EMPOWERING TRANSFORMATION

Data Centers and Progress for Business and Community Life

A Strategy Report on the Future of Data, Energy & Sustainability

Note to the reader...

Washington, DC was the setting in which Danfoss, in May 2024, convened a group of forty thought leaders in the emerging world of data centers from business, science, advocacy, government, and civil society. Their mission was to explore strategic options in response to the critical services data centers provide and the vital challenges they pose to sustainability and the life of the communities in which they are located. The event was the 2024 Danfoss EnVisioneering Symposium entitled **Sustainable Response: Data Centers**. *It followed a December 2023 workshop with fifteen experts designed to develop the Symposium agenda.*

Data centers are seen to be essential to technological developments that are at the very foundation of tomorrow's prosperity and quality of life. But they had inherent in them significant new risks that, if not understood and addressed, might slow deployment and cause the industry to fall short of optimizing the performance of those that were deployed.

This strategy paper, **Empowering Transformation: Data Centers and Progress for Business and Community Life**, *relies heavily on the outstanding presentations and discussions that the Symposium and its preceding workshop made possible.*

Special thanks to all those who participated in those events for the experience, insight, intelligence, and dedication to the future they brought to the discussion table.

Foreword

Thomas Santucci, Director of IT Modernization
Office of Government-wide Policy
General Services Administration

Danfoss's ***Empowering Transformation*** report contributes meaningfully to the dialogue on critical issues in the Information Age, where technology's reach extends across government, industry, and society. The rise of artificial intelligence will expand these impacts, amplifying both the benefits and challenges of our interconnected world. In this report, Danfoss continues to explore the essential questions that will be pivotal to the success of this transformative venture.

Today, data centers serve as the hubs of global electronic communication networks, acting as the nervous system of the modern world. While the true technical complexity of data centers remains understood by few, the relevance of data centers is increasing, necessitating broader public awareness and understanding of their technological advances and their key role in the digital era.

We need a focused public education on data centers, advocating a two-way learning approach. Experts in fields such as data management, finance, energy, and urban planning are encouraged to exchange insights, fostering collaborative partnerships. Simultaneously, community leaders and the public must become stakeholders in these conversations, with listening as critical as contributing.

The emerging concept of Integrated Systems highlights the importance of optimizing the performance of entire systems rather than focusing solely on individual components. Whether one is looking at a single building, a cluster, or a community, an Integrated Systems view pays attention to the performance of the whole. For instance, repurposing a data center's excess heat to power a community function can enhance overall community energy performance. This is more effective than simply evacuating the heat into the atmosphere and generating additional energy to power the community function.

The conversation surrounding data centers should not be limited to the United States. Our international counterparts share similar challenges, opportunities, and innovations. We can learn from one another, exchanging strategies, technologies, and expertise. Information technology is reshaping the world in profound ways, creating vast opportunities and high stakes. Collaboration and open dialogue are essential as we move forward, challenging long-held assumptions to harness the full potential of this evolving landscape.

The Danfoss report, and the symposium from which it emerged, exemplify this spirit of dialogue and inquiry, offering valuable perspectives to anyone invested in the future of data center best practices. This report marks a step toward innovation and understanding, and I am confident it will inspire further contributions from Danfoss to this critical conversation.

Danfoss' call for a new focus on public education is timely. Experts in data management, finance, electricity systems, building design and construction, community design and many other specialized fields need to share ideas and build strong collaborations.

Executive Summary

Jakob Jul Jensen, Head of Data Center Solutions, Danfoss

Danfoss is pleased to share this report on the challenges and opportunities in creating sustainable data centers. Based on insightful and thought-provoking discussion at our recent EnVisioneering Symposium, this report presents a roadmap on how data centers can reduce their carbon emissions and energy consumption. With our increasing reliance on cloud storage and data processing, and the International Energy Agency's (IEA) projection that data center electricity demand will grow from 460 TWh (terawatt hours) in 2022 to as much as 1000 TWh by 2026, it is imperative that we invest in energy-efficient data center cooling solutions. Data centers and data transmission networks are responsible for 1% of energy-related greenhouse gas emissions. To get on track with the IEA's net zero emissions scenario, emissions must halve by 2030.

