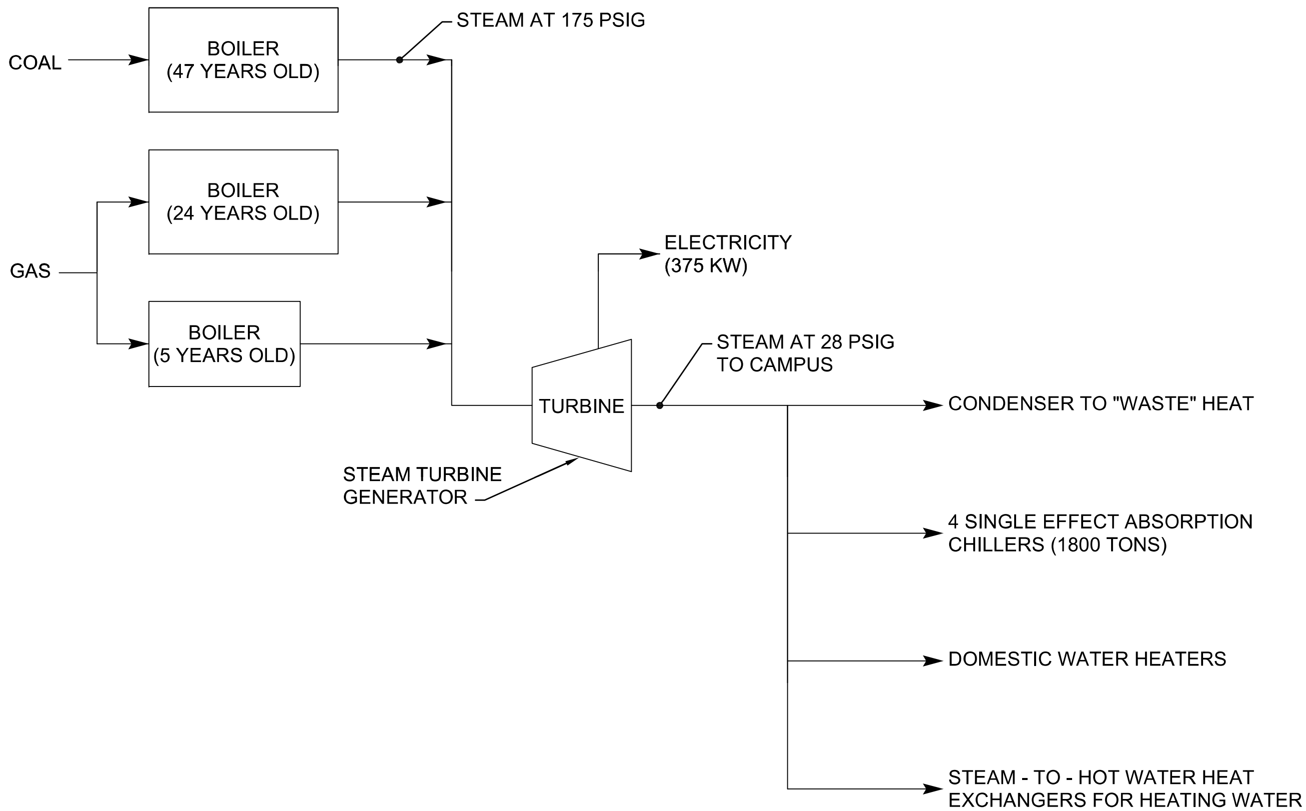
Goals

- Given:
  - The projected annual coal use for the College of Wooster is 6,500 tons per year. Based on the currently planned energy conservation methods.
- Objectives:
  - Reduce the carbon footprint of the college
  - Increase energy efficiency
  - Evaluate alternative energy sources for the plant (steam and electric)
  - Eliminate the use of coal as a fuel

CURRENT PLANT INFORMATION



EXISTING SYSTEM SCHEMATIC

Current Plant Information

System Results:

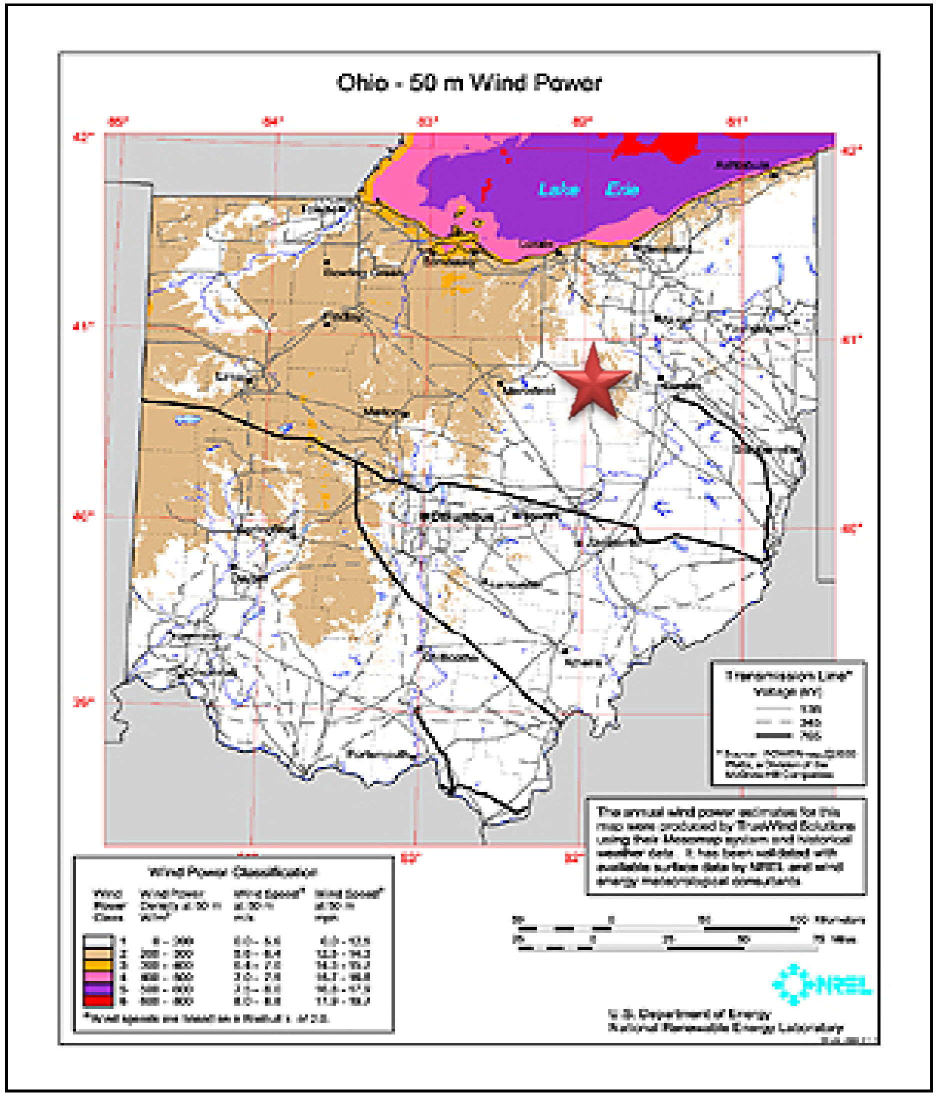
- Projected coal use after ECMs is 6,500 tons
- Coal generates 60% of the heating and 40% of the cooling for the campus
- Estimated carbon footprint using 6,500 tons of coal is 15,300 tons of CO_2 per year
- Approximately equal to 3,000 average cars

