BUILDING DECARBONIZATION COALITION

BDC Presents: Building Decarbonization Meets Water Conservation

August 29, 2024

Summary

BDC's Ashley Besic unveiled key findings from our recent brief, *Building Decarbonization Meets Water Conservation: The Potential of Thermal Energy Networks to Cool Buildings & Save Water*. The brief analyzed data from ten sites in North America that have installed thermal energy networks (TENs) to heat and cool commercial and institutional buildings. Building operators from eight of those sites reported saving a cumulative 337 million gallons of water annually, equivalent to the annual water use of 3,000 U.S. households. Kent Marsh, Vice President for Capital Planning, Sustainability & Campus Operations at Colorado Mesa University, joined to share data on components, costs, and emissions reduction from CMU's campus TEN, as well as lessons learned and future plans.

Resources

- **Recording**
- **BDC newsletter sign-up**
- **Building Decarbonization Meets Water Conservation**
- **Colorado Mesa University Geo-Grid System**

Events

- **California Policy Call:** Sep 17th, 10am PT / 1pm ET
- **NY Climate Week: Invest in the Future of Heat:** Sep 24th, 12pm PT / 3pm ET
- **BDC Presents: The Future of Gas**: Sep 26th, 10am PT /1pm ET
- **New York National Policy Call**: Oct 8th, 10AM PT/1pm ET

Presentation Outline

The Challenge

- The United States faces multiple climate-related challenges, such as decarbonization, heat waves and droughts. Cooling large buildings is associated with each challenge.
- Large commercial buildings can be "thirsty:" many conventional cooling systems rely on chillers and cooling towers that use water to evaporate heat.
- One estimate suggests that 5-15 billion gallons of fresh water are consumed daily to cool U.S. commercial spaces.

A Potential Solution: Thermal Energy Networks (TENs)

- TENs do *not* use evaporation to cool.
- Instead, these systems use ground-source heat pumps to transfer waste heat to other buildings via a network of underground pipes.

- TENs are typically installed for decarbonization benefits, including:
  - Neighborhood-scale building decarbonization.
  - No on-site combustion.
  - High efficiency reduces strain on the electric grid.
- We initiated this survey because we wanted to see what data was available to show that TENs can save water, too.

***Building Decarbonization Meets Water Conservation*: Methods and Key Results**

- The brief surveyed and analyzed self-reported data from ten TENs in the U.S. and one in Canada.
- Key findings:
  - The eight sites that reported savings in gallons saved 337 million gallons of water annually (equivalent to the annual water use of 3,000 average U.S. households).
  - Annual water savings were variable, ranging from 18% to 46%, highlighting a need for more research and standardized reporting.
  - Water savings were achieved across climate zones, indicating that TENs can save water in many climates and geographies.

Case Study: Colorado Mesa University

- Colorado Mesa University first installed its geothermal networks in 2007.
- System components
  - ~2.5 miles of central pipe loop (18” diameter), made of high-density polyethylene piping.
  - Some micro-loops located across campus, to reduce thermal energy travel.
  - 9 separate drill fields.
  - ~500 boreholes, ~600 feet deep.
  - 1,000+ heat pumps within ~1.7 million square feet of connected buildings.
  - 5 cooling towers: as a cooling backup (have not been used for some time).
  - 2 boiler plants: as a heating backup (have not been used for some time).
- How does it work?: “Least energy paths” principle
  - Heat distribution is optimized, so minimal energy is used for pumping and distribution.
  - Example: Heat pumps extract heat from a classroom or lecture hall. That heat is transferred into the water loop pipes, then moves where it’s needed: perhaps an office across campus. So the first “least energy path” is moving heat from one space to another space that needs it.
  - Drill fields are a “thermal battery.”
    - In summer, excess heat is dumped into the central loop. That waste heat is then sent down to the ground into the drill field. The earth extracts the heat from that water.
    - So when it returns to the surface, in a well-designed system, it will be the same temperature as the earth, and the whole process starts again.
- Emissions reductions
  - The carbon footprint has been reduced by 10,114 metric tons each year compared to traditional HVAC.
- Does CMU’s TEN save money?

