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AI-Driven Data Centers: Revolutionizing Decarbonization Strategies

White Paper 106

Version 1

Energy Management Research Center

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Executive summary

Data centers that once operated in the background are well known by almost everyone thanks to recent Artificial Intelligence hype. There has been a wave of new scrutiny of data center energy use and carbon emissions. However, forecasts showing future sustainability of the sector and active participation in carbon footprint reduction from the economy present optimistic perspectives. Carbon footprint reduction in every sector of the economy requires data centers. Electrification and digitization enabled by data centers will drive decarbonization, which will improve quality of life and boost technology development. By relying on renewable power sources, innovative power, and cooling technologies, data centers will continue to reduce their own emissions while mitigating major emissions from other sectors and leveraging Artificial Intelligence.

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Introduction

Mitigating global warming and reducing carbon emissions are important goals for industries. IT and advanced software housed in data centers play a critical role in decarbonization in nearly every sector of the economy. The continuously evolving capacity for computational power in centralized or edge data centers can be used to analyze emissions and make tailored recommendations, ultimately leading to carbon footprint reductions. Automating energy-intensive processes in the manufacturing industry, whether it is to improve overall efficiency or coordinate logistics and supply chains to reduce emissions from transportation, is available thanks to implementation of algorithms of Artificial Intelligence (AI) hosted in data centers. Also, the evolution of chips and other components of IT infrastructure enables more FLOPS (floating-point operations per second) for more powerful and effective AI algorithms for process improvements and efficiencies.

Electrification

Substituting technologies based on fossil fuels with solutions powered by electricity. Key benefits of electrification are higher process efficiency, reduction of greenhouse gas emissions, and straightforward digitalization.

Examples of electrification:

- replacing combustion engine vehicles with electric vehicles,
- replacing oil heaters with heat pumps in residential sector,
- introducing induction furnaces for industrial processes as an alternative to blast furnaces.

The data center sector is increasingly gaining energy efficiency, and this trend is likely to continue. Strategic deployment of colocation data centers and the building of an optimal network of nodes can solve data transfer and latency issues. Making the IT infrastructure accessible and reliable improves efficiency in other sectors of the economy that use data centers. They can work on low carbon energy sources while providing broader access to predictive analytics and repair automation to streamline maintenance and services with reduced emissions. Skeptics of data centers list key challenges like emissions from energy sources and inefficient cooling along the acoustic and hardware waste or negative impact on biodiversity.[1] Data centers are rapidly evolving, and these accusations are countered with self-driven or regulation-induced developments that have already guided performance towards a zero-carbon scenario. The fast growth of data centers as a response to digital transformation and an initially limited number of regulations in the sector caused server utilization rates far under capacity.[2]

Many groundbreaking technologies were not accepted by society at an early stage of their implementation. Data centers may share a similar history. Many people initially feared electricity, accusing it of being dangerous. Technology evolution and innovations, like developing a method to generate alternating current or moving high voltage wires in cities from overhead to underground, have increased safety and resiliency of electricity. Data centers are at pivotal point, proving their significance in advancing human civilization.

Even though many factors are involved in estimations, scenarios can change dramatically before 2050 and leveraging computational power to help solve some of the world's most urgent environmental challenges will remain important. It requires the presence of data centers in much greater number than today's count. This perspective is part of a series addressing data center-driven decarbonization of top polluters in today's business.

Data centers for sustainability

Greenhouse gasses (GHG) emissions must be reduced by 50% by 2030 and zeroed by 2050.[3] Electrification is the foundational solution for many applications because it enables assets to be directly powered by renewable resources, leaving a greatly reduced carbon footprint in the future. However, this decarbonization requires digitization of industries, processes, and applications.

