The Utility of the Future

Where digital and energy infrastructure combine.

Disclaimer

Approach

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About This Report

This report harvested publicly available information from white papers, academic studies, industrial publications and news articles to formulate the most commonly observed challenges, trends and drivers of each industry. The opportunities stated in this report are neither exhaustive nor exclusive. Throughout the report “analysts insights” boxes provide the reader with our informed opinion, whereas the bulk of the report represents what are largely considered mainstream views. An “Executive Track” provides succinct summaries of the major topics, specifically business related, whereas the rest of the text often meanders into relevant detailed operational factors. Feedback was provided by industry experts before the final draft was released. All sources are documented in the References section, and most are hyperlinked. Feedback on this report is welcome.

Abstract

This report sheds light on the partnership potential between Energy Utilities and Data Centers. Both industries are at crucial inflexion points. As energy utilities pivot towards sustainability, they are facing new challenges. Likewise, the digital economy is fast maturing, and digital infrastructure is moving from a luxury to a necessity. This report maps the operational challenges and changes facing both industries before highlighting potential partnership opportunities in the areas such as electricity flexibility, district heating, site location and shared operational competences. This report largely omits Edge developments, and focuses instead on the larger, more centralized elements of the data center industry.

Executive Summary

Both energy and digitalization are on everybody's minds today. Both play increasingly important roles in our daily lives, yet few realise how interdependent these industries truly are. Digitalization promises to re-align our economy around data and computation, but the digital economy of tomorrow will be built on the shoulders of today's electrical infrastructure. Fewer still can see the tremendous industrial and societal opportunities when two fundamental requirements of the digital age integrate.

Both the digital and energy infrastructure industries are at inflexion points

The energy industry is decarbonizing, and the data center industry is maturing. As intermittent renewables penetrate further into the electricity generation mix, flexibility becomes increasingly valuable. The phase out of flexible supply and inadequate storage capacities will make demand response the flexibility of the future. Hence the generation, consumption, storage and migration of energy will become crucial to balancing the energy grid of tomorrow, where yesterday's energy grid predominantly required adequate generation alone.

Data traffic is expected to grow exponentially over the next decade as digital use cases become increasingly embedded in our lives. The smart home, the office in the cloud, the autonomous vehicle, the robot operator are all becoming increasingly numerous as internet speeds improve. Internet connectivity will connect more consumers and more devices, all of which produce increasingly data and compute intensive workloads. The result is data centers are the fastest growing consumer of energy globally.

Data centers are a Power-to-Heat resource of the future

Data centers are becoming increasingly large generators of heat and they will soon account for 4-6% of global power consumption, of which one third is used for the cooling of heat. This heat is often generated in cities, where district heating demand is growing fastest, and where recovered heat can be recycled most efficiently. Additionally governments are fast realizing that the heat sector, which can account for more than a third of all CO2 emissions in some regions, must also decarbonize in order to reach the CO2 reduction targets laid out in the EU 2050 plan. For the district heating utility, the advantages include the consumption of “free/low CO2” recovered heat, and the accompanying reductions in prices.

Integration creates value across the entire Energy Sector

Grid constraints, expensive storage solutions and the phasing out of flexible fossil fuels all increase the value and viability of Demand Response as a source of Flexibility. IT shiftability and migratability are all valuable to the energy grid of the future because they are effectively forms of energy generation, consumption and storage. Ramping up computations during times of electricity oversupply, and ramping down IT loads during undersupply could provide data centers with reduced energy bills, and help bring stability to an increasingly unstable grid by stabilising both national and local energy grid constraints. Europe is currently accessing around 20GW of available Demand Response, but the European Commission places the total potential at 100GW, forecasted to rise to 160GW in 2030.

The large and growing size of data centers, the delay-tolerant nature of some of their workloads, and the instantaneous nature of their operations make data centers particularly applicable as providers of energy flexibility, grid stability and ancillary services. Beyond the obvious secondary revenue streams, data centers could help to further integrate renewables into the energy system. In other words, data centers could enable a fully renewable electricity mix. National Governments meet their renewable targets across both the Heat and Electricity sectors, and Local Authorities deliver cheaper, renewable energy to their residents.

"Location, Vocation, Integration" - Expanding the Opportunity beyond Energy

Hyperscale data centers face increasing pressure to deliver lower latency services. In the near future some hyperscale data centers are therefore likely to locate themselves closer to cities to solve the issue of latency. In this case, sites owned by energy utilities could be of significant value. Colocation data centers are getting larger and more numerous. Access to locations with power, fiber connection, space for potential expansion is getting more difficult. At the same time, energy utilities own significant plots of land in and around cities, where demand for colocation data centers is strongest, and where integration with district heating grids is most feasible. Data centers require locations, energy utilities own these locations. This synergy is made more opportune by the fact that energy utilities will be vacating all urban coal power plants in the next decade.

Crucially, both industries suffer from a lack of talented personnel. In fact the industries are so similar that both industries actually recruit from the same talent pools, into very similar roles. Both industries will see large numbers of employees retire within the next decade and both industries are worried about how to fill these vacancies. Here there is no secondary revenue stream, rather a consolidation and reinforcement of the primary revenue stream by pooling human resources.

Digital Infrastructure is as critical to society as Energy Infrastructure

Both industries are large, technical, complex systems who place a premium on 100% availability. Both suffer from the same forms of facility and network wide failures. Defending the entire network against downtime requires a redundant grid. The EU electricity grid is slowly becoming one redundant grid (from 27 member nation grids) and the digital grid is forming as fibres and interconnections connect increasingly redundant data centers at a global scale. Both industries deliver a similar product (critical infrastructure) to a similar customer (businesses and residents) with similar constraints (near continuous uptime). The value proposition here is shared core competences in a brand new critical infrastructure market.

The Energy Utilities of today are the blueprint of the Digital Utility of Tomorrow

There are significant societal benefits to the successful operation of both industries. While both electrical and digital power are business critical and even mission critical, digital power is not yet life-critical. The moment digital infrastructure becomes as critical to the operation of modern society as electricity, we can consider it a critical public utility. We believe the digital utility will be as critical to the 21st century as electricity was to the 20th century. Hence the development of the electric grid over the last century provides us with a blueprint for the development of the digital grid.

Capturing the Opportunity of Digital & Energy Integration

This report makes a handful of final recommendations:

- Energy services markets need to communicate better prices and value before data centers would consider providing energy services. The acknowledgement by OFGEM, the UK's energy regulator, to resolving and improving their new flexibility market is welcome news, but more needs to be done and sooner.
- Standard contracts should be created, which can act as the building blocks of any future relationship between district heating grids or distribution system operators and data centers. They are necessary given many of the above value propositions transcend typical industry boundaries. This would help solve the problem of "who pays for the CAPEX".
- Recovered heat needs to be appropriately valorized. Currently it is difficult to put a price or value on recovered heat, and in some cases recovered heat is still not considered renewable. A market for recovered heat may in the long term be the best method of incentivising recovered heat utilization. The EU's heat network decarbonization strategy should consider this.
- Data Centers should confront their aversion to complexity within the facility by bringing the energy bills under the jurisdiction of the IT staff (and away from facilities staff). This is a practical first step towards creating the competence and confidence data centers require before they can begin making data centers a source of energy flexibility.

What to expect from this report:

The contribution of this report is two-fold. The first is to map the opportunities between electrical and digital infrastructure industries. Second, this report explores a higher level, deeper connection between the electricity grid and the digital grid. The electricity grid provides us with a blueprint for the development of the digital grid, where both are vital forms of critical public utilities. Effectively this report can be used by the reader to conceptualise opportunities between both industries which neither industry could deliver alone.

Table of contents

Symbols and Abbreviations

AC
Alternating Current

ACER
Agency for the Cooperation of Energy Regulators

AFRR
Automatic Frequency Restoration Reserve

ATC
Available Transmission Capacity

BRP
Balance Responsible Parties

BSP
Balancing Services Provider

CAPEX
Capital Expenditure

CCGT
Combined Cycle Gas Turbine

CCS
Carbon Capture and Storage

CEGB
Central Electricity Generating Board

CHP
Combined Heat and Power – an embedded electricity generation technology

CO2
Carbon Dioxide – a greenhouse gas.

COP
Coefficient of Performance

DC
Direct Current

DEFRA
Department of Environment, Food and Rural Affairs

DETR
Department of Environment, Transport and Regions

DNOs
Distribution Network Operators

DSM
Demand Side Management

DSO
Distribution System Operator

DSR
Demand Side Response

DTI
Department of Trade and Industry

EB
Exabyte

EC
European Commission

EdF
Electricité de France

EER
Energy Efficiency Ratio

EGWG
Embedded Generation Working Group

ENTSO-E
European Network of Transmission System Operators for Electricity

ESI
Electricity Supply Industry

ETS
Emission Trading System

ETSU
Energy Technology Support Unit

EU
European Union

FIT
Feed-In Tariff - A form of Renewable Energy Subsidy

GW
Gigawatt-One billion watts

KPI
Key Performance Indicator

KV
Kilovolts – One thousand volts

KW
Kilowatt - One thousand watts

KWh
Kilowatt-hour – unit of electrical energy.

LCOE
Levelized Cost of Energy

MW
Megawatt – one million watts

Mwe
Megawatt of electrical output

MWth
Megawatt of thermal/heat output

NC
Network Code

NC CACM
Network Code on Capacity Allocation and Congestion Management

NC EB
Network Code on Electricity Balancing

NETA
New Electricity Trading Arrangements

NFFO
Non-Fossil Fuel Obligation

NGC
National Grid Company

OCGT
Open Cycle Gas Turbine

OFGEM
Office of Gas and Electricity Markets – regulator of the ESI in England

OPEX
Operational Expenditure

PIU
Cabinet Office Performance and Innovation Unit

POST
Parliamentary Office of Science and Technology

PUE
Power Usage Effectiveness

PV
Solar photovoltaic – a renewable generating technology

R&D
Research and Development

RCEP
Royal Commission on Environmental Pollution

RECs
Regional Electricity Companies

RES
Renewable Energy Sources

RES-E
Electricity from Renewable Energy Sources

SO
System Operator

SYS
Seven Year Statement – a report, produced annually by NGC Transmission

TS
Transmission System

TSO
Transmission System Operator

TW
Terrawatt – a trillion watts

V
Volt – a unit of electrical pressure which causes a current to flow

VAR-RES
Variable renewable energy sources

W
Watt – unit of power

ZB
Zettabyte = 10^21 byte.

List of Figures

1
State of the Industries

This chapter summarises the state of both the data center and electricity utility industries, with respect to their drivers, challenges and key trends. It serves as the background knowledge for the value propositions highlighted in Chapter 2-5.

Executive Track

Data generation is growing exponentially. The electricity consumed in processing all this data will increase from approximately 2% of global electricity consumption today, to about 4-6% of global power consumption by 2022 (Czekaj & Pietersma, 2017).

Electricity is decarbonising. Intermittent renewable energy supply is replacing concentrated fossil fuels such as coal. Flexibility is key to making electricity generation sustainable.

Fundamentally electricity generators face profitability risks, whilst the wider electricity system faces higher costs.

Electricity plays only a modest role in a nation's energy consumption. Regulators are slowly turning their attention to the Heat and Transportation industries too.

Data center providers face major challenges in the form of cost of electricity, site location, and operational risks.

Flexible generators and grid reinforcement is particularly necessary to ensure the lights stay on.

Business models are changing as new opportunities and new challenges present themselves. Change is a double edged sword.

Both digital infrastructure and electrical infrastructure are defined here as Large, Technical, Socioeconomic industries. They are vital utilities operating in the public interest. However, electricity is more mature, and the regulatory environment reflects that.

1.1 Data Center Industry

There exist three major forms of data center: Enterprise Data Centers, Colocation Data Centers, and Hyperscale Data Centers (e.g. supersized Enterprise facilities operated by Cloud Providers or major Tech Companies). With the onset of cloud-based services, the enterprise data center is increasingly being outsourced to Cloud providers (Almeida, Moura, & Vasques, 2017). Cloud providers have pursued economies of scale to the point where they are now the driving force behind Hyperscale growth. These two interrelated trends show no sign of slowing down (Cisco, 2017).

Data centers, the digital infrastructure behind data storage & computation, consumed approximately 270 terawatt hours (TWh) of electricity globally in 2012, or about 1.5% of total global power consumption (Dayarathna, Fan, & Wen, 2016). This is expected to rise to 4-6% of global power consumption by 2022 (Czekaj & Pietersma, 2017) (Datasource, 2018) as 5G and other enabling technologies unlock a host of new applications. This section outlines the key Drivers behind the exponential growth, the resulting Trends in data production and energy consumption, and the key Challenges facing the industry.

Drivers

Driving the increase in data production & consumption is the increase in speed and accessibility of the internet. Today more than 4.39 billion people use the internet, up from 500 million in 2001 (Nadhom and Loskot, 2018). More devices are joining the network as mobile network coverage spreads, and 20 billion devices are expected to be connected globally by 2020 (Nadhom and Loskot, 2018) (Datasource, 2018). Improvements in infrastructure have enabled applications to become more data intensive. Fundamentally more consumers are consuming more data with increasing frequency, as summarised in figure 1.1 below. Annual global data growth will increase from 30 Zettabytes at present, to about 175 Zettabytes in 2025 (IDC, 2018). To put that into perspective, a zettabyte is equivalent to about 250 billion DVDs.

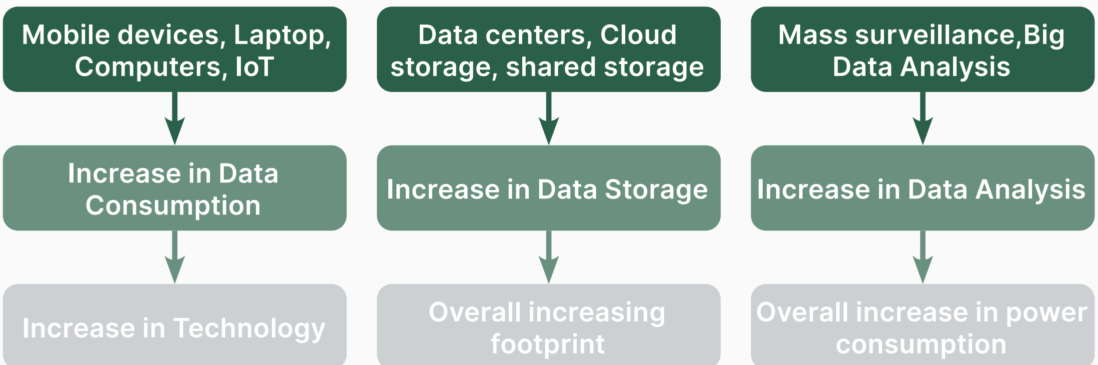

Figure 1.1) Drivers of data center growth

Trends

Data centers are finding novel ways to efficiently and sustainably compute this growing amount of data. Public Cloud providers allow enterprises to outsource their digital infrastructure, simplifying their operations (DBS, 2016). Public Cloud adoption is expected to grow at a compound annual growth rate of 27.5% up to 2022 (Louis, 2019). Data Centers are increasingly moving from smaller distributed facilities to larger concentrated facilities. This “Hyperscale Shift” leverages economies of scale and improves asset utilization to deliver services more efficiently. Higher density server racks allow more computations per server, further optimizing infrastructure. Hyperconverged Infrastructure simplifies the architecture within data centers, simplifying the computation process. Data is increasingly being processed centrally, dwarfing the traffic that is actually sent across the network. Centrally computed “within data center” data will likely triple from 5 Zettabytes in 2016 to 15 Zettabytes by 2021 (Cisco, 2017) - that’s 30x the total amount of global data created before 2003. All these trends make data more accessible to produce and consume. Hence these trends are both reacting to, and further driving, demand.

