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IFORS 2026 · Optimal Decision Making in Energy

Operational Energy Optimization at Scale:

Lessons Learned from Energy Systems with AMPL

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PRESENTATION OUTLINE

Agenda

Operational Energy Optimization

A comprehensive walkthrough of energy system optimization modeling, industrial case studies, and key takeaways using AMPL.

Overview

What is AMPL?

AMPL is an optimization modeling system used to design and solve large, complex business decisions.

A modern, comprehensive environment designed to help teams formulate, test, and deploy mathematical models at scale.

1

Expressive Modeling Language

A clean, expressive syntax tailored specifically to mathematical optimization problems.

2

In-House Solvers Interfaces

Connect directly to solvers including Gurobi, CPLEX, Xpress, Mosek, Knitro, Baron and many others.

3

Easy Lifecycle Integration

Quick to learn, build, iterate, and seamlessly connect or collaborate with your team.

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Who uses AMPL?

Organizations with mission-critical, large-scale operational environments that demand mathematical precision in production.

01

Large-Scale Optimization

Organizations solving large, complex operational optimization problems.

02

High-Speed Decisions

Environments where critical operational decisions must be fast, reliable, and repeatable.

03

Production Systems

Complex constraints and large models running consistently in enterprise production.

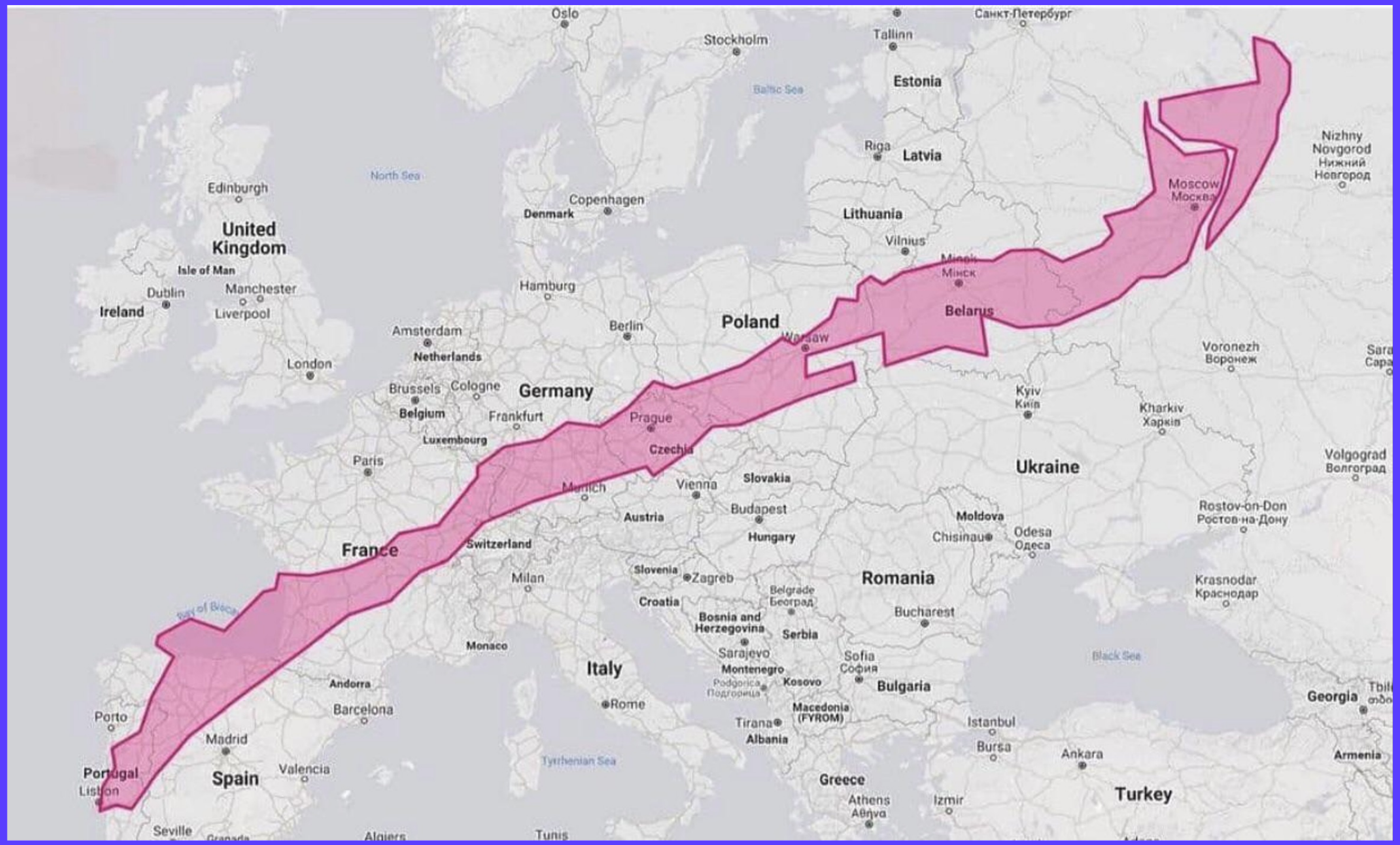
Chilean Power Market Modeling with AMPL

TM Energy Consulting

Long-Term Price Forecasting