[1] Network King, Five areas of environmental impact in data centers (2022)

[2] IBM, Are Your Data Centers Keeping You from Sustainability? (2022)

[3] Berkley Lab, A 50% Reduction in Emissions by 2030 Can be Achieved (2022)

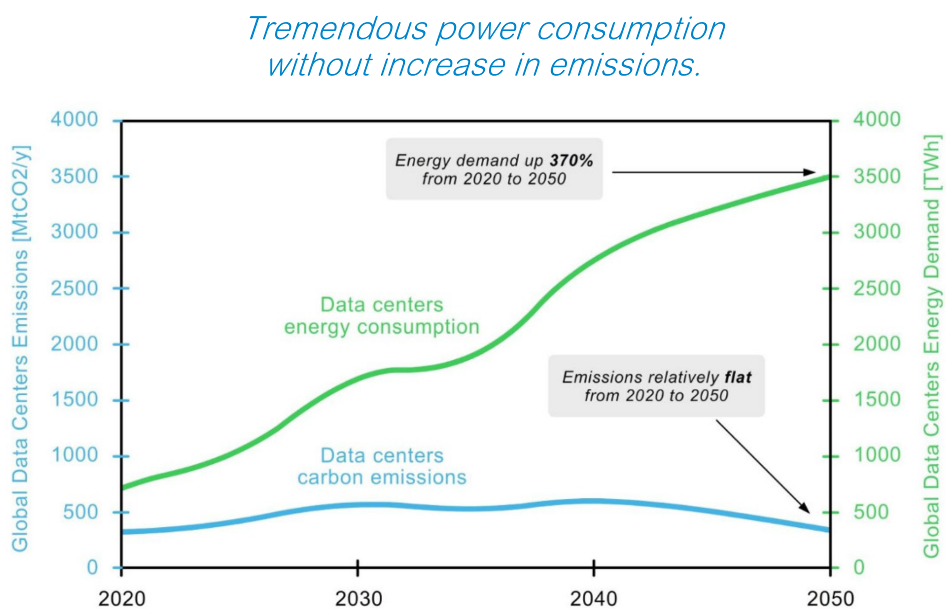
Forecast of data centers in the modern economy

The enablement effect of the IT sector on emissions will facilitate carbon footprint reduction of the highest emitting industries.[4] Reduction is amplified by the digitization of transport, industry, and buildings, and a new generation of consumers potentially making more sustainable choices. Dedicated technology developments like AI, digital twin, hybrid cloud, and wider introduction of 5G network opening possibility more sophisticated operations will secure the current trend in data center evolution.[5] Secure and complex blockchain operations, software development and operations (DevOps) activities, and computing processing of power-heavy AI algorithms require sufficient computational power and fast, reliable data transfer.

Evolution of the IT sector and data centers may follow a range of optimistic or pessimistic scenarios. As expected, the pessimistic view predicts an overall energy consumption increase across economic sectors, driven by changing consumer behaviors and the growth of increasingly digital business models.[6] The Jevons Paradox[7] indicates this activity increases carbon footprint given a pessimistic view; where an increase in data centers and a concomitant increase in their energy requirements improve the economy but damage the environment. Yet, this is becoming increasingly unlikely, as data centers are doing the work to improve their operational efficiencies and energy mix.[4]

Figure 1

Forecast of data center power consumption and emissions. (Schneider Electric estimates)



Scenarios where data centers show a positive environmental impact are becoming more likely - given these same efficiencies. When sectors employ AI to understand, manage and reduce their carbon footprint from operations, the efficiency gain is higher than expected in many cases. As sectors pursue and create AI-enabled solutions through their data centers, they support cross the portfolio optimizations -

[4] This is described in detail in a series of Schneider Electric White Papers on decarbonizing: power sector (White Paper 180), manufacturing (White Paper 167), transportation (White Paper 168), buildings (White Paper 169).

[5] Uptime Institute, Five Data Center Predictions for 2023 (2022)

[6] Universität Munster, The Center of Interdisciplinary Sustainability Research (2023)

[7] Patterns, The real climate and transformative impact of ICT: A critique of estimates, trends, and regulations (2021)

where environmental impacts are reduced twice over. Once in the data center and again on deployment in industry. These approaches support the upside scenario - where data centers deliver a more efficiency in the organization and in its energy mix.

