Reheat Furnace: Waste Heat Recovery

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Background

Cascade Steel Rolling Mills, located in McMinnville, Oregon, manufactures various steel products. They employ a large reheat furnace to heat steel billets that are rolled into final products. Exhaust gases from the process leave the furnace through the exhaust stack as lost heat energy. Figure 1 shows how this wasted energy can be turned into useful electrical power . It has the ability to reduce the overall electrical costs and carbon footprint of Cascade Steel. This project examined the current operational behavior of the billet reheat furnace and developed a waste heat recovery solution.

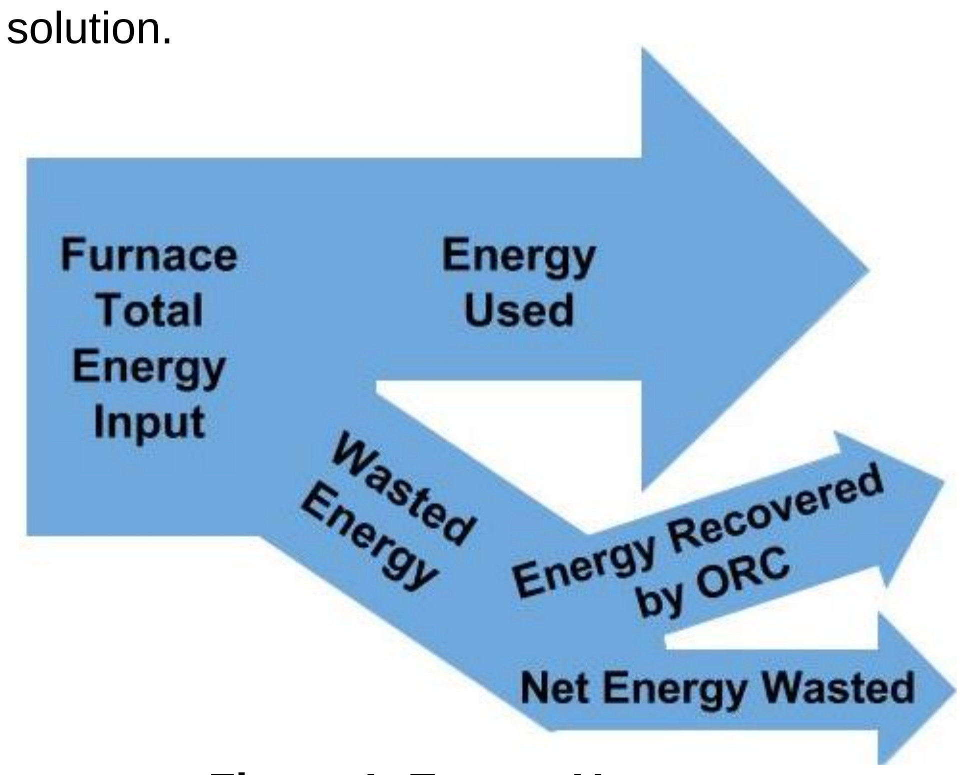

Figure 1. Energy Usage

Proposal

This project will recover wasted heat energy through electric conversion. Direct conversion technologies such as thermoelectric generators and piezoelectric generators were considered. In addition, thermodynamic power cycles such as the Rankine, Brayton and Sterling cycles were researched. These power cycles are well developed technologies, economical, and have the largest power output. Through a comprehensive feasibility analysis, the Organic Rankine Cycle (ORC) was selected as the most viable option. In this cycle, a fluid is continuously pumped in a closed loop through a heat exchanger, turbine, and condenser (Figure 2). Electricity is generated by a rotating turbine that is connected to a generator.

Vendor Selection

As there were multiple providers of ORC systems on the market, a comprehensive comparison of each manufacturer was conducted. The top companies evaluated were Echogen, Enertime, Global Geothermal, Turboden, and Infinity Turbine. A decision matrix was created and considered the power output, payback period, reliability, cost, fluid, installation, and the reputation of the vendor. The French company Enertime clearly stood out among the other competitors for their competitive price and exceptional service.

