

The Energy Trilemma

Demand Response faces three competing pressures that simple algorithms cannot solve:

For Consumers

Expensive, unpredictable bills.
Penalized for using energy
during peak times like cooking
dinner or charging cars after
work.

For The Grid

The 6 PM demand spike
stresses the system, risking
blackouts and forcing utilities
to use expensive, high-
emission 'peaker' plants.

For The Planet

Gigawatts of clean solar and wind energy generated at 2 PM are lost
forever, while we burn fossil fuels hours later.



SmartGrid: Solving the Energy Trilemma with Quantum Optimization

Team Beerantum | Quantum Boost



Beerantum

The Battlefield: Digitizing the Problem

We created a high-resolution digital twin of a home's 24-hour energy environment using 96 time steps (every 15 minutes):

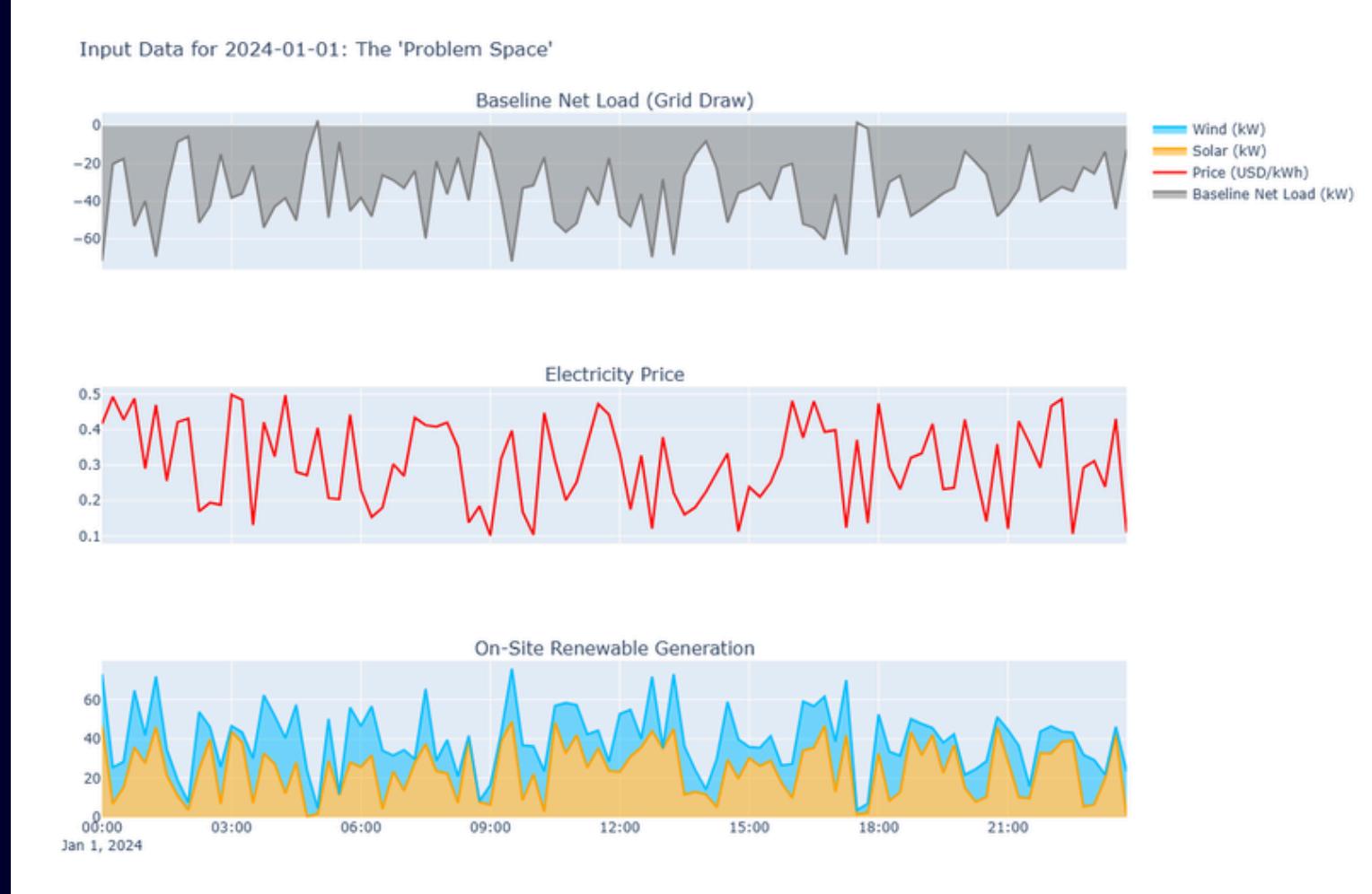
- **Baseline Load (B_t):** Non-negotiable power consumption
- **Energy Price (C_t):** Volatile 15-minute utility costs
- **Renewable Generation (R_t):** Free on-site solar and wind energy

