



# Revolutionizing Data Center Cooling: Combining Supercritical CO2 Power Generation with Magnetic Refrigeration by Infinity Turbine

Infinity Turbine  
LLC

[ TEL ] 608-238-6001

[ Email ] greg@infinityturbine.com

<https://infinityturbine.com/magnetocaloric-magnetic-cooling-by-infinity-turbine.html>

Revolutionary combination of supercritical CO2 power generation and magnetic refrigeration is transforming data center cooling, enhancing efficiency, and reducing environmental impact.



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## Revolutionizing Data Center Cooling: Combining Supercritical CO2 Power Generation with Magnetic Refrigeration

In today's digital age, data centers are the backbone of global communication, cloud computing, and data processing. However, these energy-intensive facilities face a critical challenge: managing waste heat. As the demand for computing power increases, so does the amount of heat generated by servers, CPUs, and GPUs. Cooling these systems effectively is paramount to ensuring optimal performance and energy efficiency.

A new, cutting-edge solution is emerging that combines supercritical CO2 (sCO2) power generation with magnetic refrigeration, all synchronized through a magnetic gearbox. This innovative approach could radically improve the efficiency of data center cooling, reduce energy consumption, and eliminate harmful refrigerants. Let's explore how this concept works and its potential benefits for the data center industry.

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### The Cluster Mesh Power Generation Concept

At the heart of this innovative solution is the Cluster Mesh Power Generator. This system uses a modular network of supercritical CO2 turbines to generate electricity from the waste heat produced by data centers.

#### Supercritical CO2 Turbines:

- sCO2 turbines are highly efficient at capturing waste heat and converting it into mechanical energy. When CO2 is brought to its supercritical state (above 31°C and 73.8 bar), it behaves like a dense fluid, allowing for efficient energy extraction in a compact turbine system.
- The Cluster Mesh Power Generation concept allows multiple small turbines to operate together, providing a flexible and scalable solution that can adjust to the varying levels of heat generated by data centers.

By using waste heat to drive these turbines, data centers can generate additional power, reducing their overall energy footprint and improving efficiency.

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### Magnetic Refrigeration: A Game-Changer for Cooling

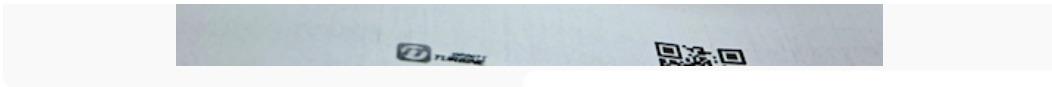
Magnetic refrigeration is an advanced cooling technology that uses the magnetocaloric effect. In simple terms, certain materials—like gadolinium—heat up when exposed to a magnetic field and cool down when the magnetic field is removed. This process can be cycled continuously to create a refrigeration effect without the need for traditional refrigerants, which are often harmful to the environment.

#### How Magnetic Refrigeration Works:

1. Gadolinium is exposed to a magnetic field, causing its magnetic dipoles to align, releasing heat in the process.
2. The heat is removed using a heat exchanger.
3. When the magnetic field is turned off, the gadolinium cools down as its dipoles return to a disordered state, absorbing heat from the surroundings.
4. This cycle is repeated to provide continuous cooling.

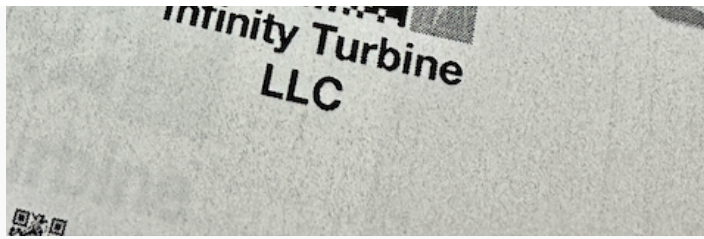
The ability of gadolinium to cool down efficiently when the magnetic field is cycled makes it an ideal candidate for data center cooling. Magnetic refrigeration offers quiet operation, high energy efficiency, and zero harmful emissions.





