Analysis of the Energy Intensity of Industrial Sectors in California

Stephane de la Rue du Can, Ali Hasanbeigi, and Jayant Sathaye, Lawrence Berkeley National Laboratory

ABSTRACT

This study first analyzes the energy use of and output from seventeen different industry subsectors in California. Then, decomposition analysis is conducted to assess the influence of different factors on California industry energy use. The logarithmic mean Divisia index method is used for the decomposition analysis. The energy intensity analysis calculated based on economic output of the sectors (value added) shows that "Oil and gas extraction" is the only sector that has higher final energy intensity in 2008 than in 1997. "Electric and electronic equipment manufacturing" and "Apparel manufacturing" show the greatest drop in final energy intensity from 1997 to 2008. Decomposition analysis results show that the activity effects in all time periods studied are positive because the real value added in chained year-2005 dollars increased during these periods. The other large effect is the structural effect. The major contributors to the structural effect are the "Electric and electronic equipment manufacturing," "Oil refineries," "Oil and gas extraction," and "Nonmetallic minerals manufacturing." The intensity effect is positive from 1997 to 2000, primarily because the final energy intensity of the "Oil and gas extraction", shows an increasing trend from 1997 to 2000. However, the intensity effect is negative during 2001 to 2007.

Introduction

During the past two decades, the structure of industry in California has been changing with the elimination of more heavy and energy-consuming industries and the rise of less energy-intensive industries such as electric and electronic equipment manufacturing. Thus, it is very important to analyze the share of each industry subsector and its effect on total energy demand. In addition, it is crucial to analyze the factors that have influenced changes in industry energy intensity in the past. For this purpose, this study first analyses the energy use of and output from seventeen different industry sub-sectors in California. The energy intensity calculated based on economic output for all sectors.

Then, decomposition analysis is conducted to assess the influence of different factors on California industry energy industry. Decomposition analysis has been employed by energy analysts since the early 1990s. By indexing certain drivers to a base year value, this analysis approach shows how energy consumption would have changed had all other factors been held constant (Unander et al. 2004). Reviews of decomposition analysis used at the national and international level include de la Rue du Can et al. (2010) and Liu and Ang (2003).

In this study, the logarithmic mean Divisia index method is used for the decomposition analysis (Ang, 2005) which is discussed in more detail in section 2. There are different studies in various countries that have conducted decomposition analysis of energy use and energy intensity of industries in various countries. International Energy Agency (IEA) has also done various decomposition analysis studies for different sectors in countries/region around the world (Unander et al. 2004, Taylor et al. 2007). IEA usually uses Laspeyres index method for decomposition analysis.

This study was part of a larger study titled "California Energy Balance Update and Decomposition Analysis for the Industry and Building Sectors" undertaken by the authors from the Lawrence Berkeley National Laboratory for the California Energy Commission. More details about the data, methodology, and results can be obtained from de la Rue du Can et al. (2011).

Methodology

Seventeen industry subsectors included in this study (see Table 1). The team collected energy use and production data and other information for these subsectors. Fifteen subsectors are included in the manufacturing industry, and two, oil refineries and oil and gas extraction, are included in the energy industries.

Energy Intensity Calculation

The energy use data come from California Energy Balance (de la Rue du Can et al., 2011), and the data on value added come from the U.S. Department of Commerce Bureau of Economic Analysis, (UDC/BEA, 2010). Using the energy use and output of each sector, the team calculated the energy intensity of each sector from the following equation:

Energy Intensity (kWh or gigajoule / unit of output) =
Energy consumption (kWh or gigajoule) / Production (unit of output) **(1)**

This study calculates energy intensity based on the economic output of each of the 17 industry subsectors. Because the industry classification system in the U.S. changed from Standard Industrial Classification (SIC) to North American Industrial Classification System (NAICS) in 1997, the value-added data before and after 1997 for each industry subsector are reported in two different classification systems which do not quite match. To reduce the uncertainty, the team decided to use the 1997 to 2008 value added data that are reported in the NAICS system for the intensity calculation in this study as well as for the decomposition analysis.

Decomposition Analysis Method

Decomposition analysis separates the effects of key components on energy end-use trends over time. Three main components that are usually considered in decomposition analysis are: 1) aggregate activity, 2) sectoral structure, and 3) energy intensity. The IEA defined these three components as (Unander et al., 2004):

1. *Aggregate activity*: Depending on the economic sector, this component is measured in different ways. For the "Industry" sector it is measured as value added or as physical output of the industry.
2. *Sectoral structure*: This component represents the mix of activities within a sector and further divides activity into industry subsectors.

3. *Energy intensity*: This component refers to energy use per unit of activity.

Different studies have used different mathematical techniques for decomposition analysis. Liu and Ang (2003) explain eight different methods for decomposing the aggregate energy intensity of industry into the impacts associated with aggregate activity, sectoral structure, and energy intensity. They argue that the choice of method can be affected by the decomposition method limitations, such as the data set (e.g., whether or not there are negative values) and the number of factors in the decomposition. Ang et al. (2010) propose the logarithmic mean Divisia index (LMDI) method based on its superior performance, recognized in the comparative studies such as the one presented in Liu and Ang (2003). One of the LMDI method's main advantages (compared to other widely used method such as Laspeyres method) is that LMDI leaves no residual term, which in other methods can be large and affect the results and their interpretation.

