Industrial Energy Intensity Trends: 1992 to 1998

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ABSTRACT

An important element of industrial energy analysis and modeling is the assessment of energy intensity trends. Energy intensity is defined as the ratio of total energy consumption over output. Energy intensity trends reflect the direction in which overall efficiency of the use of energy is headed. Usually, output is in dollar terms.

There are several factors that can change energy intensity. The installation of more energy efficient processes will decrease an industry's overall energy intensity. A change in the mix of an industry's final product or a change in raw material can also increase or decrease energy intensity within an industry. On a sectoral basis, a decrease (or increase) in total energy intensity reflects the more (or less) efficient use of energy in the industries within the sector, as well as structural shifts that occur between the industries.

The 1990s afforded the United States extraordinary economic growth. From 1992 to 1998, the nation's gross domestic product (GDP) grew at an annual rate of 3.6 percent. Industrial production expanded more robustly, growing at an annual rate of 4.3 percent. However, total industrial energy consumption increased at a substantially lower rate, 1.3 percent per year. Thus, overall industrial energy intensity significantly declined, 2.9 percent per year.

This is quite different from the industrial energy demand, production, and energy intensity trends of the late 1980s to early 1990s. For example, from 1985 to 1992, U.S. GDP grew only at an annual rate of 2.7 percent, and industrial production expanded at half that rate, 1.3 percent per year. Total energy consumption by U.S. industries increased at a rate of 1.9 percent, thus overall industrial energy intensity increased slightly by 0.6 percent per year.

It has been suggested that the recent substantial decline in industrial energy intensity is due to the new "internet" economy. This study will contend that this "internet" phenomenon is not the main driver of this trend. To examine the drivers of this trend, an assessment of the structural shifts among 2-digit SIC group will be performed. Major process changes as well as changes in raw materials and product demands will also be investigated. The study will use a database that characterizes industrial energy consumption in the U.S. from 1985 to 1998 that was developed by Energy and Environmental Analysis, Inc. (EEA).

Preliminary results indicate that the biggest factor in the decline in overall industrial energy intensity is the significant and rapid structural shift that occurred from 1992 to 1998, from the energy-intensive component of the industry to the less energy-intensive component, not only across the 2-digit SIC groups, but also within 2-digit SIC groups. This shift was also complemented by some improvement in productivity, process changes, and fuel mix changes, in a few end-uses and industries. Nevertheless, when one examines the results by industry, the energy intensities of most industries, especially the energy-intensive ones, hardly

changed. In fact the energy intensities of a few industries actually increased. The analysis underscores the importance of detailed analysis of quantitative data in analyzing the industrial sector and suggests that the fundamentals of industrial sector energy use have not changed so much as might be expected.

Introduction

Energy intensity is defined as the ratio of total energy consumption over output. The analysis of energy intensity trends in the industrial sector is an important step in understanding energy efficiency movements due to installation of more efficient equipment, structural shift, and changes in fuel mix.

Industrial energy consumption can be defined to include primary energy, or purchased energy, or fuel and power energy. For this study, total energy consumption is defined as the sum of purchased electricity, fossil fuel consumption, and renewable energy. The industrial energy consumption data draw upon original work done by Energy and Environmental Analysis, Inc.. (EEA) for the Gas Technology Institute (formerly, Gas Research Institute). The database resolves some of the known industrial sector data deficiencies by developing an industrial energy technology database from 1992 to 1998, which contains detailed characterization of industrial energy use. The database was made consistent with data from the Energy Information Administration, specifically the State Energy Data System (SEDS). The database is designed to incorporate sufficient detail by industry group (by 2-digit SIC group with further disaggregation in some industries), by region (11 GRI regions), by energy source (28 fuel types including steam and machine drive), and by end-use and technology (over 500 types of processes and equipment). The level of detail follows that of the data structure used in the Industrial Sector Technology Use Model (ISTUM-2). A complete documentation of the database methodology is reported in the GRI topical report titled Methodology for Updating Base Year Data in the ISTUM-2 Model.