Summary of Preliminary Findings

Wind Generation

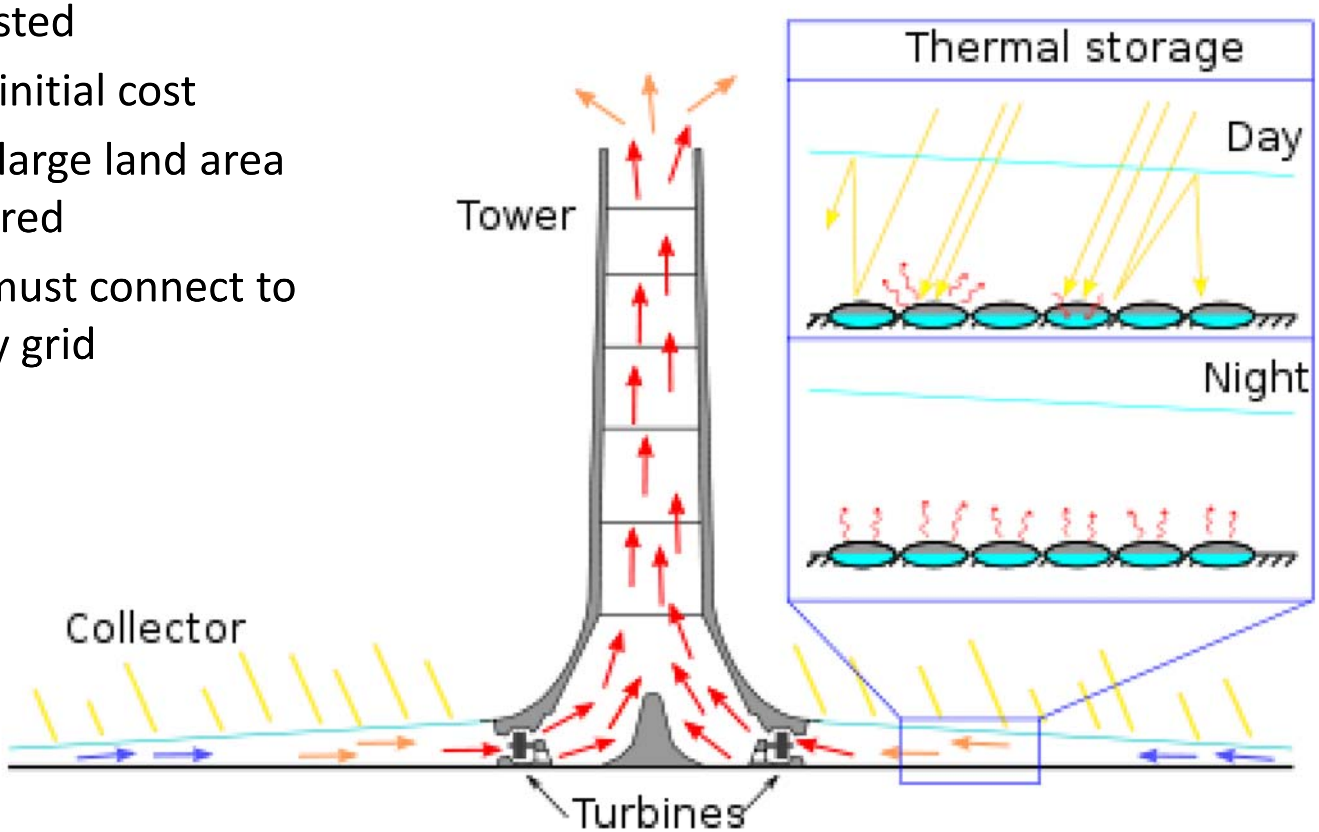
- Not Feasible
  - Insufficient wind power in northeast Ohio
  - High initial cost
  - Still must connect to utility grid

Wind turbine propellers that are used to generate electricity.



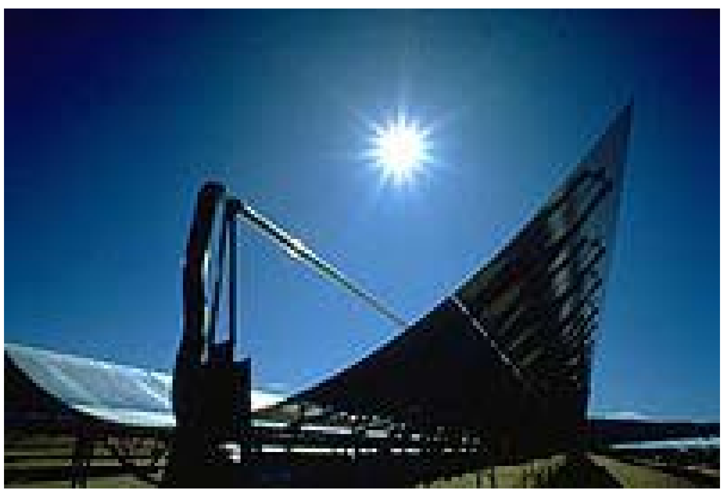
Solar Updraft Tower

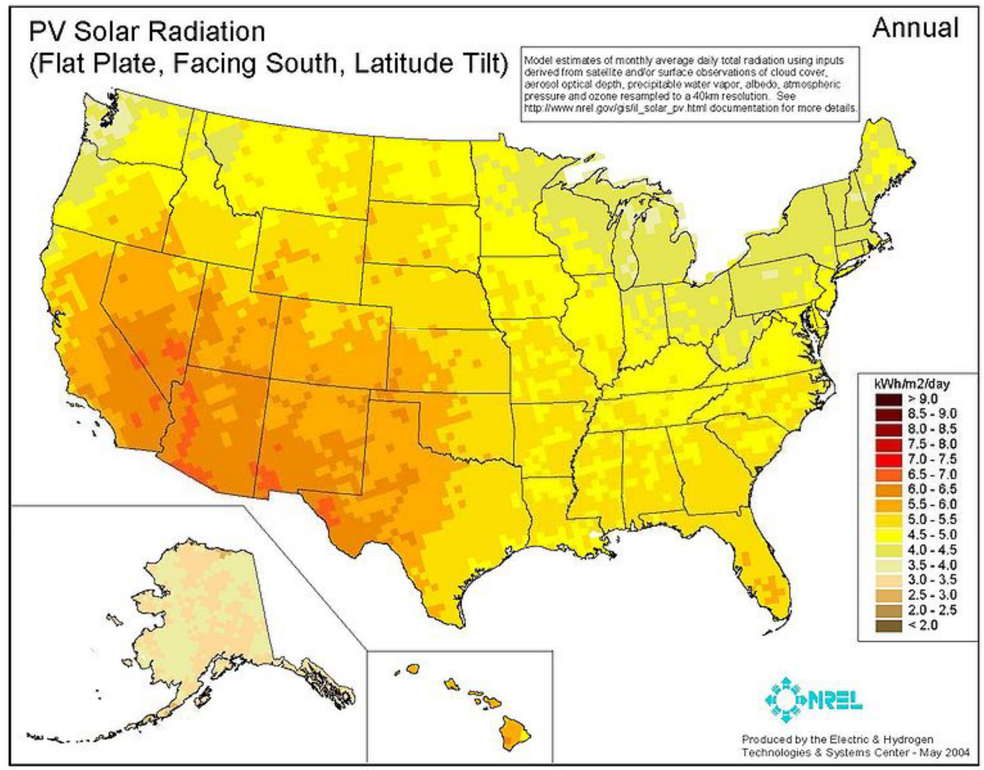
- Not Feasible
  - Untested
  - High initial cost
  - Very large land area required
  - Still must connect to utility grid



Solar (Concentrating)

- Not Feasible
  - High initial cost
  - Large land area required
  - Still must connect to utility grid





Fossil Fuels

- The remaining plant and building systems use some version of fossil fuel energy conversion.
- All generate CO_2 at varying levels
- Conversion efficiencies vary slightly depending on the system utilized
- **Fuel oil and propane** were considered but increase costs by approximately 7 fold over coal while reducing CO_2 output by only 21% to 28%. This is not a reasonable result.
- Fuel oil and propane not analyzed further

Coal - Current

- Not desirable due to high carbon footprint
- Existing boiler requires replacement
- Sulfur emissions (acid rain)

Wood

- Not feasible
  - Wood has a lower energy content per pound, thus would require about 12,000 tons per year.
  - This requires gathering and transporting all the wood waste in Wayne County.
- There is no supply chain mechanics to achieve this.
- Fuel costs become the gathering and transportation, estimated for this purpose at $30/ton.
- Due to higher consumption and lower conversion efficiencies, your site carbon footprint <u>increases</u> by 21% over coal.

