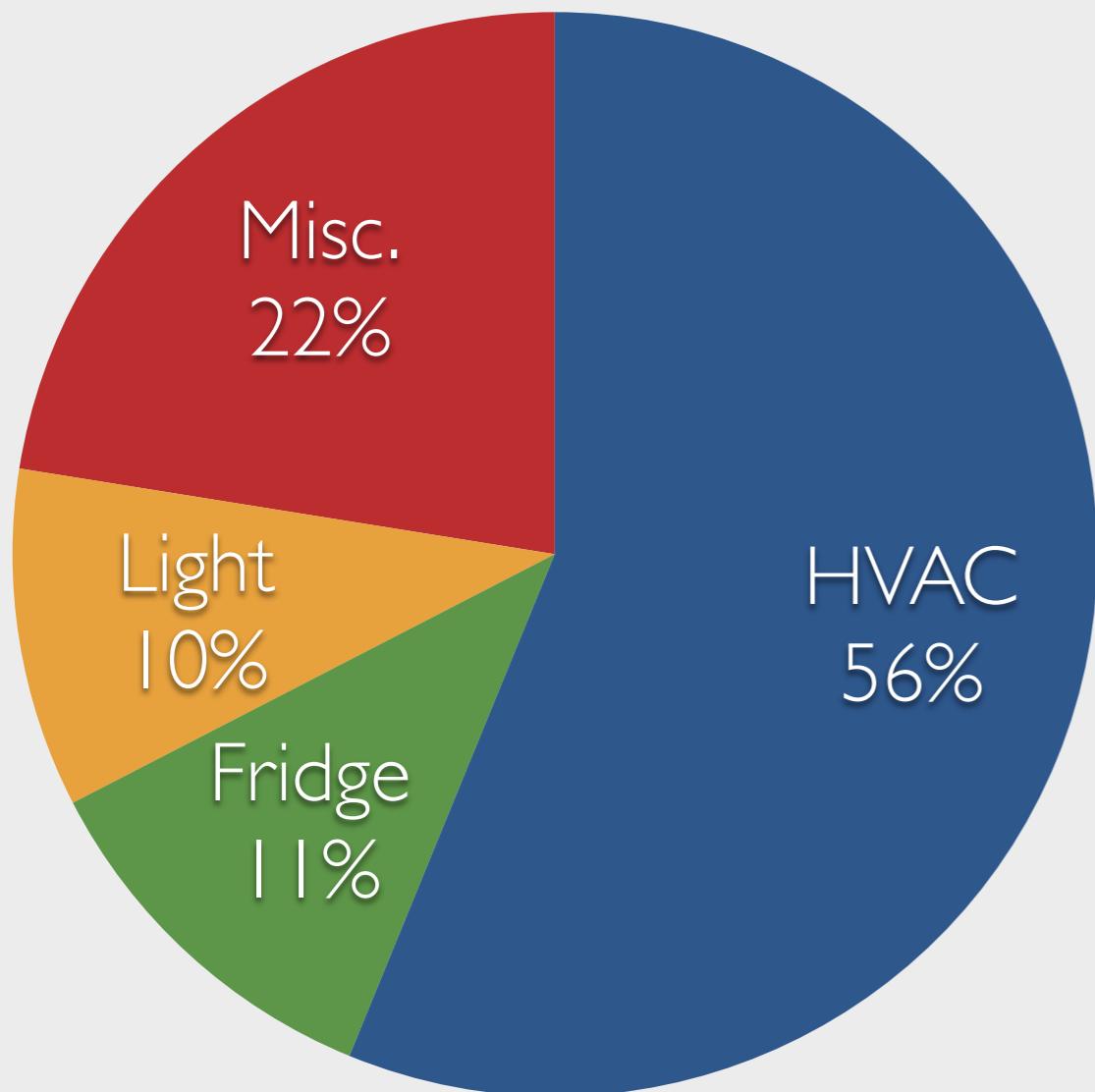


If You Measure It, Can You Improve It? Exploring The Value of Energy Disaggregation through actionable feedback

Nipun Batra, Amarjeet Singh, Kamin Whitehouse
Buildsys 2015

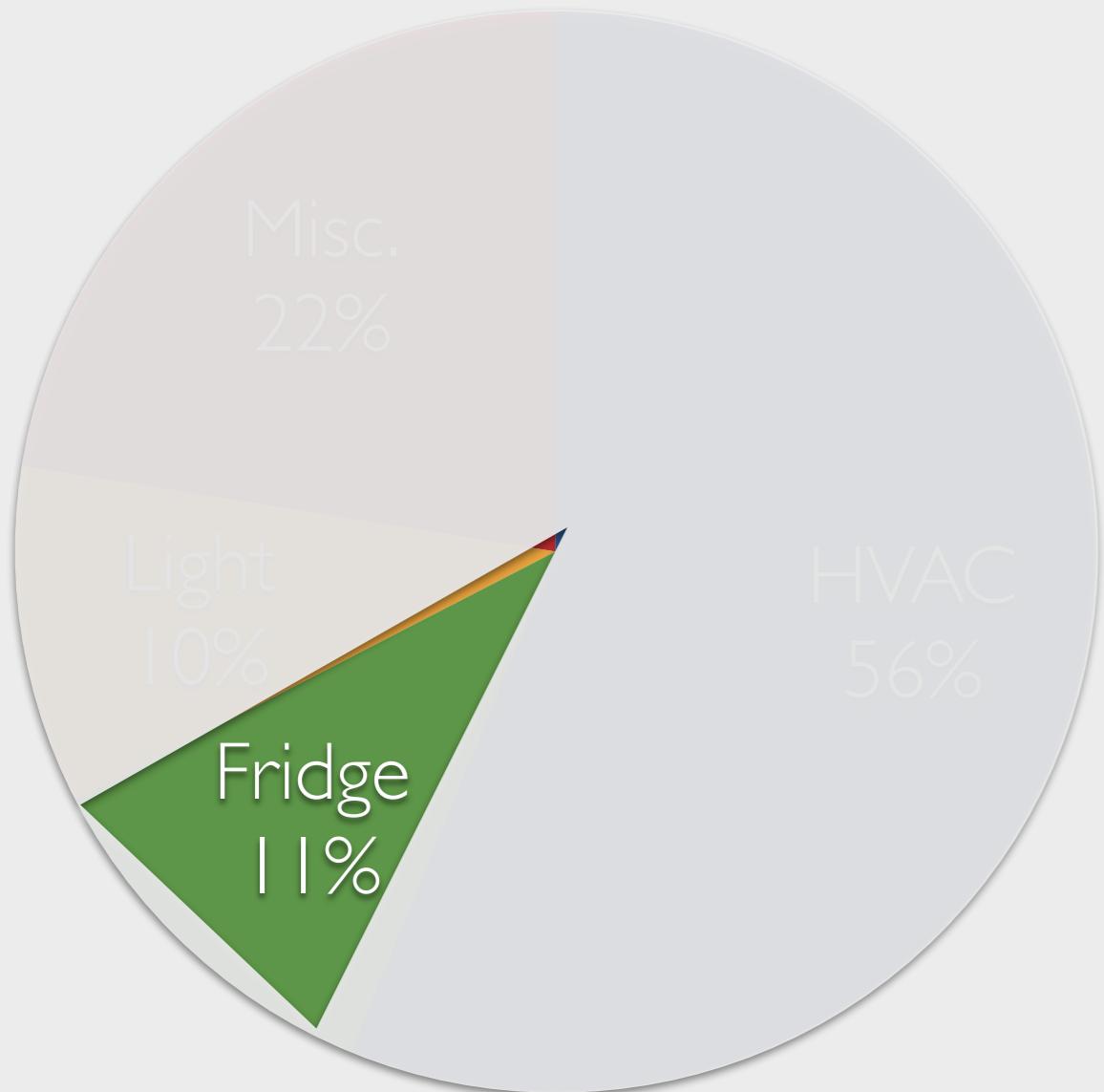
General eco feedback vs Actionable Feedback

Eco
feedback



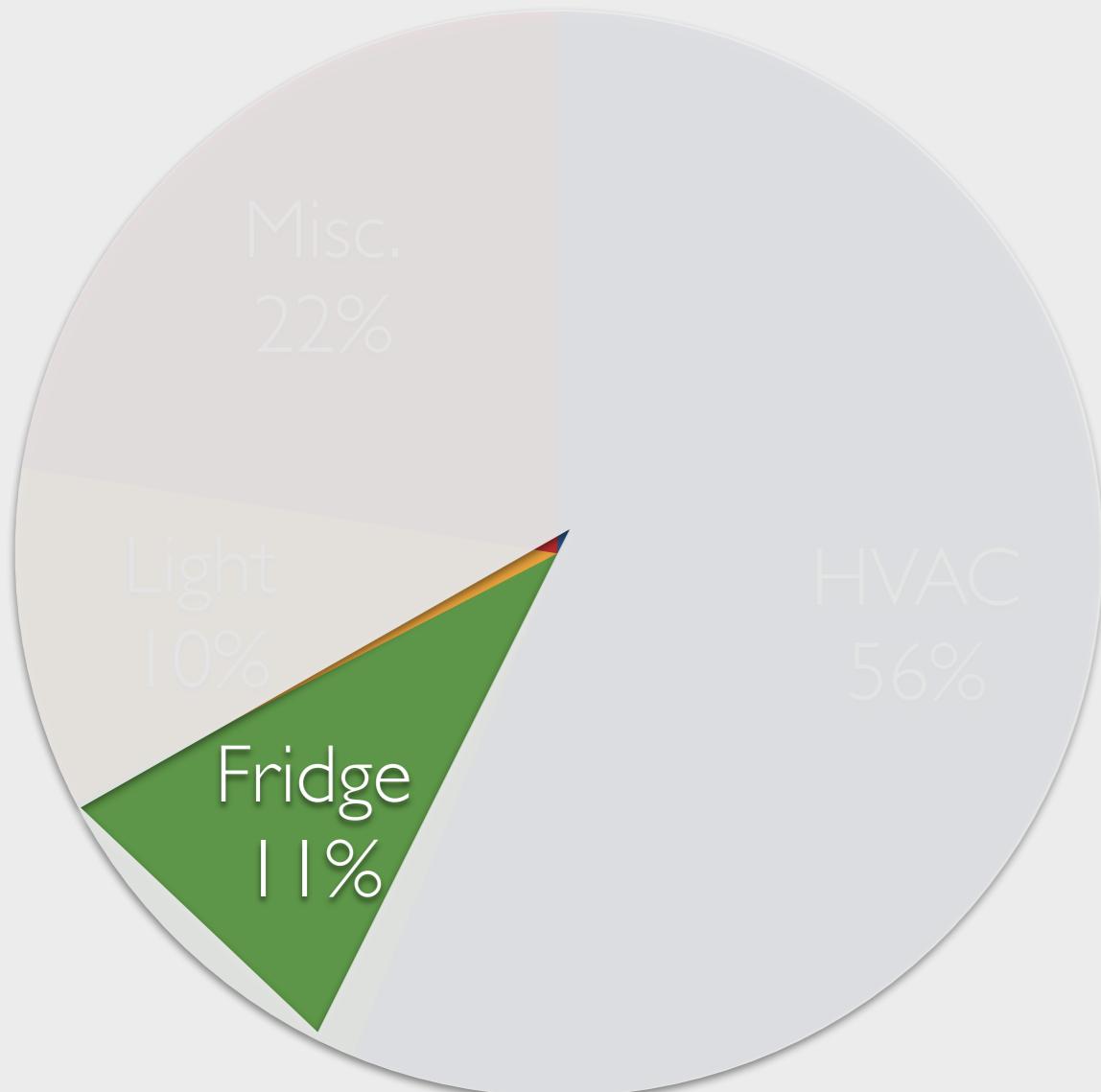
General eco feedback vs Actionable Feedback

Eco feedback



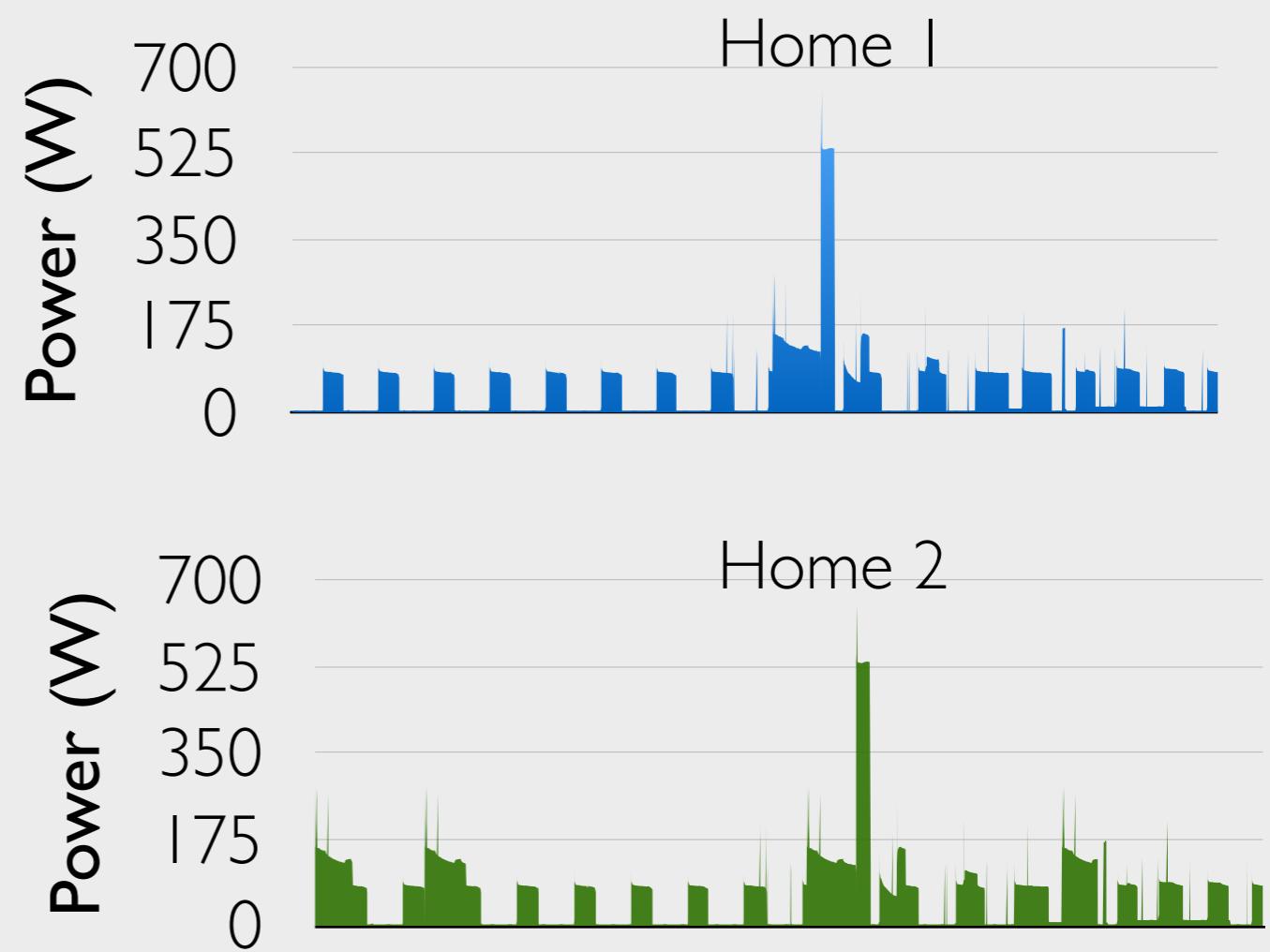
General eco feedback vs Actionable Feedback

