



# THE GREEN BREWERY PROJECT

Sustainable Brewing  
Systems, Practices  
and Technology

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Gary Fischer        Kerby Smithson



SCHOOL OF NATURAL RESOURCES AND ENVIRONMENT

# Outline for Today

- Why Sustainable Craft Breweries?
- How:
  - Inventory
  - Measure
  - Analyze
  - Implement
  - Monitor & Evaluate
- Our Findings



Google search terms to locate online resources

# What is Sustainability?

“Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”

- Our Common Future, Brundtland Commission (1987)



# Customers Demand It





# You Can Save Money\*



**\*If you're smart about it**

# A **Culture** of Sustainability



Embody the vision of the world  
in which you want to live



### Building Facts

- 9,000 sq. ft. building in Ypsilanti, MI (c. 1948)
- Opened 2006
- Located in Historic District (restrictions apply)
- Community events venue
- Must preserve aesthetics

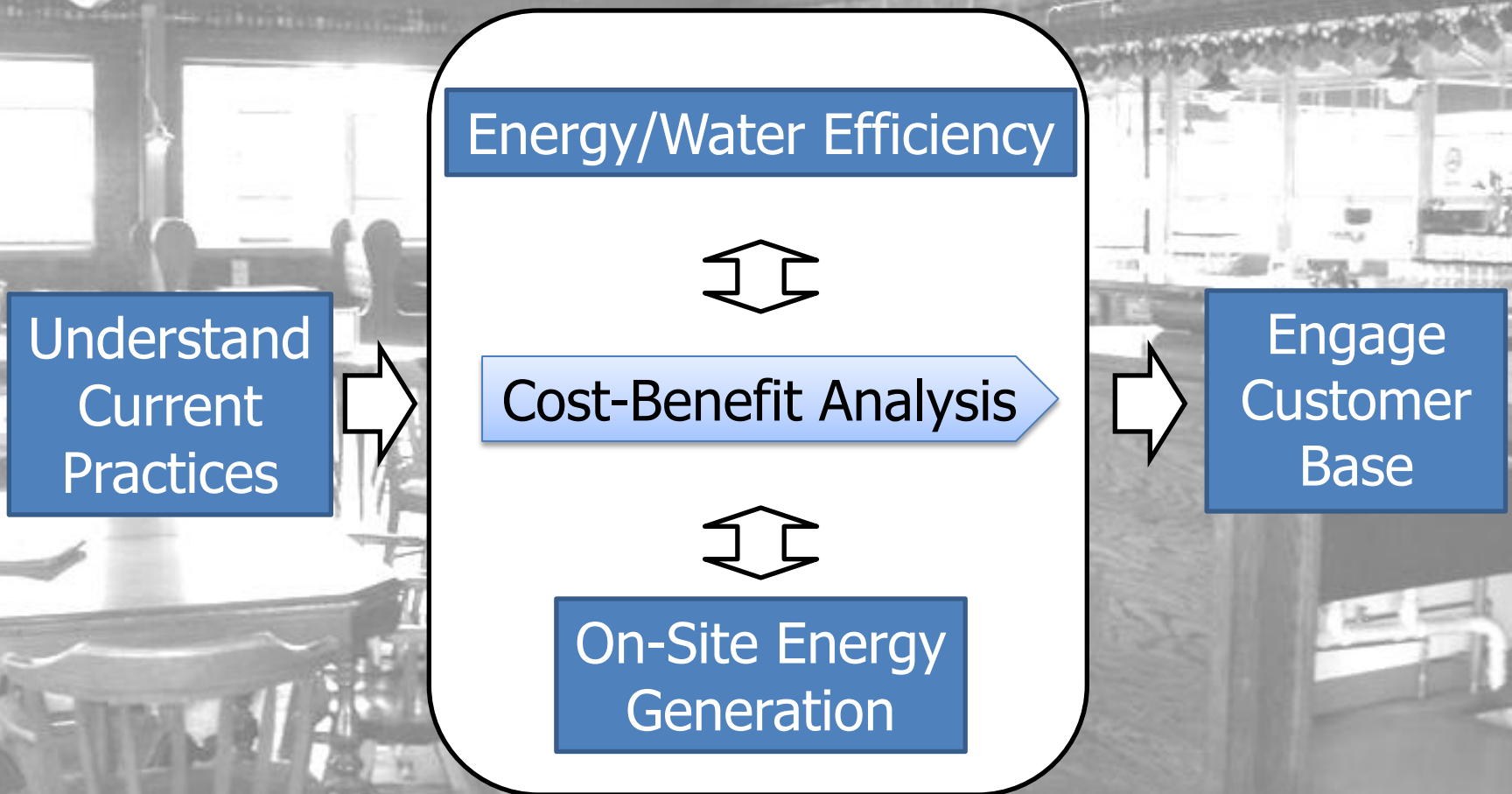
### Brewing Facts

- 3,000 BBL./yr
- Currently distributes in Michigan
- Major expansion planned this year
  - Energy upgrades
  - Capacity expansion



Rene and Matt Greff

# Our Scope





# Step 1. Inventory Resources

## Energy and Water



Audit form includes tools to evaluate:

- Food preparation
- Cooling plant
- Heating plant
- Domestic hot water
- Food preparation
- Lighting
- Renewable resource potential



Washington energy workbook

Introduction

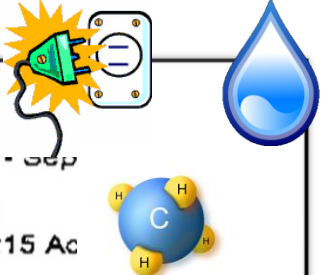
Why Sustainability?

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# Start with Utility Bills



**Current Billing Information**

Service Period Aug 27, 2009 - Sep 26, 2009  
 Days Billed 29  
 Meter Number 9413336 18  
 Meter Reading 8938 Est. - 9215 Ac  
 Difference 277  
 Multiplier 80  
 KWH Used 22160  
 Your next scheduled meter read date is on or around OCT 27, 2009

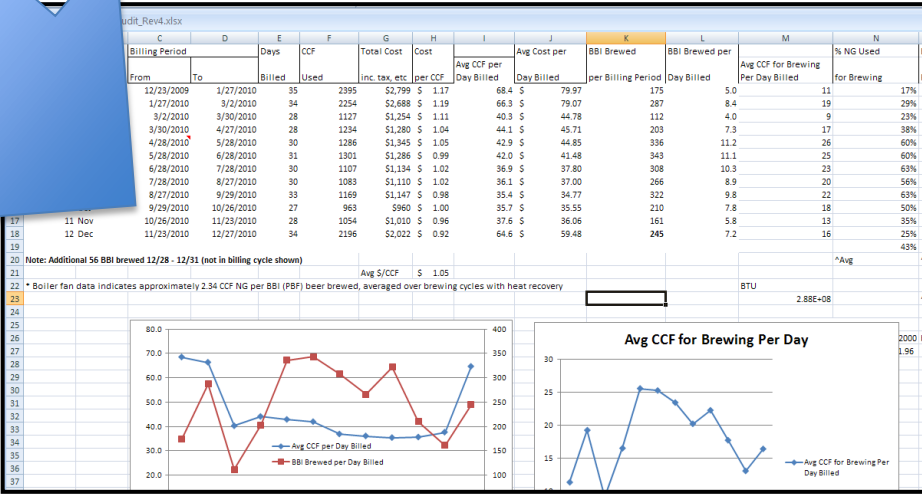
**Usage History - Average per day**

	Current Month	Last Month	Year Ago
KWH Usage	764.1	648.3	651.4
Change		17%	17%



**Current Billing Information**

Service Period Aug 28, 2009 - Sep 25, 2009



## Useful Excel Functions

- =sumif()
- =sumifs()
- =averageif()
- =averageifs()

# Energy: Pull Apart the Pieces

Cooling

Heating



Moving

Lighting

# Energy: Cooling

- Brewhouse Glycol Chiller → { Fermentation vessels  
Cold Liquor Tank
- Cold Room Chiller → Cold storage/refrigeration
- Air Handler → Space cooling





# Energy: Heating

- Boiler → { Brew kettle  
Mash/lauter tun
- Air Handler → Space Heating
- DHW Heater → { Domestic HW  
Bottling line ?
- Ovens, Grills → Food Cooking



# Energy: Lighting

- Brewhouse
- Pub
- Outdoor (perimeter, parking)



# Energy: Moving

- Pumps
- Mixers
- Motors
- Delivery vehicles



# Water

- Brewhouse
  - Mash and sparge
  - Cleaning
  - Bottling
- Pub
  - Drinking
  - Cooking
  - Cleaning
- Lavatories
  - Toilets
  - Sinks
- Other
  - Property irrigation





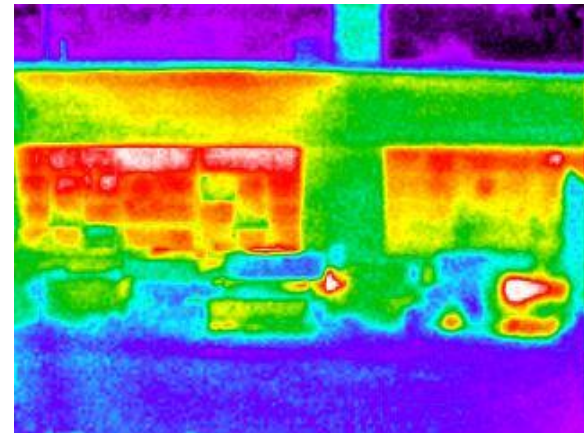
# Step 2: Measure

- Take measurements and make estimates to develop your model



# Building Envelope Study

- Some fixes are easy
- Blower door test
- Thermal imaging
- Energy modeling
  - \*Hire a professional to do safety related items





**HOBO U9 Motor On/Off Data Logger - U9-004**  
**Cheap and easy to use!**



Onset computer

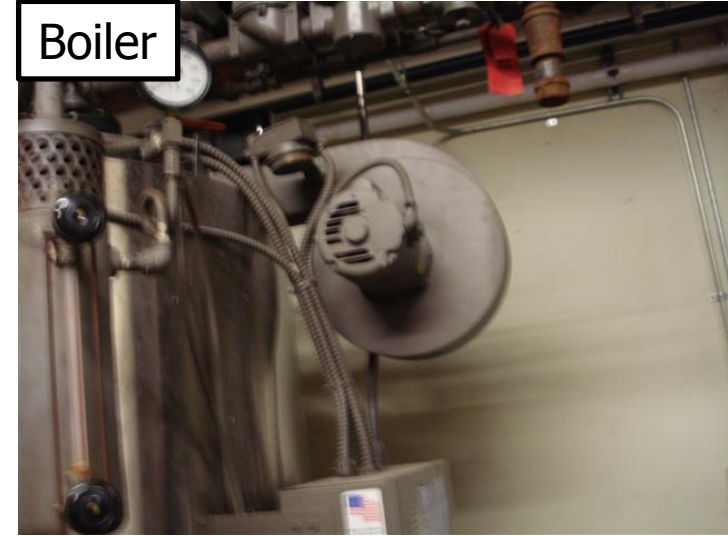


# Sensor Installation

Domestic Hot Water



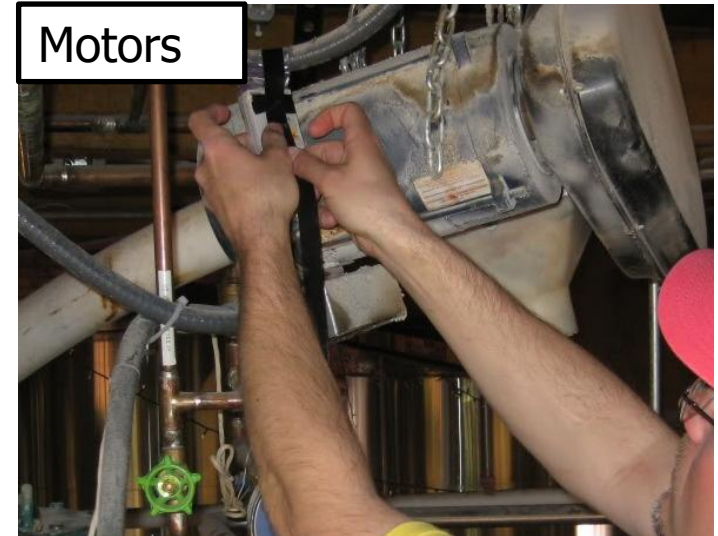
Boiler



Pumps



Motors





# Space Heating: Measure Temperature



# Space Cooling: Measure Air Handler Compressor & Fan Currents

Weather-sealed datalogger (HOBO U12-008)



