Data Centres

Decarbonising the Energy System

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Introduction

The European Union is steadily increasing its climate ambition. In April 2021, the 27 EU Member States and the European Parliament reached a deal on the European Climate Law, committing to legislation the goal to reduce 55% of net GHG emissions by 2030. Achieving these goals will require the active participation of all players in the energy system. This includes energy-intensive industries, which are vital to Europe's economy.

The ICT sector differs from many other energy-intensive industries in that it is already highly electrified. Furthermore, many hyperscale data centre operators feature some of the most progressive climate and clean energy goals in the world, and are leaders in terms of clean energy procurement, energy efficiency, and championing other clean energy technologies.[1] With that in mind, data centres have the opportunity to expand their contributions to the decarbonisation of the energy system even further.

With the appropriate market signals, data centres could become one of the key providers of flexibility services to the grid, One study estimated that a 60 MW data centre consuming 500GWh/year in Denmark could provide 22 MW in demand response,[2] while another study calculated that the theoretical potential for demand response from data centres in Europe could constitute 40 to 80% of the installed power by 2030.[3]

This report provides an overview of best practices that demonstrate how data centres are paving the way to an increasingly decarbonised energy system. The companies featured in this report are doing this in the following ways:

- by sourcing clean electricity for operations, while at the same time better matching consumption to when and where clean electricity is available;
- by providing services to the energy system through flexible demand-side management;
- and by providing waste heat to other sectors, thus increasing energy system integration.

At the same time it is important to acknowledge that these business models need to be strengthened by eliminating existing regulatory barriers and promote revenue streams that reward end-users for activating their flexibility. The right principles have already been set in the Clean Energy Package, and now need to be fully implemented at a national level.

[1] 5 ways Big Tech could have big impacts on clean energy transitions – Analysis- IEA
[2] Clausen A., Ghatikar G., Nørregaard Jørgensen B. (2014). "Load management of data centres as regulation capacity in Denmark", Proceedings International Green Computing Conference.
[3] Koronen, C., Åhman, M. & Nilsson, L.J. (2020) Data centres in future European energy systems—energy efficiency, integration and policy, Energy Efficiency 13.

1. Powering Data Centres with Clean Energy

In recent years, the sourcing of renewable energy has become a priority for companies topping the sustainability charts. Purchasing Guarantees of Origin/ Renewables Certificates allows companies to make '100% renewable' claims, while providing an extra revenue stream for producers of renewable energy. PPA deals importantly provide even more support to renewables projects, by giving a guaranteed price to producers of renewable energy, and simultaneously ensuring that companies make their sustainability goals. While these can be considered important steps towards a society powered by renewables, it is equally important to look at what steps still lay ahead. How can 100% renewable companies further push for a fully decarbonised energy system?

As data centres rely almost exclusively on electricity as an energy carrier, it is not a surprise that many data companies are at the forefront of the innovation around the purchasing of clean electricity. The sourcing of electricity is extremely relevant for data centres, as electricity can comprise as much as 70% of their operating expenses .

Now frontrunners in the data centre industry are looking for ways to not only purchase enough renewable electricity to match their consumption on an annual basis, but to also ensure that the way they purchase and consume electricity results in as few CO2 emissions as possible, at every hour of every day. At the same time, the question arises what power markets can do to further encourage clean energy sourcing and avoid all fossil fuel emissions.

MICROSOFT: Software solution for 24/7 matching of renewables

Back in 2019, Vattenfall and Microsoft already successfully piloted a 24/7 renewable energy matching programme in Sweden. As of 2020, they are extending this partnership to cover all energy consumption from Microsoft's facilities in Sweden. This includes the four new Microsoft data centres located in Gävle, Staffanstorp and Sandviken.

In the pilot project, the energy consumption at Vattenfall's headquarters in Solna and the new Microsoft headquarters in Stockholm was matched with renewable energy generated in Sweden in the same hour it was used. The result was that 94% of the total office building energy consumption at both locations was matched with Swedish wind and 6% matched with Swedish hydropower. This hourly matching will go beyond the office buildings, and be expanded to Microsoft's data centres in 2021. The impact of this expanded use of 24/7 matching on emissions is expected later this year.