The more controversial part of the definition of energy intensity is industrial output. There are a variety of data choices for output data. When doing a study of a specific establishment or industry with homogenous output, the most appropriate would be physical production (e.g. ton of paper). However, physical production becomes problematic when analyzing trends across industry groups (e.g., 2-digit SIC) or even within industry groups. The dollar value of production becomes more appropriate when looking at groups at a higher level of aggregation (e.g., 2-digit SIC, entire sector).

There are two major types of dollar value of output data available – value of shipments and value added. These data are published by the U.S. Department of Commerce. Value of shipments includes the total receipts of all products shipped, both primary and secondary, as well as miscellaneous receipts (including sales of products bought and sold without further processing). Value added, which is related to the Gross Domestic Product concept, is value of shipments less intermediate goods and services rendered.

The Federal Reserve Board (FRB) also publishes industrial production index data. The data are useful because the indices are more representative of production changes (i.e.,

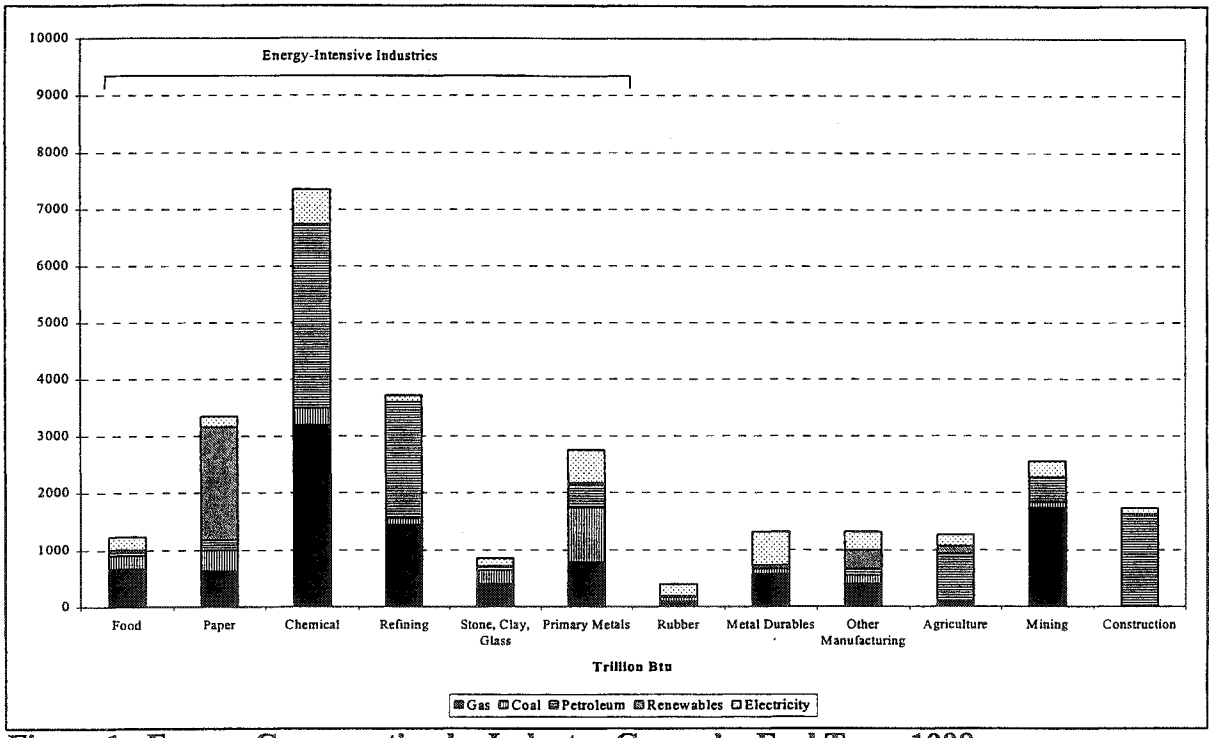

Figure 1. Energy Consumption by Industry Group by Fuel Type, 1998

data representative of production in physical units are used, when appropriate). However, it does not have data on the agriculture and construction industries. Furthermore, because it is an index measure, it cannot provide an energy intensity value for a particular year.

In this study, value added data are used. The value added data are useful in assessing the contribution of each industry group towards overall industrial production trends, which is an important part of the study.