Two types of decomposition can be performed with LMDI: additive and multiplicative (Ang, 2005). The additive LMDI approach is easier to use and interpret, and its graphical results show the effects in a clearer way than is the case for multiplicative analysis. The LMDI method can also be used to perform both changing and nonchanging analysis. Ang et al. (2010) recommend changing analysis when using the LMDI method for tracking energy-efficiency trends because the results provide a more realistic measure of the actual changes in energy efficiency over time compared to the results of nonchanging analysis. Changing analysis gives results when evaluation is conducted on a yearly basis, which is often the shortest time period for which data are available when tracking energy-efficiency trends. This analysis accounts on an almost continuous basis for changes over time in the environment in which energy is used, including structural and technological changes (Ang et al., 2010).

For this study the team used LMDI decomposition analysis. Ang (2005) provides practical guidelines for using the LMDI method. The formulas used in the additive LMDI method for decomposing energy use into activity, structural, and energy intensity effects are shown below (Ang, 2005):

$$\Delta E_{tot} = E^T - E^0 = \Delta E_{act} + \Delta E_{Str} + \Delta E_{int} \qquad (2)$$

$$\Delta E_{act} = \sum_i \frac{E^T{}_i - E^0{}_i}{\ln E^T{}_i - E^0{}_i} \ln(\frac{Q^T}{Q^0}) \qquad (3)$$

$$\Delta E_{Str} = \sum_i \frac{E^T{}_i - E^0{}_i}{\ln E^T{}_i - E^0{}_i} \ln(\frac{S^T{}_i}{S^0{}_i}) \qquad (4)$$

$$\Delta E_{int} = \sum_i \frac{E^T{}_i - E^0{}_i}{\ln E^T{}_i - E^0{}_i} \ln(\frac{I^T{}_i}{I^0{}_i}) \qquad (5)$$

Where:

i: subsector
T: the last year of the period
T=0: the base year of the period
E: total energy consumption
ΔE_{tot}: aggregate change in total energy consumption

The subscripts "act," "str," and "int" denote the effects associated with the overall activity level, structure, and sectoral energy intensity, respectively.

$$Q = \sum_i Q_i \text{ : total activity level} \qquad (6)$$

$$S_i = \sum_i Q_i / Q \text{ : activity share of sector I} \qquad (7)$$

$$I_i = \sum_i E_i / Q_i \text{ : energy intensity of sector I} \qquad (8)$$

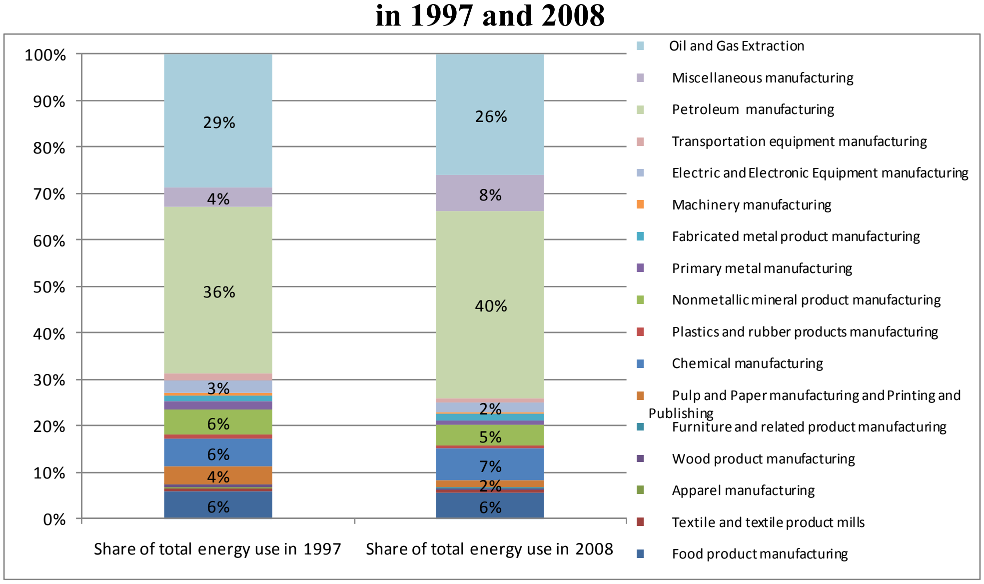
In the "Industry" sector, activity is the value added of each subsector. In decomposition analysis, energy intensity is often calculated based on economic output[1]. This is because, in the decomposition analysis, energy intensity and the output of different sectors included in the analysis are added together (see equation 2-8); for this addition to be possible, the same unit must be used for the output of all sectors.

Energy Use and Value Added Data of the California Industry

Figure 1 shows each industry subsector's share of total final California industry energy use in 1997 and 2008. It shows that "Oil refineries (petroleum manufacturing)" is the dominant energy-consuming sector in California industry followed by "Oil and gas extraction."