In order to achieve this, Vattenfall used Microsoft Azure to build and deliver a solution that allows hourly matching of renewable energy generation with demand 24/7. Energy produced from renewable sources is measured hourly, and consumption is measured by smart meters installed on locations where energy is used; using the software, these energy flows are matched hourly. This enables transparency by providing increased information about the hourly source of energy for each

MWh of consumption. Vattenfall uses this real-time information feed to cancel hourly matched Guarantees of Origin (GOs) on Microsoft's behalf. In the future, this project will not only track renewable energy production and electricity consumption on an hourly basis, but also include the time-based marginal carbon emission[4] of the GOs matched for Microsoft's datacentres and office buildings in Sweden.

However, while time-based, marginal carbon emissions are a big step towards better attribution of the carbon abatement impact from renewable energy, there are further steps contemplated in the pilot for accurate measurement of the carbon impact from renewable energy. For example, estimating the tons of carbon emissions displaced by 1 MWh of clean energy correspond to the time and location of generation. The renewable energy MWhs generated at one location on the grid may displace more carbon than that at another location, because at certain times of day not enough transmission capacity is available to deliver to customers. Looking at marginal carbon emissions – and also locational marginal carbon emissions – is therefore a step forward for companies to understand and decrease carbon emissions from electricity consumption and maximise the carbon abatement value of renewable energy.

TOMORROW: Showing data centres when and where electricity is greenest

In order to power data centres with clean electricity, getting the right information is important. In order to provide this insight, tech start-up Tomorrow has developed a platform that shows in real-time how green electricity is around the world, drawing on their large database of past, current and forecasted carbon footprint data for electricity. This information allows Tomorrow's partners to shift their energy usage to more optimal times to achieve their environmental goals.[5]

In April 2020, Google and Tomorrow announced a new partnership to reduce climate impact.[6] Building on the data from Tomorrow's platform, Google has now created their own carbon-intelligent platform, which allows them to shift computing across the globe, favouring regions and schedules where there's more carbon-free electricity.

In this way, Google is then also able to help their cloud customers reduce the carbon footprint of their computing by sharing the average hourly Carbon Free Energy Percentage (CFE%) for different cloud regions. Depending on the different requirements of workloads, their customers will be able to choose whether to prioritise carbon footprint, cost, or latency. According to Google's research, while latency and performance are more important for many customer workloads, for batch jobs or backup, carbon scores were ranked as the top characteristic more than any other factor.[7]

[4] Resurety White Paper: Local Marginal Emissions – A Force Multiplier for the Carbon Impact of Clean Energy Programs Retrieved on 23 June 2021.
[5] Tomorrow Blog: How companies reduce their carbon footprint with electricityMap API. Retrieved on 24 June 2021.
[6] Tomorrow Blog: Announcing our partnership with Google. Retrieved on 24 June 2021.
[7] Google Blog: How carbon-free is your cloud? New data lets you know. Retrieved on 24 June 2021.

WATTSDAT & RETELIT:
Optimising energy for data centres through an Energy of Things solutions

Retelit is the Italian leader in constructing tailor-made digital transformation projects. In order to reduce energy consumption in their 19 data centres (18 throughout Italy, and one in Austria), and to consume more renewable energy, Retelit has embarked on an evaluation process in order to see what kinds of investments can be made to upgrade infrastructure and simultaneously reduce their carbon emissions.

As part of this process, Retelit has chosen to launch an innovation program involving Wattsdat and their Energy of Things solution. Wattsdat specialises in smart energy, and has developed a platform that models and manages complex energy systems, based on a multi-cloud architecture. The platform connects things, technologies, consumptions, productions, prices, tariffs and incentives to continuously measure cash flow and how energy is used.

This platform gives Retelit continuous insight into their energy and environmental data. This ensures smoother data centre operations, while also giving price insights into the energy markets. With this information, Retelit will be able to offer flexibility in the balancing market by optimising the withdrawal of energy. With regards to energy sourcing, a new data centre model is currently under evaluation, which will prioritise using energy in areas where PV is being developed, in order to reduce grid losses and further contribute to improving energy performance.

