

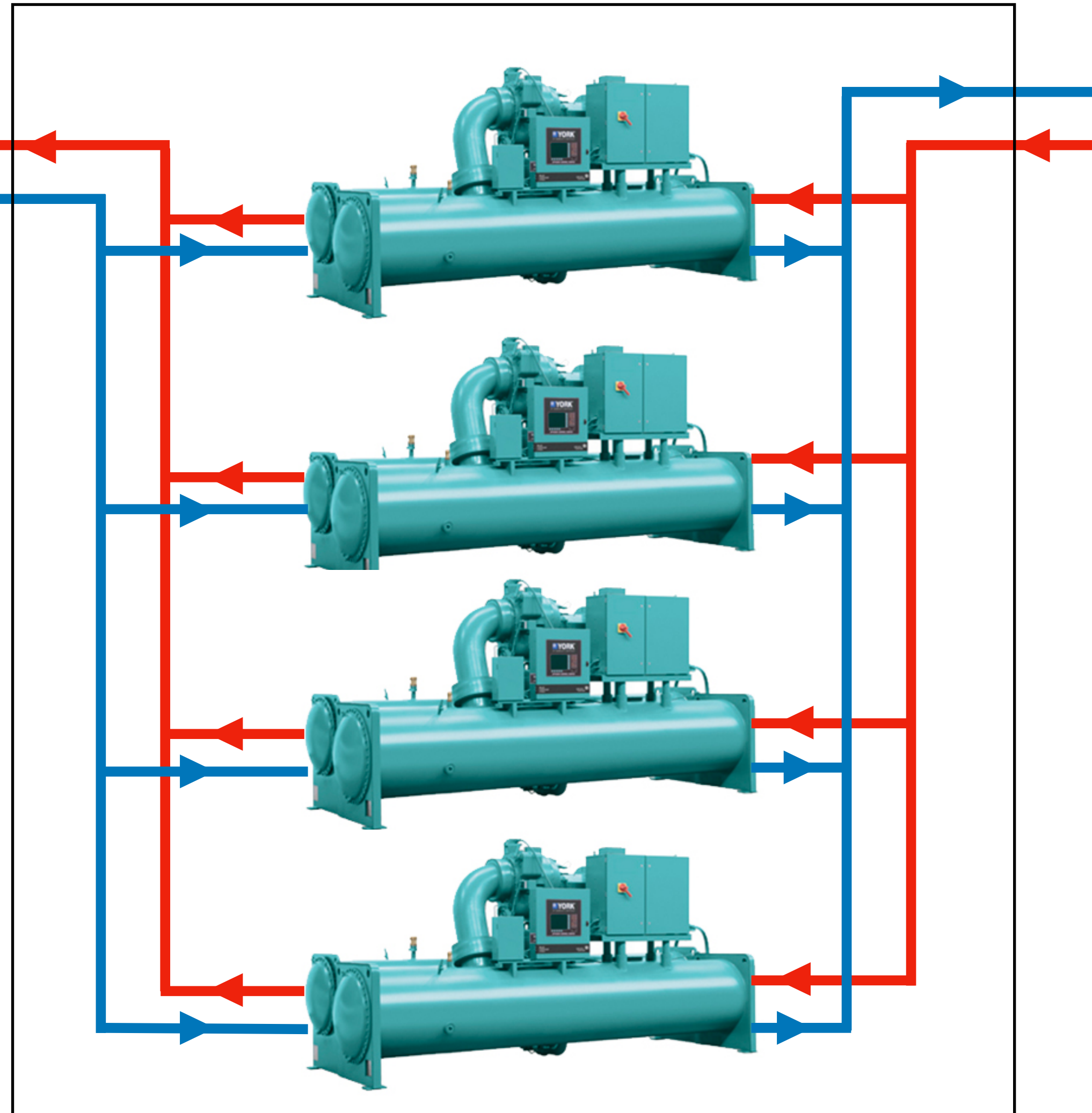
Predicting Industrial Chiller Performance

