

Microgrids and data centers

Challenges and opportunities in the transition to smart and sustainable power systems

Alexandre Matias Correia, Pedro Moura e
Aníbal T. de Almeida
ISR Open Day - Setembro 2026





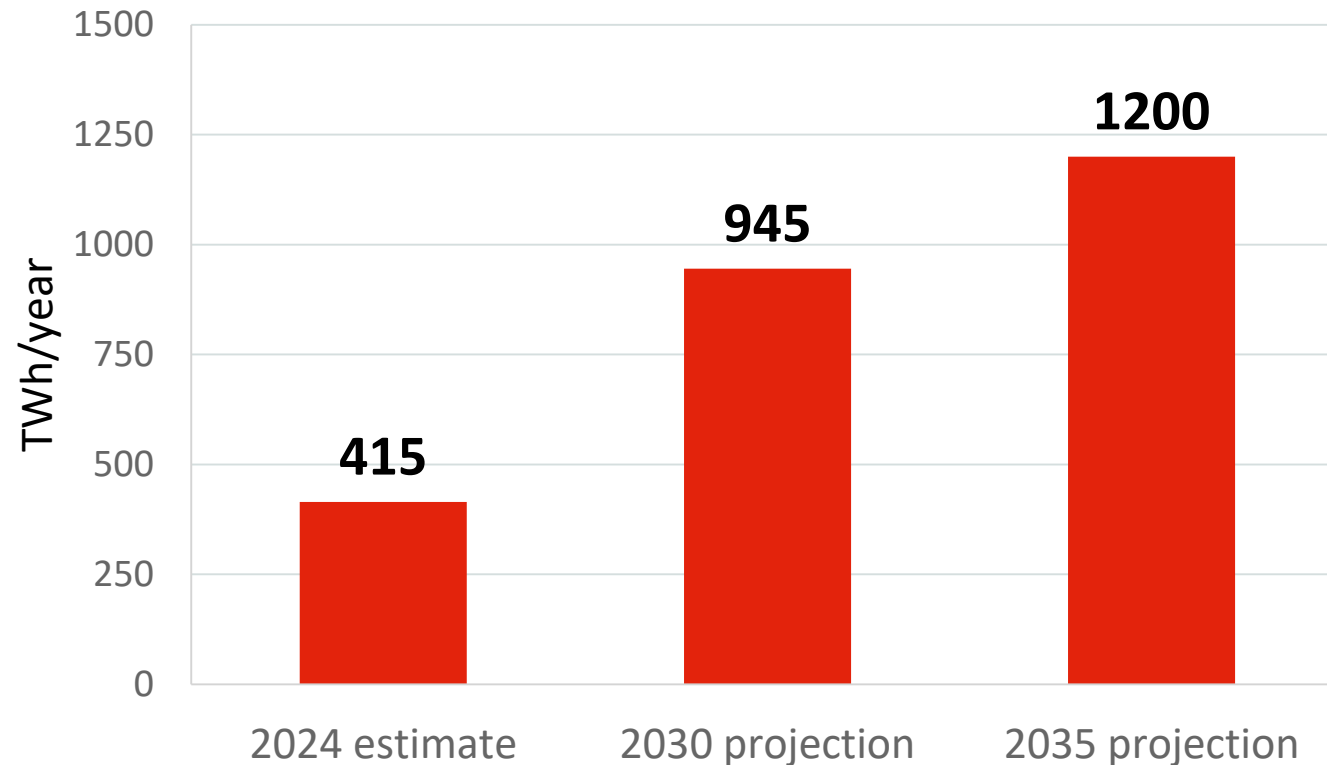
When the grid fails, what must keep running?

**Essential digital services
need a continuous energy supply.**

Microgrids can sustain that supply.
Data centers can help manage the demand.