Three controllable appliances with unique constraints create a massive search space of **2101 possibilities.**

EV Charger
1
4-hour block,
overnight only

Washing Machine
2
1-hour block,
daytime only

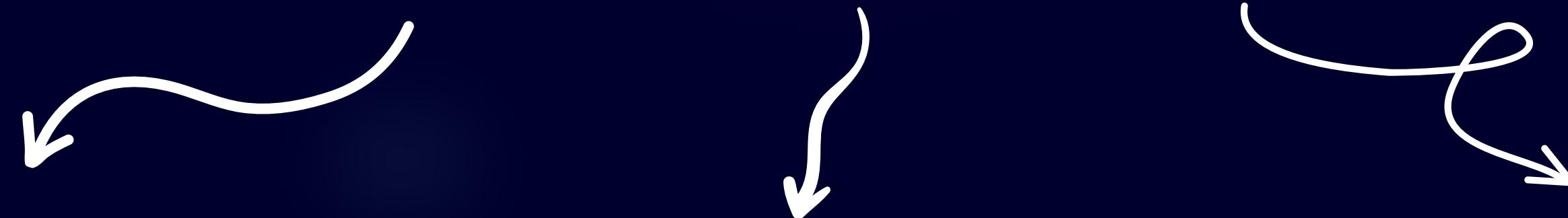
Dishwasher
3
1.5-hour block,
evening/early
morning



Objective function of the problem

Our goal: build a single cost function representing a vast energy landscape where the lowest valley is the optimal schedule.

$$\min E(x) = A * H_{cost} + B * H_{peak} + C * H_{constraint}$$



$$H_{cost} = \sum_{i,t} C_{i,t} \cdot x_{i,t}$$

$$H_{peak} = \sum_t (B_t - L_{deferable,t} - R_t)^2$$

$$H_{constraint} = \sum_i \left(\sum_t x_{i,t} - 1 \right)^2$$

Building the Digital Brain: QUBO Translation

Our goal: build a single cost function representing a vast energy landscape where the lowest valley is the optimal schedule.

$$\min E(x) = A * H_{cost} + B * H_{peak} + C * H_{constraint} \longrightarrow \min E(x) = \sum_i Q_{ii}x_i + \sum_{i < j} x_i x_j$$

01

Digitize Choices

Translate 101 possible start times into binary 'on/off' switches ($x_i \in \{0, 1\}$)

02

Set The Dials

Balance objectives with hyperparameters: A (Cost) = 0.5, B (Peak) = 3.0, C (Constraint) = 100,000

03

Build Cost Landscape

Create QUBO matrix Q with three layers: cost terms, constraint penalties, and 2,327 grid-aware interactions

The Solve: Finding the Answer

We unleashed the D-Wave SimulatedAnnealingSampler to explore the 2,327-interaction QUBO landscape.