Rated shock-resistant gloves

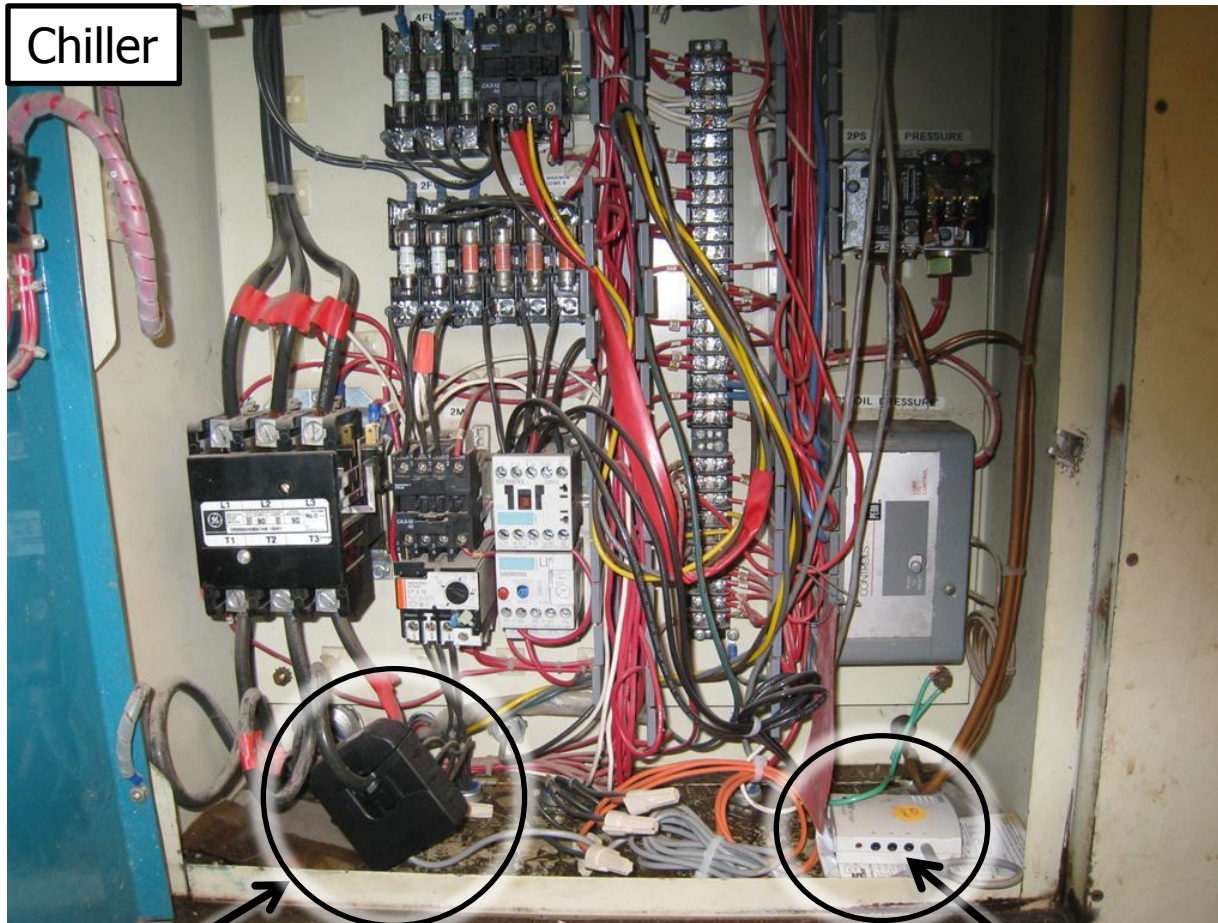
Rooftop Air Handler



Professional HVAC Engineer



# Chiller: Measure Compressor Current, Coolant Flowrate



$$\dot{Q} = \rho \dot{V} C \Delta T$$

Heat Transfer Equation

Current Amplifier

Datalogger

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# Challenges with Motor On/Off State Data Loggers



Small pumps



Portable devices



Vibrating devices



# Step 3: Analyze Data



Download Data

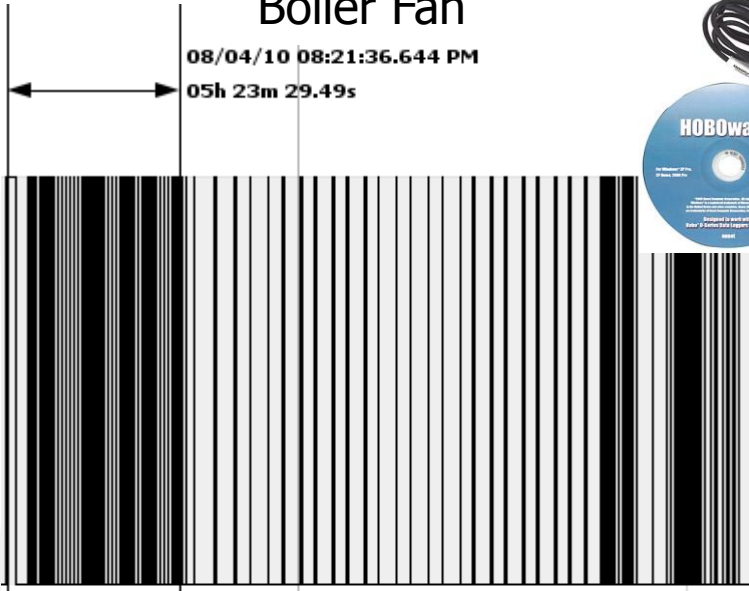
On

Off

Boiler Fan

08/04/10 08:21:36.644 PM

05h 23m 29.49s



Pre-heat HLT

Mash-In

Sparge/Vorlauf/Boil

A	B	C	D	E	F	G	H
2587	2600	05/20/10 07:09	0	0.00533	0.0220	0.0089	48.85
2588	2601	05/20/10 07:24	1	0	0	0	48.85
2589	2602	05/20/10 07:27	0	0.00542	0.0219	0.0086	48.51
2590	2603	05/20/10 07:32	1	0	0	0	48.51
2602	2604	05/20/10 07:35	0	0.00542	0.0219	0.0086	48.51
2603	2605	05/20/10 07:40	1	0	0	0	48.51
2604	2606	05/20/10 07:43	0	0.00538	0.0218	0.0082	48.51
2605	2607	05/20/10 07:48	1	0	0	0	48.51
2606	2608	05/20/10 07:51	0	0.00547	0.0219	0.0086	48.51
2607	2609	05/20/10 07:56	1	0	0	0	48.51
2608	2610	05/20/10 07:59	0	0.00550	0.0219	0.0083	48.51
2609	2611	05/20/10 08:05	1	0	0	0	48.51
2610	2612	05/20/10 08:07	0	0.00551	0.0219	0.0086	48.51
2611	2613	05/20/10 08:13	1	0	0	0	48.51
2612	2614	05/20/10 08:15	0	0.00514	0.0218	0.0082	48.51
2613	2615	05/20/10 08:20	1	0	0	0	48.71
2614	2616	05/20/10 08:22	0	0.00812	0.0218	0.0084	48.71
2615	2617	05/20/10 08:29	1	0	0	0	48.71
2616	2618	05/20/10 08:31	0	0.00514	0.0219	0.0086	48.71
2617	2619	05/20/10 08:36	1	0	0	0	48.71
2618	2620	05/20/10 08:39	0	0.00556	0.0218	0.0083	48.71
2619	2621	05/20/10 08:44	1	0	0	0	48.71
2620	2622	05/20/10 08:47	0	0.00600	0.0218	0.0083	48.71
2621	2623	05/20/10 08:53	1	0	0	0	48.71
2622	2624	05/20/10 08:56	0	0.00597	0.0218	0.0083	48.71
2623	2625	05/20/10 09:01	1	0	0	0	48.71
2624	2626	05/20/10 09:03	0	0.00610	0.0219	0.0086	48.71
2625	2627	05/20/10 09:09	1	0	0	0	48.71
2626	2628	05/20/10 09:12	0	0.00597	0.0217	0.0081	47.81
2627	2629	05/20/10 09:16	1	0	0	0	47.81
2628	2630	05/20/10 09:20	0	0.00604	0.0217	0.0081	47.81
2629	2631	05/20/10 09:26	1	0	0	0	47.46
2630	2632	05/20/10 09:28	0	0.00618	0.0216	0.0078	47.46
2631	2633	05/20/10 09:31	1	0	0	0	47.46
2632	2634	05/20/10 09:37	0	0.00600	0.0216	0.0078	47.46
2633	2635	05/20/10 09:43	1	0	0	0	47.46
2634	2636	05/20/10 09:45	0	0.00610	0.0216	0.0078	47.46
2635	2637	05/20/10 09:51	1	0	0	0	47.46
2636	2638	05/20/10 09:53	0	0.00616	0.0216	0.0078	47.46
2637	2639	05/20/10 09:57	1	0	0	0	47.46
2638	2639	05/20/10 20:00	1	0	0	0	47.46

Know:

- Gas input rate
- Time boiler is on
- Qty beer brewed

*Energy Intensity*

Natural Gas  
Barrel of Beer

# Other Tools for Analysis



U.S. DEPARTMENT OF  
**ENERGY** | Energy Efficiency &  
Renewable Energy

- Federal Energy Management Program (FEMP)
- Industrial Technologies Program (ITP) *BestPractices*
  - (see *Tip Sheets*)



Baseline 3D model courtesy Patrick Reynolds and Philip Proefrock



PVWatts

SketchUp

EERE

Introduction


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# Financial Incentives



**FEDERAL**  
Incentives/Policies for Renewables & Efficiency

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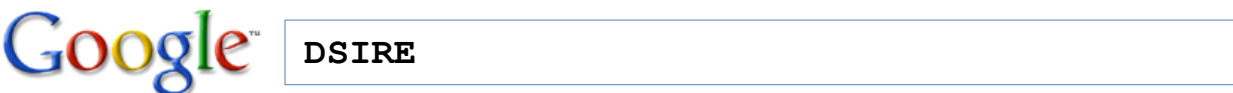
**Business Energy Investment Tax Credit (ITC)**

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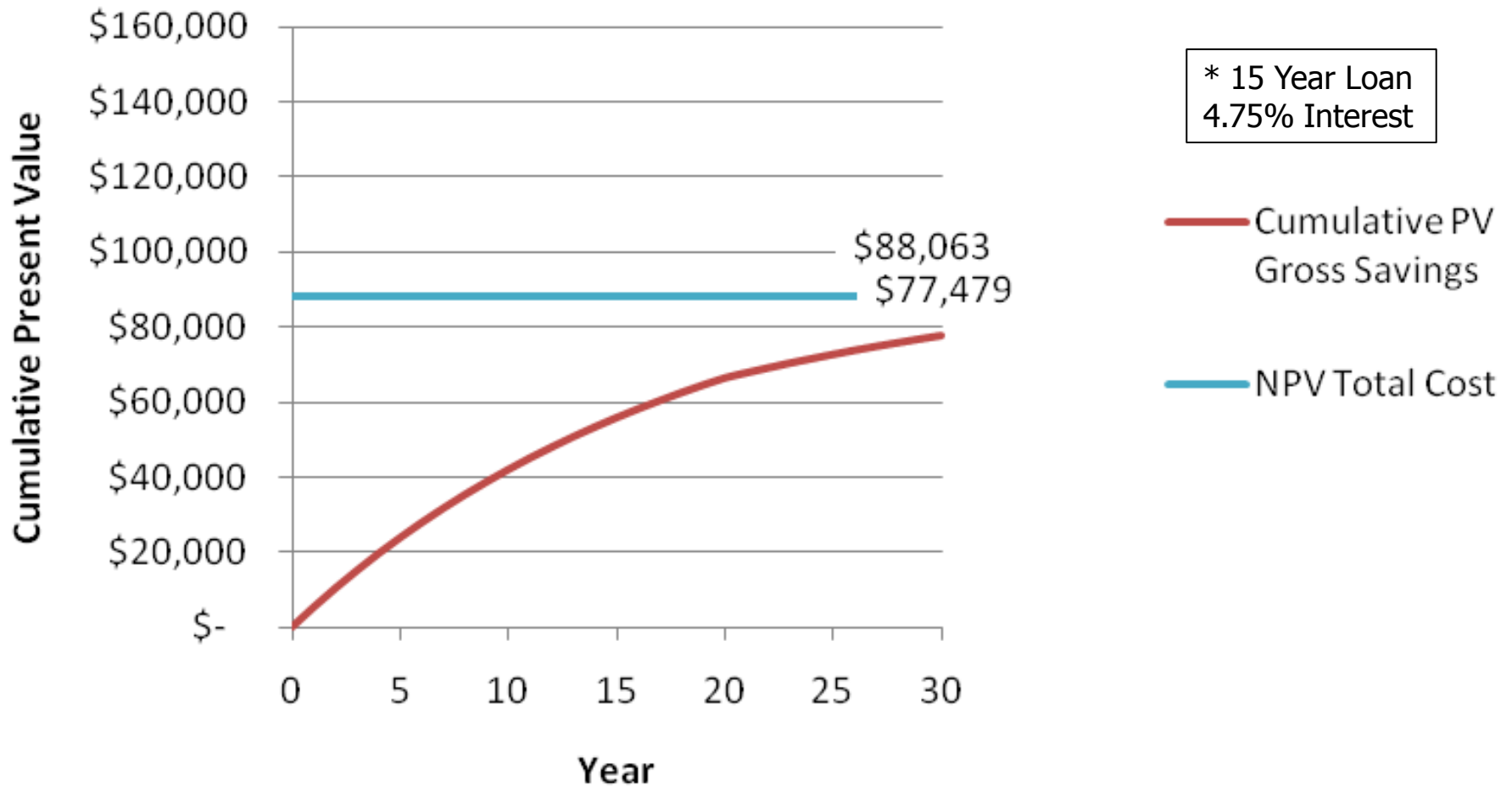
**Amount:** 30% for solar, fuel cells and small wind;\*  
10% for geothermal, microturbines and CHP\*



A red banner for the Database of State Incentives for Renewables &amp; Efficiency (DSIRE). On the left, "DSIRE" is written in large white letters with a trademark symbol, and below it is the full name "Database of State Incentives for Renewables &amp; Efficiency". On the right, there are logos for the U.S. Department of Energy (Energy Efficiency &amp; Renewable Energy), IREC (Interstate Renewable Energy Council), and the North Carolina Solar Center.



