State-Level Analysis of Industrial Energy Use

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ABSTRACT

Most analyses of industrial energy use have been conducted at the national level, in part because of the difficulties in dealing with state-level data. Unfortunately, this provides a distorted view of the industrial sector for state and regional policymakers.

ACEEE has completed analyses of the industrial electricity use in eight states, drawing upon data from a diverse set of sources to characterize the industries at a relatively high level of disaggregation. These analyses demonstrate how different state and regional mixes are from the national mix and the importance of a regionally specific approach to industrial energy policy. In addition, the data suggest that significant shifts are occurring in the industry mix in some of these states that will have important ramifications on future industrial policies for these states. This paper will provide an overview of our analytical approach, the data sources that are available, and examples of the analysis results to demonstrate the regional diversity of industrial electricity use.

Background

Industrial electricity use comprises 16 percent of all the electricity use in the United States (EIA 2001a). Past studies have shown that the industrial sector offers a large opportunity for energy savings in the United States (Alliance to Save Energy et al. 1997; Interlaboratory Working Group 2000; Laitner et al. 1995). Motors are the largest end-use for electricity, comprising approximately 70 percent of the total manufacturing electricity use nationwide (Nadel et al. 2002). There is a high potential for increasing the efficiency of motors, and therefore a large potential for electricity savings in the industrial sector.

In non-industrial sectors, reasonable estimates of state-level electricity use and savings potential can be extrapolated from national-level data based on some variables that reflect electricity use well. This results from the fairly consistent national mix in the buildings sector with the largest variation resulting from local weather variation.

In the industrial sector, however, variables that can estimate electricity use in other sectors do not reflect the actual electricity use accurately. This is the result of the large diversity in energy use within industries and the regional variations in industry mix, with many entire energy-intensive industries concentrated within just a few states or a single region. Furthermore, the industrial sector includes highly energy-intensive types of manufacturing, such as aluminum manufacturing, but also non-electric-intensive subsectors such as agriculture.

The industrial sector is disaggregated into four main subsectors: agriculture, mining, manufacturing, and construction (NAICS 11, 21, ??, and ??, respectively). Within each subsector, significant variation exists. Moreover, within an industry group such as chemical manufacturing, significant variation exists among the individual industries, and even among

individual plants. Each of these individual industries, such as the inorganic and organic chemicals industries, has different energy and economic growth characteristics, with these industry characteristics also varying by state. The state variations are due to many factors including current labor and energy costs, as well as proximity to raw materials and markets. For example, industries have been growing rapidly along the U.S.-Mexico border due to the North American Free Trade Agreement (NAFTA).

Using these pieces of information, the authors developed a methodology that estimates disaggregated, state-level industrial electricity use from publicly and commercially available data sources. The resulting characterization provides a more accurate portrayal of state industrial electric use that can be used to identify energy efficiency opportunities and plan industrial, energy efficiency programs. Although this paper focuses on characterization of industrial electricity use, the same general methodology can be applied to other fuels. ACEEE has characterized eight states based on this methodology. Five states (Arizona, Colorado, New Mexico, New York, and Oregon) are featured here as examples of the rich diversity within regions and states as well as the importance of flexibility in the methodological approach given differing data sources.

Methodology

While aggregate data on state industrial energy consumption is available from several sources (EIA 2001c), disaggregated industrial energy-use data is not readily available. The only data available is at the national or census regional[1] level (EIA 2001a). As a result, ACEEE developed methodology based upon state-level economic activity data and national energy intensity (i.e., kilowatt-hours [kWh] per unit of economic activity) to apportion the reported aggregate industrial electricity consumption to the different industries in the state.

