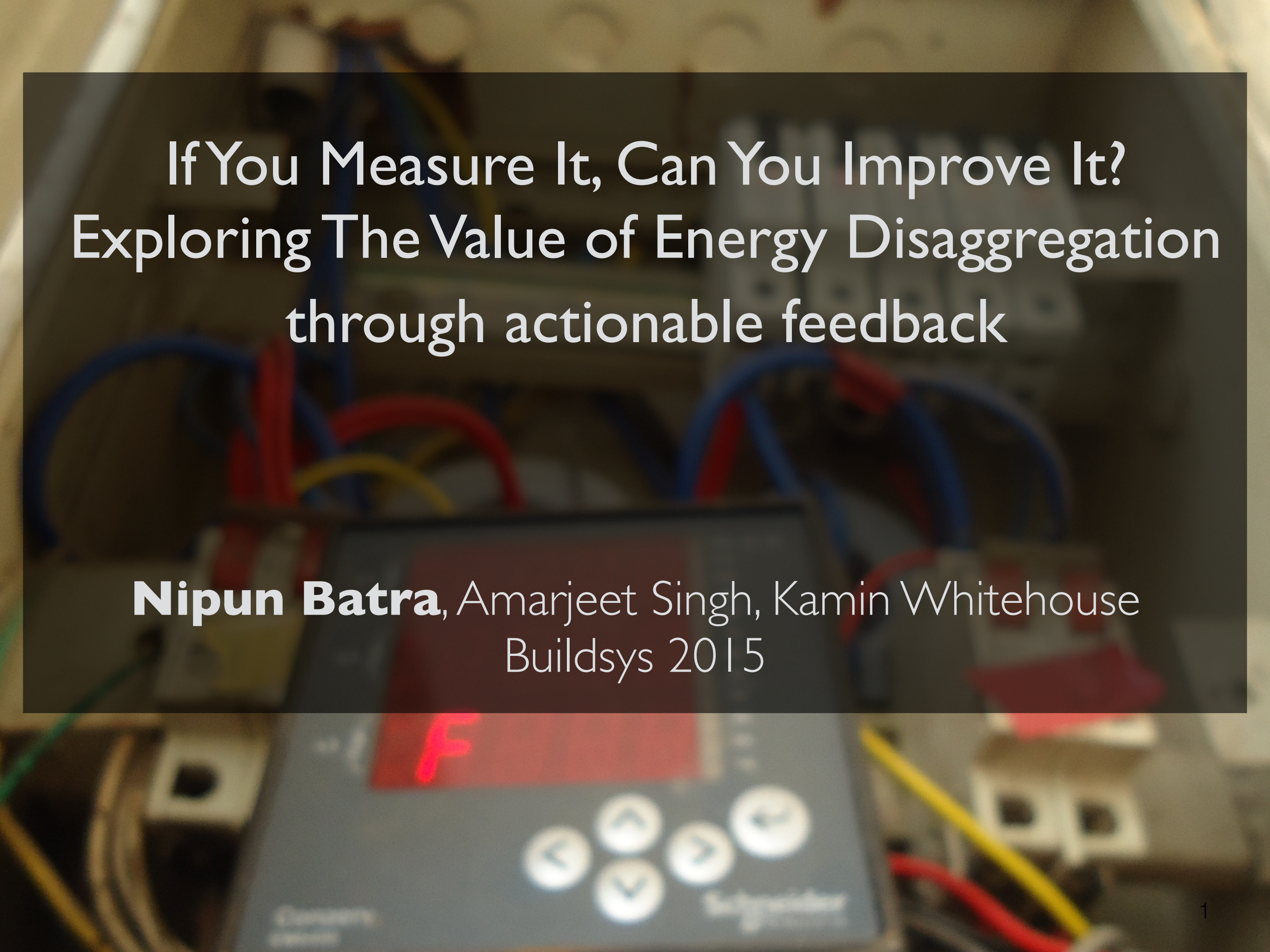


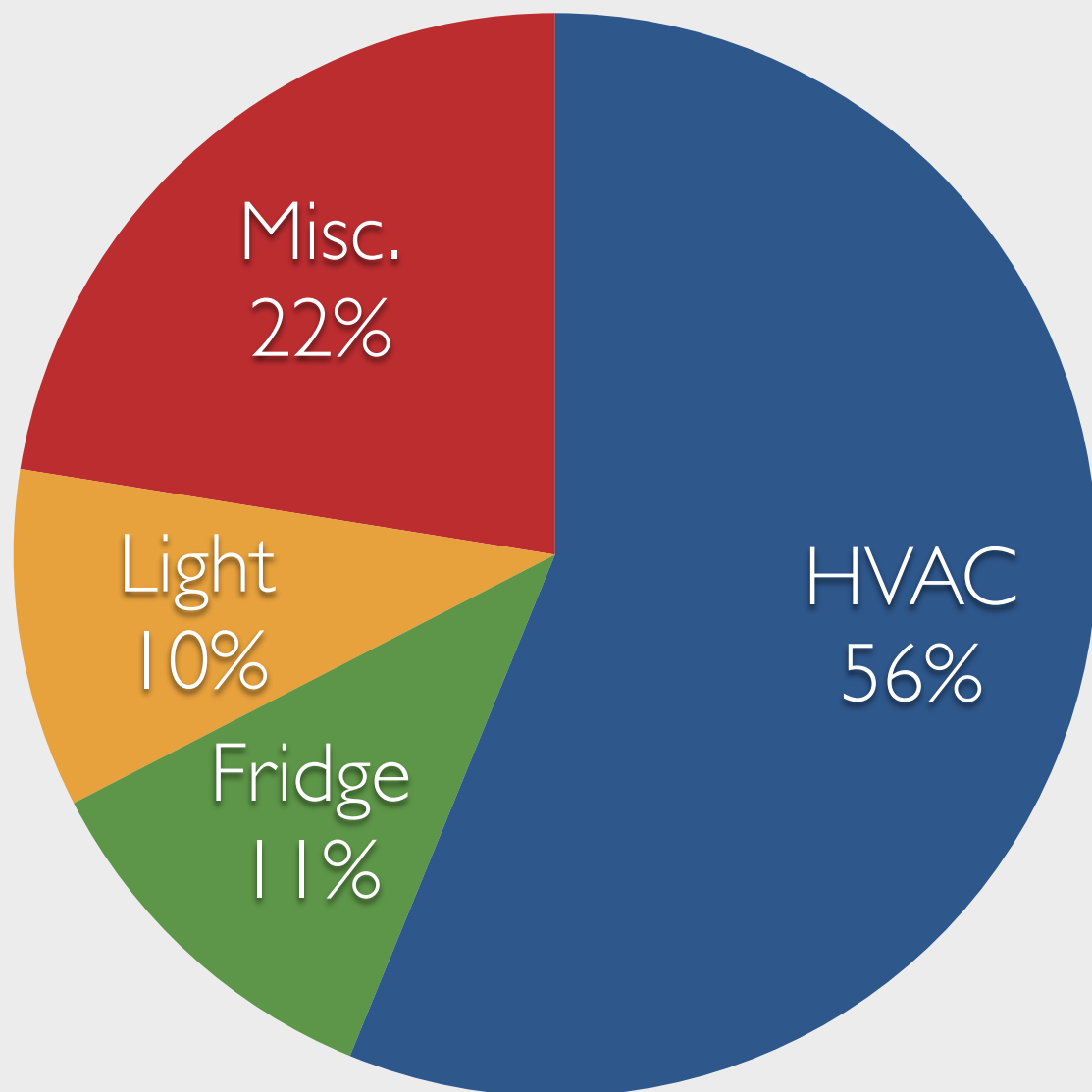


If You Measure It, Can You Improve It? Exploring The Value of Energy Disaggregation through actionable feedback

Nipun Batra, Amarjeet Singh, Kamin Whitehouse
Buildsys 2015

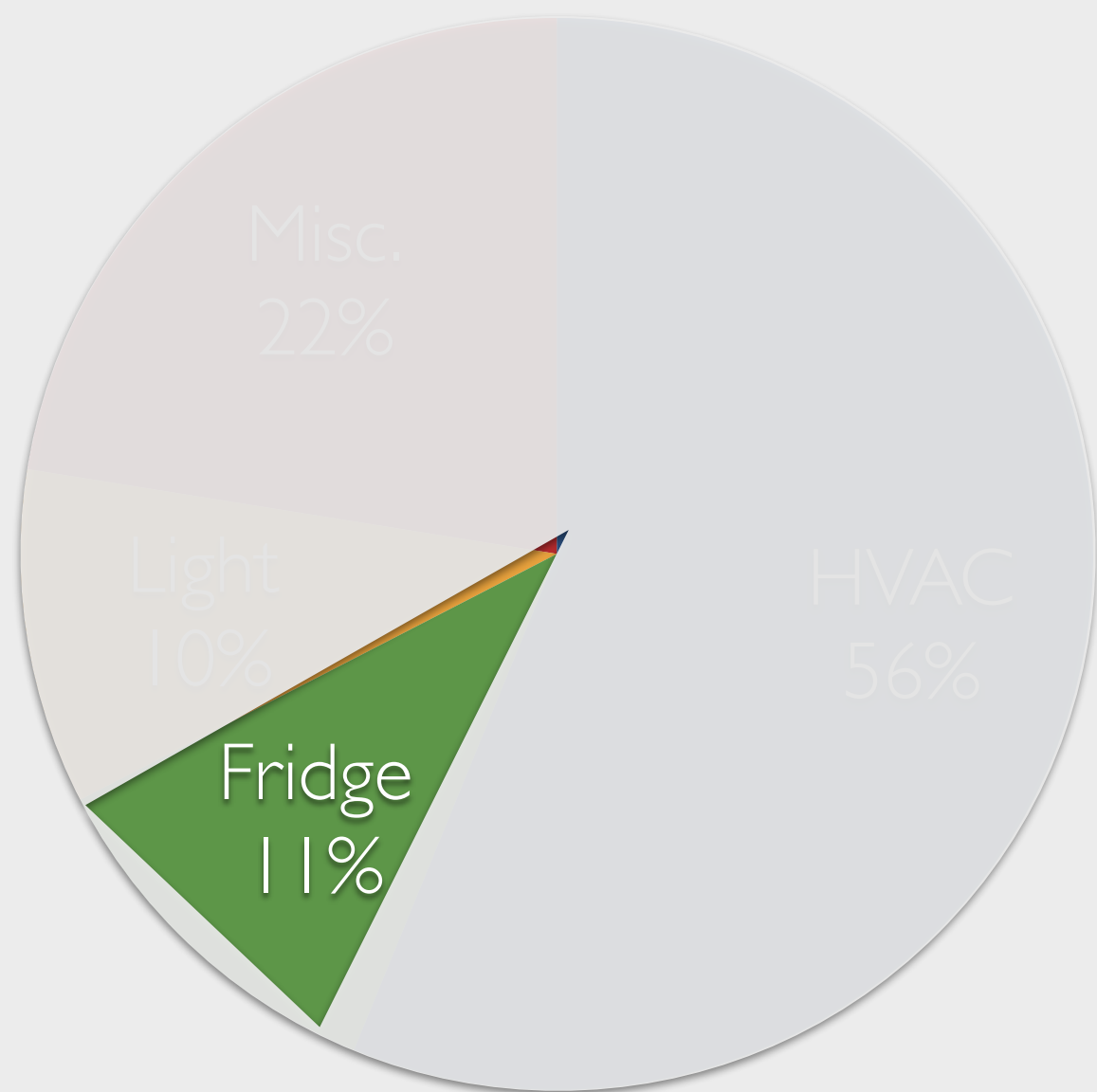
General eco feedback vs Actionable Feedback

Eco feedback



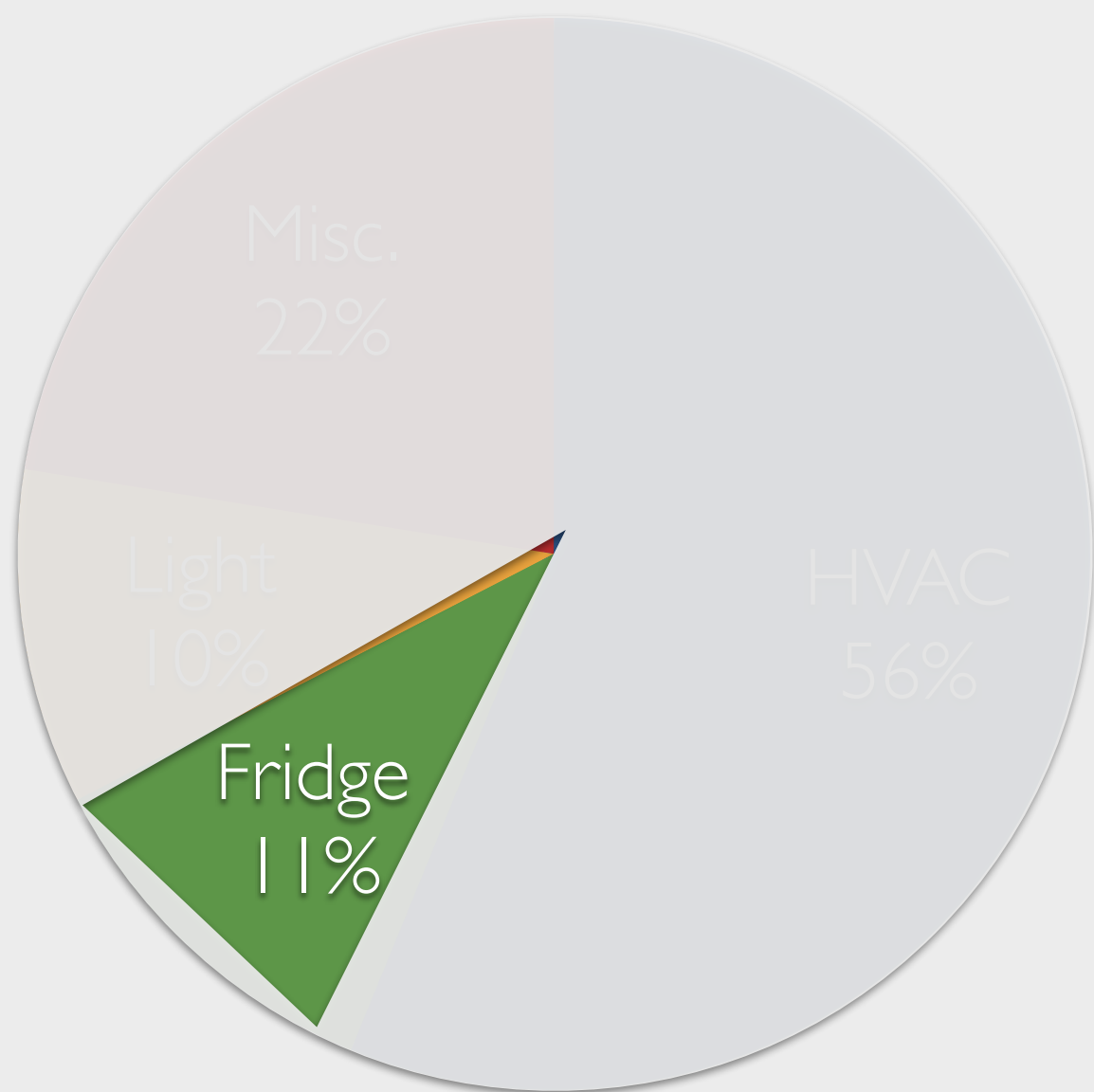
General eco feedback vs Actionable Feedback

Eco feedback



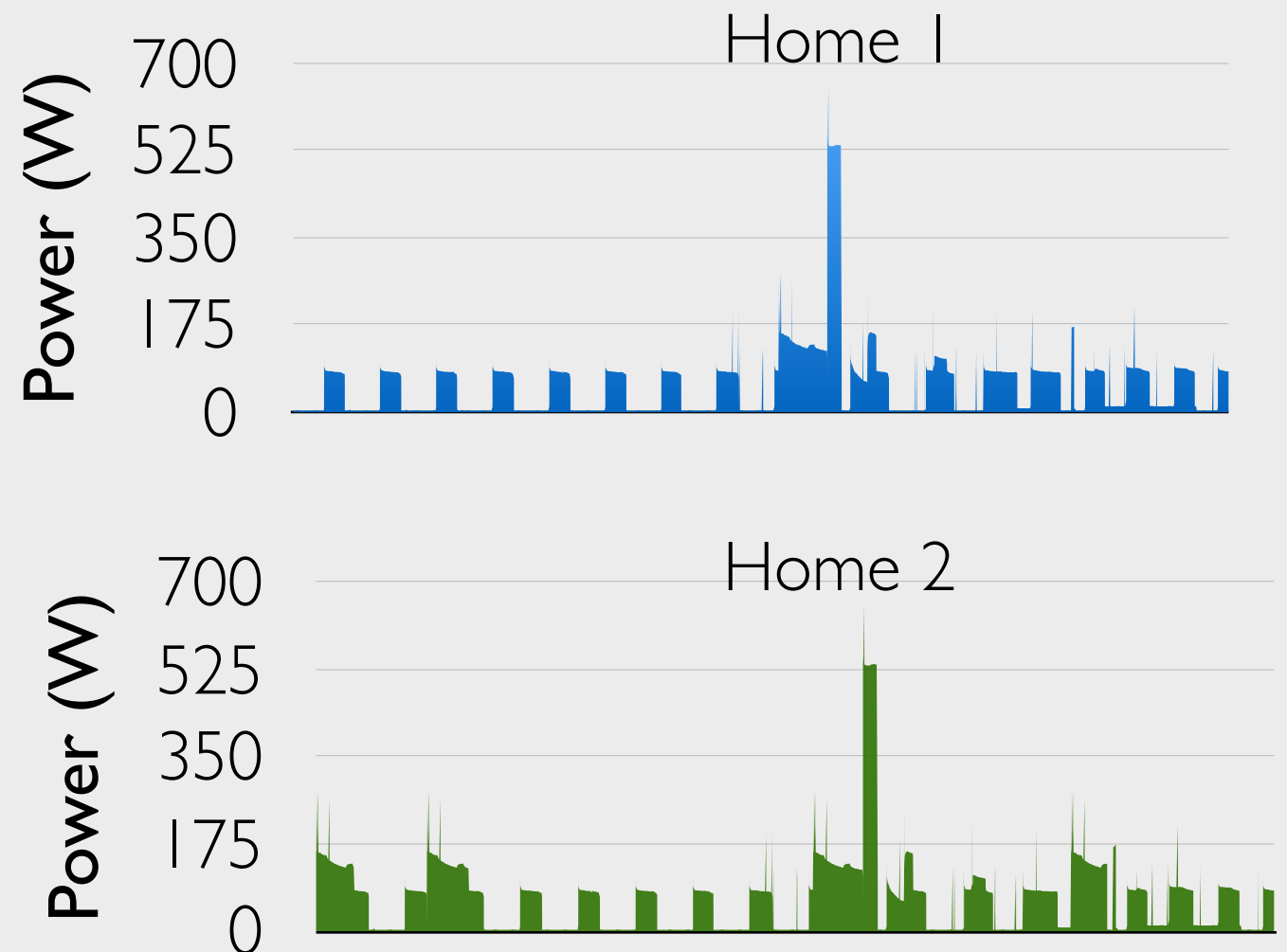
General eco feedback vs Actionable Feedback

