Design of a Biomass Cogeneration Plant

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Project Background and Objectives

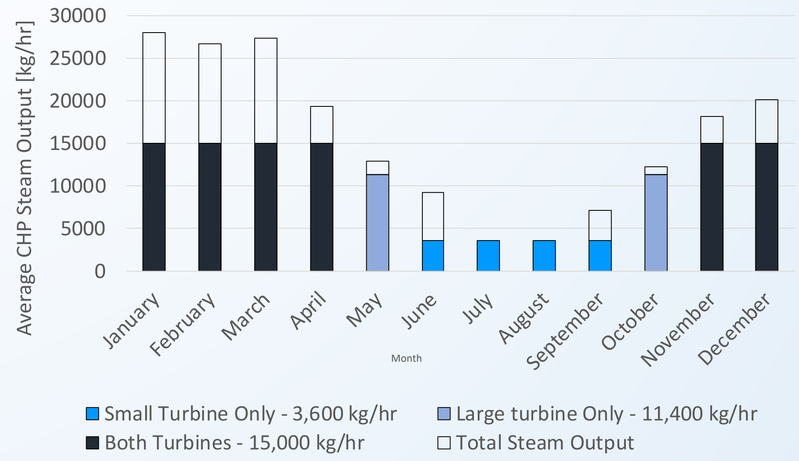
The UNB central heating plant (CHP) is tasked with generating the steam required for campus and external clients. CHP has five boilers which utilize a variety of fuels. Boiler #1, the biomass boiler, is nearing the end of its service life and must be replaced. The objectives for this project are listed below:

- Explore proven and emerging technologies as they relate to the replacement of boiler #1.
- Recommend a process to replace the current biomass boiler and its auxiliaries.
- Investigate cogeneration and determine the economic and technical viability of the design.
- Position CHP to be a reliable, efficient and sustainable source of energy and steam for UNB.

Cogeneration

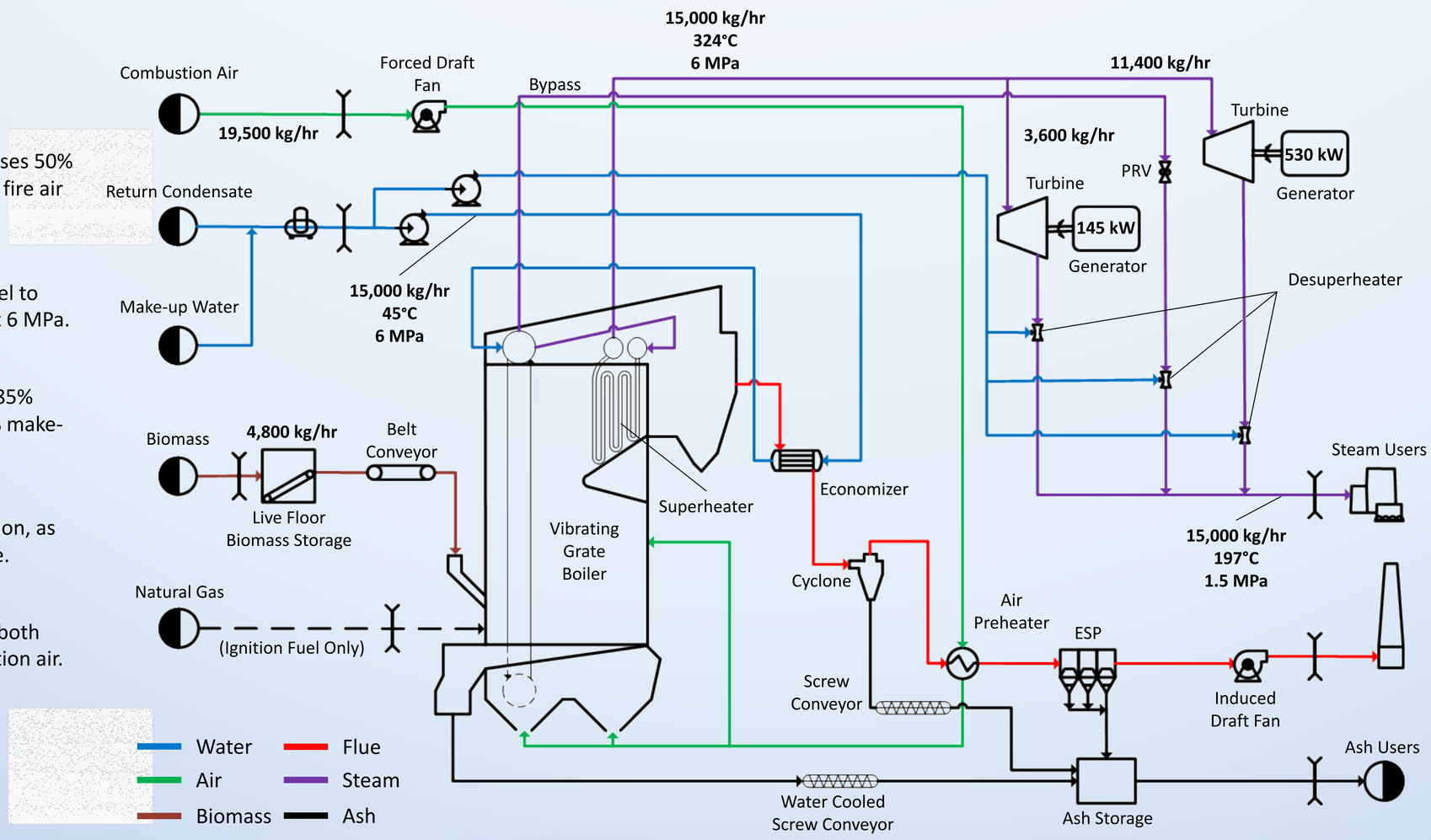
- The cost to produce a kWh of electricity was determined to be $0.08/kWh.
- When compared to the $0.11/kWh cost that NB Power charges, it was determined that cogeneration was worth further investigation.
- The proposed boiler will have a 4:1 turndown ratio and a minimum steam production capacity of 3,600 kg/hr to accommodate summer load.
- Based on the average monthly CHP steam output shown in Figure 1, the use of two turbines is the most efficient way to maximize electricity production.