To undertake any projection of future electricity use or savings potential, a base-year estimate of disaggregated energy consumption must be created for the state. ACEEE based its characterization on 1997 state data (Department of Commerce 1997), the latest year in which data for the entire industrial sector is available. The *1997 Economic Censu*s (Department of Commerce 2000b) and *1997 Census of Agriculture* (Department of Agriculture 1999) use a consistent sample frame insuring that the sector is accurately characterized. The *Economic Census* reports value of shipments and electricity use information for manufacturing, mining, and construction subsectors. The *Agricultural Census* offers farm and ranch-specific information including market value of crops and electricity use. For subsectors where electricity consumption is reported in dollars, average state electricity price for the sectors are used to convert the dollar values into electricity units.

Because of the magnitude and diversity in the manufacturing subsector, it is important to disaggregate the data beyond the subsector level. Unfortunately, disaggregated electricity consumption data is not reported for subsectors. As a result, national industry electricity intensities[2] are used to estimate energy data from the economic data. These

[1] The U.S. Bureau of the Census divides the country into census regions, with industrial sector being reported in the four major divisions: Northeast, Midwest, South, and West.

[2] As derived from industry group electricity consumption data reported in the *1998 Manufacturing Energy Consumption Survey* (MECS) (EIA 2001b) and value of shipments data reported in the *1998 Annual Survey of Manufacturing* (ASM) (Department of Commerce 2000b).

intensities are assumed to be relatively constant for this two-year period and across the various regions. These intensities are to the value of shipments data for the manufacturing energy groups (three-digit NAICS) in each state. At the sub-industry level, national intensities were applied when available, to estimate electricity consumption. In cases where this data was not available, manufacturing group electricity consumption estimates were apportioned to the sub-industry based on share of group value of shipments.

Less effort was applied to disaggregate other subsectors with less diversity (e.g., mining) or significantly smaller share of electricity consumption (e.g., construction and agriculture). Value of shipments (mining), sales (agriculture), or value of construction work (construction) were used to characterize these subsectors, but no attempt was made to estimate disaggregated electricity consumption further.

These electricity consumption estimates are then used to characterize the share of the industrial sector electricity consumption for each subsector and group. To maintain a constant total electricity consumption basis with the other sector analysis, we used estimates of share of electricity consumption to apportion the electricity consumption estimates reported in the *1999 State Energy Data Report* (SEDR) (EIA 2001c).

We then used other state and utility data sources to check our estimates. It can be difficult to incorporate these data into the baseline determination because of variations in how industrial facilities are characterized in the different data sources, sample periods that do not correspond to national data, and other data issues. However, these data can serve as valuable qualitative checks on the estimates developed using the described methodology. If allocations to key subsectors or major industry groups are significantly different from state-based data, corrections to allocations may be required.

To provide a estimate of current and projected electricity use, the base-year industrial characterization was then grown using disaggregated state gross domestic product (GDP) data purchased from *Economy.com* (2002). These data and projections were combined with national electricity-intensity change projections developed by EIA (Honeycutt 2002) to determine a disaggregated, state electricity use estimate for current and future years.