Eco feedback



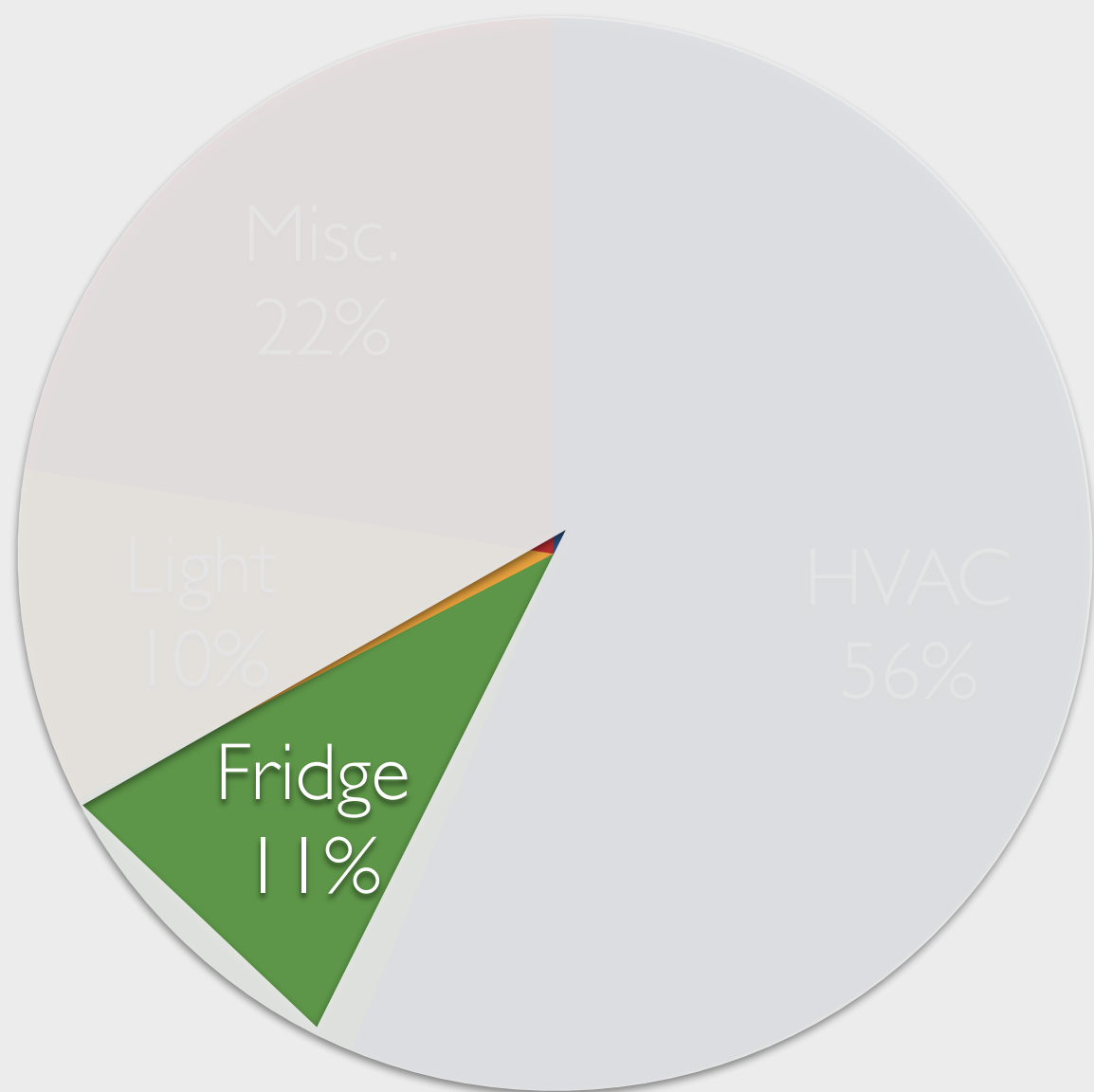
Actionable feedback

Fridge consumption over 24 hours



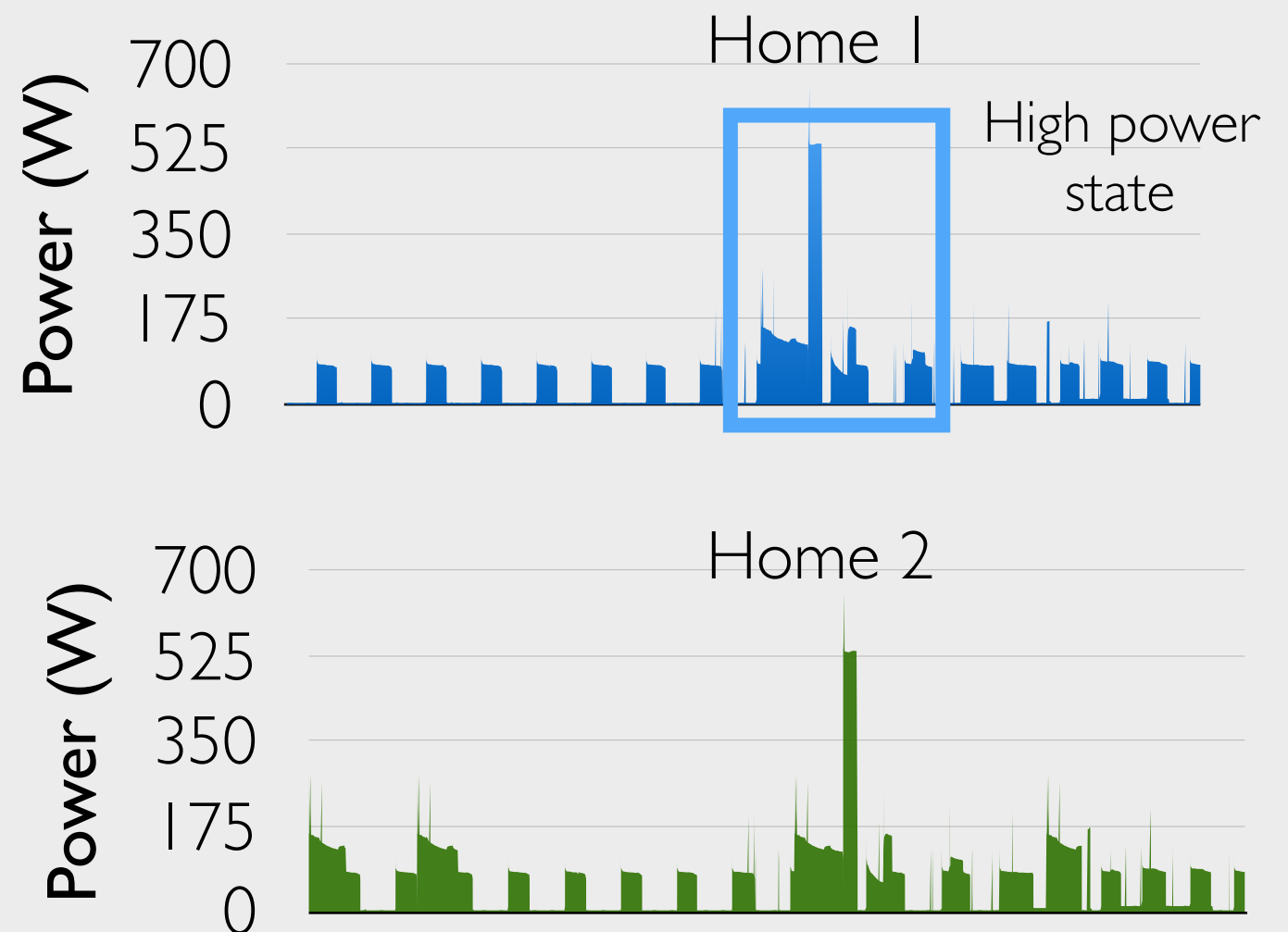
General eco feedback vs Actionable Feedback

Eco feedback



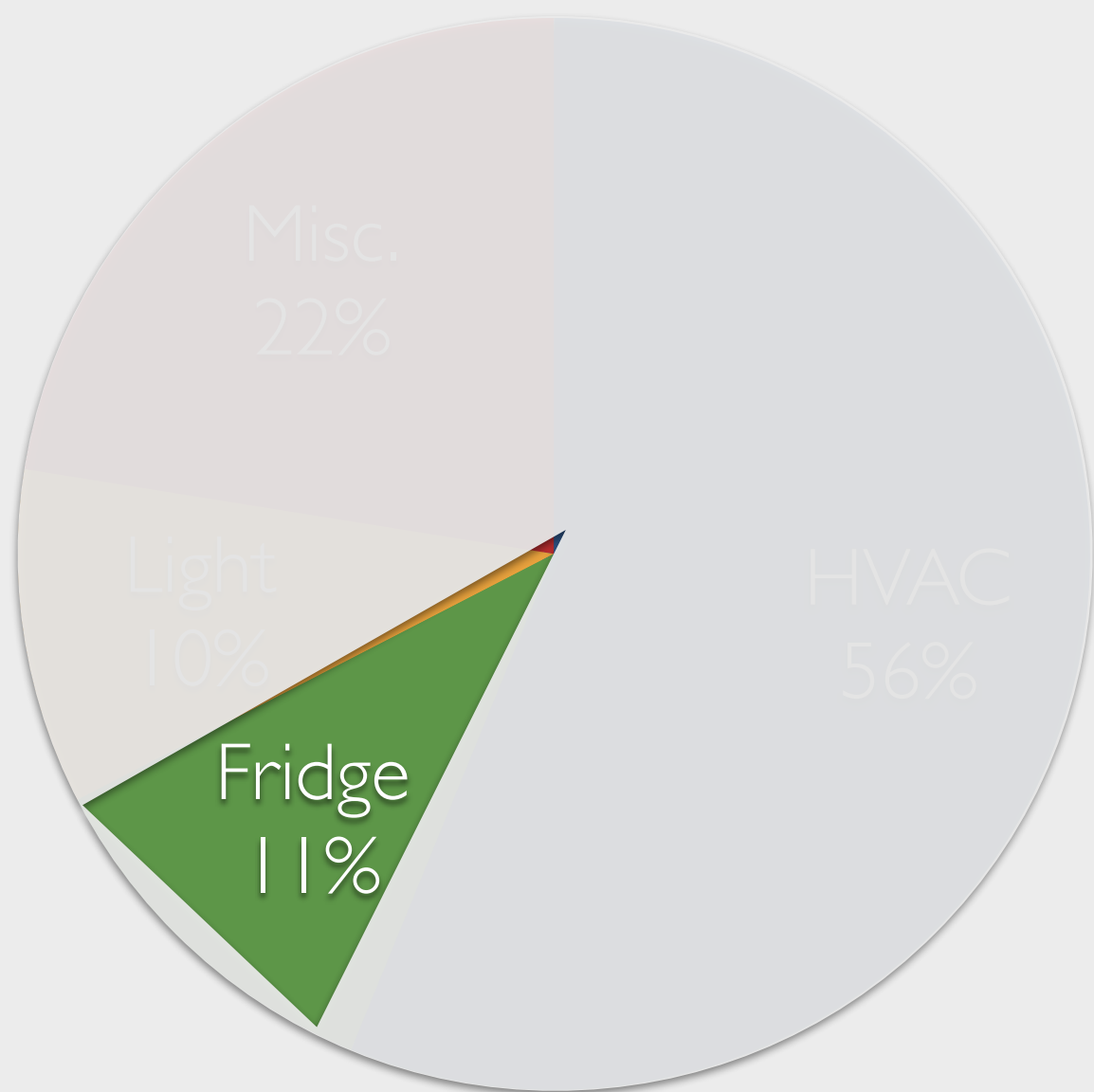
Actionable feedback

Fridge consumption over 24 hours



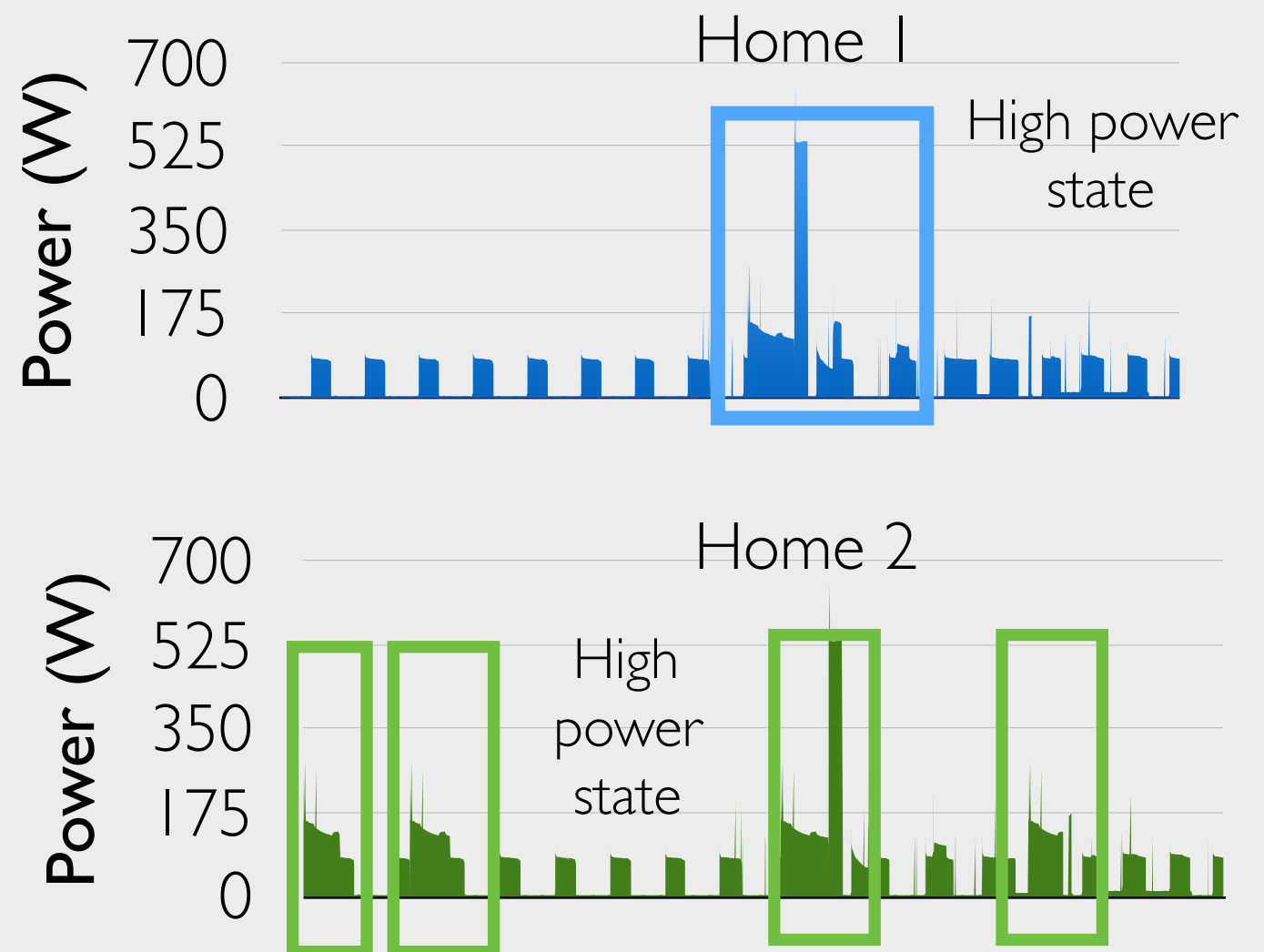
General eco feedback vs Actionable Feedback

