Sustainability at Michigan State University

Wolfgang Bauer
What is the Problem?
Energy Use & Prosperity

2010 Data
Energy: International Energy Agency
Income: World Bank

Energy Use / Person / Year (GJ)

Gross Domestic Product / Person / Year ($)
Atmospheric CO₂

- Concentration between 190 ppm and 290 ppm during the last half million years (ice core samples)
- Near exponential rise from burning fossil fuels since the beginning of the industrial revolution (hockey stick graph)
- 6-7 ppm seasonal oscillations from plant growth and decay
- Net addition of ~2 ppm/year from human activity

**FIGURE 18.28** Concentration of carbon dioxide (CO₂) in the Earth’s atmosphere in parts per million by volume (ppmv). (a) Concentration of carbon dioxide in the atmosphere during the last 420,000 years. The measurements shown are from air samples at Mauna Loa in Hawaii (green) and the South Pole (orange) and various ice core samples from Antarctica. (b) Display of the same data as in part (a), but only from 1000 AD to the present. (c) Display of the same data as in part (b), but only from 2000 to 2012.
Net addition of 2 ppm/year of CO$_2$ to atmosphere
= 16 billion metric tons / year!
= 35 times the weight of all humans on the planet
Global Average Temperature

What are we doing about it?
MSU Energy Transition Plan

• Goals
  1. Improve the physical environment
  2. Invest in sustainable energy research and development
  3. Become an educational leader in sustainable energy

• Timetable

<table>
<thead>
<tr>
<th>Year</th>
<th>Campus Renewable Energy</th>
<th>Greenhouse Gas Emission Reduction</th>
</tr>
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<tbody>
<tr>
<td>2015</td>
<td>15%</td>
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• Approved by MSU Board of Trustees, April 2012
1850: Agricultural College of the State of Michigan

1894: First Power Plant (partial electrification)

1904: 2nd Power Plant

1909: Michigan Agricultural College

1925: Michigan State College of Agriculture and Applied Sciences

1921: 3rd Power Plant

1948: Shaw Lane Power Plant

1965: T.B. Simon Plant

1964: Michigan State University

2016-2018: Re-balancing the T.B. Simon Plant

- Renewables
- Duct bank
- RICE

Image Source: http://onthebanks.msu.edu/Exhibit/1-6-A/history-of-campus-energy-use/
Fuel switch from coal to gas results in CO₂ emission reductions of 575 million pounds per year!
Environmental impact equivalent to planting a half million trees per year!
Campus Electricity Demand (Year 2013)

- Maximum: 60.4 MW
- Minimum: 26.5 MW
- Average: 38.5 MW

Spring term: May 20, 2017

Fall term:
• Totally self-contained micro-grid
• Co-generates all heat and electricity for campus
• ~ 6 TBTU primary fuel consumption
Central Problem: MSU electricity consumption has risen much faster than steam demand. T.B. Simon Plant efficiency decreased over time.

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>Electricity (GWh/year)</th>
<th>Steam (Billions of Pounds/year)</th>
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</thead>
<tbody>
<tr>
<td>1965-66</td>
<td>100</td>
<td>25</td>
</tr>
<tr>
<td>1970-71</td>
<td>150</td>
<td>30</td>
</tr>
<tr>
<td>1975-76</td>
<td>200</td>
<td>40</td>
</tr>
<tr>
<td>1980-81</td>
<td>250</td>
<td>50</td>
</tr>
<tr>
<td>1985-86</td>
<td>300</td>
<td>60</td>
</tr>
<tr>
<td>1990-91</td>
<td>350</td>
<td>70</td>
</tr>
<tr>
<td>1995-96</td>
<td>400</td>
<td>80</td>
</tr>
<tr>
<td>2000-01</td>
<td>450</td>
<td></td>
</tr>
<tr>
<td>2005-06</td>
<td>500</td>
<td></td>
</tr>
<tr>
<td>2010-11</td>
<td>550</td>
<td></td>
</tr>
<tr>
<td>2015-16</td>
<td>600</td>
<td></td>
</tr>
</tbody>
</table>

- Electricity (GWh/year): 25 klb/MWh
- Steam (Billions of Pounds/year): 14 klb/MWh
• Recycling center / surplus store
• Organic waste composting facility
• Geo-thermal array
  • Nursing building
• Anaerobic digester
  • Processing of food waste, reduction of artificial fertilizer use, electricity production
• Solar arrays
• Demand reduction
  • M$10/year energy conservation measures
  • Better building challenge
  • Data center challenge
  • Spartan treasure hunts
Solar Carport locations

LOT 83
49 MW AC

LOT 89
4.75 MW AC

LOT 92
0.84 MW AC

LOT 91
2.05 MW AC

LOT 100
97 MW AC

May 20, 2017
W. Bauer
PPA allows MSU to purchase power at a fixed price over the next 25 years.

2015 public service commission utility rate $91/MWh, but will increase. (DOE-EIA projection: 2.3%/year; last decade: 3.35%/year)

A drop in the cost of electricity would make the PPA unfavorable.

