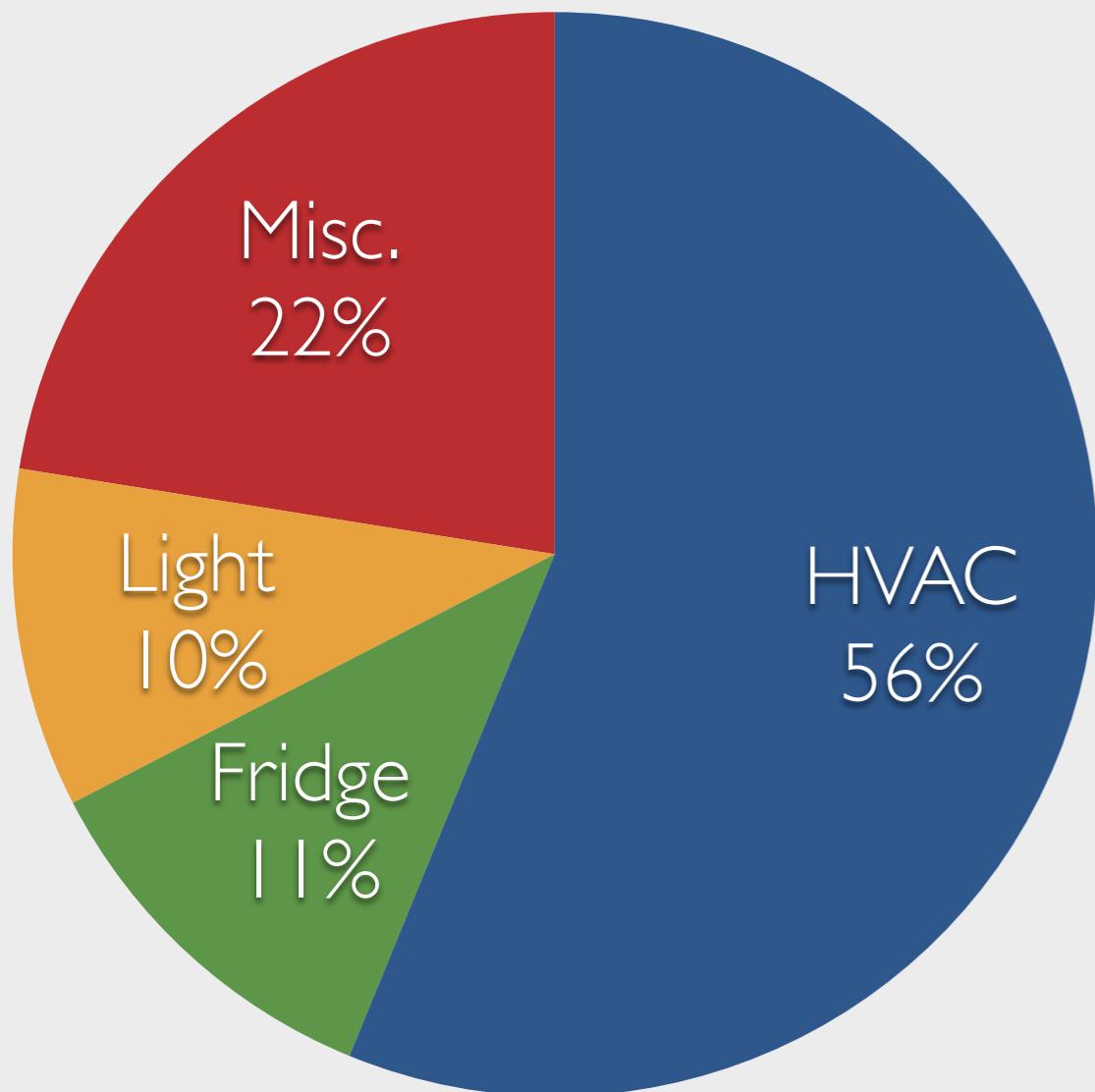


# Exploring The Value of Energy Disaggregation through actionable feedback

**Nipun Batra, Amarjeet Singh, Kamin Whitehouse**  
14 May 2016

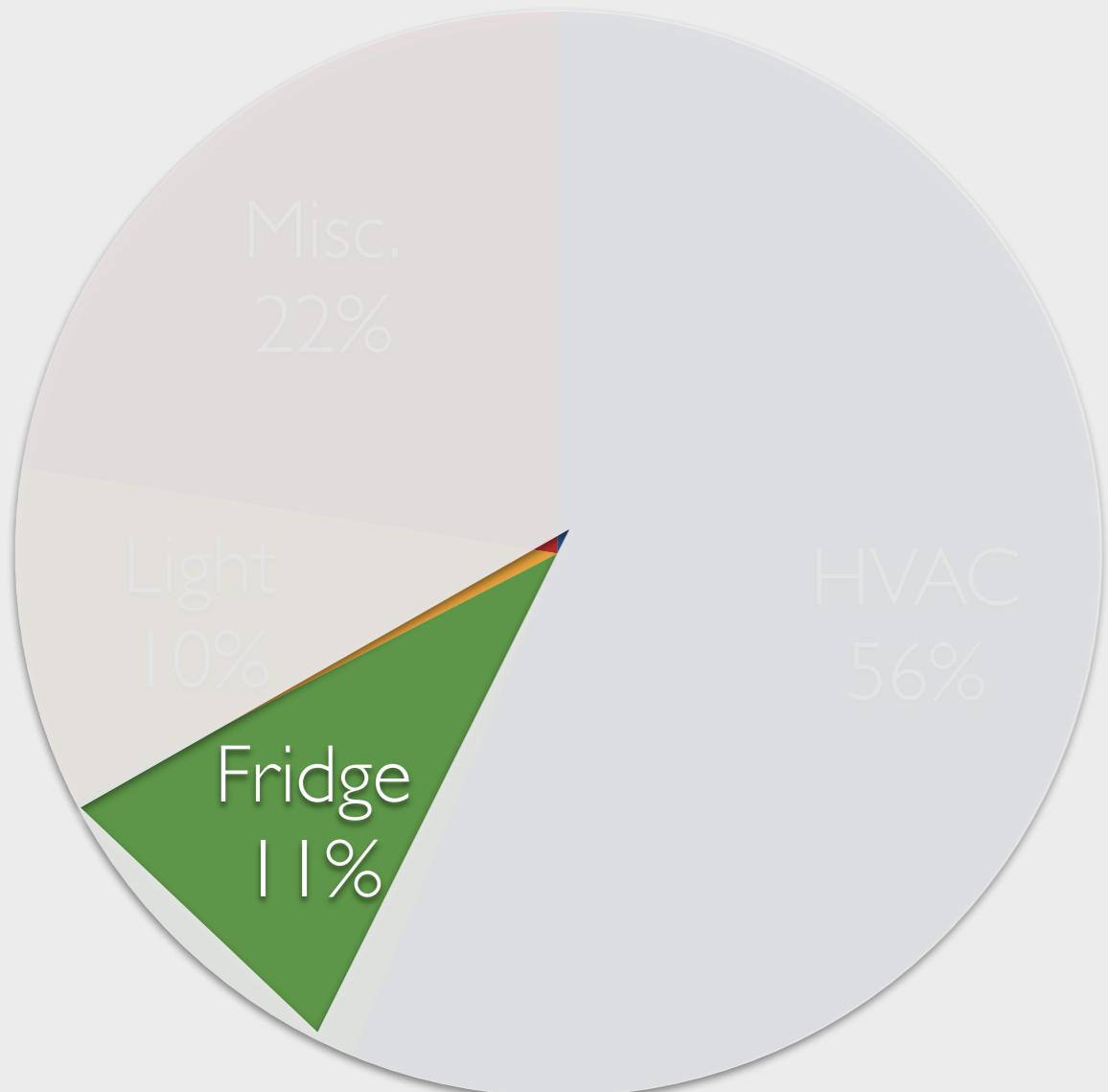
# General eco feedback vs Actionable Feedback

Eco  
feedback



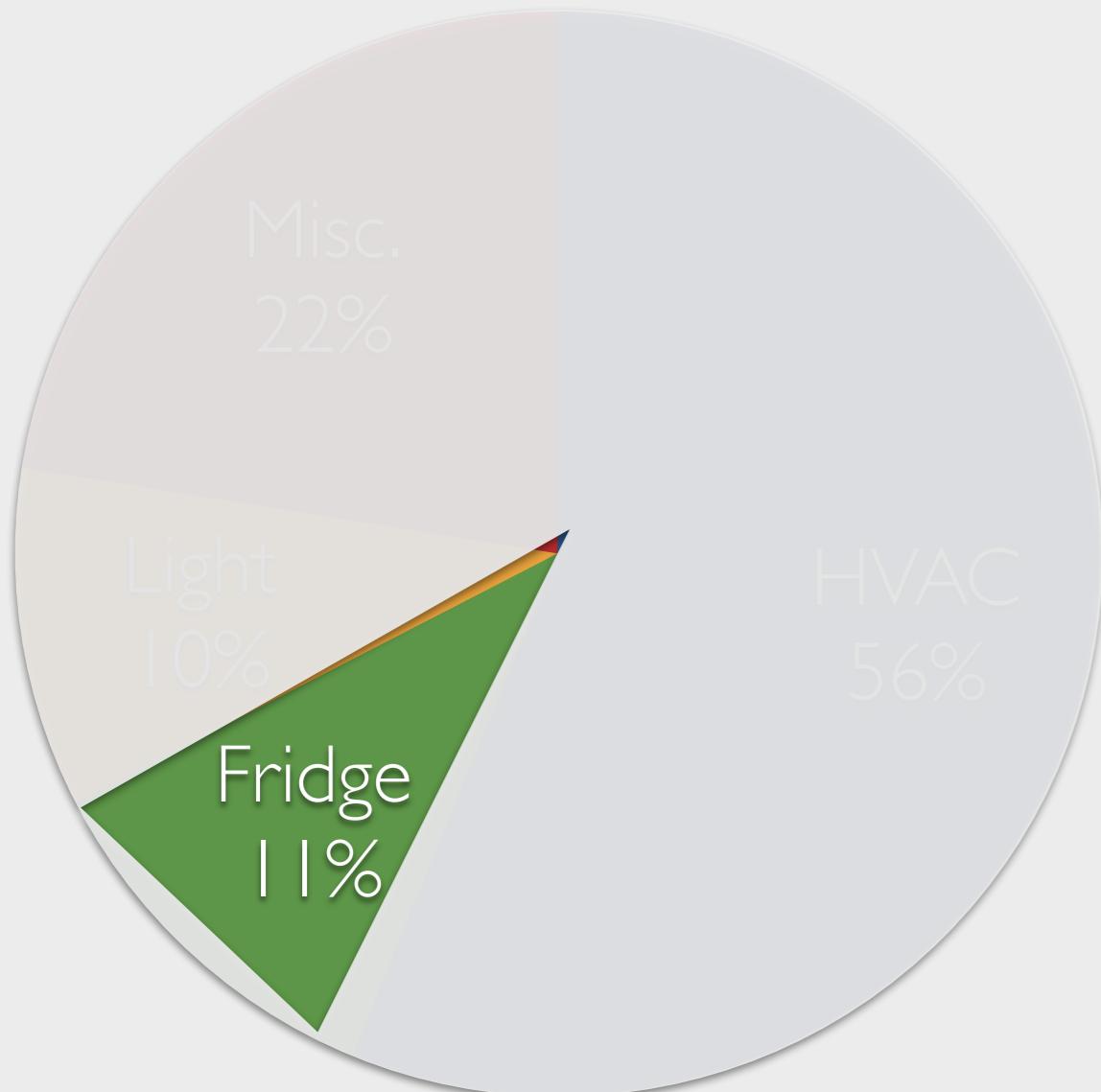
# General eco feedback vs Actionable Feedback

## Eco feedback



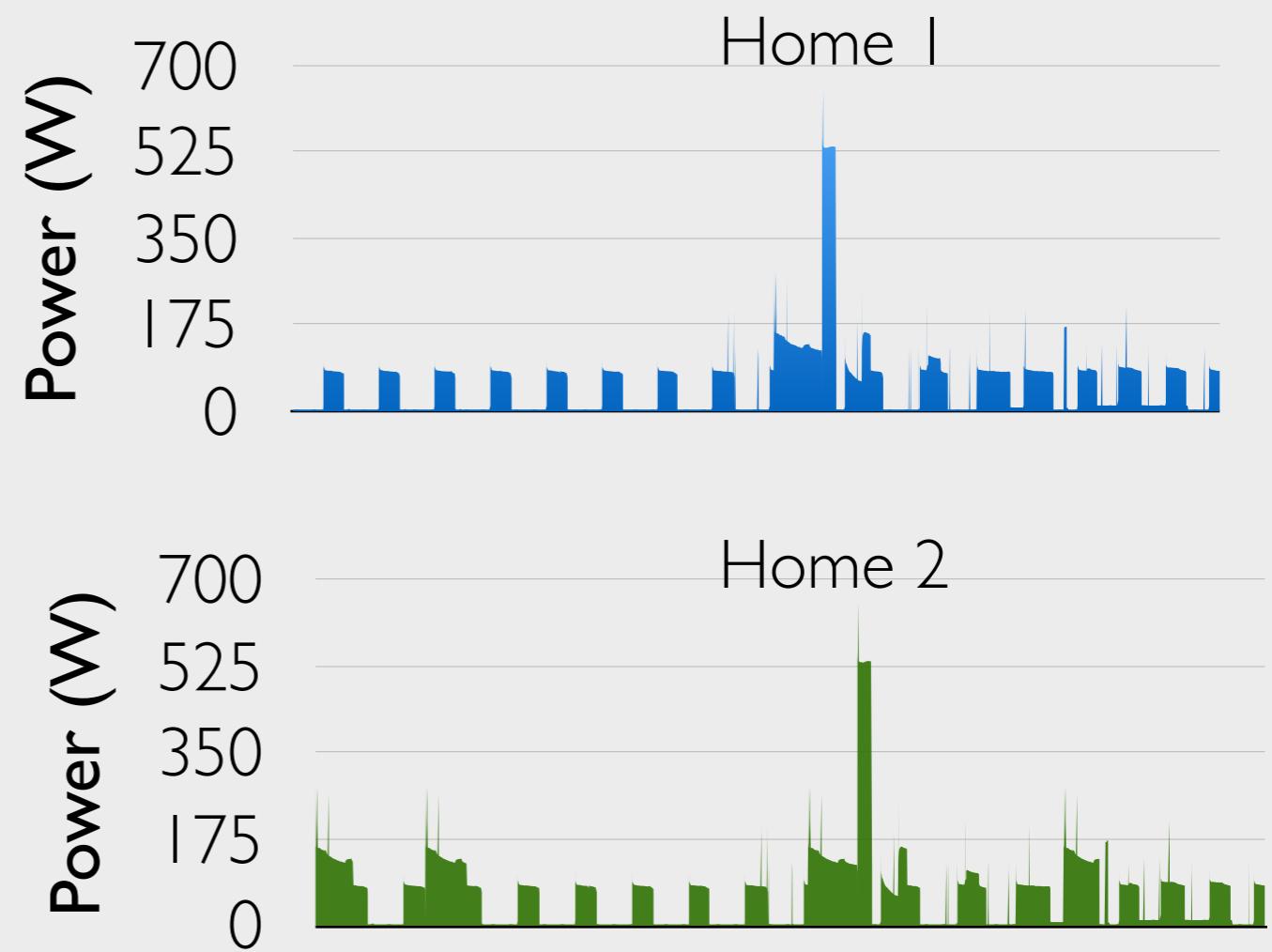
# General eco feedback vs Actionable Feedback

