Combined Heat and Power

A feasibility study for Lafayette College

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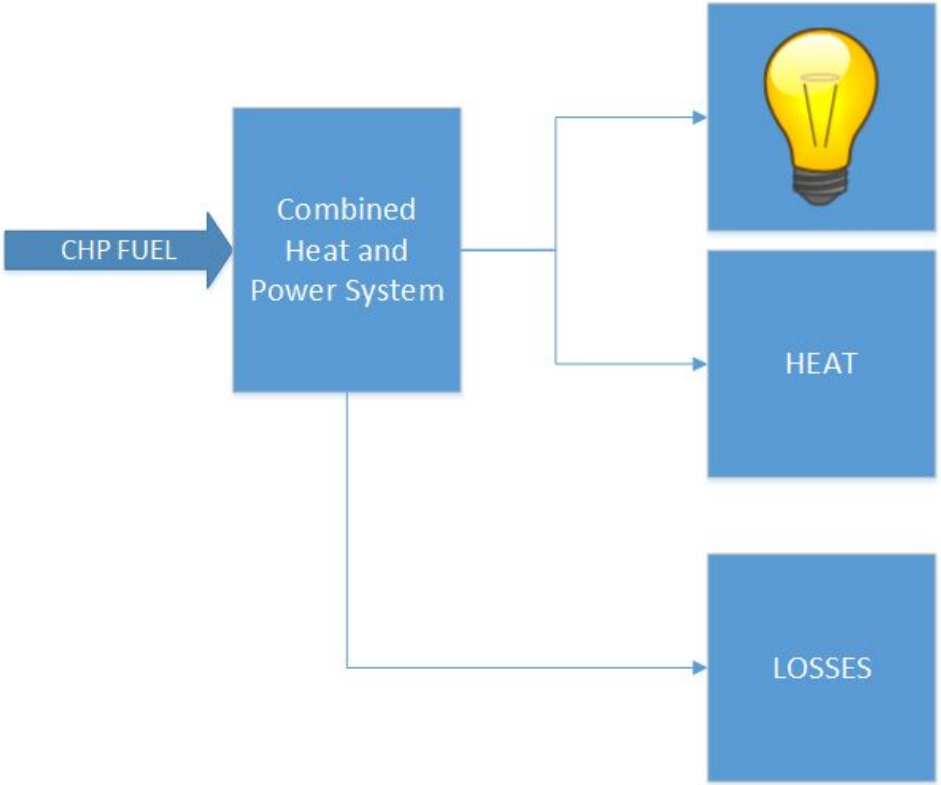
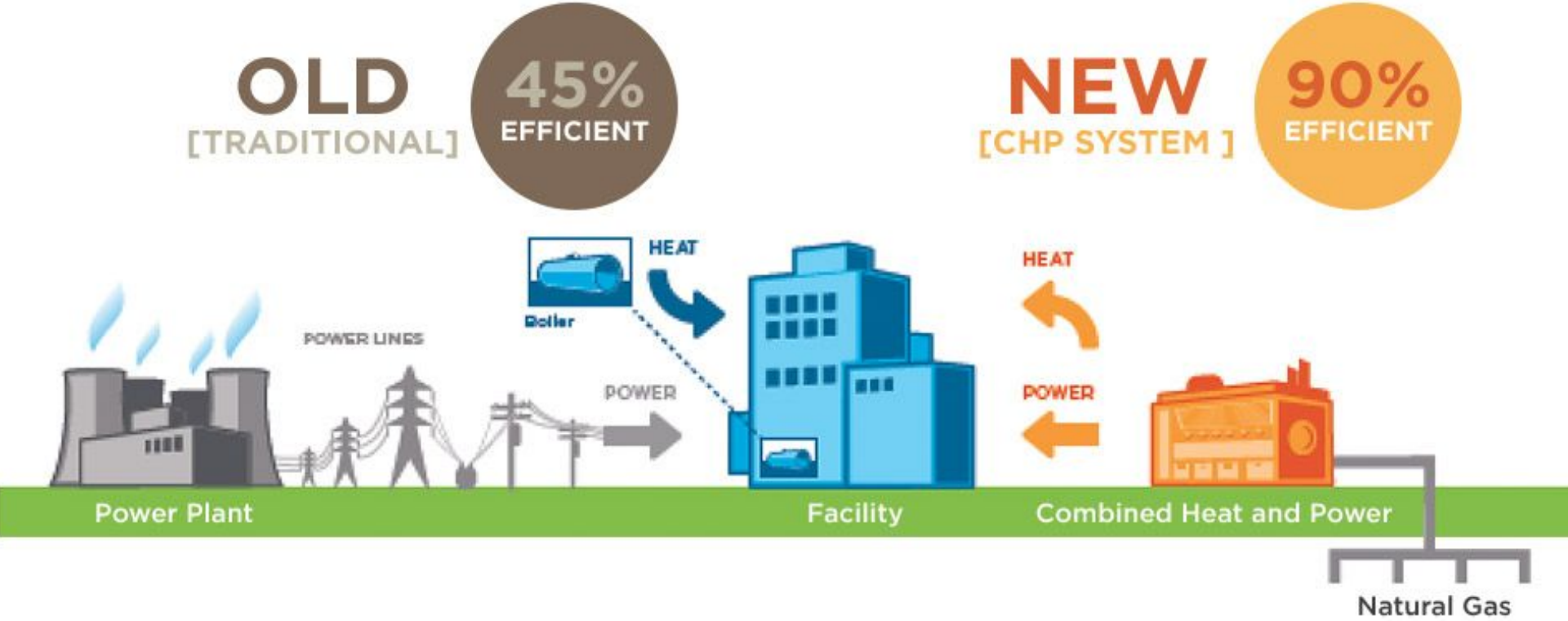
What is Combined Heat and Power?





