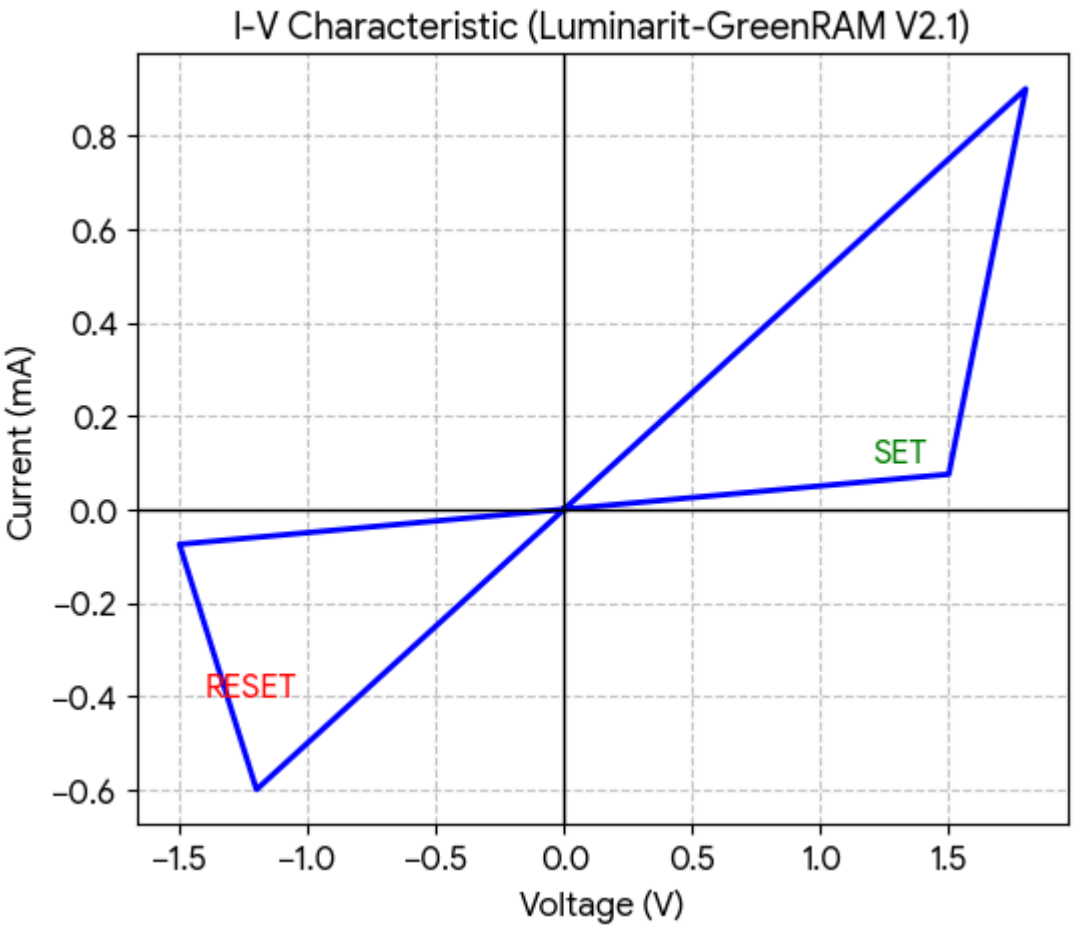
