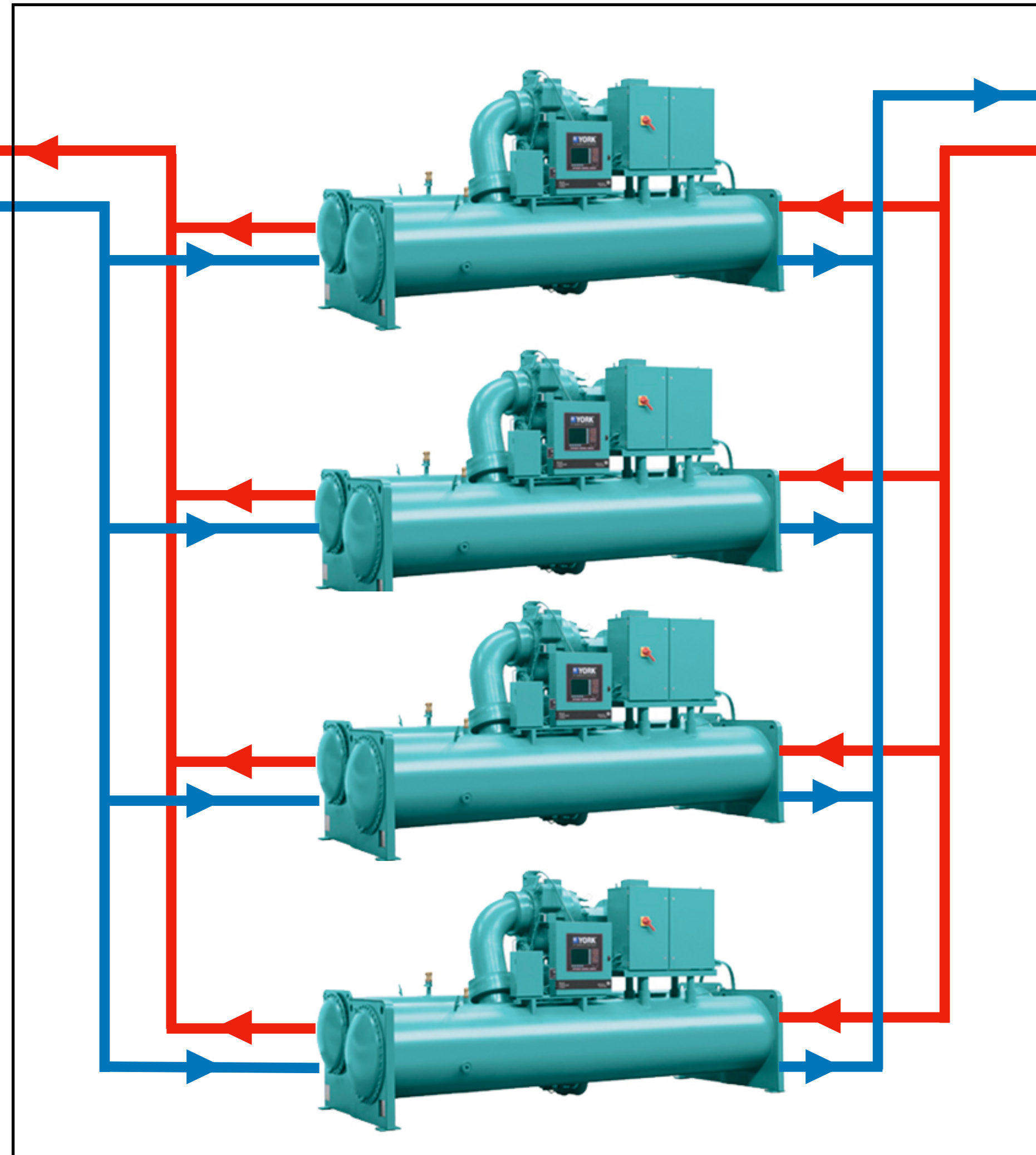# Predicting Industrial Chiller Performance

Dana Lindquist, PhD

Chiller = Heat Exchanger

Cooling towers used
to remove heat

Supply cold water
to buildings

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.