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

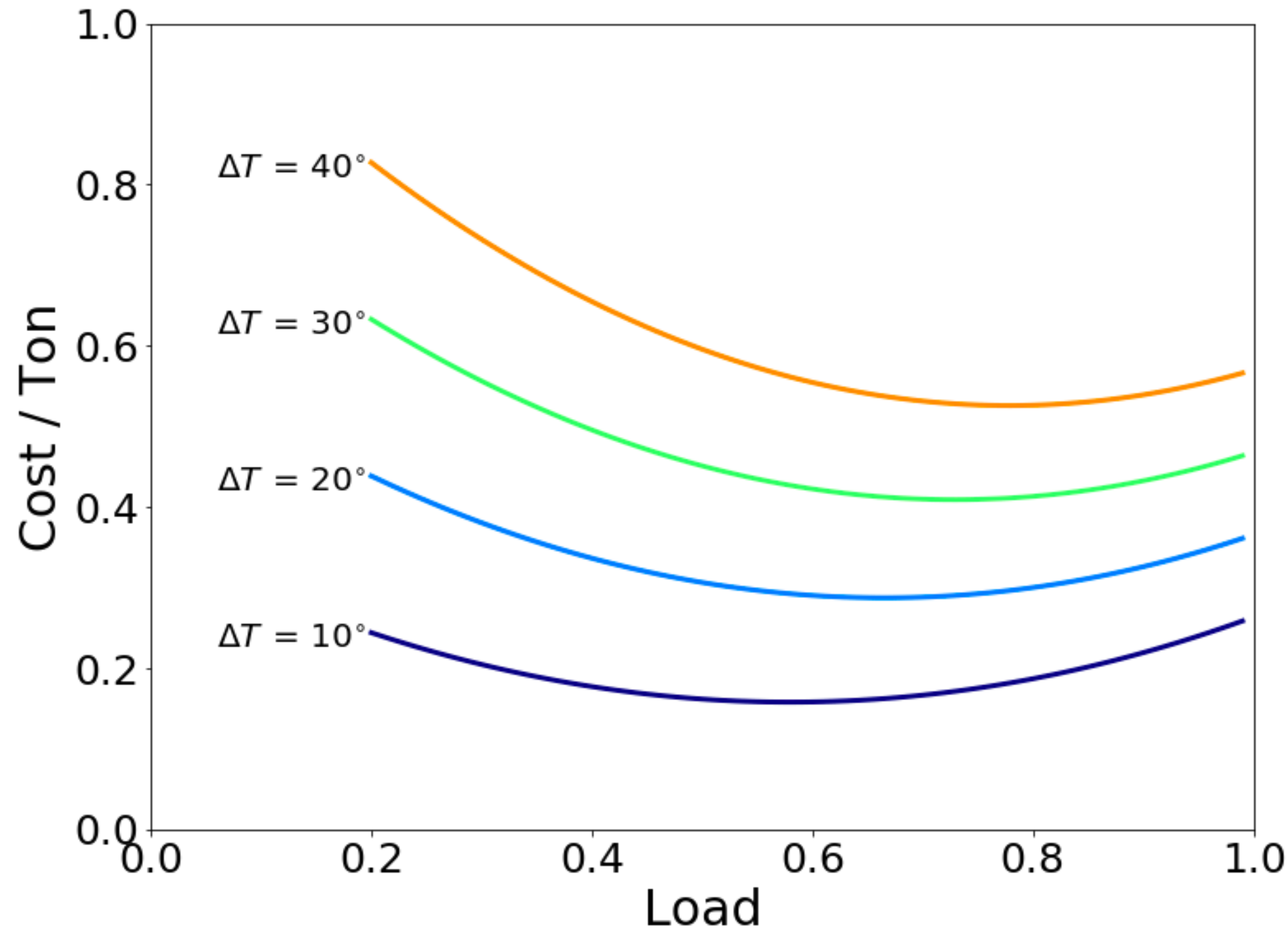
**Separate Into
Individual Chillers**

30 distinct but similar Chillers
8 different sizes & configurations

**Linear Regression
for ONE Chiller**

Scikit-learn Linear Regression with
LASSO Regularization

Just One Chiller



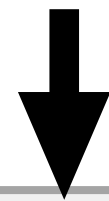
Ton = unit of refrigeration

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

Quadratic in Load

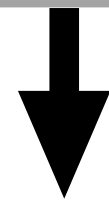
$$\text{Cost/Ton} = (A + B \Delta T) + (C + D \Delta T) \text{ Load} + (E + F \Delta T) \text{ Load}^2$$

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



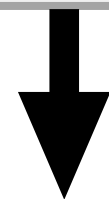
**Combine ALL Chillers
in to One Dataset**

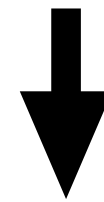
1 million data points



**Add Chiller Characteristics
to Dataset**

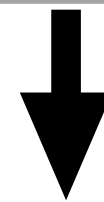
Rated Tons, Variable Speed or not, . . .





