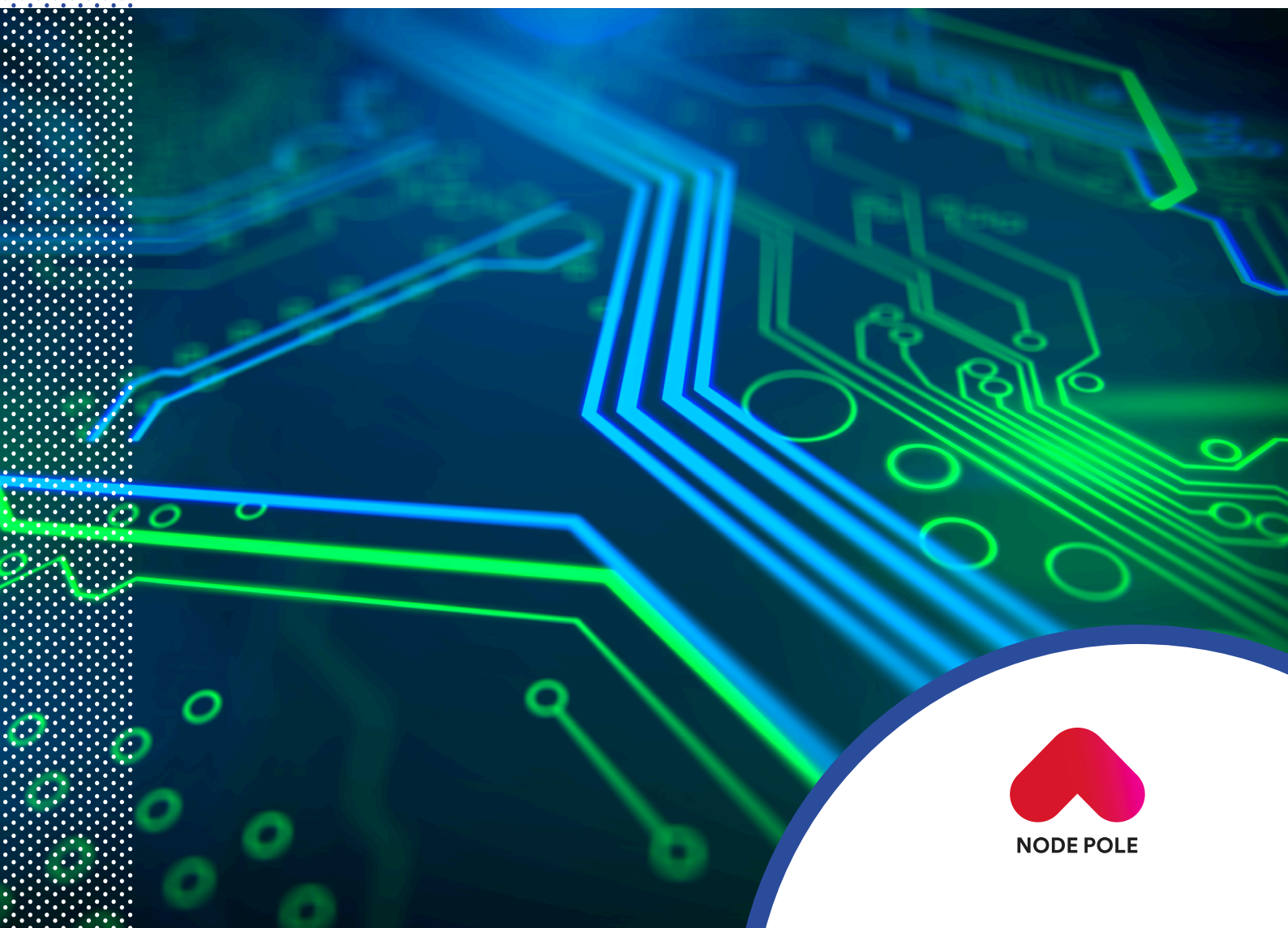
DCD > eBook

Sweden: The land of green data center opportunity

Why the data center industry should aim to #BeMoreSweden



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Christoffer Svanberg
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Introduction

When it comes to sustainability, Sweden really is the land of green opportunity. The country's unique combination of low-cost fossil-free energy in the form of near net-zero electricity, a fantastic business climate and an abundance of natural resources, make Sweden the perfect strategic destination for your data center.

In this eBook we delve into why we should all aim to #BeMoreSweden with articles showcasing the ingenuity and innovation currently emanating from this green and promised land. We highlight why Sweden could indeed be the holy (green) grail for the data center industry and explore the benefits of setting up Swedish shop.

We also sit down with Node Pole CEO Christoffer Svanberg to find out the secrets to Swedish sustainability and what we can expect next from a sustainable standpoint.

"New industries are coming to life and growing fast. Sweden and the Nordics have competences, experience, energy and land with fantastic prerequisites for letting these industries and companies grow in Sweden. It is the home of the green industrial revolution, and it is happening as we speak!"
Christoffer Svanberg CEO
Node Pole

#BeMoreSweden

What do you get when you combine clean energy, low-cost electricity, and an enviable business climate? That would be Sweden.

It's no surprise that Sweden was recently named the best place in Europe for data center investments and (not to brag) but fourth best in the world (Arcadis Data Center Location Index 2021).

The pandemic saw an insatiable increase in Internet traffic, essentially acting as a catalyst to the shifting demand dynamics for data centers.

Whether we want to admit it or not, our newfound digital diet is what saw many of us through a highly uncertain, and for some, incredibly difficult period. There was a time when Netflix binges, scrolling social media, remote communication and working from home were the daily norm, and for many, this probably isn't far from the reality today.

Casting our minds back to the height of the chaos, it's no wonder that in 2020, 1.7MB of data was created every second, by every person. In fact, 90 percent of the world's data was created in the last two years alone.

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With this rather sobering figure, data center operators undoubtedly have an astronomical challenge on their hands. Being the backbone of the Internet is quite the undertaking, and despite data centers being a largely unsung hero of the pandemic, keeping the world as we know it moving, they've unsurprisingly garnered a bit of an unfair reputation as the big bad energy guzzling wolves of our time.

Data centers have very much been caught up in the climate crisis and as a result, the demand for sustainable solutions has skyrocketed. Customers want the facilities in which they place their data to be the perfect shade of proverbial green, and they want it yesterday. If operators can't meet that need, the customer will simply find someone or somewhere that can. And one place that certainly can, is Sweden.

Why Sweden?

There are several reasons to consider investing in Sweden. With an energy mix based on fossil free sources, a robust and highly redundant grid system (thanks to development across energy intensive industries), a CO2 footprint close to zero, and low energy prices, Sweden makes an excellent business case for long term competitive advantage, alongside environmental credibility.