Additional Analysis
Central Plant and Distributed Systems

Remaining Systems or Combinations

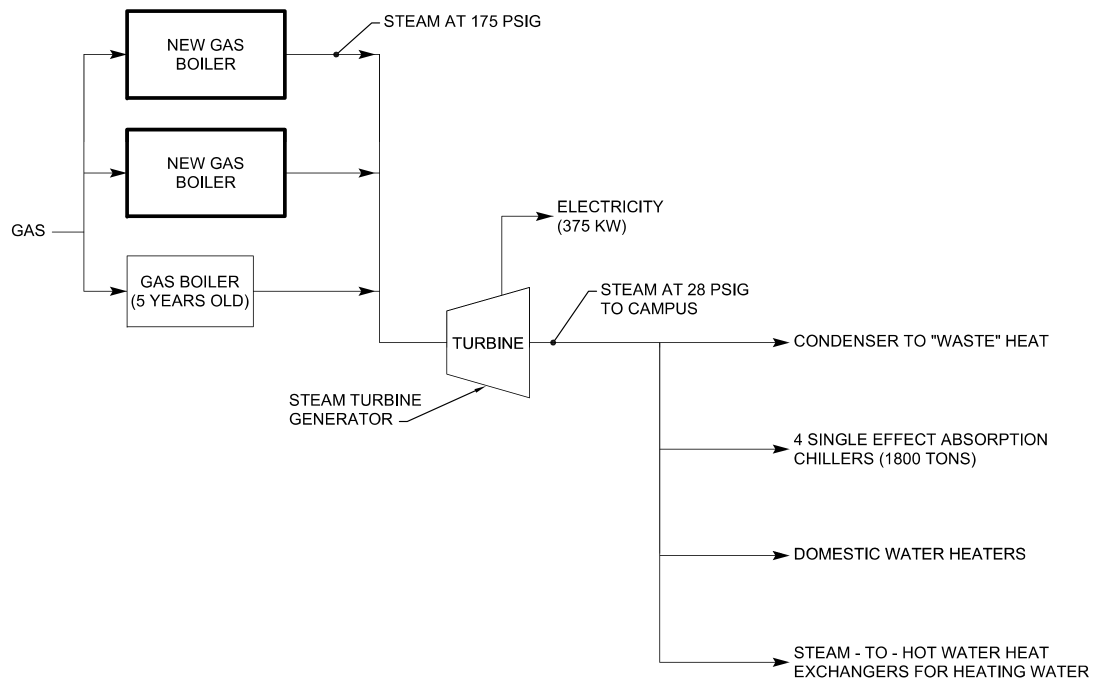
- Fuel sources
  - Natural gas
    - Biomass generation of gas
  - Electricity
  - Photovoltaics as distributed source
- System options
  - Centralized
    - Gas boilers with chillers (electric or steam)
    - Microturbines with chillers (electric or steam
- Distributed
  - Photovoltaics
  - Boilers/Chillers
  - Microturbines
  - Ground water source heat pumps
  - Ground water source hybrid system

Establish Baseline for Comparison

- Eliminate coal
- Coal boiler is 47 years old
- Gas has lower carbon footprint (40% reduction)

- Conclusion
  - Change existing coal boiler to gas
  - Replace aging gas boiler

BASELINE PLANT INFORMATION



NEW BASELINE SYSTEM SCHEMATIC

DOBER LIDSKY MATHEY BRAILSFORD & DUNLAVEY KORDA RodgersMotiskaDesign, Inc.

Natural Gas

- The plant already has natural gas boilers in place.
- Fuel supply stream is well established.
- Cost is relatively low
- Largest gas boiler should be replaced within the next 10 years.
- Another boiler should be installed now to replace the coal boiler and provide redundancy.
- Lower your carbon footprint by 40% (1,200 vehicles off the road).
- Natural gas purchased could be supplemented by a biomass digester generating gas.

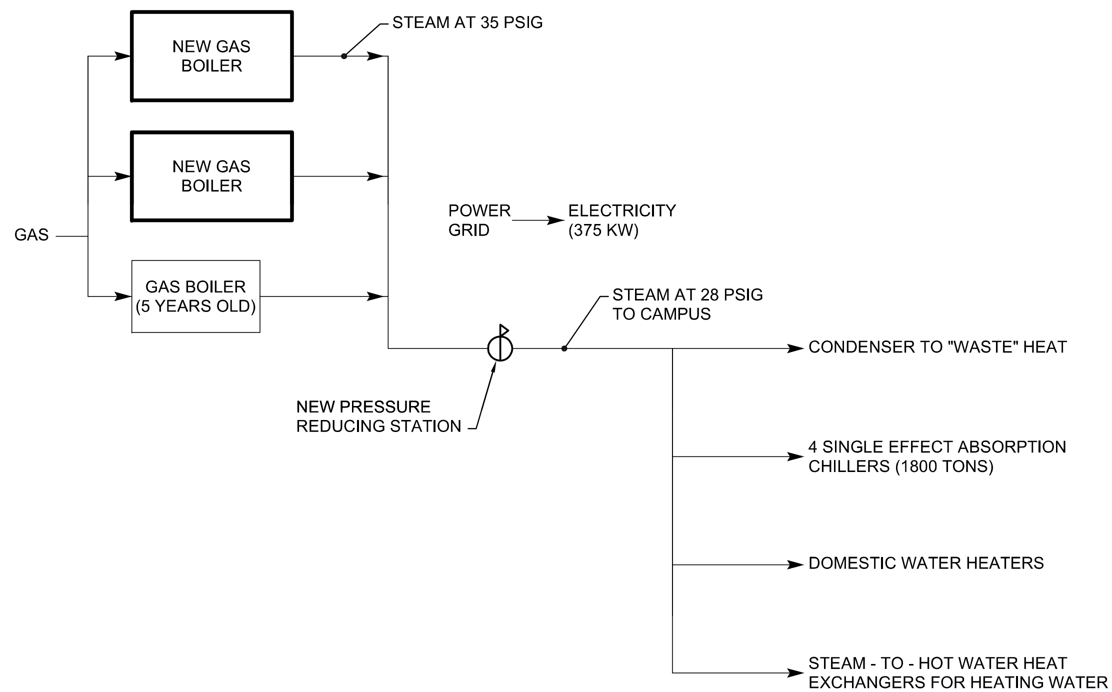
Baseline Cost and Scope

- Demolish coal boiler and all accessories (stoker, bag house, etc.)
- Provide new boiler of same size
- Retain existing feedwater equipment (condition unknown)
- Replace 24 year old boiler with new
- Retain turbine, generator and distribution system
- Estimate: $3 Million
- Projected yearly campus operating cost: $2.08 Million (gas & electric)

Eliminate Steam Turbine Generator?

- Lower steam discharge pressure at boilers (175 to 35psig)
- Achieve higher boiler efficiency
- Remove turbine generator
- Alter plant as needed

BASELINE PLANT INFORMATION



DELETE STEAM TURBINE SYSTEM SCHEMATIC

Evaluation

- The increase in boiler efficiency is about 2.75%
- Increase carbon output by almost 800 tons/per year due to increased electricity purchase
- Due to increase purchase of electricity, fuel costs increase $112,000 per year
- Cost to remove and alter plant is about $700,000
- Spend money to spend money

Conclusion: Keep turbine generator

If turbine is in poor shape, replacement is about $250,000 with an ROI of about 45% due to increased energy cost.

