TEA

THE EnergyAuthority

Building Optimization Model for Solar + Storage Hybrid Resource

Utility Analytics, Data Science Community

August 17, 2021

TEA

THE EnergyAuthority

- Was created by, owned by and exists to serve public power utilities.
- Works with over 50 public power clients, representing over 30GW of peak demand and 24GW of generation capacity across the U.S.

TEA Analytics

Trading

- Develop Trading Strategy
- Optimize Generation and Storage Assets

Portfolio Management

- Wholesale Market & Portfolio Risk Analysis
- Transmission + Congestion analysis
- IRP, Assessment of RFP and RFO

Forecasts

- Load Forecast (ST Hourly, LT Economic)
- DA + RT LMP Forecast
- Generation Forecast (MT Regional Hydro)

AMI Analytics

- Grid Management (DSM)
- Asset Management (Meter & Transformer Health Analysis)
- Customer Engagement (Rate Design, Behavior Analytics)

TEA Analysts

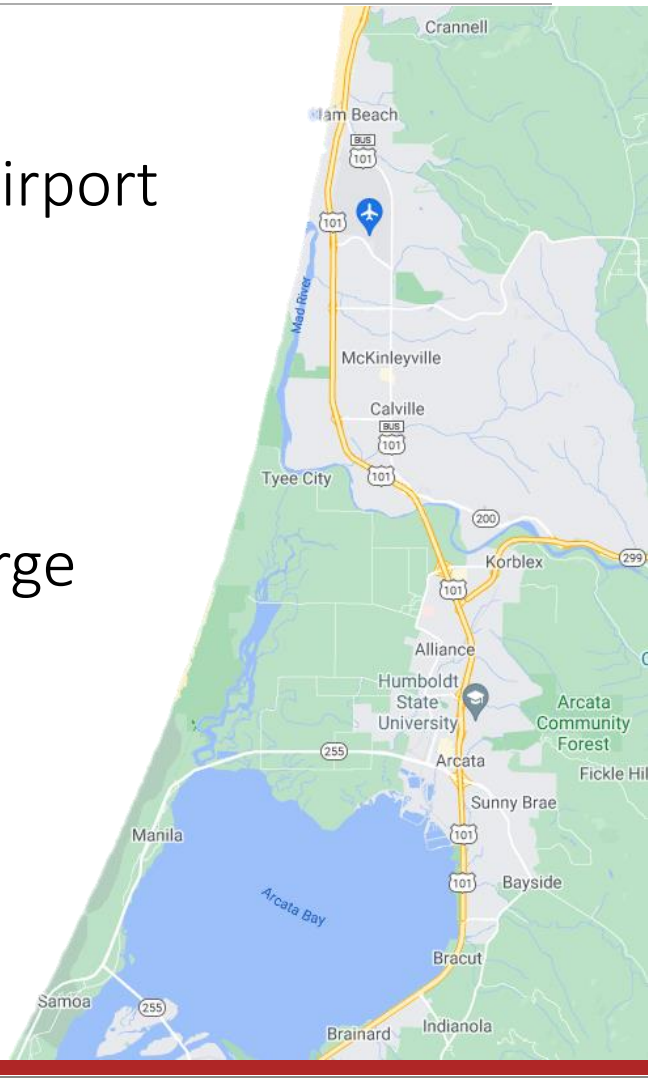
- Strategist (2)
- Congestion Right Analyst (4)
- Portfolio Analysts (15)
- Data Scientists (6)

Disciplines

- Statistical Analysis
- Financial Engineering
- Operations Research
- Data Science

Solar + Storage Hybrid Resource

- Location:
  - Redwood Coast-Humboldt County Airport
- Capacity
  - 2.3 MW Solar generation
  - 2.3 MW Tesla Storage
  - 1.48 MW charge & 1.78 MW discharge interconnection limits
- Operation
  - Nov 2021 ~
  - Microgrid, islanding capability



Today's Agenda

- Hybrid resource operation in CAISO and its challenges
- Modeling strategies and optimization formulation
- Stochastic forecasting as inputs into optimization model
- Model verification and project goals

What “Resource” is Storage?

NGR

Non-Generating Resources

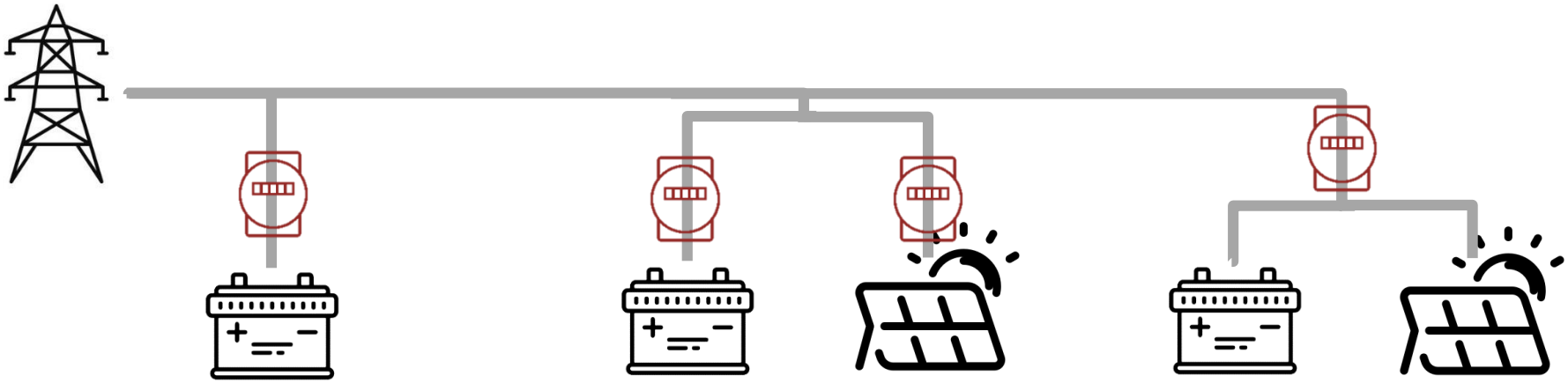
- Operational since 2012 ~

Co-Located

- Individual resources are managed independently.

Hybrid

- Multiple resources are managed as a single resource.
- Implementation in Apr 2022