Eco  
feedback



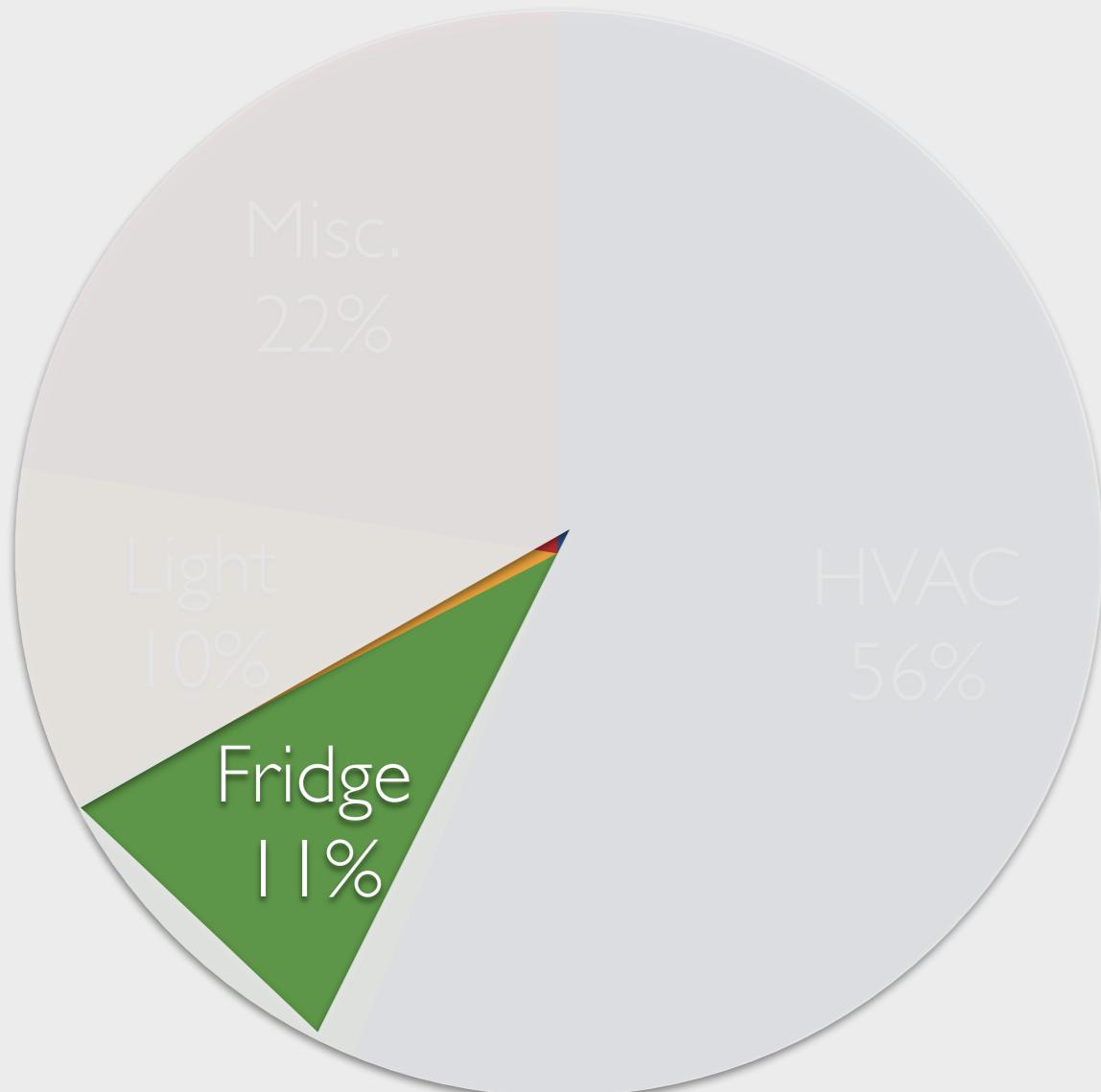
Actionable  
feedback

Fridge consumption over 24 hours



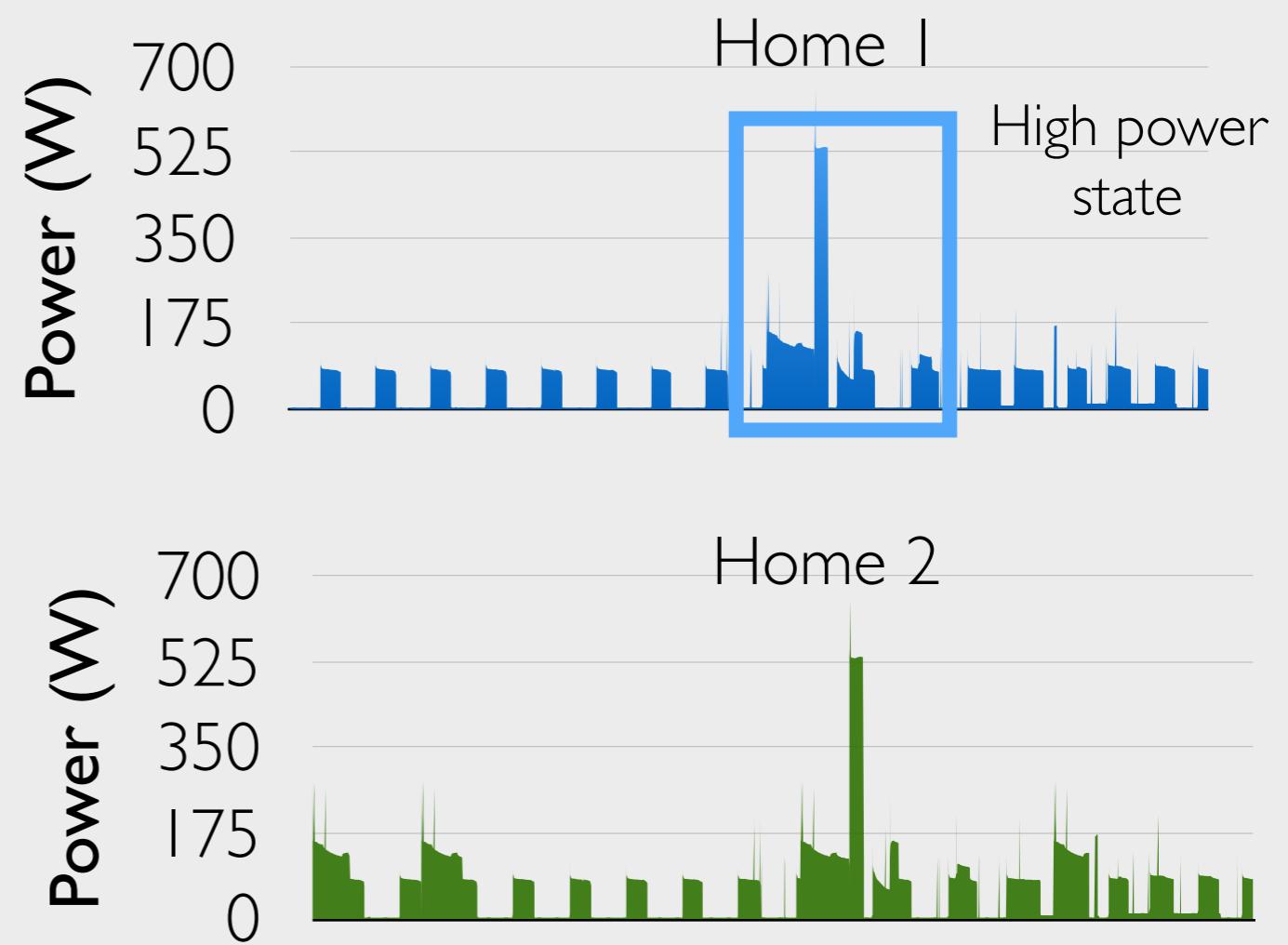
# General eco feedback vs Actionable Feedback

Eco  
feedback



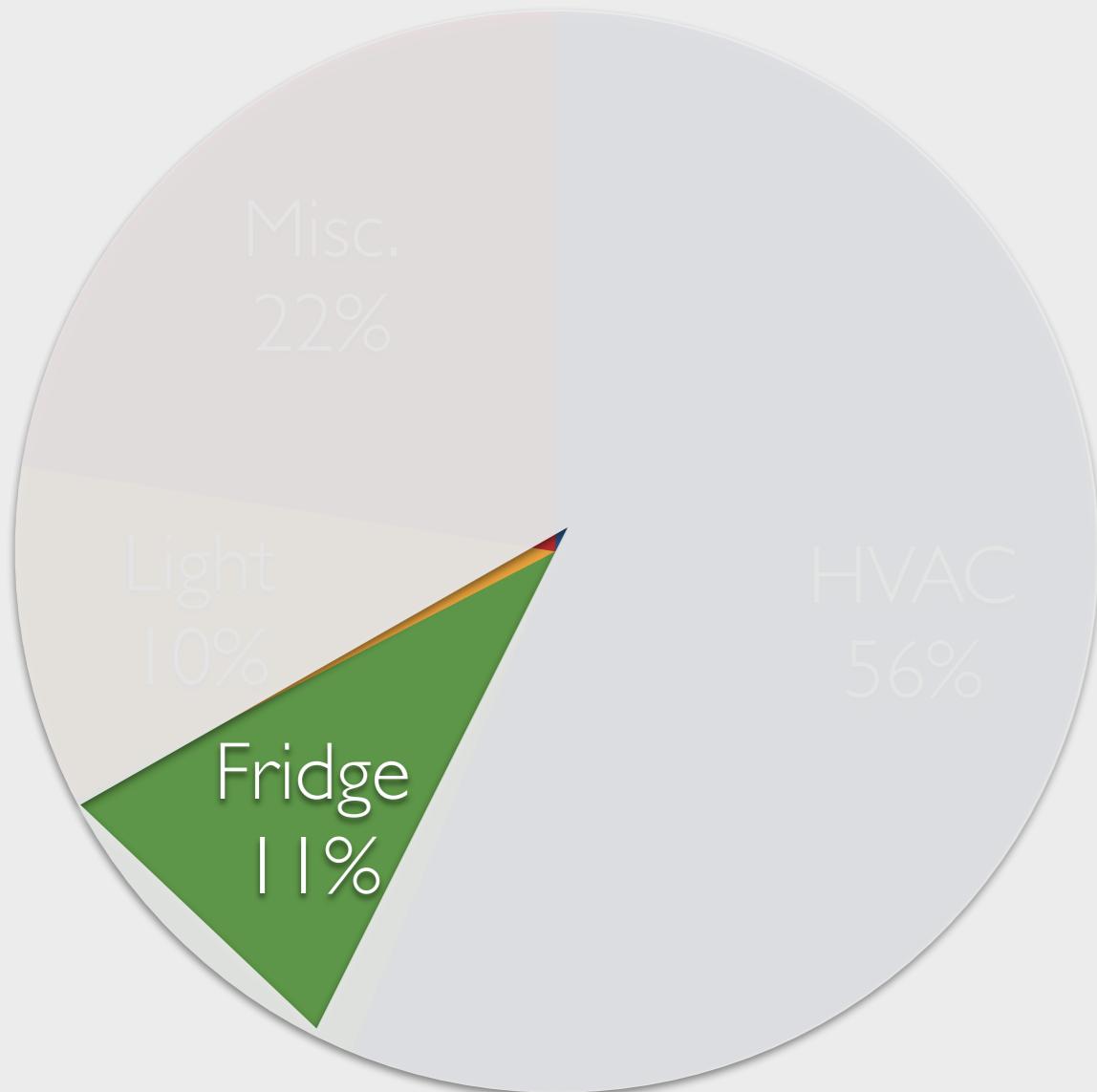
Actionable  
feedback

Fridge consumption over 24 hours



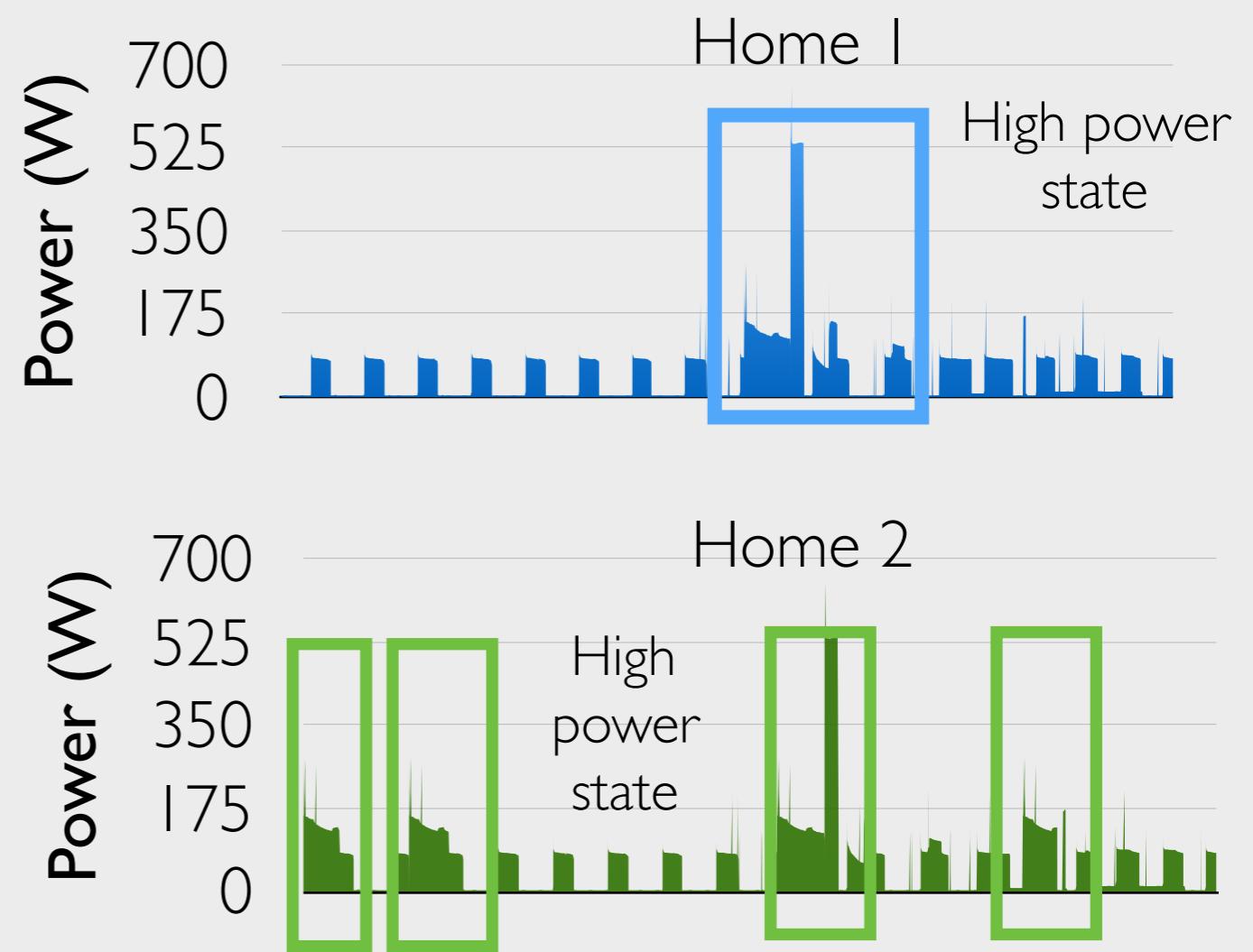
# General eco feedback vs Actionable Feedback