Opportunity costs for the land.

Potential that the technology will become obsolete.

Missing the tax credit windows.

Proposed Carport Solar Solution has financial benefits:

- Projected total net savings ~$10M for MSU over the 25 year PPA period.

Green power is now cheaper than brown power!
account manager: Peter rieks
Project Manager: jordan richardson
construction Manager: jason alphenaar
design engineer: andrew proctor
Purchasing agent: jefferson gerwig

building a brilliant tomorrow™
Saturday, May 13, 7:30 am
Illustrative Example - One day of Campus Demand

Electricity Supply Options
- Solar
- Substation Tie Line
- T.B. Simon Plant

May 20, 2017
W. Bauer
Michigan State University, in an effort to use renewable energy, is in the process of acquiring a solar panel array. The solar panels will be located in the southern section of Michigan State's campus and will cover five large parking lots via carport structures. Solar energy electricity output depends on the amount of light shining at any particular time. Since the electricity output depends upon the current weather a sudden change in cloud cover will create a reduction in the solar panel power output and create costs to import backup power go up greatly.

Our team is developing an early warning system based on remote sensors, which will enable users to anticipate changes in the output of the solar array and take appropriate action in the local profile.

By placing sensors a designated distance outside the solar panel array, a time series of the amount of light can be taken and relayed wirelessly to the control station. A software program takes the data and creates a real-time simulation of the weather around the solar panel array. Using real-time simulation, an early warning can alert users to changing weather conditions.

A sensor and microcontroller will be placed on residential homes around the area. At these locations the sensor data can be uploaded to the residential owners' Wi-Fi and to a server accessible for the software platform.
Senior Engineering Capstone Class Fall 2015

Michigan State University
Team Members (left to right)
Liqing Yao
Bengbu, Anhui, China
Qifan Wang
Jiaxing, Zhejiang, China
Spencer Krug
Grand Haven, Michigan
Nate Vargo
Rochester, Michigan
Tianhang Sun
Wuxi, Jiangsu, China

Michigan State University
Project Sponsors
Wolfgang Bauer
East Lansing, Michigan
Nathan Verhanovitz
East Lansing, Michigan
• 74,000 sqft
• Investment: $13.3 million
• 2015/16 numbers
  • MSU recycled 60% of waste
  • 216 tons of material diverted from landfill
• Public drop-off center
  • > 4 million pounds of recyclables collected
• Surplus store
  • Reusing beats recycling
MSU Anaerobic Digester

- Completed, Sep. 2013
- Research on better microbes, plants, & processes
<table>
<thead>
<tr>
<th>Feedstock</th>
<th>TS (%)</th>
<th>Planned</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(ton)</td>
<td>(%)</td>
<td>(ton)</td>
<td>(%)</td>
<td>(ton)</td>
</tr>
<tr>
<td>Dairy manure</td>
<td>12</td>
<td>7,000</td>
<td>16,000</td>
<td>9,525</td>
<td>10,554</td>
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<tr>
<td>Fruit &amp; vegetable</td>
<td>11</td>
<td>3,900</td>
<td>2,900</td>
<td>2,900</td>
<td>0</td>
</tr>
<tr>
<td>FOG</td>
<td>20</td>
<td>5,000</td>
<td>4,400</td>
<td>3,730</td>
<td>4,747</td>
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<tr>
<td>Cafeteria food waste</td>
<td>10</td>
<td>750</td>
<td>430</td>
<td>440</td>
<td>513</td>
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<tr>
<td>Milk processing waste</td>
<td>12</td>
<td></td>
<td></td>
<td>5,475</td>
<td>4,444</td>
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<tr>
<td>Packing material</td>
<td>90</td>
<td></td>
<td></td>
<td>60</td>
<td>34</td>
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<tr>
<td>Glycerin</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td>88</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td>16,650</td>
<td>23,730</td>
<td>22,070</td>
<td>20,380</td>
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Other materials include waste feed, eggs and one-offs

**Bottom Line:**
- 20,000 tons/year kept out of landfills
- 4,000 MWh/year of electricity generated

*Data: Dana Kirk*
• Study Abroad opportunity
• Biofuels
• Blog: https://deandse2014.wordpress.com
• The greenest energy is the energy we do not consume
• 25 buildings

• 4.6 million sqft
• Participation from Facilities Staff, Students, and Faculty
MSU Pilot Project: Anthony Hall
• Built 1957
• 317,200 sqft

Energy Conservation Measures
• LED lighting, variable speed fans, new steam traps, better insulation, …
• 34% energy savings
• $0.5 million / year monetary savings
• Currently 72 MSU campus data centers
• New central data center
  • Power Utilization Efficiency improvement
  • PUE < 1.3
  • Saves ~10,000 MWh/year
**MSU Energy Transition Plan**

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**Road Map:**

- Engagement of students (and other stakeholders) crucial for meeting ambitious goals

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