Eco feedback



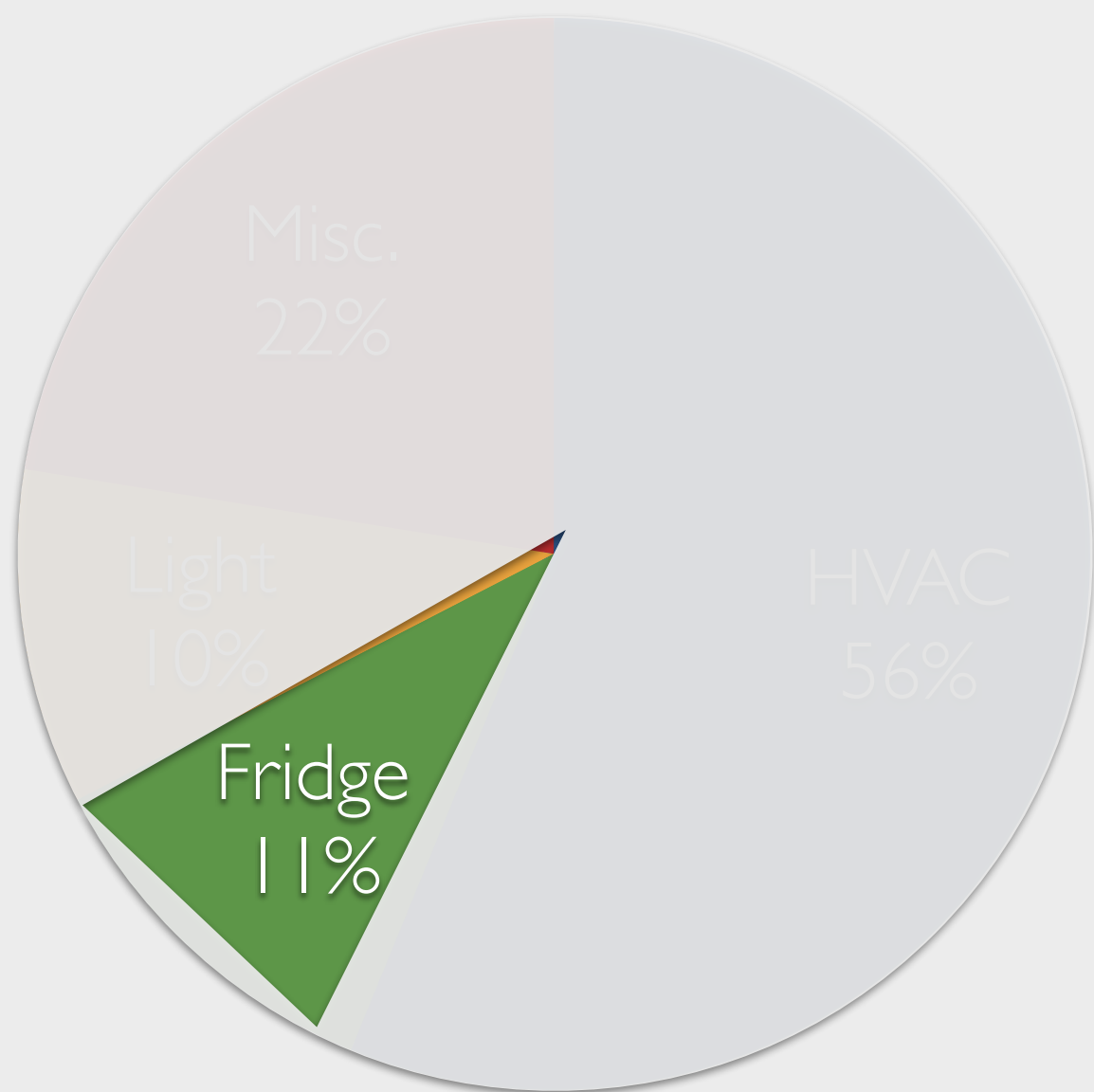
Actionable feedback

Fridge consumption over 24 hours



General eco feedback vs Actionable Feedback

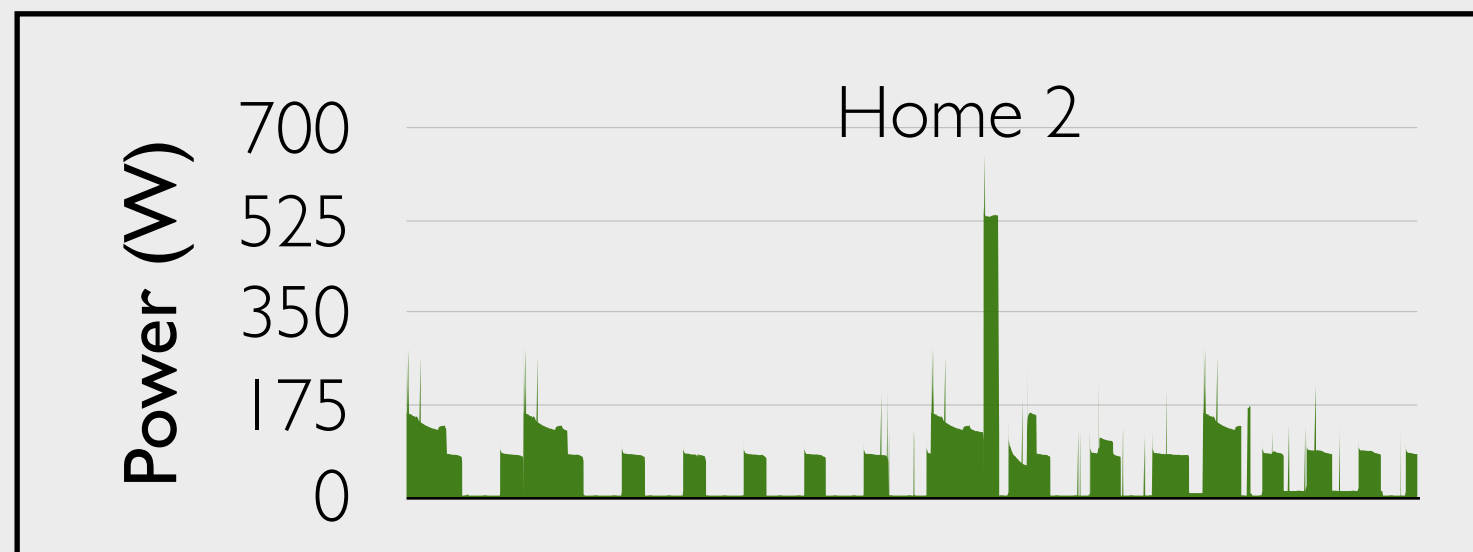
Eco feedback



Actionable feedback

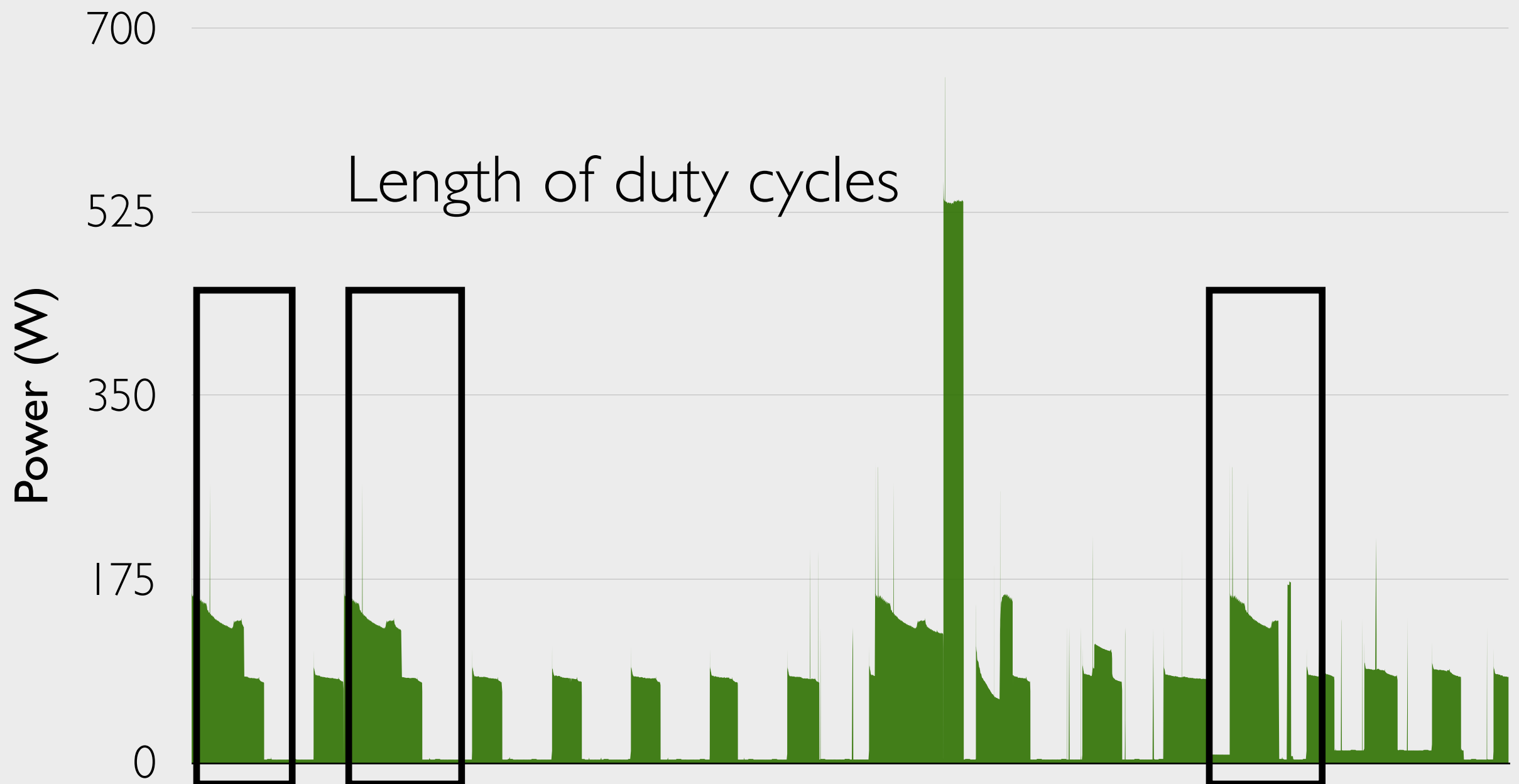
Fridge consumption over 24 hours

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



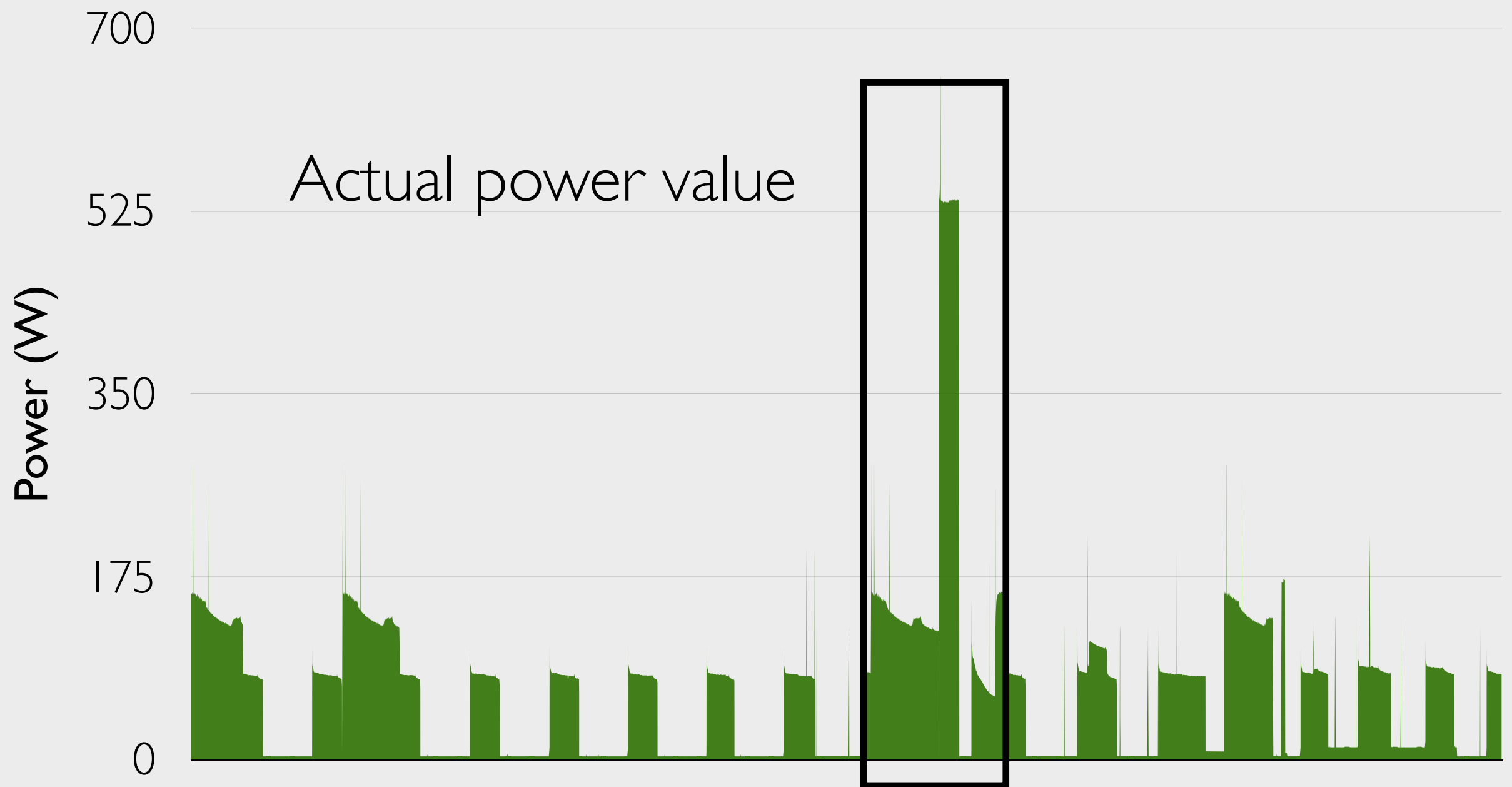
Approach overview- How to give feedback

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

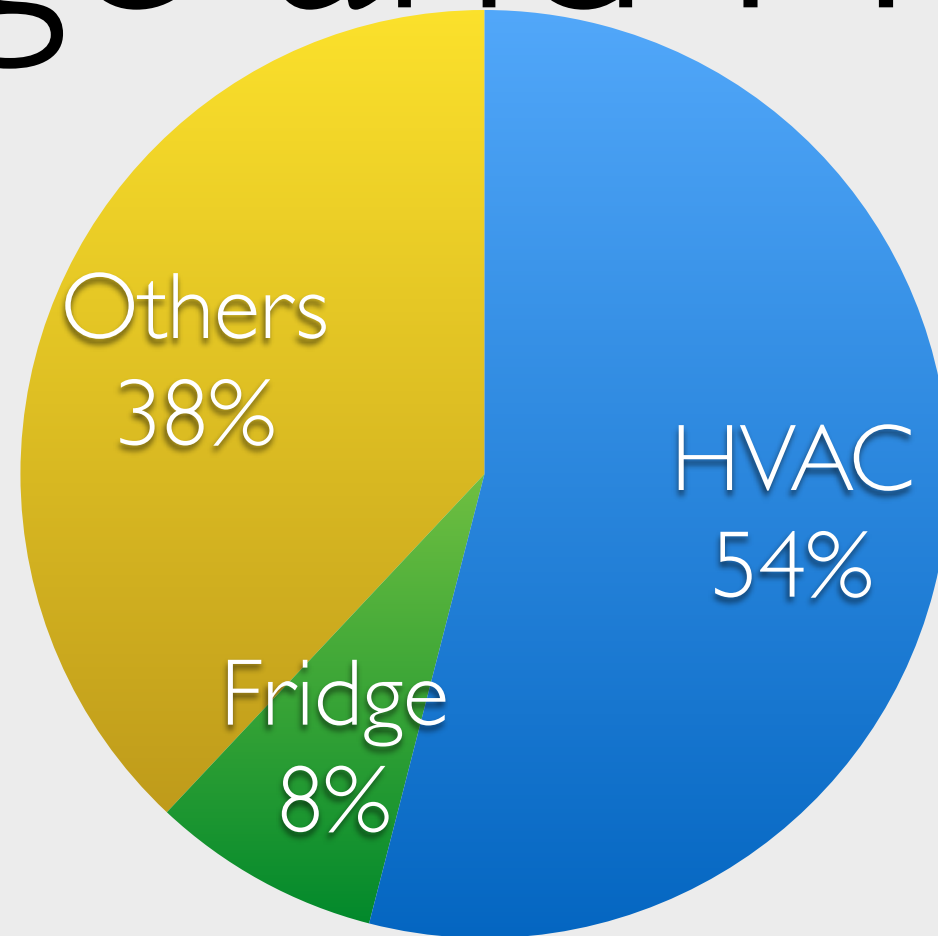


Approach overview- How to give feedback

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



Feedback methods on Fridge and HVAC



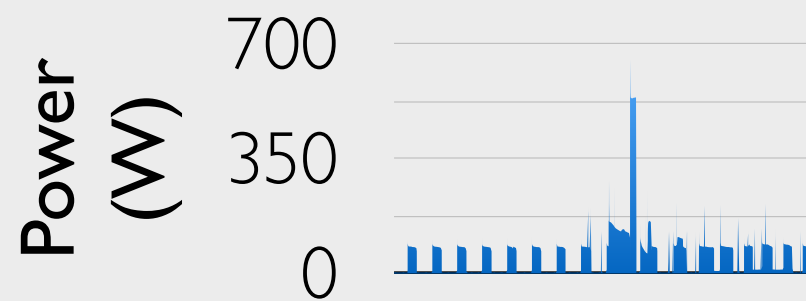
Both appliances commonly found across homes

Evaluation overview

Submetered
traces



Submeter
sensor

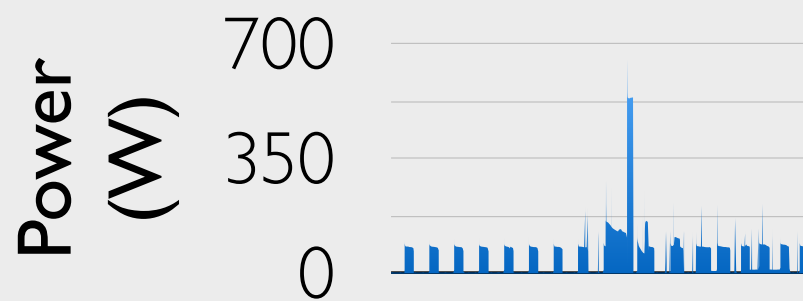
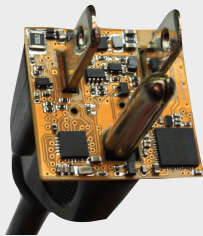


Can we give such feedback?

Submetered
traces



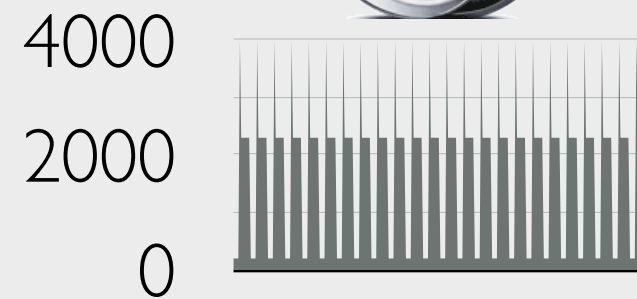
Submeter
sensor



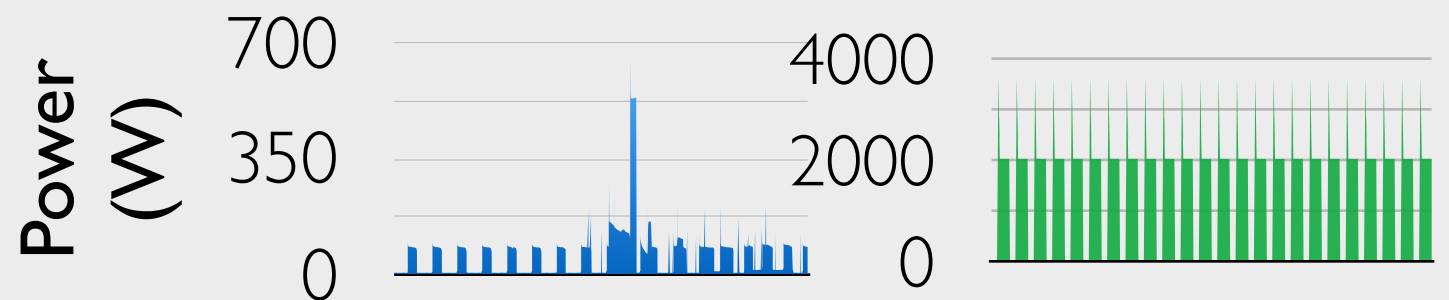
Disaggregated
traces



Smart
meter



Household
aggregate

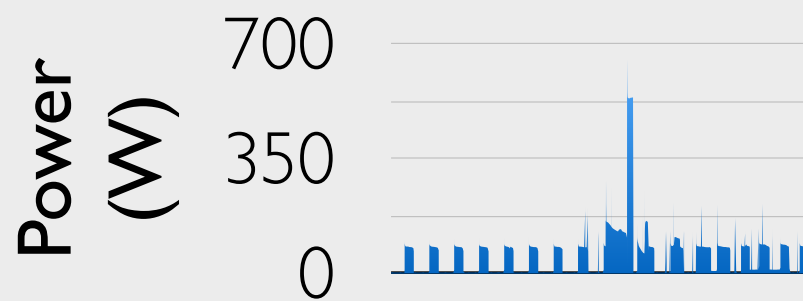


Do disaggregated traces provide features needed for providing feedback?

Submetered traces



Submeter sensor

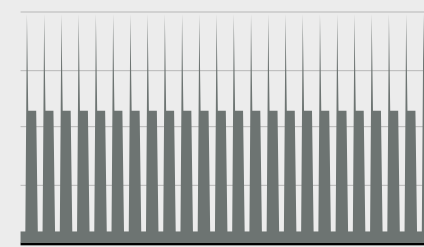


Disaggregated traces



Smart meter

4000
2000
0

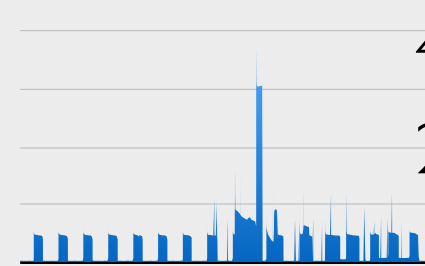


Household aggregate

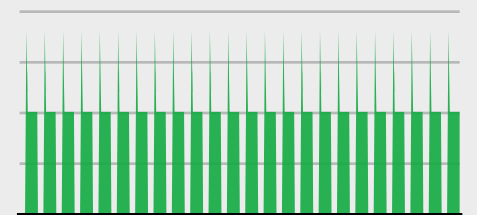
NILM

Power (W)

