KHAZANAH RESEARCH INSTITUTE

VIEWS 01/25 | 14 JANUARY 2025

Energy and Ecological Impacts of Data Centres

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Data centre industry growing at pace

Data centres are the backbone of the digital age, serving as the hubs of computing resources and storage infrastructure for everything from web browsing and email to cloud computing and artificial intelligence. In recent years, Malaysia has seen a flurry of foreign investments in data centres. From 2021 to June 2024[1], Malaysia approved twelve data centre projects, with more likely to follow. There is high hope that data centres will spur economic development through capital investments and job creation. For example, Amazon Web Services' staggering RM27 billion investment is expected to contribute RM57.3 billion to the national GDP[2].

The country is poised to become the regional data centre hub, offering incentives aplenty to promote the industry's growth[3]. However, as much as they raise economic benefits, data centres can threaten energy security and entail ecological impacts. These trade-offs should be considered

[1] BERNAMA (2024)
[2] Prakoso (2024)
[3] Fariz Abdul Aziz, Lim, and Tan (2024)

carefully. This article explores some of the implications of data centres on sustainable development.

Data centres are energy guzzlers.

Data centres are energy-intensive. These facilities house vast computing and storage equipment that must run continuously. The servers within them handle workloads like running search engines and streaming services, which require significant electrical power to process.

On average, a traditional small-scale data centre with 500 to 2,000 servers consumes anywhere between 1 to 5MW of power. A hyperscale data centre, which hosts tens of thousands of servers, consumes 20 MW to over 100 MW of power[4]. These warehouses span the size of a football pitch and consume enough energy to power a small city[5].

A large proportion of energy consumption in data centres is used in cooling, ranging from 38% to 50%[6]. Computer processors are made of transistors that give off heat as waste. Heat build-up in the server environment can damage computing performance and, worse, lead to shutdowns. Downtime in these facilities can be extremely costly. Therefore, air and thermal management are the lifelines of data centres, ensuring no computing interruption. In large-scale facilities, vast air conditioning and cooling systems consume large amounts of water and energy just to keep cool.

A popular metric of data centre sustainability is energy efficiency, measured in Power Usage Efficiency (PUE). PUE is a measure created by the Green Grid Association in 2006[7], calculated by "dividing the total amount of power entering a data centre and the power used to run the IT equipment within it"[8]. The closer the PUE is to 1, the better the efficiency[9].

Hyperscale data centres allow for much higher optimisation and scalability than small-scale data centres, as they leverage standardised hardware and efficient building designs. A hyperscale data centre, for example, can reach PUE 1.1, thus extremely efficient by definition[10].

However, PUE is also a weak indicator of ecological impact. PUE measures only the internal efficiency of data centres; it tells us nothing about the broader ecological impact of data centres. What is the size of energy consumption? Where does the data centre draw energy from? How much greenhouse gas does the power source emit? What are the implications of the added energy demand on the power system? These are all equally important questions.

[4] Patnaik (2024)
[5] AFL (2023)
[6] Ahmed, Bollen, and Alvarez (2021); Dayarathna, Wen, and Fan (2016)
[7] Burrington (2015)
[8] Gillis (2022)
[9] PUE 2.0 indicates for every two units of energy input, only half is used for IT equipment. PUE 1.0 means all energy input are used to power IT workloads, hence no waste energy or perfect efficiency.
[10] "Efficiency – Data Centers – Google" (n.d.); Shehabi et al. (2016)