Industrial Energy Demand Profile

The U.S. industrial sector includes agriculture, mining, construction, and manufacturing establishments defined within Standard Industrial Classification (SIC) codes 01 to 39. In 1998, the U.S. industrial sector consumed 27.8 quads of energy. Total value added amounted to 2.1 trillion dollars of 1996 chained dollars.

Figure 1 shows energy consumption by industry group and energy source in 1998. Energy intensity by industry group for the same year is presented in Figure 2. Within the industrial sector, there are six energy-intensive industries – food (SIC 20), paper (SIC 26), chemicals (SIC 28), petroleum refining (SIC 29), stone, clay, and glass (SIC 32), and primary metals (SIC 33). These are primarily the basic commodity industries, and thus consume a higher amount of energy and their production output is generally lower in value (in terms of dollar). In 1998, these industries accounted for 69 percent of total industrial energy consumption but only 22 percent of total value added in the United States. The energy intensity of the entire group reached 43 thousand Btu/dollar.

It is observed that the group of energy-intensive industries consumed 71 percent of natural gas, 52 percent of purchased electricity, 84 percent of coal, 66 percent of petroleum, and 82 percent of renewable energy, consumed in the industrial sector. The energy-intensive industries accounted for 79 percent of total industrial feedstock use, and 67 percent of total heat and power use.

The rest of the sector includes the rubber industry (SIC 30), metal durables (fabricated metals (SIC 34), industrial machinery (SIC 35), electronic and other electric equipment (SIC 36), transportation equipment (SIC 37), instruments (SIC 38)), other manufacturing (tobacco (SIC 21), textile (SIC 22), apparel (SIC 23), lumber (SIC 24), furniture (SIC 25), printing (SIC 27), leather (SIC 31), miscellaneous manufacturing (SIC 39)), and non-manufacturing industries (agriculture, mining, and construction).

