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

The Battlefield: Digitizing the Problem

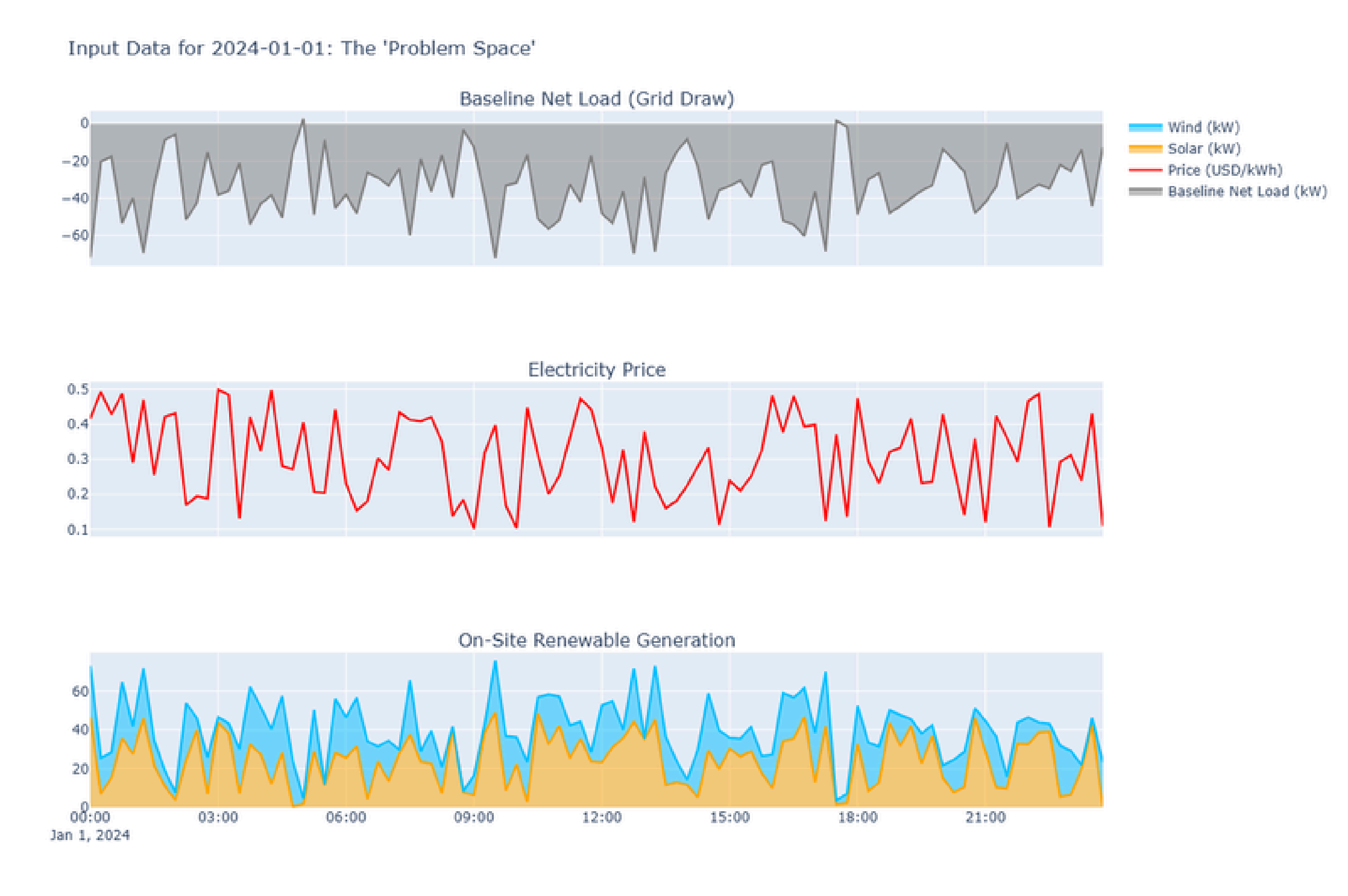
We created a high-resolution digital twin of a home's 24-hour energy environment using 96 time steps (every 15 minutes):

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

Three controllable appliances with unique constraints create a massive search space of **2**101 possibilities**.