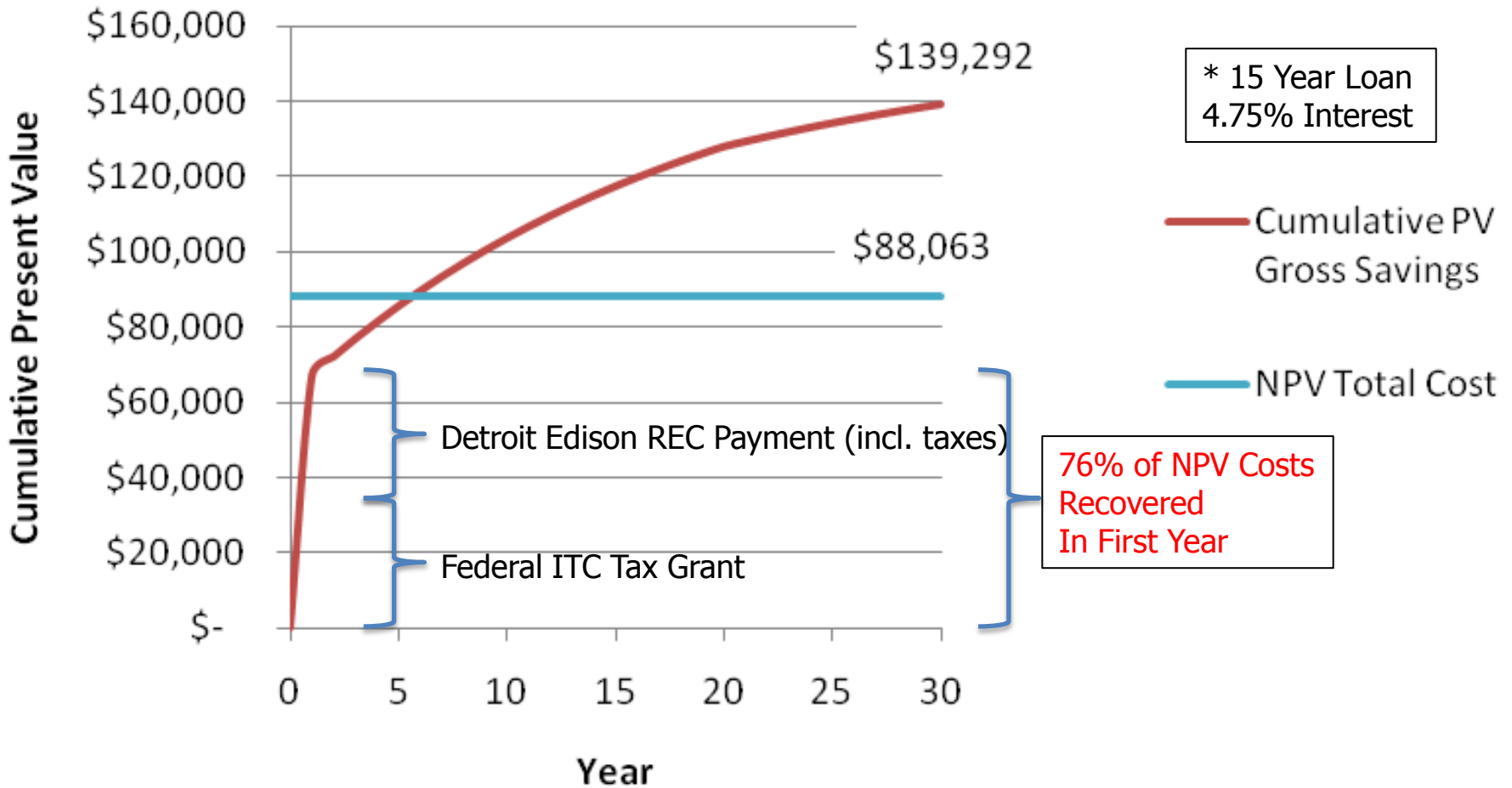
# 20 kW Solar Electric Project\*



## Payback Time: Almost Never

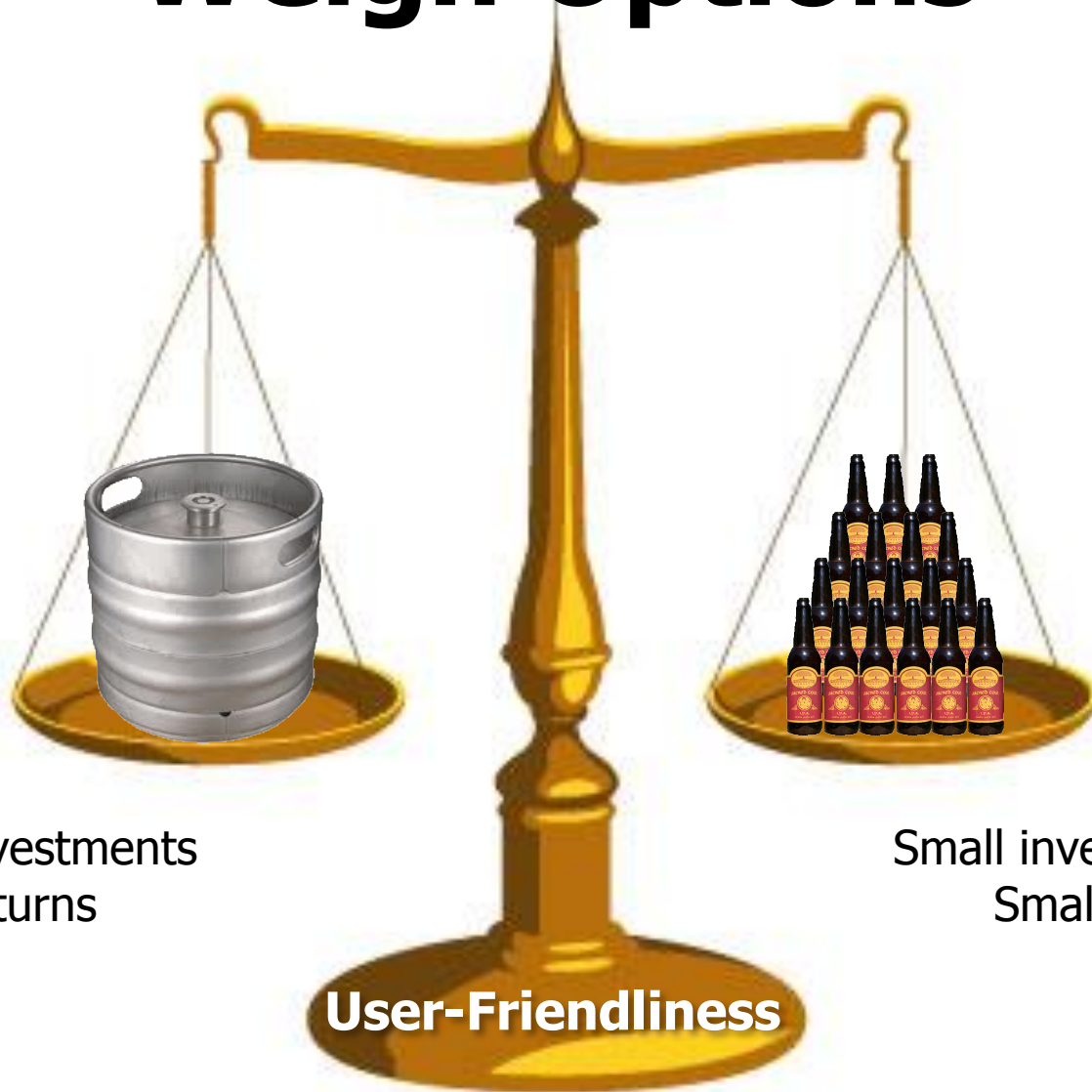


# 20 kW Solar Electric Project\* + Incentives



## Payback Time: 5 Years

# Weigh Options



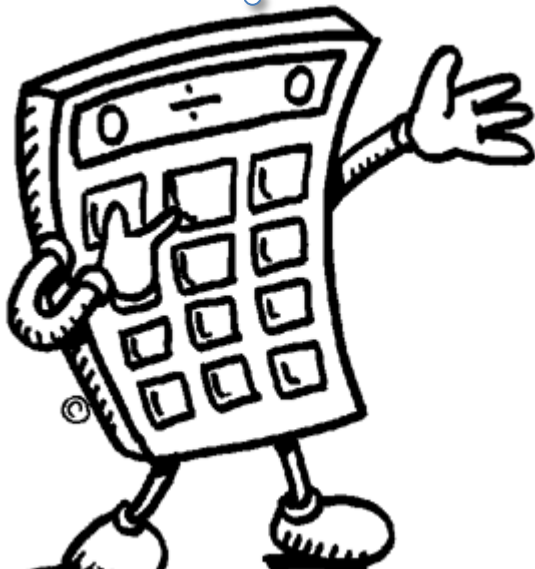
Big investments  
Big returns

Small investments  
Small returns

**User-Friendliness**

# Prioritize Options

Greater Number  
is  
Higher Priority\*



$$\frac{\text{Benefit} - \text{Cost}}{\text{Cost}}$$

\* All other things being equal!

# Energy Conservation Measures

## Required Reading

***Energy Efficiency Improvement and Cost Saving Opportunities for Breweries. An ENERGY STAR® Guide for Energy and Plant Managers (LBNL 2003)***

***A Self-Assessment Workbook for Small Manufacturers v2.0 (Rutgers 2003)***

## Sample Topics

- Brewkettle heat recovery
- Steam recompression
- Wort stripping
- Employee tasks

- Pipe and roof insulation
- Boiler combustion adjustment
- Boiler exhaust stack heat recovery
- Lighting efficiency



LBNL brewery

Rutgers self assessment

Find the solutions that work for *your* brewery

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# Water Conservation Measures

Required Reading	Sample Topics
<b><i>Reducing Water and Effluent Costs in Breweries</i></b> (various UK brewing industry entities 1998)	<ul style="list-style-type: none"><li>• Comprehensive water and wastewater management program</li></ul>
<b><i>Beer Production - Audit and Reduction Manual for Industrial Emissions and Wastes</i></b> (UN Environmental Program 1998)	<ul style="list-style-type: none"><li>• Water use reduction</li><li>• Wastewater COD and SS load reduction</li></ul>
<b><i>Technical Pollution Prevention Guide for Brewery and Wine Operations in the Lower Fraser Basin</i></b> (El Reyes Env. Grp 1997)	<ul style="list-style-type: none"><li>• Solid, liquid, gaseous pollution reduction measures</li></ul>



<http://tinyurl.com/beerwater>

Beer production audit

technical pollution prevention guide brewery

Find the solutions that work for *your* brewery

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# Step 4: Implement



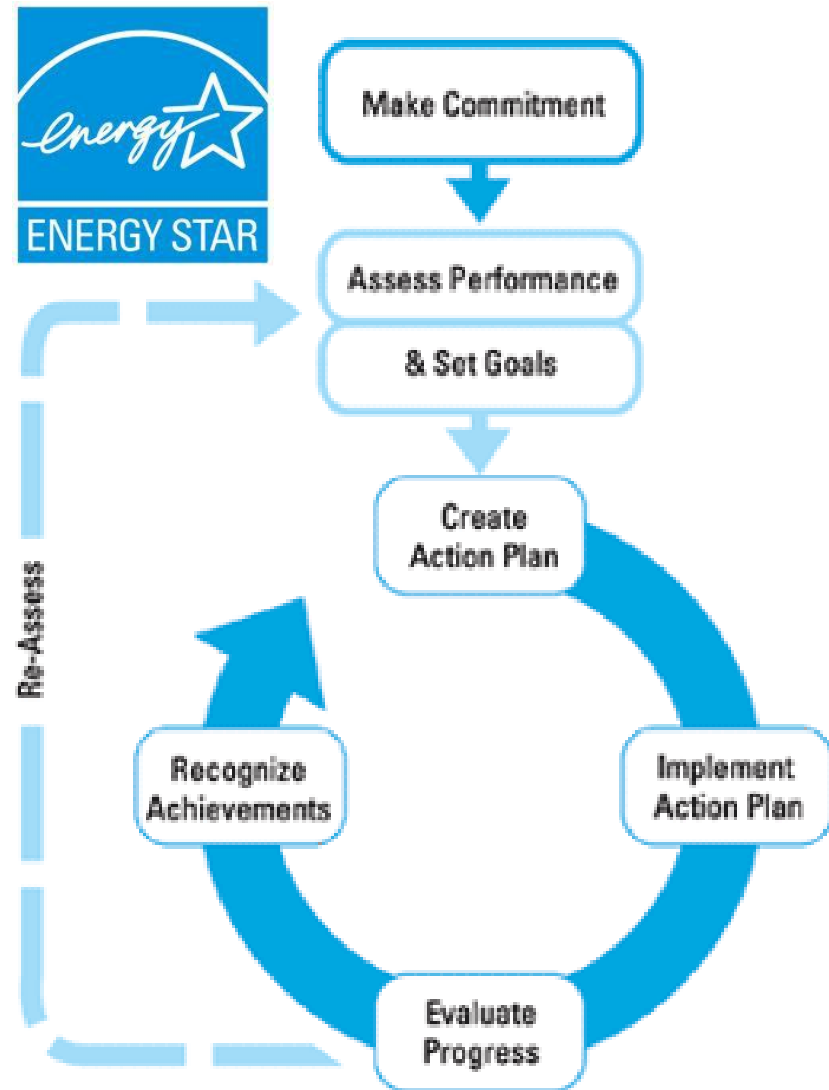
# Step 5: Monitoring & Evaluation

- Monitor for continual improvement
- Evaluate success of projects
- Uncover new opportunities
- Data to share with employees & public



# Energy Management System (EMS)

- One of the most successful and cost-effective ways to improve energy efficiency.
- Creates a foundation for improvement, provides guidance for managing energy throughout an organization.



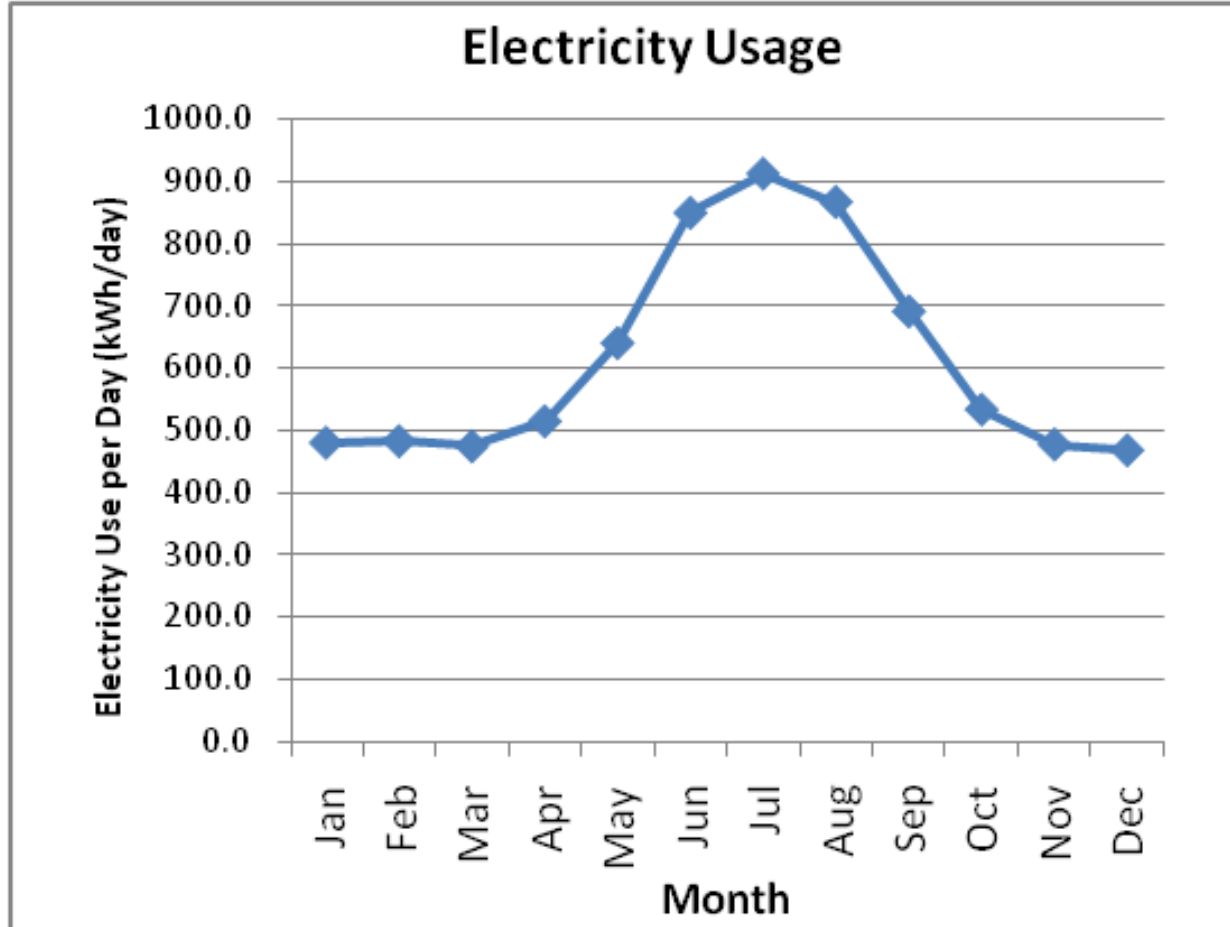


# Our Findings



(may not fit your specific needs)

