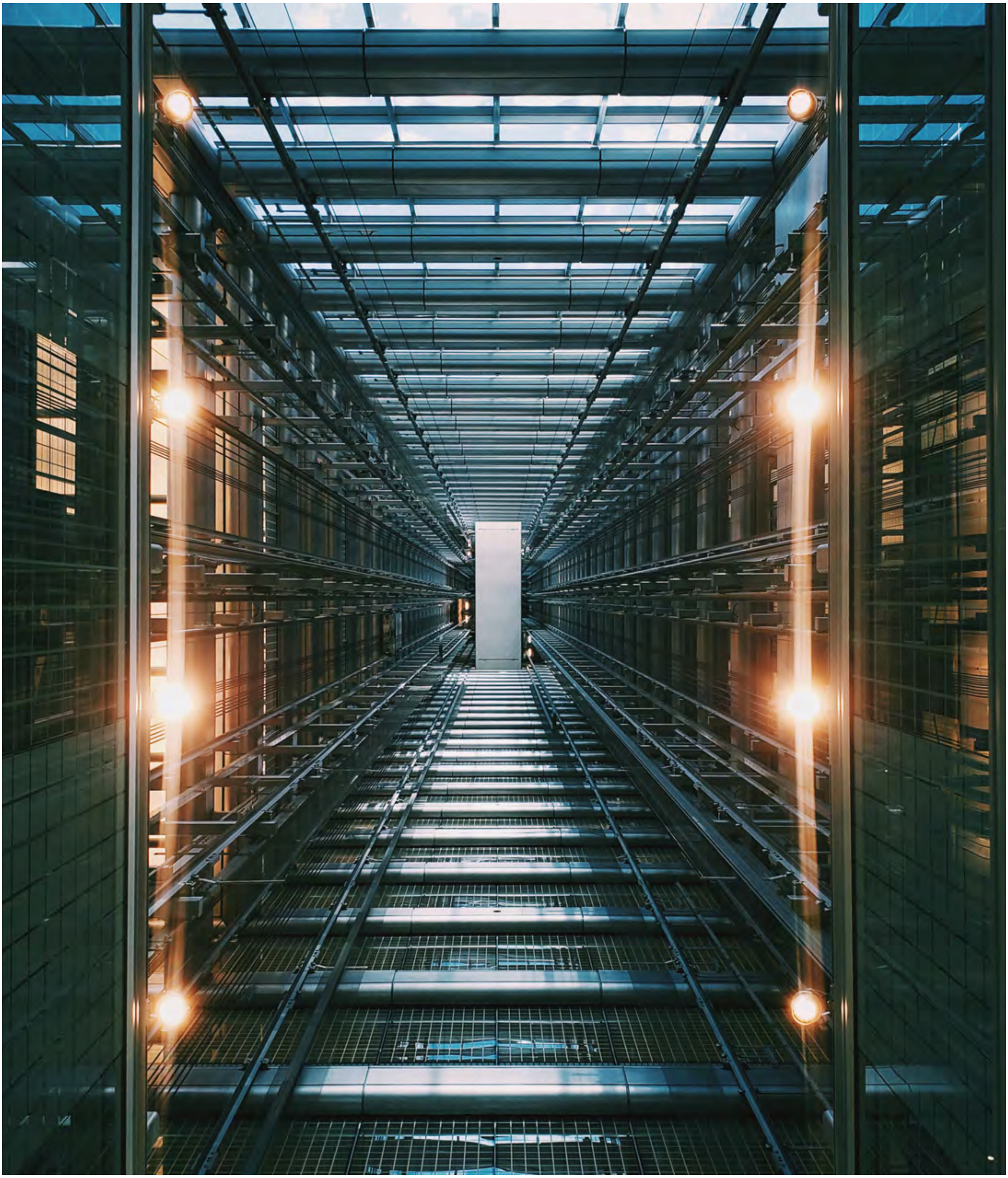
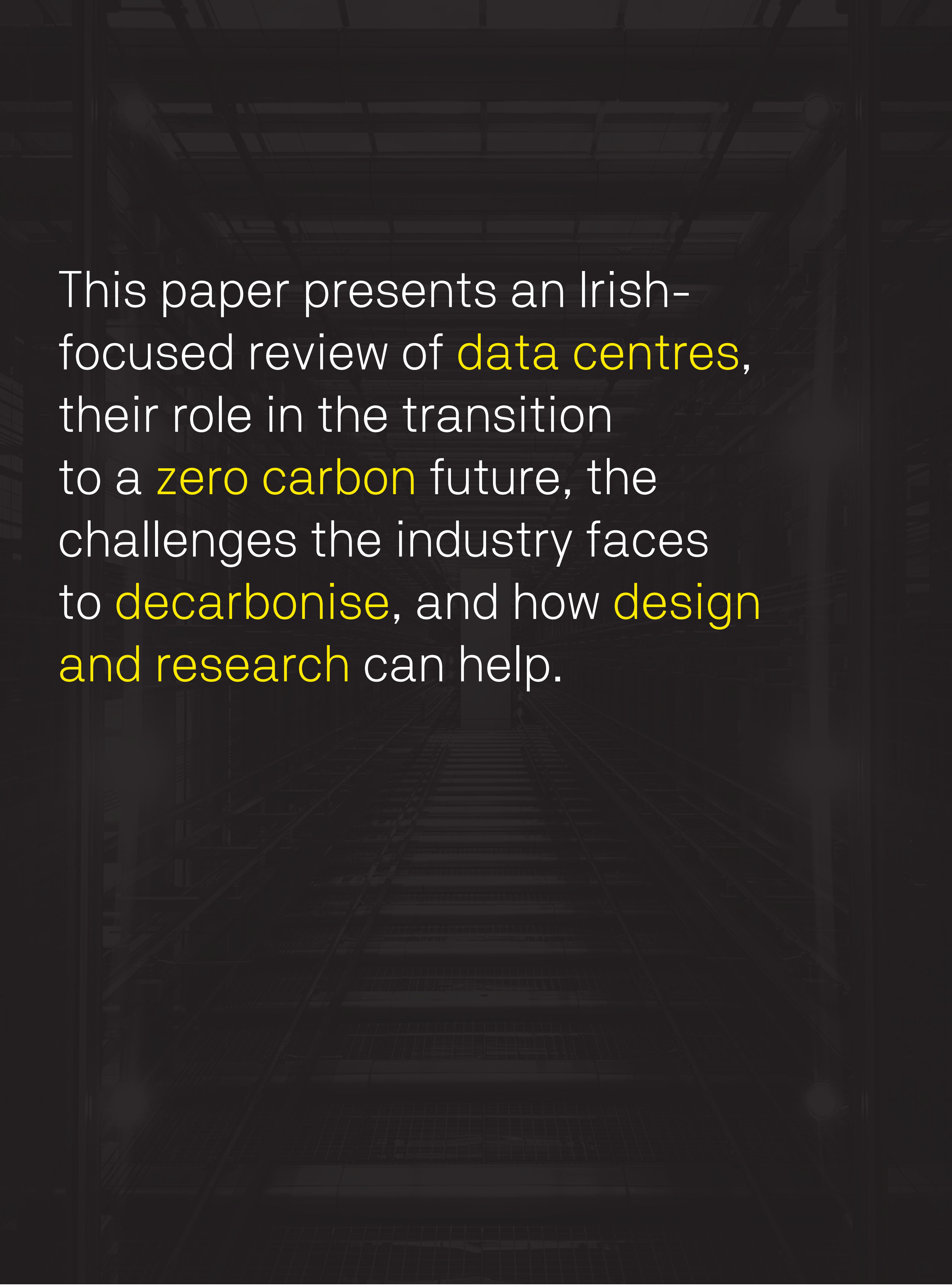
Sustainability + Research
White paper