Major investments in the region from industry giants Facebook, Google, Amazon and Microsoft are also helping close that highly publicised IT skills gap, providing good access to skilled labour and filling the region with the experience so desperately sought after elsewhere.

But trailblazing is something Sweden is used to. For the last 100 years, the country has reigned supreme as one of the most innovative economies in the world - with the likes of ABB, Ericsson, IKEA, Spotify and Klarna all starting here before going global.

A surplus of low-cost fossil free energy

Most notably, Sweden boasts some of the lowest energy prices in Europe and that doesn't look to change any time soon. A rich supply of moving water and biomass contributes to the country's high share of renewable energy, with hydropower (water) and bioenergy being Sweden's top fossil free sources.

Sweden's plentiful supply of bioenergy probably has something to do with the fact it is quite literally the land of trees, with 70 percent of the landscape blanketed in thick forest.

As for hydropower, hydroelectric power plants have been used in Sweden to generate electricity for over a century. These plants are safe and emission-free, producing fossil free electricity by running water through turbines. These plants supply almost 50 percent of Sweden's total energy needs.

And in a bid to 'make the most of what you've got', international energy company Uniper is expanding the scope of Sweden's hydropower, by investing in battery systems that can quickly support the electricity grid in the event of sudden fault or deviation.

Two of these new battery systems are set to be installed at the Bodum and Fjällsjö power plants in Jämtland, Sweden, with a total capacity of approximately 12 MW.

"Ultimately, as weather-dependent electricity production is expanded

across Sweden, the need to utilize hydropower's regulatory capacity also increases. With our battery system in Sweden, we can make better use of the flexibility of hydropower and thus increase the stability of the electricity system," says David Bryson, COO of Uniper.

And there's nothing like being prepared. Construction of the new systems began this October, in preparation for the batteries to be used during anticipated flooding in spring 2022, according to Johan Svenningsson, CEO of Uniper Sweden.

Svenningsson adds, "So far, the battery technology has shown great potential and our first operating season has more than met our expectations. Now we are anxious to continue the expansion."

And it's not only in Sweden that Uniper sees a market for the new battery system and plans broader implementation across Europe. But right now, with its stable electricity production and ability to regulate, hydropower (and the innovations that come with it) really has laid the foundation for Swedish welfare and competitiveness.

Hydrogen

Not to be confused with hydropower, hydrogen is also a key weapon in Sweden's sustainable arsenal. The country currently has a number of major industrial projects where the production and use of hydrogen is, or at least planned to be, central to one or more new value chains.

Several new initiatives and partnerships sprung up throughout 2020, with more expected in 2021/2022. Perhaps one of the most notable has been HYBRIT's investment in fossil-free steel, using hydrogen as a reduction agent, with the first delivery of 'green-steel' having now successfully made it to the first customer (Volvo Group.)

The long-term aim of HYBRIT is to transform Sweden's iron and steel industry by ending reliance on fossil fuels and reducing carbon dioxide emissions; as well as expanding its use of the technology to produce fossil-free steel on an industrial scale by 2026, which is good news for data center construction.

Low-cost electricity

Sweden has one of the lowest electricity prices in Europe, with northern Sweden boasting the lowest electricity price in the country, due to much of the energy production happening in the north. This makes the price in northern Sweden incredibly competitive on a global scale.

Low prices can be attributed to the mild winters Sweden has been experiencing (with 2020 Sweden's warmest year since records began 160 years ago), helping reduce electricity use, which in turn, lowers prices. This, combined with long periods of precipitation means reservoirs are filled to a high level, providing good conditions for that all important hydropower, that accounts for 50

'A rich supply of moving water and biomass contributes to the country's high share of renewable energy, with hydropower (water) and bioenergy being Sweden's top fossil free sources.'

percent of the country's electricity production.

On top of that, Sweden has been enjoying record wind power in recent years, which now represents over 17 percent of electricity production. Essentially, Sweden's supply of electricity can often exceed demand, which in turn pushes down prices.

But beware, there are caveats depending on where in the country you are. Southern Sweden doesn't have the same surplus as the north due to restrictions in the electricity grid. Most power is produced in northern and central Sweden, yet most consumption happens in the south; therefore, getting electricity from the north to the south does cause bottlenecks.

Faster time to market

Another one of the many advantages of Sweden, is the fact a large portion of potential data center sites are ready to build on, with permits already in place. And if you don't happen to have the relevant permit, authorities in Sweden want to work with companies rather than against them and once a permit is granted, it cannot be revoked without a valid reason. What's more, competitive land prices with Swedish currency are proving particularly attractive from the perspective of investment with dollars or euros.

Collaboration > competition

Although green credentials give companies, and in this case countries a competitive edge, none of it can be achieved without collaboration. Today, data centers account for around 2 percent of global emissions (as much as the entire aviation industry) and could rise to as much as 10 percent by 2030, so needless to say, this isn't a problem that can be tackled alone.

Sweden has always fostered a collaborative culture, which is probably why it has a lot of other countries beat when it comes to sustainability. While everyone else was busy competing amongst themselves, Sweden was busy laying the foundations needed to become the sustainability-conscious, connectivity powerhouse it is today.

In a joint op-ed that appeared in Dagens Nyheter (Sweden's most circulated morning newspaper) Member of European Parliament for Sweden, Fredrick Federly and former Node Pole CEO, Patrik Ohlund, pushed for the importance of transparency and climate labelling for digital services, and together urged Swedish lawmakers to be a driving force for the EU to adopt tougher legislation. Further testament to the collaborative culture associated with the region.

Investment and input from the top

Sweden is highly connected, serving as a hub with multiple sea cables, as well as excellent fiber networks throughout the country, which can be largely attributed to the government's enthusiasm for high-speed investment.

In fact, Swedish government strategy has delivered high speed fiber capacity to all residents and businesses, with almost 100 percent of homes enjoying access to 100Mbit/s or more.

Earlier this year, GlobalConnect - the single largest investor in the Swedish fiber market – announced its intention to invest in a new digital motorway from Berlin to the north of Sweden. This new network will handle a capacity of around 3,052 tpb (terabits per second) - enough bandwidth for 610 million Netflix users.

"It is the single largest digital infrastructure investment in Sweden in ten years and means that Sweden will be able to continue to attract the global tech giants, as digital infrastructure is a key prerequisite for continued establishment," says Regina Donato Dahlström, CEO of GlobalConnect Sweden.

Christoffer Svanberg, CEO of Node Pole echoes these sentiments saying, "We welcome this initiative to strengthen Sweden's position as a location for digital and sustainable investments. We also agree with GlobalConnect that we need these types of infrastructure improvements to continue to make Sweden more attractive to large companies that want to establish here."