Challenges

Improvements in data center technologies have been continuous and fast paced. However, data centers face significant barriers to their growth. The first and foremost is the cost of Energy. Energy costs directly impact the cost of compute and in most data centers the cost of energy is now close to 40% of the Total Cost of Ownership (TCO) (Hintemann, 2015). Energy consumption in data centers was growing at 16% annually in the US between 2005-2009 (NREL, 2014).

The second challenge to the data center industry is Location. Location requirements differ between end-customers: some value proximity, some require low-latency communication, some value security. However, the general trend across the data center industry is an increase in server rack density, number of servers, energy consumption per location, and number of locations. These locations are becoming increasingly difficult to find in urban areas.

The third major challenge faced by the data center industry, is one of Risk. Digital services are becoming more integrated in modern life, hence the impact of non-availability is greater. The importance of reliable data center operation is increasing as digital applications slowly become more life-critical and more widespread. Data, and therefore the security & availability of the data center, is of increasing importance.

Analysts Insights

Uptime Institute’s most recent survey of data center operators found that PUE levels rose for the first time ever between 2018-2019. Virtualisation technologies and Hyperscale adoption, which accelerated in the aftermath of the 2009 financial crisis, were a reaction to escalating energy costs and smaller budgets. The better server utilization rates reduced annual growth in energy consumption to just 4% by 2010. However, efficiency gains from Hyperscale adoption and virtualisation technologies have been exhausted and we expect energy consumption to rise more aggressively this decade.

1.2
Energy Utility Industry

The Energy Utility Industry is undergoing a transition. Decarbonization, Digitization and Decentralization are all occurring at the same time.

Drivers

Energy markets were typically designed to provide energy as securely and economically as possible. Today policy maker's priorities are now split between economic utility, security of supply and environmental sustainability. Since the year 2000 the EU and national governments have produced several policies that reflect this change in priorities, such as the Energy 2020 Goal of 27% renewable generation by 2030, and 33% by 2050, as well as the Energy Roadmap 2050 which aims to reduce emissions by 80-95% by 2050.

Trends

More efficient consumption habits and the higher cost of energy has resulted in overall flat trends in electricity consumption across Europe. Decarbonization is phasing coal and lignite out and Renewable Energy Supply (RES) in. RES makes up 30% of the electricity mix in markets like Germany and the UK. Decentralisation is seeing concentrated fuels phased out and diffuse fuels phased in. Wind and Solar capacity increased almost tenfold in the last decade (WindEurope, 2016). Digitization is the enabling technology behind smart grids and prosumers (consumers who can also produce electricity such as households with solar panels) but this creates new challenges for traditional electricity suppliers who may now compete with their own customers. Questions regarding grid maintenance costs are largely unanswered.

Despite a decentralisation of supply, National markets are harmonizing toward a single Internal Energy Market (IEM) in the regulatory sense as well as the physical, with significant investments in inter and intra country interconnection lines. The result is a larger and increasingly homogenous market with an increasingly distributed base of electricity generators.

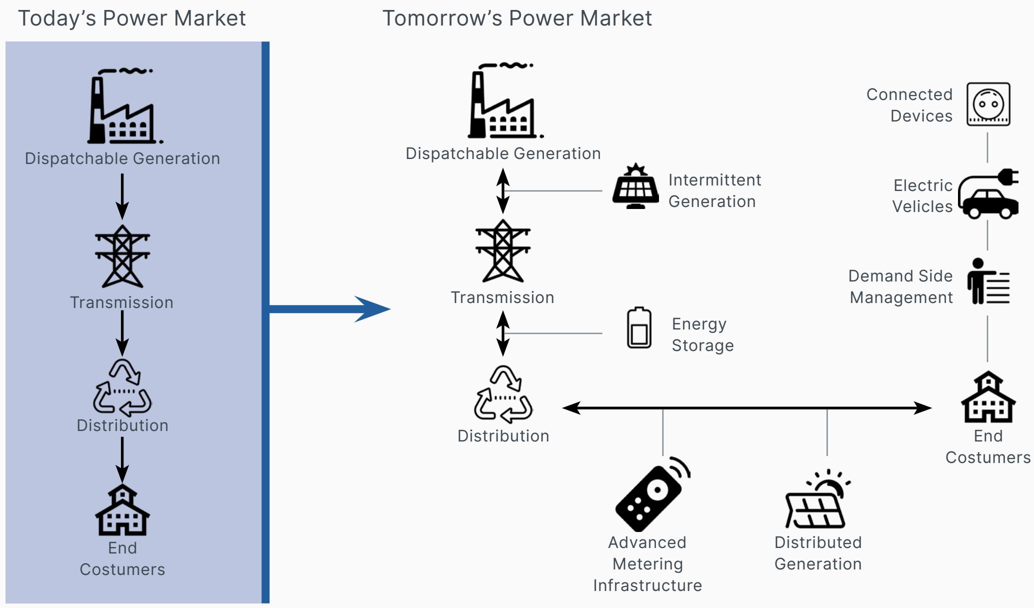

Figure 1.2) Today's power market (left), and tomorrow's power market (right), (IEA, 2017)

Challenges

Challenges around balancing, or ensuring there are enough firm generators to deal with the worst case scenario of zero production from renewables, are not new (Wachholz et al., 2017). However, they are made more difficult as intermittent RES penetrates further into the generation mix. The electricity system requires more Flexibility, and a reinforced grid to deliver supply adequacy. The challenges to higher intermittent RES are not only operational. Costs, at least in the short term, have increased considerably for end-customers and energy utilities alike (Deloitte, 2018), despite reduced wholesale costs. Electricity utilities are reluctant to keep in reserve power plants that are only used in cases of peak demand. As intermittent RES generate more electricity, it becomes more difficult for conventional electricity generators to earn money with plants that operate only some of the time. Business models for energy utilities are changing because the design of the electricity system is changing, as shown above in figure 1.2. This brings significant new operational opportunities and risks (PWC, 2017).

Analysts Insight

Electricity generators will face significant potential disruption in the near future. However it is worth noting that electricity only makes up about ⅓ of a nation's energy consumption. The rest is consumed in the form of heat, or transportation. Electricity has faced the largest amount of "green" governance however regulators are slowing realising that Heat and Transportation require significant action. Expect significant regulatory change in these areas in the next 10 years.

1.3
Socio-technical Industries

In many respects data centers and electricity generators provide a similar service. Where the electricity industry provides the service that keeps the lights on, data centers provide the service that keeps the computer operating. This paper terms this service 'Digital Power'. Minimizing planned or unplanned disruptions is essential to the successful operation of both industries. This is termed "availability" in the data center industry, and "security of supply" in the energy industry.

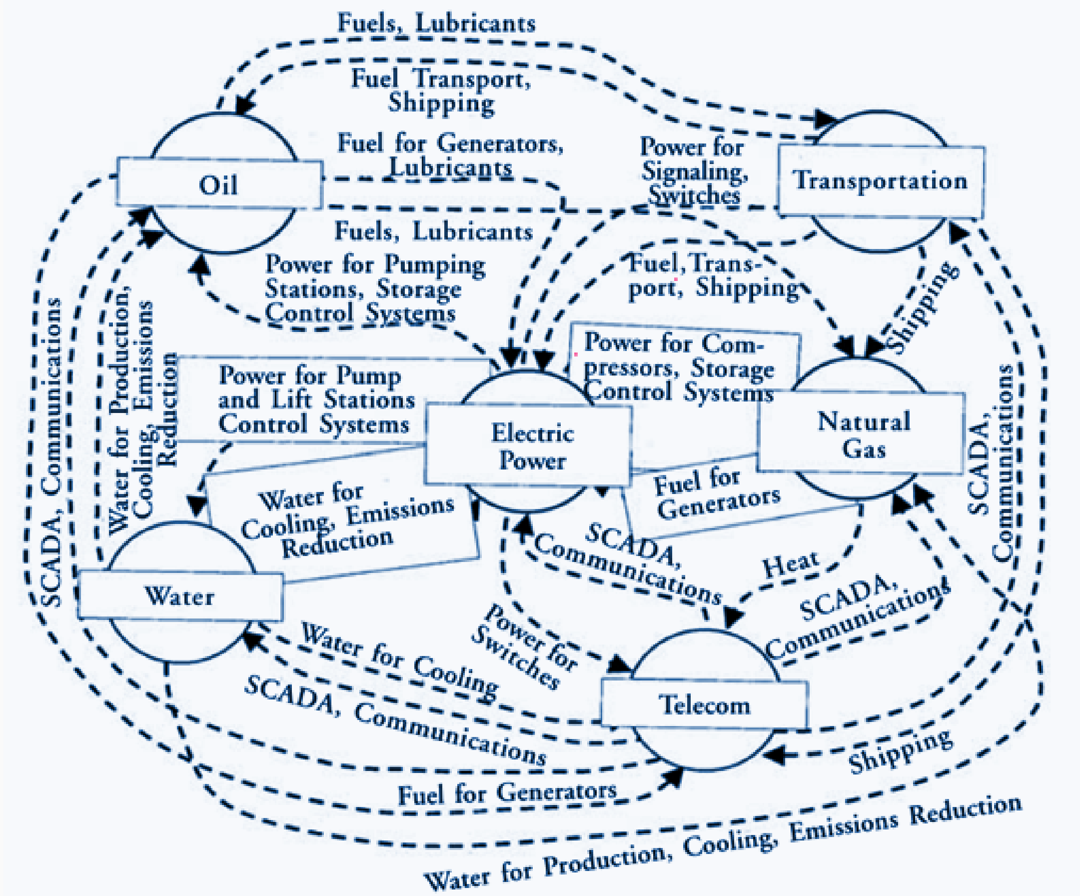

Figure 1.3) The interrelationship of Electric Power and Other Critical Infrastructure (NCSL, 2003)

Both industries support business-critical and mission-critical applications which necessitates their near continuous availability. The similarity between both industries becomes more appropriate when we consider what should happen in the event of failure. Failure of a power station to provide electrical power is at best financially painful and at worst life-threateningly catastrophic. Data Center downtime, though not yet life threatening, is financially ruinous. As many as one in three data center applications are considered "mission critical", and this will rise to one in two applications in the near future (Uptime, 2018). The moment digital applications become "life critical", digital infrastructure becomes as essential to the operation of a modern society as electricity. As shown in the figure above, "Electric" power lies at the heart of all critical infrastructure, and we argue Digital "Power" will soon be equally as important.

Thomas Hughes, author of Networks of Power, described the electricity industry as a sociotechnical Large Technical System (LTS). Electricity is sociotechnical because it is critical to the operation of society, and electricity is a Large Technical Systems because its generation, distribution and consumption are very “complex”. The same is true of data centers.

Analysts Insight

The development of electrical infrastructure is an excellent blueprint for the development pathway of digital Infrastructure. Electricity was first a novelty with a few specific use cases. The more embedded Electricity became, the more dangerous a lack of electricity became. Use cases moved from novel (streetlamps, traffic lights), to mission-critical (industrial processes, machinery), to life-critical (hospital equipment) at which point the regulatory environment changed. Digital Infrastructure has moved from novel (gaming, streaming) to mission-critical (cloud office software). Digital life-critical use cases, such as autonomous vehicles, are still years away from mass consumption. However, when it gets there, the regulatory environment will likely change significantly in the name of “vital public interests”, regulating digital “security of supply” in a similar manner to the regulatory changes of the electricity system in the 1930’s/40s.

2
Value Proposition - Heat Recovery

This section explains how the heat created in data centers can be recycled into District Heat grids.

Executive Track

Data centers are environments where electricity is converted into heat and computational power.

As rack densities get larger, and data centers get larger, data centers are becoming increasingly concentrated sources of heat.

This heat must be removed and cooled which consumes a large amount of electricity. Approximately 40% of a data center's total cost of ownership is due to cooling.

Recycling this heat, either into a low-quality heat network, or into a high-quality heat network with the help of a heat pump, is already operationally feasible.

The regulatory environment around Heat Network decarbonization and waste heat disposal is incentivising waste heat recycling.

Both heat networks and co-location data centers are located in urban areas, where demand for heat and digital infrastructure is highest.

There are natural partnership opportunities from co-locating data centers with heat grids. The result is a form of Combined Heat and Computing Power (CHCP) station.

2.1
Cooling Requirements are increasing

Processing chips inside data centers convert all their electrical energy into heat. This heat must be cooled and extracted to maintain safe working conditions for both the equipment and staff. Data Centers have two fundamental cooling requirements: maintaining ambient room temperatures, and the prevention of hotspots on equipment. Cooling both is essential and account for approximately 40% data center operating costs (JRC, 2017). The current industry standard is air cooling, where cool air is pumped into a server room, and hot air extracted (DataCenterFrontier, 2017). However, Google engineers believe air cooling is limited to racks below a maximum of 40kW per rack. Above 40kW, it is more efficient to cool data centers using liquid as the heat transport medium, because water is between 50 and 1,000 times better at removing heat than air, depending on the systems design (Data Center Frontier, 2017). The average rack density and the number of high-density racks have been climbing slowly globally, as shown below.

In 2007, energy consumption of European data centres was approximately 56 TWh. It is expected to rise to 104 TWh by 2020 (Bertoldi et al, 2012). Legrand estimate that over the next 10 years data will increase 30 fold, and number of servers will increase 1000 fold. As a result, the number of data centers (and the amount of energy they consume) will increase too.

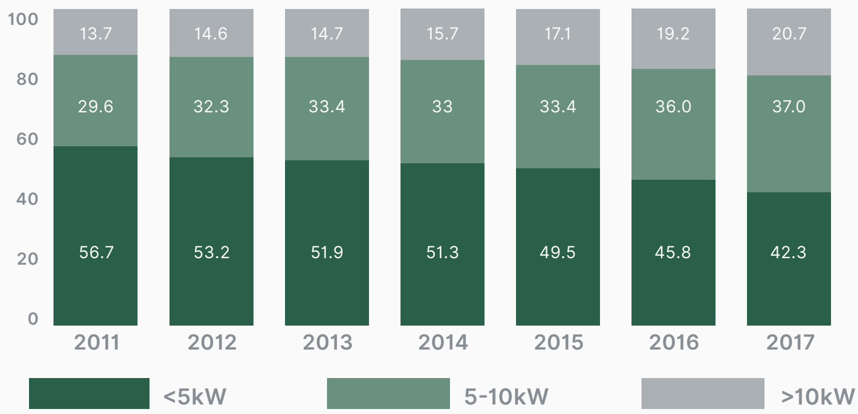

Figure 2.1) Global proportion of low, medium and high density racks (Datacenter Dynamics, 2016)

Analysts Insights

We predict this trend of increasing rack densities will accelerate. Typically high density racks were unique to high performance computing (HPC), which typically served research and simulation use cases. Not only are simulations becoming more popular (from design to gaming to AI development), but higher density racks are being used on more conventional use cases (Cloud computing) and newer niche use cases (Bitcoin mining, virtual reality). The real wildcard here is Edge computing, which promises high density computation in a distributed and decentralised architecture. Interest around Edge is huge, however no one really knows what to expect from Edge, other than delivering computation closer to the source of the data, in a more distributed fashion.

In summary, higher rack densities and more energy intensive components are making individual data centers more energy intensive. The data center industry is becoming increasingly energy intensive as more sites consume more electricity.

2.2
Liquid Cooling becoming the norm

Microsoft, Alphabet's Google, Facebook, and Baidu, have formed a working group on an open specification for liquid-cooled server racks. Google have stated publicly that their data centers now use direct on-chip water cooling for their own Tensor Processing Units (TPU's), used in High-Performance Deep Learning applications. This is a well-established cooling method taken from High-Performance Computing (HPC), i.e. the supercomputers used in academic and research organizations. It is particularly applicable to racks with a high power density (kW per rack). The latest Uptime Institute Annual Survey found 14% of data centers have employed some form of liquid based cooling (ASHRAE, 2019). As higher rack densities trend towards becoming the industry server standard, liquid cooling adoption will grow. However, with average rack densities currently around 7kW, liquid cooling will not become the norm overnight. It will come in waves, following advancements in each application niche.