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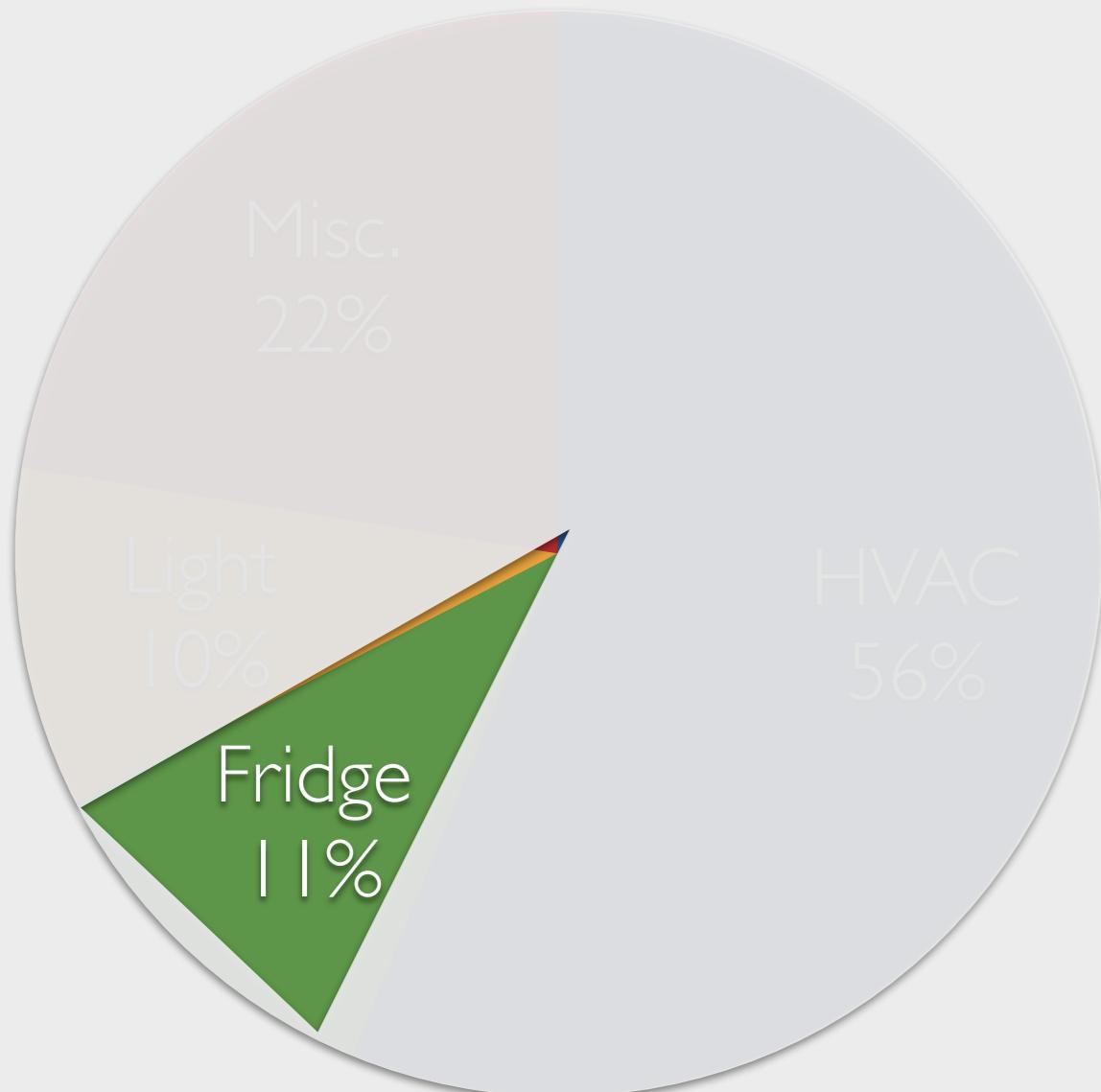
Actionable
feedback

Fridge consumption over 24 hours



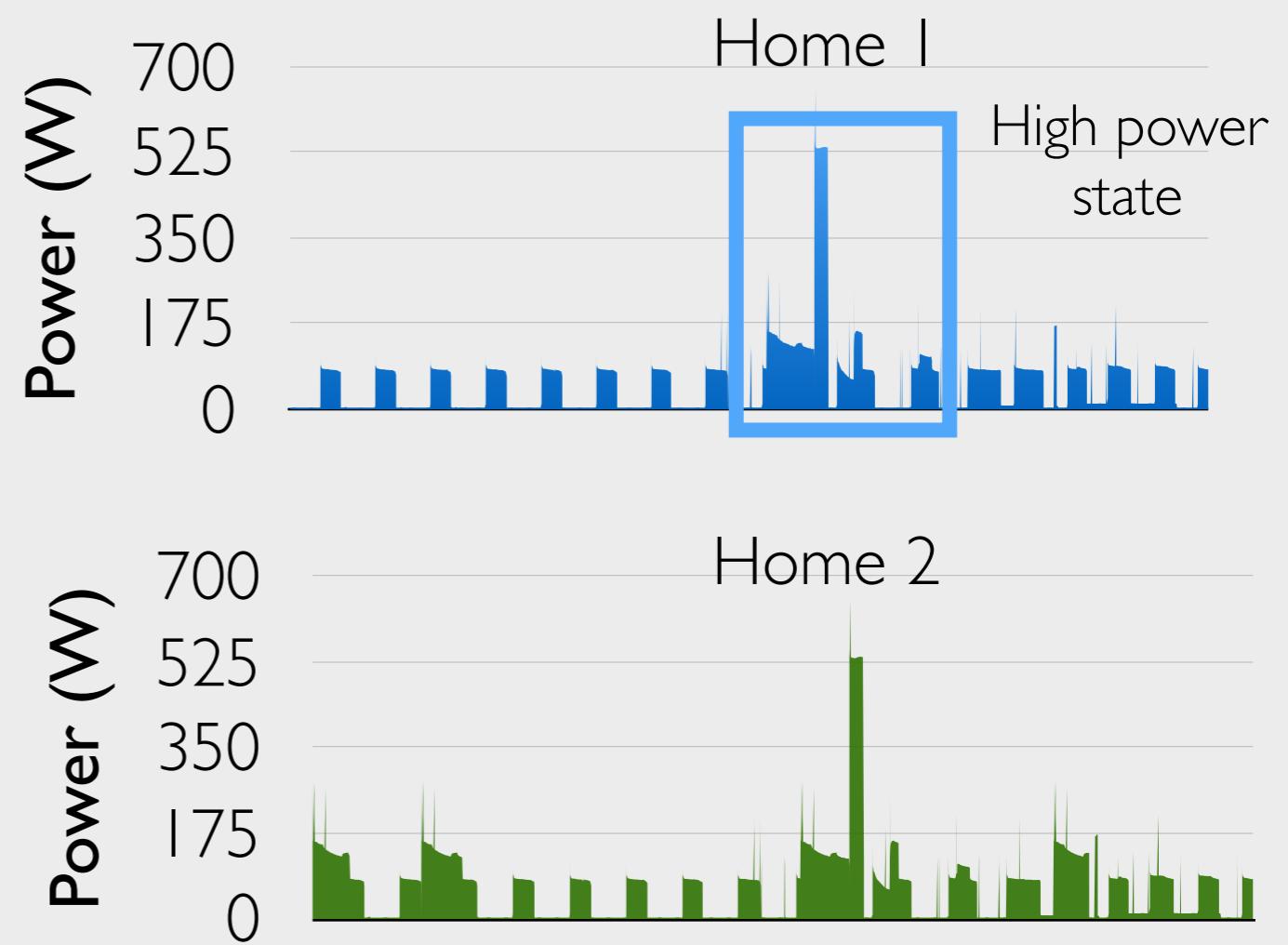
General eco feedback vs Actionable Feedback

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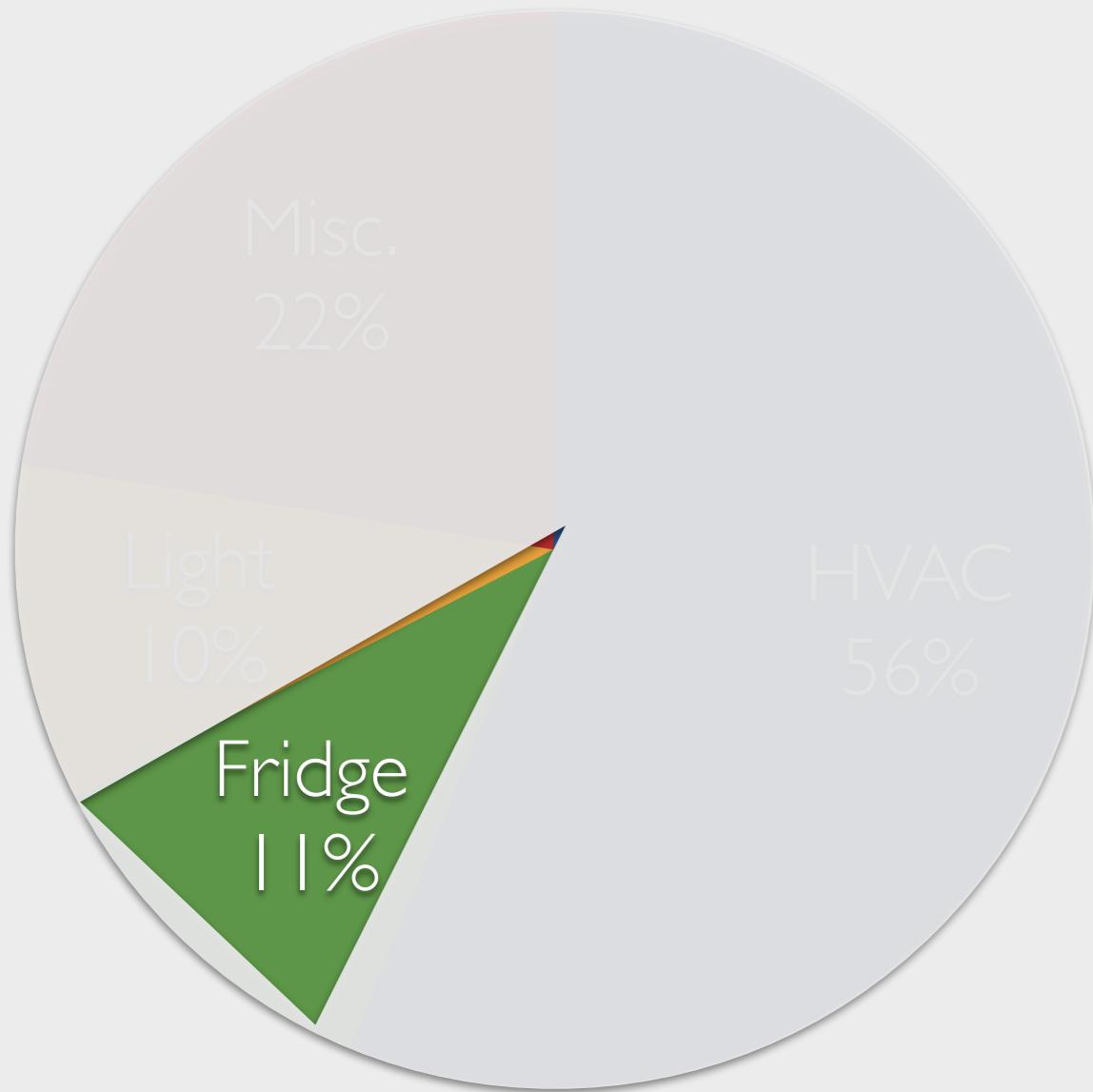
Actionable
feedback

Fridge consumption over 24 hours



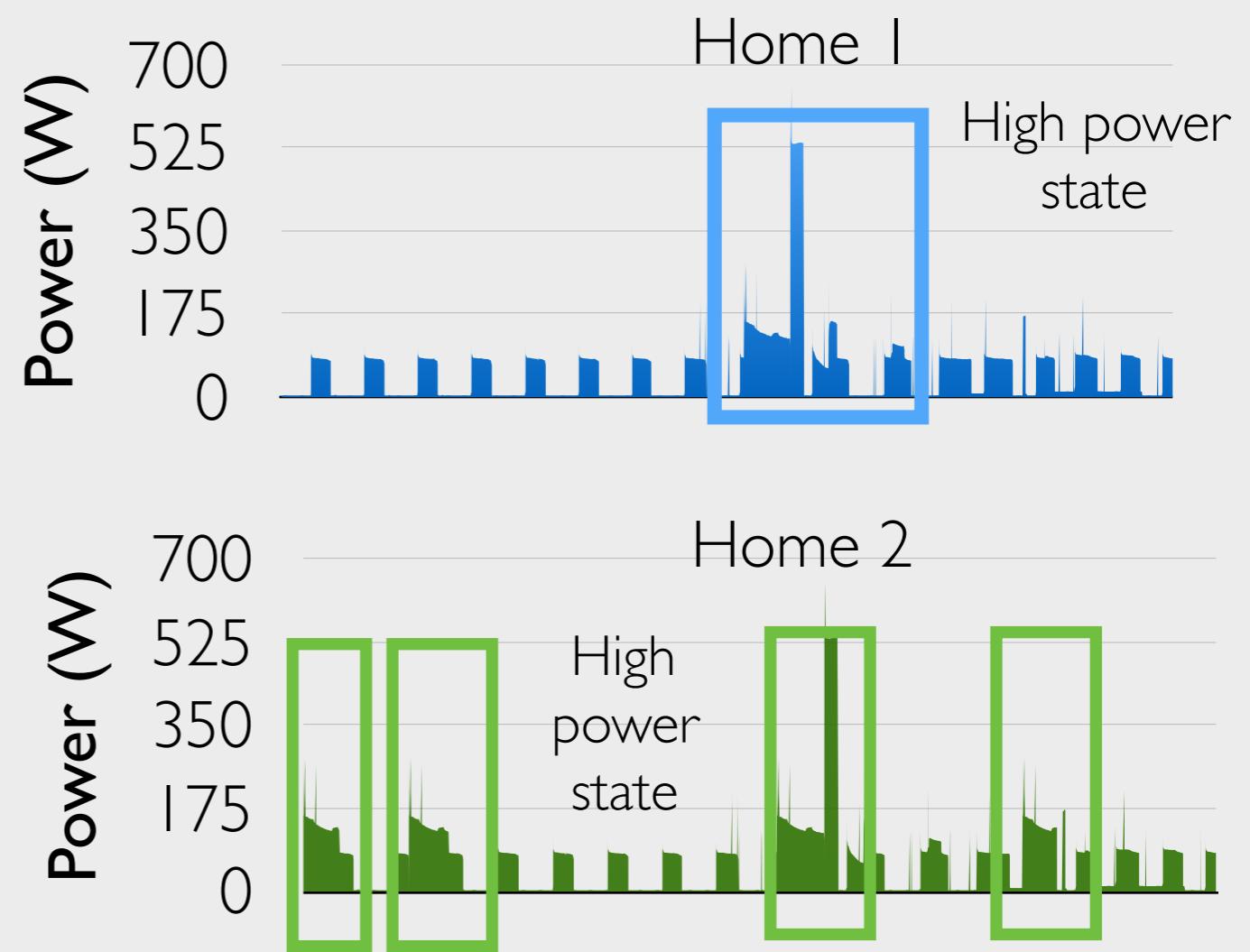
General eco feedback vs Actionable Feedback