# Electricity

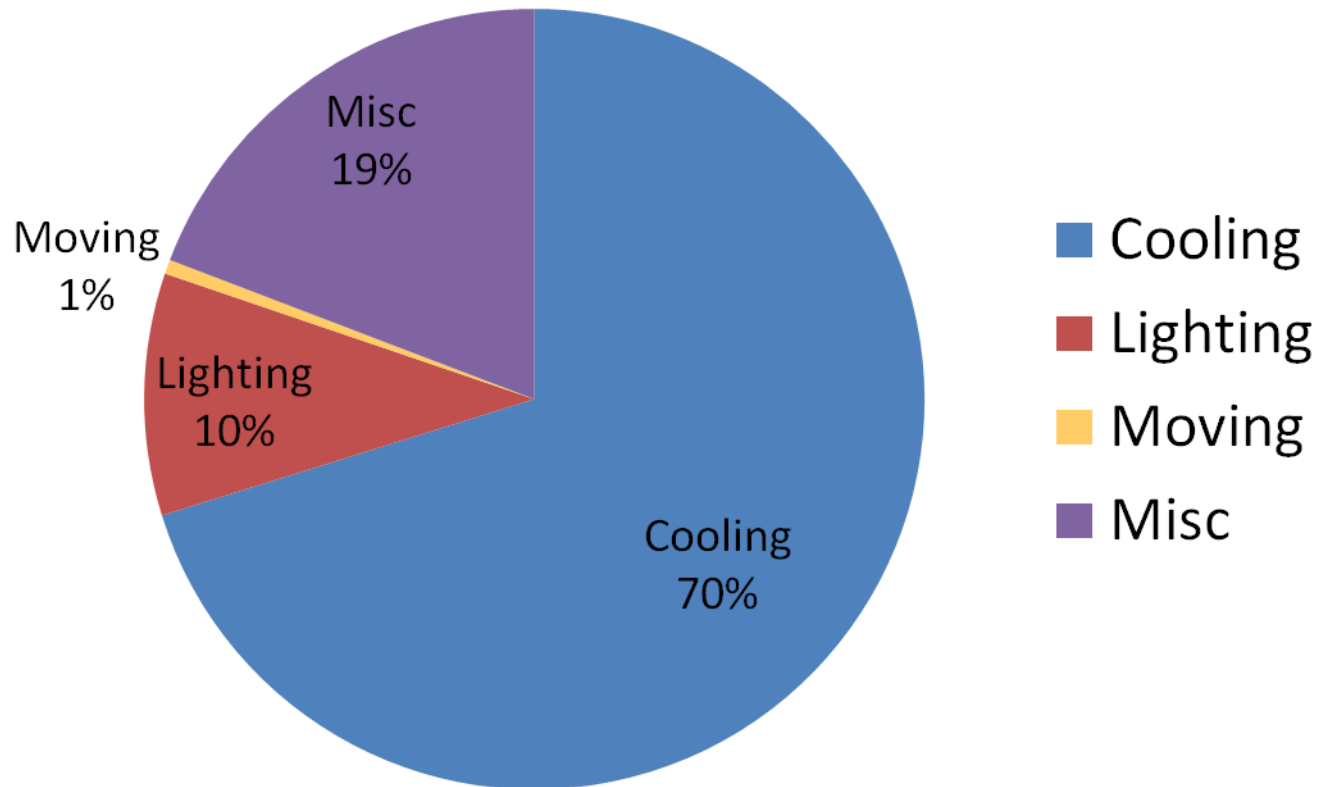


## Understand rate structure

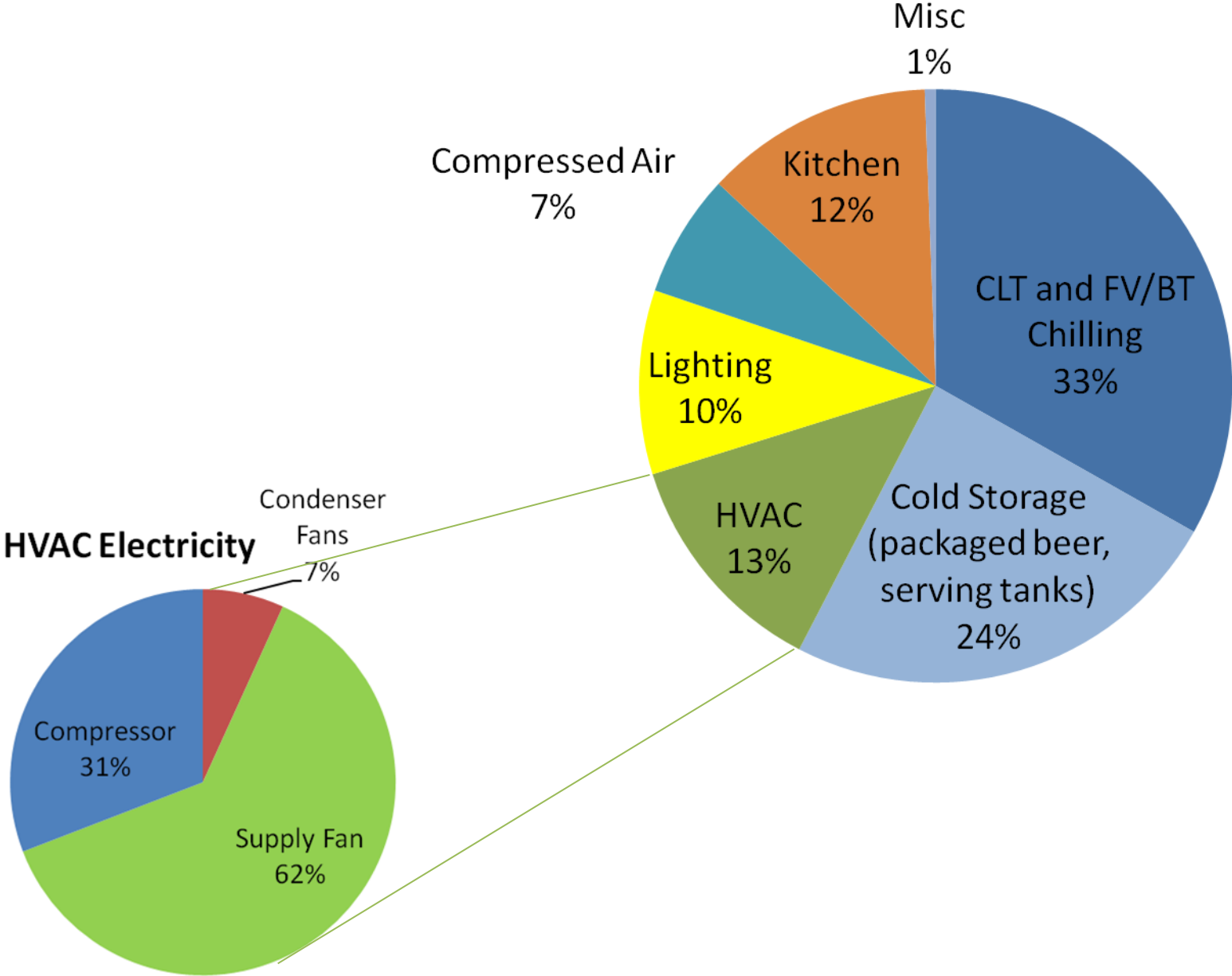
- Call Utility Representative
- Time of use charge? (aka "demand charge")
- Ratchet charges?