**Determine constants in
Quadratic based on Chiller
Characteristics**

1. Linear Regression



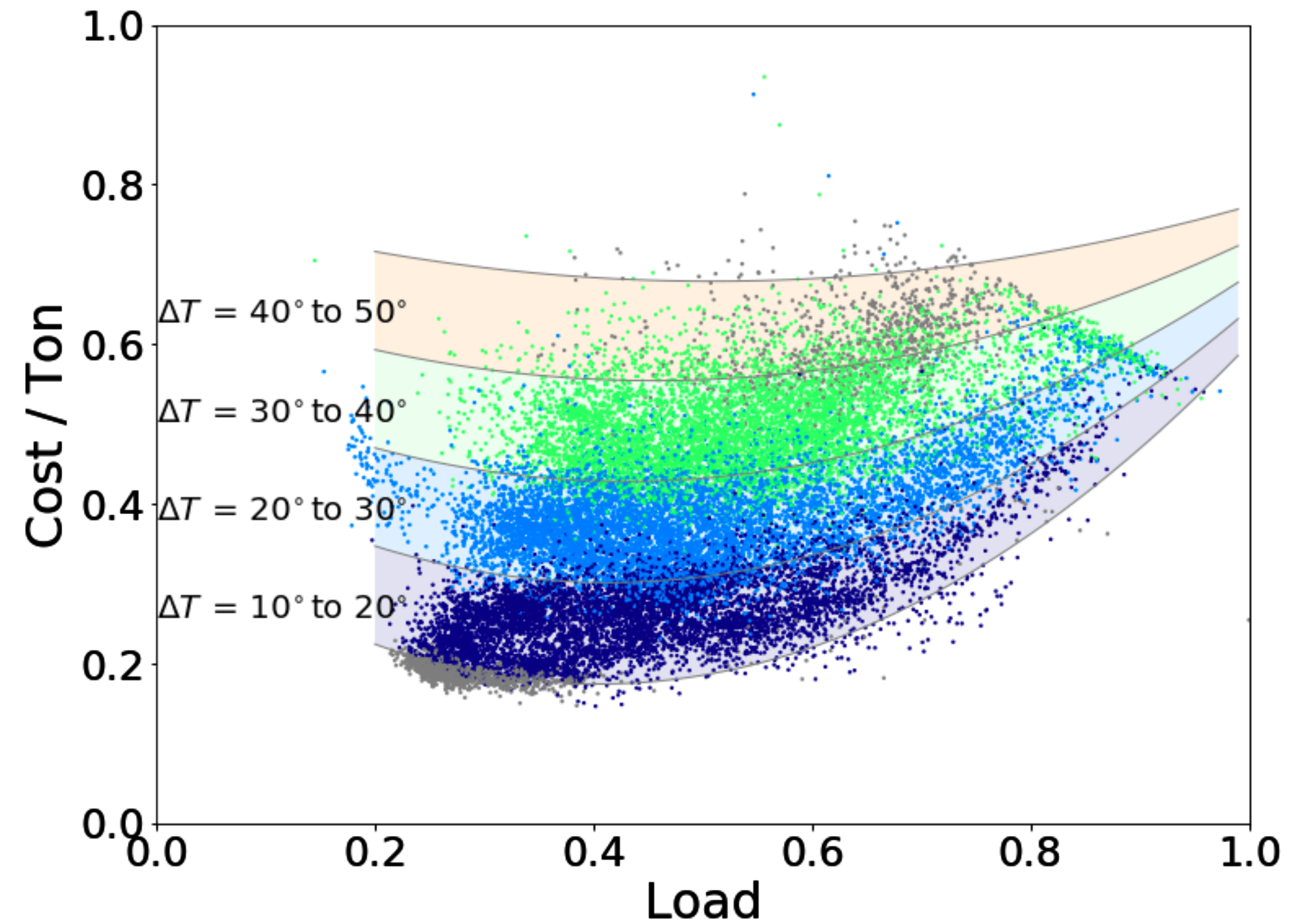
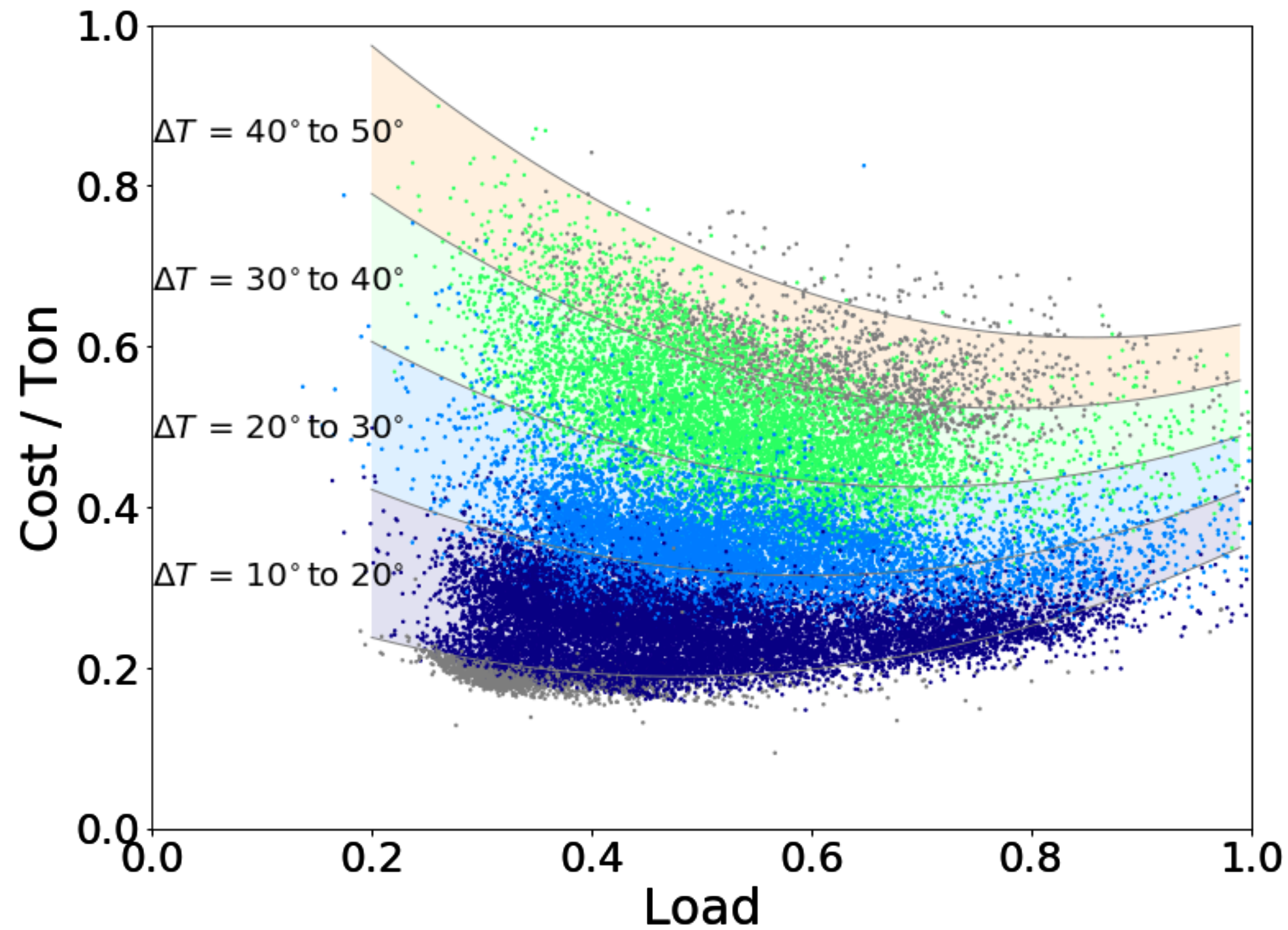
**2. Bayesian Model using
PYMC3**