306.5

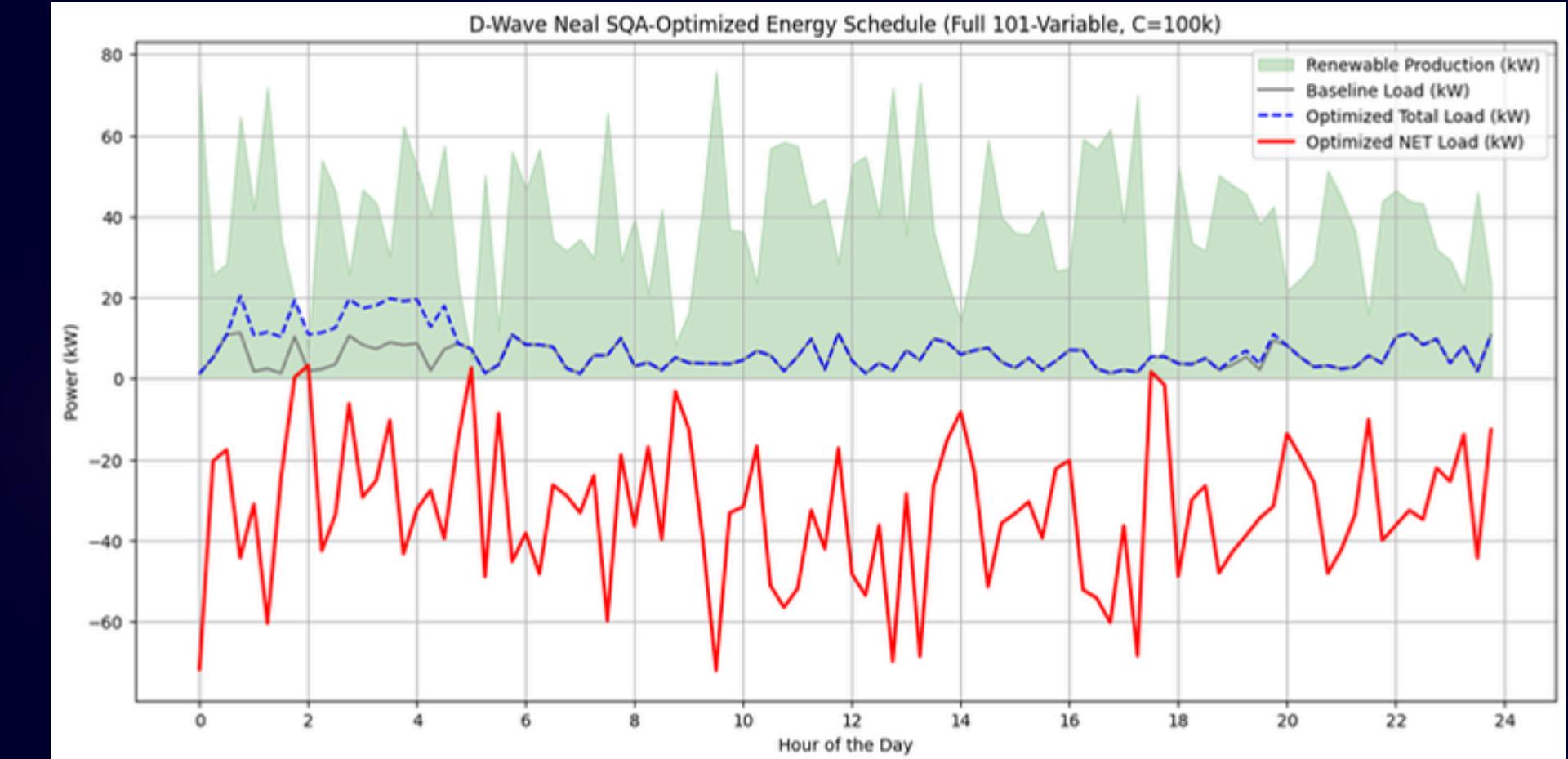
Seconds

To solve the entire 24-hour, 101-variable problem

\$55.57

Final Cost

Rock-bottom price with Grid-First priority



Optimal Schedule

- **EV Charger:** Start at 00:45 AM
- **Washing Machine:** Start at 7:00 PM
- **Dishwasher:** Start at 03:15 AM