Analysis Results

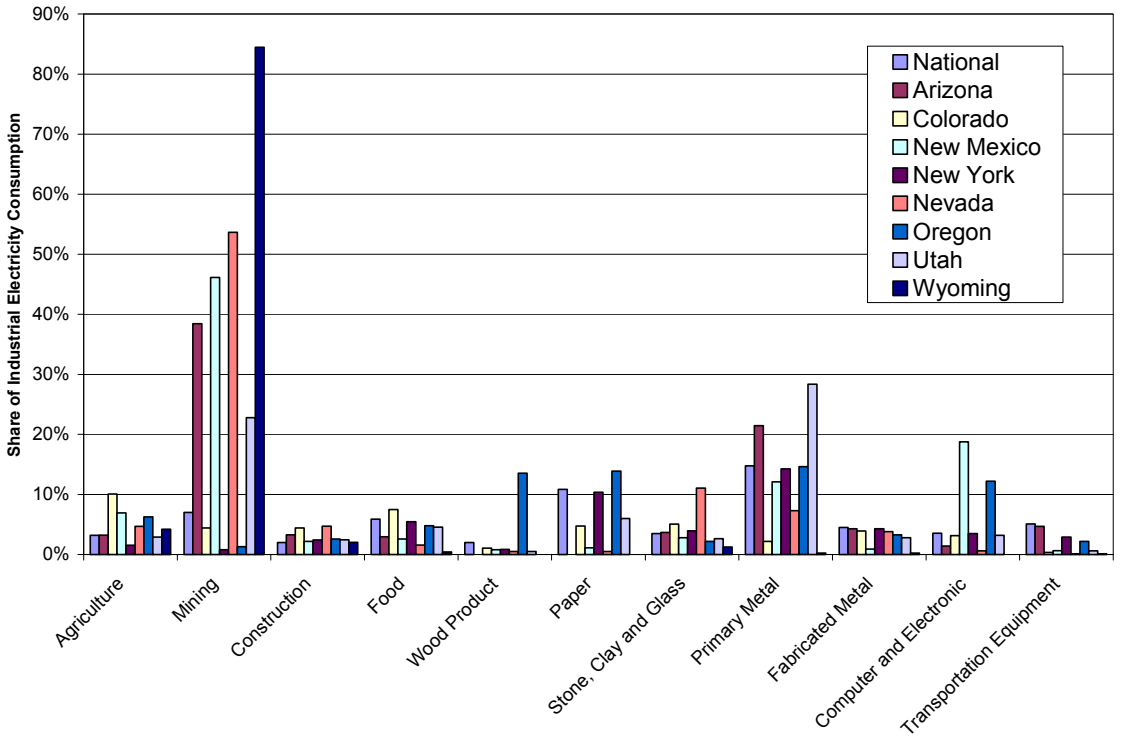
The analysis methodology has been applied to eight states so far. Six of the states were part of a regional study (SWEEP 2002) of the Southwest. Three of the states (Arizona, Colorado, and New Mexico) are closely related to one another economically, and therefore are often compared to one another. Other states analyzed in the region (Utah, Wyoming, and Nevada),[3] along with New York and Oregon, provide an interesting comparison to national averages reflecting the different balance of industrial electricity use across the states. The analysis results for the six Southwestern states also provide insights into the variations that exist at the regional levels.

[3] Taken together, these six states make up the region focused on by the Southwest Energy Efficiency Partnership. More information on this partnership can be found: http://www.swenergy.org.

Estimation of Base-Year Industrial Electricity Use

Figure 1 (overlay of states and national) compares the states analyzed by electricity use in 1997. It is clear that for these states, the national average for manufacturing does not reflect the state actual use numbers as estimated by this methodology. Similarly, the share of electricity consumed by mining and agriculture varied among the states considerably with the share being similar to the national average only by happenstance. Construction varied with the level of development activity in the state, with the construction subsector in rapidly growing states such Colorado and Nevada running at roughly twice the national average. Following is a discussion of the results of the industrial analysis for each state.

Figure 1. Share of Total Industrial Electricity Consumption by Industry Group for Eight Selected States and the U.S.



Arizona. The total, state industrial energy use in Arizona was 13,206 million kWh. Manufacturing comprised 55 percent of the industrial load in Arizona, followed by mining at 38.5 percent. The agricultural sector used significantly less electricity in the state, despite Arizona's relatively large agricultural electricity use in the overall region.

The majority of the manufacturing load was from primary metal manufacturing, which comprised 21 percent of the total, state industrial electricity demand. Primary metal manufacturing (NAICS 324) was the next largest user of electricity (21.5 percent) and was also primarily driven by one subcategory, nonferrous metal (except aluminum) production & processing (NAICS 3314). This subcategory demanded 17 percent of the total electricity use in the state and 4.65 percent of the total industrial state load. Chemical manufacturing and transportation products manufacturing were also large contributors to the state's industrial electricity demand at 7.8 and 4.7 percent, respectively.

Arizona ranked first among the Southwest states regarding overall mining electricity consumption with 5,079 kWh. This was 25 percent of the regional mining consumption, and 10 percent of the total industrial electricity consumption. Copper mining was the largest electricity draw for mining in the state (Department of the Interior 1999), comprising 95.9 percent of the mining total and 36.8 percent of the total industrial energy use in the state. Other types of mining in the state included sand and gravel, silver, and stone.