Overall, it is predicted that during 2021-2026, over $7 billion USD will be invested in core and shell development of data centers across Sweden. And it's not just data centers. Vinnova, the Swedish Governmental Agency for Innovation Systems, has invested in eight data labs to accelerate AI development in Sweden by targeting AI innovations in healthcare, smart city, transportation, real estate, and other sectors.

So, in a land thick with forest, where electricity is cheap and proverbial unicorns roam free (Sweden plays host to multiple privately held start-up companies valued over $1bn) maybe now is the time to #BeMoreSweden.

Interview: Node Pole's Christoffer Svanberg

DCD sat down with Node Pole CEO Christoffer Svanberg to find out why the green industrial revolution starts with Sweden

First thing's first, congratulations on your role as CEO. Since taking on this position, what have been your key focuses for Node Pole with regards to sustainability?

Thank you! Well, a few years ago our focus was on enlightening companies and people about the importance of having sustainability at the core of your strategy. Now thankfully that work is done, so now my key focus is creating more opportunities in Sweden for more industrial developments, projects, and investments.

Do you find more and more customers are now aware of sustainability and are asking more questions? Do you find Swedish/ Nordic customers expect more in this area?

The awareness is much higher, but there is still work to be done, especially with companies from Asia I'd say. I think most companies want to address the CO2 emissions but struggle a little bit with how to achieve that. Overall, Nordic companies have these issues closer to heart. Energy is what we encounter when it comes to questions around sustainability.

The amount of data we are producing is snowballing, driving data center demand. How important would you say the placement/location of these data centers is, for companies to stand a sustainable chance?

For the next 10 years it is absolutely crucial. Even with investments going on in energy production globally this is a slow process, and the energy mix in most markets is just terrible. Although some markets have incoming initiatives from the EU and Biden administration, I think the focus should be on low carbon emission markets such as the Nordics for the foreseeable future.

Despite the FLAP market being anything but famed for its green credentials, why do you think some operators refuse to let go of these regions?

Well so far new data centers want to be where the larger hubs are, and this is connected to the grid of fiber cables. It's not surprising that Amsterdam is a big hub with Atlantic energy cables coming in, similar to Virginia in the US. But I believe the market/customers will punish companies who don't go down the sustainability route and get rid of their CO2 emissions. A large part of this will involve relocating to markets with green energy.

Our CO2 emissions are close to zero, whereas Germany is at over 400 g per kWh. So there is a massive difference between the two countries

What sets Sweden apart from the rest of the world in terms of sustainability? Why should we all aim to 'be more Sweden'?

I think it is twofold, for one it is rooted in our Nordic region, among the people living here and the way our countries operate. We have sustainability ingrained into our way of living, everyone recycles and are keen to preserve nature. It is easy to be sustainable here, our entire system is based upon it and it shows in our numbers. Our CO2 emissions are close to zero, whereas Germany is at over 400 g per kWh. So there is a massive difference between the two countries.

Without rules and regulations, the world would probably descend into chaos. How important do you think regulation is to achieving sustainability?

The EU has made it clear that they will lower emissions so I'm just waiting to see what tools they will use. But I think there will be both penalties and incentives. No doubt there will be changes in the marketplace though.

I read a quote from yourself that said, 'Node Pole is enabling a new industrial era in Sweden, and we have excellent opportunities.' Would you be able to elaborate on this new industrial era, and what

those opportunities are? Are these opportunities potentially available to all?

Well digitalization, electrification, de-carbonization and the climate challenge are all very strong global trends that mean existing industries need to change and transform (e.g. steel) and develop as businesses.

New industries are coming to life and growing fast. Sweden and the Nordics have competences, experience, energy, land etc. with fantastic prerequisites for letting these industries and companies grow in Sweden. It is the home of the green industrial revolution, and it is happening as we speak! It is very inspiring to see how Sweden will continue to be a prosperous industrial nation for many years to come. Sweden is leading the way.

One opportunity that isn't available to all, is hydrogen, which is a huge part of the EU's plan for achieving net zero by 2050. That said, there is currently an argument as to whether hydrogen should even be classed as 'renewable' due to the fact not everyone can access it. What is your view on that?

I think it all comes down to how the hydrogen is produced. If it is produced in a sustainable way, then it should be classified as green/renewable. If it is produced using fossil fuels, you have not achieved anything in this area.

The future of the North of Sweden is bright and has a vital role to play in ensuring a sustainable data center industry in Europe

We then have the argument of "fossil free" vs renewable energy. How should we be using/classifying things like nuclear in your opinion? What is Sweden's stance on nuclear power?

I believe that nuclear has to be a part of the overall solution to energy production to combat the climate challenge. We have to get rid of burning coal and fossil fuels. Renewables are of course very important, but fossil-free is almost more important right now, which nuclear is. So for now, it's better to use the nuclear power that we have, than burning coal. Sweden has a good nuclear sector and will keep it as long as it is necessary.

With northern Sweden being plugged as a sustainable safe haven, boasting some of the world's lowest electricity prices with a virtually nonexistent carbon footprint, is there potential for an influx of data center operators vying for a place in the region? Could this put a strain on Sweden's grid?

The future of the North of Sweden is bright and has a vital role to play in ensuring a sustainable data center industry in Europe. It will put a strain on the energy grid for sure, but not more than anywhere else. As in most countries, this will be an issue, but Sweden has better pre-conditions to deal with it due to our long history of energy intensive industries since the 19th century.

Which sustainable strategies for the data center have you seen stick, or have proved to be most implemented across the board? Or equally, have there been any you have seen fail? There has been a fair amount of trial and error.

For a data center, it is all about sourcing green energy to have a sustainable data center. energy production accounts for 80 percent of data center emissions, so if this isn't green energy, the data center simply can't be green.

Finally, in your opinion, what's next for sustainability in Sweden and the rest of the world at large?

For Sweden, continued investment in the energy grid will be crucial. And for the rest of the world – stop burning fossil fuels.

Driving decarbonization

As one of the lowest emitters of CO2 in the world, the rest of us could learn a thing or two from the – natively named – 'elongated country'

With a new net-zero target of 2045 - extending beyond its international obligations - Sweden's climate policy is clearly delivering results. This is predominantly due to long-term policies to move away from fossil fuels and improve energy efficiency.

Sweden has historically used both energy and CO2 taxes to stimulate efficient energy consumption and low-carbon energy supply. As the first country to introduce the carbon tax back in 1991, the Swedish public broadly accepted the tax, and still do, testament to how seriously the country takes, and has always taken, sustainability.

