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Technical Paper

Up to 30% Additional Electric Power for AI Datacenters with Water-Free Combined Cycle Power Augmentation

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EXECUTIVE SUMMARY:

Power Augmentation for AI Datacenters with Water-Free Combined Cycle

AI is advancing faster than the power grid can respond. The U.S. is facing a genuine energy crunch: GPU racks are sitting idle because power is unavailable, while datacenters compete for substations and years-long interconnection queues. AI workloads will not wait for grid upgrades.

As many industry leaders have already recognized, the fastest path forward is the deployment of behind-the-fence power plants dedicated to serving AI datacenters. The challenge, however, is that demand for gas turbines, gas engines, and even fuel cells now far exceeds supply.

Lead times for these core baseload generation assets increasingly stretch well beyond 2030, creating a critical gap between power demand and available capacity.

The Solution: Water-Free Power Augmentation

That gap can be bridged through water-free combined-cycle power augmentation; capturing exhaust heat from gas turbines, engines, and fuel cells and converting it into additional baseload electricity.

Turboden's water-free combined-cycle technology, based on the Organic Rankine Cycle (ORC), is specifically designed to recover thermal energy from hot exhaust streams and transform it into clean, reliable electric power. This enables datacenter operators to **add hundreds of megawatts of incremental capacity by utilizing energy that would otherwise be wasted**. All that without additional fuel consumption and without using water.

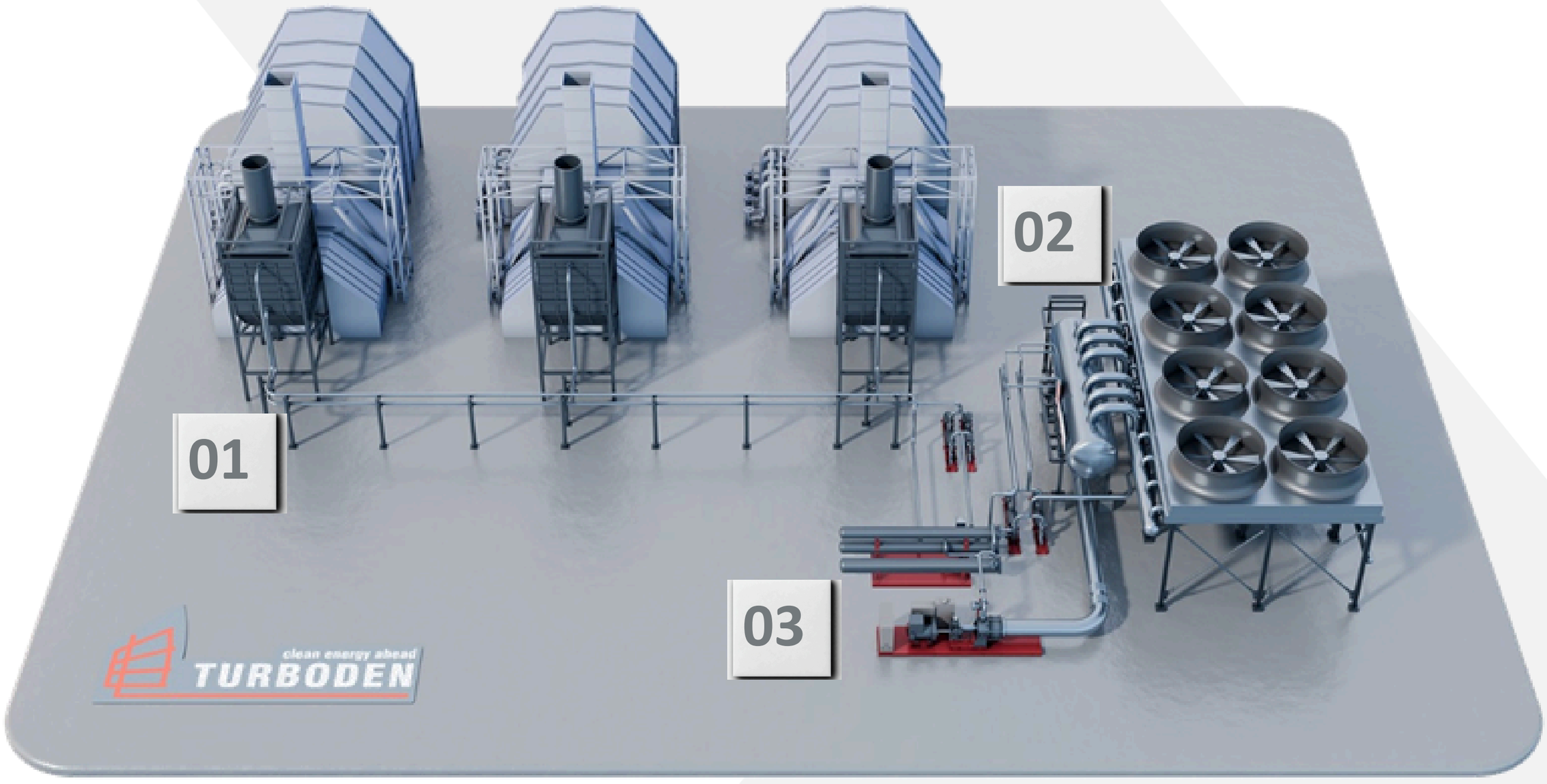
By converting lost thermal energy into usable power, ORC technology delivers zero-emission, water-free, and fuel-free power augmentation. Whether increasing the output of gas-turbine-based generation, producing additional on-site electricity, or exporting power to the grid, Turboden's Combined Cycle solutions allow datacenter owners and operators to maximize the value of every unit of fuel consumed, reduce operating costs, and materially improve the sustainability of their power strategy.