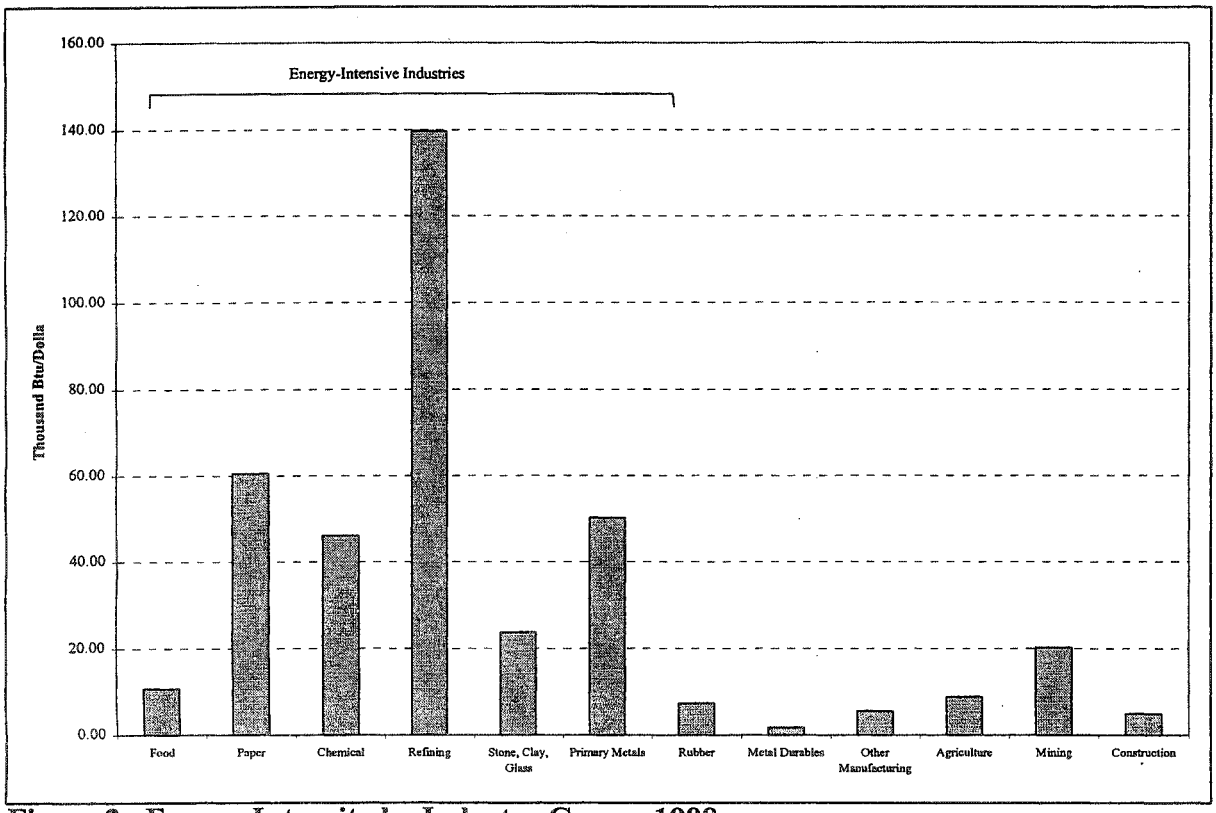

Figure 2. Energy Intensity by Industry Group, 1998

The metal durables and rubber industries are related to the computer and telecommunications equipment manufacturing industry. The metal durables include SIC 35 and SIC 36, which are involved in the manufacture of computer monitors, computer chips, and other related equipment. SIC 30 is involved in the manufacture of plastic products used in computer and telecommunications equipment cases and frames. In terms of industrial output, because of their involvement with the computer industry, these two industries were the fastest growing sub-sectors within the industrial sector from 1992 to 1998.

In 1998, the metal durables and rubber industries accounted for 37 percent of total value added of the industrial sector. However, their energy demand levels are much less,

accounting for only 6 percent of total industrial energy consumption. Thus, the metal durables and rubber industries combined, have a much lower energy intensity than the energy-intensive group, at 2.2 thousand Btu/dollar in 1998. Individually, the metal durables industry's energy intensity was 1.8 thousand Btu/dollar, while the rubber industry has 7.4 thousand Btu/dollar.

The non-manufacturing industries accounted for 20 percent of total industrial energy consumption in 1998. In addition, they also represent 30 percent of total value added in the industrial sector. Thus, their energy intensity during the same year was 9.0 thousand Btu/dollar. The other manufacturing industries consumed 5 percent of total industrial energy consumption, and accounted for 11 percent of total industrial sector value added. As a group, their energy intensity was 5.6 thousand Btu/dollar.

Production Trends

From 1992 to 1998, the U.S. Gross Domestic Product (GDP) grew at an annual rate of 3.6 percent. The industrial sector portion (summing agriculture, mining, construction, and manufacturing real 1996 chained dollars) of GDP grew at a faster rate, 4.3 percent per year, while non-industrial (the residual between total GDP and the industrial portion) grew by 3.3 percent per year.

Within the industrial sector, the industries with the fastest growth in value added from 1992 to 1998 were those related to the computer and telecommunications industry – SIC 35, SIC 36, and SIC 30. SIC 36 grew at 21 percent per year and SIC 35 grew at an annual rate of 13 percent. SIC 30 expanded annually at a rate of 6 percent. As shown in Figure 3, the metal durables and rubber industries accounted for 65 percent of the total growth in value added in the industrial sector. Overall, the metal durables and rubber industries combined, grew at an annual rate of 8.6 percent.

In sharp contrast, output of the energy intensive industries grew only by 2.2 percent per year. As a group, they only accounted for 11 percent of total industrial output growth. The petroleum refining and primary metals industries reported the fastest annual growth, 3.9 and 3.8 percent, respectively. The stone, clay, and glass and chemical industries grew at slightly slower rates, 3.3 and 3.1 percent, respectively. The food and paper industries hardly expanded, growing by 0.5 and 0.0 percent per year, respectively.

The other manufacturing group of industries actually declined, as its value added fell by almost 1 percent per year. The non-manufacturing industries expanded robustly, 3.6 percent per year, with mining and construction industries growing by 4.7 and 4.1 percent per year, respectively. The output of the agriculture industry increased only by 1.6 percent per year. The non-manufacturing industries accounted for 25 percent of total industrial production growth from 1992 to 1998.