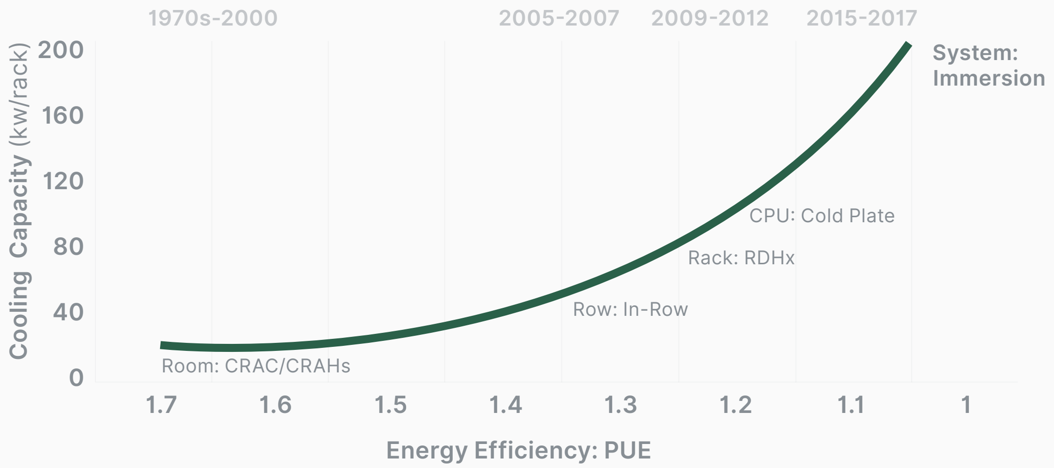

Figure 2.2) Cooling technologies and their development over time (GRC, 2019)

"With data volumes rising, air is no longer enough to cool data center equipment, a change that is opening the door to new cooling approaches."

Henrique Cecci Research director, Gartner.

2.3
District Heating - A Possible Solution

The liquid cooling output temperatures within data centers are steadily approaching the input temperatures required in District Heating grids. Output temperatures from the liquid cooling system should be in the region of 75-120° Celsius (167-248° Fahrenheit) to be eligible for conventional district heating systems. Currently waste heat emitted from liquid cooled data centers is in the region of ~50° Celsius (GRC, 2019), which puts it at the low-quality side. However we're seeing both an increase in output temperatures from data centers, as well as more low-temperature district heating grids requiring lower input temperatures. Heat pumps can also be used to convert low quality heat into high quality heat, before being injected into the Heat Grid, as shown below.

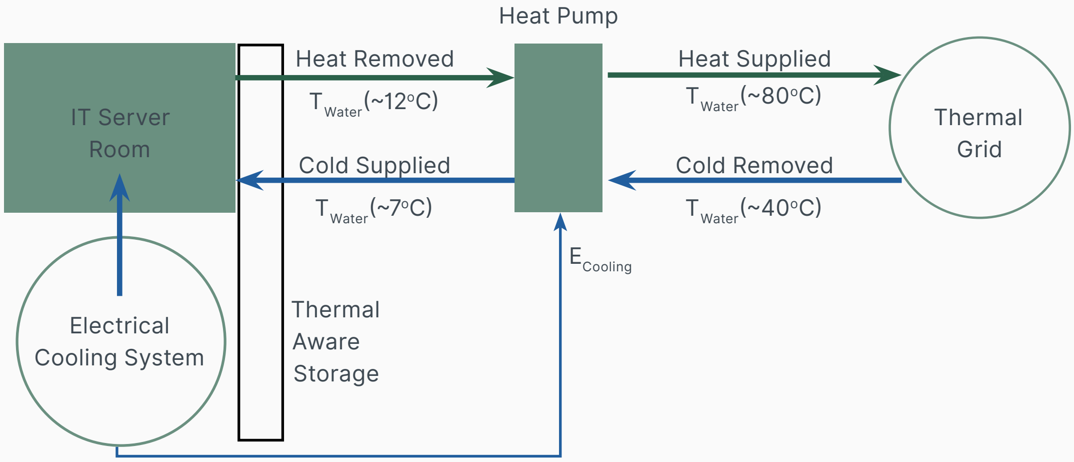

Figure 2.3) Waste Heat recovery and re-use in the District Heating Grid (Cioara et al., 2018)

2.4
Case Study - Mäntsälä, Finland

Yandex, A large Russian internet company, operates an air-cooled 10MW data center in Mäntsälä, Finland which feeds the local District Heating grid using a heat pump. Yandex were able to cut their CO_2 emissions by 40%. Yandex are eventually aiming for 60% energy re-use, the result of which could reduce the cities' use of gas in the heat network to zero.

"In this region, they've already lowered the district heat price by 10% because they can reuse our excess heat. In this way, we have a very good citizenship approach. I think we are very well-known and well-accepted here because of this"

Ari Kurvi, the firm's Data Centre Manager.

2.5
Increasing demand for District Heating

National regulators, particularly in the Nordic region, are well aware of the potential for waste heat utilization. Analysis in Denmark revealed approximately 30% of the surplus heat created by hyperscalers could be utilized annually by 2030. This equates to 2,500GWh per year (COWI, 2018). The EU's Heating and Cooling Strategy (European Commission, 2016) makes clear the requirement to decarbonize Europe's heating and cooling grids, which together make up half of the EU's total energy consumption. The Strategy covers two topics particularly relevant to District Heating, namely the integration of electricity in heating systems and the reuse of waste heat from industrial processes. This waste heat is by definition CO2 free, since it is heat that would otherwise have gone to waste. The requirement for buildings to decarbonize, and the CO2 free rating of data center waste heat makes district heating increasingly economically feasible and socially desirable.

EU countries are pursuing a CO2 emission reduction of 95% by 2050. Increasing the share of renewables in the electricity generation mix only affects CO2 emissions related to electricity generation. However, utilizing CO2-free waste heat in district heating grids has a two fold effect on a nation's emission profile since decarbonisation occurs in both the Electricity sector, and the Heat sector. Transportation and Heat are not dealt with by current regulations but regulators at the EU level have signalled their intent to decarbonise the Heat sector in due course.

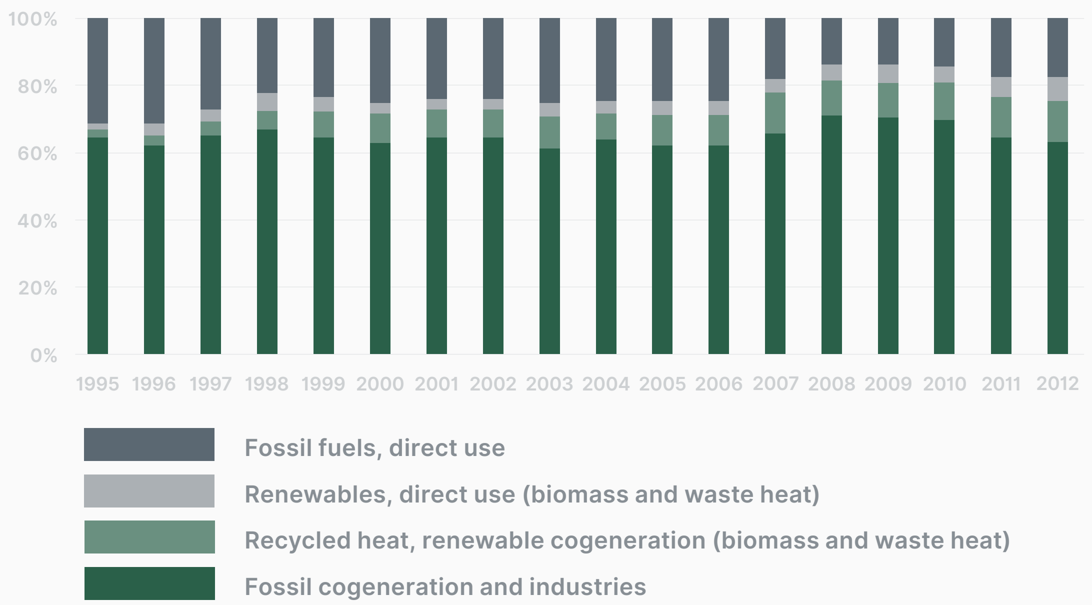

Figure 2.4) Heat sources as % share, used in EU District Heating Networks (Colmenar-Santos et al, 2017)

District Heat is still mostly produced through burning fossil fuels, either in isolation or as part of a Combined Heat and Power plant (CHP). These elements are denoted in the above graph in dark gray and dark green respectively. Less than 10% of current district heat supply comes from recycled waste heat, denoted in light green. The addition of recycled waste heat to the district heating grid is itself not new. What's new is data centers as the source of that heat.

2.6
Stricter regulations will prevent Heat 'Dumping'

Legislation to prevent the 'dumping' of waste heat is set to become tighter. For example, in the Netherlands, discharging heat into the environment is not allowed until that heat is itself cooled (Ristic, Madani and Makuch, 2015). The result being that data centers need to find novel ways to make use of, or dispose of, their waste heat. Heat dumping regulations make it more difficult for data centers to find heat sinks for their increasingly heat intensive outputs, further incentivizing the use of waste heat in district heating grids.

2.7
Decentral sources of Heat

Data centers of all sizes are growing, however, we're also likely to see more local data centers as the Internet of Things (IoT), Industrial Internet of Things (IIoT), and 5G penetrate deeper into society and deliver better connectivity between the end-device, consumer and data center. The applications of these technologies will demand local storage and rapid computation, often referred to as Edge Computing. This means more data centers will become available as potential heat sources in areas with the highest demand - urban areas.

Analysts Insight

Edge computing brings cloud-style resources closer to the source of the data, reducing latency and reducing the amount of data that needs to travel across the network. Whilst not all edge data centers will be liquid-cooled, many will be designed to use liquid cooling to support high density racks in confined spaces, where traditional cooling options won't be available. Thus liquid cooling could make it easier to deploy edge sites in locations where space is limited and large computations are necessary.

2.8
Challenges remain

There were still significant challenges to the Yandex project. "*Success requires cooperation of infrastructure operators and Cooperation is often halted when discussions turn to who will pay the initial investment*" says Mikko Aho, a sales manager at Rittal. The large initial capital costs are a political barrier to adoption, even though lower operating expenditures (compared to fossil fuel alternatives) generally support the economic case. Utilities are also wary of leaving large capital expenditures idling should the regulatory, and therefore the business environment, change. Hence a stable and structured approach to regulatory change is required to ensure utilities and data centers are confident enough to make the high initial investments.

Valorizing heat is perhaps the biggest hurdle for data centers. Putting a price on the heat that can be injected in to district heating grids is so far very difficult. Additionally, one shouldn't underestimate the physical disruption caused by building or upgrading district heating systems. There are only 3500 district Heating grids in the EU, accounting for only 12% of the Heat sector (ADE, 2018). This is expected to rise as Europeans continue to urbanize, and as the decarbonization of the heat sector becomes a higher priority, however the market is still relatively modest. Technical, political and economic challenges persist.

2.9
Summary - The Business Case

Data centers are becoming increasingly large generators of waste heat. This waste heat is being generated in cities, where district heating demand is growing fastest, and where waste heat can be recycled most efficiently. Additionally, the regulatory environment is shifting the incentive structure more favorably towards recycling recovered heat into district heating grids. For the data center, advantages include revenues from selling recovered heat and the improvements in emissions reductions. For the district heating utility, the advantages include the consumption of "CO2 free" heat, and the accompanying reductions in emissions and prices. National Governments meet their emissions reductions targets across both the Heat and Electricity sectors, and Local Authorities deliver cheap, CO2 free heat to their residents. In summary, there would be multiple winners from recycling heat from data centers.

3
Value Proposition - Electricity Services

This chapter highlights the macroeconomic value that could be derived from using data centers as a source of Electricity flexibility or to support the grid with Fast Frequency Response (FFR).

Executive Track

All economies of the EU have committed to reducing carbon emissions by increasing their share of renewables in their electricity generation mix

As intermittent renewables penetrate further into the generation mix, flexibility becomes an increasingly important feature of the electricity system.

Typically sources of flexibility are already either exhausted (such as Hydro power), inefficient (such as intermediate chemical storage) or require significant long term investment (Grid reinforcement)

Demand Response, a means of maximising existing resource utilisation, is likely to play a more important role in the future electricity system.

Data centers, with their real-time management and some degree of workload flexibility, are good candidates for Demand Response schemes. They can “shift” load to outside of peak hours, or deliver surplus energy stored in their batteries and on-site generators to the grid at times of undersupply.

A federation of data centers, operating as a fleet, can “migrate” load from areas of high demand to areas of low demand. This could solve balancing and local grid constraint issues.

There are still significant challenges to proper Demand Response market function, however demand response will play a far larger role in the electricity system and data centers can play a far larger role in the demand response schemes.

3.1
Flexibility is key to Managing the Energy Transition

The priorities of the European Internal Energy Market (IEM) are now split between security of supply, economic utility and environmental sustainability. The latter two factors explain the drive towards Renewable Energy Sources (RES) and decarbonization.

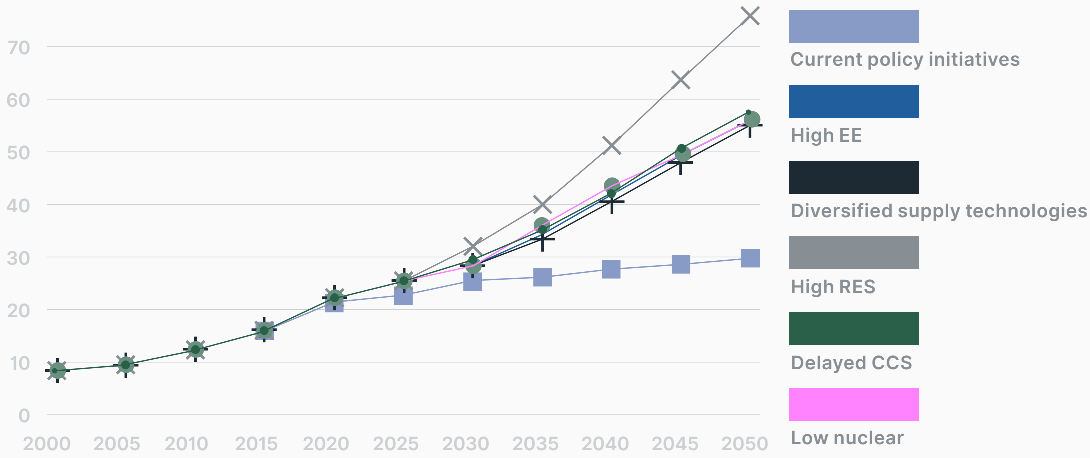

Figure 3.1) Renewable Penetration Pathways as a percentage of the EU Electricity mix (Howes, 2018)

Flexibility is necessary to ensure demand and supply can be matched at every given point in time to keep the electricity system stable. Flexibility can therefore be described as the capability to dynamically compensate imbalances in supply and demand, as well as bottlenecks in the grid. There are different forms of flexibility, with different time horizons, acting on the different markets. Primary reserves (activate within seconds), secondary reserves (activate within a few minutes) and tertiary reserves (activated within 15 minutes) are typically supply-side solutions to balancing the grid and correspond with the balancing market. The intra-day, day ahead and forward markets require longer term forms of flexibility (EPRS, 2016).

Intermittent renewable fuel sources like Wind and Solar are fundamentally very volatile, thus a high penetration of renewable energy supply creates both balancing and grid challenges. As volatile renewables are phased in, the demand for flexibility increases. As flexible fossil fuels are phased out, the supply of flexibility decreases, exacerbating the challenges (NREL, 2010). Overall the value of flexibility is of increasing importance in markets where intermittent RES are well penetrated, and all European electricity markets have signalled their intention to substantially increase RES penetration from anywhere between 30-70% of total generation mix by 2050, as shown in figure 3.1.