1	**EV Charger** 4-hour block, overnight only
2	**Washing Machine** 1-hour block, daytime only
3	**Dishwasher** 1.5-hour block, evening/early morning

2^{101} Possibilities



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The Battlefield: Digitizing the Problem

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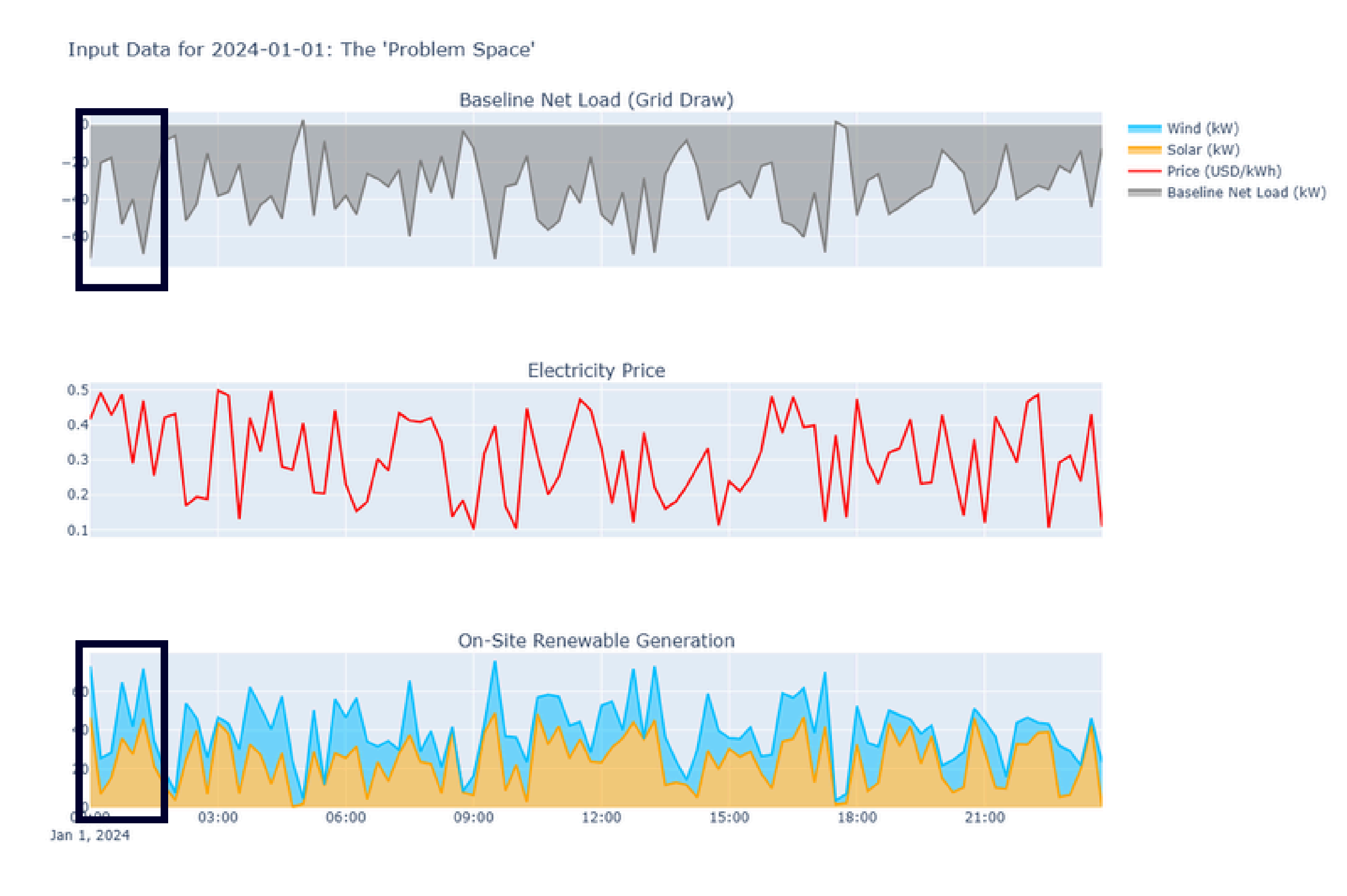
Three controllable appliances with unique constraints create a massive search space of **2101 possibilities**.

