3. Factors Affecting Energy Intensity

A large body of literature addresses the measurement of energy efficiency and energy intensity. In this chapter, we discuss various factors related to measuring changes in energy intensity.

As we mentioned earlier, energy analysts typically use energy use per dollar of gross domestic product (GDP) as a measure of energy intensity. In many cases, analysts and policymakers disaggregate energy use to examine energy intensity for each of the four major energy-consuming sectors—residential, commercial, industrial, and transportation. These earlier studies have used various measures of energy intensity including indicators of demand, such as energy use per capita for residential buildings, transportation energy use per vehicle mile traveled, and commercial energy use per square foot of office space, among other measures. Sometimes, the choice of energy intensity measure depends on the questions being addressed; other times, it depends on the available data.

In this report, we examine changes in energy intensity in each state as a whole as well as changes in energy intensity in the states’ residential, commercial, industrial, and transportation sectors over the 1977–1999 study period.

Factors That May Explain Differences Across the States

In attempting to better understand the variation in energy intensity changes among states, we identified a number of factors that may explain why some of the 48 contiguous states had different patterns of energy intensity than others. Those factors include:

- Energy prices
- Composition of an economic sector’s output (e.g., the mix or type of industrial or commercial activities)
- Capacity utilization

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1See, for example, Schipper (1997); Schipper and Murtishaw (2001); Kydes (1999); EIA (1995); and Dowlatabadi and Oravetz (unpublished).

2In this report, we use source energy as the unit of measure of energy consumption. Source energy is the amount of energy used in producing energy (e.g., electricity) and transporting it to the end-use destination (e.g., a consumer’s home). By comparison, site energy is the amount of energy used at the end site (e.g., electricity used to run home appliances).
Price has been a major influence on energy use, and therefore energy intensity, and the price of energy can differ significantly from state to state. In particular, electricity prices differ considerably due to the energy requirements of fixed capital (e.g., commercial buildings), the types of technologies in use, fuel availability, the ability to move electricity across large areas (prior to recent innovations in electricity markets), and regulatory requirements.

In 1999, the highest average electricity price among the states was three times greater than the average lowest price. Fuels vary in price primarily due to transportation costs and constraints. Over the entire period of our analysis (1977–1999), the price of energy fluctuated; however, over the subperiod 1988–1999, prices did not vary much from year to year, and the real cost of many energy sources actually declined over this period.

The composition of an economic sector’s output is an important determinant of energy intensity. Economic output factors include, for example, the mix or type of industrial or commercial activities. These activities, in turn, drive the demand for energy. For example, states with heavy manufacturing as a large percentage of their industrial sector would have a different energy intensity trend than states in which the amount of heavy manufacturing is shrinking. The structure of a state’s economy and the differences among states in the composition of their economic output are key to understanding shifts in energy intensity. We discuss those differences later in this report.

Production capacity can also affect energy intensity. Manufacturing facilities running at 50 percent capacity may have higher energy intensities than facilities running at 100 percent capacity because fewer gross dollars are earned for each dollar of energy used to keep those facilities operating. Some fixed energy costs occur regardless of how much use a facility gets, and these costs decline with use as a proportion of total energy costs (although for older facilities, energy intensity may increase as utilization of the facility approaches 100 percent).

Capital investment and new construction can also impact energy intensity. States with more-rapid growth in new capital investments or new construction may experience declining energy intensity because new building structures and
facilities tend to be more energy efficient than older buildings in the existing infrastructure. It may not always be the case that states with a larger amount of new construction will experience declining energy intensity, but as the average age of commercial buildings declines (i.e., as new buildings become a larger percentage of total building space), commercial energy intensity should also decline.

Population growth and other demographic factors, such as the level of employment, employment growth, and growth in income, influence energy use and therefore have an impact on energy intensity. As a population becomes wealthier, energy use and energy intensity may rise due to the increased use of energy-consuming equipment (such as computers and household appliances), construction of larger homes, and the purchase of new vehicles, among other factors that change as incomes grow. Because the population and income growth rates vary among the states, these factors are important in determining the differences in energy intensity among the states. For example, the highest state GSP per capita is more than twice that of the lowest state GSP per capita.

