Toward 24/7 Carbon-Free Energy: Innovations, Challenges, and the Path to Fully Decarbonized Grids

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Introduction

Transitioning to a completely decarbonized energy grid is critical in the global effort to combat climate change. The concept of 24/7 carbon-free energy is emerging as a pivotal strategy in achieving this goal (Finon, 2013)
. This approach involves matching every kilowatt-hour (kWh) of electricity consumed with an equivalent amount of zero-emission energy generation on an hourly basis (Kopsakangas-Savolainen et al., 2014)
. This concept is gaining traction with energy buyers such as corporations and governments. By committing to 24/7 carbon-free energy, these energy buyers aim to reduce reliance on fossil fuels and mitigate the challenges associated with fluctuations in energy demand while also driving the grid to Net-Zero (Audoly et al., 2014)
. There has been research from premier institutes such as Princeton University and McKinsey and Company that highlights the decarbonization potential of hourly matching to deploy advance renewable energy systems for both buyers and the energy grid. This concept has, so far, been able to draw the attention of major corporations and governmental bodies who have pledged to join the 24/7 Carbon-Free Energy Compact (24/7 Carbon-Free Energy Compact, n.d.)
. This compact aims to reshape the energy purchasing practices across various sectors. The adoption of this approach presents significant opportunities for decarbonization, however, it also introduces a lot of complexities to the energy purchasing landscape. This paper aims to understand the motivations behind growing commitment to 24/7 carbon-free energy, the challenges faced in its implementations, and the pathways available for energy buyers to navigate this consequential shift towards fully decarbonized grids.

What is 24/7 Carbon-free Energy?

Carbon-Free Energy refers to the generation of electricity that does not result in direct carbon dioxide emissions. The concept of 24/7 Carbon-Free Energy represents an innovative strategy aimed at accelerating the decarbonization of electricity systems. This approach empowers organizations to fulfill their entire electricity demand using carbon-free resources consistently—every hour, every day, and in every location. The framework of 24/7 Carbon-Free Energy is anchored in several key principles. First, there is an emphasis on time-matched procurement, which involves aligning hourly electricity consumption with corresponding carbon-free electricity generation. This hourly synchronization is crucial as it links clean energy purchases directly to the actual consumption of electricity. Second, local procurement is a vital aspect of this strategy. It entails sourcing clean energy from the local or regional electricity grids where consumption takes place. This approach is essential for effectively reducing the electricity-related emissions for which consumers are directly accountable. Third, the framework is technology-inclusive. It acknowledges the urgent need to establish zero-carbon electricity systems swiftly, allowing for the involvement of all available carbon-free energy technologies. This inclusivity is vital for fostering innovation and progress in the energy sector. Fourth, there is a focus on enabling new generation. This entails prioritizing the delivery of additional carbon-free electricity to facilitate the rapid decarbonization of electricity systems. Lastly, there is a commitment to maximizing system impact by targeting the dirtiest hours of electricity consumption, which are characterized by the highest reliance on fossil fuel generation. In summary, 24/7 Carbon-Free Energy seeks to create a sustainable future by ensuring that clean energy resources are utilized effectively and efficiently, ultimately leading to a significant reduction in carbon emissions (Miller, 2020)

Understanding the Shift: Why and How Buyers Are Adopting 24/7 Carbon-Free Energy?

Fully decarbonizing electricity grids requires generating carbon-free energy when it is needed, not just during periods of when the sun is shining or the wind is blowing. Large energy buyers can play a key role by investing in carbon-free energy technologies to fill gaps left by wind and solar generation and by managing their electricity demand to better align with when carbon-free energy is generated. Under 24/7 carbon-free energy purchasing approaches, buyers match their electricity usage with carbon-free supply around-the-clock typically using resources located on the same grid where the electricity is consumed. Some buyers have turned to this approach as the next step to drive decarbonization after having achieved 100% renewable energy purchasing goals on an annual basis (Babatunde et al., 2019)

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This approach outlines a long-term objective for electricity purchasers while also providing a framework for evaluating the timing and methods of energy procurement and demand management. Although it is improbable that buyers will achieve perfect hourly alignment with carbon-free energy instantaneously, they can make gradual progress. Initially, they can focus on comprehending the hourly electricity load profiles of their facilities and investigating the alignment— or lack thereof— between their hourly clean energy acquisitions and their facilities' demand (Ampimah et al., 2018)

. Even in the absence of precise hourly electricity load data for each facility, buyers might estimate their facility loads by extrapolating data from individual buildings or by utilizing average hourly load profile data as a substitute.

Depending on the specific electricity market in which the buyer operates, it may be possible for them to engage directly with electricity suppliers. This engagement will enable them to enhance their hourly alignment with carbon-free energy sources. This can be achieved through diversifying their portfolio of clean energy resources or by incorporating dispatchable assets such as energy storage. Buyers might also consider strategies to reduce or shift their electricity consumption patterns to overlap with the generation profiles of carbon-free energy. Transitioning to a model of 24/7 carbon-free energy requires various resources such as increased data, tools, methodologies, and financial investments. However, by identifying and implementing strategies to improve the hourly match over time, buyers may discover cost-effective approaches to make meaningful progress towards 24/7 carbon-free energy. (Zhao & You, 2020)

Buyers committing to 24/7 carbon-free energy.