By partnering in this initiative, Retelit and Wattsdat are creating a replicable and scalable model that can also be adopted by other customers, and in this way to have a bigger impact in the energy transition through digital transformation.

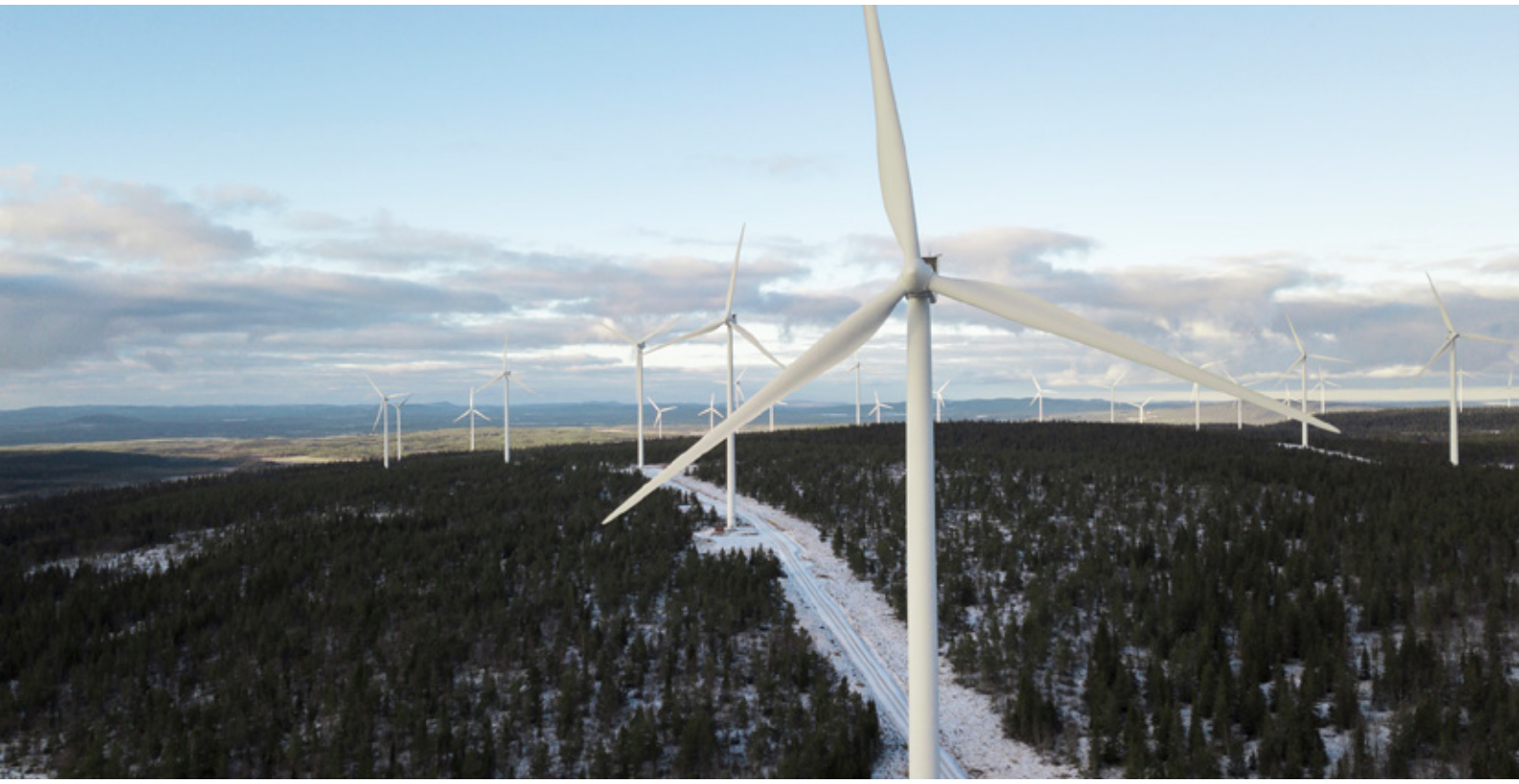


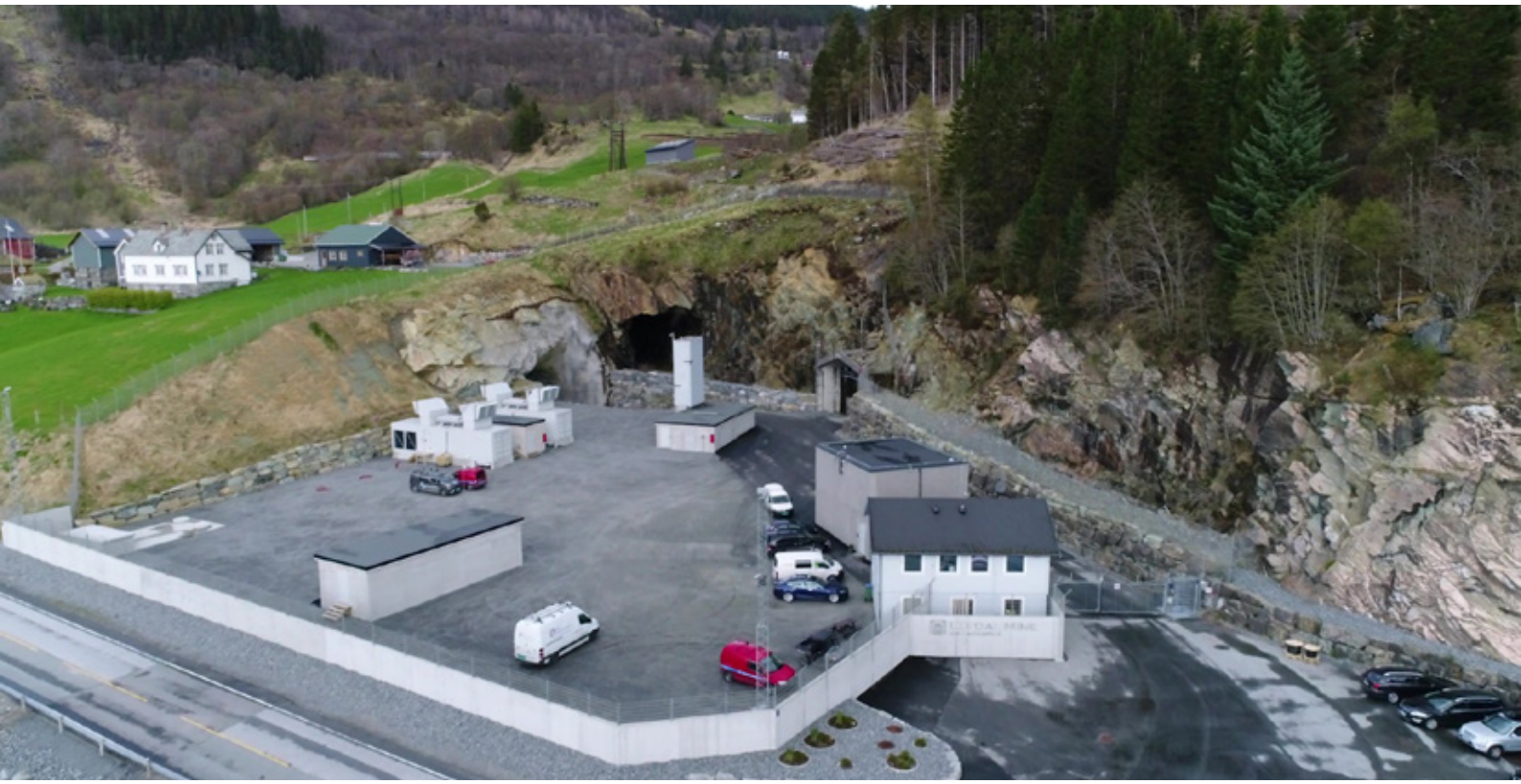
ABB: Highly efficient data centre powered by 100% local renewables

The Lefdal Mine data centre, operational since May 2017, is built 150 meters into a mountain in what was formerly an underground mine. Located on Norway's west coast, between Måløy and Nordfjordeid, the six-story mountain hall facility sets a new standard for the data centre industry.