Electric Chillers v. Steam Absorption Chillers

- Replace steam units with electric centrifugal chillers
- Most accessory equipment remains with minor changes

Estimated cost of construction: $1.74 million

Carbon footprint reduction of over 5,000 tons/year at full plant load

Savings: $480,000/year (based on estimated load profile)

Return on investment = 27%

Conclusion: Replace steam chillers with electric centrifugal

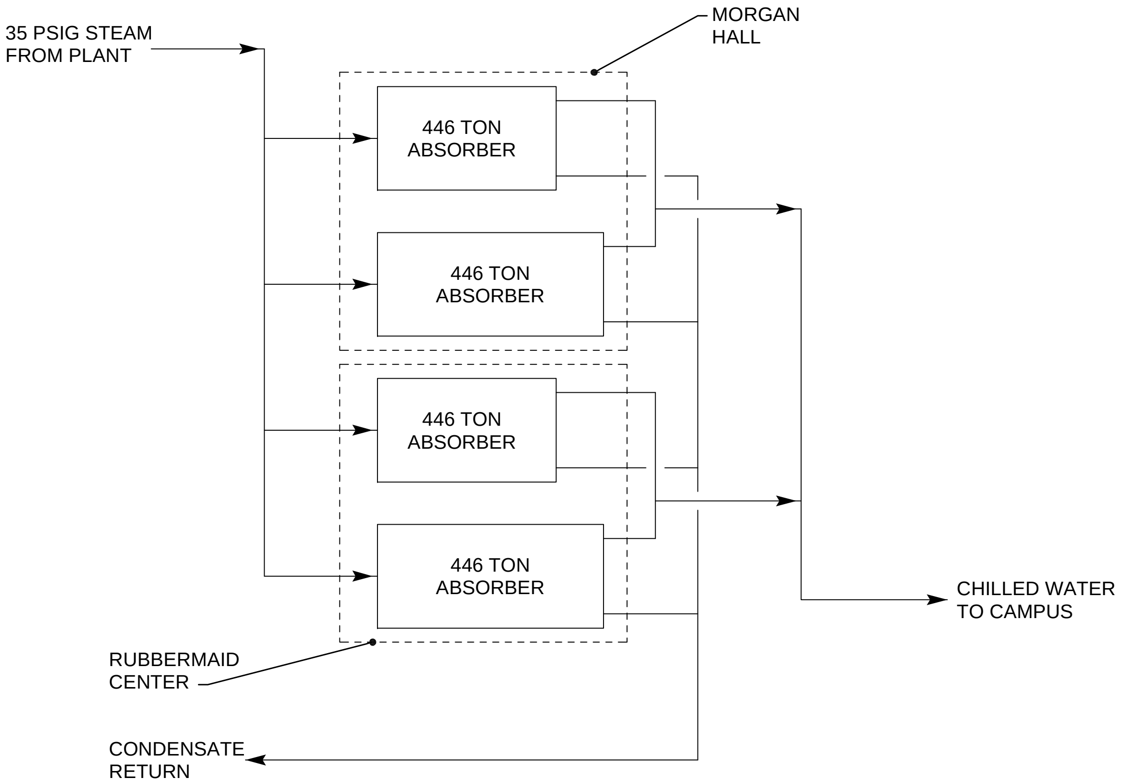
Electric Chillers v. Steam Absorption Chillers

Further: Replacing chiller removes base steam load from boilers thus steam turbine is no longer as feasible to retain in operation through cooling season.

Combined Impact

- $368,000 /yr savings minimum
- 2,200,000 first cost
- Reducing carbon by 4500 tons
- ROI = 16.7%

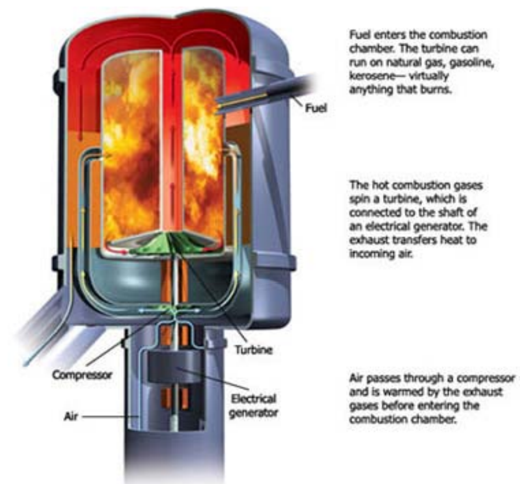
ELECTRIC CHILLERS V. STEAM ABSORPTION CHILLERS

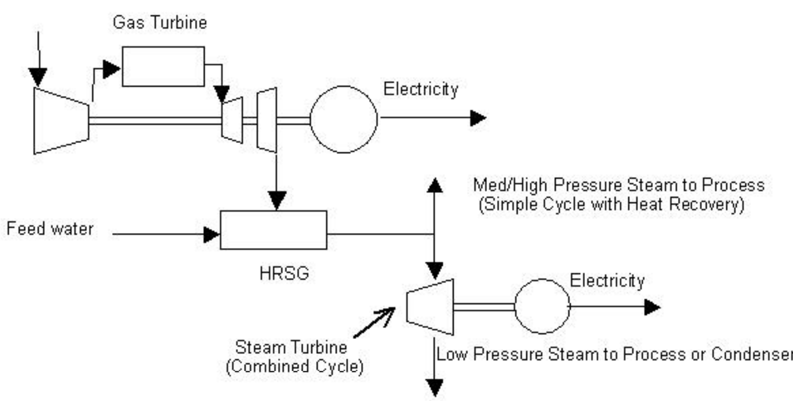


CURRENT CHILLER SYSTEM SCHEMATIC

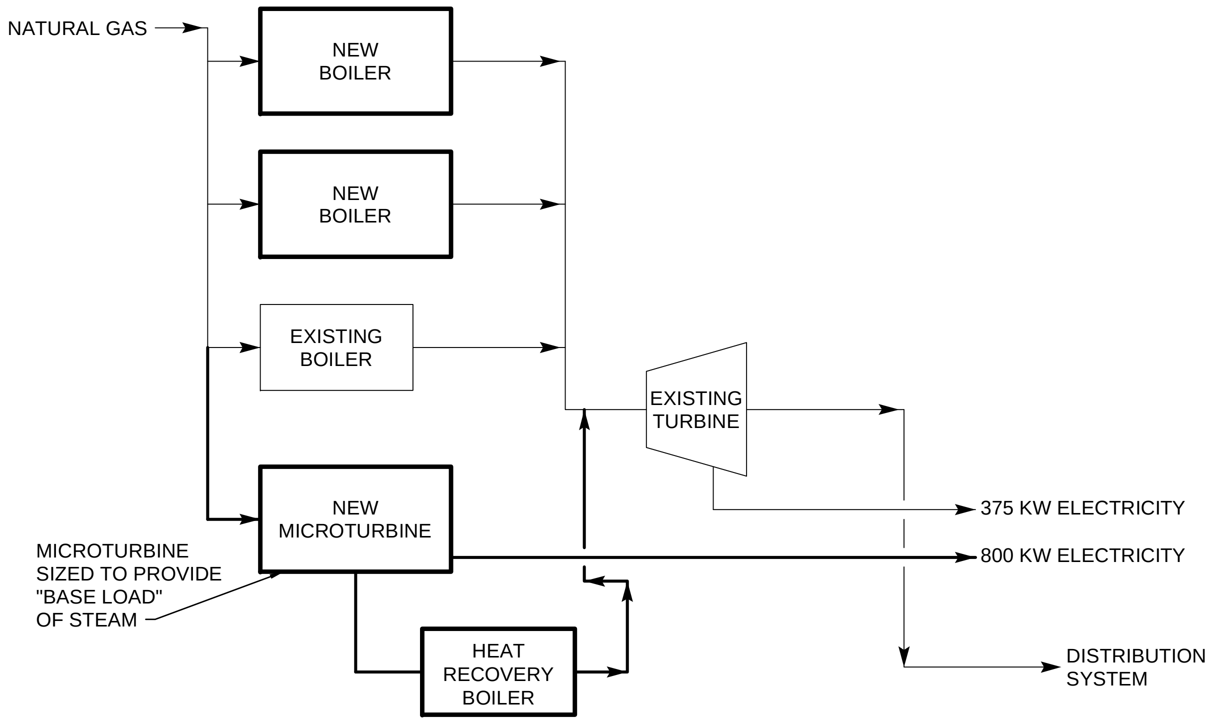
Centralized Microturbines (natural gas)