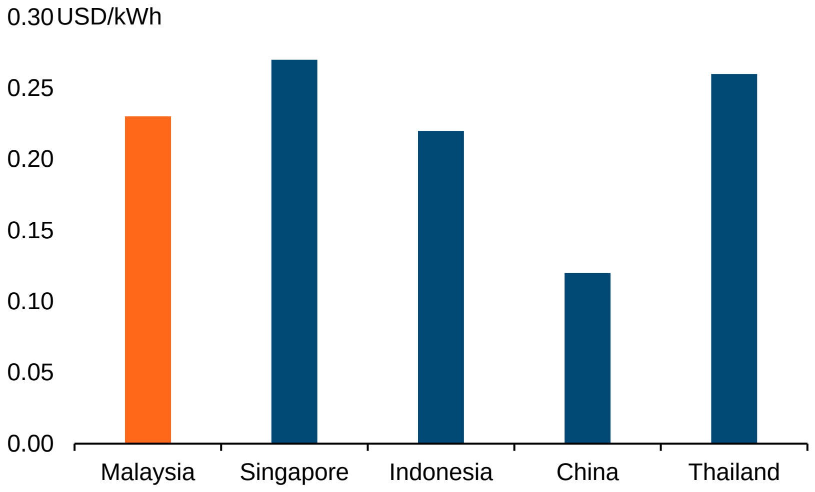
Grid capacity problems

Data centres consume a lot of electricity. An influx of data centres connecting to the grid is expected to run up power demand. In Malaysia, electricity demand from data centres is projected to reach 7.7GW by 2030 and 20.9GW by 2040[11], most of which are concentrated in peninsular Malaysia. With more set to arrive, the country needs to take a balanced approach to data centre development and energy planning.

Like any industrial project, data centre operators consider the same factors in their location strategies, such as transportation networks, power grids, water supplies, labour markets, et cetera[12]. Malaysia is attractive for two reasons: stable electricity costs and network infrastructure. This combination tends to draw cloud supplier data centres that serve clients beyond local demand[13].

Compared to other countries in the region, Malaysia boasts a relatively affordable electricity cost for industry (Figure 1). Stable electricity prices supported by a single-buyer market and subsidisation through Imbalance Cost Pass Through (ICPT)[14] , along with a mature power system, ensure a reliable electricity supply, making Malaysia one of the prime locations for data centre operators.

Figure 1: Industry electricity prices by country, 2019



Source: CEIC (n.d.)

As the energy appetite of data centres looms large, there are worries over the strain they might put on our national grid. Their massive energy demand can overwhelm the current power system,

[11] T. Y. Lee (2024)
[12] Ensmenger (2018)
[13] Greenstein and Tommy Pan Fang (2020)
[14] Sibeperegasam et al. (2021)

at a time when energy transition is gaining urgency. A bit of a back-of-the-envelope calculation can give an idea of the size of their impact.

A way to gauge the impact of added electricity demand on the power system is by looking at its impact on capacity utilisation. The installed capacity of electricity is the maximum amount of energy a system can produce at one time. The utilisation rate is the ratio between the maximum demand on the power system and the rated capacity, measured as the Capacity Factor. To ensure grid stability and reliability, a reserve margin, or extra capacity above peak demand, is crucial to respond to power surges and outages. A rule of thumb for a healthy reserve margin is typically around 20%[15].

As of 2021, Peninsular Malaysia has an installed capacity of 29.4GW of electricity generation, and its available capacity is at 26.5GW with a reserve margin of 42.5%. The gross electricity generation is 138,423GWh, and the total electricity consumption is 118,365GWh. The current capacity factor is at 59.6%.

Assuming an unchanged generation capacity, an added demand of 7.7GW pushes the capacity factor up to 88.7%. This means that the average generation is near full capacity over a year. In 2021, the peak demand in Peninsula Malaysia reached 18.6GW. Assuming data centres introduce another 7.7GW at peak load, this leaves our reserve margin at around 0.8%. A low reserve margin can lead to higher risks of power outages or blackouts when balance cannot be restored quickly during load imbalance.

Indeed, both power demand and generation capacity will continue to grow. Moreover, neither power plants nor data centres always run at maximum capacity. The hypothetical scenario above illustrates the magnitude of their impacts. Nonetheless, as the energy transition ensues, energy system transformation introduces other risks that complicate the picture.

Carbon footprint of data centres

Energy consumption is the primary source of data centres' carbon footprint. Carbon emissions from energy use—dubbed "scope two emissions"—cover indirect emissions from purchasing electricity or cooling[16]. The emissions are a function of the fuel source of the grid to which the data centre is connected.

Currently, Malaysia's power system is composed mainly of fossil fuels. The Peninsula grid emission factor (GEF) stands at 0.77GgCO_2e per GWh[17], of which a major part of the emissions is contributed by coal. A 7.7GW energy use can roughly amount to 52MtCO_2e in a year, close to half of what the power system emitted in 2022.