Eco
feedback



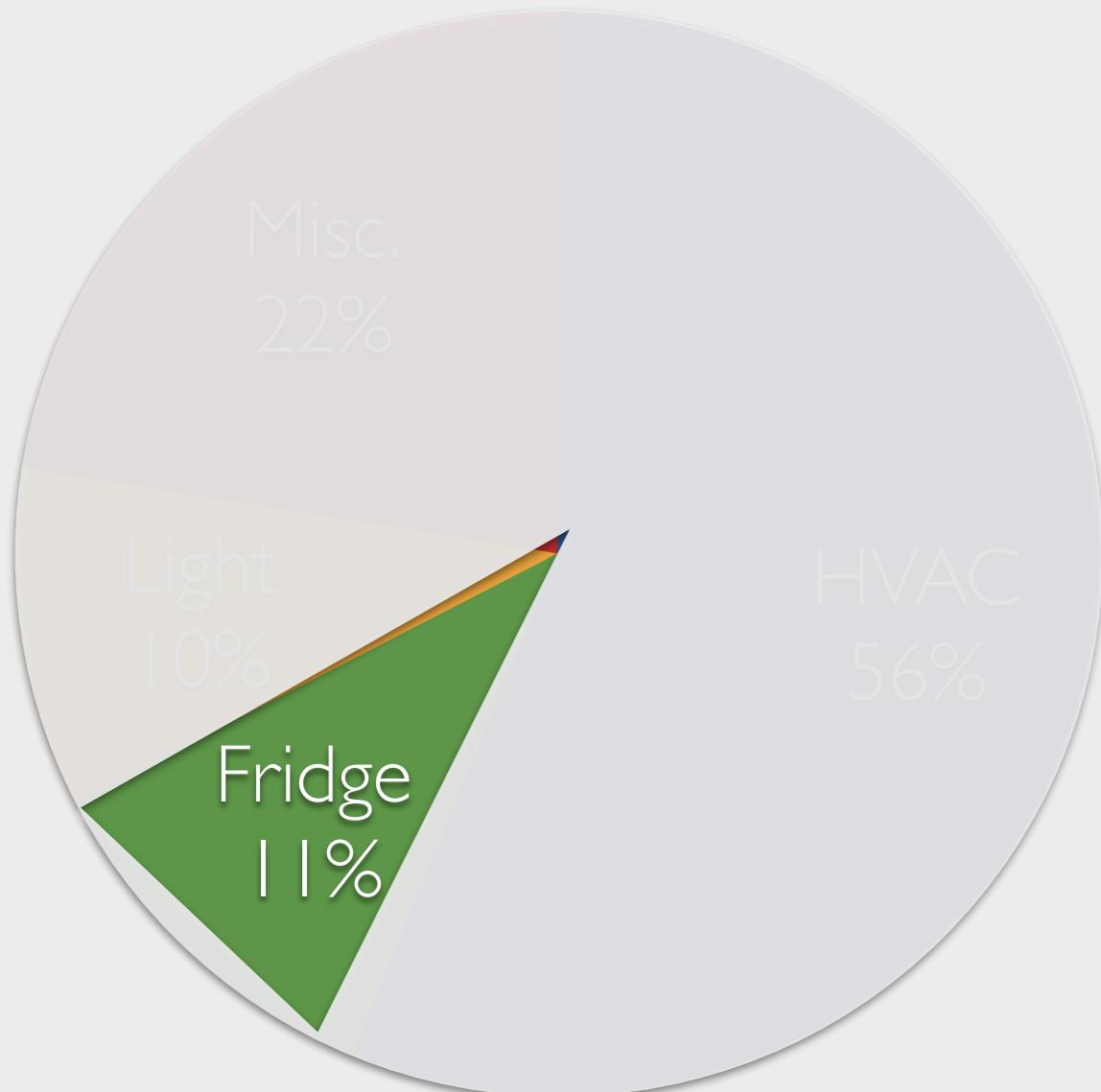
Actionable
feedback

Fridge consumption over 24 hours



General eco feedback vs Actionable Feedback

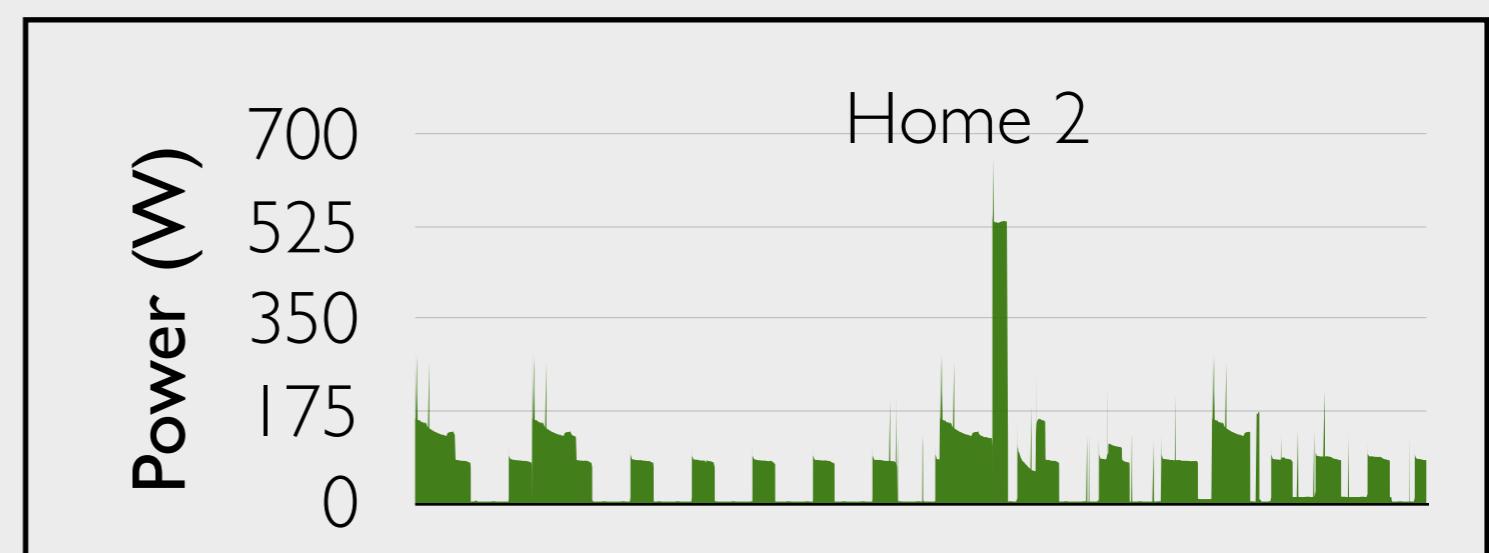
Eco
feedback



Actionable
feedback

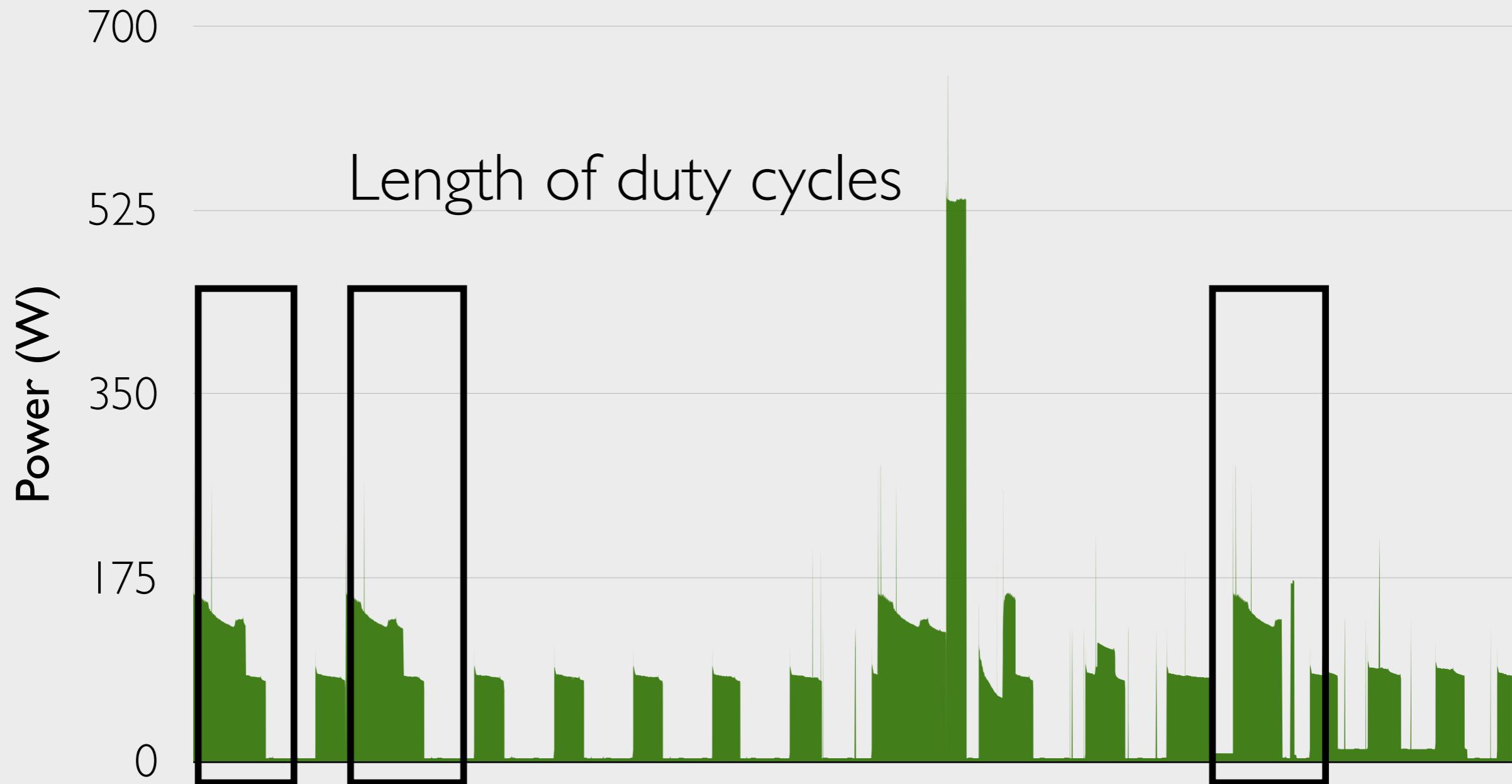
Fridge consumption over 24 hours

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



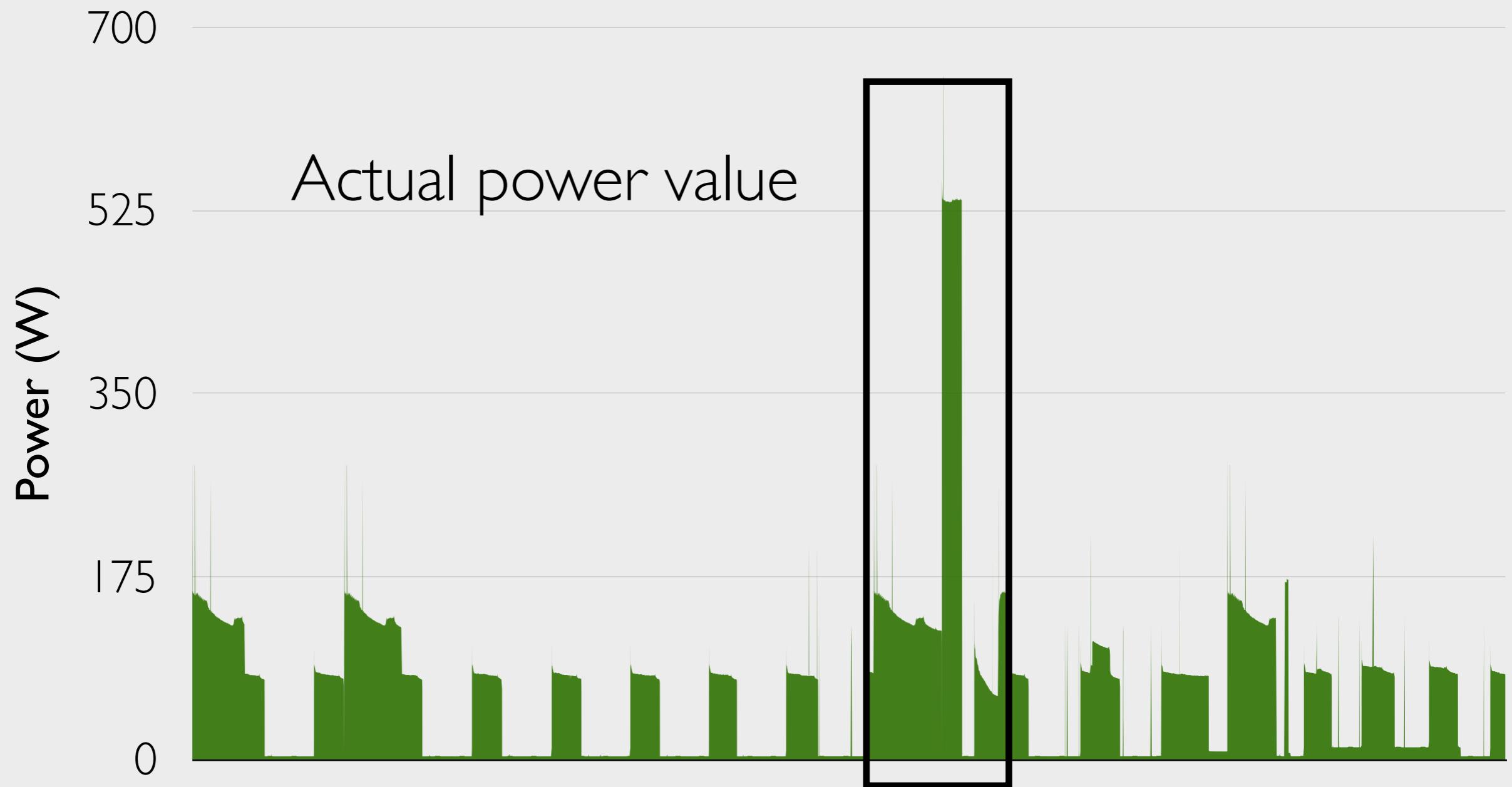
Approach overview- How to give feedback

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

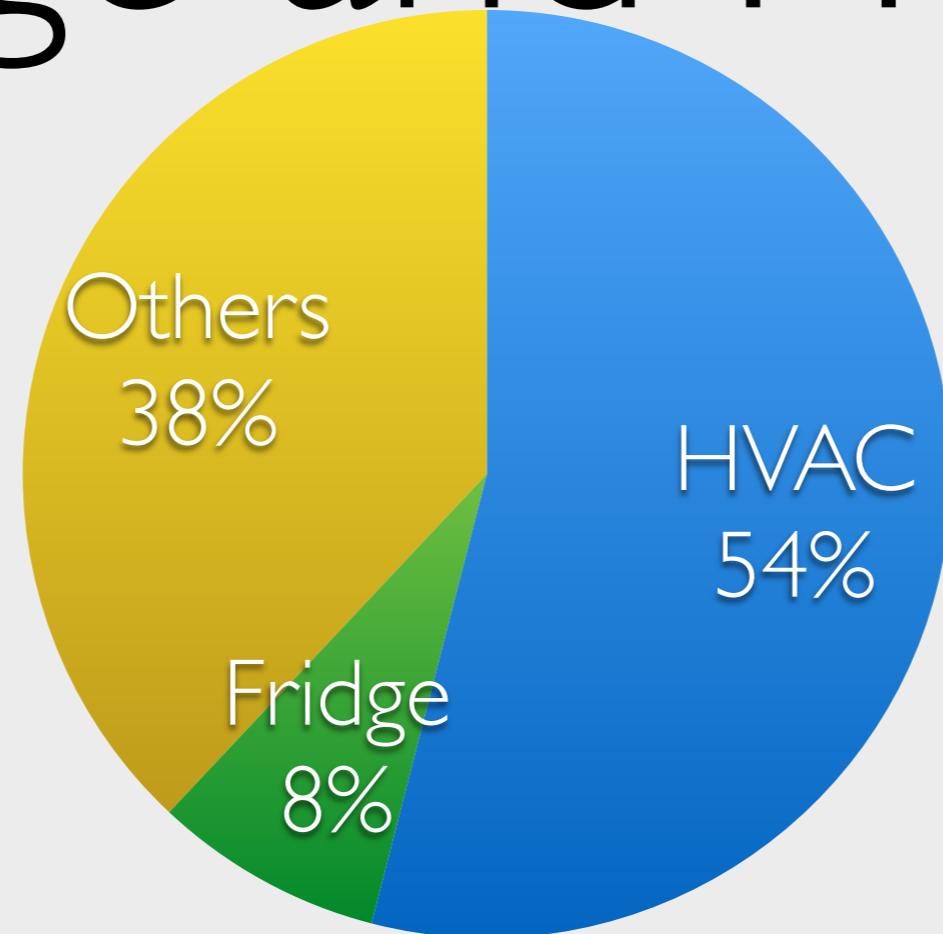


Approach overview- How to give feedback

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



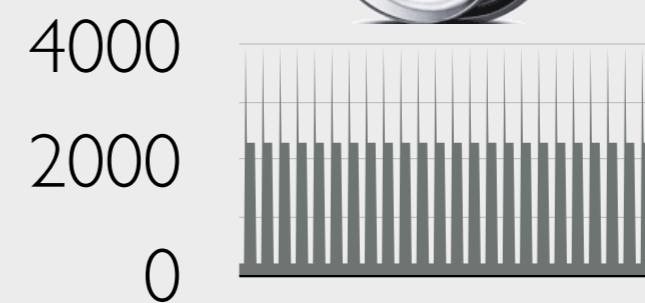
Submeter
sensor



Disaggregated
traces



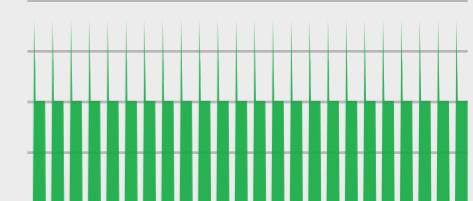
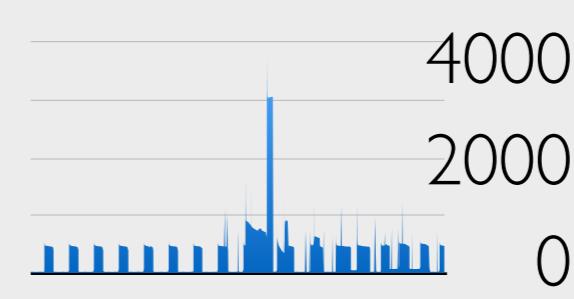
Smart
meter



Household
aggregate



Power (W)

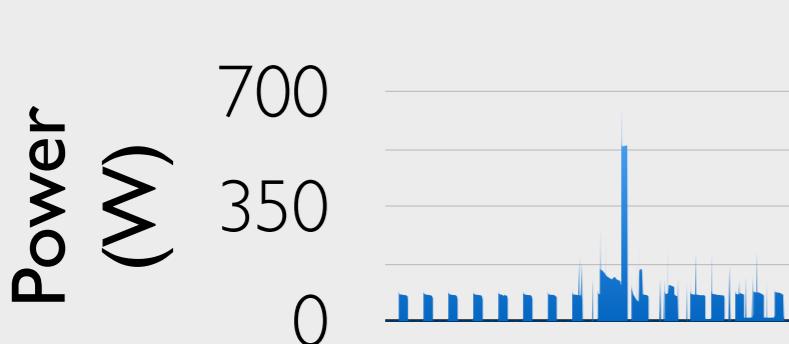


Do disaggregated traces provide features needed for providing feedback?