Eco  
feedback



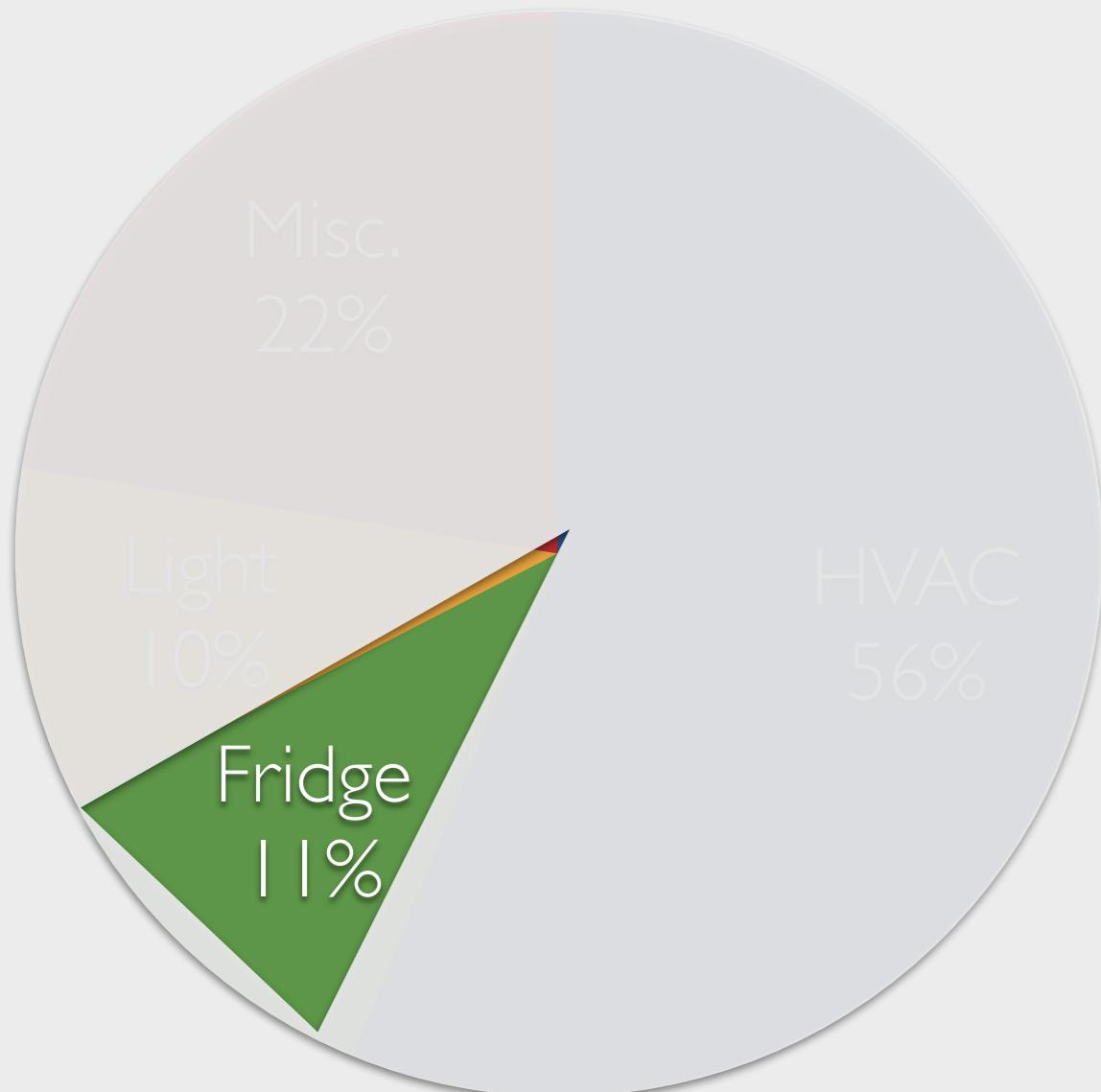
Actionable  
feedback

Fridge consumption over 24 hours



# General eco feedback vs Actionable Feedback

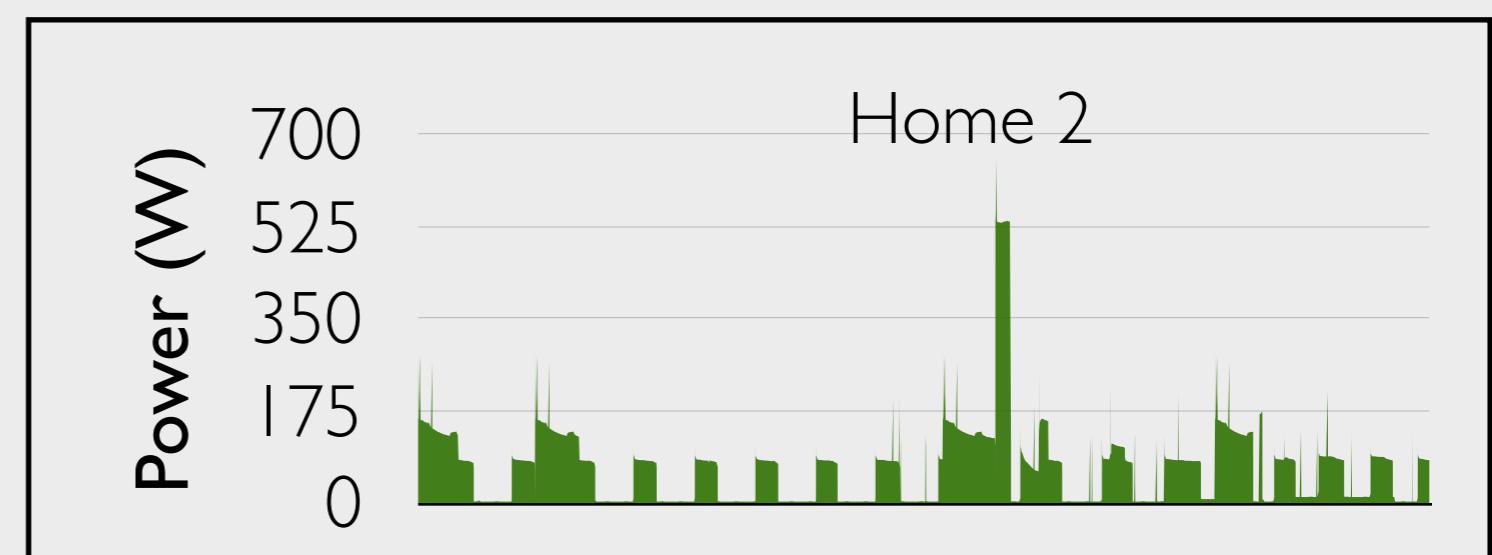
Eco  
feedback



Actionable  
feedback

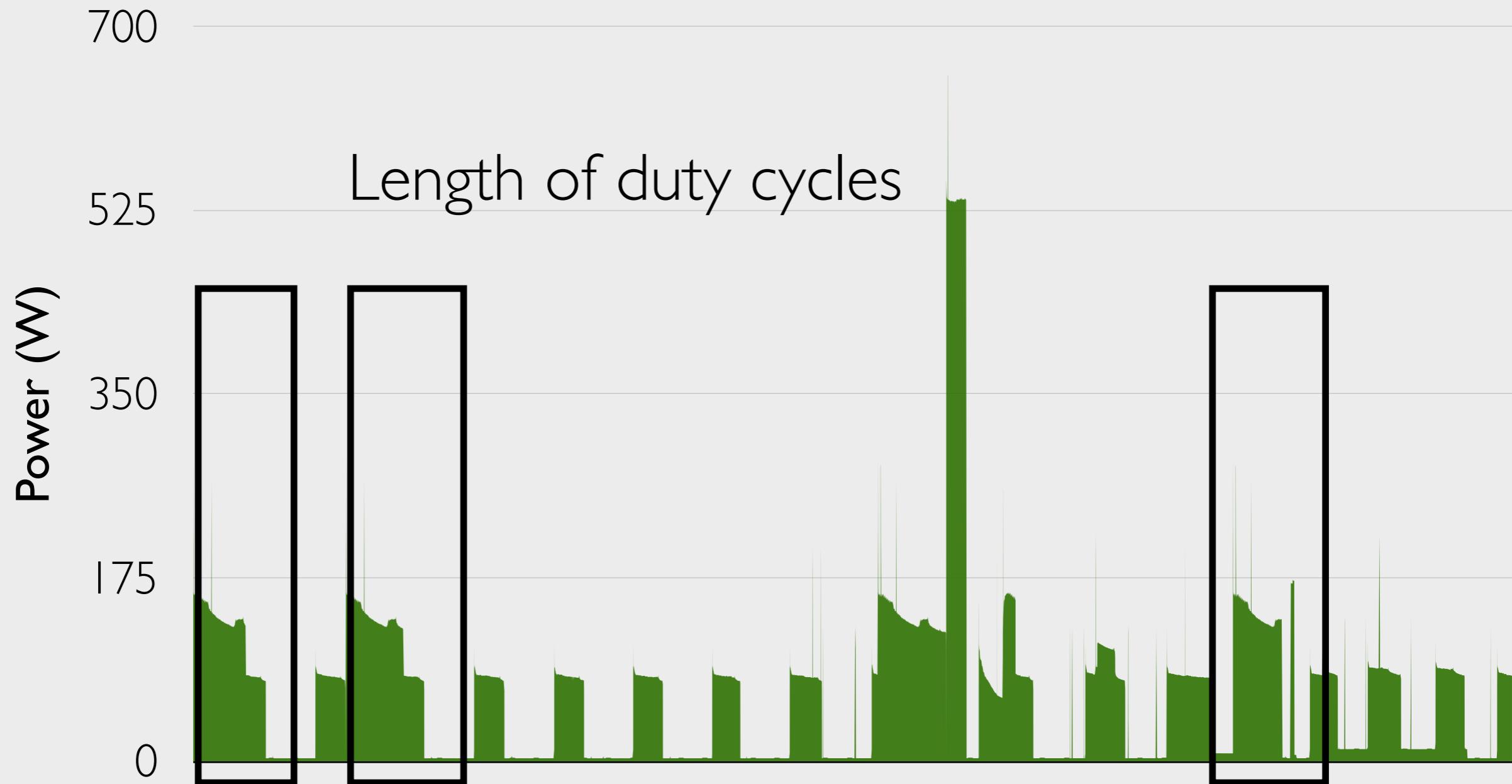
Fridge consumption over 24 hours

Your fridge **defrosts too much**,  
wasting **30%** energy



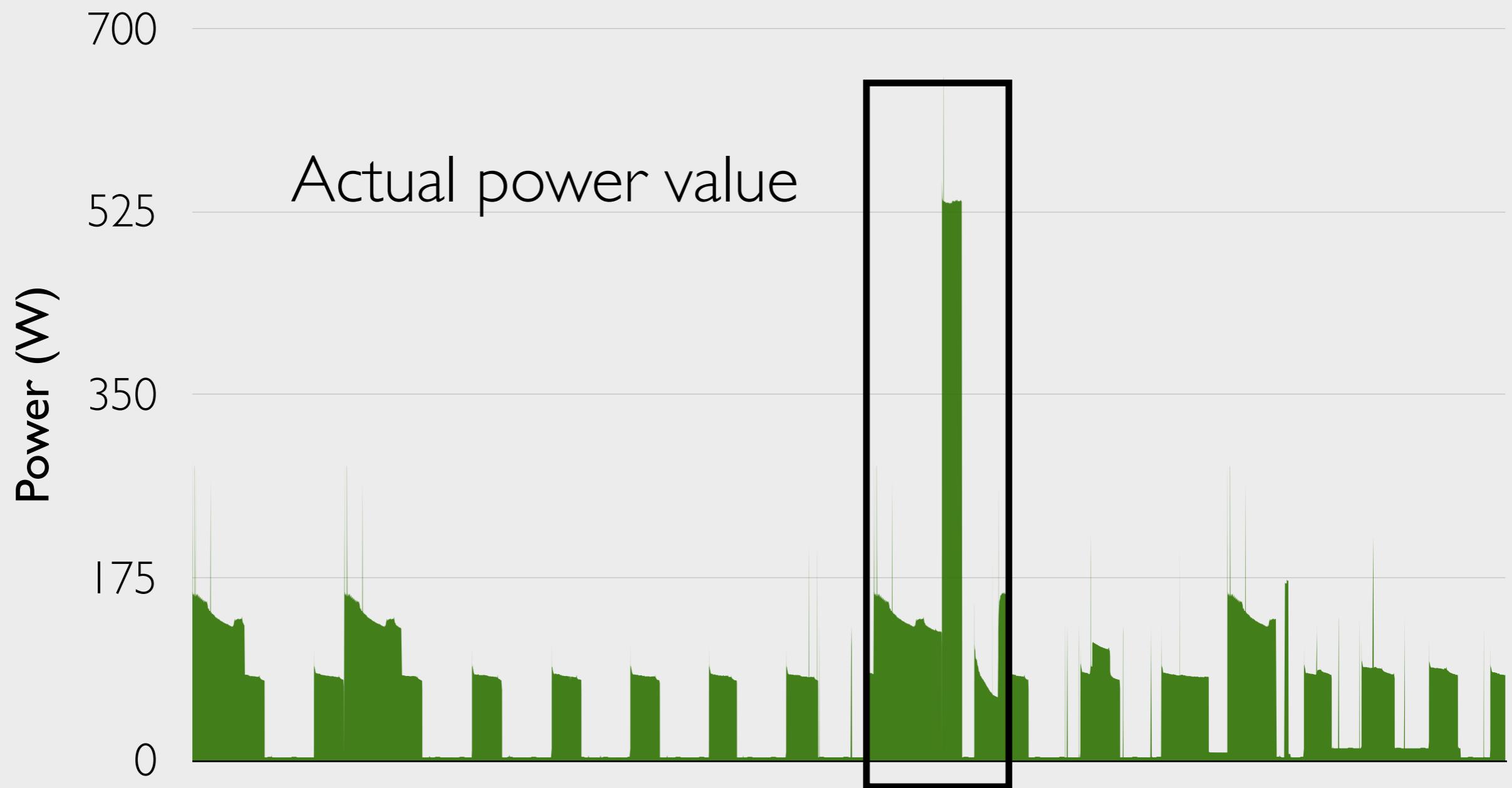
# Approach overview- How to give feedback

