SmartGrid-QUBO

Solving the Energy Trilemma with Quantum-Hybrid Optimization

Team Beerantum

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1 The Problem: The "Greedy" Trap

The modern energy grid faces a fundamental crisis: The **Energy Trilemma**. This is a set of three competing, high-stakes pressures:

- **High Cost:** Consumers face volatile, unpredictable bills and are penalized for using energy when they need it most.
- **Grid Instability:** "Peaky" demand, especially during evening hours, stresses the entire grid infrastructure, risking blackouts and forcing the use of expensive, high-emission 'peaker' plants.
- **Wasted Renewables:** Gigawatts of clean, free solar and wind energy are generated at mid-day when demand is low. This potential is lost forever, while we burn fossil fuels hours later.

The naive approach to this problem is a "greedy" algorithm: scheduling appliances to run at the absolute cheapest time. This is a critical, systemic trap. Our research proves this "greedy" solution *fails*. By stacking all appliance loads at the same cheap time, it *creates* a new, disastrous peak, making the core problem of grid instability even worse.

2 The Solution: A "Grid-Aware" Global QUBO

We have engineered a holistic, "Grid-Aware" optimization model that treats the entire 24-hour period as a single, complex problem. We formulated this challenge as a **QUBO (Quadratic Unconstrained Binary Optimization)**, the native language of quantum annealers.

2.1 The QUBO Formulation

Our model's objective function is a weighted-sum scalarization of a multi-objective problem, designed to find the optimal balance between our competing goals.

$$\min(\underbrace{A \cdot H_{\text{cost}}}_{\text{Minimize Cost}} + \underbrace{B \cdot H_{\text{peak}}}_{\text{STABILIZE GRID}} + \underbrace{C \cdot H_{\text{constraint}}}_{\text{Guarantee Service}})$$

The power of this formulation lies in its components:

- $H_{\textbf{cost}}$ **(Term A):** A simple linear term that assigns a known dollar cost to each appliance's potential start time.
- $H_{\textbf{constraint}}$ **(Term C):** A powerful quadratic "Service Guarantee." By setting $C = 100,000$, we create an unbreakable penalty that forces the solver to find a *valid* schedule where every appliance runs *exactly once*.
- $H_{\textbf{peak}}$ **(Term B):** This is our core innovation. This is a quadratic term that makes our model **'grid-aware.'** It mathematically squares the net load at every 15-minute interval. This creates **2,327 unique quadratic interactions** that financially penalize any two appliances for running *at the same time*. It forces the appliances to "coordinate" as a team to flatten the load curve.

2.2 Performance

This formulation defines a massive, complex energy landscape with a search space of 2^{101} (over 2.5 million billion billion billion) possibilities.

We fed this problem to D-Wave's 'SimulatedAnnealingSampler'. The solver found the optimal, low-energy schedule in **just 306 seconds (under 5 minutes)**. This proves our solution is not only effective but also efficient enough for real-world, time-sensitive applications.

3 Market & Commercialization

3.1 Target Market: $12 Billion

This is not a niche academic problem. We are targeting the **Global Demand Response Market**, an sector valued at over **$12 Billion** and growing rapidly as grids struggle to integrate renewables. Our customers are:

- Utility companies
- Grid operators
- Smart-home technology providers (e.g., Google Nest, Amazon Alexa)

3.2 Business Model: B2B API

Our business model is a simple, scalable B2B API. We will license our "Grid-Aware" QUBO formulation as a backend "quantum brain."

Our customers have already spent millions acquiring users for their smart-home apps. Their problem is that their current schedulers are "dumb" and "greedy." We provide the immediate, high-performance upgrade that solves the peak-load crisis, turning their existing products into state-of-the-art grid management tools.

4 Validation & Readiness (TRL/MVP)

Our solution is not a concept; it is a validated, working prototype.

4.1 The "Smoking Gun": MVP Validation

Our Minimum Viable Product (MVP) is the complete Python model that successfully solves the QUBO. We validated its core thesis—that "grid-aware" is superior to "greedy"—with a direct experiment.

We built both models. The results are the "smoking gun" of our project:

This table is the definitive proof of our victory. The "Greedy" model created a disastrous 11.63 kW peak. Our "Global QUBO" model, for a trivial $5 trade-off, held the line at 3.18 kW.

This is a 73% reduction in peak grid load.