Sustainability is ingrained into Swedish culture, everyone recycles, wants to take care of nature, and as a result they produced Greta Thunberg, alongside many other environmentally conscious Swedish citizens.

As of April 2021, Sweden had the highest carbon tax rate worldwide, at 137 US dollars per metric ton of CO2 equivalent. The strong CO2 taxation in the country has been a highly successful driver for decarbonization across many sectors.

The IEA (The International Energy Association) - of which Sweden has been a member country since 1974 - has suggested that the taxation should be utilized further, and that tax reductions and exemptions should be regularly reviewed to enable different industries to further cost-effective CO2 mitigation.

A (climate) conscious effort

The majority of Sweden's electricity comes from hydropower (45 percent) and nuclear (30 percent) with a growing contribution from wind power (17 percent) and heating supplied mainly via bioenergy-based district heating and pumps (8 percent).

That said, Sweden's emissions stem primarily from the transport sector, which despite having moved away from the use of oil in residential and commercial sectors, and substantially reducing its use in industry, is something transport is still heavily reliant on. But the government is making a conscious effort to improve matters, and has set a target to reduce transport emissions by 70 percent from 2010 to 2030, investing in electrification and advanced biofuels to

Sweden plans to use hydrogen in many large industrial investments, to produce everything from fossil-free steel, to e-methanol fuel for shipping

support transport decarbonization.

The country is also strongly advocating for industrial decarbonization and is already home to one of the first major projects for hydrogen based steel production, which, for the purposes of this eBook, is a positive step for more sustainable data center construction.

But why is Sweden pioneering fossil-free steel? Mainly because it can, and because if the steel industry was a nation, it'd be the fifth largest carbon emitter in the world.

Sweden has a long and prominent history of mining and steel making, with SSAB already boasting the most effective steel mill in the world. Swedish steel companies have long been at the forefront of innovation and effectiveness in the industry and this is a natural next step.

And let's not forget location. Swedish steel industry giants the likes of SSAB and LKAB are already located in northern Sweden, with access to fossil-free energy, a very unique resource that not many other steel making companies have access to, especially not where most are situated today.

The fossil-free steel making process is still of course highly energy intensive, therefore the competitively priced energy mentioned earlier in this eBook means fossil-free steel can be made at an attractive price, and cheap energy is certainly a dealbreaker.

Carbon criminals

Upon writing, the latest available figures showed that Sweden is currently producing 13 grams of CO2/kWh. Being an island you've of course got Iceland coming in at a smug 0g of CO2/kWh and Norway, at 8g of CO2/kWh, but it's all in the name of saving the planet, which we must remember is ultimately a collaboration, not a competition.

But whilst it's not a competition, it is worth calling out those that aren't doing so well. Quite frankly they don't even seem to be trying. From Sweden's 13g per kWh, we then see a substantial and rather dramatic leap to our not so distant neighbours Germany, who are kicking out 412g of CO2/kWh; the Czech Republic at 505g of CO2/kWh and Poland, emitting a whopping 707g of CO2/kWh.

Farther East, the situation worsens, with China emitting more carbon than the entire developed world combined, closely followed by the US and India. The lack of presence from Chinese president Xi Jinping at the recent COP26 event has even had analysts and activists weighing in on what this absence could mean for China's climate pledges.

Headed for hydrogen

We've established that Sweden is doing pretty well in the carbon emission stakes, but it wants to do better. There is always room for improvement, so to reduce emissions further, Swedish multinational power company Vattenfall and German-based Uniper have been key instigators for the use of hydrogen. Although it's good to see a German based company help lead the charge, given the scale of the country's carbon emissions.

In recent years, hydrogen has emerged as one of the most important pieces of the climate change puzzle. As mentioned earlier, Sweden plans to use hydrogen in many large industrial investments, to produce everything from fossil-free steel, to e-methanol fuel for shipping. This is part of a larger international trend and many countries are now expanding their hydrogen investments.

Sweden is perfectly positioned to benefit from the hydrogen hype, but these plans could well be slowed down by a lack of regulation. In order for Swedish companies not to lag behind global competition, a robust, regulatory framework is required as to how hydrogen will be transported and handled. Today's regulations aren't yet complete, which could risk slowing down Sweden's progress.

During a recent seminar at Arena Energi, Energiföretagen presented a timeline with a number of suggestions as to what needs to be done, by whom and when, in order to benefit hydrogen.

These proposals have also been incorporated into the national hydrogen strategy that the Swedish Energy Agency presented in November 2021.

Among other things, the Swedish Civil Contingencies Agency (MSB) has been called upon to create regulations for national safety requirements for hydrogen and hydrogen pipelines, and that the Swedish government should work in the EU to prevent direct connection to fossil-free electricity production.

This will be the starting point for urgent work among ministries and authorities to get the necessary regulations for hydrogen in place. And when it comes to sustainability Sweden isn't a country to rest on its laurels. From its citizens, to government authorities, to key players in industry, Sweden has been coming together in the name of sustainability long before most of us even bothered to recycle.

The country is an environmental pioneer, whose efforts are positively impacting a wide and ever-growing range of industries. Hopefully this climate-conscious culture will have more geographies following suit, and ultimately, help rebuild the data center's reputation from an enemy of the environment, to a sustainable necessity for modern life.

Holistic cooling at the world's most efficient data center

After an EU-funded project built a data center with a PUE of 1.0148 (in Sweden of course) can that be translated to the rest of the world?

In early 2019, a small group of researchers launched an ambitious project that they hoped would change how data centers are built and regulated.

The idea? Build the world's most efficient data center. In just a few years, they would hit that milestone, developing a system with a power usage effectiveness (PUE) of just 1.0148.

It didn't begin that way.

"We always wanted to have a showroom to highlight how our power is very clean here, and free of disturbances," the director of the Boden Business Agency, Nils Lindh, explained.

"Our view was that you don't need any backup power or Uninterruptible Power Supply (UPS)-type function here."

Swedish municipality Boden, already home to a number of data centers, envisioned a small deployment on municipal land, simply for the purpose of showing off its ample supplies of green power power, primarily provided by a hydroelectric dam.

To develop the project, the BBA turned to UK firm EcoCooling and Hungarian developer H1 Systems, both of whom had previously worked in Boden.

"And then as we conceptualized this idea and started talking to investment advisors, one of them pointed out this Horizon 2020 program," H1's then-general director László Kozma explained. Horizon 2020 was a huge €60 billion European Union research program that ran from 2014 and 2020. Nestled amongst its many tenders, Kozma found that the EU was looking to build a data center with a PUE of below 1.1.