http://www.igsgeneration.com/distributed-generation/combined-heat-power/

We were faced with the challenge of how to help CHP gain enough momentum to be a competitive initiative amongst other pressing priorities.

SOCIAL | TECHNICAL | POLICY | ECONOMIC | ENVIRO

Social Analysis

CHP @ Bucknell

In 1998, Bucknell converted from coal fired boilers to a steam-run cogeneration plant

- Emissions reductions
  - 1996 - 60,000 MTeCO2
  - 1997 - 37, 756 MTeCO2
- Savings = $1,000,000/year

Other Colleges & Universities:

- Williams 2004
- Smith College 2005
- Holy Cross 2010

If a school comparable to Lafayette implemented CHP on campus almost two decades ago, why hasn’t Lafayette College?

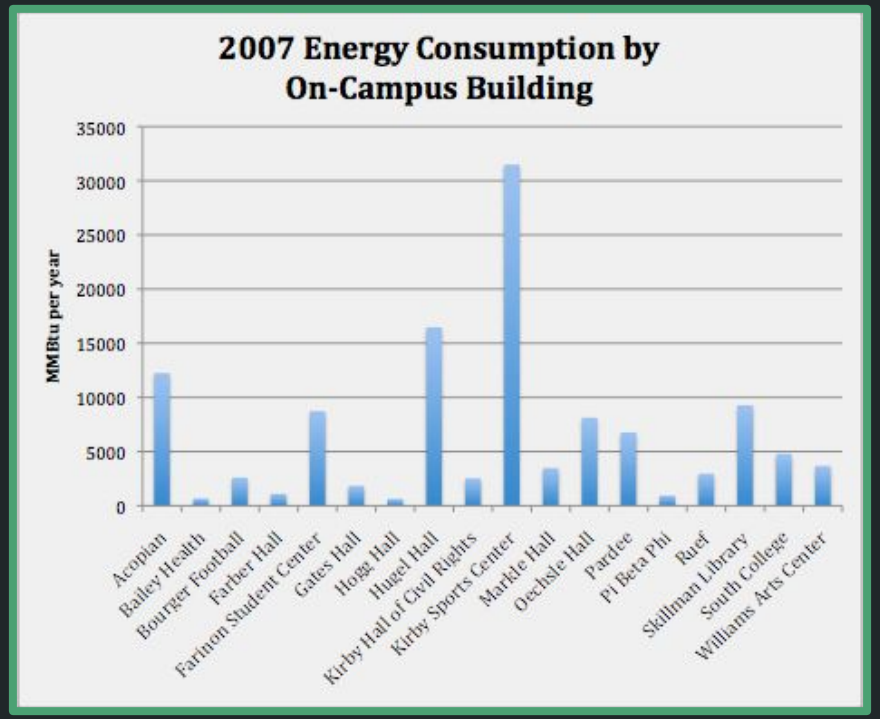