Look for patterns

# Electricity Use

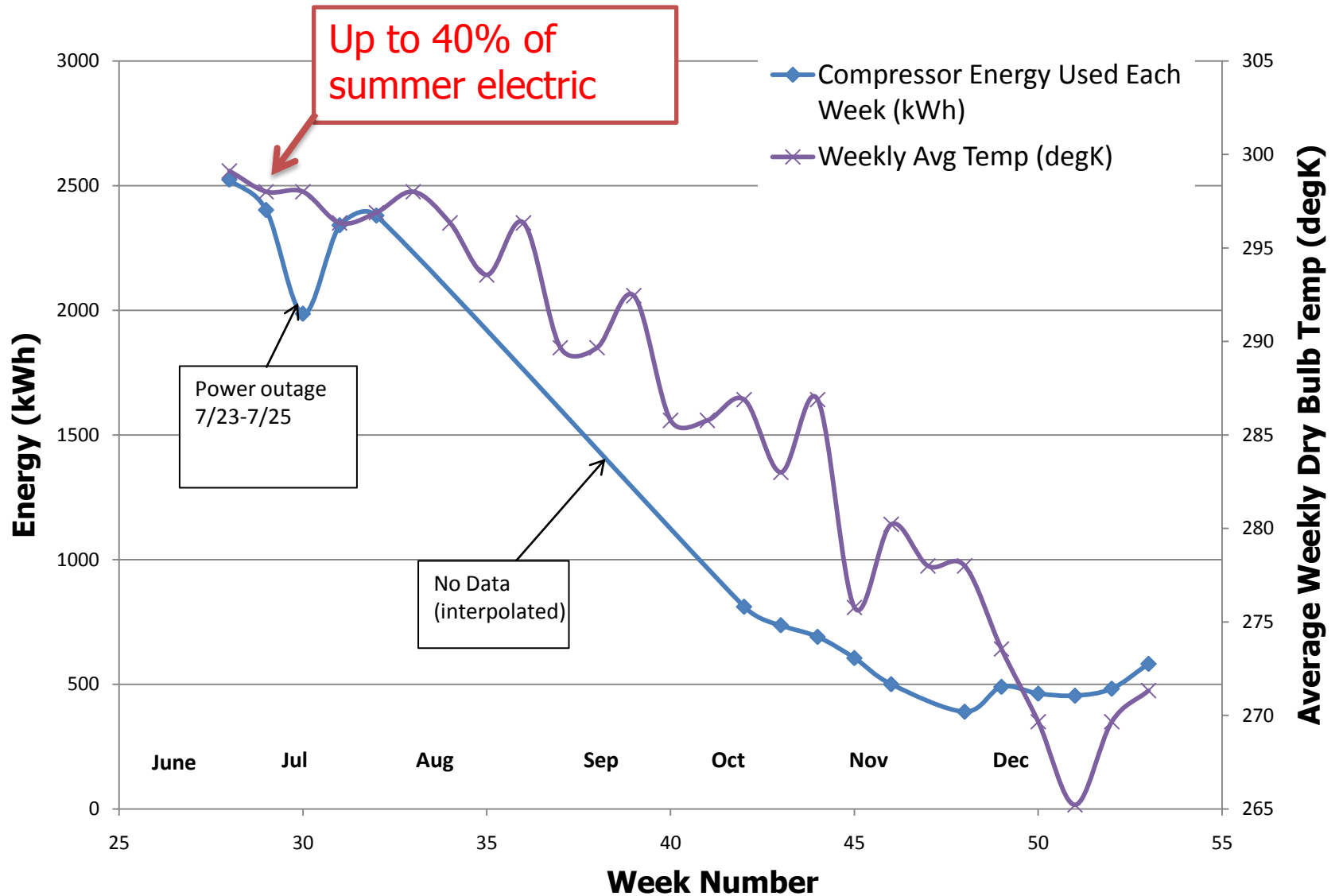


# Electricity Use

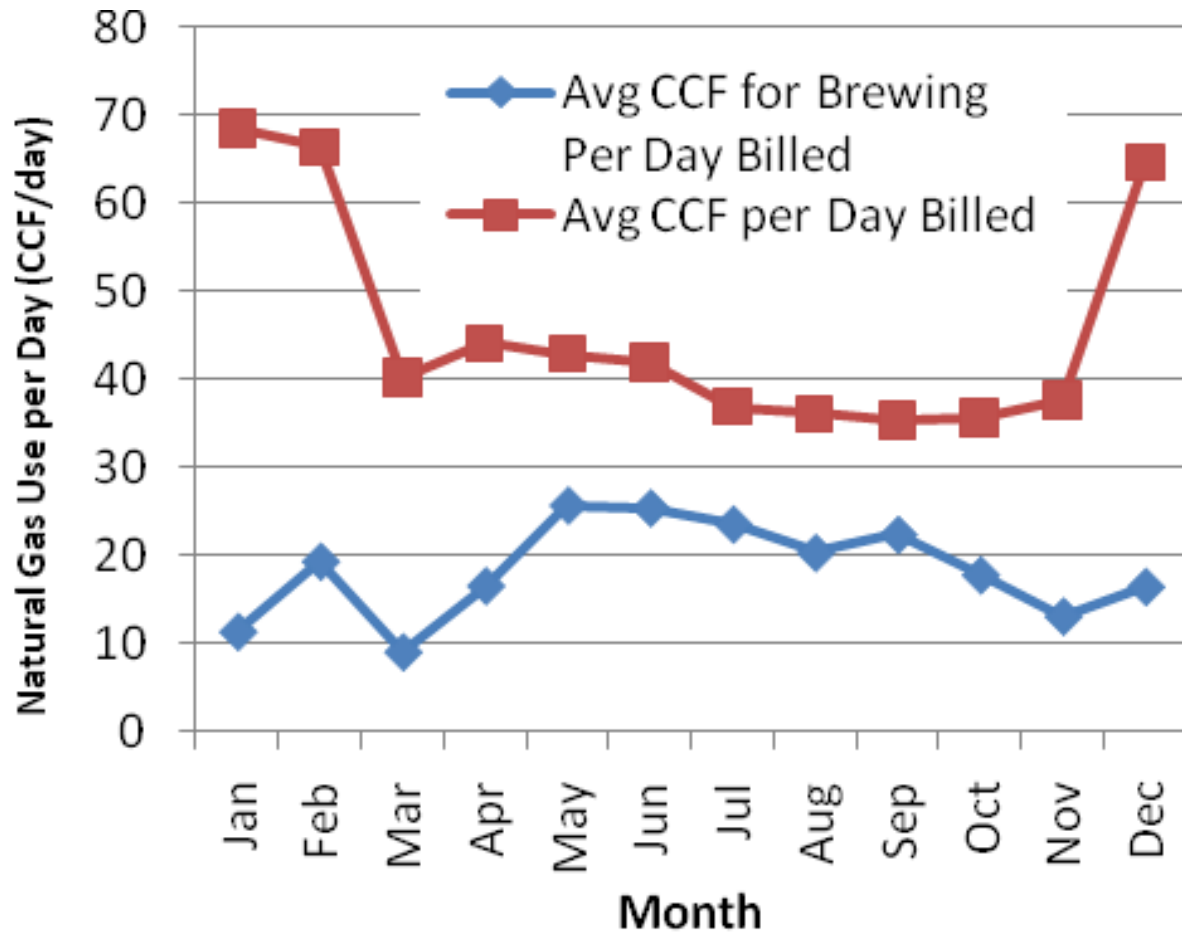




# Weekly Glycol Chiller Compressor Energy Usage (kWh) Scales with Ambient Temperature

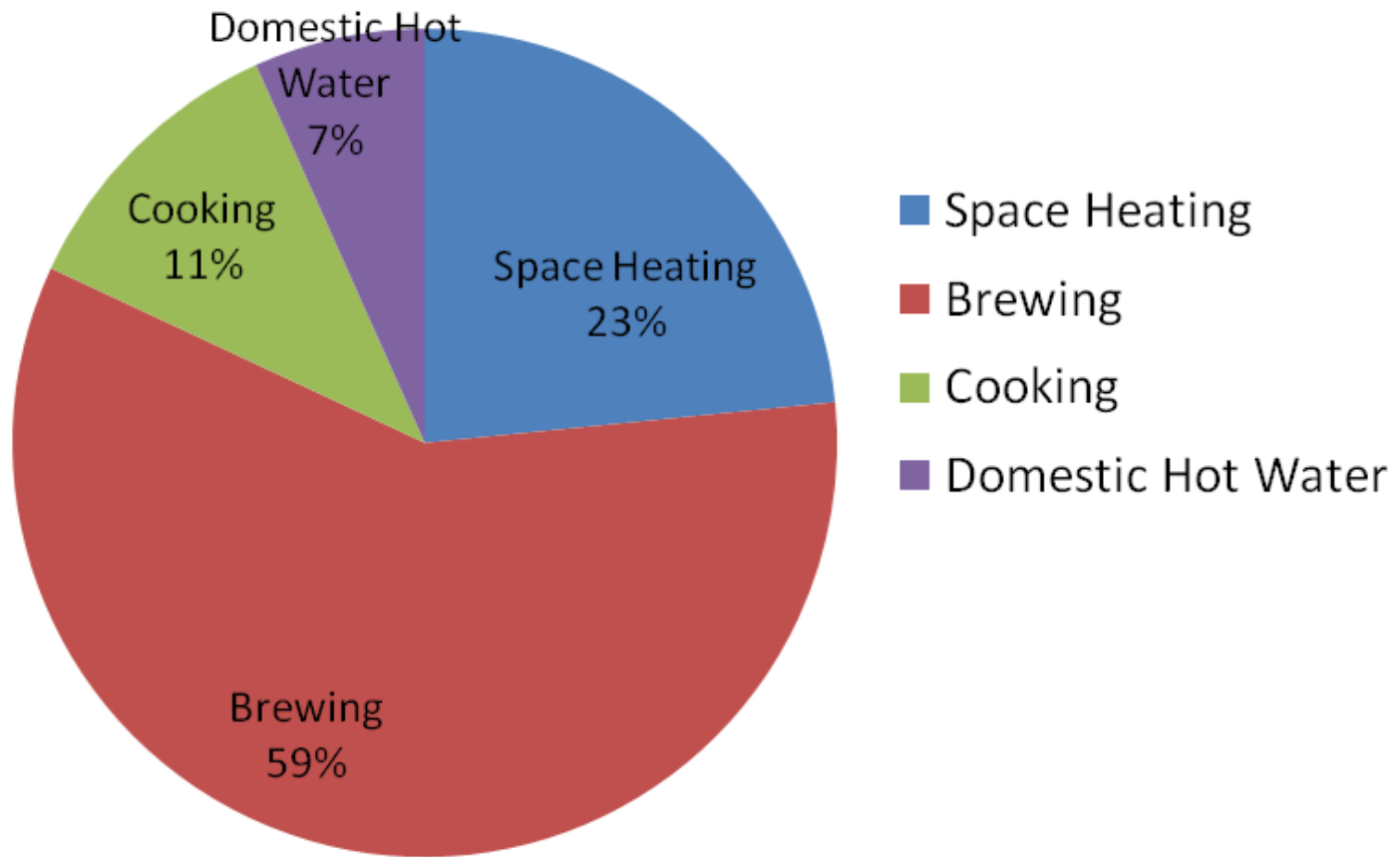


# Natural Gas



Look for patterns

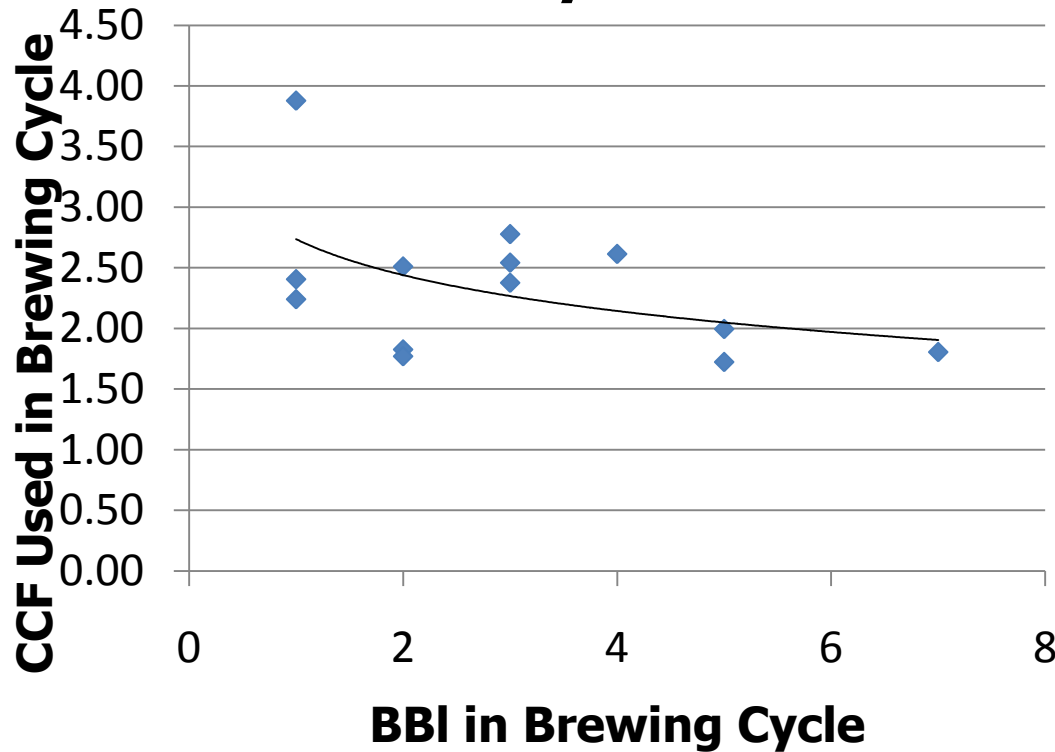
# Natural Gas Use



# Heat Exchanger Saves Gas

(but, how much?)

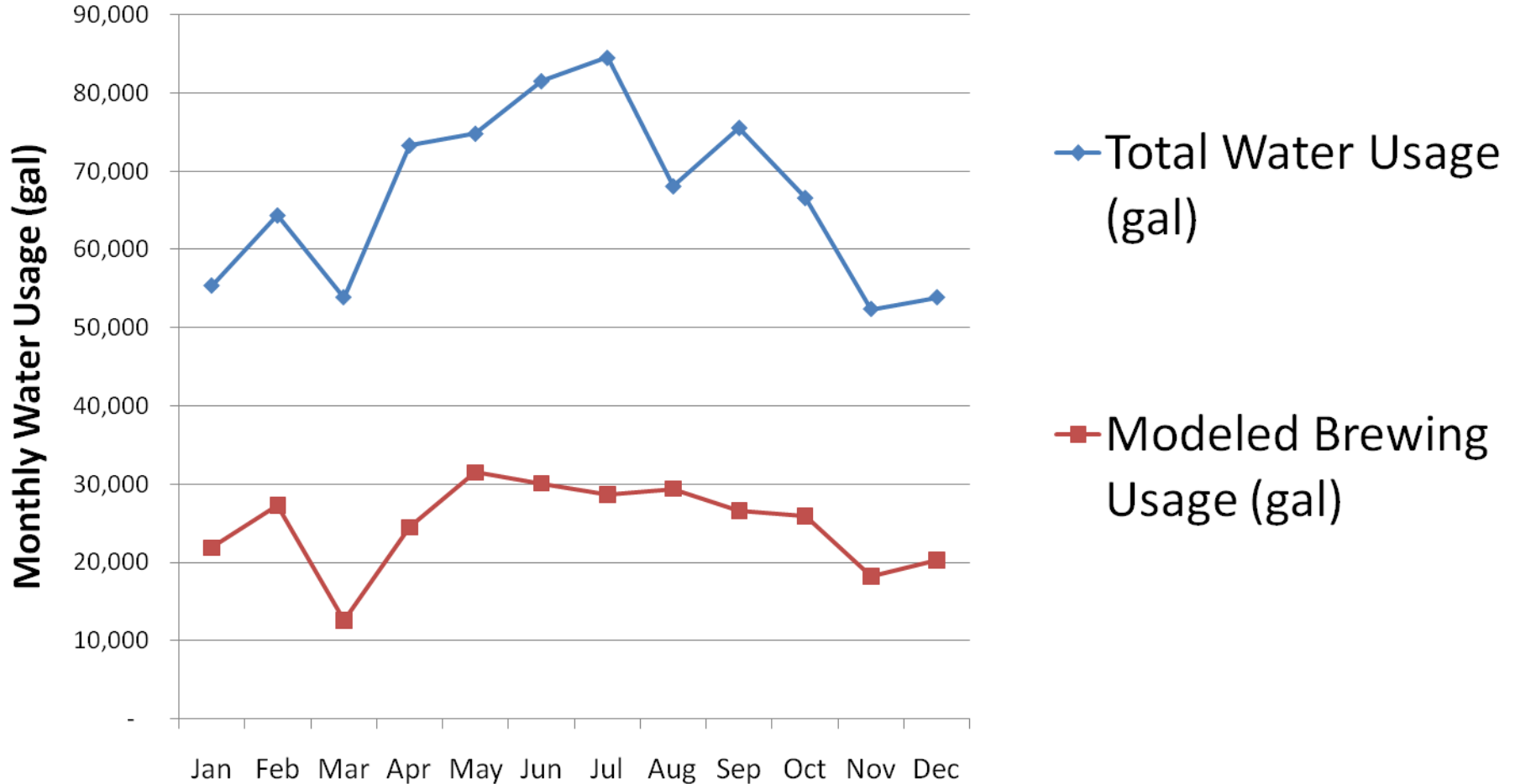
## CCF per BBI vs. # Batches in Cycle



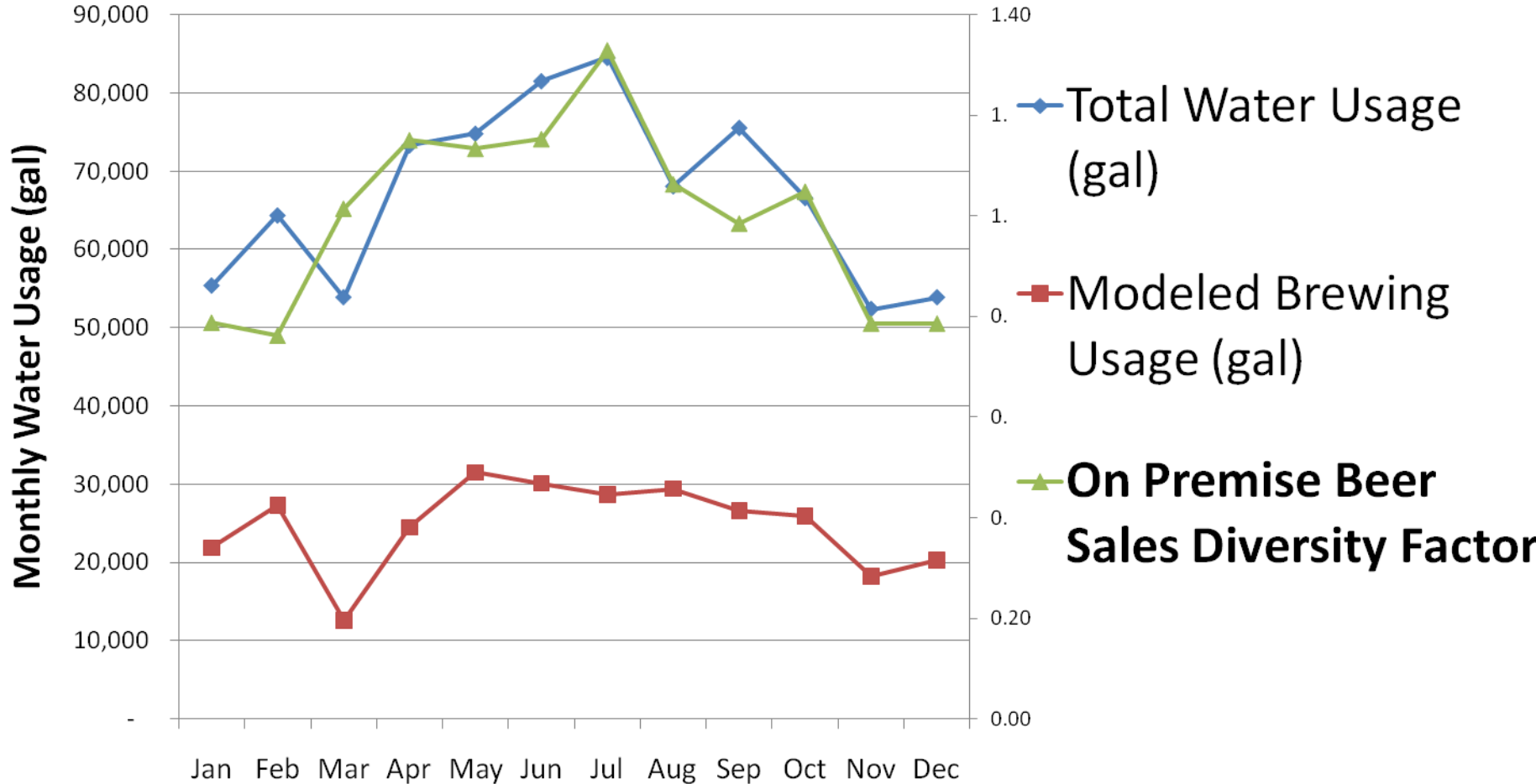
Consecutive Batches	Est. CCF/BBI
1	2.75
2	2.45
4	2.15
8	1.85