1	**EV Charger**	4-hour block, overnight only
2	**Washing Machine**	1-hour block, daytime only
3	**Dishwasher**	1.5-hour block, evening/early morning



The renewable energy is not always available when the demand is high !

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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.

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

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

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

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

Hyperparametter set: $A \ll B \ll C$

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

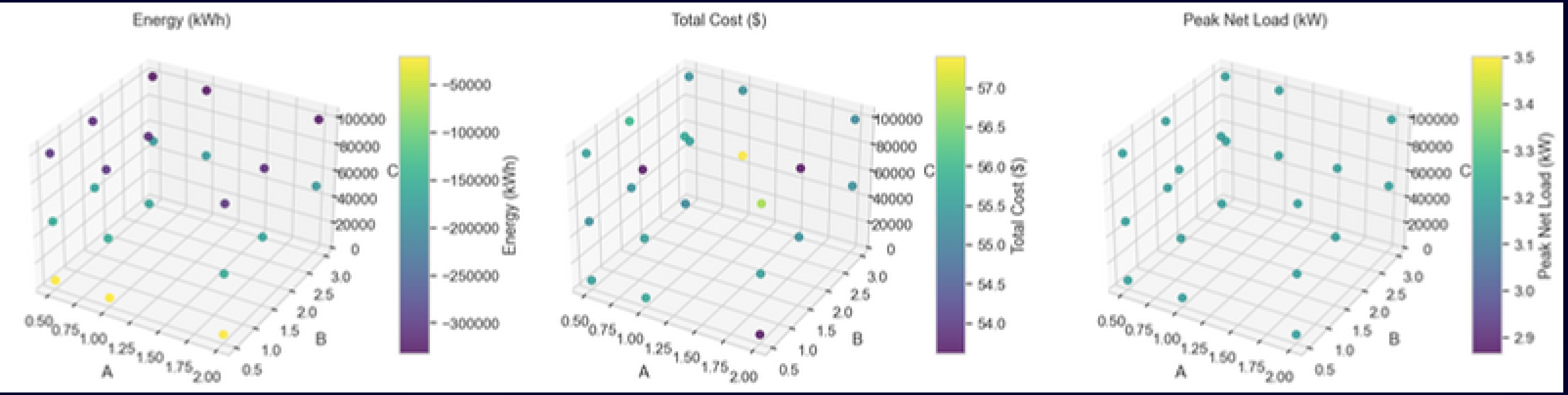
03

Build Cost Landscape

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

Hyperparameter Optimization: Proving Our Dials with D-Wave SimulatedAnnealingSampler