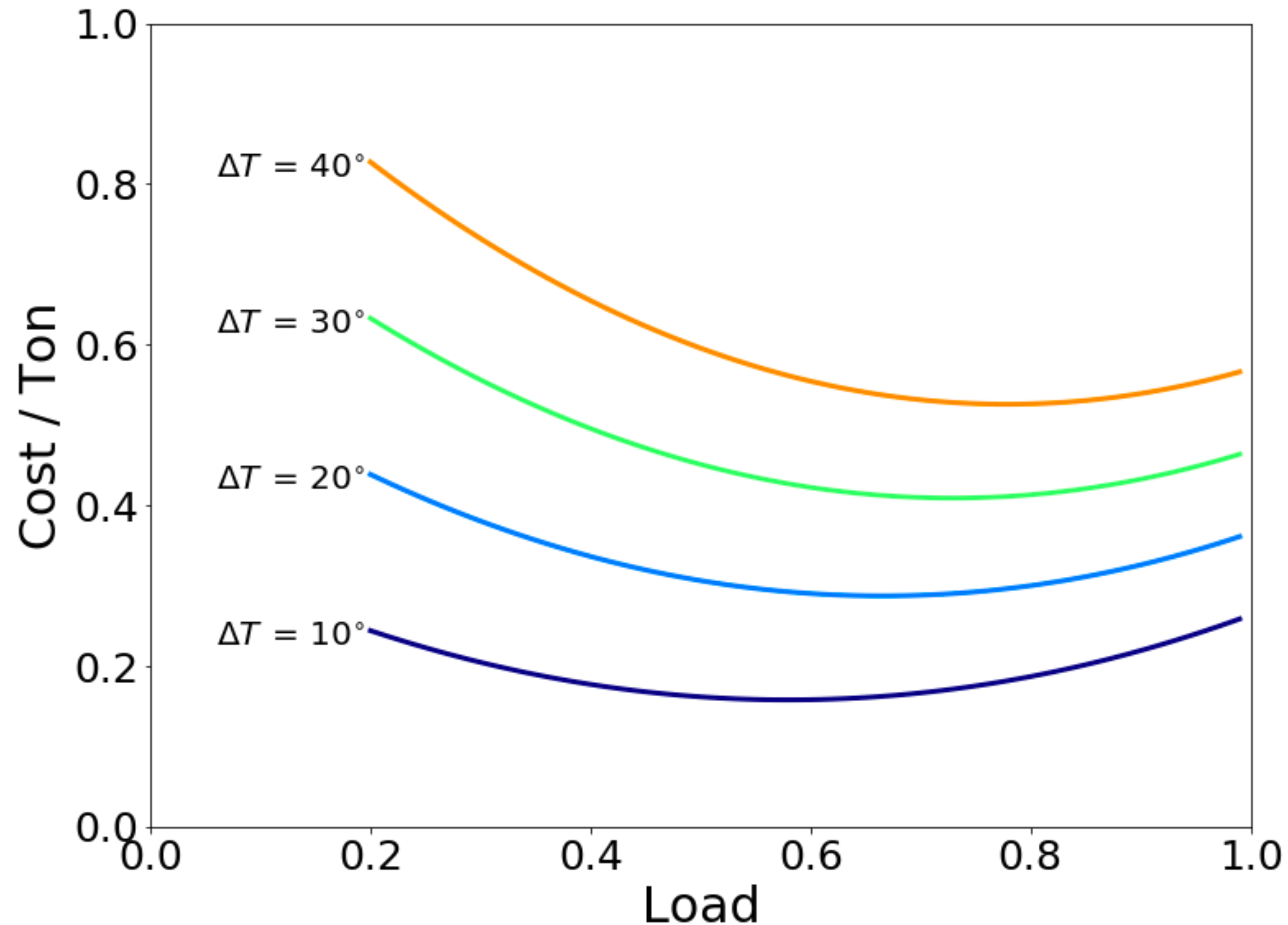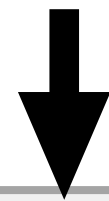|	
Gather/Clean Data	Remove data when Chiller in ALARM or just starting or stopping
↓	
Separate Into Individual Chillers	30 distinct but similar Chillers 8 different sizes & configurations
↓	
Linear Regression for ONE Chiller	Scikit-learn Linear Regression with LASSO Regularization
↓	

Just One Chiller

Ton = unit of refrigeration

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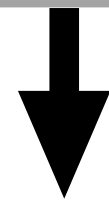   (fraction of max power)

Quadratic in Load

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

(chart) Cost / Ton vs Load, with curves labeled $\Delta T = 40°$, $\Delta T = 30°$, $\Delta T = 20°$, $\Delta T = 10°$

Want to predict *A, B, C, D, E & F* based on chiller characteristics
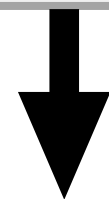
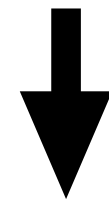**Combine ALL Chillers in to One Dataset**

1 million data points

Add Chiller Characteristics to Dataset

Rated Tons, Variable Speed or not, . . .