RKD

Data Centres

and their role in Ireland's zero carbon transition





This paper presents an Irish-focused review of data centres, their role in the transition to a zero carbon future, the challenges the industry faces to decarbonise, and how design and research can help.

01

Energy ≠ Electricity

Data centres account for 14% of Ireland's electricity consumption but <4% of our final energy consumption (all energy: electricity, gas, oil etc.)[2]

02

Renewable surplus

Data centres could use artificial intelligence to maximise use when abundant renewable energy is available.[26]

03

Excess heat

It is estimated that excess heat from data centres could be used to supply 20% of district heating by 2040 in Denmark.[29]

04

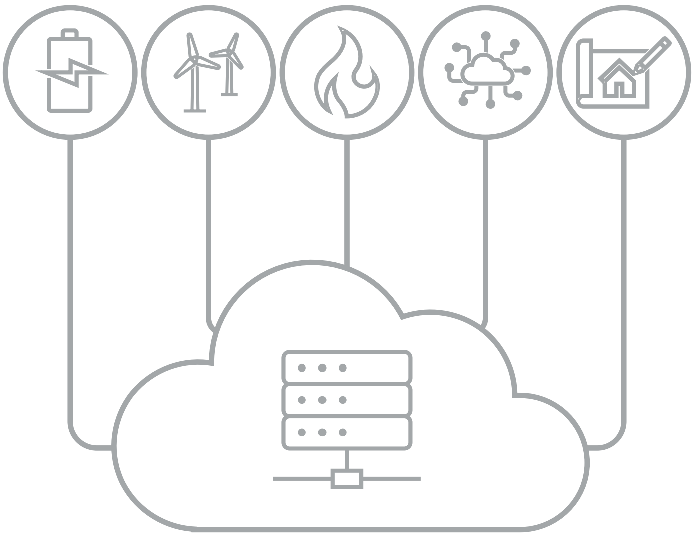
Smart technologies

The efficiency gains from smart technologies can save 8 to 10 times more greenhouse gases than caused by the information and communication technology sector.[7]

05

Design matters

Creative design thinking can enable data centres serve their full functional life expectancy while also facilitating the sustainable reincarnation of data centres into something else in the future



Data centres are only recently attracting attention on global & national energy balance sheets.[2]

Data centre energy demand

The final energy consumption from the Information and Communications sector in Ireland has increased from being almost negligible in 2008 (0.3 TWh) to approximately 5 TWh per year in 2021.

CODE SUMMARY

```
> We use data for many things;
> Some of those things enables us
  become more efficient;
> Data centres manage data;
> Alternatives to data management e.g.
  on-site servers also require energy
  (and might in fact be more energy
  intensive);[1]
> Well designed data centres can
  maximise functional lifespan and
  create adaptive reuse solutions;
> Data requires energy from
  electricity;
> Electricity can be generated from
  renewables;
> Data centre owners can invest in
  renewable energy;
> Data centres also produce heat;
> Heat can be used to supply district
  heating systems;

>>> We need data to progress, but we
    need to progress with caution.
```

At 5 TWh, Information and Communications (most of which is from data centres ~4 TWh[3]) accounts for just under 4% of Ireland's final energy consumption[2] and 14% of its electricity consumption.[3] Globally, the share is even lower with data centres accounting for less than 1.5% of global electricity use.[4] Although the global and national share of final energy consumption from data centres is small, the market is growing at pace.