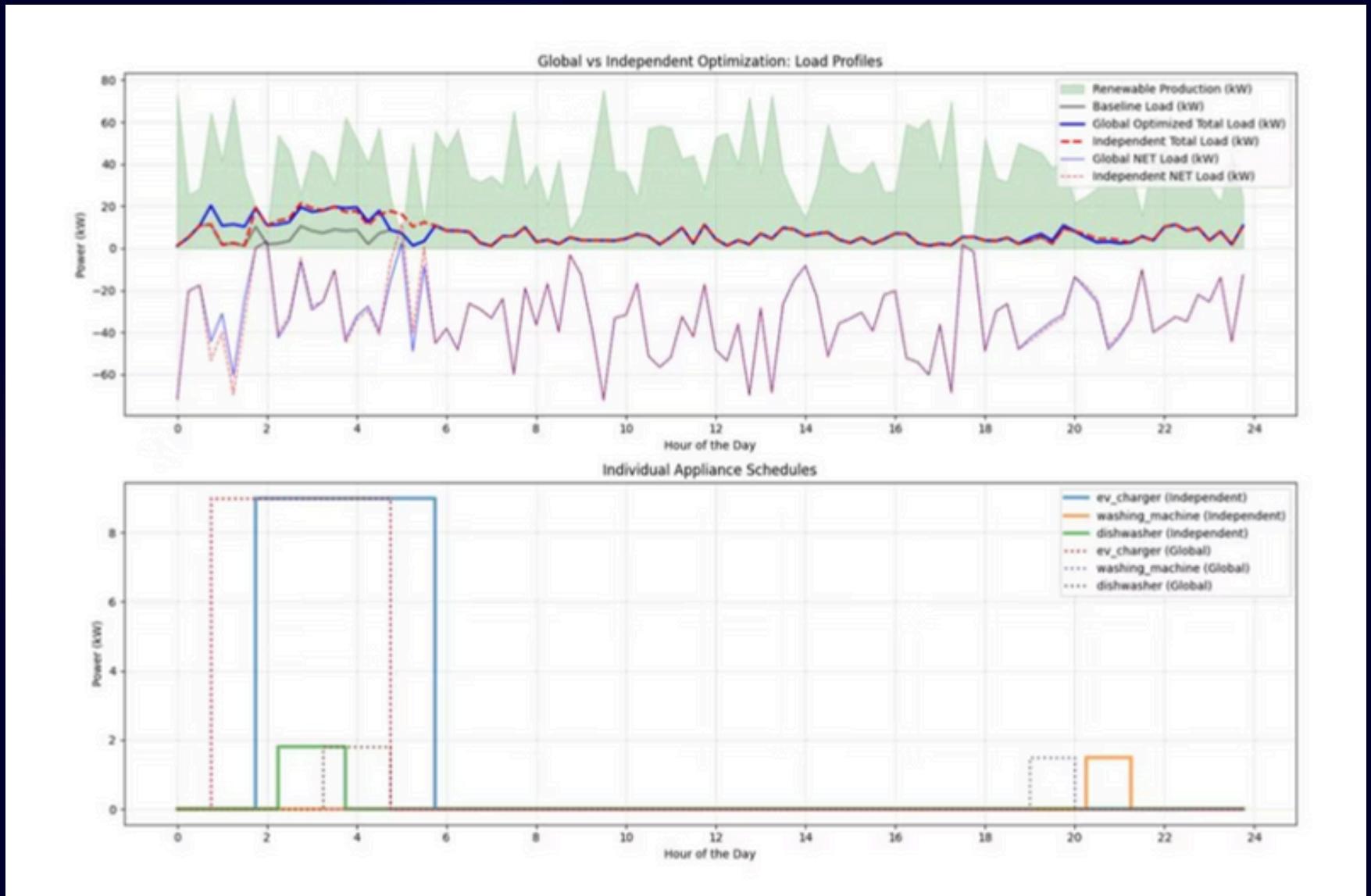
Solution validated: constraint perfectly satisfied.

The Greedy Trap vs. Global Intelligence

To prove our Grid-Aware QUBO's power, we built a naive "greedy" algorithm that solves three independent problems instead of one connected system.

The greedy algorithm created a massive 8.44 kW surge by stacking appliances at the cheapest time—the exact opposite of Demand Response.