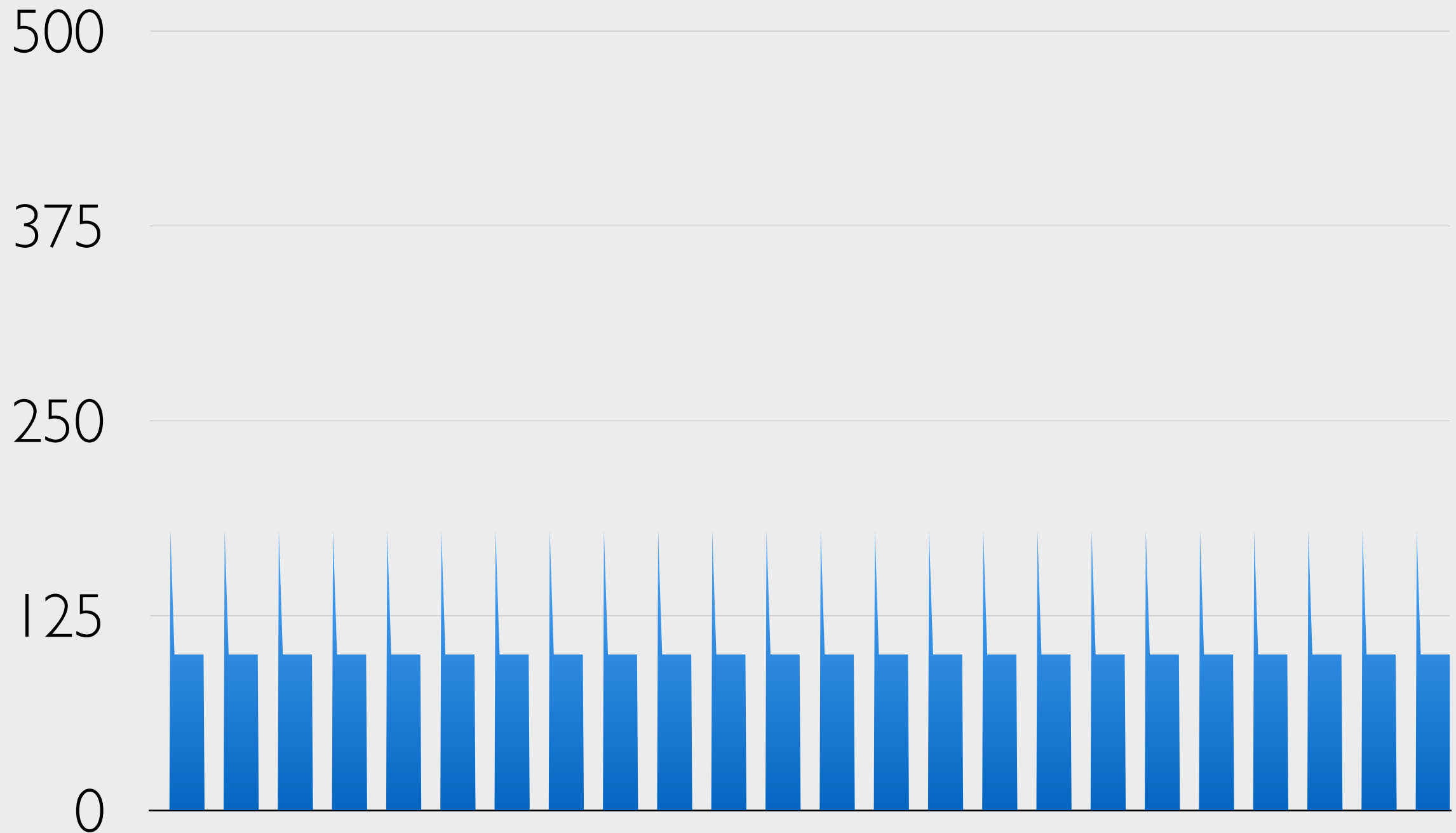
700
350
0



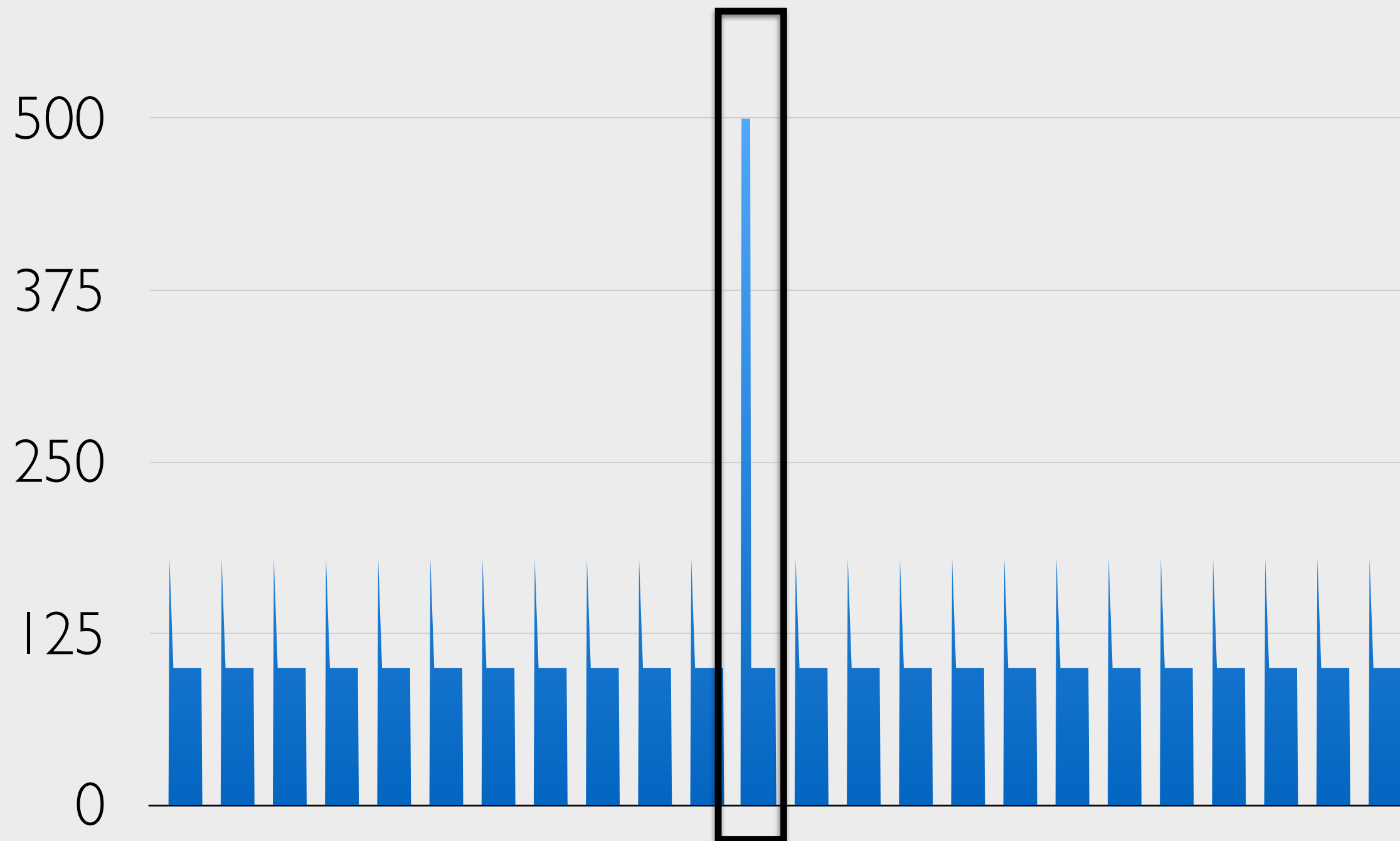
4000
2000
0



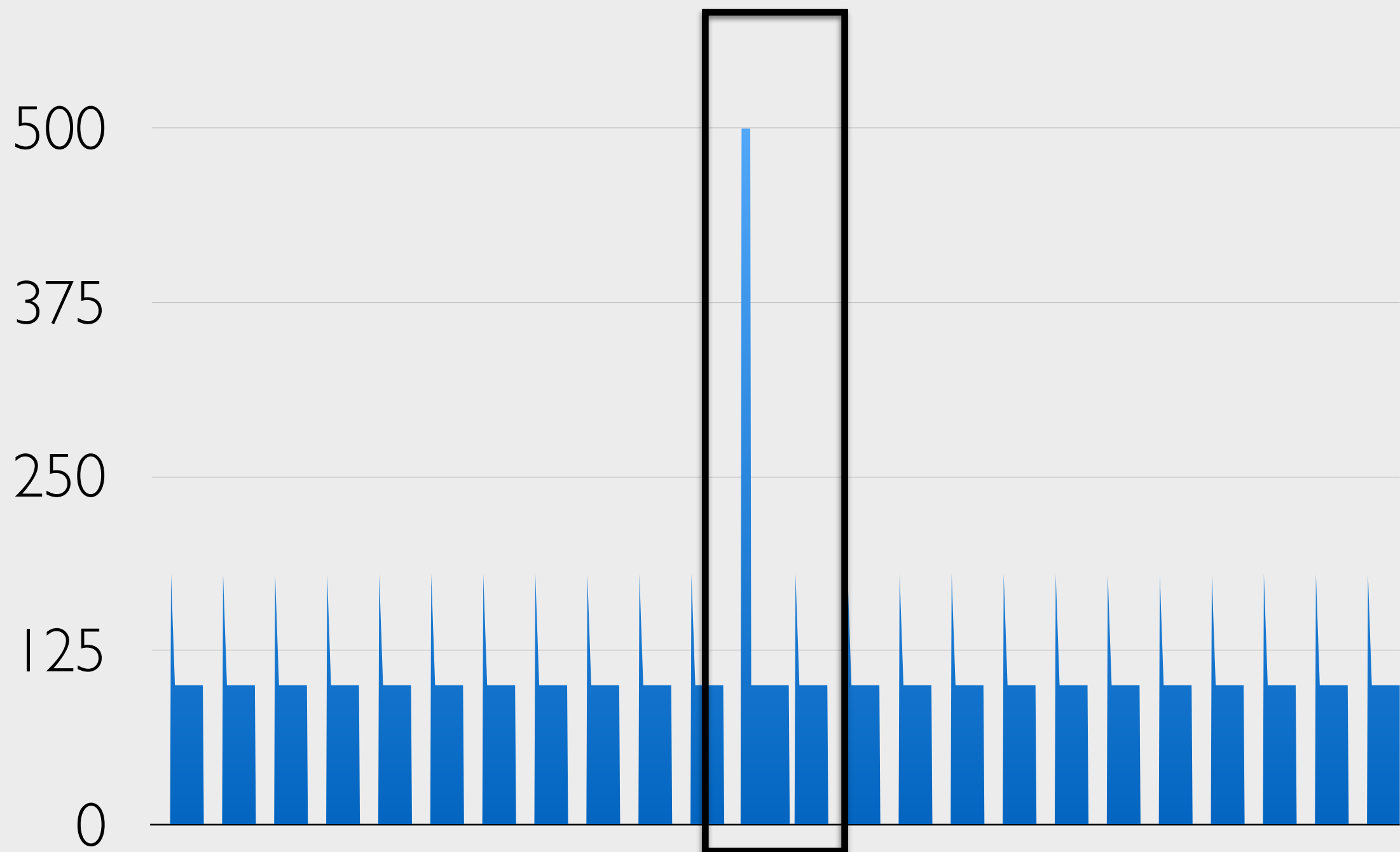
Fridge is a duty cycle based appliance;
compressor turns ON and OFF
periodically



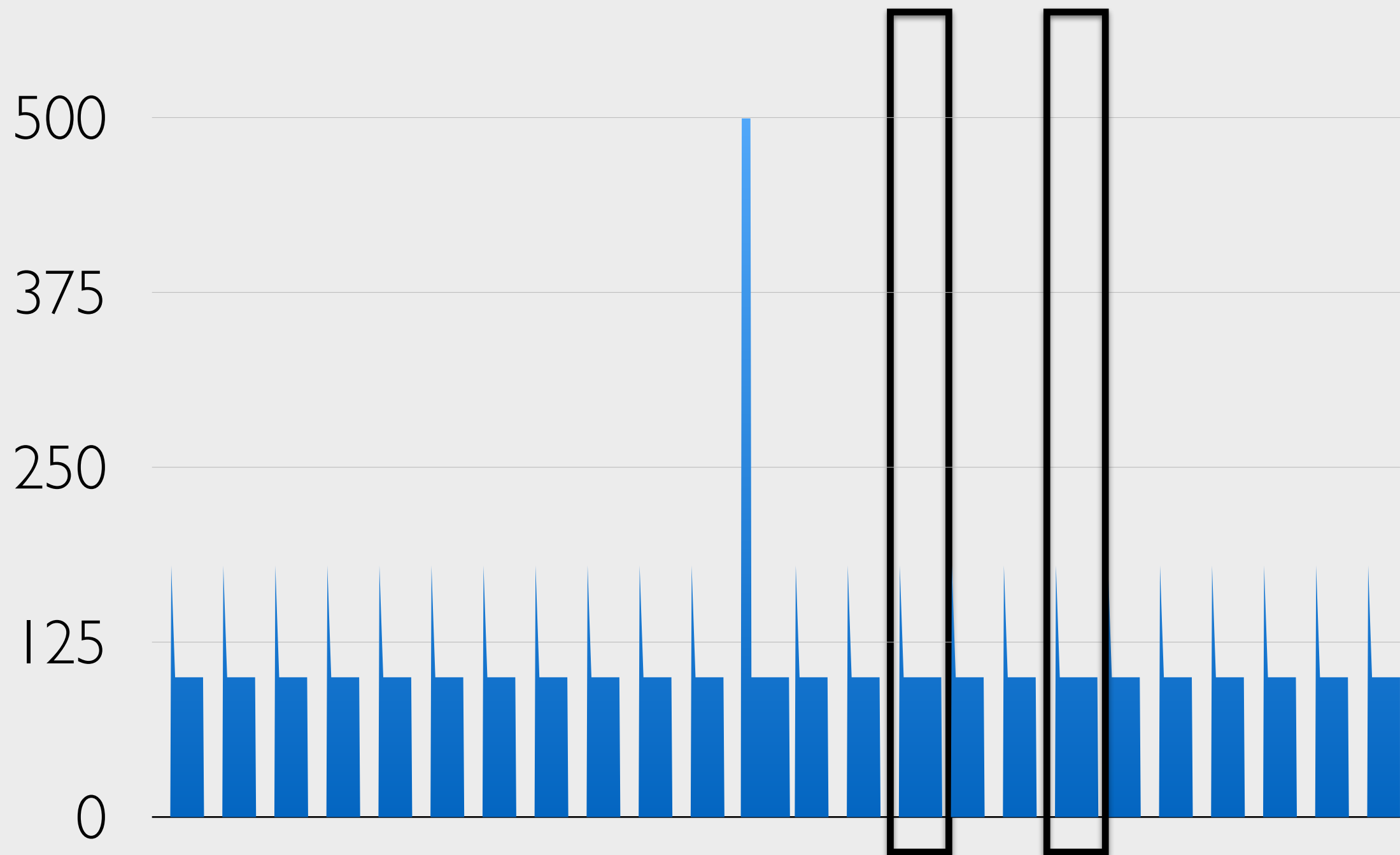
Defrost cycles occurs periodically and
consume high amount of power



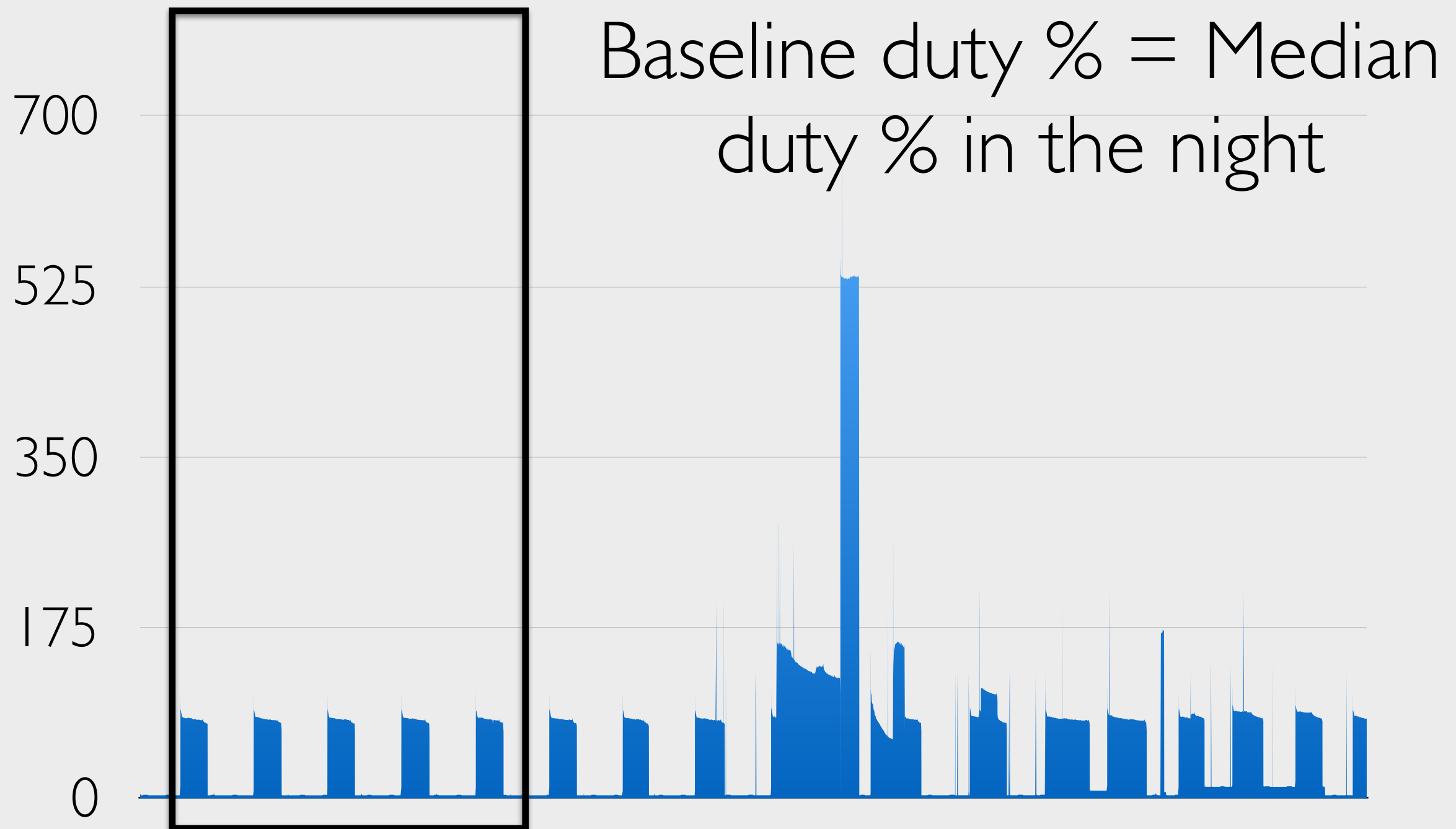
Defrost introduces heat increasing ON
duration of next cycles