Forecasting marginal prices for Chile's national grid to support commercial, operational, and investment decisions across multiple scenarios.

TM ENERGY CONSULTING



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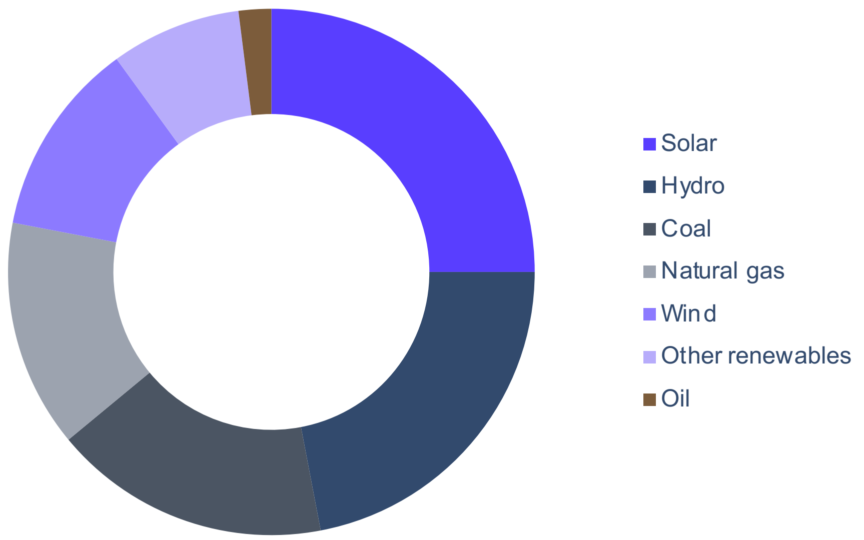
Chile's Energy Market: Context & Landscape

Installed Capacity — End of 2025

Technology	Capacity	Share
Solar PV	11.7 GW	30%
Conventional hydro	6.9 GW	18%
Wind	6.0 GW	16%
Natural gas	5.3 GW	14%
Coal	3.2 GW	8%
Diesel / fuel oil	3.1 GW	8%
Other renewables[1]	1.4 GW	4%
Total	**38.6 GW**	**100%**

[1] Biomass, geothermal, mini-hydro. Plus 1.9 GW battery storage (non-generating). Source: CEN / ACERA / CNE, approx., Dec 2025.

Generation Mix — 2025



~67% of generation is renewable; **solar + wind ~38%** of energy injected — a new record.

Source: Coordinador Eléctrico Nacional (CEN), Ember, IEA — full-year 2025, approx.

A Uniquely Shaped Grid

~4,300 km north–south, only **~180 km** wide on average — one of the world's most elongated grids, now unified as the single Sistema Eléctrico Nacional (SEN).

NORTH
Atacama Desert: world-class solar resource; large mining loads

CENTER
Santiago metro area: the country's demand center

SOUTH
Andes & Patagonia: hydro, wind and geothermal potential

Key Challenges Ahead

- **Transmission bottlenecks —** Over 70% of transmission projects face delays; renewable buildout is outpacing the grid.
- **Rising curtailment —** ~6 TWh of clean energy curtailed in 2025 (+8% YoY), concentrated in the sunny north.
- **Hydrological variability —** 2025 ranks among the 5 driest years on record; hydro generation fell 23%.
- **Grid security & demand growth —** The Feb. 2025 nationwide blackout exposed vulnerabilities as mining demand keeps rising.