[15] J. Lee and Cho (2022)
[16] United States Environmental Protection Agency (2020)
[17] Energy Commission (2024)

As the country ramps up its effort to pursue energy transition, the government has laid out plans for the power system to transition away from fossil fuels. This would undoubtedly improve the carbon footprint of data centres based on the sheer amount of energy demand.

In 2022, roughly 47% of electricity in Malaysia was supplied by burning coal and 34% from natural gas[18]. The National Energy Transition Roadmap (NETR) envisions the power mix to reach 51% renewable energy and 38% natural gas initially in 2040 and progressing to 69% renewable energy and 29% natural gas by 2050[19].

Power system transformation involves phasing out coal-fired generation and integration of variable renewable energy (VRE) like solar and wind into the grid. These changes entail larger swings in the grid's net load due to the unpredictability of renewable energy supply[20]. A higher RE mix can inadvertently lead to higher chances of power system imbalance, exposing the system to power outages. Variability requires a higher level of balancing reserves, including backup generators or energy storage, as well as grid reinforcement, such as in transmission infrastructures, to manage instabilities.

Data centres need a continuous supply of electricity. As VRE introduces variability, power generation and grid infrastructure enhancement are crucial. It should not be overlooked that energy security is an important condition for development. The energy pressure of data centres on power system transition will influence the energy security of other grid users and, worse, affect vulnerable communities' access to reliable electricity. It is imperative that the energy needs of citizens be met before data centres[21].

Corporate greenwashing stands in the way

Currently, data centres that report carbon neutrality do so by purchasing offsets in the form of Renewable Energy Certificates (RECs)[22]. Data centres operating in locations where the grid utility cannot provide sufficient renewable energy resort to buying certificates tied to renewable energy generated on other grids. These certificates allow data centres to claim the use of renewable electricity while not physically receiving the delivery of renewable electricity[23].

Critics of RECs have decried this as greenwashing. This is especially the case for low-quality products like unbundled RECs that are separated from electricity delivery. A data centre purchasing unbundled certificates essentially "claims" renewable energy use but, in practice, is not any cleaner than other users of the same grid. There are two implications of the use of RECs: first, unbundled RECs neither contribute to grid decarbonisation nor sufficient emission

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[18] IEA (2024a)
[19] Ministry of Economy Malaysia (2023)
[20] IEA (2024b)
[21] Jacob (2024)
[22] Judge (2023)
[23] Xuan Qiu and CELI (2023)

reduction[24]. Second, defective accounting rules in REC use raise the propensity of "double-counting"—complicating, even undermining climate actions[25].

As most data centres operated by multinationals are spread throughout the world, often in locations that fulfil conditions of their energy needs, they are likely to manage their sustainability targets by way of tradables. For example, the world's largest colocation data centre provider, Equinix, reported that 45% of its energy use was matched by RECs[26].

The risk of double-counting should not be overlooked. Malaysia's international commitment to address climate change rests on reducing carbon intensity, which requires substantial emissions reduction. An important part of achieving our pledged goals is emissions accounting. Currently, there are no clear accounting rules for reconciling cross-border trading of energy attributes like RECs with national emissions inventory. If the local utility cannot provide sufficient renewable energy, companies can claim carbon neutrality by buying RECs from elsewhere; the emissions produced from fossil generation to power their REC-matched power use still count, a situation that amounts to "no additionality"[27].

Ideally, companies operating in developing states can help propel renewable energy buildout through Power Purchase Agreements (PPAs) or other forms of cooperation. The usage of RECs by multinationals in developing countries is dishonest at best and thwarts developing countries' climate action at worst.

AI ramps up energy needs

From 2010 to 2015, global electricity demand from data centres has been more or less level—in the range of 200TWh—in spite of the growing size of the industry and skyrocketing internet traffic[28], thanks to the efficiency gains from computing and a shift to hyperscale data centres which offset the growth[29]. In 2022, IEA renewed the range of energy use estimates upwards to 340TWh for that year, accounting for 1 to 1.3% of global energy use[30]. The agency forecasted in the same report a doubling of data centre energy use by 2026 due to rising demands from both AI and cryptocurrencies[31].