The report highlights the dual challenge of leveraging data center technology for economic benefit while addressing the environmental impact. Data centers can become valued energy contributors in their communities, but investment and public education are needed:

- Experts from industry, academia and non-governmental organizations (NGO) can educate communities on data center functions and needs and the technologies available to integrate data centers into community energy systems.
- As part of educating the public, data center experts can create a roadmap of the data center ecosystem, demonstrating its ongoing evolution and innovation, and the economic value data centers can provide.
- Utility leadership is critical in discussions on green power investments, grid upgrades and heat recovery via a district energy system.
- While heat reuse is still in its infancy in the U.S., there are organizations and initiatives that are advancing its adoption, but more education and emphasis on district energy infrastructure and heat capture technologies can help move heat reuse into the mainstream.
- Finally, the development of standards for design and function can educate communities and their leaders on the optimal construction and integration of data centers. Public-private partnerships are key to creating these standards and guiding the conversation.

The Danfoss report calls for a strategic approach to data center design and management, emphasizing the need for sustainability in the digital age. By aligning data operations with environmental goals, businesses and communities can harness the full potential of the digital economy while mitigating its environmental impact. The report serves as a roadmap for civic leaders, community planners, and industry executives to navigate the challenges and opportunities of the evolving data landscape.

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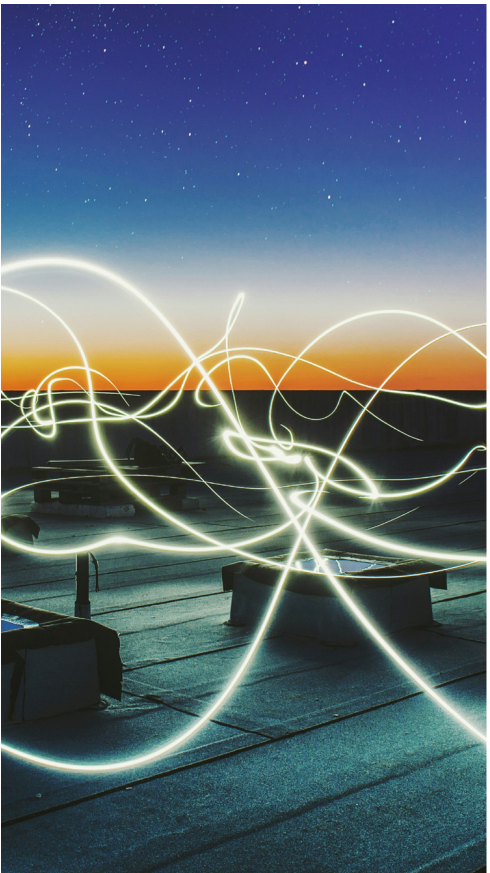
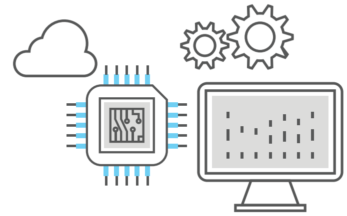




Megatrend: Data and Sustainability

With the emergence of Artificial Intelligence (AI), a fresh wave of data-driven transformation is cresting. The megatrend in data networks and especially *data centers* will play a critical role and offer extraordinary opportunities for business and communities alike. But the electricity required to realize those opportunities fuels another megatrend – growth of global carbon emissions.

The *Enabling Transformation* report is designed as both a portal and a roadmap into a new era. It is being offered to business and community leaders and planners whose insight, agility, and acumen are needed for the historic change ahead.

The future that is about to be written comes atop several decades of deep and rapid change. Today's cell phone far outstrips the computing power that first put human beings into outer space – a result of a *digital revolution*.

Digitization has radiated out from its tightly held origins to become the near universal medium of commerce, governance, and society at large. That shift is one of today's great megatrends. The most dramatic business opportunities, macro and micro, are now rooted in that transformation. AI, with its extraordinary capacity to learn and create, brings the digital megatrend to a new maturity – and intensity.