The massive data centre is powered exclusively by renewable energy produced locally, while being cooled by water from a nearby fjord. ABB has supplied the critical power infrastructure, which provides clean energy generated by four glacial hydropower stations and two windmill farms with a combined capacity in excess of 300 MW.

Data centres are among the biggest consumers of energy. Yet Lefdal Mine is more efficient, because it uses cold water from the 565 meter-deep fjord as a coolant. The data centre is located below sea level, eliminating the need for expensive high-capacity pumps to lift the fjord's water to the cooling system's heat exchangers. The result is that the data centre's cooling solution will have power usage effectiveness (PUE) – the industry standard for energy efficiency - of between 1.08 and 1.15 for 5 kW rack, making it among the greenest data centres in the world with 30-40 percent energy savings over traditional data centres.

To meet the powering challenges due to the physical size of the facility, ABB has built a medium-voltage backbone for the entire facility. To meet any emergency situation, ABB also provides a decentralised UPS (uninterruptible power supply) system, which means that each section inside the data centre has its own UPS installation. If there is a problem with the grid, the UPS kicks in within a couple of milliseconds and ensures reliable power supply until the backup generators come online. [8]



[8] ABB solutions power Europe's greenest data center in Norway. Retrieved on 23 June 2021

2. Providing System Services to the Electricity Sector

Data centres can provide important services to the electricity system to which they are connected. A typical data centre will have an Uninterruptible Power Supply (UPS) system, which ensures that even if there is a disturbance in the grid, this will not hinder critical operations. Such a UPS consists of a battery pack that can take over the critical load immediately, until either the grid comes back online or back-up generators ramp up to take over from the battery pack until the grid is up and running again. Because it is so crucial for data centres to remain operational at all times, there is a significant amount of redundancy built into these UPS systems – meaning that often the battery pack could fail entirely, and there would be another battery pack ready to take over the job.

Depending on the technical capabilities of the UPS, there are various ways they can provide energy services to the grid. At the very least, it is possible to participate in demand response programmes by going into islanding mode, and thus decreasing the demand on the grid by the entire load amount. More advanced technical capabilities allow for the data centre to be partially supplied by the grid, and partially by the UPS, meaning that the amount of electricity being drawn from the grid can be moderated more precisely. Technically, it would also be possible for the UPS to work bi-directionally, meaning it could also feed the stored electricity from the storage solution back into the grid, resulting in even more flexibility.

If the appropriate market framework is in place, such grid-interactive UPS systems can provide important system services to grid operators, and create additional revenue streams for operators.

SCHNEIDER ELECTRIC: Remotely dispatchable UPS for energy optimisation and grid services

Due to the highly mission-critical nature of data centres, almost all of the major subsystems are fully redundant. This includes subsystems such as UPS, batteries, generators, and cooling. In fact, even during extreme conditions such as natural disasters, most such facilities can run autonomously for days. These subsystems include redundant UPS batteries that represent a significant amount of on-site energy storage. In almost all locations these overprovisioned battery systems sit idle for most of the year.

Schneider Electric has identified four key methods to monetize UPS energy storage through their dispatchable UPS solution by optimising energy onsite and providing services to the grid.

- Time-of-use load management
- Demand charge management
- Third-party signalled or demand response event participation
- Third-party capacity aggregation

By responding to price signals (e.g. when cheap renewable electricity is flooding the grid), data centre operators can use their energy storage to load shift as much or as little as they see fit, in order to optimise the timing of their energy demand. Data centre operators

could also choose to over-produce ice or chilled water during periods of lower electricity prices.

A data centre operator can also reduce their demand charges by placing some or all of the IT load on the UPS battery for a period of time. Because demand charge reduction is implemented by reducing the peak demand, this approach is often referred to as "peak shaving". The profile of a data centre's IT load is relatively flat, therefore peak shaving may only make sense during hot days when the cooling system peaks, which could set a higher demand charge for the entire month or even year.