Why Combined Cycle Matters for Datacenters

Replacing simple-cycle operation with a combined-cycle approach delivers measurable, bottom-line benefits:

- **Additional Power Within 15 Months** - Recover exhaust heat and convert it into usable electricity, increasing total system efficiency by up to 30%.
- **Fuel-Free Power Generation** - Produce incremental electric power with no additional fuel consumption, maximizing output from existing assets.
- **Zero Additional Emissions** - Lower carbon intensity and support decarbonization goals with no incremental pollutant emissions.
- **Flexible Integration** - Seamlessly integrates with gas turbines, gas engines, and solid-oxide fuel cells across a wide range of power configurations.
- **True Baseload Performance** - Deliver reliable, 24/7 power aligned with the continuous operational requirements of AI datacenters.
- **Water-Free Operation** - Air-cooled condensers eliminate water use - ideal for arid regions, constrained sites, and datacenter environments.
- **Reduced Cost of Power** - Monetize waste heat to improve project economics, shorten payback periods, and lower the effective cost of electricity.

Water-Free Combined Cycle Offers a Ideal Combination of Clean, Reliable, and Fast-to-Deploy Power



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In a water-free combined cycle system, waste heat from the gas turbine or engine exhaust is first captured through an oil heat exchanger.
Hot exhaust gases pass across finned tube bundles while a closed loop of thermal oil circulates through the exchanger, absorbing the heat.
The thermal oil acts as a stable, non-evaportaing heat-transfer medium, enabling efficient energy recovery while avoiding water consumption, scaling, or freezing risks typically associated with steam-based systems. Because the oil remains in the liquid phase throughout the entire heat transfer process, the system also ensures precise and reliable temperature control.

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The heated oil then transfers its energy to the system's working fluid within an evaporator. In this stage, the thermal oil flows through one side of the heat exchanger while the organic working fluid flows through the other, causing the working fluid to vaporize and become a high-pressure vapor.
This vapor expands through a turbine coupled to a generator, converting thermal energy into mechanical power and ultimately electricity.