In reviewing these figures, it is important to understand how Department of Commerce values the output of the computer industry. Hedonic pricing on semiconductors, computer hardware, and computer software was incorporated into the National Income and Product Account starting in 1986. The methodology was implemented to resolve measure-

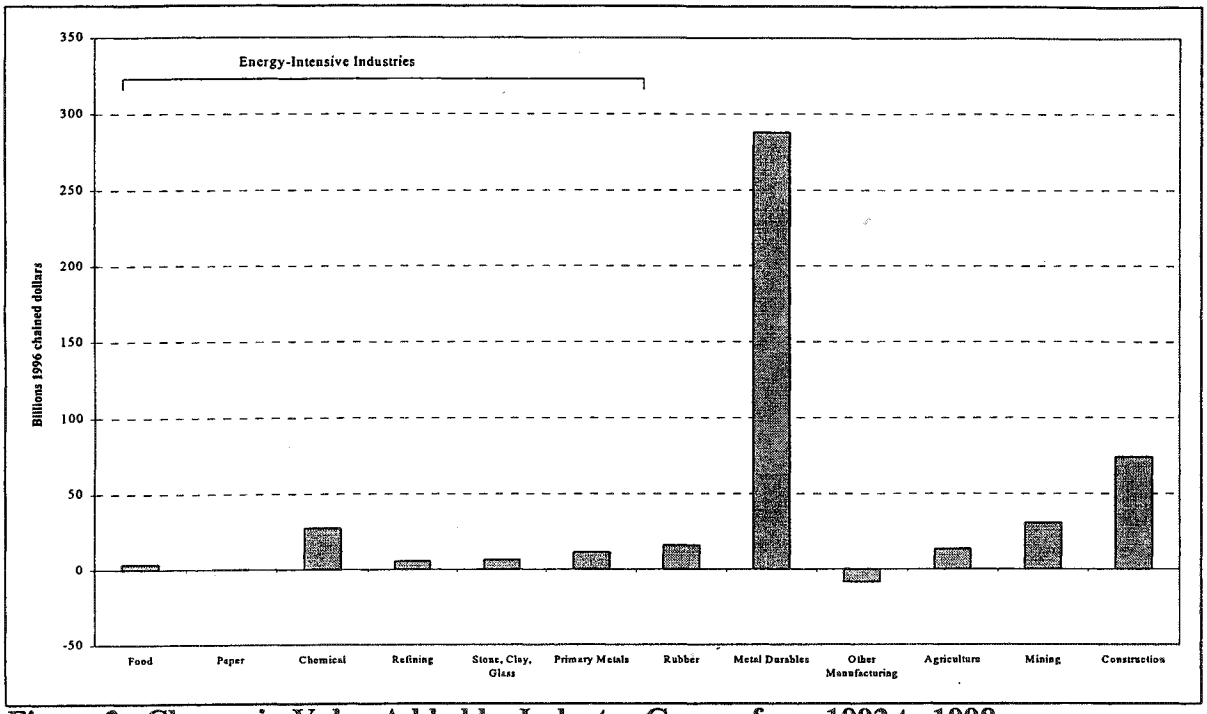

Figure 3. Change in Value Added by Industry Group, from 1992 to 1998

ment problems arising from the high tech goods rapidly changing level of quality and the falling production costs and prices, associated with these goods. The result of the use of hedonic pricing by the agency is the adjustment of the output value of the industry many times over the original output sales value.[1] As such, it is believed that the increase in the value of output of the computer industry is exaggerated, that is, that the growth rates of 21 and 13 percent for SIC 36 and SIC 35, respectively, are substantially more than the actual production growth.

Energy Consumption and Intensity Trends

From 1992 to 1998, despite the robust industrial output growth, energy consumption in the industrial sector increased at a much less slower rate, from 25.7 to 27.8 quads, or by 1.3 percent per year. Thus, overall industrial energy intensity declined substantially, from 16.0 to 13.4 thousand Btu/dollar, or by 2.9 percent per year.

To understand why energy consumption in the sector was relatively slow, it is important to assess the energy consumption trends by industry group. And because the energy-intensive industries are the main drivers of energy consumption in the sector, it is important that each energy-intensive industry be analyzed. Equally significant, is the analysis of energy demand of the fastest growing industries. Thus, the energy consumption trends of the metal durables and rubber industries are also analyzed.

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[1] Cassidy, John. November 27, 2000. "The Productivity Mirage," *The New Yorker*. New York.