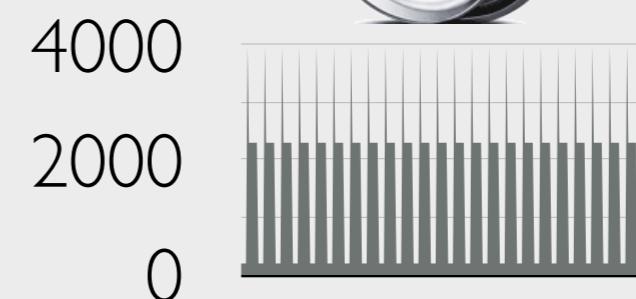
Submetered
traces



Submeter
sensor

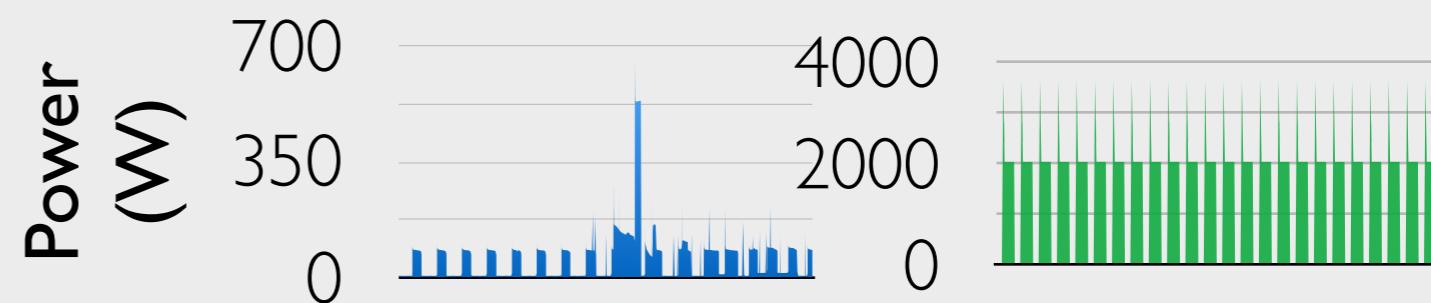


Disaggregated
traces

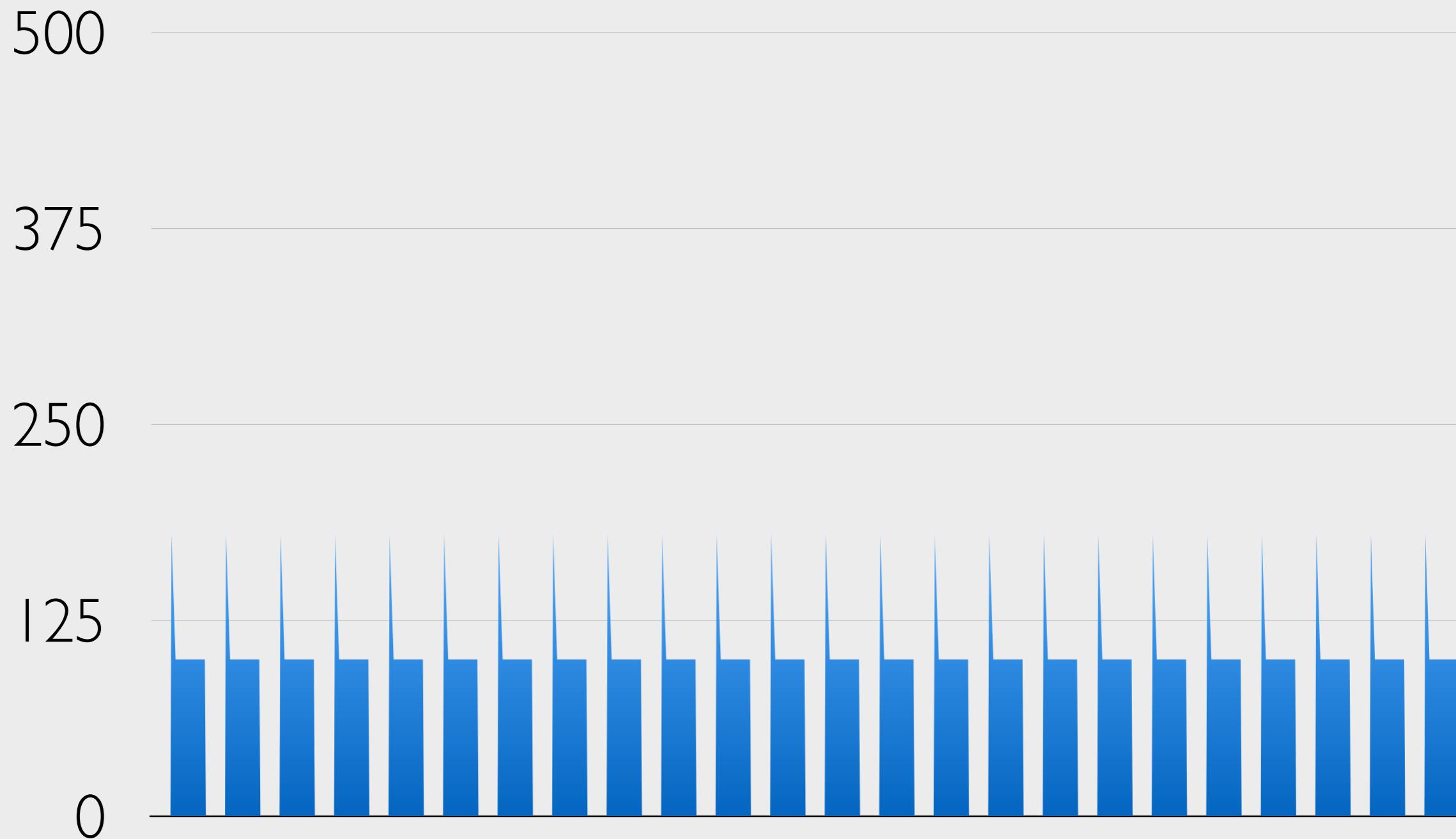


Smart
meter

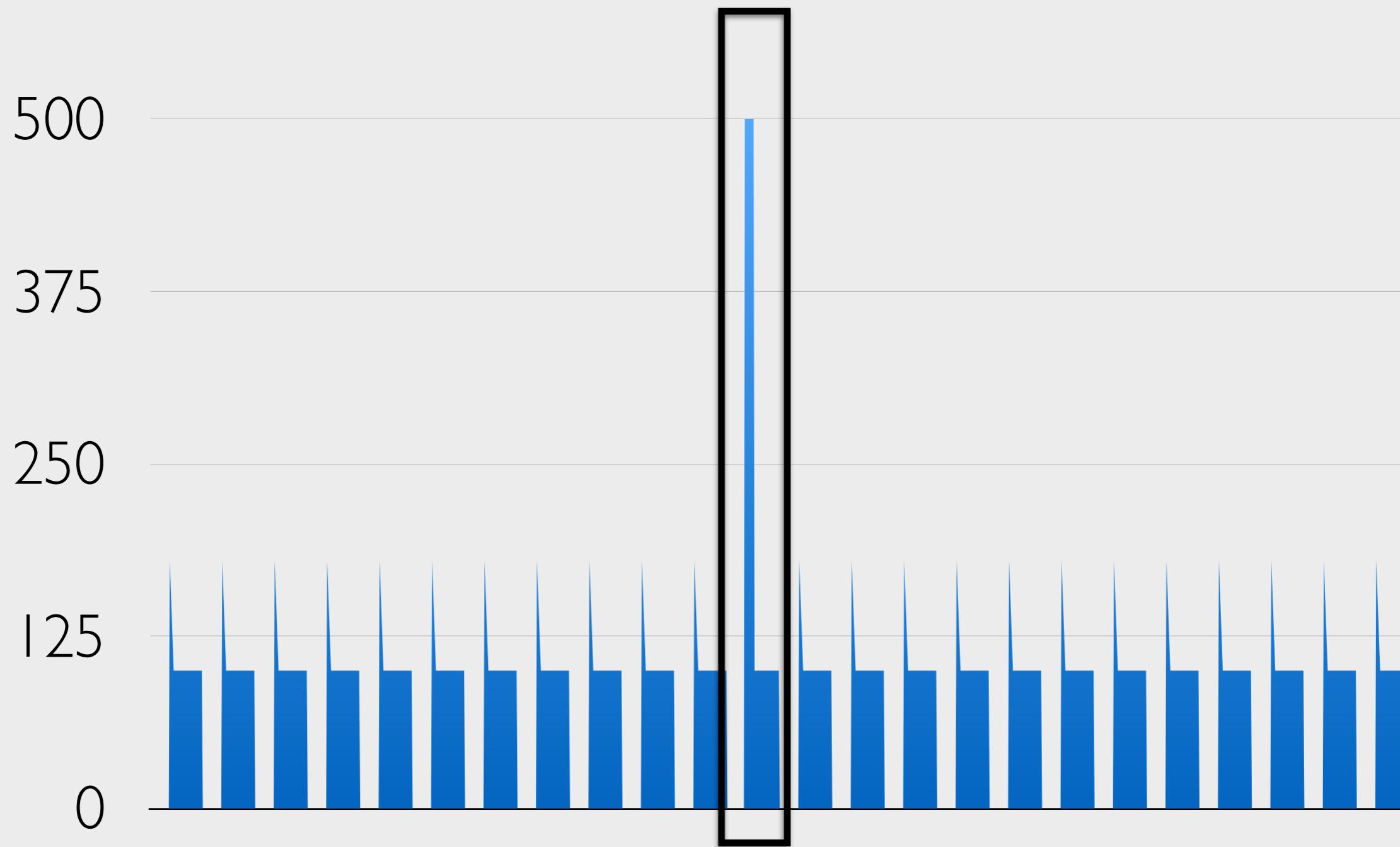
Household
aggregate



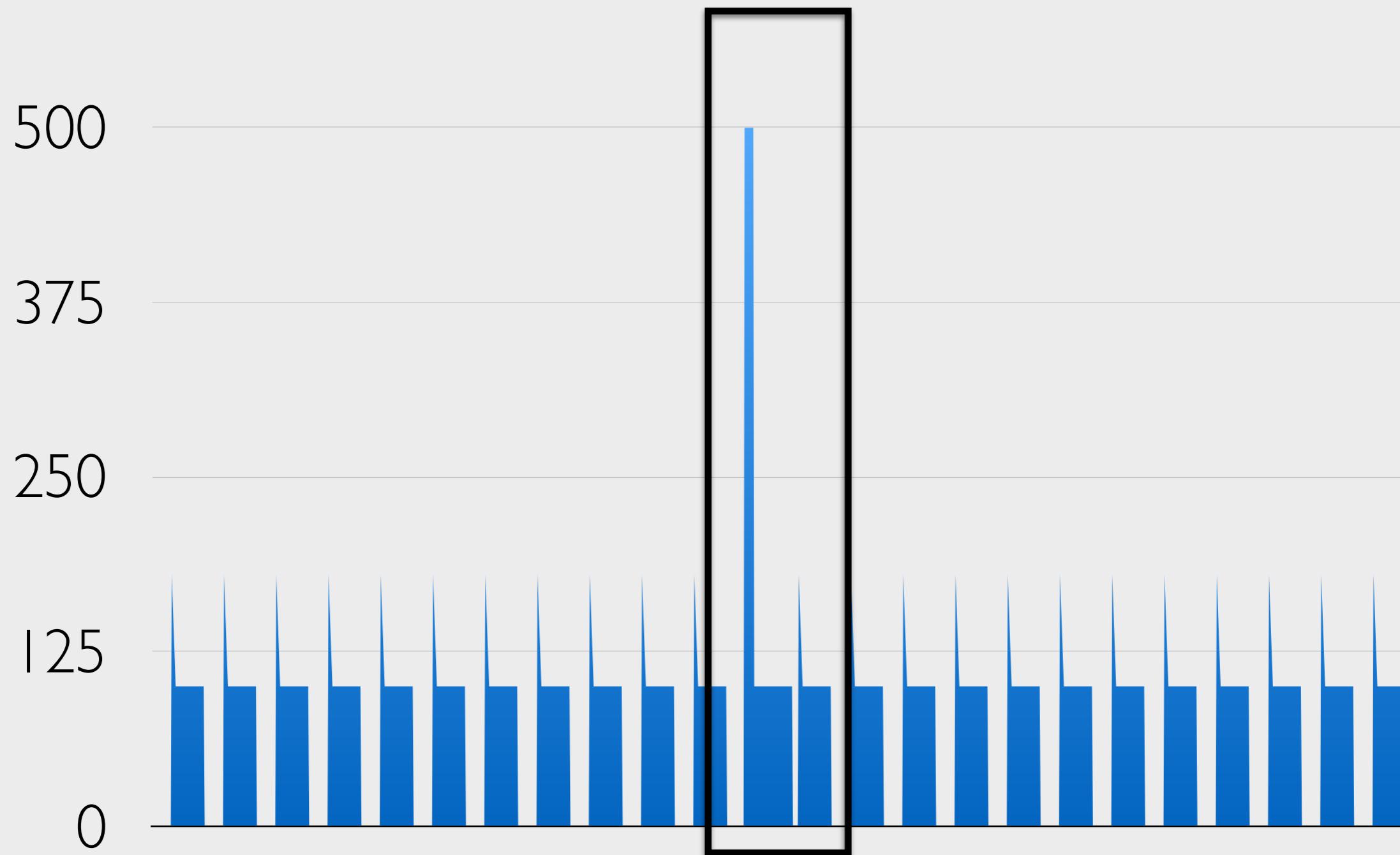