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After expansion, the low-pressure vapor enters an air-cooled condenser where it releases residual heat to ambient air and condenses back into a liquid.
The condensed working fluid is then pumped back to the evaporator to repeat the process, completing the closed loop.
This fully sealed, water-free cycle eliminates cooling water requirements, minimizes maintenance, and ensures reliable, continuous operation while converting otherwise wasted heat into clean, additional power.

Datacenters’ power needs overlap with Water Free Combined Cycle baseload power generation

Water-Free Combined Cycled is a mature reliable, affordable, and clean solution that can add thousands of megawatts (MW) to datacenters ensuring a reliable, baseload power supply. Multiple reports from source such as Chacartegui et al. (2009), Applied Energy “Alternative ORC bottoming cycles for combined cycle power plants. points to the significant potential and multiple benefits of implementing water-free combined cycle in facilities that operate simple cycle gas turbine, gas engines and fuel cells.
The Turboden water free combined cycle project operates unattended with minimal maintenance, operates with multiple and different heat sources, responds to power need fluctuations effectively, adds zero emission the datacenter carbon profile, require minimum permitting, and is among the fastest power solutions to deploy in either new construction or a retrofit projects.

Unattended Operation & Minimal Maintenance

Turboden’s water-free combined cycle is inherently aligned with how modern data centers are built and operates. **The solution turns otherwise-wasted exhaust heat into dependable baseload electricity without adding the operational burden of a traditional steam bottoming cycle**. Because it does not require cooling water, it avoids cooling towers, make-up water systems, blowdown management, water treatment chemistry, and the permitting/availability risks that come with water-based power systems. For data center operators who increasingly face water constraints, community scrutiny, and strict uptime expectations this “no-water, no-steam” architecture removes a major source of complexity while still capturing meaningful incremental megawatts from existing prime movers.

A key advantage for data centers is unattended operation. Turboden’s combined cycle plants are designed for automated, continuous service with remote monitoring and diagnostics, allowing them to run as a “set-and-forget” asset alongside gas turbines, engines, or fuel cells. That operational model maps directly onto data center realities utilizing existing teams without any additional training and integration into SCADA/BMS and existing alarm workflows. The Turboden solution operates with automated start/stop sequences and predictable response to load changes supporting the data center requirement for consistency rather than constant operator intervention.

Minimal maintenance is the other decisive fit. The core technology behind the water-free combined cycle solution is the Organic Rankine Cycle (ORC) which is designed to avoid many of the maintenance-intensive elements of steam cycles - no boilers, no steam drums, no water-side scaling/corrosion regimes, and no rotating equipment exposed to wet steam conditions. With fewer auxiliary systems and simpler balance-of-plant, the routine maintenance profile is reduced to standard mechanical/electrical inspections and planned service intervals that can be synchronized with prime mover outages. For a data center, that means no need for specialized technicians on standby, and fewer unplanned disruptions while improving overall site efficiency and helping stretch limited fuel and interconnection capacity further.

In practice, that combination of water-free design, unattended operation, and minimal maintenance makes Turboden's solution feel less like a "power plant project" and more like a reliability-grade infrastructure add-on.

The Turboden's power solution helps data centers extract more electricity from the same fuel and equipment footprint, with a control philosophy and staffing model that matches the industry's operational DNA: high automation, high availability, and low operational overhead.

Flexible Operation

Turboden's water-free combined cycle technology is fundamentally a heat-to-power "adapter", it can sit downstream of multiple prime movers and process heat sources and convert energy, that would otherwise be rejected to atmosphere, into useful electric power. Because the ORC is designed to automatically adjust to changes in exhaust temperature and mass flow, it remains stable across the real operating variability you see in packaged gas turbines, reciprocating engines, fuel cells, and industrial process streams, the change shows up primarily as a change in net power output, not a loss of operability.

That flexibility becomes especially valuable in data-center architectures that blend different power generating assets. The Turboden's control approach is designed for variable conditions and strong part-load behavior, including the ability to operate down to ~10% of nominal load, a key attribute when the upstream heat source is cycling, or optimized for maintenance.