- It is very cost-effective, because heat pumps are very efficient. (The coefficient of performance, at certain times of year, is in excess of 8.)
- It consumes less than half of the electricity per square foot compared to a conventional HVAC system; thus, the campus buys fewer kWh from the utility.
- The university has expanded, and each new building is connected to the TEN. CMU *would have spent* significantly more in their annual utility expenses had they installed traditional heating and cooling systems in their new buildings.
- Savings are transferred to the students in the form of lower tuition and fees.

- Financial investment and costs
  - The university benefited from a leadership team willing to invest in the TEN despite some unknowns—and they are glad they did.
  - The most sustainable, long-term life-cycle cost options usually have the highest up-front costs; this TEN is no exception.
  - The total cost of initial construction: ~$20 million.
    - Drill fields alone represent ~$6.4 million.
  - Energy savings of ~$1.5 to $1.6 million each year, equaling system payback of just over 12 years.
    - The lion's share of resources in the system are HDPE pipes that will be in the ground forever. That resource will be paid back in 12 years.
- Lessons learned
  - In 2007, the original heat pumps did not tolerate extreme temperature differences between the water loops and interior temperatures; they shut down if the ΔT was too small.
    - This has changed; new technology operates over a broader ΔT spectrum.
  - In 2007, not many mechanical engineers were familiar with TENs. That has changed over the last 15 years.
  - In 2007, there was no contractor in town that could install HDPE pipe that was thermally fused; however, this technology is now used all over the U.S., and there are 3-4 contractors in town that have no problem installing it.
  - The lack of construction and installation standards and testing procedures still presents an occasional challenge.
- What's next for CMU's TEN?
  - The system has gained a lot of attention in the last two years.
  - CMU received $9 million in spending authority to connect the rest of the campus into the TEN.
  - Opportunity to better match cooling loads with heating loads.
  - Opportunity to extract waste heat from sanitary sewer systems, and dump waste heat into it; working with the City of Grand Junction Public Works Department.
  - Opportunity to help guide Codes & Standards for IGSHPA (International Ground Source Heat Pump Association).

<u>Closing Remarks</u>

- Why care now about TENs and water?
  - Water is only getting scarcer and the earth is only getting warmer. We need solutions now.

- Legislation in seven states across the country has allowed utilities to adopt, own, and operate TENs.
- 20 pilots have been initiated or constructed across the country by utilities and community groups. Data collection, including potentially on water use, will be a crucial part of these pilots.
- The Inflation Reduction Act provides significant federal tax incentives for ground-source heat pump installations in commercial buildings.

- Recommendations
  - Standardize data on building water usage to understand how TENsc can help achieve multiple sustainability goals.
  - Make data public.
  - Consistently track and measure buildings' water savings.

Q & A

1. **What are the projected ongoing repair and maintenance costs? Is there a significant increase or decrease compared to the past conventional system?**

Kent Marsh, CMU: Let's compare heat pumps with boilers and cooling towers. In a classroom building, I may have had a large cooling tower on the roof, and I may have one or two efficient boilers. There are fewer components to maintain than a TEN, but those components are much larger and the parts are much more expensive.

So that is replaced with 300-400 heat pumps, depending on the size of the building. These heat pumps can be as small as one or two tons, but they aren't "technology-rich." By far, the biggest part of our TEN are the high-density pipes that sit in the ground. No one knows it's even there. We never touch those. The valves, the pumps—we use run-of-the-mill pumps, and we always have spares so if one dies, we go to the next one. So it's not super maintenance-intensive. I don't think that more ongoing costs come with owning or maintaining a thermal energy network.

Jess Silber-Byrne, BDC: Do I remember correctly that the tuition would be 2% higher today if it wasn't for installing the TEN?