Current Issues

- Wanting to be a more self-sustaining campus
  - In 2008, President Daniel Weiss signed the Presidents' Climate Commitment (APUPCC)
  - Students & Sustainability
    - SEES
    - LEAP
    - Engineers Without Borders
    - LaFarm, etc
- Power outages due to storms and severe weather conditions
  - Hurricane Sandy

↳ Lack of a strong environmental identity

Research & Findings

- GHG Inventory : calculates emissions from 2005-2013
- Entech’s Energy audit - 2007
- Climate Action Plan - 2011
- Z&F Consulting - 2012
- Energy Policy



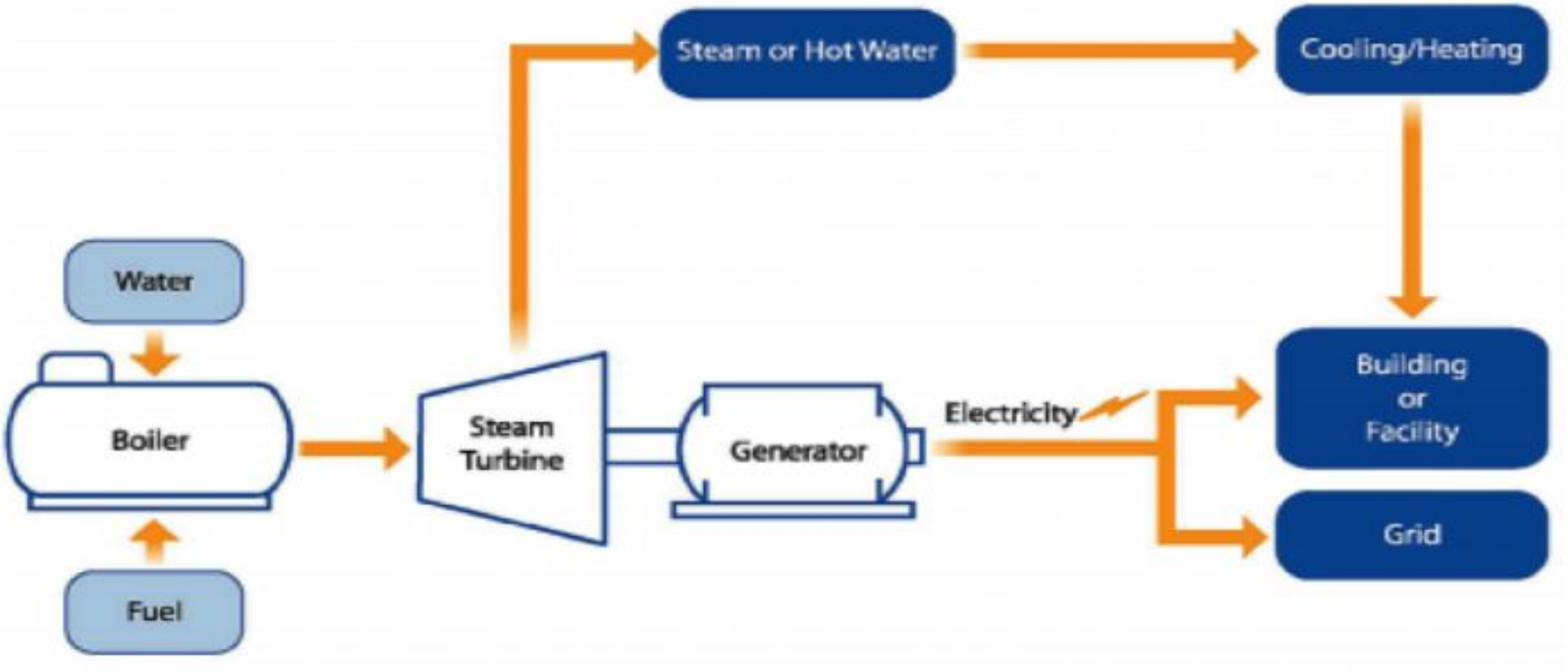
A selection of On-Campus Building's Energy Consumption from Entech's 2007 Energy Audit (Climate Action Plan, 20).