On the electrical side, this same control philosophy supports the kind of fast operational response that matters for modern generative-AI facilities. Training and inference clusters can swing power demand quickly as workloads shift and cooling plant parasitics change. In that environment, the ORC technology is well suited to follow a site-level power swings thanks to its capacity to generate power efficiently at deep part load (down to ~10%) and modulate output without the operational penalties associated with water/steam bottoming cycles.

Practically, that means you can operate the ORC as a highly controllable "extra megawatt layer" in the microgrid stack: it can stay online at very low loading during low-demand periods and then ramp up quickly as the data center load rises. Where your project assumptions call for extremely rapid, those dynamics are best grounded in grid-stability studies such as a PSSE dynamic model. In the PSS®E modeling effort, the Turboden ORC can be represented in the same transient stability framework used for other microgrid resources, providing a credible basis to show how the ORC participates in frequency/voltage behavior and how it integrates with the controls strategy for a data-center microgrid.

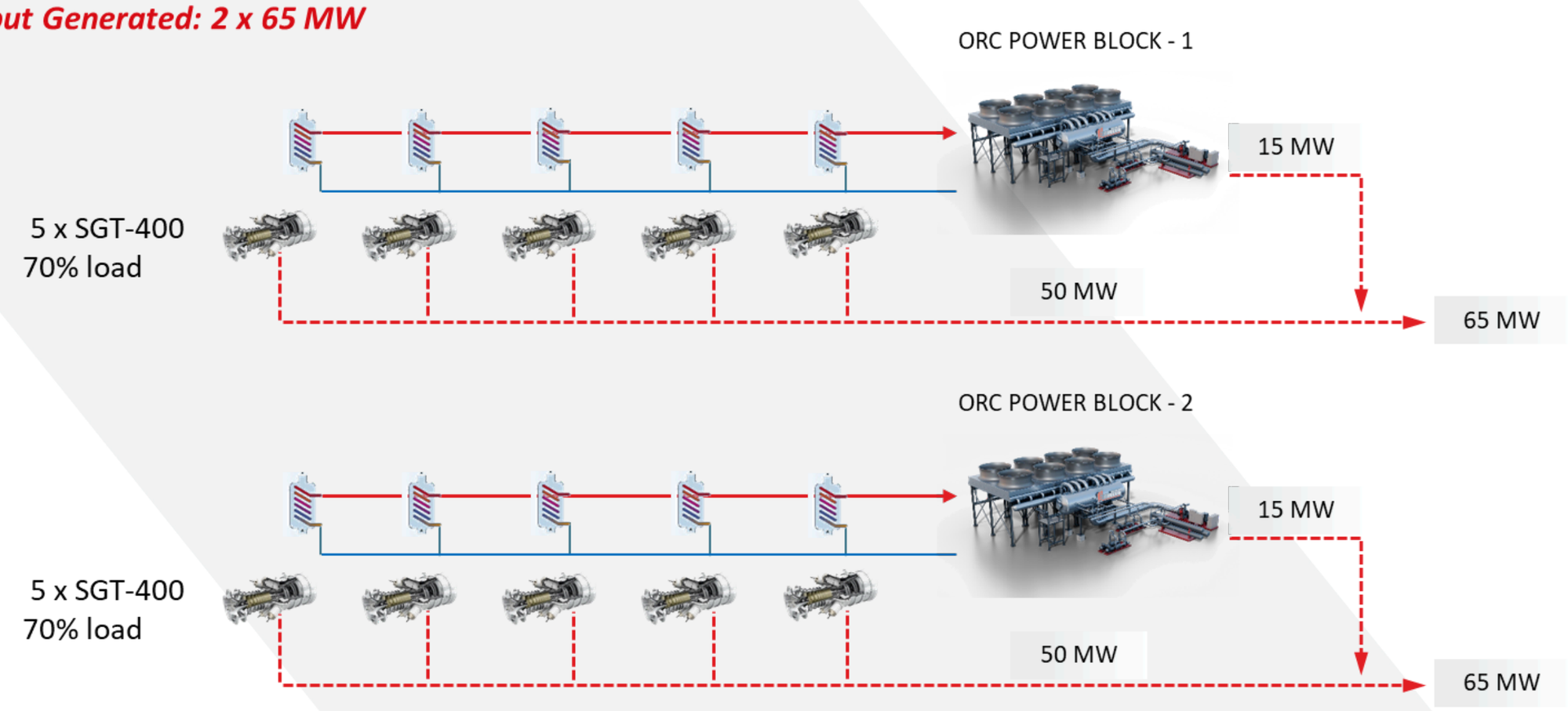


Fig. 1: Flexible configuration

Emission Free / Fuel Free Power

Turboden's water-free combined cycle (ORC) stands out as a fuel-free, emission-free power solution that directly supports data centers' decarbonization goals. By converting waste heat from existing on-site assets, such as gas turbines, engines, or fuel cells, into additional electricity, the ORC produces power without burning incremental fuel and without generating incremental emissions. From a carbon-accounting perspective, every kilowatt-hour produced by the ORC lowers the effective emissions intensity of the data center, helping operators demonstrate tangible Scope 1 and Scope 2 reductions without compromising reliability or uptime.