The agricultural sector in Arizona comprised 3.2 percent of the industrial electricity use in the state and 0.8 percent in the region. Regionally, Arizona ranked second in agricultural electricity use with 15.7 percent of the total consumption for the region. There were 6,000 farms in Arizona, using 426 billion kWh of electricity.

Colorado. The state industrial energy use total in Colorado was 10,786 million kWh. Like Arizona, Colorado's primary industrial electricity demand was manufacturing, comprising 67 percent of the electric demand. Mining was the next largest demand at 19.7 percent. Agriculture also contributed significantly to electricity use in the industrial sector in Colorado at 10.1 percent.

Chemical manufacturing (NAICS 325) ranked second in industrial electricity use with 12.4 percent. About one-fifth of the chemical manufacturing electricity (2.8 percent of total) was used by pharmaceutical and medicine manufacturing (NAICS 3254). The next largest block of industrial electricity use was primary metal manufacturing (NAICS 331) at 11.5 percent. The bulk of this use was by electrometallurgical ferroalloy product manufacturing (NAICS 331112) with 91 percent of the three-digit NAICS category and 10.3 percent of the total industrial energy use for the state. This is an intense electricity use subsector, however, and provided only 69 percent of the total value of shipments.

Colorado consumed the least amount of mining electricity of the Southwestern states at 2,130 kWh. This made up 11 percent of the regional mining demand. Despite this, mining in Colorado consumed 4 percent of the total industrial load for the region. Colorado boasts a fairly diverse mining industry. Combined gemstone and cement mining had the largest economic impact on the state from the mining sector. Sand and gravel, and stones followed them.

The agricultural sector in Colorado used 10.1 percent of the industrial electricity use in the state and 2.18 percent in the region. Colorado's agricultural electricity consumption was the highest of all the Southwestern states (42 percent). This corresponded with Colorado having the largest total number of farms in the region (28,268) and—not surprisingly—the largest electrical expenditures on agriculture of the region (40 percent). Fifty percent of all agricultural land in Colorado was irrigated, and irrigated land in Colorado used four percent more electricity than non-irrigated land.

New Mexico. The total industrial energy demand for New Mexico was 5,809 million kWh in 1997. Mining used 46.3 percent of the total industrial electricity use in New Mexico. Manufacturing came in a close second with 44.6 percent of the electricity demand. New Mexico had the highest growth rate in the industrial sector in the region. Initiatives such as the DOE Southwest Border Energy and Technology Collaboration Program[4] and increased border trade accounted for the strong growth rate in manufacturing.

[4] Information of the DOE Southwest Border Energy and Technology Collaboration Program can be found at http://energy.gov/HQPress/releases00/seppr/pr00241.htm.

Nearly half of New Mexico's industrial electricity consumption was due to mining (46.3 percent). New Mexico ranked fourth among the Southwestern states for electricity consumed in mining at 2,687 kWh. This translates to 13 percent of the regional mining demand and 5 percent of the total, regional industrial electricity use.

Computer and electronic manufacturing (NAICS 334) comprised 18.8 percent of use. This load may be largely based on a single electricity-intensive chip manufacturing campus. Primary metal manufacturing (NAICS 331), using 12.1 percent, was the other large manufacturing demand.

The agricultural sector in New Mexico used 7 percent of the industrial electricity use in the state and 0.76 percent in the region. New Mexico was home to 18.9 percent of the region's total farms (14,094) and consumed 14.9 percent of the agricultural electricity in the region. Nearly half of the 46 million acres of farmland in New Mexico was irrigated, and irrigated farms in New Mexico consumed 7.5 percent more electricity than their non-irrigated counterparts.

New York. In 1997, the state of New York industrial sector consumed 40,000 million kWh of electricity. Manufacturing comprised 94.5 percent of the industrial load in the state. Mining comprised much of the remainder at 4.5 percent, and agriculture comprised 1 percent.

