Design & Implementation of Modern Biomass Systems

Heating the Midwest
Minneapolis, MN

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Modern Biomass Systems

Modern wood boilers provide clean and efficient options for meeting commercial facility thermal demands in individual buildings or district energy systems. Clean and efficient appliances are available for all facility scales, and locally available wood fuel types.

Cord Wood Boilers

Courtesy Main Energy Systems

Wood Pellet Boiler

Courtesy Viessmann

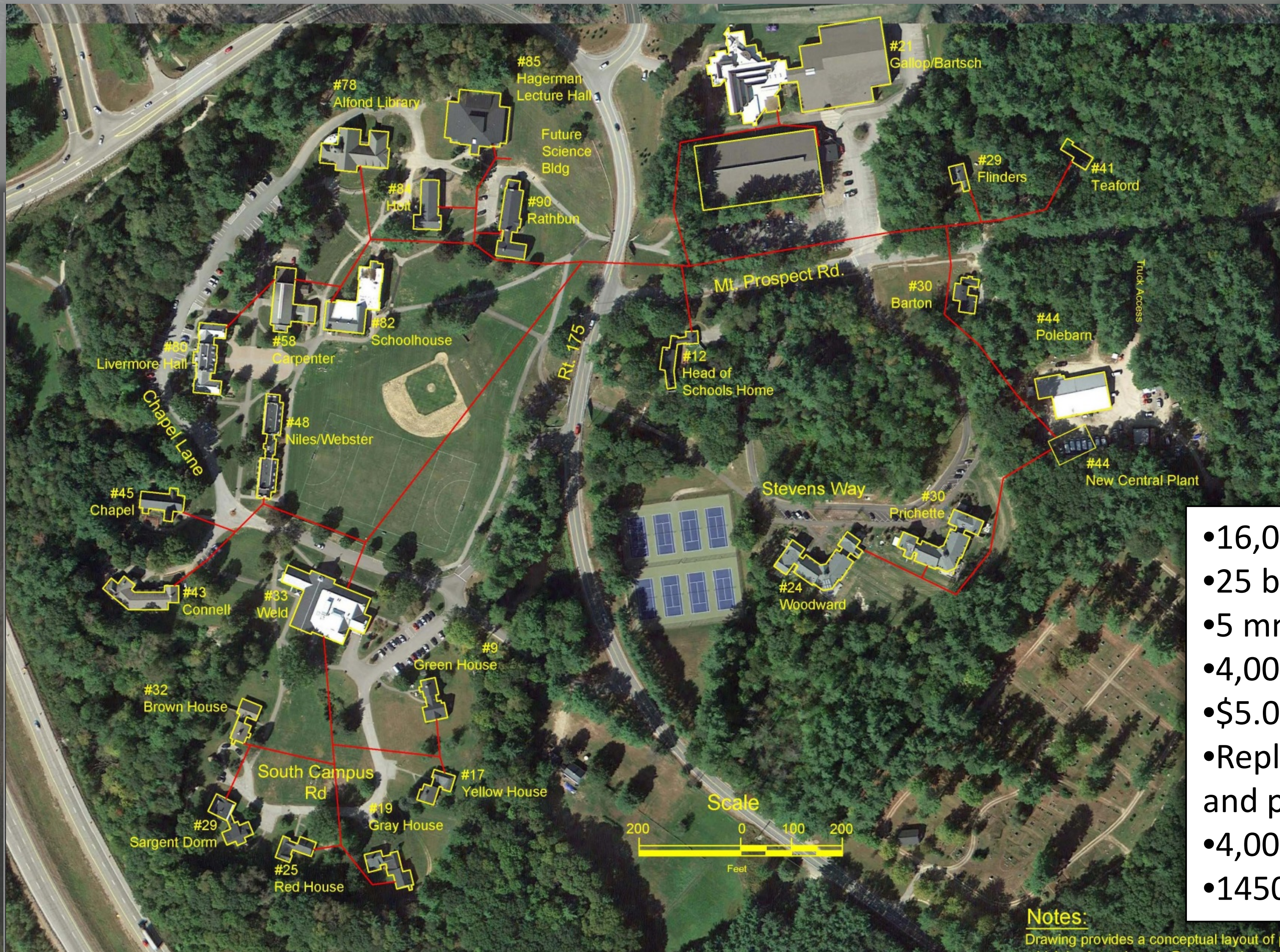
Wood Pellet / Chip Boiler

Wood Chip Boilers

Facility Gross Square Feet

Holderness School Biomass District Heating Project – Plymouth, NH

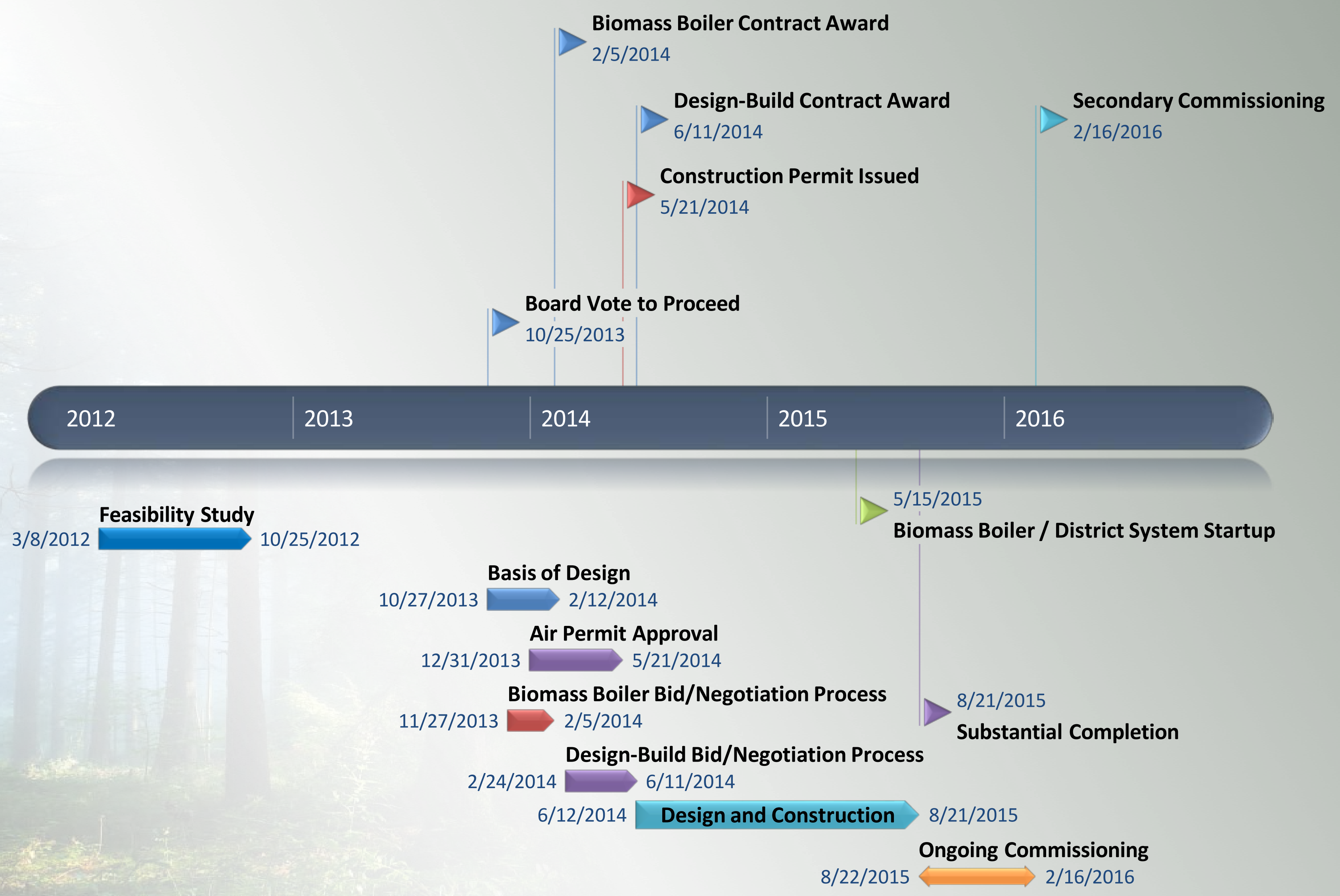
5 mmBtu/hr (20 Btu/hr/sf), 4,000 gal storage - 250,000 sf - ~17,000 mmBtu/yr



- •16,000 lf underground hw piping
- •25 buildings connected