An article published by the Sustainable Energy Authority of Ireland (SEAI) in August 2022[5] showed that while data centres are growing quickly (an increase in demand of approximately 400 GWh per year), the addition of renewable electricity to the electricity grid is growing at an even stronger pace (an increase in supply of approximately 1300 GWh per year).

For every year the demand from data centres increases, the additional supply of energy from renewables has matched it by a factor of 3—at least for now.

The percentage of electricity consumed as a proportion of the entire national energy need differs between countries.

22%

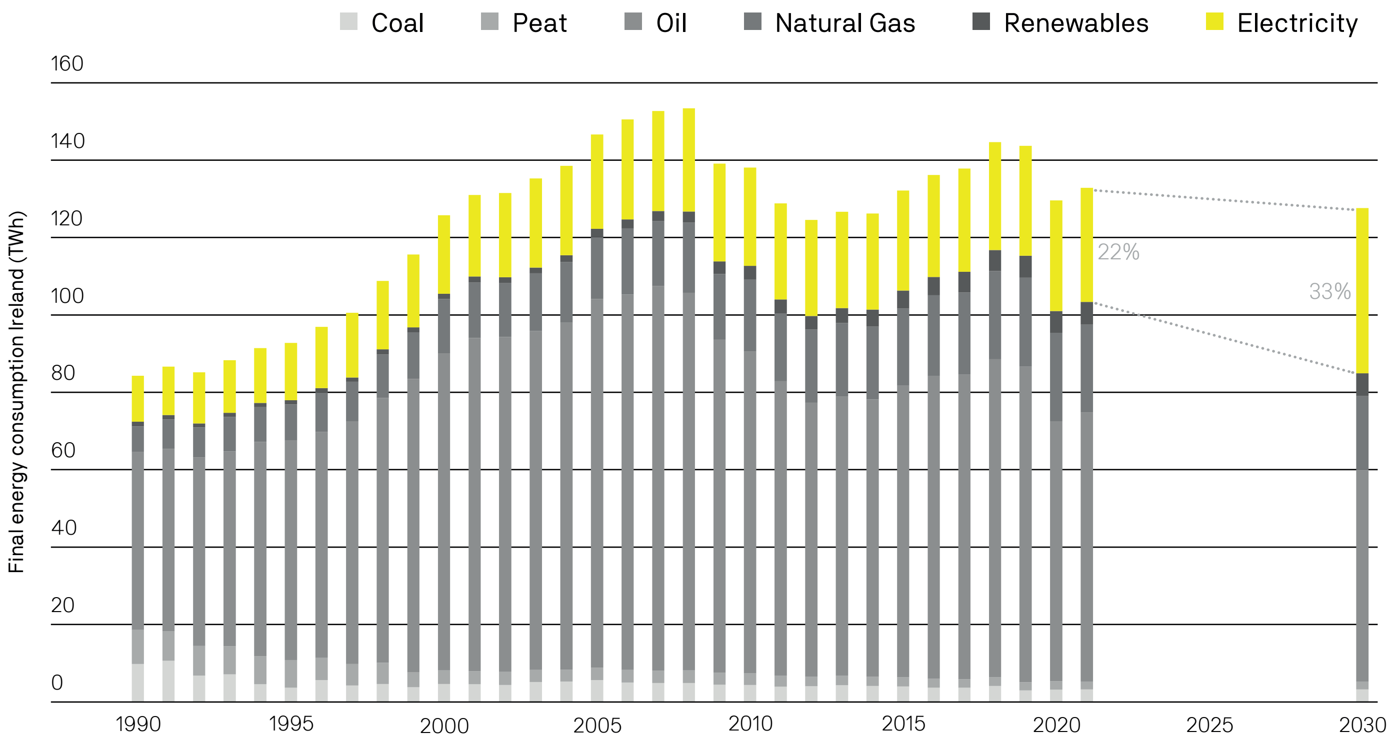
of Ireland's energy consumption is electricity

The electrification of current technologies, e.g. heating (boilers) and transport (combustion engine vehicles), are considered key strategic pillars for global decarbonisation. Given these planned, and necessary, dynamic changes to global and national energy profiles, it makes sense to compare the energy consumption of data centres with total energy consumption rather than just electricity.

As of 2021, electricity only accounted for 22% of Ireland's entire energy consumption. The remaining energy needs for Ireland come primarily from the combustion of fossil fuels at source of use (e.g. cars, boilers, incinerators, etc.). Using EirGrid's predictions for heat pump and Electric Vehicle (EV) uptake,[6] and assuming a direct replacement with less efficient historical systems, the electricity share would increase from 22% to 33% of Ireland's energy portfolio by 2030. Although the installation capacity of data centres is set to increase significantly, their overall share of the entire energy profile by 2030 would be less than 10%. Still significant, but also relatively small compared to some other sectors.

A big piece of a small portion?

Energy vs. Electricity



The things we count vs. the Internet of things we don't

EirGrid estimates a 45% increase in electricity demand by 2030 due to increases in both data centre consumption and electricity from other sectors, such as the residential and transport, as they switch from combustion technologies to heat pumps and EVs respectively.[6]

While the increase in electricity demand is quantified, the reduction in demand from the entire energy ecosystem (electricity and fossil fuels) through technological advancements is generally unquantified. Those technological changes rely on smart systems which themselves rely on a data source.