This attribute also translates into simpler and more predictable air permitting. Because the ORC does not introduce a new combustion source, it does not add regulated pollutants such as NO_x, CO, SO_2, or particulate matter. For data centers located in non-attainment or air-constrained regions, this can be critical, the ORC increases on-site electric output without triggering the permitting complexity, offsets, or public scrutiny that often accompany new fuel-fired generation. In practice, this can shorten development timelines, reduce regulatory risk, and provide greater confidence when scaling capacity to meet fast-growing AI workloads.

Equally important for data center operators is **energy price stability**. Since the ORC uses no fuel of its own, its cost of electricity is fundamentally insulated from fuel price volatility, whether driven by natural gas market swings, geopolitical events, or regional supply constraints. Once installed, the ORC delivers electricity at a highly predictable, long-term marginal cost, effectively "locking in" value from heat that would otherwise be wasted. For data centers managing multi-year power budgets and hyperscale expansion plans, this fuel-price immunity provides a hedge that complements PPAs and behind-the-meter generation strategies.

Taken together, these characteristics position Turboden's water-free combined cycle as more than an efficiency upgrade - it is a sustainability and risk-management tool. It lowers carbon footprint without adding emissions, eases compliance with tightening air regulations, and stabilizes a portion of the data center's energy cost base. For operators navigating the intersection of AI growth, environmental accountability, and volatile energy markets, the ORC offers a rare combination of clean power, regulatory simplicity, and long-term economic resilience.