Data center growth creates local power challenges

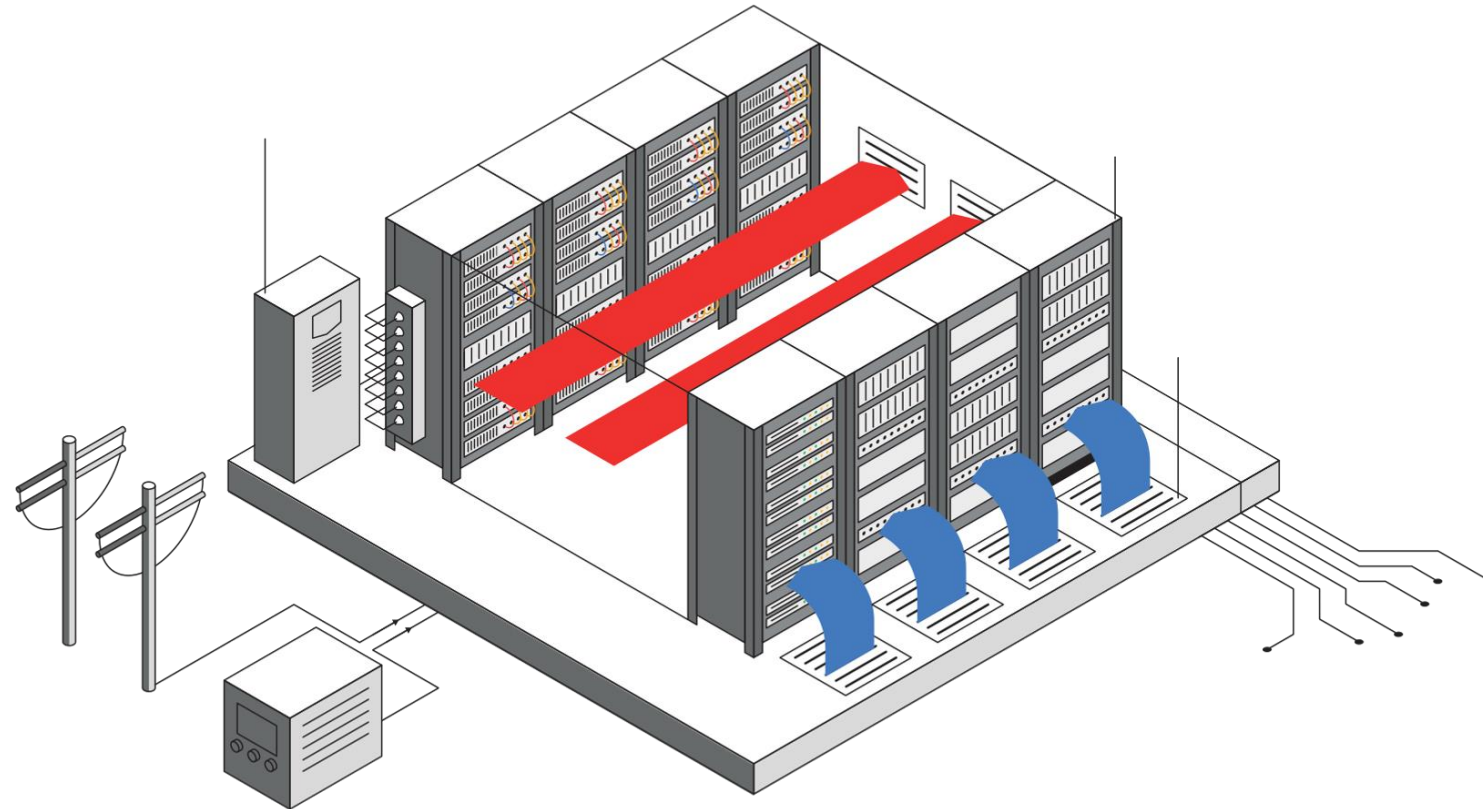


The local connection matters

Large loads cluster in particular places.

Generation and grid expansion take time.