Figure 4 presents the energy-intensity trends by industry group from 1992 to 1998. During this period, total energy consumption of the energy-intensive group of industries grew at an annual rate of 1.5 percent. Thus, for the entire group, energy intensity declined only slightly, 0.6 percent per year. More importantly, despite a slow growth in energy consumption (as they represent only 11 percent of total industrial production growth), the energy-intensive industries still accounted for over 75 percent of the total growth in energy consumption in the entire industrial sector. Thus, it is evident that the energy consumption growth in the sector is still reliant on the energy-intensive industries.

The fastest growth in energy consumption among the energy-intensive industries was in the food and paper industries, with 3.5 and 2.4 percent per year, respectively. These are significantly faster than their rates of production growth, as these same two industries actually reported the slowest growth in production among the energy-intensive industries. As such their energy intensities actually increased, 3.0 and 2.4 percent per year, respectively. Furthermore, these two industries combined, accounted for over 42 percent of the increase in energy consumption among the energy-intensive industries.

The increase in energy intensity in the food industry during this period, is attributed to the faster production growth of the energy-intensive sub-industries (including wet corn mill, beet sugar, soybean oil mill, and malt industries), relative to the less energy-intensive sub-industries. In fact, during the same period, the industry's steam intensity increased, as the energy-intensive sub-industries tend to require more steam. The paper industry also experienced similar circumstances, as the energy-intensive components of the industry (including paper mills, pulp mills, and paperboard mills) grew substantially faster than the less-intensive ones. Like the food industry, the energy-intensive sub-industries of the paper industry are steam intensive, and as such, steam intensity of the industry actually increased during this period.

The rest of the energy-intensive industries experienced much slower growth in energy consumption relative to the growth in their production. Thus, these industries also experienced declining energy-intensity. For example, while production in the chemical industry grew at an annual rate of 3.1 percent, its energy consumption increased only by 1.6 percent per year, thus its energy intensity declined 1.5 percent per year. Nevertheless, this industry still represented 40 percent of the total growth in energy consumption among the energy-intensive industries. The slow demand for energy in the chemical industry was brought about by the slow growth of the petrochemical and basic chemical sub-industries, which are the more energy-intensive component of the industry. The fastest expansion in production occurred in the less-energy intensive, higher dollar value segments, such as drugs, and soaps and detergent manufacture.

The primary metals industry enjoyed the fastest decline in energy intensity among the energy-intensive industries. Energy consumption from 1992 to 1998 in the industry grew only by 0.4 percent per year. With the fastest production growth, this industry, thus reported the fastest energy-intensity decline, by 3.3 percent per year. The continued shift from integrated steel mills to minimills is a major contributor to the continued increase in overall energy efficiency in the industry. The minimills have successfully penetrated the flat-rolled and higher-end product market segments of the industry, which has then increased their mar-

