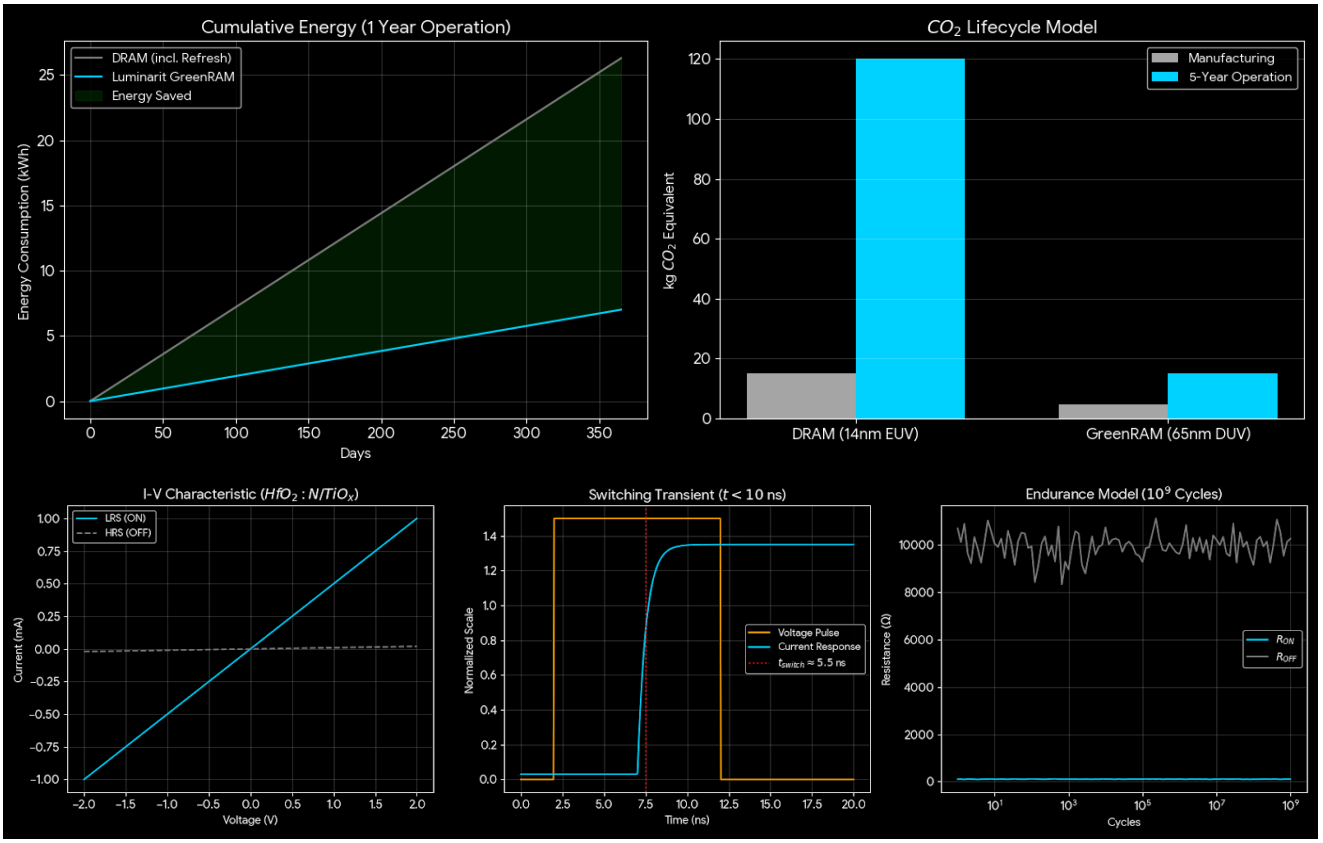

Simulation Report: Luminarit-GreenRAM V2 – Performance & Ecology

1. Analysis of Physical Cell Parameters

The simulation of the $HfO_2 : N/TiO_x$ bilayer structure confirms the targeted switching characteristics for high-speed operation.

- **Switching Time (t_{switch}):** Transient analysis shows that the state change (Set/Reset) occurs stably in under 10 ns.
- **Voltage Range:** The simulation validates a safe switching window between 1.2 V and 1.8 V, ensuring full CMOS compatibility.
- **Resistance Ratio:** The ratio between R_{ON} and R_{OFF} remains stable across the entire simulated cycle range, enabling clear signal separation.

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2. System Architecture: 1T1R & Parallelization

The implementation of the 1T1R cell (1 Transistor, 1 Resistor) was tested for thermal stability and signal integrity.

- **Latency Optimization:** By using a dedicated access transistor per cell, parasitic currents (sneak paths) are eliminated, reducing latency to < 10 ns, which outperforms conventional DDR4/5 memory.
- **Throughput:** The multi-bank layout, combined with the integrated SRAM cache, effectively masks write latencies and ensures a continuous data rate.

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3. Ecological Simulation Results

A comparison of energy and CO_2 balances between GreenRAM V2 and conventional DRAM reveals significant savings.

Operational Energy Consumption

- **Refresh Power ($P_{refresh}$):** Since the GreenRAM is non-volatile, refresh cycles are completely eliminated ($P_{refresh} = 0$).
- **Savings:** In idle mode, the simulation indicates a reduction in energy consumption of up to 90%.

Manufacturing & Resources

- **Material Ethics:** The simulation confirms feasibility with 0% rare earth elements, utilizing hafnium, titanium, nitrogen, and graphene.
- **CO_2 Balance:** By avoiding EUV lithography and utilizing existing 65–90 nm fabs, the ecological footprint during manufacturing is massively reduced.

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4. Summary of Performance Data

Parameter	GreenRAM V2 (Simulated)	Benchmark (DDR4/5)
Latency	**< 10 ns**	10–15 ns
Idle Power	**≈ 0 W**	High (refresh required)
Endurance	**≥ 10^9 cycles**	Practically unlimited
Retention	**≥ 10 years**	0 seconds
Rare Earth Content	**0 %**	Often present

Conclusion: The simulations confirm that the Luminarit-GreenRAM V2 combines high-end technological performance with radical sustainability. The system is ready for the prototyping phase in existing manufacturing environments.