Energy-Smart Electronic Systems (ES2)

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Data Center Waste Energy Recovery and Re-Use

Data centers are a growing source of "waste energy." In fact, recent figures show that data centers alone are responsible for more than 2% of the United States' total electricity usage. With the steadily increasing demand for computing services in all sectors of the economy, and the rapid adoption and transition to cloud-based computation and storage, electricity demands will continue to soar over the next few years.

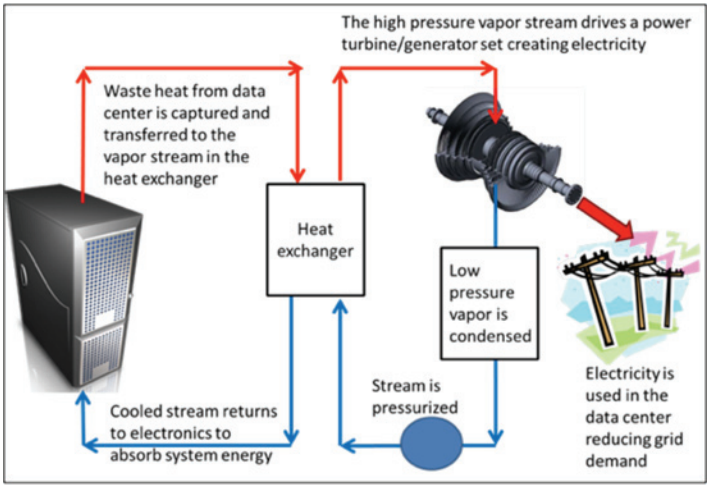
With these increases in computing demands, the processing load on the data center servers escalates. Increased load leads to increased chip power and possible overheating of the electronics. To maintain reliability and prevent system failure excess heat must be removed from the server. The heat is typically removed using either extensive air conditioning systems or using a liquid coolant stream. As the air or liquid removes the heat from the electronics, the coolant stream itself heats up, generating what is referred to as "waste heat." This waste heat is then often discharged directly to the environment though cooling towers.

This breakthrough research has focused on identifying the most promising methods and technologies for using the energy transferred to this coolant stream, rather than discharging it to the surroundings. This project's goals have been to: 1) comprehensively analyze and optimize two key methods of waste heat recovery; and, 2) produce validated computer models for use in analyzing the potential benefits to facilities of being able to choose the best system and then to calculate and optimize the return on investment.

Data centers produce large amounts of waste heat, but it is at relatively low temperatures (80 °C/176 °F). Most existing waste heat recovery systems are optimized for performance at temperatures closer to 300 °C/572 °F. Lower temperature waste heat recovery is challenging because fewer options exist for its industrial re-use. Thus to date, it has been difficult for organizations to justify the investment required to recover the waste heat. The low value of this waste heat compared with the value of the business and the potentially large capital investment required for waste heat recovery equipment means that from a business point of view it remains difficult to justify the long and sometimes uncertain return on investment.

Up to this point none but the largest organizations have been able to investigate the possibility of waste heat recovery and consequently there are very few global examples of such schemes being applied to data centers. The traditional concepts for re-use of low temperature heat include localized hot water heating, or public heat distribution such as district heating systems. These applications are of limited appeal and provide a tenuous justification at best for organizations to invest in energy recovery. In contrast, this research demonstrates realistically how companies can recover waste heat and re-use it on-site for electrical power production and/or by operating a waste heat powered refrigeration cooling cycle, both of which reduce overall energy consumption and cost.

Using the optimized designs and operational models developed here, organizations will be able to easily consider all options for energy re-use from their data center facilities, and the organizations can expect reduced overall energy consumption and lower energy costs. In addition, the contribution to global warming will be significantly reduced. If applied globally, the industry will not only recognize significant financial savings, but will also avoid the potential negative public image associated with the rapidly growing energy consumption of IT facilities and their environmental impact.



An example of a waste heat power-producing cycle. The waste heat is captured from the data center and used as the heat source to boil an organic liquid. The high pressure vapor that forms when boiled spins a turbine, generating electricity. The low pressure vapor exiting the turbine is condensed, re-pressurized and the cycle begins again.

Economic Impact: The high cost of energy and the depletion of limited resources are two of several issues driving significant interest in the capture and reuse of waste energy. If energy that is typically "wasted" can be reused, significant economic and environmental impacts can result. Given the significant energy consumption in data centers, the ability to capture and reuse energy offers the potential for massive reductions in energy consumption globally. A "typical" data center may contain 250 server racks, with each rack containing 42 to 64 servers. A single data center may therefore dissipate as much as 3-6 MW of power in the form of waste heat. Assuming that 90% of this waste heat can be captured and converted to electricity in a low temperature vapor power cycle at 10% efficiency, the data center can produce 300-600 kW of power from waste heat. Over the course of year, with 85% online operational time and considering a purchased electricity cost of $0.08/kWh, a company can save $175,000-$350,000 in annual power costs alone. However, when one also considers that the servers providing the waste heat to the power cycle may now be removed from the data center cooling system, the savings increase substantially. If a data center is dissipating 3-6 MW of power as waste heat, and the data center no longer needs to provide cooling to these systems, the savings can easily exceed $1,000,000 - $3,000,000 per year in electricity and operational costs, with subsequent reduction in load on the national power grid. Thus investing in capital equipment to recover and reuse waste heat will result in significant and positive impacts on the user's bottom lines and on the environment.

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