On Accounting for Energy Savings from Industrial Productivity Improvements

Kyriaki Papadaratsakis, Donald J. Kasten, Michael R. Muller
Rutgers University, Center for Advanced Energy Systems

ABSTRACT

Many energy related technical assistance programs, such as the federally funded Industrial Assessment Center (IAC) program, have broadened the "energy audit" into an industrial assessment that includes improvements in waste minimization, pollution prevention and enhancements in productivity. The integration has proven successful because of the natural inter-relation between these streams and the ability to interest management.

Often the impact of productivity projects on energy use in the plant is ignored or underestimated. It is quite clear that the appropriate metric in evaluating energy impacts of productivity related projects would be improvements in energy intensity. However this task remains difficult because energy intensity is not yet generally accepted as a metric in energy auditing programs whose primary focus is on energy consumption. We propose a hybrid approach where improvements in energy intensity are rescaled as an "effective energy savings." Experiences from the DOE Industrial Assessment Center program are used as well as data from the program's publicly available database. It is shown that while in many of the recommended productivity improvements there is an associated absolute reduction in energy use, more commonly a productivity recommendation leads to an increase of total energy use. Handled incorrectly this can lead to a negative energy impact which could result in increased paybacks and misleading indications about energy efficiency.

The procedure is simply to determine the improvement in overall plant productivity achieved by a particular project and calculate the improvement in energy intensity. This method is applied to the IAC program and its database maintained at Rutgers and shows a dramatic impact on program metrics. About 50% of the effective energy savings identified are directly from productivity improvements, with the remaining half coming from the elimination of negative energy impacts. Recommendations are also presented for implementation of this scheme to other energy efficiency programs.

Introduction

Improving energy efficiency can impact manufacturers in several ways. In scenarios where production is constant, increasing energy efficiency and decreasing energy intensity will lead to a reduction in consumption and an associated reduction in greenhouse gas emissions. However, it is also important to look at the benefits of energy efficiency in an environment where production is increasing. In theses cases, while consumption increases, a decrease in plant energy intensity will result in minimizing that growth. In addition, energy efficiency projects will increase competitiveness and provide for the long-term health of the industry and its workers.

Clearly there is debate on the role of industrial growth, especially in hard "cap and trade" scenarios. However at this point the US has embraced a pro-growth policy with a focus on reducing energy intensity. In May of 2001, the White House issued the National Energy Policy urging the president to take measures to improve the energy intensity of the U.S. In a similar manner, national energy efficiency programs and offices are beginning to realize a need for incorporating energy intensity into their mission statements. One example is the U.S Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE 2003). EERE set a priority to "Increase the Efficiency / Reduce the Energy Intensity of Industry." Also, the new Industrial Technologies Program goal is to decrease the energy intensity of the U.S (EERE 2002). To handle concerns about greenhouse gas emissions (such as CO_2) the Department of Energy has launched the Presidents Climate VISION (Vieth and Malcomb, 2003). Climate VISION aims at reducing greenhouse gas emissions by reducing the greenhouse gas intensity. Since a reduction in energy intensity results in a reduction of carbon intensity (Sun 2003), it becomes apparent that dealing with the issue of energy intensity even when energy consumption increases aides in goals to reduce emission intensity.

Studies utilizing energy intensity as an accounting tool on a macroscopic scale provided groundwork for incorporating energy intensity across an entire sector of industry. Laitner and Finman (2001) found that significant improvements in energy efficiency could increase productivity in the U.S. economy. The study suggests a change in perspective on quantifying the savings associated with energy efficient technologies that can provide a significant boost to overall productivity within the U.S. economy. A related study (Ruth, Price & Worrell 2001) discusses how energy intensity could be used as a benchmarking tool in both the macroscopic scale (sectors of industry) and microscopic scale (per plant). In this way, goals could be set to decrease the energy intensity of a plant or sector in terms of energy per product output. Such an evaluation tool will minimize variations due to economic measures and aide in increasing energy efficiency. Combining these ideas, energy intensity can be used on a per plant basis to account for non-energy recommendations as being energy conscious.

On a microscopic scale, per plant or company, technical assistance programs can begin incorporating energy intensity as an accounting method or tool in performing audits. Many energy related technical assistance programs, such as the federally funded Industrial Assessment Center (IAC) program, have broadened the "energy audit" into an industrial assessment that include improvements in waste minimization, pollution prevention and enhancements in productivity. An earlier study (Mitrovic & Muller 2000) outlined a method and provided case studies on how a technical assistance program could benefit by using energy intensity as an accounting practice to track "virtual" energy savings in energy intensive productivity recommendations with case studies from the IAC program.