The data center is an energy system too



**Energy demand
depends on**

IT/computing needs

Cooling

Power conversion

UPS and backup

There are four types of Data Centers: hyperscale, colocation, enterprise, and edge



Hyperscale facilities

Owned by companies such as Google, Microsoft, Meta, and Amazon that deploy Internet services and platforms at massive scale. Very high power consumption with hundred thousands of servers

Colocation companies

Provide wholesale and retail colocation leasing, typically deploying large and very large data centers. Many companies will share server space and capacity in a colocation facility.

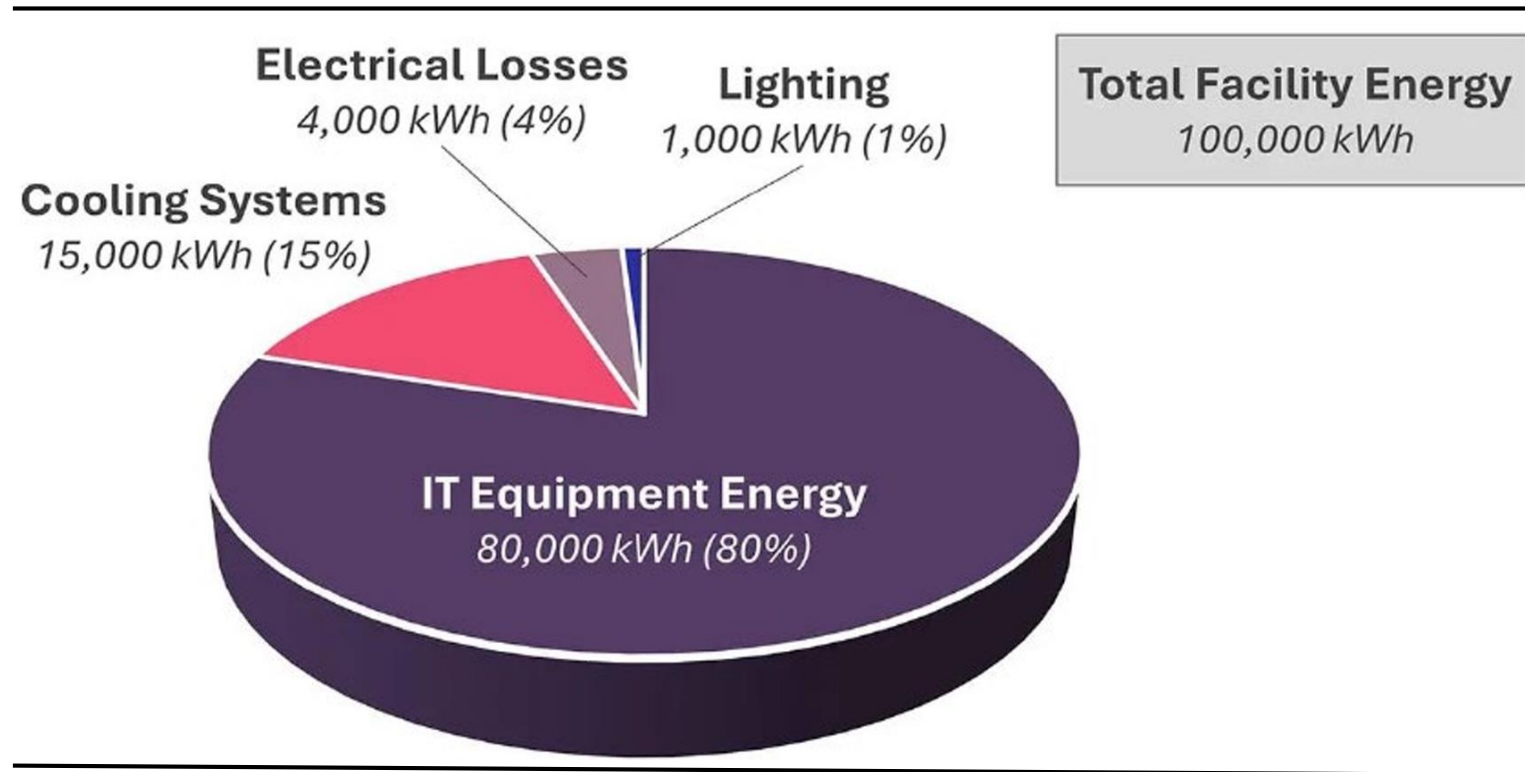
Enterprise sites

Are owned and operated by single organizations such as banks and phone companies for their internal operations. Their advantage is security and control, but they may have low utilization rates, rigid designs, and long upgrade cycles. Some enterprises are moving less sensitive data to colocation sites.