Determine constants in Quadratic based on Chiller Characteristics
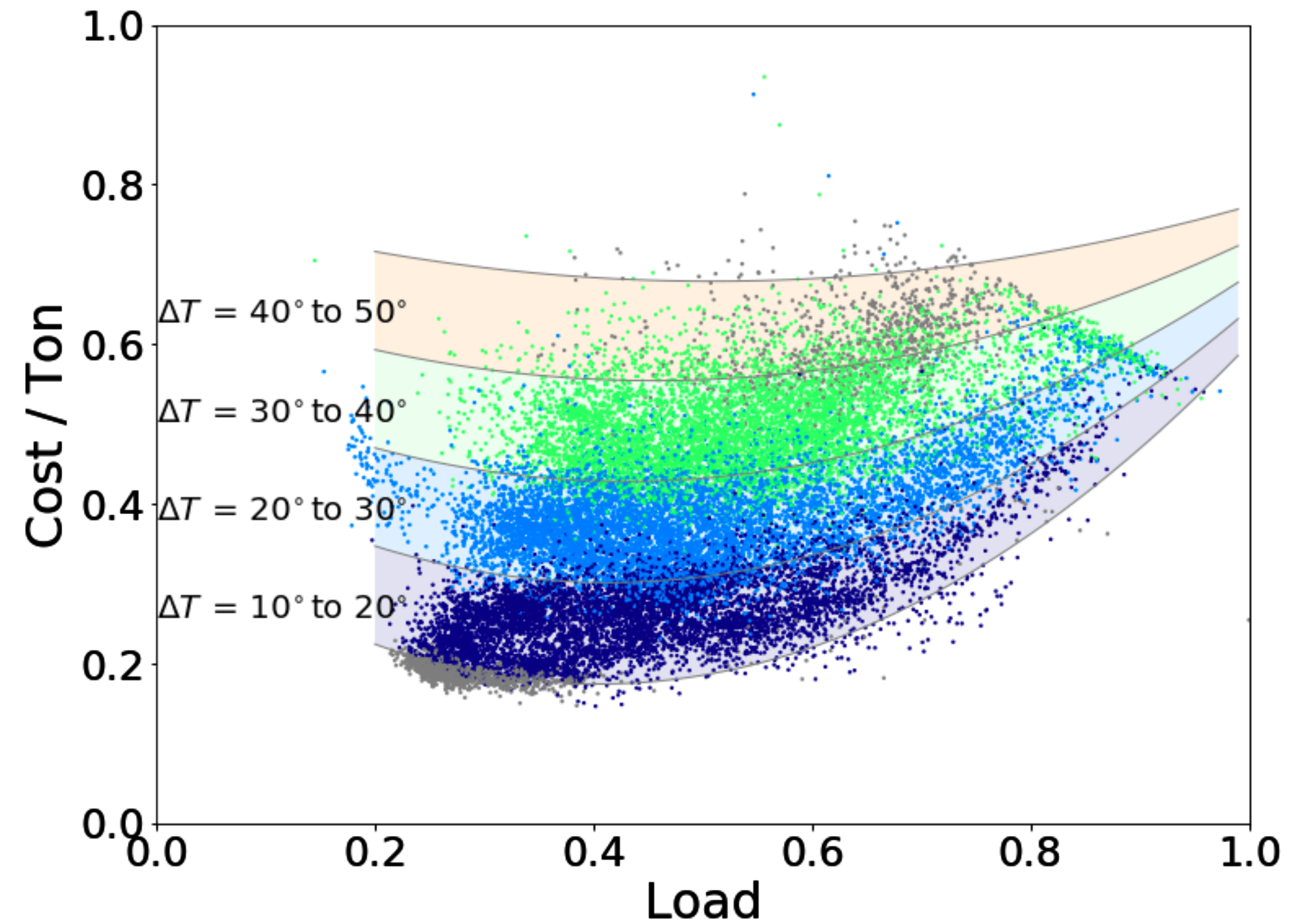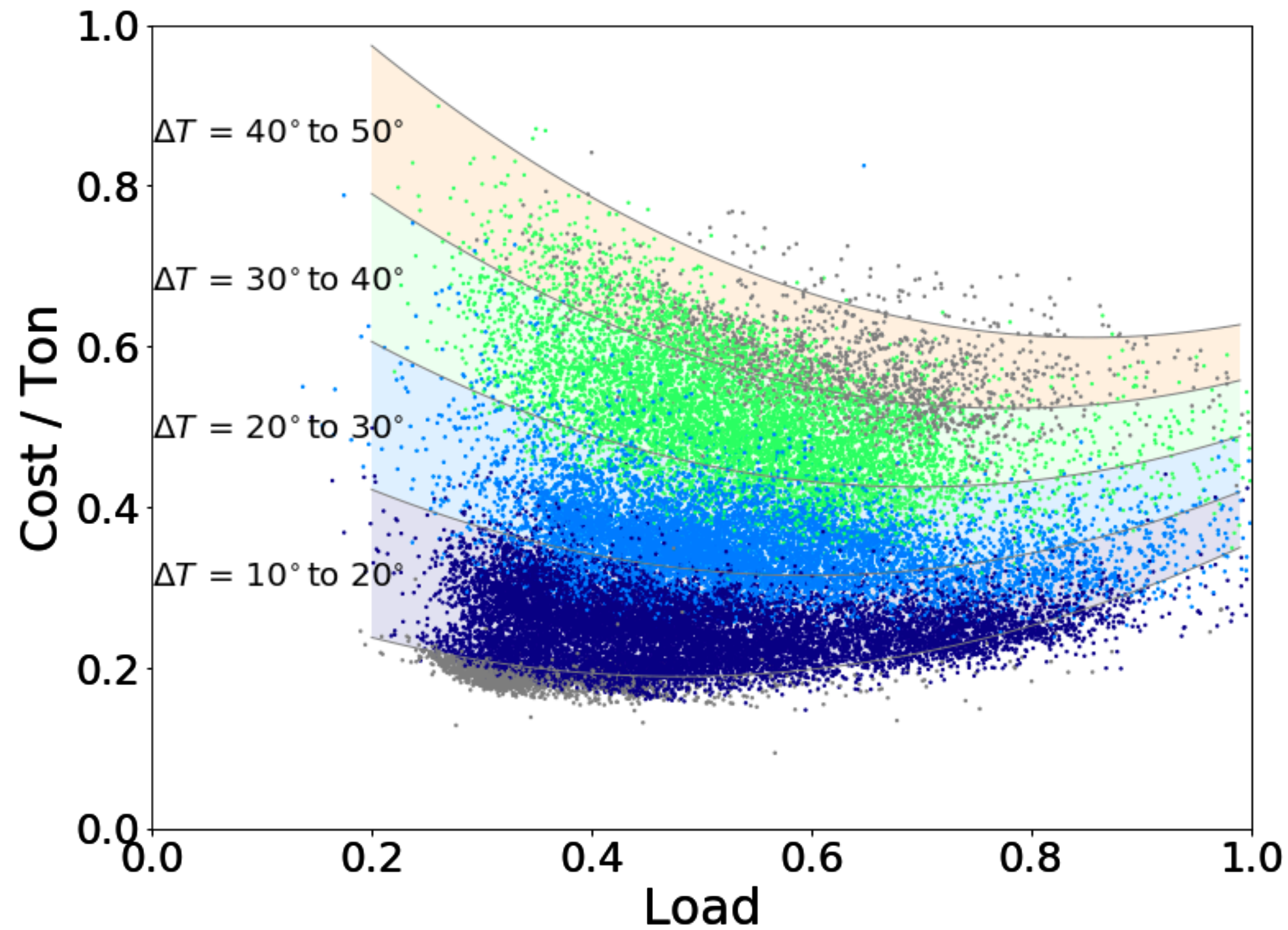
1. **Linear Regression**