Fridge is a duty cycle based appliance;
compressor turns ON and OFF
periodically



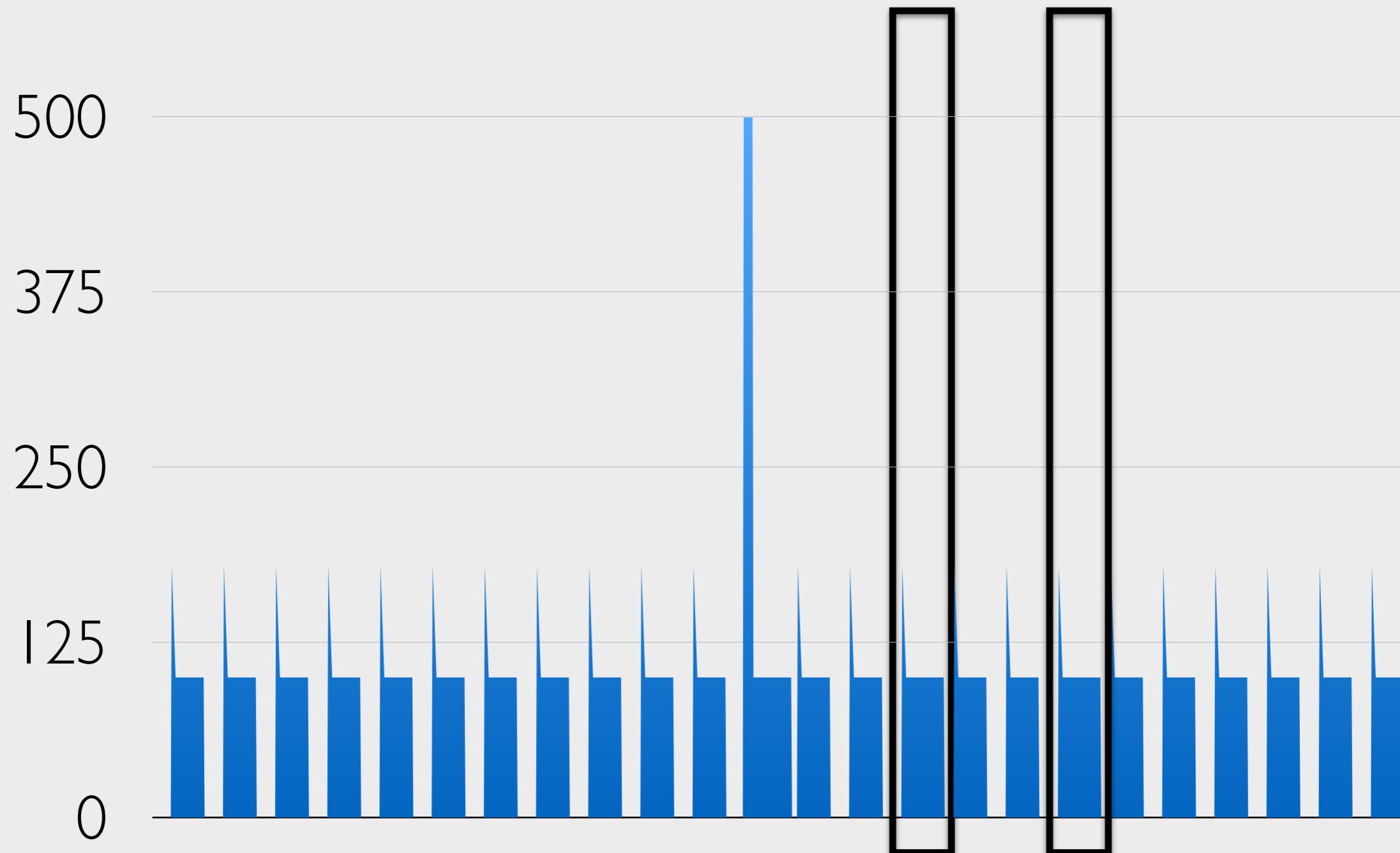
Defrost cycles occurs periodically and consume high amount of power



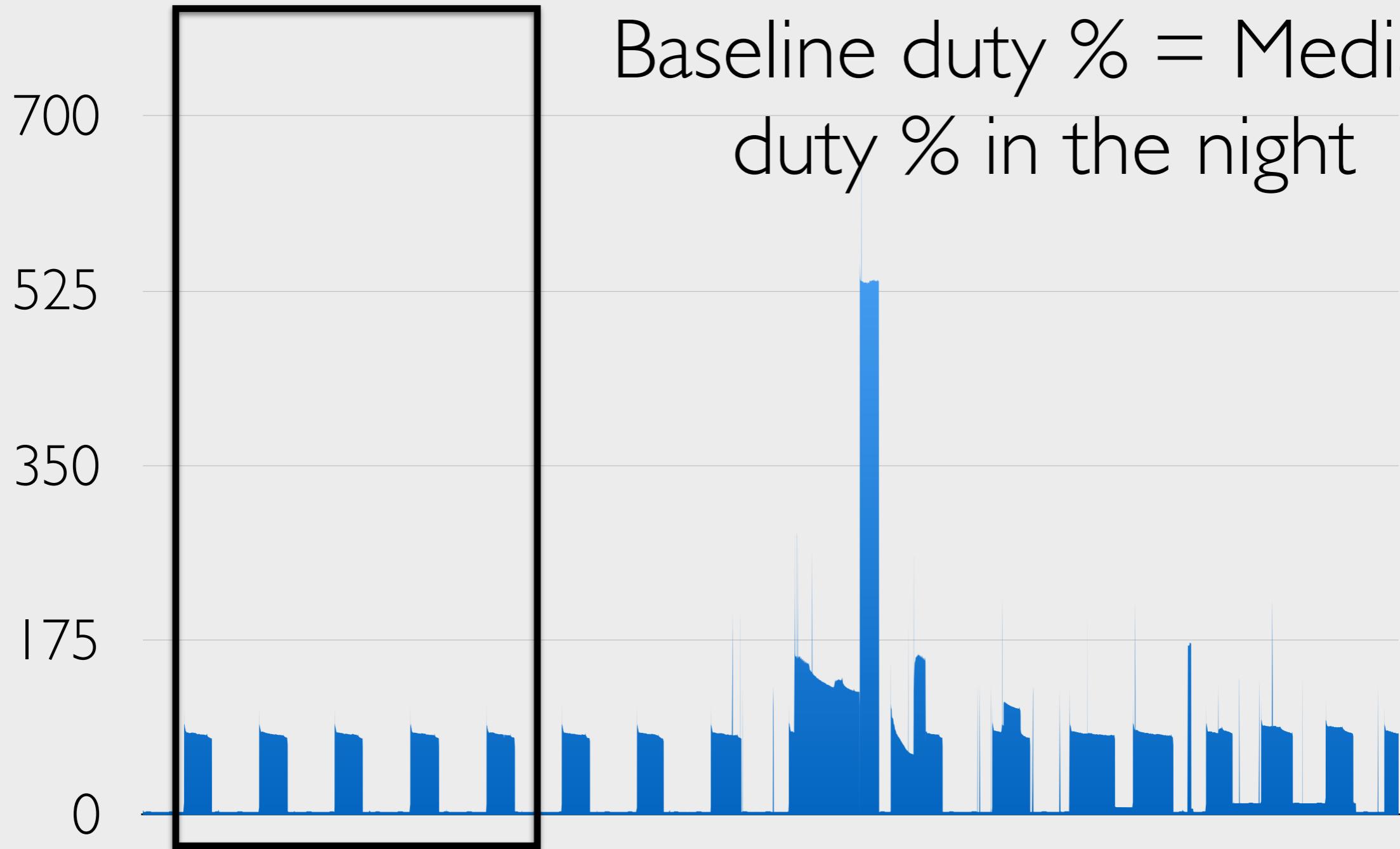
Defrost introduces heat increasing ON duration of next cycles