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

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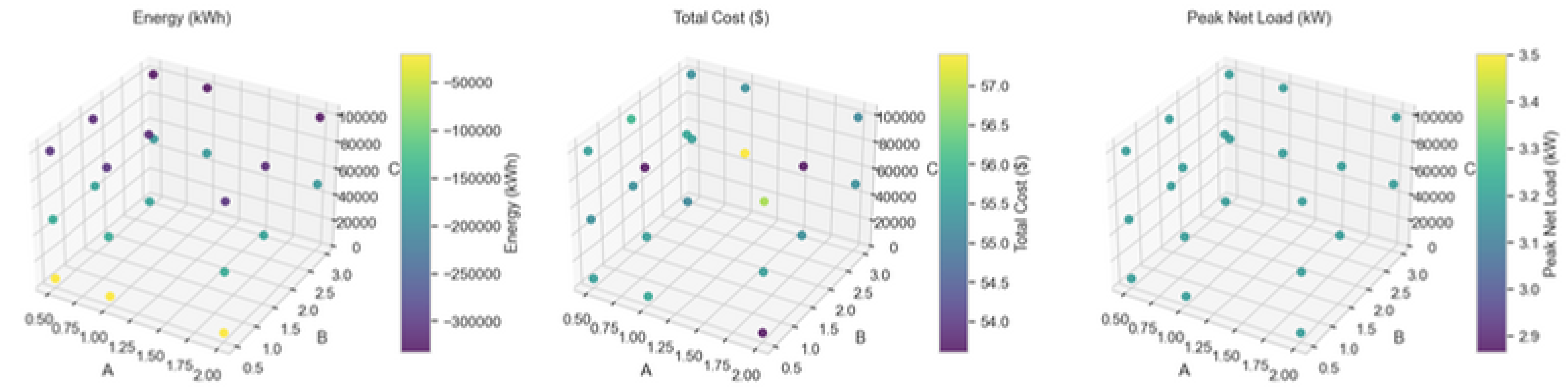
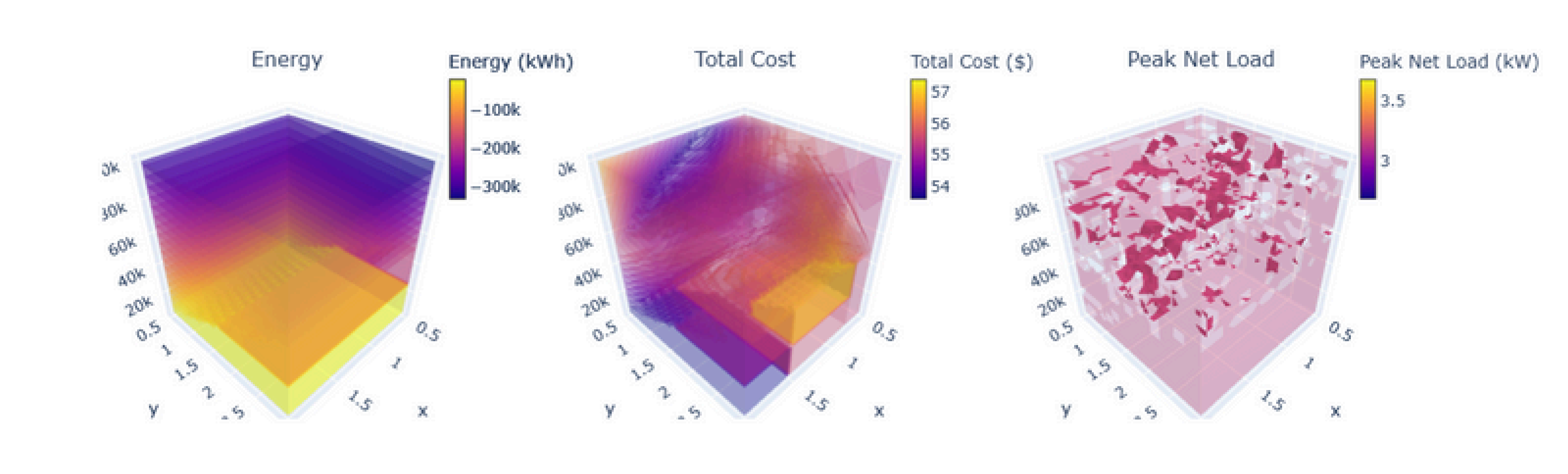
Hyperparameter Optimization: Proving Our Dials

Minimum energy and minimum cost do not occur at the same time.