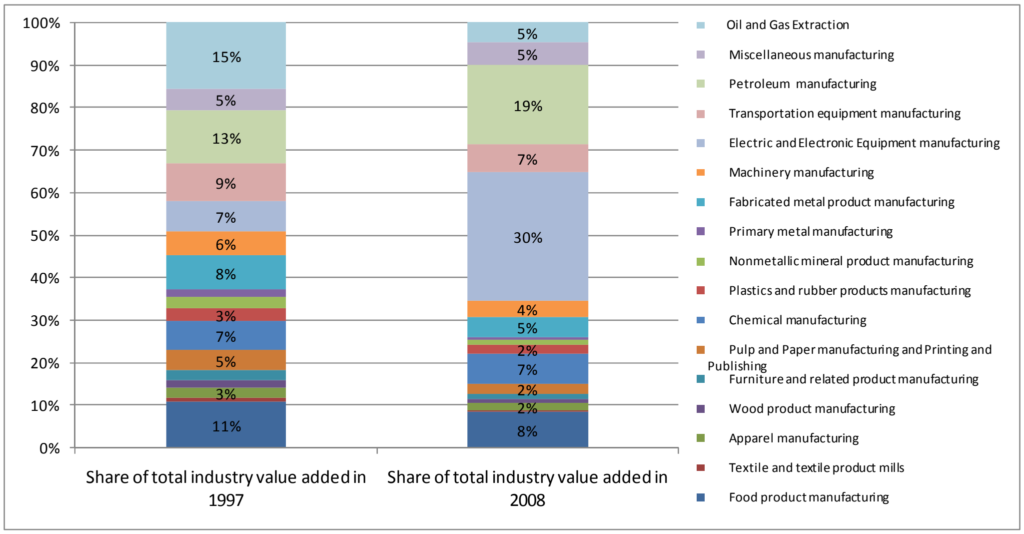
Figure 2 shows the change in value-added mix of California industry between 1997 and 2008. It is clear that "Electric and electronic equipment manufacturing" is growing and dominates the value-added share of California industry. The "Electric and electronic equipment manufacturing" sector's value-added share (in chained 2005 dollars) of total industry value added in 1997 is 7 percent; this figure increases to 30 percent in 2008.

Figure 1: Manufacturing Subsector Shares of Total Final California Industry Energy Use in 1997 and 2008



[1] It should also be noted that "hedonic price indexes" are used in the calculation of value added in chained year-2005 dollars. Hedonic price indexes are statistical tools for developing standardized per-unit prices for goods, such as computers, whose quality and characteristics change rapidly (Landefeld and Bruce, 2000). This may have a slight impact on the increased share of value added attributable to the "Electric and electronics equipment manufacturing" sector. However, Landefeld and Bruce (2000) argue that only a small share of the increase in measured growth in industry is associated with the use of hedonic price indexes.

Figure 2: Change in Value Added (chained 2000 dollars) Mix of California Industry in 1997 and 2008



Results and discussions

Energy Intensity of California Industry

Energy intensity based on economic output. The electricity and fuel intensities calculated are added to calculate the total final energy intensity for each sector. Table 1 shows that "Oil and gas extraction" has the highest final energy intensity in term of energy use per dollar of output in 2008 followed by the "Nonmetallic minerals" and "Oil refineries" sectors. The lowest final energy intensity in 2008 is for "Apparel manufacturing" followed by "Electric and electronic equipment manufacturing." Figure 3 shows the trends in final energy intensity. "Oil and gas extraction" is the only sector whose final energy intensity is higher in 2008 than in 1997. "Electric and electronic equipment manufacturing" and "Apparel manufacturing" show the greatest drop in final energy intensity from 1997 to 2008.

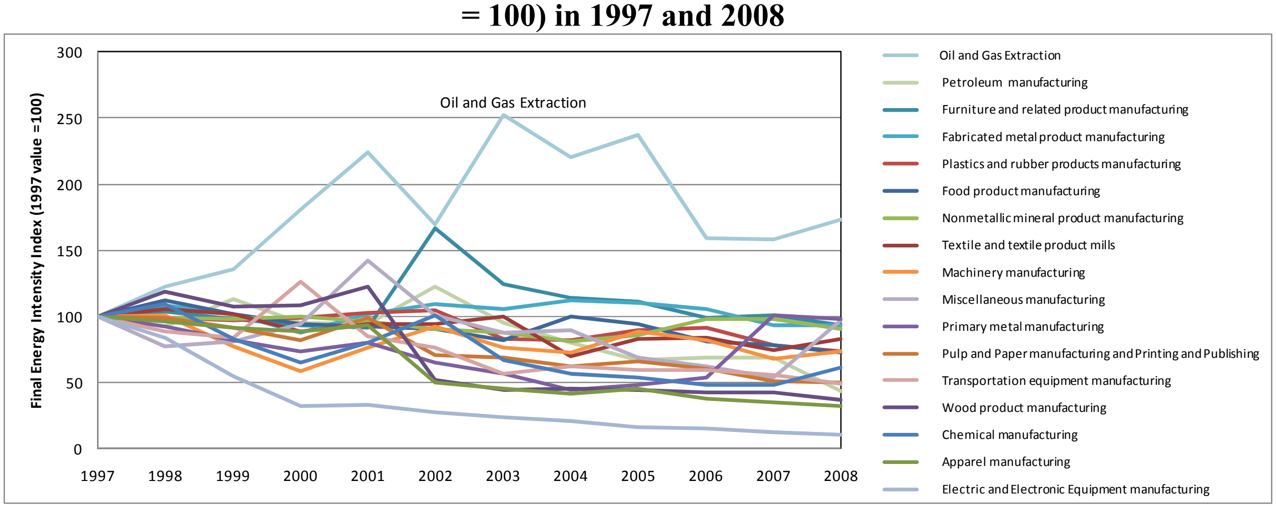
Because energy intensities are calculated based on the sectors' economic output (i.e., value added in millions of chained year-2005 dollars), an increase or decrease in energy intensity does not necessarily show the actual change in the energy efficiency of the sector. This is one of the main limitations when energy intensity is calculated based on the economic output of industrial sectors rather than physical output. On the other hand, physical indicator at this level of aggregation (subsectors) can also be misleading indicator of energy "efficiency".