Solar Uncertainty

Solar

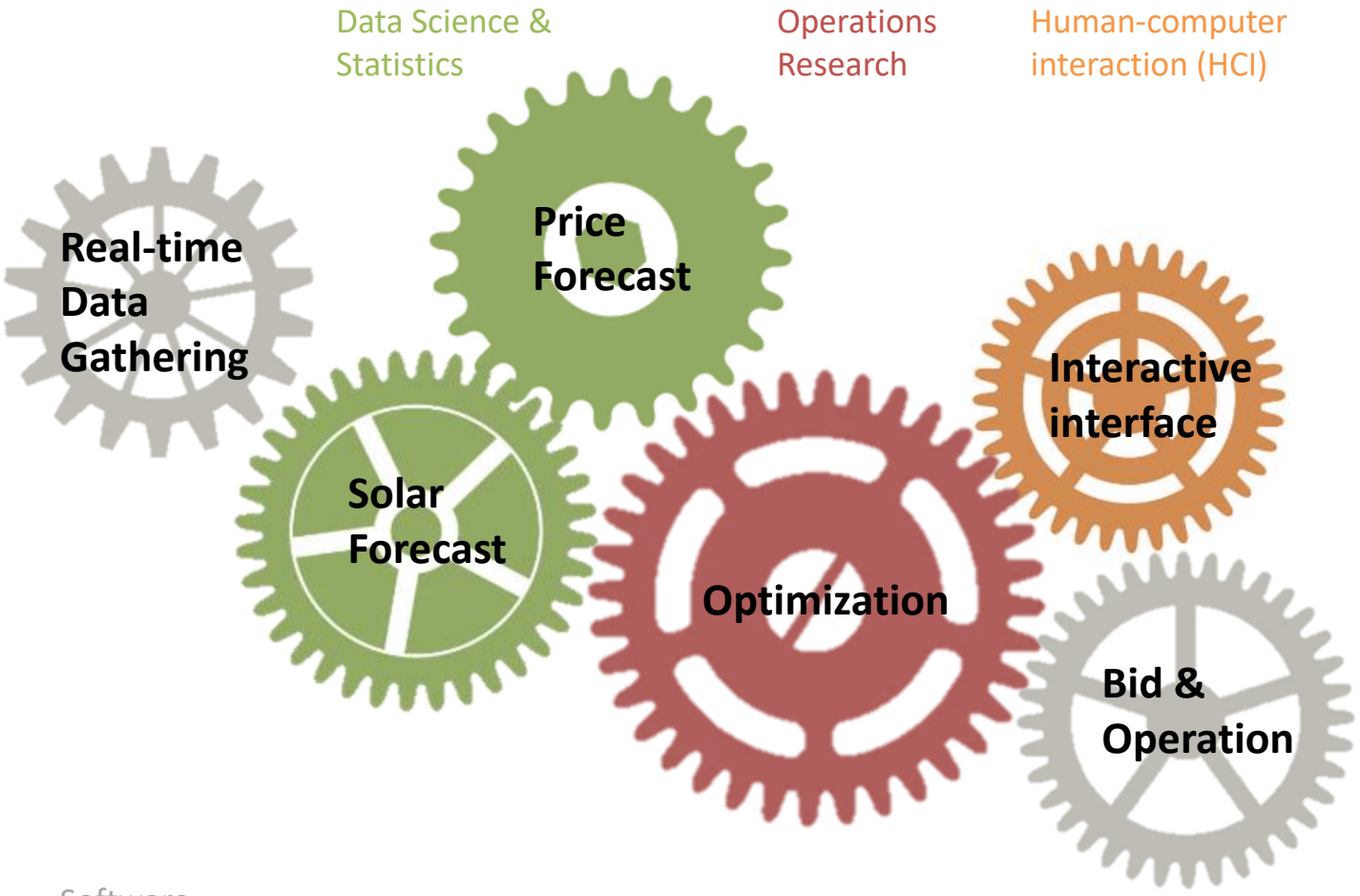
- CAISO provides solar generation forecast.
- Bids for solar generation is automatically updated until the operation hour and settled against the forecast.

NGR & Hybrid

- You need to bid into the market, and you are responsible for following final CAISO dispatch instructions.
- RT bids are submitted 75 min before the start of the flow. Model run 120 min before flow.

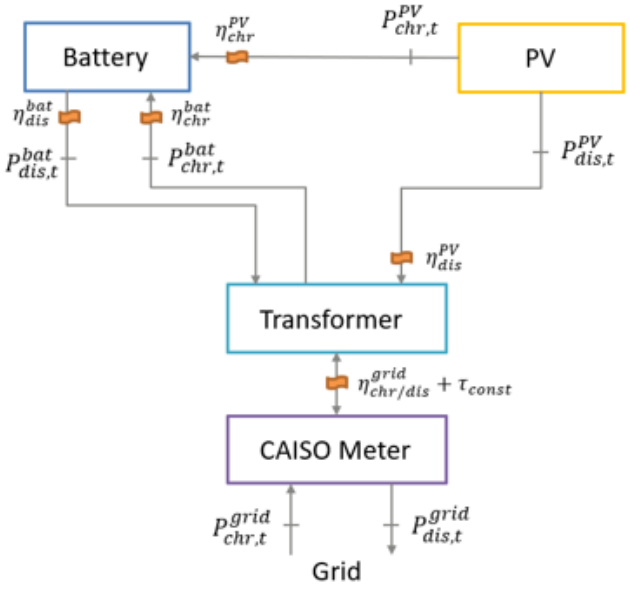
Modeling

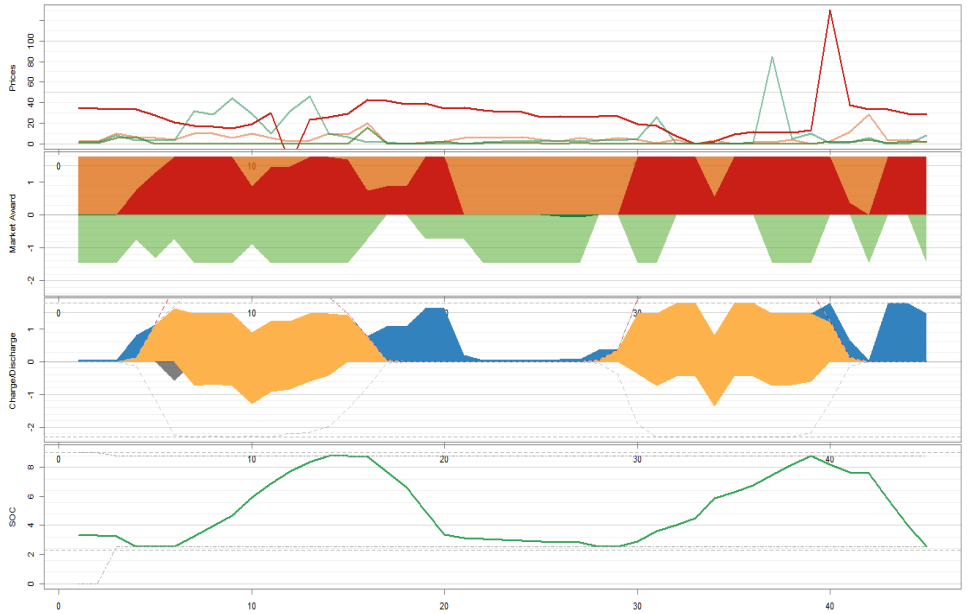
Operational Components



Terminology

- State of Charge (SOC) in MWh
- Roundtrip efficiency & other losses
- Day-Ahead (DA), Real-Time (RT)
- Energy Market, Ancillary Services (AS), Regulation Up and Down, Spin, non-Spin





Agile Model Development in 2021

Dev complete

- (1.1) Initial "Baby-Crawling" Model
  - Deterministic, Energy-Market-Only
- (1.2) Baby-Crawling plus
  - No concurring grid-charging & pv-charging
- (2.0) EnergyOnly -Stochastic
- (3.0) Energy&AS