Electricity 4.0

Combination of electricity potential, a superior to fossil fuels power source, and digital tools allowing smart management of infrastructure.

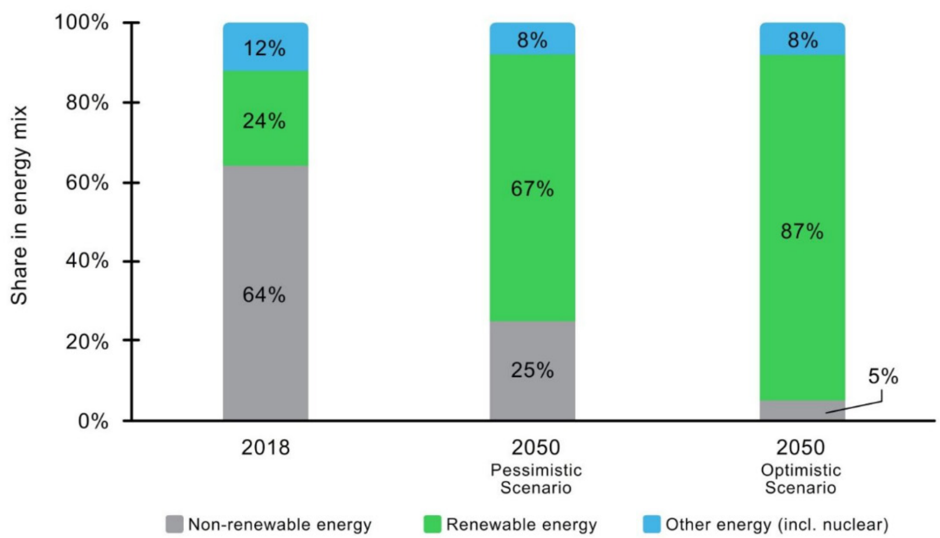
Electricity is proven to be up to 5x more efficient than other energy sources thanks to fewer losses along the supply network. Electricity is also the best vector for decarbonization that opens the possibility to form a network of devices connected to Internet. AI-aided smart management of supply and demand provides process efficiency and relieves main power grid.

Global data continues to rise driven by AI and digital lifestyles. Large amount of information will be transferred to and processed in data centers, which will have to continue growing in number and capacity. Skepticism on the negative impact of that development on the environment can be mediated with information in Figure 1. Our projection referring to data center sector, from smallest local edge to large enterprise data centers, is based on different scenarios forecasting low emissions intensity from electricity production in 2050 (Electricity 4.0), close to 0.1 kg CO2/kWh.[8,9] Centralized and edge data centers produce around 330 MtCO2/year,[10] but even with continuous build-out, we project that carbon emissions will track around that number for the next 30 years due to efficiency improvements and ramping up of renewable electricity supply (see Figure 2). A slight disruption of data center emissions and power demand curves is caused by a similar trend in data processed forecast, between 2020 and 2030.[11] Increased computing intensity thanks to power and computation-intensive training of AI algorithms causes a single, short-term impact.

Adding to global decarbonization will be a shift to renewable power sources.

Figure 2

Change of energy sources to renewables – optimistic and pessimistic scenarios.
Schneider Electric, Back to 2050 (2021)



Experts estimate that data processing, storage, and transmission use 1% of global electricity.[10] This share has hardly changed since 2010, even though the number of internet users has doubled, and global internet traffic has increased 15-fold, according to the International Energy Agency.[12] Unchanged emissions from data centers and growth of the IT sector with rapid increase of processed data in the coming decades in fact decreases the unitary net carbon footprint of data centers. Required for cloud, enterprise, telecom, and emerging technologies, data centers

[8] Nature Communications, A global comparison of building decarbonization scenarios by 2050 towards 1.5–2 °C targets (2022)

[9] Ener data, CO2 intensity of electricity generation (2023)

[10] IEA, Data Centres and Data Transmission Networks (2023)

[11] Schneider Electric, Tradeoff Tool: Data Center & Edge Global Energy Forecast

[12] IEA, Data centers and energy – from global headlines to local headaches? (2019)

need another level of reliability, quality, and physical infrastructure design to reach climate change objectives. Lowering overall consumption of energy is a challenge for data center operators. This requirement exists along with lower carbon intensity of the infrastructure.

