INTRO

The opportunity to save $150,000 in electrical energy costs is being missed every year at the University of Idaho.

Hello. My name is Ryan Oliver and I am a member of the senior design team consisting of Chad Dunkel, Donald Haines, and Chris Anderson. Over the next twenty minutes I am going to explain where these savings would come from.

Transition

The UI Steam Plant, constructed in its present location in 1927, has historically utilized—fuel oil, pulverized coal, and natural gas to operate its boilers. Then in 1988 a wood fired boiler was commissioned, allowing the UI combined heating and cooling facility to utilize a renewable fuel source, wood chips, in its primary boiler.

What was not done in 1988, and has still not been done due to interdisciplinary stagnation, was to implement a cogeneration system.

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As an interdisciplinary engineering capstone senior design team our objective was to perform a feasibility analysis for implementing such a cogeneration system at the Steam Plant. We brought together the combined engineering knowledge from the fields of Bio-Agricultural, Mechanical, and Electrical Engineering.

Additionally, significant non-engineering components were involved with this project including: communication, technical writing, ethics, business, finance, project development and politics.

Transitional Statement: Before we talk about what a cogeneration system at the UI Steam Plant would look like let's first look at the current system.

Current System

This is a block diagram representing the campus steam distribution system. As you may know, heating of campus buildings as well as some cooling is done by steam. The condenser element in the diagram represents the entirety of campus.

Approximately 90% of steam supplied to campus on a yearly basis comes from the wood boiler. The additional 10% is produced by natural gas boilers during times of maintenance on the wood boiler or during times of peak load, in mid-winter or mid-summer. Boilers in the steam plant produce steam at 150psi.

A Pressure Reducing Valve (PRV) is needed to drop the distribution pressure of steam on its way to campus. Currently system distribution pressure is 60psi.

Heat transfer through heat exchangers and steam absorption chillers occurs around campus, as steam enters, goes through a phase change, and leaves as liquid. A seven mile network of pipes make up the steam distribution and condensate return piping network. At the South West corner of the Steam Plant, all returned condensate is stored in a Condensate Return Tank. The condensate is then pumped into a Dearator Tank. Finally the loop is completed when a Feedwater Pump supplies the water necessary from the Dearator Tank to maintain the levels in the boiler steam drums as steam is continuously supplied to campus.

Transitional Statement: Now that we have heard a simplistic explanation of the current system lets focus on proposed change.

Proposed System

I would like to draw your attention to the new red element in the block diagram. This element represents a non-condensing backpressure steam turbine mated to synchronous generator and replaces the PRV element from the previous diagram. The necessary steam pressure reduction formally achieved by the PRV, now is accomplished by the turbine with the added benefit of power generation.

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The turbine, generator and all supporting equipment can easily be placed in an unutilized space on the South side of the Steam Plant, next to Line Street.

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Initially, six different system designs were considered and presented to the University of Idaho Utilities and Engineering Director. These systems ranged in complexity from a simple non-condensing backpressure turbine arrangement capable of generating 1 MW of power, to a full-condensing, multi-stage turbine rated to produce 15 MW. Non-dimensional scaling analysis confirms the choice of the Single Back-Pressure Turbine Model as the option to pursue.

Transitional Statement: The financial benefits associated with a cogeneration system are best understood under the light of an economic analysis.

Economic Analysis

With the decision made to pursue a cogeneration system utilizing a non-condensing back pressure turbine, it was necessary to determine the appropriate system components and contact vendors for their costs.

The turbine selected was a Dresser-Rand K Frame model, rated at 50,000 lbs/hr of flow. Enough torque is produced by this turbine to operate a generator of 1 Mega Watt.

When retrofitting an existing system into a cogeneration system, additional fuel costs are important to consider. You may be wondering where these additional fuel costs come from. As you may recall, the turbine has the desirable benefit of reducing the steam pressure to the campus distribution level. However, it also extracts energy from the steam, resulting in less heating energy available within the steam to meet campus heating demand. To compensate for this reduction in energy, more steam must be produced, translating to more fuel consumed.

The Current Fuel Costs, represented by the blue bars on the graph, come from Steam Plant records from the fiscal year of 2012. The red bars on the graph represent the additional fuel necessary to meet campus heating demand and the green line represents the amount of revenue associated with the generation. You will notice for the months of May and August there is no generation revenue, and no additional fuel costs. This is because for these months, it was not economically viable to operate the turbine, due to the moisture content and species makeup of the wood, the cost of wood chips, and the cost of natural gas

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For the college, as a public institution, all projects considered should have a Simple Payback Period of 15 years or less. This means the project should pay for all costs associated with it within that timeframe. However, a more accepted business practice is to calculate the Internal Rate of Return achievable from a project. In this case, the decision criteria for whether to proceed with a project or not is whether the IRR exceeds the Minimum Annual Rate of Return for the business or institution in question.