The IAC Program maintains an extensive database maintained at Rutgers, The State University of New Jersey that stores information on all assessments completed, including energy and monetary savings seen by each individual assessment. The IAC program began incorporating productivity recommendations into their audits in 1997. Since then, productivity related recommendations account for 13% of all the recommendations made since their integration. The total dollar savings for all recommendations since 1997 is $853 Million. Of this, productivity recommendations contribution to the total dollar savings is $423 Million. This means that productivity recommendations account for almost 50% of the dollar savings from all recommendations made since 1997.

Since the IAC has not incorporated energy intensity into their database it becomes apparent that the energy savings in a productivity recommendation is low compared to energy related ones; on average only 2% of the energy savings found in all recommendations (reference Table 1). In fact, most productivity related recommendations in the IAC database show a negative impact on energy consumption savings. Therefore, they appear to be ineffective and contradictory to the programs mission to reduce energy consumption. In this case, energy intensity would be the appropriate metric. However, since it is not commonly accepted as a tracking tool in technical assistance programs, savings can be accounted for using an effective energy savings.

Table 1. Energy Savings Impact in IAC Recommendations

1997 to Present (4152 Assessments)	
All Recommendations	**Productivity Recommendations**
13,813 MMBtu	269 MMBtu

Therefore, the goal is to create a model for productivity related recommendations that identify a pro-active approach in terms of energy intensive productivity recommendations leading to an energy efficient practice and to test it on an existing resource. The perfect resource for this goal is the IAC database. A method will first be identified as the Effective Energy Savings method. This method discards traditional views of absolute energy savings since increases in energy are expected with growth. Instead, an overall improvement in energy intensity is sought that shows an energy efficient growth. The EES method will use energy intensities to demonstrate if an increase in production will benefit energy savings. This will be followed by case studies that will demonstrate individual types of cases that are more and less obvious in the IAC database utilizing this method. Finally, the energy impact of productivity related recommendations in the IAC program would be tested using the EES method. It will be clearly shown that technical assistance programs will be able to demonstrate that productivity related recommendations are positive tools that support energy saving programs. Then, using the IAC database as a model, it will be shown that such a method works and can be used as a new accounting method in technical assistance programs.

Calculating the Effective Energy Savings

Now that the need for identifying a solution to the energy accounting issue has been identified, the new accounting technique called the effective energy savings method will be explained. Calculating the effective energy savings is a three-step process. The process begins at the plant level, incorporating the current practices. By current practices, the annual energy consumption from all sources and the annual production need to be obtained. These are required to calculate the *current energy intensity (CEI).* The CEI will give the total *current energy consumed (CEC)* per *production quantity* (PQ). To simplify the calculation, the unit for the total energy consumption will be in MMBtu from all energy sources consumed in the entire facility. The production unit will vary by manufacturer (i.e., lbs, tons, units, etc.) but for the purpose of the explanation it will be referred to as a widget. Therefore, the CEI will be in units of MMBtu/widget. The CEI is calculated as follows:

$$CEI = \frac{CEC}{PQ} \quad \textbf{(1)}$$

The next step considers the productivity recommendation's impact on the plants energy intensity. Thus, the suggested action from the recommendation will be used to calculate the *New Energy Intensity (NEI)*. This is calculated from the proposed energy consumption resulting from the recommendation, and the new production level. The proposed energy consumption is the sum of the CEC and the *additional energy consumption (AEC)*. The new production level is the sum of the PQ and the *additional production quantity (APQ)*.

$$NEI = \frac{(CEC + AEC)}{(PQ + APQ)} \quad \textbf{(2)}$$

Please note, that additional energy consumption does not imply that this method can only be used when energy consumption increases. It can also include cases where energy consumption decreases or where energy consumption does not change. However, an increase in production quantity is implied.

Finally, the effective energy savings can be calculated. This is accomplished by one of two methods. The first is a two-step process that calculates the *current energy at the new intensity (CENI)*. CENI is a value of energy consumption. It assumes that if the current 100% of production does not change, what the energy consumption is at the NEI. Thus,

$$CENI = \frac{CEC \times NEI}{CEI} \quad \textbf{(3)}$$

Now, the *effective energy savings (EES)* can be found. EES is the difference in energy consumption for the first 100% of production for the old and new intensities.

$$EES = CEC - CENI \quad \textbf{(4a)}$$

Or, if simplified, the EES can be calculated in one step by substituting equation 3 into equation 4a as follows:

$$EES = CEC - \frac{(CEC \times NEI)}{CEI}$$

Or,

$$EES = CEC \times \left[1 - \frac{NEI}{CEI}\right] \quad \textbf{(4b)}$$

Therefore, calculating the EES does not require calculating CENI, even though this can be a useful step.