# Water



# Water



**Conclusion: a lot of water is being used for something to do with beer sales...**

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# Our Top Picks for Corner Brewery: Building & Energy

- Energy Management System
- Process Integration and Automation
- Maintenance
- Solar PV
- Pipe Insulation
- Upgrade heat exchanger
- Brewkettle heat recovery
- Boiler flue stack heat recovery
- WTW heat pump for process cooling and heating
- High-efficiency halogen and fluorescent lights
- Double pane windows or operable shutters
- Optimize ceiling fan use

# Maintenance

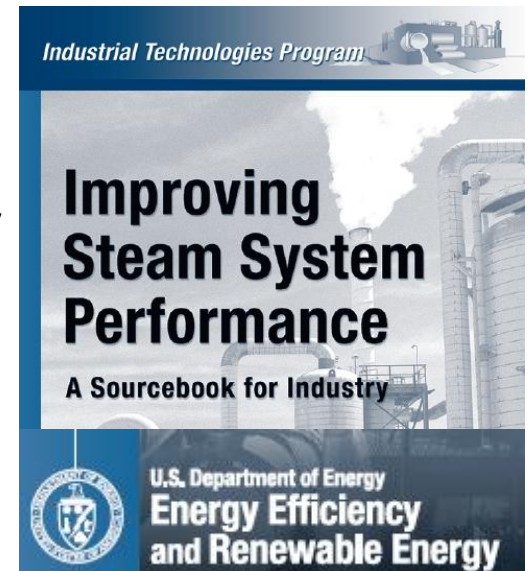




# Steam System Improvements

- Minimize excess air
- Clean boiler heat transfer surfaces
- Install heat recovery equipment (feedwater economizers and/or combustion air preheaters)
- Improve water treatment to minimize boiler blowdown
- Recover energy from boiler blowdown
- and more...

See *Improving Steam System Performance:  
A Sourcebook for Industry*



Guidelines for Energy Management

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# Upgrade Heat Exchanger

- Multiple stage heat exchanger can recover up to 35-36 kBTU/BBI wort cooled
- Corner Brewery's single stage heat exchanger is recovering 19 kBTU/BBI wort cooled



Source: Hackensellner (2000)

# Solar Electric



95x Evergreen 210W Polycrystalline Panels



83x Thistle 240W Monocrystalline Panels

# Waste Heat Recovery

- Brewkettle and Boiler Flue Stack Heat Recovery
- Integrated systems, e.g. New Belgium Brewing Co.
- Existing systems can be retrofitted with this feature.

Method	Example	Used by
Direct Heat Exchanger	Spray condenser	Soo Brewing Co – Sault Ste. Marie, Michigan
Indirect Heat Exchanger	Economizer	Atwater Block Brewing Co – Detroit, MI



# Water-to-Water Heat Pump

## Heat Pump Benefits

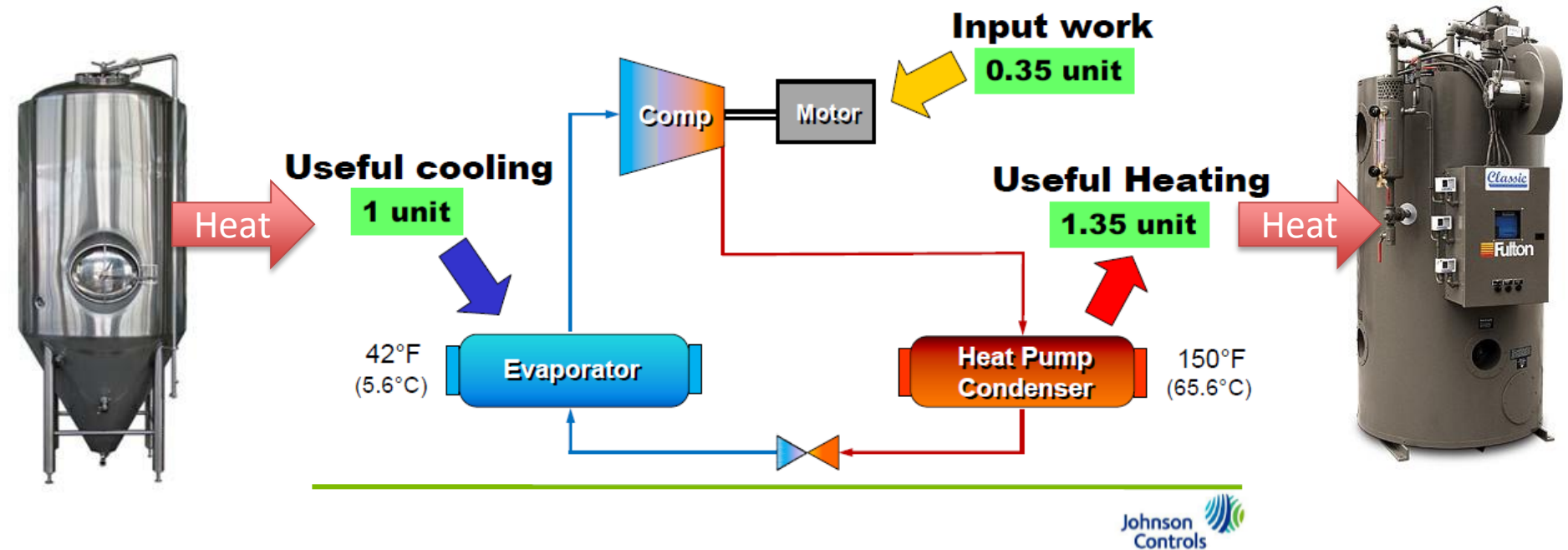
### Economic Advantages

- Operational Savings

$$\text{Cooling COP} = 1.00 / 0.35 = 2.9$$

$$\text{Heating COP} = 1.35 / 0.35 = 3.8$$

$$\text{Combined COP} = 2.35 / 0.35 = 6.7$$

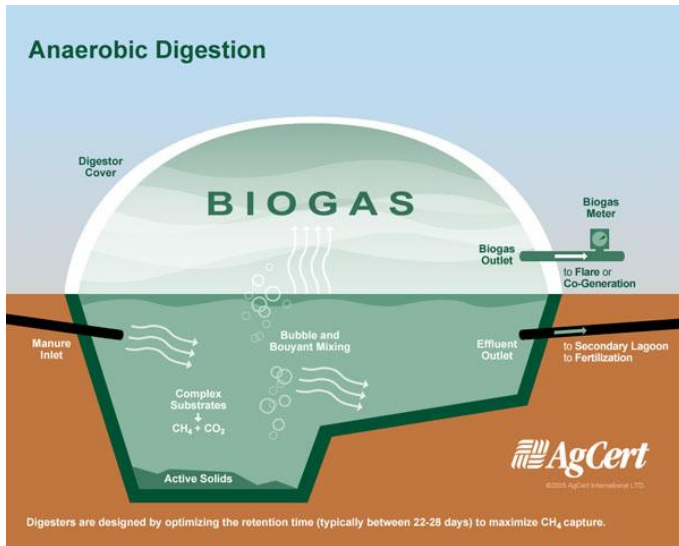


## Simultaneous heating and cooling

# Our Top Picks for Corner Brewery: Water

- Submetering
- Low-flow faucets
- Low-flow or dual flush toilets
- Wastewater biogas
- Rainwater collection for irrigation