Predict quadratic constants

Has the ability to extend this analysis to
more chiller characteristics

Results

Two DIFFERENT 900 Ton Chillers

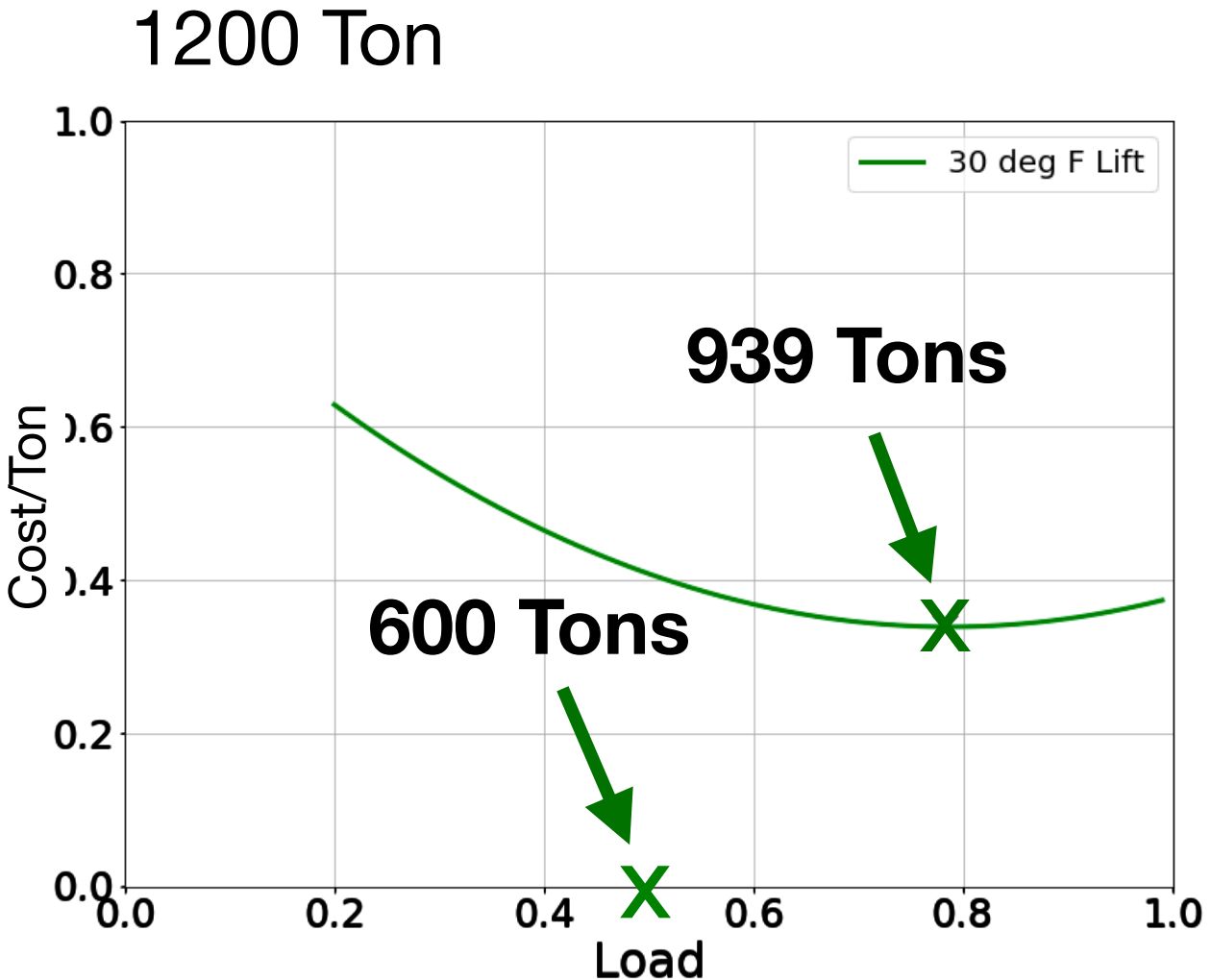
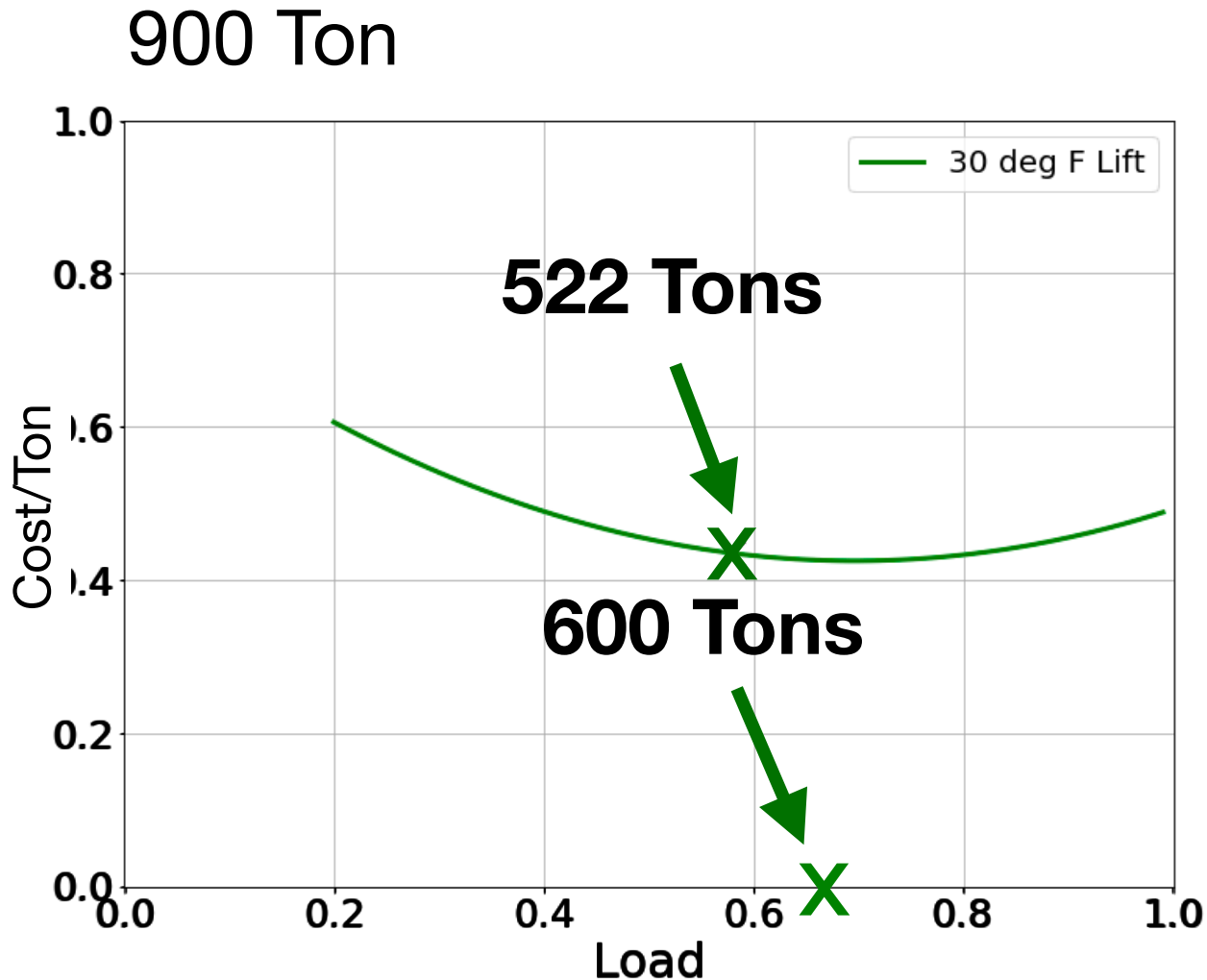