The development of AI in recent years has raised concerns about computing energy consumption. AI requires a lot of power. As the development of large language models (LLMs), which are large in size and complexity, accelerated, the computing resources required to run them skyrocketed.

LLMs are large machine learning that performs Natural Language Processing (NLP) tasks, such as generating texts or images. The training of LLM is energy intensive. Models are trained on

[24] Bergamo (2023)
[25] Ma and Duan (2024)
[26] Equinix (2022)
[27] Sautam Naik (2021)
[28] Malmodin and Lundén (2018); IEA (2017)
[29] IEA (2017); Jones (2018)
[30] IEA (2023)
[31] Ibid.

terabytes of data, requiring more computing resources and energy than traditional data centre activities. It was estimated that the training of OpenAI's LLM GPT-3 consumed around 1,287MWh and contributed to 552tCO_2e[32].

Training is only a partial picture of AI energy costs. Following training, an AI system is rolled out to consumers where it can be used to generate output, known as the inference phase. Studies have suggested that the energy demand of the inference phase could be considerably higher[33]. For example, an AI-powered Google search query uses nine times more energy than conventional Google search[34].

The energy costs and ecological impacts of AI can be hard to pin down. Cloud service providers are increasingly dispersing data centres globally, as geo-distributed infrastructures allow providers to exploit energy price differences, lowering network expenses and bringing services closer to clients[35]. The geographically distributed nature of AI system deployments makes it extremely challenging to estimate their energy costs.

There are also inequities associated with geo-distributed data centres. As multinational cloud service providers disperse their data centres throughout the world, data centres can exact disproportionate environmental impact in certain regions, leading to inequitable socio-ecological ramifications[36]. For example, water usage in cooling systems depends on outside temperatures. Data centres operating in cooler climates can save up to nine times the water usage compared to those in hot, arid areas, adding to the water stress of those regions[37].

Towards a sustainable data centre hub?

Given the trade-offs in both energy risk and ecological impact, governments should be more strategic in planning for the industry. Countries like Ireland and Singapore had put moratoriums on the building of new data centres due to the grid pressures following a period of influx[38]. To restrain their risks, regulations of the data centre industry can be considered.

In Malaysia, guidelines are in place to steer sustainable data centre development, such as the Planning Guideline for Data Centre issued by the Ministry of Housing and Local Government. Johor, one of the major beneficiaries of the recent data centre boom, also recently launched its state-level planning guidelines for data centre development. Efficiency metrics like PUE remain the preferred measure of sustainability.

The Malaysian Communications and Multimedia Commission's (MCMC) Technical Code for Green Data Centres, updated in 2024, provides the minimum requirement for data centres. The standard requires a minimum of 1.9 PUE and below 1.5 PUE for data centres to qualify as "green" facilities.

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[32] Patterson et al. (2021)
[33] Patterson et al. (2021); de Vries (2023)
[34] de Vries (2023)
[35] Hogade and Pasricha (2022)
[36] Li et al. (2024)
[37] Karimi et al. (2022)
[38] Traynor (2024); Swinhoe (2024)

Meanwhile, the Malaysian Investment Development Authority specified PUE requirements for new data centres to be eligible for tax incentives, ranging from 1.4 to 1.7 depending on size and capacity[39,40].

Other metrics like Carbon Usage Efficiency (CUE) directly measure the external impact of data centres. However, CUE is tied to the power utilities from which data centres source their electricity, something data centre operators might have less control over. The sustainability of data centres must consider their outward impact onto the environment and society at large, it is key that better sustainability metrics are used.

Malaysia has set ambitions to become the region's sustainable data centre hub. However, there are considerable challenges in balancing the energy needs and ecological impacts of data centres with other sustainable development goals important to the country. The vast energy demand and corresponding carbon footprint from data centres may affect our performance in achieving ambitious national climate goals, as set out in our international commitments. The country must ensure that the needs of data centres do not override other developmental goals.

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[39] Malaysian Investment Development Authority (2024)

[40] The guideline also set specifications for water and carbon usage effectiveness. The CUE requirement for tax incentives eligibility is 0.76GgCO_2e/GWh for peninsula Malaysia, which is around the range of power system emissions factor.

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