The *coin of the realm* in the digital era is electronically represented *information – electronic data*. AI builds on that foundation. The nexus of all the dramatic progress now on the horizon is the intersection of information and *electricity*. Progress will now move forward through electronic communications networks, the managing nodes of which are *data centers*, the new and proliferating facilities that leverage energy as the medium of *and* an instrument for managing data.

An important part of the data center story revolves around the challenges of leveraging energy for those purposes. This report focuses especially on resource challenges.

One dimension of that mega-story emerges from the state of America's infrastructure. A decade ago, the discussion was of the grid needing a trillion-dollar investment to keep up with the demand for power. In the interim, pressures to shift to non-carbon-based electricity have steadily grown. The new vision for the grid is one rooted in highly distributed energy sources that are woven together by the strands of a new transmission and distribution system, managed by "smart" electronics and providing wide access to "green" electrical power. It is generally recognized that utilities are facing a substantial gap between that vision and their current reality.

Energy is at the heart of another great drama, as well – the sustainability crisis. The energy that powered technological and industrial progress for the past two centuries and more still comes largely from fossil-based fuels. It is the source of the carbon emissions that drive climate change. The natural resources on which progress currently depends, and the specific opportunities of the emerging data-driven future, are also driving a climatic crisis and broader concerns for overall sustainability.

While reliance on fossil fuels has declined as a percentage of the mix, 60% of the electricity generated in the US in 2023 was still fossil fuel based, according to the U.S. Energy Information Administration. Given the emerging scale of data network infrastructure, the future of data and of climate are inextricably linked. Business and community leaders should take that linkage seriously.

The future must be both *data-based* and *sustainable*. Aligning those two principles is among the most important challenges in today's technological, industrial, and policy agenda. *Enabling Transformation* is an *early alert* briefing on vital challenges and opportunities of the new world of data centers – those critical points of confluence where the data of the digital age is assembled, stored, organized, managed, analyzed, and leveraged for decisions.

This report brings together many of the threads that form the fabric of data center success. It is a guide that will help civic leaders, community planners, private sector executives and others engaged at the local level assess what is known, unknown, required, and possible – perhaps just over the horizon. *Enabling Transformation* taps the expertise of individuals working on the cutting edge of change to illuminate the historically unique path forward, with its many urgent opportunities.

The Challenge: Digitization, Energy and Community Design

Digital technology, especially the evolution of microprocessors, transformed how products and services are delivered. It facilitates near instantaneous communication. Digitization of the economy has created vast efficiency, effectiveness and value. It led a revolution not only in economic operations, but in the quality of life those operations create.

Cloud computing and services, lightning-fast computation, the Internet of Things, radically innovative business models and a wealth of new products are among the most visible impacts that have ratcheted up the overall quality of life. Advancing digitization also made possible the shift to the remote work opportunities now sought by many Americans, according to McKinsey & Co. Everything from quick access to local transportation to overnight availability of a vast array of products from all over the world have become routine facets of everyday life for hundreds of millions of people.

Artificial intelligence is entering that already "wired" world. The potential of AI technology is built on its use of data to empower machines to perform tasks that formerly required humans. Machines that incorporate AI can perceive their environment, learn from experience, problem solve, make judgments and decisions, and create. They simulate human cognitive functions and, with experience, can often surpass human performance. AI is the foundation of a "smart" Internet of Things. It enables a Smart Grid.

Central to AI is its capacity to process vast amounts of data, recognize patterns, and discern and weigh the evidence for judgment. It can learn, adapt, execute, reassess, and act again. Digitization thus raised the value of data by making it available in large volumes more or less instantly.

Major innovations have cascading consequences. Digitization requires data centers that are energy intensive, requiring vast amounts of electricity. They can also require substantial quantities of water. And in both construction and operation, they can have a large carbon footprint. There are also societal impacts.