Components of AI, including the recent rise of generative AI, impact not only data center energy use, but also the related pathway of infrastructure development. New AI-related trends drive new paradigm of the data center evolution concerning AI training and AI implementation. This process is described in greater detail in Schneider Electric White Paper 110, "*The AI Disruption: Challenges and Guidance for Data Center Design*".

The IT sector is tightly bonded with production and other energy-intensive branches of the economy. Solutions tailored for sector-specific problems often show the unprecedented position that data centers have in modern economy.

Data centers support decarbonization of the economy

Decarbonization of economy will most likely be an outcome of assets electrification and digitalization.

Important aspects that need to be addressed in a discussion on the effect of data centers on sustainability are the biggest polluters with their key challenges and top drivers for economy decarbonization. The biggest polluter is the energy sector, with 15.8GtGHG emissions in 2022, followed by transport (8.4GtGHG) and manufacturing (6.3GtGHG).[13] Decarbonization must start with electrification of processes and operations to improve energy efficiency and logistics, focusing on the sector-dedicated regulatory environment. A green future will come with digitalization and a wider application of AI utilizing sensors within Internet of Things (IoT) along fast data transfers. Only electrification will allow reaching decarbonization targets and follow the optimistic scenario of sustainable economy. It is inevitable that decarbonization requires digitization, and this will not happen without broad implementation of data centers.

Decarbonization begins with a dramatic shift from fossil fuels power sources to electricity by 2050.