Alex Lull – Will Burton – William Cammack
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(Left to Right)

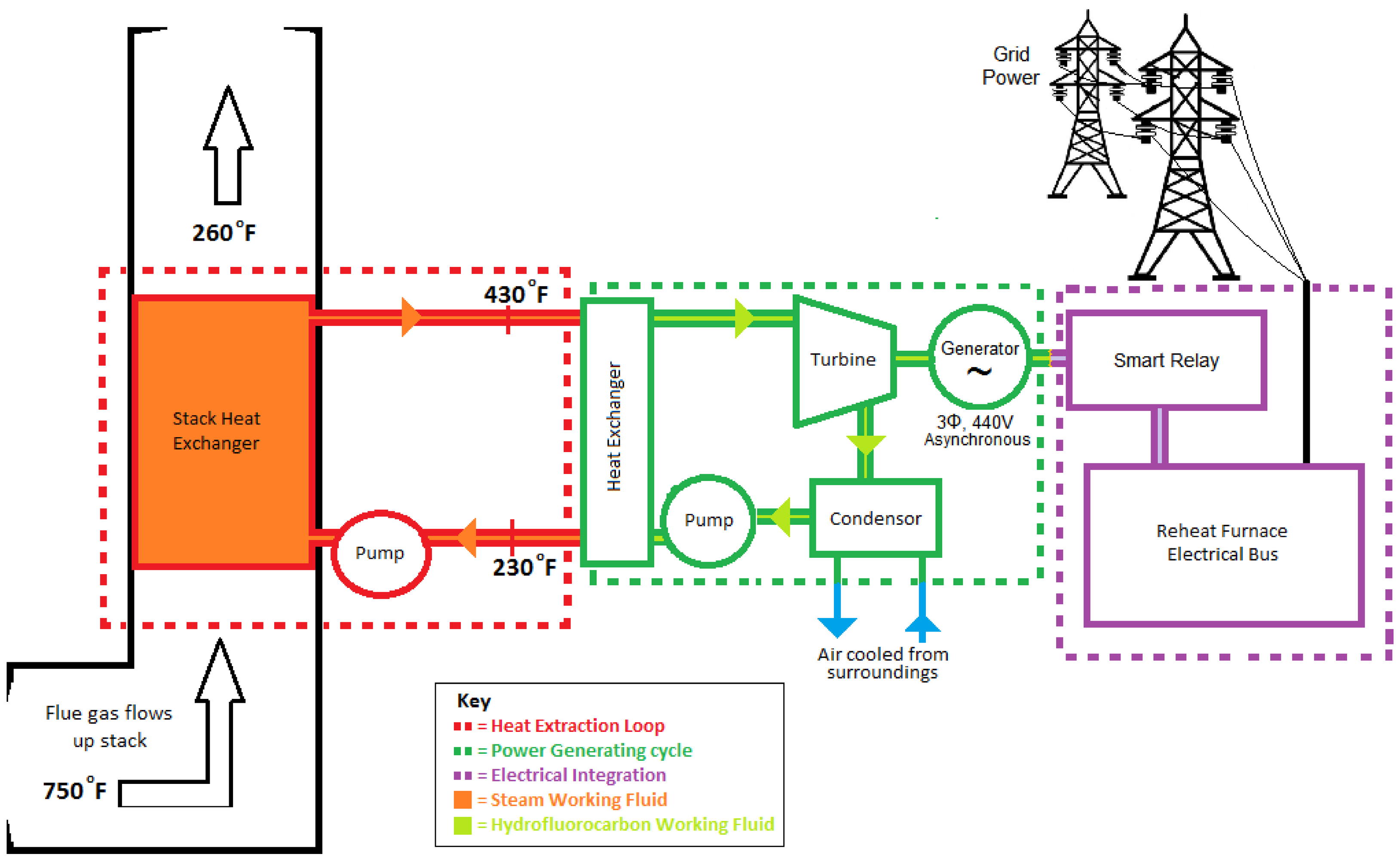

Figure 2. The Waste Heat Recovery System

Final Design

Power Generating Cycle

Enertime's Orchid ORC module was recommended for generating electricity. This unit utilizes a Hydrofluorocarbon (HFC) working fluid. The table below briefly highlights the system.

Enertime Orchid ORC	
Power Output	785 kW
Full System Cost	$3 Million
Annual Savings	$263,400
Operating Cost	.005 $/kW-h
Payback Period (Without Incentives)	13.87 Years
Lifetime	20 Years
Size	40x13x20 ft.
Weight	50,000lb

Heat Extracting Loop

As seen in Figure 2, the thermal energy from the exhaust stack will be transferred to the power generating cycle through a heat exchanger. Water flowing through a series of tubes will absorb heat and reduce the exhaust stream's temperature from 750˚F to 260˚F. This cooled temperature was chosen so that corrosion (caused by condensation) would not develop. The captured thermal energy is then transferred to the power generating cycle for electrical conversion. Since the heat exchangers tubes restrict airflow, a slight pressure drop will occur within the stack. To account for the pressure drop and prevent a harmful backpressure, the exhaust fan will be upgraded.