The actual final energy *use* of California industry does not change much from 1997 to 2008, with a slight overall decrease of 6 percent (Figure 4). However, overall value added increases with the exception of a short period of decrease in 2001 and 2002 because of the recession and collapse of many information technology companies. The real industry value added presented in chained 2005 dollars increases by 67 percent from 1997 to 2008. The significant real value-added growth, while having an almost constant energy use, results in a substantial decrease in energy intensity. One important point is that "Electric and electronic equipment manufacturing" alone accounted for 30 percent of the real industry value added in 2008 although this sector accounts for only 2 percent of total final industry energy use. If the "Electric and electronic equipment manufacturing" value added is excluded from the total real value added of industry, the overall industry value-added increase from 1997 to 2008 is only 25 percent compared to the 67 percent in chained 2005 dollars. The significant impact of this sector on total industry energy intensity should be kept in mind while interpreting the results of energy intensity and decomposition presented here.

Table 1: Total Final Energy Intensity of Different California Industry Subsectors in 1997 and 2008 (Unit: Billion Btu/millions of chained 2005 dollars)

No.	Subsector	1997	2008	Change in 2008 compared to 1997
1	Food product manufacturing	5.3	3.9	-27%
2	Textile and textile product mills	7.7	6.3	-17%
3	Apparel manufacturing	1.0	0.3	-68%
4	Wood product manufacturing	3.7	1.4	-63%
5	Furniture and related product manufacturing	0.6	0.5	-7%
6	Pulp and Paper manufacturing and Printing and Publishing	7.8	3.9	-50%
7	Chemical manufacturing	8.6	5.3	-38%
8	Plastics and rubber products manufacturing	2.9	2.1	-27%
9	Nonmetallic mineral product manufacturing	21.5	19.4	-10%
10	Primary metal manufacturing	9.3	9.2	-2%
11	Fabricated metal product manufacturing	1.6	1.5	-7%
12	Machinery manufacturing	1.1	0.8	-27%
13	Electric and Electronic Equipment manufacturing	3.7	0.4	-90%
14	Transportation equipment manufacturing	1.6	0.8	-51%
15	Oil refineries sector	28.1	12.3	-56%
16	Miscellaneous manufacturing	8.3	8.0	-3%
17	Oil and Gas Extraction	18.4	31.8	73%

Figure 3: Change in Total Final California Industry Energy Intensity Index (1997 intensity = 100) in 1997 and 2008



To show even more clearly the effect of the “Electric and electronic equipment manufacturing” sector on total final industry energy intensity, we calculated the final California industry energy intensity between 1997 and 2008 with and without “Electric and electronic equipment manufacturing." Figure 5 shows the result of the analysis. When "Electric and electronic equipment manufacturing" is excluded from the analysis (both value added and energy use), the final energy intensity increases significantly with a slower declining trend over the 1997-2008 period. The difference in final energy intensity of these two cases (with and without "Electric and electronic equipment manufacturing") in different years varies between 5 percent and 41 percent with an average 23 percent increase in final energy intensity when "Electric and electronic equipment manufacturing" is excluded (Figure 5).

Figure 4: Trends of California Industry Value Added, Final Energy Use, and Final Energy Intensity Indexes (1997 intensity = 100) in 1997 and 2008