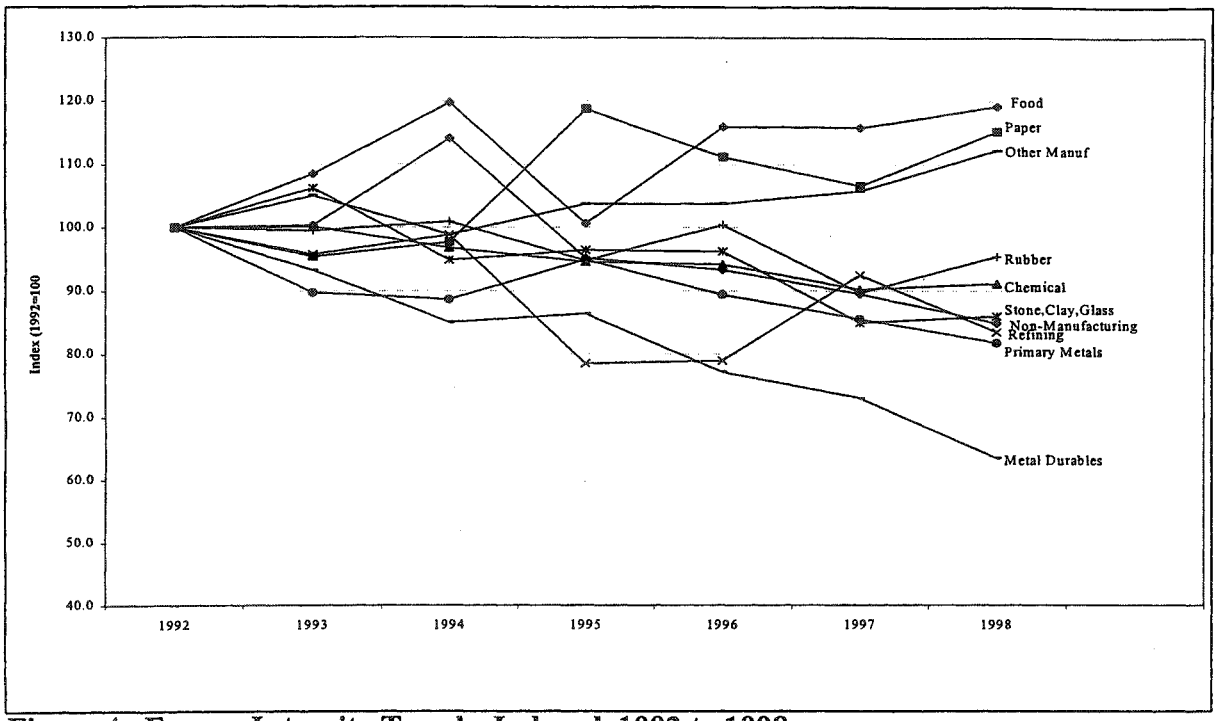

Figure 4. Energy Intensity Trends, Indexed, 1992 to 1998

ket share of total steel production. Also, the industry enjoyed the fastest growth in cogeneration, which increased 14 percent per year, from 1992 to 1998. The persistent slowdown of the primary nonferrous segment (which is more energy-intensive) combined with the growth of the secondary and semi-fabrication segments (which is less energy-intensive), also contribute to the decline in energy-intensity in the primary metals industry.

The refining industry experienced the second fastest decline in energy intensity among the energy-intensive industries. From 1992 to 1998, energy consumption for this industry grew at a slow pace, 0.9 percent per year. Thus, energy intensity for this industry declined by 3.0 percent per year. There is an issue that needs to be raised regarding the production value for the refining industry. While value added for the industry is reported to have grown by 3.9 percent annually, refinery output data from the Energy Information Administration (EIA) show that output in terms of barrels actually grew only by 1.7 percent per year. In fact, when we use the EIA output instead of the value added, energy intensity for the industry actually declined by only 0.8 percent per year. Steam intensity also declined in the industry, as capacity expansion was more heavily set in the downstream segment of refinery operations.

Energy consumption in the stone, clay and glass industry only increased by 0.7 percent per year. This is substantially slower than its production growth. Thus, energy intensity for this industry declined by an annual rate of 2.5 percent. There are three factors contributing to the decline in energy intensity. First, from 1992 to 1998, the less energy-intensive and higher value segment of the industry grew faster than the more energy-intensive segment (includes flat glass and cement manufacture). Second, the cement industry continues to switch from coal and natural gas to the cheaper waste fuels. This presents some data complication, since SEDS does not track consumption of waste fuels. As such, the

possible increase in waste fuel consumption is not incorporated in the data, rather only the decrease in coal and natural gas consumption. Third, the flat glass and cement industries continue to install more efficient equipment, including electric boosters and oxyfuel furnaces in the glass industry, and dry kilns, preheaters, and precalciners in the cement industry. This component actually does reflect energy efficiency.

Despite accounting for 65 percent of the growth in production of the entire industrial sector, the metal durables and rubber industries accounted for only 8 percent of the total increase in energy consumption over the entire sector. Energy consumption in the rubber industry grew significantly, 5.2 percent per year, while energy consumption in the metal durables industry grew only slightly, 0.9 percent per year. Thus, energy intensity in the rubber industry fell annually by 0.8 percent, while energy intensity in the metal durables industry declined substantially, by 7.3 percent per year.

The remarkable reduction of energy-intensity in the metal durables industry can be attributed to several factors. First, the growth in value added is probably substantially faster than physical production growth because of the "hedonic" pricing procedure that the U.S. Department of Commerce includes in the calculation of the values. Second, the computer industry, because it is a fairly new industry with new plants and equipment, has had the opportunity to install the latest and most energy-efficient equipment and processes.