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

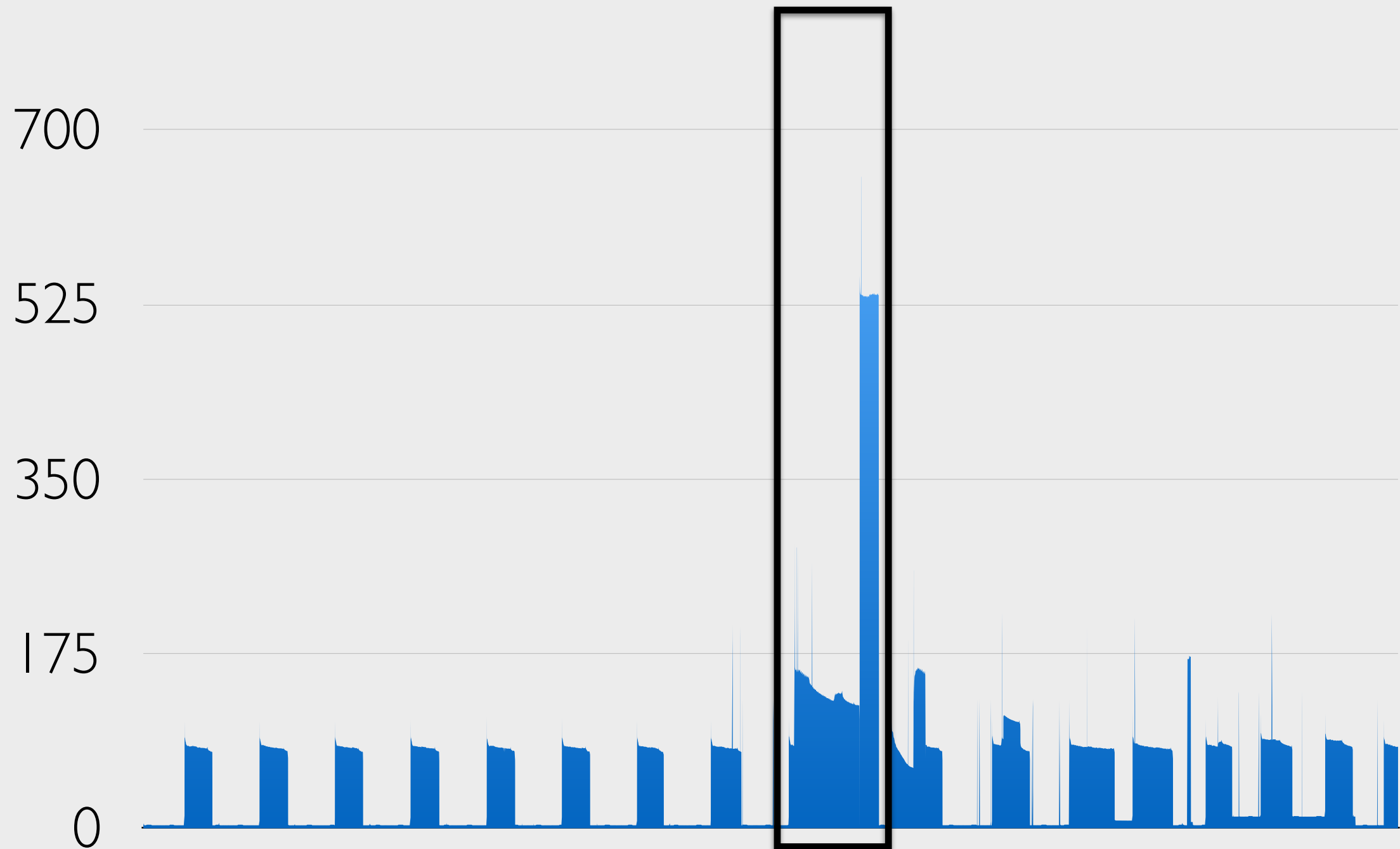


Night hours typically have “baseline” usage



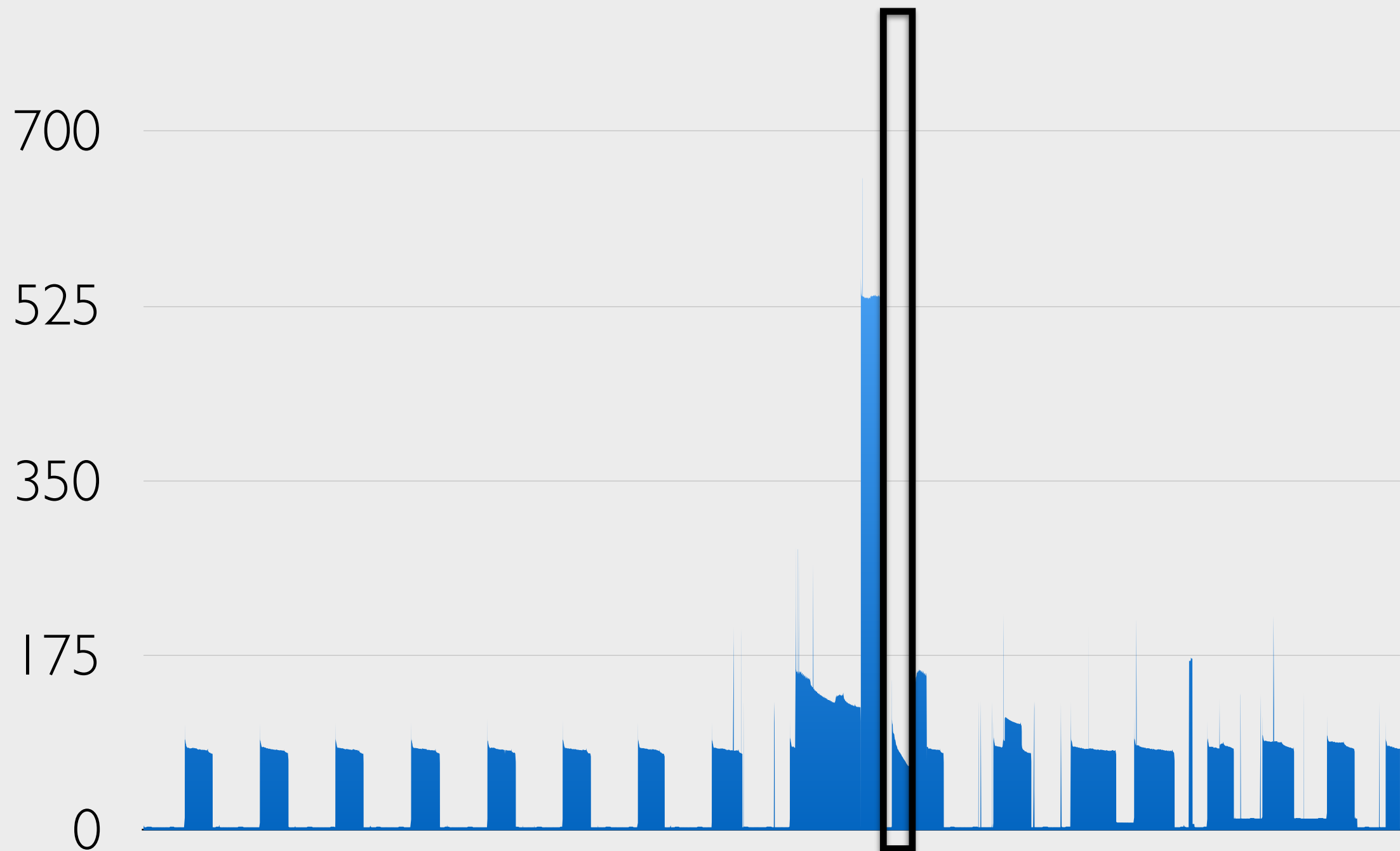
Defrost energy

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



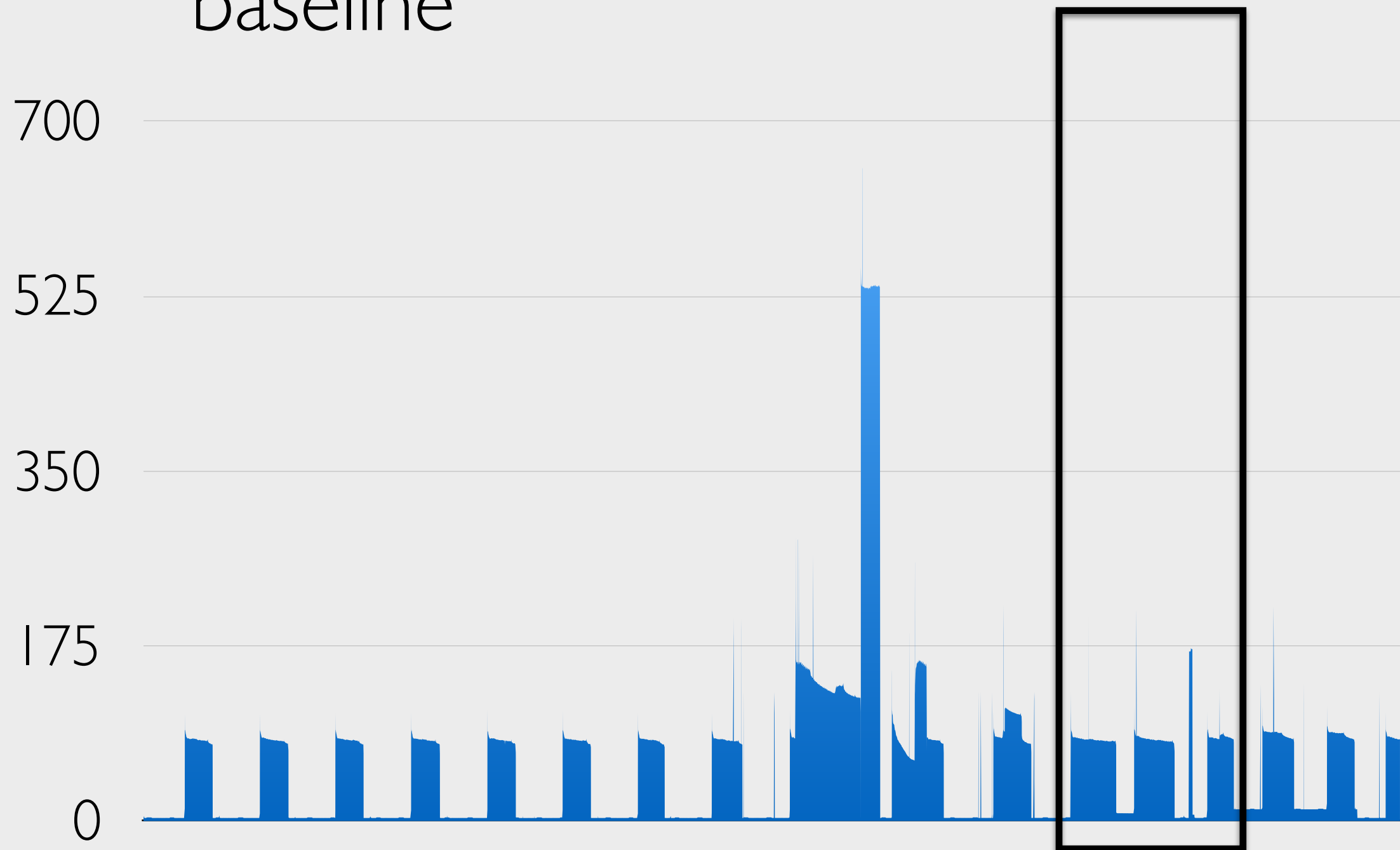
Defrost energy

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



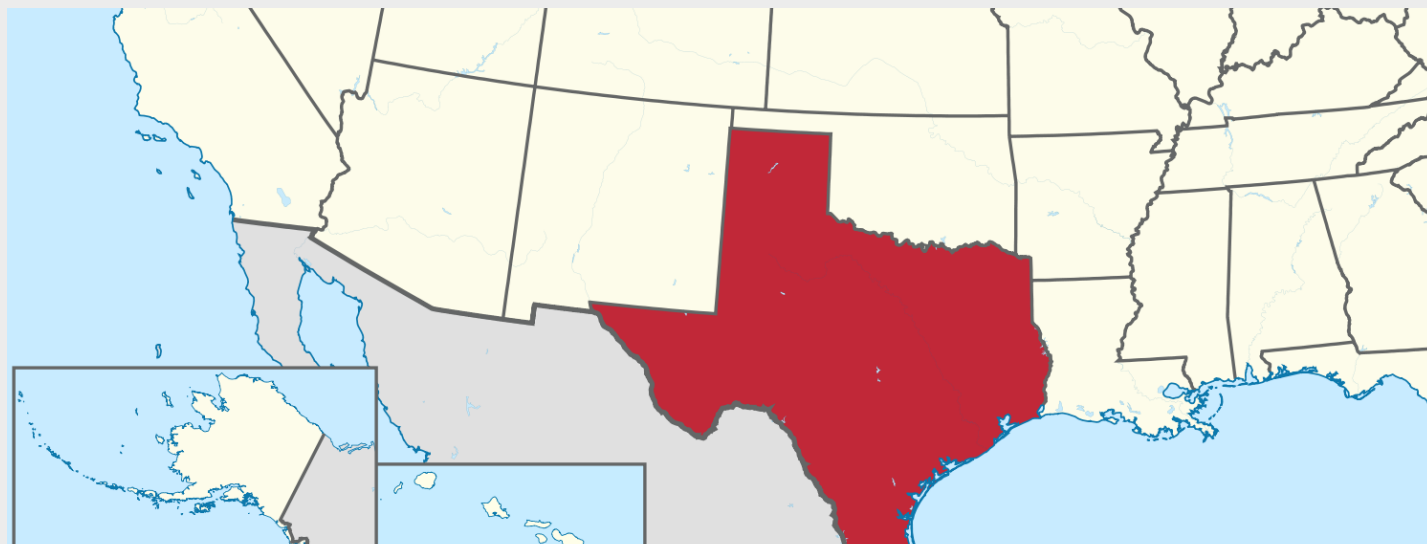
Usage energy

Usage energy = Extra
energy consumed over
baseline



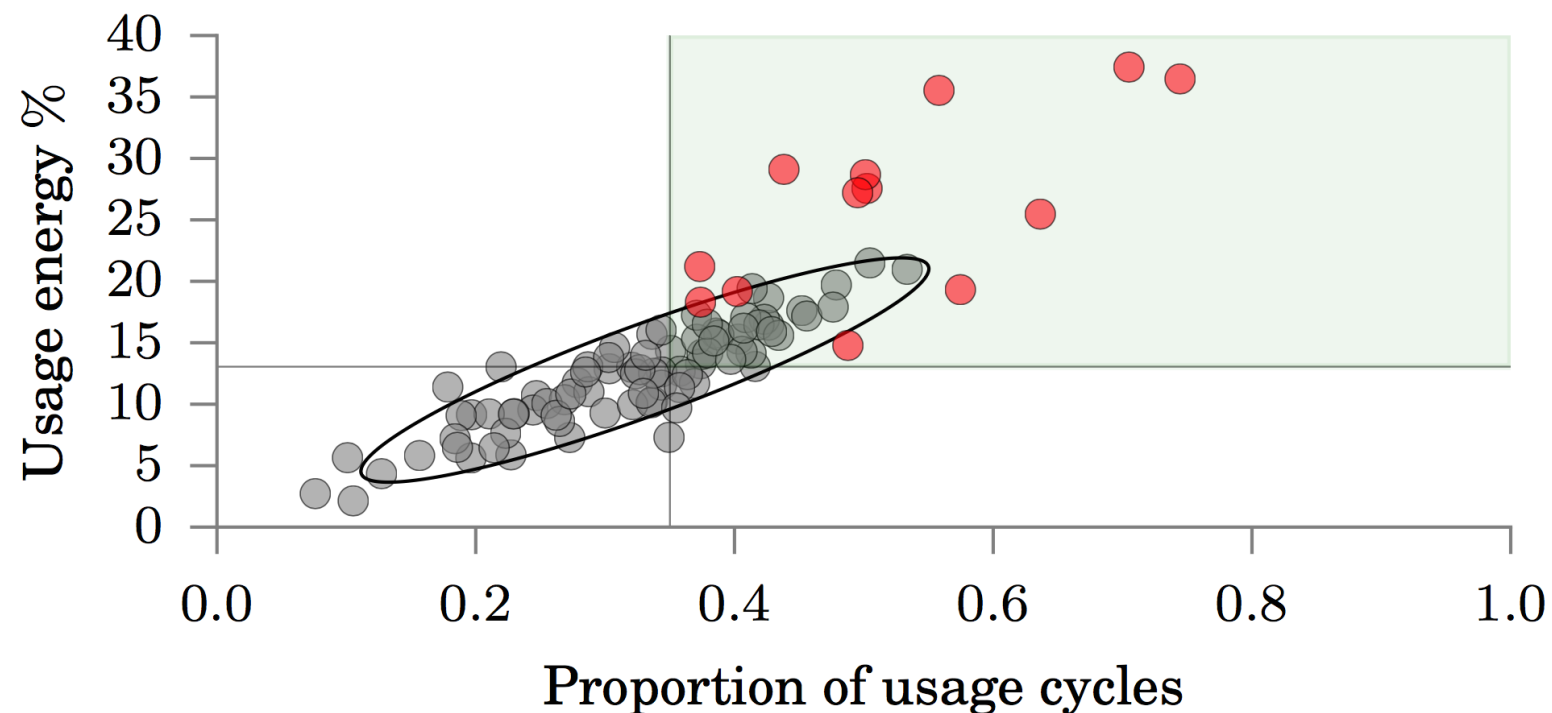
Experimental setup

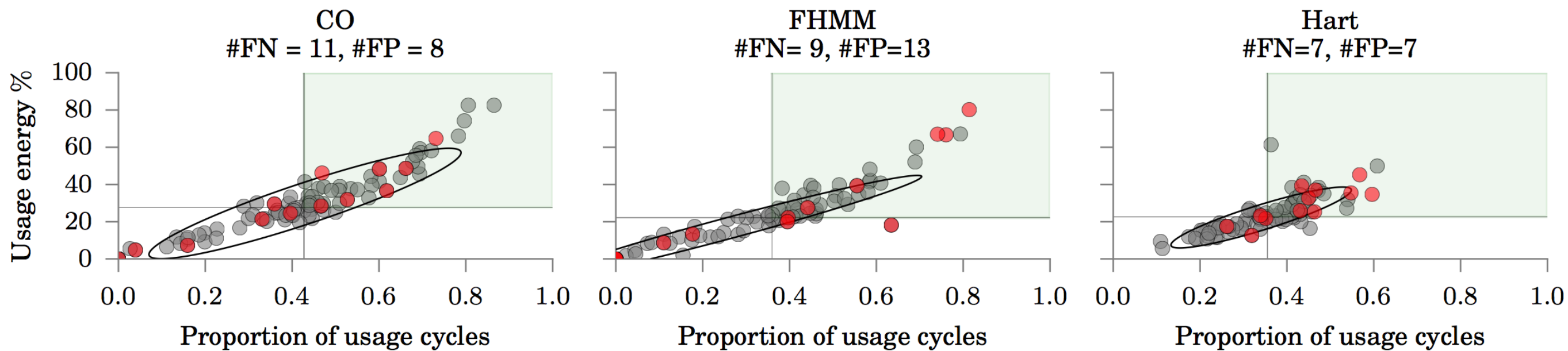
Wiki Energy data set



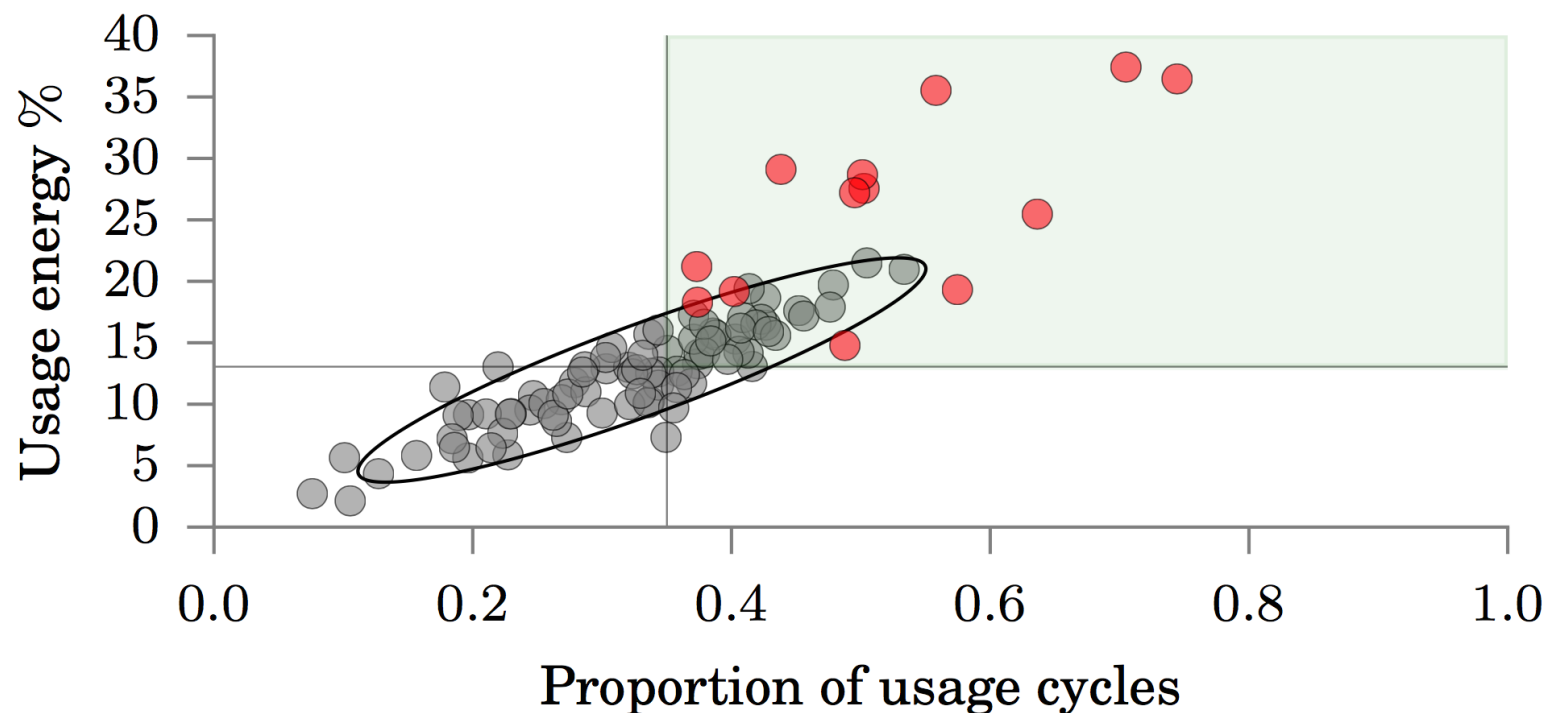
1. 97 fridges
2. 58 HVAC

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

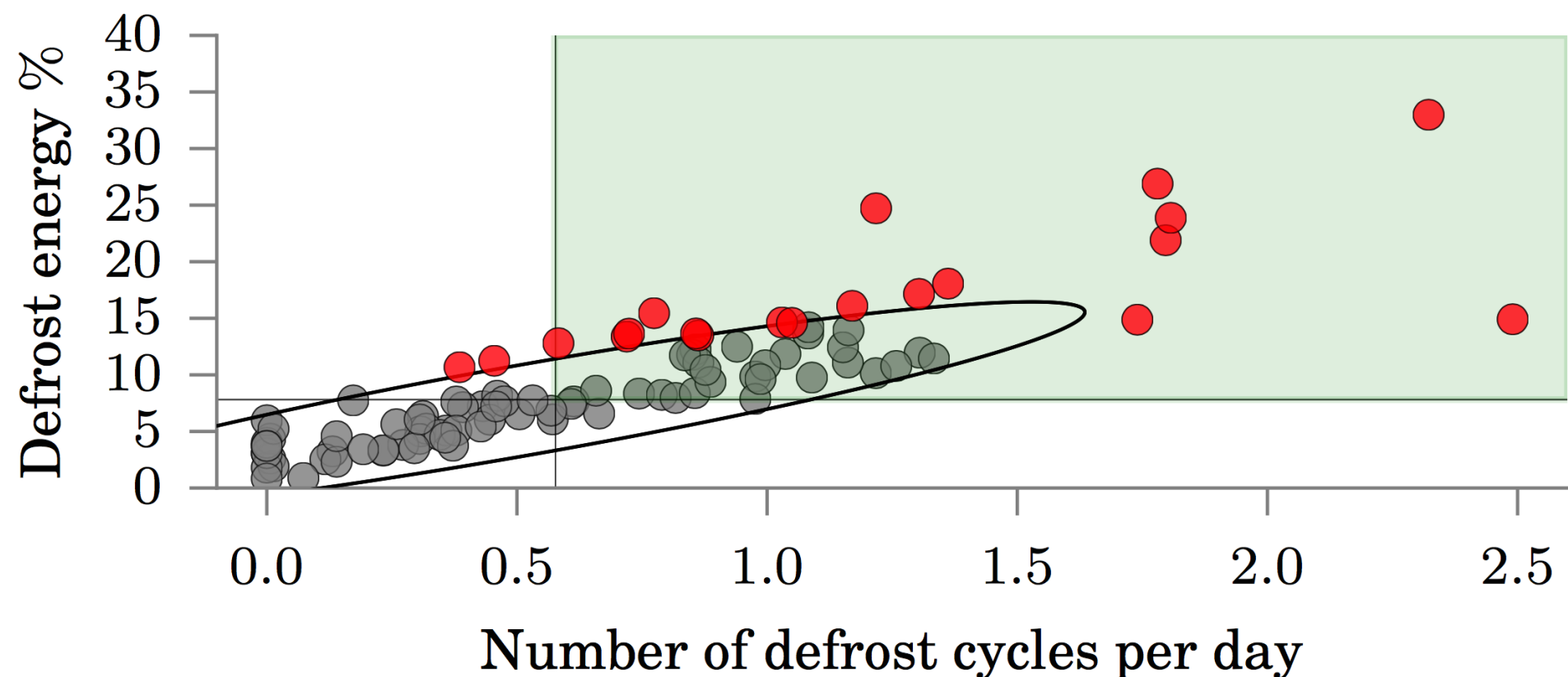




NILM algorithms show poor accuracy in identifying homes which can be given feedback based on **usage energy**