"Third-party signalled" events entails that the data centre operator makes a commitment to a third party to reduce the load on the grid in exchange for a payment (by reducing consumption or by placing loads on back-up power). Depending on the country, there are programs that could be as simple as responding to occasional events, as well as more involved programs with specific capacity commitments or even second-by-second frequency regulation.

One way to increase participation of data centres in grid services is to be aggregated virtually so they can be bid into more programs. In such cases geographically distributed assets are controlled by a third-party aggregator and bid as an aggregated asset. This can also be referred to as a virtual power plant (VPP).[9]

ENEL X: Using Backup Generators to Earn Demand Response Payments

For a data centre, operational stability is crucial. Resiliency solutions like backup generators are essential tools to ensure system reliability, and data centres often have extensive resiliency measures in place. But these tools can have other benefits. By monetizing their backup generation to earn payments through demand response programs, data centres can use generators to find new revenue streams, too.

One telecommunications company in Calgary, Alberta, saw an opportunity to use their generators to earn incentive payments in the Alberta Operating Reserves (OR) program, a type of Demand Response. The company has earned more than $400,000 participating in OR since 2014. To take part in OR, a business agrees to lower their energy use by a certain amount if the local grid is strained, and in exchange earns payments for being on standby.[10]

Because of the importance of uptime, it was crucial that an OR directive not cause any disruption to the data centre. Directives are the times when Enel X instructs customers to lower their energy use, and these only happen a handful of days each year—most days, the data centre is paid simply for their willingness to turn down their energy. By using a closed circuit transfer switch, the data centre experiences no disruption in power. When they are notified of an event, whoever is on duty at that time simply walks over to the generator and transfers all load onto their backup system.

[9] Schneider Electric Whitepaper: Monetizing Energy Storage in the Data Center. Retrieved 25 June 2021.

Businesses have ten minutes to respond to a directive, but switching to backup generation simplifies the process.

The data centre uses the generators often, even outside of an OR event. This allows them to be sure the generators are working in case of an emergency. Enel X customers frequently tout this as a benefit to enrolling generators in DR—without occasional directives, customers may otherwise go years without using their generators, and are often unprepared in case of a true emergency.

SIEMENS: Replacing Diesel Gensets with Battery Energy Storage Systems

Since a diesel generator always means a certain amount of carbon emissions are unavoidable, companies are looking to other solutions. Now, a new technology – the battery energy storage system or BESS – has emerged that can put an end to the quest for data centre carbon neutrality. Centred around lithium-ion (Li-on) batteries, BES systems are emission free and have better capital and operational expenses than a corresponding diesel genset configuration. Their potential for supporting and stabilising the grid while generating additional revenues means the payback period is only between five to seven years: a win-win for the energy system.

With a BES system, data centre operators can shift load from the grid onto the back-up system a hundred times faster than with a diesel genset. This fast switchover time is a key enabler to further cost reduction. This is because the size of the UPS battery pack can be up to 90% smaller, which frees up more space for IT equipment or can reduce the footprint of the building.

For data centre operators seeking unlimited hours of autonomy at site conditions can implement a hybrid solution composed by BESS and cloud technology. Cloud infrastructure allows operators to shift computing workloads to another data centre, in case of long outages. Hyperscale cloud providers are pioneering this approach. Enterprise and corporate data centre operators, for which cloud technology is largely available, can find themselves in a similar situation. According to a 451 Research report “more than 90% of organisations” are projected to adopt cloud technology.

By embracing full decarbonisation, data centres can not only ensure an economically viable business model, but they can also futureproof their operations, provide grid stabilisation services, and move to the positive side of the energy equation.

[10] Enel X Case Study: Data Center Captures New Value with Existing Energy Assets. Retrieved 8 July 2021.

