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January 31, 2024

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RE: Thermal Energy Network Final Comments

Dear ICC Staff,

Thank you for the opportunity to provide comments on the geoscience and geoengineering aspects of technologies applicable to Thermal Energy Networks (TEN), with a specific focus on Illinois. This topic was broadly discussed in the ICC-sponsored Workshops, but I would like to provide additional information that may be helpful in developing strategies for implementing TEN.

As Principal Research Scientist at the Prairie Research Institute (PRI), a Research Institute located at the University of Illinois Urbana-Champaign (U of I) campus (https://prairie.illinois.edu), I am working on multiple projects to characterize the underground geological conditions that impact the design and efficiency of geothermal energy systems. Having this baseline information has been shown to reduce overall installation costs and implement the most suitable technology.

The PRI has a long history of over 50 years assisting the citizens of Illinois in understanding the potential applications and benefits of utilizing geothermal energy resources for energy efficiency and conservations efforts in the State. The early research focused on the temperature of groundwater, geothermal heat pumps systems and capture of thermal energy during the disposal of industrial waste. More recently, over the past decade, the PRI has conducted research on how groundwater flow impacts the design and operation of geothermal energy systems. This work has involved real-time monitoring of field demonstrations integrated within the campus' energy system and the feasibility assessment and experimentation of new geothermal technologies that could be used in community or district geothermal energy networks. With colleagues at the U of I, as part of the Illinois Geothermal Coalition (https://geothermal.illinois.edu), a new generation of professionals in the geothermal industry is being trained and outreach and education programs are being developed to improve the knowledge base, which is critical for the wider adoption of geothermal energy systems, such as geothermal energy networks.

The State of Illinois and the broader Midwest region are recognized as the roots of the geoexchange industry in the U.S. with several industry-supporting organizations and geothermal heat pump manufacturers located here. Also, the region's climate and geological and hydrogeological conditions have made the region an ideal place to develop geothermal energy systems. The large seasonal temperature variations, relatively soft and uniform geologic formations, and abundant groundwater are ideal conditions for maximizing the benefits of geothermal energy resources.

Technology Development for Geothermal Energy Networks

The Earth can be considered a "thermal battery" which can be optimized for seasonal thermal energy storage. When determining the design parameters and operational capacity of geothermal energy networks, it is critical to have a thorough understanding of the underground conditions. This includes knowing the heat transfer paradigm being used, whether conduction or advection, and the drilling conditions. Furthermore, as discussed in the Workshops, there are a range of geothermal technologies (borehole geoexchange and direct heating and cooling) that can be considered for deployment. However, the potential technologies were not discussed with specific reference to the subsurface conditions in Illinois which may be different than in the examples provided.

The following is a non-exhaustive list of geothermal resources, technologies, and applications that could be utilized in community or district geothermal networks in Illinois. A more exhaustive discussion is provided in this Illinois Geothermal Coalition white paper (https://geothermal.illinois.edu/wiki). Researchers from the U of I are exploring their application for the Blacks in Green® "Sustainable Chicago Geothermal" community geothermal heating and cooling project, funded by U.S. Department of Energy.

- **Geoexchange (Closed Loop Systems)**: Includes both horizontal ground and vertical borehole heat exchangers, which are the most common geothermal energy system. Geoexchange systems with vertical boreholes are typically used in areas where open land is limited. In Illinois, the vertical boreholes are typically drilled to depths of 300–500 feet (90–150 m). To better utilize land in urban areas new regulations are being implemented in states, such as New York, to drill up to 800 feet (245 m)[1]. Also, companies, such as Celsius Geothermal, are drilling multiple inclined holes from a single drill site to reduce space[2]. Furthermore, Genesys Geothermal has developed the CLAD (Closed Loop Advection Device) system[3] that requires an 80% smaller area than other closed-loop geothermal systems. In addition, innovative technologies are being used for monitoring and improving the performance analysis of geothermal borefields. At the Epic Healthcare campus located near Madison, Wisconsin fiber-optic distributed temperature sensing (DTS) is being used to quantify how groundwater flow impacts underground heat transfer and energy storage[4]. My team also applied this approach at the U of I in the pre-design of a geothermal borefield for the Campus Instructional Facility[5]. Along with distributed thermal response testing (DTRT), thermal property measurements of intact geologic samples improved the overall underground characterization leading to a significant cost reduction making the project feasible.

