# Energy Efficiency Analysis of Manufacturing in Southeast Michigan

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## About Me

Sawyer Smith is a collegiate athlete, former business owner, and is in his fourth year at Wayne State University studying economics and global studies.

## Project Introduction

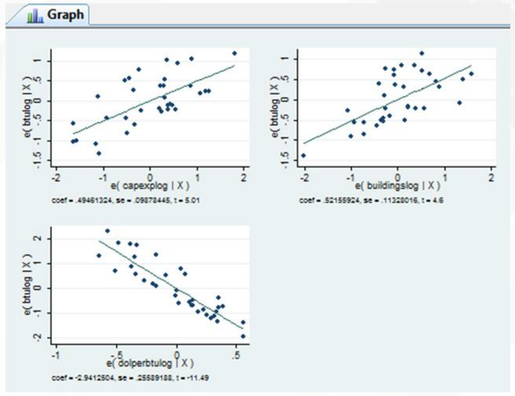
Because of certain constraints, energy consumption data by manufacturing sector is not available at the local or state level. This project solves that problem by highlighting the relationship between energy consumption and the economy and using that relationship to scale down the national level data.

## Relation to Sustainable Manufacturing

Sustainable manufacturing has three parts: Economic, Social, and Environmental. This methodology allows for an insight into energy efficiency at a local level in the manufacturing industry. As data become more available over time, a relationship between economic indicators, social outcomes, and energy efficiency can be formed and strengthened.

## Approach

To gain an insight into what affects energy consumption, a pooled cross-sectional model for 2006 and 2010 was constructed.




| 2006 | | 2010 | |
|---|---|---|---|
| VARIABLES | (1) btulog | VARIABLES | (1) btulog |
| capexplog | 0.651*** | capexplog | 0.495*** |
| | (0.134) | | (0.0988) |
| dolperbtulog | -3.153*** | dolperbtulog | -2.941*** |
| | (0.328) | | (0.256) |
| buildingslog | 0.392** | buildingslog | 0.522*** |
| | (0.153) | | (0.113) |
| Constant | -0.186 | Constant | 0.397 |
| | (1.425) | | (1.218) |
| Observations | 34 | Observations | 35 |
| R-squared | 0.901 | R-squared | 0.923 |
| Standard errors in parentheses | | Standard errors in parentheses | |
| *** p<0.01, ** p<0.05, * p<0.1 | | *** p<0.01, ** p<0.05, * p<0.1 | |

Model: $BTU = \beta_0 + \beta_1 CAPEXP + \beta_2 BUILDINGS + \beta_3 DOLPERBTU + \varepsilon_n$

**Broader trends:** Capital expenditure ratios and building ratios reflect the great recession of 2008. The price elasticity reflects falling energy intensity in the manufacturing industry and the law of demand. The capital expenditure ratio from 2010 will be used.

The methodology for calculating energy efficiency at all levels is as follows:

1.) National level of energy consumption and loss percentage for different types of energy and sectors

$$\varepsilon_{ij} = \frac{\alpha_{ij}}{\sum_{j=1}^{N} \alpha_{ij}} \qquad \mu_{ij} = \frac{\Im_{ij}}{\sum_{j=1}^{N} \Im_{ij}}$$

2.) National to state level conversion using the capital expenditure ratio from the model and detailed process and non-process energy

$$\delta_j = \frac{\theta_j}{\vartheta_j} \times 0.495 \qquad \beta_{ij} = \varepsilon_{ij} \times \beta_j \qquad \beta_j = \gamma_j \times \delta_j \qquad \pi_{ij} = \mu_{ij} \times \beta_{ij}$$

3.) State level energy consumption and loss can then be calculated

$$TEC_j = \sum_{i=1}^{N} \beta_{ij} \qquad TEC = \sum_{j=1}^{M} TEC_j \qquad TEL_j = \sum_{i=1}^{N} \pi_{ij} \qquad TEL = \sum_{j=1}^{M} TEL_j$$

