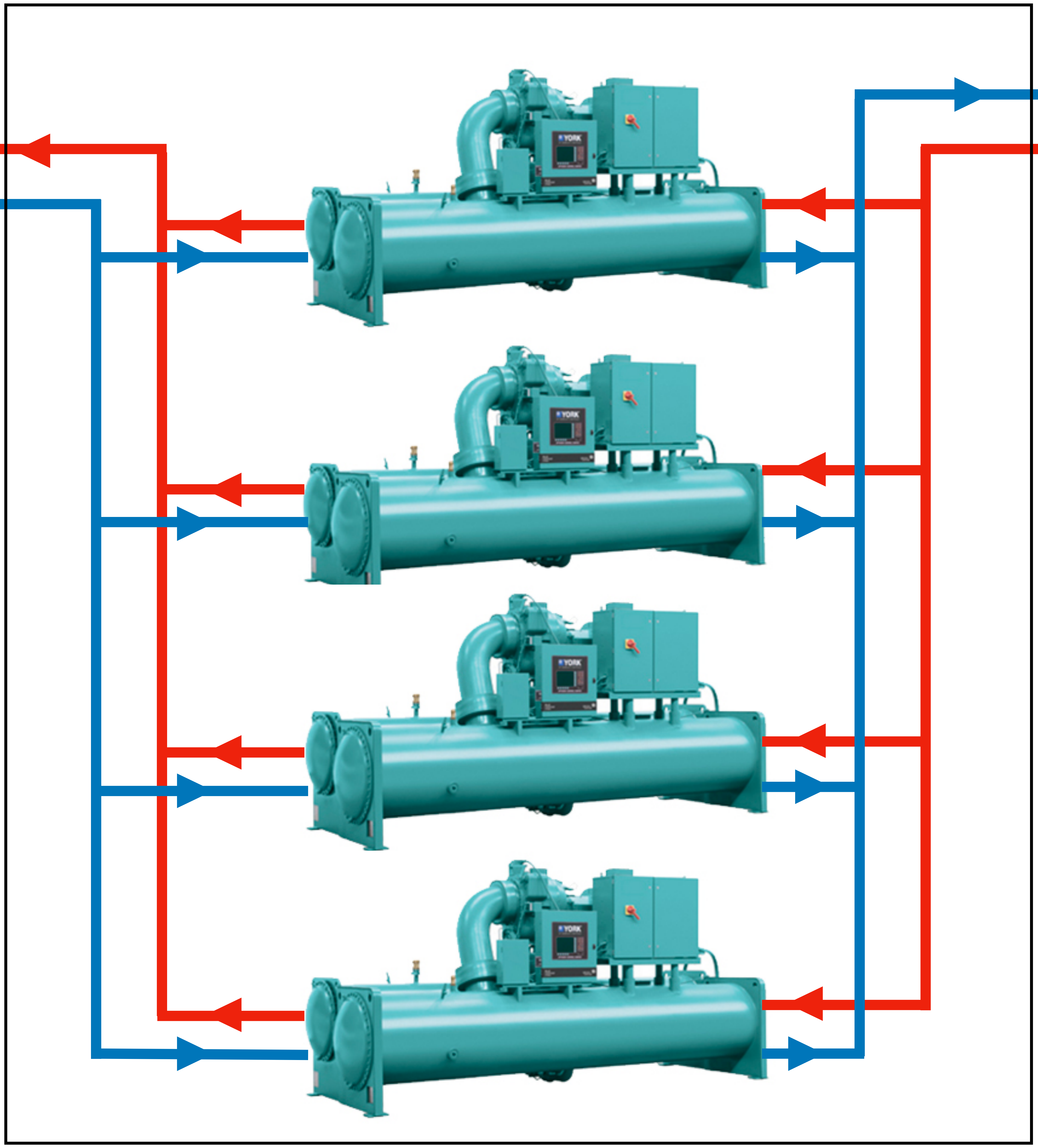
Predicting Industrial Chiller Performance

