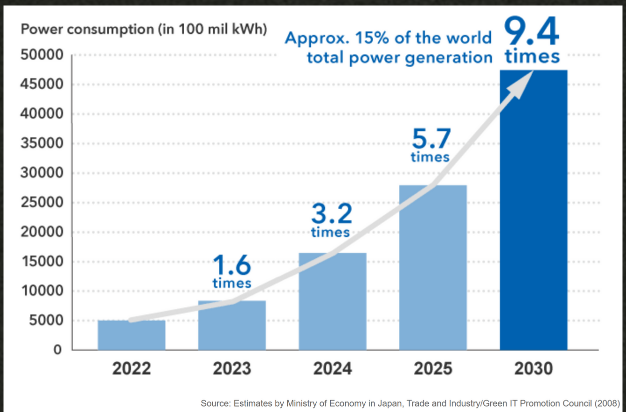
An Energy-Efficient Cooling System for Future Data Centers

ADVAY SUDARSHAN | ARYAN PANIGRAHI | YUGE JI
advays2 | aryanp3 | yugeji2   Team #45

Targeting SDG 12: Responsible Consumption and Production
& SDG 13: Climate Action

THE CHALLENGE

With the ever-increasing demand for computational power across all sectors of our society, data centers are rapidly becoming more energy-intensive. It is predicted that within the next decade, the power consumption of data centers is going to increase by a whopping 9.4 times compared to today's rate of consumption.



Furthermore, Professor Yogendra Joshi from the Mechanical Engineering department at Georgia Institute of Technology has this to say:

> **"Some people have called [the increasing cooling requirements] the Moore's Law of data centers. The growth of cooling requirements parallels the growth of computing power, which roughly doubles every 18 months."**

At a time where energy efficiency is of the utmost priority, it is critical to identify how to cool data centers efficiently and minimize the required energy.

ADDRESSING THE SDGS

- The ongoing silicon chip shortage serves as a reminder that we should fully utilize our current resources and reduce excessive exploitation of raw materials.

- As demand for computational power rises, so will carbon emissions due to an increased combustion of fossil fuels to power data centers. This leads to worsening effects of climate change, unless we work to improve the efficiency of data centers. Therefore, it is crucial to identify how the power consumption of servers can be minimized through means such as improving the effectiveness of cooling systems to reduce the environmental impact.

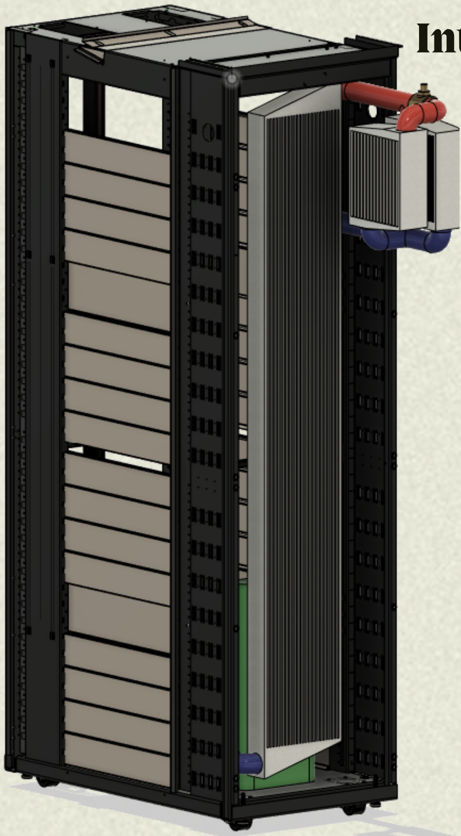
How can we improve data centers to ensure RESPONSIBLE CONSUMPTION and PRODUCTION and REDUCE CARBON EMISSIONS?

- Heat from data centers needs to be removed to provide a suitable operation condition for servers. This process only adds to the already high power consumption, with cooling and ventilation systems amounting to an average of 40% of data centers' energy use.

