Role of Energy Storage in Sustainability

Intel Sustainability Focus

Sustainability is a key pillar of Intel RISE[1] which aims to works with others to create a more responsible, Inclusive, Sustainable world, enabled through technology and our collective actions. By 2030, the aim is to achieve net positive water use, 100% renewable power, zero waste to landfill and to explore technologies to reduce carbon impact of Data Centers (DC).[2]

There are several dimensions to achieving environmental sustainability in DCs. Most important is reducing the carbon footprint, of which the primary driver is DC energy consumption.

In the preceding decade, DCs primarily measured PUE (Power Usage Effectiveness) for efficient use of power. Around 2010, GreenGrid created two additional metrics beyond PUE to better reflect the TCO and the sustainability goals of a modern DC:

- WUE (Water Usage Effectiveness) which measures the water usage of the DC in liters per kilowatt-hour, L/kWh
- CUE (Carbon Usage Effectiveness) which measures the carbon emission / kWh.

Major DC operators have already invested heavily in renewables in an attempt to displace grid-supplied carbon-based energy sources. Renewables such as solar and wind alone are insufficient to support DC operations 24/7 on 100% green energy; since their power generation is variable, these renewable power sources cannot assure the 100% reliability and availability of power supply to DC operations. As such DC operations today are Carbon neutral (carbon capture and offsets) vs. being carbon free or Zero Carbon. For Green energy sources such as solar & wind, a breakthrough in energy storage is required to move operations to 100% green energy! As such, Intel continues to explore and supports exploration of solutions to deliver 100% reliable Zero Carbon Power. Energy Internet Corporation (EIC) is one such solution that holds promise for both energy grid of the future as well as for the future of DCs.

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[1] 'Responsible Inclusive Sustainable Enabled', See Intel 2030 RISE Strategy and Goals, https://www.intel.com/content/www/us/en/corporate-responsibility/2030-goals.html

[2] https://csrreportbuilder.intel.com/pdfbuilder/pdfs/CSR-2020-21-Full-Report.pdf#page=69
"Achieving Carbon Neutral Computing" Intel 2020-21 Corporate Responsibility Report, intel.com

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EIC DCES

Environmental sustainability is now a primary objective for all companies. Over the last decade, DCs have become indispensable to modern business, as the role of data, information and computing has become ubiquitous. Since DCs and their operations are now prevalent across all industries, Environmental sustainability is an important consideration in DC design.

In addition to Environmental Sustainability, it is also important to reduce the Total Cost of Ownership (TCO), by containing the first order cost factors in a DC (cost of power and cooling). Meeting both objectives is challenging.

The approach under development described here gives a DC system architecture that yields DC configurations at different scales that can lower the total costs of energy consumption, achieving zero carbon footprint, rather than paying a premium for being green and sustainable. Furthermore, it indicates a roadmap towards other sustainability benefits, such as cooling which reduces carbon footprint by reduction of waste heat, with water usage and restoration,

The way to achieve Zero Carbon is to use renewables as the exclusive power source, combining them with energy storage of duration long enough to deliver continuous, reliable power, despite daily intermittencies, and seasonal variations in renewable power generation. By "long-duration" we mean therefore duration not of hours, but of days and weeks. There has been simply no storage technology available that can scale up to the durations of a week to a month necessary to provide 100% renewable power. Considering battery technologies as an alternative would increase the cost of power by factors of 20 to 50X the cost of power today.

Our solution is a Data Center Energy System (DCES) architecture (see Fig 1), delivering highly available, reliable power and cooling, at any scale and location. It does this with a power plant, operating exclusively on renewable power sources, storing energy for long duration (weeks).

The DCES Power system has two components. As Fig 1 shows, the DCES power plant uses raw-power from a renewable source and uses long-duration storage to deliver reliable power to the DC. The DCES architecture can also provide functionality to substitute for a chiller plant, by providing a flexible cooling interface that does not use water.

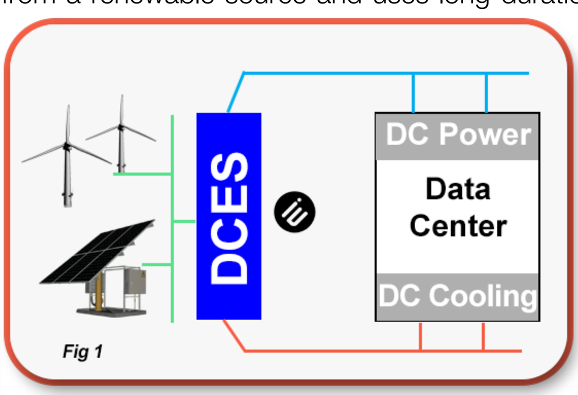


Fig 1

An Energy Internet Corporation Ei System Architecture is illustrated in Fig 2 below. The Ei system connects to one or more grids, or renewable power feeds through its standard interfaces. The Ei System is a power plant that deliver high quality of service power on demand. It draws power from renewable sources (or grid as back-up), delivers power to DC, and stores the surplus power in its long duration storage systems.