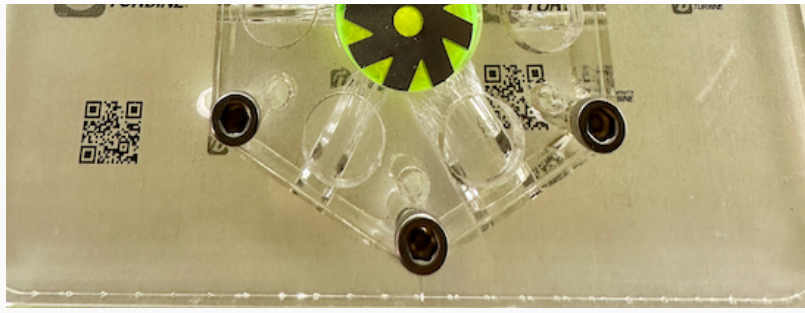
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## Evaluation of the Concept: Introducing a Magnetocaloric Heat Pump to the Condenser End of a Supercritical CO2 Turbine for Data Center Waste Heat

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### Concept Overview:

The proposed concept involves using supercritical CO2 (sCO2) turbines to convert waste heat from a data center into power, with the magnetocaloric effect integrated into the condenser side to provide high-efficiency cooling. The idea is to utilize the existing neodymium magnets (or another magnetocaloric material) for cooling at the turbine's back end to create an extreme cold environment, which would improve cycle efficiency by increasing the temperature differential (temperature spread).

### Key Components:

1. Supercritical CO2 Turbine: Converts waste heat (90-140°F) from the data center into power. sCO2 turbines typically operate best with higher temperature gradients between the heat source and the cooling side.
2. Magnetocaloric Heat Pump: This uses the magnetocaloric effect to generate cooling by cycling a magnetocaloric material (such as gadolinium) through a magnetic field. As the magnetic field is applied and removed, the material undergoes cooling and can absorb heat from the system.
3. Neodymium Magnets: If the turbine already has rotating neodymium magnets (or other magnetic materials), these could be leveraged to create or enhance the magnetocaloric cooling effect on the condenser side.

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### How the Magnetocaloric Cooling Affects the Turbine's Performance:

#### 1. Increased Temperature Spread:

- In a thermodynamic cycle, efficiency increases with a larger temperature difference between the heat source (waste heat from data centers) and the cooling sink (condenser).
- Introducing extreme cold on the backend of the turbine, through magnetocaloric cooling, would lower the condenser temperature. This increases the temperature difference between the input heat (from the data center) and the cooled CO2 after it passes through the turbine.
- With a larger temperature spread, the turbine can extract more mechanical energy from the expanding CO2, improving overall cycle efficiency.

#### Example:

- If the waste heat entering the turbine is at 60°C (140°F) and the magnetocaloric cooling reduces the condenser temperature to -20°C (-4°F), the temperature spread would be 80°C (144°F), significantly increasing the energy recovery potential compared to a typical cooling temperature of 30-50°C (86-122°F).

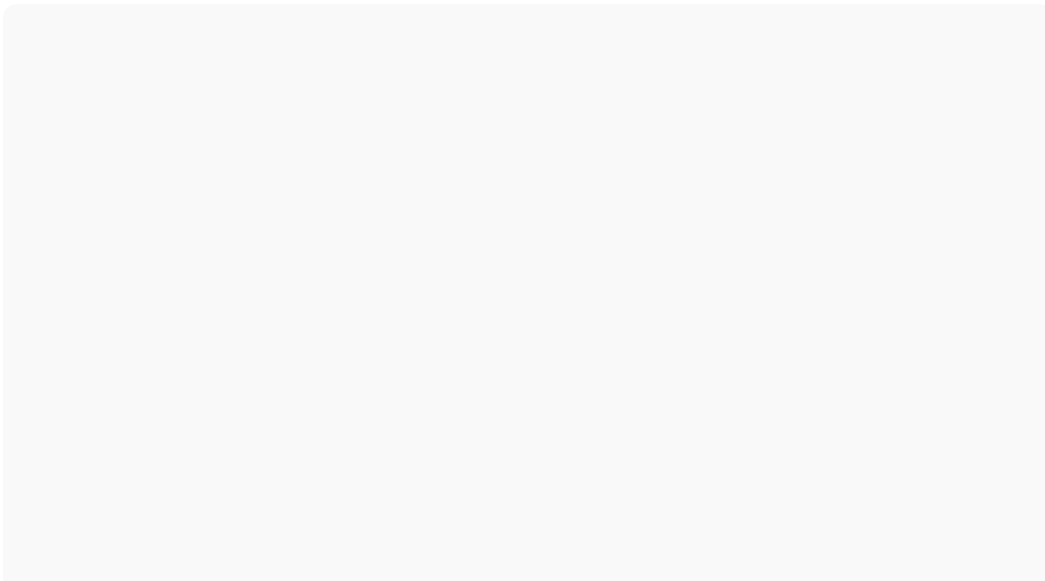
#### 2. Enhanced Efficiency and Power Output:

- By cooling the CO2 to extremely low temperatures on the condenser side, the CO2 will become denser, increasing the pressure differential across the turbine. A higher pressure drop means more energy is available for the turbine to convert into mechanical power, thus boosting the power output.
- In theory, the greater the temperature spread, the higher the thermodynamic efficiency of the cycle. For supercritical CO2, operating at a lower backend temperature can significantly increase efficiency due to its unique properties.

#### 3. Potential for Reduced Load on Traditional Cooling Systems:

- The magnetocaloric heat pump could reduce or even replace the need for traditional air or water cooling systems, which are typically less efficient and require external cooling water or chillers.
- Since the magnetocaloric effect does not rely on refrigerants or compressors, it can provide sustainable and efficient cooling.

#### 4. Energy Savings:



## Innovative Cooling Technology: Harnessing Magnetocaloric Heat Pumps Using Ferrofluid and Neodymium Magnets

As the world seeks more energy-efficient and environmentally friendly cooling solutions, magnetocaloric heat pumps are emerging as a promising alternative to traditional refrigeration systems. These systems utilize the magnetocaloric effect to achieve cooling without relying on harmful refrigerants or energy-intensive mechanical components. But what if we could take this technology a step further?

Imagine a system that suspends magnetocaloric materials in a ferrofluid, driven by alternating magnetic fields from neodymium magnets. This approach could potentially revolutionize cooling technology, especially in applications where high-efficiency and non-mechanical solutions are essential.

### What Is a Magnetocaloric Heat Pump?

A magnetocaloric heat pump works by leveraging the magnetocaloric effect. This phenomenon occurs when certain materials, such as gadolinium, undergo a temperature change in response to an applied magnetic field. When a magnetic field is introduced, the material's magnetic dipoles align, releasing heat to the surrounding environment (heating phase). When the magnetic field is removed, the material absorbs heat, resulting in a cooling effect (cooling phase).

### The Concept: Magnetocaloric Ferrofluid Heat Pump

The proposed concept takes the magnetocaloric effect one step further by introducing a novel approach: creating a ferrofluid containing gadolinium particles coated with iron. Here's how it would work:

- Gadolinium Coated with Iron:** Gadolinium is a well-known magnetocaloric material, and by coating it with iron, the particles become magnetic and more responsive to magnetic fields. This enhances the control over the particles when exposed to magnetic flux.
- Suspension in Oil (Ferrofluid):** By suspending these gadolinium-iron particles in oil, we create a ferrofluid—a liquid that can be manipulated using magnetic fields. This allows the magnetocaloric material to be circulated efficiently through the cooling system.
- Alternating Magnetic Fields:** The system would employ alternating magnetic fields generated by magnetic coils or neodymium magnets to apply and remove the magnetic field as needed. This induces the magnetocaloric effect, continuously cycling the fluid between heating and cooling phases.

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### How the Magnetocaloric Ferrofluid System Works:

- Magnetic Field On:** When the magnetic field is applied, the gadolinium particles align their magnetic dipoles, releasing heat to their surroundings. This heat can be removed using a heat exchanger or other cooling systems.

- Magnetic Field Off:** When the magnetic field is turned off, the gadolinium particles return to a disordered state, absorbing heat from their environment, which creates the cooling effect.

By repeating this process and using the fluid to carry the heat/cool phases, the system can create a continuous cooling cycle without relying on traditional mechanical compressors or refrigerants.

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### Advantages of the Magnetocaloric Ferrofluid Heat Pump:

1. **Efficient Heat Transfer:**

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## Magnetic Refrigeration: A Breakthrough in Energy-Efficient Cooling

As the demand for energy-efficient and environmentally friendly cooling technologies continues to rise, magnetic refrigeration is emerging as a revolutionary alternative to traditional refrigeration systems. Leveraging the magnetocaloric effect, this innovative method can provide cooling without relying on harmful chemical refrigerants or mechanical compressors. But how does magnetic refrigeration work, and what temperatures can it reach? Let's explore this cutting-edge technology.