In EirGrid's recent outlook report for Ireland's electricity capacity[6], the sectoral split of Ireland's electricity consumption presented on pages 22/23 notes, *"28% of all electricity demand is expected to come from data centres and new tech loads."*

The subsequent section (p. 24) notes, *"For our forecast it is particularly important to allow for the effect of smart meters, as this acts to temper future forecasts of peak electricity demand."*

In essence, data centres will increase our direct electricity demand but many of the things they do will improve efficiencies, and reduce demand indirectly.

Although difficult to quantify precisely, given the myriad of potentially benefitting economic sectors (mobility, manufacturing, agriculture, buildings, energy), the Global eSustainability Initiative (GeSI)[7] estimates that, *"smart ICT solutions can save eight to ten times more greenhouse gases than caused by the entire ICT itself."*

Another study found that half of Germany's 2030 greenhouse gas emission reduction targets could be met through the rapid deployment of digital technologies.[8]

Data centres will increase our direct electricity demand, but many of the things they do will improve efficiencies and reduce demand indirectly

Smart ICT solutions can save 8–10 times more greenhouse gases than caused by the entire ICT itself.

Critiquing the building (i.e. the data centre) using atomistical analysis ignores the role data (the output of a data centre) has in the net zero carbon transition.

What data does

When we think of data generally, we usually think of cloud storage and the requirement to upgrade our subscription so we can add more photos and videos to our personal archives.

But data is much more than this. Data, digitalisation and, IoT (Internet of Things) technology specifically, enables the realisation of efficient towns and cities that house smart buildings, connected by intelligent transportation systems, fed by efficient production facilities and dynamic energy networks.[9]

Without data, the smart functions and hence benefits of these would not be realised. Luo et al.[10] reference how modern building technologies that focus on reducing energy waste and optimizing operations can reduce the energy use by up to 50%, citing the requirement of access to a diverse and integrated set of data to enable it.

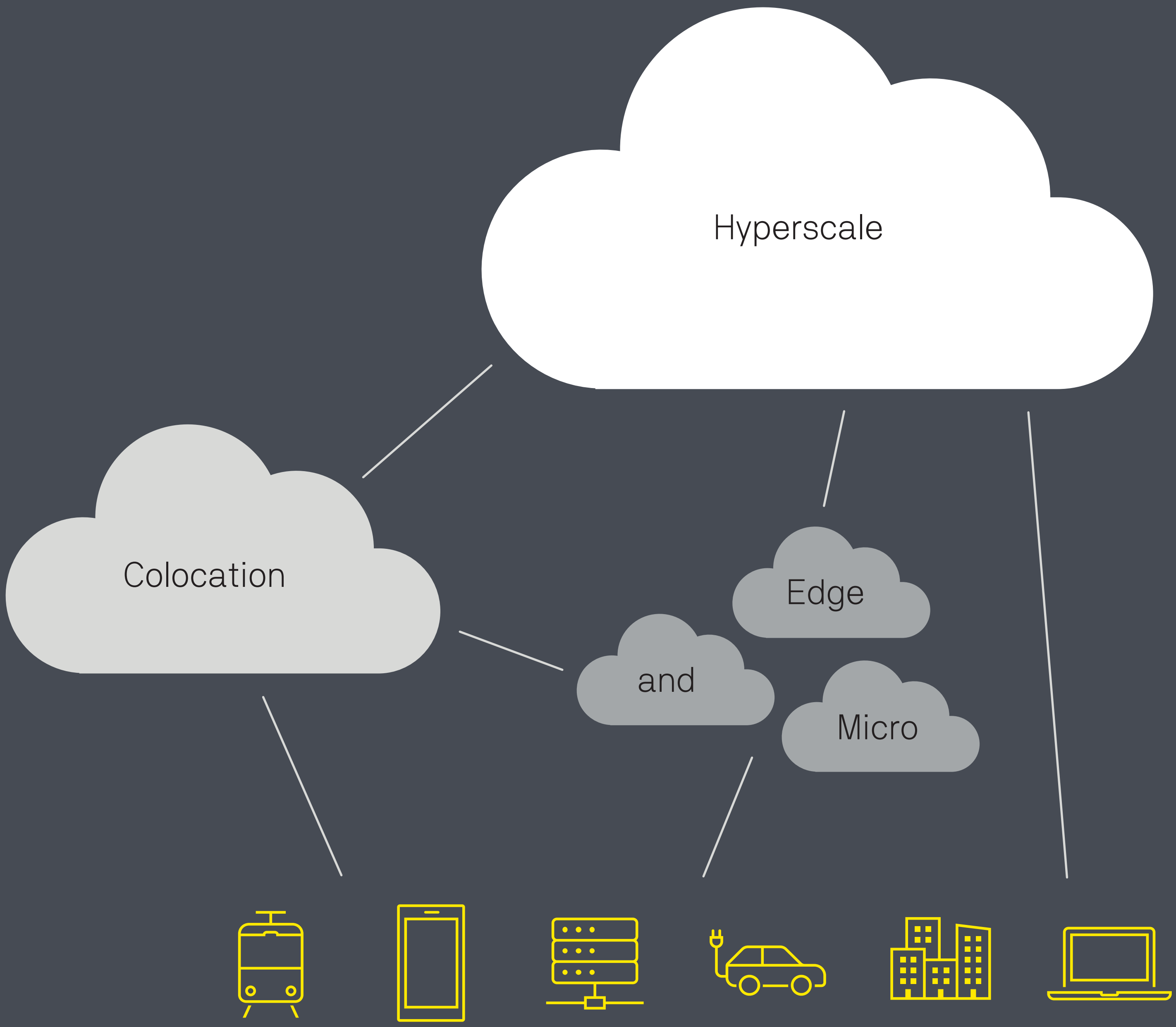
Data is even used to enhance climate science. Sebestyén et al.[11] studied the role data has to play in climate science and concluded that, *"The analysis highlights how data and models focusing on the specific areas of sustainability can be bridged to study the complex problems of climate change"*.