Figure 1 - Turbine Utilization Chart



Proposed System

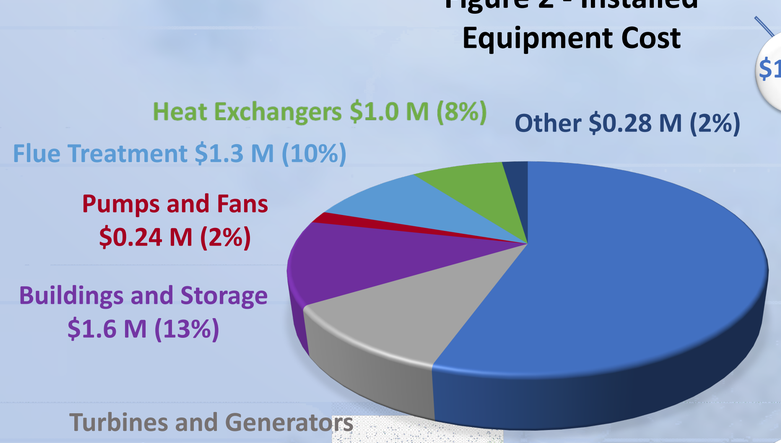
- The vibrating Grate Boiler uses 50% under fire air and 50% over fire air to control emissions.
- The boiler combusts hog fuel to convert water into steam at 6 MPa.
- Feedwater is composed of 85% return condensate and 15% make-up water.
- Natural gas is used for ignition, as well as a backup fuel source.
- Flue gas is used to preheat both the feedwater and combustion air.



- Varying Superheated Steam Outputs
  - 3,600 kg/hr – Only small turbine online, 145 kW output
  - 11,400 kg/hr – Only large turbine online, 530 kW output
  - 15,000 kg/hr – Both turbines online, peak output of 675 kW
- During an intermediate boiler output, saturated steam bypasses superheater and goes through a pressure relief valve (PRV) before being sent to users.
- 99.9% of the particulate in the flue gas is removed using a cyclone and an electrostatic precipitator (ESP).
- The ash is collected and sold for agricultural use.

Economic Analysis

Figure 2 - Installed Equipment Cost



- $17M — Total Capital Cost
- $13M — Installed Equipment Cost
- $15M — Fixed Capital Investment
- $55k — Working Capital
- $1.5M — Start-Up Expenses

Annual Operating Costs $3.4M

Net Annual Profit $5.0M

Figure 3 - Cumulative Cash Flow

	% of Installed Cost	Annual Revenue	Return on Investment	Internal Rate of Return	Payback Period
Total Plant	72%	$8.5 M	33%	32%	3 Years
Electricity Portion	28%	$0.5 M	1%	3%	38 Years

Conclusions and Recommendations

- New vibrating grate biomass boiler was successfully designed with **76%** thermal efficiency.
- The electricity portion of the design is **not economically feasible** on its own.
- Boiler #1 should be replaced with another **steam only process**
- The use of biomass fuel is in line with new campus **climate change action plan.**

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