Model Scope & Optimization Problem

Physical realism built in

- DC power flow with piecewise-linear losses; N-1 security on line capacities
- Ramp rates, startup/shutdown times, minimum output constraints
- Primary and secondary frequency reserves and inertia requirements
- Storage cycle limits and individual fuel pricing per plant (LNG, gas, coal, diesel)

Model formulation

- Deterministic unit commitment; monthly horizon, hourly resolution
- Hydro availability scenarios: dry / wet / average year
- Reservoir levels link consecutive months, carrying water across seasons
- Objective: minimize cost of serving demand while meeting reserve and inertia requirements

Model Scope & Fidelity

Full topology of the real Chilean power system

Component	Scale
Buses (substations)	**200+**
Transmission lines	**280+**
Generation plants	**1,000+**
Time resolution	**Monthly × hourly**

The Optimization Problem

Problem size for a typical month

Metric	Original	Presolved
Rows (cons)	**1.92M**	**782K**
Columns (vars)	**2.88M**	**1.53M**
Nonzeros	**8.76M**	**5.86M**
Integer entities	**366K**	**284K**

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The Business Problem

Key outputs delivered

01 Marginal costs per bus (LMP) to value project revenues and structure medium- and long-term PPAs

02 Unit dispatch for fuel procurement: coal and gas plants buy fuel ahead based on generation estimates

03 Curtailment estimates for renewables: lost generation and revenue that no one reimburses

04 Transmission decoupling from congested lines: enables sensitivity analysis on grid expansion and delays

Results Delivered

Solved with AMPL + FICO Xpress

Barrier + crossover on the LP relaxation, terminating at a 0.77% MIP gap — well inside the 4% target.