**Specific features** of trace to infer **why** energy usage is high

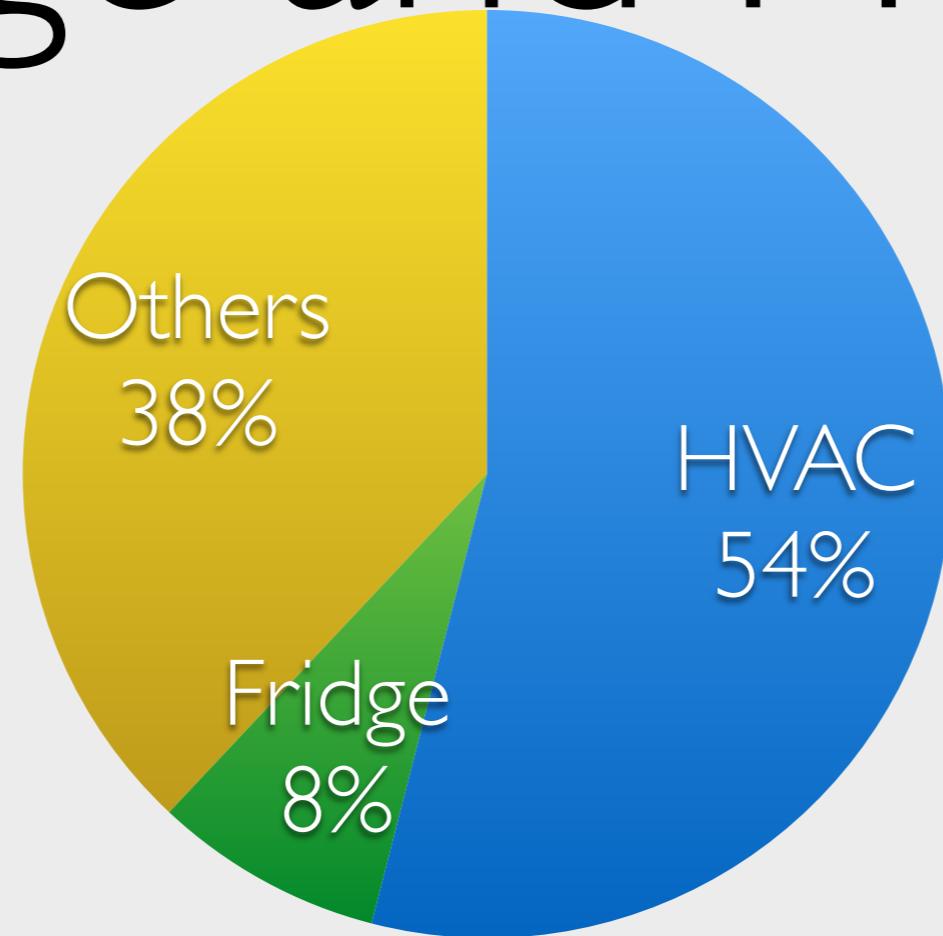


# Approach overview- How to give feedback

**Specific features** of trace to infer **why** energy usage is high



# Feedback methods on Fridge and HVAC



Both appliances commonly found across homes

# Evaluation overview

Submetered  
traces



Submeter  
sensor

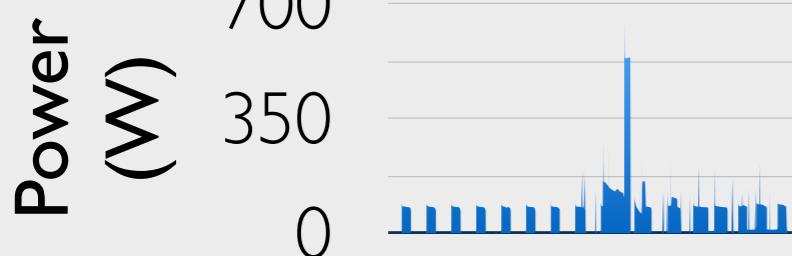


# Can we give such feedback?

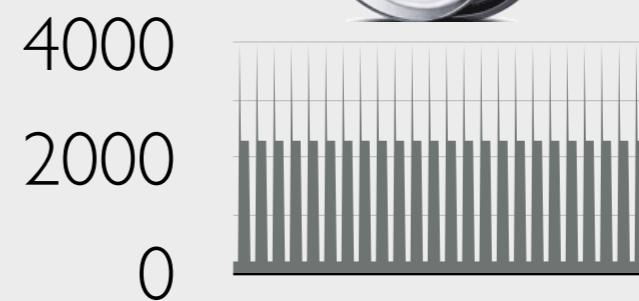
Submetered  
traces



Submeter  
sensor

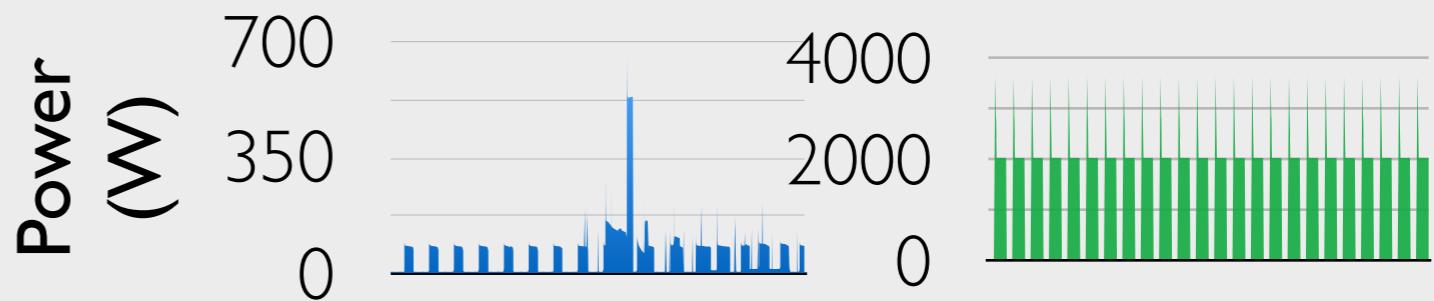


Disaggregated  
traces



Smart  
meter

Household  
aggregate

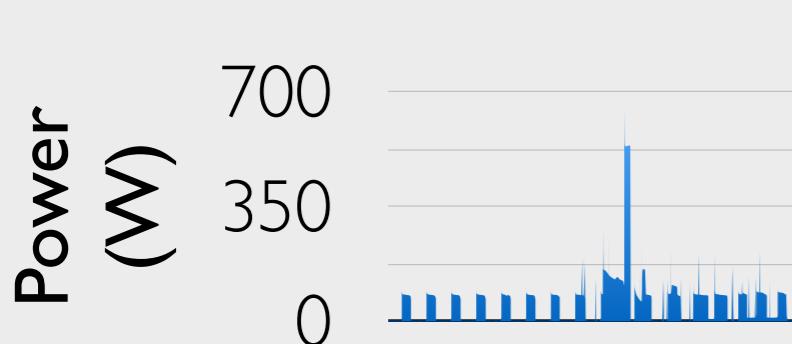


# Do disaggregated traces provide features needed for providing feedback?

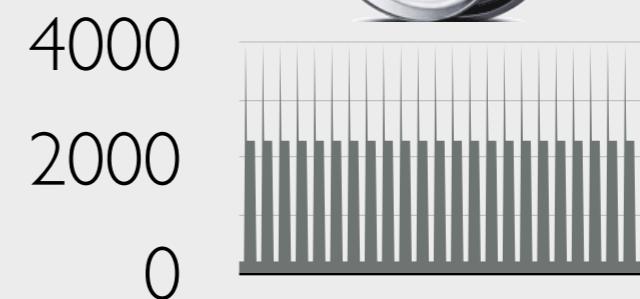
Submetered  
traces



Submeter  
sensor

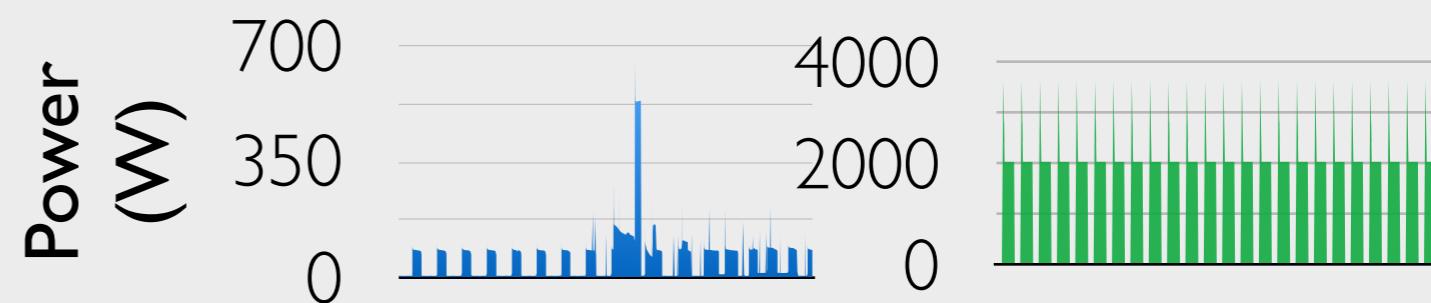


Disaggregated  
traces

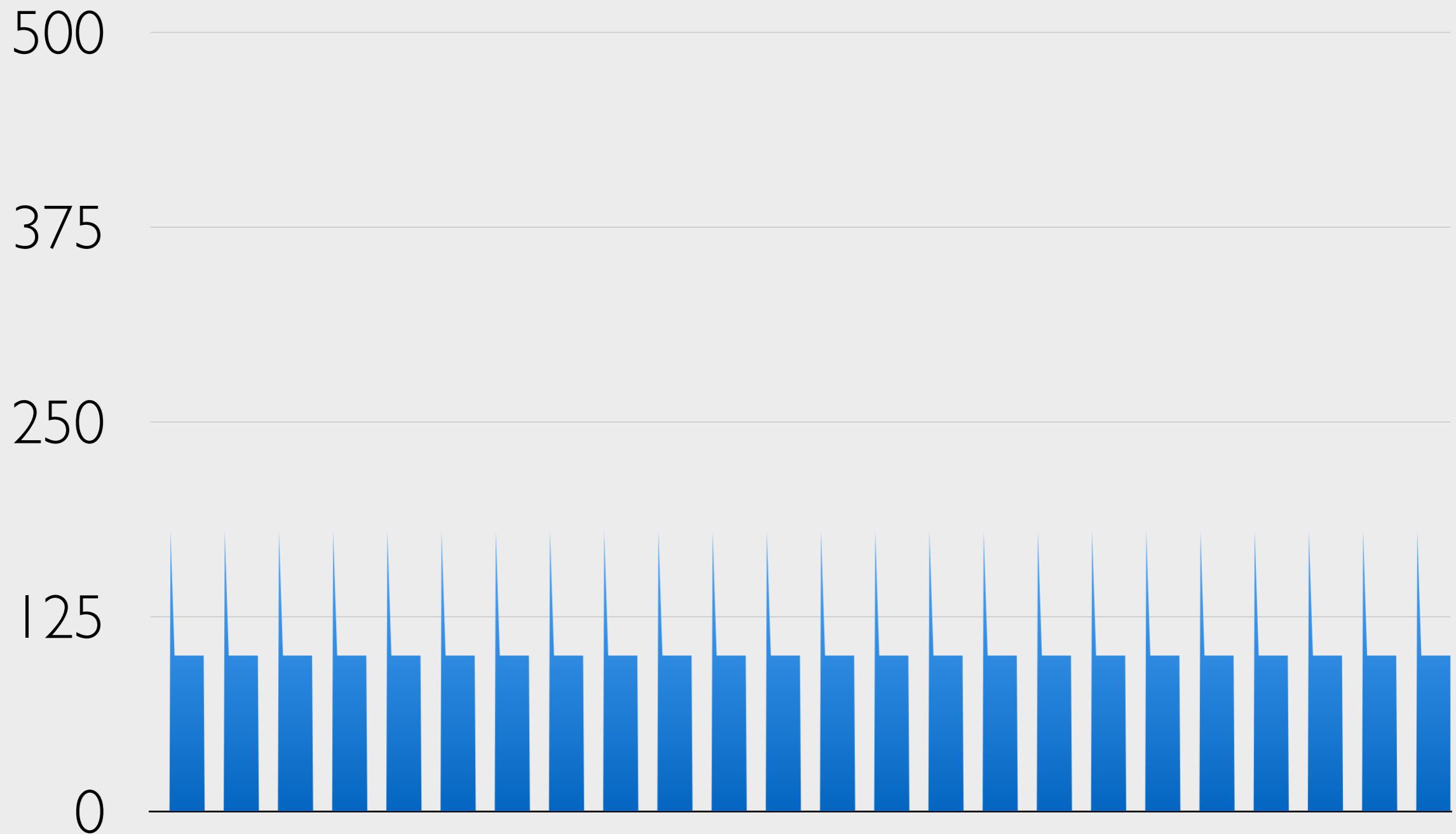


Smart  
meter

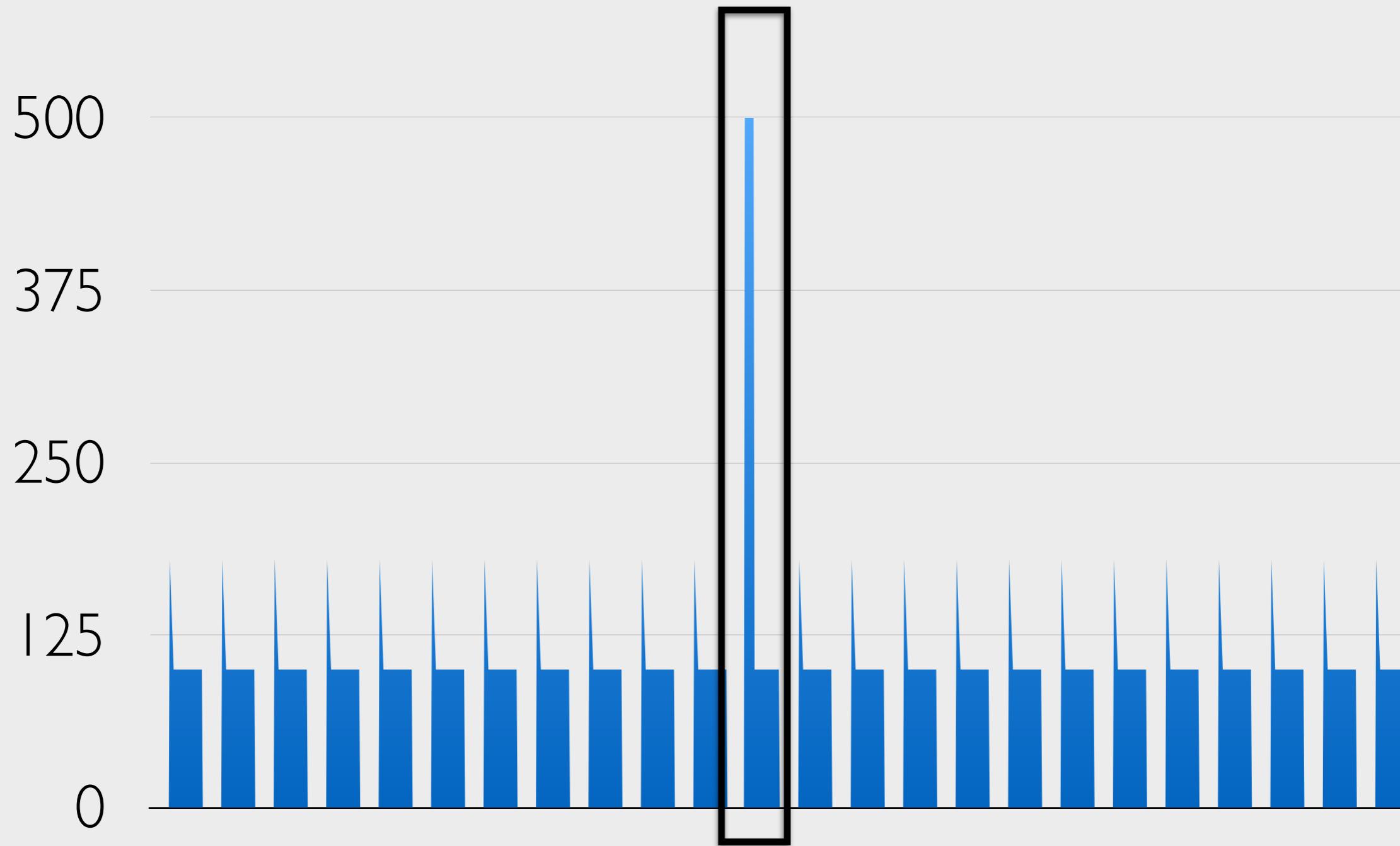
Household  
aggregate



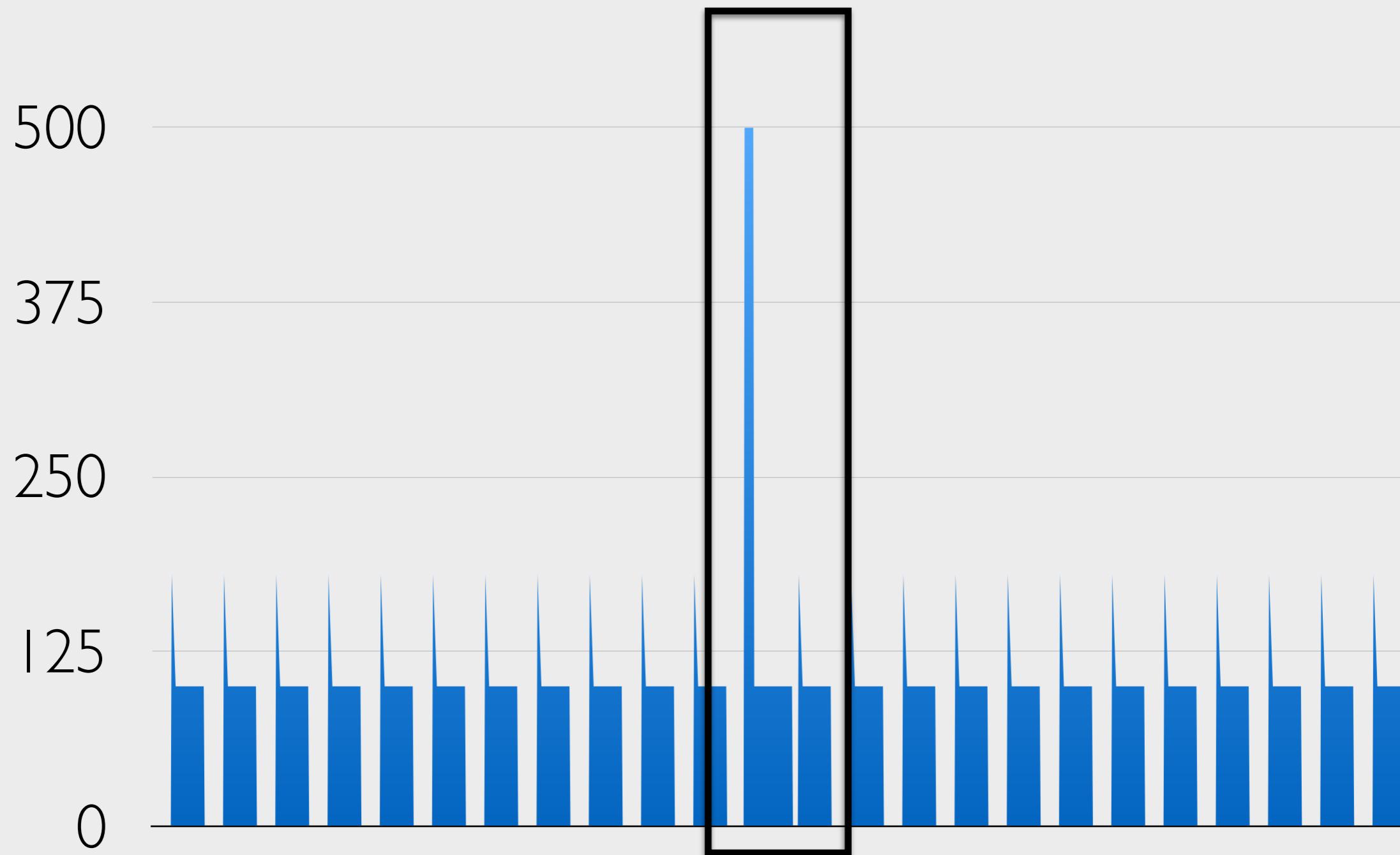
Fridge is a duty cycle based appliance;  
compressor turns ON and OFF  
periodically



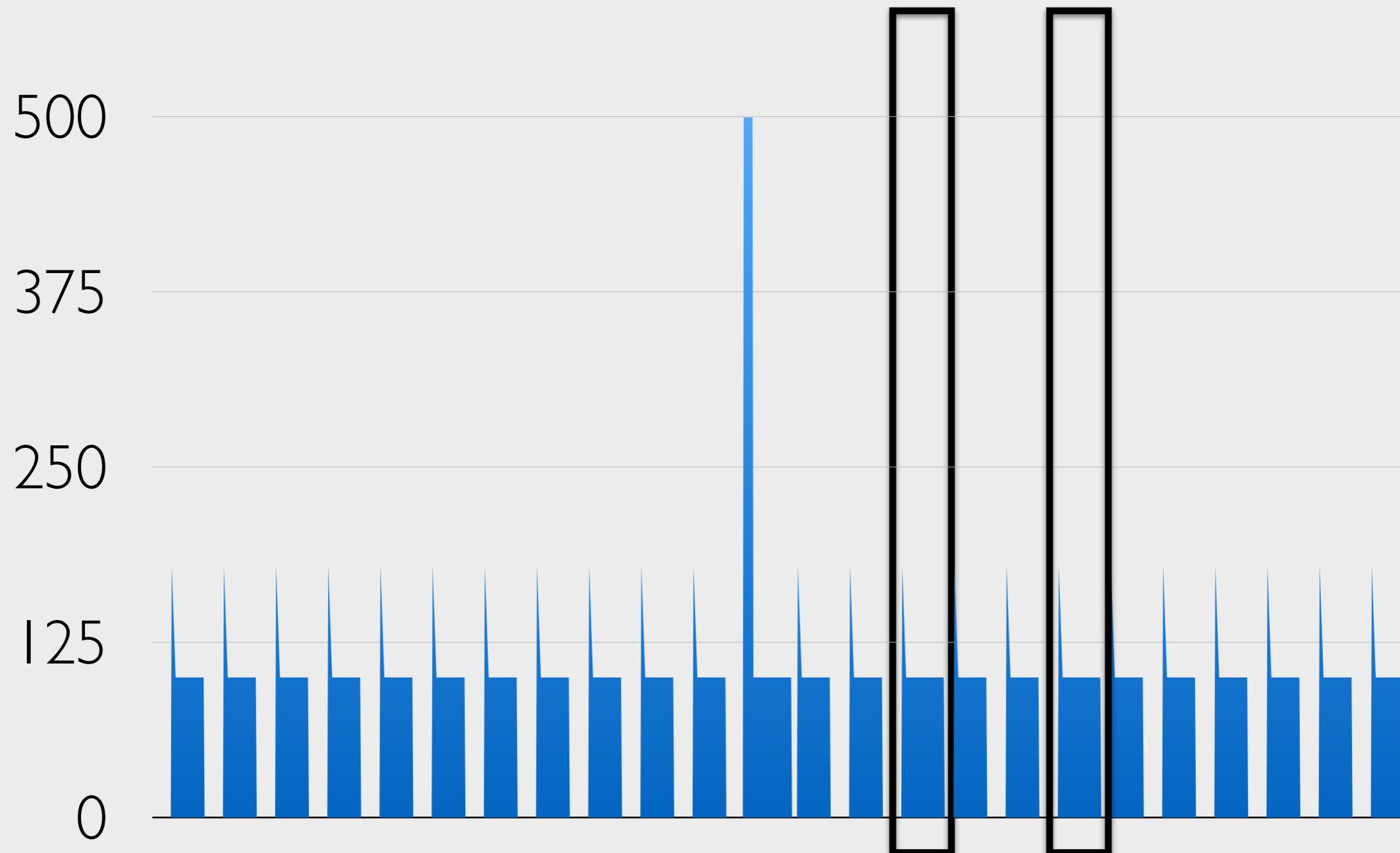
Defrost cycles occurs periodically and consume high amount of power



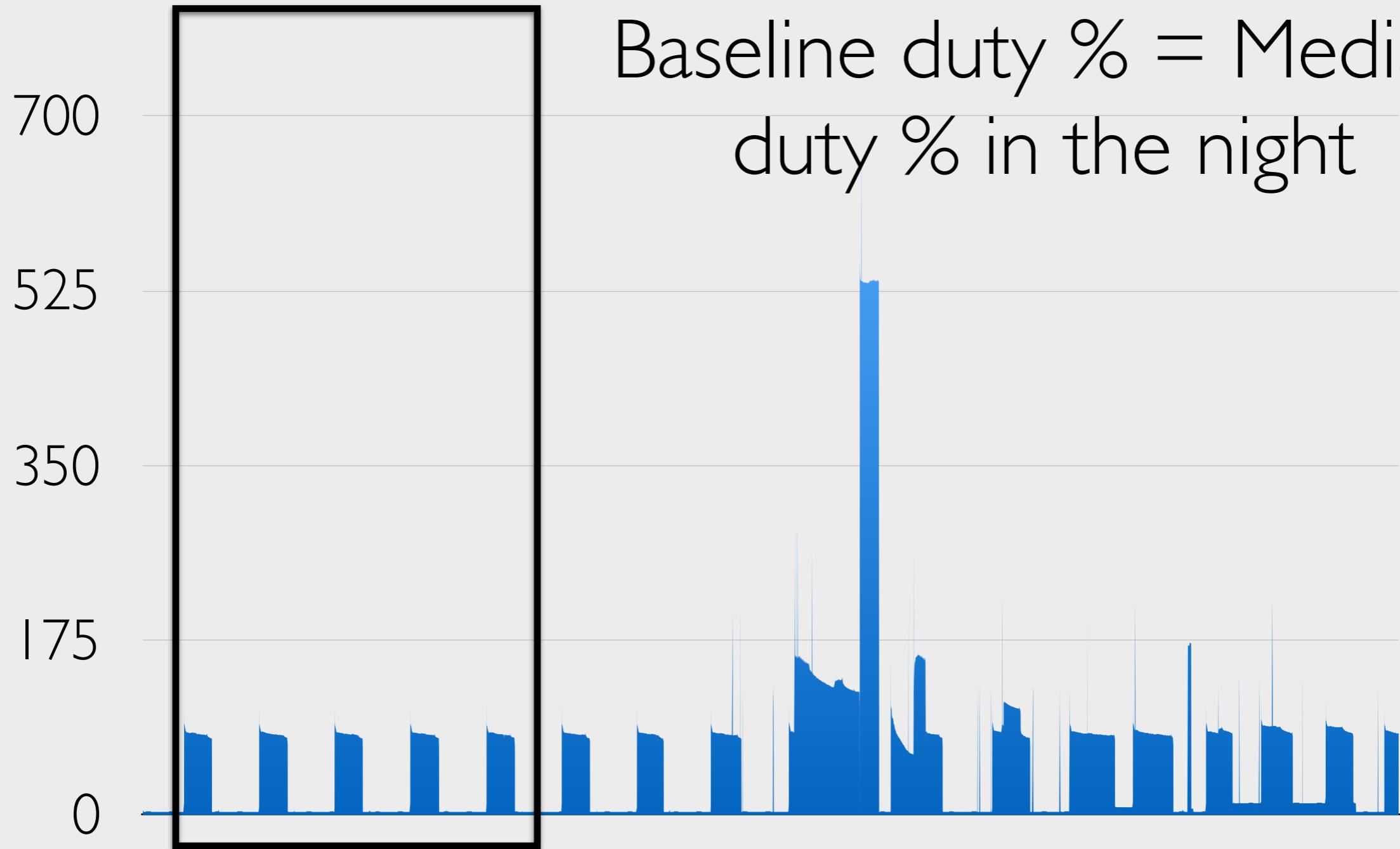
Defrost introduces heat increasing ON duration of next cycles



Fridge usage increases compressor ON durations (and reduce compressor OFF durations)

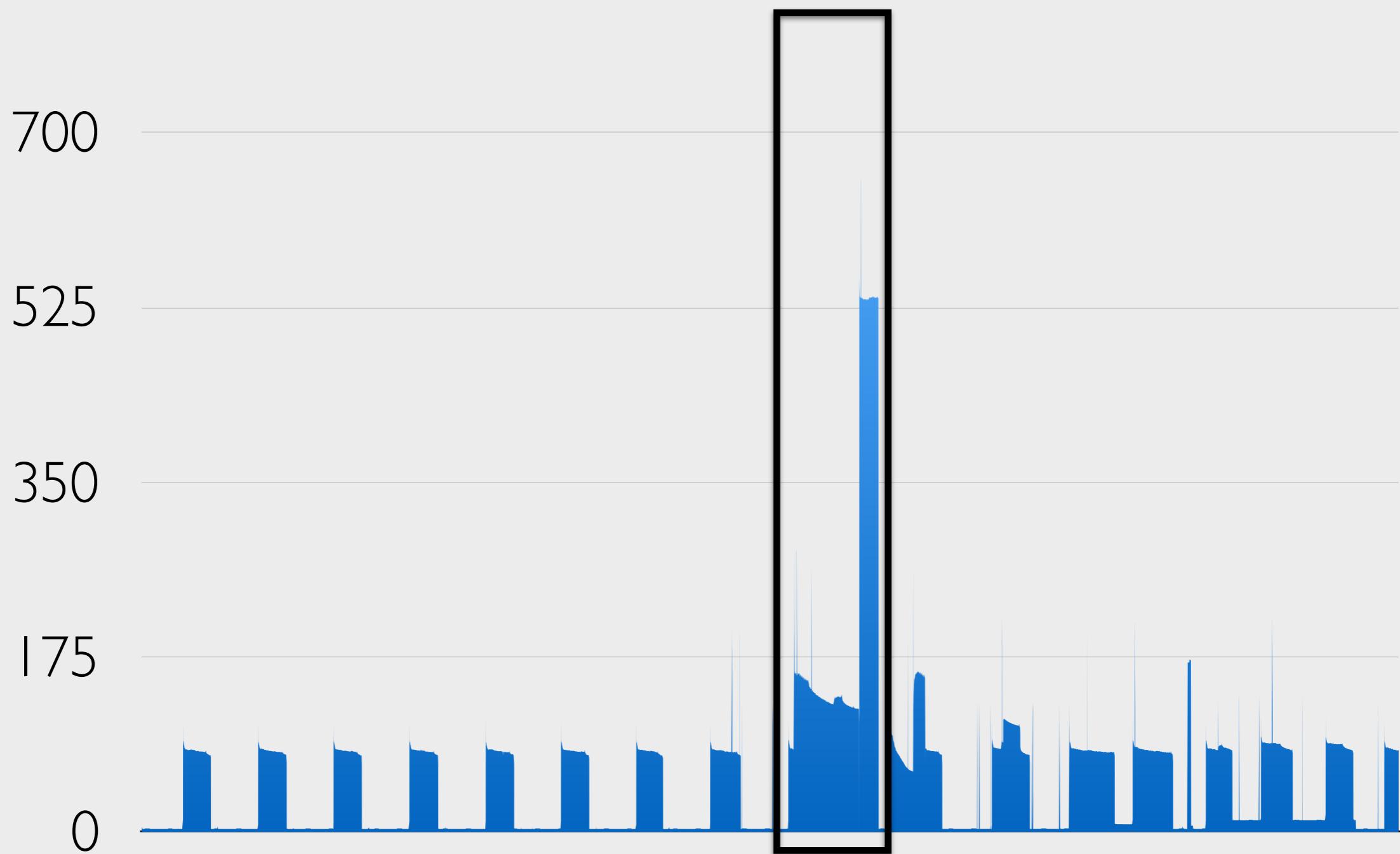


# Night hours typically have “baseline” usage



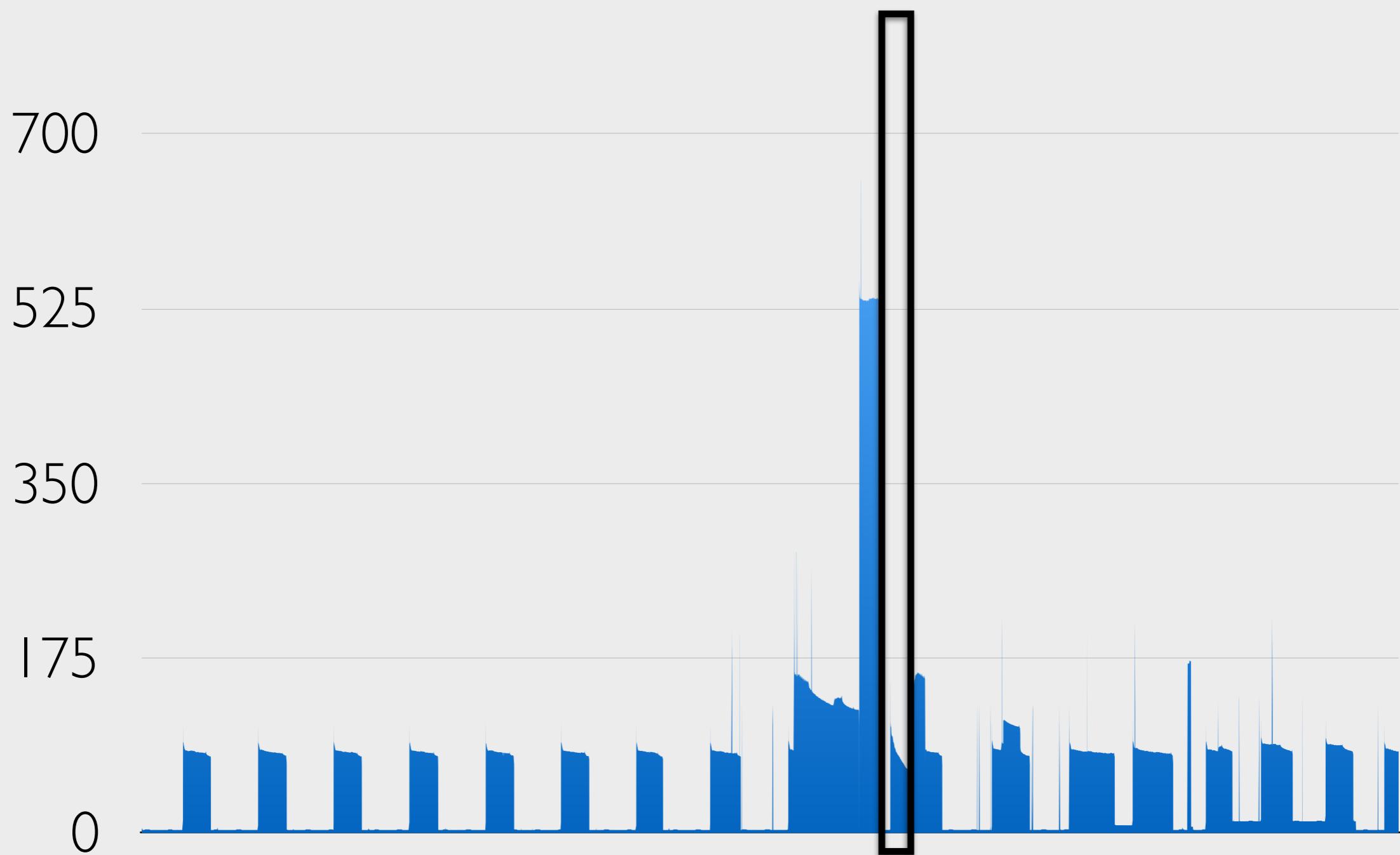
# Defrost energy

Defrost energy = Energy consumed in defrost state +  
Extra energy consumed in next few compressor cycles



