STATISTICAL ANALYSIS OF ENERGY CONSUMPTION IN US MANUFACTURING

by

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Abstract

This study examines aggregate energy consumption data from the US manufacturing sector to identify drivers of energy efficiency in industrial processes. In particular, the study explores whether the presence of high regional electricity prices induces decision-makers to operate more efficiently. Regional energy utilization intensity (EUI) figures indeed indicate a correlation between energy efficiency and electricity prices, but several outliers defy this trend and provide insights into the idiosyncrasies of certain industries which insulate them from internalizing the financial impact of excessive energy consumption, even in the presence of high electricity prices. Namely, high EUI figures are correlated with onsite generation and processes reliant upon fuels as opposed to electricity. Location along the supply chain also impacts apparent energy consumption with low-margin commodities resulting in higher EUI due to their lower denominators in the determining formula (MJ\text{s} per dollar of product shipped) and vice versa for higher-margin products. In addition to this mathematical quirk, the study identifies other shortcomings of the data, discussing their implications and options for their rectification.

Problem Definition

While experts agree that a multitude of cost-effective energy reduction schemes abound in the private sector, management often forgoes NP\textsuperscript{V} positive projects in energy efficiency that would deliver shareholder value in addition to their substantial positive externalities in the form of carbon reduction. These profitable efficiency investment opportunities have been chronicled in
top-down studies such as the McKinsey abatement curve (see figure below)\(^1\) as well as industry-level analyses by, among others, the National Association of Manufacturers.\(^2\)

Despite philosophical support from its own trade group, manufacturing remains one of the most inefficient sectors in the US economy. While the country as a whole averages around 9 mega joules of energy consumed per dollar of GDP, manufacturing census data indicate that industry consumes on average 8.6 mega joules per dollar of product shipped, not including the remainder of the lifecycle impacts such as transportation, consumption, and disposal.\(^3\) Likewise, 1/3 of the energy consumed in the US goes to this sector, and with transportation a close second, a sizable portion of that footprint might be allotted to manufacturing as well.\(^4\) Moreover, while industrial output may be declining as a share of GDP

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\(^1\) [http://www.mckinsey.com/Client_Service/Sustainability/Latest_thinking/Costcurves](http://www.mckinsey.com/Client_Service/Sustainability/Latest_thinking/Costcurves)


as the US continues its shift toward a service-based economy, efficient management of the dwindling sector’s constrained economic resources remains more important than ever before.

This study does not intend to explain the reasons behind these forgone investments in energy efficiency. Others have tackled the drivers behind this mismanagement extensively. The Lawrence Berkeley Lab has chronicled the impact of the principal-agent problem upon energy consumption decisions throughout various sectors, indicating that this market failure may insulate decision makers from the impact of price signals.\(^5\) To counteract the impact of the principal-agent problem, corporations have long-incorporated stock options linking the financial outcomes of the firm with managers’ compensation packages.

We may also assume that short-term decision making and moral hazard also play significant roles in forgone efficiency investment during capital budgeting, especially considering the job insecurity hanging facing decision makers as this sector competes with low-cost providers in developing countries which engenders risk aversion and managerial inertia on the part of manufacturing managers. In terms of hedging against that specific problem, Oxford economists have identified bonus deferment schemes as an effective deterrent against mistaken short-term management.\(^6\)

Finally, we cannot underestimate the impact of limited financial resources in a zero-sum capital budgeting process. In any attempt to solve this capital budgeting impediment, the American Recovery and Reinvestment Act has allocated over $150 million to support industrial efficiency projects, including district heating infrastructure and individual grants to cash-strapped

\(^6\) http://www.economics.ox.ac.uk/index.php/papers/details/department_wp_571/
enterprises. Indeed, theories abound for the causes and potential remedies for forgone efficiency investments, or any NPV-positive managerial actions for that matter.