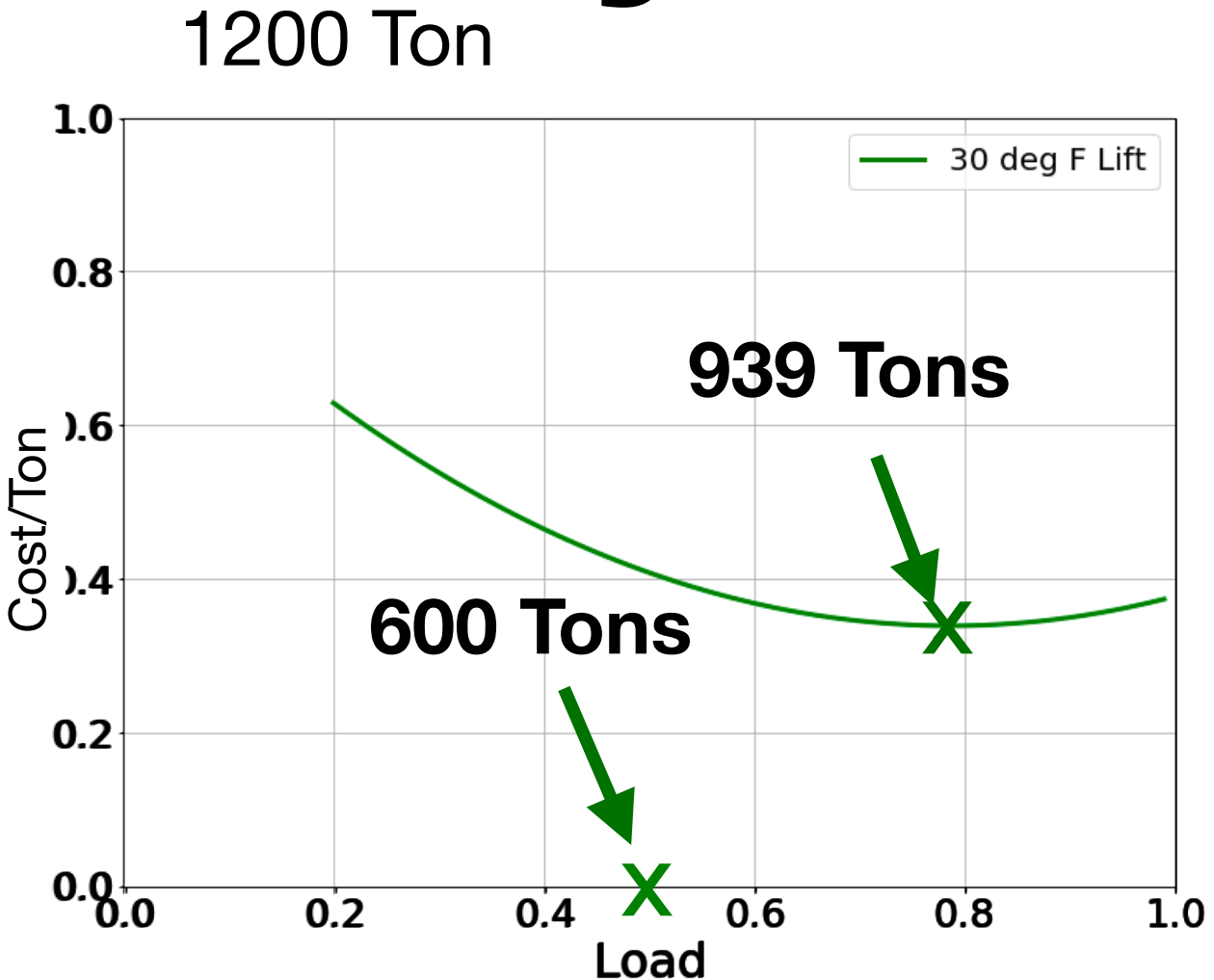
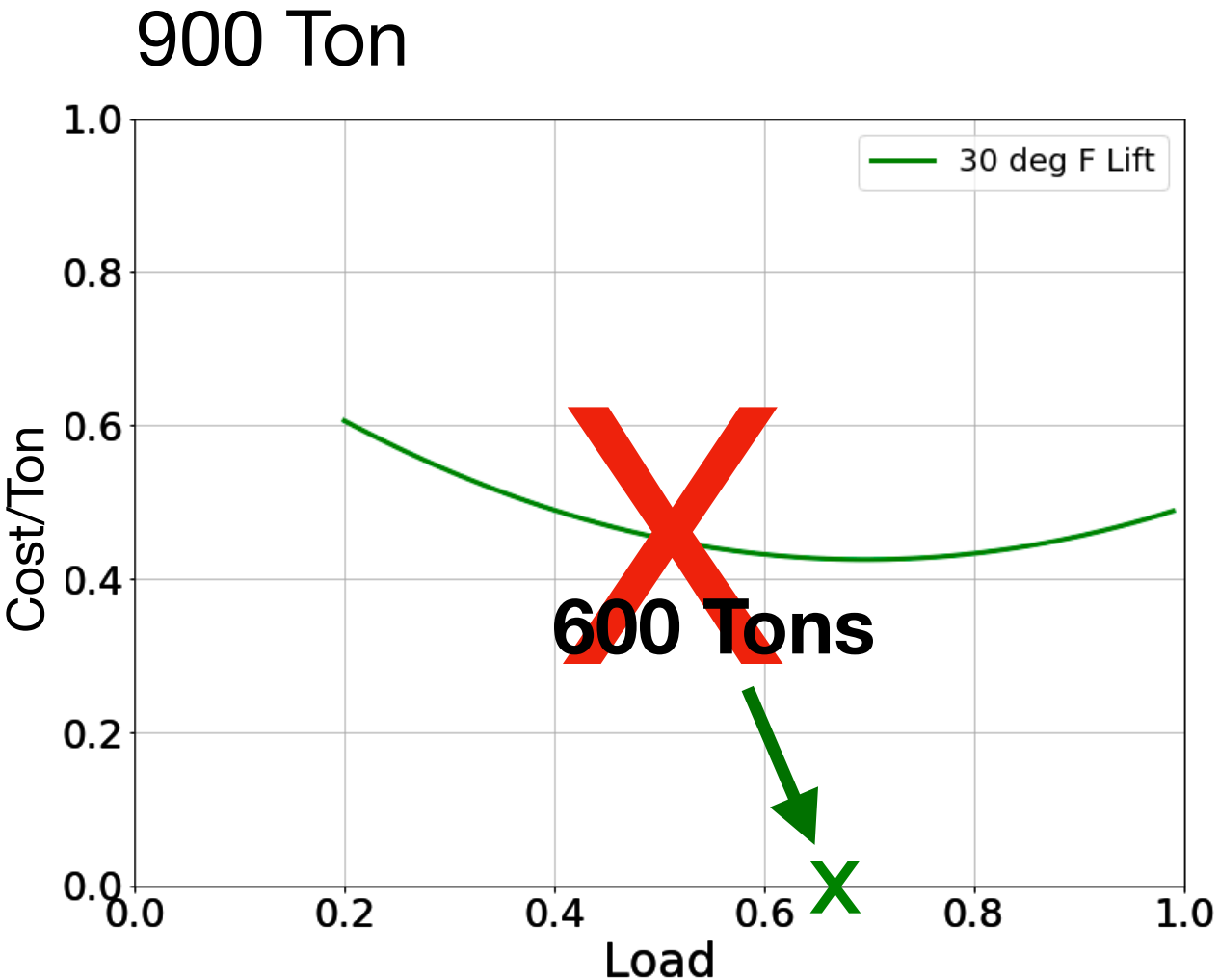