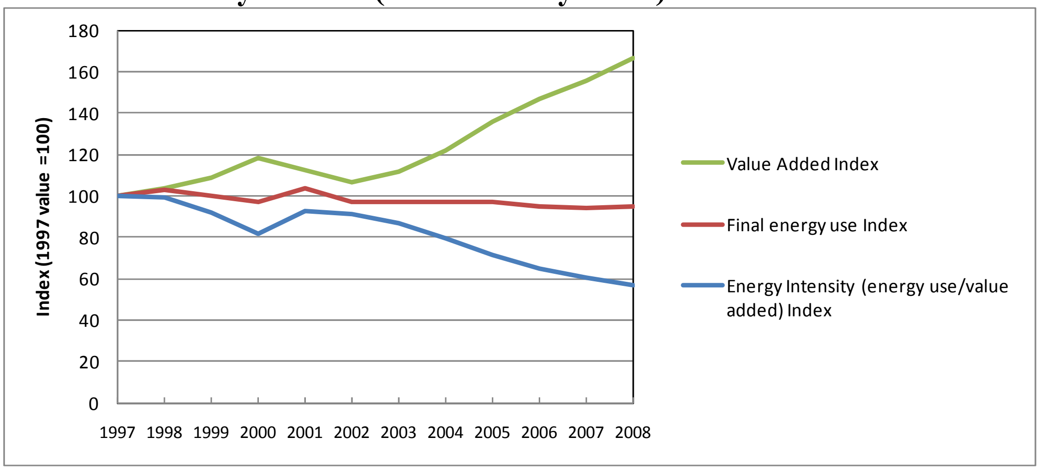
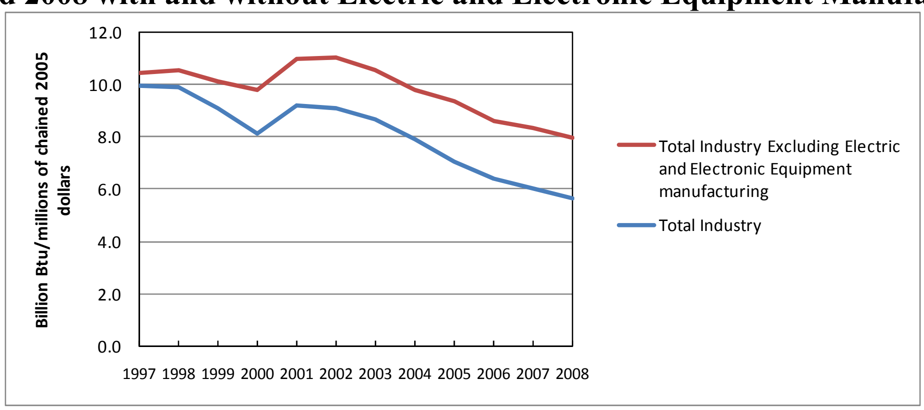


Figure 5: Total Final California Industry Energy Intensity Index (1997 intensity = 100) in 1997 and 2008 with and without Electric and Electronic Equipment Manufacturing



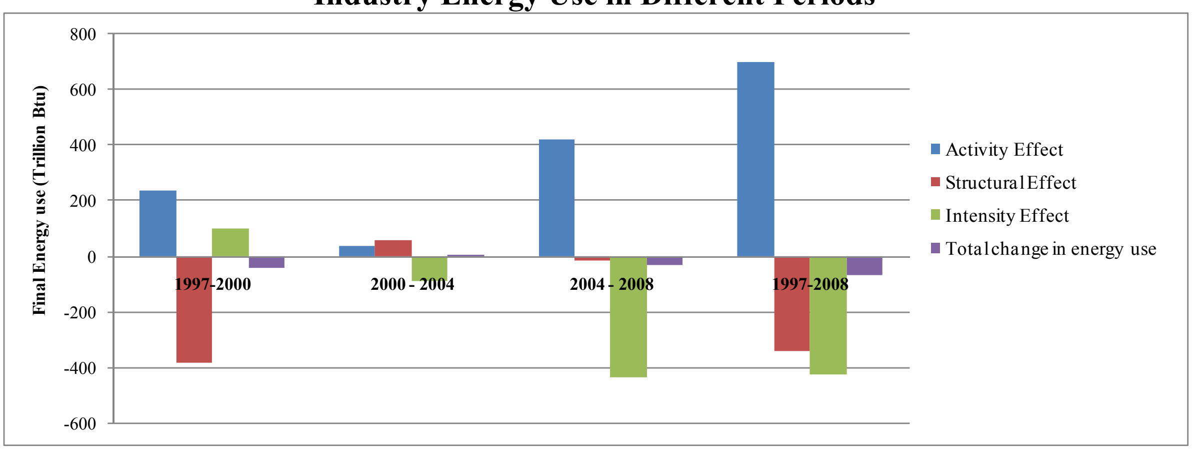
Decomposition of the Energy Use for the California Industry

The team performed LMDI decomposition analysis for California industry for three time periods: 1997-2000, 2000-2004, and 2004-2008. The team chose these three periods based on the final California energy intensity trends from 1997 to 2008. The team also carried out decomposition analysis for the entire period, 1997-2008, to show the overall change in energy use. As mentioned in the methodology section, additive decomposition analysis was used as well as the changing analysis method, in which the base year moves from year to year. Figure 6 shows the results of the additive decomposition analysis of total final energy use for the entire California industry sector for the time periods mentioned above.

Figure 6 shows that, from 1997 to 2000, activity and structural effects are the two dominant effects that act in opposite directions. Although the activity effect increases the final energy use by 239 trillion Btu, the structural effect reduces it by 382 trillion Btu during the period 1997-2000. Once the intensity effect (100 trillion Btu) is taken into account, the overall final energy use by industry declines by 43 trillion Btu during this period. However, during the next period, 2000-2004, the two major effects are structural and intensity effects. Unlike in the previous period, during the period 2000-2004, the intensity effect reduces the final energy use by 91 trillion Btu while the structural effect increases it by 59 trillion Btu. The overall change in final energy use by California industry during this period is a 5-trillion-Btu increase, which is a small change.

