Amazon system delivers data center waste heat

The e-commerce giant will achieve net-zero energy at its Seattle headquarters through an innovative partnership with a downtown neighbor.

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Amazon headquarters campus, Seattle.

Achieving net-zero energy on building projects is becoming an increasingly realistic goal given current and emerging building technologies, design approaches and more engaged and educated occupants. But even with a well-charted and proven road map, the majority of projects face inherent constraints that hinder the aggressive pursuit of net zero at scale. Fortunately, new district paradigms are emerging that are practical and achievable. The concept of heat sharing – harvesting neighboring energy resources that would otherwise be wasted – is one such opportunity, which can help enable the step change in efficiency needed for building projects to achieve high-performance outcomes.

Amazon's corporate headquarters in the Denny Triangle neighborhood of downtown Seattle is the setting of one recent example of a local energy district that exploits such a synergy within an urban environment. The corporation has a unique arrangement with a data center building across the street to recover waste heat from server operations for use in the hydronic heating system serving its headquarters campus. This arrangement benefits both parties – reducing Amazon's electricity use, in keeping with the company's sustainability principles, and providing the data center building owner, Clise Properties, with a way to utilize its excess heat.

A CREATIVE COLLABORATION

Amazon's new 1.1 million-sq-ft Doppler building was occupied in late 2015 as the first phase of a planned buildout on the three-block Denny Triangle campus. It will ultimately comprise three high-rise towers, each at approximately 37 stories with its own meeting center, plus one mid-rise office building of 16 stories. The Doppler building houses a central heating plant and is interconnected via water piping with the Westin Building Exchange across the street. Formerly Westin Hotels' headquarters, the 34-story building is now a hub for more than 200 telecommunications and Internet-based companies, with their operations occupying around 70 percent of the total 400,000 sq ft of space.

Data centers are inherently very highly reliable sources of heat – a natural byproduct of the server farms. The heat generated at this facility, equivalent to 11 MW per day, was previously rejected year-round through cooling towers on its roof, consuming energy and water at a high cost to the owner. Now – since January 2016 – when Amazon needs to warm its buildings in winter, up to 5 MW of this otherwise wasted heat can be transferred to the online retailer's district energy system.

UP TO 5 MW OF OTHERWISE WASTED HEAT CAN BE TRANSFERRED TO AMAZON'S DISTRICT ENERGY SYSTEM.

Amazon has contracted to purchase this data center waste heat through a third-party entity that has enabled the neighbor-to-neighbor transaction: Eco District LLC, formed by Clise Properties and its Seattle-based contracting firm McKinstry. Before the agreement came together with Amazon, these two Eco District partners had been discussing what the data center might do with its waste heat other than releasing it to the atmosphere. For its part, Amazon, together with WSP USA, had been considering options for the design of the Denny Triangle campus energy system – which at one point included the possibility of tapping waste heat from a potential on-site data center that ultimately was not built. Eventually, Amazon and Clise Properties (which had sold Amazon the land for its urban headquarters) became aware of their mutual interests and agreed to collaborate on the waste heat recovery project.

The design of Amazon's first office high-rise, the 37-story Doppler building, includes the central plant located in the basement, equipped with heat recovery chillers that take the low-grade heat byproduct and boost it to temperatures suitable for building heating. In addition, the building contains a 400,000-gal water tank that also stores low-grade heat for the Amazon district energy system and can be tapped by the Westin Building Exchange as an emergency water source.

The 37-story Doppler building, which houses the central plant, was the first office tower to open on the Amazon campus.

Amazon's second office tower, the 1.1 million-sq-ft Day One building, opened in November 2016 and is also served by the district heating loop. Outside this tower, construction is proceeding on The Spheres, an eye-catching, five-story landmark set for completion in early 2018. The Spheres will comprise three giant interconnected glass domes that will house 40,000-some plant and tree species from around the world as well as spaces where Amazon employees can work or relax.

Amazon currently intends to leverage the data center heat resource to help heat its buildings in the Denny Triangle, whose district heating loop will serve the five office buildings and meeting centers totaling over 5 million sq ft of space by 2022.

KEY STAKEHOLDERS

The Amazon-Eco District heat-sharing strategy required solutions to a number of planning, permitting and technical challenges, including engineering design and construction coordination of a district energy system that cost-effectively harvests, transports and utilizes the data center's waste heat for a growing corporate campus. At the same time, successful implementation of the strategy required the stakeholders (see next page) to find solutions to the business challenges, including negotiating a mutually beneficial financial contract and establishing Eco District LLC – the Clise Properties-McKinstry partnership – as the third-party entity to serve as the waste heat recovery project administrator.

It also required the emergence of a persistent and effective project champion, Craig Norson of Seneca Group, Amazon's development management firm, who advocated for the implementation of a district energy system – presenting lifecycle and cost-benefit analyses and ensuring that the concept remained on the table throughout the various discussions. In so doing, he helped maintain momentum for district energy until both Amazon and Eco District LLC were comfortable and their heat-sharing contract could be executed.