- •5 mmBtu/hr biomass boiler
- •4,000 gals thermal storage
- •$5.0 M project ($0.3 M grants)
- •Replace 95% annual fuel usage (fuel oil and propane)
- •4,000 thermal RECs annually
- •1450 mtCO2/yr net carbon offset

Holderness School Biomass District Heating Project – Plymouth, NH

Project Timeline



Delta T and Pipe Sizing

- Design delta T of 45°F (170 – 215°F)
  - All components designed to allow ops up to 230°F
  - Building controls in some buildings allow hydronic systems to be optimized, but ability to ensure low building operating temperatures was limited
  - Actual return water has been consistently between 160-170°F during cold weather conditions
- Detailed modeling completed with pipeflow
- Pipe sizes ranged from 1¼" to 6" (EN253 preinsulated pipe, direct bury)

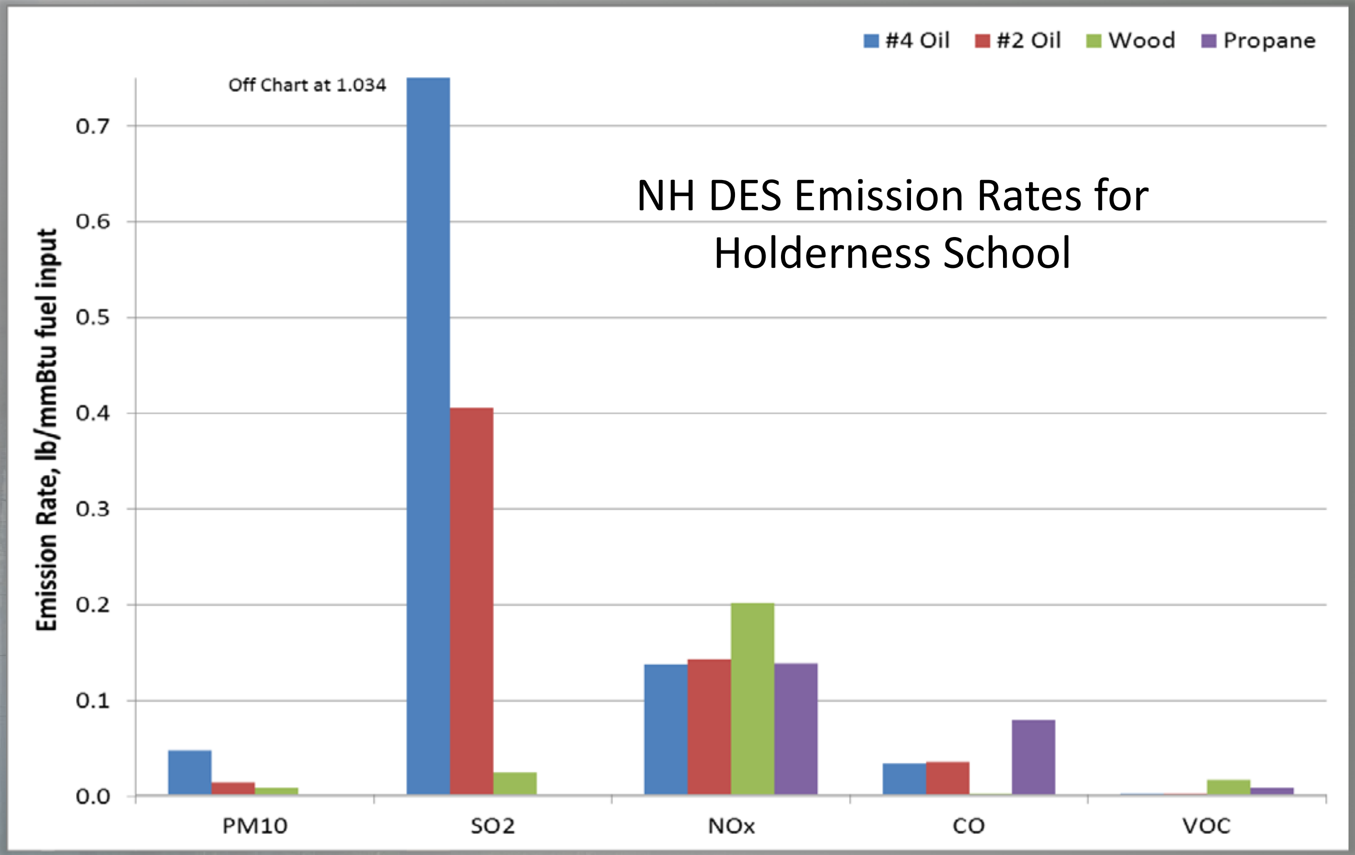
www.HoldernessBiomass.org

District Energy System Payback
(courtesy of biomass)