Edge centers

Serve local Internet of things and telecom networks. Placed closer to users or data to reduce latency and improve real-time processing. Many sites are decentralized, which difficults management.

Distribution of data center energy consumption by component



Source: Nadel, Steven. 2025. Opportunities to Use Energy Efficiency and Demand Flexibility to Reduce Data Center Energy Use and Peak Demand. Washington, DC: ACEEE.

Scale & trajectory of electricity demand



Concentration + peak coincidence

- AI-focused facilities can draw power comparable to heavy industry, but are geographically clustered.
- Grid constraints and connection queues are often driven by a limited number of peak hours each year.
- In the U.S., data centres' share of system-wide peak demand is projected to rise from ~6% today to ~13% by 2030 (IEA).

Illustrative stress points

- Interconnection & transmission upgrades take years; compute demand can ramp much faster.
- Reliability requirements (N+1, backup power) shape site selection and resource mix.
- Some jurisdictions have imposed limits or paused new connections where demand threatens system adequacy.

Impacts on the clean energy transition



Upside potential

- **Catalyses new clean generation** via long-term contracts (PPAs) and co-located projects.
- **Flexible computing** can help absorb variable renewables (shift to low-carbon hours/regions).
- Waste-heat recovery can displace fossil heating in district energy systems.

Downside risks

- Tight timelines and reliability needs can trigger new fossil capacity if grids are constrained.
- If flexibility is unmanaged, loads can coincide with peaks and raise system costs (All people pay!)
- Water stress and local opposition can slow projects and shift them to less optimal sites.



A microgrid coordinates a local energy system

Local generation + storage + loads under coordinated control

Connected to the grid

Exchange power and coordinate local resources.

Operating as an island

Maintain an electrical balance within a defined boundary.

Islanding requires suitable controls, protection and a source that establishes voltage and frequency.

The opportunity is coordinated operation



Existing capability	Role within a microgrid
UPS and batteries	Reserve power, with controlled use of any available flexibility
On-site generation	Local supply during normal operation and outages
Cooling and computing	Demand management within service and thermal limits
Site controller	Coordinate assets and the connection to the utility