Data centers first arose in a security intense environment and have significant security requirements – all of which can be problematic for the more relaxed environment and aesthetic of a community. More broadly, their size, location, appearance, and requirements have at times become sources of controversy and polarization.

A recent Goldman Sachs report offers an overview of the electricity challenges attendant to the anticipated growth of data centers. The April 2024 publication summarizes the firm's view of the future:

Driven by AI, broader demand and a deceleration in the pace of energy efficiency gains, global data center power demand is poised to more than double by 2030 after being relatively flat in 2015-20. This growth is the primary catalyst alongside increasing manufacturing/industrial production and broader electrification trends, to an acceleration in US electricity demand CAGR [Compound Annual Growth Rate] to 2.4% through the end of the decade from 0% in the last decade. We believe supporting data center driven load growth will require investment by Utilities of $50 Bn in new power generation capacity. We assume a 60/40 split between gas and renewables…

The International Energy Agency projects data center electricity demand will grow from 460 TWh (terawatt hours) in 2022 to perhaps 1000 TWh as early as 2026. Such projections reflect both growth in the number of data centers and in their energy intensity.

Traditionally, data centers were expected to consume 4 - 6 kW per rack. Today, cloud computing providers and other hyperscale data centers are using 10 - 14 kW. AI-ready racks operate in the 40 - 60 kW range. Overall, the growth of AI is expected to drive demand from 17 GW in 2022 to 35 GW in 2030.

Those numbers can have large consequences for almost any community. Local generation and distribution can easily be pushed beyond capacity by such increases in load. The investment required for sufficient added capacity can likewise be a significant hurdle. And then there is the carbon footprint.

According to a recent study by MIT researcher Steven Gonzalas Monserrate, "the Cloud now has a greater carbon footprint than the airline industry. A single data center can consume the equivalent electricity of 50,000 homes. At 200 TWh annually, data centers collectively devour more energy than some nation-states. Today, the electricity utilized by data centers accounts for 0.3 percent of overall carbon emissions, and if we extend our accounting to include networked devices like laptops, smartphones, and tablets, the total shifts to 2 percent of global carbon emissions."

Understandably, the size of the data center world is growing and will grow rapidly – holding important opportunities for business and communities. According to Synergy Research Group, the capacity of hyperscale data centers alone doubled in the last four years. The number of facilities reached over 1,000 at the end of 2023, and SRG anticipates an additional 120–130 new hyperscale data centers per year for the next decade.

The prospect of a new data center has sometimes generated sharp community backlash. They sometimes are perceived to have a negative impact on local quality of life. The buildings are large and the construction processes protracted and disruptive of community life. Often built as windowless buildings, they can be seen as a bad aesthetic fit. They use large swaths of land, precluding conservation and other community-focused uses, put a strain on infrastructure, and threaten residents with higher local taxes to pay for the added infrastructure required.

A more intangible but not less real source of resistance arises from a broader social anxiety about change being experienced across the developed world. Community governments are sometimes perceived as offering data center macro investors with global presence better deals and more accommodating pathways than are received by smaller local enterprises. And after several decades of dramatic shifts driven by globalization, communities have strong impulses to preserve the preexisting qualities that first attracted residents and have kept them there.

Such trends make it easy to overlook the advantages that data centers can bring to a community. They bring investment and jobs, both directly and indirectly through the economic ecosystem of goods and services required by the people who work at the data centers. They provide the opportunity for the community to manage the data the community creates and to benefit from its monetization – benefits that would otherwise pass to other communities. By enhancing regional prosperity, they can raise the local tax base and ease pressures on tax rates. And since data centers can readily be created in vacant industrial and commercial buildings, they can bring new vitality to faltering regional economies. All of those factors (and more) deserve to be weighed in the data center-community equation.

Still, data centers – growing in size, number, and resource intensity – can easily be seen as large and demanding impacts of a very new future on traditional communities that have been designed and built over years if not generations to meet the needs and interests of the people who live there. The NIMBY impulse can be strong, the future costs are hovering and uncertain, and the environmental impact nearly the opposite of what is being sought by policy makers and citizens.