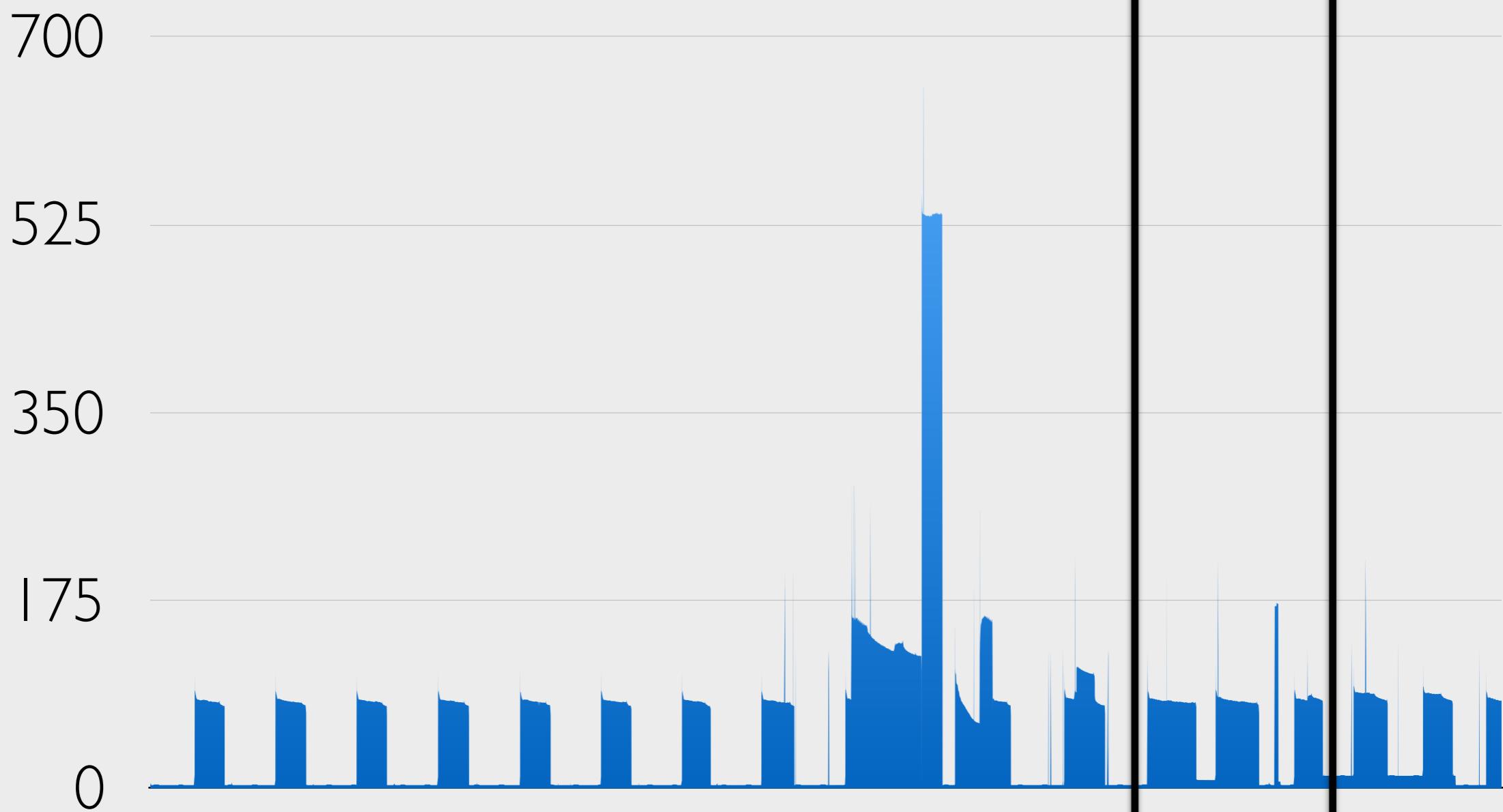
# Defrost energy

Defrost energy = Energy consumed in defrost state +  
Extra energy consumed in next few compressor cycles



# Usage energy

Usage energy = Extra  
energy consumed over  
baseline



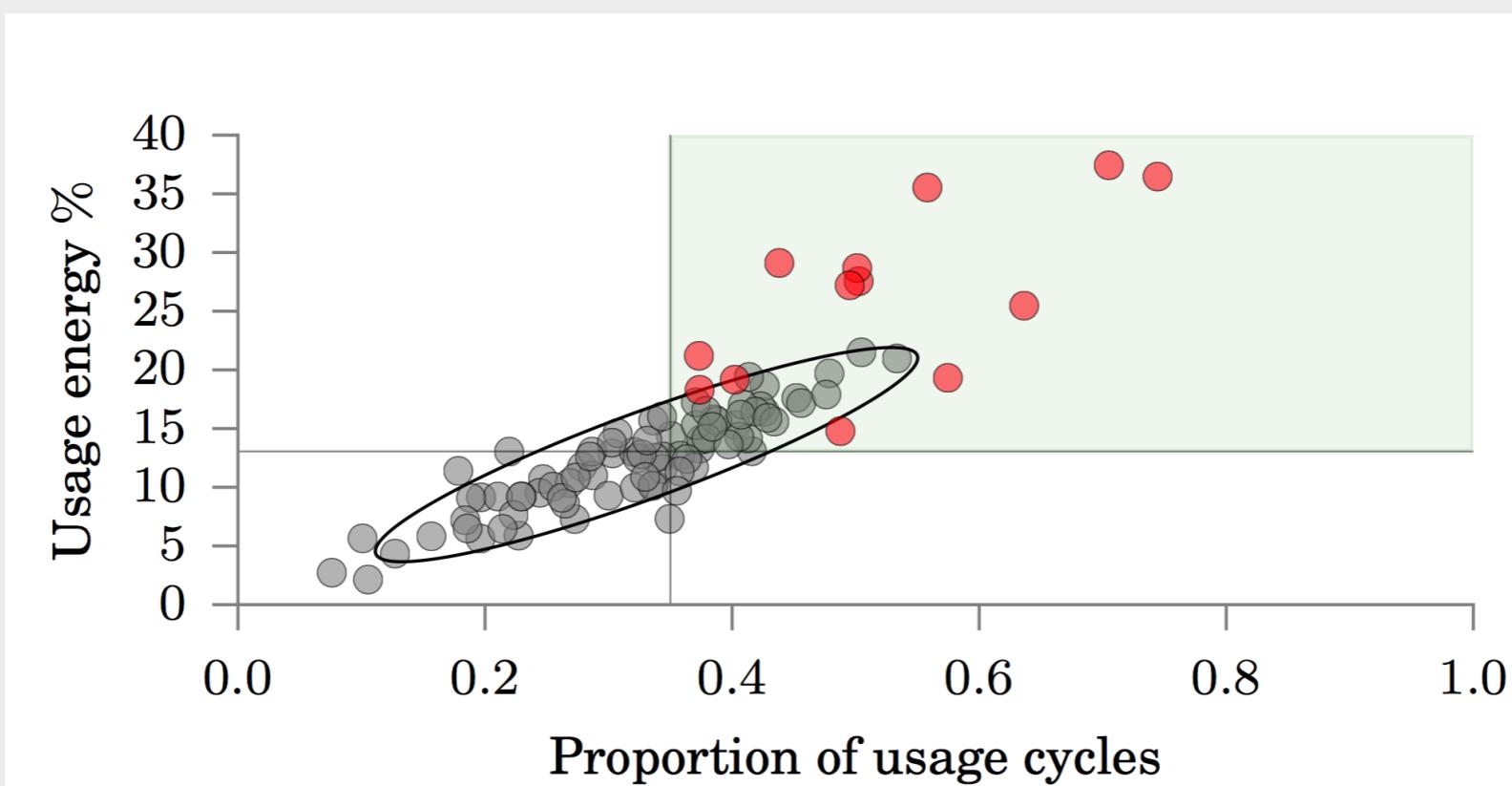
# Experimental setup

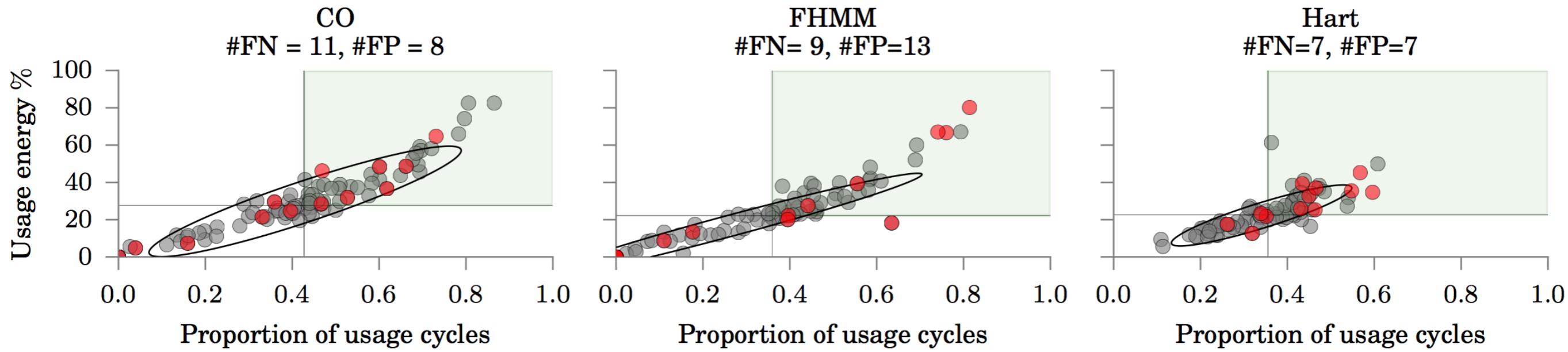
## Wiki Energy data set



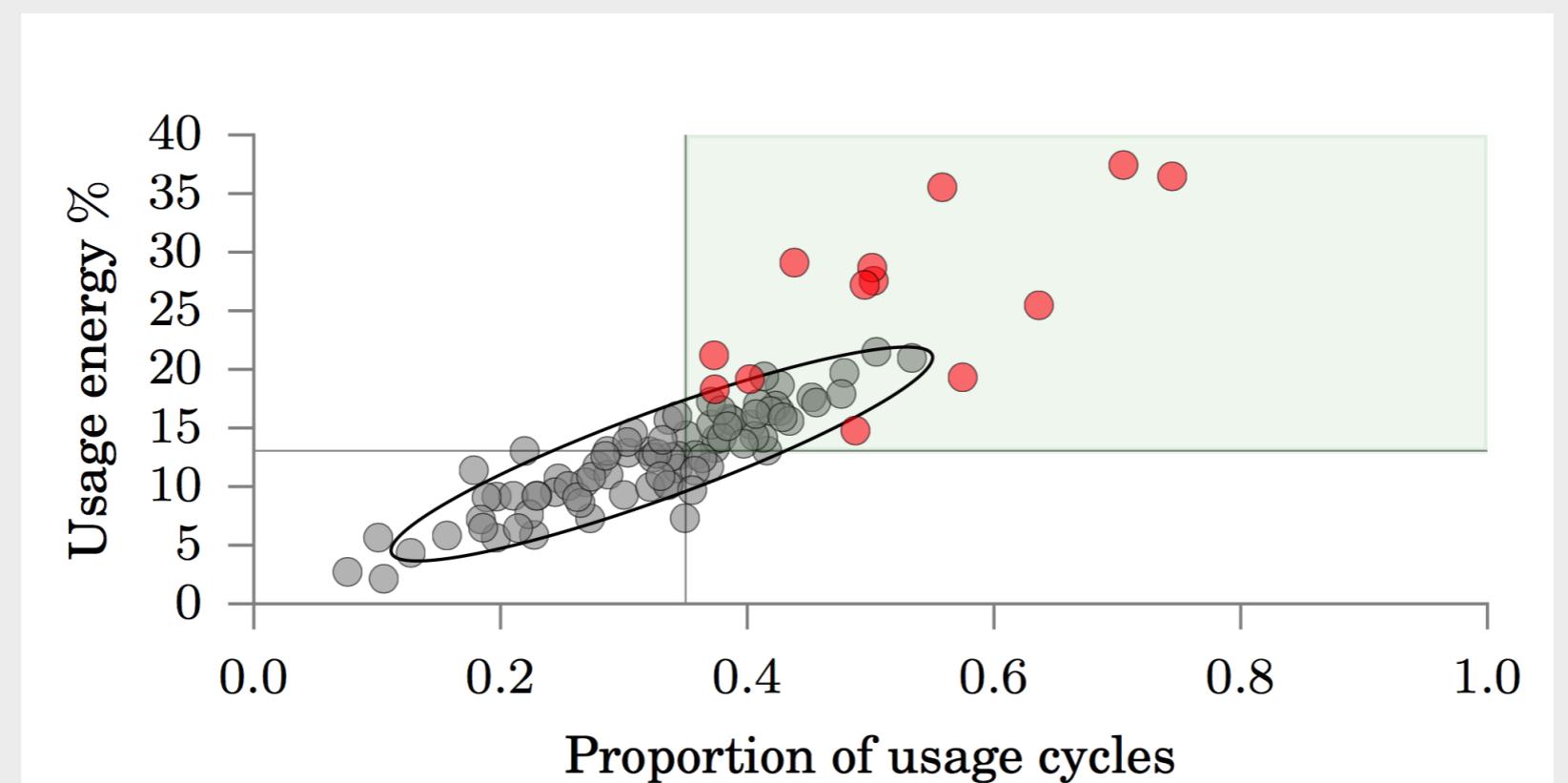
1. 97 fridges
2. 58 HVAC

| 3 out of 95 homes can be given  
feedback based on **usage energy** saving  
upto 23% fridge energy

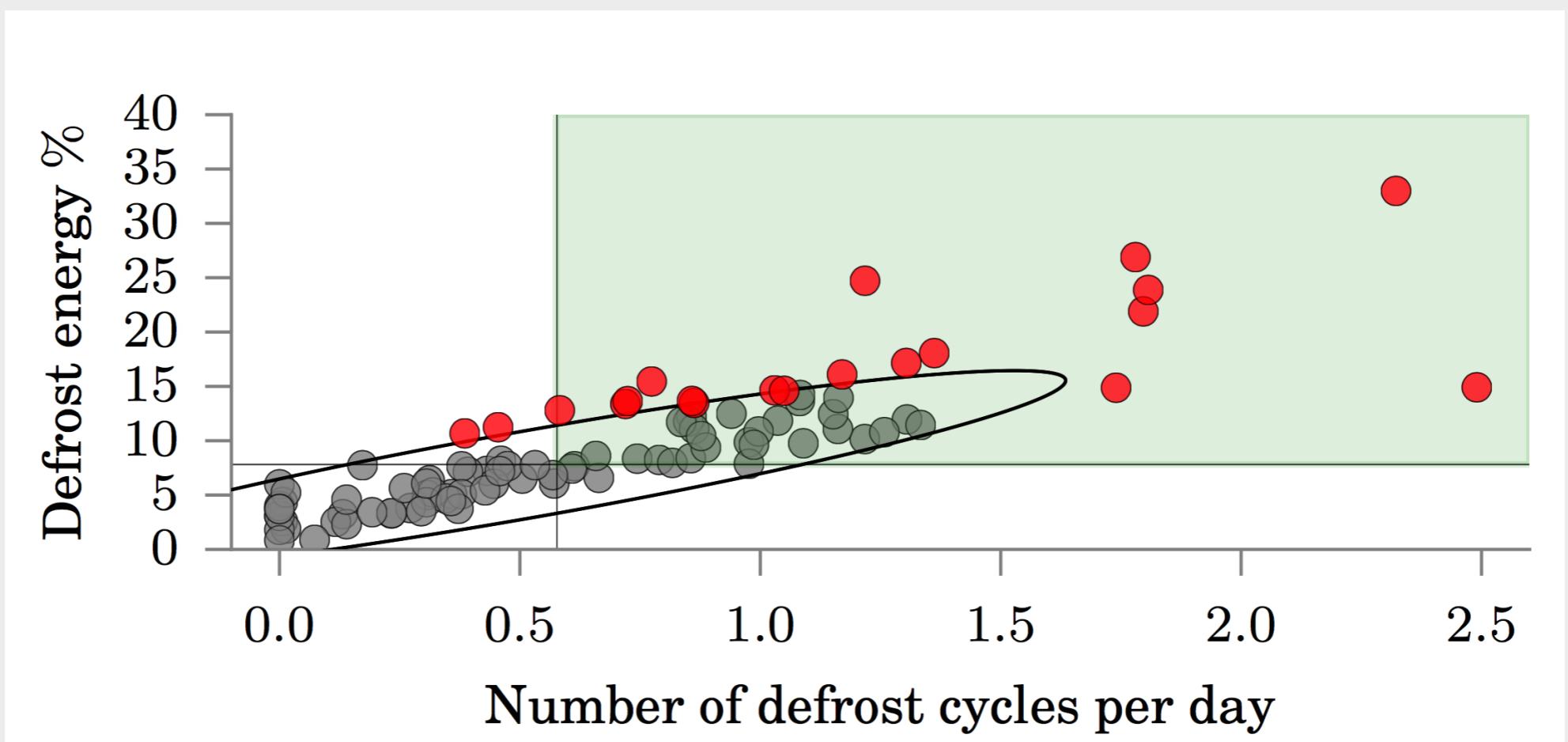




NILM algorithms show poor accuracy in identifying homes which can be given feedback based on **usage energy**

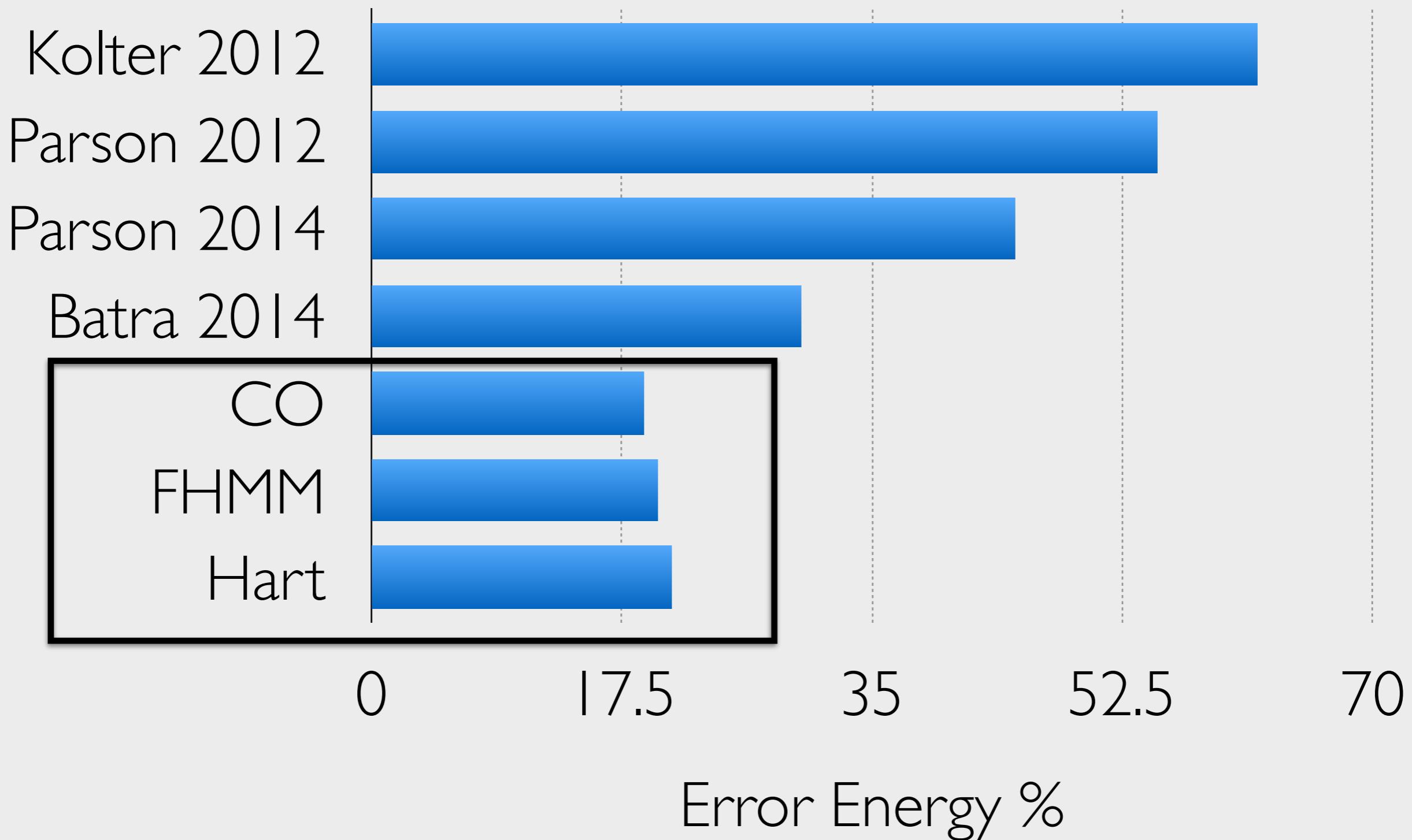


17 out of 95 homes can be given feedback on **excess defrost** saving upto 25% fridge energy