3.2
Where is Flexibility found in the current Electricity System?

In the traditional model, electricity was provided by two types of generators: baseload generators, which run at nearly constant output; and flexible generators which met the variation in demand and provided operating reserves. Traditionally flexible generators were gas, oil, hydro and coal. Different fuels exhibit different amounts of flexibility, and different degrees of dispatchability (the ability to rapidly ramp generation up or down). Hydro and gas sources are the most flexible and can take minutes to ramp up, while nuclear and lignite are the least flexible and can take days or weeks to ramp up and down.

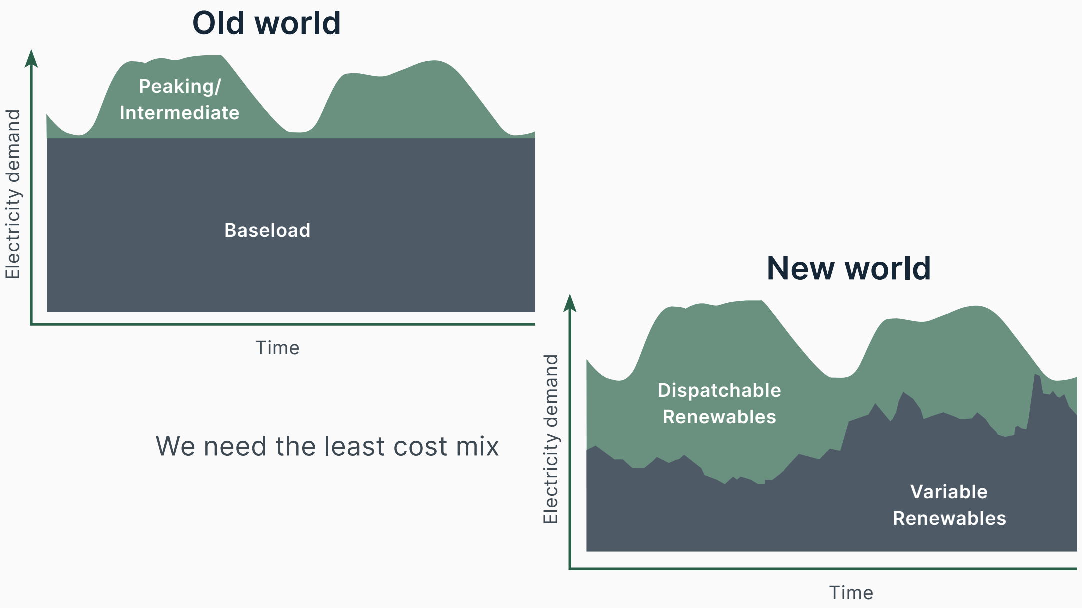

Figure 3.2) Showing the change in the electricity mix between traditional markets and high RES markets. (ARENA, 2018)

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Figure 3.2 is an impression of the "post-transition" electricity system from Australia's Renewable Energy Administration *ARENA, 2018*. Notice the increased variability of renewables and the near absence of baseload. We believe the above figure is accurate for very high RES penetrated systems. Where flexible generators previously followed electricity demand, flexible generators will in future follow variable renewable supply. This is a fundamental change to the electricity grid architecture.

Flexibility can be exhibited on the supply side, demand side, through energy storage systems or grid systems (Strbac et al., 2012).

Storage systems such as battery storage in vehicles may become popular but their costs are disproportionately expensive compared to the amount of electricity they could actually store. The price for battery storage will always come on top of the price of energy generation. Hydro and pumped storage, though effective, have all but been exhausted in Europe and it is unlikely we'll see them play a much larger role. Intermediate storage possibilities are being considered right now, however their transformation efficiency is quite low because energy must be transferred, then transferred back into electricity. Alternative intermediate products such as hydrogen and methane, are still nascent. There are some proof of concept facilities that demonstrate this, however none are operating commercially.

Grid reinforcement and cross border interconnectors are centralised solutions and will reduce the overall volatility of consumption and intermittent generation through a 'geographical smoothing effect', however this effect is limited to the quantity and capacity of the interconnector cables. Intra- and inter-national transmission cables take a long time to plan and build - upwards of 5 years (Roepke, 2012). Renewables are actually being built faster than cables can be laid, as is the case in Germany where wind generation in the North has grown enormously, and the interconnection cables between the North and South are still yet to be built (Bauknecht et al, 2018).

On the supply side, fast ramping coal and lignite will likely be phased out, and gas will probably be used as a flexible transition energy source, and not as a firm source of capacity (Izadi, 2017). Nuclear capacity will be dependent on the country in question. France for example has built a considerable supply of nuclear power stations whilst Germany has vowed to remove nuclear altogether from their mix by 2022. Few new nuclear power plants are planned in Europe.

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Due to low operating costs and high initial costs, Nuclear is typically run as base load and is rarely used as a source of flexibility *(OECD,2012)*. Thus Nuclear is used inflexibly for economic reasons, not technical reasons. Could nuclear operate flexibly? This debate rages in France and Germany *(Morris, 2018)*. It is true that France frequently ramps up and down nuclear generation, however it does so in a unique manner. The fleet of 58 reactors don't uniformly power down. Instead one reactor is often sacrificed completely while the other reactors maintain standard operation. Experts argue that frequent ramping for nuclear could create more strain and therefore more maintenance costs. The truth is it's never really been tried, and when it has, it's been on old reactors close to the end of their design life, and on reactors who were never previously designed to ramp. The jury is still out on whether nuclear is compatible with renewables. Most experts say it isn't however it is a space well worth watching.

3.3
Demand Response to play a larger role in Flexibility

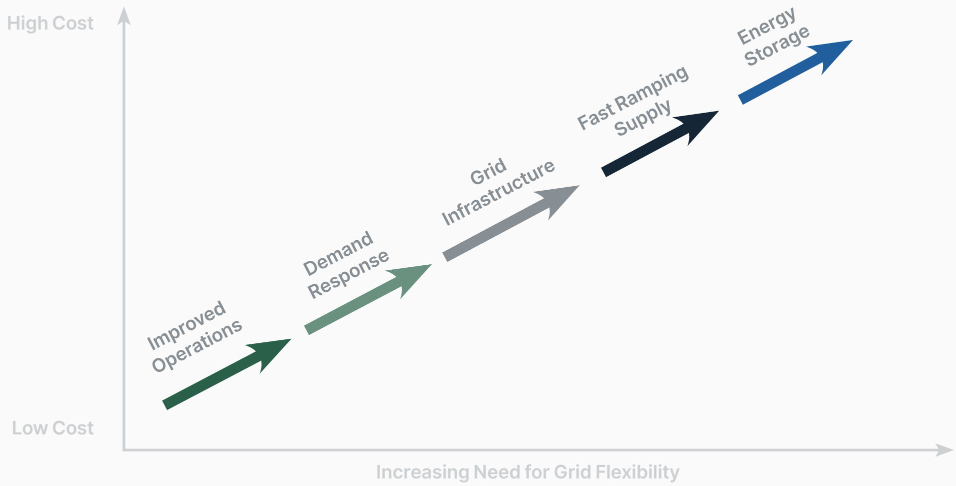

Figure 3.3) Relative costs associated with different forms of flexibility (NREL, 2010)

As figure 3.3 shows, Storage, Fast Ramping Supply and Grid Infrastructure are relatively expensive forms of creating system flexibility. The increasingly feasible alternative is Demand Response (DR). A set of actions taken to alter electrical demand through price signals or incentive payments to ensure the electricity system remains stable. DR saw limited use in the traditional electricity market where supply was altered to match demand. The market of tomorrow will see demand altered to match renewable supply (Ghatikar et al., 2012).

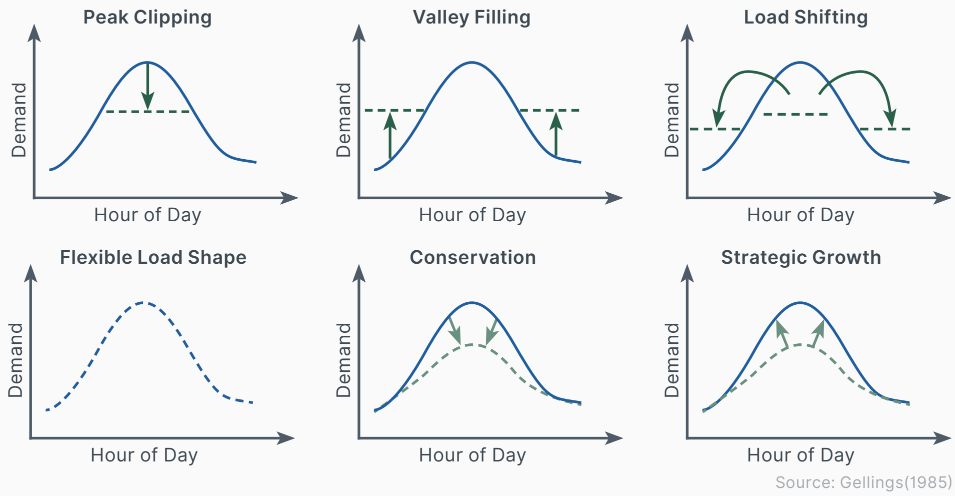

Figure 3.4) Demand Response provides different forms of flexibility (Gellings, 1985)

Demand Response is often the most economical form of flexibility because it requires few new transmission or distribution investments. It can also satisfy a number of forms of flexibility, as shown in figure 3.4 above. Europe is currently accessing around 20GW of available Demand Response, but the European Commission places the total potential at 100GW, forecasted to rise to 160GW in 2030 (European-commission, 2018). 20% of the world's electricity consumption will be eligible for demand-response by 2040.

3.4
Barriers to Demand Response adoption

Monetizing demand response is still a challenge. Most consumers cannot trade directly into the electricity markets because they are too small. Aggregators typically combine the demand response of small customers to produce a pool of flexibility which can be sold into the electricity markets. Every aggregator needs an agreement with each electricity supplier, and every customer needs a clause enabling aggregators to engage in demand response on their behalf. However, there is no incentive for electricity suppliers to include aggregators in their contracts with customers because this undermines many areas of their business model. First, it creates a balancing risk - a third party delivering intra-day deals in a suppliers balancing group reduces the suppliers control. Second, it prevents the electricity supplier from knowing how much demand is truly required. Without this data, suppliers cannot optimise their generation portfolio. Thirdly, the electricity supplier in question may earn a significant portion of its revenue when electricity prices are high. Including Demand Response in their supplier contract potentially lowers their income from high price generation. Lastly, the aggregator, and consumer, are trading electricity that the supplier has generated. The argument is still on-going over whether the supplier should be remunerated for the electricity they have originally supplied.

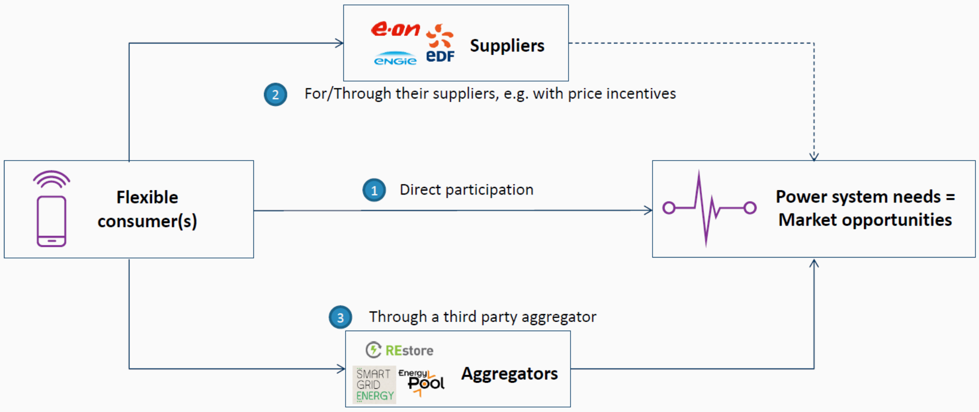

Figure 3.5) Demand Response market design (Veraeghe, 2017)(EU-IRE, 2017).

The market design is shown above. Aggregators and Electricity suppliers have no incentive to work together to deliver Demand Response. Some electricity utilities have started to create their own aggregator units, which solve: a) the issue of data transfer, b) the issue of optimised generation portfolio, and c) the issue of remunerating the appropriate body for electricity supplied. If the electricity supplier is the flexibility supplier, the issue is solved.

Market design is therefore the largest barrier to adoption of demand response. There is no incentive for the centralized generator to adopt or enable demand response. Most European member states have recognised this and are beginning to enforce “acceptance” of demand response where aggregators aren’t required to obtain permission from the electricity supplier, or to compensate the supplier for lost income (Baker, 2017). This however has a knock-on effect on the profitability of centralized electricity generators (CEPA, 2014). It is worth noting that the markets with the most advanced penetration of RES are generally the markets with the most developed Demand Response frameworks, as shown in figure 3.6 below.

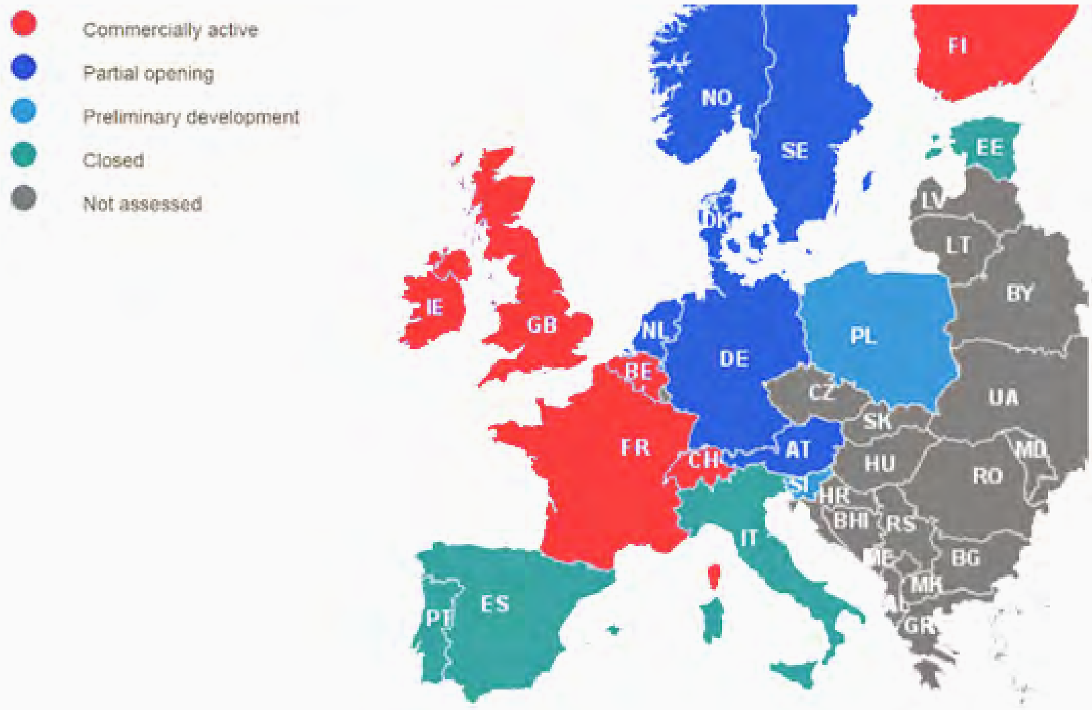

Figure 3.6, Map of Demand Response Regulatory Development in Europe (SEDC, 2017)

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We believe that as intermittent RES penetrates further, the opportunities in the demand response market for all players increases. For aggregators, the higher need for flexibility creates opportunity. Consumers receive lower electricity costs because aggregators provide a hedged, low risk customer for their flexibility. For the Electricity Supplier, at higher RES penetration the wholesale market price is likely to collapse, removing the value of their generating portfolio. Ownership of inflexible generation will therefore drive up balancing costs. The Supplier (with a large inflexible generating fleet) cannot earn during periods of exceptionally low wholesale prices. Implementing their own form of DR, or working with independent aggregators, may be the lesser of two evils and ensures at least a partial return on their assets. EU Regulators are contemplating mandating “forced acceptance” of aggregators in the contracts of electricity suppliers. Though forced acceptance may help in the short term, we believe the energies of the regulators are best served by reducing barriers to entry, clarifying party responsibilities and ensuring markets are sufficiently fast and liquid. As the above map shows, France, Belgium, UK and Ireland have thus far made the most progress in these areas, and The Association for Decentralised Energy estimates potential for demand side response of 9.8 GW by 2020 in the UK alone *(National Grid, 2016).*

3.5
Data Centers as a source of Demand Response

The Lawrence Berkeley National Laboratory (LBNL) studied the flexibility in power consumption of four data centers under different management approaches and found that energy consumption could be reduced by 5% in 5 minutes, and 10% in just 15 minutes without changing the information technology (IT) workload schedule (Ghatikar et al., 2012; Liu et al, 2017). That is to say, this was accomplished using only adjustments to the building's management e.g temporarily setting a higher air conditioning temperature.