It should be underscored that every step in the shift to carbon free electricity reduces the carbon footprint of the data world and supports the sustainable growth of data center capacity. With AI set to increase the electricity load of a data center by a multiple of five, however, and carbon-based electricity still the most common, the climate consequence of data centers will ratchet up dramatically.

One AI application more than illustrates the trend. Kevin Okemwa reported recently on Windows Central that recent "research highlights that ChatGPT uses 17 thousand times more electricity than an average US household consumes…" Moreover, "the data scientist behind the study states that the AI sector might consume between 85 and 134 TWh annually by 2027, translating to half a percent of global electricity consumption."

The Mission: Align Data and Sustainability

In today's rapidly advancing world, aligning data management with environmental sustainability is not just a choice; it is a necessity. That necessity sets a central mission for industry, governance and science. So it is important to understand the reasons why alignment is crucial. Here are four – leading samples of a larger collection.

1. **Urgency and Importance:** Aligning data centers with sustainability isn't just another task on the to-do list—it's a top-tier priority. Our resilience, continuity, and overall quality of life depend on it. Data centers are as crucial to our era as factories were to the Industrial Age, driving prosperity. However, this prosperity will be short-lived and eclipsed by its unintended consequences without sustainability. Aligning data operations with eco-friendly practices is non-negotiable.

2. **Defining Modern Data Centers:** Today's data centers are more than just server farms. Major manufacturing facilities, hospitals, air traffic control centers, and other large infrastructures generate and rely heavily on vast amounts of data. These facilities need seamless control and access to their data. Hence, our approach to data centers must be comprehensive, considering data generation, usage, transmission, and storage across all sectors of our complex economy.

3. **Urban Integration:** Integrating data infrastructure into urban planning is now essential. Just as urban design has historically incorporated energy, water, and transportation networks to serve factories, hospitals, and residences, it must now include data infrastructure. Communities must view their design through the lens of total data requirements, ensuring they can support not only local needs but also provide data services beyond their borders. In that context it is useful to note that low carbon energy can support growth in the volume of data coupled with a declining carbon footprint – so the centrality of green energy to the future of community design is only reinforced by the growing reliance on data.

4. **Embracing Change:** The science and technology behind data management are constantly evolving. This means our approach to aligning data centers with sustainability must be adaptable. Data centers require significant investments, and their ecosystems must be flexible enough to evolve with technological advancements. They should be designed, built, managed, and upgraded or retired with this continuous evolution in mind.

In summary, the future of data centers lies in their seamless integration with sustainable practices across important features of community design. By prioritizing this alignment, redefining what data centers encompass, integrating them into urban planning, and embracing their dynamic nature – and *only* by doing so – we can ensure that data centers are enabled to drive prosperity in an environmentally sustainable and enduring way.

Specific pathways to alignment:

> ***Holistic Vision***
>
> ***Designing for Energy Efficiency, Heat and Community Integration***
>
> ***Retrofits***

Holistic Vision: The overarching idea of data centers needs to comprehend changes in data sources and management requirements, evolving community needs, the dramatic changes in the world of data anticipated from AI, and developments in the technologies, design, and use of community infrastructure.

The vision will need to encompass multiple dimensions of the public and private sector ecosystem within which data centers operate:

- Financial models
- Green energy
- Building renovation and retrofit
- Policy and regulation– local, national and international.
- Effective security