- Current servers do not operate under full load due to ineffective cooling. With better cooling and increased load, the same computation may be achieved with fewer servers.

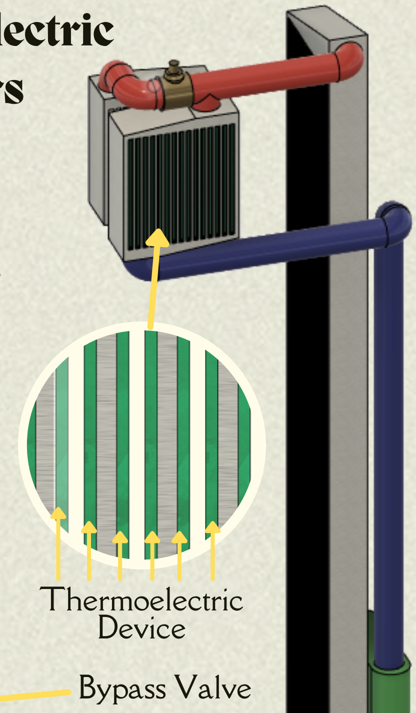
Our Solution

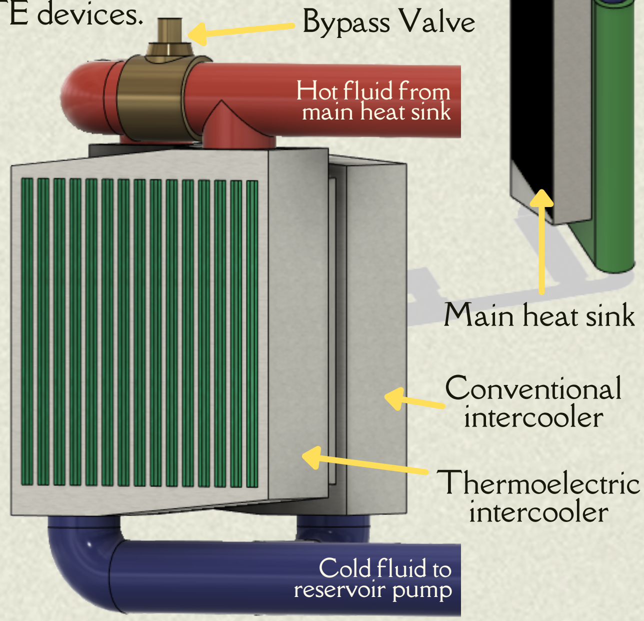
Introducing the Rear-mounted Thermoelectric (TE) Cooling System for Rack Servers



How does it work?

Heat exits the rack server from the rear and gets absorbed into the main heat sink, entering our cooling system. The warmed up fluid then travels into the overhanging section of intercoolers for simultaneous power generation and cooling. One of the two intercoolers is conventional while the other has a unique design, as shown by the model on the right. Attached on every fin of the intercooler is a layer of thermoelectric (TE) material. The cool air flows by the TE layer, creating a temperature difference between the layer's two faces, thus generating electricity. In the microscopic illustration on the right, the green layers represent the TE devices.





One important consideration in this design is ensuring that servers remain functional in case of a failure in our TE devices. For this reason, we added a bypass tubing and valve, as shown by the model on the right. By default, the fluid only travels through the TE intercooler. The bypass valve labeled in brown automatically opens once the server temperature reaches a set limit, allowing the fluid to flow into the conventional intercooler, reducing risk of overheating.

Large data centers usually have arrays of server racks. If our cooling system is installed on multiple racks, airflow can be directed to pass through a line of intercoolers, as illustrated by the model on the left. This localized cooling design, contrary to the traditional method of cooling the entire server room, improves efficiency and is recommended by the U.S. Department of Energy.

Moreover, as TE technologies mature, we expect the fluid pump to be powered solely by the absorbed heat energy.