LOCAL

~30 min

per month · i7-12700, 128GB RAM

CLOUD · NEXTMV

~10 min

per month

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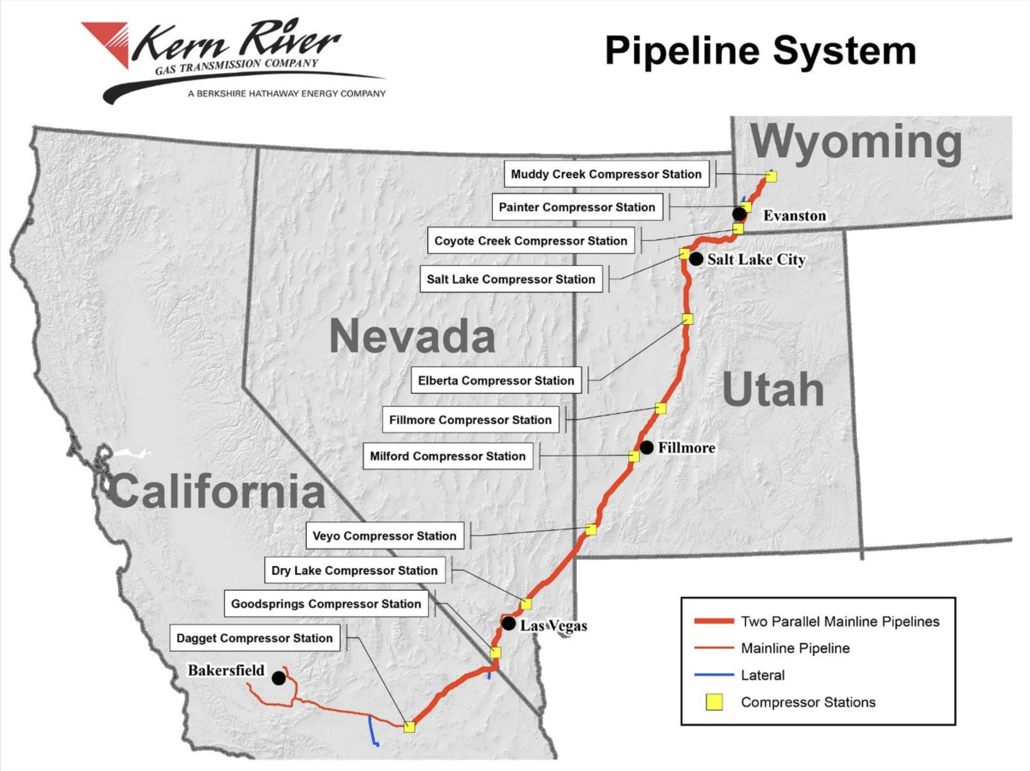
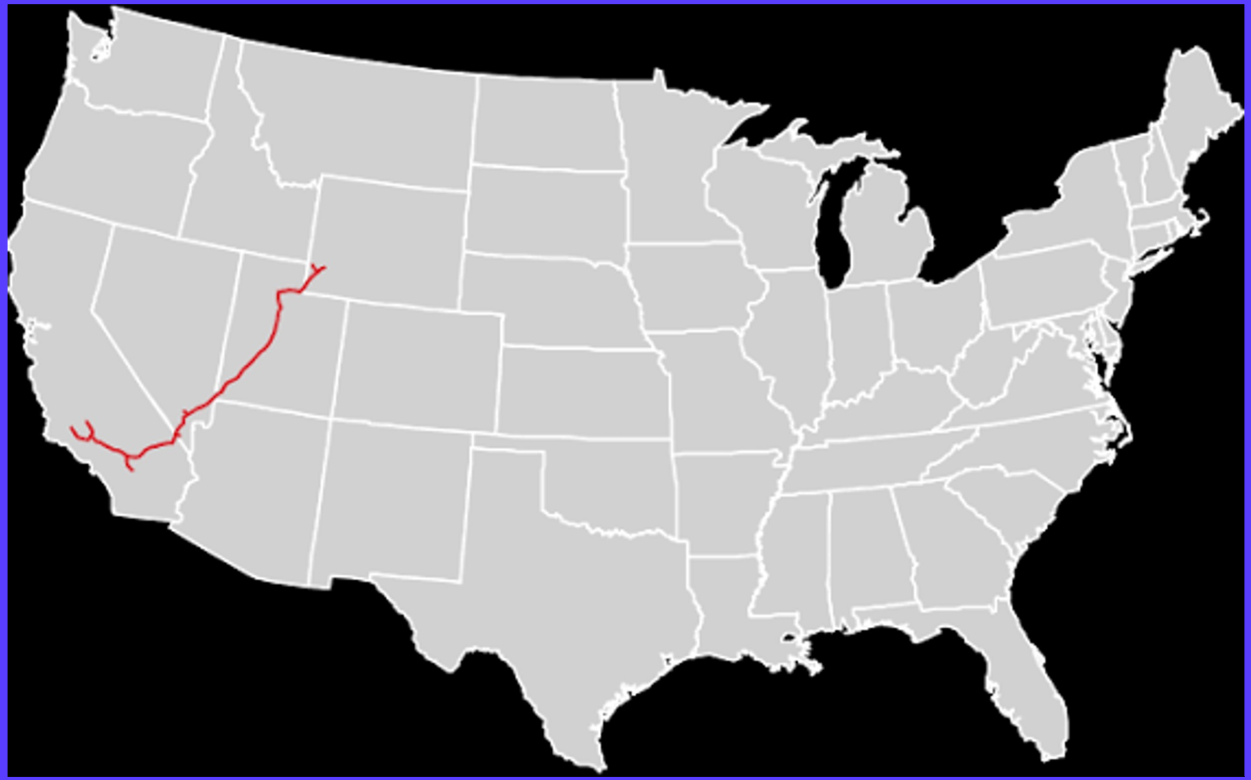
Case Study 2 · Natural Gas Networks

Gas Pipeline Scheduling

Kern River’s interstate pipeline moves gas from Wyoming to California under FERC rules, 266,000 Dekatherms every day. Its AMPL-based Scheduling Engine enforces contracts and physical limits in sequence, running since the 1990s, now used by seven U.S. pipelines.