Instead of attempting to explain these drivers any further, we will analyze an aggregate data set from the US Census Bureau called the Manufacturers Energy Consumption Survey (MECS) in search of further clues to specific conditions in which these impediments to efficiency investment appear to be worst. Hopefully, ascertaining the microeconomic scenarios in which management seems especially inhibited from investing in energy efficiency might help policy makers and shareholders to preemptively encourage energy efficiency investment in at-risk management populations. The data available are admittedly imperfect, and likewise, I also suggest possible steps to improve upon our access to information in this realm and areas in which further research may help expand our understanding of this pervasive problem.

**Overview of the MECS survey**

The data set utilized in this study is sponsored by the Energy Information Administration (EIA) of the Department of Energy with the US Census Bureau acting as its collection agent. While other data sets such as the Annual Survey of Manufacturers also provide information on this sector, the Manufacturing Energy Consumption Survey (MECS) provides the only aggregate data set devoted to energy consumption in its eponymous sector. The study polls a 15,500 sample of companies from various sectors stratified according to the North American Industry Classification System (NAICS); this polling occurs quadrennially, although the most recent data

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8 http://www.census.gov/econ/overview/ma0400.html
used here are from 2006. The data collected subsequently provide feedstock for a multitude of studies (in addition to this one) conducted by the Bureau of Economic Analysis as well as the EIA’s own National Energy Modeling System (NEMS) and Annual Energy Outlook (AEO); the data are also shared with the International Energy Agency to provide a profile of US industrial energy consumption to the outside world. Survey respondents are required by law under the Federal Energy Administration Act of 1974 to participate, with civil penalties levied between $2,750 and $5,000 per diem.

**Hypothesis**

The MECS survey provides an invaluable glimpse into the energy consumption profile across the various NAICS industrial classes, oftentimes cross-referenced by census region. In dissecting the MECS data, we would expect those industries deploying a higher proportion of energy management personnel and auditing/control activities would receive greater efficiency results and that these results would be proportionate. We would also expect industries operating in regions of higher relative energy prices would also display a greater relative tendency to deploy such strategies and that these results would be proportionate to the discrepancy in energy prices between regions.

**Methodology**

This study deploys comparative analysis of descriptive statistics, and scatter plots of MECS data with a focus on regional and behavioral breakdowns. More rigorous statistical methodology

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9 [http://www.census.gov/econ/overview/ma0400.html](http://www.census.gov/econ/overview/ma0400.html)
10 [http://www.census.gov/econ/overview/ma0400.html](http://www.census.gov/econ/overview/ma0400.html)
11 [http://bhs.econ.census.gov/bhs/mecs/SUR84_158.html](http://bhs.econ.census.gov/bhs/mecs/SUR84_158.html)
such as multivariate regressions proved infeasible due to the varying disaggregation of the data across the various tables. For example, regional breakdowns were provided for energy intensity metrics but forgone for employment profiles and efficiency initiatives, making a cross-section regression impossible. Another challenge encountered throughout this process included how to normalize disparate metrics for comparison, which was tackled through a standardized energy utilization intensity (EUI) as MJ per dollar of product shipped. Although this choice carries its own shortcoming which we will discuss later. Again, while EUI data were provided in the survey according to region, other metrics such as the employment of energy efficiency managers or the participation in certain energy auditing/control activities were not delineated by region, which impeded application of the hypothesis to all of the survey’s indicators.

**Results**

As expected, energy utilization intensity (EUI) proved generally lower in regions with high electricity prices – namely, the northeast and west (regions 1 and 4) – and vice versa in the two low-cost regions. EUI may be used as a proxy for our efficiency hypothesis as it indicates MJ per dollar of
shipped product; lower values indicate greater efficiency, and while high values correspond with more energy-intensive processes, the data can be further teased to compare the same industries across regions in addition to the bird’s-eye comparison of the regions as a whole. Interestingly, total average manufacturing intensity per dollar of product shipped fell below the national average per dollar of GDP. This does not indicate that the manufacturing sector is especially efficient compared to the rest of the economy; on the contrary, this imbalance naturally emerges from the omission of transportation energy intensity from the value chain in the MECS data, while transportation obviously pertains to broader GDP EUI metrics.