The tangibility gap

From a perception standpoint, the challenge data centres face is the tangibility-gap between what they do and what they are physically. The intangible nature of data immediately places it at a disadvantage when paired with the unfamiliar buildings which house data's necessary computational infrastructure. Hence the energy consumer is not the data centre but rather our need for data itself.

It would appear our demand for data is set to increase globally. This means we need somewhere to store, process and transfer the data, whether that be on multiple sites in a heavily decentralised system of servers or by way of a localised data-centre-focused IT system.

Close-proximity data processing (edge and micro data centres) benefit from low latency while cloud and, to a lesser degree, colocation data centres benefit from high efficiency processing as they can be finely designed for purpose. Peuhkuri[1] reported that distributed and individual IT would be more energy intensive than centralised IT. Another study conducted by S&P Global Market intelligence estimated that cloud-based options can reduce energy usage by 80%, and carbon emissions up to 96%, when compared with on-premises computing.[12]



The data centres ecosystem
Similar to natural ecosystems, the future of data centres, and civilisation's integration with them, will likely also be a diverse ecosystem of data centre types and sizes ranging from hyperscale to micro—each serving a different purpose.

How much of this data do we need?

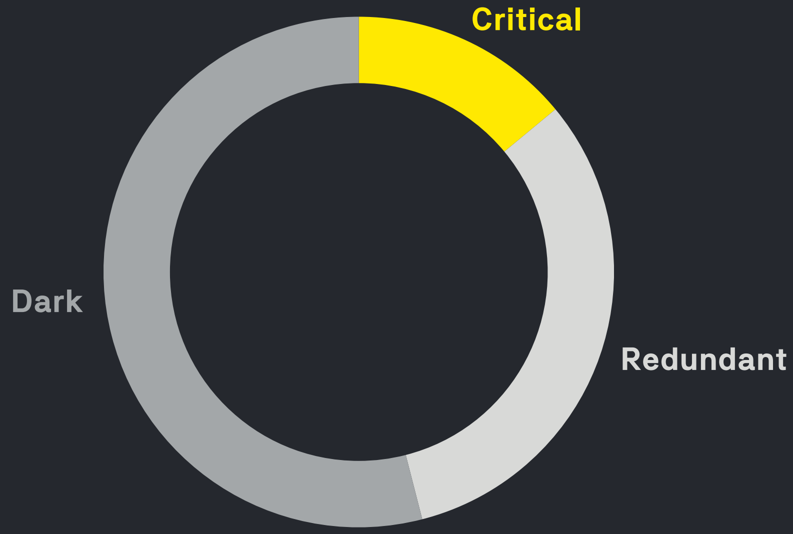
With our demand for data set to increase, is it possible that we won't need all the data we currently store and process? According to a paper published in the Journal of Cleaner Production, the answer to that question is: we won't.[13]

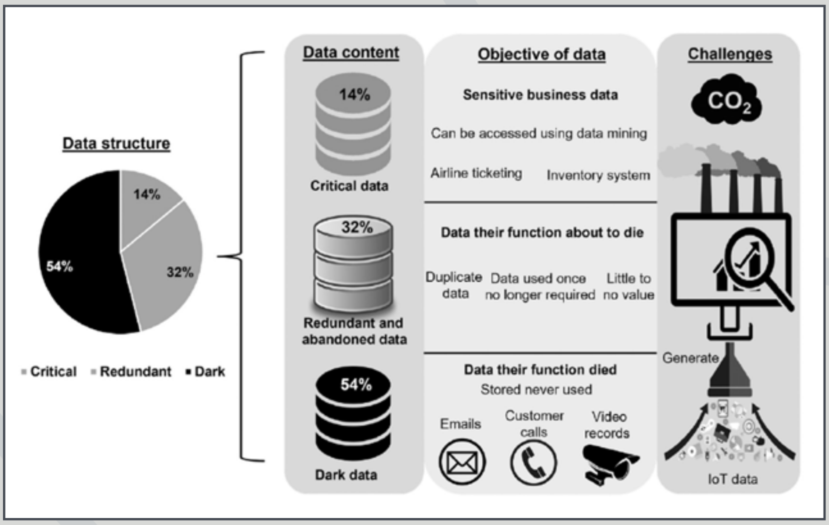
Dark data

The authors found that over 80% of data content can be defined as either "Dark" (stored data that is never used) or "Redundant" (data of little to no value).

So, as well as optimising the data centre ecosystem, we need to ensure the efficiency gains made by the industry do not excuse the excess consumption of unnecessary data.

This data centre efficiency rebound effect needs to be avoided.