Kent: That's right. So we looked at how much electricity we would purchase today at our blended rate of 14 cents per kilowatt hour, versus what we actually purchased, and found that the net savings for our students equated to a 2% reduction in what we *would* be charging for tuition today had we not installed the TEN.

2. **Are the backup boilers on the system connected to piped gas, or are they fueled by tanked fuels?**

Kent: Yes, the boilers are connected to gas, but we kept those just for a worst-case scenario. There's a heat exchanger between the boilers that allows us to move heat from the boiler into the central loop. So for example, if I made a mistake this winter and built a new residence hall, and the existing TEN doesn't have enough capacity for it, we may have to turn that boiler on as a backup. But then, we would move forward in the future with an additional drill field or some other way to get heat.

3. **What kind of software manages the thermal exchange between buildings, the loop, and the bore field? And is it custom and unique to your system?**

Kent: We have a TRANE Tracer Summit for direct digital controls in the buildings, which tell the pumps in the building where to send the water. And we have a larger dashboard, based on the hierarchy of the Tracer Summit system, that is the "brains" that instruct which pipes turn on, which pipes move water into the ground versus moving water through the central loop, etc. There likely is some customization for our campus, but it's not anything different than any large campus would have.

4. **Are the key decision makers in these situations amenable to TENS, or is it a concept that takes time to warm up to?**

Ashley Besic, BDC: It varies not just by state, but by coalition. Being a coalition-based organization, we defer and rely on non-profits, municipalities, other utilities, regulators, labor, and others. Each coalition contains various combinations of stakeholders. Each has a different motivation [for adopting or pursuing TENs], and it's hard to generalize the motives for most folks, but a lot of it comes from: Community needs, an existing climate commitment, and a sense of wanting to make sure no one gets left behind. That speaks to the BDC's role and need in making sure this solution is equitable. So even if a coalition doesn't have certain members involved, we ask questions like, “Who do you want to be involved? Who's not involved yet that you want to be involved, and are there any reasons why you would want to have a separate table for other folks?” Because we do believe everyone should be a part of the conversation and a part of the work, but we work at different tables sometimes.

Kent: From a narrower perspective, I think higher education struggles with TENs because many campuses are heated by steam boilers and those systems are old and need to be replaced. An institution needs to take a step back and say, “We know we have to replace the infrastructure for our steam. Should we consider different technologies? Can we consider a TEN?” I think it's important for higher ed to open their eyes to the possibilities, because once you replace that steam plant [with another], it will be there forever, and you will have sunk so much cost to replace it.

Ashley: Yes. Some of the reasons that universities [in our brief] were drawn to a TEN, specifically, was that they wanted to replace their failing steam system with something better. For example, Oberlin had made a climate commitment, and installed a thermal energy network that molded to the needs of the facility.

5. **Do you have any recommendations on how to introduce new technologies for demonstration in a TEN?**

Ashley: I would start with examining the situation folks are in, because that will result in different solutions. For example, think about how utilities work—whether they're private or publicly owned, whether they're dual-fuel, or they're just gas or just electric...all of that plays into how innovative we can be, as a community, when coming up with solutions. [Additional] ownership models also present a massive opportunity for us to think creatively and be innovative, and allows for private non-utility investment. A good example is EcoSmart Solution and Taurus Investments, working together to build sustainable communities. EcoSmart builds what they call the GeoGrid, in which they, as private developers, build this geothermal infrastructure for their master-planned communities. They never even look at gas infrastructure. They're constantly looking at ways to make the grid more efficient and control peak load demand in both winter and summer.

Utility TENs pilots, like in Framingham, Massachusetts, also show that innovation will come not just in the technology, but how we identify, deploy, maintain and run these pilots, and turn them into actual capital projects that anyone—utility, campus, or anyone for that matter—can do.

Kent: Broadly what I'll say is that I believe that higher education should lead by example. Colorado Mesa University, and I assume many other institutions, are interested in technology advances. However, there will be questions such as: Is it more cost-effective? Does it save in the long-term? What does it look like? And would we consider it? Absolutely.