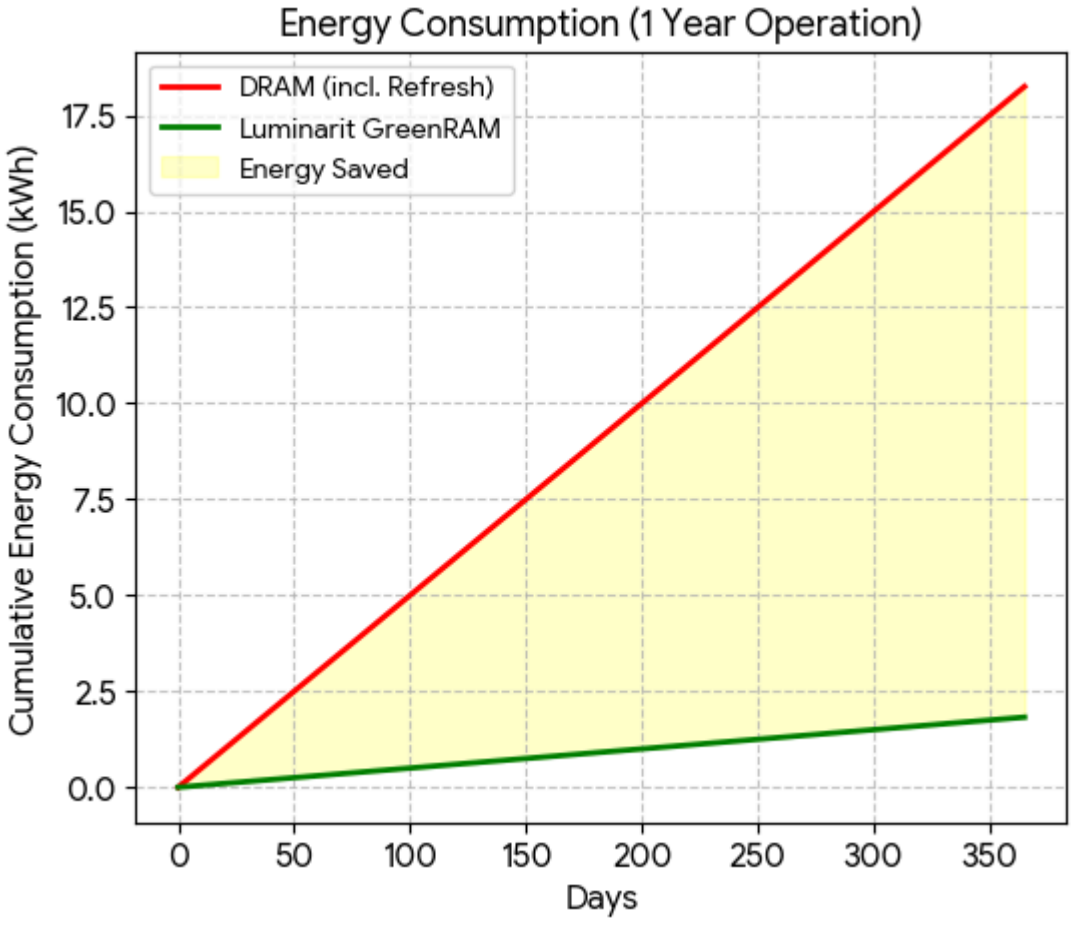
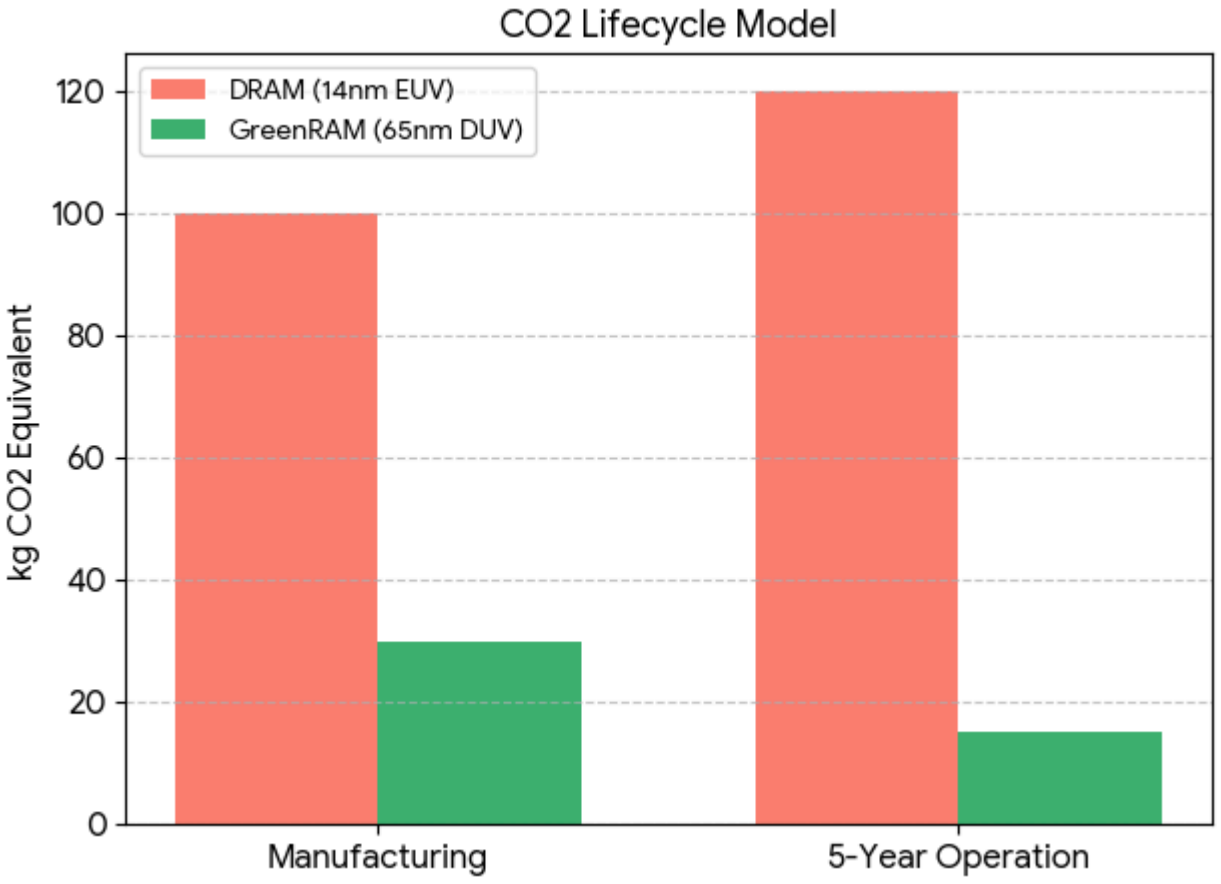