EATON: Commercialising frequency response services from the UPS system

Power management company Eaton has launched a frequency response energy solution which enables commercial and industrial facilities like data centres, manufacturers and airports to help stabilize the grid and contribute to the integration of more renewable power. While continuing to power critical applications, Eaton's Energy Aware solution helps grid operators address emergency fluctuations in system frequency which occur as a result of increasing variable renewable energy. Eaton has worked to bring the solution to market by partnering with Enel X, which enables organizations to take part in EirGrid's procurement of system services program (DS3) and earn revenue for doing so.

Eaton's 2019 proof of concept with Enel X and EirGrid at its Dublin headquarters has demonstrated how this solution manages critical loads and mission critical applications, reduces Eaton's energy consumption and improves grid stabilisation. Pilot projects have proven that the technology provides a viable and fast-acting power reserve to the grid while maintaining the UPS's primary function of securing electrical loads, further de-risking any instability from the country's increasing use of renewable generation. Since then actual data centre deployments have been established in Sweden, Norway and Finland - proving the technology and the environmental and commercial benefits for data centres (Statnett, Basefarm, Bahnhof, Statnett).

Further deployment of fast frequency response (FFR) services comparable to EirGrid's program could allow a greater proportion of data centres to leverage existing, under-utilized UPS assets at scale, throughout the EU. If grid operators embrace the development of effective markets for FFR services through products such as grid-interactive UPS systems that can provide fast response at lower energy volumes, they can achieve a cost-effective option for mitigating decreasing grid inertia.

In the USA, Eaton's technology has also been put to the test by Microsoft to find a way to put Microsoft's assets to work around the clock. In a technology demonstration with PJM, a regional transmission organization (RTO) serving 13 states and the District of Columbia, the UPS exceeded the operator's requirements for accuracy, response time and precision on a self-scored test, proving the technology's ability to serve as a viable DER.

HELEN: Saving 5-10% of electricity costs through demand response

Helen offers companies the Demand Response service that brings considerable savings, even hundreds of thousands of euros per year. The search engine company Yandex gained a 5–10 percent saving in electrical energy costs at its data centre in Mäntsälä due to Helen's demand response service.

In Helen's Demand Response service, a company is part of a virtual power plant, which has a task of balancing Finland's power grid. Suitable regulated power loads and back-up power generators are selected for the virtual power plant, and they are controlled during national grid disturbances or shortage of electricity. Helen pays the company financial compensation for load control or being on standby and sells the demand response to the national grid.

Helen has several business customers who have already joined Demand Response, and Helen is also strongly expanding these operations. The Demand Response service is particularly suitable, e.g. in greenhouses, water pumping stations and cold storage facilities, as well as data centres.

Yandex's data centre in Mäntsälä uses a lot of electricity and therefore benefits from the Demand Response service. Yandex joined Helen's Demand Response in 2016, and the results are even better than expected by either party. With a dynamic UPS system of 8MW, and by installing a Siemens Decentralised Energy Management System (DEMS), provided by Helen free of charge, Yandex became the first data centre in the world to provide FCR.

Overall, Yandex's data centre gained a 5–10 percent saving in electrical energy costs with Demand Response. In addition, waste heat is also recovered and utilised as district heat in Mäntsälä, further establishing Yandex' green values.

3. Integrating Data Centres into the heat sector

Data centres can also have a considerable impact beyond the electricity system. Most of the electricity that is used in a data centre creates waste heat as a by-product that could be used in other sectors. This is why, in some places, this heat is funnelled towards a nearby heat network, where it is used to heat nearby buildings. Unlike other sources of heat that come from burning fossil fuels, data centres can be a reliable future supply for heat networks.

Digitalization and AI allow for new possibilities to coordinate between different energy systems. Going forward, it makes sense for smart electricity grids and smart thermal grids to respond to one another, in order to achieve optimal solutions for the individual sector as well as the overall energy system.

AMAZON: Heating local community buildings in Ireland through data centres

In Ireland, Amazon Web Services (AWS) has started working with the South Dublin County Council (SDCC) to recycle heat from its data centres. The new District Heating Scheme in Tallaght, South Dublin, will provide heat recycled from the recently-completed AWS data centre to public sector, residential, and commercial customers. The system will initially heat 47,000 m2 of public sector buildings – an area three times the size of the city's Croke Park stadium pitch – as well as 3,000m2 of commercial space and 135 affordable rental apartments. This is projected to save 1,500 tonnes of carbon per annum during the first phase of the Tallaght District Heating Scheme, the equivalent of a 60 per cent reduction in carbon emissions.