Google and Microsoft are one of the first corporate buyers who have both announced plans to match all their electricity demand on an hourly basis with carbon-free energy by 2030. The independent power producer AES is set to provide Google's data centers in Virginia with a minimum of 90% carbon-free energy on a continuous basis. Google has noted that it incurred a slight additional cost for securing 90% carbon-free energy in comparison to standard retail electricity (Corporation, 2021)

. Google has also signed a contract with energy company ENGIE to supply 24/7 carbon-free energy for its data centers in Europe and with the community choice aggregation agency Silicon Valley Clean Energy in

California with carbon-free energy for its data centers there (ENGIE and Google Sign 24/7 Carbon-Free Energy Supply Agreement in Germany and Strengthen Existing Collaboration, 2021)
. Moreover, Google has also forged an agreement with NV Energy to provide them with 350 megawatts of Solar power and 280 megawatts of battery storage (Walton, 2020)
. Microsoft on the other hand, has signed a deal with Swedish utility Vattenfall to supply three of its European data centers with 24/7 renewable energy (Vattenfall to Deliver Renewable Energy 24/7 to Microsoft's Swedish Datacenters, 2020)

What are some of the issues with 24/7 carbon-free energy?

24/7 carbon-free energy presents a promising pathway towards reducing carbon emissions and achieving sustainable energy systems. However, this approach is not without its challenges. The primary issues associated with 24/7 CFE include:

1. The high costs of implementation

Implementing 24/7 carbon-free energy requires significant financial investment in infrastructure, technology, and energy storage systems. The costs associated with these investments can be prohibitive, especially for regions with limited financial resources. The transition to carbon-free energy sources often involves retrofitting existing systems or building new infrastructure, which can be costly and time-consuming (Muradov, 2014)

2. The need for advanced energy storage solutions

The intermittent nature of renewable energy sources such as solar and wind necessitates the development of efficient energy storage solutions to ensure a consistent energy supply. Current energy storage technologies, while improving, still face limitations in terms of capacity, cost, and environmental impact, which can hinder the reliability of 24/7 CFE systems (Dunlap, 2020)

3. The variability of renewable energy sources

Renewable energy sources are inherently variable and dependent on environmental conditions, which can lead to mismatches between energy supply and demand. This variability requires sophisticated grid management and forecasting techniques to balance supply and demand effectively, which can be challenging to implement on a large scale (Harvey, 2010)

These challenges necessitate careful consideration and strategic planning to ensure the successful transition to a carbon-free energy system.

While the challenges of 24/7 carbon-free energy are significant, they are not insurmountable. The development of integrated renewable energy systems (IRES) and advancements in energy storage technologies offer potential solutions to some of these issues. Moreover, strategic policy interventions and international cooperation can help mitigate the socio-economic impacts and ensure a more equitable transition to carbon-free energy systems. However, achieving 24/7 CFE will require concerted efforts from governments, industries, and communities to overcome these challenges and realize the benefits of a sustainable energy future.

What is next for 24/7 Carbon-free Energy?

The concept of 24/7 carbon-free energy is increasingly gaining traction; however, significant efforts remain necessary to enhance its accessibility for a broader range of consumers. Expanding its reach will require a coordinated effort that includes:

1. Getting support from a diverse group of stakeholders is essential while the concept gains traction. For now, the concept is still relatively niche and lacks popularity like the concept of 100% renewable energy. Realizing the goal of 24/7 carbon-free energy demands a degree of market insight that may be beyond the reach of small buyers. Increasing participation might require small scale community networks or energy cooperatives that can help increase the scale and reach of the small buyers.
2. Customers need to be able to access their hourly consumption data easily in an easy to comprehend fashion. This will allow them to understand how their energy use aligns with carbon-free energy and how they can better transition to 24/7 carbon-free for their entire load.
3. Renewable energy generation is tracked annually. Moving to hourly tracking adds additional complexity and traceability challenges which could be addressed through more granular data in the energy attribute tracking systems.
4. 24/7 carbon-free energy holds the promise to drive investment in new technologies that could help grids shift to being 100% clean. Although these technologies may come at a premium, over time, they could achieve cost parity. This would then enable incorporation of these new clean and dispatchable technologies to further clean the grid.

Conclusion

The transition to 24/7 carbon-free energy represents a critical and innovative approach to achieving fully decarbonized electricity grids. This strategy not only emphasizes the importance of aligning energy consumption with carbon-free generation on an hourly basis but also highlights the significant role that large energy buyers, such as corporations and governments, can play in driving this change. While the adoption of 24/7 carbon-free energy presents substantial opportunities for reducing reliance on fossil fuels, it is accompanied by a range of challenges, including high implementation costs, the need for advanced energy storage solutions, and the inherent variability of renewable energy sources. Addressing these challenges will require strategic planning, investment in technology, and collaboration among various stakeholders. Many types of carbon-free energy and related technologies are available on the market today. These include renewable sources like wind, solar, geothermal, and hydroelectric energy, as well as sustainable biomass. There are also non-renewable carbon-free options, such as nuclear power, along with energy storage solutions like batteries. The clean energy sector is also focused on developing and bringing to market new technologies, such as long-lasting energy storage systems, low-carbon hydrogen, advanced nuclear power, next-generation geothermal, and methods for capturing and storing carbon. These innovations can contribute to efforts against climate change. As the concept gains traction, expanding its accessibility and understanding among a broader audience will be essential for realizing its full potential. There is a role for everyone at each step of the process, from the technologies that create carbon-free electricity to how this electricity is bought and used. Rapid progress and innovation are needed, which includes: more clean energy buyers moving past just meeting annual renewable energy goals to a 24/7 Carbon-Free Energy approach that aligns electricity supply with hourly demand on the same grids where it is consumed. The creation of new products and services that provide clean energy to consumers all day. The development and introduction of advanced Carbon-Free Energy and demand management technologies. Changes in policies to allow access to 24/7 Carbon-Free Energy and to speed up the decarbonization of the electricity grid. Access to hourly energy data to guide and support decarbonization efforts. Ultimately, the successful implementation of 24/7 carbon-free energy could not only facilitate a significant reduction in carbon emissions but also pave the way for a sustainable energy future, driving innovation and investment in clean energy technologies.

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