Descriptive statistics give us a clearer picture of the volatility and general tendencies of the various regional data. While the Northeast has both the lowest mean and standard deviation, the South and Midwest are the least efficient on average, while the latter proves much more volatile than the former. The West, on the other hand, proves of average efficiency (with an identical mean to the dataset as a whole) but also the most volatile in terms of outliers.

As an explanation for this volatility, we will analyze the specific outliers in the data shortly. However, on a general note, it proves interesting to compare the rates of industrial price discounts along regional lines. Because only those businesses exceeding 200 kilowatts of average power demand qualify for the industrial price discount, we would expect that regions offering the highest discounts in this regard would result in higher volatility in the data. This contention naturally emerges from my primary hypothesis because, if electric price signals in fact drive energy efficiency investment, then the varying severity of these price pressures across businesses of different sizes should result in higher volatility within data from identical regions. Indeed, that assessment generally holds true, although outliers such as the proceeding price-insulated industries skew the relationship nonlinearly.

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Outlier Analysis

After cross-referencing the NAICS industry codes with the outliers, some general trends emerge indicating how and why certain industries may be insulated from the electricity price signal at the center of my hypothesis. First, these industries tend to be independent from regional electric prices due to their utilization of onsite electricity generation or stored fuels in their production processes instead of grid power. Secondly, their location along the supply chain typically impacts their profit margins, with upstream, high-volume commodity markets commanding lower margins than their downstream counterparts. Due to the determining formula in EUI calculation (MJ/$ of product shipped), this mathematical quirk results in generally-descending EUI metrics as we move downstream.

With these drivers in mind, we find another explanation for the high volatility of the Western region as we look to the consumer electronics and iron industries operating in the region. Again, because the EUI data measure industry efficiency in terms of dollars of product shipped, highly competitive commodity markets such as semi-conductors are penalized for their low-margins. The decline in poly-silicon value has exacerbated this effect, in addition to the fact that

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14 These data from 2012 meant to illustrate discount ratios but are deflated from the 2006 prices impacting the rest of this analysis due to the economic downturn and proliferation of cheap shale gas. Derived from http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epm_5_6_a
semiconductor manufacturers are facing excess capacity utilization currently.\textsuperscript{15} The fixed energy consumption costs associated with their plants cannot be amortized into the value of their shipped product because of the aforementioned glut of poly-silicon and the commoditization of semiconductors on the global market. Thus, semiconductors have various extraneous pressures buttressing this high EUI metric.

Iron, on the other hand, is an inherently energy intensive process in which we would expect managers exposed to electricity prices would behooved to pursue efficiency. But the inputs into mining and smelting are basically detached from regional electricity prices. Although diesel prices may be high in the coastal states, much of the mining occurs in the interior of the region where fuel taxes loosen dramatically. Smelting would also be strategically positioned in the eastern corridor of the region for staging to automobile manufacturers and “steelers” in the Midwest. The fuel inputs for this process depend upon the melting point of the metal involved. Low melting point alloys such as zinc or tin will typically utilize electric furnaces which would accordingly subject the manufacturer to regional electricity prices. Interestingly, such so-called “nonferrous” metals which do not contain iron turn out to fall on the more efficient side of the spectrum in this region (below 1

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{iron_smelting_eui_by_region.png}
\caption{Iron Smelting EUI by Region}
\end{figure}

MJ/$ product) because of their exposure to electricity prices. On the other hand, iron’s relatively high boiling point (4-5 times higher than nonferrous metals) requires a much hotter furnace, typically burning coke. This fuel input is a byproduct of oil refineries and thus exists in a separate realm of commodity prices from regional electricity rates. Consequently, regardless of electric price region, the iron industry outstrips its manufacturing counterparts in terms of EUI.