2. **Bayesian Model using PYMC3**

Predict quadratic constants

Has the ability to extend this analysis to more chiller characteristics

Results

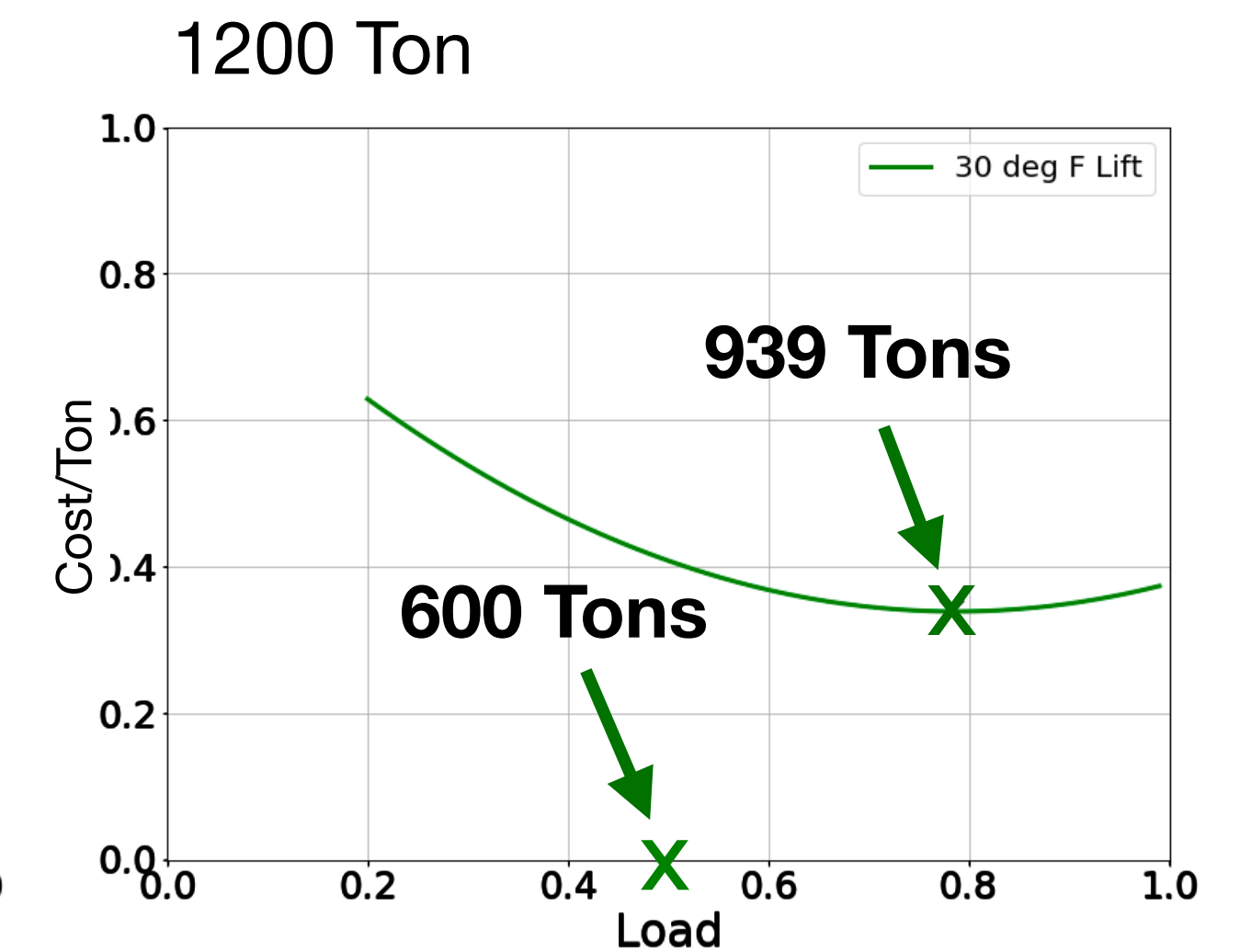Two DIFFERENT 900 Ton Chillers
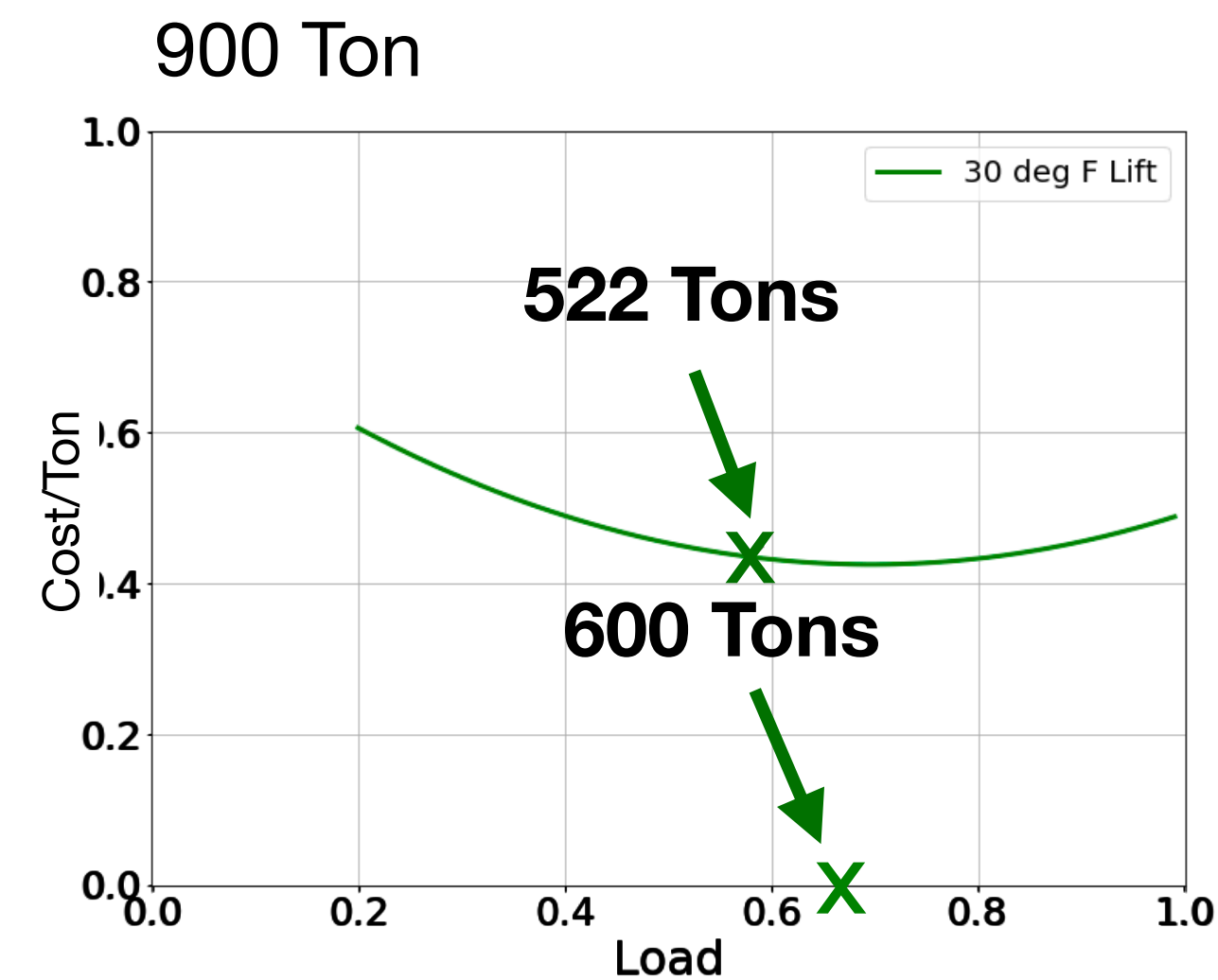