The EES method can also be to calculate for dollar savings; however, this is not favorable since the economic value of such a number is not a constant. The significance of such a number can change. Therefore, only the energy component is considered.

Observing equation 4b, three scenarios can be identified that will affect the value of EES. These scenarios can be viewed in the table below.

Possible Scenarios	EES
NEI =CEI	No Impact
NEI>CEI	Negative Impact
NEI<CEI	Positive Impact

The obvious desired situation is when EES shows a positive change, meaning energy savings exist. However, without calculating NEI and CEI, it can be difficult to predict the value of EES. Instead, to explore the EES method, three identifiable types of case studies will be explored instead. These case studies will show that an improvement on energy intensity and the effective energy savings can occur whether energy consumption increases, decreases or stays the same. Alternatively, no improvement in effective energy savings can occur for the same cases.

Case Studies

Utilizing the extensive IAC database, four types of case studies were recognized to be of importance to evaluate because these are typical examples of what should be expected in industry. If one considers the EES method to be an array of cases, one can begin to narrow the possibilities. Energy intensity is affected directly by two inputs; units of production and energy consumption. Since the current trend is growth in industry, production will always increase. Therefore, energy consumption remains as the only variable that can increase, decrease or remain the same. In the scenario where production rises, energy intensity can change depending on the energy consumption. Three possibilities will be examined where energy intensity is optimally decreased (when energy consumption increases, decreases or remains the same). Then we will examine a case where a energy efficient productivity recommendation creates a decrease in energy consumption, but an increase in energy intensity results.

Case 1

Case 1 examines a non-energy productivity recommendation that increases production and lowers the energy intensity to produce an effective energy savings.

A manufacturer of corrugated cardboard must stop production every sixteen hours for a half hour in order to retrieve cardboard pieces between the printing machine and the belt conveyor sending them to packaging. This downtime results in a loss of production of 468,000 cardboard sheets per year. Currently, the manufacturer produces 14,976,000 cardboard sheets per year with a total annual energy consumption of 27,417 MMBtu. It has been recommended that an extension of the existing vacuum collector be placed under the printing machine to pick up the fallen cardboard pieces and eliminate the downtime. Since there are no additional energy costs, using the Effective Energy Method, the CEI is calculated using the plants current energy and production values.

$$CEI = \frac{27{,}417}{14{,}976{,}000} \frac{MMBtu/yr}{sheets/yr} = .00183\, MMBtu/sheets$$

Now the NEI is calculated. Due to no additional energy consumption (or savings), the AEC (Additional Energy Consumption) is zero.

$$NEI = \frac{(27{,}417 + 0)}{(14{,}976{,}000 + 468{,}000)} * \frac{MMBtu / yr}{sheets / yr} = .00178\, {}^{MMBtu}\!/_{sheets}$$

Since NEI<CEI, an effective energy savings is expected.

$$EES = 27{,}417 MMBtu / yr \times \left[1 - \frac{.00178\ MMBtu / sheet}{.00183\ MMBtu / sheet}\right] = 749 MMBtu / yr$$

A 2.7% savings in the effective energy was realized! Although it appeared this recommendation had no impact on energy consumption, a positive impact on EES was found.

Case 2

Case 2 focuses on a typical case where there are consumption savings. In this case, larger effective savings are realized and can be accounted for in the future.

An IAC audit was performed on a manufacturer of grey iron castings. The manufacturers annual production is 45,200 tons with an annual energy consumption of 236,142 MMBtu. To increase production capacity, it was recommended that an additional recuperator be installed to the furnace. This recommendation will save the company 19,100 MMBtu/yr of natural gas and allow for a production increase of 14,125 tons. Using the same method as case 1, the CEI and NEI are calculated as 5.22 MMBtu/ton and 3.65 MMBtu/ton, respectively.

Since NEI<CEI, an effective energy savings is expected. Also note that the expected annual energy savings is *subtracted* from the current energy consumption since the new energy consumption will be reduced. The EES is found to be 71,024 MMBtu/yr. This case shows an EES of 30%! This is a typical case that an EES is expected due to apparent energy consumption savings, but is not always the case.