Again, while industry in the Northeast generally exhibited sensitivity to electricity prices, comparably high prices did not deliver the same efficiency effects across the board in the west. We may also attribute this aberration to the prevalence of wood products manufacturing in that region, with the propensity to utilize biomass trimmings for on-site electricity generation and decoupling from the pressures of regional electricity prices. Indeed, this effect of onsite electricity generation in buttressing net energy demand holds true across industries and regions. By conducting a regression between onsite electricity generation and net electric demand, we find a strong correlation of nearly 0.8.

Moreover, by isolating the paper industry data and comparing across regions, we find that the industry’s highest EUI readings were reported by manufacturers in the Western region. In addition to the price insulation derived by the generation of onsite electricity via biomass trimmings, the anomaly of higher EUI in an expensive electric region may also be thanks to

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16 http://en.wikipedia.org/wiki/Foundry#Melting
cheaper rates in the hydro-powered Northwest were most wood products industry activity occurs.

A multitude of other counter-intuitive insights emerge as we delve into the idiosyncrasies of outliers within the data. Paradoxically, we see the same industry represented in both the “good” and “bad” buckets, vis-à-vis EUI. Take transportation products, for instance. While “automobile production” stands out as one of the least energy intensive manufacturing processes, “transportation equipment” turns out to be one of the worst consumers of energy on a per dollar basis. Again, this ties back into the metrics utilized in the MECS analysis. While the component suppliers to the car companies must stamp steel to produce low-margin supplies to ship to automobile manufacturers, their customers merely put together these various energy-intensive parts through a streamlined (hence, efficient) assembly-line process. This dual outlier comparison (one high, one low) speaks to the inequitable comparative analysis that we may conduct by reacting to these data at first blush.\textsuperscript{17}

Additional insights may be gleaned from apparent contradictions between rates encountered in the electric power market versus the more commoditized nature of storable fuels utilized for on-site generation of power and heat for production processes. These disconnections prove

\textsuperscript{17} http://www.eia.gov/emeu/meecs/meecs2006/2006tables.html
especially concerning when evaluating the balance of energy equation for petrochemical production, namely oil and gas. While the highly consolidated petrochemical industry was able to withhold proprietary information for disclosure, the chemicals sector as a whole consumed over 200,000 GWh of electricity, which is more than a fifth of all industrial electricity consumption for a manufacturing subsector accounting for about 10% of GDP.\(^\text{18}\) Compounded by the extraction and transport of crude feedstock, such skew in the energy balance (so-called energy cannibalism)\(^\text{19}\) casts further doubt upon the well-to-wheels efficiency of fossil fuels for transportation.

\[\text{Lime EUI by Region}\]

In addition to petrochemicals, lime production proves especially independent of regional electricity prices and consequently results in the most energy intensive manufacturing process across the board. Throughout the process of drilling into limestone, blasting out the rock, and trucking the material to crushing facilities, this sector rarely encounters the regional electric price signals at the center of our hypothesis. With this phenomenon in mind, we may test a corollary hypothesis that the lime industry will tailor its energy intensity according to the dominant price signal in their decision making – namely,

\(^{18}\) http://data.worldbank.org/indicator/NE.EXP.GNFS.ZS  
\(^{19}\) http://www.azimuthproject.org/azimuth/show/Energy+cannibalism
diesel prices. Indeed, the EUI readings for lime production closely mirror the price profile for gasoline (and thus diesel) prices by region. While the cheapest prices abound in the rocky mountain region of the West, the highest diesel price signal occurs in the Northeast.

Accordingly, EUI of lime production peaks in the Western region and proves least intensive in the Northeast.