Accomplishing the heat recovery project also required collaboration with a number of city departments, including the Office of Sustainability and Environment. The Seattle Department of Transportation issued permits allowing the two property owners to install water piping in public rights-of-way below several streets. Public utility Seattle City Light has also paid out rebate incentives to Amazon rewarding its building energy efficiency.

LIMITING FACTORS TO NET ZERO

With its waste heat recovery system, Amazon's Denny Triangle campus has achieved a step-change increase in heating efficiency from what is conventionally used in Seattle – a key step down a road for Amazon in eventually decarbonizing its building portfolio. However, even with motivated owners and talented project teams like those involved in the Amazon project, certain buildings are generally identified as poor net-zero energy or net-zero carbon candidates. These include, for example, those with high energy- or water-use intensity (e.g., hospitals or data centers) as well as high-rises that lack sufficient space and/or solar exposure for effective on-site renewable energy. In urban areas, even if a building design appears on paper able to achieve net zero, projects may not be able to annualize out to net-zero energy during operation. For example, if the electric utility is configured as a highly reliable network grid, the utility is likely to prohibit backfeeding excess on-site-generated electricity. So, the utility grid cannot serve as the "battery" to take energy generated by the building at those times when there is excess.

Climate, too, can affect a project's net-zero energy candidacy. Highly efficient

The Spheres, comprising three giant interconnected glass domes, is set for completion in early 2018.

Amazon heat-sharing project stakeholders

- **Amazon**
- **Eco District LLC (Clise Properties, McKinstry)**
- **WSP – district energy system designer**
- **University Mechanical – mechanical contractor for the Doppler and Day One buildings plus The Spheres meeting center**
- **ATS Automation – Amazon building controls contractor**
- **NBBJ – Denny Triangle campus architects**
- **Acorn Development – Amazon's development arm**
- **Seneca Group – development management firm working for Amazon**
- **City of Seattle**

air-source heat pumps may not be the most feasible solution for buildings in cold locations with a significant annual need for heat (which can result in reliance on on-site fossil fuel combustion or electric resistance heat). Even low-rise office buildings in moderate climates are seeing a trend toward increased occupant density – meaning higher internal energy loads, which are also often unpredictable to estimate or manage.

AN INNOVATIVE DISTRICT STRATEGY

Although it's not new, the idea of an energy district for heating and/or cooling is increasingly being considered as a path to help enable high-performance buildings. Even those conventional district heating systems that use renewable fuels like biomass, for example, rather than fossil fuels can provide a significant advantage in reducing the carbon footprint of those buildings served – even if they somewhat paradoxically do not necessarily reduce energy consumption.

Traditional energy districts found on college or corporate campuses and in some cities have installed centralized utility plants to produce district steam for heating and chilled water for cooling, for reasons of economics, ease of maintenance and/or to support climate action goals. An even more innovative strategy is one like that employed by Amazon that leverages an identified synergy – for example, an urban campus that harvests waste heat from a neighboring enterprise owned by another party – to assure a reliable, cost-effective source of heat energy that can benefit both parties and the environment.

A "WIN-WIN" SOLUTION

The concept of a local energy district based on heat sharing was embraced by Amazon as a cost-effective alternative to conventional heating solutions – which include electricity, a common heating source in Seattle – for the Denny Triangle campus. The concept was also embraced by the owners of the Westin Building Exchange as a means to reduce operations and maintenance costs, generate revenue and potentially enable them to expand their enterprise within the same building footprint.

THE FINISHED DISTRICT ENERGY SYSTEM WILL AVOID APPROXIMATELY 80 MILLION KWH OF ELECTRICITY USE OVER 25 YEARS.

Although this district energy solution had a higher first cost for Amazon than more traditional heating solutions that complied with Seattle's strict energy code, the corporation is realizing a number of financial and sustainability benefits over the system's lifecycle. Based on the engineering consultant's cost analysis, it has been estimated that the finished district energy system will avoid approximately 80 million kWh of electricity use over 25 years, providing good value for the corporation.