Conclusions: Lafayette Moving Forward

- Lafayette's first Sustainability Coordinator and Energy Manager started in November
- President Byerly announced the college's plan to expand the size of our campus over the next 6-8 years
- Dependent on whether Lafayette College Administration makes CHP a priority

Technical Analysis

Prime Mover: Steam Turbines & Reciprocating Engines



Synchronous Generators

- Self-exciting
- Complex
- Costly to safely connect to the grid
- Provides greater electrical power reliability

Radial System

- Most common type of distribution grid system
- Single path for power flow
- Easiest and least costly

Technical Analysis Conclusion

Policy Analysis

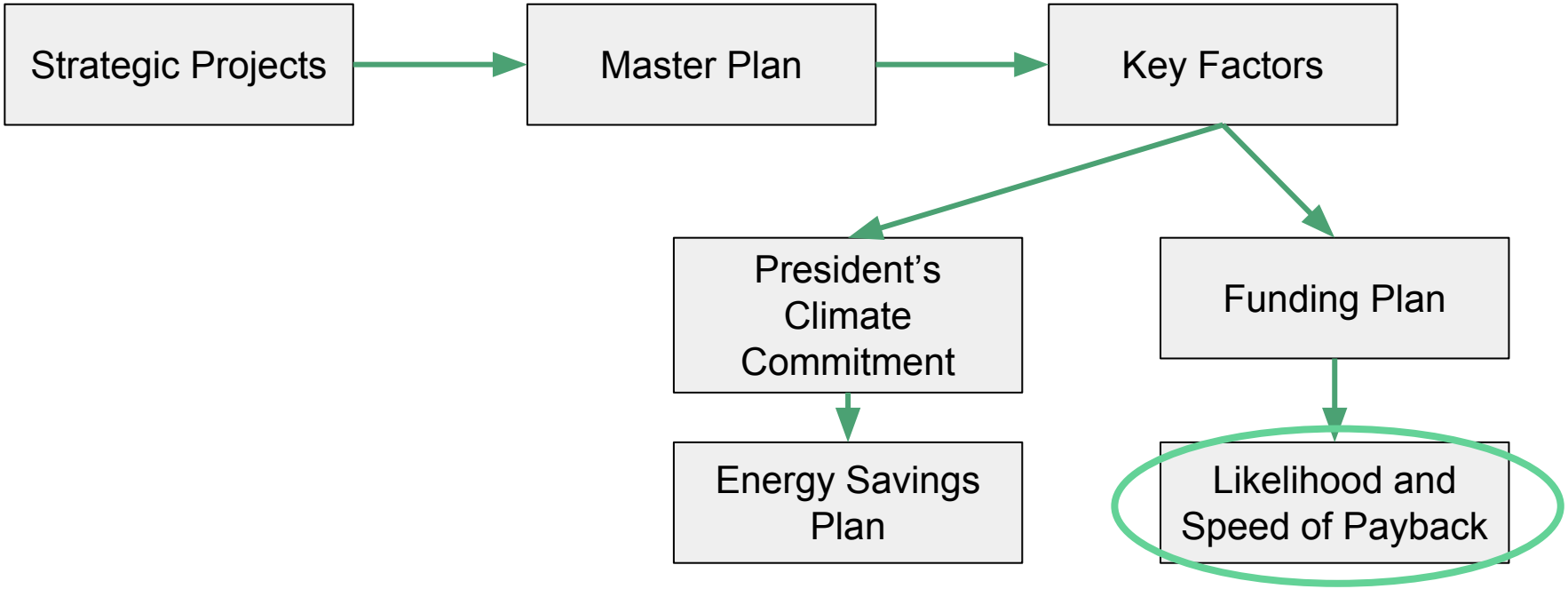
Federal and State

“A number of issues can affect decisions to invest in CHP. They can include government policy towards climate change and carbon emissions, energy policy including trading arrangements, planning and power station consent policy, and fiscal incentives.” - Dr. Mark Hinnells, Centre for Alternative Technology

Lafayette Policy

1. Environmental Sustainability - College Values Statement
2. 2008 President's Climate Commitment
3. Energy Policy

Lafayette Process Analysis



Economic Analysis

Costs & Perceived Benefits of CHP

Cash Flow Analysis

- Using data from the US Dept. of Energy 2016 and adjusting it to Lafayette College, this data table was created to depict cost breakdowns of the two CHP technologies of interest.