Simplest Operation-able Model

Coming

- (4.0) Energy&AS, multi-segment bidding

Forecasting/OR vs Data Science

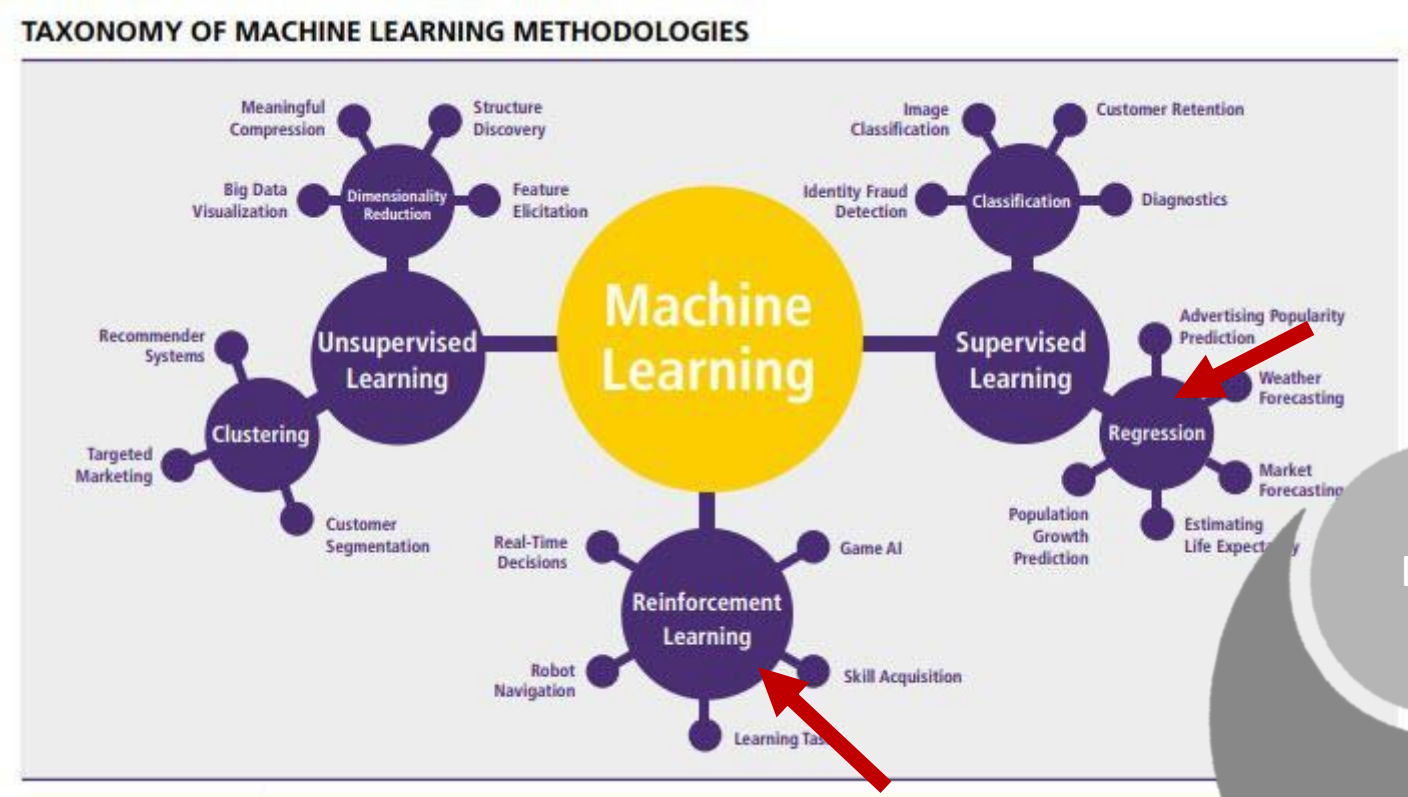
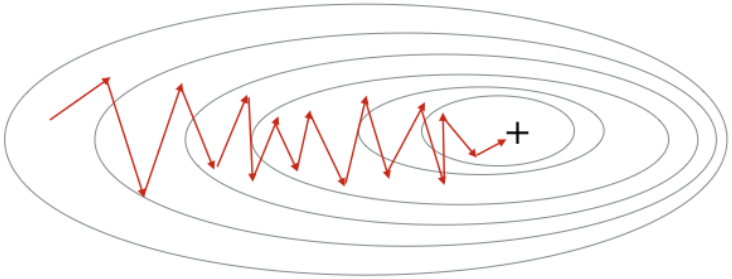


Figure 10: An overview of machine learning techniques; **Source:** Jha, V.

“Optimization” in DS/OR

Data Science

- Optimization: Gradient Decent (non-linear optimization)
- Challenge: solving the formulated problem
- Stochastic:
  - Stochastic Gradient Descent



Operations Research

- Optimization: Linear Programming (LP), Mixed-Integer Programming (MIP)
- Challenge: formulating the problem
- Stochastic: Inputs & formulation
  - Robust Optimization (constraints on the worst cases)
  - Risk terms in objective
- Think Linear.

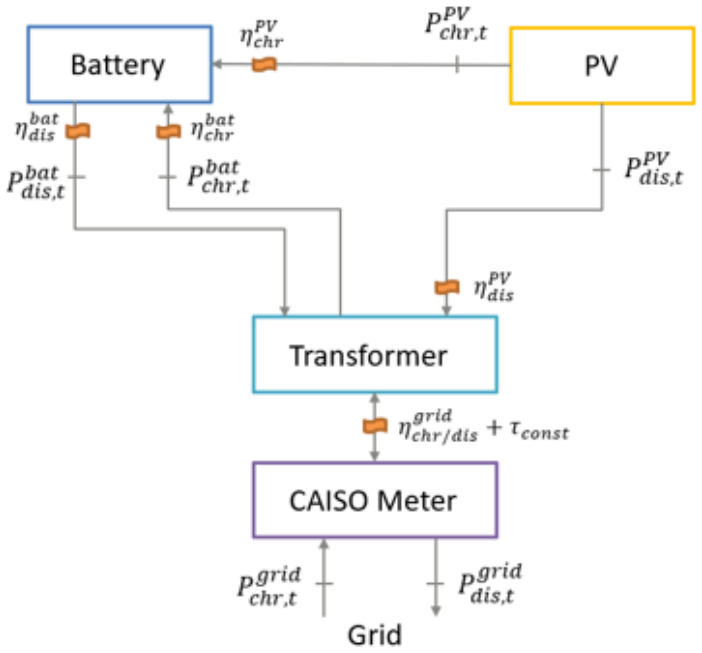
$$\text{If} \quad (1) \quad \left(\sum_{j \in J} a_{1j} x_j \le b_1\right) \quad \text{is satisfied,}$$
$$\text{then} \quad (2) \quad \left(\sum_{j \in J} a_{2j} x_j \le b_2\right) \quad \text{must also be satisfied.}$$

Linearization Tricks

$$\sum_{j \in J} a_{1j} x_j \ge b_1 + \epsilon - Ly$$
$$\sum_{j \in J} a_{2j} x_j \le b_2 + M(1 - y)$$

Optimization Formulation

- MIP (Mixed Integer Programming)