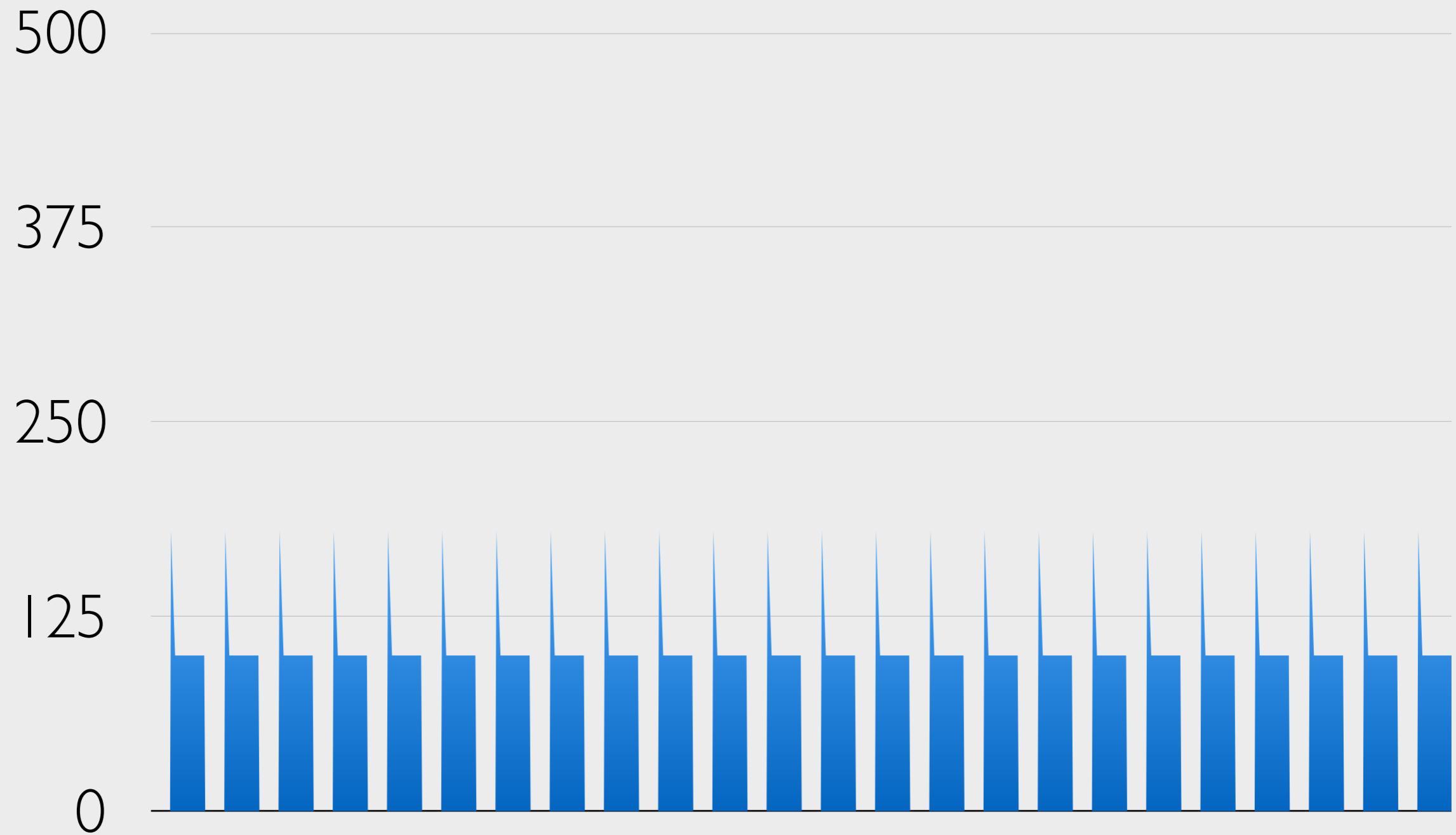


Such feedback can't be given with disaggregated traces, since these techniques fare poorly on defrost detection.

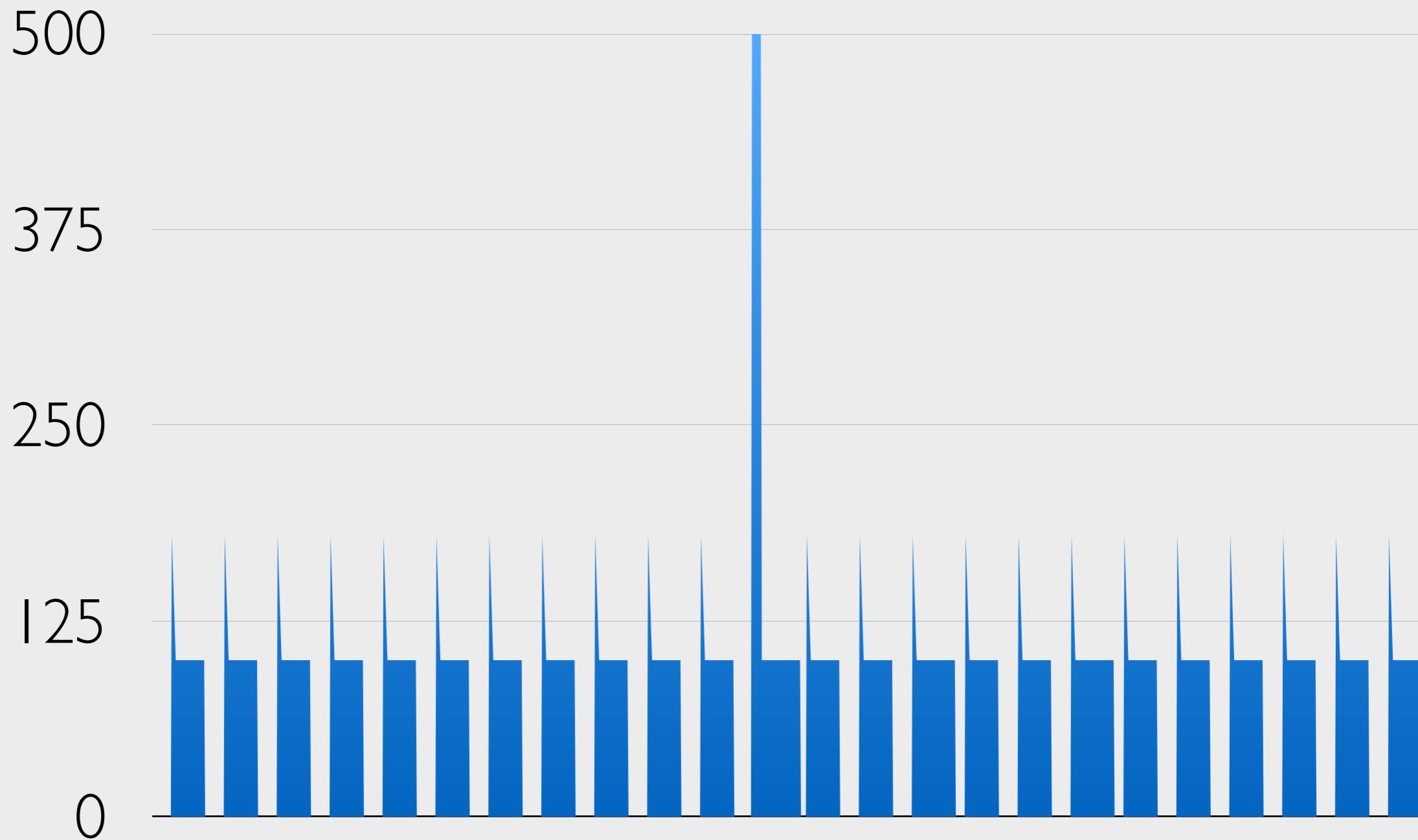
Benchmark NILM algorithms on our data set  
give accuracy comparable or better than  
state-of-the-art



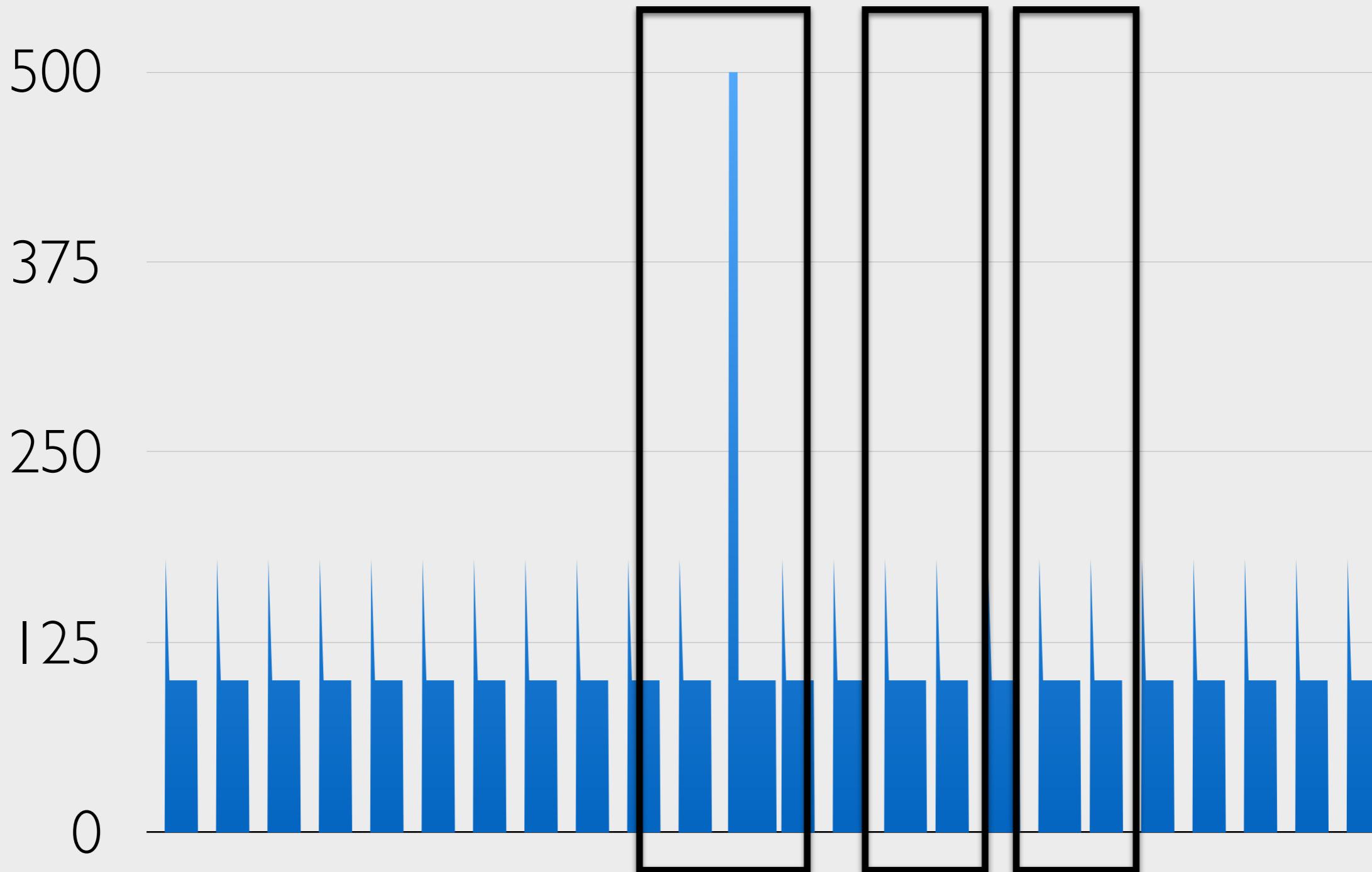
“Average” error in energy would be low even  
if NILM predicted this



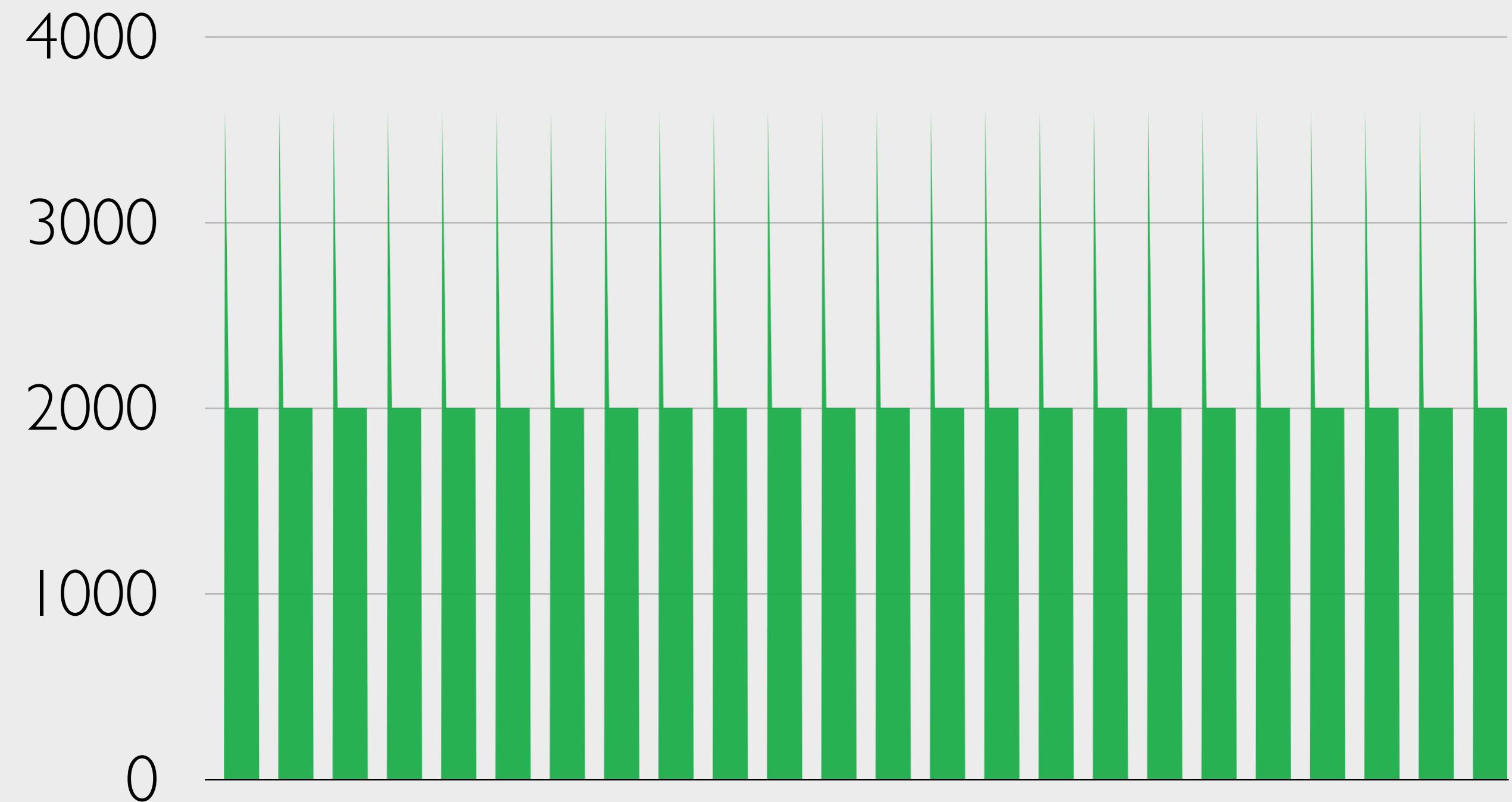
But, we wanted to predict..