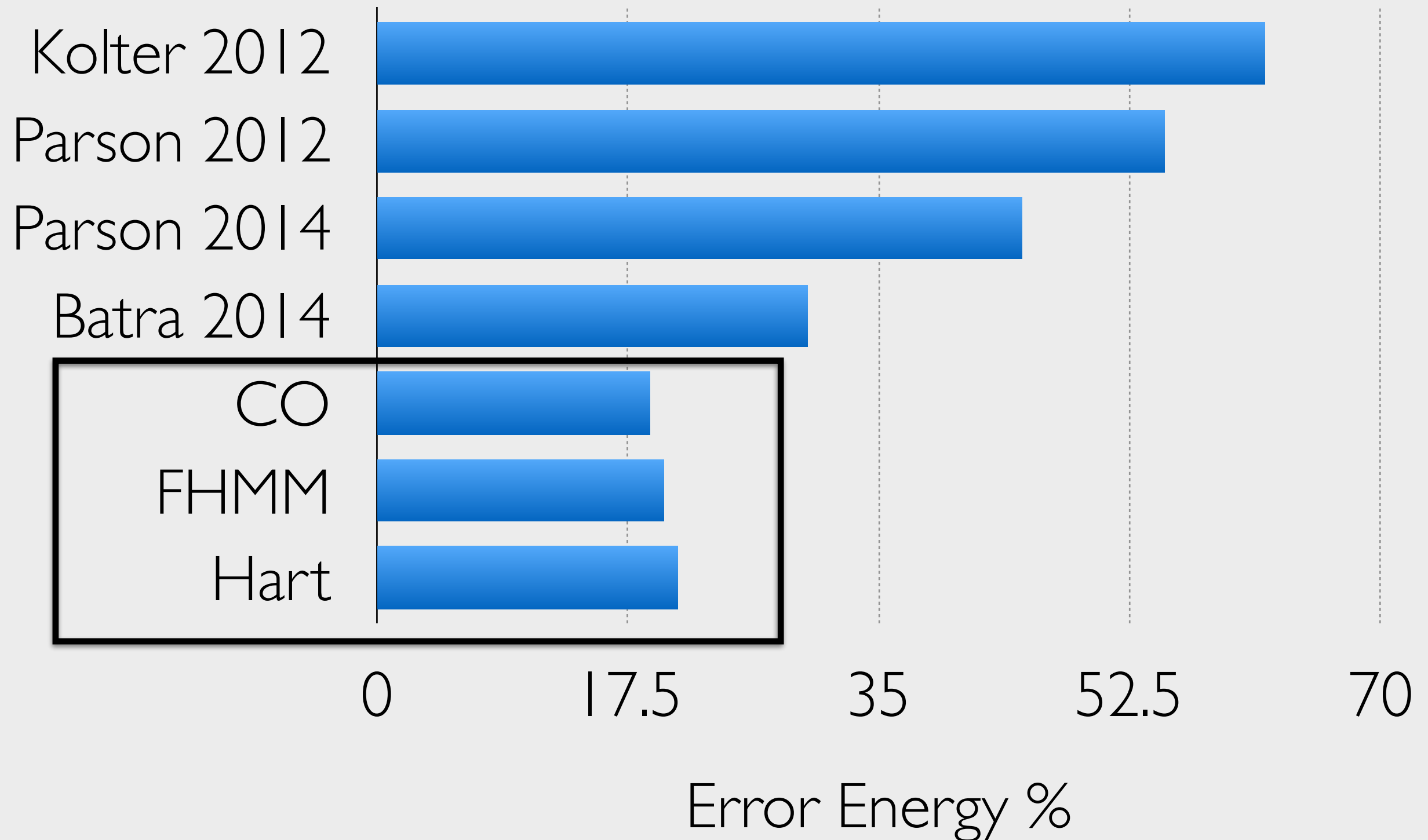


17 out of 95 homes can be given
feedback on **excess defrost** saving
upto 25% fridge energy

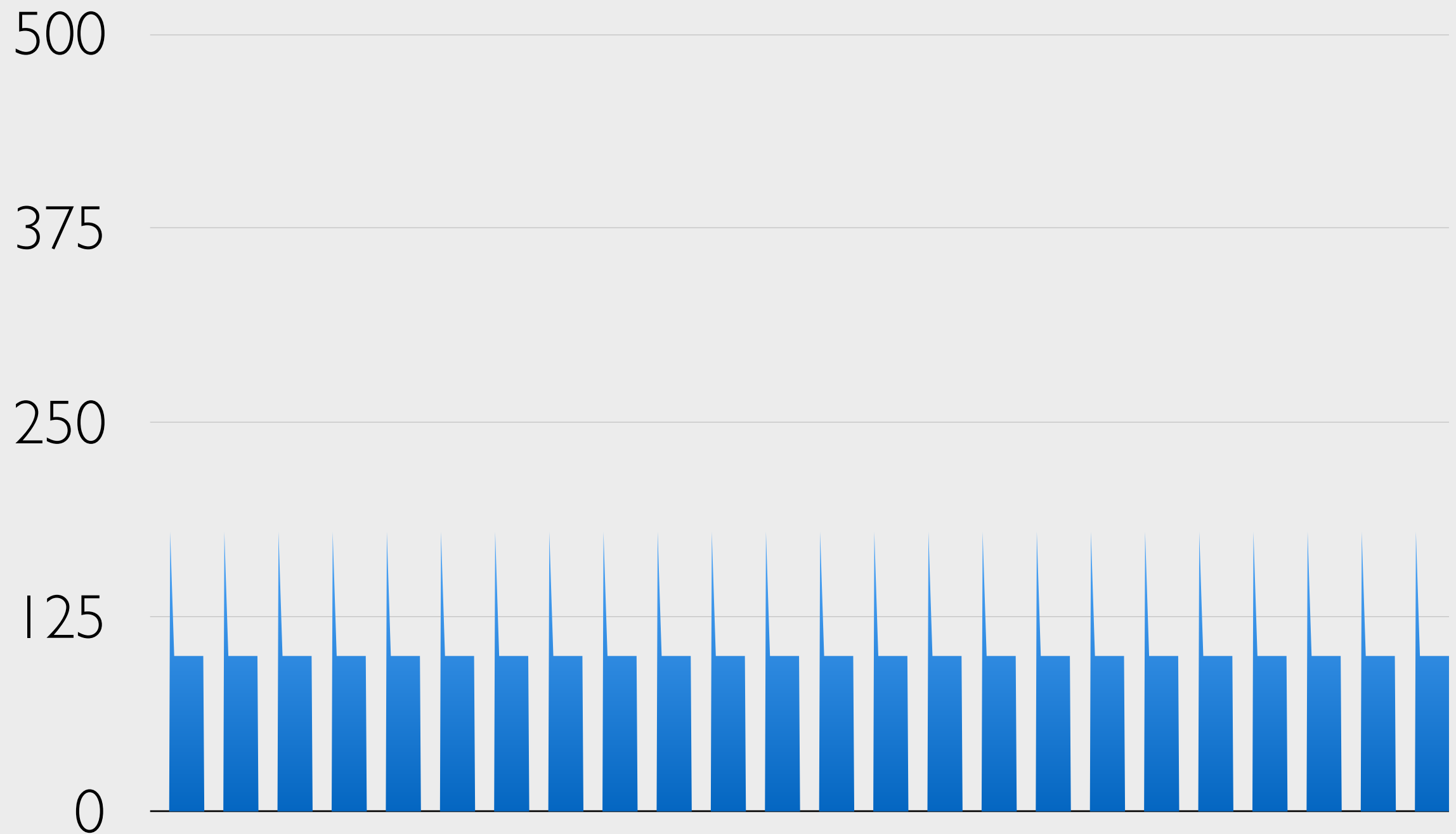


Such feedback can't be given with disaggregated traces, since these techniques fare poorly on defrost detection.

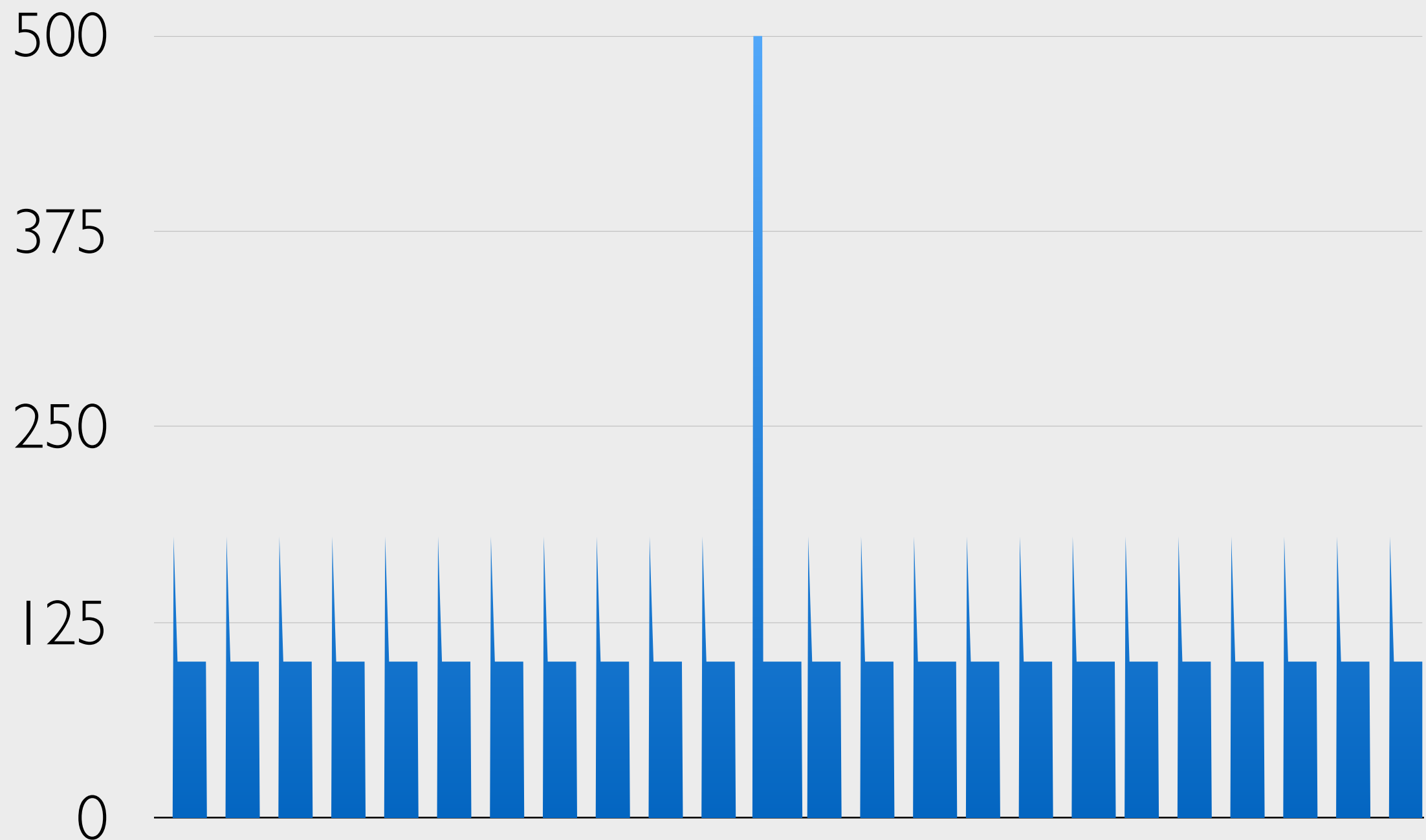
Benchmark NILM algorithms on our data set
give accuracy comparable or better than
state-of-the-art



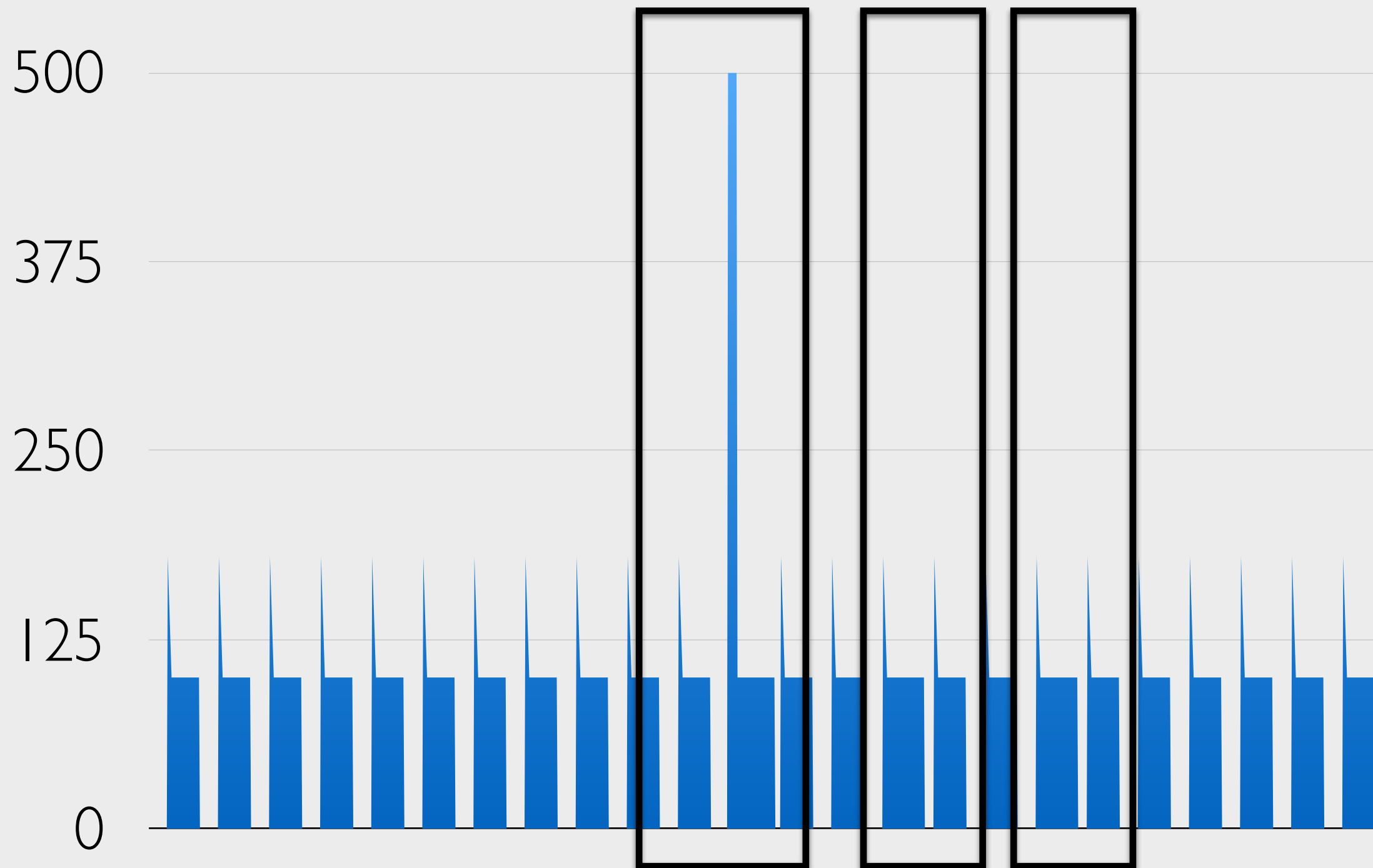
“Average” error in energy would be low even
if NILM predicted this



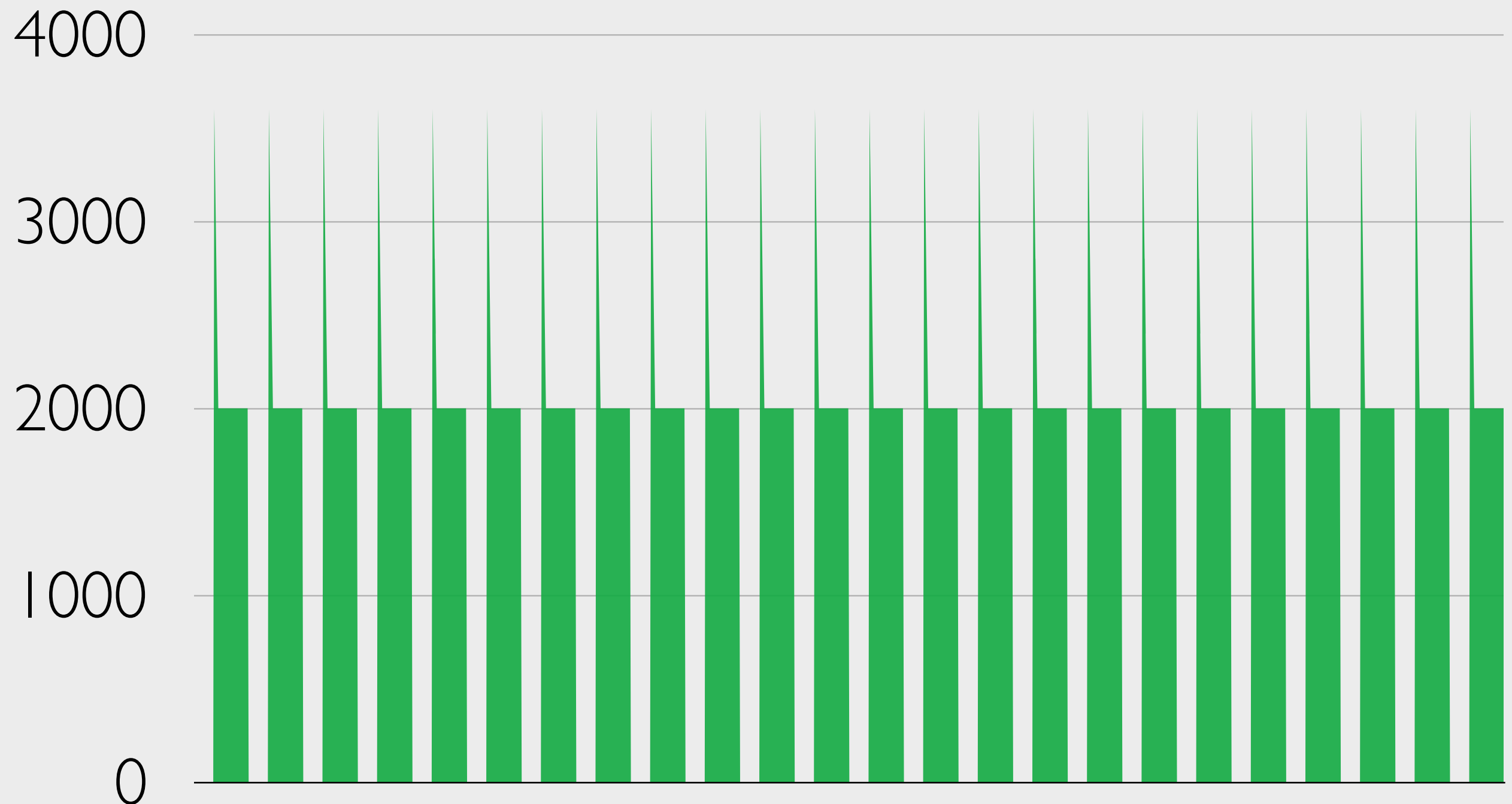
But, we wanted to predict..