Interpolated with 'linear' + fallback to 'nearest'

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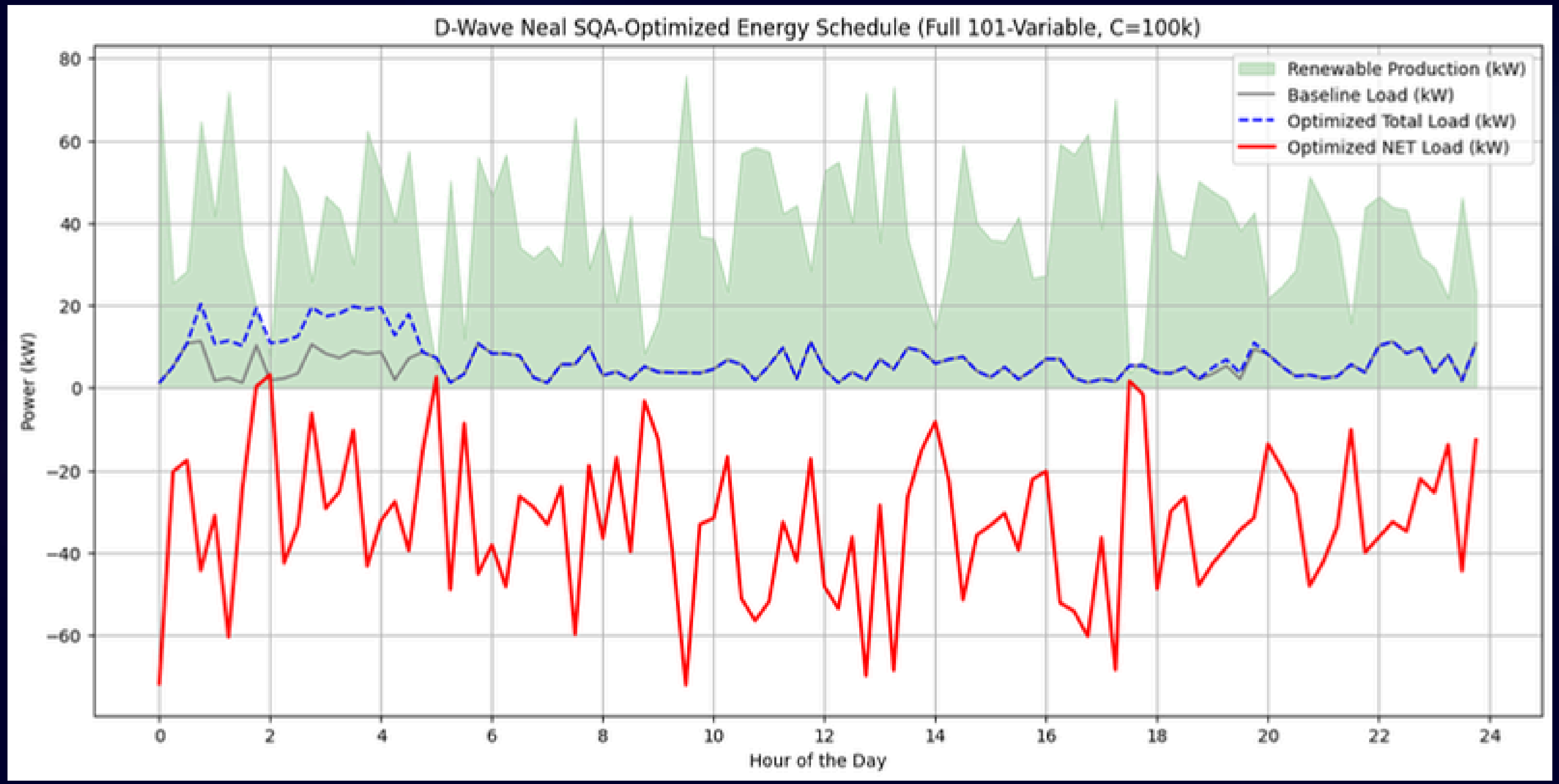
The Solve: Finding the Answer

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.