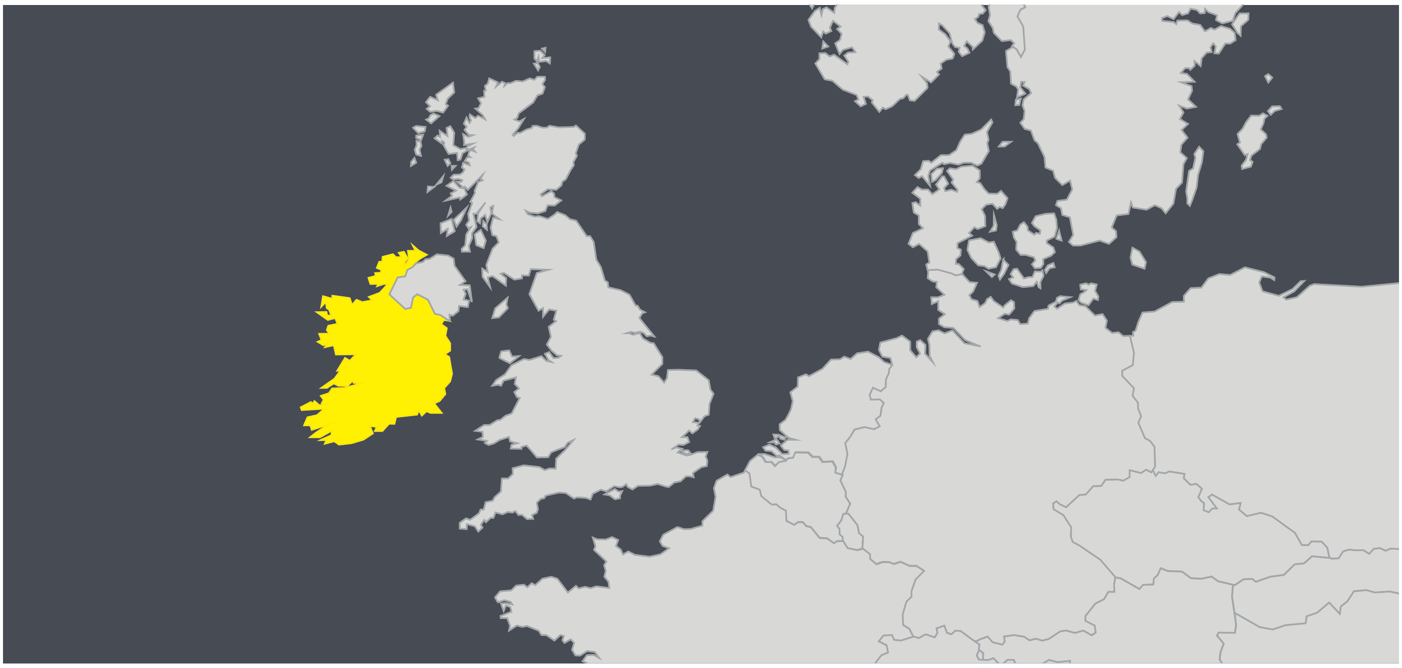




General content format of big data classifications – taken from Kez et al.[13]

80%

of data content can be defined as either “Dark” (stored data that is never used) or “Redundant” (data of little to no value)



Why Ireland and what does it gain?

Ireland is a sensible location for data centre hosting for several physical and economic reasons. In terms of real estate risk, Ireland's unique geographical location and stable political nature minimises the risks from natural and/or human-caused disasters.

Ireland also boasts other political and economic advantages when compared to other similarly low-risk countries (most notably its low corporate income tax), while its mild climate means that the cooling demand, which makes up the greatest share of data centre energy consumption after the servers,[7] is minimised. A further advantage is its relatively low water scarcity compared to some other European countries.

If the world, its resources, and its needs, were managed at a global level, there would be a compelling case to be made for Ireland as a global focal point for data centres—but civilisations and societies are much more complex than a simple boardgame; local incentives are needed.

Several local economic and social benefits to hosting data centres in Ireland are described in depth in a report conducted by Baringa.[14] One of these benefits is the reduced latency (increased speed) experienced by those in close proximity to data centres where real time data transfer, critical to IOT technology, is enabled. This particular benefit has seen an increased demand for edge data centres which focus on proximity over scale.

Renewables have a critical role to play in powering our data

Baringa's report[14] also references the myriad of job opportunities data centres bring in the form of both direct and indirect employment. The report references how the construction and operation of data centres involves 230 different job roles and notes how Ireland has now developed an export industry in data centre construction owing to its experience and expertise in delivering DC projects.[14]

Indirectly, the Organisation for Economic Co-operation and Development (OECD) estimated that in 2017, 312,000 people in Ireland were employed in "ICT task intensive" jobs, many of which will be cloud enabled and hence indirectly rely on data centres.

Cost vs. benefit

With most societal benefits comes an associated cost. We need to ensure that data centres are powered by a sustainable energy source if Ireland is to have any chance of meeting its emission reduction targets. Ireland has huge untapped renewable resources in the form of offshore wind, theoretically making 100% renewably powered data centres feasible. But while Ireland's renewable energy potential could meet its energy demands long-term, solving the short-term challenges will require huge effort from multiple sectors.