Data center owners closely monitor and control the power consumption of their IT and cooling equipment, which makes data centers particularly suited to real-time demand response (Ghatikar et al., 2012). Combine real-time management with flexible IT workloads, and data centers become a potentially large and reliable source of demand response.

Figure 3.7) Data center daily operation energy profile (KWh)(Cioara et al., 2019)

Many typical data center workloads are delay-tolerant, and could be rescheduled to off-peak hours (Cioara et al., 2019). The result is a form of workload "shifting", which would preserve the integrity of the grid during peak hours whilst providing DC's with reduced peak energy costs. The graph above is indicative of real time and delay tolerant workloads. Blue columns denote energy consumed in cooling and hence the additional amount of energy that could be shifted.

A further, more powerful form of data center demand response involves a data center acting amongst a federation of data centers, where data centers can "migrate" workloads between data centers, as opposed to "shifting" workloads in time at the same data center (Ghatikar et al., 2012; Basmadjian, et al., 2016) In other words, a single data center could shift load in time, and a federation of data centers could shift workloads in space and time, with added redundancy. This is a form of flexibility that could balance the national grid and resolve local grid constraints.

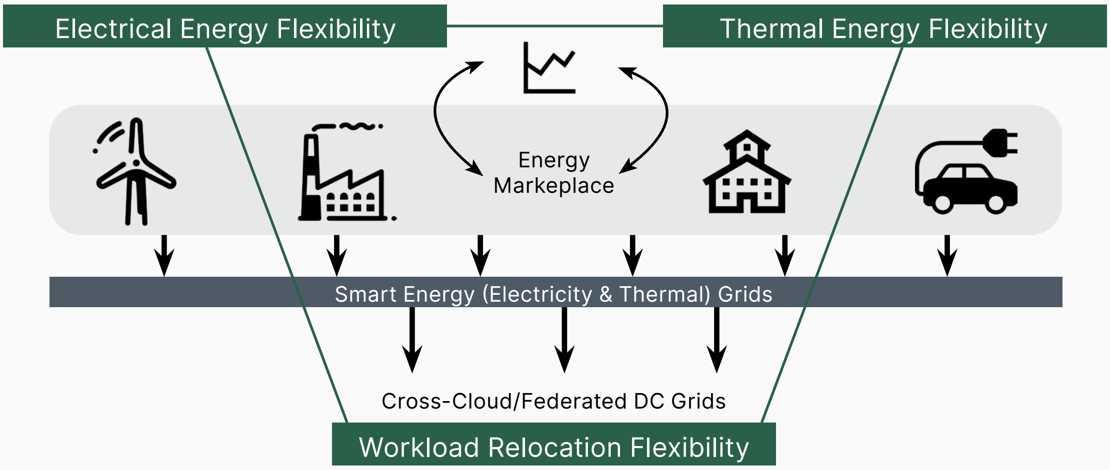

Figure 3.8) A federated data center Architecture can shift load in space and time (Cioara et al., 2019)

The viability of data center demand response is made more apparent when compared with the alternatives. Wierman,2015 found one 30MW data center could deliver financial savings between $500,000 - $5,000,000 when compared to equivalent MW of battery storage.

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Combine real-time management, discretionary workloads, and increasing numbers of data centers and the result is a potentially large source of flexibility. In macroeconomic terms there is considerable potential value available. The challenge is successfully monetizing and extracting it.

3.6 Challenges for Data Center Demand Response

Data centers may hesitate to participate in Demand Response programmes because data centers are typically in the business of avoiding down-time, minimizing risk and maximizing availability (Uptime, 2018; Liu et al., 2014). Participating in demand response programmes may reduce availability or lead to a higher risk of down-time. This risk is exacerbated by the potential surrendering of control to aggregators. This is control that the data center may not have in the first place - retail colocation data centers simply provide space, security, power and fibre to tenants who operate their own IT workloads independently. Changes to the Service Level Agreements need to occur to improve IT shiftability of customer workloads however complexity and risk are still barriers to adoption. Hyperscalers and enterprise data centers, with aligned IT and Facilities staff have more control over their workloads, are best placed to capitalise on Demand Response. Aggregators and data centers need to clarify their risks, contractual obligations, and ensure the right pricing & incentive structure (CBInsights, 2019), before Demand Response truly becomes viable for data centers.

A major barrier to data center adoption of Demand Response comes not from the data center, but from the regulators. Typically Demand Response includes many small-scale contributors who have little bearing on the price they're offered. Hyperscale data centers, with much larger energy consumption volumes, could exert a significant degree of influence on the price at which they respond which creates a degree of risk for both regulators and aggregators (Zancanella and Bertoldi, 2017).

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Note that Demand Response is still an infant industry even before considering Data Centers as a source. When the Demand Response markets mature, (and they will need to as Intermittent RES penetrates further), we believe Data Centers will be one of the biggest players in the Demand Response space. OFGEM, the UK energy regulator, published a report in June 2019 committing to improve flexibility markets in the UK, and much of this involves improving the price mechanism by which the value of flexibility is communicated.

3.7
Ancillary Services

In certain markets such as Ireland, the Uninterruptible Power Supply (UPS) systems employed by data centers have been used to support the electricity grid. As intermittent renewables are phased in, the variability in frequency of the electricity grid (50Hz, plus or minus 1%) increases. At times when the grid needs support, the UPS system, used in conjunction with data center batteries and on-site generators, can help provide Fast Frequency Response (FFR). Data centers are particularly effective at this because they can “kick-in” instantaneously. FFR markets already exist in many countries, and the need for such markets are increasing. The UK will likely form their own FFR market in the next few years.

3.8
Summary - The Business Case

Increased renewable penetration make flexibility an increasingly important part of the electricity system. Grid constraints, expensive storage solutions and the phasing out of flexible fossil fuels all increase the value and viability of Demand Response as a source of Flexibility. Energy generation, consumption, storage and IT shiftability and migratability are all valuable to the energy grid of the future. There are regulatory and technical barriers still to be resolved (Acer, 2014), but we’ve seen some European markets make good progress in developing their flexibility and frequency response markets. Data centers are a large and growing consumer of energy, and their workloads are somewhat flexible, making data centers the ideal candidate for demand response in the near future. Data center demand response could satisfy both national and local energy constraints through load shifting, load migration and smart building management.

There are many winners to data center demand response systems. Data center operators could reduce their energy costs, and create a secondary source of revenue. This could be passed on to customers in the form of reduced costs. Electricity consumers would benefit from a more secure and economical electricity system while Distribution and Transmission System Operators would benefit from a larger pool of local and national flexibility - flexibility across balancing, intra-day, day-ahead and longer horizon markets. Data centers would therefore help to integrate renewables into the energy grid, increasing the penetration of renewables in our energy supply.

4
Value Proposition - Locations

This chapter will explain the challenges facing colocation and hyperscale data centers before explaining the Location related opportunities of partnering with utilities.

Executive Track

Hyperscalers have increasingly been built across northern Europe and the Nordic countries because land is cheap, the climate is cool and renewable power is abundant, reliable and inexpensive.

Challenges facing Hyperscalers include difficulty in finding locations with such high power ratings, and the disposal or large amounts of heat.

Colocation data centers have clustered around cities, typically financial hubs - Frankfurt, London, Amsterdam, Paris.

Challenges facing Colocation data centers include finding locations Proximal to Internet Exchanges with good access to Renewable Power, and a high Power Rating. Local government typically pose challenges with respect to the planning process.

Utilities can solve these challenges. They have sites proximal to cities, which are redundantly supplied with electricity and fibre. Utilities will vacate some of these sites in the near future as they shed their coal (and nuclear) plants.

Utility sites also offer further advantages such as large, secure sites that can expand “on-site”. On-site expansion “campus style” is common for Hyperscalers in rural areas but it is particularly applicable for colocation data services in competitive urban locations.

Some Utility sites are Combined Heat and Power plants (CHP). Such sites are readily able to deal with the large amounts of heat created by data centers - and hyperscale facilities in particular - by injecting this heat in to district heat grids.

4.1
The Growth of Hyperscalers

The Nordics, Ireland and Iceland (referred to here as the Northern Ring) are increasingly favorable destinations among hyperscale projects for several reasons: favorable climate, availability of land and low cost of renewable, reliable power (RIPE, 2016).

The ambient outdoor temperature allows the data center to utilize “free cooling”, where outside air is used to cool the data center, reducing the overall cost of cooling, as shown in table below. Additionally, the cooler climate reduces failure rates among equipment, reducing the likelihood of disruptions.

Geographical Zones	Countries	Temperature Range(°C)	RH Range(%)	Average PUE
Nordic countries	Denmark, Finland, Norway, Sweden	18-26	20-80	1.71
UK and Republic or Ireland	England, Scotland, Wales, Northern, Ireland, Republic of Ireland	17-30	8-80	1.83
Northern/Central Europe	Austria, Belgium, France, Germany, Hungary, Luxembourg, The Netherlands, Portugal, Poland, Switzerland	14-28	16-75	1.72
Southern Europe/Meditetrranean	Gibraltar, Greece, Italy, Malta, Spain, Turkey, Monaco, Romania, Bulgaria	16-26	20-80	2.00

Figure 4.1) Temperature and Humidity analysis of Europe (Avgerinou, Bertoldi and Castellazzi, 2017)

Beyond being nations of relatively low population density and hence having a slightly cooler property market, the Northern Ring are actually very well connected in terms of internet connectivity. They act as bridges between different markets, for example: Ireland and Iceland connect Europe with the US, Sweden & Finland have good connections between continental Europe and Russia, whilst Norway & Denmark connect with the UK and continental Europe (Li et al., 2019).

Renewable energy is more abundant and less expensive in the Northern Ring, which explains their popularity with hyperscale players like Google, Microsoft. The Nordic Electricity Grids are also far more advanced with respect to their ability to handle volatile RES such as wind and solar. Hydroelectricity and geothermal also play larger roles in their electricity mix, which aren’t nearly as volatile. The result is low cost, reliable renewable energy.

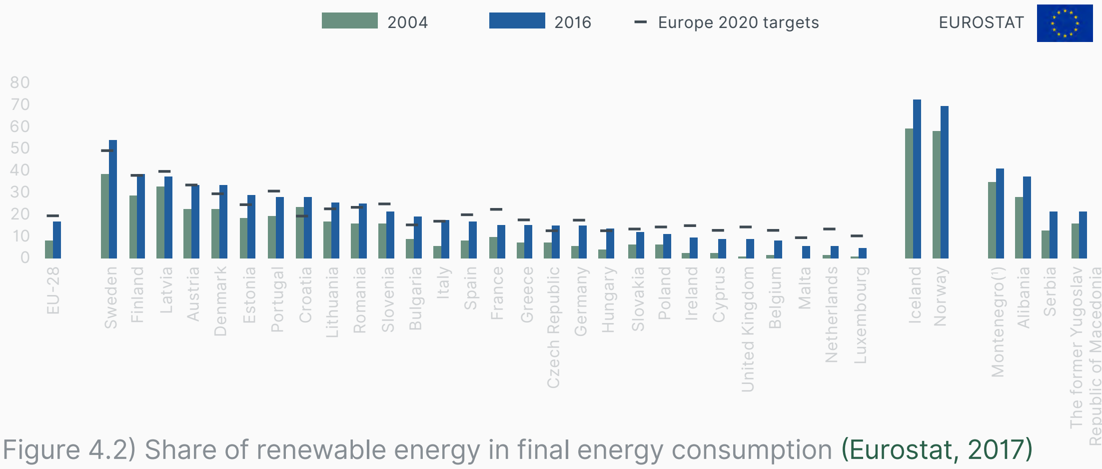

Figure 4.2) Share of renewable energy in final energy consumption (Eurostat, 2017)

Analysts Insight

Low cost land, cool climates and good internet connectivity explain the popularity of Hyperscale self-builds in the Northern Ring. We expect more Hyperscale facilities to enter the Nordics in the years to come from second tier technology companies such as Uber, as well as new Chinese players like Tencent and Alibaba. Denmark believe 10 hyperscale facilities will be built in Denmark alone before 2030 *(COWI, 2018).*

4.2 The Challenges for Hyperscale

Hyperscalers face slightly different challenges to Colocation facilities. Namely they face the problem of removing large amounts of waste heat. The global Hyperscale market will soon be worth ~$71.2 billion by 2022, registering an annual growth rate of 20.7% during the forecast period 2016 - 2022 (Allied Market Research, 2016). Hyperscale infrastructure will be responsible for >50% of all installed servers, up from 30% today, and more than 50% of network traffic and stored data by 2023 (Cisco, 2017). Hyperscalers deploy virtualization, economies of scale and best practices to improve efficiency and the results are ~ 300 European facilities with huge amounts of excess heat. Locations with such concentrated power availability will become harder to find as Hyperscalers continue to grow in number and size, but it is the disposal of this heat which hyperscalers truly struggle to solve.

Analysts Insight

Whilst traditionally found in rural areas, some hyperscalers will transition to more urban environments as new workloads force data storage and computation closer to the end user. This trend will be slow but data-intensive applications are becoming more real-time such as in Artificial intelligence, Gaming & IoT applications.

"It's forcing a shift, with the hyperscalers now moving services closer to the users. The cloud guys built their data centers where power was cheap. Now latency is a huge issue" said Phill Lawson-Shanks, the Chief Innovation Officer at EdgeConneX.

The counter-argument to this shift is to have Edge data centers enter the urban sphere, in a distributed manner. This would change the architecture of the digital grid (Note Edge and Hyperscale working in addition to one another, not at the expense of one-another). The jury is still out on which architecture is most likely, but we do know latency and bandwidth issues are pressuring us to move computation and storage closer to the source of data.

4.3 The Growth of Colocation Data Centers

Colocation facilities, by contrast, operate in the concentrated FLAP markets of Frankfurt, London, Amsterdam, Paris. CBRE research indicates that 70% of total European "take-up" in the data center real estate market in 2016 and 2017 was across these cities. There are two reasons why FLAP is so concentrated: Proximity to Internet Exchanges and Ecosystem Clustering.

To satisfy latency sensitive demand, data centers operate close to major internet exchanges and fast, well connected fibers (Czekaj & Pietersma, 2017). Internet connectivity is so valuable that direct access to fiber is a competitive advantage. Hence the data centers that serve these industries (such as Financial services) operate in the very same regions. It is no coincidence that the biggest data center markets are in close proximity to the largest Internet exchanges, i.e. LINX in London, DE-CIX in Frankfurt, AMS-IX in Amsterdam. For comparison, we see the same trend in the US, where the existing internet exchanges in e.g Northern Virginia and Silicon Valley are the fastest growing data center regions.

The entire data center ecosystem, from suppliers to service providers, cluster together. The result is massively concentrated nodes of data center ecosystems around FLAP markets. Enterprises also disproportionately choose colocation providers close to their operations. It stems from a belief that if things go wrong, having the provider close by would perhaps fix things quickly. Amazingly, most providers in the UK are within a 30-minute drive of their clients, so this behavior is firmly rooted in the psychology of enterprise CIO's, whether they are aware of it or not.