"I knew that a Hungarian company has only a two to three percent probability of being selected," Kozma recalled. "But this might be that two percent – and we already had a good start with an international consortium: a British cooling manufacturer, a Swedish municipality agency, and a Hungarian small / medium enterprise."

It was time to expand the plan from beyond a simple showroom, to "something a lot more serious," he said. The group brought in the Research Institute of Sweden (RISE), based in the nearby city of Luleå – which was already home to a huge Facebook data center - to boost its pitch deck, and help with the project.

"And after that, we went back to this project advisor at Horizon who said that there was one thing still missing – a big European name," Kozma said. "There's this unofficial list of 25 research institutions whom you have to take into your consortium to raise the probability of your winning."

It was well known that the larger economies got most of the Horizon 2020 money – science magazine Nature found that 40 percent of the program cash went to Germany, France, and the UK.

The group turned to the Fraunhofer Institute as the final member of the team, and Lindh concedes that political machinations were at play, "Germany being the largest contributor to the European Union, we thought it would be good

"Putting an air-cooled data center in the north of Sweden, you have tons of fresh cold air. Obviously we took advantage of our geographical location, but we also took advantage of the fact that we had control"
László Kozma, former general director, H1

BTDC hoped to prove just how efficient data centers could be if they put efficiency at the forefront of design, and to create a more open approach to holistic cooling, by putting the work in the public domain

to have a German research institute involved," he said.

It worked. In October 2017, the group was awarded a €6 million contract titled 'Bringing to market more energy efficient and integrated data centers.' "That was the title they gave us, and it's what it would have been if we wrote it," Kozma said. "Our idea and the European Commission's idea just fitted 100 percent.

Now, the group had just 36 months to pull it off.

As the BBA began work on permitting, H1 drafted data center designs, and EcoCooling conceptualized cooling methods, the Fraunhofer Institute had one year to develop a system for synthetic workloads.

"Our responsibility in the project was to design a benchmark to emulate real world applications," Fraunhofer's head of Modeling and Networking Reinhard Herzog said. "And based on that benchmark, we tried to evaluate if the cooling policies work under the noisy behaviour of real world applications, not just the stable artificial synthetic workloads that we used as tools."

Based on their work building smart city tools for Hamburg, the Fraunhofer Institute created a set of workloads that "resembled a smart city application with a lot of sensor data flowing in and some stream processing, and then evaluation dashboard application workloads," Herzog said. "And the other scenario we modelled was for predictive maintenance applications."

Both were scaled up to the data center level, and designed so that the researchers could run the same workloads again and again as they tested out different cooling configurations.

"So, after all this preparation phase, it was six or seven months of building," H1's Kozma recalls. "The building was inaugurated in the first months of 2019. I remember it was cold."

DCD visited the facility at the time, with our very own Max Smolaks making similar observations on the unusually frigid temperatures at the time.

"What we are doing with this project is we are creating a very efficient, and therefore low cost, operating system. This is going to enable the little guys," Alan Beresford, EcoCooling MD, told us at the time. "By little, I mean truly small operators, compared to the world of multi-gigawatt operators: less than 100kW."

Indeed, the Boden Type Data Center One (BTDC) was quite small – a 500kW deployment consisting

Sweden provided not just cold temperatures, but also ample green energy, with a surety of stable supply.

of four modular pods. One was filled with Open Compute Project CPU servers gifted to RISE by Facebook, one filled with GPUs for rendering, and another bursting with crypto mining ASICs, with the fourth left as a control room.

In each of these pods, the team tried out its own approach to fighting heat: holistic cooling.

"We were able to take control of the fans in the servers and slow them down," Professor Jon Summers, RISE scientific leader in data centers, said. "And we synchronize the IT fans with the cooler fans."

Controlling the whole data center as a single system, the cooling was architected around keeping chips at a constant temperature, no matter the workload level. "There's a controller on the server that would constantly change the fan speed so that the CPU temperature was 60 degrees," Summers said.

"And as the fan's speed changed it would send that information to an algorithm which would then tell the cooler what speeds it needs to operate at to match the fan speeds of all these servers so that you get a neutral pressure."

"It becomes a very well-balanced system, but you need the communication between the various layers."

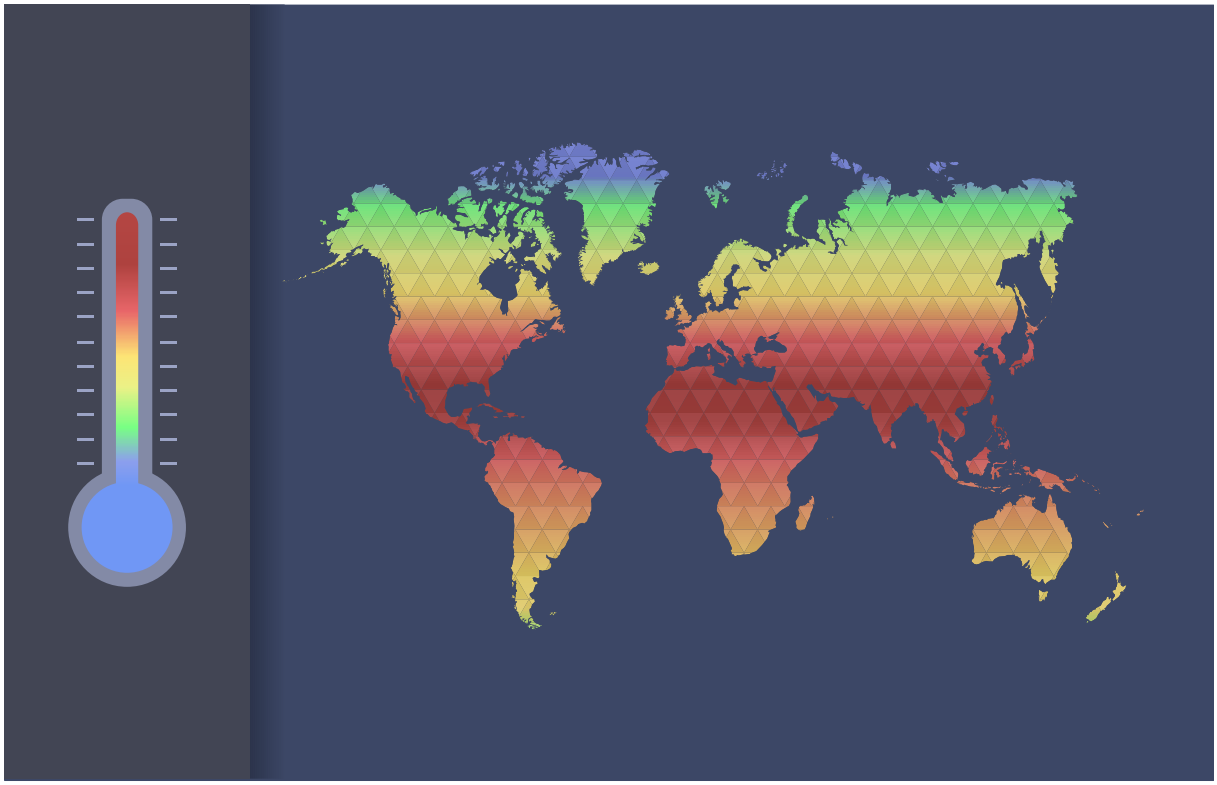
This proved remarkably effective at eking out efficiency gains, as the whole data center's cooling system worked in unison, rather than different aisles and servers fighting each other.