No water or air permit allows for faster project development and implementation

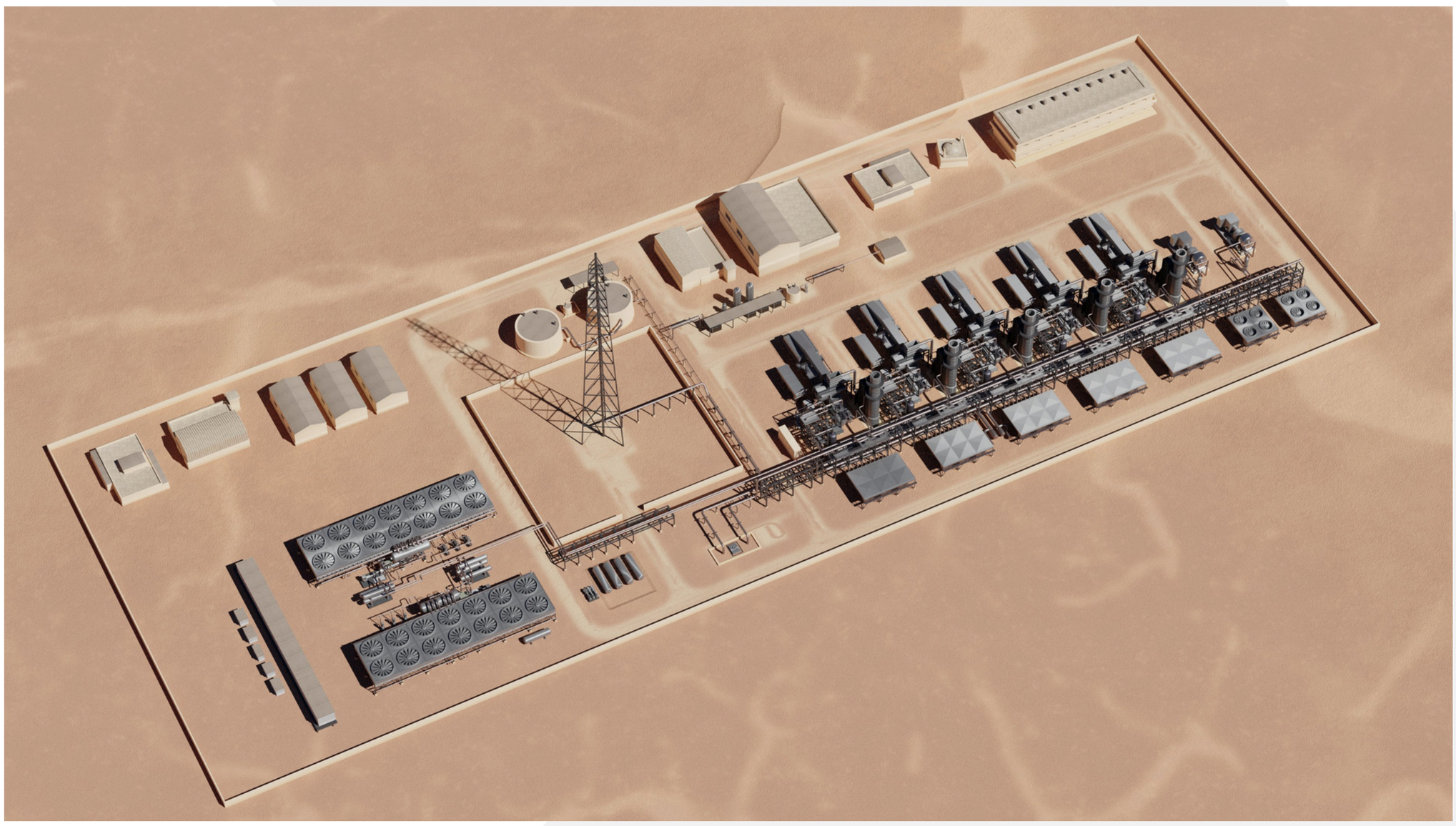
Turboden's water-free combined cycle (ORC) materially simplifies the permitting pathway for data-center power plants, directly supporting faster project execution. Because the ORC does not require cooling water, it eliminates the need for water-withdrawal permits, discharge permits, cooling-tower approvals, and ongoing water-management compliance. In regions where water rights are constrained, contested, or subject to lengthy environmental review, this alone can remove months or even years from the development timeline. **For data-center developers working on aggressive AI-driven deployment schedules, avoiding water permitting is often the difference between a viable project and one that stalls in regulatory review.**

On the emissions side, the ORC adds no new combustion source and therefore does not materially increase regulated air pollutants such as NO_x, CO, SO_2, or particulates. This significantly reduces the complexity of air-permit modifications when adding incremental on-site generation capacity. In many cases, the ORC can be incorporated under existing permits for the prime mover, or through streamlined administrative amendments rather than full permit reopeners.

Beyond permitting, Turboden's water-free combined cycle also aligns exceptionally well with the construction and commissioning cadence of modern data-center power plants. The ORC system is modular. Typical erection and installation timelines are on the order of 4 - 5 months, which closely matches the delivery and installation schedule of packaged gas turbines and large engines. This enables parallel construction rather than sequential critical paths, allowing the ORC to be brought online without delaying first power.