Costs	Reciprocating Engines	Steam Turbines
Principal	$7,085,600	$3,542,800
Annual >O&M >Natural Gas >Electric	$1,120,625 $560,000 $416,625 $144,000	$880,625 $320,000 $416,625 $144,000

Decisions

- Steam turbine CHP technology is the most advantageous to Lafayette College
  - Cost is the least negative over its life-cycle.
  - Payback period is short at 1.9 years when looking at incremental cash flows.
  - Calculated annual costs for O&M and heat/power production is reduced through turn act as savings or cash Lafayette College now “has”.

Savings	CHP Reciprocating	CHP Steam
PW	$ 14,957,541.31	$ 21,491,221.31
AW	$ 1,200,563.42	$ 1,724,695.98

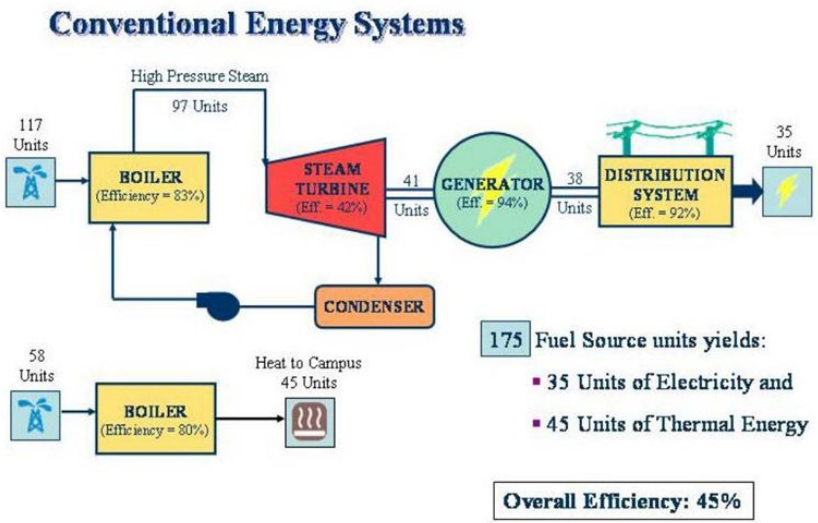
Calculated Incremental Cash Flows

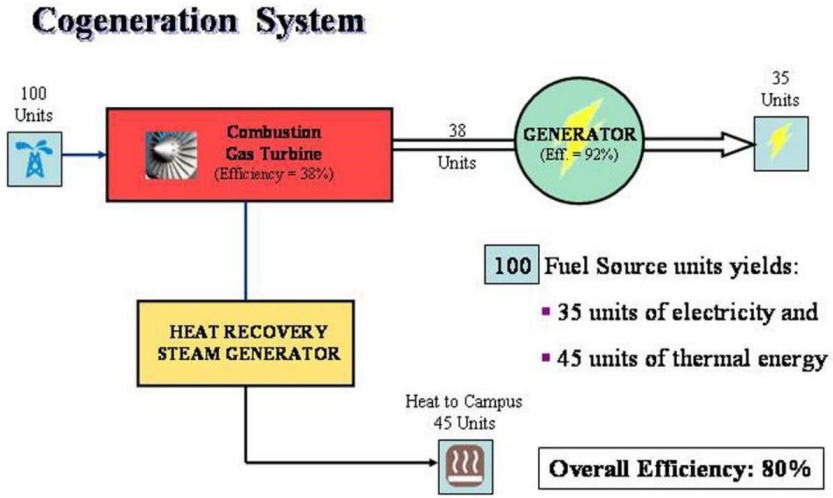
Environmental Analysis

Life-Cycle Analysis

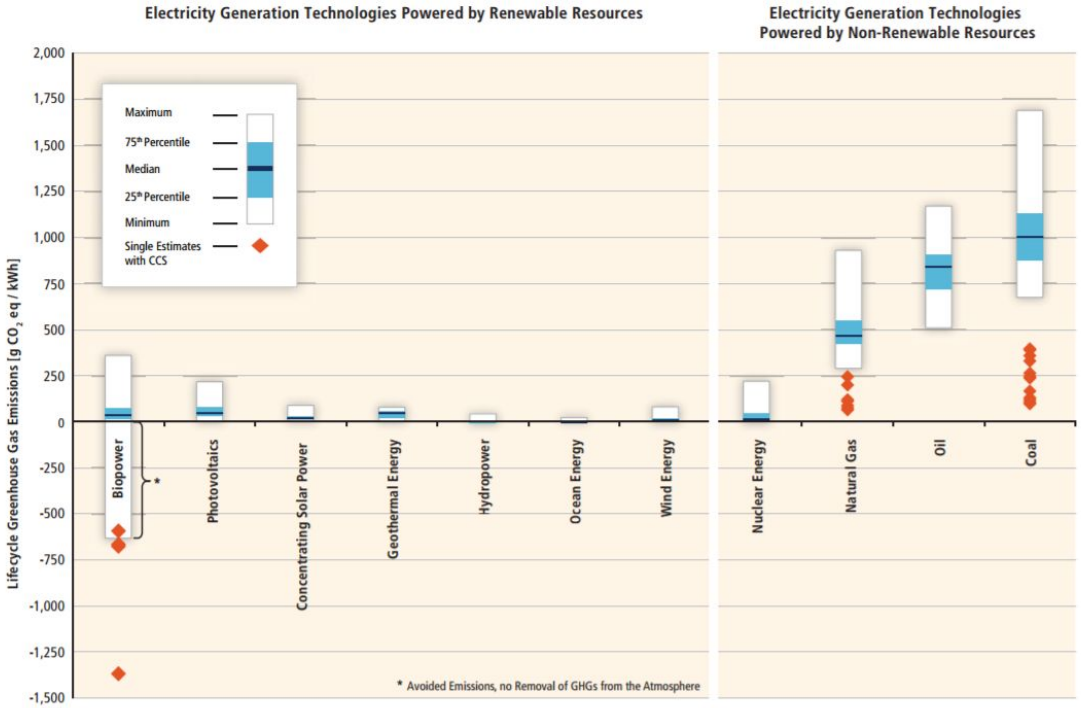
- In comparison to a conventional system CHP system has a reduced environmental impact
- The fuel used greatly depends on the ultimate environmental impact

Efficiency


Conventional Energy Systems
High Pressure Steam
97 Units
117 Units
BOILER (Efficiency = 83%)
STEAM TURBINE (Eff. = 42%)
41 Units
GENERATOR (Eff. = 94%)
38 Units
DISTRIBUTION SYSTEM (Eff. = 92%)
35 Units
CONDENSER
58 Units
BOILER (Efficiency = 80%)
Heat to Campus 45 Units
175 Fuel Source units yields:
35 Units of Electricity and
45 Units of Thermal Energy
Overall Efficiency: 45%


Cogeneration System
100 Units
Combustion Gas Turbine (Efficiency = 38%)
38 Units
GENERATOR (Eff. = 92%)
35 Units
HEAT RECOVERY STEAM GENERATOR
Heat to Campus 45 Units
100 Fuel Source units yields:
35 units of electricity and
45 units of thermal energy
Overall Efficiency: 80%

Potential Impact of CHP



- Further Infrastructure Management and Construction
- Sustainable Design and Development for Curriculum
- More Renewable Energy

Conclusions

Conclusion

1. Recommendations
    - Lafayette College should pursue implementing CHP

2. Next Steps
    - Complete a Technical, Economic, and Environmental Assessment based off Lafayette College data (not provided at this time)
    - Work to update policy and improve recognition of energy and heat production and consumption
    - Review and advise how CHP can be integrated into Campus Master Plan