Dana Lindquist, PhD

Chiller = Heat Exchanger

Cooling towers used to remove heat



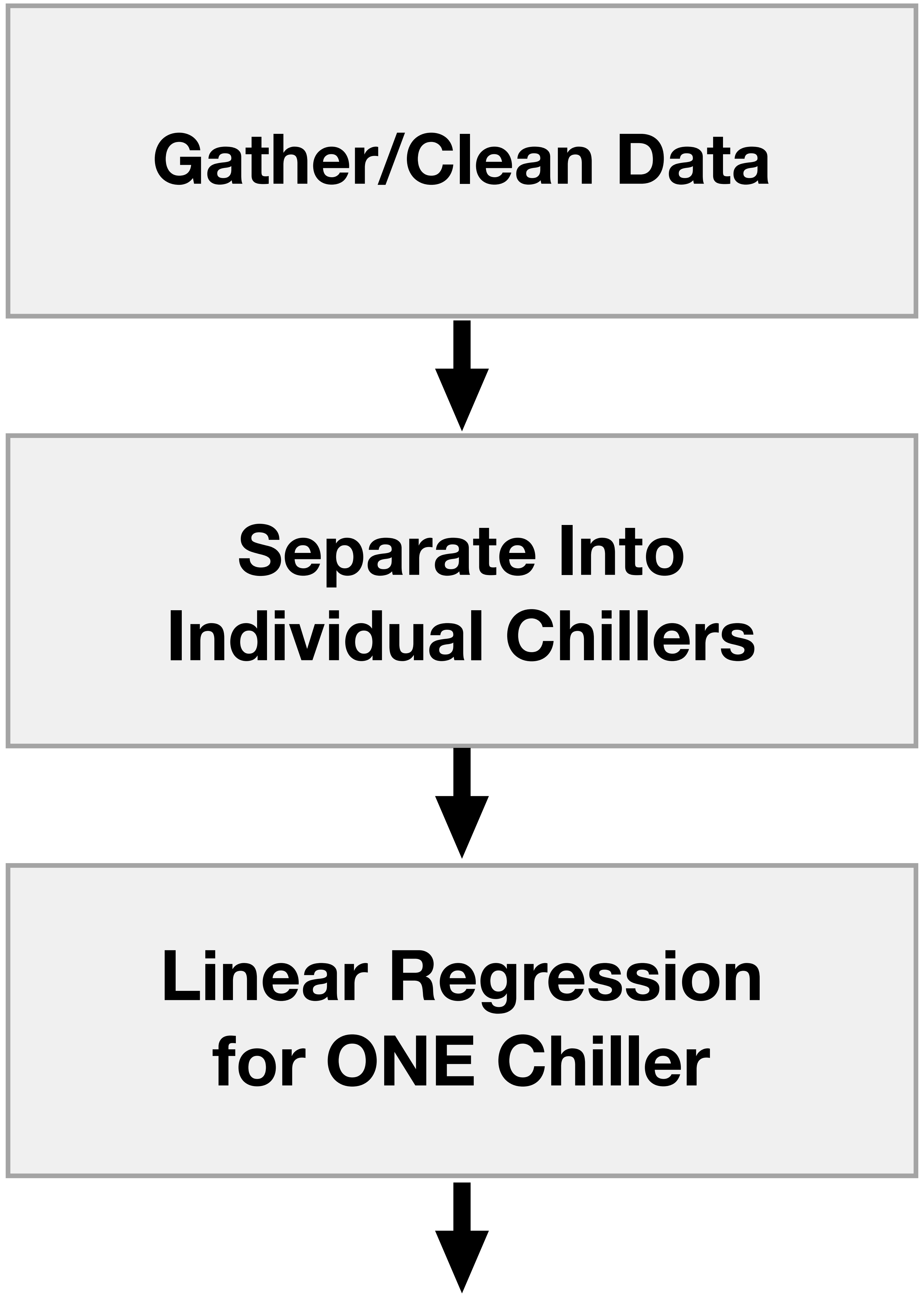
Supply cold water to buildings

OPTIMUMENERGY

Thank you to Optimum Energy For providing chiller data

Chiller Plants

- Chiller manufacturers provide some limited design specifications when they sell a Chiller (usually end up collecting dust in a filing cabinet).
- Most Chiller Plant operators do not think about efficiency.
- Optimum Energy collects data on Chiller Plants.