- $320,000/yr savings and revenue => 15 yrs
  - $270,000 in operating savings and $50,000 in thermal RECs
- Avoided costs significant, cleaning up years of deferred maintenance
- Biomass ~17% of project costs, provides value to cover 100% of the annual financing cost of $310,000
  - Same annual budget provides brand new system replacing 19 individual boilers and failing steam district system

Central Plant Building, Site Work, Paving	$1,100,000
District Piping System, Site Work, and Interconnections	$2,000,000
Central Plant BOP	$650,000
Biomass System	$850,000
General Conditions, Owner's Engineer, CA, CM, Commissioning, Permitting, Financing, etc.	$400,000
Total	**$5,000,000**

Biomass Systems Can Offer Improved Air Quality



Key Approaches:

- Match size to load
- Integration / controls
    - Thermal storage
- Air quality modeling to inform design and public
- Appropriate, cost effective, and energy efficient back-end controls

Air quality modeling showed a dramatic improvement in air quality at Holderness School, and that NAAQS would be met under all ambient and operating conditions.

How is heat used? – Generation, Distribution, and **Quality**

Steam

- Temperature
- Pressure
- Uses (heating, humidification, etc.)
- Building or process operating schedule
- Allowable variance

Hot Water

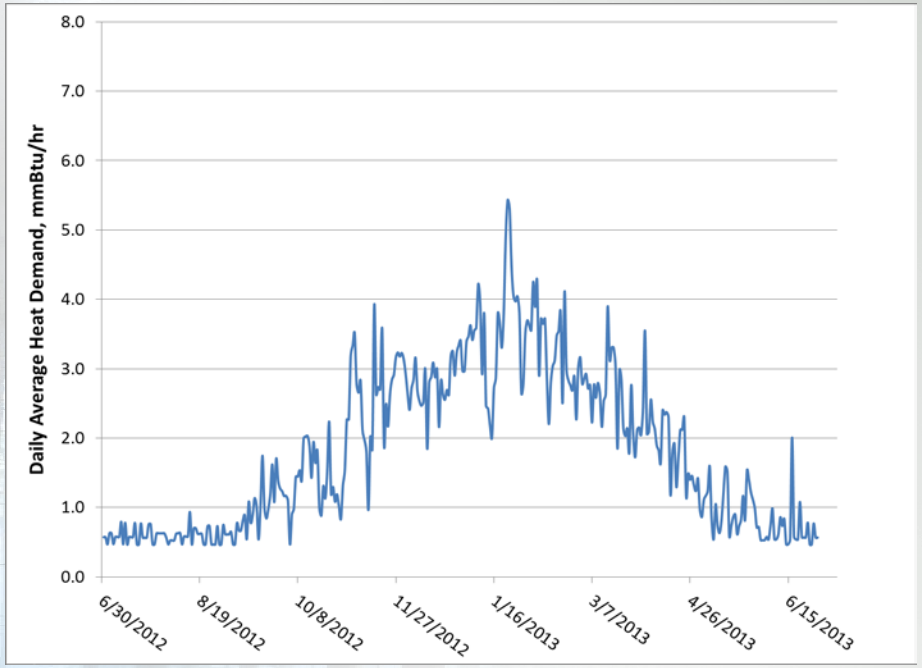
- Required temperature
- Uses (pool, DHW, heating, laundry, drying, etc.)
- Building or process operating schedule
- Allowable variance

Forced Air

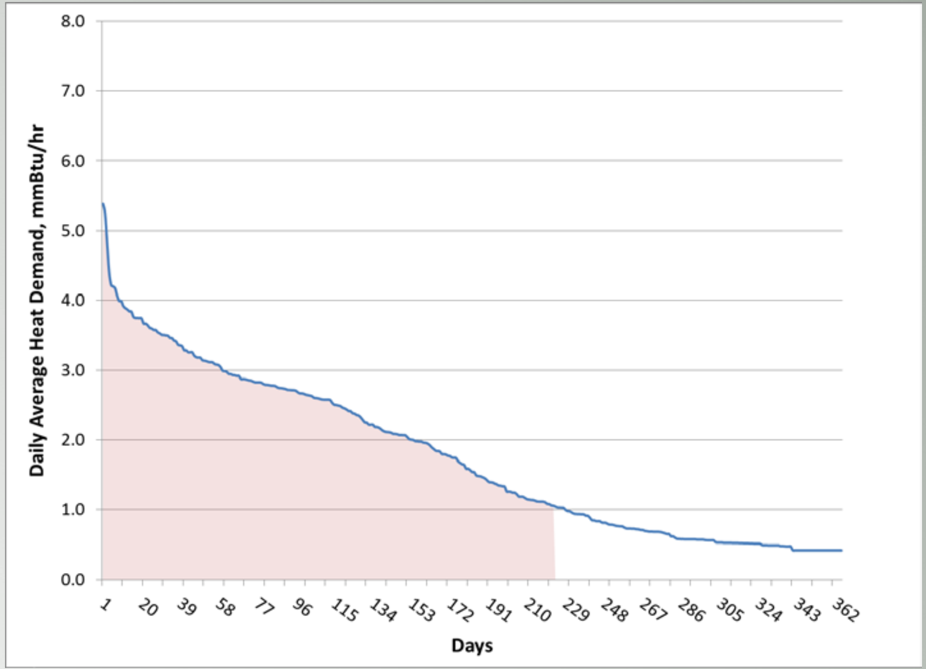
- Required temperature
- Required air flow
- Uses (heating, drying, etc.)
- Building or process operating schedule
- Allowable variance