FEASIBILITY

1 EFFICACY OF CURRENT TECHNOLOGIES

There has been significant improvement in the efficacy of TE devices:

In 2019, the Vienna Institute of Technology developed a new TE material made from iron, vanadium, tungsten, aluminum, and silicon. This TE material doubled the previous world record for the amount of electrical energy produced. This means that certain processors and sensors can now be self-powered!

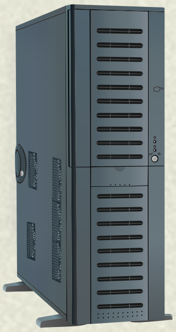
In 2021, a team from Northwestern University devised a method to manufacture TE devices using widely-available tin and selenium powders, dramatically lowering the cost of production while maintaining the TE devices' efficacy.

2 PROMISING RESEARCH RESULTS

A study conducted by Ford and sponsored by the California Energy Commission has shown that the use of TE devices in HVAC systems results in a 33% drop in A/C compressor power consumption and a 12% reduction in climate system energy usage. The TE devices have also proven their durability over 60,000 cycles under varying operating conditions ranging from -20°C to 75°C.

3 ALTERNATIVE DEVICES

To augment TE devices in electricity production, alternative technologies such as thermoelectrochemical cells and cells driven by thermally regenerative electrochemical cycles can also be implemented. However, these are more complex systems involving specially-crafted electrochemical cells, creating more chances of system failure.



SCALABILITY & REPLICABILITY

1 Modularity

Except for the TE intercooler, all components can be obtained either off-the-shelf or outsourced, catering to the specifications of any server system.

2 Retrofit Design

Our design does not modify internal components of the server, as it is simply appended to the rear end of server racks. This makes our solution accessible to all server systems of today and tomorrow.

REFERENCES AND ACKNOWLEDGEMENTS

Special thanks to UIUC Mechanical Engineering Department Associate Professor and Associate Head of Undergraduate Programs Sanjiv Sinha (sanjiv@illinois.edu) for his time, giving us useful insights into thermoelectric devices and helping to shape the direction of our project.

"Battling Server Overheating, Enemy of Data Centers." TDK, 28 July 2020, https://www.tdk.com/en/featured_stories/entry_015.html.

Cheung, Hoi Ying, et al. "Fact Sheet: Improving Energy Efficiency for Server Rooms and Closets." Fact Sheet: Improving Energy Efficiency for Server Rooms and Closets (Technical Report) | OSTI.GOV, 1 Sept. 2012, https://www.osti.gov/biblio/1172953.

Maranville, Clay W. Ford Thermoelectric HVAC Project (Final Report). United States. https://doi.org/10.2172/1607865

Rahimi, Mohammad, et al. "Emerging Electrochemical and Membrane-Based Systems to Convert Low-Grade Heat to Electricity." Energy & Environmental Science, The Royal Society of Chemistry, 21 Dec. 2017, https://pubs.rsc.org/en/content/articlelanding/2018/ee/c7ee03026f#!#:~:text=Low-grade%20heat%20from%20geothermal%20sources%20and%20industrial%20plants,has%20great%20potential%20to%20be%20converted%20to%20electricity.

Service, R. F. (2021, August 2). Cheap material converts heat to electricity. Science. Retrieved November 28, 2021, from https://www.science.org/content/article/cheap-material-converts-heat-electricity.

"Controlling Heat in Large Data Centers with Improved Techniques." ScienceDaily, Georgia Institute of Technology, 6 June 2009, https://www.sciencedaily.com/releases/2009/06/090602161940.htm.

III, Allison A. Bailes, and Allison A. Bailes III. "Using Server Farms to Heat Buildings." GreenBuildingAdvisor, 8 Aug. 2018, https://www.greenbuildingadvisor.com/article/using-server-farms-to-heat-buildings.

Vienna University of Technology. (n.d.). New material breaks world record for turning heat into electricity. Retrieved November 28, 2021, from https://phys.org/news/2019-11-material-world-electricity.html.

Solution models created with Autodesk Fusion360.