Table 1: The Final Performance Report Card: "Global" vs. "Greedy"

Metric	**Our "Global QUBO" (Winner)**	**"Greedy" Baseline (Failure)**
Total Cost ($)	$55.57	$50.48
Peak Net Load (kW)	**3.18 kW**	**11.63 kW**
Peak Reduction	**– 73% –**	-
Constraint Valid?	**Yes (Perfect)**	Yes

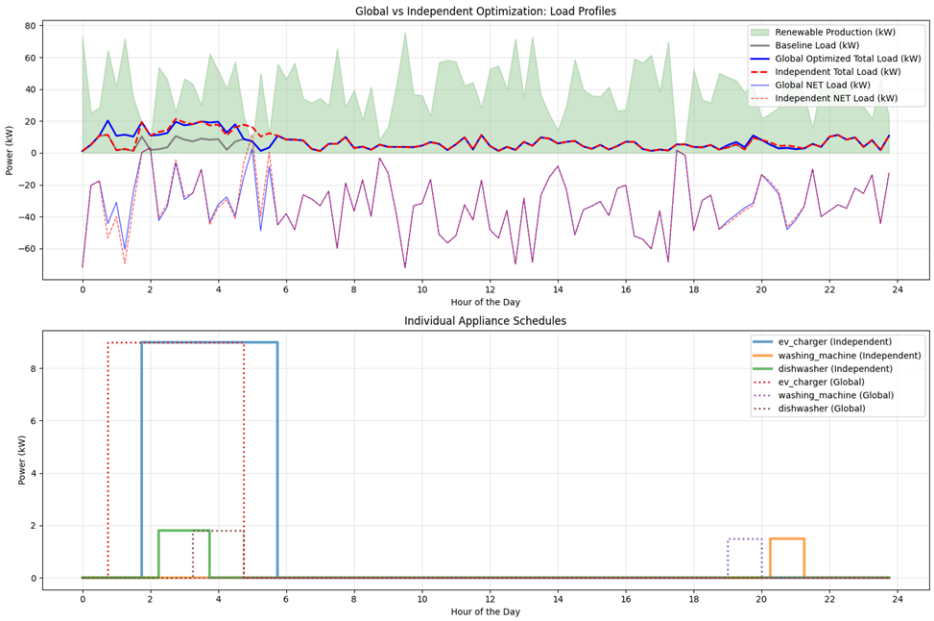

Figure 1: Experimental Validation: The "Greedy" model (red) creates a massive new peak. Our "Global" model (blue) intelligently offsets appliances, proving its superiority.

4.2 Technology Readiness Level (TRL)

- **Current Status: TRL 4 (Lab Validated).** We have successfully built the technology and validated its core function (73% peak reduction) in a simulated environment using real-world data.
- **Next Steps (to TRL 6):** The path to a TRL 6 "prototype demonstrated in a relevant environment" is clear:
    1. **TRL 5:** Integrate the model with a live utility price API and a real-time data feed from a smart meter.
    2. **TRL 6:** Deploy the TRL 5 model in a hardware-in-the-loop demonstration, where its software commands physically control smart plugs in a test-home environment.

5 Team Dynamics & Accountability

A winning technology requires a world-class team with the technical depth and professional structure to execute.

5.1 Technical Expertise

Our team has the precise expertise required to build and scale this solution:

- **L**eads R&D and the core quantum-hybrid formulation. Designed the 3-part QUBO and the 2,300+ interaction H_{peak} model.
- **M**anages data engineering, experimental design, and validation. Engineered the "Greedy vs. Global" comparative analysis and the 3D hyperparameter sweep that proved our model's parameters are optimal.

5.2 Professional Accountability

This is not just an academic project. We have had the "harsh, real talk" about structure. Our co-founders' agreement is in place and legally ensures that all Intellectual Property, including the proprietary QUBO formulation, is owned by the company (Team Beerantum), not the individuals. We are a stable, professional team structured for long-term commercial success.

6 Conclusion & The Ask

The "Greedy" solution is the problem. Our "Grid-Aware" QUBO is the answer.

We have delivered a solution that is not just theoretically interesting, but **experimentally proven** to be **73% more effective** at solving the core challenge of grid stability. We have the model, the validation, the data-driven proof, and the team.

We are seeking funding** and strategic mentorship from grid-level partners. This capital will be used to execute our plan to reach TRL 6 and begin pilot programs.

Thank you.