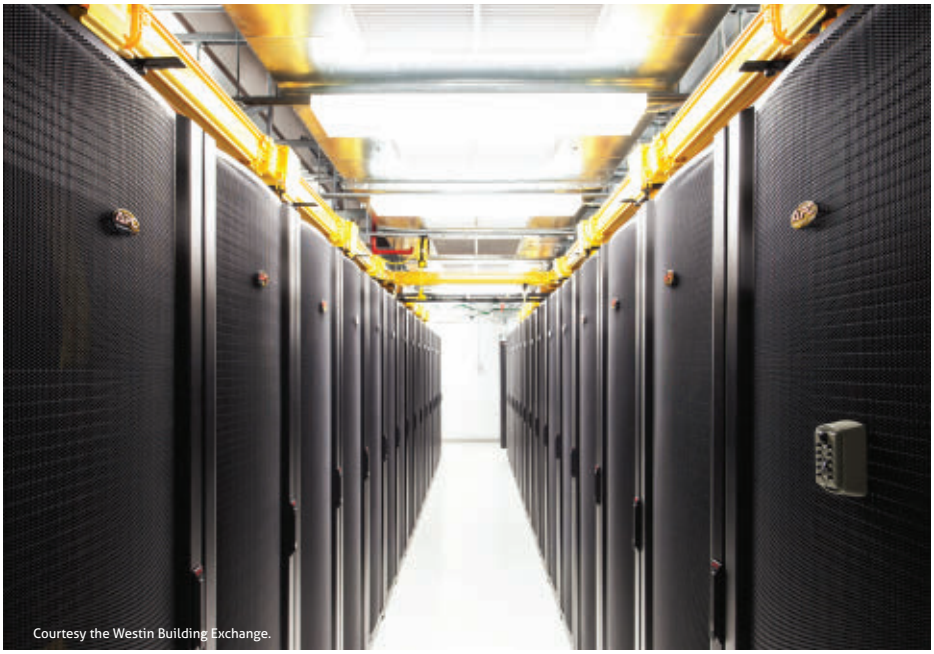
The system is designed to serve the campus as it is built out, eliminating some of the costs associated with maintaining complete central plant equipment and systems in each individual office tower. The district energy solution will also enable the compliance of each building as it was designed and permitted with the successive versions of Seattle's strict energy code (2009, 2012 and 2015) that are or were applicable as the campus is being built out. Moreover, Amazon's heat-sharing district energy system contributes to furthering the company's environmental sustainability initiatives. (These include, for example, sustainable packaging and office design, responsible product sourcing, and aiming to achieve 100 percent renewable energy usage through such projects as hosting rooftop solar installations at fulfillment centers and establishing wind farms.)

Clise Properties also realized financial benefits from the arrangement with Amazon by avoiding some maintenance and operational costs associated with operation of the Westin Building Exchange's rooftop cooling towers, including the costs of water and electricity. As a further benefit, the agreement with Amazon gives Clise Properties access to emergency cooling water should it be needed by the data center building.

MECHANICAL DESIGN AND CONSTRUCTION CHALLENGES

Compared with the business challenges and coordination with other stakeholders, the mechanical engineering design and systems required to harvest and utilize the data center's waste heat for the Denny Triangle campus were relatively straightforward. An existing cooling water loop in the Westin data center building normally rejects the computer-heated water to the cooling towers on the roof. Now, as part of the waste heat recovery project, a heat exchanger has been installed in the Westin basement. A second water loop runs through the data center facility and under the street between this heat exchanger and the central plant in the Doppler building.

In the central plant, the feeder loop is connected to a second heat exchanger, which extracts the low-grade waste heat at approximately 55-65 degrees F; from there, the water is conveyed to heat recovery chillers, which function like heat pumps to raise the temperature of the waste heat water to 130-140 F. This hot water is then distributed in winter



The Westin Building Exchange houses the operations of more than 200 telecommunications and Internet-based companies.

to warm the Amazon campus buildings through hydronic terminal units such as variable air-volume boxes, radiators and radiant floors, and fan coils.

ENSURING SYSTEM RELIABILITY

The district energy system is designed for reliability and the option of heating each building individually, should that be necessary. An existing standby power system in the Westin Building Exchange maintains the operation of the data centers (and generation of waste heat) in the event of an interruption of service from the electrical grid. The critical mission of the data center and its uptime requirements provide an inherently higher reliability for Amazon than is typical for corporate office buildings.

The mechanical system on the Amazon Denny Triangle campus is designed with backup boilers in each office tower to provide auxiliary heating for the coldest days of the year, when the purchased waste heat piped from the data center building is insufficient. Contracting for the base heating load seen by the campus rather than the peaks enabled more cost-effective sizing and utilization of the waste heat recovery system and a better load factor for the Amazon-Eco District transaction. Moreover, the boilers and associated equipment and piping that have been installed in each individual building could provide for independent heating operations in the unlikely event that circumstances lead to a future termination of the heat-sharing agreement.

Because it is unique, the Denny Triangle district energy system is controlled by a custom-designed, fully commissioned building automation system. The controls contractor, ATS Automation; WSP, the consulting engineer; and University Mechanical, the mechanical contractor; worked closely together to ensure that this system meets the needs of the campus district energy network today and in the future.

A TRANSFERABLE TECHNOLOGY

Design and construction of Amazon's Denny Triangle campus continues. The third high-rise office tower, approximately 1.1 million sq ft, was under construction as of spring 2017; and design was in progress on the fourth and fifth buildings, which when complete by 2022 will bring the building space served by the district energy system to over 4.5 million sq ft.

The district energy strategy and technology employed in this project could be leveraged elsewhere in commercial real estate – with appropriate, district-level "outside-the-box" thinking and opportunity seeking. This strategy does not typically present itself because cities are not currently planned and built in a way that easily facilitates it. That said, this strategy has been realized at Amazon's new headquarters in Seattle, providing a model for innovators elsewhere. The realization required vision on the part of each of the stakeholders and, in no small measure, the initiative and continuous coordination efforts of a project champion within the property development firm that serves Amazon.

Although there are challenges in harvesting what is otherwise viewed as waste beyond a project's traditional boundaries, some creativity, applied locally, can bring great results. Success requires the right technical opportunity, the right political climate and a motivated, cooperative group of stakeholders who can make decisions in the context of projects where upfront dollars are precious and schedules are tight.

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