Case 3

In case 3, an increase in energy consumption is usually a recommendation not desired by technical assistance programs. Here, with the EES method can show how it can be a desirable approach with the new accounting process.

A residential lighting fixture manufacturer produces 200,000 lamps annually. When an IAC audit was performed, they saw that a bottleneck in the production was the furnace. The IAC suggested adding an additional glass furnace to increase production by 25% (50,000 lamps/yr). This would consume an additional 1,022 MMBtu/yr. Therefore, using the Effective Energy Method, The CEI is .21336 MMBtu/lamp and the NEI is .714776 is

MMBtu/lamp. NEI<CEI, therefore, effective energy savings are expected. The EES is 7,717 MMBtu/yr.

An EES improvement of 18% is found even though the energy consumption would not favor the IAC database in terms of energy savings. Many recommendations similar to this one are made in the IAC program that appear to impact energy saving attempts negatively, but actually due improve energy saving attempts as can be seen by the effective energy method.

Case 4

In case 4, an interesting view is seen when an EES is not realized even though there are energy consumption savings. This case proves that energy intensity should be a standard approach in productivity recommendations.

In a plant that manufactures car and forklift batteries, 10% of productivity was lost during 4 months of the summertime. The loss in productivity is due to the delay in battery charging time from heat buildup in the summer. If cooling is provided to the three charging rooms in the facility, the charging time of the batteries can be reduced increasing productivity during the summer months. Currently, the manufacturer uses 490,633 MMBtu to produce 3.5 million batteries. It has been recommended that chillers be added to the operations to increase productivity. In addition to increasing productivity by cutting charge time for batteries, adding chillers also increase productivity by 1% annually if acid is cooled to 44°F before it is pumped into the batteries. The energy savings for implementing this recommendation is 35,091 MMBtu while increasing production by 156,000 batteries.

The current energy intensity is .14018 MMBtu/Battery. Consequently, the new energy intensity due to this recommendation is 0.14380 MMBtu/Battery. Since NEI>CEI, an effective energy savings cannot be expected. The EES is –12,670 MMBtu/yr. This recommendation shows that a decrease in energy consumption can relate to an increase in energy intensity (relating to an increase in the effective energy consumption). Therefore, energy intensity should be an indicator when using the EES method instead of energy consumption for productivity related recommendations even for cases were consumption goes down.

Modeling the EES on the IAC Program

The case studies reviewed show how productivity related recommendations could be seen as energy conscience projects. When viewed in terms of effective energy consumption, a visible savings is realized. In this manner, a growth in industry can be seen as energy conscience. Eventually, this will lead to a practice of optimizing energy intensity to increase effective energy consumption savings. Now, an attempt will be made to account for specific energy consumption savings on a technical assistance program model. The place to begin is with the IAC program. Please recall from Table 1 that the IAC program saved an average of only 269 MMBtu's per assessment.

By accounting for the energy intensity in these recommendations, a larger effective savings will be shown. By reviewing productivity recommendations, one can calculate the historical effective energy savings for the program and form assumptions for future savings.

First, an overview will be presented on the previous accounting methods for energy consumption savings for a sample year. Then, by using the effective energy savings method, the effective energy savings will then be calculated for the productivity related recommendations and compared to the previous methods of accounting.

Before we proceed, a brief description of the database and how it was searched must be mentioned. A list of reports that contained productivity recommendations was retrieved from the database. The current production level and energy consumption data needed could be calculated from the "Assessment" database. However, it was difficult to measure the NEI since increases in production were not available in the "Recommendation" database. Each recommendation had to be searched individually to find the increase in production. Since this would be an unnecessary lengthy task, a sample year was chosen.

The IAC program began incorporating productivity recommendations into their database in the fiscal year 1997. The initial constraints to the data search were productivity related recommendations since 1997 (searching by Fiscal Years and recommendation type). Since there are thousands of productivity recommendations from all these years, a random year was taken for examination to obtain a sample of results. The year chosen was the IAC Fiscal Year 2000, which contains reports from September 1999 to August 2000. One half of these reports (350 reports) were examined for the study.