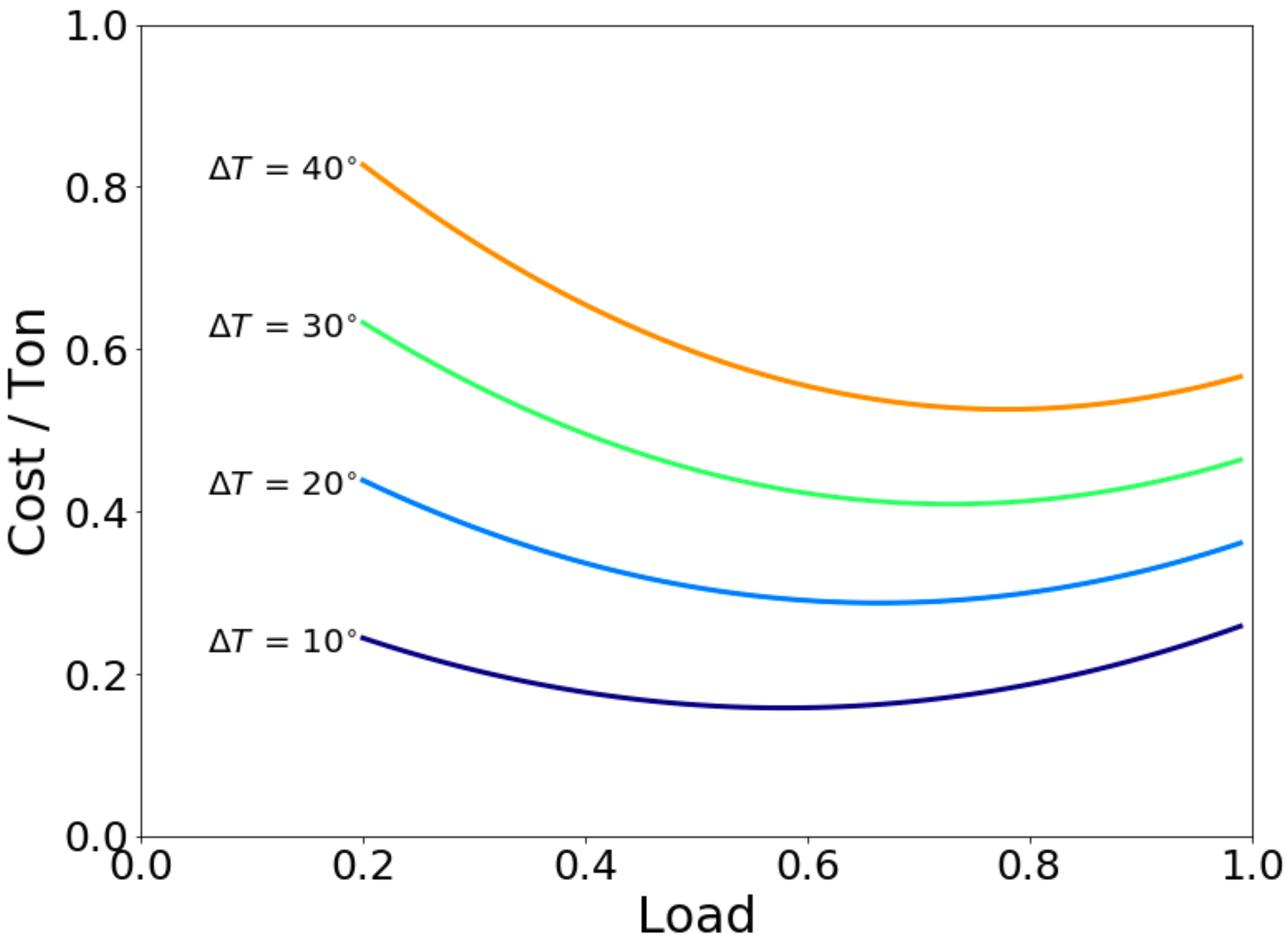


Remove data when Chiller in ALARM or just starting or stopping

30 distinct but similar Chillers
8 different sizes & configurations

Scikit-learn Linear Regression with LASSO Regularization

Just One Chiller



Ton = unit of refrigeration

Load = how hard the
Chiller is working
(fraction of max power)

Quadratic in Load

$$\text{Cost/Ton} = (A + B\,\Delta\text{T}) + (C + D\,\Delta\text{T})\,\text{Load} + (E + F\,\Delta\text{T})\,\text{Load}^2$$

Want to predict *A, B, C, D, E & F* based on chiller characteristics

Combine ALL Chillers in to One Dataset

1 million data points

Add Chiller Characteristics to Dataset

Rated Tons, Variable Speed or not, . . .