"We achieved a PUE of 1.0148," Summers said. "Yes, insane."

The data center building was also designed for efficiency, dropping the plenum for a design akin to a chicken coop, allowing for a natural chimney effect (also known as the stack effect, where differences in air density leads to air buoyancy). "Did we know in advance we'd reach that PUE?" Kozma said. "No, at the beginning of the project, most of the people in our team thought we could reach 1.07-1.08.

By turning to holistic cooling, dropping the UPS, using a different design, and several other features, it's hard to directly say just how big a part each innovation played in achieving a PUE record. "To answer that, I should have built a kind of a normal building next to this and measured them against each other," Kozma said – but they only had a budget for the one system.

The location also provided advantages. "The directive from the EU was to go for the lowest PUE possible," Summers said.



"Putting an air-cooled data center in the north of Sweden, you have tons of fresh cold air," although he added there were some challenges of dealing with the air when it was well below freezing.

Sweden provided not just cold temperatures, but also ample green energy, with a surety of stable supplies.

"Obviously we took advantage of our geographical location, but we also took advantage of the fact that we had control," Summers said. "We went for the lowest inlet temperature we could possibly get away with, 15°C (59°F), which is easily achievable 312.5 days of the year."

H1 built a simulation to test out whether the BTDC would be feasible in other locations, using historical climatic data on six European cities. The data center could remain within American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) conditions for five of the cities, but in Athens it would slightly step out of the boundaries "two or three percent of the hours in a year," Kozma said. "Of course, the climate is changing, and we used historical data," he cautioned.

There's also the issue that removing the UPS – responsible for a couple of points of PUE efficiency – is just not feasible for many locales. Unlike Sweden, they may not have as reliable grids.

Still, "the experiment worked," Summers said. "Slowing fans that didn't need to be spinning allowed us to achieve a much better PUE."

One issue with the result is PUE itself. "I'm very critical of PUE," Summers said. "It's not a metric that you would use to describe the energy efficiency of a data center in its entirety."

PUE is the ratio of the total amount of energy used by a data center, to the energy delivered to computing equipment.

Therefore, it does not penalize you for using inefficient IT hardware – you could run a 200MW IT deployment capable of a single petaflops (10^15 floating point operations per second) of compute that could have a lower PUE than a 2MW deployment capable of 10 petaflops.

"The problem is that we didn't have another metric that we use to represent that," Summers said. "Although the EU Commission was interested in us exploring other metrics, or maybe coming up with a metric ourselves, there is no simpler metric than PUE, unfortunately."

The issue of PUE continues to exercise the data center sector in Europe. The EU has pledged to reach continental carbon neutrality by 2050, and the data center sector has promised to help, by reaching the goal by 2030, in a Climate Neutral Data Centre Pact. However, to convince the EU of its bona fides, the Pact has promised to create a new metric which will improve on PUE.

With all of PUE's flaws, it's still one of the few ways we have of measuring efficiency. At an annual PUE of 1.0148, BTDC outperformed every other facility in the world – including the previous frontrunner, the US National Renewable Energy Laboratory's Energy Systems Integration Facility, which reached 1.032 in 2017.

Most of the commercial world is well short of this mark, but hyperscalers like Google and Facebook boast PUEs of 1.10 or less (in cooler countries), thanks to huge investments in energy efficiency, and some economies of scale.

It's possible that hyperscalers may use some form of holistic cooling.

"We found out that they know what they're doing with cooling at Facebook, but they haven't told the world about it," Summers said.

Instead, BTDC hoped to prove just how efficient data centers could be if they put efficiency at the forefront of design, and to create a more open approach to holistic cooling, by putting the work in the public domain.

The project may also pressure server manufacturers to open up fan controls, and could also help European regulators which – despite the work of the Pact – still looks ready to crack down on this energy-hungry industry.

One hurdle to applying the work is that holistic cooling is not feasible for colocation data centers, where servers are owned by tenants, who will not hand over control to the colo owner. Colos simply cannot control every fan of every server in every rack.

Still, the project is finding life in enterprise data centers used by single clients.

EcoCooling "uses holistic cooling control in all its deployments now," Summers said. "I think that their customers are seeing the value in that immediately."

For H1, there has also been some demand. "There was a Bulgarian company who wanted what was built in Sweden," Kozma said. "For a small Hungarian company, it didn't make sense to go to Bulgaria to build, so we helped them to design it and after that a local company will build it. Another will be built in Norway with the same idea."

Fraunhofer, too, plans to commercialize the work. "The tool itself is open source," Herzog said. "But we're using it to make studies on the scalability of our applications, and on behalf of cities when they are trying to design what kind of application they need to rent from data centers."

As for Boden Type One, it's still there. Instead of knocking it down, asset owners H1 and EcoCooling sold the project. It's now set to be expanded and used as one of Europe's largest visual effects rendering farms.

Innovation on ICE

Being a major data center destination, Sweden has a unique research establishment – the Infrastructure and Cloud Research & Test environment (ICE) – pushing energy efficiency forward

Two years ago, Sweden was placed top in the European Innovation Scoreboard by the EU Commission. This vindicated years of educational policy, and reflected a national willingness, both public and private, to invest in research and innovation, creating partnerships joining academia and enterprise to drive the country's economy forward.

Sweden also harbors the perfect conditions for building the energy-greedy, monolithic structures that process the reams of data that keep the world's digital wheels turning. But even perfect conditions won't quash a data center's appetite for power.

By researching how to make these facilities more energy-efficient, Sweden's climate contribution can do more than simply house energy intensive data centers with a low carbon electricity supply within its own geography, but have a positive effect beyond Swedish borders too.

Entering a new era

Thus, it is unsurprising that a publicly funded Swedish research institute in Luleå – both an industrial and an academic hub, the location of two of Facebook's hyperscale facilities and the second biggest contributor to the country's GDP – is combining these two fields of expertise, having launched a fully functioning data center devoted entirely to research and development of new cloud and infrastructure technologies.