Thermal Load Modeling Critical to System Sizing

Modeled Daily Average Demand



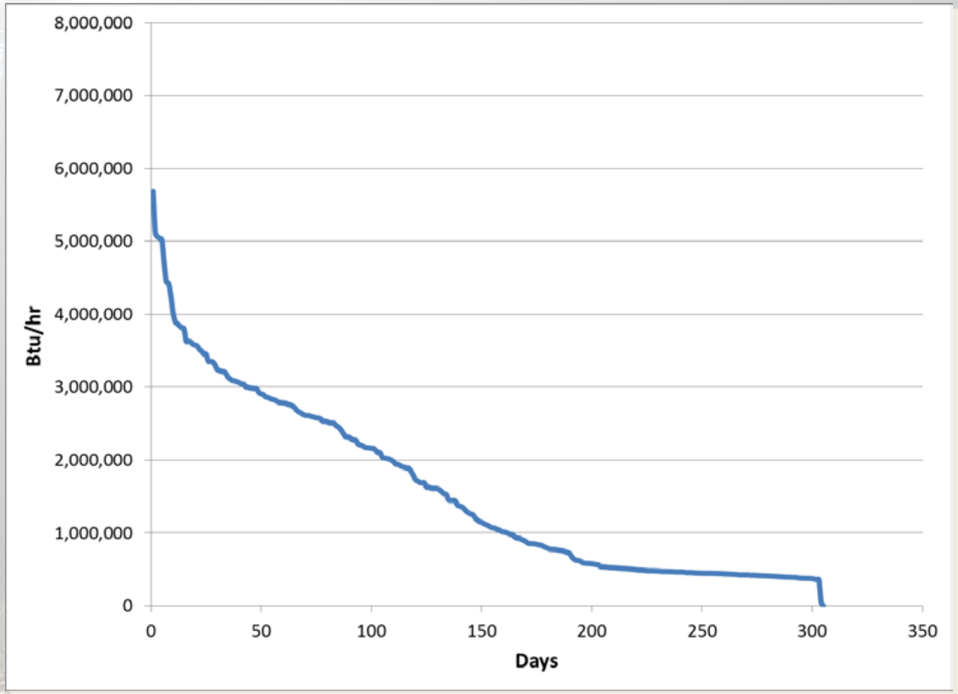
Load Duration Curve / Planned Biomass Coverage



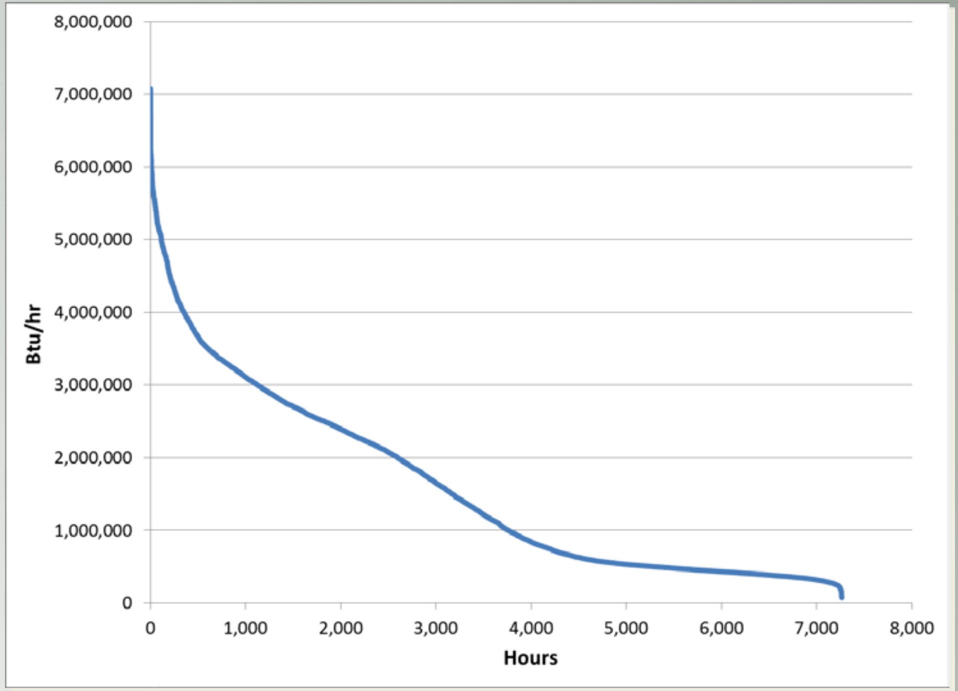
- Installed capacity of all existing buildings = 13.3 mmBtu/hr
- Modeled peak hourly demand for all buildings (no coincidence factor) = 10.4 mmBtu/hr, estimated district system peak of 7.5 mmBtu/hr
- Peak **daily average** demand of 5.4 mmBtu/hr for all existing campus buildings
- Multiple biomass boilers considered, system setup for adding future capacity

Actual Holderness District Loads

(April 2016 – Feb 2017)



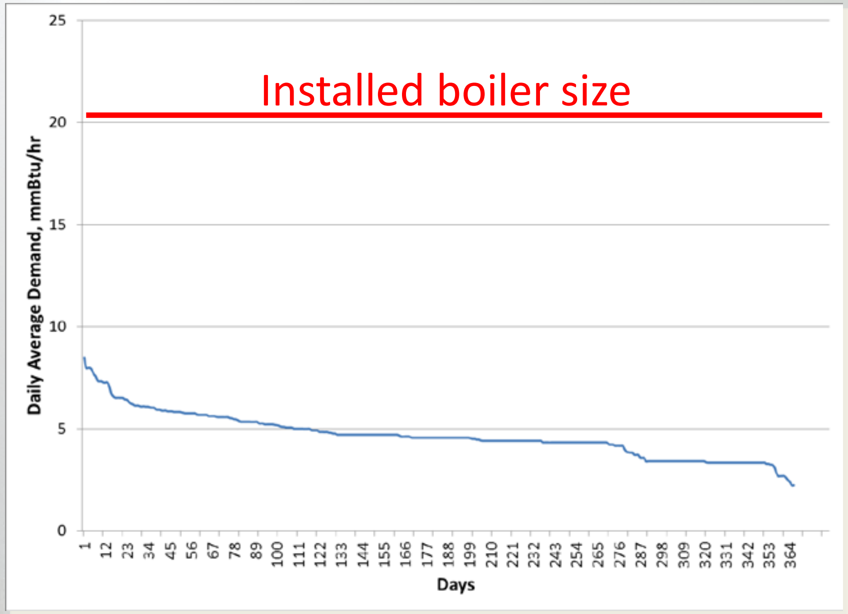
Daily Average Demand (305 days)