Large DC store energy as compressed air in subsurface reservoirs, Compressed Air Energy Storage or CAES, such as depleted oil/gas reservoirs, salt caverns, aquifers or hard rock formations. They use above-surface Liquid Air Energy Storage (LAES) as a back-up, produced by an add-on process of converting the compressed air to liquid air.

Small DCs use only LAES, as subsurface storage may become expensive. Ei plants use battery to provide the quick response and manage the transient power flow. This feature along with the battery's ability to always stay adequately charged enables it to substitute the UPS function. The Ei plants also serves as a substitute to a diesel generator.

Ei software optimizes the operation of its own plant, while interfacing with the power and cooling circuits and the infrastructure management system of the DC, and the grid circuits feeding it power.

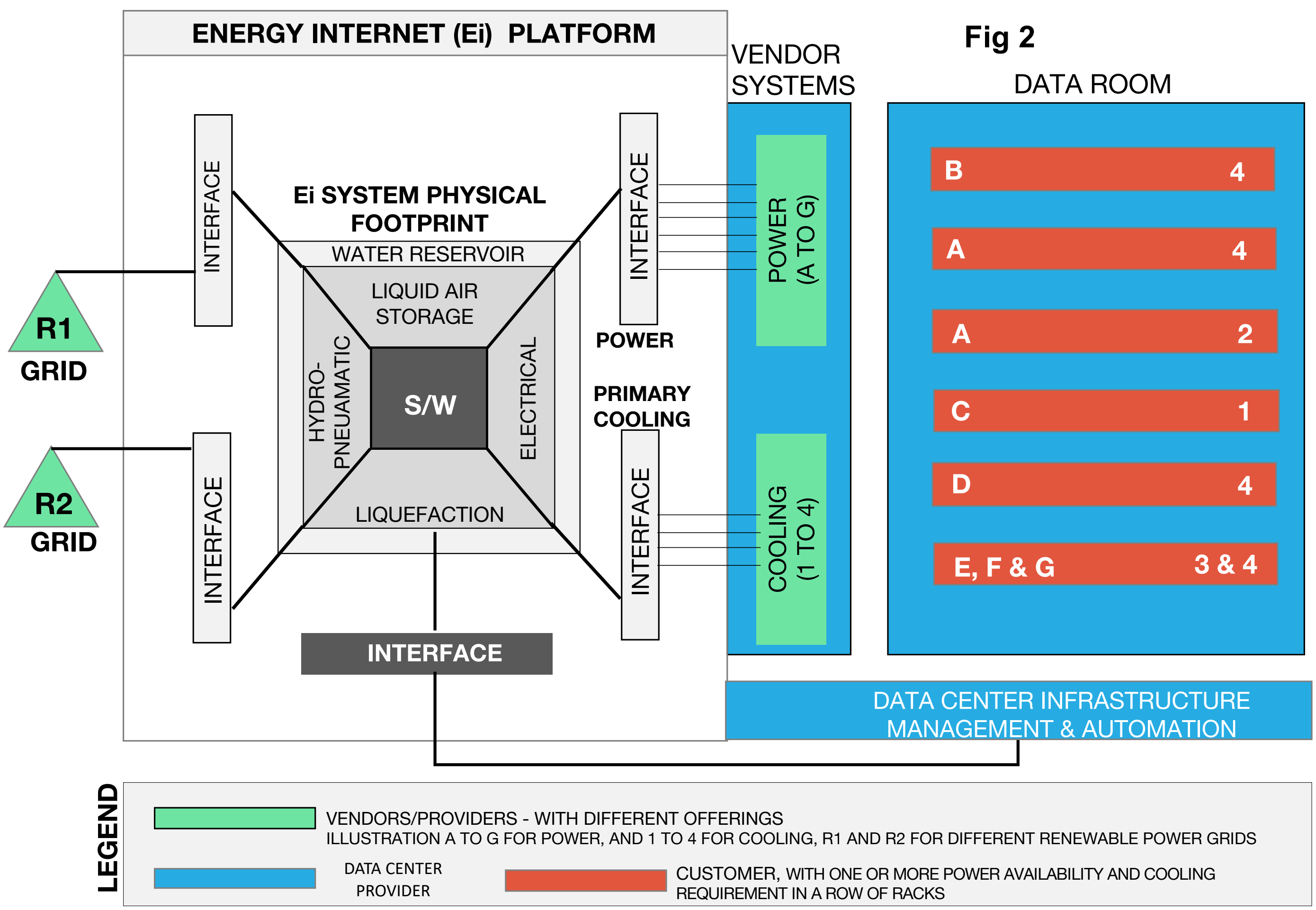


Fig 2

The power supply to a DC has a very traditional supplier-consumer relationship with provisioned power and metered power being the key metrics. The DCES Architecture provides for demand-shaping and optimization DC operations by utilizing its telemetry.