Determine constants in Quadratic based on Chiller Characteristics

1. **Linear Regression**

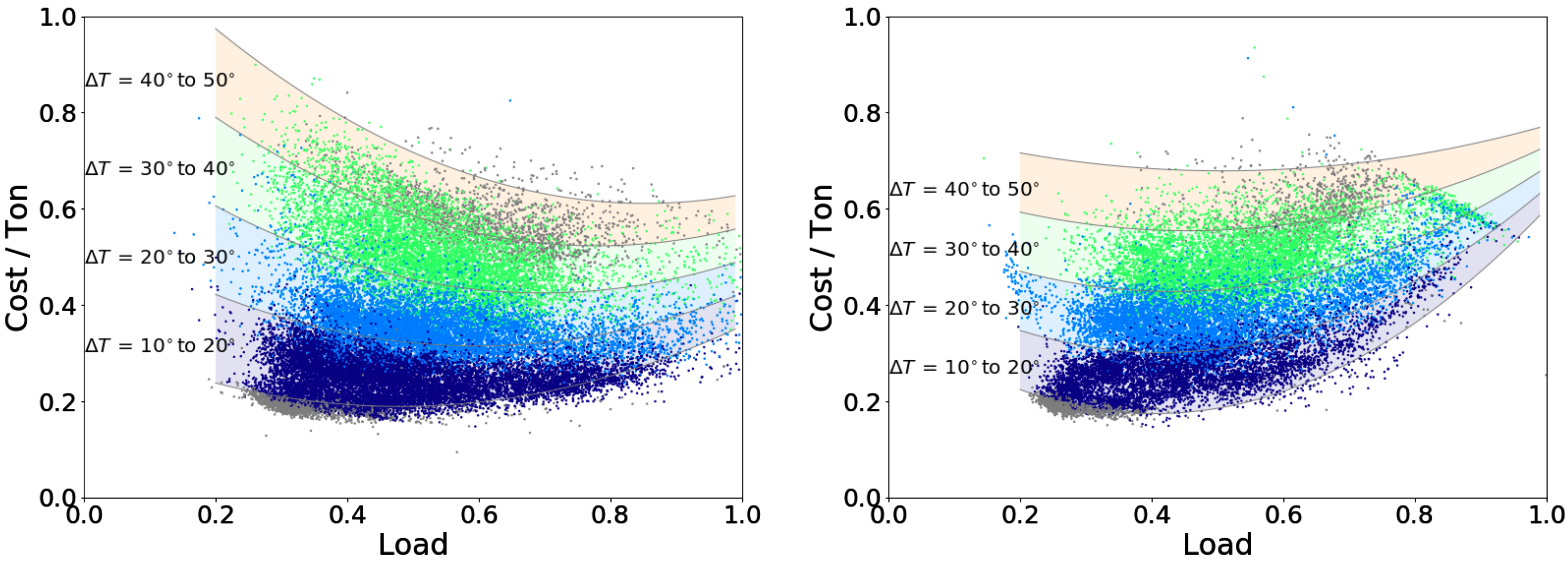
Predict quadratic constants

2. **Bayesian Model using PYMC3**

Has the ability to extend this analysis to more chiller characteristics

Results

Two DIFFERENT 900 Ton Chillers



How to Run the Plant Efficiently?

Requirement:

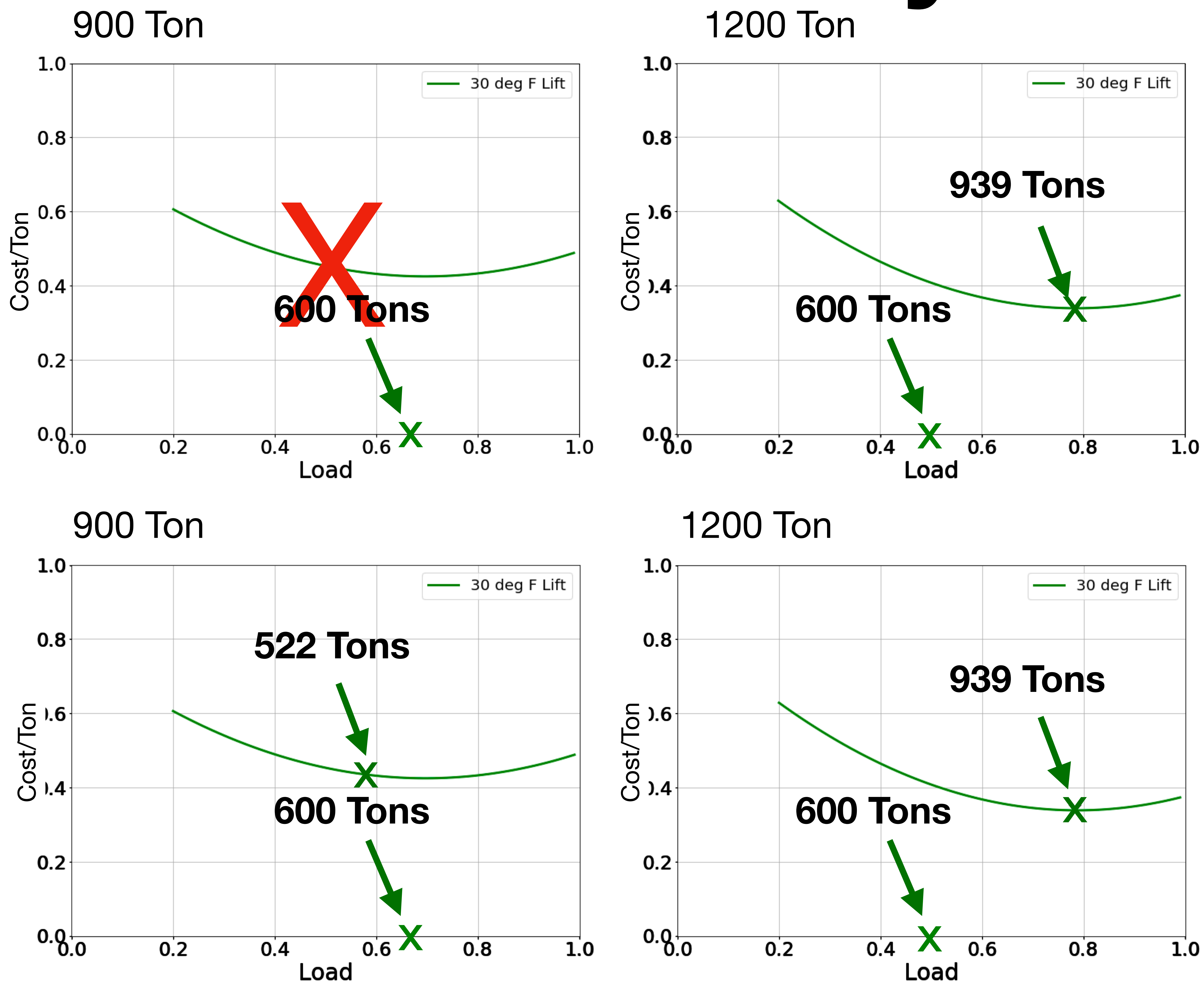
2400 Tons of cooling

30° F ΔT

Goal: Lowest Cost

Run all 4 chillers at 600 Tons each

Saving $12,000 (16%) per year



Conclusion

Given the data, we can predict Chiller performance

With a model for the system, we can make intelligent decisions on how to operate the system.