The last period, 2004-2008, has a very large positive activity effect (+421 trillion Btu), a large negative intensity effect (-437 trillion Btu), and a minor structural effect (-16 trillion Btu). Overall, final energy use in this period decreases by 32 trillion Btu. When looking at the whole period, 1997-2008, we can see that only the activity effect is positive and increasing final industry energy use while the structural and intensity effects are pushing final energy use downward. The sum of these three effects is the decline in final energy use by 70 trillion Btu in 2008 compared to 1997.

Figure 6: Results of Additive Decomposition (Changing Analysis) of Final California Industry Energy Use in Different Periods

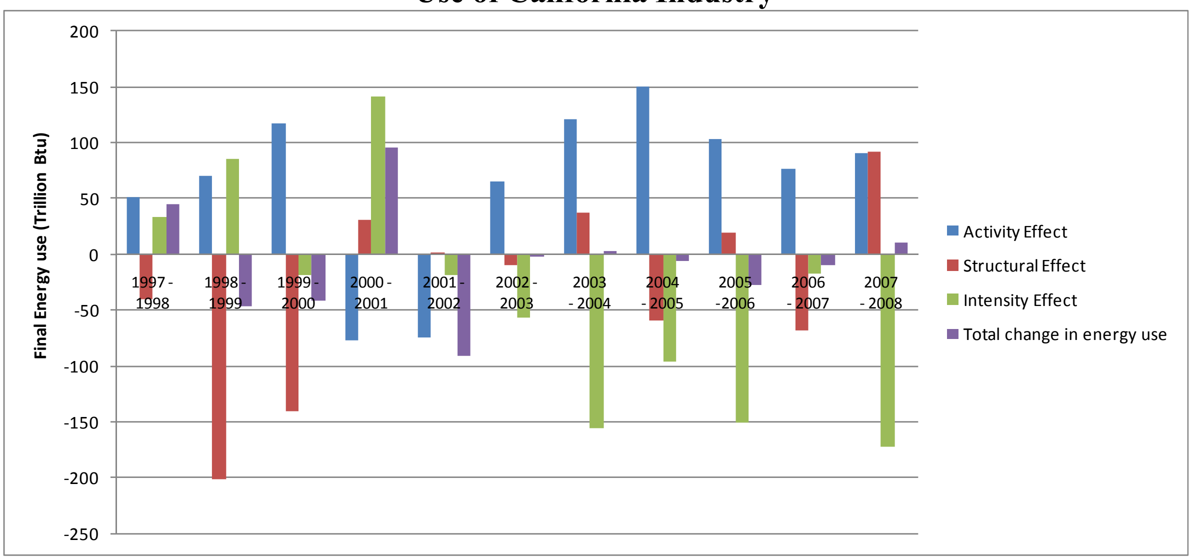


The activity effect in all periods is positive because the real value added in chained 2005 dollars increased during these periods (see Figure 4). However, the real value added dropped in 2001 - 2003 compared to that in 2000. This was mostly a result of the recession that started in 2000 in California and the U.S. Figure 7 presents the results of the additive decomposition (changing analysis) in annual format, and Figure 8 presents it by industry subsectors.

The structural effect is also large. As shown in Figure 8, the major contributors to the structural effect are the "Oil and gas extraction," "Oil refinery," "Electric and electronic equipment manufacturing," "Nonmetallic minerals," sectors. While the "Electric and electronic equipment manufacturing" sector share of total industry value added increases from 7 percent in 1997 to 30 percent in 2008, its final share of total energy use decreases from 3 percent in 1997 to 2 percent in 2008. The share of value added of "Oil refineries" also increases from 13 percent to 19 percent during 1997 and 2008. This significant increase in the value-added shares of "Electric and electronic equipment manufacturing" and "Oil refineries" means that share of value added from top energy-consuming sectors such as "Oil and gas extraction" decreases from 15 percent in 1997 to 5 percent in 2008, and "Nonmetallic minerals" decreases from 3 percent in 1997 to 1 percent in 2008. "Oil refineries," "Nonmetallic minerals," and "Oil and gas extraction" are highly energy-intensive industries with final energy intensities of 12.3 Billion Btu per million of chained 2005 dollars, 19.4 Billion Btu/million of chained 2005 dollars, and 31.8 Billion Btu/million of chained 2005 dollars in 2008, respectively. These intensities are much higher than those of other industry subsectors. Therefore, even a small change in the share of value added of these three sectors will have a significant impact on structural effect (see Figure 8).

Figure 7 shows that the intensity effect is positive during the period 1997-2000, which pushes the final energy use upward. This is again mainly because of the top energy-consuming sector, "Oil and gas extraction." As mentioned, the energy intensity of this sector is much higher than that of other sectors (Table 1). Moreover, the final energy intensity of this sector shows an increasing trend from 1997 to 2000. The result of these two factors is a positive intensity effect, shown in Figure 6 for the first period. In the other two periods, as well as the whole period of 1997 to 2008, the intensity effect is negative.