The DCES architecture provides large reliability, resiliency, operational and deployment flexibility benefits:

- It is modular, scalable, rapid deployment and easy to maintain and upgrade. Prefab modules delivered from inventory, of standard unit sizes - 0.5 MW, 5 MW and 64 MW – are designed to plug and play, for rapid deployment and scaling the footprint with customer demand.
- They can be deployed in an N+x architecture (N units guaranteed to deliver the rated capacity service, supported by 'x" redundant units to come live as needed in the event of any maintenance or failure). This improves service availability and maintenance & upgrades.
- LAES systems, where deployed, provide an any-scale cooling interface - for air cooling, liquid immersion cooling or liquid air cooling at rack/server level.
- They can shave extended power peaks and thus help DC power infrastructure operate at higher levels of utilization.
- They promote flexibility to plug into any power distribution (AC/DC, etc.) or cooling interface required in the data rooms.

There are several drivers to reducing TCO for the DCES Architecture described here, to make it superior to other energy storage/power plant technologies. First it is important to recognize it is not a pure energy storage solution, but a solution that provides reliable buffer capacity to manage the variability of a renewable power supply, comprising storage and power generation capabilities.

The first cost driver is capital expense of surface equipment. Mature pumped hydro technology and electrical switchgear is used in its different configurations to keep capital cost competitive.

A second driver is marginal cost of storage. For subsurface storage, the marginal cost of storage is zero. Larger energy storage does not entail any significant extra capital or operating costs, unlike competing battery technologies, where the cost scales with the battery storage capacity required.

A third cost driver is roundtrip efficiency- the ratio of average energy generated by an energy storage system for every unit of energy injected in it. Lower roundtrip efficiency potentially increases capital cost, because larger power charging capacity is required for poorer roundtrip efficiency. The roundtrip efficiency for a commercially mature system is expected to be between 68-72%, inferior to battery technologies (85+ %), but sufficiently high to reduce TCO compared with competing alternatives.

Finally, a driver in favor of energy storage is that the cost of renewable generation is artificially high because of their variability – renewables are unable to dispatch and sell all the power they generate. By making

100% of renewable power dispatchable, energy storage can reduce the TCO of energy consumption while achieving a zero-carbon footprint.

In summary, a greenfield DC can be:

- Zero Carbon 100% renewable power
- Lower TCO
- Secure; islanded, grid-backed-up or grid-power-interfaced; highly scalable; and deployed rapidly
- Supportive of flexible levels of infrastructure availability (power & cooling) from 2 9s to 6 9s to different segments of a DC cluster.