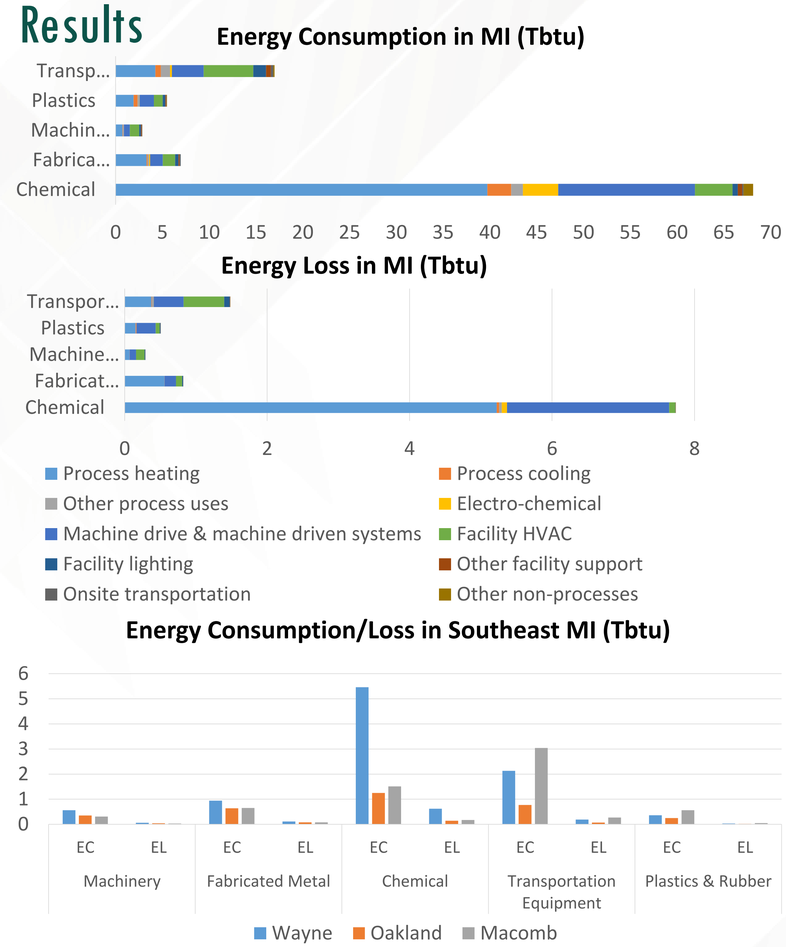
4.) State to county level conversion can be made and calculated using state level results

$$EC_{kj} = \frac{TEC \times \psi_{kj}}{\omega_{kj}} \times 0.495 \qquad EC_k = \sum_{j=1}^{M} EC_{kj} \qquad EL_{kj} = \frac{TEL \times \psi_{kj}}{\omega_{kj}} \qquad EL_k = \sum_{j=1}^{M} EL_{kj}$$

5.) Carbon dioxide emissions can be converted from national to state and county levels with the energy consumption numbers

$$\varsigma_j = \frac{\Omega_j}{\Psi_j} \qquad \tau_j = \phi_j \times \varsigma_j \qquad CE_{kj} = \frac{\tau_j \times \kappa_{kj}}{\ell_j}$$

## Results




### Carbon Dioxide Emissions

| Sector/Region | Michigan (MMT) | Wayne (MMT) | Oakland (MMT) | Macomb (MMT) |
|---|---|---|---|---|
| **Machinery** | 0.31 | 0.06 | 0.04 | 0.03 |
| **Fabricated Metal** | 0.73 | 0.10 | 0.06 | 0.07 |
| **Chemical** | 3.44 | 0.28 | 0.06 | 0.08 |
| **Transportation Equipment** | 1.89 | 0.24 | 0.09 | 0.34 |
| **Plastics** | 0.68 | 0.04 | 0.03 | 0.07 |

## Conclusions and Acknowledgements

The economy has a close relationship with energy consumption and these estimates can be used by policy makers and plant owners. A formal economic impact analysis of energy efficiency can be made at the local level in the future as data becomes more available. This work is supported by NSF REU program (Award No. 1461031). Special thanks to Aida Rankouhi, Majid Moradi, Mohammadmahdi Farsiabi, and Adit Doza.

References

1. U.S. Census Bureau (2010). *Annual Survey of Manufacturers: Geographic Area Statistics: Statistics for All Manufacturing by State.* Retrieved from https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ASM_2015_31AS101&prodType=table
2. U.S. Census Bureau (2007). *Manufacturing: Geographic Area Series: Industry Statistics for the States, Metropolitan and Micropolitan Statistical Areas, Counties, and Places: 2007. Retrieved from* https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ECN_2012_US_31A1&prodType=table
3. *U.S. Energy Information Administration - EIA - Independent Statistics and Analysis. (2010). Retrieved from* https://www.eia.gov/consumption/manufacturing/data/2010/#r1
4. *Manufacturing Energy and Carbon Footprints (2010 MECS). (2010, November). Retrieved August 2, 2017, from* https://energy.gov/eere/amo/manufacturing-energy-and-carbon-footprints-2010-mecs

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