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

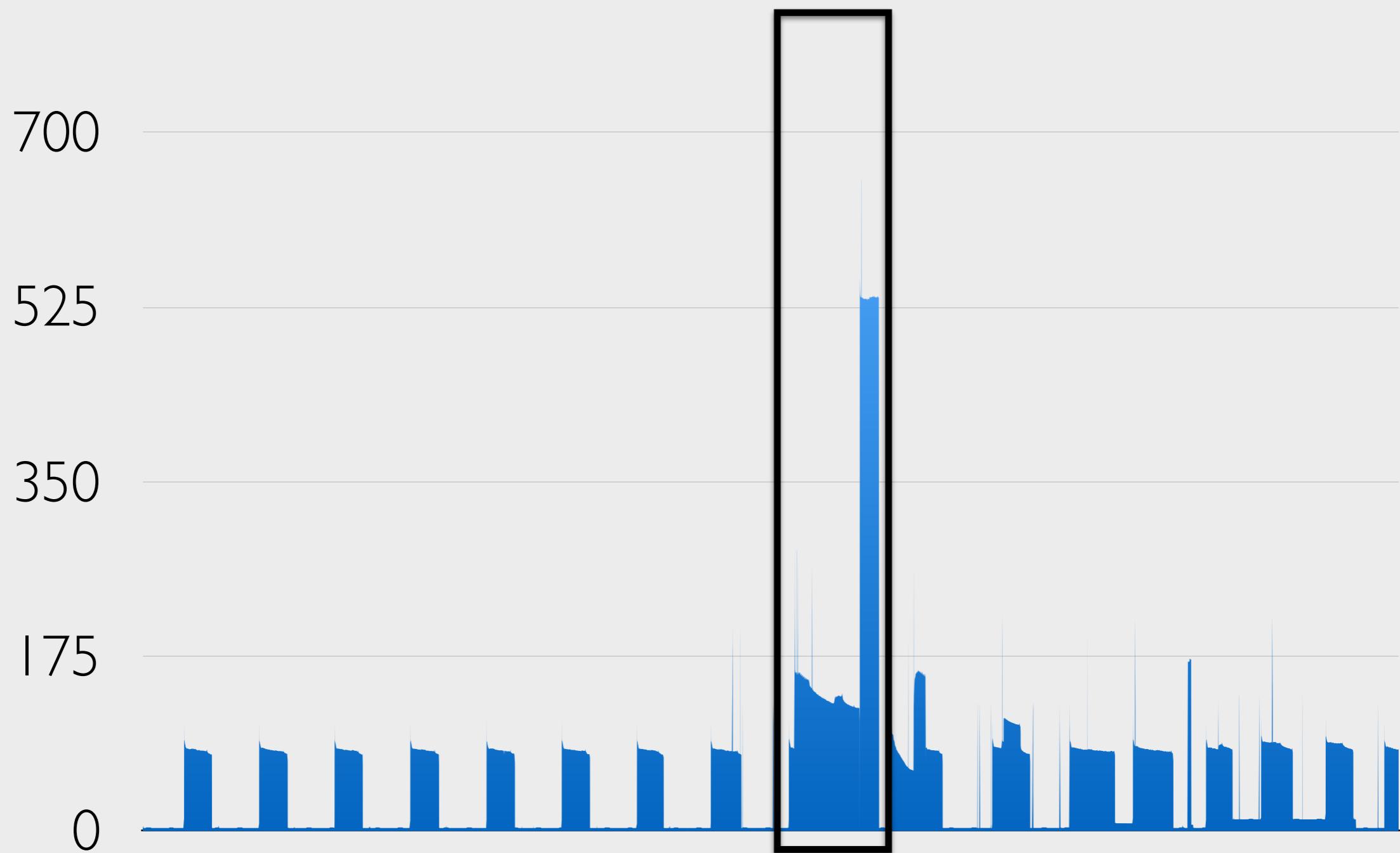


Night hours typically have “baseline” usage



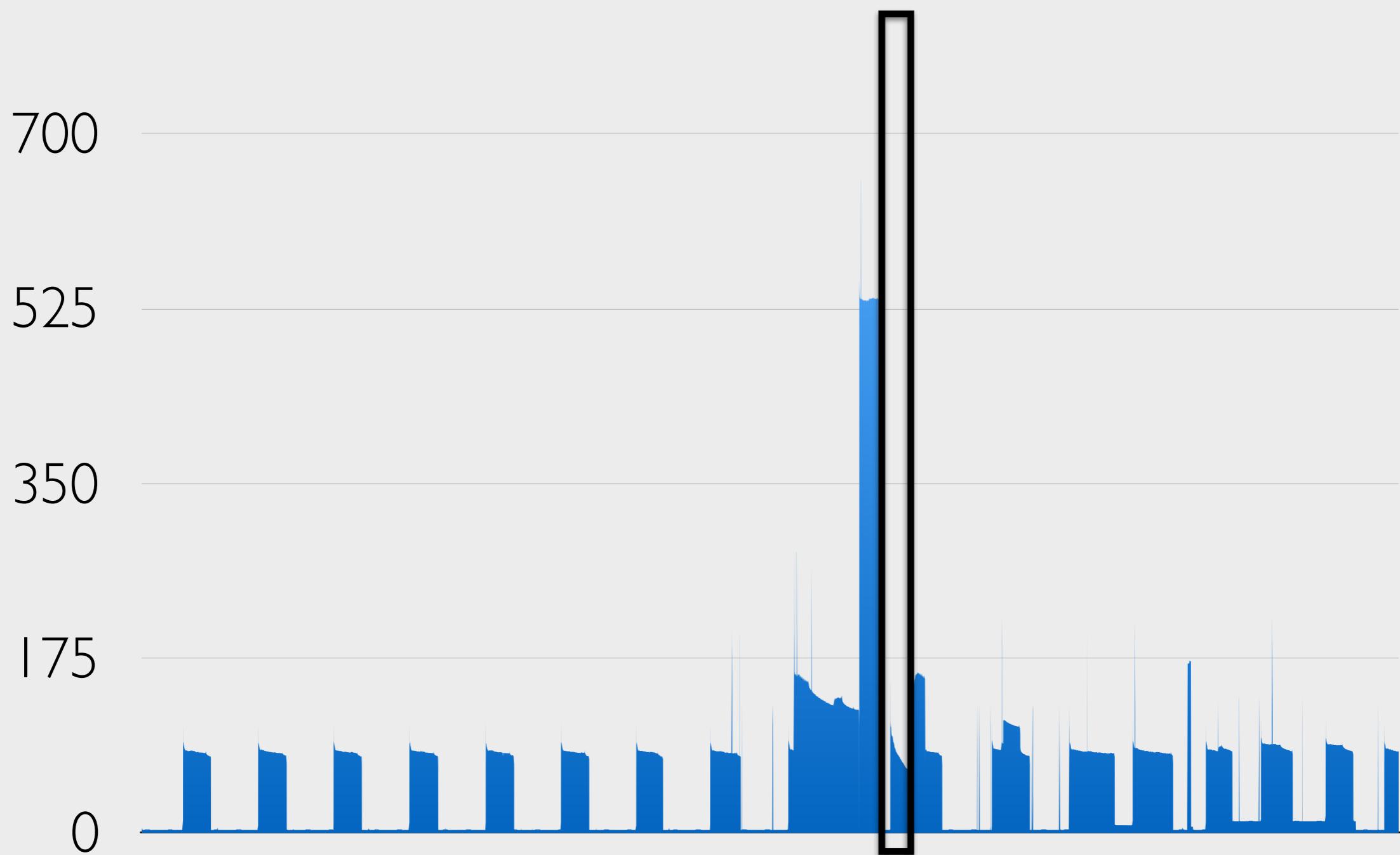
Defrost energy

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



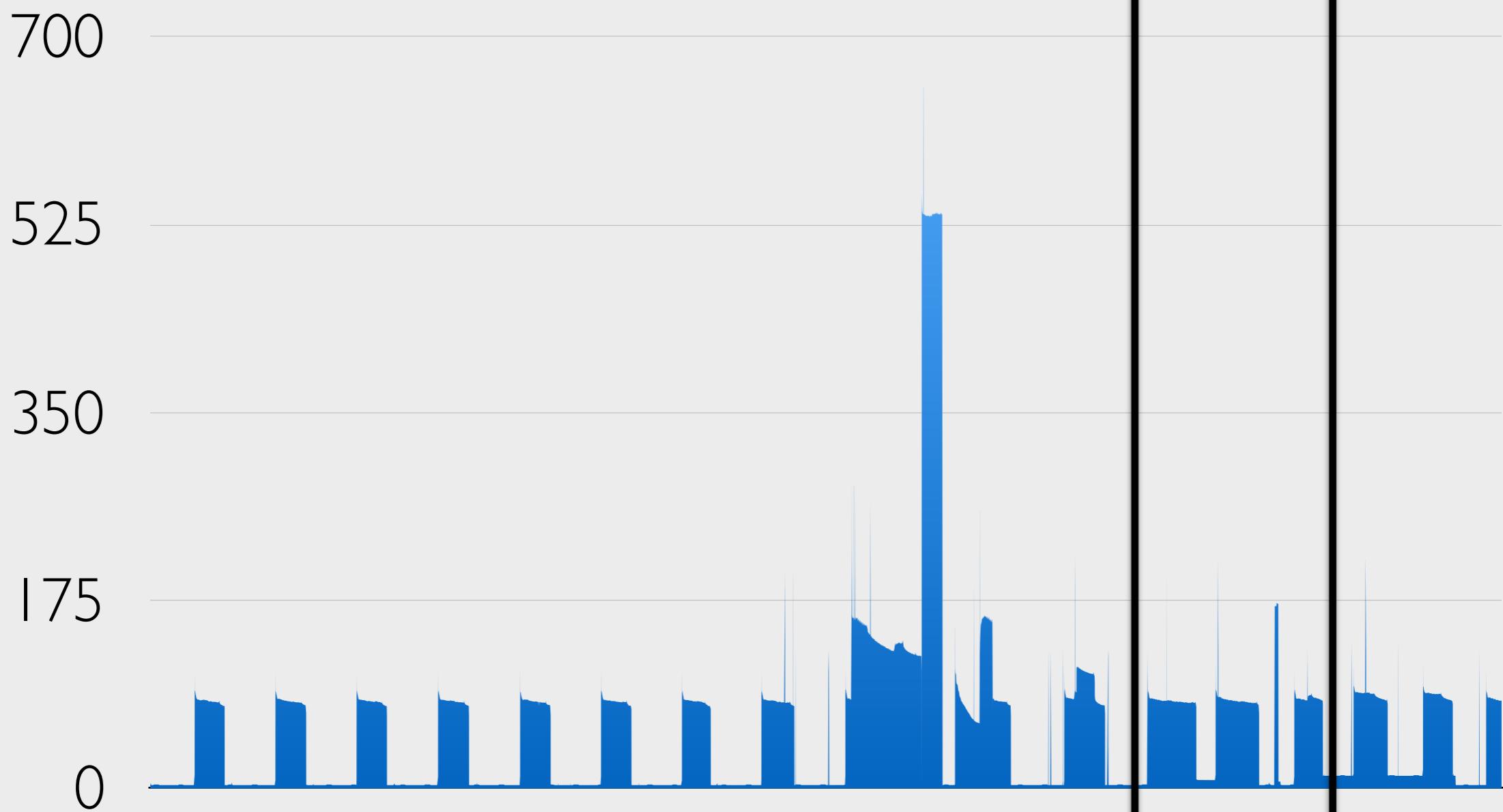
Defrost energy

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



Usage energy

Usage energy = Extra
energy consumed over
baseline



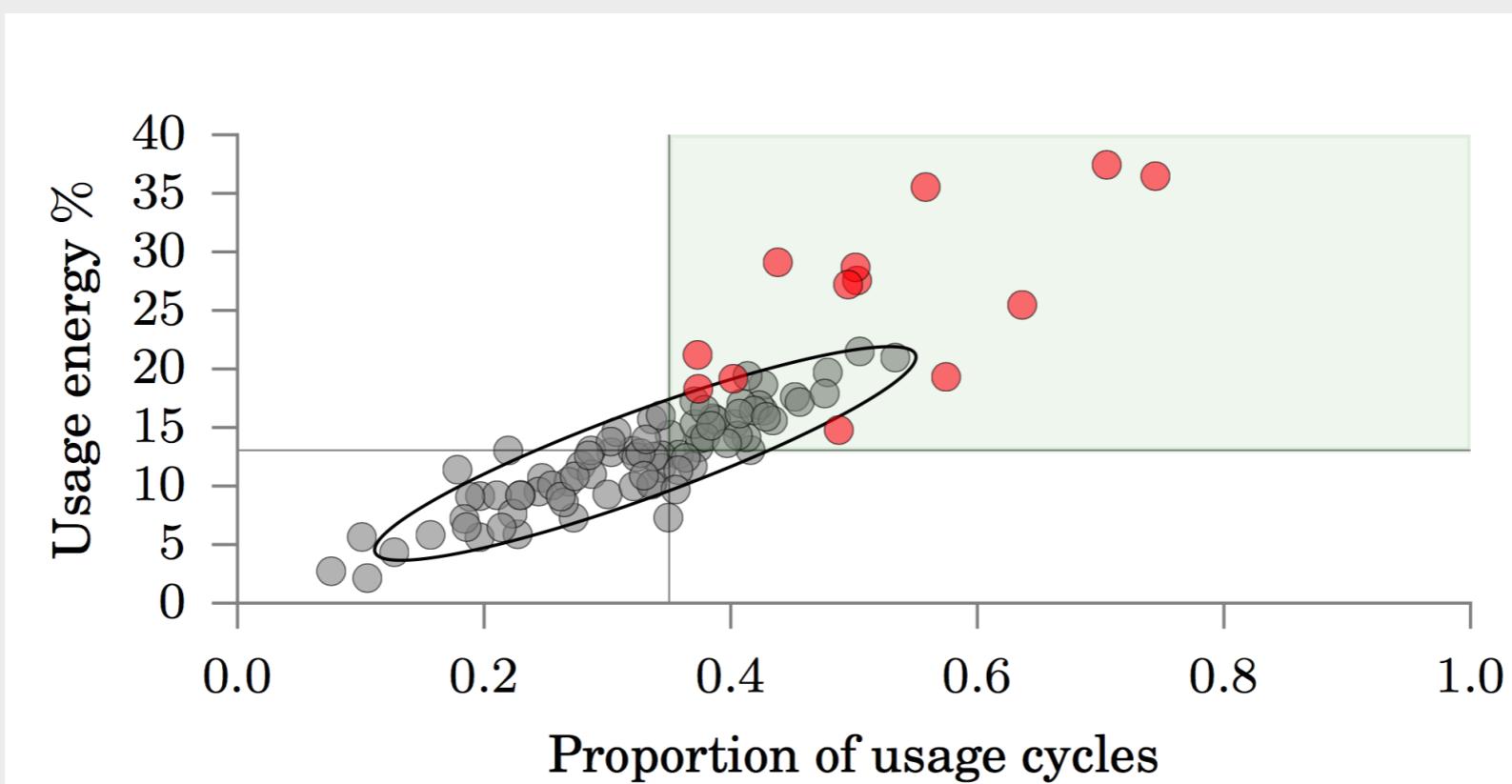
Experimental setup

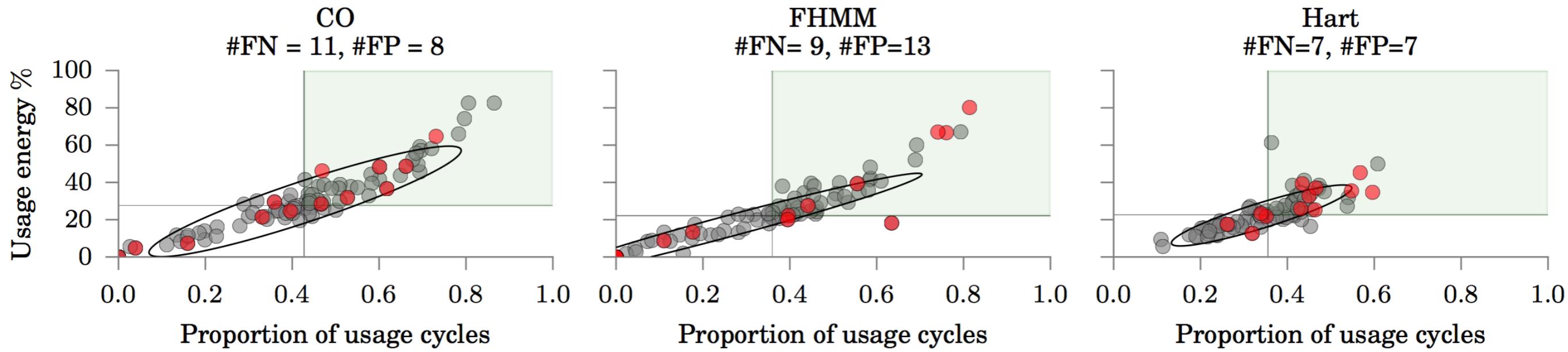
Wiki Energy data set



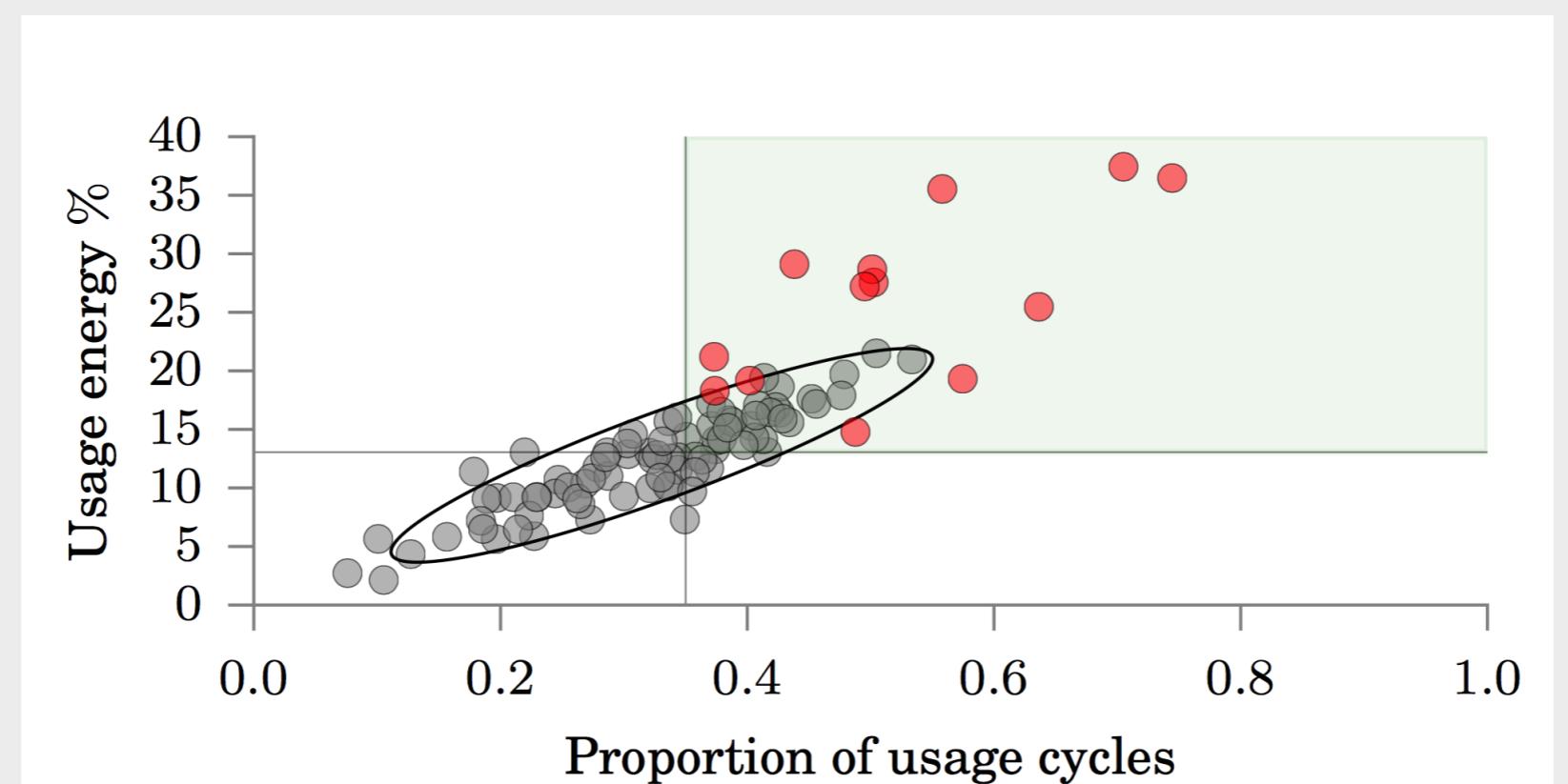
1. 97 fridges
2. 58 HVAC