How to Run the Plant Efficiently?

Requirement:
2400 Tons of cooling
30° F ΔT

Goal: Lowest Cost

Save \$12,000 (at 600 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

Dana Lindquist, PhD

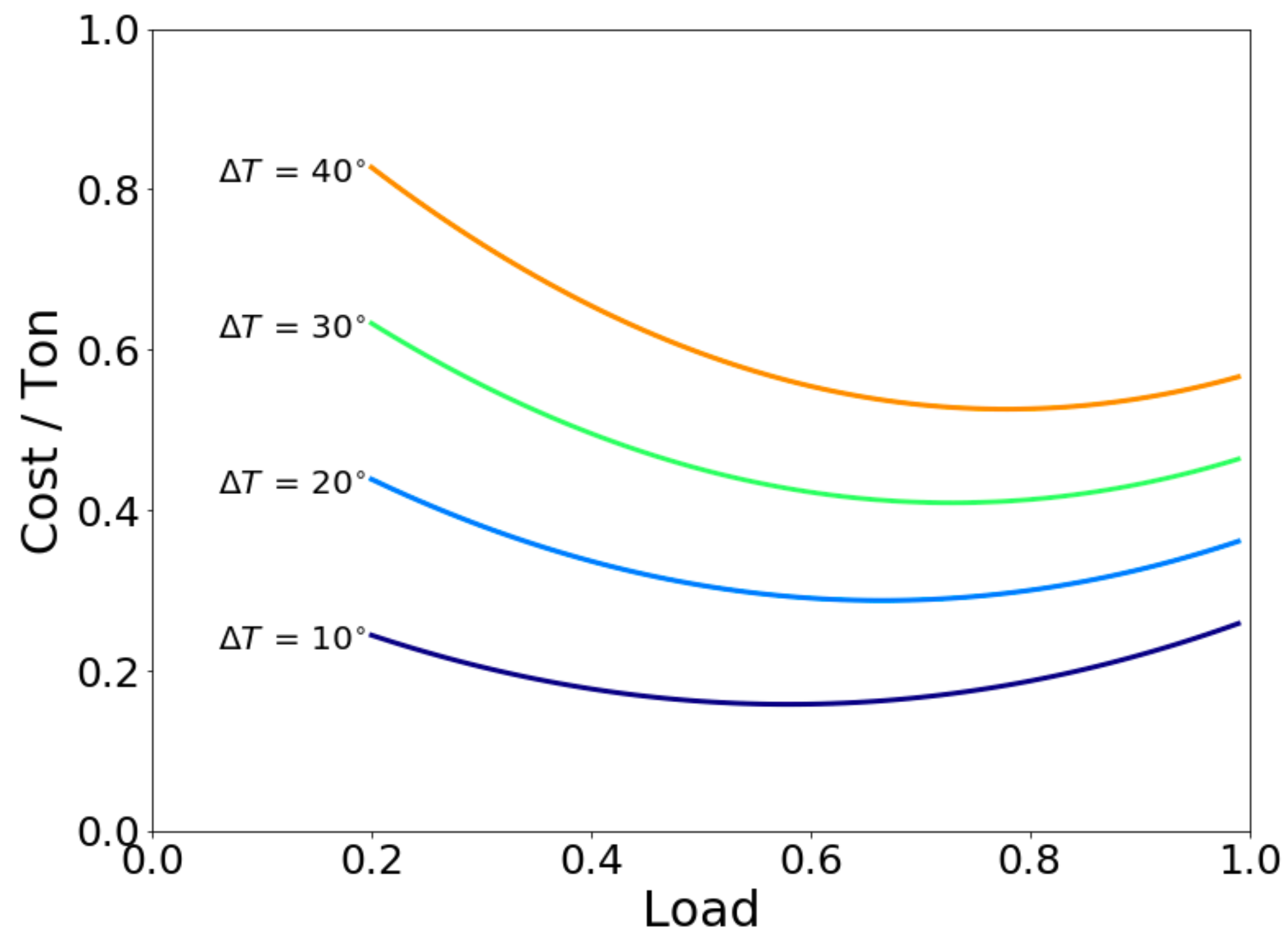
✉ danalindquist@silverbeach.com

www.linkedin.com/in/danalindquist

