REALISING SUSTAINABLE COMPUTE CAPACITY FOR DAILY DIGITAL APPLICATIONS

In today's business world, integrating ESG criteria is no longer a choice but an obligation. Sustainability is particularly relevant for the data centre industry which is characterised by a high power consumption.

Globally, only few data centres have a comprehensive sustainability approach. In contrast, AQ Compute currently develops its high-performance computing (HPC) data centre in Norway, integrating various innovative concepts to combine energy and cost efficiency with significant CO_2-equivalent (CO_2e) reductions. AQ Compute is part of Aquila Capital, an investment and asset development company focused on generating and managing essential assets in clean energy and sustainable infra-structure. The company manages several wind farms and the largest portfolio of small hydro power plants in Norway. Given the strong local footprint, the first location for AQ Compute's venture was a conscious decision.

Aquila Capitals's renewables portfolio in Norway not only offers direct access to local green energy, but also allows AQ Compute's clients to sign power purchase agreements (PPAs), ensuring that the contracted power is sourced from renewable sources. It is also part of AQ Compute's holistic approach to sustainability which, apart from using renewable energy, foresees to integrate high-efficiency cooling technologies and enables the reuse of waste heat, actively reducing the data centre's ecological footprint.

In order to quantify the CO_2e emissions that AQ Compute's data centres save compared to conventional ones, a customised CO_2e calculator has been established by AQ Compute[1]. This tool compares the carbon footprint of AQ Compute's data centre ("NO-DC1") near Oslo to data centres in eleven other European countries.

The CO_2e calculator is a decision-making tool. It enables companies to calculate how many CO_2e emissions can be reduced by either moving hardware from legacy on-premises data centres to a colocation data centre or by deploying newly acquired hardware in Norway.

The calculator focuses on direct and indirect CO_2e emissions of the power supply and does not take into account other indirect emissions associated to the building, the operation or the management of the data centre. The CO_2e emissions have been determined by incorporating the following three main emission drivers:

A) Emissions associated with the electricity consumption from the power grid

B) Emissions associated with the fuel consumption of the power back-up generators

C) Emissions avoided by reusing the waste heat

The following sections describe the impact that the three drivers have on CO_2e emissions.

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1) AQ Compute's calculator: https://aq-compute.com/#calculator

A) Emissions associated with electricity consumption from the power grid

The first factor depends on two aspects: the emissions factor related to the power grid's electricity mix and the data centre's electricity consumption.

a) The emissions factor of the power grid

The electricity mix across European countries deviates considerably in terms of energy generation from fossil fuels and renewable sources. The average carbon intensity of each country's electricity mix is defined by CO_2e kg per kWh of generated electricity. The values have been obtained from AQ Green Tec[2], which has been extracted from different sources[3], and are shown in Figure 1.

Country	Emissions factor	Emissions factor 100%	Year
Austria	0.102	0.0160	2018
Belgium	0.207	0.0151	2018
Germany	0.401	0.0342	2019
Ireland	0.353	0.0258	2018
Italy	0.248	0.0181	2018
Luxembourg	0.069	0.0050	2018
Netherlands	0.441	0.0322	2018
Norway	0.0189	0.0014	2018
Portugal	0.31	0.0226	2018
Spain	0.276	0.0201	2018
Switzerland	0.016	0.0012	2017
United Kingdom	0.3072	0.0224	2018

Figure 1: emissions factors of different European power grids

[2] AQ Green TeC is also part of Aquila Capital: https://www.aq-greentec.com
[3] Sources: carbonfootprint.com (2020), European Energy Agency (2020), Norwegian Energy Regulatory Authority (2020), Umweltbundesamt (2020)

In the case of AQ Compute's NO-DC1, the power supplied to the data centre is secured from 100 percent renewable sources. However, due to the nature of power supply, it is physically impossible to obtain 100 percent renewable energy from the power grid, even if it is guaranteed, e.g. by PPAs. This is based on that fact that also the emissions of the green energy supply chain must be considered (i.e., life cycle analysis emissions), which means that the emission factor will always be above zero.