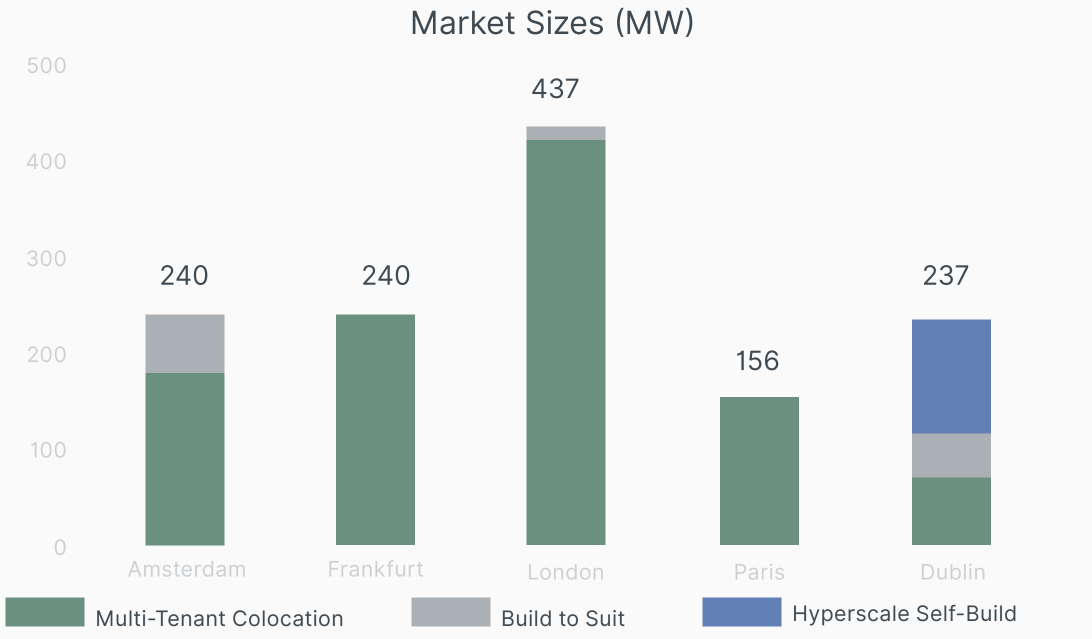

Figure 4.3) CBRE Research on the size of the Data Center Market

4.4 The Challenges for Colocation data centers

The above explains why colocation centers have concentrated around FLAP over the last 20 years. Location is key. However, as data centers continue to grow in size and quantity the challenges they already face will be exacerbated. AFCOM, 2018 State of the Data Center Industry report indicates the average number of data centers managed per organization will increase from 8.1-10.2 over the next three years. This equates to 4,000 more facilities by 2020 in the United States alone (Friedman, 2018) and we can expect Europe to exhibit similar trends. The challenges include: Proximity to Internet Exchanges, Access to Power, Access to Renewables, and dealing with Regulators and Local Government.

Proximity to Internet Exchanges

Access to fiber is critical. Internet speed determines location. FLAP markets are increasingly saturated, and whilst building fibers is not too difficult, finding land close to fibers and Internet Exchanges is increasingly difficult and expensive.

Analysts Insight

Colocation providers have now started “Land Banking” in the FLAP markets to ensure they can satisfy future demand in locations with good access to fibers and internet exchanges. *“I think a lot of these companies are taking down more land and looking beyond the first 30 megawatts to their next data center requirement,”* said Jeremy Myers, Director of Real Estate at EdgeCore. *“You’re seeing more of a land grab because of the way data center users’ needs have grown so radically. All the low-hanging fruit was picked long ago.”*

Access to Power

Access to abundant and reliable power is fundamental. Europe is made up of a series of reliable electricity grids, however experts all acknowledge that with the onset of distributed electricity supply, and a higher share of intermittent renewable energy production, electricity grids will become more strained. Grid capacity in urban areas is already strained and continued growth in the data center industry will further strain it (UptimeInstitute, 2019). Colocation data centers are also getting larger and more abundant, as the previous sections have explained. *"In this sector, you can run out of power before you run out of space. Valuations are based on power"* says Patrick Lynch, managing director for data center solutions at CBRE.

WHAT ARE THE BIGGEST CHALLENGES FOR YOUR ORGANIZATION IN THE NEXT THREE YEARS? (MRA)

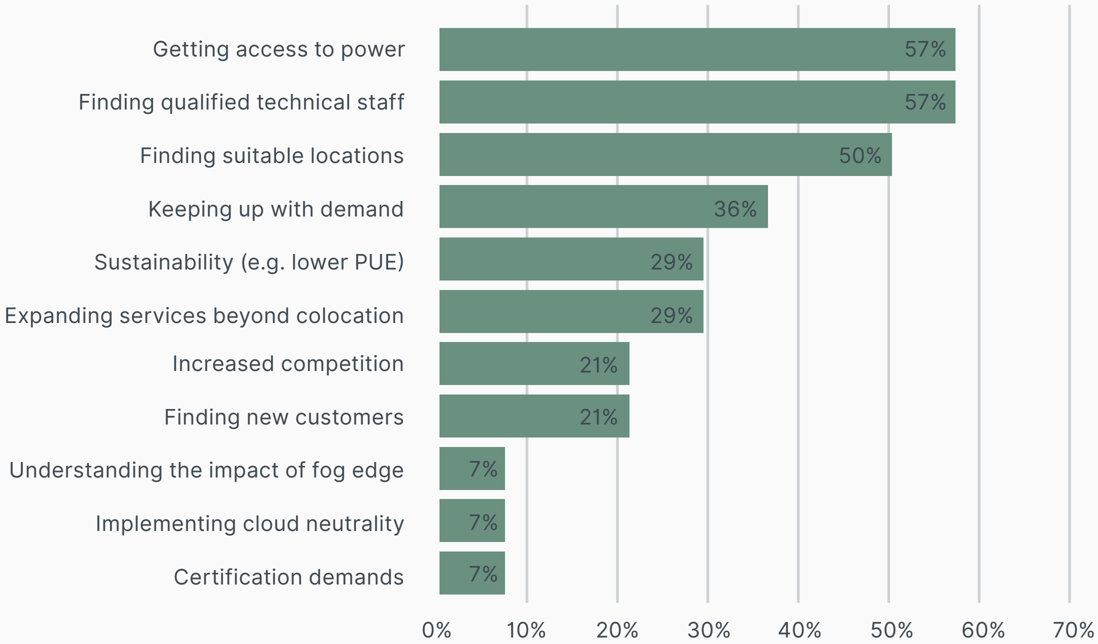

Figure 4.4) Dutch Data Center Alliance Survey Results 2018 (DDCA, 2018)

Access to Renewable Energy

Demand for renewable energy by data centers is on the rise, with 83% of data centers intending to use more renewables in the near future, in part due to the popularity of Energy Reuse Factor (ERF) as a data center metric (AFCOM, 2018). Data centers have tried using ocean-water as a cooling medium, and Wind as a source of energy, neither are reliable and both come with significant costs. Data centers have significantly increased their share of RES in their consumption mix through power purchase agreements (PPA's). However renewable energy, and therefore the number of PPA's, is limited and demand for renewable PPA's is growing very quickly. Current regulatory frameworks typically only allow PPA's to be purchased in the same grid region where the renewable energy is generated, which means FLAP markets can't make use of the abundance of renewable energy generated by the Nordics. This is exacerbated by the significantly higher cost of renewables across the FLAP region than in the Nordics (Jakob Dybdal et al., 2018).

Price of Real Estate

The price of land in the FLAP markets are some of the highest in Europe (Datasource, 2018). House prices have on average tripled since the year 2000, and investment in the FLAP cities is larger than others (PWC, 2018).

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Data center providers are satisfying their desire for proximity more strategically. Equinix, for example, has moved many of its data centers out of central London, 20 minutes North, where they save 20% in land costs. Slough, an out of town suburb to the west of London with good transport and network connections and relatively cheap land prices, is fast becoming a data center hub in its own right.

Dealing with Regulations

Local, state, and federal governments often provide incentives for data center construction. Examples include tax abatements, ease of permitting, expedited access to rights-of-way and support for fiber access. However, all too often the planning process is long, and the government is a hindrance, not a help. The Nordic market is an example of a data center friendly market, with rebates on energy tax for data centers of up to 95%. Facebook recently scrapped plans to build their Athenry data center in Dublin, citing the long planning process as the primary cause.

4.5
Energy Utilities can solve Data Center Location Challenges

Access to Proximal Land

Fundamentally colocation data centers require real estate proximal to their centers of demand - cities. Currently electricity utilities own significant plots of land in urban areas due to both their electricity generation and district heating assets. If data centers could “co-locate” with utilities, or purchase this land outright, they could satisfy both future demand and their colocation bias towards clustering around FLAP markets. The result would be a radical way of delivering the same service at a far better price.

Access to Fiber

For about three decades now, electrical utilities have been installing optical fiber to monitor and control the diverse elements of their transmission and distribution networks as well as provide for their communications needs. In other words, electrical utilities already have a redundant network of fibre, and redundantly connected sites. These services are often currently sold to customers and third parties however either the sale of these sites, or the operation of data centers by energy utilities on these sites could leverage this pre-existing fibre network.

Access to Power

Electricity utility sites are typically connected redundantly to the grid and capable of handling large amounts of electricity, which makes them perfect locations for data centers. If data centers operated on such land they would have access to a large and redundant supply of electricity, solving the issues around power access limitations.

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Eleven EU nations have either begun closing their coal fleets or have announced their intention to shutter all coal generation by a specific date. This includes France by 2023, Italy and the UK by 2025, and the Netherlands (home to Europe’s three newest coal plants) by 2030 *(Moore et al., 2018).* This equates to 35.5GW of operating coal, roughly 22% of total EU generation. Coal generation facilities are built very close to the consumers they serve, namely cities. These soon to be shuttered sites could be converted into colocation or hyperscale data centers. Such sites are proximal to FLAP markets, well fed by fiber and well designed for large electrical loads.

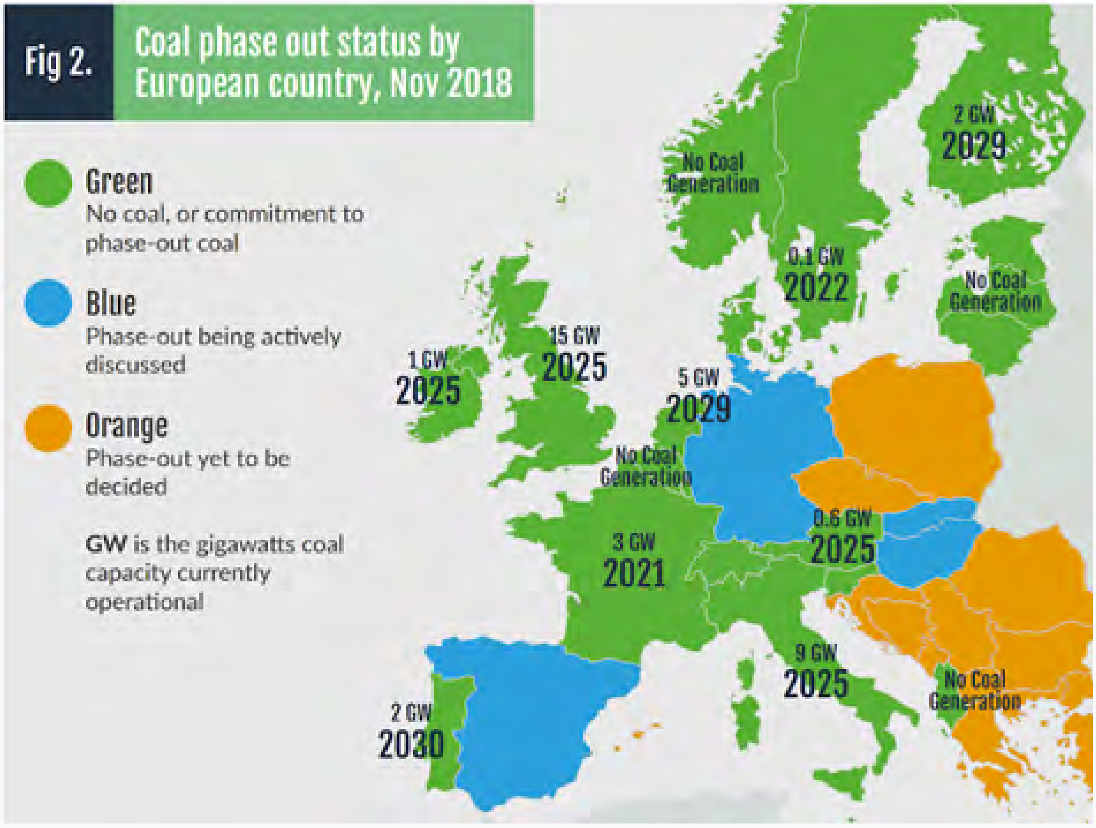

Figure 4.5) Coal phase out in Europe (Moore et al., 2018).

4.6
Energy Utilities can unlock new potential

Utilities don't just solve issues that data centers currently face. They offer additional advantages, namely Integration with District Heating, as detailed in chapter 2, as well as Expandability.

Proximity to District Heating

Demand for district heating in the FLAP regions is increasing. Additionally, policy makers are beginning to understand that energy sustainability must apply to the heat and transport networks as well as the electricity network. The Dutch data center industry is preparing to compel district heat grids to purchase the waste heat from major data center hubs in Amsterdam. Should colocation facilities be built on electricity utility sites (either operating or decommissioned) the sale of waste heat to district heating grids could be made technically and economically more feasible. This is especially true for sites known as Combined Heat and Power plants (CHP), where a route into the district heat grids already exists.

Hyperscale facilities could also benefit from heat recovery & utilization, as previously discussed in chapter 2. However, they are not likely to need the help of electricity utilities in finding sites.

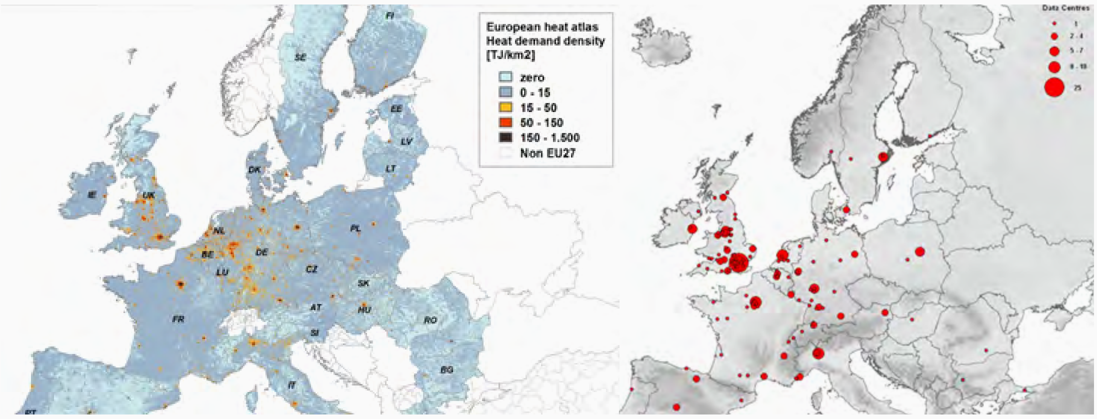

Figure 4.6a (left) and Figure 4.6b (right), District Heating Demand is highest in regions where data centers cluster (Avgerinou, Bertoldi and Castellazzi, 2017)

Expandability

Currently old warehouses and industrial buildings are often repurposed into data centers because industrial buildings can bear the load of data center equipment, which are significantly higher than, for example, office loads. However, repurposing old warehouse buildings still limits the ability of collocation data centers to expand, and brings to the fore issues around building security. Utilities typically surround their power stations with a large amount of securely fenced empty land. This land could be used for data center expansion. The ability to expand as demand expands is crucial. This would allow colocation facilities to form “campuses” on the same site, where data halls could be built one after another as demand required.

