measured in thousands of BTUs consumed per 1987 dollar of output, is projected to decrease from its 1997 level of 6.78 to its projected 2020 level of 5.5. This almost 19 percent decrease does not include electricity-related losses. The inverse of these intensity measures would be efficiency measures of 147.4 dollars of gross output per million BTUs in 1997, and 181.8 in 2020, an efficiency increase of 23.3 percent, or an annualized rate of **0.9 percent**.

Industrial energy use is being projected to grow by almost 25 percent during the period, while gross output is projected to grow by 54 percent. These are useful broad measures for the full Industries of the Future program, as the industrial sector includes non-manufacturing components such as mining.

In the High Technology case, "(e)arlier availability, lower costs, and higher efficiencies are assumed for more advanced equipment." (EIA 1999) Industrial energy consumption in 2020 is projected to be 31.32 quads, for an energy intensity ratio of 5.11 thousand BTUs per 1987 dollar of GDP. Again, gross output is projected to grow by 54 percent, but delivered industrial energy use is being projected to grow by only 16 percent during the period, for an almost 25 percent decrease in energy intensity. Converting to the efficiency measure discussed above, the same 147.4 dollars of gross output that would be created per million BTUs in 1997 is projected to increase to 195.75 in 2020, an increase in efficiency of 32.8 percent, or an annualized rate of **1.2 percent**.

Narrowing our comparison to the glass industry, EIA's reference Case Forecast estimates a ratio of 8.06 thousand BTUs per 1987 dollar of output in 2020, an annualized energy efficiency improvement of **0.9** percent in the Reference Case. In the High Technology case, the forecasted annual energy efficiency improvement rate would be 1.5 percent. To achieve industry's vision, higher rates of improvement will be needed. An unpublished report prepared for EIA (Arthur D. Little, Inc. 1998) suggests that energy required for melting glass could be reduced by 47 percent over twenty years in an aggressive technology situation, for an annualized decrease of 3.1 percent.

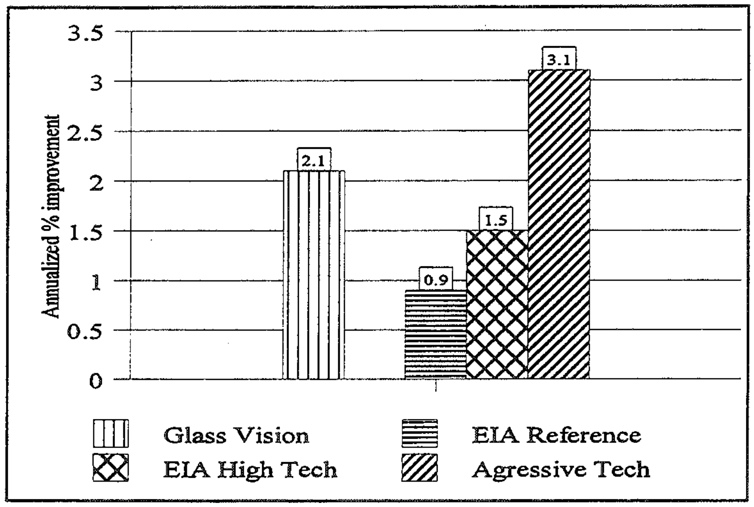

Figure 3. Glass Efficiency Forecasts - 1997 to 2020

MECS and Measuring Industry Progress in Meeting Its Goals

Future MECS will track the progress of energy efficiency improvements by U.S. industry. It will also allow some opportunity to examine the penetration of new technologies in OIT industries of the future. The 1998 MECS being fielded in 1999 will provide a baseline for a range of advanced technologies. New technologies will be added as they are successfully commercialized and begin to penetrate markets. For the mining industry the Census of Mineral Industries at the U.S. Census Bureau could be utilized.

Conclusions

DOE's Office of Industrial Technologies Industries of the Future program has dramatically changed the way government is working with industry. It has provided industry with an opportunity to develop a consensus vision of its 2020 future and has stimulated considerable effort to develop technology roadmaps to reach its vision. In particular, reaching these goals will require implementation of near term cost-effective opportunities identified through OIT's "integrated delivery" approach and will require considerable capital investment. In the context of U.S. industrial competitiveness and efforts to improve efficiency to meet environmental goals, the DOE program holds considerable promise to encourage greater industry cooperation. All of the participants, private and government, also recognize the need to cooperate in longer term, high risk R&D seeking new improved technologies for the future. The challenge is daunting as industry through its visions has set great challenges for itself and for the role of technology.

The rates of technology improvement implied in these visions and in the roadmaps will stretch both technological and financial resources if these goals are to be reached. In particular, reaching these goals will require considerable capital investment to speed capital stock turnover. These issues will require policy consideration and analysis to better understand what may be needed to reach these goals.

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