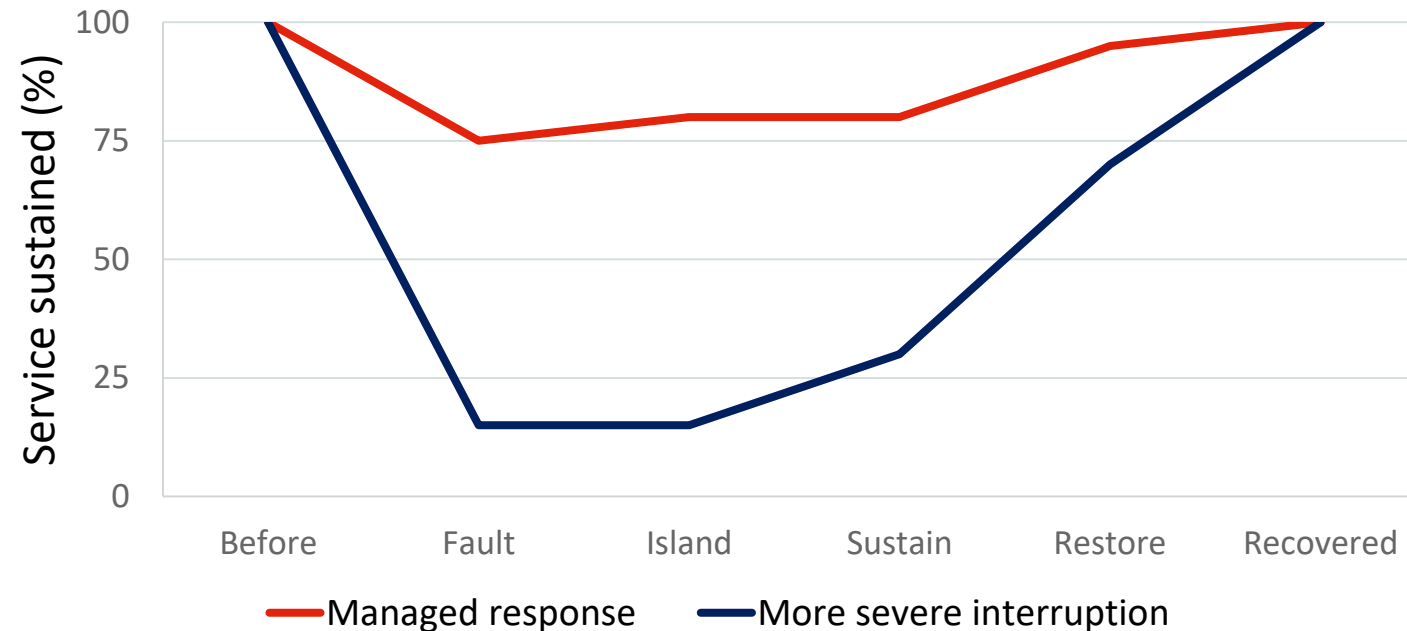
The same assets serve different operating priorities



Situation	Primary objective	Example action
Normal conditions	Efficient service delivery	Use local renewables and manage peaks
Warning of disruption	Prepare for an outage	Increase reserves and defer eligible tasks
Grid outage	Sustain essential services	Island safely and manage critical loads
Recovery	Restore stable operation	Reconnect safely and stagger restarting tasks

Impact of resilience on disruption

Resilience: how much service survives, and how quickly does it recover?



Depth of disruption

Time under disruption

Recovery of critical service



Some computing can move in time

Time-sensitive services

Interactive applications and essential network functions need immediate availability.

Deferrable work

Eligible batch jobs and background processing can wait within agreed deadlines.

**A microgrid controller can request a power limit.
The computing scheduler decides which eligible tasks can move.**



Google demonstrates the demand-side contribution

Non-urgent computing shifts away from periods of grid stress.

What the pilots show

Computing schedules can provide useful flexibility to the power system.