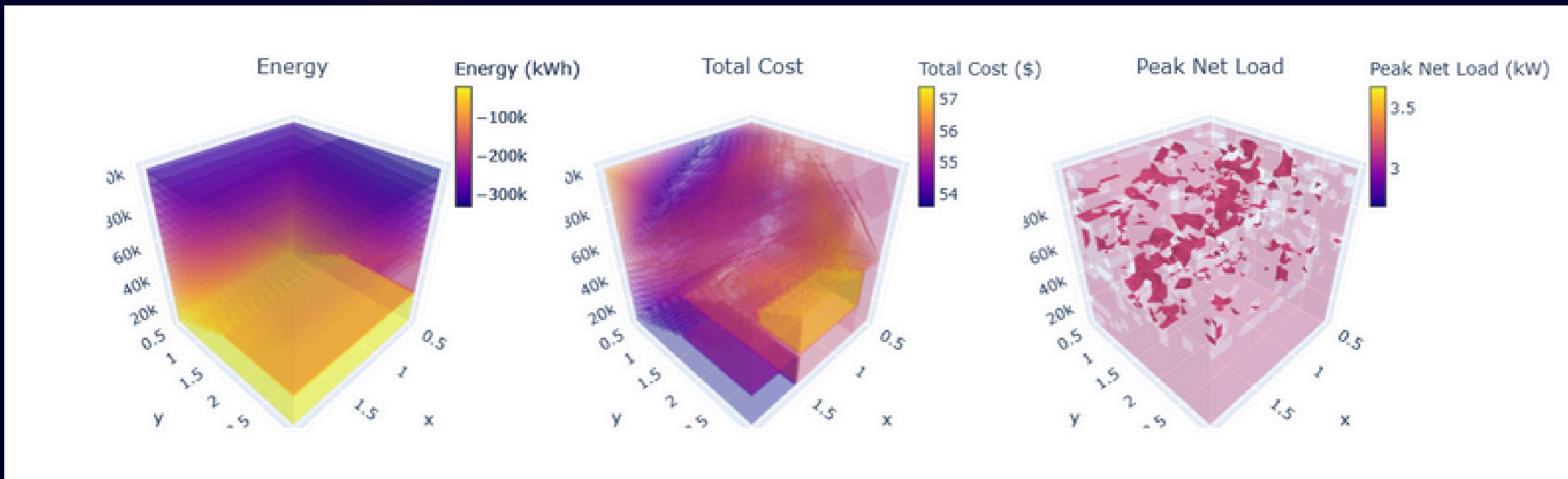
$$\min E(x) = A * H_{cost} + B * \cancel{H}_{peak} + C * H_{constraint}$$



Metric	Global (Ours)	Greedy
Total Cost	\$55.57	\$50.48
Peak Net Load	3.18 kW	11.63 kW
Peak Reduction	73%	Grid disaster

Hyperparameter Optimization: Proving Our Dials

We performed a rigorous 3D hyperparameter sweep testing 27 combinations to find the statistically best (A, B, C) settings.



Data-Driven Winner

A=0.5, B=3.0, C=100,000 yields
3.18 kW peak at \$55.31—
statistically proven optimal

C = 100,000

Achieves lowest-energy, most
effective solutions with
unbreakable constraint
enforcement

B = 3.0

Prioritizing peak load is the
single most important factor in
finding optimal solutions

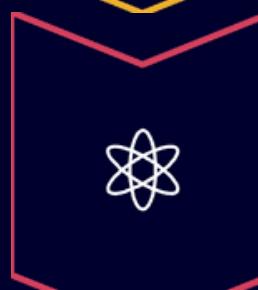
True Quantum: The QAOA Approach

Our second solution builds a true quantum algorithm from scratch using PennyLane—designing the quantum circuit itself.