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

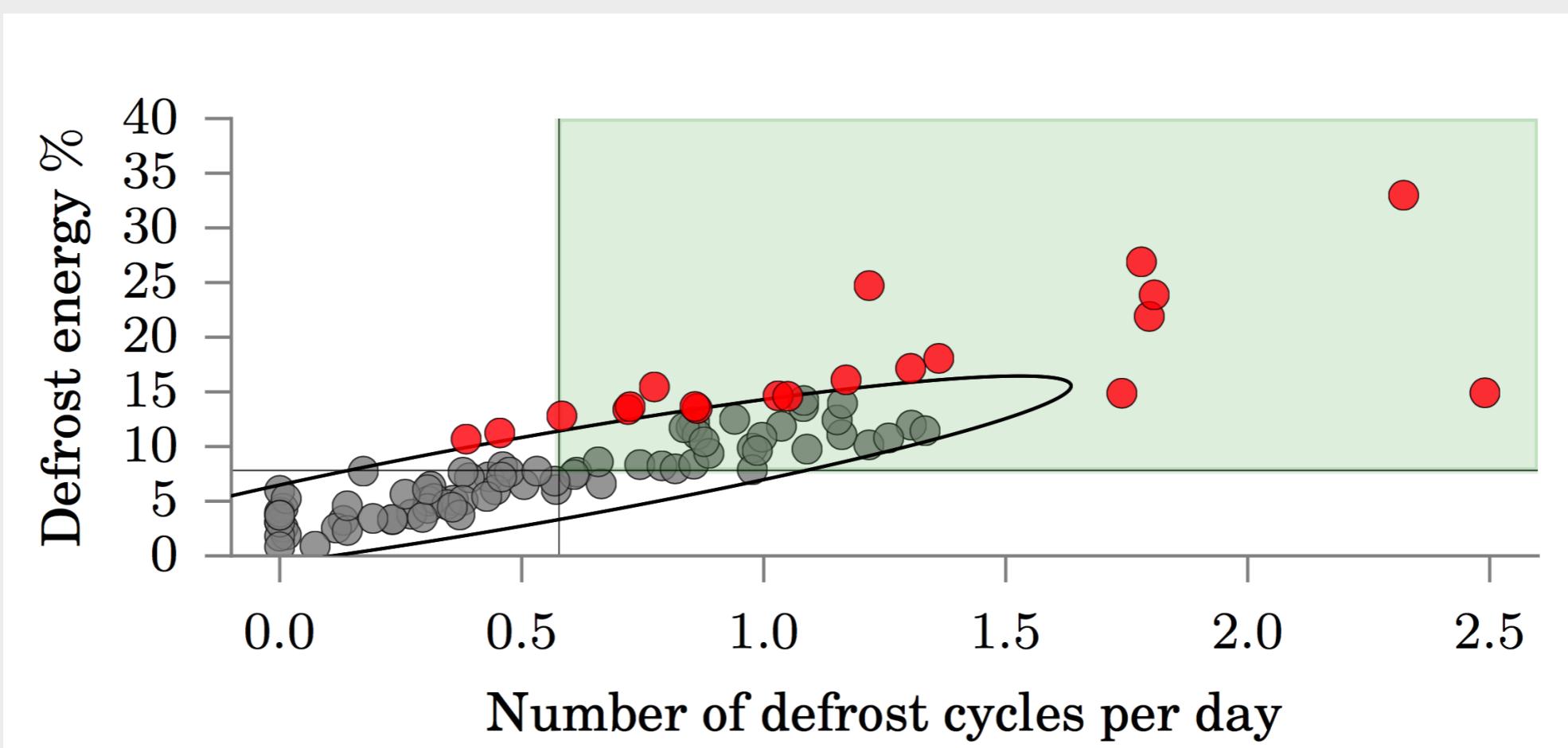




NILM algorithms show poor accuracy in identifying homes which can be given feedback based on **usage energy**

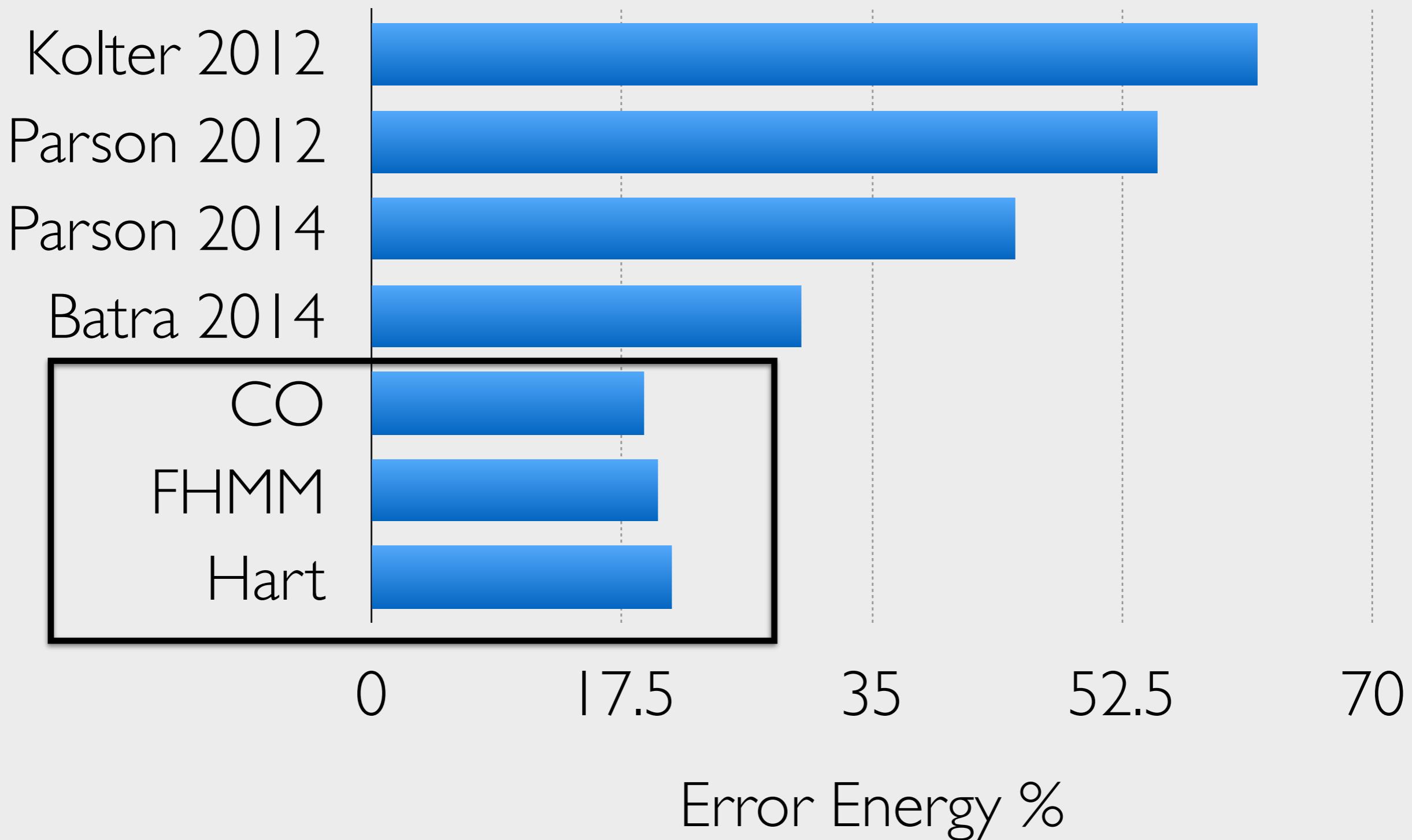


17 out of 95 homes can be given feedback on **excess defrost** saving upto 25% fridge energy

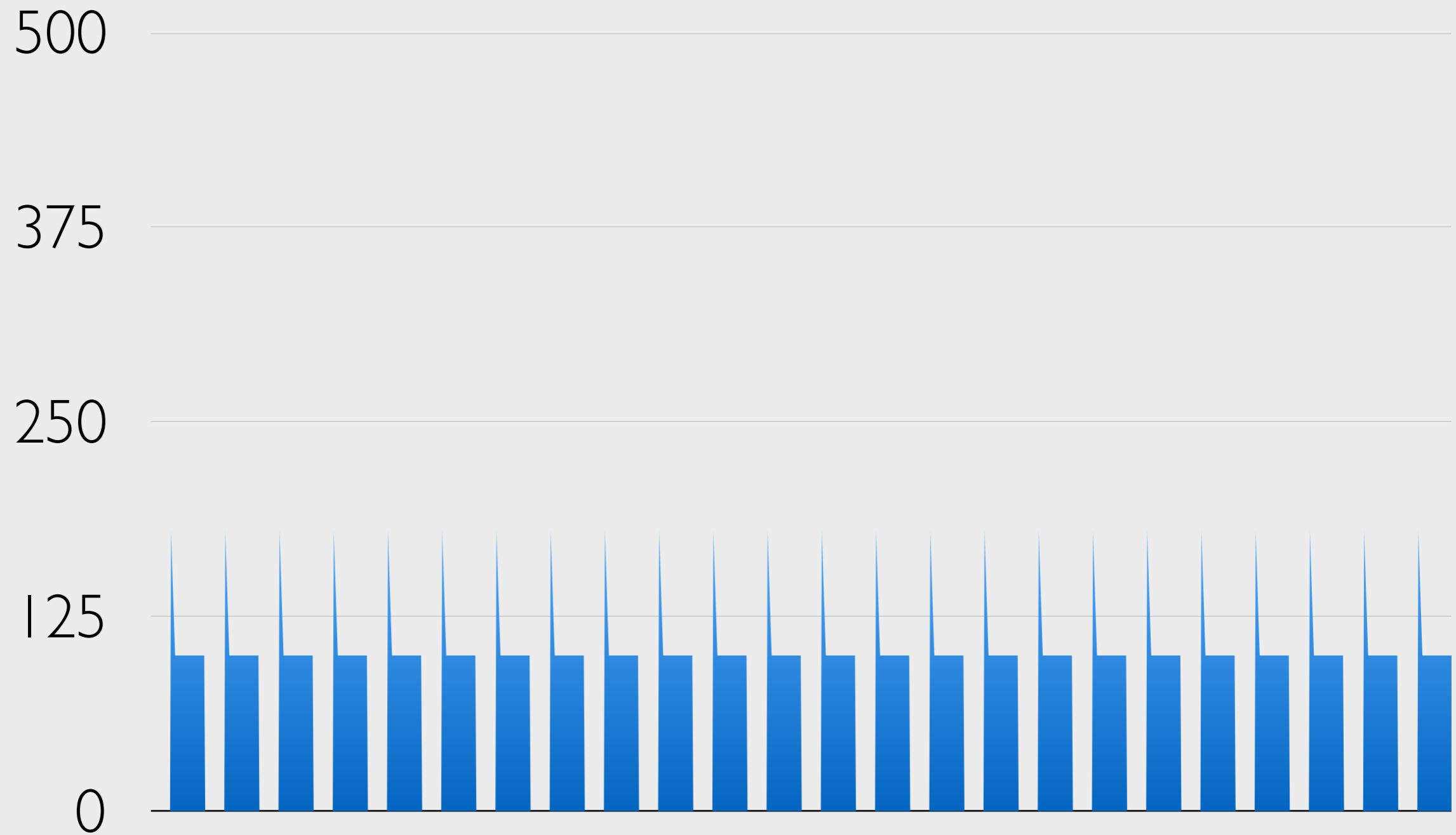


Such feedback can't be given with disaggregated traces, since these techniques fare poorly on defrost detection.

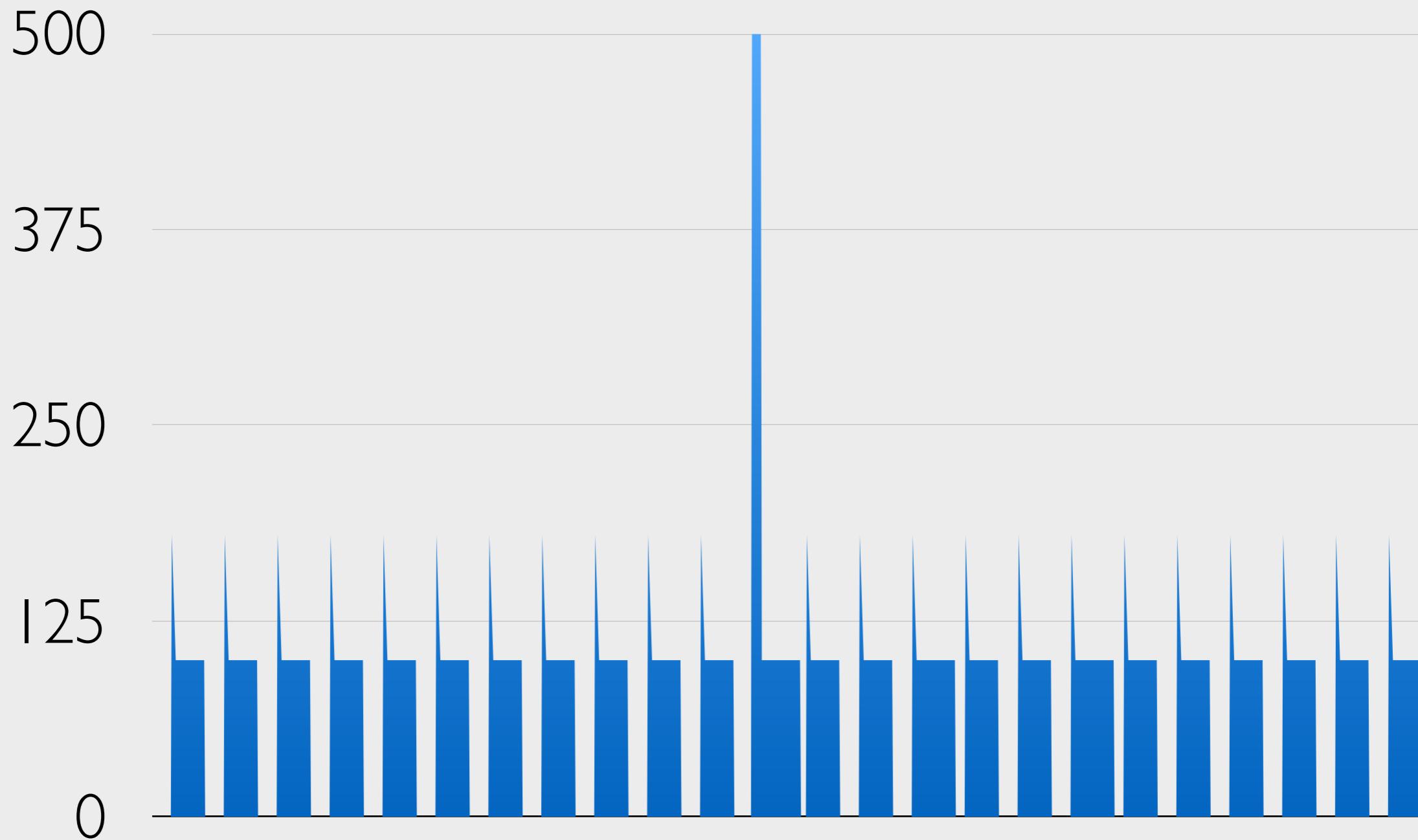
Benchmark NILM algorithms on our data set
give accuracy comparable or better than
state-of-the-art