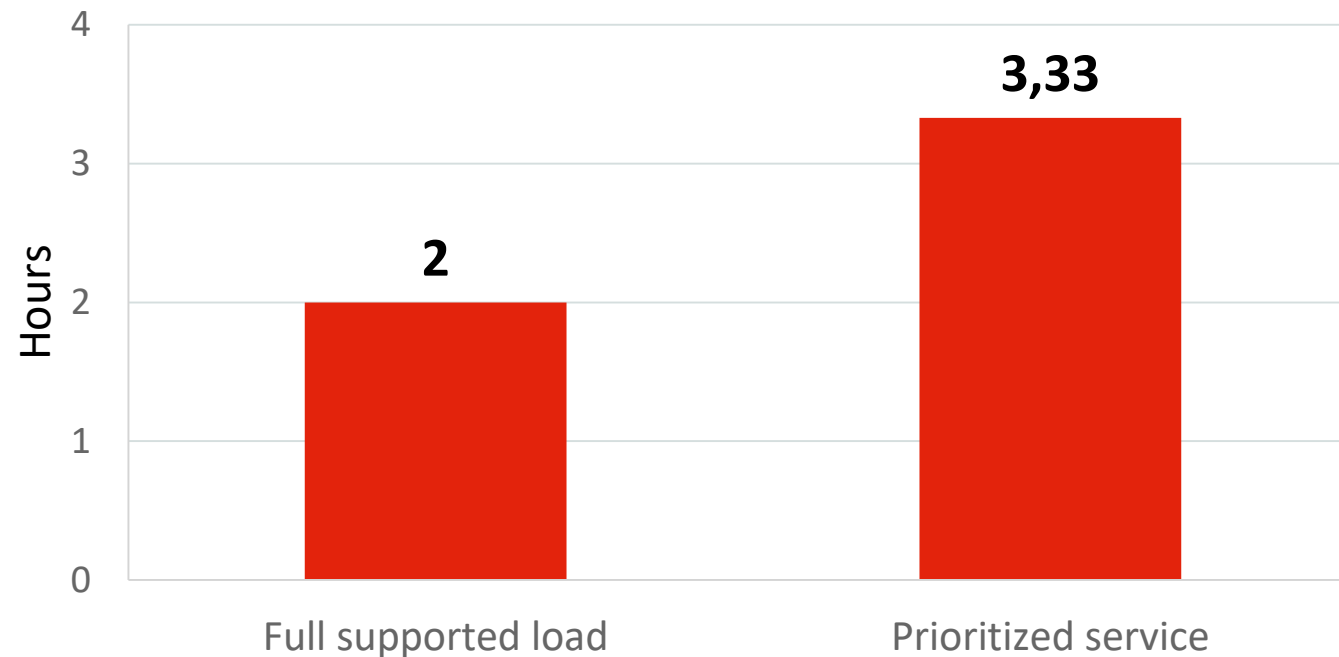
What transfers to microgrids

A local energy controller could use the same principle to conserve reserves.



Lower demand extends the same energy reserve

Usable reserve: 2 MWh No generation during the outage



1 MW load
 $2 \text{ MWh} \div 1 \text{ MW} = 2 \text{ h}$

0.6 MW load
 $2 \text{ MWh} \div 0.6 \text{ MW} \approx 3.3 \text{ h}$

About 67% more time, with less load served.



Efficiency reduces the burden on the microgrid

**Less energy per useful computing task
means less energy to supply during an outage.**

Inside the facility

Efficient IT and cooling reduce electricity demand and heat rejection.

At the site boundary

Useful heat recovery can connect the data center with nearby heat demand.

Demand response via flexible computing (example)



Why batteries matter

- BESS can reduce peak grid draw and respond faster than diesel-based backup in many scenarios.
- A “grid-interactive” design can deliver curtailment or ancillary services while maintaining uptime.
- Integrating BESS with workload management expands the controllable portion of the load.

Case study (simulation + HIL):

NREL + Verrus validated a 70-MW grid-interactive data centre platform (Vulcan) to test control strategies and grid services.

Mitigation architecture (typical)



Compute (IT) load



Cooling & facilities



UPS + BESS



Grid interface



Sustainability and resilience require joint planning

Clean energy when available

Use local renewable generation and schedule eligible demand to match supply.

Energy when it is needed

Maintain enough dependable capacity and reserve for the outage scenario.

Renewables are variable and storage is limited.
Fuel-based backup carries emissions and supply-chain dependence.