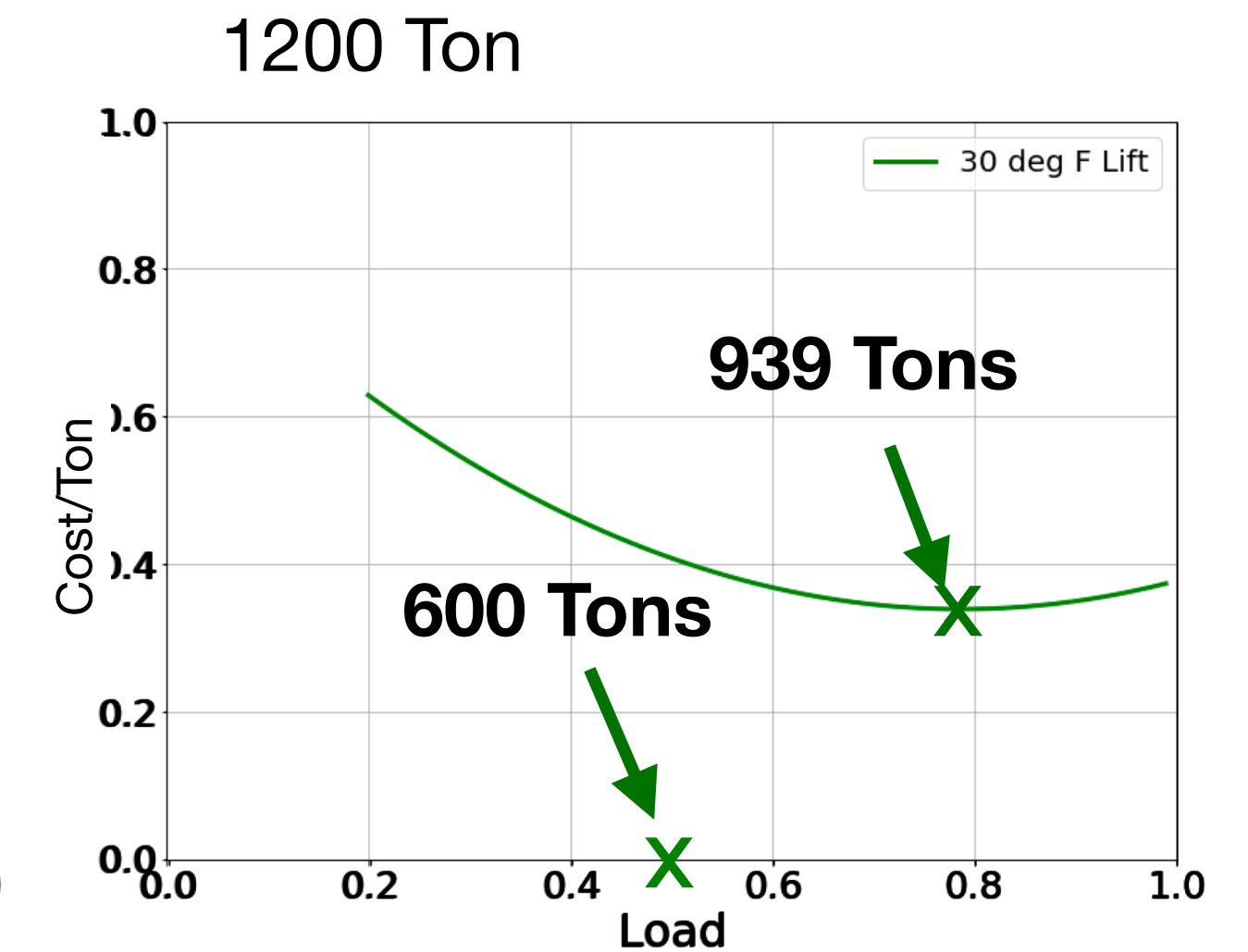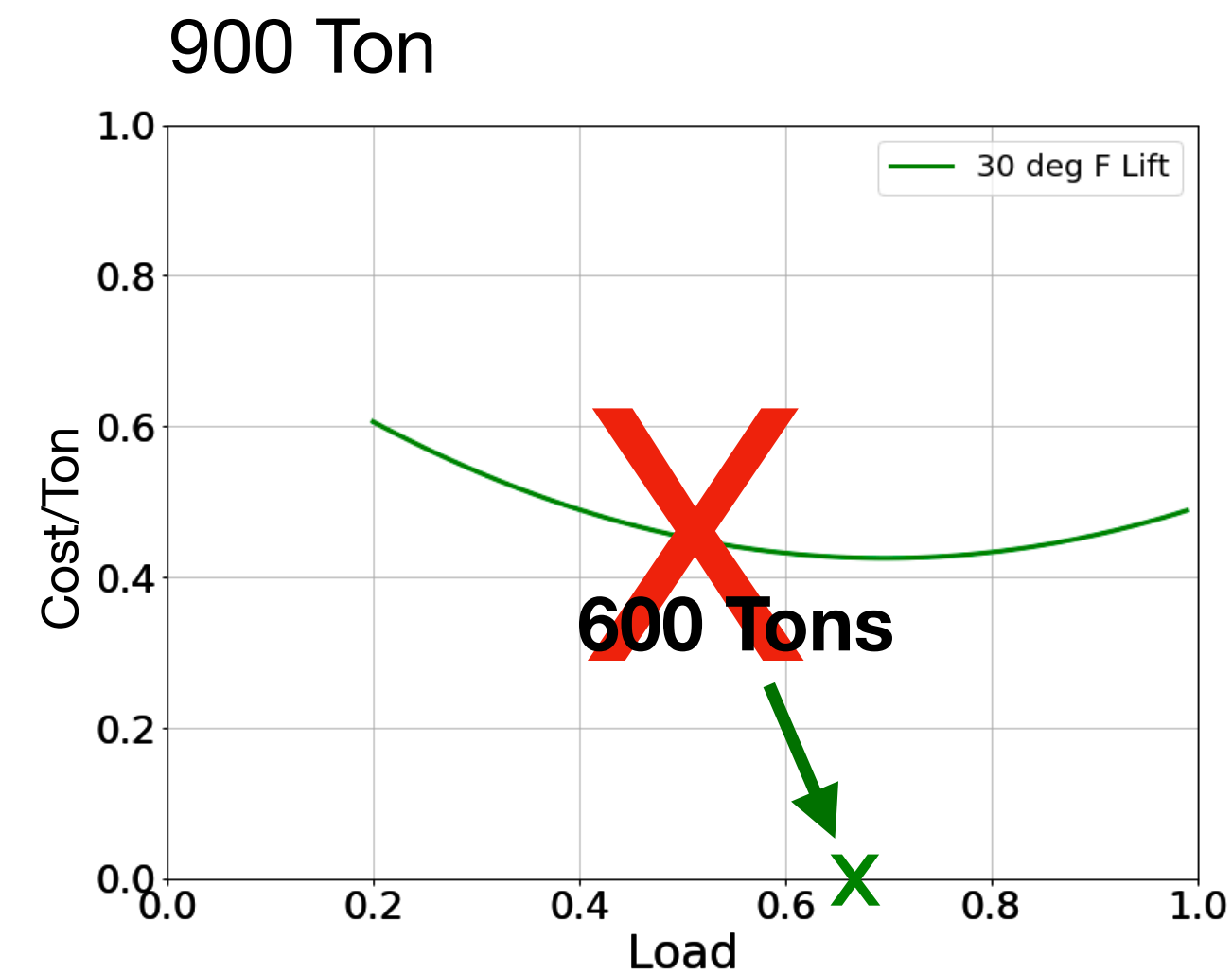
How to Run the Plant Efficiently?