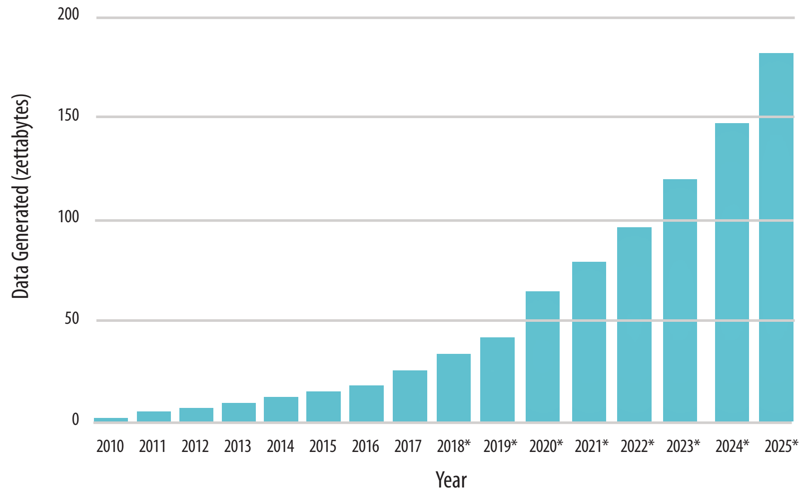
Designing for Energy Efficiency and Heat: The capacity of microprocessing chips is growing exponentially, with reports of expanding new boundaries appearing regularly in the press.

Insiders suggest that no ceiling is in sight. The volume of data being created, transmitted, stored, processed and analyzed is growing at a parallel pace. AI will more than redouble that growth, and technology will need to be responsive – not in decades, but in years and even months.

Global Data Generated Annually

Source: Exploding Topics, Amount of Data Created Daily (2024) by Fabio Duarte, June 13, 2

The grid load created by data centers, and their impact on greenhouse gas emissions, will be influenced by such variables as buildings' structures and hardware, their inherent electricity requirements, methods of cooling, and modes of locating and connectivity, including connectivity to their surrounding communities.



Excess heat and the need for cooling will be especially important to the design of future data centers and their electricity requirements. Data centers generate substantial heat, which degrades the hardware, so cooling is essential.

Consequently, in addition to the energy intensity of data center buildings and their hardware, cooling practices play a major role in data center electricity consumption. According to Dataspan, cooling now accounts for about 40% of total data center electricity consumption. And while some emerging technologies may offer equipment with greater heat resilience or lower electricity consumption, heat is widely expected to remain a major challenge for data center equipment.

See more about Energy Used in Several Cooling Methods by clicking here. (https://datacenters.microsoft.com/wp-content/uploads/2023/05/Azure_Modern-Datacenter-Cooling_Infographic.pdf)

There are three basic principles of data center design:

• Energy Efficiency

A full menu of criteria has emerged at the intersection of data center buildings and operational impact. Overlaps with design issues are present. But the defining feature is the concrete functionality of the buildings in which data centers are housed. So, it is not simply a design concern, but how the building, once designed and delivered, is managed – and how the design structures and operational practices empower that management for impact.

As Goldman Sachs analysts have observed, energy efficiency gains have been plateauing, due in part to the technologies and strategies employed to achieve early efficiency targets.

High performance building envelopes generally have not been prioritized in data centers. Data center managers have *wanted* the heat to escape. Mechanical system improvements in commercial buildings have tended to max out because of a combination of equipment complexity, costs at ascending levels of efficiency, and the limits of the technology itself. Finally, the need for cooling the equipment in data centers puts energy efficiency comparatively on the back burner.

Energy efficiency takes on a new significance, however, if it follows a broader integration of the data center into the community. And that integration brings into view energy sourcing and the grid, community energy systems, and building retrofit.

• Leveraging Excess Heat Through Community Integration

Data centers ratchet up the need for local power generation and distribution. As a result, it is becoming increasingly common for communities hosting these data centers to require that new facilities provide their own electrical power sources and microgrids.

Possible sources – either already being deployed or seriously discussed – range from micro nuclear power plants to solar farms, wind farms and other available sources of green electricity. Innovations in heat pumps are now raising the prospect that excess heat can be upgraded and recycled as electricity for the data center itself. Smart grid capabilities are available to help ensure supply and microgrid reliability.

Excess heat, however, offers other ways for data centers to integrate with communities to achieve substantially better energy efficiency at a holistic level, embracing both the data center and the community. The critical question is whether that heat – which is typically evacuated into the atmosphere – can be put to some productive use. The concepts for such a pathway to holistic, community scale energy efficiency, and thereby reduced overall GHG emissions, are *waste heat capture* and *district energy systems*.