Electrical Integration

The ORC's power will be generated by an asynchronous generator that is connected to the reheat furnace's electrical bus in parallel with the grid. In order for the electricity to be used, the generator's phase angle, frequency, and voltage will be precisely regulated by a smart relay. The integrated ORC system will be capable of meeting up to 33% of the reheat furnace's electrical needs.

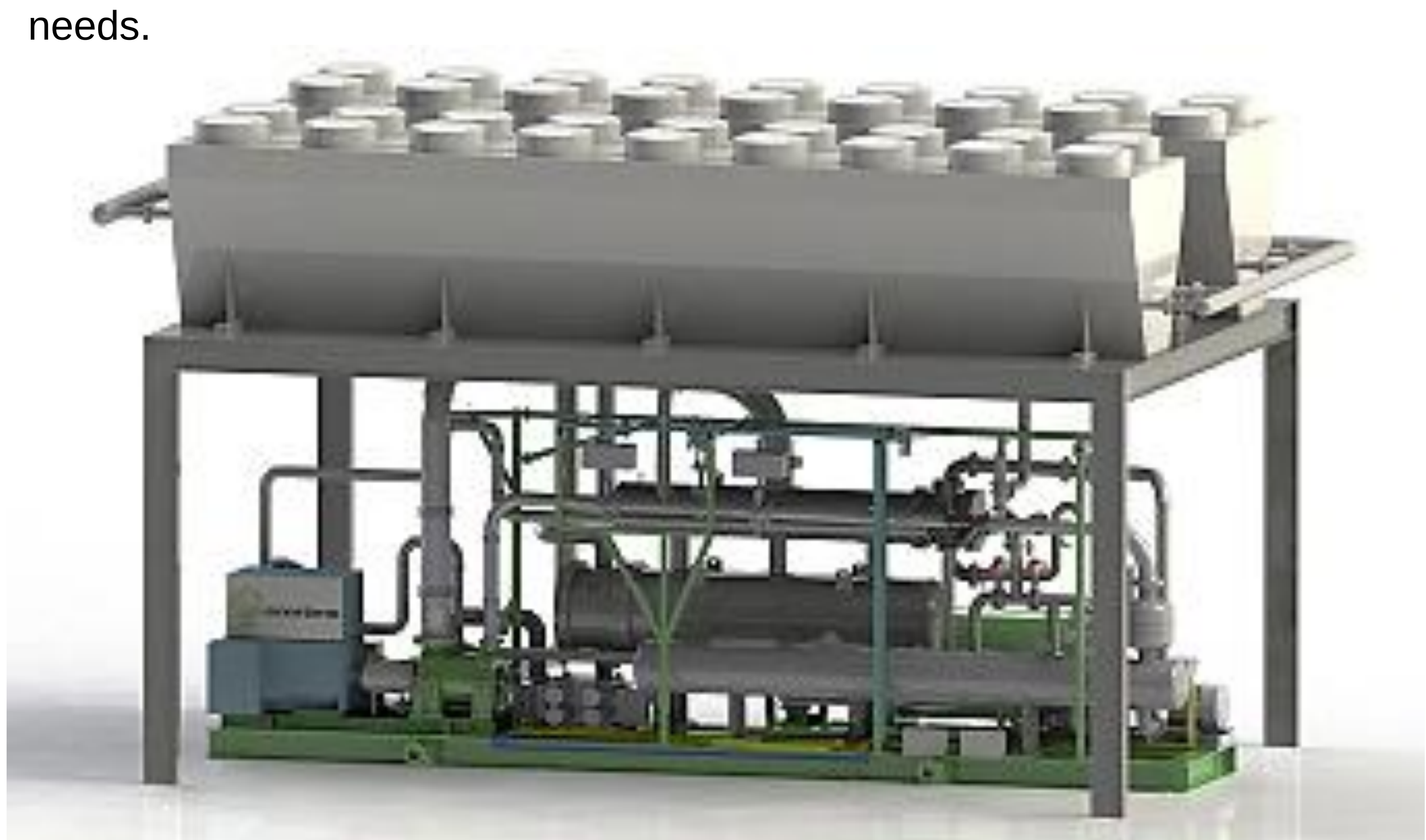

Figure 3. Enertime Orchid Power Generating Module

Modeling

Determining the amount of power that could be recovered from the exhaust stream was the first step of this project. This helped determine the economic feasibility of the project and size an ORC unit. With the maximum theoretical power output obtained, a more realistic model was needed to address actual losses due to turbine and pump inefficiencies, and size constraints for condensers and evaporators. A model demonstrating a basic steam Rankine cycle was developed using Engineering Equation Solver (EES). The table below shows the estimated power outputs.

Modeling Results	
Available Thermal Energy	5MW
Max. Theoretical Output	2.5 MW