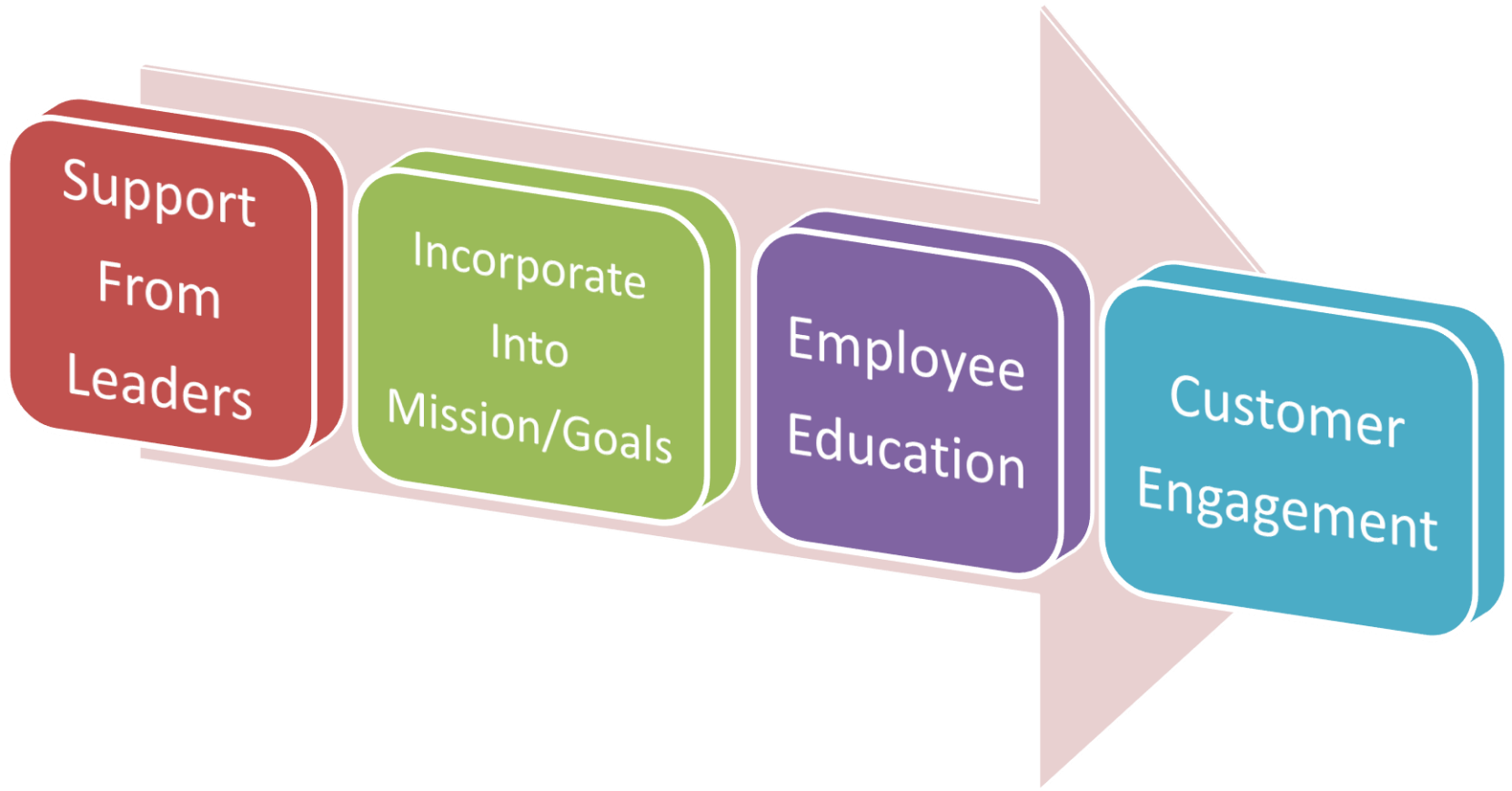
# Wastewater Biogas



# Other Possibilities for Your Brewery

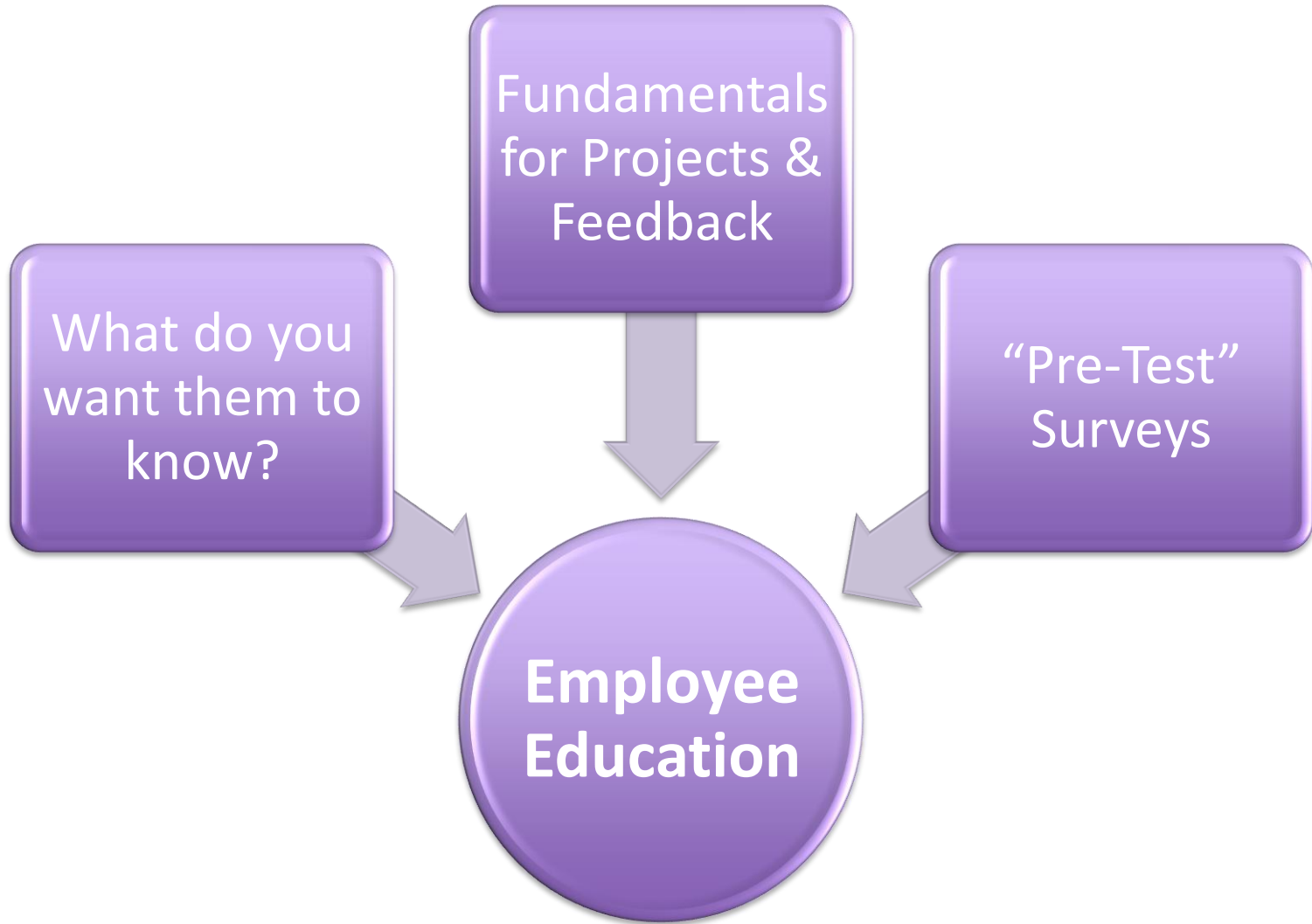
- Programmable thermostats
- Insulation
- Solar awnings
- High-volume low-speed fans (HVLS)
- Cogeneration
- Greywater
- Natural lighting
- Occupancy sensors
- Dimmable CFLs, LEDs, cold cathode
- Drop-lighting
- Geothermal
- Solar hot water

# Education & Engagement Program

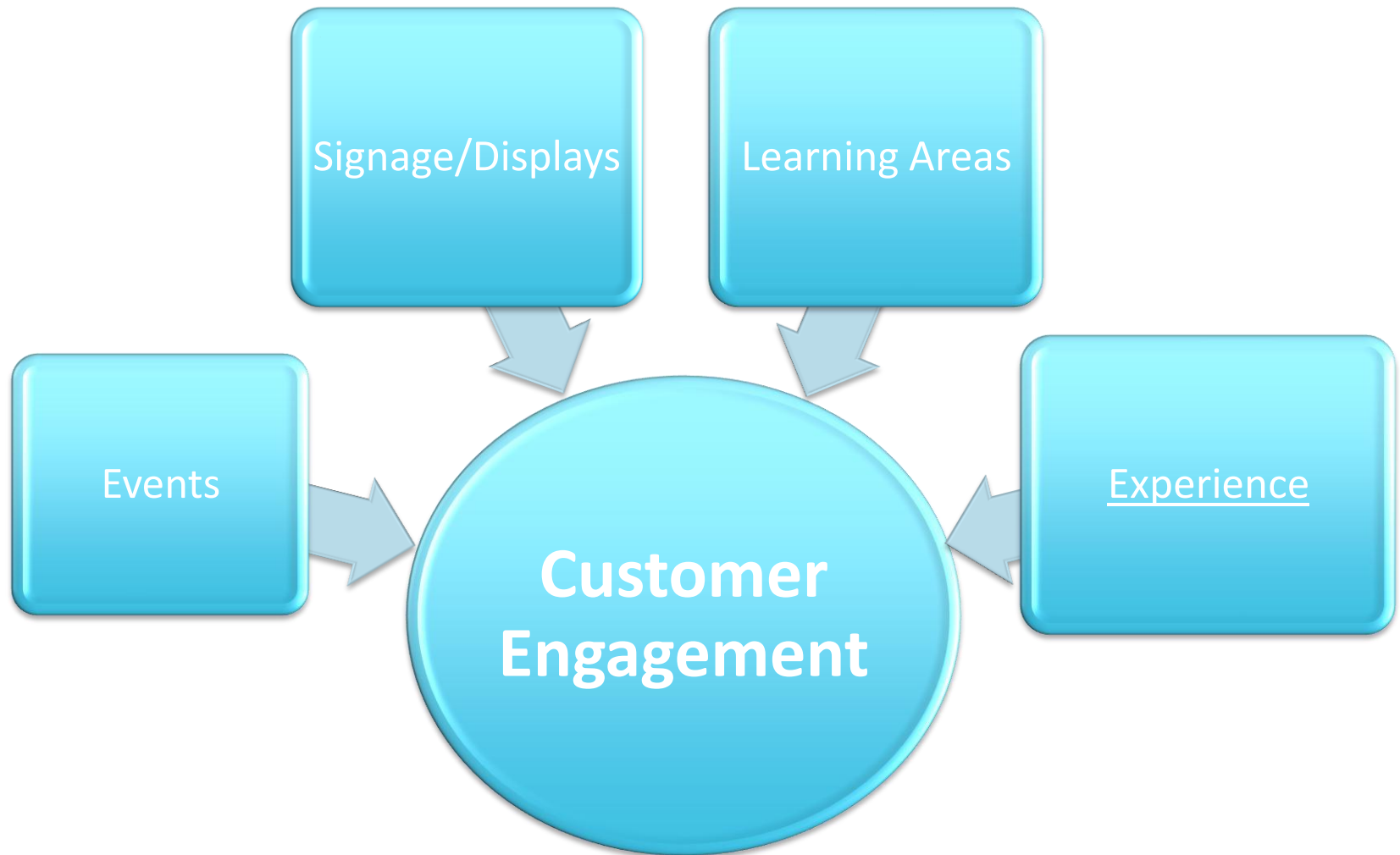




# Education & Engagement Program



# Education & Engagement Program



# Resources for Environmental & Sustainability Employee Education



[www.neefusa.org](http://www.neefusa.org)

Business & Environment Tab

# Summary

- Sustainability & Craft Breweries
- 5 Steps to Greater Sustainability
  - Inventory
  - Measure
  - Analyze
  - Implement
  - Monitoring & Evaluation
- Engagement

# Thanks To...

- Craft Brewers Association
- Matt & Rene Greff
- Corner Brewery Staff
- University of Michigan School of Natural Resources & Environment





# THE GREEN BREWERY PROJECT

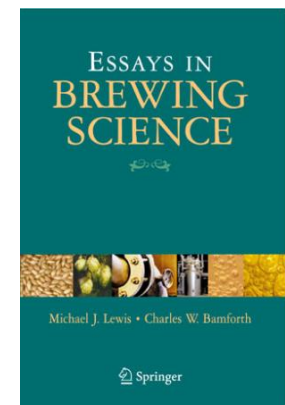
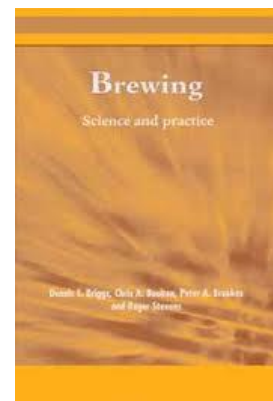
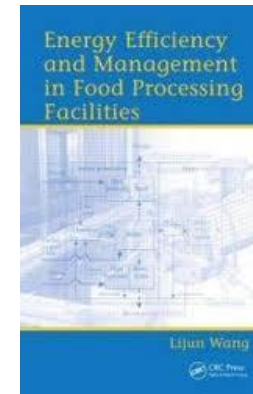
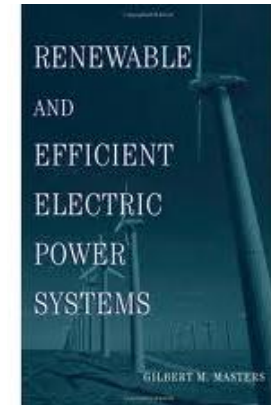
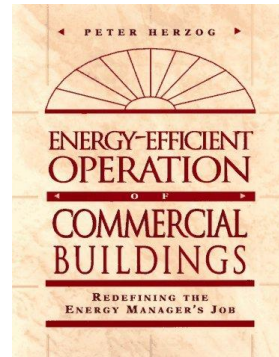
Jazmine Bennett  
Jarett Diamond  
Gary Fischer  
Kerby Smithson



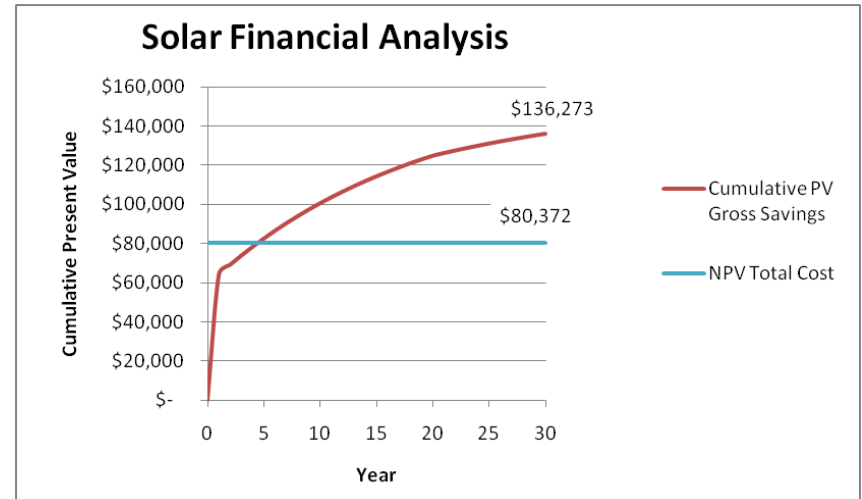
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# A Few Good Books

- Herzog, Peter. *Energy-Efficient Operation of Commercial Buildings. Redefining the Energy Manager's Job.* McGraw-Hill, 1997
- Wang, Lijun. *Energy Efficiency and Management in Food Processing Facilities.* CRC Press, 2009.
- Masters, Gilbert. *Renewable and Efficient Electric Power Systems.* John Wiley & Sons, 2004.
- Lewis and Bamforth. *Essays in Brewing Science.* Springer, 2007.
- Briggs, et al. *Brewing: Science and Practice.* Woodhead Publishing, 2004.



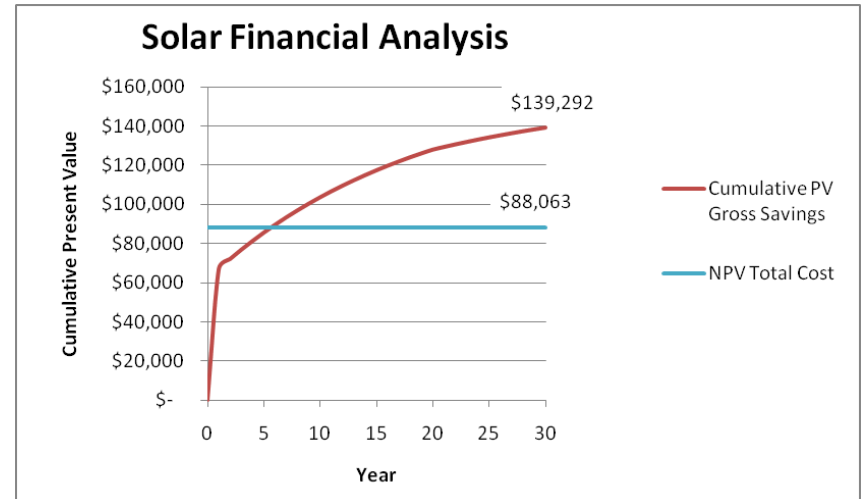
# Solar Photovoltaic 1



Payback Year	5
Year 1 PV Gross Savings	\$64,210
Annual Car-Years of CO <sub>2</sub> Offset	4

83x Thistle 240W Monocrystalline Silicon Photovoltaic Panels

# Solar Photovoltaic 2

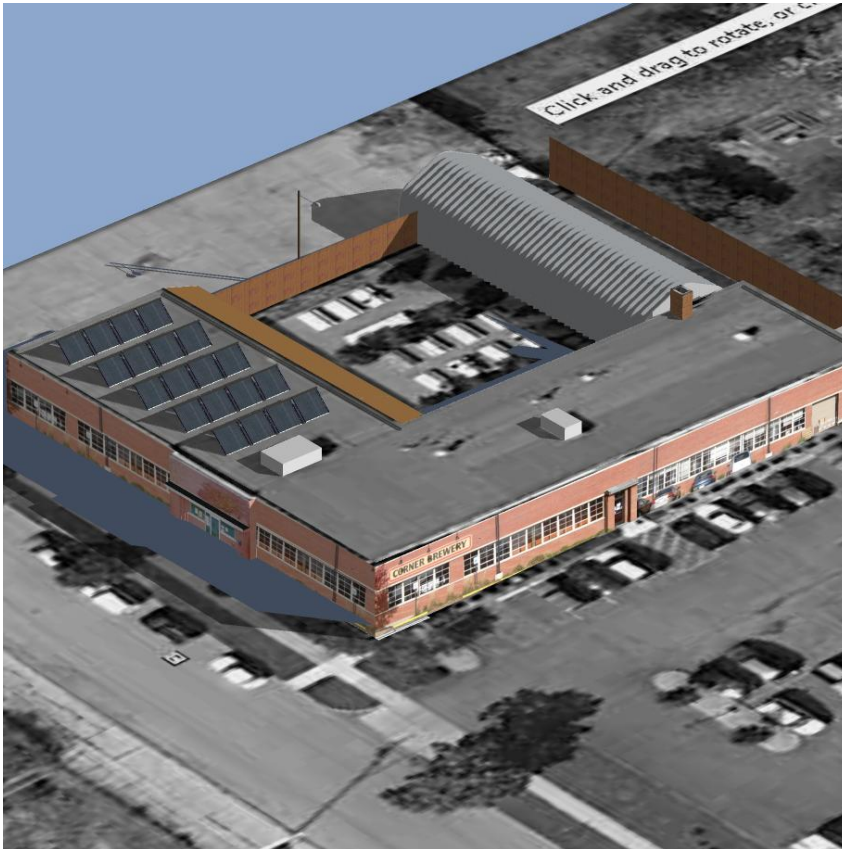


Payback Year	6
Year 1 PV Gross Savings	\$67,120
Annual Car-Years of CO <sub>2</sub> Offset	4