Regular grade gasoline prices at retail outlets by region
for March 12, 2012 (dollars per gallon, including taxes)


**Linking Supply Chain Location to EUI**

In the same vein as our discussion of outliers, a general sketching of winners and losers vis-à-vis energy utilization intensity provides insights into how efficiency investment decisions and capabilities might be influenced by the idiosyncrasies of certain industries, notwithstanding their relative burden of regional electricity rates. Moreover, as we think about the connections between these disparate NAICS classifications, we can trace the leakage of energy utilization intensity to further clarify our understanding of what drives manufacturing energy consumption on an aggregate level.
As alluded to in our discussion of outliers, high-ticket items such as automobiles and aircraft result in low energy intensity ratings because of their heavily weighted denominators in the EUI formula \((\text{MJ}/\$)\) of product shipped. In other words, expensive products appear energy efficient regardless of how consumptive they may be in reality. This same effect holds true for computers and pharmaceuticals, as well as little-known additives to iron smelting called electrometallurgical ferroalloys. Additionally, nonferrous metals (including gold, brass, and anything else non-iron) fit this description of expensive products that may be hiding their energy intensity through high sticker prices.

Some efficient performers buck this trend of high-prices and thus presumably operate at high efficiencies despite the EUI formula’s bias towards expensive products. Sugar, for instance, falls far below the average EUI of the sample but pales in comparison to the exorbitant prices in the aforementioned industries. Producers of non-cellulosic organic fibers (i.e. nylon and polyester) also prove efficient manufacturers on average despite their low cost product. Notwithstanding these favorable indicators, though, we should not necessarily commend these industries for their efficiency because of the aforementioned problem of EUI leakage across the supply chain which typically penalizes upstream providers of commoditized materials and other low-cost component parts. The last step in the supply chain may not require extensive consumption of energy to, for instance, divvy sugar into packets and sacks or spin polyester into fabric; however, the preceding processes may be extremely energy intensive, including sugar cane cultivation, transport, and refinement and, alternatively, the extraction of oil and refinement of the input polymer.
On that note, the following discussion of the relatively inefficient sectors must carry the dual
caveats of low prices inflating EUI metrics and the general energy subsidization of downstream
consumption. Many of these energy intense industries supply commodities to highly
competitive global markets where high volume and low margins necessarily depress the
denominator in the EUI calculations. Accordingly, as most of the economic value is added
downstream by consumers of these commodities, these supplying industries essentially
subsidize the energy consumption of their customers. For instance, iron smelting, aluminum
foundries, and even semiconductor manufacturers all provide commoditized products to the
downstream consumers mentioned earlier in this section who apparently lead the pack in
terms of EUI; on the other hand, their suppliers provide some of the most outstanding outliers
on the high-end of EUI, so a fair assessment of either side of the spectrum should take into
account this relationship between outliers on either extreme. Again, this distortion of real EUI
impacts calls for a systems-based approach such as input-output analysis.

Of course, some industries are inherently inefficient regardless of their product value or
location along the supply chain. Cement, for instance, lies somewhere along the middle of its
supply chain, with mining, lime, and petrochemicals all preceding its production.²⁰ Interestingly,
each of those steps are also highly energy intensive in their own right, and the downstream
consumption of cement through construction is energy intensive as well; however, construction
(as well as mining) is not part of this survey because it falls outside the EIA definition of
manufacturing. In any case, cement provides an example of a middleman adding value to
commodities but still exhibiting extraordinary energy intensity.

²⁰ http://en.wikipedia.org/wiki/Cement#CO₂_emissions
Food manufacturing also provides several cases in which the intermediate, value-adding industries still display high EUIs. From beverages and tobacco to fruits and vegetables to dairy processing and even animal slaughtering, each of these industries proves highly energy intensive despite their central location along the supply chain. As with sugar, we expect the lion’s share of energy intensity to fall under the cultivation step of production, but unlike the efficient process of packaging sugar, the processing of these food products contradicts the trend of downstream efficiency. Because of the perishability of these products versus the longer shelf life of sugar, their EUI metrics are inflated by the inevitable need for refrigeration in every step of their production processes.