France has been excluded from the comparison table because France's power grid has a very small CO_2e emissions' factor due to its significant dependency on nuclear power. There is an open debate about nuclear power in Europe and, while some countries have banned it, others embrace it as a "clean" power supply. Since nuclear power's pollution is of a different kind and difficult to quantify, the data of countries with a high reliance on nuclear power would introduce biases in the calculator.

b) The electricity consumption of the data centre

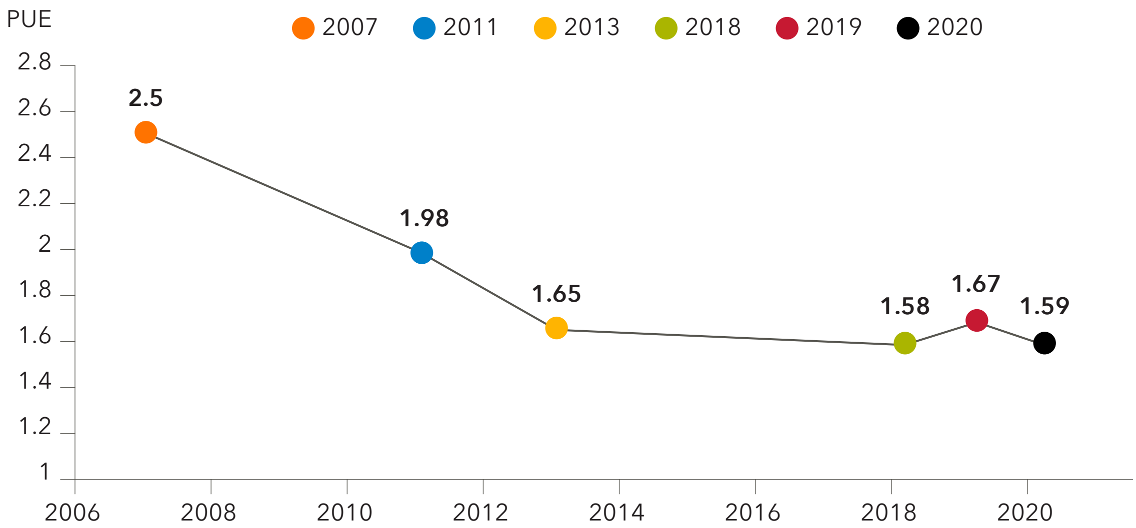
The electricity consumption of a data centre is mostly related to its energy efficiency which in turn is highly dependent on the cooling system used for removing the heat from the IT equipment.

Most recently commissioned data centres in Europe are still using traditional air cooling for IT and non-IT equipment. A lot of heat is generated in the operation of the electronical components of a server and can lead to overheating when the hardware is not kept cool. PCs use small fans incorporated in the mainboard to extract heat, which can be dissipated into the surrounding air. In a data centre, the sheer number and high density of servers produce too much heat to properly dissipate it without thoroughly planning a cooling system. Every unit of power supplied to the IT-components is transformed into heat and must be removed from the facility. Conventional cooling systems were using chillers and air conditioning.

The most common metric to measure energy efficiency in the data centre industry is the Power Usage Effectiveness (PUE), which is the ratio between the total energy used in a data centre and the total energy used for the IT-components of that data centre. Besides the IT-components, a data centre contains mainly power supply and cooling supply systems. The power supply system (cables, switchgears, and batteries of the uninterrupted power supply systems) is subject to power losses and, hence, requires more energy to counteract the losses. The cooling system uses electrical energy to cool down the IT-components. Typically, for each unit of cooling energy, ¼ to ½ unit of electrical energy is needed. Therefore, the total energy used in a data centre is calculated by adding up the energy used for the IT-components, the power losses and the electricity consumption of the cooling systems. The smaller the power losses and the less electricity required to provide cooling, the closer the PUE is to 1.0:

$$\text{PUE} = \frac{\text{Total energy supplied to the data centre}}{\text{Total energy supplied to the IT systems of the data centre}}$$

Figure 2 shows that the average PUE values of the data centres have decreased from 2.5 in 2007 to 1.59 in 2020. In 2007, for each energy unit used by the IT-components, 1.5 additional energy units were needed for the rest of the equipment (non-IT systems, basically in charge of power and cooling supply). Nowadays, data centres need almost three times less energy for the operation of the non-IT systems compared to 2007.



What is the average annual PUE for your largest data center?