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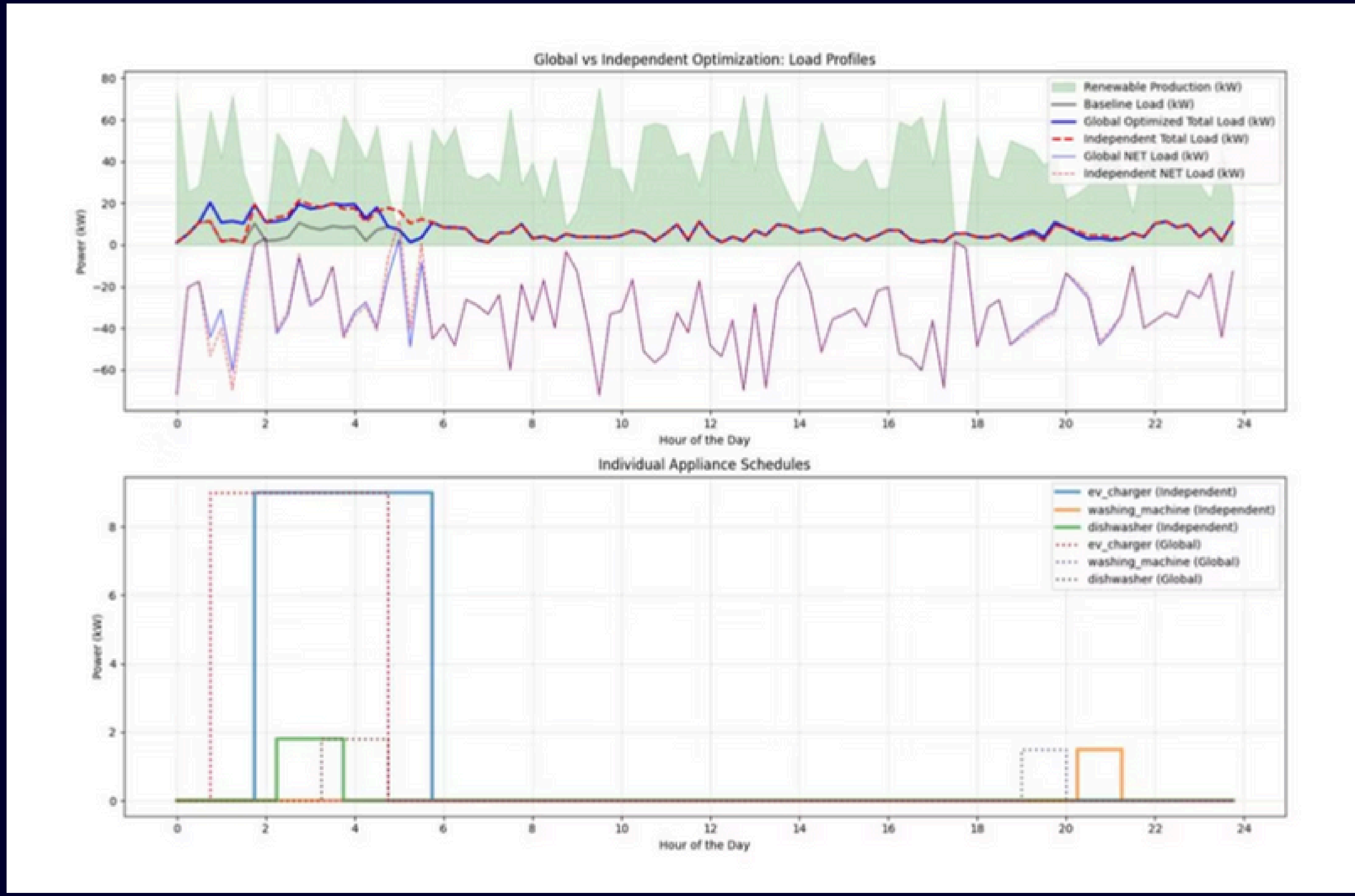
The Greedy Trap vs. Global Intelligence

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



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.

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

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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]

ThankQ !