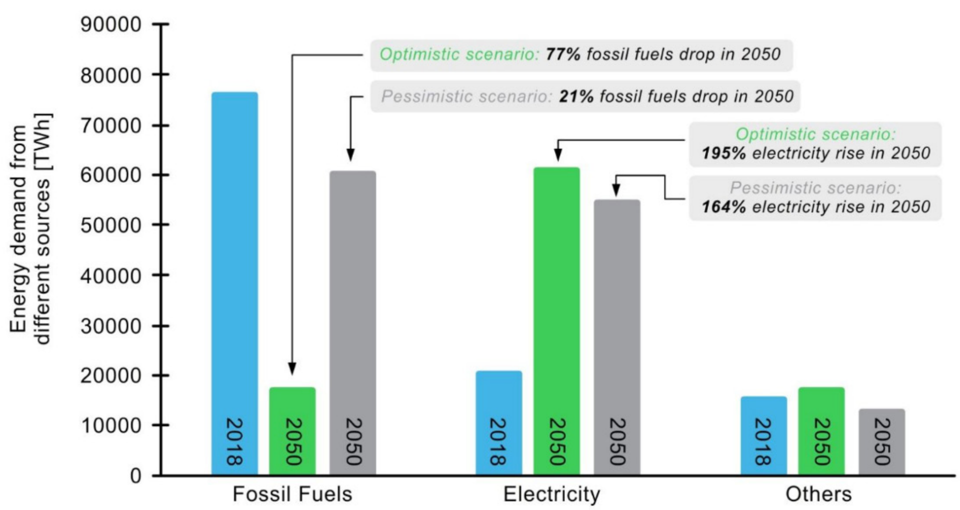


Figure 3

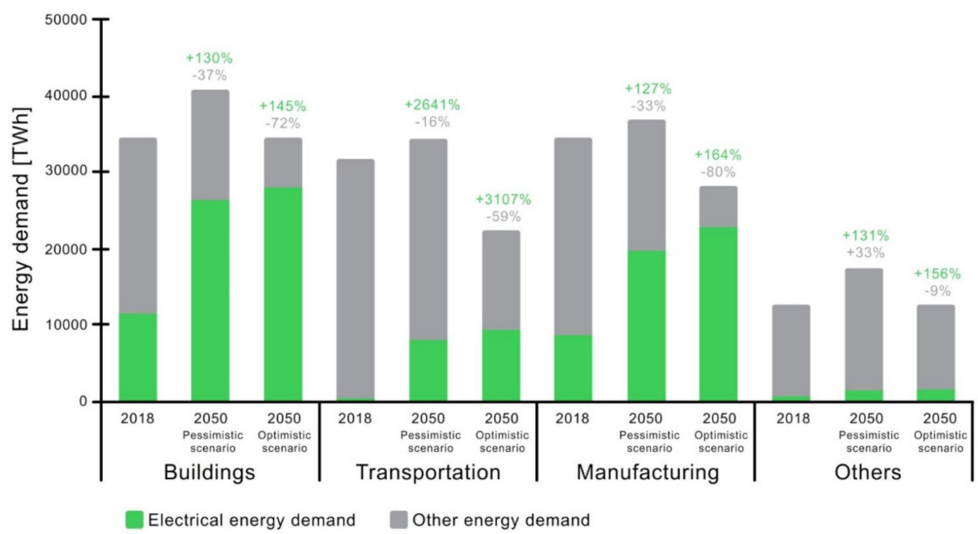
Change of global energy sources – optimistic and pessimistic scenarios. Schneider Electric, Back to 2050 (2021)

We predict a 28Gt reduction of global GHG emissions from all industries by 2050. The role that data centers play in decarbonization is fundamental to meet the optimistic scenario. Even with a skeptical and conservative estimate that 10% of decarbonization is dependent on data centers, the benefit is 2800Mt removed from economy for 367Mt emitted. An optimistic estimate of 30% shows a benefit of 8400Mt for 367Mt emitted. Data centers compose negligible share of total global emissions, and this value is predicted to remain nearly unchanged in the coming decades. The expected growth of electricity use in most sectors thanks to transformation of energy generation and distribution (see Figure 3, Figure 4) require implementation of technologies hosted in data centers.[13] Emissions are not aligned with energy demand Industry growth, enabled by AI algorithms housed in data centers, will cause larger participation in total emissions when following pessimistic scenario. Analogous situation is expected for buildings and transport, where digital technologies housed in data centers participate in reducing carbon footprint, allowing to cumulatively reduce 84% global emissions in 2050.

As we see buildings, transportation, and industrial application electrify, the optimistic scenario forecasts reduction in power demands.

Figure 4

Change in energy demand for different industries – optimistic and pessimistic scenarios.
Schneider Electric, [Back to 2050](#) (2021)



Artificial Intelligence for sustainability

From machine learning representing narrow AI (ANI) to the so-far-unreachable machine consciousness strong AI (ASI), Artificial Intelligence has opened new possibilities in various areas. Deep learning extracting and clarifying components of data is used to decarbonize the energy grid in NAM,[14] robotics impersonating human actions participate in decarbonizing cities in Asia[15] and in oceans,[16] while random forest algorithms using decision trees provide energy stability in developing countries and help with electrical vehicles charging load predictions.[17] Simple machine

[13] Schneider Electric, Back to 2050 (2021)

[14] Energies, A Deep Learning Approach for Exploring the Design Space for the Decarbonization of the Canadian Electricity System (2023)

[15] Journal of Environmental Management, Towards low-carbon development: The role of industrial robots in decarbonization in Chinese cities (2023)

[16] Marne Pollution Bulletin, Ocean oil spill detection from SAR images based on multi-channel deep learning semantic segmentation (2023)

[17] Energies, The Application of Improved Random Forest Algorithm on the Prediction of Electric Vehicle Charging Load (2018)

learning provides technology to reduce emissions from the energy grid[18] and from the shipping industry.[19] Expert systems imitating human decisions improve operations in Japan's steel industry.[20] Fuzzy logic validating decisions aid decarbonization of urban areas in Europe[21] and support assessment of corporate sustainability in the manufacturing sector.[22] These are all branches of AI already heavily used in the sustainability journey. It is only the beginning. As more businesses join, more impact will be reported, providing more sustainable data centers are available to handle necessary tasks.