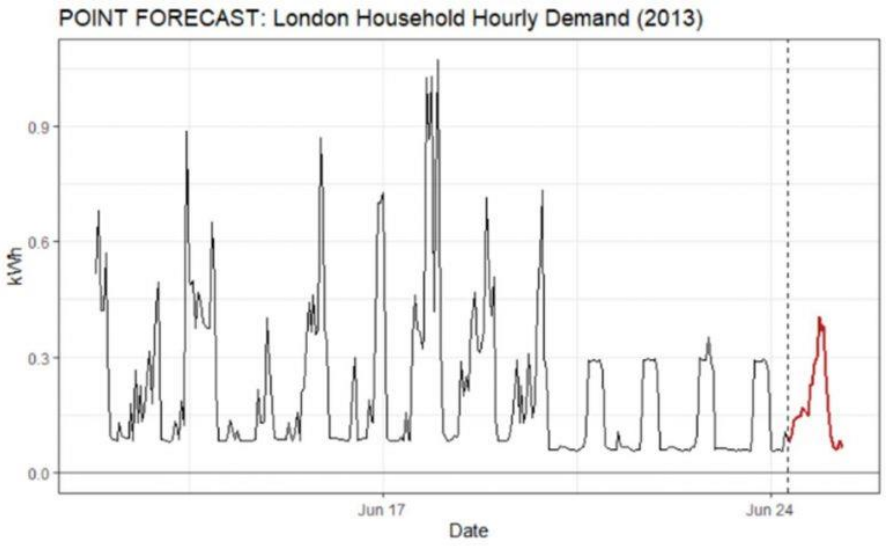


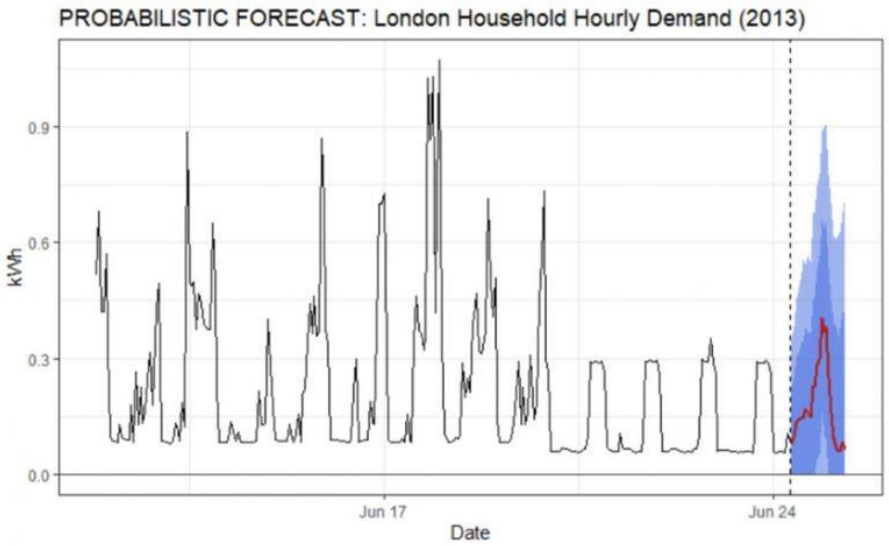
- Objective: Maximize energy and AS revenue
- Decision Variables:
  - (11 continuous + 2 binary) x #hours x #Scenarios (~6000)
- Constraints
  - 20 x #hours x #Scenarios (~10,000)
    - SOC calculation
    - Power Balance
    - Charging, discharging grid capacity limits
    - Scenario relationship
- Solver: glpk (an open source solver)

Forecasting Model

Common Issue in Probabilistic Forecast

- What's your use for your probabilistic forecast?
  - Most model assumes that it's the end results.
    - e.g. Calculating upper limits for transformer capacity?

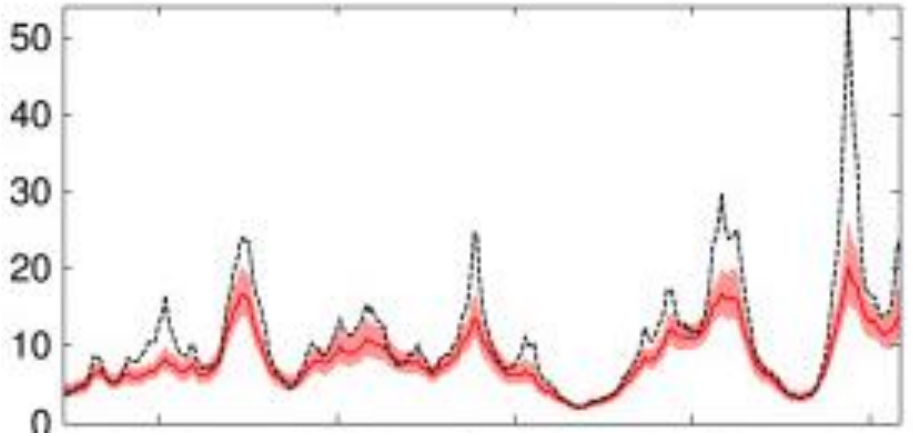




Source: https://utilityanalytics.com/2021/06/probabilistic-electricity-consumption-forecasting/

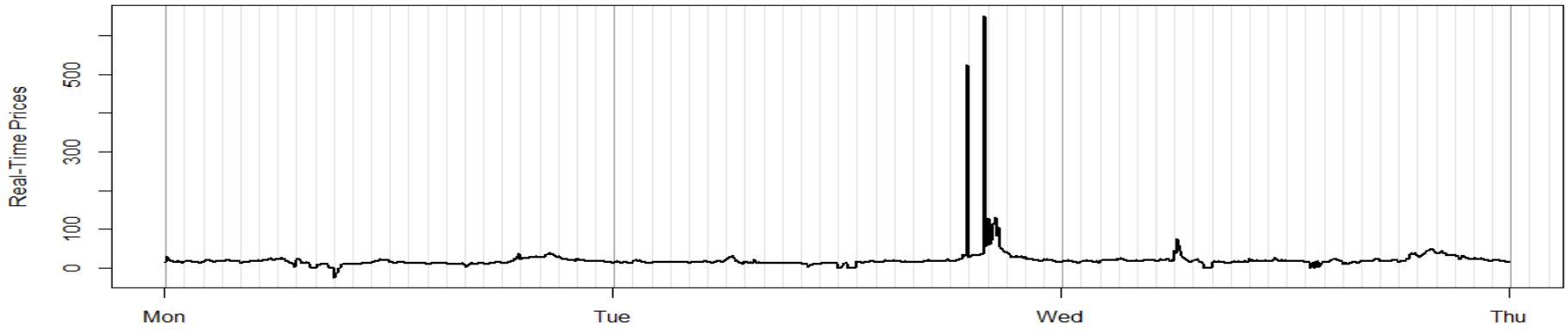
Calculating Errors

- Error as Gaussian distribution (Forecast + Error)
- Blanketing error values vs Scedasticity
  - Example: There are days when forecast is likely to be more accurate, and when we expect larger error variances (think weather).
- What do you do with spiky time series?
  - Good point forecast is a “moderate” forecast.