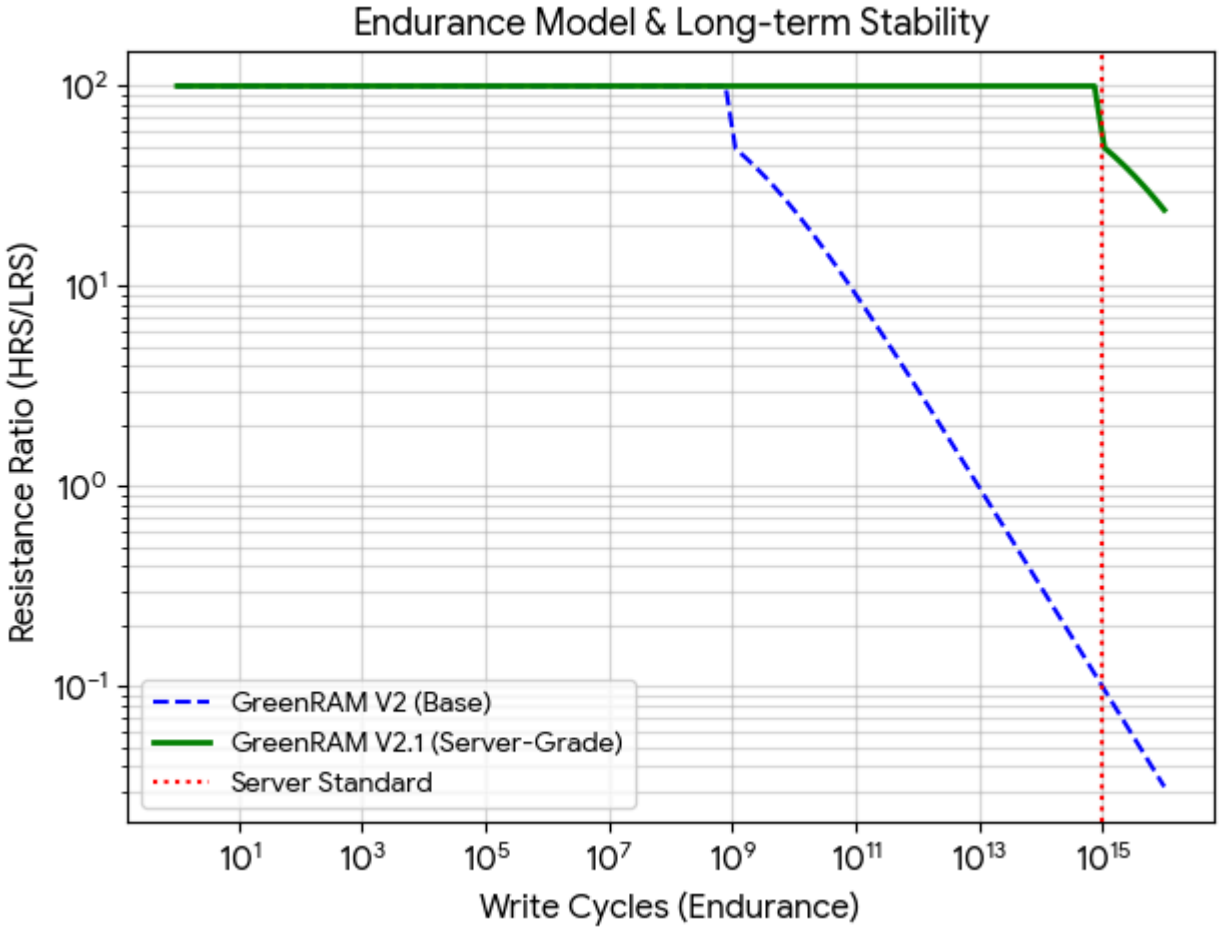