- **Open Loop Systems and Aquifer Thermal Energy Storage**: These systems are much less common in the Midwest region and require different permitting and borehole completions. Safeguards are taken to meet water quality standards as groundwater is pumped from and returned to the aquifer. In Europe, this geothermal energy resource is more widely developed, and groundwater is considered a promising storage medium due to its high heat capacity and low thermal conductivity[6]. Due to its widespread availability the seasonal storage of heat and cold in shallow groundwater is appealing. The development of low temperature geothermal resources (<150°F; <65°C) do not have any technological or scientific challenges, but their widespread evaluation/assessment and technology adoption at the district or community scales is in its infancy. There are several projects looking at the economic, environmental, and social

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[1] "Geothermal Wells Deeper Than 500 Feet," New York Department of Environmental Conservation. Available at https://dec.ny.gov/environmental-protection/oil-gas/well-owner-and-applicants-information-center/regulated-well-types/geothermal-wells-deeper-than-500-feet
[2] "Angled Drilling: Drilling Off Center - But On Purpose!," presentation by Dmitry Kuravskiy, NY-GEO 2023 Conference (April 26, 2023). Available at https://www.youtube.com/watch?v=e4rTJPL1-s8
[3] "CLAD – A Simple Genius Heat Exchanger," presentation by Roshan Revenkar, May 2023 Dig Deeper Webinar (May 26, 2023). Available at https://www.youtube.com/watch?v=0rtyFWnjxfk
[4] "Long-term Temperature Monitoring of a Campus-Scale Geothermal Exchange Field using a Fiber-Optic Sensing Array." Available at https://pangea.stanford.edu/ERE/db/GeoConf/papers/SGW/2023/Attri.pdf
[5] "Subsurface Characterization, Monitoring, and Modeling of a Geothermal Exchange Borefield for the Campus Instructional Facility at the University of Illinois at Urbana-Champaign." Available at https://hdl.handle.net/2142/111796
[6] "Worldwide application of aquifer thermal energy storage – A review." Available at https://doi.org/10.1016/j.rser.2018.06.057

benefits of developing geothermal systems at the city scale[7]. Capturing and storing waste heat underground would significantly reduce greenhouse gas emissions and counteract the urban heat island effect. New downhole technologies like Darcy Solutions' groundwater-sourced geothermal technology[8] provides much larger capacities with fewer wellbores. This technology would be suitable for areas of northern and central Illinois where glacial aquifers are found along modern river valleys and in buried ancient bedrock valleys, such the Mahomet Bedrock Valley and Troy Bedrock Valley.

- **Deep Direct Use Geothermal Systems**: Deep direct-use is an emerging technology area in the geothermal sector that draws on lower temperature (100°F–300°F; 40°C–150°C) geothermal resources[9]. Unlike traditional geothermal heat pump systems, thermal energy is extracted and stored at much deeper depths in porous sandstone formations. This new technology utilizes existing oil and gas drilling methods and well completion strategies and could offer greater opportunities for geothermal resource development throughout the U.S. In the Midwest region, these geothermal resources are found in deep sedimentary basins. One of these basins, the Illinois Basin, underlies most of the state and two formations (St. Peter and Mt. Simon Sandstones) are the target geothermal resources. These prolific and porous formations are currently being used for carbon capture and storage. The U.S. Department of Energy funded six feasibility studies between 2017 and 2020 and a project team led by the U of I evaluated the low temperature geothermal resource in the Mt. Simon Sandstone[10]. The formation contains at least 1.32×10^3 exajoules of thermal energy that is equivalent to combusting 216 billion barrels of oil. Because relatively few wellbores are needed to extract the large volumes of heated brackish to saline waters, deep direct-use geothermal systems are scalable for end-users with large and varying energy demands, such as city neighborhoods, educational and hospital campuses, industrial complexes, and military installations.

- **Repurposing Abandoned and Idled Oil and Gas Wells (Borehole Thermal Energy Storage)**: In central and southern Illinois where oil and gas wells are currently being decommissioned, there is the potential to repurpose these wells for long duration storage (>10 hours) of thermal energy. Studies by U of I researchers[11] show these wellbores in the Illinois Basin can be an effective means to store excess thermal energy from industrial sources and other renewable energy sources like wind and solar electricity generation during off-peak hours. Heated or cooled water could then be extracted when through a closed loop when demand exceeds the generated capacity.

We offer to provide further technical assistance during the Commission's effort to develop a regulatory structure for utility thermal energy networks.

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[7] "City-Scale Geothermal Energy Everywhere to Support Renewable Resilience – a Transcontinental Cooperation." Available at https://pangea.stanford.edu/ERE/pdf/IGAstandard/SGW/2023/Goetzl.pdf
[8] "Darcy® Sustainable Heating and Cooling," https://darcysolutions.com
[9] "Heat from Beneath the Ground – Working to Advance Deep Direct-Use Geothermal," U.S. Department of Energy, https://www.energy.gov/eere/articles/heat-beneath-ground-working-advance-deep-direct-use-geothermal
[10] "Geothermal Heat Recovery Complex: Large-Scale, Deep Direct-Use System in a Low-Temperature Sedimentary Basin," Final Report to the U.S. Department of Energy. Available at https://doi.org/10.2172/1821557
[11] "Geothermal 'battery' repurposes abandoned oil and gas well in Illinois, researchers report," https://news.illinois.edu/view/6367/626315322

Respectfully Submitted,

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