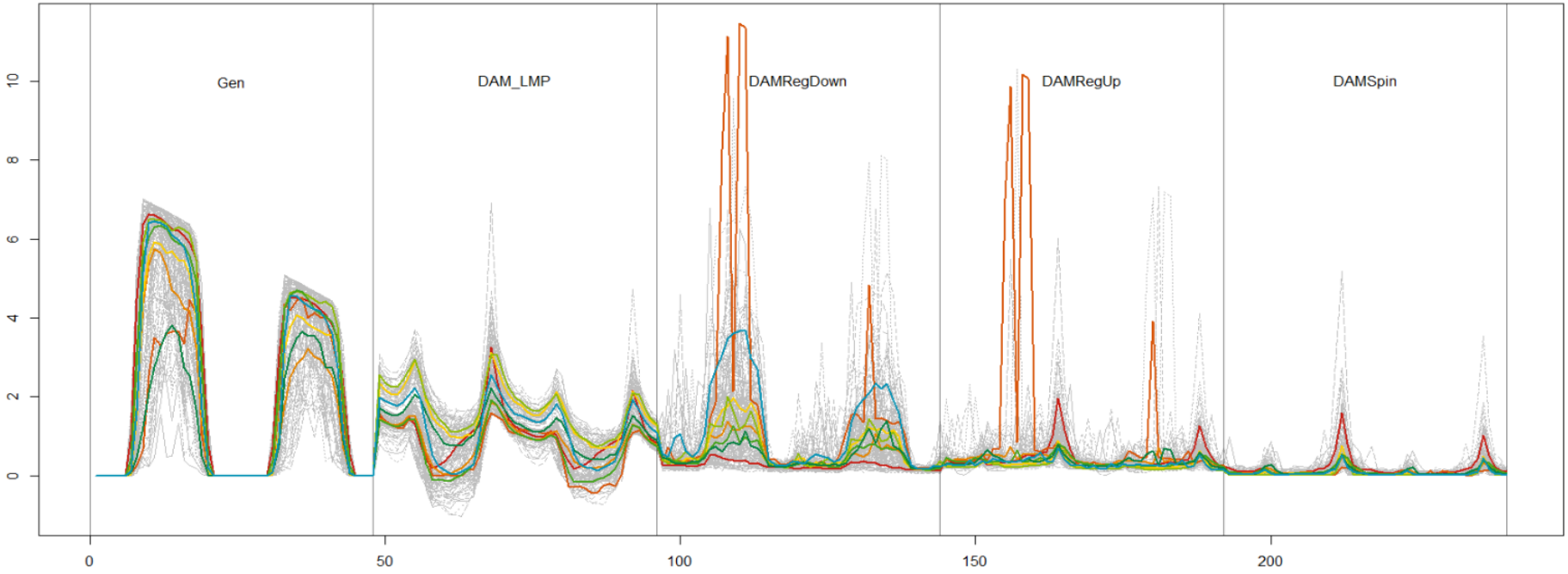
Alternative Method

- Observation:
  - Relative hourly shape matters, more than forecasting accuracy.
  - Controlling the number of scenarios matters, while capturing the distribution of possible outcomes.
- Approach
  - Come up with scenarios first, and assign probability using ML.



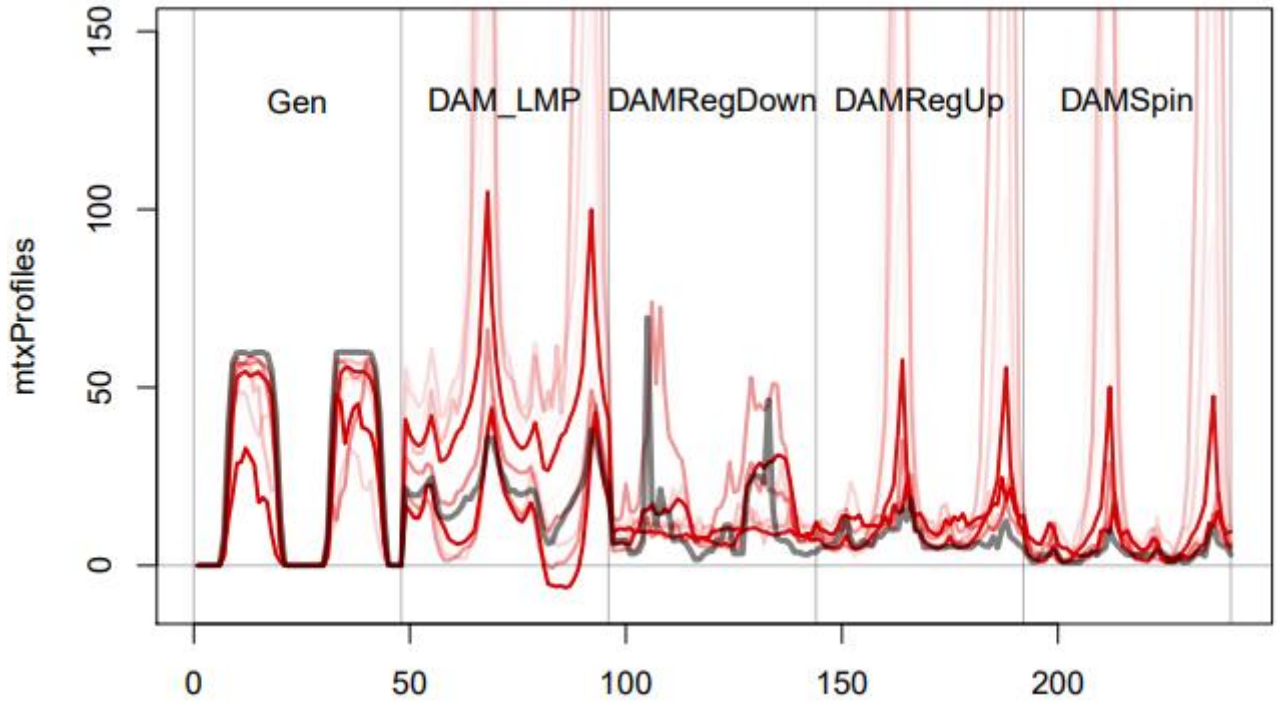
Profiling: K-means

- Importance discrimination with Scaling
  - All power prices are scaled together
  - More weight on Solar
  - More weight on the first day