- Small (30-500 Kw) gas-fired turbine generators
- Exhaust gas used to generate high pressure steam (HPS) in a heat recovery device.
- HPS passes through a generator for more electricity
- Low pressure steam from the generator is distributed to the Campus
- Overall conversion efficiency is approximately equal to gas boilers





CENTRALIZED MICROTURBINE



CENTRAL PLANT MICROTURBINE SCHEMATIC

Centralized Microturbines

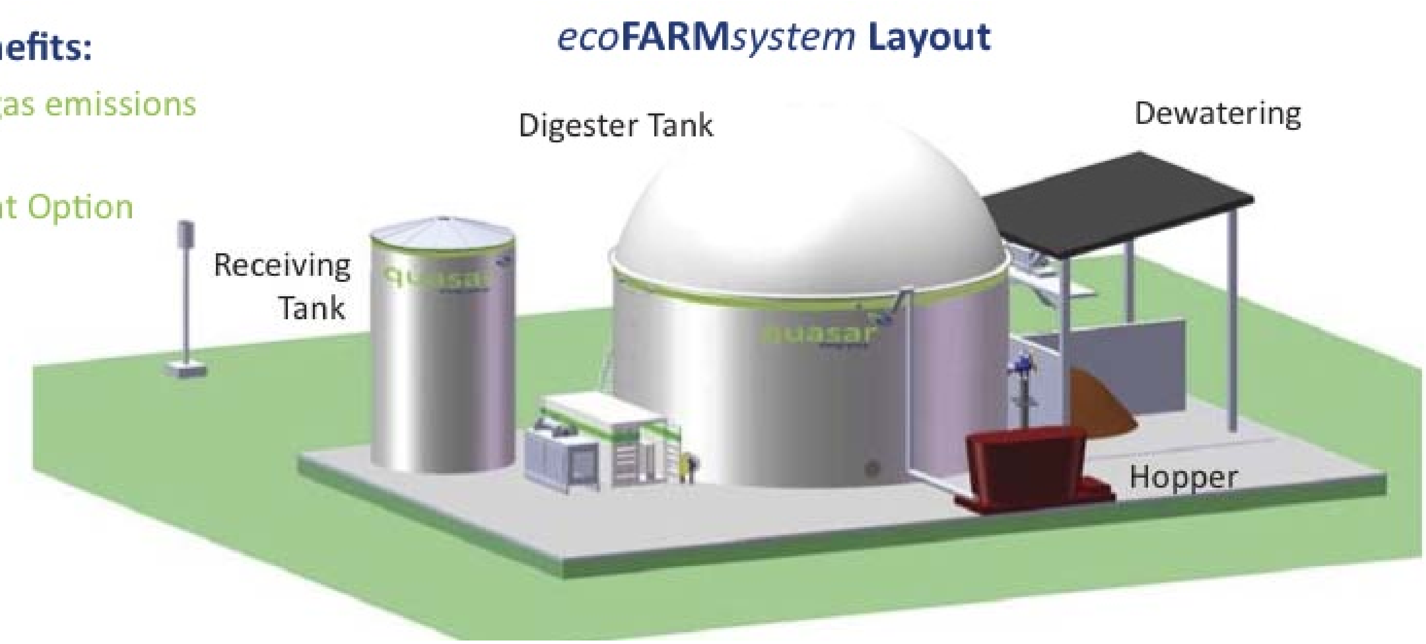
- The microturbine would be sized to provide the steam for the base load of 4,700 lbs./hr. (1/6 of peak, based on Dynamix Report)
- Generate 800 kW of electricity
- Estimated Cost $4.2 million (including new boilers)
- ROI based on 1.2 million increase is 8.9%
- Increase gas consumption, but decrease purchased electric
- Increase maintenance
- Savings of $107,000/year
- Carbon footprint remains same as base
- Conclusion: Not feasible due to ROI below 10% and no change in carbon footprint

Biomass

- Use an anaerobic digester to turn manure, food waste, crops, and other products into gas.
- Can be “plugged into” the campus natural gas piping anywhere

Environmental Benefits:

Reduce greenhouse gas emissions
Odor Reduction
Nutrient Management Option



Biomass

- Site carbon footprint produced will be similar to natural gas
- Landfill waste reduction and the subsequent release of gas creates a reduction in the overall carbon footprint
  - Reduces methane "offgassing" which has 33 times the global warming potential of CO_2 (NASA)
- Fuel savings of $200,000 to $300,000
- Byproducts can also provide revenue
  - Bedding ($50/ton)
  - Fertilizer
  - Compost

Biomass

- Depending on ratios of waste products used, a single digester could provide 12% to 45% of the central plant's gas needs per digester.
- Supply system not in place. Cost is mainly transportation.
- Full replacement of consumed natural gas would require:
  - The daily manure from over 9,200 dairy cows (5 cows/student)
  - 63,300 tons food waste plus 21,100 tons manure per year
- Installed cost of approximately $5 million
- ROI of 4 to 6%

Biomass

- Waste streams within a 50 mile radius could not be easily identified. (economically feasible)
  - OSU and Ohio Department of Development identify only 78,800 tons of cattle waste in all of Wayne County
  - Similarly the study indicates municipal waste as the source with the most potential
- Total potential energy available
  - Wayne County: 1000-3500 billion Btu's per year
  - Stark County (nearby): 21,000-28,500 billion Btu's per year offers a good opportunity
  - Wooster consumes 191 billion Btu's/year
- Pursue possible potions with Akron waste disposal groups
- While total fuel replacement may not be feasible, the global warming potential of all CO_2 generated can be accounted for by recovering the methane from approximately 2600 tons of food waste per year

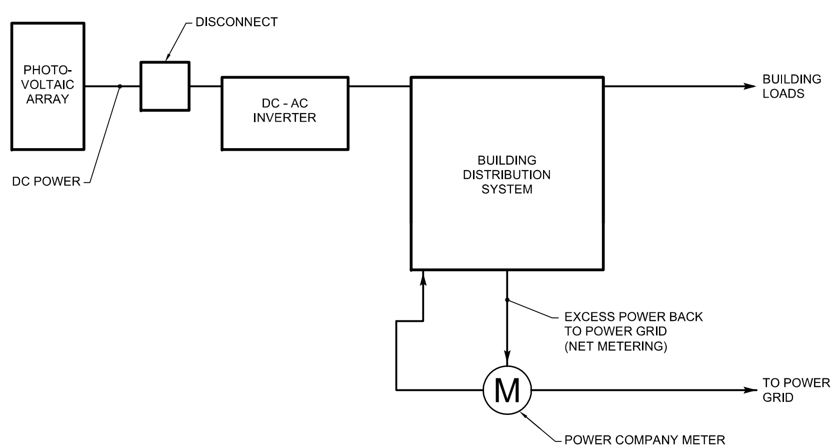
Distributed vs. Central Generation

- Centralized system requires a distribution piping system
- Distribution losses are 2% to 5% of the total
  - Steam
  - Chilled Water
- Many fuels allow distributed heating and cooling systems
- It follows that distributed heating systems will lower fuel cost, but will result in higher maintenance costs (more equipment)
- Photovoltaics on building

Solar – Photovoltaics – Distributed

- Solar to electric conversion efficiencies are rapidly increasing
- Still connect to the power grid
- Manufacturing costs are decreasing

PHOTOVOLTAIC SYSTEM



Solar – Photovoltaics – Distributed

- Building and PV Properties
  - 45,000 square feet building
  - 3 stories
  - 15,000 square feet of roof area
  - 80% of roof covered with PV array = 12,000 square feet array
  - PV generates about 10 watts/square foot of panel
  - This yields a 120 kW system
  - Approximate installed cost of $6/watt = $720,000
  - Each installed kW produces about 1,100 kWh/year
  - 132,000 kWH not purchased from an electric company

Solar – Photovoltaics – Distributed

- Analysis
  - Zero Carbon Footprint
  - Savings: $6,300 in fuel cost
  - $720,000 Installed Cost
  - 30% Federal Tax Credit
  - $150,000 State Grant - figured first
  - Net Cost: $399,000
  - ROI of 1.6% per year
- Future Note: The industry expects to decrease the installed cost by 50% within the next three years. Assuming incentives are still in place at that time, this results in an ROI of 4.3%.