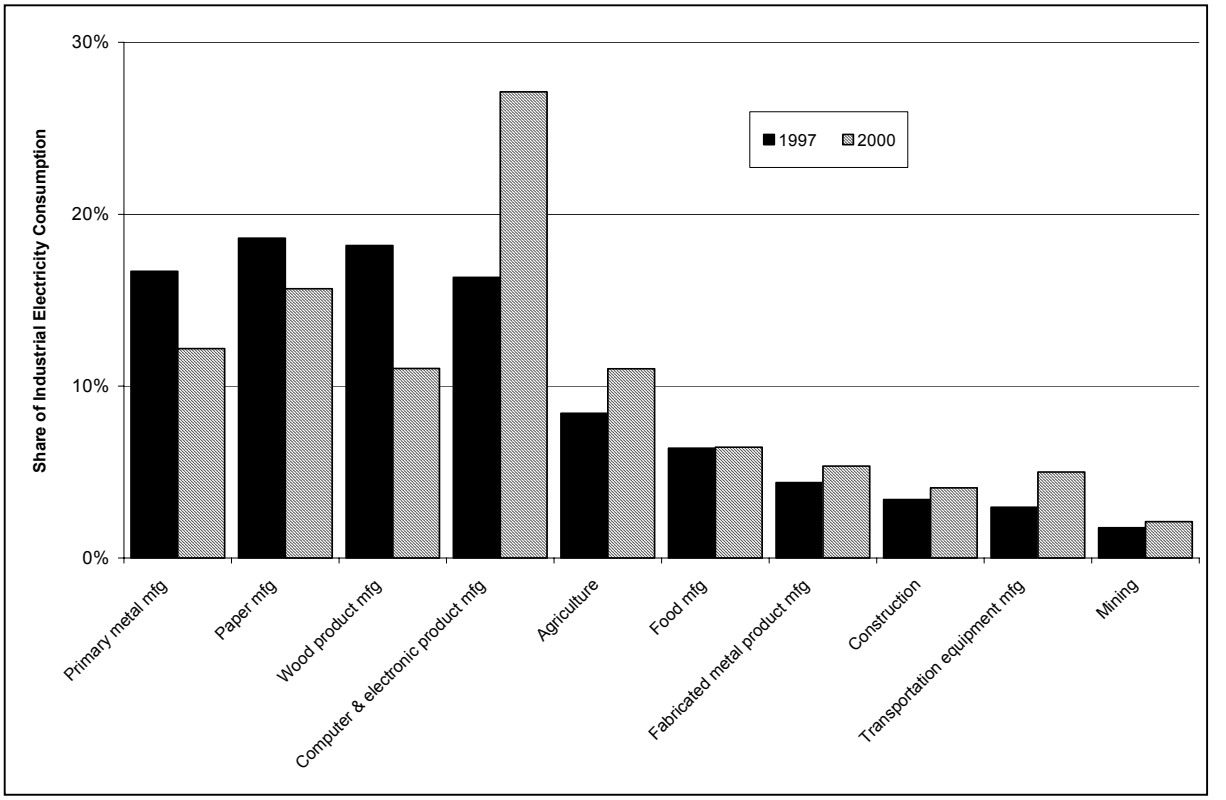
Within the manufacturing sector, chemical manufacturing (NAICS 325) dominated at 25 percent of the manufacturing electricity use. Primary metals manufacturing (NAICS 331) used 15 percent of the manufacturing load, mostly dominated by the subcategory alumina and aluminum production and processing (NAICS 3313) at 13.8 percent. Paper manufacturing (NAICS 322) also used a significant amount of electricity at 11 percent of the state's manufacturing total.

Oregon. In 1997, manufacturing dominated industrial electricity use, with the agricultural sector contributing about 8 percent and a modest 2 percent being contributed by mining. The state has seen dramatic changes in its structure over the past few years.