The long term potential

According to a strategic masterplan of the Shannon Estuary's future,[15] recently reviewed by global engineering experts Bechtel, there is 70 GW of untapped offshore wind energy available.[16] However, *"the vast wind energy potential within the Estuary's sights will remain just that—potential—unless this resource is connected to sources of demand."* [16]

When it comes to identifying a demand for this intermittent source of energy, one option is to directly export the surplus electricity through interconnectors (e.g. the Celtic Interconnector). A second option is to store the surplus (in the form of battery storage and/or green hydrogen), while a third option, referenced in Baringa's report, would be to actually increase the growth on the Island of Ireland through the likes of data centres and export the refined product in the form of computer services.[14]

The short term challenge

Identifying continuous demand is a long-term challenge. First we need to enable the supply by building the offshore wind turbines, and to do so we need adequate ports, and port infrastructure. But a recent report commissioned by Wind Energy Ireland[17] noted that, *"there is a significant lack of suitable port infrastructure across Europe and particularly within Ireland at present."* Additionally, while we are upgrading our ports and installing offshore wind turbines, we also need to be improving our electricity grid, making it both stronger and more flexible. A recent EirGrid report[18] notes that, *"we must also plan for a great deal of new grid infrastructure – such as underground cables, pylons and substations."*

Although a long-term renewable energy source is viable, immediate short-term investment for infrastructure and other technologies such as solar and onshore wind is needed. Near future projections for Ireland's renewable energy generation from ~4.5 GW to ~20 GW is expected to come from solar and onshore wind initially, with offshore wind only expected to accelerate at the end of this decade.[6]

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How data centres benefit from good design

Powering our DCs with clean energy is a national challenge. Designing them efficiently is largely an industry challenge.

Like all things, data centres have an expected lifetime: one which is derived from the ever changing functional requirements of IT, and one where poor design decisions and short-sighted planning can render a data centre functionally obsolete in under 7 years,[19] a tragically short expected lifetime for a host of servers housed in a structure made of some of the most durable materials on our planet.

Enter the designer

This is where design and planning is crucial. Peering above the parapet of a capital cost-only decision making approach and accounting for maintenance and operational costs, while visualising the potential for expansion, can maximise the functional lifetime of DCs.

"Whether starting from scratch or modernizing and retrofitting, proper planning and design will safeguard speed, efficiency, flexibility and scale in your new data centre which must meet new demand caused by the Internet of Things (IoT), Big Data and the world being on 24/7." [20]

Choosing an appropriate design, enabled by experienced designers, could potentially double the functional lifetime of a data centre.

Functional vs physical obsolescence

Even with the most thorough, well-thought-out, future-proofed design, the functional requirement of a data centre is highly unlikely to ever outlive the durable structure that houses its computational infrastructure. This is largely due to the rate at which IT innovation advances (and hence short functional life of IT equipment) compared to the average lifetime of the materials the DC structure is made of (primarily concrete and steel).

The fact that these materials will not likely ever experience physical obsolescence during the functional lifetime of a data centre opens the door to design thinking. Innovation is needed to find solutions that will enable the adaptation of data centres for other purposes once they have served their maximum functional lifetime.

7 years

Expected lifetime of a poorly-designed data centre

DESIGN MATTERS

Enter the designer... again

While tracking the long-term future needs of the information and technology sector is near-impossible, planning for eventual obsolescence would be prudent. Finding solutions for functionally obsolete buildings through adaptive reuse is a challenge facing the entire construction sector, not only for DCs but for the full range of building typologies. Key to this venture is identifying similar functions.

Perhaps the best solution for data centres is to save the structure and creatively repurpose the interior as another DC, thereby closely matching the function. A study conducted by HKS[21] found that reusing the concrete components of an older data centre, could save 88% of the embodied carbon emissions of a complete new construction. Alternative solutions exist, for instance repurposing one storage medium for another—from data storage to commercial storage.

Warehouses and data centres share several requirements (e.g. low lighting), making for a good second life, but other potential solutions exist and can be realised with creative design thinking.

In essence, design not only enables data centres to realise full functional life expectancy; it also facilitates the sustainable reincarnation of data centres into something else, or from something else into data centres.

> Commercial spaces already have a layout that is designed for product shelves, and the same spaces can be used for data centres and storage racks.[22]

Supply (renewables) & demand (efficiency)

One looming question is whether data centres can ever achieve “net zero” status, whether that be “net zero carbon” or “net zero energy”,[23] and whether that includes the embodied energy and carbon in the materials which are used to construct a data centre.

For a DC to be truly net zero carbon, it would need to supply more renewable energy then it requires to offset this capital/embodied energy and carbon expenditure. A net zero data centre future would be one that is powered by renewable sources, that minimises demand through efficiency, and that manages and exports its waste heat.

Supply – Renewables

Maintaining a continuous supply of renewable energy is crucial for any DC with ambitions to achieve any form of “net zero”. Whereas this can be achieved at a national level (probably the most sensible solution), some studies have shown that they can theoretically be self-sufficient under certain conditions. For example, by using only PVs in Singapore,[23] or using PVs and free cooling in Turkey.[24]

Demand - Efficiency

On the demand side of the equation, efficiency is the key, and can be achieved at several different levels. Processors and servers can enhance their efficiency and have done so impressively over the last number of decades, but there are also less obvious means to reduce carbon emissions.

Data centres serve many purposes, some of which require immediate response (e.g. IoT), but other energy-intensive computational services (e.g. doing payroll[25]) could be computed later at times of low energy demand. DCs could use Artificial Intelligence (AI) to shift these loads to times when renewable energy generation is abundant.[26]

This potential demand response benefit was also identified by Cioara et al.,[27] who developed a model to investigate how DC's energy flexibility could be exploited to create synergies at smart city levels.