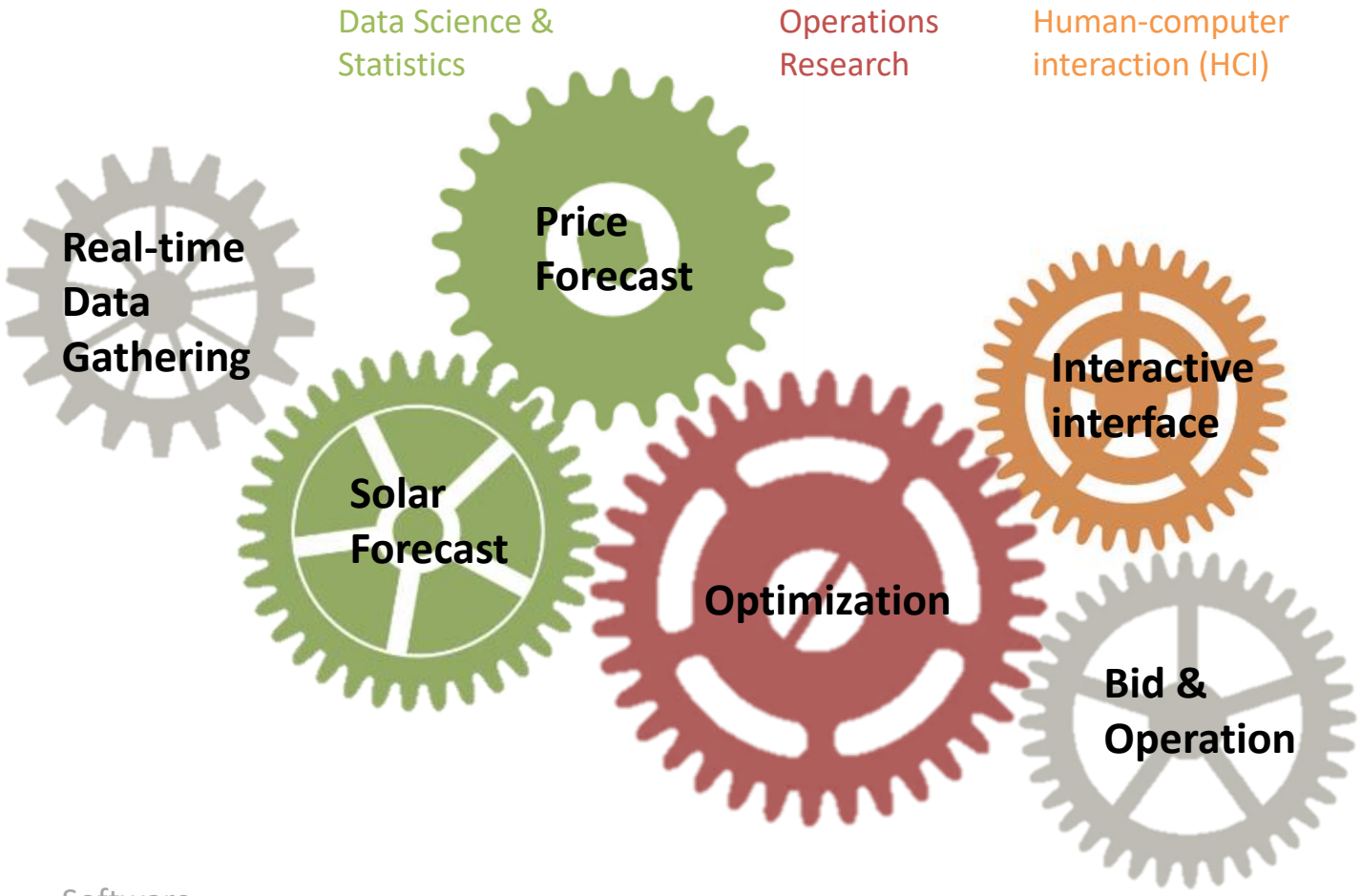


Predictive Classification

- Approaches:
  - multinomial classification (one-to-rest)
  - Random forecast



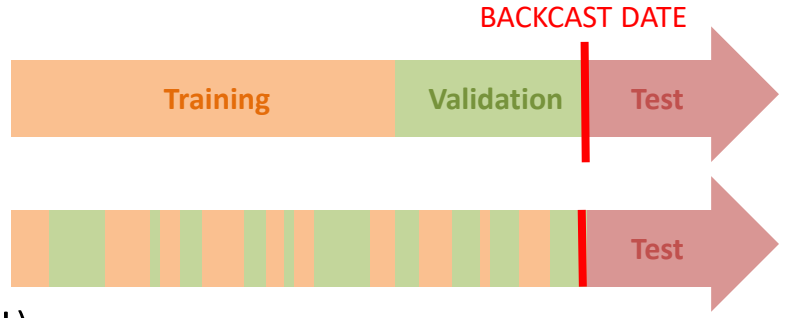
Operational Components



Verifications & Metrics

Backcasting in Data Science

- Regression
  - Partition into 3: train/validate/test.
- Time Series Forecasting
  - Additional care
    - Information leak (keep it ex-ante!)
    - Replicate training and tuning schedule within backcasting
- Operations Research Backcasting
  - Additional care…



As of 2021-01-03 10:00:00

- Going to bid for HE13 (the flow starts in 2 hours)
- SOC up to HE10 known.
- DA for the next day complete at 8:00
- RT award known up to HE12.
- SOC_RT estimate from HE12 bid is known, and will be updated with SOC + Award_RT.

Date	HE	Gen_DA	Price_DA	Award_DA	SOC_DA	Gen_RT	Price_RT	Award_RT	SOC_RT	SOC	Gen
2021-01-03	6	0.00	37.39142	0.00	84.00	0.0000	28.94661	0.0000	83.9575	83.9575	0.00
2021-01-03	7	0.00	40.90580	0.00	84.00	0.0000	30.21127	0.0000	83.9575	83.9575	0.00
2021-01-03	8	1.29	38.29182	1.30	84.00	2.7750	25.08602	2.7000	89.1415	89.1415	9.18
2021-01-03	9	16.50	27.89921	16.50	84.00	20.1525	5.06433	-22.1000	125.9895	125.9895	23.96
2021-01-03	10	29.35	6.95224	29.40	84.00	26.9450	14.35104	-15.3000	159.7855	158.8935	25.83
2021-01-03	11	26.71	0.65865	-15.50	126.24	27.1125	15.32399	-15.1000	193.5555	NA	35.84
2021-01-03	12	28.10	-0.01700	-14.10	168.48	31.2375	15.88510	31.2000	NA	NA	30.93
2021-01-03	13	29.63	3.10973	-12.60	210.72	NA	NA	NA	NA	NA	31.07
2021-01-03	14	32.67	4.77343	32.20	211.20	NA	NA	NA	NA	NA	19.25
2021-01-03	15	26.59	15.59274	26.60	211.20	NA	NA	NA	NA	NA	25.46
2021-01-03	16	16.58	28.88355	16.60	211.20	NA	NA	NA	NA	NA	5.99
2021-01-03	17	0.00	40.55652	0.00	211.20	NA	NA	NA	NA	NA	0.00
2021-01-03	18	0.00	58.20205	52.80	158.40	NA	NA	NA	NA	NA	0.00
2021-01-03	19	0.00	49.85030	52.80	105.60	NA	NA	NA	NA	NA	0.00
2021-01-03	20	0.00	47.37538	21.60	84.00	NA	NA	NA	NA	NA	0.00
2021-01-03	21	0.00	45.63975	0.00	84.00	NA	NA	NA	NA	NA	0.00
2021-01-03	22	0.00	42.31646	0.00	84.00	NA	NA	NA	NA	NA	0.00
2021-01-03	23	0.00	39.30123	0.00	84.00	NA	NA	NA	NA	NA	0.00
2021-01-03	24	0.00	36.28600	0.00	84.00	NA	NA	NA	NA	NA	0.00
2021-01-04	1	0.00	33.94637	0.00	84.00	NA	NA	NA	NA	NA	0.00
2021-01-04	2	0.00	32.36586	0.00	84.00	NA	NA	NA	NA	NA	0.00
2021-01-04	3	0.00	32.89556	0.00	84.00	NA	NA	NA	NA	NA	0.00
2021-01-04	4	0.00	32.57848	0.00	84.00	NA	NA	NA	NA	NA	0.00
2021-01-04	5	0.00	32.95470	0.00	84.00	NA	NA	NA	NA	NA	0.00
2021-01-04	6	0.00	35.70969	0.00	84.00	NA	NA	NA	NA	NA	0.00
2021-01-04	7	0.00	39.45222	0.00	84.00	NA	NA	NA	NA	NA	0.00
2021-01-04	8	1.92	35.12976	1.90	84.00	NA	NA	NA	NA	NA	9.72
2021-01-04	9	12.87	26.79485	12.90	84.00	NA	NA	NA	NA	NA	17.19
2021-01-04	10	18.92	16.02174	18.90	84.00	NA	NA	NA	NA	NA	27.54
2021-01-04	11	13.34	10.29815	-28.90	126.24	NA	NA	NA	NA	NA	36.56
2021-01-04	12	12.20	6.89511	-30.00	168.48	NA	NA	NA	NA	NA	30.66
2021-01-04	13	10.65	9.00059	-31.60	210.72	NA	NA	NA	NA	NA	8.78
2021-01-04	14	10.53	11.77660	10.00	211.20	NA	NA	NA	NA	NA	10.38
2021-01-04	15	11.01	15.49464	11.00	211.20	NA	NA	NA	NA	NA	12.77
2021-01-04	16	11.00	28.43518	11.00	211.20	NA	NA	NA	NA	NA	13.69
2021-01-04	17	0.01	40.85995	0.00	211.20	NA	NA	NA	NA	NA	0.00
2021-01-04	18	0.00	54.20222	52.80	158.40	NA	NA	NA	NA	NA	0.00
2021-01-04	19	0.00	48.30361	52.80	105.60	NA	NA	NA	NA	NA	0.00
2021-01-04	20	0.00	44.97708	21.60	84.00	NA	NA	NA	NA	NA	0.00
2021-01-04	21	0.00	43.97662	0.00	84.00	NA	NA	NA	NA	NA	0.00
2021-01-04	22	0.00	40.66146	0.00	84.00	NA	NA	NA	NA	NA	0.00
2021-01-04	23	0.00	37.95858	0.00	84.00	NA	NA	NA	NA	NA	0.00
2021-01-04	24	0.00	35.25571	0.00	84.00	NA	NA	NA	NA	NA	0.00
2021-01-05	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
2021-01-05	2	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
2021-01-05	3	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00