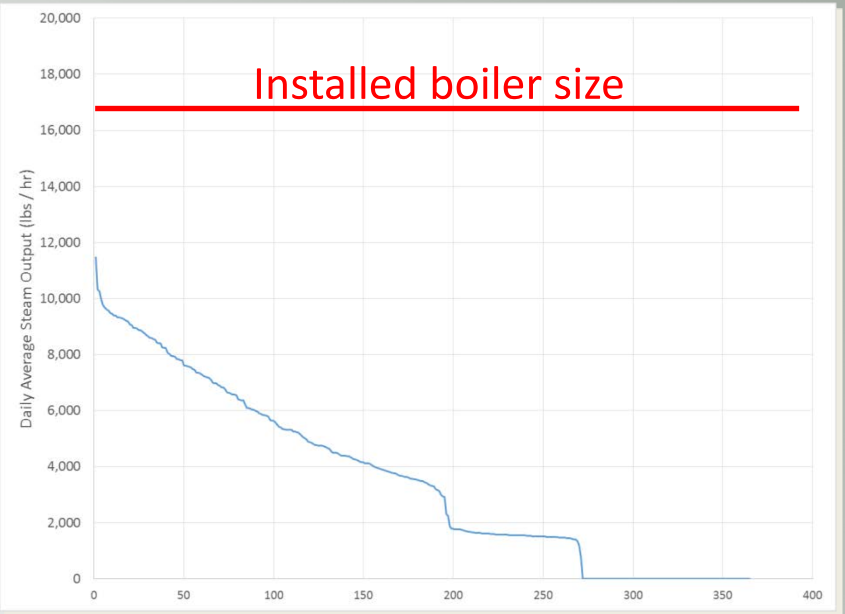


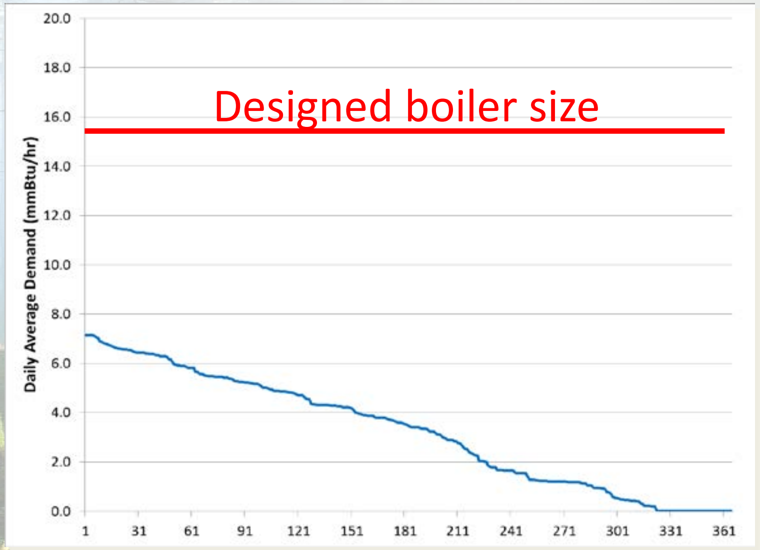
Hourly Demand (305 days)

- Peak **daily average** demand of 5.7 mmBtu/hr for all existing campus buildings
- Peak hourly load of 7.1 mmBtu/hr
- 99 hours (1.5%) above 5 mmBtu/hr, only 10 not fully covered by biomass with thermal storage

Comparison of load models to installed or designed biomass boilers serving district systems