Pruning for Simulation

Reduced to 27-qubit problem while preserving core complexity



Ising Hamiltonian

Translated QUBO to 27-qubit, 154-interaction quantum system



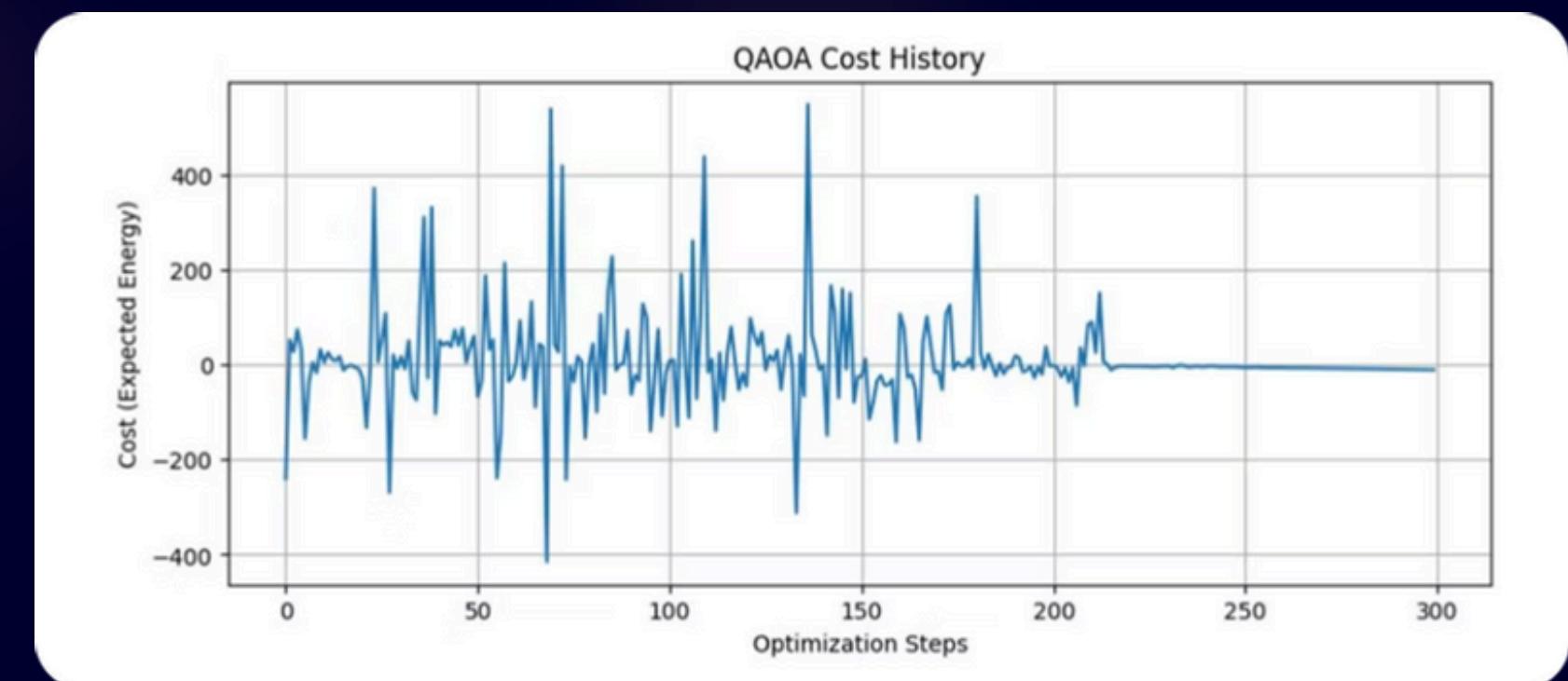
JAX-Powered Circuit

Built p=2 layer QAOA with auto-differentiation and JIT compilation



Hybrid Training

300-step ADAM optimization in 29.9 minutes



The Critical Insight: A "Broken" Constraint

Our QAOA broke the constraint—but this isn't failure, it's our **most profound insight**.