The Gas Day

A standardized 24-hour scheduling period that does not align with the calendar day. It begins and ends at a fixed hour (e.g. 9:00 a.m. Central Time) set by pipeline operators and regulators — every nomination, delivery, and operational activity is referenced to it.

GAS DAY — 24 HOURS

Timely	Evening	ID1	ID2	ID3
1 2 3	4 5 6	7 8 9	10 11 12	13 14 15
`model_cycle 1–3`	`model_cycle 4–6`	`model_cycle 7–9`	`model_cycle 10–12`	`model_cycle 13–15`

● *= SUB_CYCLE_1 (first subcycle of each block)*

5 cycles × 3 subcycles = **15 engine runs** per gas day

`param model_cycle in 1..15` • `param gisb_cycle -> TIMELY | EVENING | ID1 | ID2 | ID3`

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Kern River: Rules, Not Just Optimization

01

Rules apply sequentially: contract limits, balancing, pool loops, then curtailment.

02

A three-pass filter-gross-exact solve narrows cuts to single-Dth precision.

03

Piecewise-linear objectives let a linear solver break priority ties exactly.

04

The same AMPL engine has run in production since the 1990s — and still does.

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Model Details

Model Scale & Architecture

Explainability vs Raw Complexity

The underlying LPs are small and typically fast to solve. The real engineering effort goes into explainability: every cut must trace back to a specific rule and a “reason code” a shipper can understand, not just an optimal number a solver produced.

Sub-Problem Scaling

Full production-scale cycles (~8,500–10,000 nominations) solve multiple models. Individual sub-problems (after AMPL's own presolve) have ~20,000 variables and up to ~5,000 constraints.

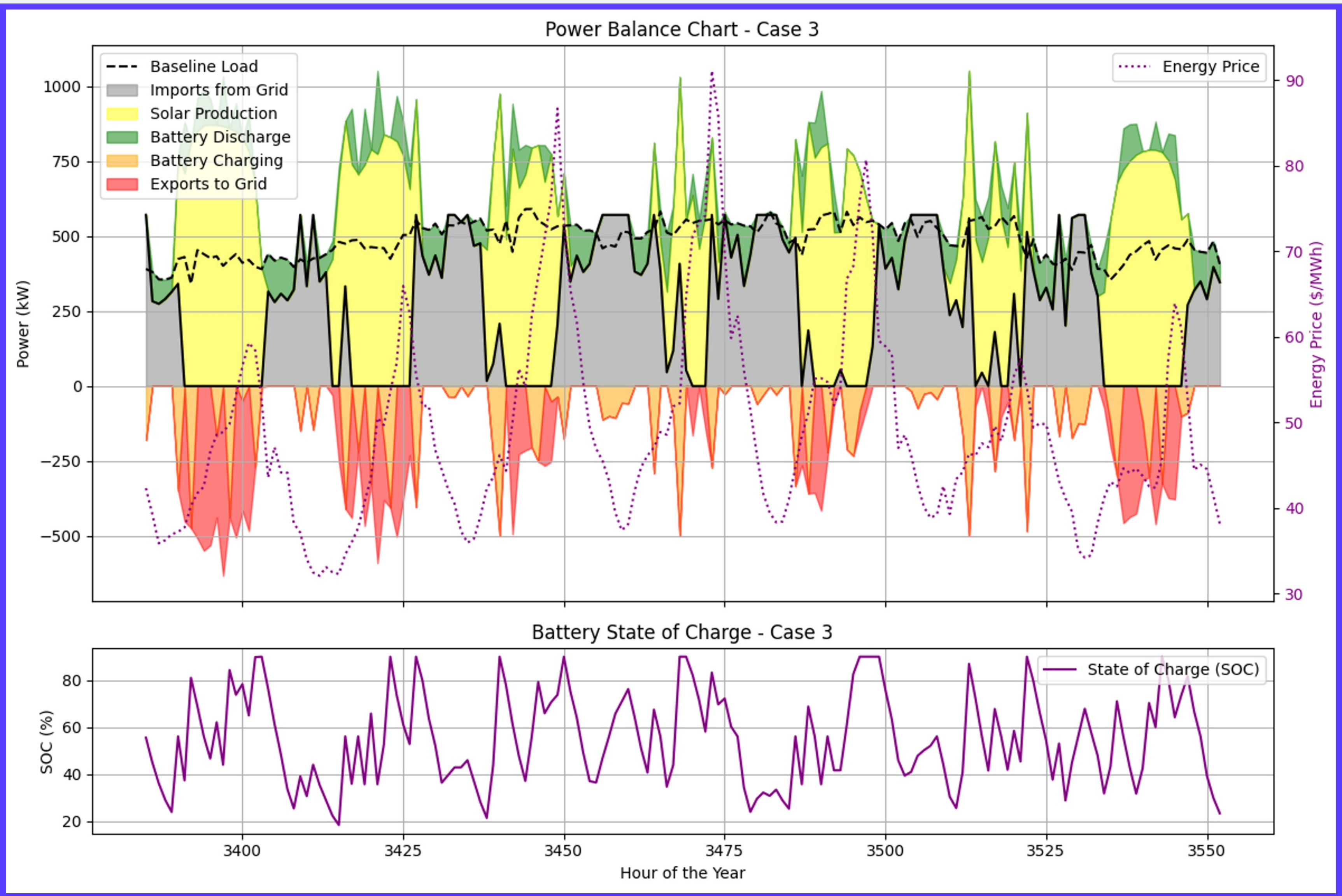
Dataset Scale	Solves	Total Run Time
~8,500 noms (typical)	—	208–226s
~9,700–10,000 noms (typical)	236–616	171–390s
~8,600–9,700 noms (edge cases)	1,984–3,342	1,185–1,370s (20–23 min)