95x Evergreen 240W Polycrystalline Silicon Photovoltaic Panels



# Solar Hot Water



Payback Year	9
Year 1 PV Gross Savings	\$25,016
Annual Car-Years of CO <sub>2</sub> Offset	3

20x Apricus AP-30 Evacuated Tube Solar Thermal Panels



# Geothermal Heating and Cooling

- ~55 degF at six feet under
- Ideal for applications with simultaneous heating and cooling
- High up-front costs



# Two Cogeneration Technologies

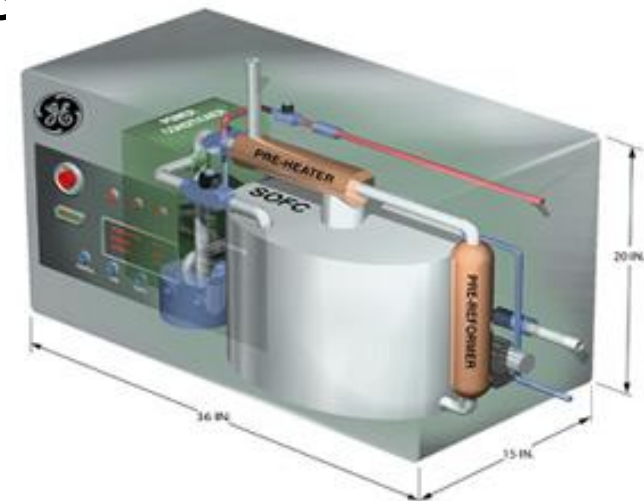
## Microturbine

- Natural gas, propane
- 30 kWe minimum capacity
- Smaller turbines being developed

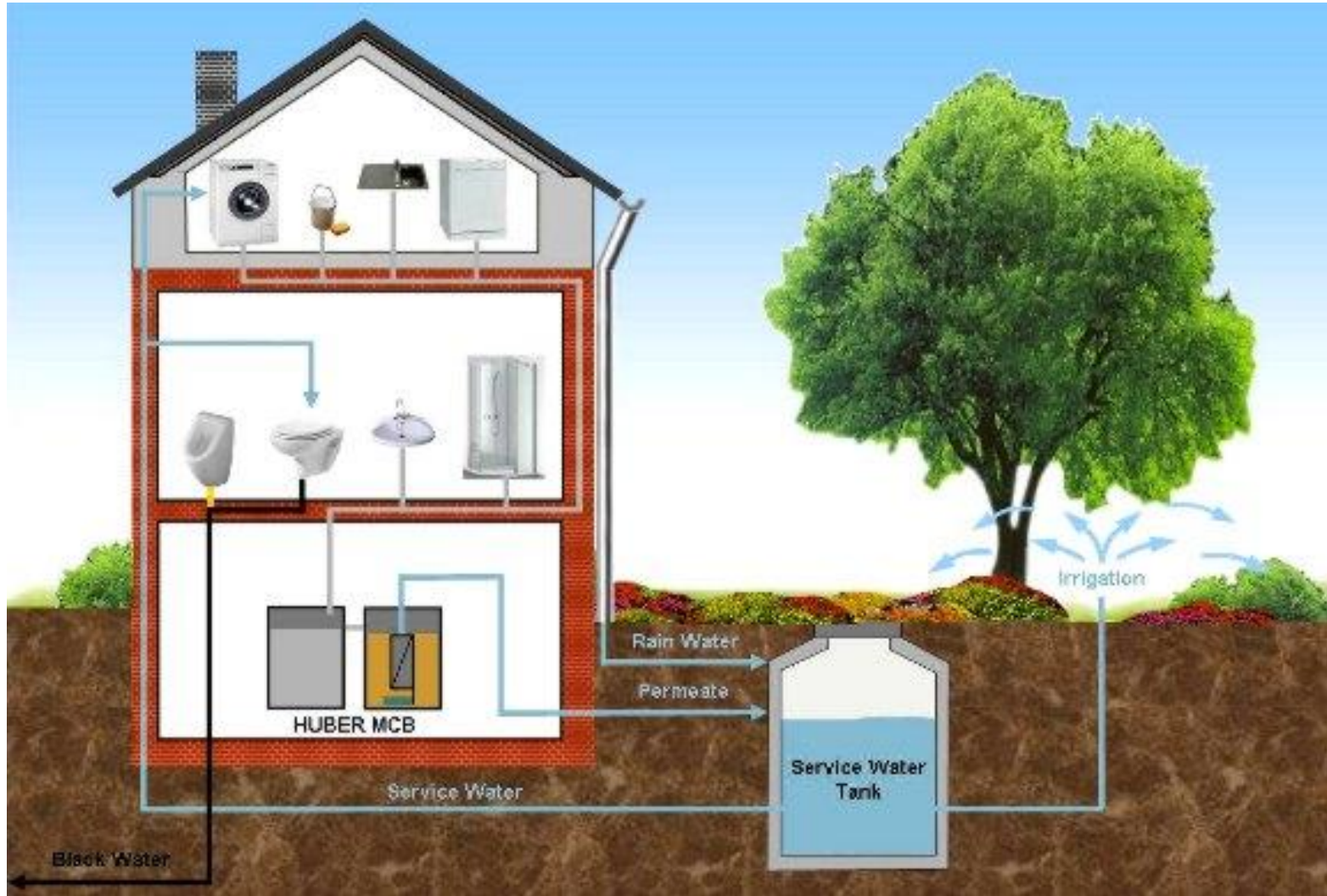


## Fuel Cell

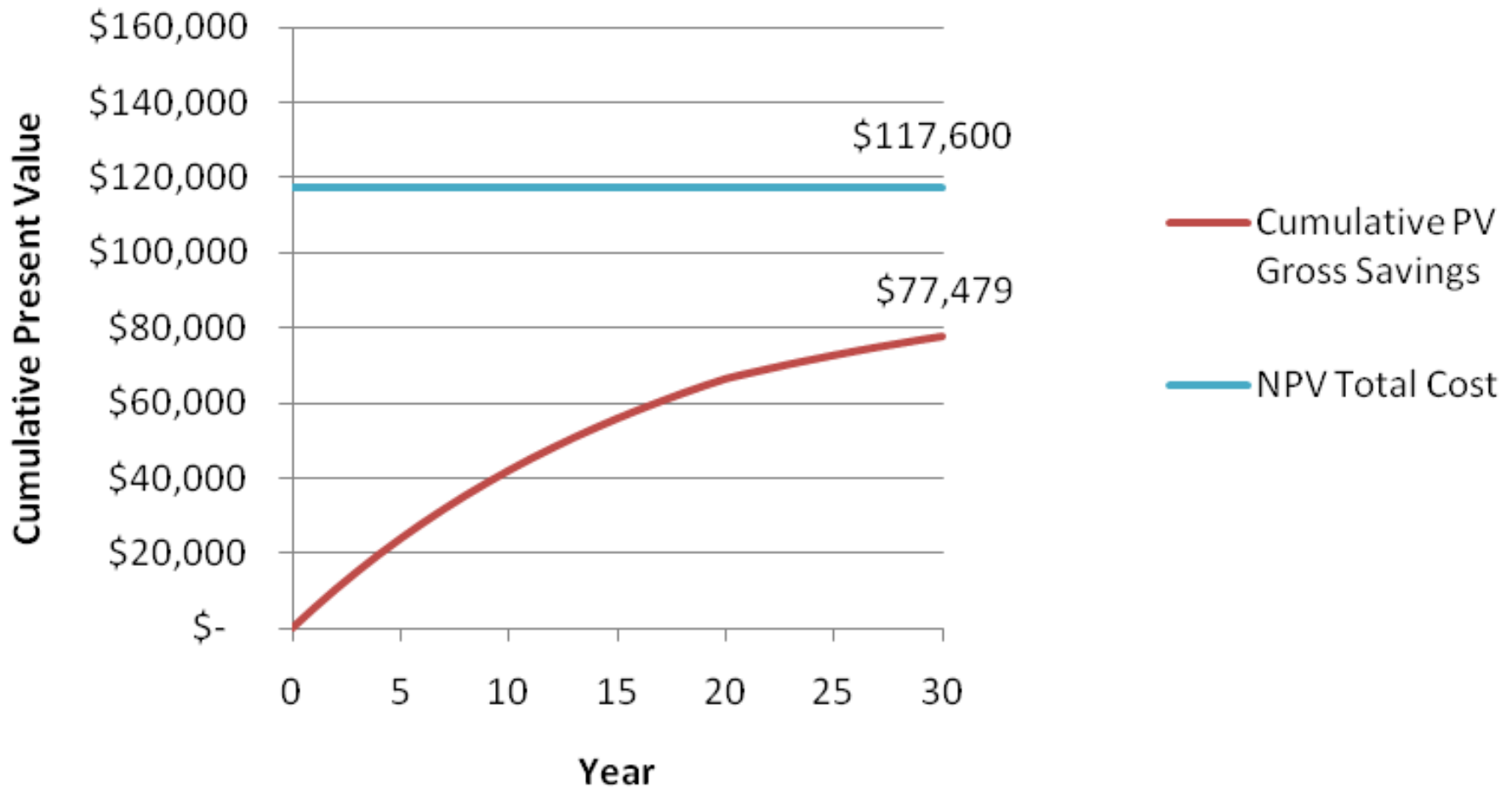
- Natural gas, biogas, propane, hydrogen, methanol
- Proton Exchange Membrane
- Solid Oxide Fuel Cell



# Greywater



# Solar Electric Project

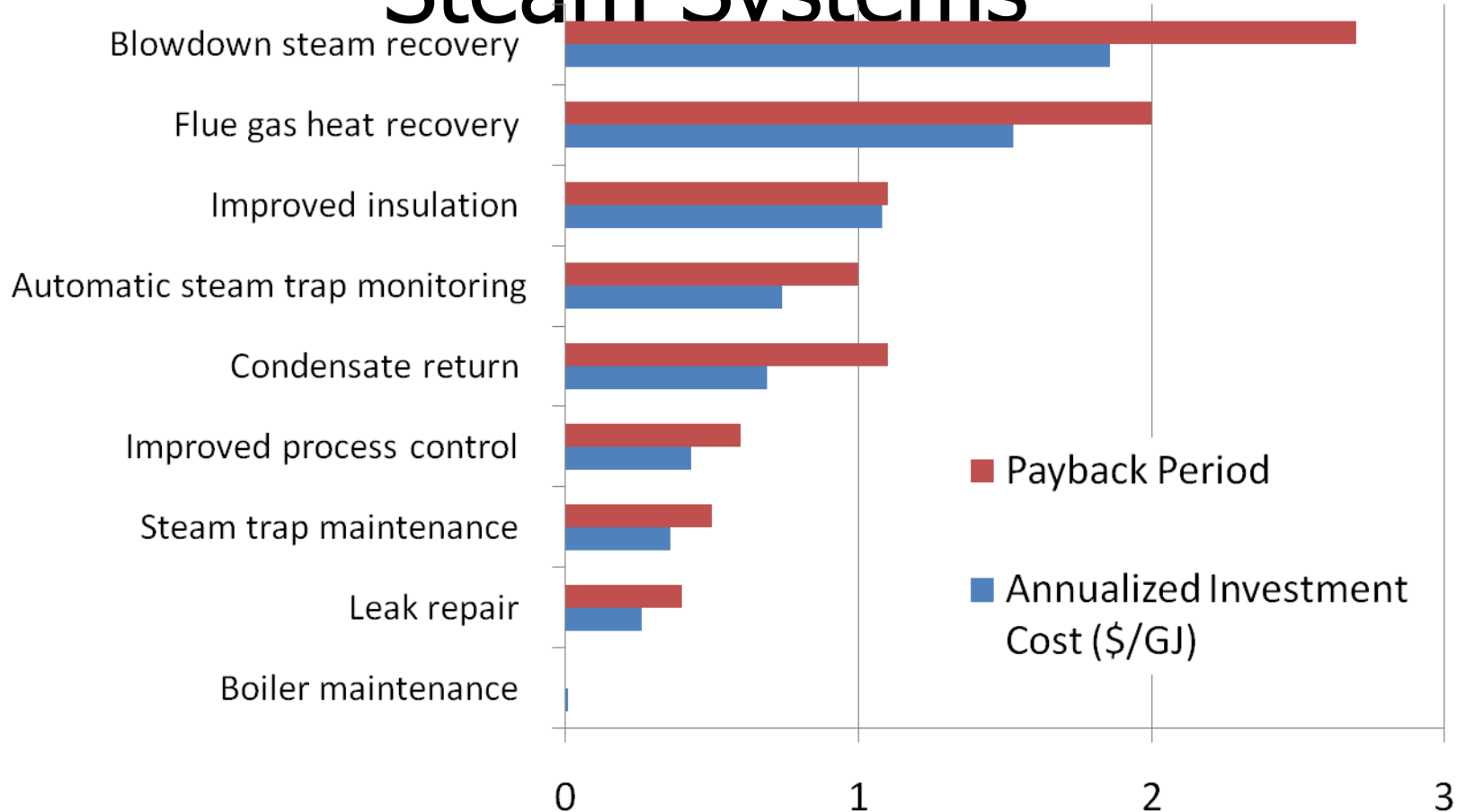


(Without financing or incentives)

## Payback Time: Never



# Energy Efficiency Measures for Steam Systems



(shorter bars are better)

Source: Einstein, et al. *Steam systems in industry: Energy use and energy efficiency improvement potentials*. Lawrence Berkeley National Laboratory. Paper LBNL-49081.