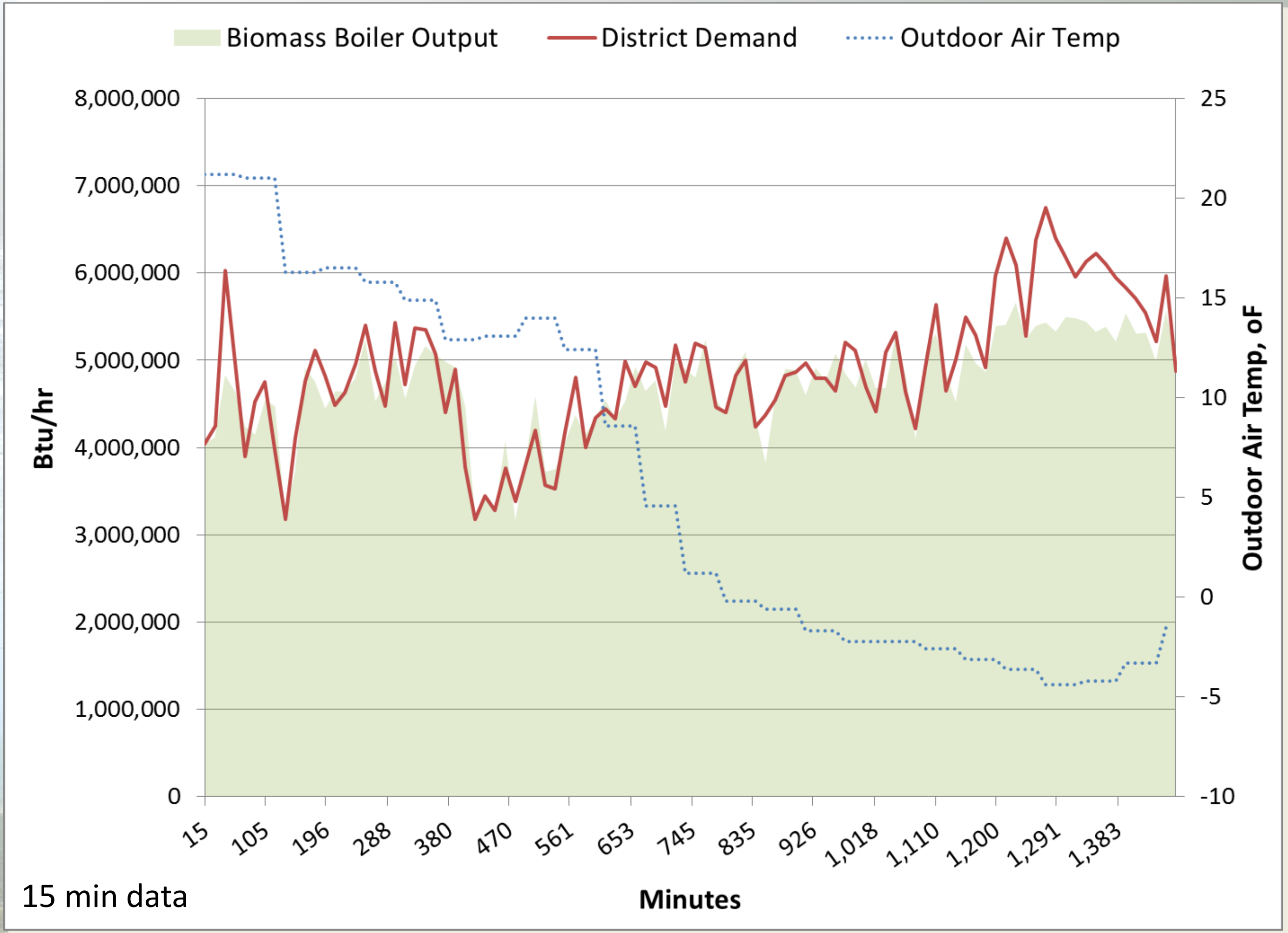






- Leaving the efficient operation range increases emissions, decreases efficiency, and can result in operational issues
- Typical efficient operating ranges of biomass systems are 20-100% or 33-100%
- Single units are often used due to cost considerations, and, when sized appropriately can usually cover 80-95% of load
- Two or more units can be used to cover 100%

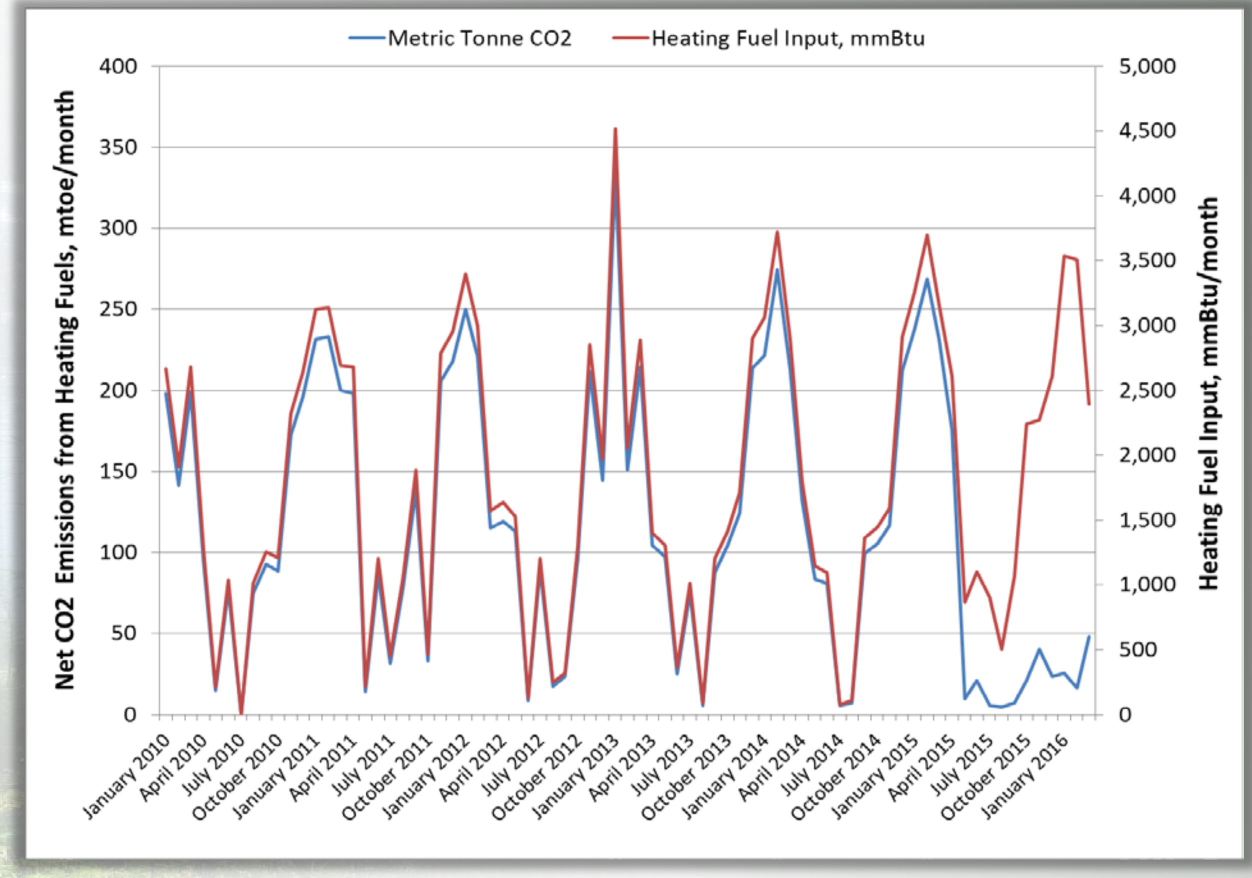
Thermal storage increases biomass thermal efficiency / load coverage / hydraulic separation / provides buffer between load and boiler