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### What is Magnetic Refrigeration?

Magnetic refrigeration relies on the magnetocaloric effect (MCE), a phenomenon where certain materials heat up when exposed to a magnetic field and cool down when the magnetic field is removed. The most commonly used material in magnetic refrigeration is gadolinium (Gd), which exhibits strong magnetocaloric properties near room temperature.

In a magnetic refrigeration system:

1. A magnetic field is applied to the magnetocaloric material, causing it to heat up by aligning its magnetic dipoles.
2. The heat is removed through a heat exchanger.
3. When the magnetic field is turned off or reduced, the material cools down as its magnetic dipoles become disordered, allowing it to absorb heat from its surroundings.
4. This cycle of heating and cooling is repeated, creating a continuous cooling effect.

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### How Fast Does Magnetic Refrigeration Cycle?

The speed of the magnetic field cycling in a magnetic refrigeration system plays a crucial role in determining its efficiency and cooling power. The cycling frequency, or how often the magnetic field is applied and removed, typically ranges from 1 Hz to 10 Hz (1 to 10 cycles per second).

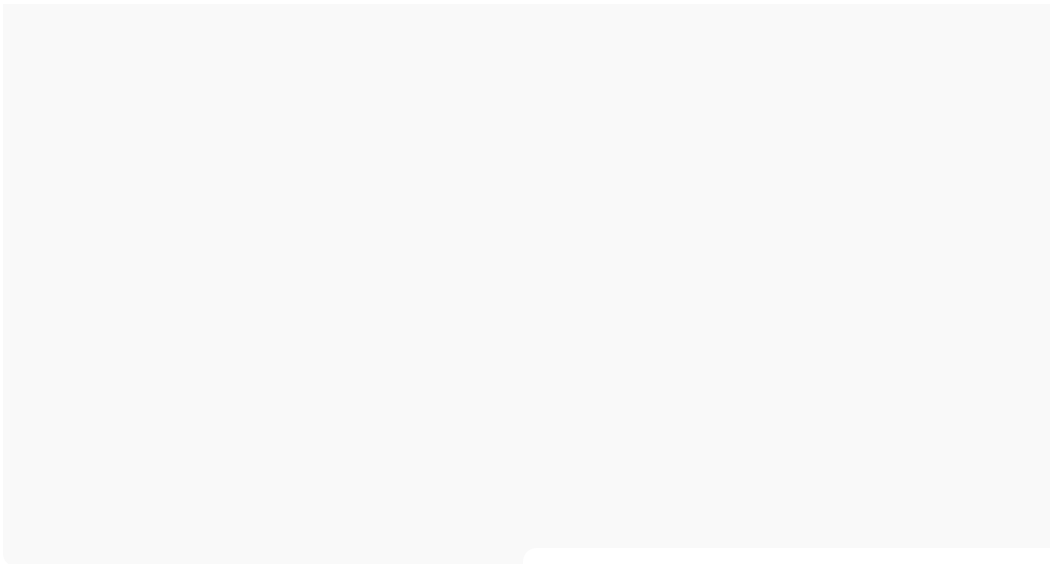
- 1-3 Hz: This range is common for smaller-scale applications such as domestic refrigerators or laboratory cooling systems. Slower cycling provides sufficient time for the heat exchangers to transfer heat efficiently.
- 5-10 Hz: In more advanced and industrial applications, the system can cycle faster, allowing for more frequent heat transfer and greater cooling power. However, cycling too quickly can result in thermal lag, where the magnetocaloric material doesn't have enough time to fully release or absorb heat before the next cycle begins.
- Thermal Lag: As cycling speed increases, thermal lag may occur, reducing the overall efficiency of the system. To maintain optimal cooling performance, the system must balance the cycle speed with the material's ability to exchange heat.

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### What Temperatures Can Magnetic Refrigeration Achieve?

The temperatures that can be reached with magnetic refrigeration depend on several factors, including the magnetocaloric material used, the strength of the magnetic field, and the design of the cooling system.





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