RISE SICS North, a subsidiary of applied information and communication technology research institute, was launched specifically to allow Europe's academic institutions and businesses to take on data center related projects in a simulated environment.

The institute's data center, the SICS Infrastructure and Cloud Research & Test environment (ICE), was built as a sort of innovation incubator, to boost European capability within the data center industry.

The initiative is based on the premise that the world is set to enter a new era, with compute power in huge demand. To enable this, the data center industry must build on existing knowledge to develop elaborate, software-controlled IoT systems, capable of operating autonomously while leveraging machine learning to its full potential.

Projects currently underway seek to improve knowledge in the fields of data center automation, air-flow technologies, "industrial symbiosis," as Minde calls it, or micro-grid integration, data collection and monitoring, and machine learning for the data center

The head of research for Ericsson, Tor Björn Minde, is the project's CEO. He told us that ICE was launched to attract companies and projects to the area around Luleå, a rapidly growing hub for data traffic and high-end data center hosting. "This will enable sustainable competence development," he said. "New innovations and skilled people are needed to develop the Swedish economy."

Up from only three staff members in January last year, the facility now operates with twelve people, he said, "and we have a €2.3 million ($2.84m) annual turnaround."

Funding comes from all directions: "From companies – Vattenfall, ABB, Ericsson, Facebook. We get regional and national subsidies, and we have one EU project at the moment as well."

A playground for the industry

The 600 square meter facility is a gift that just keeps giving; all manner of experiments and novel equipment fill the room, such as a liquid cooling tank designed and built in-house, a miniature network operations center to test out DCIM systems, and an ABB microgrid controller.

The research data center's first room-in-room module came online in February 2016, based on Dell SmartEdge Rx730xd servers with GPU acceleration and both OpenStack and Hadoop storage.

Then in May 2017, a second, more flexible "lab-like" module was launched, with more power and faster networking connections than its

predecessor, and this time equipped with a combination of Dell and OCP v2 servers, standing on raised floors and partitioned using industrial PVC curtains.

The latter, Minde tells us, like everything else in there, is something they are testing out. Another setup, more experimental still, will be an OCP lab, fitted with edge PDUs; though for now, only a switchboard has been installed.

Another object of study was brought to the lab by Jon Summers, a senior lecturer at the UK's University of Leeds, also RISE SICS North's scientific leader and an expert in computational fluid dynamics (CFD) and energy efficient cooling systems: a glass box the size of a room, designed by DigiPlex, which is in fact a small, contained wind tunnel for airflow experiments.

Researchers are also exploring the possibility of using chimneys to create drafts powerful enough to act as fans in HVAC systems, in the form of four retrofitted 19-inch racks containing OCP servers, placed in a cross to allow for a chimney in the center.

Soon, Minde tells us, the site will have its own solar panels, a thermal storage bank and a heat pump for waste heat reuse.

Throughout the facility, networking operations are monitored by Zabbix 3.0 open source software, and additional sensors have been placed on PDUs, power switches, servers, network switches, UPS systems, coolers, power meters, thermometers and corrosion sensors, collecting between nine and ten gigabytes a day from 30,000 measurement points per module. The data is then fed to a Hadoop cluster using Apache Kafka processing software.

Projects currently underway seek to improve knowledge in the fields of data center automation, air-flow technologies, "industrial symbiosis," as Minde calls it, or micro-grid integration, data collection and monitoring, and machine learning for the data center.

The study of "Artificial Intelligence for Data Center Microgrid Interaction," funded by the Swedish Energy Research Centre, looks at the possible applications, as well as the pros and cons, of integrating AI into a single controllable entity that would link a microgrid with a data center, in view of making it possible to take temperature, solar radiation, electricity cost and workload forecasts into account when operating an edge module.

"DC2BD" is a heat reuse project backed by Forest Developing Technologies and Future Eco, which is exploring the possibilities of using heat from data centers to dry biomass.

More widely, it seeks to demonstrate that creating a circular economy, where a data center would help create bio-coal or biofuel, and generate heat as part of a district heating system, for instance, is possible.

The facility is also the basis for a data analytics project called D-ICE, a platform that enables data owners and data scientists to share information – the former gaining from in-depth analysis of their data using new tools, and the latter obtaining access to the reams of information necessary to test out new methods.

The 60 plus companies participating in projects (although, Minde tells us, approximately 40 are actively involved) are continuously invited to see the research institute and improve their own efficiency and sustainability practices, while contributing to the wider European market.

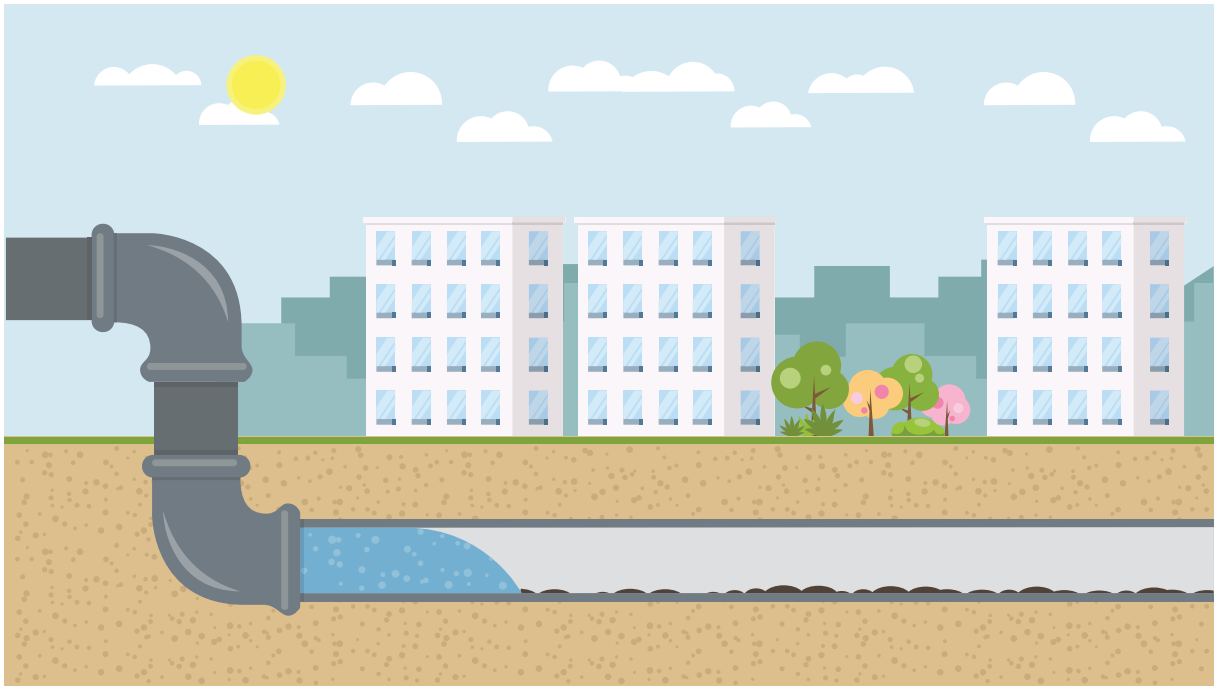
Cyclic innovation

For Minde, innovation goes in cycles, from the bottom, through the hardware stack, up the software layers, in alternating phases.