4.7 Summary - The Business Case

Both Northern Ring Hyperscalers and FLAP colocation data centers suffer from an excessive amount of heat to be cooled, and we will see excess heat creation increase in concentration and abundance as data center power consumption continues to grow. Electricity utilities could help resolve this by “co-locating” data centers along sites on the district heat network.

Electricity Utilities own and operate sites with large, redundant power access and redundant fibre access. These sites are typically located near cities. Coal plants especially are likely to be decommissioned. These sites are perfect locations to build and operate data centers.

Colocation data centers also suffer from a chronic lack of spaces. All current challenges are being increasingly strained as data centers continue their inexorable growth. Energy Utilities offer colocation data centers a potential antidote to most of their issues. Space, power, connectivity and expandability could be solved either by sharing, purchasing or collocating at the sites currently owned by energy utilities.

5 Value Proposition - Operational Synergies

Both industries are very complex, require near continuous availability and are potentially life-critical in the event of failure. Similar motivations and similar operating requirements correspond with similar risk prevention & mitigation measures. This chapter evaluates the operational challenges faced by both Electricity Utilities and Data Centers at the Facility level and Network level. This chapter argues that the operational similarities are in fact shared core competencies of each industry.

Executive Track

Both Industries are motivated to ensure maximum availability and minimum disruption because both industries provide consumers with business-critical infrastructure.

Individual data centers and utility facilities defend against down-time by mitigating access, component and procedural risks, in very similar methods.

Both industries recruit from the same talent pool for incredibly similar roles. Both industries struggle with the same personnel shortages and an "ageing out" of experienced workers.

The Electricity system mitigates against system failure by using a redundant grid. A redundant digital grid is, though nascent, still forming.

Governance and regulations are incredibly important to the electricity grid, which is harmonizing in both the physical and regulatory sense towards one EU market. The digital grid doesn't face the same sort of system wide regulations, and the ease with which data can travel across borders makes regulation null and void however regulators are slowly trying to bring data under some form of regulation. Eventually data centers and the digital grid will be regulated the same way electricity grids are...in the public interest.

The value proposition here lies in the shared motivations, similar products, shared customers, shared core competences and soon to be similar governance structures.

5.1
Facility Reliability

This section defines a facility as an individual data center or power station. Defending a large technical system from downtime requires a broad range of measures, both technical and human (Uptime, 2018). Both facilities defend themselves from downtime across three major risk areas: Access, Component, and Procedural risks.

Mitigating Access Risks

Unauthorized access is prevented using concentric rings of physical security. Perimeter security measures include vegetation management, well-lit reinforced concrete walls and armed guards. Biometric facility access systems restrict access to pre-approved persons, who are given permission to operate in limited authorized zones. Self-build facilities are designed using reinforced concrete and minimize window access wherever possible. Visitors are often weighed & timed in & out. Intruder alert systems and mantraps prevent unauthorized access, while guards & cameras continuously patrol the facility. Even local traffic patterns can be scrutinized to ensure the facility is not at risk from malicious attack.

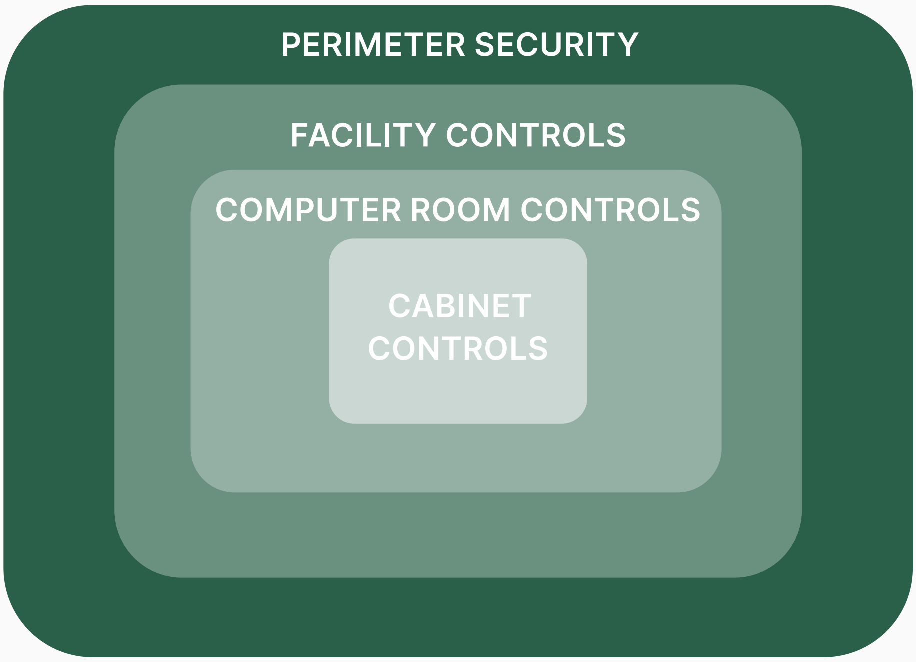

Figure 5.1) The Four Layers of Data Center Physical Security (Anixter, 2012)

Mitigating Component Risks

There are thousands of components in LTS's, which means there are many possible paths from component fault to facility downtime. Both industries defend against such risks by continuously monitoring components, through many thousands of sensors. Equipment alarms and management software keep staff informed of potential sources of failure, who act to bring the facility back to minimal risk. Both industries struggle to manage the risks of retrofitting or refurbishing legacy equipment due to the complexity of integrating legacy equipment with modern equipment, and the need to maximize availability.

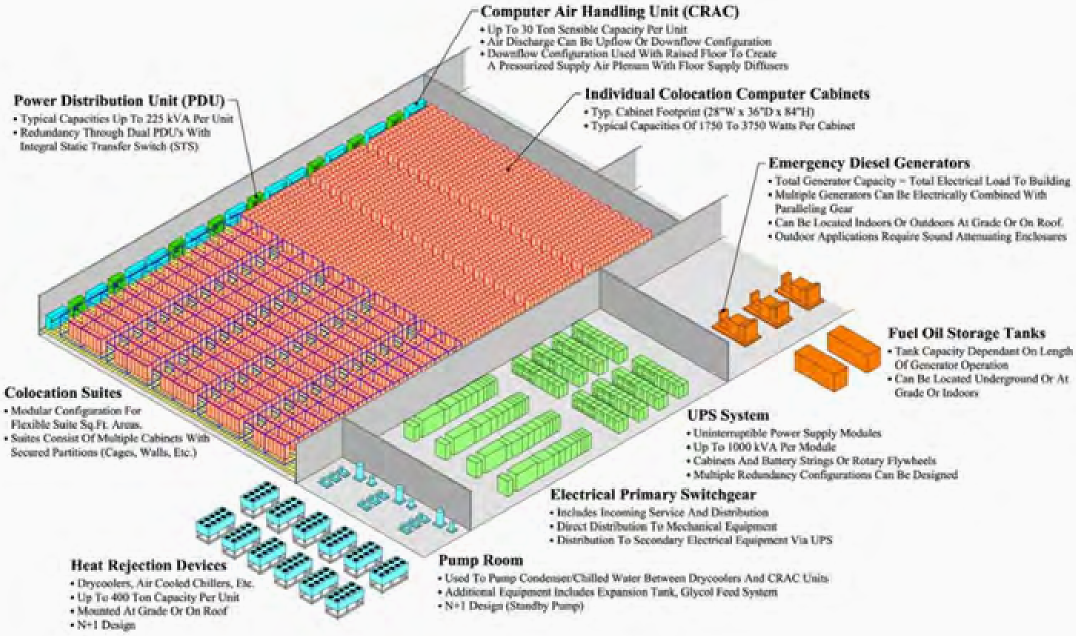

Figure 5.2) An illustration of data center complexity. (Beaty, Quirk and Dunne, 2019)

Mitigating Procedural Risks

It is important to note that the failure cascade can move between technical component failures and human failures. Human and technical risks are completely interrelated, and the matter is further complicated when one considers that humans can be both the potential producers of, and defenders against, downtime. The table below is indicative of wider data center facility downtime. In all categories given, humans play a significant role.

Category	Fraction	Description
Maintenance	17%	Routine maintenance (for example, upgrading the software and firmware of network devices).
Hardware	13%	Failing devices (for example, faulty memory modules, processors, and ports).
Misconfiguration	13%	Incorrect or unintended configurations (for example, routing rules blocking production traffic).
Bug	12%	Logical errors in network device software or firmware.
Accidents	11%	Unintended actions (for example, disconnecting or power cycling the wrong network device).
Capacity planning	5%	High load due to insufficient capacity planning.
Undetermined	29%	Inconclusive root cause.

Figure 5.3, Common causes of Facebook's data center disruptions 2011-18 (Meza, 2018)

Scheduled downtime for maintenance attempts to prevent failure by addressing component issues before they become a problem, however the requirement to keep availability at the 99.9999% means scheduled downtime is reduced to the bare minimum, exposing the facility to more risks. Inadequate maintenance is a large risk factor and further reiterates the trade off between availability, downtime and operational economics. Redundancies and safety systems prevent faults and minor disruptions from cascading into a system failure. However, It is precisely this tolerance of faults that allows both types of asset to operate in a "degraded" state. That is to say, both industries are operating closer to failure than they should be (Cook, 2000).

5.2
Network Reliability

Network Reliability is the macro view of the system's ability to deliver electric or digital power, where section 5.1 referred to the ability of individual facilities to generate electric or digital power. Both industries employ complex and redundant systems to defend against failure. This section refers to the major issues plaguing the network-wide reliability of both industries. They are a lack of skilled Personnel, Governance issues and Grid fragility.

Personnel Shortages

Both industries suffer from a lack of talent. Many employees are at risk of "ageing out", and both industries are failing to attract new talent, as shown in the diagram below. The matter is made more difficult due to the complex staffing needs of the industry, from facility to mechanical, electrical, IT, networking staff. Heterogeneity between power stations and data centers respectively makes it difficult for formal training programmes to prepare staff for the industry. For example, Google's data center configuration is different to Facebook's.

How many years experience do you have in the technology industry

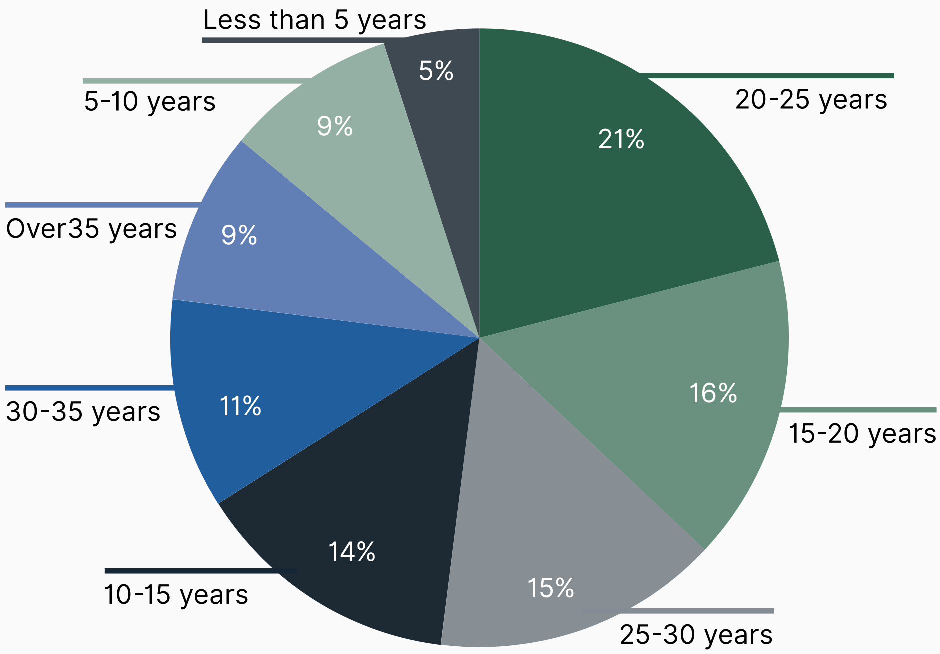

Figure 5.4) experienced data center persons are not being replaced (Uptime, 2018).

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In the data center industry, hyperscale facilities and hyper converged infrastructure have simplified the working environment, enabling data centers to do far more with far fewer employees. However, such reductionist improvements have actually enabled the industry to grow very quickly with little investment in staff. Almost 40% of organizations now report difficulty finding qualified candidates, and almost 20% struggle to retain staff *(Uptime, 2018).*

“Those that started in the industry are now starting to retire. Through normal growth we’d be able to handle that, but with an industry that’s doubling in size every four or five years, that means a doubling in requirements as well”. Lee Kirby, President of Uptime Institute

New recruits are difficult to find for several reasons. The industry itself is still very low profile, the career development path is poorly defined, and the work-life balance is perceived to be poor. The talent pool of Science, Technology, Engineering and Mathematic graduates (STEM) is small. Industrial groups are only now waking up to the need to recruit from a wider pool, and ringfence larger budgets for in-house training. Traditional energy generators, such as fossil fuels and nuclear, have an uncertain future and a negative public perception which deters entry into these industries. The newer renewable industry has grown ten-fold in ten years. Growth has simply outpaced the supply of staff. Neither Data Centers nor Energy Utilities attract typical STEM graduates. In fact just 10% of Data Center recruits are STEM Graduates (Basalisco et al., 2018). The UK energy industry alone will suffer a 200,000 personnel shortage over the next 10 years.

Grid Reliability

Grid reliability concerns the ability of the grid to deliver electrical or digital power. This is the combined architecture of the interconnected system. It should contain enough redundancies to ensure isolated disruptions don’t cause local or system wide failures. Whilst facilities can be made redundant, it is more difficult to make the entire network redundant. Power lines and fiber optic cables traverse the country, making them difficult to defend. Hence many disruptions to service occur on the remote sections of the network, not in the power stations or data centers themselves. Figure 5.5 demonstrates this. While the most common failure cause is on-premise power issues, network failures account for the second largest share of failures. As data center architectures become more network-orientated and complex, the “Grid” reliability will become increasingly important.

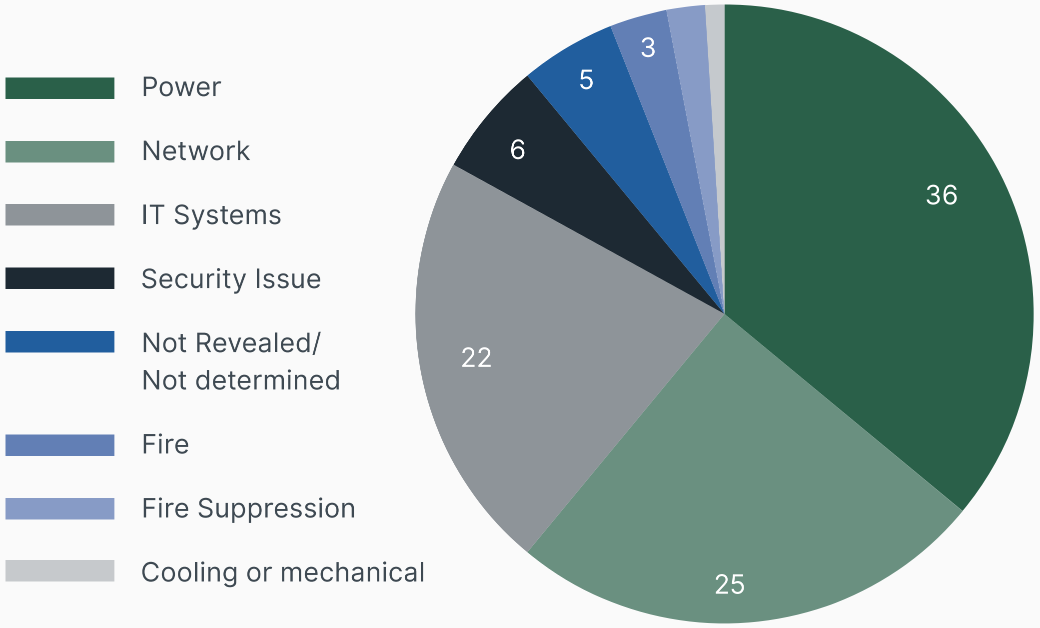

Figure 5.5) Primary causes of major downtimes “during 2016-2018, expressed as % (Uptime 2019)

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The Electricity Grid is a redundant Grid, and this redundancy defends against isolated failures. The Digital Grid is not yet a fully redundant system, but it is heading in that direction. What were once individual data centers connected to a network of fiber, is fast becoming a network of redundant data centers connected to multiple redundant fibers. Large cloud providers, such as Amazon AWS, have created “availability zones” where clients operate across multiple availability zones, ensuring redundancy should one zone fail. The digital grid is fast approaching comparable levels of reliability with the electricity grid.