Why Backcast?

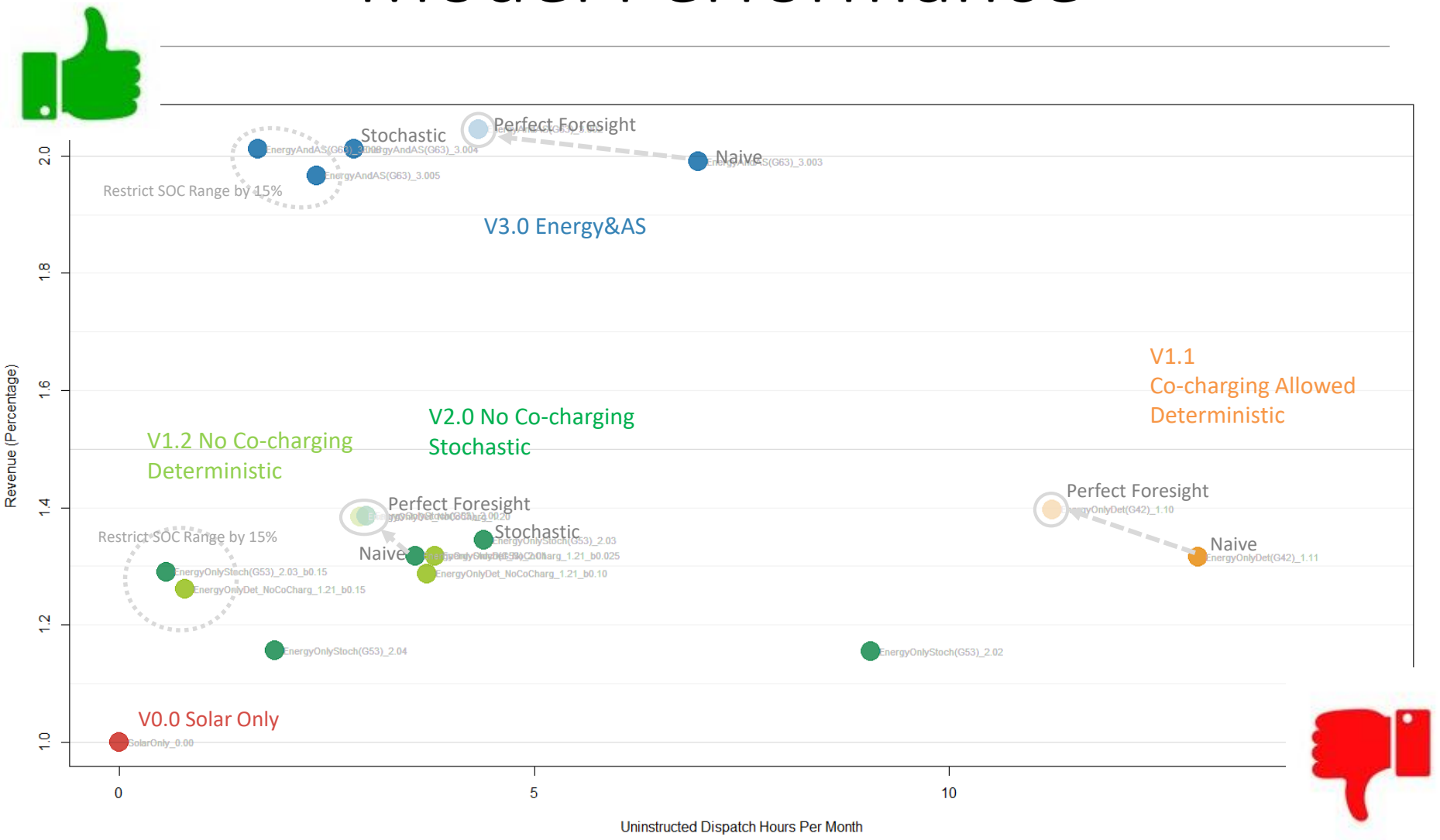
Settings

- Jul-2020, Oct-2020, Jan-2021 & Apr-2021
- Mock solar data
- 1 Day-Ahead run + 24 RT runs per day