The largest electricity-using industry group in 1997 was primary metal manufacturing, dominated overwhelmingly by primary aluminum. Paper, wood products, computer equipment manufacturing, and agriculture completed the top five electricity users in the service territory. Together these industries used approximately three-fourths of the industrial electricity use.

By 2000, however, a series of factors had caused a shift in the two largest industrial electricity users in Oregon. Figure 2 outlines the highest energy consumers within the industrial sector in 1997 and 2000, reflecting these shifts. These factors included repercussions of the California energy crisis, which coupled with overcapacity in the aluminum market led to the virtual elimination of that industry in Oregon. It appears unlikely that this industry will return due to changes in the global aluminum market. Similarly, increases in electricity prices combined with declining old-growth timber inventories led to a decline in the wood products and primary paper industries. The outlook for these industries is equally uncertain. During the same period, a large growth occurred in the computer industry within the territory. The growth in the electronics industry continued a trend that had been occurring for over two decades, and while market downturns in the past two years have caused a reduction in electricity use by this sector, many experts anticipate that this sector will recover in Oregon along with the hi-tech industry at large.

Figure 2. Changes in Industrial Electricity Use in Oregon, 1997–2000



The agriculture sector also experienced significant growth. According to interviews in the state, this reflects a shift in the sector toward greater on-farm processing. It has always been difficult to differentiate food processing and farming, and this trend in Oregon may indicate that these two sectors should be treated somewhat together since many of the major processes, such as refrigeration and cold storage, are common between both sectors.

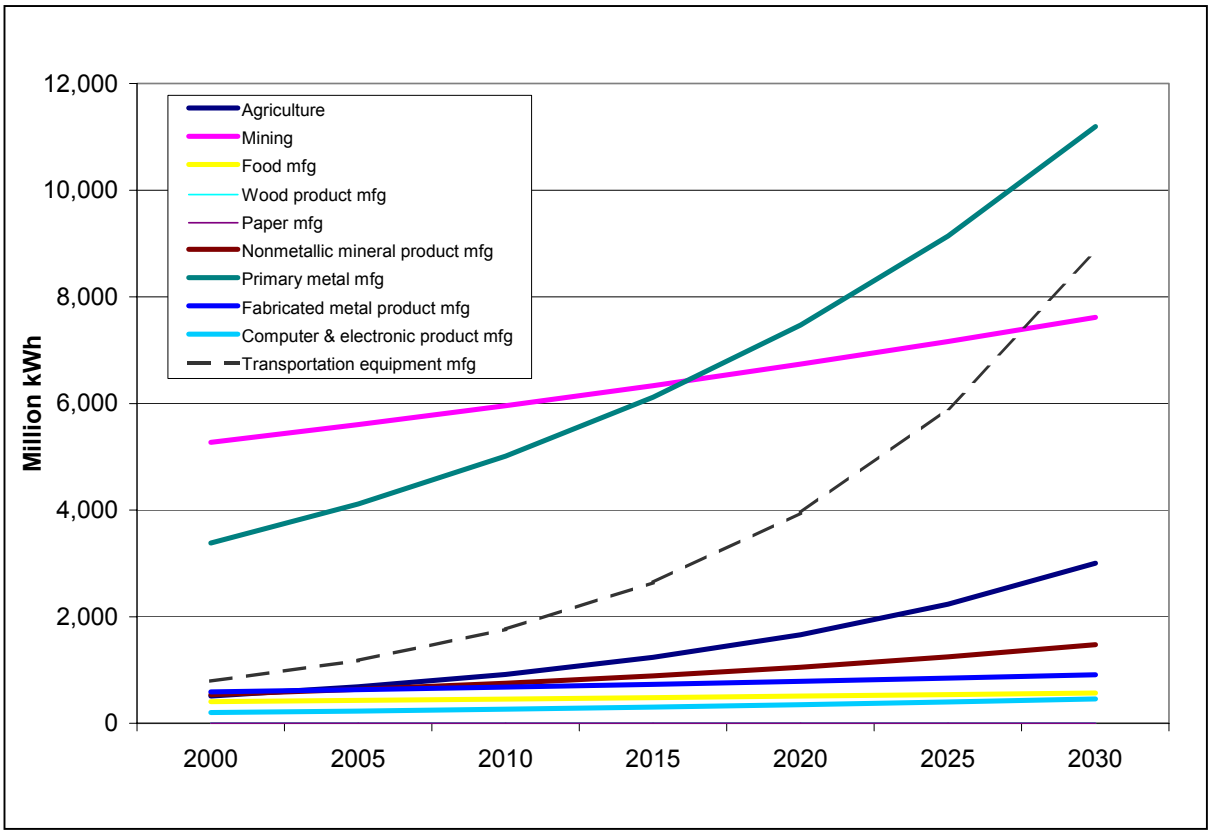
In 2000, the single largest consumer of industrial electricity was computer and electronic product manufacturing, which includes computers and peripherals, as well as semiconductor manufacturing. This industry group represents over one-fourth of the electricity used in the service territory. Paper and wood product manufacturing maintained their positions as second and third largest electricity users. Primary metal manufacturing had the largest shift, losing 8 percentage points and falling to the fifth-ranked position.