Thank You

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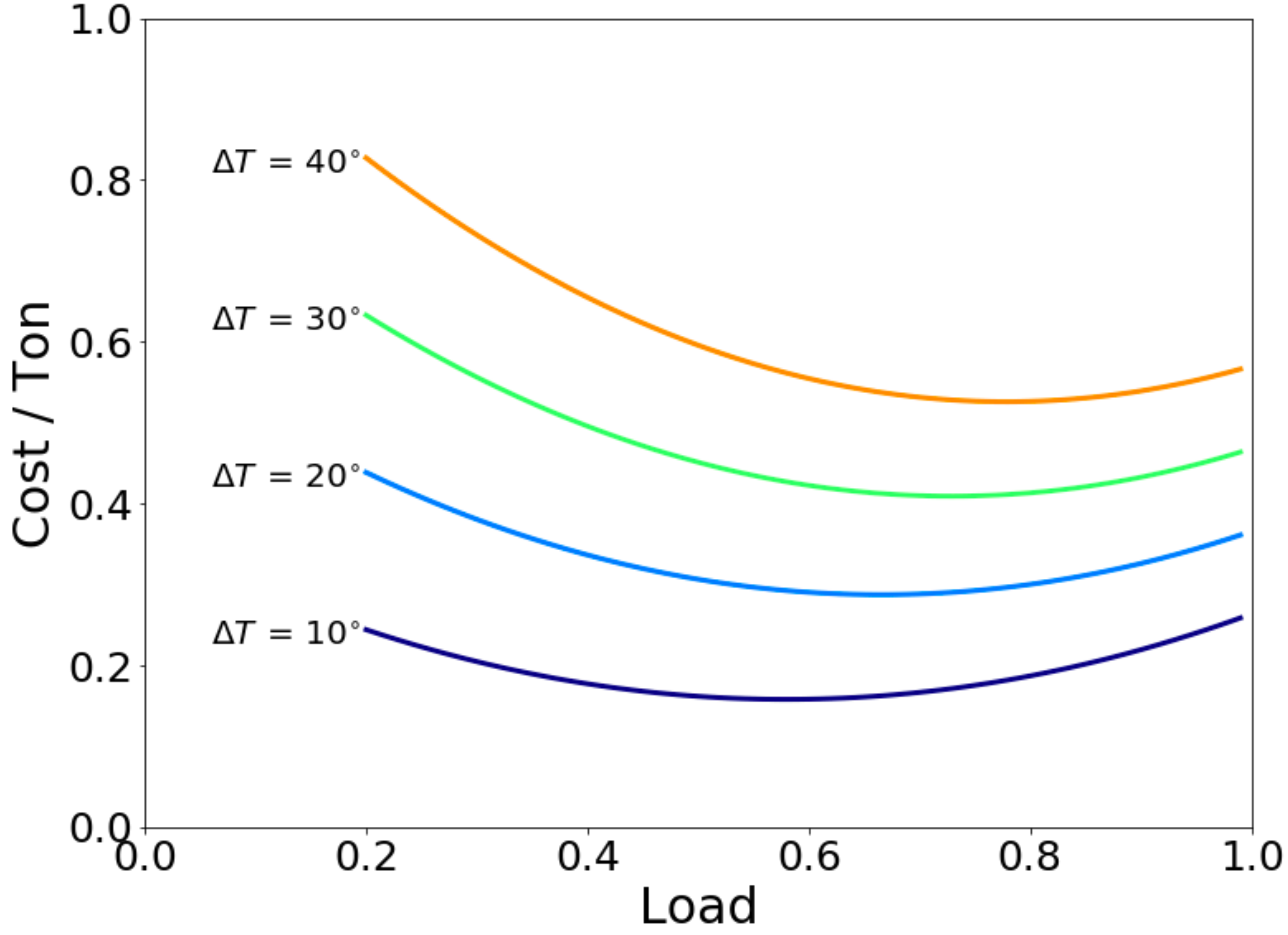
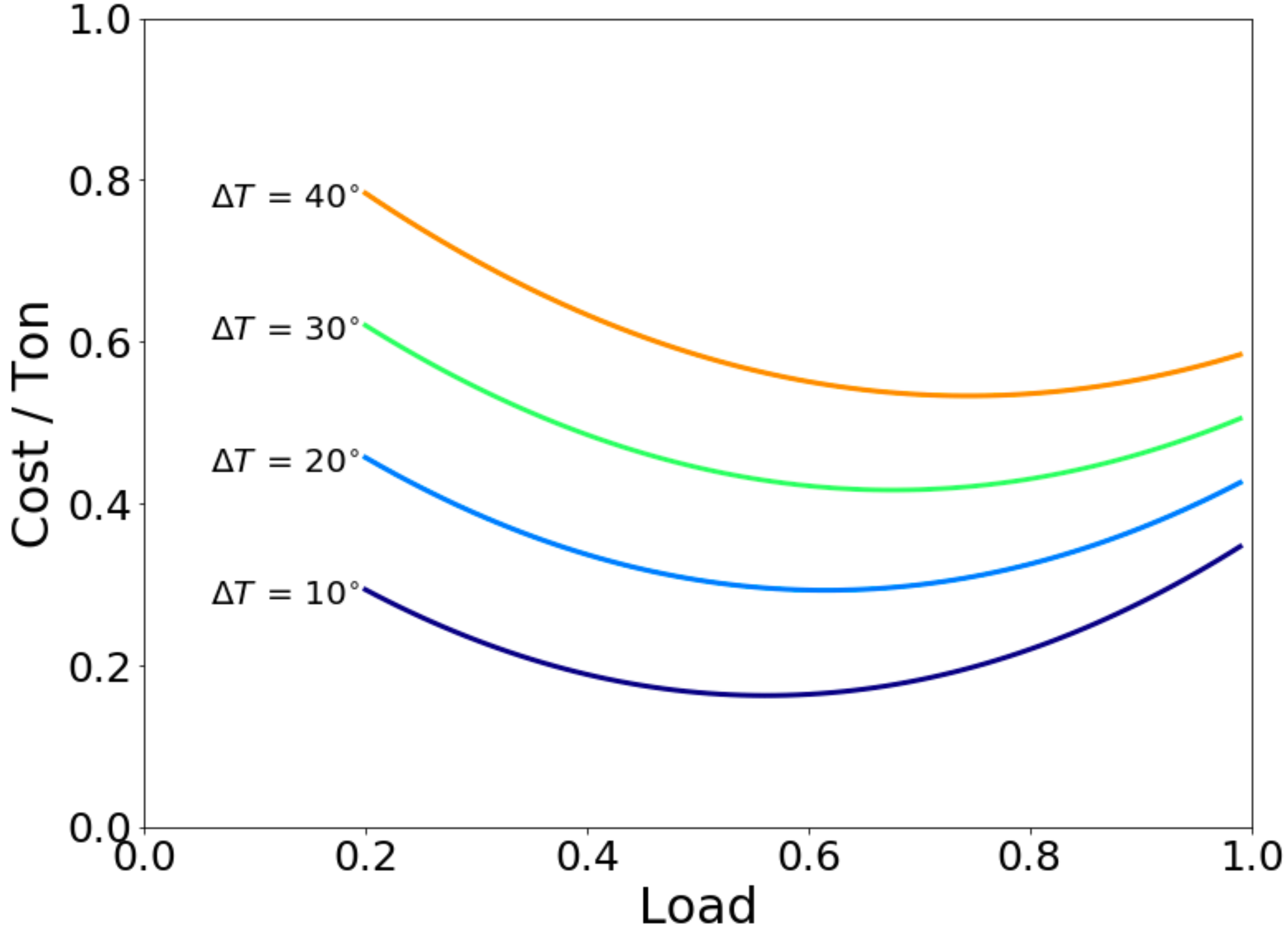
PyMC3