This decision making process is easiest to understand in a Cash Flow Diagram.

[Talk about values on Figure. Annual savings: ~$150,000]

Transitional Statement: This economic analysis relied upon a fluids and thermodynamic engineering study to develop the values for fuel costs and turbine revenue.

Methodology

This figure represents a flowchart of the engineering study. Working our way down from the top of the diagram, we start with recorded data from Steam Plant operation for the fiscal year of 2012. This data was used to generate values for Boiler Efficiency and Campus Average

Monthly Heating Requirement. Boiler Efficiency and Campus Average Monthly Heating Requirement were the foundational pieces, used to calculate everything from Fuel Requirement to Turbine Power Output, to Fuel Costs and Savings.

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These calculated values for Boiler Efficiency and Campus Heating Requirement are for the current system, but will remain constant with the implementation of a cogeneration system because campus will always need heat regardless of what type of system is operating in the Steam Plant.

[Discuss graphs and trends, campus demand changes throughout year]

On initial inspection, one might think a mistake was made if the fuel content of wood is changing throughout the year. However, these wood chips are supplied by lumber mills, and the moisture content varies seasonally, as log decks and chip stacks are kept outside.

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One pivotal term, the elephant in room, remains to be explained. Turbine isentropic efficiency is a measure of a turbine's effectiveness at extracting energy from steam, and is an essential term in predicting the performance of the turbine in the system. However, this value is specific to each turbine and is measured via a test bench at the time of manufacturing, and is considered proprietary information, and therefore unavailable.

Transitional Statement: Coordinating with the University of Montana Associate Director of Engineering and Utilities, our team visited the

Montana cogeneration facility in Missoula to acquire data and validate our model for predicting a turbine's isentropic efficiency.

Montana Data Validation

We developed a model for predicting power generation, but needed to validate that our results were representative of what happens in the real world. Inputting the data from Montana into our model we developed the operating points, represented as blue dots, for Power Output vs. Flow Rate. We were very fortunate to have access to the actual manufactures Power Output vs. Flow Rate curve, represented as the red, green and purple stepped curve, for the UM system. As you can see the operating points calculated in our model, fit very well over the manufacture curve.

Transitional Statement: Being comfortable with our ability to predict power output we can turn our attention to turbine isentropic efficiency.

The tricky thing about isentropic efficiency is that it varies with flow rate. And, as you may recall from the Campus Average Monthly Heating Requirement, a turbine at a University will be operating under a variable flow rate throughout the year. Using the data from the previous figure along with known operating pressures of the system, we generated an Isentropic Efficiency vs. Flow Rate curve. Note that the average flow rate is around 20,000 lbs/hr which corresponds to the highest isentropic efficiency. This is how a turbine should be sized to a system.

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Comparing our calculated values with the manufactures, an average percent difference is seen of 12%. This is representative of a limitation in our analysis, but one we have chosen to accept.

Transitional Statement: We have spent a fair amount of time discussing and developing the financial benefits of operating a cogeneration system at the University of Idaho. But as an institution of higher learning a more compelling reason to invest in cogeneration might be the educational benefits.

Functional Interdisciplinary Laboratory

As a member of the, Department of Energy Funded, University of Idaho Industrial Assessment Center, I and everyone involved in the program have benefited greatly from tours and mock energy assessments at the UI Steam Plant.

We envision the opportunity to extend this experience further to a wider student body in the form of a functional interdisciplinary laboratory.

This interdisciplinary laboratory will immerse engineering, business, and environmental science students in an environment where the things talked about in textbooks are done in practice.

For instance undergraduate engineering analysis of real world thermodynamic modeling, fluid analysis, and power system analysis could all be based on working systems, just North of Line Street.

Business students could have the opportunity to develop operational profiles for a real revenue generating application.

Environmental science students could investigate water treatment, flue gas emissions, and methane as an alternative fuel sources.

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Conclusion

In summary, throughout our efforts to model the current system and develop cogeneration alternatives we discovered the University of Idaho is a strong candidate for renewable energy implementations. $150,000 in annual savings can be achieved from a project which will pay for itself in nine years and also have clear educational benefits. Locally, a near identical system successfully operates at the University of Montana, and can serve as a knowledge base for operational concerns.

However, if this is such a good idea, why was it not done in 1988 at the time of upgrade to a wood boiler? Our conclusion is that the most significant obstacles to project implementation lie beyond engineering and in the fields of Law, Business and Politics.