Digital Energy Grid Hackathon Submission

1. Team Information

Team Name: Hawkins Academy
Institution / Organization: Imperial College London

Team Members:
Julia Metz: MSc Student
Matheu Boucher: MSc Student

Contact Emails:
julia.metz24@imperial.ac.uk
matheu.boucher@imperial.ac.uk

Discord Usernames:
julia_metz
matheuboucher

2. Problem Focus

Problem 2: Compute–Energy Convergence in a DEG World

3. Solution Overview

Our solution treats data centers and AI workloads as flexible energy assets that can participate in energy markets while maintaining service quality. The core innovation is a multi-agent system where compute facilities post their flexibility capacity as offers on a Beckn protocol marketplace and grid operators or energy providers post their needs. A master orchestrator agent matches these offers and needs using an interpretable cost function that balances electricity costs, carbon intensity, and flexibility market revenue. Each agent can accept or reject proposals based on their own constraints like service level agreements, thermal limits, or safety requirements. This creates a transparent marketplace where compute workloads shift to times when electricity is cheaper and cleaner, data centers earn revenue from providing flexibility, and grids get the demand response they need to integrate renewables and prevent overloads.

4. Technical Architecture

Our system uses four types of agents working together through Beckn protocol workflows. Compute agents represent individual data centers or server clusters and publish catalog items describing their flexible capacity, including how much load they can shift, when they can shift it, and what constraints they have around temperature limits and service level agreements. Grid agents represent distribution system operators and post their needs for load flexibility when they forecast congestion or need to balance renewable generation. A carbon tracking agent continuously monitors the grid's carbon intensity by source, tracking whether electricity is coming from nuclear, wind, solar, gas, or coal, and provides this data to the cost function and for detailed carbon accounting. The master orchestrator agent sits in the middle as the marketplace coordinator, collecting all the offers from compute agents and all the needs from grid agents, then running an optimization that considers multiple objectives.

The cost function used by the master orchestrator is interpretable and can be customized by region or provider. It weighs factors like electricity price per megawatt hour, real-time carbon intensity, revenue from flexibility markets under P415, and operational constraints. The carbon-aware scheduling component prioritizes workloads during low-carbon-intensity periods and rewards compute agents for choosing cleaner time windows. When the master orchestrator proposes a match between a compute agent's offer and a grid agent's need, both agents independently evaluate whether they can accept it. The compute agent checks if deferring the workload would violate service agreements or cause thermal issues, while the grid agent verifies it meets their local regulations and safety requirements. They can reject and the orchestrator will find alternative matches.

Data flows through the system from multiple sources. Grid agents receive real-time frequency and voltage data, demand forecasts, and congestion predictions. The carbon tracking agent pulls from carbon intensity APIs and generation mix data to determine marginal emissions. Compute agents monitor their job queues, classifying workloads into tiers based on how much deferral flexibility they have, from critical inference requests with millisecond requirements to training jobs that can shift by hours or days. The master orchestrator logs every decision with timestamps, data sources used, which cost function was applied, agent responses, and settlement outcomes, creating a full audit trail for regulatory review under P444.

All agent interactions happen through Beckn protocol workflows. Compute agents use Beckn to publish catalogs of available flexibility, grid agents use Beckn search to discover these catalogs when they need demand response, the master orchestrator manages the select and order lifecycle, and confirmed orders trigger actual workload shifting with fulfill and complete messages for settlement.

5. Agent Workflow

The workflow begins with compute agents continuously publishing their flexibility capacity as Beckn catalog items, describing what compute resources they have available, what time windows they can offer flexibility in, and their pricing. Grid agents monitor the grid state and when they forecast an upcoming event like congestion at a substation or a large spike in renewable generation that needs balancing, they issue a Beckn search request describing their need for load reduction or increase with specific timing and location requirements. The master orchestrator receives these search requests and matches them against the published compute agent catalogs, running its cost function optimization to find the best combinations that minimize cost and carbon while maximizing flexibility revenue.

The orchestrator proposes matches by sending select and init messages through Beckn protocol to the relevant compute and grid agents. Each agent independently evaluates the proposal against their constraints. A compute agent might reject if the timing conflicts with a high-priority training job or if their cooling systems are already at capacity. A grid agent might reject if the offered flexibility doesn't align with their specific feeder requirements. If both accept, the Beckn confirm message triggers the actual workload adjustment. The compute agent begins deferring jobs, shifting batch processing to later time windows, or queuing inference requests with acceptable latency buffers.

Throughout execution, the carbon tracking agent provides real-time updates on emissions impact, calculating exactly how much carbon was avoided by shifting the workload to a cleaner time period and which generation sources were displaced. All of this feeds into a Streamlit dashboard that visualizes the marketplace in real-time, showing which agents are posting offers, which needs are being filled, energy flows between compute and grid, cost savings accumulating, and carbon reductions achieved. When the flexibility period completes, the grid agent sends Beckn update and complete messages, triggering financial settlement and the master orchestrator logs the full transaction for audit and P444 compliance.

6. Business Model & Impact

The business model creates value for all stakeholders through a marketplace approach. Data centers monetize something they already have, which is scheduling flexibility in their workload execution, turning it into a revenue stream by participating in flexibility markets under P415 while simultaneously reducing their electricity costs by shifting load to cheaper time periods. AI and compute companies reduce their cost per inference and cost per training run by allowing their workloads to be scheduled during optimal grid conditions, and they gain precise carbon accounting data that helps them meet sustainability reporting requirements and demonstrate their environmental commitments to customers and regulators.

Grid operators gain access to large flexible loads that can respond quickly to balance renewable generation and prevent grid congestion, avoiding the need to activate expensive peaker plants or implement emergency load shedding. This is particularly valuable as renewable penetration increases because compute loads can absorb excess solar during midday or shift away from evening peaks when solar drops off. Energy providers and flexibility aggregators can use the platform to coordinate distributed compute resources as a Virtual Lead Party under P415, aggregating many smaller data centers into a portfolio that provides reliable grid services.

The carbon tracking agent creates additional value by providing granular, source-specific carbon accounting. Instead of using average grid carbon factors, AI companies get precise data on what generation sources powered their specific workloads, whether it was nuclear, offshore wind, or gas peakers. This level of detail supports scope two emissions reporting and allows companies to make credible carbon-neutral compute claims. The data can also feed into emerging carbon pricing mechanisms and voluntary carbon markets.

Scalability comes from the modular agent design. The system can start with a single data center participating in local flexibility markets and expand to coordinate multiple facilities across regions. The interpretable cost function can be customized for different regulatory environments, with different regions prioritizing cost versus carbon versus reliability differently. The Beckn protocol foundation means other types of flexible assets like battery storage, electric vehicle fleets, or industrial loads could be integrated into the same marketplace using the same workflows.

The dashboard enables both autonomous operation and human oversight. Under normal conditions the agents handle everything automatically, making thousands of micro-decisions about workload scheduling and market participation. But operators can monitor the marketplace activity in real-time and take manual control during emergencies or unusual grid events, overriding agent decisions if needed. This human-in-the-loop design builds trust and meets regulatory requirements around maintaining operational control of critical infrastructure.

7. References / Inspiration

Carbon-aware computing research from major tech companies shifting workloads to follow renewable generation. P415 Virtual Lead Party frameworks for aggregating distributed energy resources. Recent carbon pricing methodologies from environmental economics research. National Grid carbon intensity APIs that provide real-time generation mix data. Beckn protocol specifications for decentralized marketplaces applied to energy sector use cases.

8. Declarations

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Deadline: 23/11/25 18:00 GMT