Storage allows 5 mmBtu/hr boiler to meet higher demands from system

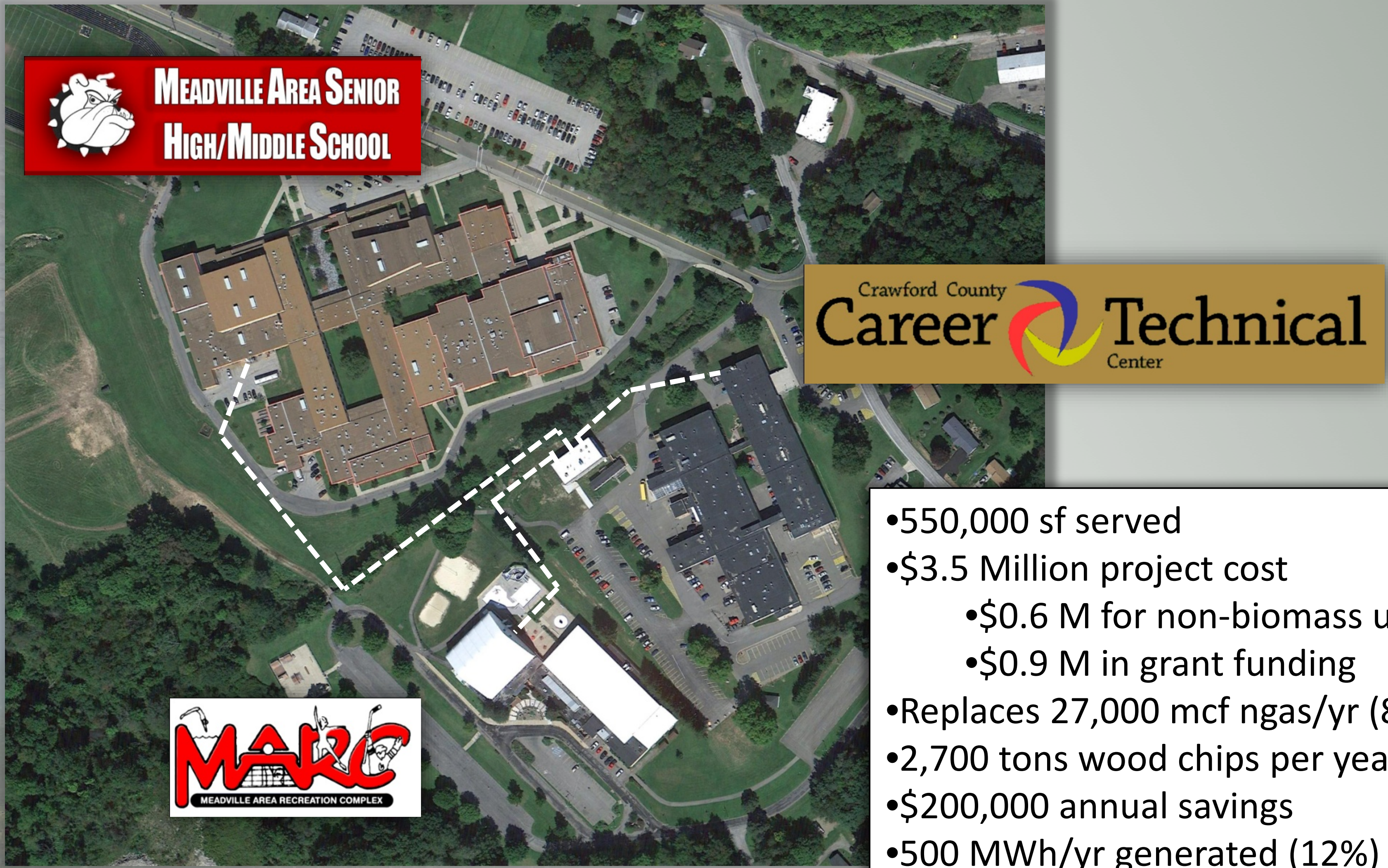
Carbon Benefits

- This varies with energy demand in individual buildings, depending on what fuel they were using. Here is the actual energy input (mmBtu) and net GHG emissions (CO2 equivalents) for every month at Holderness from 2010 through early 2016.



Crawford Central Biomass CHP District Energy

8 mmBtu/hr (15 Btu/hr/sf), 6,000 gal storage - 550,000 sf - ~34,000 mmBtu/yr



- 550,000 sf served
- $3.5 Million project cost
    - $0.6 M for non-biomass upgrade
    - $0.9 M in grant funding
- Replaces 27,000 mcf ngas/yr (80%)
- 2,700 tons wood chips per year
- $200,000 annual savings
- 500 MWh/yr generated (12%)