On average, an assessment in the year 2000 contained an energy consumption savings of 9,192 MMBtu. The productivity related recommendations in 2000 average an energy consumption savings of –179 MMBtu. A 50% sampling of the recommendations made in the year 2000 with productivity related recommendations were reworked using the EES method. From this sample, each recommendation was ascertained if this would fit the model for the EES method. For this step, all that was required was that a change in production was made and, to check if additional energy costs were (if any) included. If the recommendation did fit the model for the EES method, the necessary information was collected from the report that could not be included in the database due to its constraints. Once this information was collected on a spreadsheet, the EES calculations were automatically computed and the results were known.

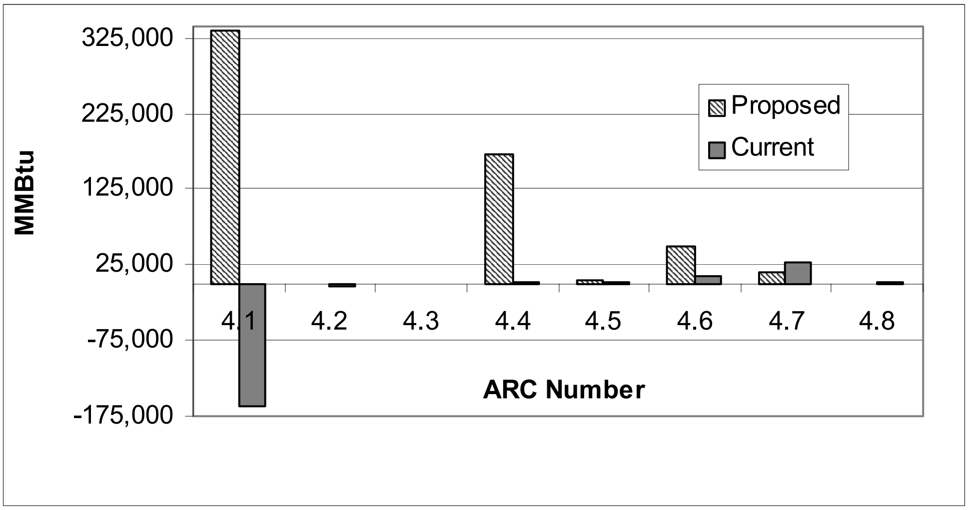
From 50% of the reports, the total Effective Energy Savings was 628,466 MMBtu. If it is extrapolated over all 700 reports, an Effective Energy Savings of 1,256,872 MMBtu is achieved. These results yield a change in the average productivity recommendations for 2000 to 1,800 MMBtu.

In order to view the overall impact on the IAC program and its goals, the sampling will be used to estimate energy consumption savings for the program as a whole since the beginning of productivity related recommendations into the program. In table 2, the value of the impact has been estimated to include savings from productivity related recommendations since its implementation in 1997. With the Effective Energy Savings method, it is predicted that the accounted consumption savings each assessment will be 15, 882 MMBtu. This translates into an additional energy consumption savings of 8,590,488 MMBtu. Therefore, by accounting for the energy intensity of productivity related recommendations, they not only become a large dollar saver for manufacturers, but a value to technical assistance programs.

	1997 to Present (4152 Assessments)		2000 (700 Assessments)	
	All Recommendations	Productivity Recommendations	All Recommendations	Productivity Recommendations
Current Method	13,813 MMBtu	269 MMBtu	9,192 MMBtu	(179) MMBtu
EES Method	15,882 MMBtu	2,069 MMBtu	11,171 MMBtu	1,800 MMBtu

In an attempt to organize the information obtained during the IAC assessments in the IAC "Recommendation" database, a coding system was developed called the A*ssessment Recommendation Code (ARC)*. By examining the type of recommendations that exhibited an effective energy savings by ARC number, a pattern was found that would indicate what type of productivity recommendations could be expected to have high effective energy savings. These recommendations would be encouraged while the recommendations with effective energy consumption cancelled from the program. These results can be viewed in Figure 1. Generally, the productivity recommendations dealing with equipment, labor, or process changes decreased the energy intensity of the plant and increased the effective energy savings. These recommendations are found in ARC numbers 4.1, 4.4 and 4.6. These types of recommendations would be more likely to succeed in a program interested in reducing energy intensity. This information can be useful to the IAC program for their future attempts at reorganizing the ARC Manual.