Basic Steam Cycle Output	600 kW
Vendor Estimated Outputs	650kW-1.4 MW

Incentives

In order to subsidize the cost of the complete system, state and federal energy grants and incentives were explored.

- Energy Trust of Oregon's Energy Conservation tax credit may cover up to 35% of the cost
- The pending bills S.913 and S.2189 will allow funding for Waste Heat to Power projects
- The pending bill H.R. 4916 will extend a 30% tax credit for Waste Heat Recovery projects

Environmental Impact

The electricity is generated as a byproduct of the reheat furnace . The waste heat recovery system will reduce the need for the purchasing electrical grid power. By recovering 785 kW, the system will reduce Cascade Steel's emissions by 257.31 metric tons of CO_2 annually (Figure 4). Pending legislation would incentivize the reduction of carbon footprints for the industrial sector via a tax. Under this legislation, the ORC could save Cascade Steel up to an additional $15,439 annually.

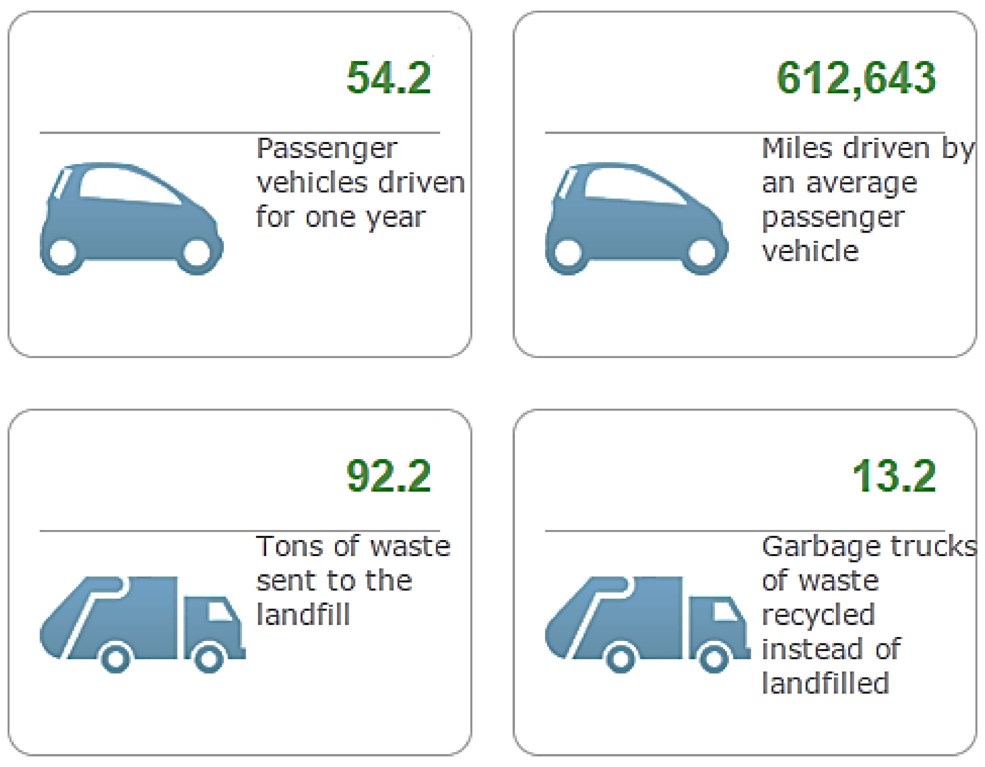

Figure 4. Carbon Reduction Equivalencies

Deliverables

- Project Report
- EES Model
- Recommendations
- Placement Selection

Senior Design
George Fox University