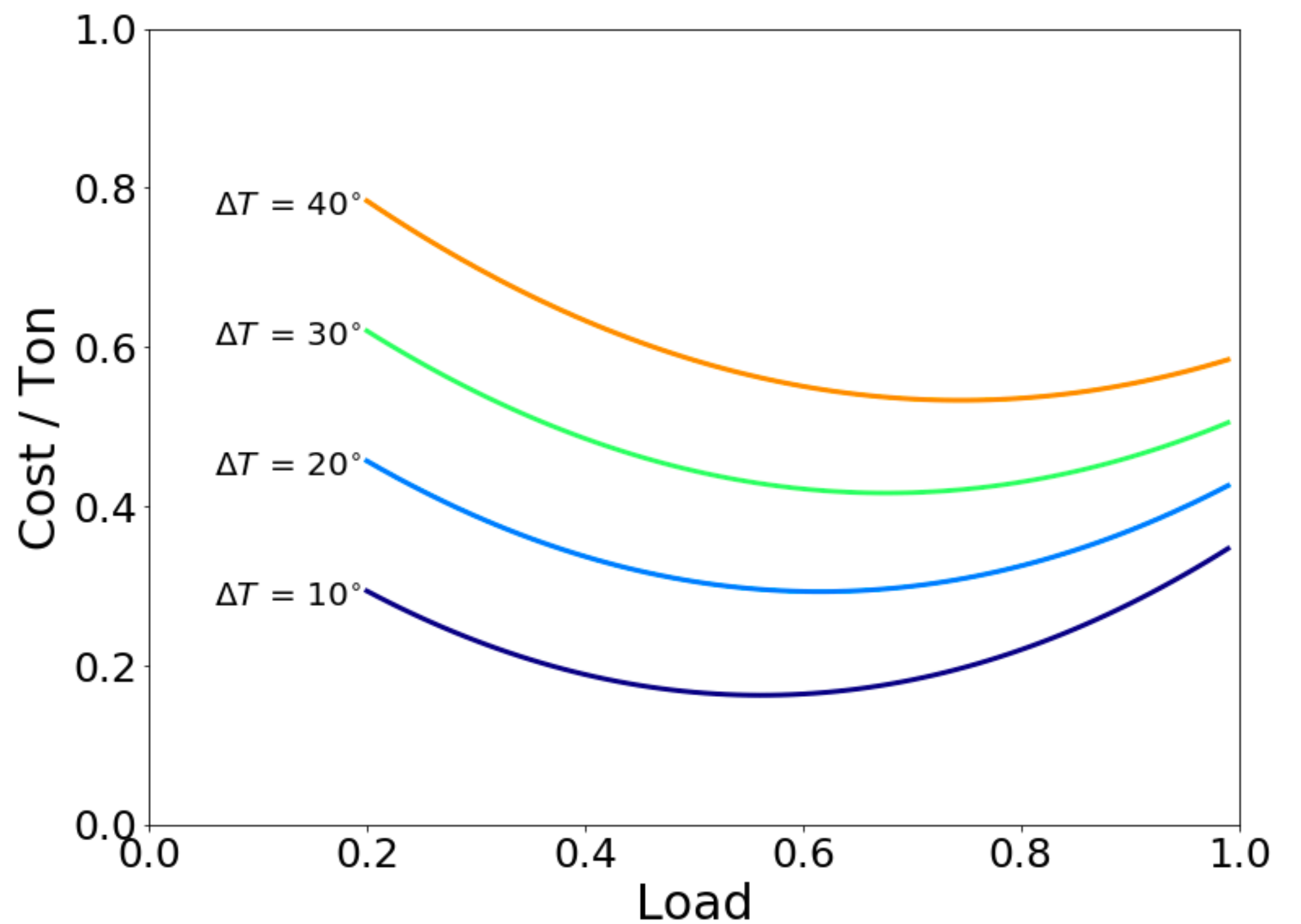
github.com/Stitchmaker

PyMC3

Scikit-learn Linear Regression



PyMC3



PyMC3

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

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

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

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