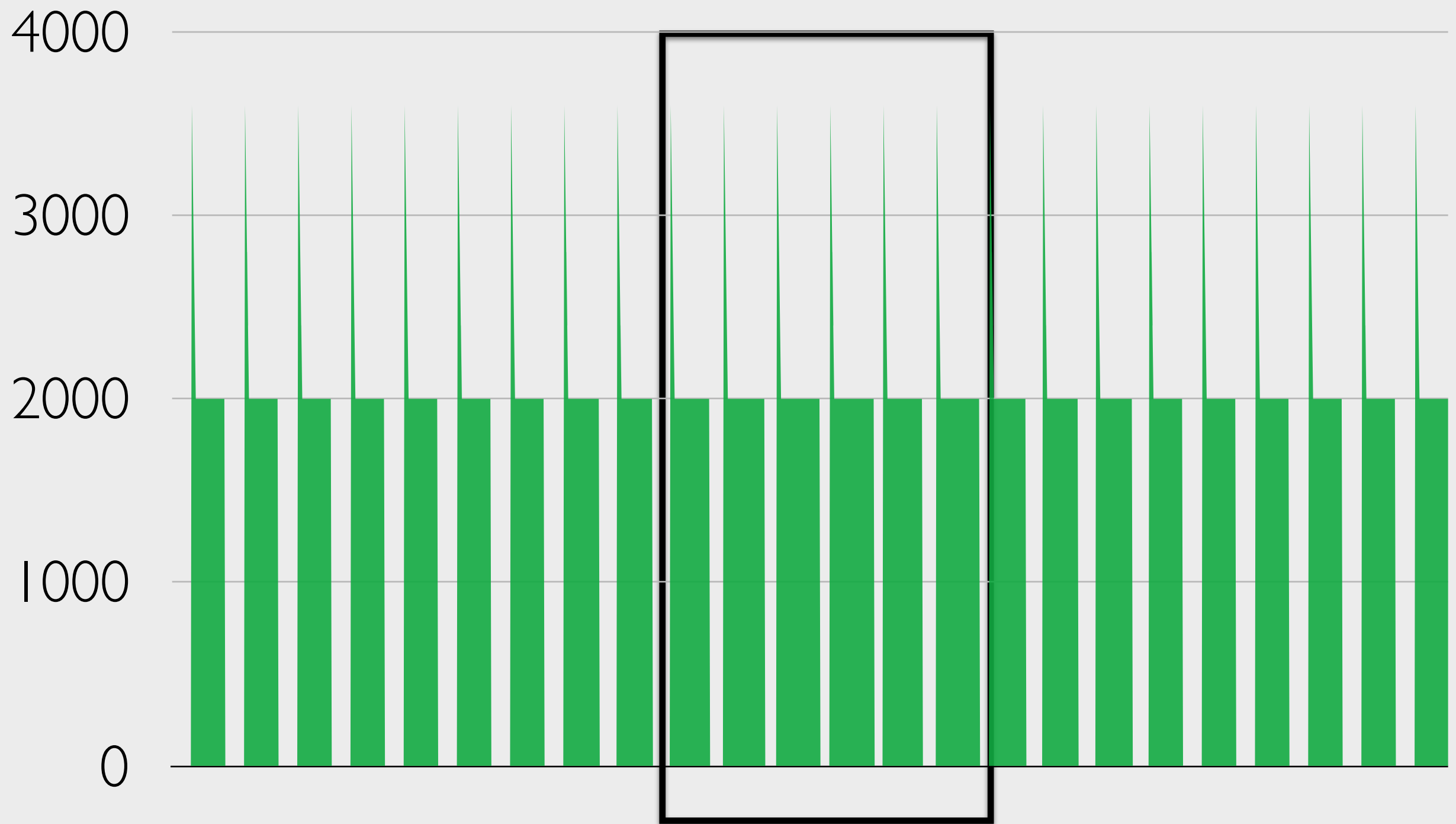
It's the details that we care about



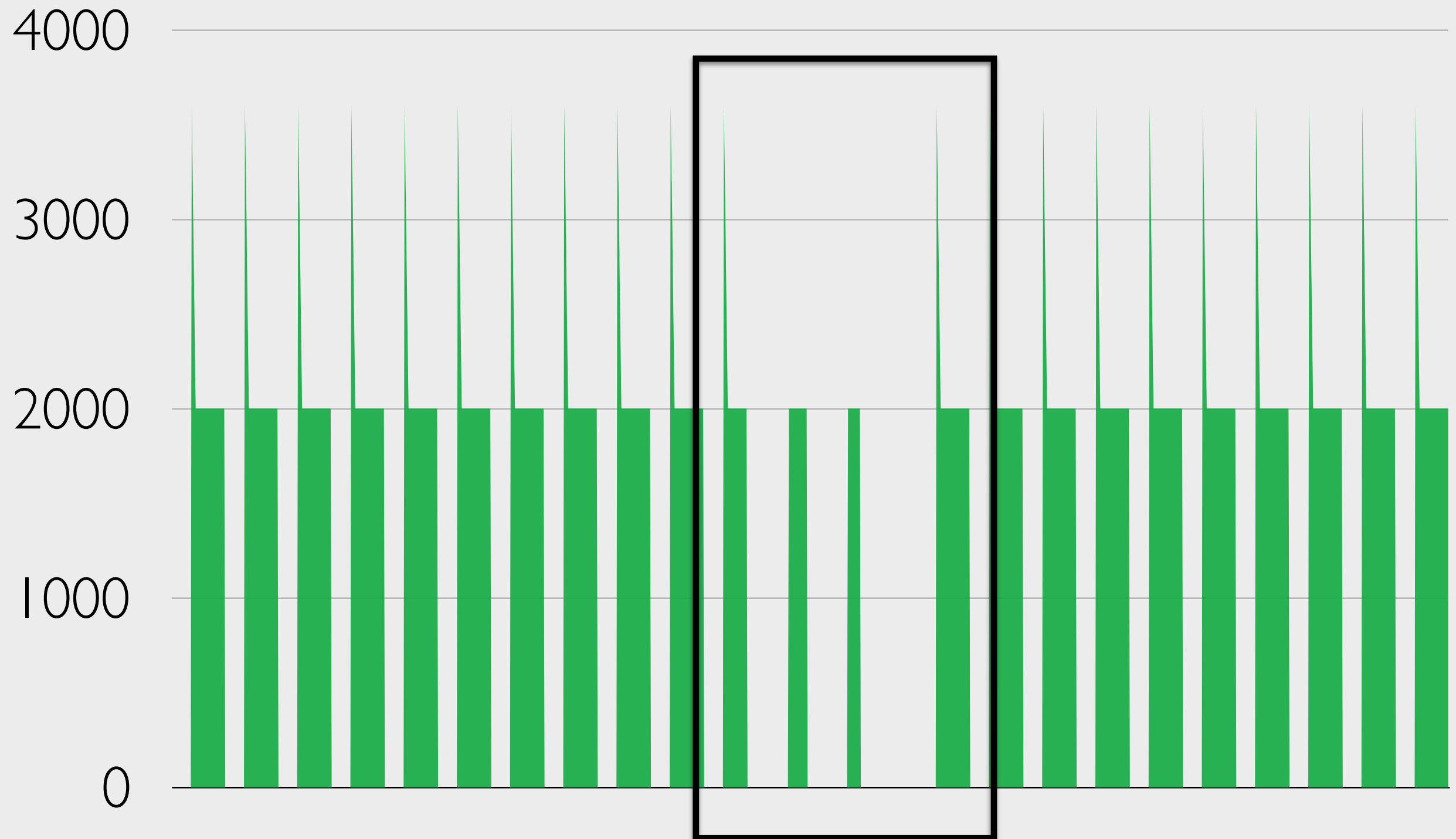
Like fridge, HVAC duty cycles to maintain the set temperature



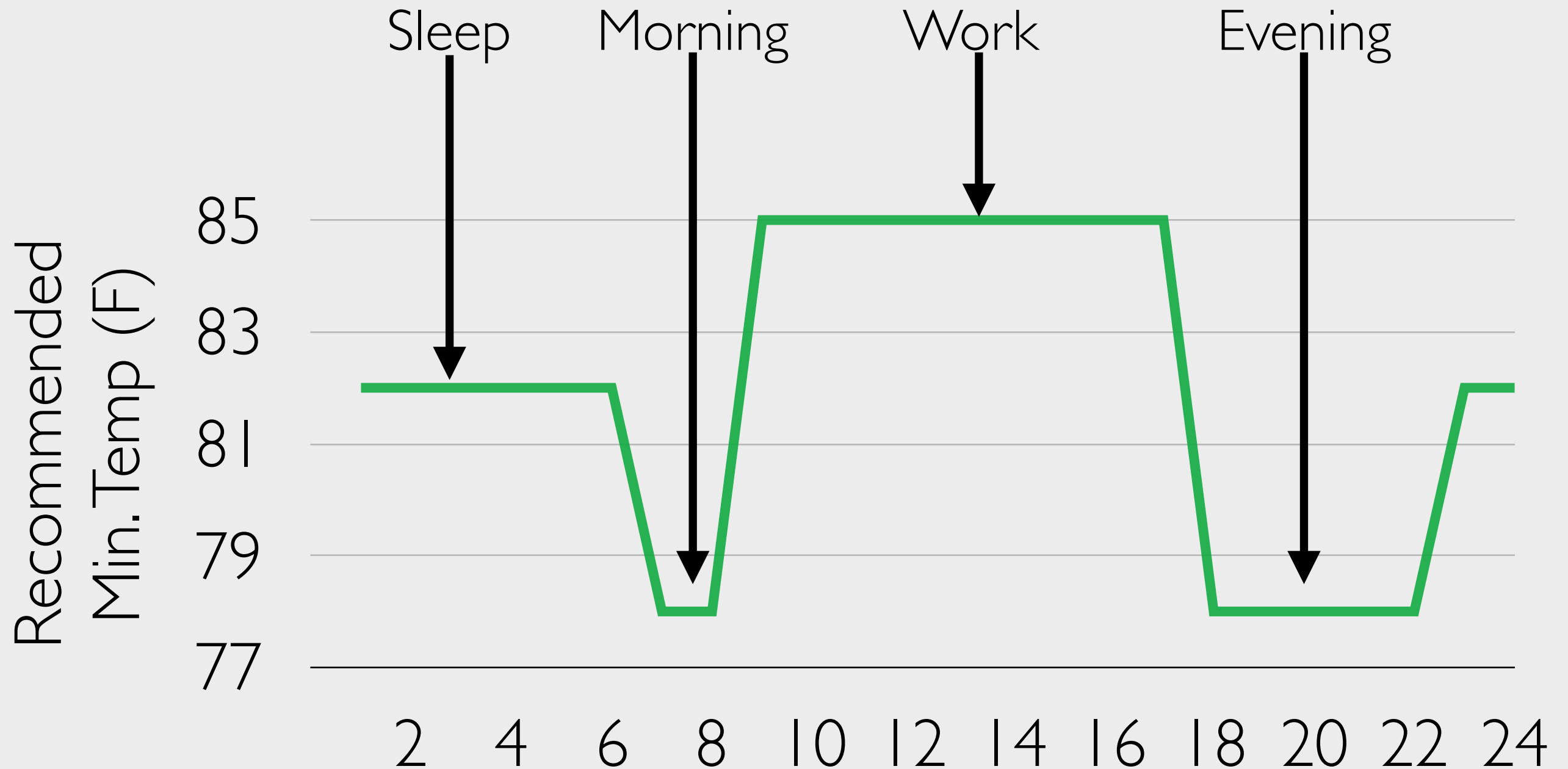
As temperature increases during the day,
more energy required to cool the home



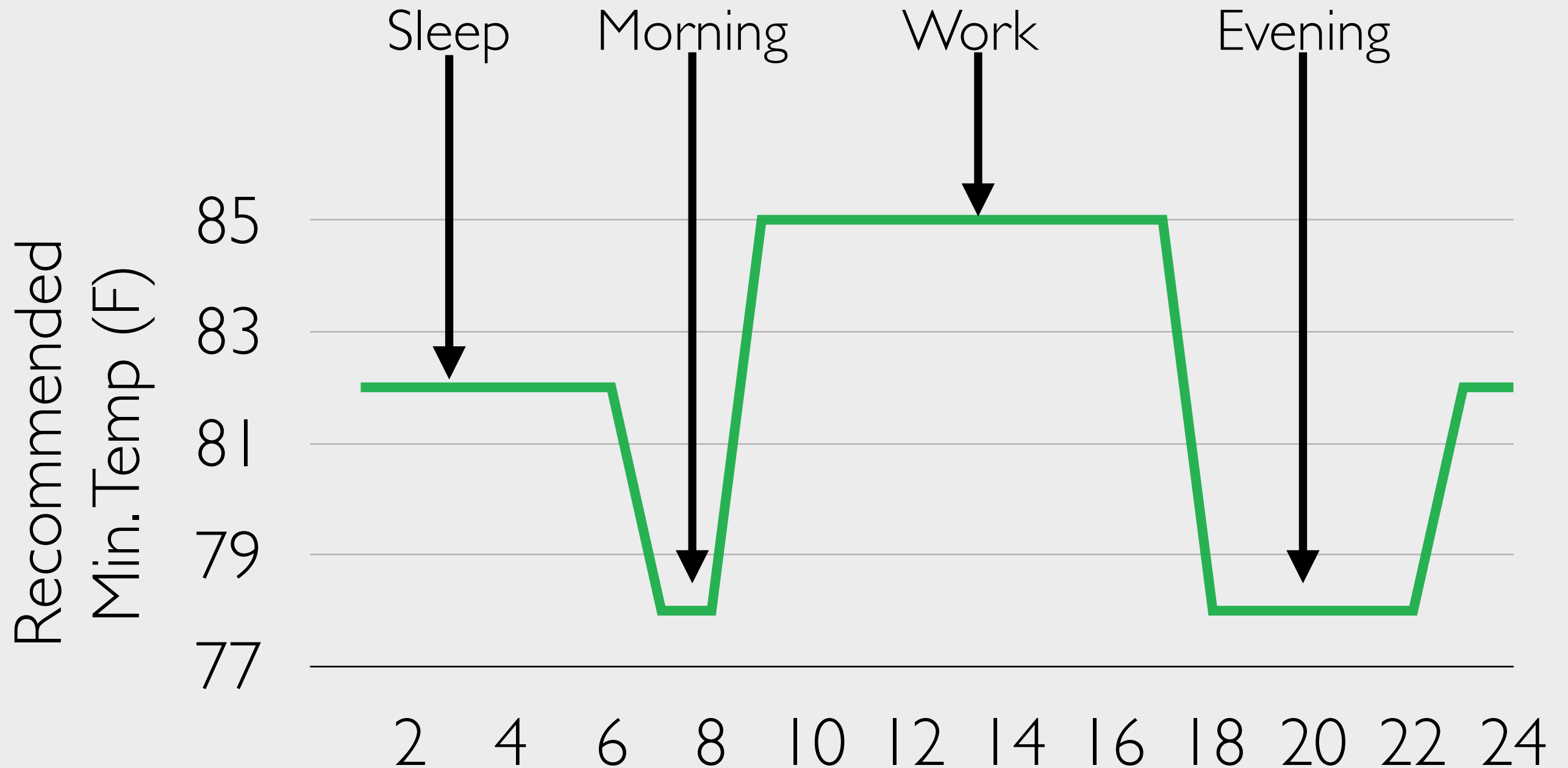
People typically turn up the temperatures when they leave home