Requirement:
  2400 Tons of cooling
  30° F ΔT

Goal: Lowest Cost

Savial $12,000 (1600 Tons each

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.
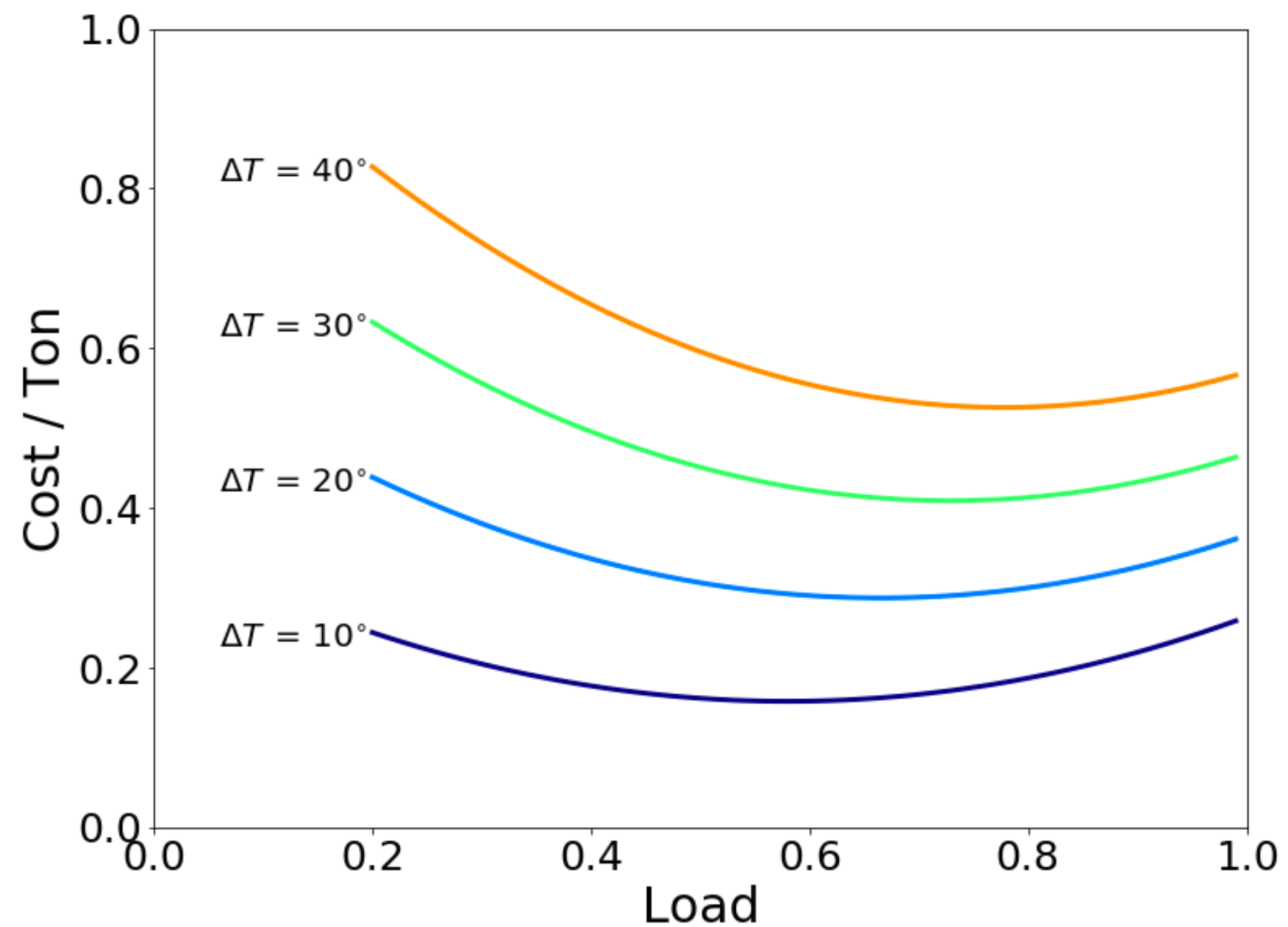
Thank You