Climate also influences energy use and explains some of the energy intensity variation among the states, in particular for the residential and commercial sectors. For instance, northern states have higher heating loads, and southern states have greater cooling loads. Different regions within a state may also experience different annual fluctuations in temperature, and so the effect of climate on energy intensity may vary across regions in a state as well as across states and may vary from season to season.

Technological change can also influence energy intensity. New technologies can make energy use more efficient, but new energy-consuming devices can also increase energy intensity for some end uses. For example, super-efficient refrigerators can significantly reduce household energy use per capita, but increased penetration of air-conditioning into households and the increasing size of homes over the past ten years could increase energy intensity. In most cases, we would assume that technological change would affect all states equally, although state energy policy measures could result in different effects among the states.

Finally, government energy policies and actions can influence the choice of energy-consuming technologies and subsequently affect energy intensity. For example, building codes instituted at the national, state, or local levels can influence how energy is used in new buildings and can therefore impact energy intensity in the residential and commercial sectors. The scope and number of building codes in the states vary widely. State-funded DSM programs, as another
example, can promote efficient energy use and encourage the purchase of more energy-efficient appliances.

Factors That May Explain Differences Across the Energy-Consuming Sectors

Energy intensity in the energy-consuming sectors changes over time for various reasons.

**Industrial Sector**

In the industrial sector, energy use may differ from state to state, or over time, due to factors that include:

- Changes in the industrial mix
- The value of the end product
- Capital turnover
- Improved energy efficiency
- Climate differences.

For example, Pennsylvania’s industrial mix has changed over time. The energy-intensive steel industry now constitutes a smaller percentage of the state’s industrial sector than it has in the past, which in turn impacts the state’s industrial energy intensity.

**Commercial Sector**

Factors that may influence energy use in the commercial sector include:

- The amount of square footage of floor space in commercial buildings
- Employment in the commercial sector
- New construction
- Energy-related building codes
- Improved energy efficiency in commercial buildings
- Climate differences.

For example, Nevada has experienced rapid growth in commercial office space over the past decade. Given that newer buildings tend to be more energy-
efficient than older ones, one would expect the overall energy intensity in Nevada’s commercial sector to be lower now than it was a decade ago.\textsuperscript{3}

\textit{Residential Sector}

In the residential energy-consuming sector, factors that may affect energy use include:

- The number and size of homes
- The number of people in households
- The amount of new construction
- Building codes
- The introduction of new energy-using devices
- Climate differences.

For example, some northern states, in which homes were traditionally built without air-conditioning, have seen a rise in central air-conditioning in new and existing homes, thereby increasing the energy intensity in those states’ residential sector.

\textit{Transportation Sector}

In the transportation sector, factors that may influence a state’s energy use include:

- The price of energy
- The amount of individual transport (i.e., personal automobiles) versus mass transit
- The amount of freight traffic.

For example, energy use may be higher in states with a significant amount of freight movement.

Table 3.1 on the next page lists some factors that affect energy use and changes in energy intensity. As noted earlier, an extensive body of literature describing the factors that effect energy use can provide further information.

\textsuperscript{3}Although commercial energy intensity in Nevada is in fact lower now than it was a decade ago, we cannot attribute it to any specific cause at this time.
Table 3.1
Possible Factors Associated with Changes in Energy Intensity, by Energy-Consuming Sector

<table>
<thead>
<tr>
<th>All Sectors</th>
<th>Industrial Sector</th>
<th>Commercial Sector</th>
<th>Residential Sector</th>
<th>Transportation Sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate</td>
<td>Industrial mix</td>
<td>Number of buildings</td>
<td>Number of households</td>
<td>Passenger transit (mass versus individual transit)</td>
</tr>
<tr>
<td>Economic growth</td>
<td>Value of end products</td>
<td>Amount of floor space</td>
<td>Amount of floor space</td>
<td>Freight traffic</td>
</tr>
<tr>
<td>Price of energy</td>
<td>Capital turnover</td>
<td>Commercial sector mix</td>
<td>Number of household members</td>
<td>Automobile type and use</td>
</tr>
<tr>
<td>Energy efficiency</td>
<td>Capacity utilization</td>
<td>Employment levels</td>
<td>Income levels</td>
<td>Air traffic</td>
</tr>
<tr>
<td>Technological changes</td>
<td>New construction</td>
<td>Employment levels</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Government policies and actions</td>
<td>New energy-using devices</td>
<td>New energy-using-devices</td>
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