EnergyStar.gov recommended HVAC setpoint schedule

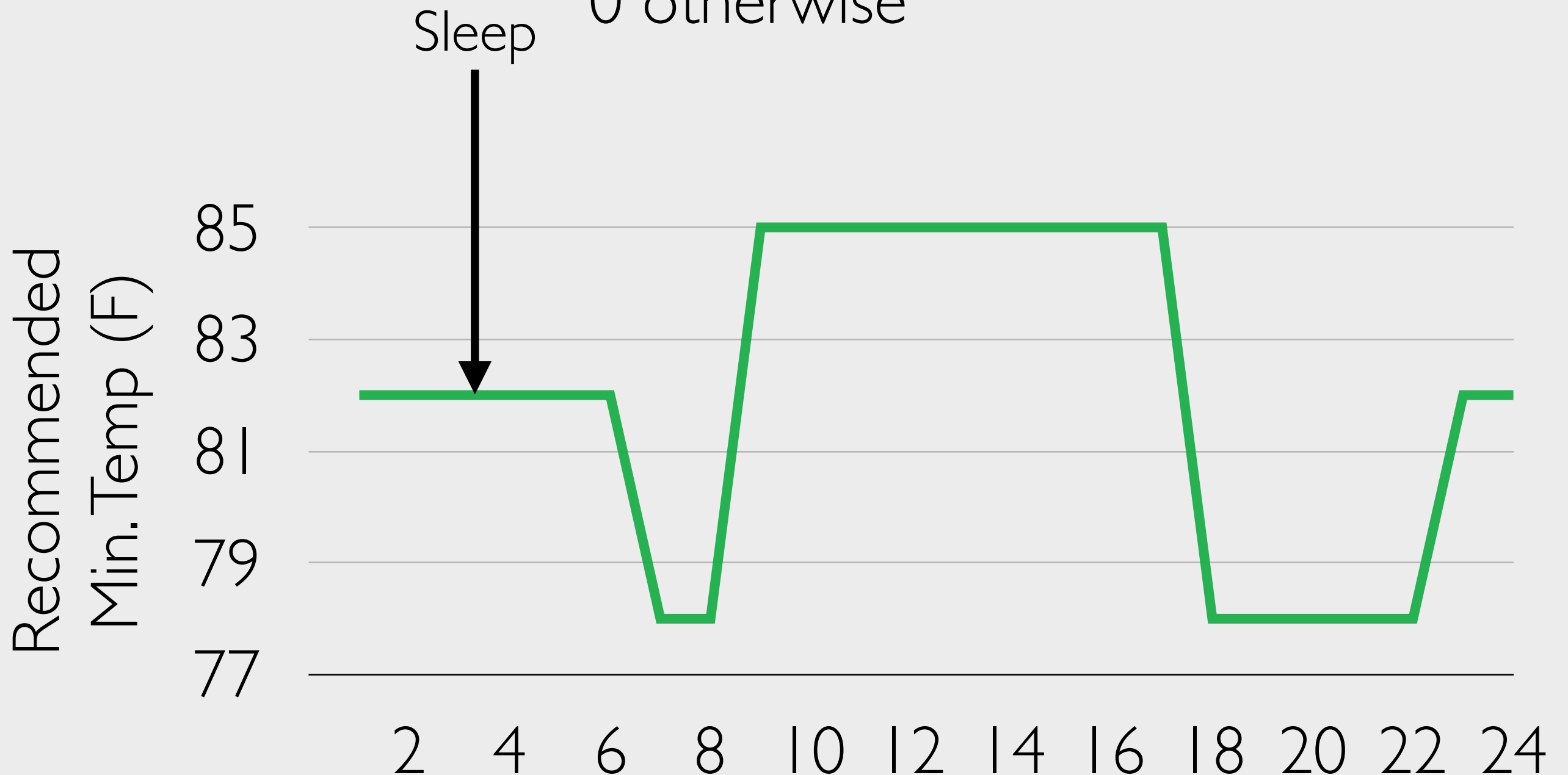


Setpoint schedule score



Setpoint schedule score

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



Learning HVAC setpoint

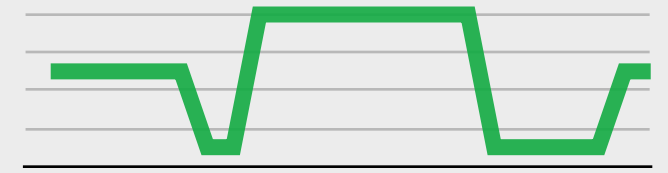
Weather



85

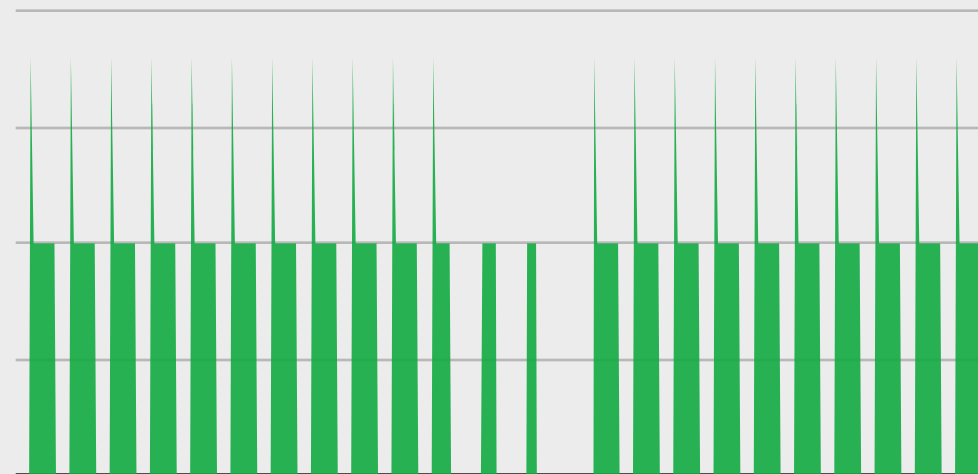
77

Learnt setpoint



5 10 15 20

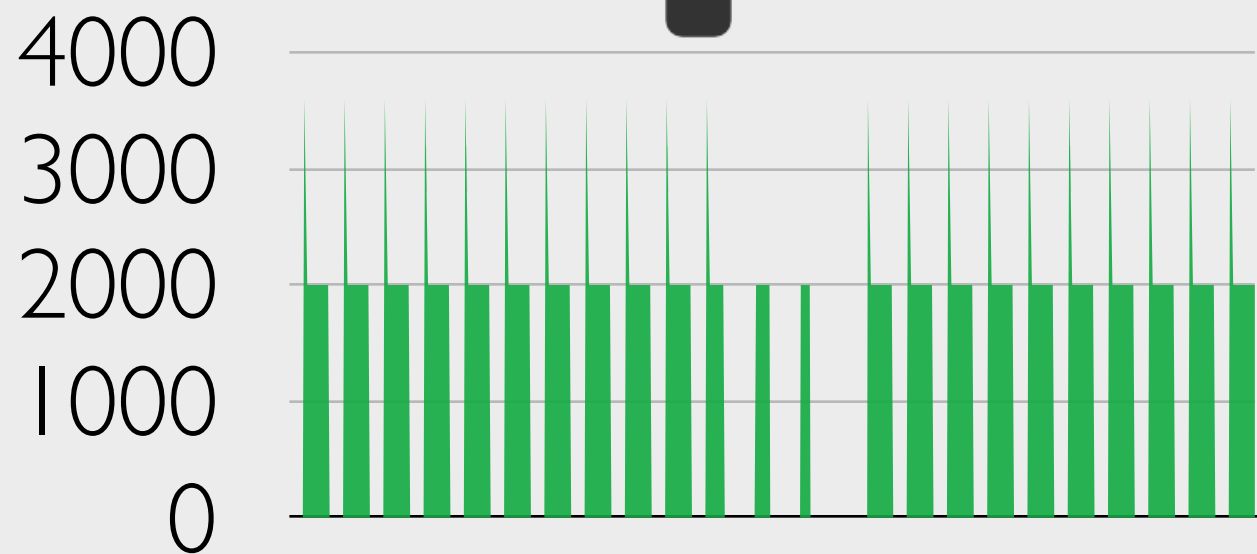
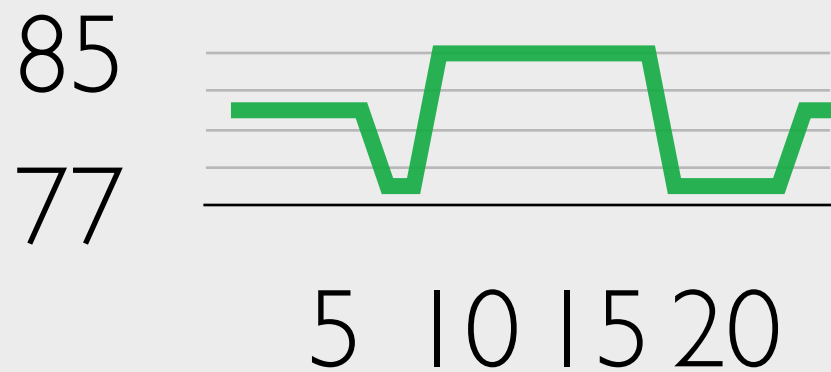
4000
3000
2000
1000
0



HVAC trace

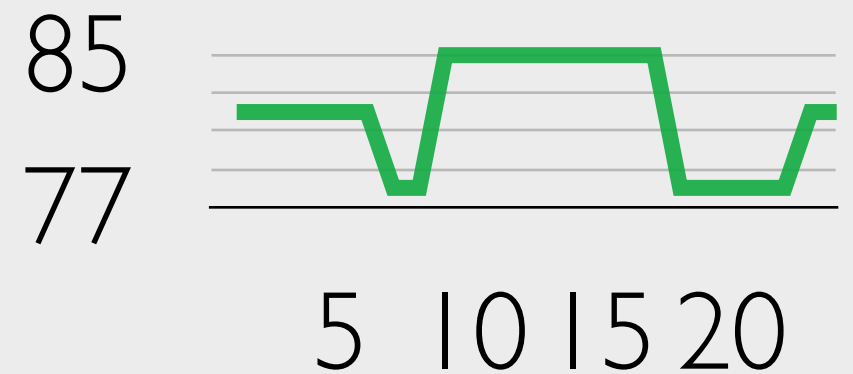
Giving feedback

Learnt setpoint

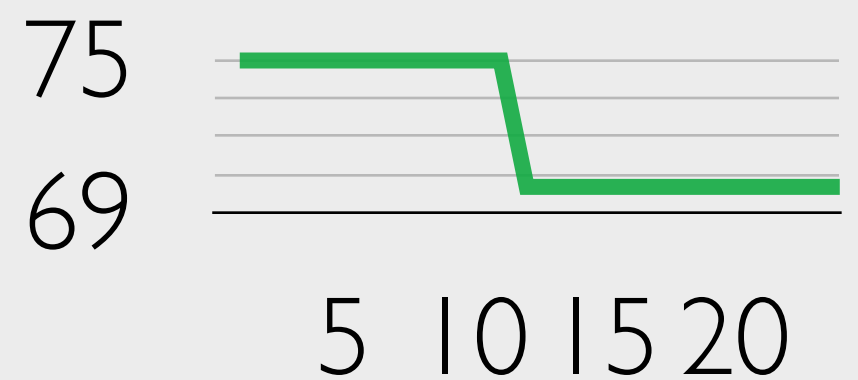


Features from HVAC trace

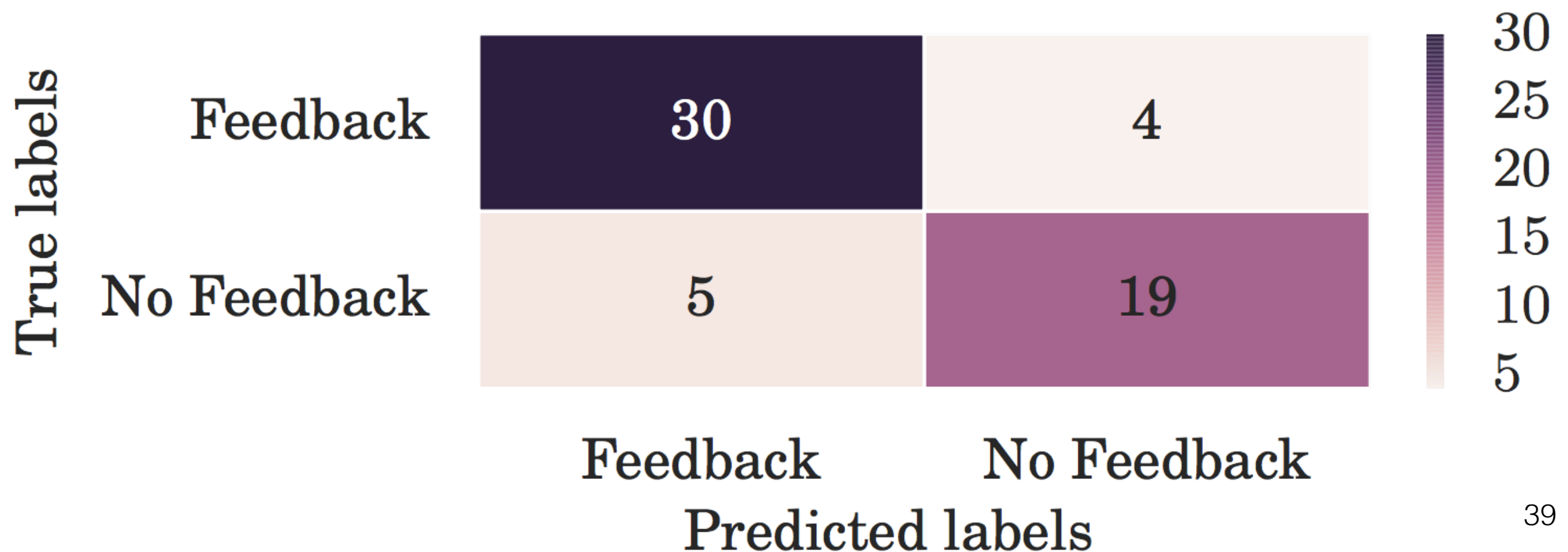
Don't need feedback

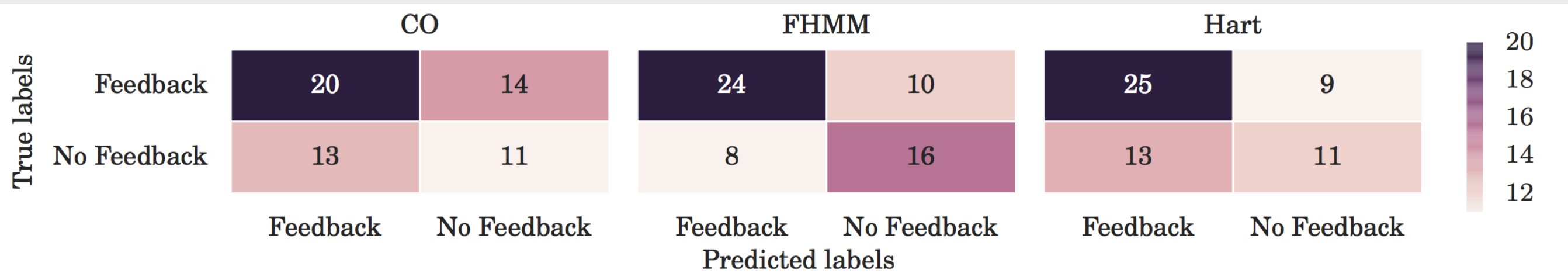


Need feedback

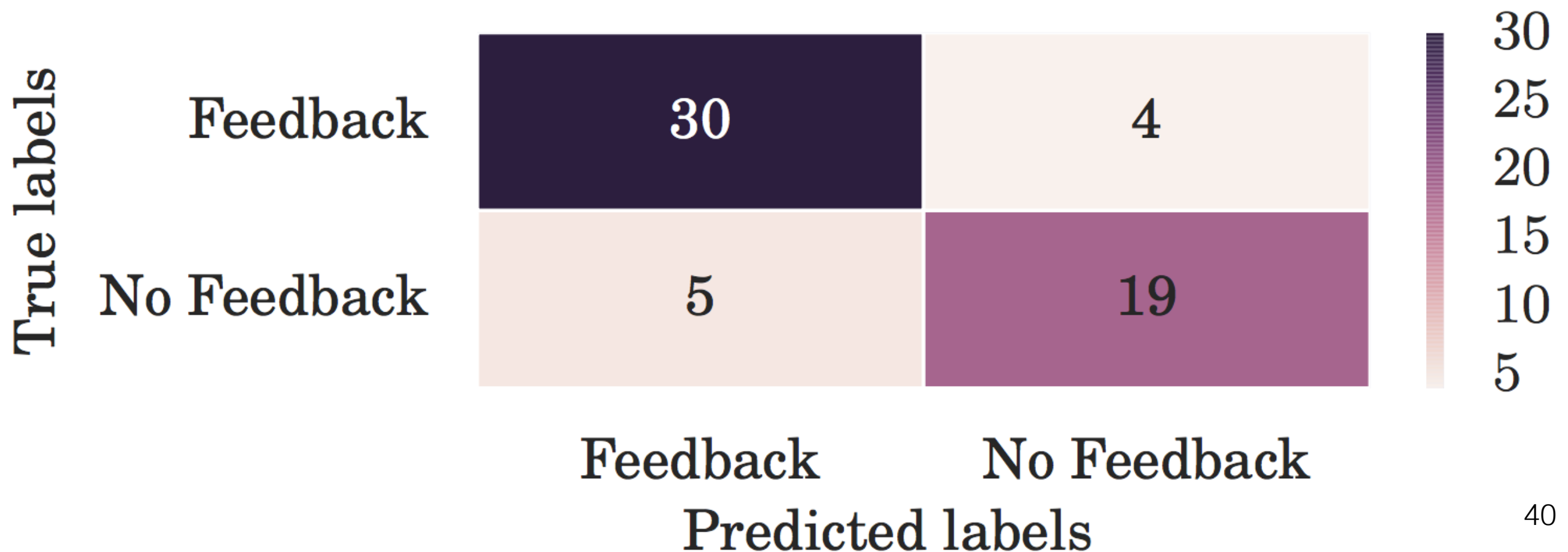


84% accuracy on giving feedback using submetered traces

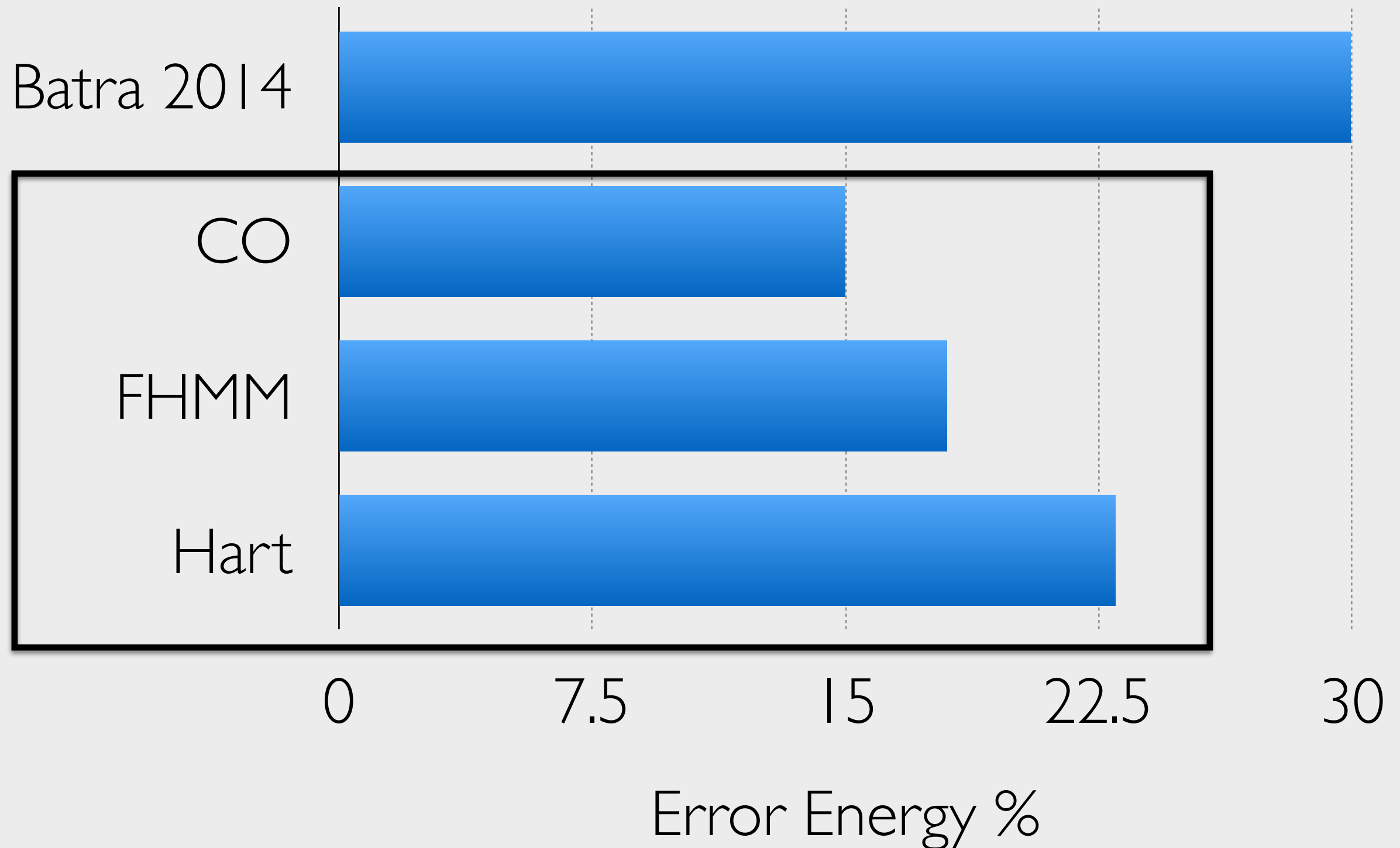




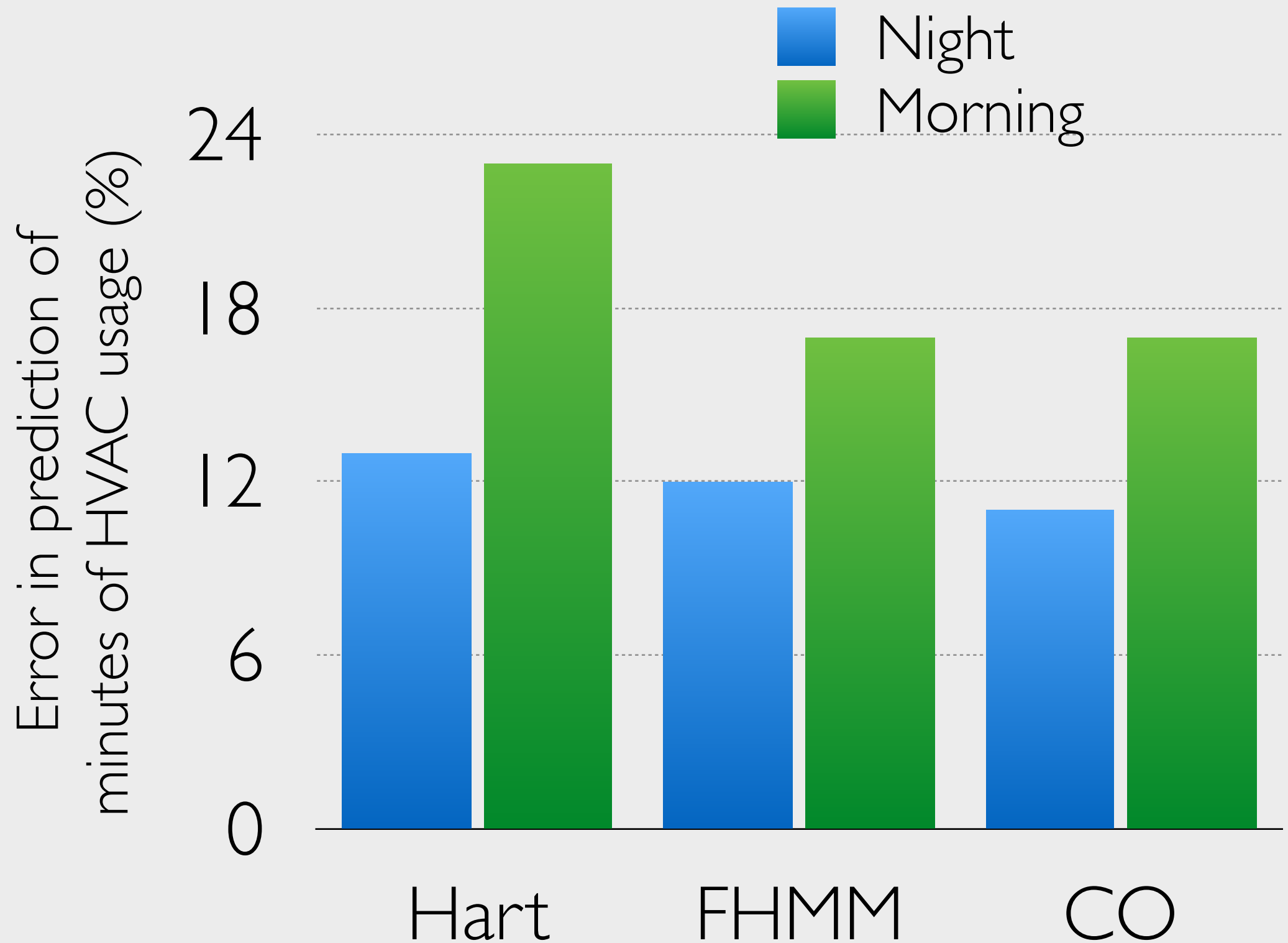
NILM methods give 15-30% worse accuracy for feedback



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**