Case study: OATI data center microgrid

A mission-critical data center within a microgrid

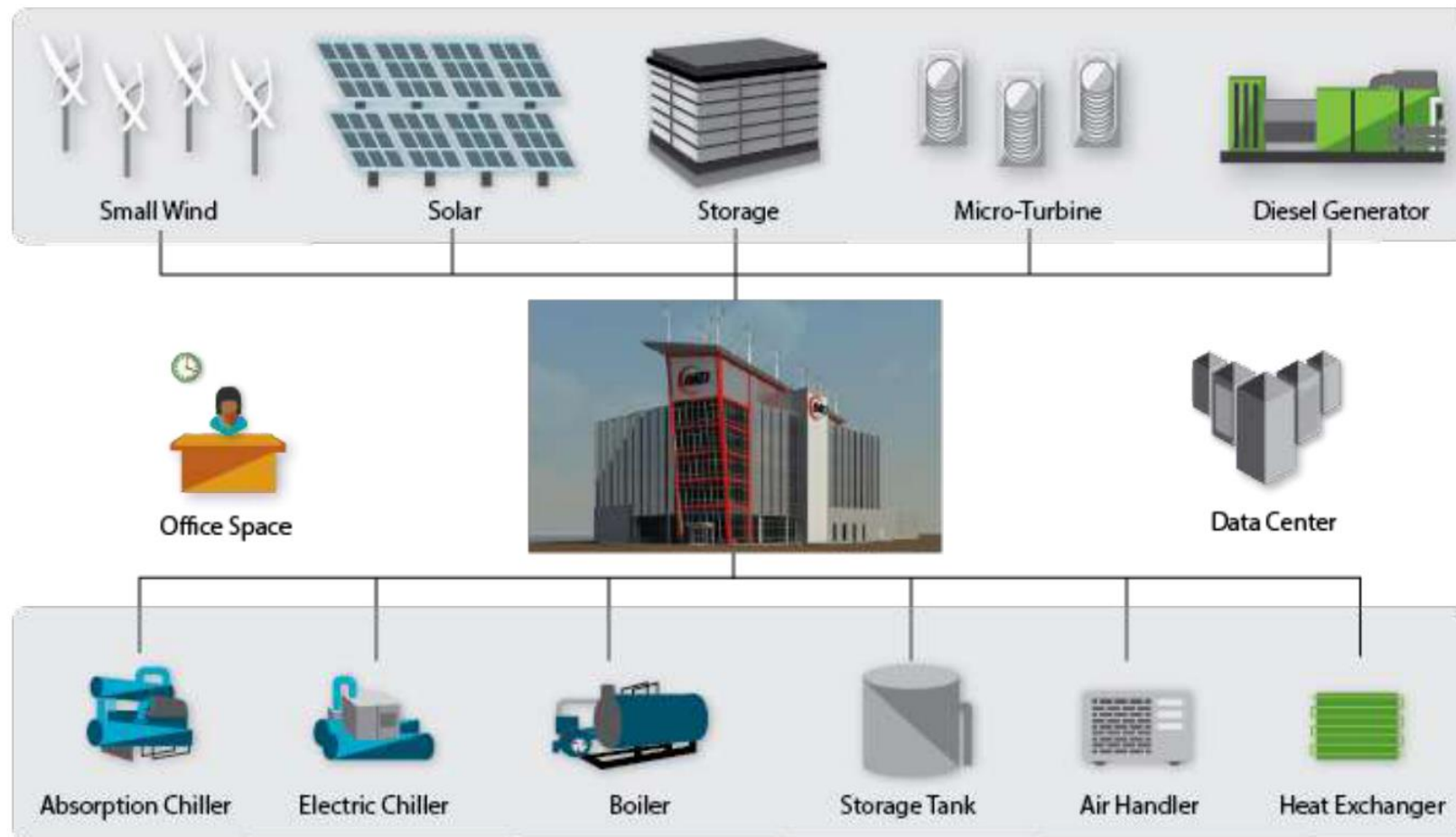


Project element	Reported capacity
Data center	500 kW
Photovoltaic array	150 kW
Battery storage system	≈230 kWh
Natural gas microturbine generation	600 kW

Shared electrical and thermal management connects on-site supply with facility needs.

[1, 4, 7] Reported original installation. CEC specifies 125 kW / 231 kWh battery storage.

OATI coordinates an entire building energy system



**Bloomington,
Minnesota**

Commissioned
in 2017

Additional resources

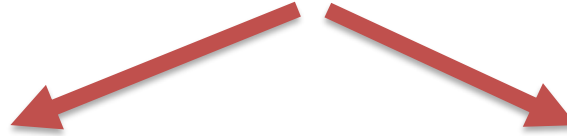
24 kW wind

1.5 MW diesel backup



GridMind coordinates dispatch and operating modes

The controller coordinates resources
according to the operating mode



Connected to the utility

Schedule local resources alongside grid supply.