Key project components

300 cy storage

chips

8 mmBtu/hr boiler

175# steam

200 kW turbine/generator

10# steam

Steam to hot water heat exchanger

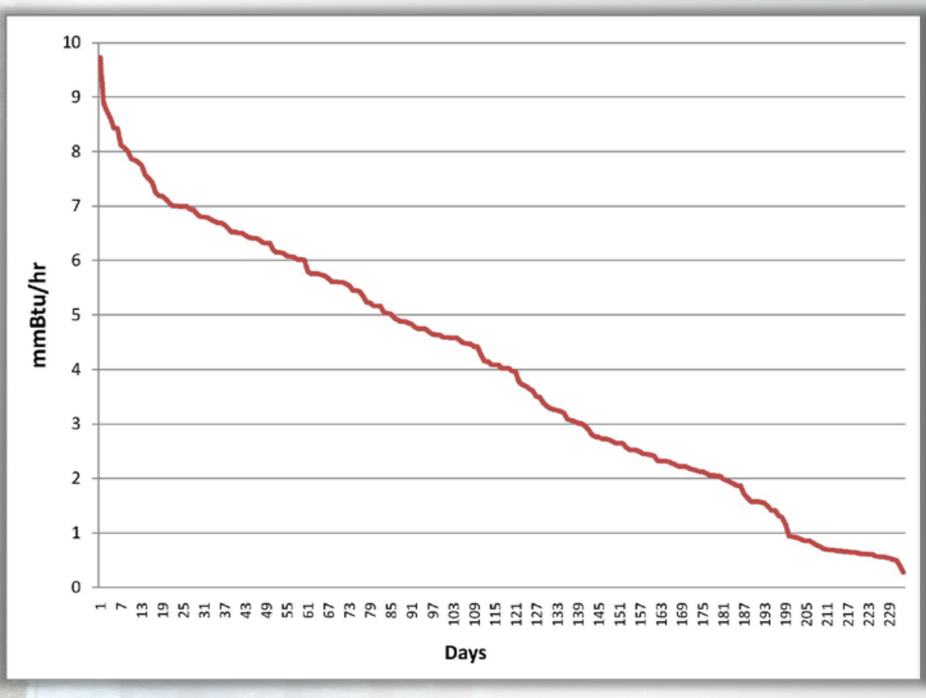
210°F H2O

6,000 gallons thermal storage

200°F H2O

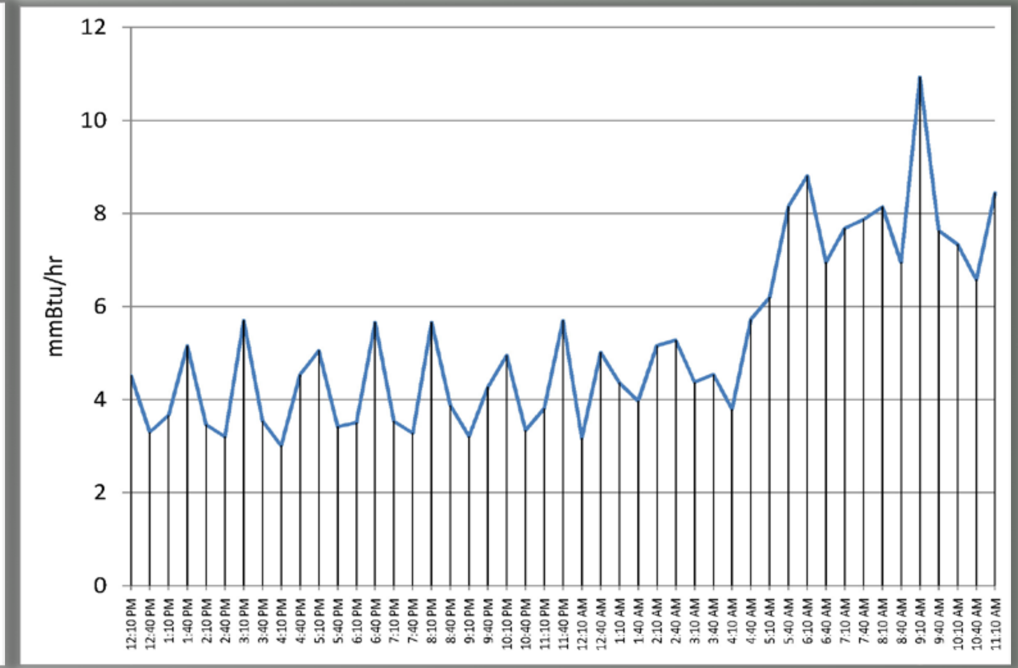
HX and Distribution Pumps to three facilities

Thermal load modeling



Daily Average Heat Demand

Curve shows the average hourly output for each day during the heating season.



High School Demand, 24 hrs in Jan 2010 (portable Btu metering)

Modeling Sources:

- Use records/bills
- Portable BTU meter
- Building envelope modeling
- Operating parameters
- Weather data

Thermally-led CHP can provide electricity at <$0.02/kWh (energy cost)

Commercially Available Closed Cycle Biomass Power Generation Options

- Backpressure steam (~5-15% electrical efficiency)

Courtesy Skinner

- Organic Rankine Cycle (~15-20%)

Courtesy Turboden

Tips:
- Use behind the meter to maximize value of electric generated
- Year-round load helpful to economics
- Lower quality heat needed onsite = better CHP potential

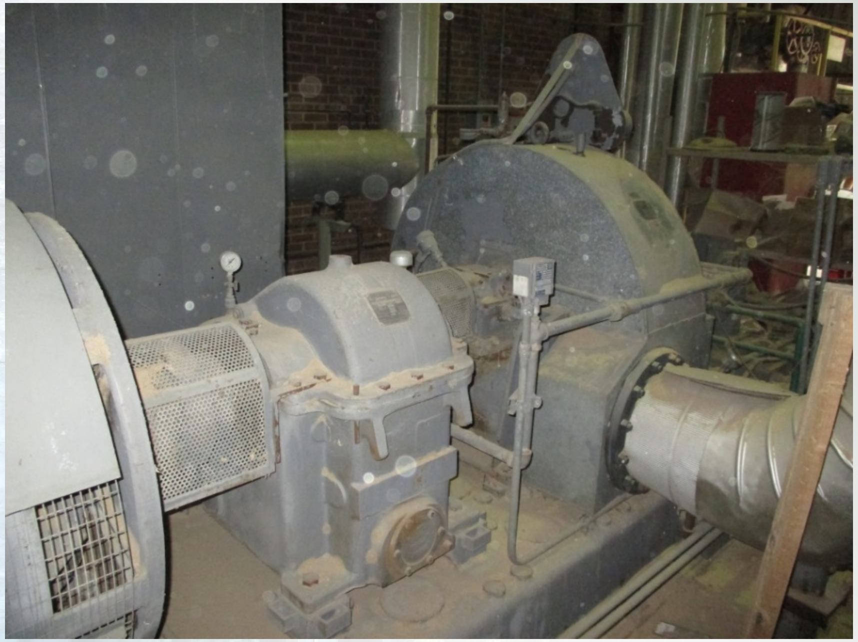
Thermally-led Biomass CHP Economics (Single Stage Backpressure Steam Turbine Example)

- 1 ton wood = 10 mmBtu (HHV) = $40
  - 155 kWh
  - 6.8 mmBtu steam

- **$40 in wood offsets $65 in energy costs**
  - 8.5 mmBtu natural gas at $6.00/mmBtu ($51)
  - 155 kWh from grid at $0.09/kWh ($14)

- **Without using the heat, purchased $40 of wood to offset $14 of electricity**

CHP word of caution - oversizing



- Many idle turbines at plants
- BPS turbine trips out when dropping below ~25% of capacity
- Sizing should be based on detailed load modeling and not boiler size

Biomass, CHP, District Energy Services

Small and large-scale programs and projects

- Study
- Design
- Financing Consulting / REC Aggregation
- Permitting / Interconnection Agreements
- Project / Construction Management
- Commissioning
- Operations
- Technical and Economic Policy Consulting

WES is a member of:

BTEC Biomass Thermal Energy Council

www.biomassthermal.org

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