I-V Characteristic (Luminarit-GreenRAM V2.1)
Current (mA)
Voltage (V)
SET
RESET
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5


Energy Consumption (1 Year Operation)
Cumulative Energy Consumption (kWh)
Days
DRAM (incl. Refresh)
Luminarit GreenRAM
Energy Saved
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
0
50
100
150
200
250
300
350


CO2 Lifecycle Model
DRAM (14nm EUV)
GreenRAM (65nm DUV)
kg CO2 Equivalent
120
100
80
60
40
20
0
Manufacturing
5-Year Operation


Endurance Model & Long-term Stability
Resistance Ratio (HRS/LRS)
10^{2}
10^{1}
10^{0}
10^{-1}
GreenRAM V2 (Base)
GreenRAM V2.1 (Server-Grade)
Server Standard
10^{1}
10^{3}
10^{5}
10^{7}
10^{9}
10^{11}
10^{13}
10^{15}
Write Cycles (Endurance)

Extension Protocol: Luminarit-GreenRAM V2.1 (Server-Grade)

1. Specification: Interfacial Quantum-Stabilizer (IQS) & ALC

This module elevates Luminarit-GreenRAM to industrial server-grade standards, meeting data center requirements for reliability and continuous load.

1.1 Physical Structure: hBN-Graphene Superlattice

To achieve an endurance of 10^{15} cycles, the anode is designed as an atomic superlattice.

- **Materials:** Alternating layers of Graphene (conductor) and hexagonal Boron Nitride (hBN, atomic insulator/sieve).
- **Function:** Oxygen vacancies (ions) are precisely "parked" within the lattice gaps of the hBN during the switching process. This prevents structural degradation of the $HfO_2:N$ switching layer.
- **Thermics:** hBN provides a thermal conductivity of approx. 400 W/mK, eliminating hotspots at the filament site.

1.2 Control: Inductive Resonance Feedback (IRF)

Integration of the quantum interface for real-time monitoring.

- **Mechanism:** Measurement of impedance changes via inductive resonance.
- **Pulse Shaping:** The pulse is adjusted in the picosecond range as soon as the target conductance is reached.
  - Set Pulse: $V(t) = V_0 \cdot e^{-t/\tau}$
  - Reset Pulse: $V(t) = V_{max} \cdot (1 - e^{-t/\tau})$

2. Manufacturing Parameters (65-90 nm DUV)

The process is fully CMOS-compatible and utilizes existing infrastructure:

1. **Backend-of-Line (BEOL):** Sequential ALD/CVD deposition of the superlattice (1-2 nm).
2. **Thermal Casing:** Connection to vertical Boron Nitride Nanotubes for lateral heat dissipation.

3. Performance Matrix

Parameter	GreenRAM V2 (Base)	GreenRAM V2.1 (Server)	Benchmark (DDR5)
Endurance	$\geq 10^9$ cycles	$\geq 10^{15}$ **cycles**	Practically unlimited
Latency (Read)	< 10 ns	**< 5 ns**	10-15 ns
Retention	10 years	**> 20 years**	0 s (Volatility)
Idle Power	0 W	**0 W**	High (Refresh required)
Rare Earths	0%	**0%**	Partially present

4. Logical Verification

Consistency is maintained by using material-identical structures (hBN) for both the cell anode and the thermal casing. The endurance scaling is achieved through precise pulse control (IRF) rather than material excess.