Although AI is one of the reasons we need more data, an article prepared by Linesight[26] notes that, *"Overall, the shift to machine learning should benefit data centres by lowering costs and improving efficiencies."*

Heat recovery & construction materials

20%

By 2040, the excess heat from data centres could be used to supply 20% of district heating

Heat recovery

Cooling accounted for ~30% of DC's energy requirement in Europe in 2018.[7] If this extracted heat could be used elsewhere (e.g. district heating), that portion of a data centre's energy consumption could be theoretically offset, bringing DCs ever closer to a net-zero status. This idea has also been referenced by Technological University Dublin's Prof Brian Norton in an interview with the Irish Examiner:

"Thinking a bit more holistically, and thinking of data centres as part of an ecosystem in particular locations, so that you are looking at distributed production of rural energy locally and distributed use of the huge amounts of waste heat that data centres produce." [28]

One Danish study[29] noted that, although the increase in data centres will require an increase in energy supply, they could be used to offset some of the district heat requirements. The authors estimated that by 2040 the excess heat from data centres could be used to supply 20% of district heating.

According to an EU-wide study, a quarter of available waste heat in Europe could come from data centres.[30] Heat, in the context of data centres, is a large-volume, low-temperature typology of heat. This means that, unlike industrial-style waste heat, heat pumps are required to elevate the temperature to a useful level.

Construction materials

Today's data centres are predominantly constructed of concrete and steel. From a security perspective, few materials could match these, but from a sustainability perspective, other solutions might exist in the form of timber, hemp, or even mycelium, according to some researchers.[31]

However, before these solutions make any real impact, several big questions need answering through research and pilot studies, with a specific focus on security in relation to data centre applications. A more immediate low-embodied carbon solution might be to specify low carbon versions of concrete and/or steel instead of replacing the material altogether.

Final thoughts

Although the energy demand of data centres is still relatively small globally, the demand for digitalised technology is growing.

This digitalisation boom is a key tool in global efforts to decarbonise across all sectors and requires infrastructure in the form of transmission systems and data centres to carry out its function. The growth requires innovation across the entire supply chain, from construction of the data centres to the operation of the microprocessors. Competition in the industry, coupled with ambitious sustainability goals, is driving innovation within the industry across all system components.

The long-term future appears to be one where data centres exist as part of an ecosystem of renewable energy supply and different-sized data processing facilities, serving varied purposes, which maximise demand during periods of excessive renewable energy supply using self-learning algorithms—and which provide fuel in the form of waste heat for district heating systems in towns and cities.

In the short term in Ireland we need to proceed with caution. We do not want to miss out on an opportunity, but we are in a major transitional period where the energy we use on a daily basis is becoming increasingly electrified: the way we heat our homes (boilers to heat pumps), the way we travel (combustion engine vehicles to EVs), the way we store and process information (physical to digital storage).

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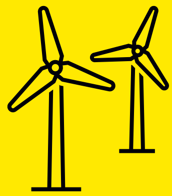
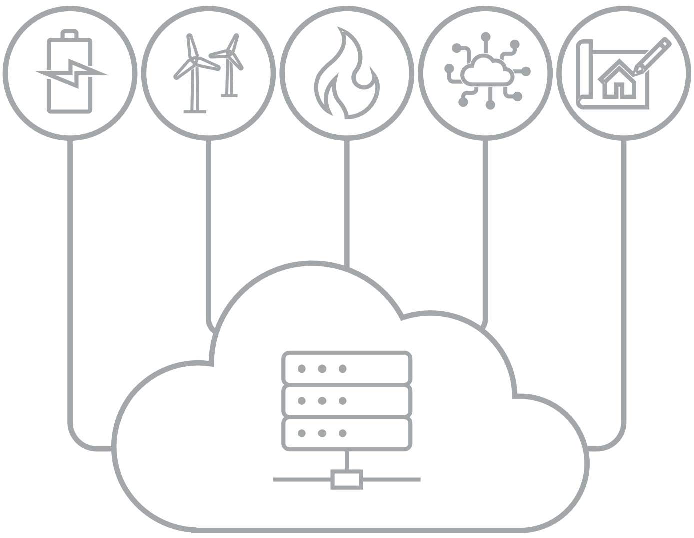


In conclusion

As the demand for electricity increases, we must ensure that the supply of renewable sources increases at an even greater rate. While the long-term future potential for Ireland is an abundant one, several short-term challenges remain for us to tackle.



Ireland’s Data Centre Sector
SWOT Analysis

	Short Term	Long Term

Strengths	// Mild climate
	// Stable political situation
	// Low security risk
	// Low seismic risk
	// Industry experience
	// Low corporate tax
	// Educated workforce
		// Considerable offshore wind energy potential
		// Relatively low impact risk from climate change compared to other countries
		// Source of excess heat for a district heating system

Weaknesses	// Grid infrastructure requires upgrading
	// Relatively low solar energy potential
	// Undeveloped district heating system (missed opportunity)
	// Shortage of skilled labour
		// Low local demand for energy surplus
		// Offshore wind infrastructure and ports require considerable upgrading to ensure DC’s are powered by renewable energy

Opportunities	// Industry learnings
	// Job creation
	// Reduced latency and improved efficiency
	// Investment in renewables from large enterprises
		// Attracts investment
		// Exportation of design knowledge and skills accrued
		// Exportation of data and services
		// Further growth in IT sector and job creation

Threats	// Increases grid peak load
	// Might require backup generation and addition of fossil fuels
	// No/slow action = potential loss of investment
		// Sector success could take land away from other potential sectors
		// Wind industry fails to deliver while DC industry succeeds resulting in high demand but low renewable supply

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