6. **Is there a possibility that any energy is lost during the thermal exchange process? Is it computed how much is lost if any?**

Kent: I'm certain there is. But where is it lost? I'm not sure. The majority of our system exists in the ground. Those pipes are surrounded by sand and other material as bedding and then we compact the earth back on top of it. I'm sure there are ways for us to lose heat energy throughout the process, but I suspect it's not very much.

7. **Is the TEN location specific?**

Ashley: We have a database of all TENs that we are aware of. In the brief, we highlighted those that shared complete data on water use and water savings, as well as heating and cooling tons. For the most part, we relied on publicly available data.

Kent: You could ask, "Will TENs work throughout the U.S. and the world?" I would say "Yes, they will," but you need to match the load. For instance, we're cooling-dominant in Colorado. We have more heat than we can use. We need to match the amount of heat pulled out of the building with a resource that needs that amount of heat. I assume that the TENs you reviewed in Canada and further north have the opposite problem: they need heat, and must match where they are pulling heat from with areas that need the heat.

8. **[In chat] I imagine many of the components in this system, such as the HDPE, are created using fossil fuels. Are there any ways to move away from these fossil fuel generated materials or is that just a tradeoff that we have to accept?**

While TENs eliminate onsite combustion and fossil fuels for heating and cooling, it is true that there is embodied carbon in the equipment needed to run these systems. Likewise, the electricity that runs the heat pumps will likely be generated by fossil fuels until the grid is powered by 100% clean, renewable energy. Hopefully, over time, this embodied carbon and the use of fossil fuels to generate electricity will both decrease. (See the U.S. Department of Energy's Industrial Decarbonization Roadmap, which aims to reduce emissions generated by manufacturing the types of materials you describe.)

Vaclav Smil writes in "Energy And Civilization: A History" that every transition to a new form of energy requires deploying existing forms of energy, and our journey to renewables is no different: "The transition from wood to coal had to be energized by human muscles, coal combustion powered the development of oil, and…today's solar photovoltaic cells and wind turbines are embodiments of fossil energies required to smelt the requisite metals, synthesize the needed plastics, and process other materials requiring high energy inputs" (Smil, 2015, 203). However, the shift to renewables differs from past transitions in its focus on both climate and justice. Uniquely, this energy transition is driven not *only* by new technological innovations or economic opportunity, but by policy intervention, equity considerations, and a widely-acknowledged need to reduce emissions.

9. **[In chat] How could AI technology integrate with TENs to enhance the technology?**

[Answer supplied by chat user]: A colleague of mine is working with FacilAI that is doing exactly that: machine learning for campus-scale energy optimization.

Using AI to find solutions to building decarbonization strategies is on the mind of many stakeholders in energy efficiency and building electrification. A recent article by Ding et al. (2024), "Potential of artificial intelligence in reducing energy and carbon emissions of commercial buildings at scale," examines the role of AI in reducing emissions across building equipment, occupancy, control and operation, design, and construction. There could be an application for these solutions to be integrated with TENs.

10. **[In chat] Have there been any municipal regulatory permitting barriers for TENs?**

At the municipal level, TENs must abide by local permitting laws. "How to Develop A Thermal Energy Network," a resource and manual developed by Vermont Community Thermal Networks, advises that interested community or municipal leaders must consult local boards, convene a design review board, and seek legal consultation on town planning and local land use bylaws, zoning, and environmental regulations.

A regulatory hurdle does exist at the state level. The "obligation to serve" is a key statute that can be interpreted to restrict gas utilities from selling any form of energy other than gas; it can prevent neighborhood-scale decarbonization, including with TENs, if a single customer in the neighborhood wishes to continue using gas. Amending this statute can bring consumers more choice in their energy source and allow utilities to evolve their business model for a decarbonized world. The BDC wrote a report outlining this statute and makes recommendations to decarbonize it safely and equitably: Decarbonizing the Obligation to Serve.