Explaining the purpose of the institute, he said, "We [at RISE SICS North] improve on the foundation stuff; maybe now we're going into a new hardware cycle; we have a lot of new innovations in the hardware side, there's a lot of interest in the new types of hardware, and then the software will innovate on top of that. We at SICS are an integral part of that development."

Sharing warmth the Nordic way

We head to Sweden to watch data turn into pellets



Heat means different things to different people. To a data center operator, it is the enemy, a problem to be overcome and removed as quickly as possible. But to a family in the middle of a fierce winter, heat is a friend, a vital source of life.

There are some who hope to turn that dichotomy to good use, and harness the waste heat produced by data centers. DCD visited a campus in Sweden which is doing just that.

"When we started, it was all about reusing heat in the district heating system," Jan Fahlén, EcoDataCenter site development manager, told DCD.

Heating up

Located in the small city of Falun, the company's eponymous Swedish campus hopes to use its heat for a variety of purposes. "We have expanded our plans so that we can use it in wood pellet production. In the future – depending on the location – we have thought about greenhouses and fish farms."

EcoDataCenter has installed large underground pipes that carry hot water to the combined heat and power (CHP) generating plant next door, run by Falu Energi & Vatten.

The CHP facility, which provides heat for both Falun and nearby Borlänge, also produces wood pellets that are sold across the country for heating. Standing in front of a mountainous pile of sawdust, Falu Energi's sustainable development engineer Lars Runevad explained: "So we put the sawdust on six meter-wide mats, and blow hot air over it."

Sawdust comes to the plant with 50-55 percent moisture content, but needs to leave it with no more than 10 percent. "Otherwise we can't produce wood pellets that will last and it will start to degrade and mold," Runevald said.

Currently, the CHP uses its own heat from burning residual wood and biomass in two giant 30MW boilers. But, during the winter months, all that heat has to be used for the city, so pellet production shifts to using

propane gas, and when it gets too cold it shuts down entirely.

"Now, with a data center nearby, we can prolong the season," Runevald said. "We can produce more wood pellets than we would otherwise have been able to."

Starting at B

B1, the first data center hall on the EcoDataCenter campus, will send up to 10MW of waste heat to dry pellets. As it consumes electricity from renewable sources, EcoDataCenter bills itself as not just climate neutral, but as 'climate positive.'

"I think that sustainability will be a requirement for customers moving forward," CEO Lars Schedin told DCD. But with one hall built and barely occupied, most of the company's plans are still up in the air – pending major customer contracts.

During our tour earlier this year, we counted just a handful of operational racks in the 800 square meters (8,611 sq ft) of space in B1. "That hall was opportunistic in its nature," site manager Dan Andersson said. Follow up halls "B2-3 and the rest of this site will be business-driven."

The wooden skeleton of B2 looms large over the site, looking odd to those not used to seeing wooden frames – but it's a relatively common approach in Sweden.

"We use cross-laminated glulam wood for two reasons," Fahlén said. "The first is sustainability, we don't use as much carbon dioxide as with concrete. The other reason is really for fire protection.

"You will ask me, why, wood burns?," Fahlén preempted. "Yeah, it does, but laminated wood doesn't burn that way – try to put fire on this, you won't be able to."

Using wood can also be quicker to deploy, and a wooden ceiling makes it easier to hang things from, he claimed. B1 is still covered in steel plates, however, to get a higher security rating, something they do not plan with B2-3.

Keeping secure

"In Sweden, we thought eternal peace came at the end of the '90s," Andersson said. Standing to attention with the alert posture of a two-decade military veteran, he went on:

"Now we realize that this isn't the fact, so the government is putting a lot of pressure on the state departments, on the regional department, and on municipalities. They have to step up to have more resilience - this includes data centers."

Having a high state security rating allows EcoDataCenter to offer space to government departments, while other businesses have asked it to get ISO certifications and meet the EN5600 standard. CEO Schedin said that there is currently no demand to get an Uptime certified tier rating, but claims B1 meets Tier IV specifications, while B2-3 may be Tier III.

Work is underway on the second hall, but "we won't fully build B2 until we have a customer," Fahlén said. "That way we can have a choice if we like high-performance computing (HPC) or colocation or wholesale."

The company is in talks with a large potential customer for a 30MW wholesale deal, Fahlén said, but that could fall through. After acquiring Fortlax in June 2019 and its two facilities in Piteå, northern Sweden, EcoDataCenter is also trying to convince Fortlax's clients to buy space in Falun.

"The largest customer in Fortlax is the automotive company BMW," Schedin said. "That kind of core manufacturing industry is currently a big user of high-density capacity, a market segment that is growing quite rapidly.

"In two years' time, you will have a lot of companies in the automotive industry looking for 2-3MW of capacity."

Andersson added: "BMW will come to Falun and look at what we've got – the needs they have are greater than the capacity we have left up in Piteå."

Schedin hopes that once a large anchor tenant like BMW is found, it will lead to others quickly following, but the company can't wait until that happens, he said: "We have to have an extreme pace."

Looking for an anchor

Beyond Falun, EcoDataCenter has ambitions in the surrounding Dalarna County: "Our goal is to have something in the area of 500MW across three or four sites," development manager Fahlén said.

"It's already out. We have an MoU for a place just 50 kilometers from here in Smedjebacken, for 150MW."

The company hopes to dub the region 'Dala Quincy' after the small US settlement. "Quincy is just this little town in Washington state with numerous data centers," Fahlén said. "It's our model."

Eyeing locations near dwindling steel and paper mills that are steadily reducing their power loads, EcoDataCenter hopes to acquire and build facilities in the Nordic area, and may even venture further out into the wider FLAP market – the region including Frankfurt, London, Amsterdam, and Paris.

Backed with SEK1 billion (US$105m) from REIT Areim, its priority is to find places "where the heat could also be reused," Schedin said. "Our main target is always to reuse the heat."

EcoDataCenter has installed large underground pipes that carry hot water to the combined heat and power (CHP) generating plant next door, run by Falu Energi & Vatten

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