Geothermal - Distributed

- Circulating water loop serves water-source heat pumps
- College of Wooster has land
- More energy efficient due to inherent heat recovery and stable ground temperatures
- More maintenance labor due to units spread throughout the building
- Complicates Campus planning due to wells or piping fields

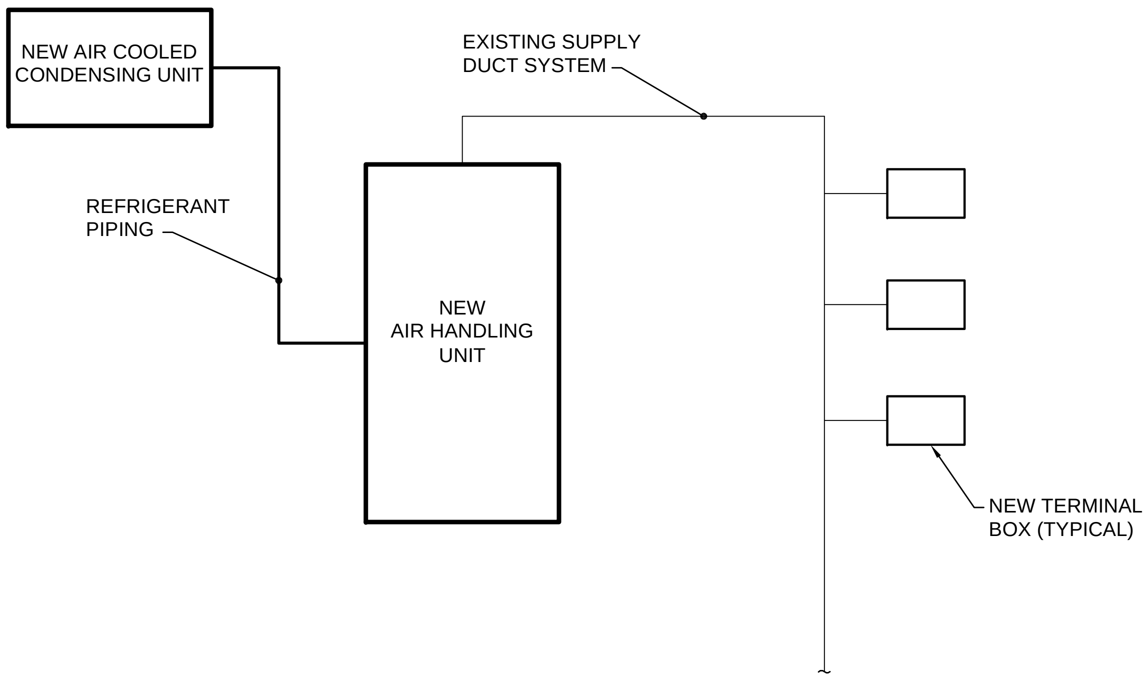
Energy Modeling (Taylor Hall)

- An energy model was performed on a 44,000 square foot sample building.
- Purpose: Compare system variations and energy/CO_2 impacts.
- All building parameters were held constant.
- Only HVAC system parameters were varied.
- The initial costs consider some re-use of hardware (ductwork, distribution, etc) as in renovating Taylor Hall.
- The building was input as a college classroom building of the same approximate size of Taylor Hall.
- The specific parameters of Taylor Hall would require an extensive survey.

The systems considered were as follows:

SPLIT SYSTEM VAV

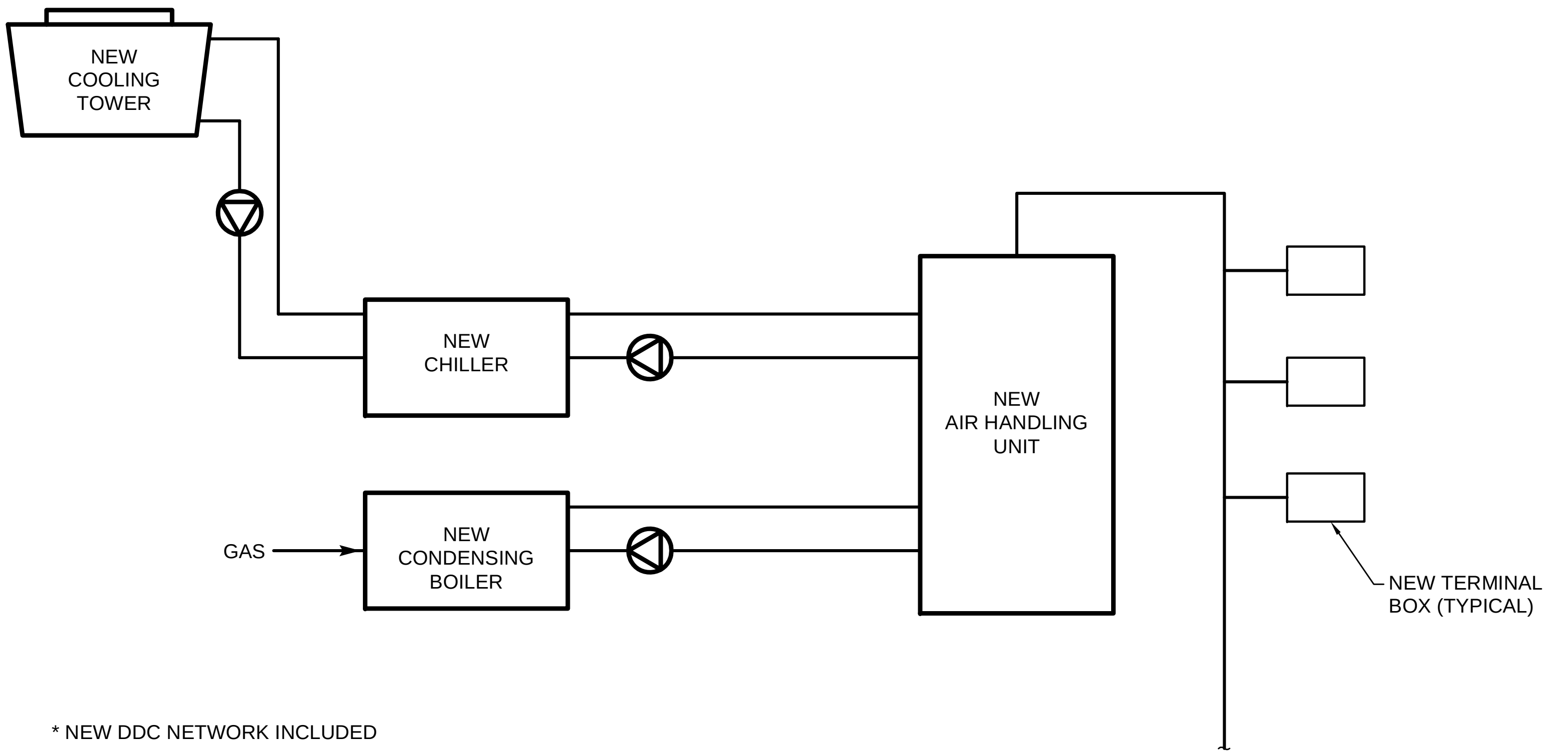
THIS IS A REPLACEMENT SYSTEM CONSIDERATION FOR TAYLOR HALL



* NEW DDC NETWORK INCLUDED

SYSTEM SCHEMATIC

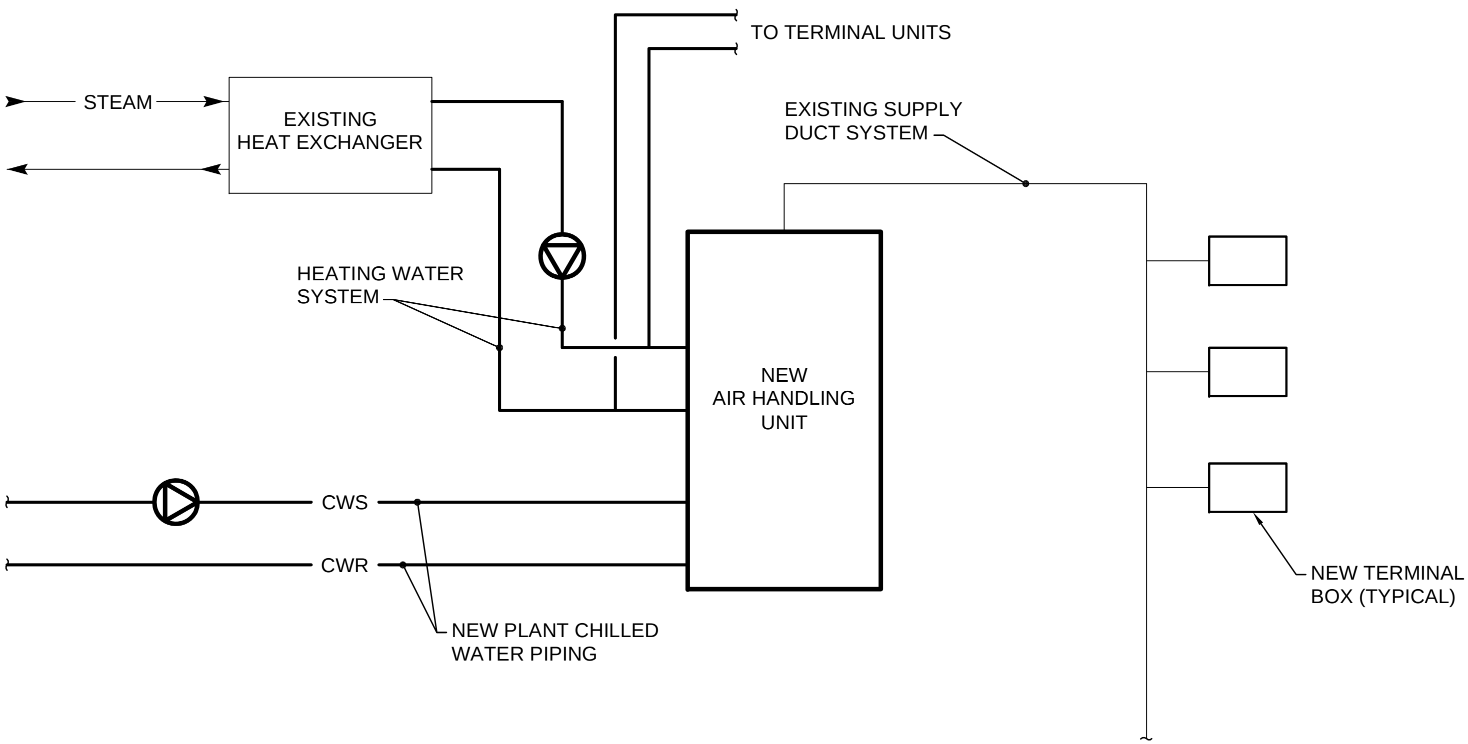
BOILER AND CHILLER CONTAINED IN BUILDING