Figure 7: Annual Results of Additive Decomposition (Changing Analysis) of Final Energy Use of California Industry

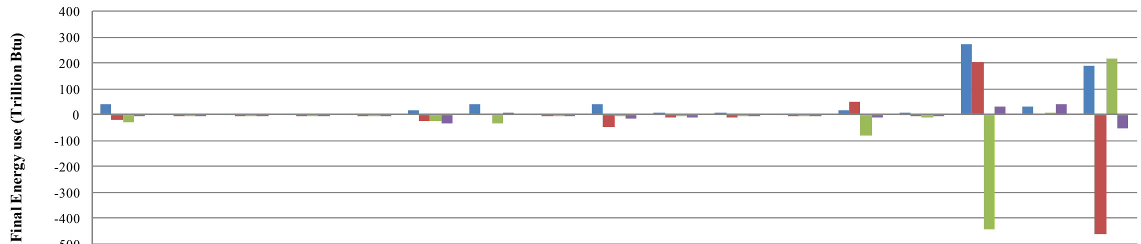


The annual decomposition results in Figure 7 also show that the activity effect increases the final energy use of the industry in all annual periods except 2000-2001 and 2001-2002 when there was a decreasing trend in the real value added of the industry. The structural effect decreases the final energy use of the industry in most of the annual periods.

In 2001-2002, while the real value added of the "Electric and electronic equipment manufacturing" declines, its share of the total manufacturing sector value added declines slightly as well. At the same time, the share of real value added for the top two energy-intensive sectors – "Oil and gas extraction" and "Nonmetallic minerals" – increases during this period, which results in a positive structural effect for the period. The significant jump of intensity effect in 2000-2001 is because of the sudden drop of real value added of the industry at the start of the recession.

Final energy use of the industry increased during this period, which resulted in a significant increase in the final energy intensity.

Figure 8: Results of Additive Decomposition of Final Energy Use of California Industry by Different Industrial Sectors, 1997-2008



	Food product manufacturing	Textile and textile product mills	Apparel manufacturing	Wood product manufacturing	Furniture and related product manufacturing	Pulp and Paper manufacturing and Printing and Publishing	Chemical manufacturing	Plastics and rubber products manufacturing	Nonmetallic mineral product manufacturing	Primary metal manufacturing	Fabricated metal product manufacturing	Machinery manufacturing	Electric and Electronic Equipment manufacturing	Transportation equipment manufacturing	Petroleum manufacturing	Miscellaneous manufacturing	Oil and Gas Extraction
Activity Effect	43	5	1	2	1	17	41	6	39	7	9	4	16	7	273	34	192
Structural Effect	-20	-6	-1	-3	-1	-24	2	-5	-49	-12	-10	-3	52	-4	205	1	-462
Intensity Effect	-27	-2	-3	-5	0	-25	-36	-3	-7	-6	-1	-3	-78	-10	-444	8	216
Total change in energy use	-5	-3	-2	-6	0	-32	7	-3	-17	-11	-2	-2	-10	-8	34	42	-54

Breaking down the decomposition analysis results by industrial sectors shows the contribution of each sector to the overall results (Figure 8). In all industrial sectors, the activity effect on final energy use is positive during the period analyzed. The structural effect of all industries is negative, however, except for "Oil refineries," "Electric and electronic equipment manufacturing," and "Chemical manufacturing." This implies that the share of these three industries in the total value added of the industry sector increased from 1997 to 2008, and the share of all other industries decreased. Only "Oil and gas extraction" and "Miscellaneous manufacturing" have positive intensity effects. This confirms the fact that only the final energy intensity of "Oil and gas extraction" increased in year 2008 compared to energy intensities in 1997. The increasing trend in the energy intensity of the "Oil and gas extraction" sector is mainly because it is getting more and more difficult to extract oil as a result of oil well depletion. Therefore, energy-intensive technologies/ processes such as enhanced oil recovery are used, which results in greater energy use per barrel of oil extracted.

The final energy intensity of "Miscellaneous manufacturing" increased sharply until the year 2001 and then showed a decreasing trend until the year 2008 where it ended slightly lower than year 1997. The overall effect of this trend is a very small positive intensity effect. The "Oil refineries" and "Oil and gas extraction" sectors are the two sectors that have major influence on the overall energy use change in the industry category during this period because both are highly energy intensive, so changes in the share of their value added and in their final energy intensity will result in large structural effect and intensity effects, respectively. In the case of California industry, the structural and intensity effects of these two sectors act in opposite to each other (Figure 8).

Conclusions

The analysis described in this paper first examined the energy use of, and output from, 17 different industry subsectors in California. The energy intensity analysis results show that "Oil and gas extraction" is the only sector that has higher final energy intensity in 2008 than in 1997.

"Electric and electronic equipment manufacturing" and "Apparel manufacturing" show the greatest drop in final energy intensity from 1997 to 2008. Because the energy intensities are calculated based on economic output of the sectors (i.e., value added in millions of chained year-2005 dollars), an increase or decrease of energy intensity does not necessarily correspond to the actual change in the sector's energy efficiency. This is one of the main limitations when the energy intensity is calculated based on economic output of industrial sectors rather than based on physical output.