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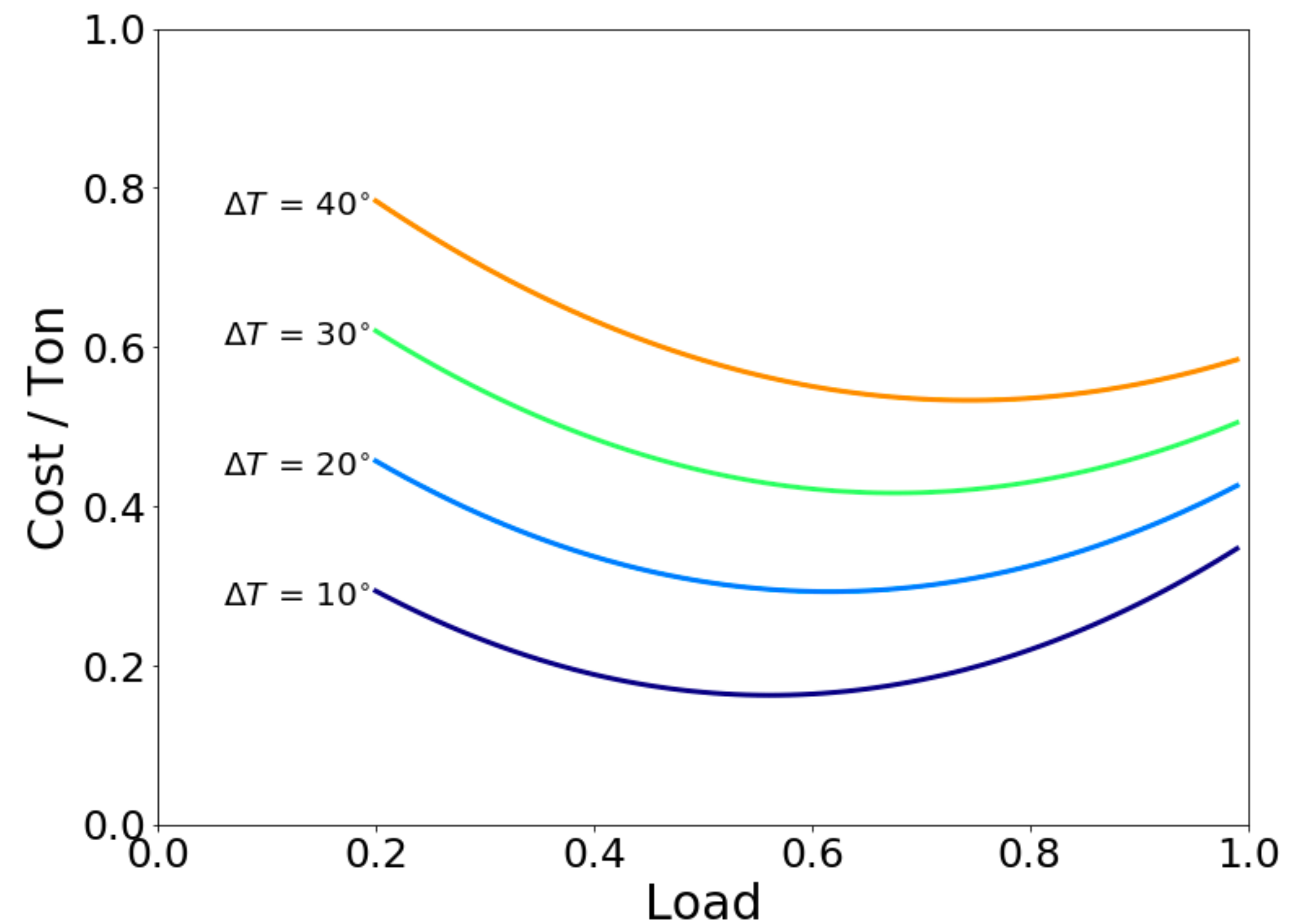
in www.linkedin.com/in/danalindquist

○ github.com/Stitchmaker

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