Communities need heat for building spaces and water, and they need cooling. The excess heat of data centers can help meet those needs. By either building new district scale energy distribution systems or tapping into existing district systems, excess heat can be used to heat air, heat water (for direct use or to later heat air), or through thermal technologies, to cool air and (if needed) water. With heat pump innovations, the excess heat of data centers can be used to provide electricity to communities through district systems (i.e., microgrids), as well. Such innovations can put the relationship between data centers and communities on a new and more collaborative footing. Evacuating excess heat directly into the atmosphere, or perhaps through a body of water or other liquid and into the atmosphere, means the energy is essentially wasted. But through heat capture technologies and district energy systems, the energy in the heat can be harnessed to benefit the community.

Heat reuse can indirectly reduce the community's carbon footprint: whatever is done with excess heat requires no new power generation – hence no new GHGs. By putting wasted energy to a new use, waste heat capture and district energy systems can create a new data center community equation.

The potential of heat capture and district energy systems is ultimately even broader than simply energy source substitution. The climate crisis is driving a movement toward green energy. Green electricity is typically from sources that are widely distributed – for example, wind and solar. Such electricity needs to be transmitted and distributed with great coordination. To do so will involve a massive investment in a new kind of grid with substantial information, communications, and AI capacities.

The requirements of widely used green energy include district systems into which excess heat, including the excess heat of data centers, can be – and needs to be – integrated whenever possible. Providing sufficient green electricity to meet current and growing electricity demand is an immense challenge. By substituting waste heat for wind, solar, and other sources of green power, waste heat capture and district energy systems can play a vital role in making green grids practical and viable for communities seeking to cut or eliminate carbon emissions from electrical power use.

• Retrofit Existing Building Stock for Sustainability

The pace of technological and practical evolution in data management, buildings and energy systems brings to the fore an additional operational challenge: retrofits. Rapid change means that deployed technologies will become obsolete. The rate of obsolescence in data centers is striking, with servers being replaced at least every five years. And that pace will quicken with the diffusion of AI.

Waste Heat Capture Technology: A Case Study

Liquid Cooling and Heat Reuse

Liquid cooling in data centers represents a significant opportunity for sustainability and energy reuse. Unlike traditional air cooling, which disperses heat into the atmosphere, liquid cooling captures heat more effectively, creating elevated temperatures that can be repurposed for various applications. This process not only enhances cooling efficiency but also opens up new avenues for energy conservation and community support.

Liquid cooling systems use water or specialized coolants to absorb and transfer heat more efficiently than air. This results in higher outlet temperatures, which are ideal for heat recovery and reuse. However, while liquid cooling can generate heat in the range of 30-60°C (86-140°F), this is often lower than the 70-100°C (158-212°F) required by traditional district heating systems. Despite the lower temperatures, there are still numerous ways to effectively utilize this heat.

Modern district heating systems, engineered to operate at lower temperatures (around 40-70°C), can effectively harness the heat produced by liquid cooling systems. To extend this utility to traditional district heating networks, heat pumps can be utilized to raise the temperature of the waste heat to the required levels. Additionally, the lower-grade heat can be directly applied in buildings for underfloor heating or preheating domestic hot water. This can be achieved through a heat recovery unit that exchanges heat between the domestic water and the return water from the liquid cooling system, maximizing energy efficiency and reducing overall heating costs.

Beyond residential use, the elevated temperatures produced by liquid cooling can be harnessed in industrial processes that require specific heat levels, such as pasteurization, drying, or chemical processing. By utilizing this heat, industries can reduce their reliance on external energy sources, which in turn lowers operational costs and emissions.

Moreover, data centers located near renewable energy sources like geothermal or solar thermal plants can integrate the waste heat from liquid cooling into these systems. For example, this heat can be used to preheat water for geothermal plants, improving their efficiency, or it can be stored for later use in solar thermal applications.