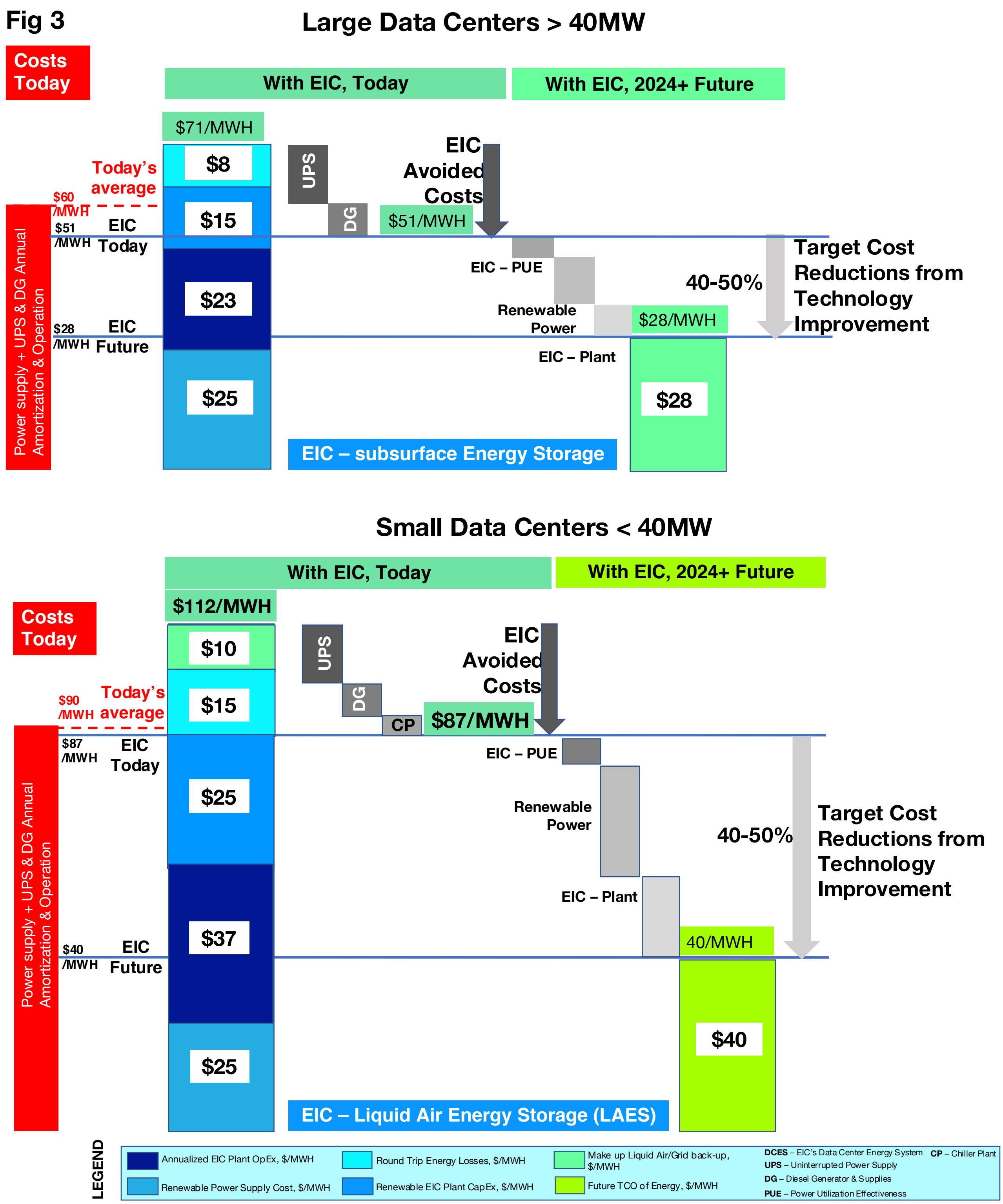
The architecture points to a roadmap to:

- Eliminate the need for standby diesel generators, using utility feeds as additional backup power if needed
- Serve UPS function of uninterrupted power
- Provide highly scalable cooling to support high power density racks (e.g., 100 kw/rack)
- Avoids the need for power reserves for peak loads, allowing the DC to operate at higher average levels of infrastructure utilization.

What might be the impact of cost drivers on overall TCO? Fig 3 gives illustrative examples on the improvements that might be expected in the average unit cost of energy, accounting for the amortized equipment costs over its lifetime (30 years), costs of plant operations, renewable energy purchase and storage losses. Two DC scales are considered for purposes of illustration – small and large. The larger scale example is modeled to provide highly reliable power on an islanded basis, with weeks of energy storage in the form of CAES, that can sustain extended absence of renewable power generation. The smaller scale solution considers LAES to provide reliable power, ideally by using the grid as a back-up (but in case of edge DCs, with no grid interface, liquid air resupply on stock-outs). For the assumptions made in each model, the approximate percentage improvements in costs are shown including savings in avoided costs from avoiding expenditure on diesel generator and UPS (and chiller plant and water use, in case of LAES) can be avoided. While actual savings will vary depending upon specific circumstances, the model examples suggest effective savings of 20-30% from avoided DG/UPS/Chiller costs which represent a significant saving on an annualized cost basis. DCs can increase their savings further by appropriately buying and selling power (demand response with utility for instance) and increasing their overall utilization levels and revenue earning potential.

DCES costs are expected to further reduce the above numbers, as costs of renewable power and system efficiencies improve.

Fig 3



* Total Costs of Ownership – Including costs of power, amortized infrastructure and operations costs, on an MWH delivered to data center, with EIC's 2022 commercial product installation. Does not reflect the reduction energy consumption with EIC of upto 10%. LAES uses waste heat to generate additional power and thus avoids consuming power for cooling when in use. This improves Power Utilization Effectiveness (PUE).

** TCO cost reductions are as a result of lower expected renewable supply cost, as well as improvements in efficiency and reductions in EIC Capital and Operation expenses

Conclusions

Intel is exploring EIC as an energy storage option for DC and energy grid of the future. Intel also is exploring complementing / augmenting EIC's solution through Intel telemetry and management interface that enables seamless integration of EIC solution with Intel-hardware based Data Centers.

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* Intel is leading provider of processors and systems powering smart devices and data centers.
Energy Internet Corporation (EIC) provides Zero Carbon Power Supply solutions at any scale of power use, for highly reliable and continuous power based on long duration energy storage and renewable sources of power.
Lummus Technology LLC, via its Green Circle LLC business entity, is a leading technology innovator at the forefront of the energy transition, decarbonization of assets, and the circular economy. Green Circle is EIC's strategic partner on the DCES initiative.