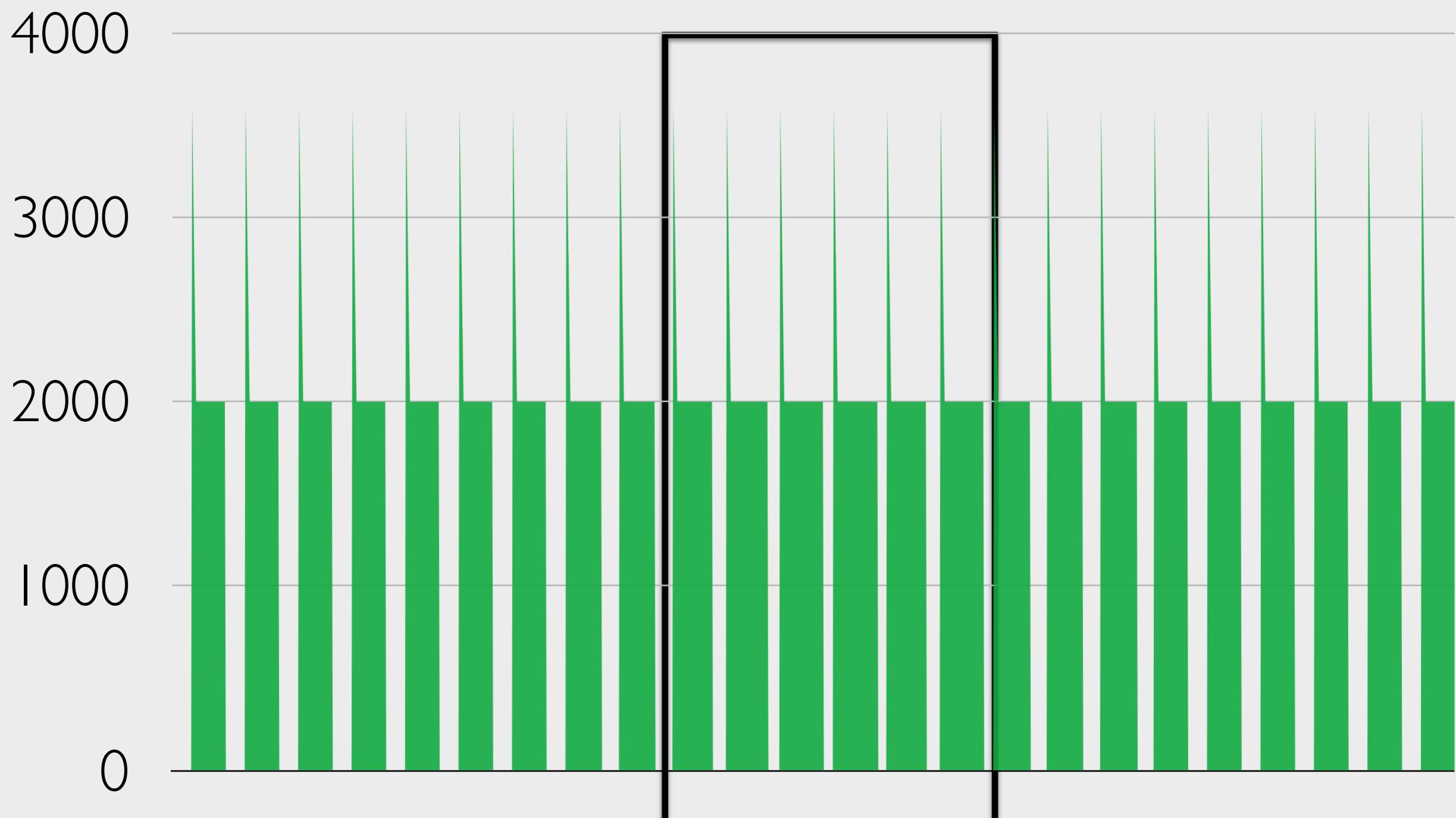
# It's the details that we care about



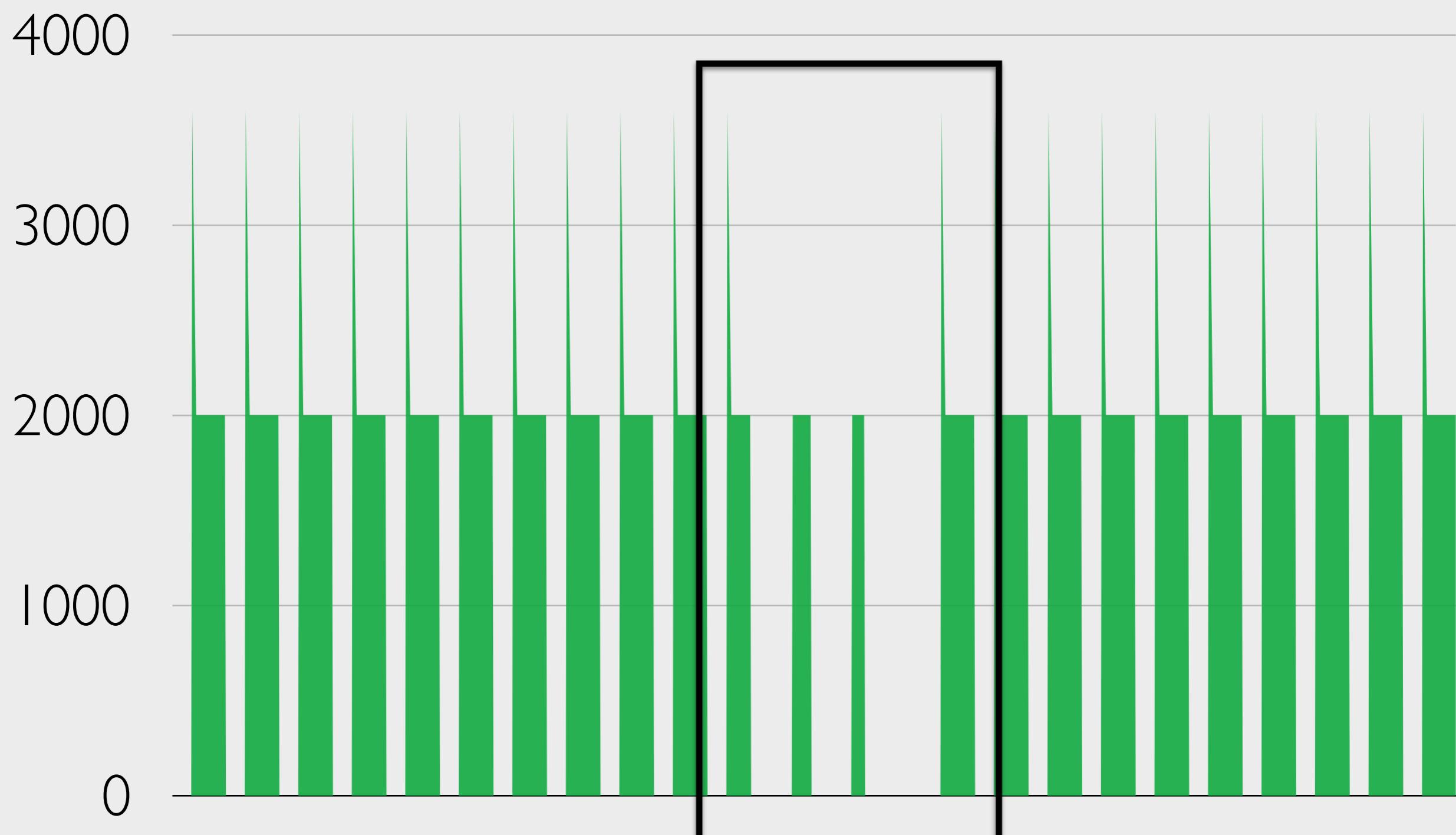
Like fridge, HVAC duty cycles to  
maintain the set temperature



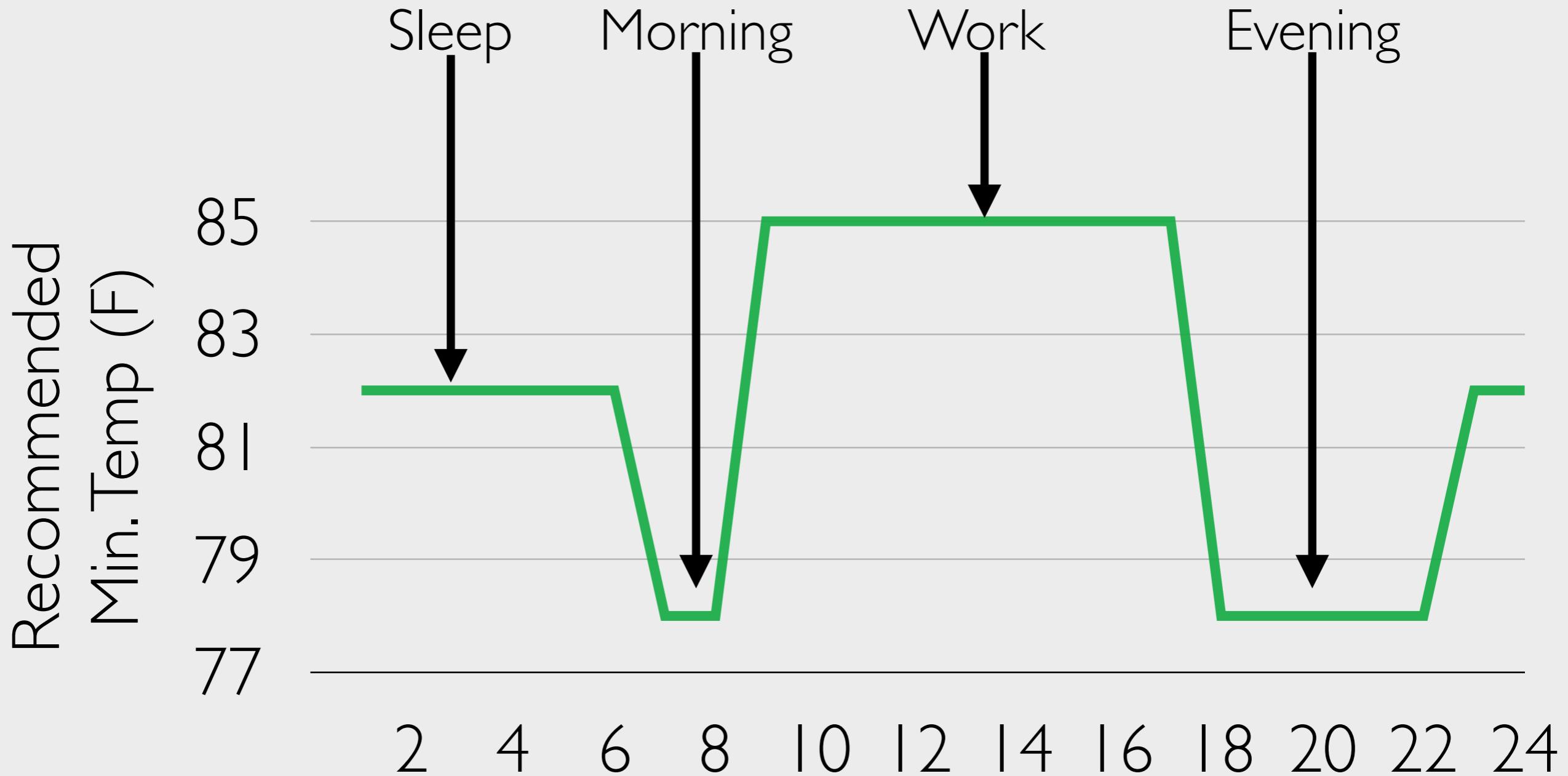
As temperature increases during the day,  
more energy required to cool the home



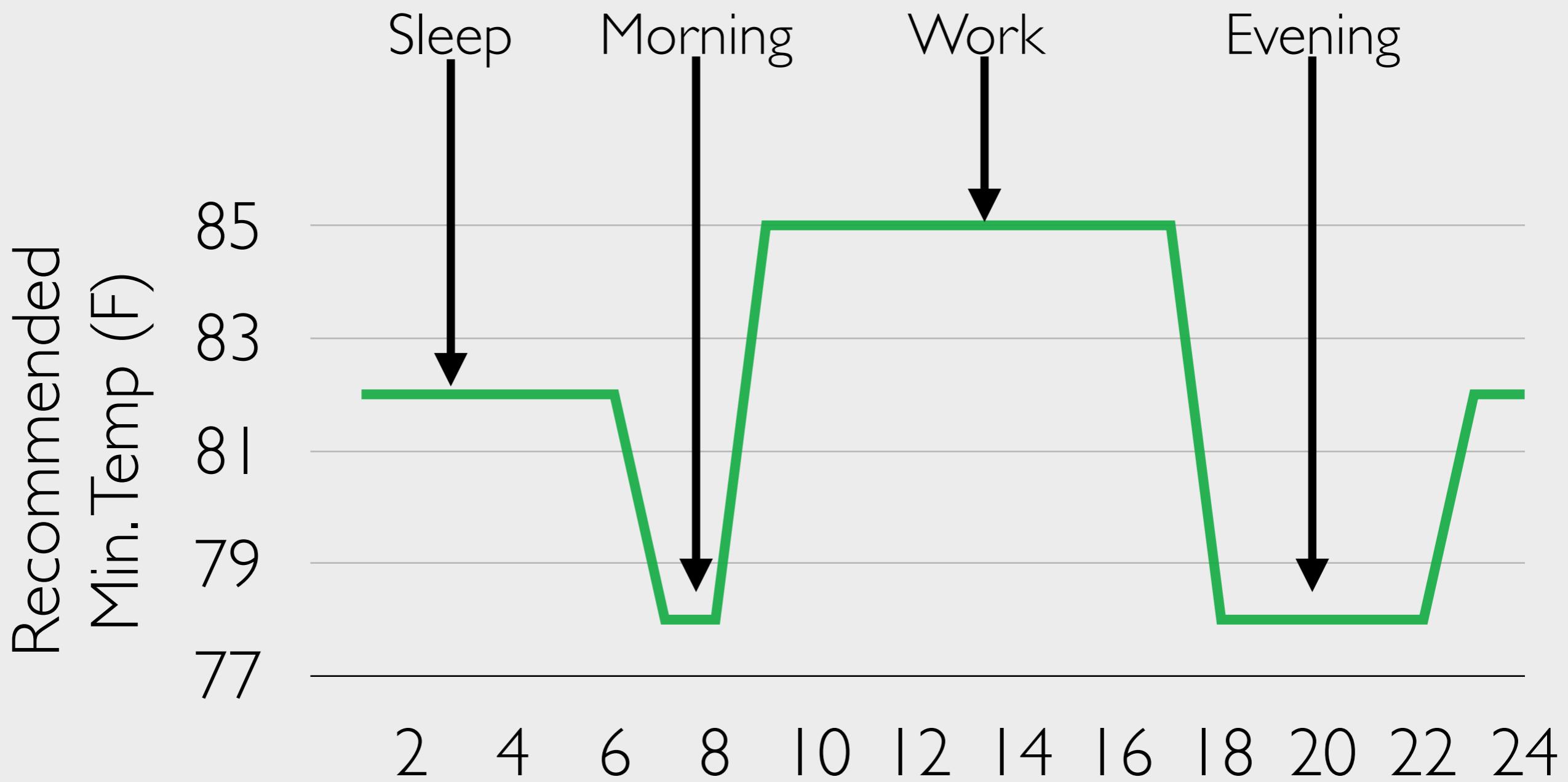
People typically turn up the temperatures when they leave home



# EnergyStar.gov recommended HVAC setpoint schedule

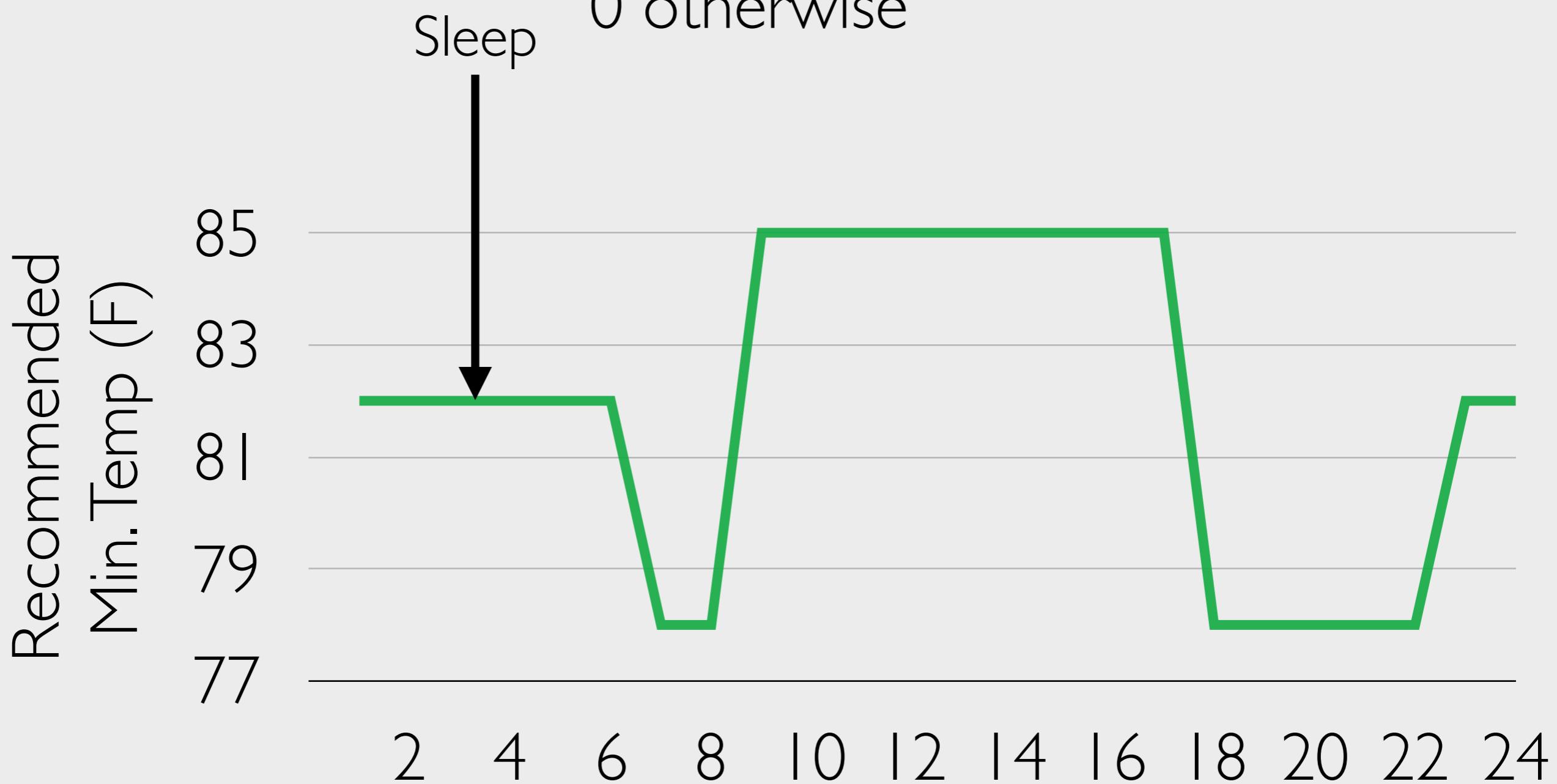


# Setpoint schedule score



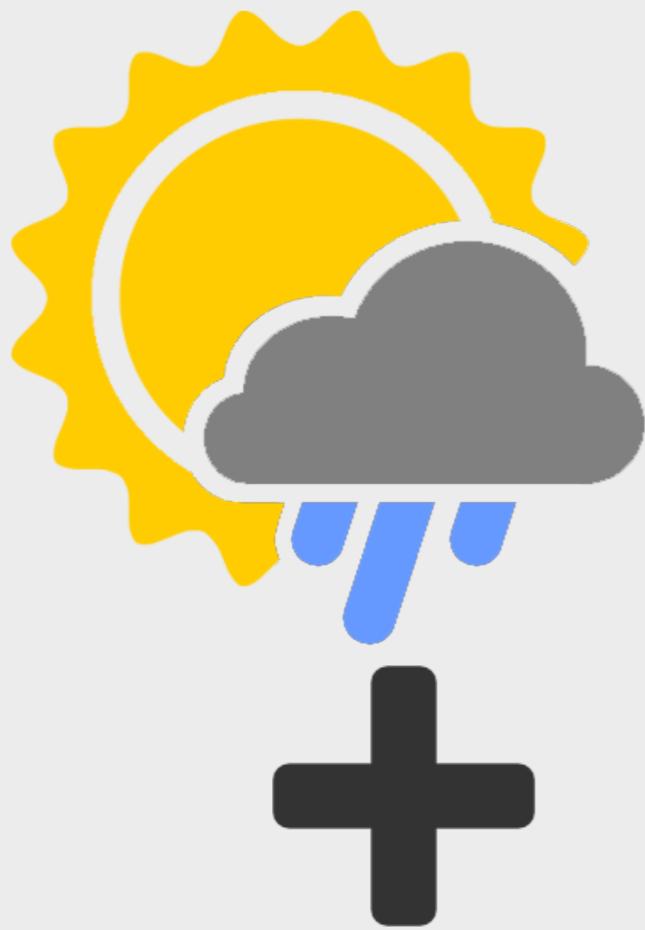
# Setpoint schedule score

Sleep score = 1 if sleep temp. > 82,  
 $(82 - \text{temp.})/4$  if  $78 < \text{sleep temp.} < 82$   
0 otherwise

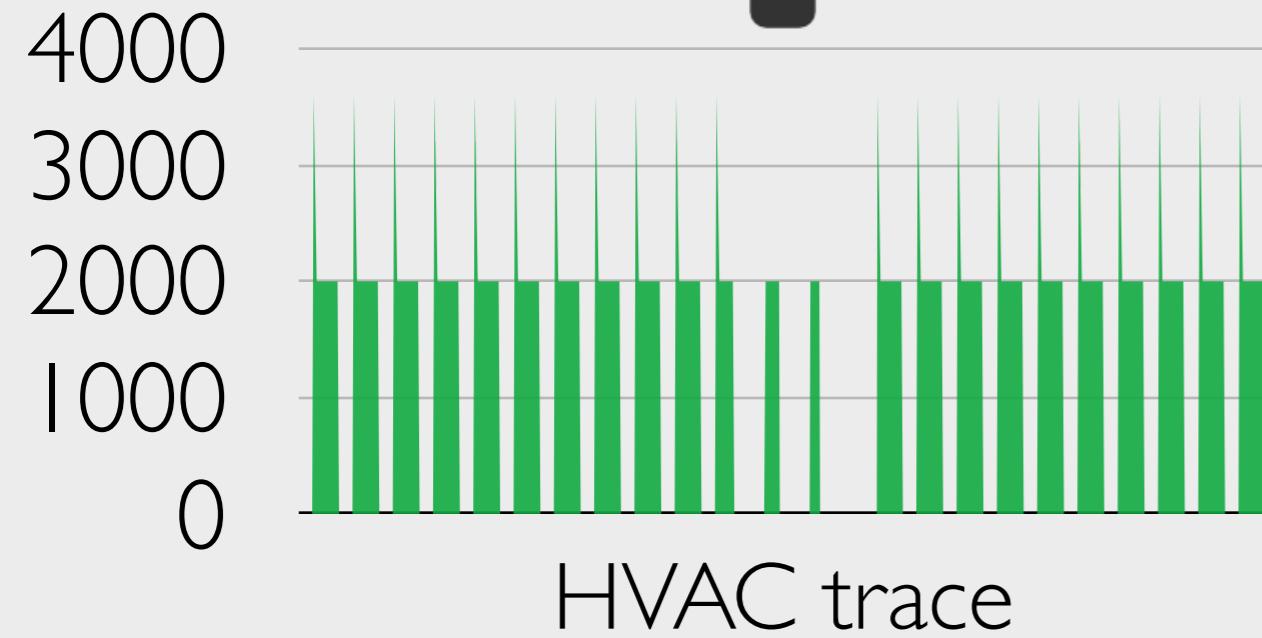
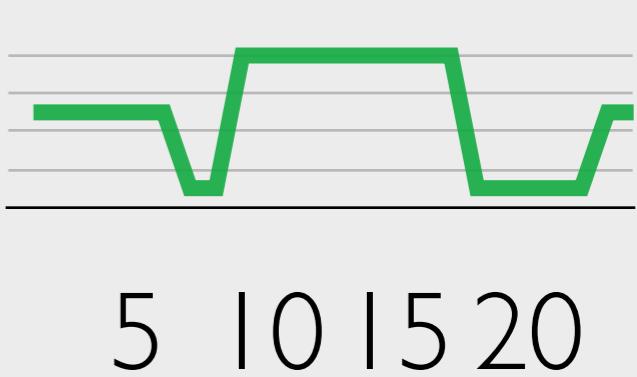


