Thesis Project Portfolio

Design of a Thermal Conductivity Measurement Device for Cryogenic Applications

(technical research project in Mechanical Engineering)

The Making of Data Center Alley: Proponents and Critics

(sociotechnical research project)

An Undergraduate Thesis

Presented to the Faculty of the School of Engineering and Applied Science

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Bachelor of Science, School of Engineering

Quinn Early

Department of Mechanical Engineering

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Executive Summary

Humans' current rate of natural resource use is unsustainable and already causing catastrophic ecological changes. Governments and companies must therefore work together to improve computing efficiency as artificial intelligence becomes prevalent and the economy continues to transition online. However, there are countless approaches to pursue more efficient computing. The capstone project took a quantum computing approach, where the group built a measurement apparatus to test the material properties for minerals used in this emerging technology. The sociotechnical analysis is more policy-oriented and discussed how governments, utilities, local environmental groups, and other actors interact to affect data center projects. To promote energy security and carbon neutrality, efficiency concerns must be addressed if we are to meet the rapidly increasing demand for computing resources.

The technical goal was to design and fabricate a cryogenic measurement insert for an evaporation fridge that reaches temperatures as low as 1 Kelvin. Since quantum computing happens at extremely low temperatures, it is imperative to know how various materials will act in those regimes to design a more efficient system. The group met various objectives that constrained system design. The insert accurately measured thermal conductivity of crystals and other minerals. Its wires and hardware were easy to reconnect. It operated in vacuum conditions to prevent damage to the electronics. It also had to fit in the cooling system's narrow opening and use materials that minimize heat flow from the surface to the cold base. Finally, the electrical systems had to be resistant to system noise and function in cryogenic conditions. The group split into sub-teams to carry out project tasks effectively, overcoming financial and time constraints along the way. In the end, the insert did not test thermal conductivity in a 1 Kelvin environment due to lack of availability of test equipment but were able to test these properties at room

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temperature and at 77 Kelvin. The cryogenic instrument advanced the understanding of lowtemperature materials needed for quantum computing. In doing so, the group pursued more efficient computational technologies.

Without strategic infrastructure planning and energy policy, Virginia will struggle to maintain its position as the data center industry's global epicenter. The sociotechnical work therefore discusses how advocates and critics of new data centers have advanced their agendas in the state. Complex economic, social, and environmental relationships are first defined as elements of an actor-network. These concerns are then linked to actors – among them consumers, utilities, state legislators, and technology corporations-based on how actors strategically use them. The paper uses a mix of primary and secondary data to determine how data center development and acceptance depends on input from the network. From the perspective of residents, organization into interest groups has led to increased anti-data center lobbying and has halted certain projects on environmental grounds. Data center constructors and local legislators often suppress this dissent by highlighting the high-skilled jobs and infrastructure improvements that they bring, even overstating their benefits. Energy companies like Dominion maintain public support by emphasizing their lower-than-average costs to consumers while delaying or abandoning sustainability initiatives. Finally, parallels between traditional development strategies and the data center actor-network are identified. Grounding the research with established theory also highlights the changing dynamics of social acceptance as they pertain to modern computing facilities. The blending of traditional and modern approaches yields an original policy and social analysis of "Data Center Alley" in Northern Virginia.

Overall, I learned a lot about effective communication by viewing the two components of the thesis as an integrated whole. In the technical project, cooperation between electrical, vacuum,

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structural, and sample mount subgroups was crucial to ensure the devices systems functioned when put together. We also held each other accountable through weekly update meetings, sometimes with our capstone advisor. During assembly and testing we also worked as a whole group, with each team explaining and balancing its needs with others. On the sociotechnical side, I learned a lot about how powerful actors rely on strategic communication and public perceptions to advance their agendas. I quite enjoyed the blend of technical knowledge and policy analysis in this research, especially by linking different actors by their priorities/conflicts. This year I gained a new perspective of how slow-moving government intervention can fall short in regulating emergent technologies, which can lead to massive profits for utilities and technology corporations alike.