Cloud to edge computing enable the use of sophisticated tools supporting carbon footprint reduction in every area of human activity, i.e., transport, industry, or power generation. Independently, if based on a centralized network and large data centers, or on a distributed network of edge nodes like cars, smartphones, or smart home devices, AI plays a key role in driving individual users' actions towards a net-zero emissions goal.

The evolution of power sources and distribution will not happen without the presence of the IT sector. Electrification without digitalization supporting power management and data control is unrealistic. Considering large units as well as local edge data centers, AI algorithms need a reliable and secure infrastructure. Edge AI, an alternative to on-premises AI and cloud AI, is expected to play a vital role in economy transformation with real-time analyses of data from localized sensors. Gartner claims that by 2025, as much as 75% of data will be generated outside of centralized facilities.[23] Cloud AI offers scalability and carries a potential to process copious amounts of data required for model accuracy. Some bespoke benefits from using edge AI include reduced cost and improved performance of business activities, real-time analytics, easier or enabled product servitization, facilitated IT/OT integration, and improvement of machine learning algorithms. Security risk and the inaccuracy of some models along with limited processing power and heterogeneous characteristics of edge environments still need to be resolved before broader adoption of the edge AI technology.

Recently observed growth of AI models generally leads towards a clear goal – induction of behavioral evolution, making Green AI a new standard. Algorithms that are environmentally friendly will solve problems with necessary access to large amounts of data. This can be challenging because codes are not yet optimized in embedded systems or constrained by limited resources.[24]

Green AI can be achieved with several scenarios. Strategic selection of data center location, where machine training takes place, may have a strong impact on the overall carbon footprint of the project. This strategy will benefit mostly time- and latency-insensitive, large workloads. Solution for simpler algorithms is in reduction of

[18] Sustainability, Machine Learning Techniques for Decarbonizing and Managing Renewable Energy Grids (2022)

[19] Procedia Computer Science, A Comparative Research of Machine Learning Impact to Future of Maritime Transportation (2019)

[20] IFAC Proceedings, A Hybrid Expert System Combined with a Mathematical Model for BOF Process Control (1992)

[21] Energy Conversion and Management, A new fuzzy model of multi-criteria decision support based on Bayesian networks for the urban areas' decarbonization planning (2022)

[22] Sustainability, A Fuzzy Logic-Based Tool for the Assessment of Corporate Sustainability: A Case Study in the Food Machinery Industry (2017)

[23] Gartner, Innovation Insight for Edge AI (2022)

[24] PACIS 2023 Proceedings, Organizational Adoption of Green Artificial Intelligence: An Institutional Perspective (2023)

the amount of machine learning models through quantization and knowledge distillation, or in using models partitioned into discrete regions with fewer features.

Conclusion

Data centers are cornerstones of digital economy. By improving efficiency and sustainability parameters, data centers become a low GHG emitting solution to reduce carbon footprint in top polluting sectors of human activity like transportation, manufacturing, and power generation. Predicted further evolution of data centers will result with a more efficient ratio between energy demand and emissions, providing green computational power instrumental for decarbonization. Adaptation of smart algorithms forecasted to decrease global carbon footprint by orders of magnitude require data centers in AI training and inference. The most advantageous impact is realized when optimization occurs across different electrified industries, making AI an essential component that helps to address the complexity of this process. There is no chance to follow the optimistic scenario reaching desired levels of sustainability and ecology in human activity without broader implementation of data centers.

About the authors

Marcin Wegrzyn is Research Analyst for the Data Center Research Center at Schneider Electric. He publishes in areas of Data Centers, and Commercial and Residential Buildings. He holds Master of Polymer Technology degree, PhD in Industrial Engineering and Production and MBA. Marcin has over 10 years R&D research experience in academia and industry.

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Results-oriented, Steven transforms ideas into products, solutions and systems. His areas of focus include innovation, AI, hydrogen, sustainability, 5G and 6G, cloud and edge computing, DCIM, BMS, and EDMS.

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