* NEW DDC NETWORK INCLUDED

SYSTEM SCHEMATIC

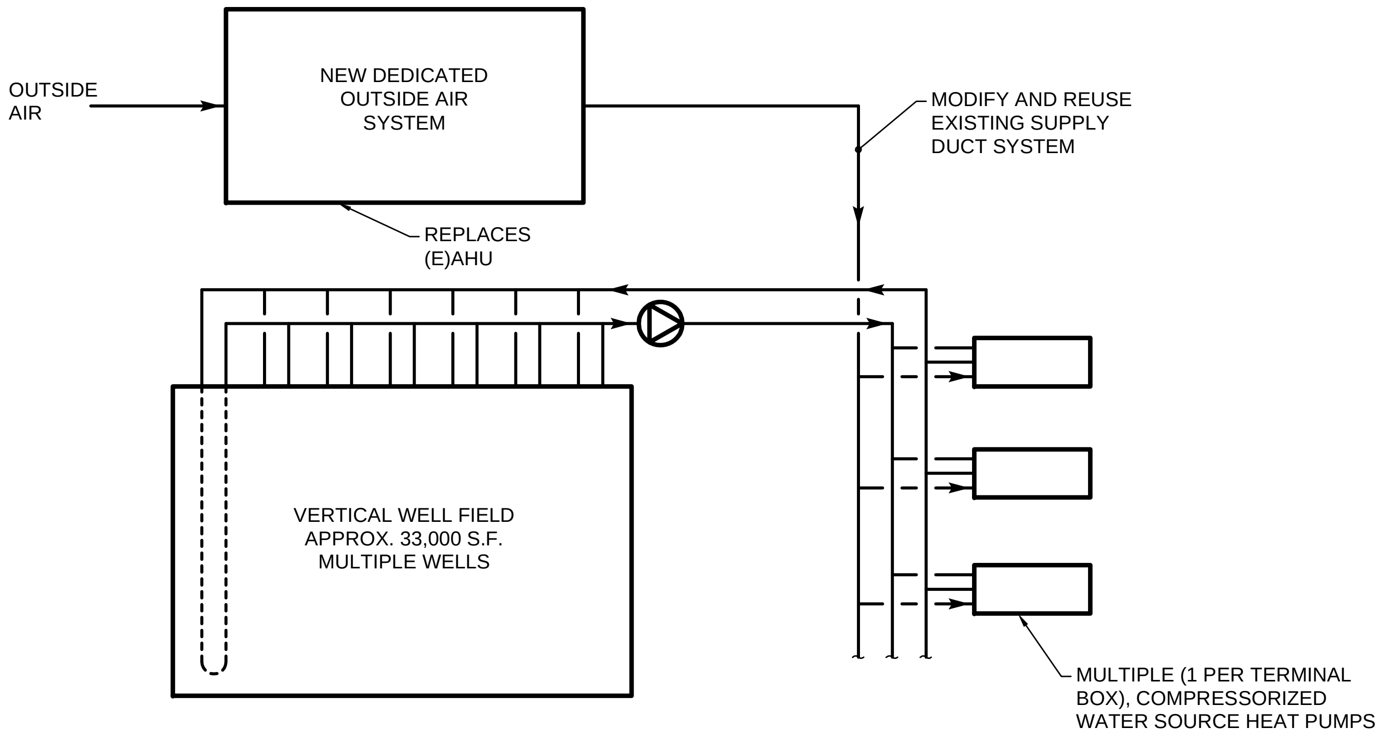
CENTRAL PLANT



* NEW DDC NETWORK INCLUDED

SYSTEM SCHEMATIC

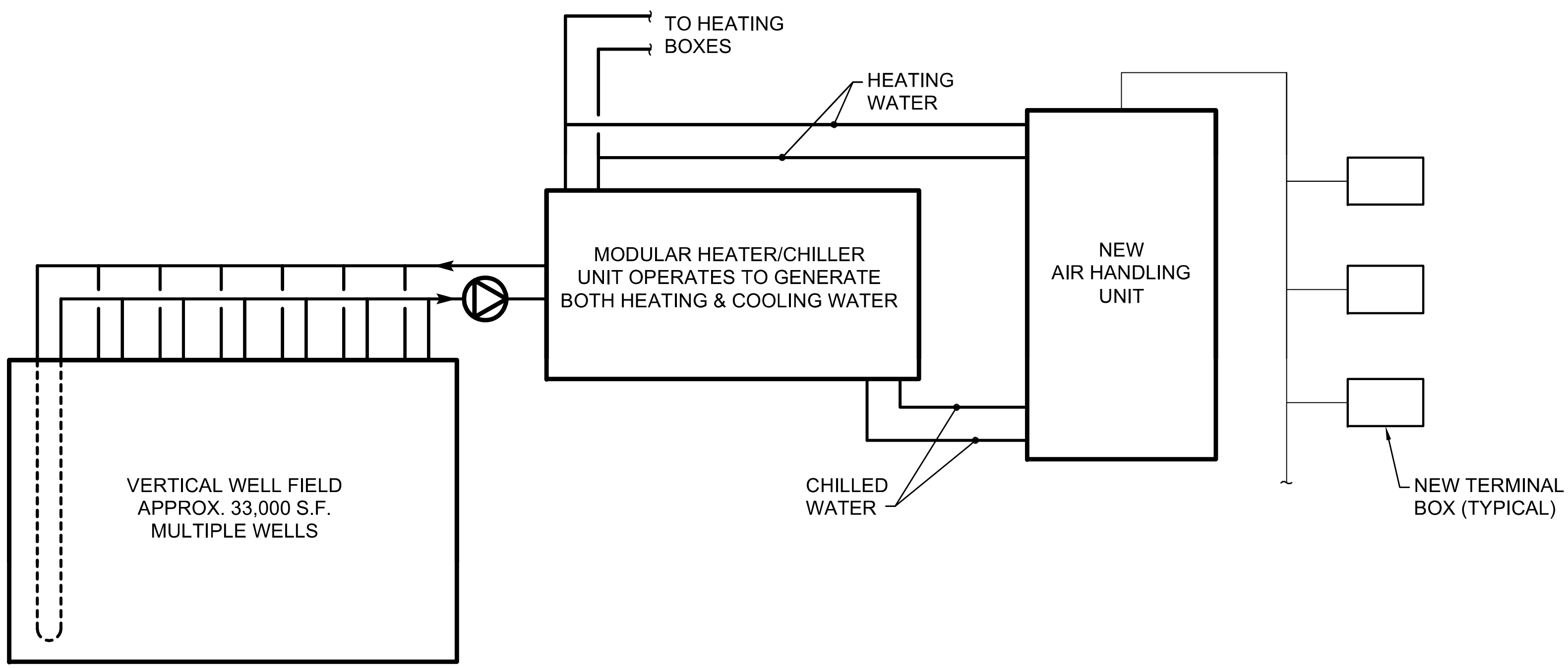
GROUND WATER SOURCE HEAT PUMP



* NEW DDC NETWORK INCLUDED

SYSTEM SCHEMATIC

GROUND WATER SOURCE HEAT PUMP - HYBRID



SYSTEM SCHEMATIC

Modeling Results - Taylor Hall

System	Initial Cost	Energy Cost	ROI***	CO_2 tons/year	%CO_2 Reduction
Existing Dx	$0	$48,700	*	296.00	*
Split System Dx	$1,021,000	$45,100	0.4%	284.00	4.0
Boiler/Chiller	$1,150,000	$44,590	3.2%	250.80	15.3
Central Plant**	$1,290,000	$47,440	0.5%	264.09	10.8
GWSHP	$1,480,000	$25,300	5.1%	91.23	69.2
GWSHP Hybrid	$1,239,000	$26,410	10.2%	76.64	74.1

- The hybrid system provides a 28.2% reduction in CO2 emissions and an 8.6% ROI.

* This system is the baseline comparison.
** System includes 500 feet distribution pipe and a portion of the plant cost.
*** ROI based on change over Split System Dx upgrade price, but current energy cost.

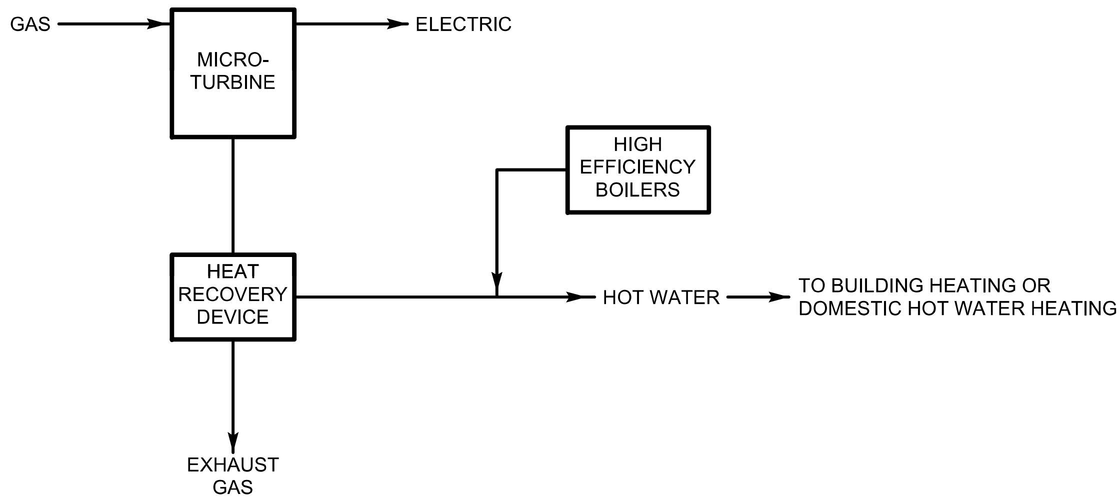
Greenfield Building (44,000 square feet)

System	Initial Cost	Energy Cost	ROI***	CO_2 tons/year	%CO_2 Reduction
Dx System	$1,012,000	$43,100	*	284	*
Boiler/Chiller	$1,232,000	$44,590	0.2%	251	11.7
Central Plant**	$1,408,000	$47,440	-0.6%	264	7.0
GWSHP	$1,320,000	$25,300	6.4%	91	67.9
GWSHP	$1,320,000	$26,410	6.1%	77	73.0

* This system is the baseline comparison.
** System includes 500 feet distribution pipe and a portion of the plant cost.
*** ROI based on cost increase from Dx System.

MICROTURBINES DISTRIBUTED

- MODELING PROGRAM DOES NOT ACCOUNT FOR THE USE OF MICROTURBINES
- DIAGRAM OF A BUILDING-BASED MICROTURBINE



SYSTEM SCHEMATIC

Microturbines Distributed

- Increases natural gas consumed, but saves purchase of electricity.
- Increases maintenance costs.
- Analyzed a single 30 kW microturbine. (assume base load)
- Initial Cost Increase: $53,000 to $61,000
- OP Cost Savings: $5,610 savings to $1,100 additional pending electrical conversion efficiency, includes maintenance cost increase.
- ROI = -1.8% to 10.6%
- Carbon Footprint: Each 30 kW microturbine saves 10 tons of CO_2.
- This is compared to a boiler/chiller baseline heating/cooling system, not a geothermal system.
- Better for larger building/larger base heating load.

Conclusions and Recommendations

- Central Plant - As long as you have one
  - Natural gas conversion from coal
  - Replace steam absorption chillers with high efficiency electric
- Distributed - Overtime
  - Ground water source heat pumps in a hybrid system.
  - If building has a large 'base' heat load and geothermal is not feasible, microturbines should be reviewed.
- Biomass
  - Pursue identifying local waste streams.
  - Install a digester to "offset" carbon footprint