Another related factor is the production capability of the computer and telecommunications industry towards the manufacture of smaller components with equal or more power. Computer chips, cellular telephones, and other equipment have been shrinking in size, but their quality and power have not diminished, in fact, they have increased. Therefore, it is possible that this industry could have produced substantially more units of product but with lesser use of raw materials, energy and other inputs.

The slight reduction of energy-intensity in the rubber industry was supported by the significant growth in energy consumption in the industry. The growth in energy consumption is connected to the modest production growth of the energy-intensive segments of the industry, tire manufacture and plastic product manufacture, combined with production growth in the less-energy intensive segment.

Internet Use in Industry[2]

According to a recent survey from the National Association of Manufacturers, although 80 percent have company websites, only 32 percent of manufacturers in the country are using electronic commerce in their businesses. Most of these businesses are using computer technologies to perform e-commerce transactions, coordinate product designs, communications, manage inventory, provide training, and provide customer services. Undoubtedly, these computer uses reduce overall costs, but nevertheless, they are not the energy-intensive tasks in most manufacturing plants. As such, it is not expected that computer use has significantly reduced energy consumption.

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[2] The discussion in this section is drawn from the report, Economics and Statistics Administration, U.S. Department of Commerce,. June 2000. *Digital Economy 2000.* Washington, DC.

It has been noted that the evidence of information technology contributing to large productivity gains in industry is mixed. Industries producing information and computer technologies are those experiencing substantial gains in productivity. According to the Bureau of Labor Statistics, SIC 35 and SIC 36 enjoyed the fastest growth in multifactor productivity from 1990 to 1996. Industries outside SIC 35 and SIC 36 however, have not reflected the same results. There has been relatively less growth in the use of computers and information technology in process industries. There is also evidence of reduced productivity in industries that have invested on these technologies. Furthermore, it has been observed that for these new technologies to substantially impact productivity, it has to be combined with other business investments, such as new strategies, new business procedures, and new organizational structure.

In conclusion, although the emergence and use of new computer and information technologies have been remarkably strong over the last decade, it is overly optimistic to imply that it has substantially contributed to overall energy efficiency improvement in the U.S. industrial sector.

Summary and Conclusions

It has been claimed by some that the internet and the related new economy phenomenon has been the major contributor to declines in overall energy intensity in the industrial sector. The authors contend that this is not the case. It is true that the computer and telecommunications industry is a major consideration in the decline in energy intensity, but not as a result of the increased productivity from the use of their equipment.

As presented above, the role of the energy-intensive industries is still a major consideration when assessing energy demand trends in the industrial sector. Despite their slow to moderate growth in production, these industries still account for a majority of the growth in energy consumption. On the other hand, the role of the less-intensive industries, specifically the metal durables and rubber industries, is a major factor when assessing industrial production trends in the industrial sector. From 1992 to 1998, these industries accounted for 65 percent of total growth in value added for the entire sector. Nevertheless, they only accounted for a small portion (8 percent) of total increase in energy demand.

Given the importance of the energy-intensive industries over industrial energy consumption, it is essential to consider their energy-intensity trends. As was shown above, the energy-intensity trends of these industries, varied from one industry to another. For example, the food and paper industries, which reported a slow production growth, reported significant increase in energy consumption, and thus their energy-intensities increased. Their energy consumption growths were driven by the growths of their energy-intensive sub-industries. The rest of the energy-intensive industries experienced declines in energy-intensity, driven by structural shifts within the SIC group (with the less energy-intensive sub-industries growing faster in terms of production) and continued process changes.

The primary factor that drove the decline in overall energy intensity in the sector was the decline in energy intensity of the industries related to the computer and telecommunications industry – metal durables and rubber industries. These industries are substantially less energy-intensive, but have higher dollar value of output. The enormous

production growth of the industries, as reported by the Department of Commerce, was not paralleled by energy consumption growth in the same industries. As mentioned above, there are several factors that caused the divergence between production and energy consumption in these industries. These factors include the faster growth in value added versus physical production due to "hedonic" pricing, the shrinking in size of computer and telecommunications equipment, and the modernity of the computer industry.

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