State Trends in Industrial Electricity Use

For the design of industrial programs, as important as analyzing past use is understanding how the mix of industrial electricity consumption will change in the future. As demonstrated by the recent changes in Oregon, targeting programs based on past consumption can entail risks (see Figure 2). Applying the GDP forecasts to extrapolate state electricity use in the future, we can see that Oregon is not the only state that will experience a shift in electricity use in the industrial sector. For example, a dramatic shift in Arizona (see

Figure 3) from mining to primary metal and transportation equipment manufacturing is projected.

Figure 3. Projected Industrial Electricity Use Trends in Arizona by Industry Group



These forecast results demonstrate the shifts that are occurring in the industrial sector within states that are not generally seen through extrapolation of national data. The results also show that the energy mix in some states in our research (for example, Oregon) is changing due to the economic climate and changes in industry. The methodology outlined in this paper is useful for identifying trends in industrial electricity use in each state, and thus designing energy programs that are tailored specifically to state's needs. This information is particularly important for the manufacturing subsector because studies (Interlaboratory Working Group 2000; Shipley et al. 2002) have demonstrated that significant energy efficiency opportunity exists in industries that are making capital investments in new facilities or refitting existing facilities.

Need for Further Research

This paper has discussed an application of this methodology to electricity use at the state level. The methodology should also be applicable to other fuels as well. However, the application to non-electric energy sources (e.g., natural gas, oil, and coal) poses some challenges not encountered with electricity. These challenges include:

- The ability of many industrial facilities to switch between fuels (e.g., substitution of gas for oil) based on availability and price;
- State and regional fuel availability issues;
- Significant use of waste fuels by some industries;
- Lack of state-specific, disaggregated fuel use data disaggregated by fuel as well,;
- More significant variation in fuel use within an industry than exists with electricity due to local variations in price, resulting in more limited ability to use national intensity data; and
- Significant use of fuels for electricity generation in some industries (e.g., cogeneration or combined heat and power [CHP]).

The application of this methodology to non-electric industrial energy use will need to be tested to determine its workability. The value of the results may prove valuable to policy makers and program designers. Dealing only with aggregate non-electric energy use can reduce the challenges in the non-electric fuels analysis, though this will likely reduce the utility of the results.

Discussion and Conclusions

The analysis of these eight states has demonstrated that reasonable estimates of the disaggregated electricity consumption can be developed using the methodology presented in this paper. As is demonstrated, significant variation exists among states so that using national industrial electricity use data for developing state policies and programs cannot be justified. This analysis should prove valuable to policy makers in that it both identifies the current relative magnitude of different industries' electricity use and projects important trends of the future. While significant uncertainty remains in the estimates, knowledge about general trends should be what is most important for most policy purposes.

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