Roughly 40–60% of total run time is actual solve time; the rest is data I/O, model (re)building, and reporting overhead.

Case Study 3 · Battery Storage

BESS Valuation & Operation

One AMPL model values a battery (plus optional solar) hour-by-hour across a full year — 8,760 hours — across every revenue stream at once: bill savings, wholesale energy arbitrage, and frequency-regulation markets. The same formulation supports both investment analysis and day-ahead dispatch.



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Use Case Details

Industrial site (785 kW peak demand) in the PJM ISO service territory 0.5 MW / 1 MWh BESS + 1 MW Solar PV

CASE 01

Just BESS

No market participation

OPTIMIZATION TYPE
LP (Linear)

VARIABLES (26,312)
Continuous: 26,312
Binary: 0

CONSTRAINTS (17,946)

SOLVE TIME

< 1s

CASE 02

BESS + Solar

Wholesale participation

OPTIMIZATION TYPE
LP (Linear)

VARIABLES (34,924)
Continuous: 34,924
Binary: 0

CONSTRAINTS (26,107)

SOLVE TIME

< 15s

CASE 03

BESS + Solar

Wholesale + freq. regulation

OPTIMIZATION TYPE
MIQCP (Quadratic)

VARIABLES (69,761)
Continuous: 61,051
Binary: 8,710

CONSTRAINTS (121,903)

SOLVE TIME

~1:15 min

CASE 04

BESS (optimized size) + Solar

Wholesale + freq. regulation

OPTIMIZATION TYPE
MIQCP (Quadratic)

VARIABLES (69,765)
Continuous: 61,054
Binary: 8,711

CONSTRAINTS (139,450)

SOLVE TIME

~6:30 min

Try the Model: Lite version available on [Google Colab]

Same Battery, Three Scenarios

Layering Value Streams

Real case, 500 kW / 1 MWh BESS, 20-year horizon. Bill savings alone barely pencil out — adding market participation changes the picture entirely.

Bill Savings Only

ROI 2.6%, NPV $16K. Demand-charge and rate savings alone, no market participation.

Wholesale Energy

Add solar PV and wholesale energy sales: ROI 24.3%, NPV $432K.

Frequency Reg.

Add frequency regulation on top of energy sales: ROI 49.3%, NPV $875K in year one.

Lessons Learned

Key Takeaways

Five Lessons from AMPL in Production

01

Real world is uncertain, but not every model must be stochastic.

02

Start simple. Understand the core business need first.

03

You're designing a decision system, not just a model. Use the right tools.

04

Models are living systems — they evolve, they don't end.

05

Data comes first — garbage in, garbage out.

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Thank You!

Do you have any questions?

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