Source: Uptime Institute Global Survey of IT and Data Center Managers 2020, n=445

Figure 2: data centre average PUE values in the past two decades

The data shown in Figure 2 stems from the annual Uptime Institute Survey 2020 and includes all the data centres under operation worldwide, independent of their age. However, newly built data centres are more efficient: their PUE values range between 1.2 and 1.4[4]. PUE values highly depend on the technology used for cooling as well as on the climatic conditions of the location. This value slightly varies throughout Europe depending on (warmer or colder) temperatures. As a matter of simplicity, 1.3 has been considered as the average PUE value of a traditional, newly built data centre across Europe.

It is worth noting that older data centres could have been considered in the comparison as well, since the decision of moving IT hardware from a data centre to another might be motivated by the need to replace old infrastructures with poor energy efficiency (on-premise legacy data centres). Older data centres might have PUE values similar to the ones depicted in Figure 2 for 2007. However, the comparison with new data centres seems to be more objective, allowing users to compare AQ Compute's data centre with the alternative of building a new state-of-the-art data centre as well as selecting colocation options in a different European country.

The CO_2e calculator quantifies the amount of CO_2e emissions that can be generally avoided when choosing to install IT capacity at the AQ Compute data centre compared to standard data centre values. For a more accurate and customised calculation, AQ Compute can be contacted directly[5].

[4)] Uptime Institute: https://journal.uptimeinstitute.com/data-center-pues-flat-since-2013/
[5)] AQ Compute contact: info@aq-compute.com

Why are the PUE values of the AQ Compute's NO-DC1 so low?

The AQ Compute data centre in Norway has a cooling system based on a highly efficient free air-cooling. The average yearly temperature is 4.6°C at the location[6], which enables the use of the natural cooling energy available in the air. The cold air outside the DC refrigerates the exhaust air inside the data centre by means of a rotary heat exchanger. This indirect natural air cooling can be used as a sole source of cooling approximately 85% of the year. The rest of the time, chillers provide the necessary temperature to cool down all the IT-components even during the hottest days of the year. The average design PUE of the data centre using only natural air-cooling is 1.16.

Please note that AQ Compute's NO-DC1 offers multiple TIER-equivalent classifications (from TIER 1 to TIER 3), due to the different redundancy needs of different clients and different IT-equipment. The higher the TIER level, the higher the back-up power requirements. This increases power losses and, hence, the PUE-value. In our case, the PUE of 1.16 is calculated without considering losses associated with batteries. Depending on the intensity of usage of power back-up systems and the usage of the IT-systems themselves, the PUE can vary a couple of points up or down. In future releases of this CO_2e calculator, a live PUE value for AQ Compute`s NO-DC1 could be used for more accurate results.

In addition, the contribution of water-cooling to reduce the PUE is an important component. This working assumption comprises a hybrid data centre with 83 percent of water-cooled IT power and 17 percent of air-cooled IT power. The water-cooled elements are cooled down with direct hot water that captures the heat directly at the chip[7]. Hardware water inlet temperatures can be as high as 50°C and water outlet temperatures can reach more than 60°C. The only power needed for the water-cooling system is associated with the water pumps, motorised valves and dry-coolers. Since the 60°C outlet fluid can be easily cooled down using the ambient air, even with the expected maximum outdoor temperatures at the location (31°C), no chillers are necessary for the water-cooled IT-components. The decrease in power requirement translates into an increase in efficiency and, hence, into a lower PUE (as low as 1.054).