Figure 1. Energy Savings in Productivity Related Recommendations by Arc Numbers for the Current and Proposed Cases



Conclusions

The ideal goal is to increase industrial productivity and at the same time decrease energy consumption. Since this is not always the case, industry will grow even if energy consumption increases. Therefore, one could only aide industry in growing by reducing its energy intensity. This paper examined how a technical assistance program could aide industry on a plant-by-plant case in reducing its energy intensity and accounting for potential effective energy savings. Using the effective energy savings method, energy accounting can be applied to give a energy savings based on the plants current conditions and recommendations.. Originally it appeared that productivity related recommendations are not aiding in the IAC's program mission to save energy. However, one must consider that the ideas presented in these productivity recommendations are good ideas that should be implemented. By reducing the energy intensity (energy per production unit) and finding the specific energy consumption, there exists a new way to account for productivity related recommendations. This method can justify productivity recommendations in energy auditing programs.

To incorporate this process, the problems encountered need to be solved while conducting the research for this paper. With the current layout of the database, it becomes very difficult to directly calculate energy savings with the EES method. The database does not track changes in production. Attempts are currently being made to improve the IAC database. To track the energy impacts of productivity assessment recommendations, a new resource code was added to the database. The P3 resource code will indicate productivity improvement associated with an assessment recommendation. This resource code will track the increase in production as a percent of the current production.

The ARC manual can also be reorganized to segregate recommendations that affect energy consumption and by recommendations that are just operational or administrative. Eventually, the IAC program (and other energy audit programs) can begin to gear their productivity recommendations to those equating a decrease in energy intensity and an increase in the effective energy savings.

Now that a method has been established for productivity based recommendations impact on energy savings and has been proven effective, it is time to take it to the next step. One step would require testing it on other databases. However, we believe this would yield similar results. Therefore, incorporating the effective energy method into databases or accounting methods for productivity related recommendations should be considered the next step until a better method is presented and tested.

Acknowledgements

Special thanks are extended to Mr. Fred Glaeser, the database Analyst from the Center for Applied Energy Systems, for his assistance with the IAC database. Also, special thanks are extended to Jill Mesonas and Siddika Pasi for their assistance.

References

[DOE] Department of Energy. 2001. *National Energy Policy: Reliable, Affordable and Environmentally Sound Energy for America's Future*. Available online: http://www.whitehouse.gov/energy/chapter4.pdf. Washington, D.C.: U.S. Department of Energy.

[EERE] Office of Energy Efficiency and Renewable Energy, Department of Energy. 2003. *About the Office of EERE*. Available Online: http://www.eere.energy.gov/office_eere/mission.html. Washington DC: U.S. Department of Energy.

[EERE] Office of Energy Efficiency and Renewable Energy, Department of Energy. 2002. *Strategic Plan*. Available online: http://www.eere.energy.gov/office_eere/pdfs/fy02_strategic_plan.pdf. Washington DC: U.S. Department of Energy.

Finman, Hodayah, and John "Skip" Laitner. 2001. "Industry Energy Efficiency and Productivity Improvements." *Proceedings of the 2001 ACEEE Summer Study of Energy Efficiency in Industry, Proceedings Volume 1, Increasing Productivity Through Energy Efficiency,* 561-570. Washington, DC: American Council for an Energy Efficient Economy.

Mitrovic, Bojan and Michael R. Muller. 2002. "Energy Impacts of Productivity Improvements in Manufacturing." Industrial Energy Technology Conference. Houston, TX.

Muller, Michael R. and Donald J. Kasten. 2000. *The ARC, Assessment Recommendation Code System for the DOE Industrial Assessment Center Database, Version 8.0.* New Brunswick NJ: Rutgers, The State University of New Jersey.

Muller, Michael R., Fred Glaeser and Carole Trabachino. 2001. *The DOE Industrial Assessment Center, User Information, Version 8.1*. New Brunswick NJ: Rutgers, The State University of New Jersey.

Ruth, Michael, Ernst Worrell and Lynn Price. 2001. "A Process-Step Benchmarking Approach to Energy Use at Industrial Facilities: Examples from the Iron and Steel and Cement Industries," *Proceedings of the 2001 ACEEE Summer Study of Energy Efficiency in Industry, Proceedings Volume 1, Increasing Productivity Through Energy Efficiency,* 149-160. Washington, DC: American Council for an Energy Efficient Economy.

Sun, J.W. 2003. *The natural and social properties of CO_2 emission intensity.* Energy Policy, 31 (3):203-209.

Vieth, Jill and Drew Malcomb. 2003. *Bush Administration Launches 'Climate VISION'.* Available Online: http://www.energy.gov/HQPress/releases03/febpr/pr03037.htm. Washington, D.C.: U.S. Department of Energy.