Animal slaughtering provides an especially interesting case within food manufacturing because, although generally less energy intensive than average manufacturing processes, its higher EUI in the West versus other regions bucks the trend established in our hypothesis. Stricter regulatory norms in California may cause this anomaly. While it may pain environmentalists to consider the tradeoff between animal welfare and energy efficiency, EUI readings double between the two high-price regions as manufacturers grapple with more stringent animal cruelty standards in the California market.21

The prevalence of waste-to-energy onsite generation at such facilities would also tend to

insulate these manufacturers from regional electricity rate profiles, further clarifying cause for the antithetical EUI profile of the animal slaughtering industry.

**Gap Analysis**

While we applaud the legislation and allocation of resources devoted to the collection of the data utilized in this analysis, the presentation of the information could be modified to facilitate improved future study of manufacturing energy consumption such as this one. While a completely disaggregated dataset with individual firms’ proprietary data would provide the most value, the need for confidentiality will impede such a perfect scenario. That said, the EIA may maintain the confidentiality of its respondents while augmenting the variables across which we may cross-reference the data and conduct informative regressions on the basis of industry, census region, management style, etc. Instead, the data here only cross-reference by region for selected metrics while abstaining for others. Again, such an augmented breakdown of the data would maintain the confidentiality of respondents while expanding opportunities for more rigorous statistical studies.

Despite this authority bestowed by Congress and the substantial financial teeth behind it, the MECS survey still falls short of painting a perfect picture of the energy consumption landscape. While the need to protect of individual respondents’ confidentiality is understandable, this loophole consequently results in a smattering of acronyms across the database redacting information that might expose proprietary profiles of energy consumption. We would presume this shortcoming would occur most often in consolidated industries with too few actors to maintain anonymity. Indeed, upon further inspection and cross-referencing with NAICS codes,
data were withheld most often in consolidated industries such as plastics, petrochemicals, paper, aerospace, etc.  

The other problem with the data reveals a shortfall across the manufacturing sector as a whole—namely, ignorance of one’s own energy consumption. Oftentimes, the answer “Don’t Know” constitutes the majority of responses to certain questions, which indicates that many companies have little-to-no staff who are responsible for managing their energy consumption, or even accounting for it. Indeed over half of all manufacturers reported not only forgoing the hiring of a manager dedicated to energy issues but forgoing any of the energy management initiatives listed in the survey; many more again answered “Don’t Know,” which implies the same lack of dedicated staff on their payrolls or efficiency initiatives in their operations.

With this understaffing in mind, another of the data’s shortcomings pertains to accuracy and relates to the extensive structure of the questionnaire itself. With over 200 questions across over 60 pages, the survey presents an arduous task for managers to tackle, and although including such a myriad of questions intends to provide the clearest picture of energy consumption possible, fatigue and/or irritation on the part of the respondent might erode the accuracy of responses.  

Although required by law to reply to the census, it is unclear what penalties, if any, would apply to inaccurate responses, and with over 15,000 establishments included in the data, enforcing such a statute would be infeasible. Alternatively, the data should include information on statistical quality, such as prediction errors, which would not correct inaccuracies but would further clarify the reliability of this self-reported dataset.

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22 www.OneSource.com
Another interesting insight from identifying EUI outliers again pertains to the effect of the per dollar denominator upon determining relative industry efficiencies. Under this scheme, aircraft production appears to be one of the most efficient processes known to man. The huge sticker price for aircraft puts downward pressure on the denominator and pulls the EUI metric below 1 MJ per dollar of product; however, the absolute energy consumption of this sector is quite high (20 trillion BTUs per year – or about one half of the entire US automobile industry). Moreover, as with autos, the aluminum smelting and fabrication into component parts involves massive consumption of electricity and other fuels; however, those inputs are not factored into the ultimate footprint for which the aircraft manufacturer is subjected.\(^{24}\) Thus, an input-output assessment taking a systems approach to the data would help clarify these interconnections.\(^{25}\)