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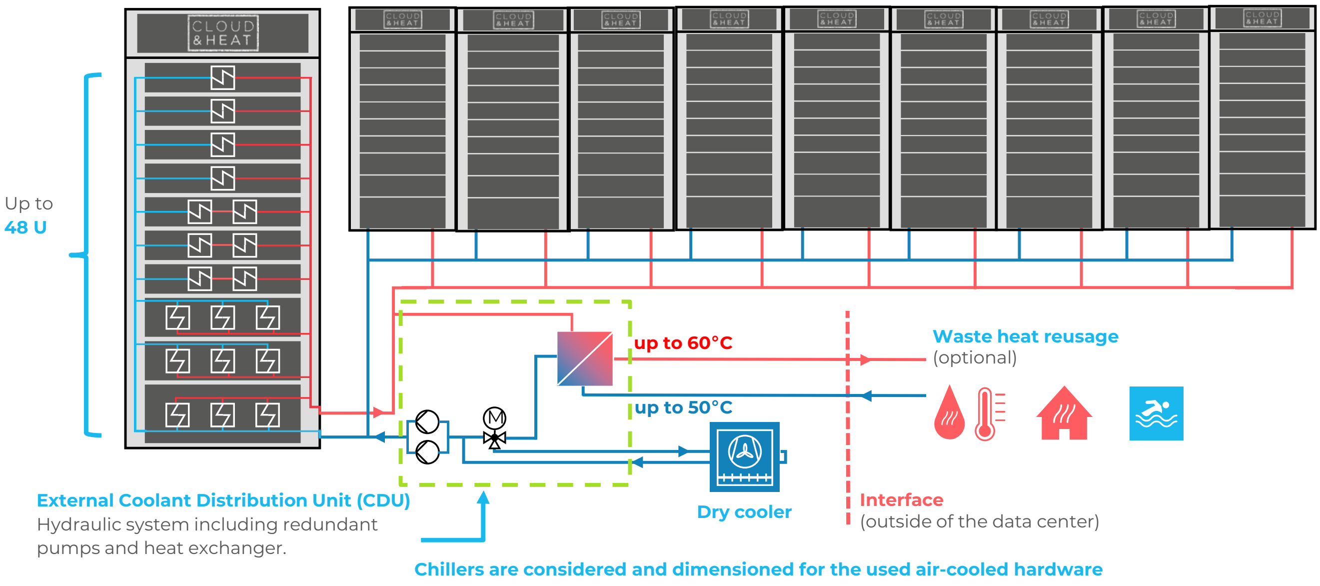
6) Average temperature: https://en.climate-data.org/europe/norway/buskerud/hønefoss-9918/
7) Cooling Technology from Cloud&Heat Technologies: https://cloudandheat.com



If the waste heat is reused, the remaining heat is transferred to a place with heating demand (such a residential area or a greenhouse requiring space heating) and the dry-coolers can be taken out of the equation. The PUE can then be as low as 1.047 – it should be noted that transforming excess energy/ heat into a valuable good is not considered in this context yet. In this specific case, the PUE could fall below 1.0[8], depending on the reusage factor: this would happen if the reused energy compensates the energy used by non-IT components.

$$PUE_{heatreuse}{}^{8} = \frac{\text{Total energy supplied to the data centre - Total energy reused}}{\text{Total energy supplied to the IT systems of the data centre}}$$

How are these CO_2e emissions calculated?

CO_2e grid = Total DC power x running hours per year x power grid emissions factor

Total DC power = Total installed ITpower × PUE

A) Fuel consumption emissions

The second factor that plays a role in the CO_2e emissions of a data centre is the fuel consumption of the power supply generators which are a standard (and inevitable) component of a data centre. The data centre would practically rely on the power grid the entire year, unless there is a power blackout or a planned supply from the backup generators, which may happen occasionally for maintenance reasons. Moreover, the generators, which are usually supplied with diesel fuel, need to be turned on periodically for a couple of hours to examine their correct functioning. Full-load tests must also be accomplished from time to time. This requires burning diesel fuel and, hence, forces the data centre operator to emit further CO_2e New concepts for data centres without diesel generators are becoming increasingly popular, examples are hydrogen tanks, utility-scale batteries or direct connection to power plants among others.

8) This is a manipulation of the PUE definition for simplification matters. By definition, the PUE lies between 1 and ∞ and cannot fall under 1. Some sources have defined this equation as a new metric, the ERE (energy reusage effectiveness): The green Grid. (2010). ERE: A METRIC FOR MEASURING THE BENEFIT OF REUSE ENERGY FROM A DATA CENTER. https://www.thegreengrid.org/en/resources/library-and-tools/242-ERE%3A-A-Metric-for-Measuring-the-Benefit-of-Reuse-Energy-From-a-Data-Center-

These alternatives would further reduce the CO_2e emission balance. However, it is still uncertain that state-of-the-art data centres are guaranteed to be reliable and function properly (equivalent to TIER III certifications) without diesel generators. As a result, generator-related emissions remain part of the calculation.

CO_2e emissions for the generators are assumed to be the same (diesel emission factor: 1.27 $kgCO_2e/kWh$) for all data centre types and countries. The emission factor of diesel generators is supposed to be a standard and does not change much across locations in Europe.