The heat generated by data centers through liquid cooling offers valuable opportunities for community collaboration and support. In colder climates, this waste heat can be channeled to nearby residential and commercial buildings, providing district heating that reduces the need for fossil fuels and lowers heating costs. In agriculture, the waste heat can be used to heat greenhouses, extending growing seasons, increasing crop yields, and improving food security. Public amenities, such as swimming pools and recreational centers, can also benefit from partnerships between data centers and local municipalities, where free or low-cost heating can reduce operational costs and strengthen community ties.

While the potential benefits are substantial, several challenges must be addressed. Significant investment is required for the infrastructure needed to transport and utilize the heat, such as pipelines for district heating or retrofitting industrial processes. Additionally, depending on the region, there may be regulatory or legal barriers that must be navigated to implement heat reuse projects. Finally, efficiency losses can occur when transferring heat over distances, which must be accounted for during project planning.

Liquid cooling in data centers offers a powerful tool for sustainability and community engagement. By capturing and repurposing the waste heat, data centers can significantly reduce their environmental impact while providing tangible benefits to surrounding communities and industries. This approach not only supports decarbonization efforts but also fosters stronger ties between data centers and the communities they serve, creating a more sustainable and resilient future"

Conclusion: A Call to Action

The importance of data for decision making, communication, and implementation all point to the need for a systematic approach to data centers. They will be central to economic operations, social discourse, and overall progress. They will also be a major challenge to sustainability, which is now seen as an existential issue. Data centers are as vital to national infrastructure as electricity grids, transportation methods, water management and telecommunications. A strategic approach is warranted.

Five targets for action stand out:

1. **Public education:** It is now critical to provide communities and their leaders with a roadmap of the emerging world of data, the opportunities and risks it involves, and the strategies and technologies at their disposal. The effort should combine outreach with online educational initiatives, collaborations with industry, academia, NGOs and multiple sources of in-the-field insight.

2. **Mapping the Technological and Economic Ecosystems of Data Centers:** While it is not widely understood, the world of data and data centers is well defined, rapidly innovating, and brimming with economic opportunities. A first step in public education of communities and their leaders is to create a readily understandable roadmap of what, until now, has been a comparatively esoteric world.

3. **Leadership By Utilities:** Data centers require vast amounts of electricity along with energy efficiency – in their buildings, their technology, and their community integration. Today's utilities are the entity best positioned to inform and integrate the needs of multiple communities and suppliers of critical resources. Utilities are needed at the table on such issues as green power investment, distributed energy and grid coordination.

4. **Heat Capture and Reuse Deployment:** Waste heat from data centers is a large and rapidly growing resource. But recent energy practices have not emphasized district energy system opportunities and heat capture innovations are new and not widely known. Education and finance need to bring data center heat capture and reuse into the American mainstream.

5. **Professionally Informed Standards:** The public sphere – specifically, publicly owned or operated buildings – are ripe to provide proof-of-concept illustrations of what is possible and optimal. Private-public partnerships to articulate such lessons in the form of prototype standards will make an invaluable contribution.

The world is on the cusp of an era of deep innovation and dramatic social and economic impact. Data centers will be the critical crossroads of all the forces driving that veritable revolution in technology, prosperity and quality of life. Technology and practice are evolving rapidly. But the data center industry is still new enough for community and business leaders to shape its trajectory. Now is the moment for action.

Appendix

1. With heat pump innovations, the excess heat of centers can be used to provide electricity to communities through district systems (i.e., microgrids), as well.
2. There are several organizations and initiatives in the US that support data center heat reuse from which much can be learned:
   - Amazon - maintains an innovative heat reuse system at its Seattle headquarters. This system captures excess heat from the Westin Building Exchange data center. Instead of venting heat into the atmosphere, the Westin Building pipes heat to a central plant in Amazon's Doppler tower.
   - IDEA/International District Energy Association - The organization promotes district energy systems that can integrate data center heat reuse to achieve larger-scale waste heat utilization.
   - Deep Green - A renewable energy company that has invested significantly in data center heat reuse technology.
   - Washington States Industrial Symbiosis Program - The program offers grants for research and development projects, including those focused on data center heat reuse.

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