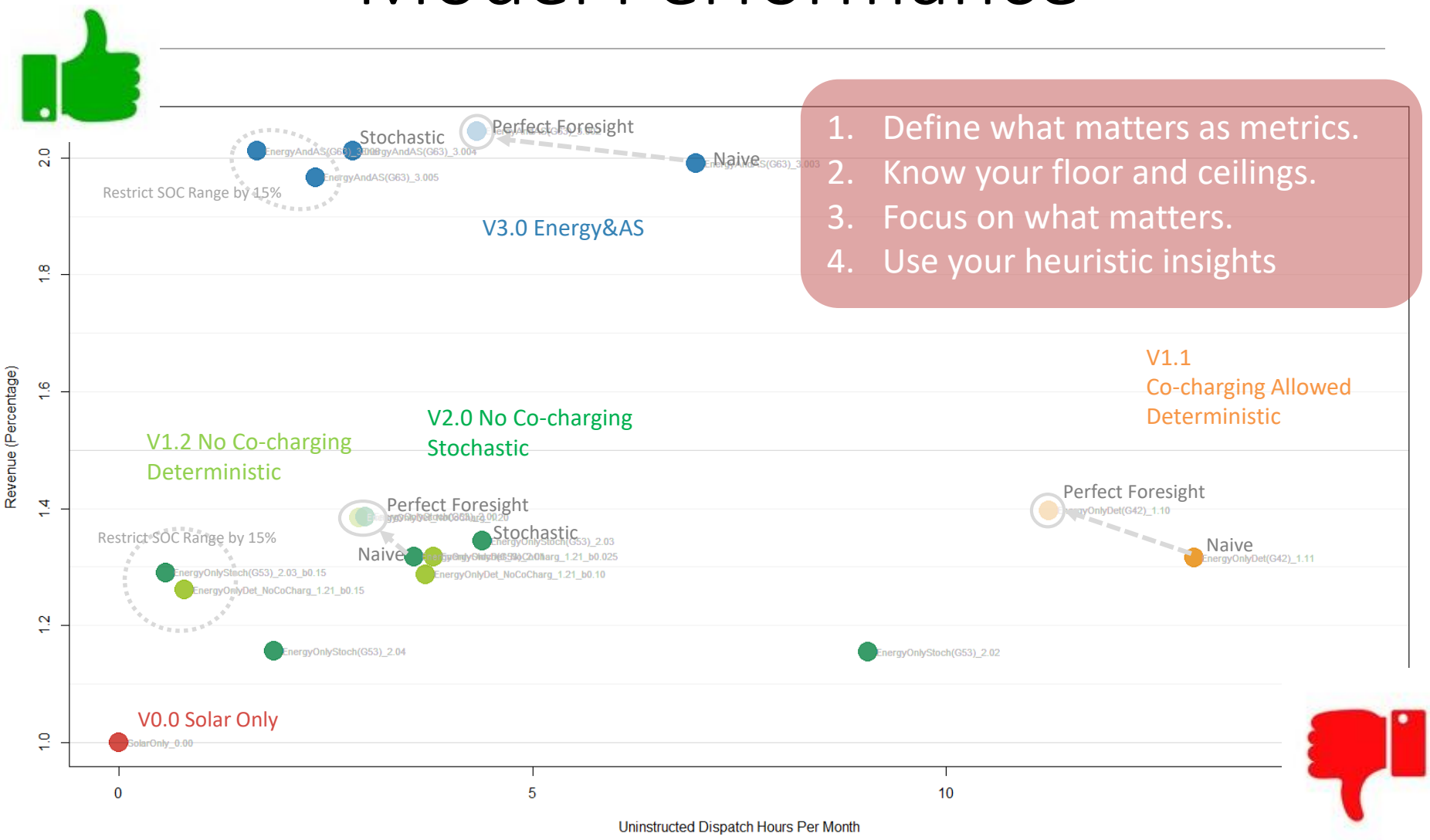
Why Backcast?

- Check additional complexity is actually worth.
- Make sure that optimization produces reasonable results under many different scenarios.
- Make sure that model results are actually operational in 5 min granularity.

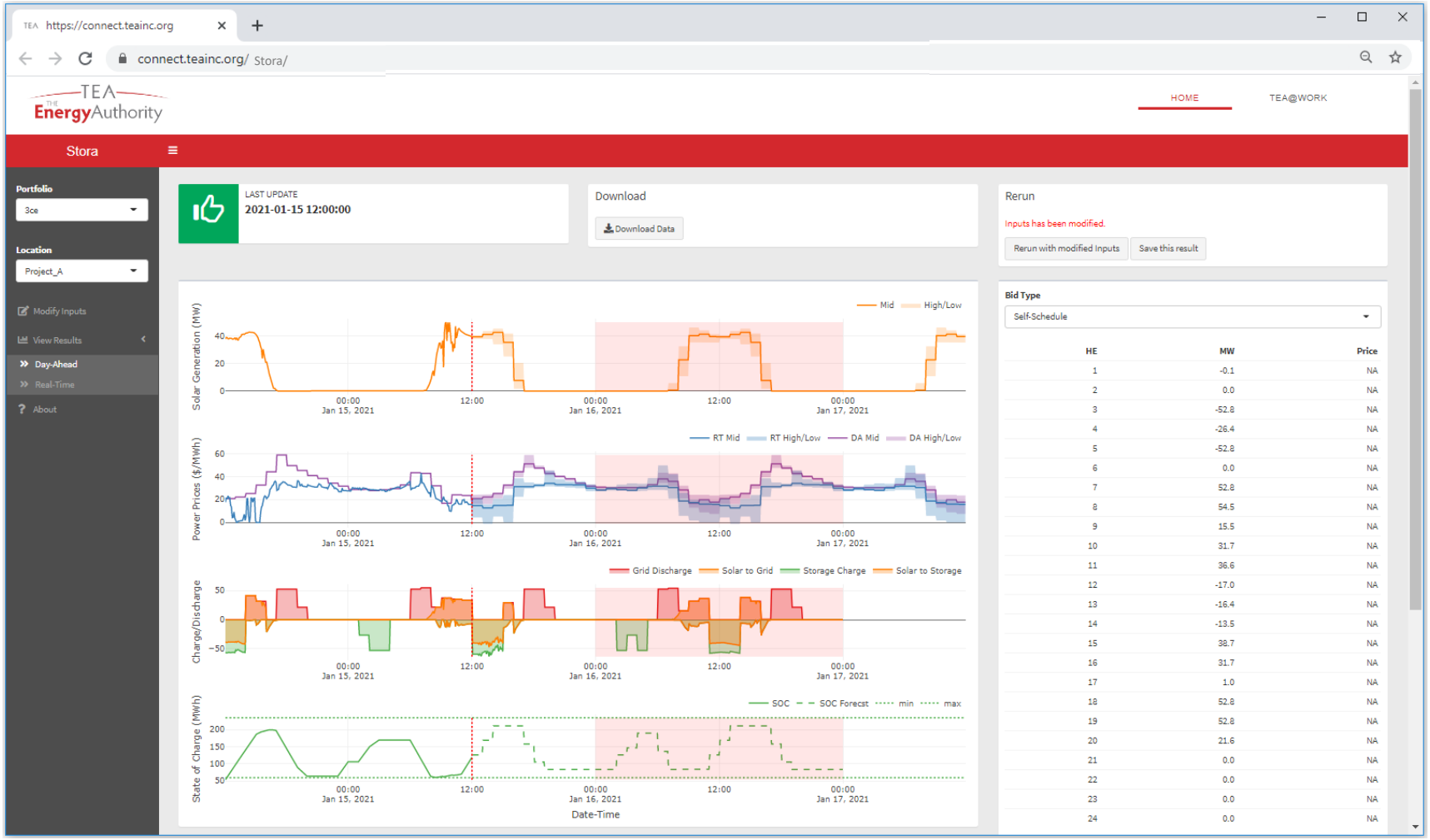
Model Performance



Model Performance

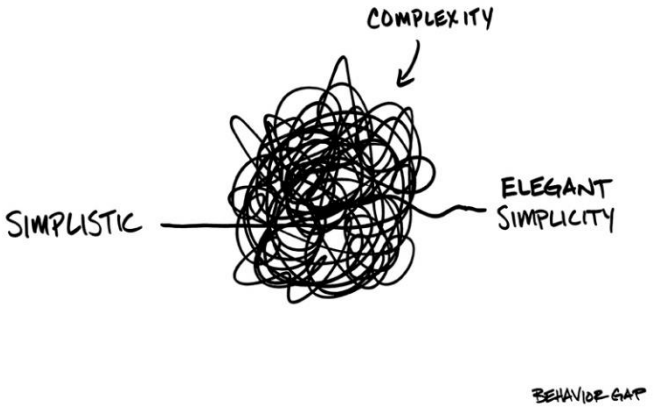


Operational User Interface



Lessons Learned

- Know your requirements & goals.
- Find methods that suite the problems.
- Know how to evaluate your model.
  - Don’t scamper of building realistic backcasting
- Adopt agile deployments
- Try to find a solution beyond complexity by studying the behavior of the system.



Acknowledgement

Model Development Team

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Thank you! Questions?

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