Balance energy cost with operating priorities.

During a grid disturbance

Coordinate islanding and local supply.

Prioritize loads within the resources available.

Dispatch inputs include solar forecasts, energy prices and temperature.



Microturbine heat also supports heating and cooling

Combined cooling, heating and power

Output or process	Role at the facility
Electricity generation	Supply building and data center electrical loads
Recovered exhaust heat	Provide useful heat for the building
Heat-driven absorption cooling	Use recovered heat to support cooling

The recovered heat comes from the gas microturbine.
Fuel use and emissions remain part of the assessment.

[4] Dunham Associates, OATI project description. [7] CEC (2018), pp. 53–54.



OATI's business case starts with service continuity

≈ **\$1.5 million**

Historical microgrid-specific investment estimate

Excludes the diesel generator and the wider data center project.

Potential value

Protect critical operations

Use energy assets in daily operation

Enable eligible grid services

Published material does not establish a verified payback, annual savings or outage autonomy.

The main challenges sit at the interfaces



Interface	Challenge to resolve
Power system and IT	Protect service deadlines while changing demand
Daily savings and backup	Preserve the energy reserve required for an outage
Devices and controllers	Coordinate equipment and maintain safe local fallback
Site and utility	Agree on protection, connection and operating limits
Investment and operation	Value resilience and verify savings without double counting

Success needs more than one metric



Objective	Useful measure
Digital continuity	Critical services sustained and time to recovery
Electrical resilience	Autonomy and unserved critical energy
Resource efficiency	Total electricity and energy per useful task
Environmental performance	Emissions over time, water use and useful heat
Economic viability	Lifecycle cost, with a separate value for avoided disruption



A practical route starts with service priorities

01

Define essential services

Include IT, cooling and network dependencies.

02

Map resources and limits

Measure loads, usable reserves and control capabilities.

03

Test coordinated operation

Start with monitoring, then controlled flexibility trials.

04

Validate outage and recovery behavior

Use credible scenarios and supervised transition tests.



Where does the research go next?

Microgrid baseline

Dynamic resource management

Resilience over time

Critical load protection

Data center extension

Joint control of energy and computing

Metrics tied to essential digital services

Load scheduling and ancillary services

How much useful digital service can the available energy sustain?



Microgrids and data centers can support each other

Microgrids can protect essential digital services.

Data centers can contribute flexible demand and make better use of local energy.

The opportunity depends on coordinated control, protected reserves and evidence from real operation.

Microgrids and data centers

Challenges and opportunities in the transition to smart and sustainable power systems

Obrigado pela vossa atenção!

Alexandre Matias Correia

Alexandre.correia@isr.uc.pt



Departamento de Engenharia Eletrotécnica e de Computadores
Universidade de Coimbra

References: data center context and examples

[1] Alexandre Filipe Matias Correia

Optimization and Management of Microgrids to Deliver High Power Quality in Critical and Disaster Situations
Ph.D. thesis, University of Coimbra, 2026.

[2] IEA (2025)

Energy and AI. Section: Energy demand from AI.

[3] Mehra and Hasegawa, Google Cloud (2023)

Supporting power grids with demand response at Google data centers.

[4] Dunham Associates

OATI project description and project photograph. Accessed September 2026.

[5] U.S. Department of Energy (2024)

Best Practices Guide for Energy-Efficient Data Center Design.

[6] Google (2021)

We now do more computing where there's cleaner energy.



References: OATI case study

[7] Asmus, Forni and Vogel, California Energy Commission (2018)

Microgrid Analysis and Case Studies Report, CEC-500-2018-022.
OATI case study, pp. 51–56.

[8] OATI, Microgrids for data centers

Current data center offering and proposed operational benefits.

[9] OATI, Advanced microgrid and asset controls: OATI GridMind

Resource scheduling, load priorities and operating modes.

[10] OATI, Microgrid Technology Center featured by Factor This (2025)

Company-reported live demonstration at the operating site.