Digital Energy Grid Hackathon

1. Team Information

- Team Name: **ThermoTrace**
- Team Members (2–4):
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2. Problem Focus

☑ **Problem 2:** Compute–Energy Convergence in a DEG World

3. Solution Overview

We used the idea of three reinforcement learning agents with roles:

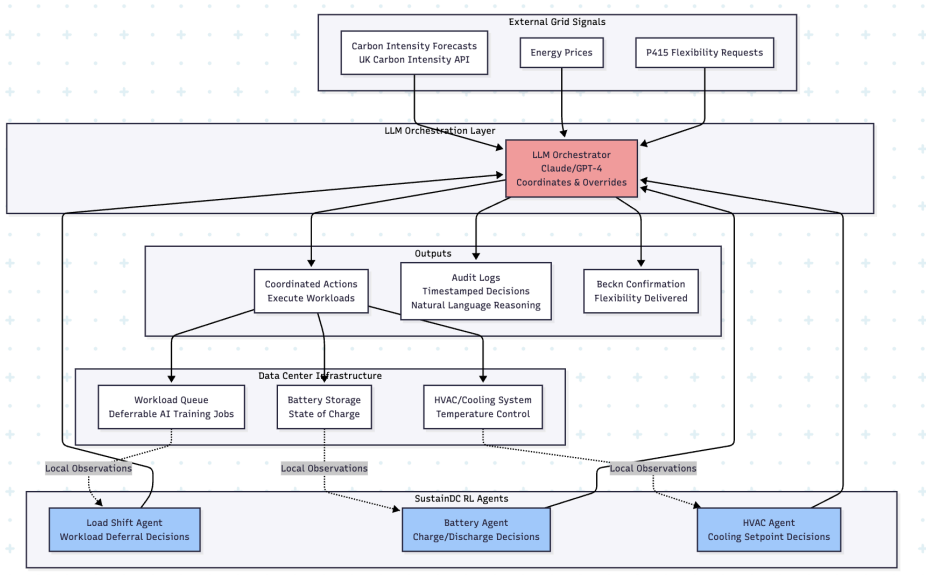
1. Shifting workloads around.
2. Control of the battery for storage.
3. HVAC for cooling.

These agents make choices on their own without working together. We introduce LLM orchestrator that sits on top of these three agents. It reads signals from the grid through Beckn.

The grid sends requests for flexibility and forecasts of carbon intensity. The data center answers by saying which compute workloads it can be shifted. The LLM makes sure that all agents respond in a coordinated way when carbon intensity is high and the grid needs to be flexible.

Key advantages: The LLM can explain every choice in plain language for regulatory audits. It lets P415 take part in the flexible market. It makes sure that isolated agents don't miss out. We believe this will improve the results even better than if optimization were done without coordination.

4. Technical Architecture



SustainDC's Foundation
HP Labs made a multi-agent reinforcement learning space to help data centers work better. Three specialized agents trained for different goals. The Load Shift Agent cuts down on the costs of delays in work. Battery Agent makes the most of storage space. HVAC Agent finds a balance between cooling energy and temperature limits.

The gap in coordination: Each agent makes its own decisions based on what it sees in its own area. They can't understand what grid operators want or what the market is saying.

The Beckn Grid Interface
We add a layer that uses the Beckn Protocol to connect to the outside grid. The data center gets grid signals like carbon intensity forecasts, energy prices, and P415 flexibility requests. It publishes back through Beckn catalog endpoints that show available deferrable compute capacity with windows of flexibility.

LLM Orchestrator
The LLM can read grid signals that individual RL agents can't. It gets suggestions for actions from all three SustainDC agents. Then it decides on coordinated actions that might go against what each agent wants. The goal of optimization is to lower the cost of each inference while keeping carbon intensity levels low. Every choice has natural language reasoning.

5. Agent Workflow

1. **Grid Signal:** uses Beckn endpoints to share its list of deferrable compute. Grid operators use Beckn's discovery and status protocols to send requests for P415 flexibility, carbon intensity forecasts, and energy prices.
2. **Agent Decision-Making:** 3 RL agents makes its own decisions:
    a. **The Load Shift Agent** chooses which tasks to put off or do.
    b. **The Battery Agent** decides when to charge and when to discharge.
    c. **The HVAC Agent** chooses how cool it should be.
3. **LLM Coordination Layer:** The LLM orchestrator gets decisions from both the agents and signals from the outside grid that the agents can't see. It finds conflicts or missed chances, like when Load Shift wants to run workloads during times of high carbon intensity or when P415 flexibility payments are higher than deferral costs. The LLM coordinates by changing what agents do to match grid signals that is explainable with natural language reasoning for checking the P415 settlement.

6. Business Model & Impact

ThermoTrace deploys the optimization system on multiple data centers as a managed service. They handle Beckn Protocol integration. Data centers share flexibility revenues with ESCOs while maintaining SLAs.

Revenue sources:
1. P415 payments (£3,000/MWh during grid stress).
2. Energy bill savings of 15-35% by running compute during low-price periods.
3. A large data center paying £36M annually saves £5-12M. Carbon credit monetization from verified emissions cuts (IPMVP standard).

CO2 impact: Shifting 30% of workload from high-carbon (270 gCO2/kWh) to low-carbon windows (28 gCO2/kWh) cuts 21,780 tonnes CO2 annually per data center. Equivalent to removing 4,700 cars.

Grid benefits: UK's 10-12 GW flexibility target by 2030 avoids £5-6 billion in peaker plant infrastructure.

Transparency: LLM audit trails enable P415 settlement verification. ESCOs earn performance-based fees.

Beckn standardization enables multi-region coordination. More participants improve grid forecasting and flexibility payments.

7. References / Inspiration

Foundation & Implementation:

1. **SustainDC: A Multi-Agent Reinforcement Learning Benchmark for Sustainable Data Centers**
   HP Labs, 2023
   GitHub: https://github.com/HewlettPackard/dc-rl
   Our project forks this codebase and adds the LLM orchestration layer on top of their three-agent system.
2. **UK National Grid Carbon Intensity API**
   https://carbonintensity.org.uk
   Real-time and forecast carbon intensity data for coordination decisions.
3. **Beckn Protocol**
   https://becknprotocol.io
   Open protocol for grid-data center coordination workflows.

Regulatory & Market Context:

4. **Ofgem P415: Virtual Load Profile for Demand Response**
   https://www.ofgem.gov.uk/publications/direction-modify-balancing-and-settlement-code-p415-virtual-lead-parties
   UK flexibility market settlement mechanism that enables data centers to participate as demand response providers.

8. Declarations

Our Contribution: The MIT License covers all of the original work we did for this hackathon submission, such as the LLM orchestrator, the Beckn Protocol integration layer, and the audit logging system.

Foundation Work: This project is based on SustainDC (HewlettPackard/dc-rl), an open-source benchmark for multi-agent reinforcement learning for data center optimization. It is also released under the MIT License. We give credit to HP Labs for their important work. Our part is to add the coordination layer on top of their three-agent system.

Third-Party Components: We make use of these open-source tools:

1. The SustainDC benchmark suite is from HP Labs and is licensed under the MIT License.
2. Beckn Protocol specifications (an open standard)
3. UK Carbon Intensity API (a public data source)

Our repository README lists all of the dependencies and attributions.