Scikit-learn Linear Regression



PyMC3



PyMC3

$$Cost/Ton_{obs} \;=\; (A \;+\; B\,\Delta T) \;+\; (C \;+\; D\,\Delta T)\,Load \;+\; (E \;+\; F\,\Delta T)\,Load^2$$

$$Cost/Ton \;=\; \mathcal{N}(Cost/Ton_{obs}, \mu, \sigma)$$

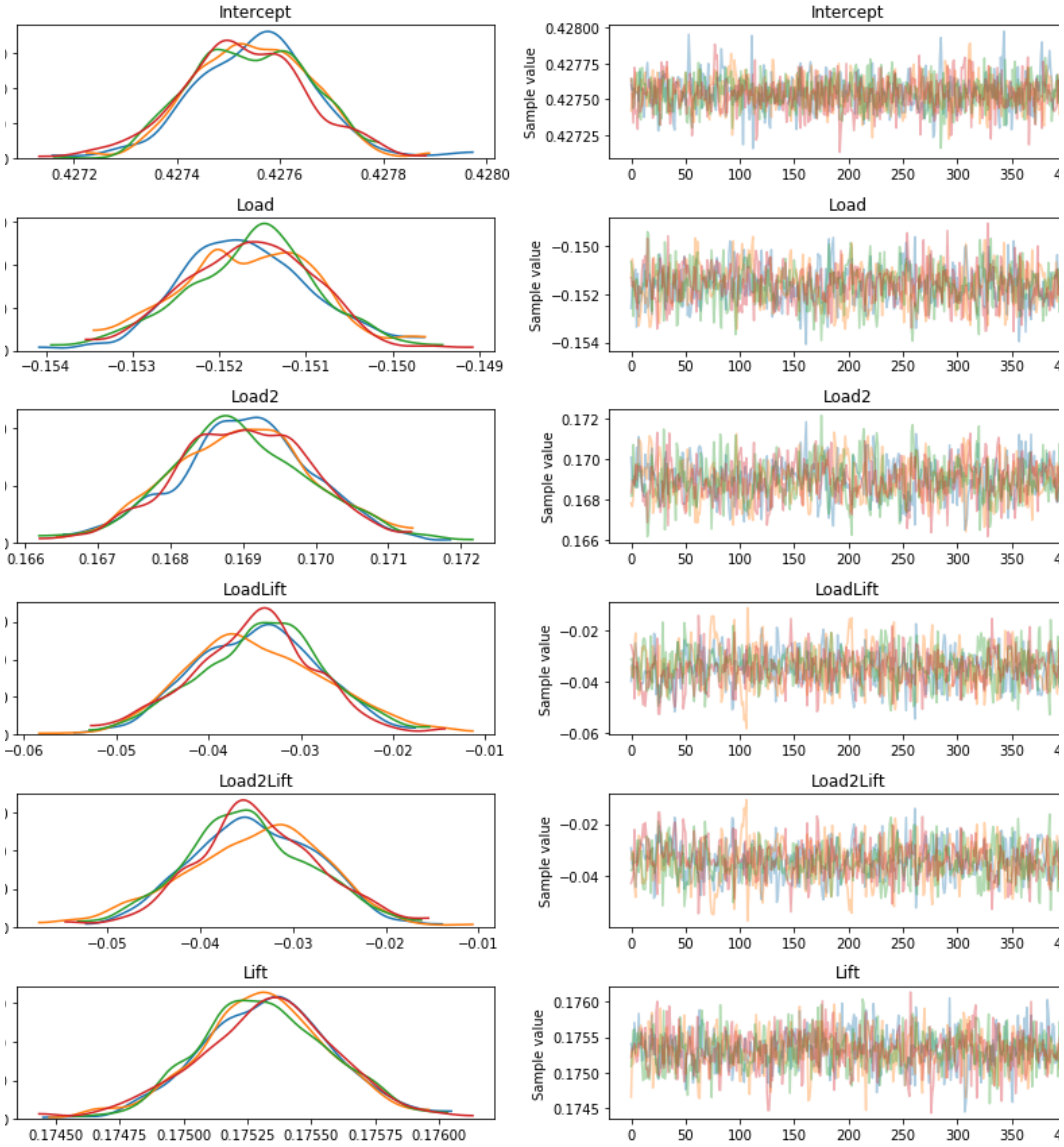
$$A, B, C, D, E \,\&\, F \;=\; \mathcal{N}(\mu, \sigma)$$

PyMC3

```
with Model() as model:
    sigma = HalfCauchy('sigma', beta=10)
    inter = Normal('Intercept', 0, sd=.01)
    D_coef = Normal('Load', 0, sd=.01)
    D2_coef = Normal('Load2', 0, sd=.01)
    DT_coef = Normal('LoadLift', 0, sd=.01)
    D2T_coef = Normal('Load2Lift', 0, sd=.01)
    T_coef = Normal('Lift', 0, sd=.01)

    # Define likelihood
    likelihood = Normal('kWTon', mu=inter +
                D_coef * X['Load'] + D2_coef*X['Load^2'] + T_coef*X['DTLift']
                + DT_coef*X['Load^2*DTLift'] +
                D2T_coef*X[‘Load^2*DTLift'],
                sd=sigma, observed=y)
```

PyMC3



Intercept
Intercept
Sample value
Load
Load
Sample value
Load2
Load2
Sample value
LoadLift
LoadLift
Sample value
Load2Lift
Load2Lift
Sample value
Lift
Lift
Sample value