How are these CO_2e emissions calculated?

$$CO_2e \text{ fuel} = \text{Total DC power} \times \text{running hours per year} \times \text{genset fuel emissions factor}$$

A) Emissions avoided by reusing the waste heat

Even if the heating system coupled with the data centre contributes to its cooling concept, it cannot be considered exclusively as a part of it. From AQ Compute's point of view, the heat reuse of a data centre contributes to lowering the CO_2e emissions in a global balance and cannot be ignored from a carbon footprint perspective. The usage of such waste heat saves a considerable amount of energy, which otherwise would be needed for heating. The waste heat can be used for different heating purposes such as heating of households, greenhouses, fish farming, saunas, wood drying, water desalination or even for transforming it into cooling energy.

The higher the temperature of the waste heat, the easier it is to use it and transfer it to the end user. Nevertheless, some heating applications such as greenhouses (especially the ones based on hydroponics) or fish farming can work with low temperatures. The aim of this project is to use not only the high temperature heat provided by water-cooled IT-components but also part of the heat dissipated by air-cooled IT-components. In addition, having different types of heat demands allows a more efficient reuse of the waste heat of the data centre depending on different daytimes, weekdays (e.g. working vs. weekend/holidays) and seasons (e.g. winter vs. summer).

How are the CO_2e emission avoidances related to heat reuse calculated?

In Norway, the most common way of heating is by means of a heat pump, which is driven by electrical power.
A heat pump is a machine that takes the heat from the outside and, with electricity supply, provides more heat to the inside. It is using the same principle as a chiller but with the aim for heating instead of cooling down. The Coefficient of Performance (COP) factor defines the efficiency of the machine and is measured as the ratio between the energy provided by the machine in form of heat and the energy supplied to the machine in form of electricity. Typically, a COP factor of three for the heating function of heat pumps is assumed, meaning that a third of the heating energy provided by the heat pump is required to be supplied by power from the grid. In the calculations, the standard Norwegian carbon factor for the electricity grid is considered, which is the most typical source of power used for heat pumps.

Further, it is assumed that not all the energy used by the data centre is captured for reuse. Additionally, some losses or excesses of heat have been considered. Even if the pipes and conducts are insulated to the extent that almost no losses occur and the heat can be stored in insulated tanks, a heat capture factor of 75% has been considered.

The maximum amount of CO_2e avoided with heat reuse in a Norwegian context is calculated as follows:

$$CO_2e \text{ avoided}_{heatreuse} = \frac{\text{Total DC power}}{\text{COP heat pump}} \times \text{running hours per year} \times \text{heatcapture factor} \times \text{Norwegian power grid emissions factor}$$

This quantity of CO_2e avoided by reusing the heat can be higher than the CO_2e emissions emitted by the data centre. Furthermore, the amount of CO_2e avoided by waste heat reuse could be even higher if it substitutes the use of a natural gas boiler. This is the most common source of heating for most purposes in European households. Even if the emission factor of natural gas is lower than the emission factor of many European power grids, the overall efficiency of a gas boiler is generally lower than the efficiency of a heat pump.

Total CO_2 emissions:

$$\text{TOTAL } CO_2e = CO_2e \text{ grid} + CO_2e \text{ fuel} - CO_2e \text{ avoided}_{heatreuse}$$

Forest surface and CO2e emissions offset

Since the CO_2e emissions are usually compensated by planting trees, the calculator shows the equivalent of the CO_2e emissions in hectares (ha) of mixed forest. The equivalent of 1 ha forest for 11 tons of CO_2e sequestered annually, has been considered.

Offsetting CO_2e emissions is becoming increasingly relevant for ESG strategies of many companies. Since more and more sectors integrate digital business models and require third party digital infrastructure for their businesses, keeping a low carbon footprint (and being able to display it) becomes a pilar of essential business spheres. AQ Green Tec is specialised in measuring and monitoring the carbon footprint of businesses and offers various options to verify and offset them.

As part of a broader European strategy, AQ Compute wants to show that more digitalisation is not always equal to pollution. The company intends to be the main actor in decarbonising the colocation data centre market in Europe, actively contributing to a more sustainable society in an increasingly digital world. The high-performance computing data centre under development in Norway will be commissioned in the second quarter of 2022.

For more information about AQ Compute's activities or a tailor-made calculation, visit the website ***(https://aq-compute.com)*** and the LinkedIn channel ***(https://www.linkedin.com/showcase/aq-compute-/)*** or contact us via mail: ***info@aqcompute.com.***

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[9] Coefficient of Performance: https://learnmetrics.com/coefficient-of-performance/
[10] Forest and CO_2e: https://www.baysf.de/de/wald-verstehen/wald-kohlendioxid.html)

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