Governance

Network reliability depends as much on the governance of the grid as it does on physical redundancies. Whilst the European Grid may be physically integrating, it is still governed as 27 national grids with sometimes conflicting national interests. The 2003 Rome blackout is an example - Swiss and italian grid operators did not communicate to prevent an isolated disruption cascading into a 1.5 day blackout. EU regulations are slowly changing this, and the European electrical grid will ultimately harmonise towards one physical grid, with one single regulatory body. However, this will take a long time. Data centers however are not regulated in a manner where homogeneity of governance is necessary. 27 EU member states regulate their data center industries differently, but the ability to shift data easily and quickly means governance plays no role in “network stability”...yet. GDPR and other legislation are aimed at anchoring data to a member state to bring data under some form of jurisdiction.

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We believe data centers will eventually be regulated “in the public interest”. This will take a long time, but eventually data centers will be regulated and governed as electricity is today. What does that mean? It could mean a standard rate of computation, in much the same way there are standard residential and industrial electricity lines of differing voltages.

5.4
Summary - The Business Case

There are major operational similarities between both industries. They’re both large, complex, technical systems who aim to maximise uptime. Both suffer from the same forms of facility and network wide failures. Both suffer from a lack of talent. In fact the industries are so similar that both industries actually recruit from the same talent pools, into very similar roles. There are significant societal benefits to the successful operation of both industries. While both electrical and digital power are business critical and even mission critical, digital power is not yet life-critical. The moment digital infrastructure becomes as critical to the operation of modern society as electricity, it will be regulated in the same manner i.e. a public utility.

This value proposition is based on the fact that both industries deliver a similar product (critical infrastructure) to a similar customer (businesses and residents) with similar constraints (near continuous uptime) under soon to be similar regulation. The value proposition is shared core competences in a brand new market.

6
Conclusions and Recommendations

Both the digital and energy infrastructure industries are at inflexion points. The energy industry is decarbonizing, and the data center industry is maturing. Once digital applications become life-critical, they become as necessary to modern life as electricity is today. The development of the electric grid over the 1900's is therefore a template for the development of the digital grid in the 2000's. This chapter summarises the four major areas of partnership potential between energy utilities and data centers before highlighting recommendations.

6.1
Recovered Heat Utilization in District Heat Grids

Data centers are becoming increasingly large generators of heat and they will soon account for 4-6% of global power consumption of which one third is used for cooling of heat that could be utilized in emerging heating network. This recovered heat is being generated in cities, where district heating demand is growing fastest, and where recovered heat can be recycled most efficiently. Additionally governments are fast realizing that the heat networks, which account for more than a third of all CO_2 emissions, must also decarbonize in order to reach the CO_2 reduction targets laid out in the EU 2050 plan. This means more district heating grids will be built, and the supply of district heat will decarbonise. The regulatory environment is therefore shifting the incentive structure more favorably towards data center waste heat utilization in district heating grids.

For the data center, advantages include revenues from selling recovered heat and the improvements in emissions reductions. For the district heating utility, the advantages include the consumption of "CO_2 free" heat, and the accompanying reductions in emissions and prices. National Governments meet their emissions reductions targets across both the Heat and Electricity sectors, and Local Authorities deliver cheap, CO_2 free heat to their residents. In summary, there would be multiple winners from recycling recovered heat from data centers.

6.2
Demand Response in Electricity Markets

As intermittent renewables penetrate further into the electricity generation mix, flexibility becomes increasingly valuable. The phase out of flexible supply and inadequate storage capacities will make demand response the flexibility of the future. The large and growing size of data centers, and the delay-tolerant nature of some of their workloads, makes them particularly applicable as providers of demand response. Shifting IT workloads in time may help data centers optimize their electricity bill, but it could also play a serious role in stabilizing the grid by consuming more energy at times of energy oversupply, and consuming less energy at times of undersupply.

The increasingly federated nature of data center operations, where workloads could shift from data center to data center, could also help solve grid constraints. There are challenges to adoption, namely the underdeveloped nature of most demand response markets, and the aversion to risk suffered by many data center operators, and the unclear incentive structure between aggregators and electricity suppliers. However, these challenges are in the process of being resolved, and when they are we believe data centers will be at the forefront of providing demand response.

6.3 Location Opportunities

Colocation data centers are getting larger and more numerous. Access to locations with power, fiber connection, space and potential expandability is getting more difficult. At the same time, energy utilities own significant plots of land in and around cities, where demand for colocation data centers is strongest, and where integration with district heating grids is most feasible. There is significant partnership potential between colocation data center and energy utilities in urban environments.

Hyperscale data center challenges are based around their consumption of significant amounts of electricity and their disposal of significant amounts of heat. Integration with district heating is a cost effective solution, however district heating grids are not as numerous in the rural environments typically occupied by Hyperscalers. Note hyperscale data centers face increasing pressure to deliver lower latency services. In the near future some hyperscale data centers are therefore likely to locate themselves closer to cities to solve the issue of latency (Warrenstein et al., 2016). In this case, sites owned by energy utilities could be of significant value.

6.4 Operational Opportunities

Both industries are large, technical, complex systems who place a premium on availability. Both suffer from the same forms of facility and network wide failures. Facility downtime is prevented by defending access, component and human failures.

Defending the entire network against downtime requires a redundant grid. The electricity grid is slowly becoming one redundant grid (from 27 member grids) and the digital grid is forming as fibres and interconnections increasingly redundantly connect data centers globally. Lastly, and most crucially, both industries suffer from a lack of talented personnel. In fact the industries are so similar that they actually recruit from the same talent pools, into the same roles. Hence both industries deliver very similar services in very similar ways, with very similar challenges. The opportunity here is for one critical infrastructure provider to expand into the provision of another critical infrastructure market.

6.5 Recommendations

This report mapped the potential opportunities between Data Centers and Energy Utilities. It is clear both industries share many competences and can combine to create new types of value. Additionally, the direction of both industries (decarbonization and maturation of the energy and digital system respectively) is making the aforementioned opportunities more economically feasible.

The aim of this report was to illuminate the cross industry opportunities for the reader. The recommendations given below will help to turn the concepts outlined in this report into a reality:

- The EU should make membership of the Data Center Code of Conduct Scheme mandatory. This will aid in the reporting of otherwise hard to come by statistics regarding data center energy consumption.
- Colocation data center IT professionals and facility-level professionals should find a way to address potential electricity flexibility in service level agreements with tenants.
- Hyperscale data centers should (if they haven't already) factor in the ease with which excess heat can be utilized in district heating into their site selection procedure.
- Data center providers and municipal authorities should look seriously at sites that energy utilities will be decommissioning in the near future. These are perfect hubs from which the "smart city" infrastructure can be built.
- Standard contracts should be created, which can act as the building blocks of any future relationship between district heating grids and data centers. This will help solve the problem of "who pays for the CAPEX".
- Before the "smart cities" dream can truly be realised, demand response markets need to function properly. This requires proper incentives from the energy flexibility market players - Aggregators, electricity suppliers, consumers and regulators. OFGEM, the UK's energy regulator, are aware of this but more work needs to be done.
- Recovered heat needs to be appropriately valorized. Currently it is difficult to put a price or value on recovered heat. A market for recovered heat may in the long term be the best method of incentivising recovered heat utilization.
- Data Center supply chains, particularly Original Equipment Designers (OED's) should shift design parameters from reducing energy consumption, to ease of energy reclamation. Such a move would make waste heat utilization even easier to implement.
- Data Centers should confront their aversion to complexity within the data center by bringing the energy bills under the jurisdiction of the It staff (and away from facilities staff). This is a practical first step towards making data centers a source of energy flexibility.

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Glossary of Terms

A

Access risk - A risk of unauthorized access to the data centre usually mitigated by applying several layers of physical and software based securities

Aggregators - are the companies that combine the demand response of small customers to produce a pool of flexibility which can be sold into the electricity markets

B

Business critical applications - The applications of technology which are now critical to certain businesses such as online hailing services, online banking and alike

C

Colocation Data Centers - data center facility in which a business can rent space for servers and other computing hardware. Typically, a colo provides the building, cooling, power, bandwidth and physical security while the customer provides servers and storage.

Colocation providers - Colocation providers provide space, power, cooling, and physical security for the server, storage, and networking equipment of other firms and also connect them to a variety of telecommunications and network service providers with a minimum of cost and complexity.

Combined Heat and Power plant - These plants consists of engines running on some fuel (liquid or gaseous) to produce electricity. The fuel is burnt in the engine which is connected to a generator. Heat produced by burning the fuel is recovered and used to produce high pressure steam which in turn runs the turbine to produce electricity, and the heat steam is also used to heat the heat grids.

Component risk - the risk of failure of a component or “part”.

Contractual obligations - Those duties that each party is legally responsible for in a contract agreement

D

Data center - A data center is a networked infrastructure facility offering multilayer protection and barriers from service disruptions such as power failures, physical and network intrusion, connectivity and limited storage.

Decarbonization - The term is used for reduction of carbon inputs to the environment or of greenhouse gas (GHG) emissions such as CO2 or CH4

Deep Learning - is a collection of algorithms used in machine learning, used to model high-level abstractions in data through the use of model architectures.

Delay-tolerant workloads - a certain degree of delay can be built into the completion of this workload.

Demand Response - is a matter of balancing customers' need for electricity with the power company's output. The goal of energy efficiency is to lower the overall energy use, while demand response is geared at lowering consumption at specific times based on a change in price.

Digital Power - is defined as the simultaneous provision of electrical and computational power to produce digital intelligence. Digital Power is the rate at which digital intelligence can be supplied over time.

District Heat Grids - heat networks that typically cover a municipal area and are under the (a tleast partial) ownership of the local municipality.

E

Ecosystem Clustering - The FLAP countries are connected in every respect such as internet as well as power and electricity. This concentration of connectivity creates an eco-system clustering effect.

Edge computing - Edge computing enables the ability to perform data computation close to the data source instead of going through multiple hops and relying on the cloud network to perform computing and relay the data back.

F

Facility level - data centers or power stations. Concentrated generating nodes on the network

Fiber - Corresponds to optical fiber network which is used to transmit telephone signals, Internet communication and cable television signals.

Flexibility - is described as the capability to dynamically compensate imbalances in supply and demand, as well as bottlenecks in the grid

Flexible generators - The term corresponds to electricity production facilities and their flexibility to increase or reduce electricity generation. Conventional sources such as hydro, coal and gas are considered the most flexible generators because electricity generation can be controlled easily. Nuclear fuel is least flexible

G

Geothermal - Geothermal energy is the heat from the Earth. It's clean and sustainable.

Green governance - Green governance is a proposal for collective governance constructs towards local sustainable development. It requires a policy and governance framework that helps facilitate the reduction of resource use and environmental pressures.

Grid capacity - The maximum electricity load a grid can bear without decreasing the voltages or completely shutting down a facility.

H

Heat dumping - It is a term used to express the rejection of waste heat to the environment in the form of hot gases or hot liquid streams. Heat dumping is prohibited and waste heat must be used efficiently to reduce environmental impacts.

Heat pumps: A Heat pump is a mechanical-compression cycle refrigeration system that can be reversed to either heat or cool a controlled space. Air conditioning compressor is a heat pump that pumps the heat out from the room to outer environment.

Hotspots - The term hotspots used here represents the localized heating at some surfaces due to excessive processing demands in the data centers. This kind of uneven heated surfaces of the same equipment results in reduction of operational life of electronics.

Hyper scale Data Centers - A hyperscale data center is less like a warehouse and more like a distribution hub. A hyperscale facility support thousands of physical servers and millions of virtual machines. Systems are optimized for data storage and speed to deliver the best software experience possible.

Hyper converged Infrastructure - Hyper-converged infrastructure offers the benefits of combining server, storage, networking and software into a pre-integrated package. It is a software-defined IT infrastructure that virtualizes all of the elements of conventional "hardware-defined" systems

I

Intermittent renewable fuel sources - They includes wind, solar PV, and wave power.

Internal Energy Market - The centralization of the European Energy markets towards one internal market.

Internet of Things - The Internet of Things, or IoT, refers to the billions of physical devices around the world that could be connected to the internet, collecting and sharing data.

L

Land Banking - Land banking is a real estate investment scheme that involves buying large blocks of undeveloped land with a view to selling the land at a profit, or using the land at a later date, when it has been approved for development.

Low-latency communication - Latency is defined as the time required to get back the reply from a server or a computer. Higher bandwidth does not help in reducing the latency. Therefore simple low-latency networks are developed that can open doors for various applications such as high speed trading.

M

Malicious attack - A malicious attack is an attempt to forcefully abuse or take advantage of someone's computer, whether through computer viruses, social engineering, phishing, or other types of social engineering.

Migrate workloads - workloads can be migrated from one data center to another. There are many possible reasons for moving workloads between different data centers i.e. Upgrading from versions that are no longer supported, Extending or replacing a data center, Implementing a disaster recovery plan.

Mission-critical applications - A mission critical application is a an application that is essential to the survival of a business or organization. When a mission critical system fails or is interrupted, business operations are significantly impacted.

N

Network level - The entire system

Network Reliability - Network reliability is the probabilistic measure that determines whether a network remains functional when its elements fail at random.

Nordic - The Nordic countries make up the northernmost part of western Europe, extending into the Arctic. They include Finland, Iceland, Norway, Sweden, and Denmark.

Nuclear energy - The electric energy produced by nuclear reactors.

P

Procedural risk - The data center may be susceptible to procedural risks where certain procedures adopted in the data center may not be secure enough to protect the system from intruders.

Processing chips - The integrated circuitboards

Public Cloud provider - Public cloud is a term for cloud computing services offered over the public Internet and available to anyone who wants to purchase them. Public cloud providers includes AWS, Microsoft Azure etc.

R

Rack densities - defines the amount of energy being consumed in kW per rack. In past the rack densities were 8 to 10 kW. While the modern data centers with efficient cooling systems can have rack densities of 50 to 80 kW.

Regulatory frameworks - are sets of guidelines and best practices. Organizations follow these guidelines to meet regulatory requirements

Reinforced grid - The grid that can supply power without any interruption reinforcing the grid often involves building additional, redundant power lines.

S

Security of supply - It is the reliability of the energy system to continuously meet the consumer needs.

Server racks - Server Racks offer durable construction that ensures a stable platform for valuable network and server equipment.

Society critical - The systems important to the running of society.

Storage systems - Energy storage systems such as batteries

T

Terawatt - A unit of power equal to one million million (10^12) watts.

V

Virtual reality - Virtual reality (VR) is an experience taking place within a simulation, which can be similar to or completely different from the real world.

Virtualization technologies - in which an application, guest operating system or data storage is abstracted away from the true underlying hardware or software.

W

Waste heat - The heat generated from data centers and other systems

Workload shifting - Delaying or bringing forwards IT workloads.

Thank you.

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