Next, decomposition analysis results show that the activity effects in all time periods studied are positive because the real value added in chained year-2005 dollars increased during these periods. The other large effect is the structural effect. The major contributors to the structural effect are the "Electric and electronic equipment manufacturing," "Oil refineries," "Oil and gas extraction," and "Nonmetallic minerals manufacturing." Although the "Electric and electronic equipment manufacturing" sector's share of total industry value added increased from 7 percent in 1997 to 30 percent in 2008, this sector's share of final industry energy use decreased from 3 percent in 1997 to 2 percent in 2008. The share of value added of "Oil refineries," which is an energy-intensive sector, also increased from 13 percent to 19 percent during this period. This significant increase in the share of value added of these two sectors results in a decrease in the share of value added attributed to the other two top energy-consuming sectors ("Oil and gas extraction" and "Nonmetallic minerals"). "Oil refineries," "Nonmetallic minerals manufacturing," and "Oil and gas extraction" are highly energy-intensive industries. Therefore, even a small change in the share of value added of these three sectors will have a significant impact on structural effect.

The intensity effect is positive from 1997 to 2000, primarily because the final energy intensity of the top energy-consuming sector, "Oil and gas extraction", shows an increasing trend from 1997 to 2000. The results of this study show that energy-intensive sectors such as "Oil refineries," "Nonmetallic minerals," and "Oil and gas extraction" use more energy per value added, and, although they account for a large share of California industry's final energy use (71 percent in 2008), they together produced only 25 percent of the total industry value added in 2008. In contrast, the "Electric and electronic manufacturing" sector accounted for 30 percent of the industry value added alone while just consuming 2 percent of the total final industry energy use in 2008. These four sectors have a major influence on the results of the decomposition analysis.

It should be noted that "hedonic price indexes" are used in the calculation of value added in chained 2005 dollars reported by the U.S. Department of Commerce's Bureau of Economic Analysis. The use of these price indexes is partly responsible for the "Electric and electronics product manufacturing" sector's large share of value added, but its effect is small. Also, it should be highlighted that the energy intensities calculated based on the value added of industrial sectors are not always good indicators of the energy-efficiency performance of the sectors.

The results of this decomposition analysis can be used for designing the policies that in the medium to long term will support energy-efficiency improvements that will result in a less energy-intensive industry structure.

Acknowledgements

The authors would like to thank Guido Franco of the California Energy Commission for his steady support through the period of the study and for providing substantial input during the different phases of the project. The study also benefited greatly from intellectual and data inputs from Andrea Gough, Keith O'Brien, and Gordon Schremp at the California Energy Commission; Channele Wirman and Dean Fennell at the Energy Information Administration; Larry Hunsaker, Marc Vayssieres, and Webster Tasat at the California Air Resources Board; Steve Smith at Pacific Northwest National Laboratory; and Ignasi Palou-Rivera at Argonne National Laboratory. The authors are extremely thankful to all the other professionals who contributed to the study and provided data and helpful comments in a timely manner. We extend our gratitude to Nan Wishner for her constructive editing, and finally to our colleagues at LBNL, David Fridley and Eric Masanet, for their careful and instructive review.

References

Ang, B.W., 2005. The LMDI approach to decomposition analysis: a practical guide. Energy Policy 33 (2005) 867–871.

Ang, B.W.; Mu, A.R.; Zhou, P., 2010. Accounting frameworks for tracking energy efficiency trends. Energy Economics, Volume 32, Issue 5, September 2010, Pages 1209-1219.

Bureau of Economic Analysis, U.S. Department of Commerce (BEA/UDC), 2010. Gross Domestic Product by State. Available at http://www.bea.gov/regional/gsp/

de la Rue du Can, S., J. Sathaye, L. Price, and M. McNeil. 2010. Energy Efficiency Indicators Methodology Booklet. May 2010. Berkeley, CA: Lawrence Berkeley National Laboratory. LBNL-3702E

de la Rue du Can, S.; Hasanbeigi,A.; Sathaye, J., 2011. California Energy Balance Update and Decomposition Analysis for the Industry and Building Sectors. Berkeley, CA: Lawrence Berkeley National Laboratory. Report prepared for the California Energy Commission, (In press).

Landefeld, J. S. and Bruce T. G., 2000. A Note on the Impact of Hedonics and Computers on Real GDP. Survey of current business 80 (December 2000): 17–22.

Liu, F.L.; Ang, B.W., 2003. Eight methods for decomposing the aggregate energy-intensity of industry. Applied Energy 76 (2003) 15–23

Unander, F. , M. Ting, L. Fulton, D. Justus, and S. Karbuz. 2004. Oil Crises and Climate Challenges: 30 Years of Energy Use in IEA Countries. Paris: International Energy Agency.

U.S. Bureau of Labor Statistics (US/BLS), 2010. Producer price Index-Industry data – discounted series. Available at http://data.bls.gov:8080/PDQ/outside.jsp?survey=nd