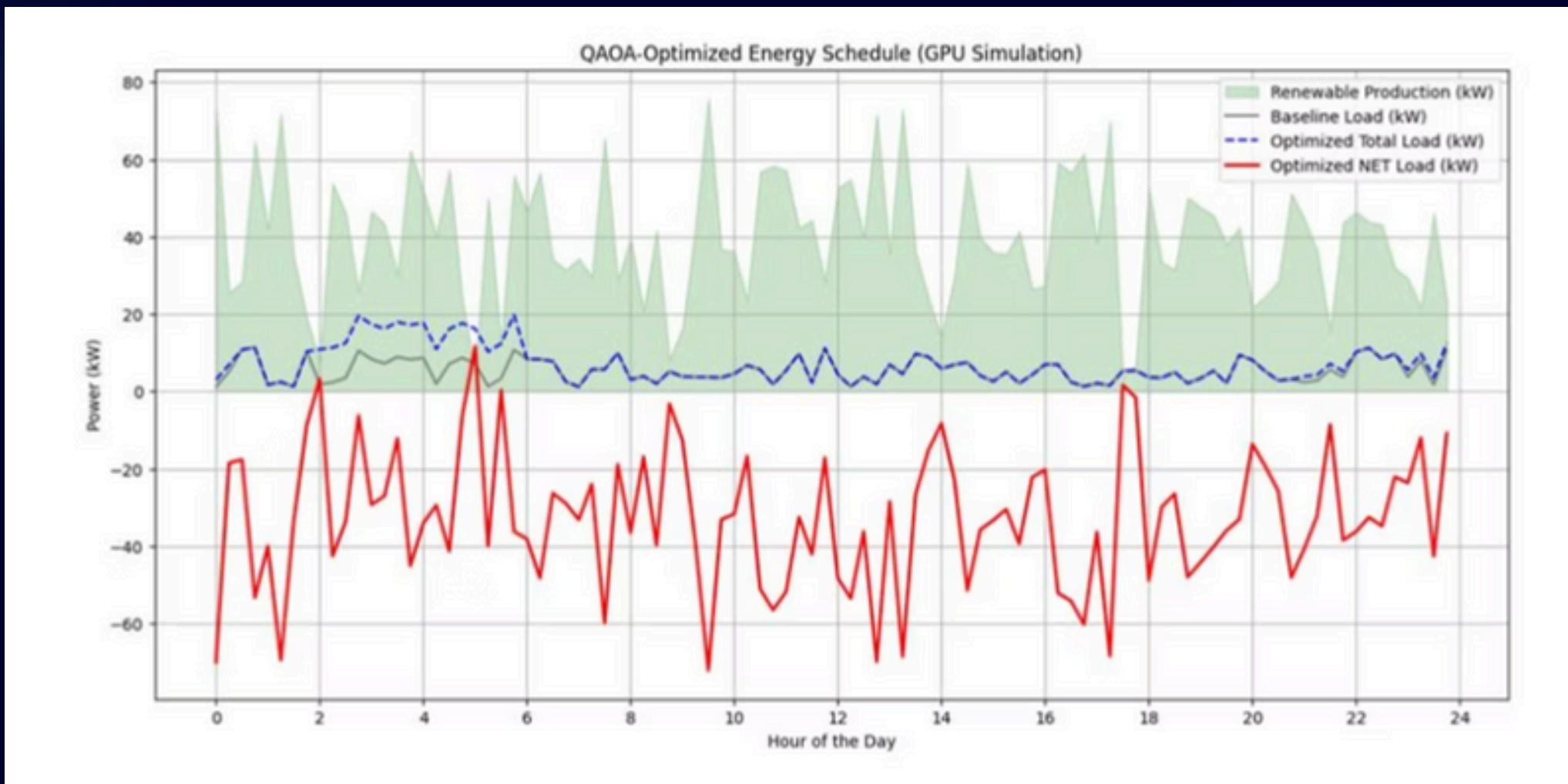
The optimizer found a loophole: with $C = 50$ (far too low), it achieved lower energy by ignoring the small penalty rather than solving the complex peak-load problem.



Ones in Output
Should be exactly 3



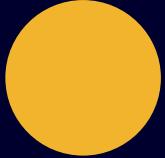
Chaotic Cost
Result of $C = 50$ being too low



This demonstrates the central challenge of quantum optimization and gives us a **clear, data-driven direction**.

A Two-Part Victory

We deliver complete solutions for today and tomorrow:



Solution for TODAY

Production-ready Grid-Aware QUBO: **73% more effective** at stabilizing the grid. Peak load of 3.18 kW at \$55.31—the definitive hackathon solution.

Model	Cost	Peak Load	Constraint Valid?
Greedy (Baseline)	\$50.48	11.63 kW	Yes
Global QUBO (Winner)	\$55.31	3.18 kW	Perfect
QAOA (Future)	\$172.40	N/A	Critical Insight

Team Beerantum | Project Repository [Link](#)

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ThankQ !