South Dublin County Council has established Ireland's first publicly owned, not-for-profit energy company, which has commissioned Fortum, an experienced Finnish energy supply company, to carry out the design, installation, and operation of the scheme. AWS will provide recycled heat free of charge to the scheme which, when combined with additional heat pump technology, will be sold on to end users at low cost by the district heating company, trading as Heatworks.

The collaboration between AWS engineering teams, Fortum, SDCC, and City of Dublin Energy Management Agency has resulted in a customized and unique low-carbon solution utilising recycled heat from a data centre – the first example of its kind in Ireland. The supply of low-cost, low-carbon heat is also expected to attract innovative businesses and development to Tallaght town centre, facilitate educational programmes and start-up opportunities in renewable energy solutions, as well as helping to mitigate fuel poverty as the heat network expands over time.

CATALYST: Multi-commodity marketplace for heat, electricity and flexibility services

In the CATALYST project, a consortium of partners has been investigating the role that data centres could play in the energy transition. Because data centres have an intrinsic amount of redundancy, they can provide important services to different sectors and open up new revenue streams - without affecting core actives. This could mean delivering ancillary services in the electricity system, but also providing waste heat to District Heating and Cooling networks.

CATALYST also implements a "follow the energy" policy. This means moving computational loads to areas where there is more renewable energy, or scheduling delay tolerant workloads to times when there are more favourable weather conditions for renewable energy. This is done through a secure and traceable migration of IT load between synergetic, geographically disjoined data centres. This also means by migrating the IT load to the locations where spare energy is available or where heat in needed.

In order to achieve this, a framework was also developed for data centres to assess different types of flexibility (electricity, heat and IT workload), which could then be traded in a multi-commodity market place accessible to other flexibility prosumers. This framework was tested in various scenarios at four data centres in France, the Netherlands, Poland, and Italy, which were fully operational at the time of this project. By contributing to both the electricity and thermal grids, the project concluded that using these sources of flexibility could increase revenue streams for data centres while also increasing local grid stability.

Conclusion

In this paper, we looked at three ways in which data centres are contributing to the decarbonisation of the energy system. Firstly, this can be done by using green energy to power data centres. Many corporations are shifting away from simply purchasing enough renewable energy to cover annual consumption, and looking at how they can buy renewable energy that is produced when and where it is actually being used. Secondly, this can be done by providing valuable system services to the electricity grid, so it can continue to incorporate more and more renewables. Lastly, since the energy transition will require a full decarbonisation of the energy system, including other sectors, this can be done by providing heat to other sectors.

As we saw from the numerous cases included in this publication, these strategies are already being implemented. However, to strengthen these business models, it is now crucial to eliminate existing regulatory barriers and shape enabling frameworks for the active participation of all energy end-users, including energy-intensive industries. At an EU level the Electricity Market Design has already set the right principles. Now Member States are being called on to timely transpose them in national provisions.

In addition, revenue streams to reward end-users for the activation of their distributed flexibility and for their participation as a prosumer should be promoted through EU legislative frameworks. The revision of the Renewables Directive should incentivize a real-time 24/7 flexible consumption of renewable energy and the Data Centre Sustainability Indicators in the revised Energy Efficiency Directive should enhance the activation of distributed flexibility as a way to contribute to system efficiency. These are short-term EU legislative opportunities that EU policy-makers should grasp in order to support the cost-effective achievement of the 55% GHG emission reduction target for 2030 and increase the industrial competitiveness of energy-intensive industries, as urged by the EU industrial strategy.

smartEn is the European business association integrating the decentralized solutions of the clean energy transition. We create opportunities for every company, building and car to support an increasingly renewable energy system.

Our vision is that every European benefits from playing an active role in the clean energy transition.

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