For data-center developers, this combination - simplified water and emissions permitting plus a short, predictable erection cycle - translates directly into shorter development cycles and faster time to revenue. Instead of being a late-stage efficiency add-on, Turboden's water-free combined cycle can be planned and executed as an integral part of the initial power-plant buildout, delivering incremental megawatts with minimal regulatory friction and without slowing the aggressive schedules demanded by AI and hyperscale data-center growth.

Water Free Combined Cycle Power – Turning Waste Heat to Fuel Free Power (a Case Study)



AI training clusters are pushing power infrastructure beyond grid limits. GPU-dense facilities require continuous baseload, fast ramping, water-free operation, and high efficiency, all delivered on accelerated timelines. This case study demonstrates how a water-free combined cycle using Organic Rankine Cycle (ORC) technology augments large gas turbine plants to create additional power which is completely emission free and fuel free.

The Problem

Large gas turbine power plants serving compression mission-critical loads – similar to critical loads at datacenters, must deliver:

- Continuous baseload power
- High reliability and fast response
- Maximum efficiency with minimal water consumption
- Low emissions

In many installations, a significant portion of the gas turbine exhaust energy remains unrecovered, especially where traditional steam bottoming cycles are impractical due to:

- Water scarcity or zero-water constraints
- Operational complexity and maintenance intensity
- Slow ramp rates incompatible with dynamic datacenter loads
- Space and infrastructure limitations

This leaves valuable thermal energy unused - energy that could otherwise increase available power capacity without adding new fuel-burning assets.

The Solution

Turboden implemented a **water-free combined cycle architecture**, integrating **Organic Rankine Cycle (ORC)** systems downstream of **large-frame gas turbines**. Instead of relying on water-intensive steam cycles, the solution:

- Converts that thermal energy into emission-free electricity
- Operates entirely without water, eliminating cooling towers and water treatment
- Maintains high availability with unattended, low-maintenance operation
- Recovers exhaust heat from gas turbines using ORC technology

The ORC system functions as a true baseload power augmenter, seamlessly integrated with the primary gas turbines.

The Results

The water-free combined cycle delivers outcomes directly aligned with **datacenter power requirements**:

- Incremental baseload power capacity without additional fuel consumption
- Higher overall plant efficiency and improved heat-to-power utilization
- Zero incremental emissions
- Exceptional operational reliability, with minimal operator intervention
- Fast ramping and deep turndown capability
- Reduced infrastructure footprint compared to steam bottoming cycles

This configuration effectively transforms a conventional gas turbine plant into a datacenter-ready power backbone.

CONCLUSION :

Water Free Combined Cycle Offers a Viable Power Augmentation Solution to Data Center

As the digital world accelerates and the demand for resilient, fast-delivered power grows exponentially, the datacenter sector stands at a defining crossroads. Gas-powered facilities, whether based on turbines, engines, or fuel cells, offer reliability and scalability, but without the integration of advanced energy-efficiency technologies, they risk locking in high operating costs and unnecessary emissions for years to come.

ORC-based Waste Heat to Power systems turn this challenge into an opportunity: they convert thermal losses into clean, dispatchable electricity, boosting the overall efficiency of the power island while reducing its environmental footprint.

In an industry where every megawatt matters, for uptime, operational cost reduction, and increasingly for regulatory compliance, the ability to generate additional carbon-free power from what was once merely waste heat becomes a strategic advantage. It enhances competitiveness, strengthens ESG performance, and supports a more resilient and sustainable energy architecture.

Simply put: ORC is no longer a “nice-to-have” add-on, it is the key that unlocks the full potential of fuel-driven open-cycle power solutions for next-generation datacenters. Those who embrace it early will set the benchmark for efficient, future-proof digital infrastructure, and Turboden is ready to lead the way.

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