As we have seen through the preceding outlier analysis, the apparent profiles of relative efficiency may not convey the reality in which energy utilization is distributed across the supply chain. That said, while the per dollar approach to calculating EUI may unfairly identify winners at the expense of losers, shifting the metrics to a volume- or employee-based approach would create its own misconceptions, penalizing high-volume or labor-intensive manufacturers unfairly. Taking a cue from the realm of Lifecycle Analysis (LCA), a basic utility function could be instituted to normalize these results (by, for instance, determining the contribution of the product to a specific function), although such an approach would be more costly and would carry its own distortive effects.\(^{26}\) For instance, while institutions such as Carnegie Mellon provide user-friendly tools for LCA comparisons, undertaking such a process for the hundreds of

\(^{24}\) \url{http://www.eia.gov/emeu/mecs/mecs2006/2006tables.html}

\(^{25}\) \url{http://www.investopedia.com/terms/i/input-output-analysis.asp#axzz1tC4Kw1Sk}

\(^{26}\) \url{http://www.eia.gov/emeu/mecs/mecs2006/2006tables.html}
points in the dataset would require significant time and thus money. Moreover, such an LCA approach would further aggregate the data and increase the difficulty of teasing out nuances in market behavior as I have attempted in this study.

While these alterations in the presentation of the data each carry their own benefits and drawbacks, they are by no means mutually exclusive. Thus, such a multi-pronged approach to fleshing out the information in as many ways possible would better serve the business community and policy makers as we attempt to understand the drivers of energy efficiency investment in US manufacturing.

**Next Steps**

Whether or not future publication of the MECS dataset address these shortcomings, a multitude more studies may be conducted to improve our understanding of energy consumption in the manufacturing sector. For one, a firm-level case study of energy efficiency investment decisions may take a deep dive into one particular industry while disguising the identity of the firm in question. In the event that no firms are willing to risk exposing their proprietary information (and thus profit margins, risk-profiles, etc.), further research could take one or two industries in particular to analyze the best and worst actors regarding energy efficiency. While this study took a superficial look at the outliers in the data set and potential reasons for their anomalous profiles, a more rigorous industry analysis could build upon the theories established here and uncover further nuances in the manufacturing landscape. Further research might analyze these MECS data along the lines of policy mechanisms’ severity across

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27 http://www.eiolca.net/index.html
regions. For instance, do regions with more stringent codes of environmental protection display greater energy efficiency? Many other analyses could similarly dovetail with this study by investigating the impact of different profiles in the labor market or the impact of firm size and economies of scale on energy efficiency. Incorporating data from the Annual Survey of Manufacturers along these lines would prove challenging but potentially insightful.

**Conclusion**

This study has shown that regional electricity prices generally impact energy efficiency profiles of US manufacturers. Notwithstanding that general trend, certain industries buck this trend via their utilization of onsite electricity generation or fuel sources independent from grid power. Moreover, industries’ location along the supply chain typically impacts their profit margins and thus their apparent EUI readings dependent upon the formula MJ/$ of product shipped; this results in generally descending energy intensity metrics as we move from upstream providers of commoditized products towards higher profit margins downstream. In addition to this misleading mathematical phenomenon, other shortcomings in the data set require rectification to improve future study of this arena. Ultimately, increased transparency in manufacturing energy consumption will help inform policy makers and business managers optimize their decision making to the mutual benefit of shareholders and the environment.
Works Cited and Consulted


http://www.azimuthproject.org/azimuth/show/Energy+cannibalism

http://bhs.econ.census.gov/bhs/mecs/SUR84_158.html

http://www.caseplace.org/d.asp?d=4616

http://www.caseplace.org/d.asp?d=4254

http://www.caseplace.org/d.asp?d=4438

http://www.census.gov/econ/overview/ma0400.html

http://data.worldbank.org/indicator/NE.EXP.GNFS.ZS

http://www.economics.ox.ac.uk/index.php/papers/details/department_wp_571/


http://en.wikipedia.org/wiki/Foundry#Melting


http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_5_6_a

http://www.eiolca.net/index.html

http://escholarship.org/uc/item/3m1781f1#page-1

http://factfinder2.census.gov/faces/tableservices