# Learning HVAC setpoint

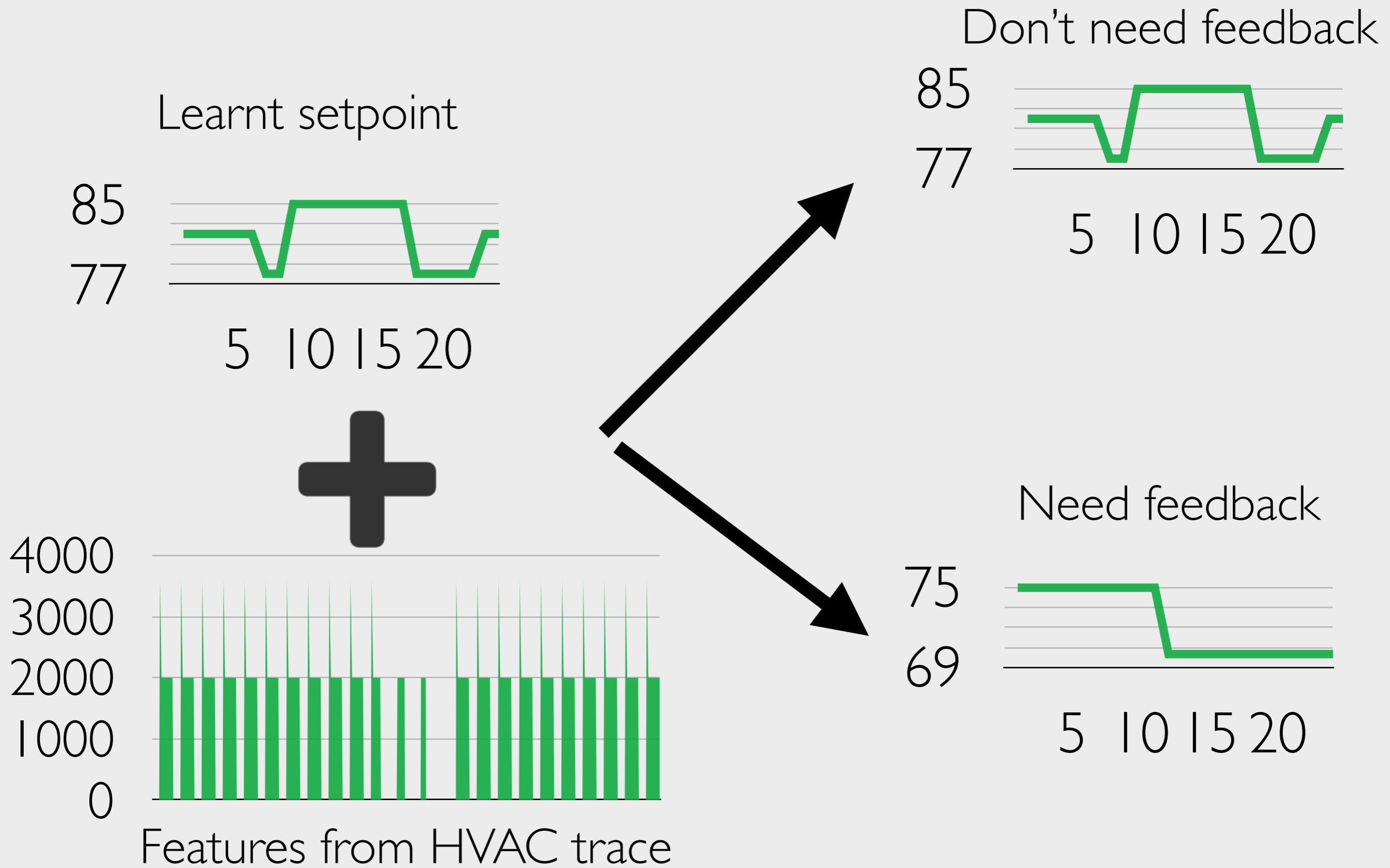
Weather



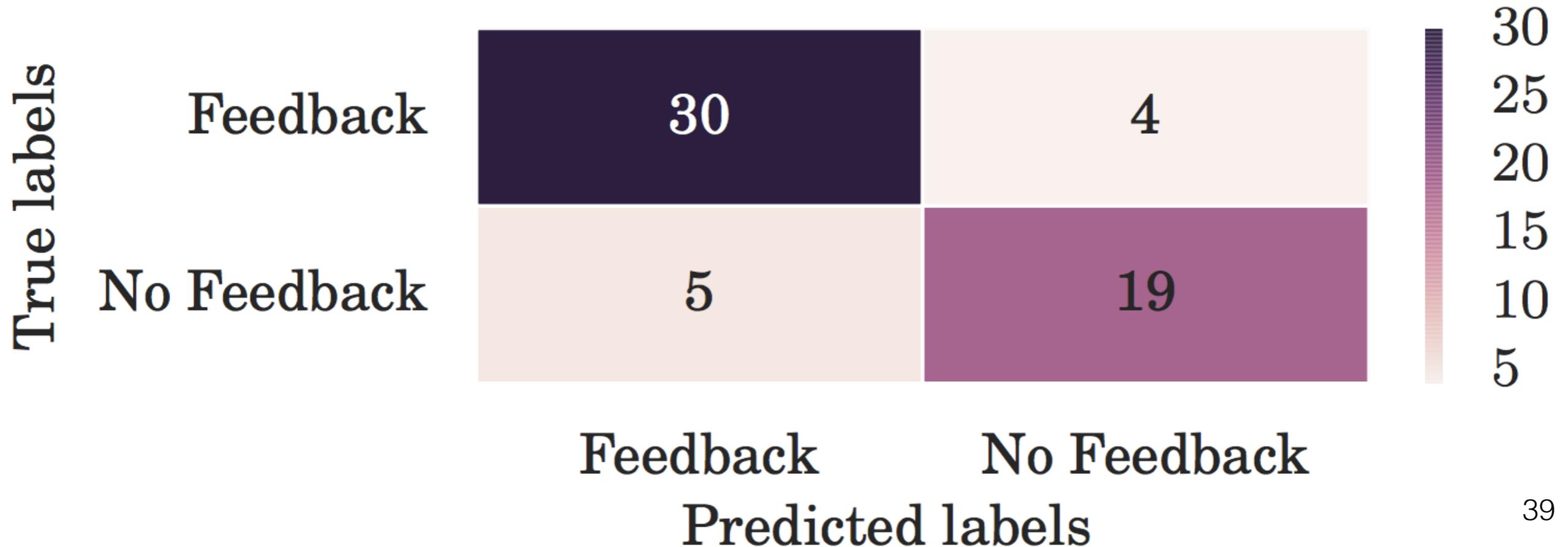
Learnt setpoint

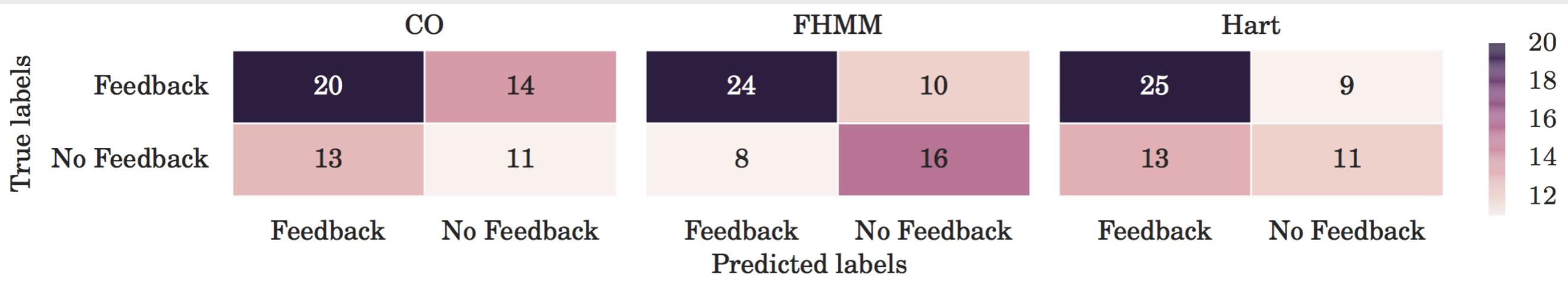


# Giving feedback

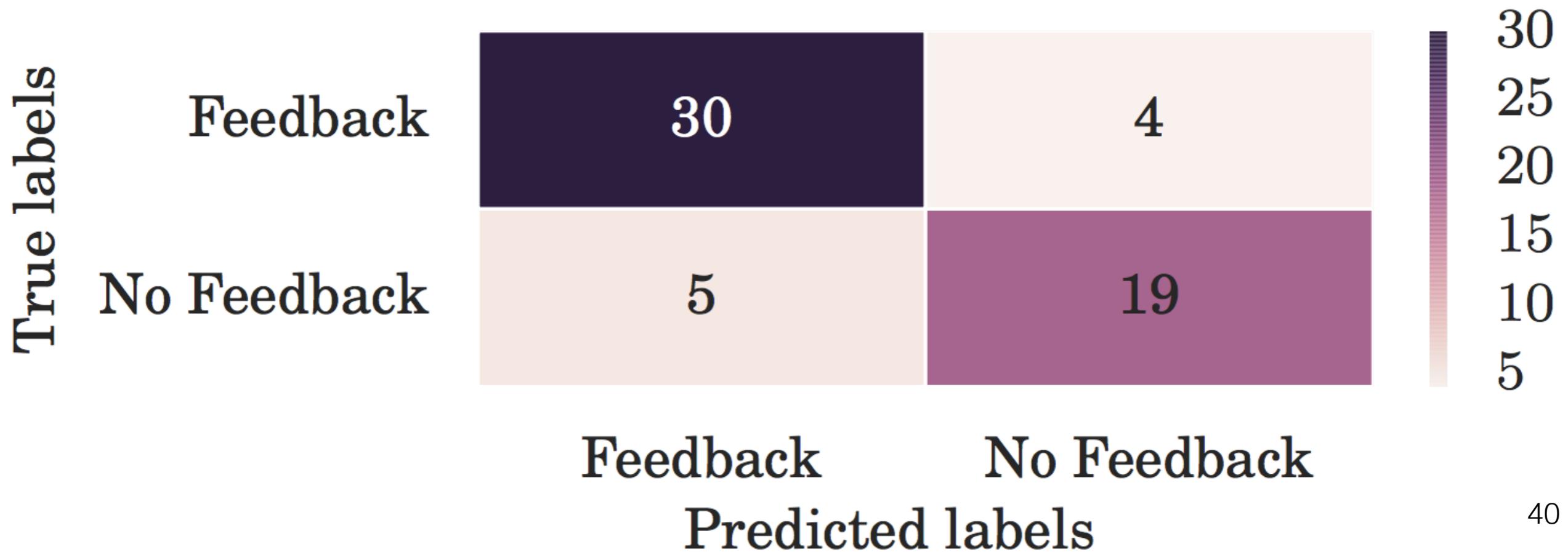


84% accuracy on giving feedback using  
submetered traces

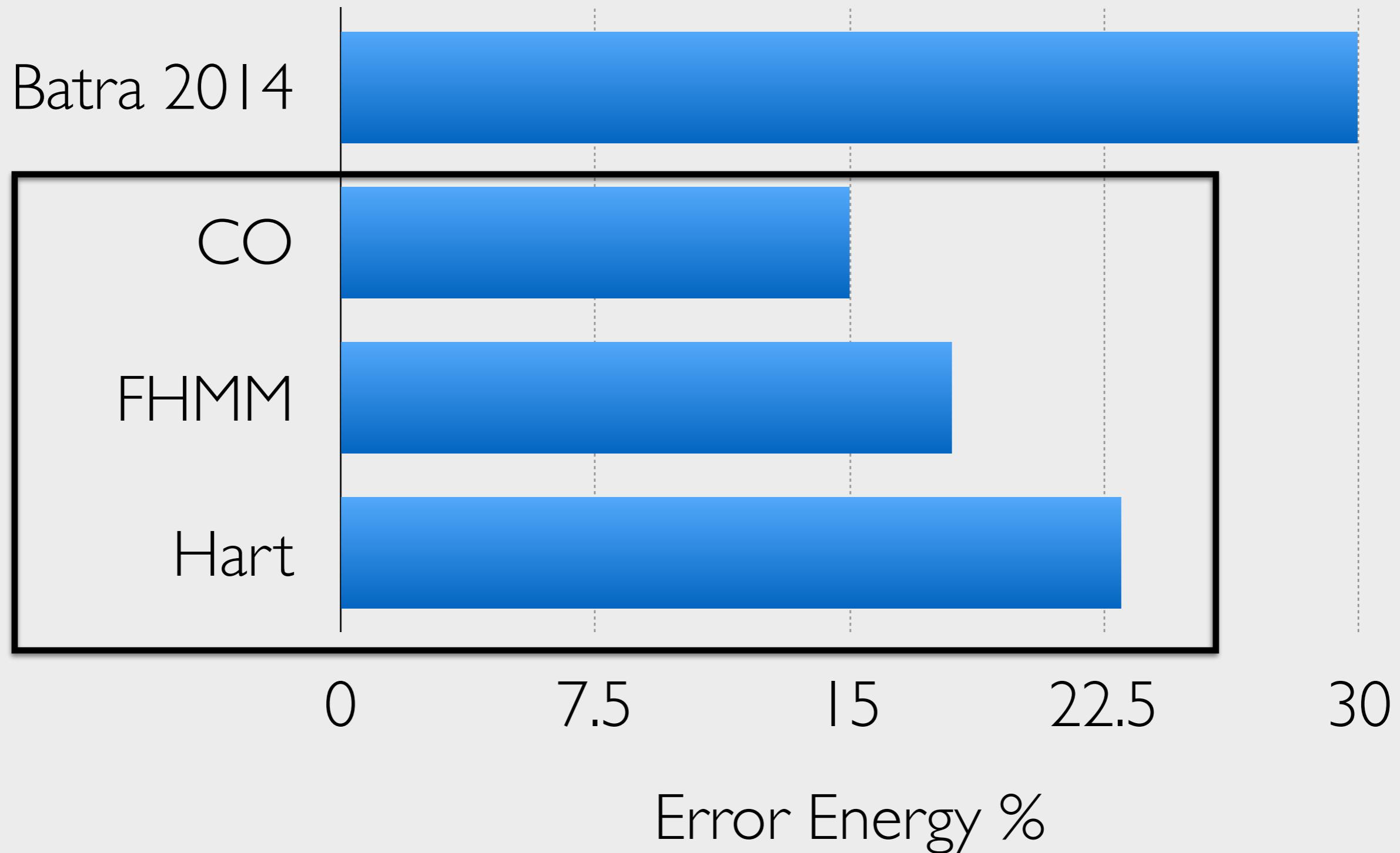




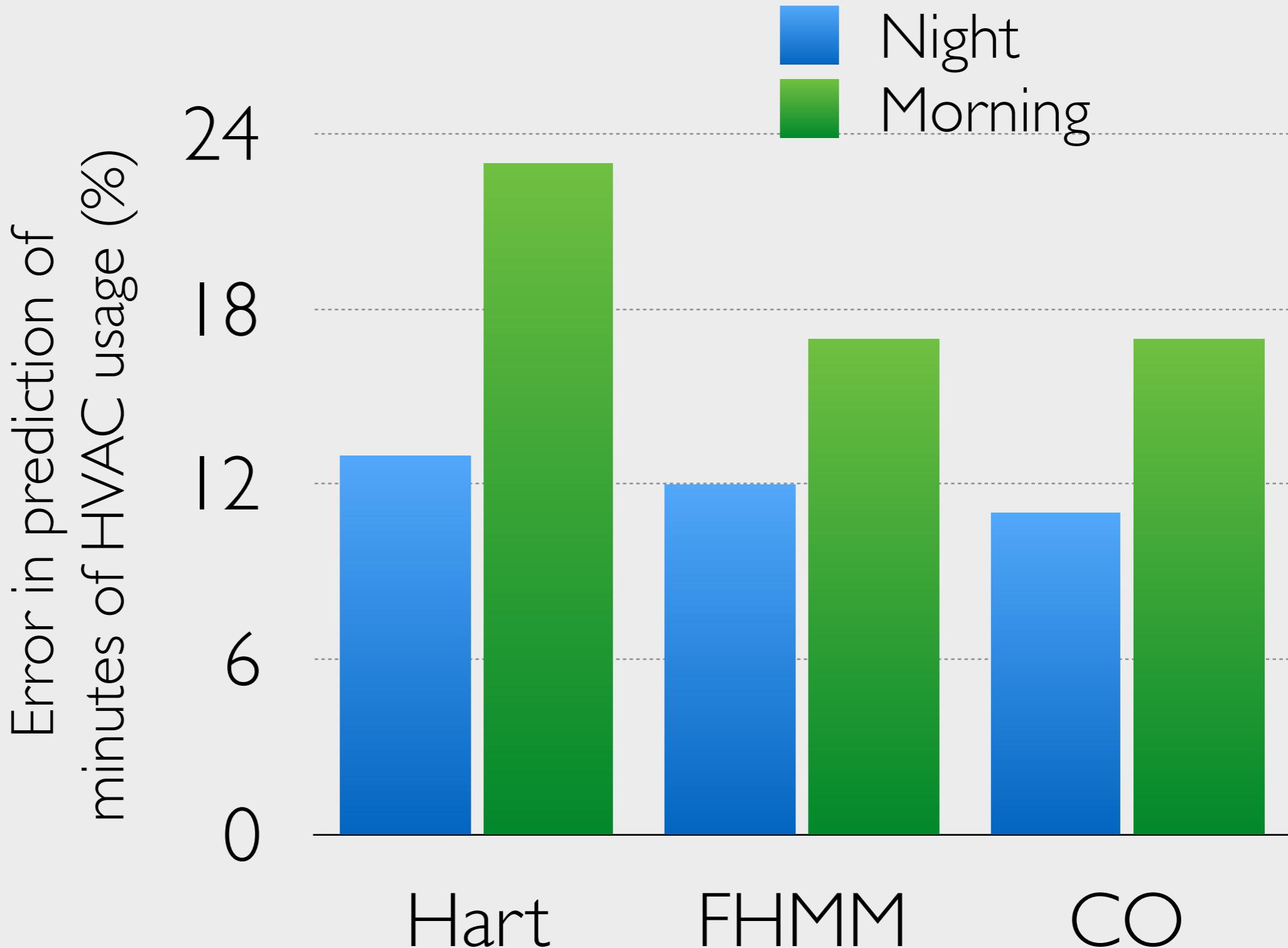
NILM methods give 15-30% worse accuracy for feedback



Benchmark NILM algorithms on our data set  
give accuracy comparable or better than  
state-of-the-art



Morning hours which have lesser NILM accuracy are important for HVAC feedback



# Conclusions

Appliance level data **does** enable actionable energy saving feedback

# Conclusions

Appliance level data **does** enable actionable energy saving feedback

**BUT**

Results show that we need to **revisit the metrics** by which we **measures progress**