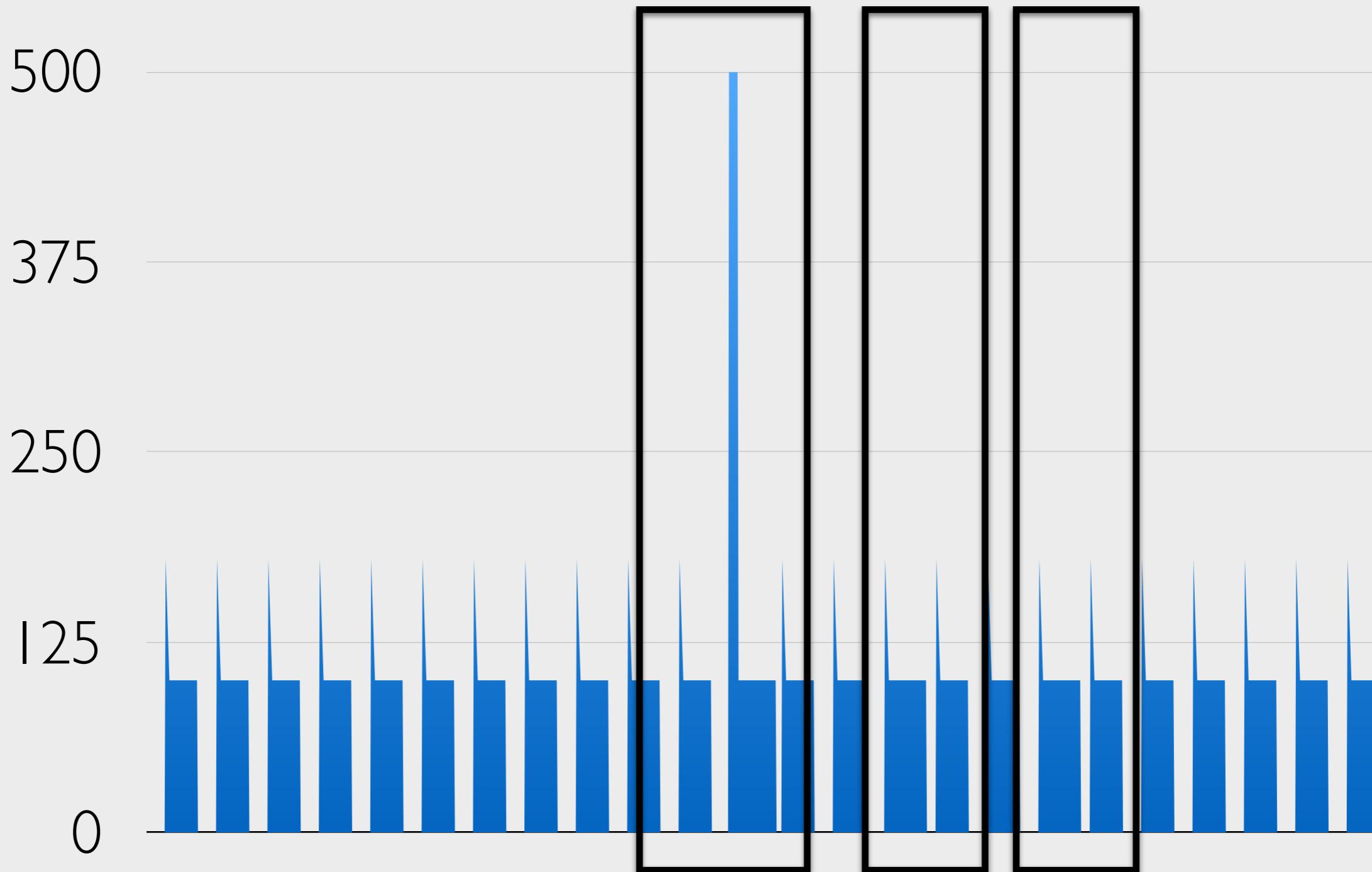
“Average” error in energy would be low even
if NILM predicted this



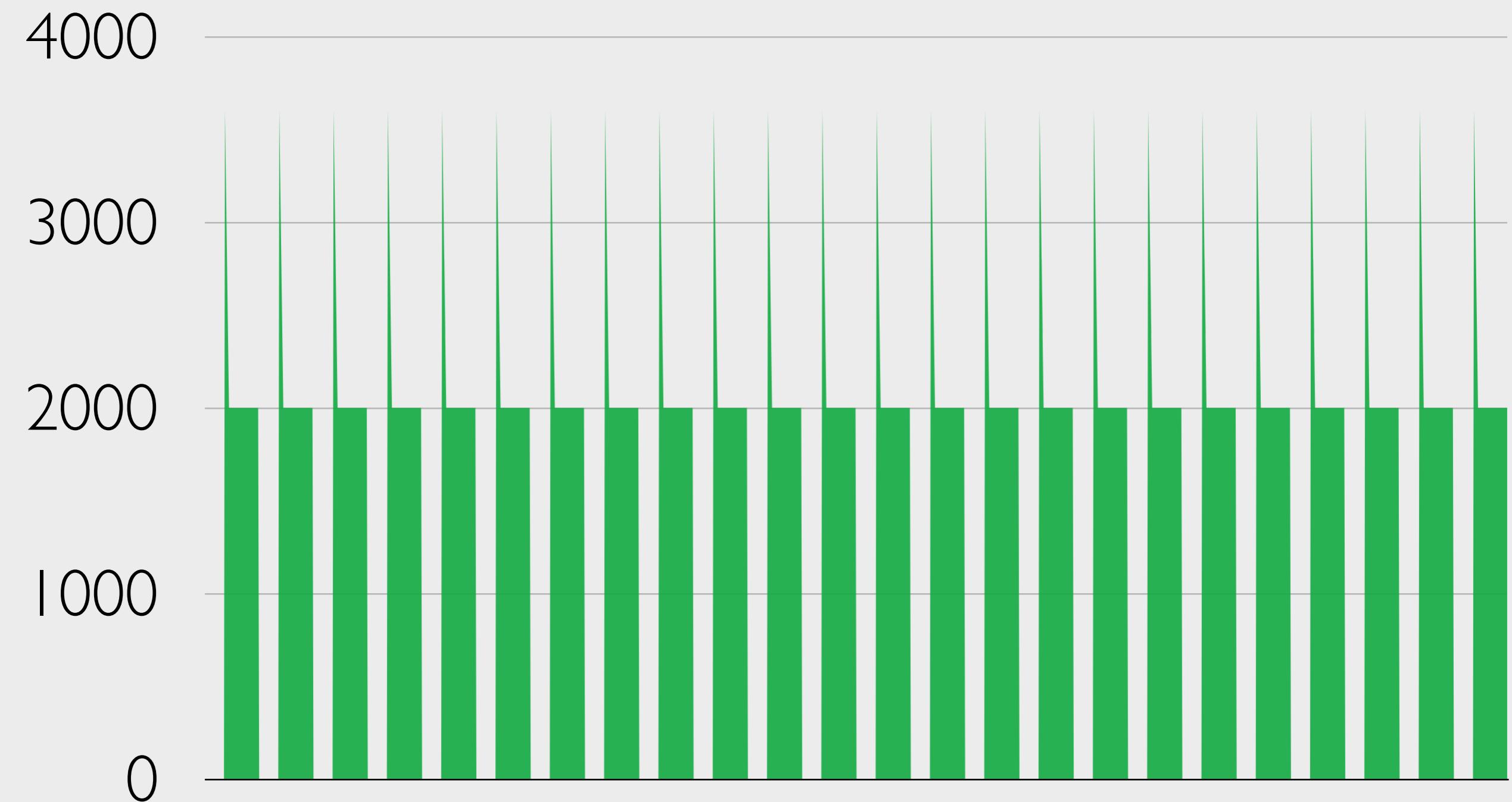
But, we wanted to predict..



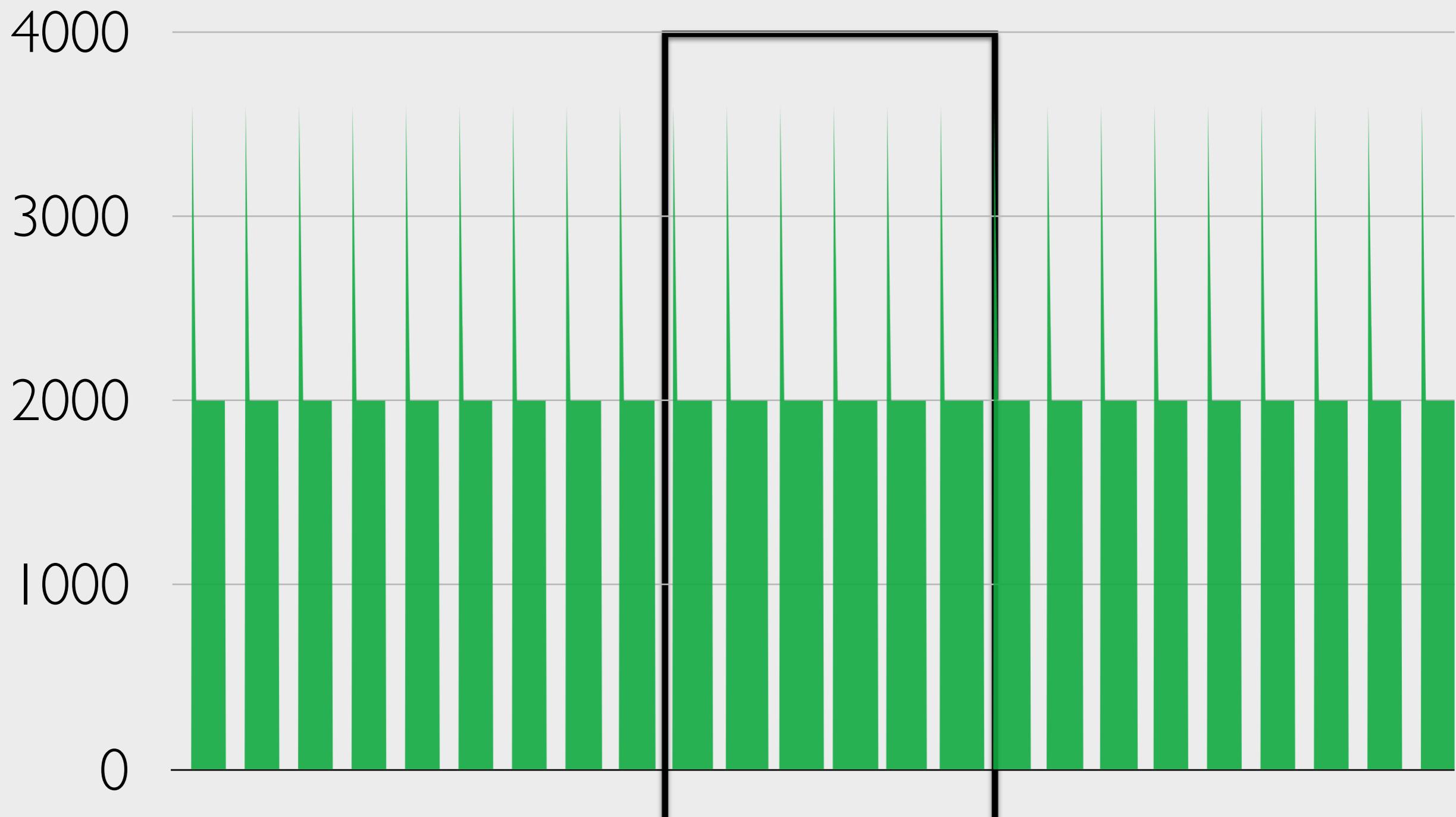
It's the details that we care about



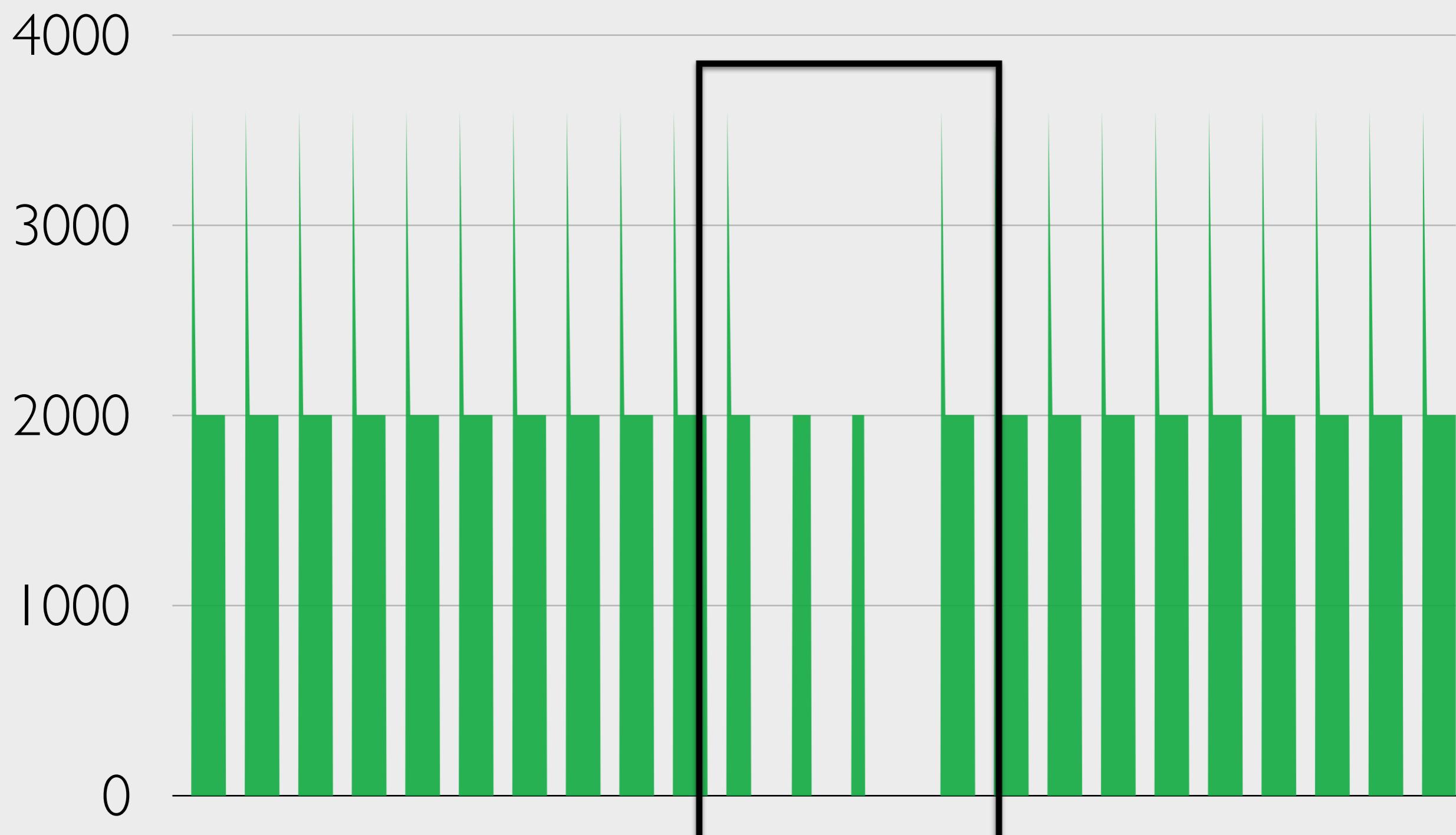
Like fridge, HVAC duty cycles to
maintain the set temperature



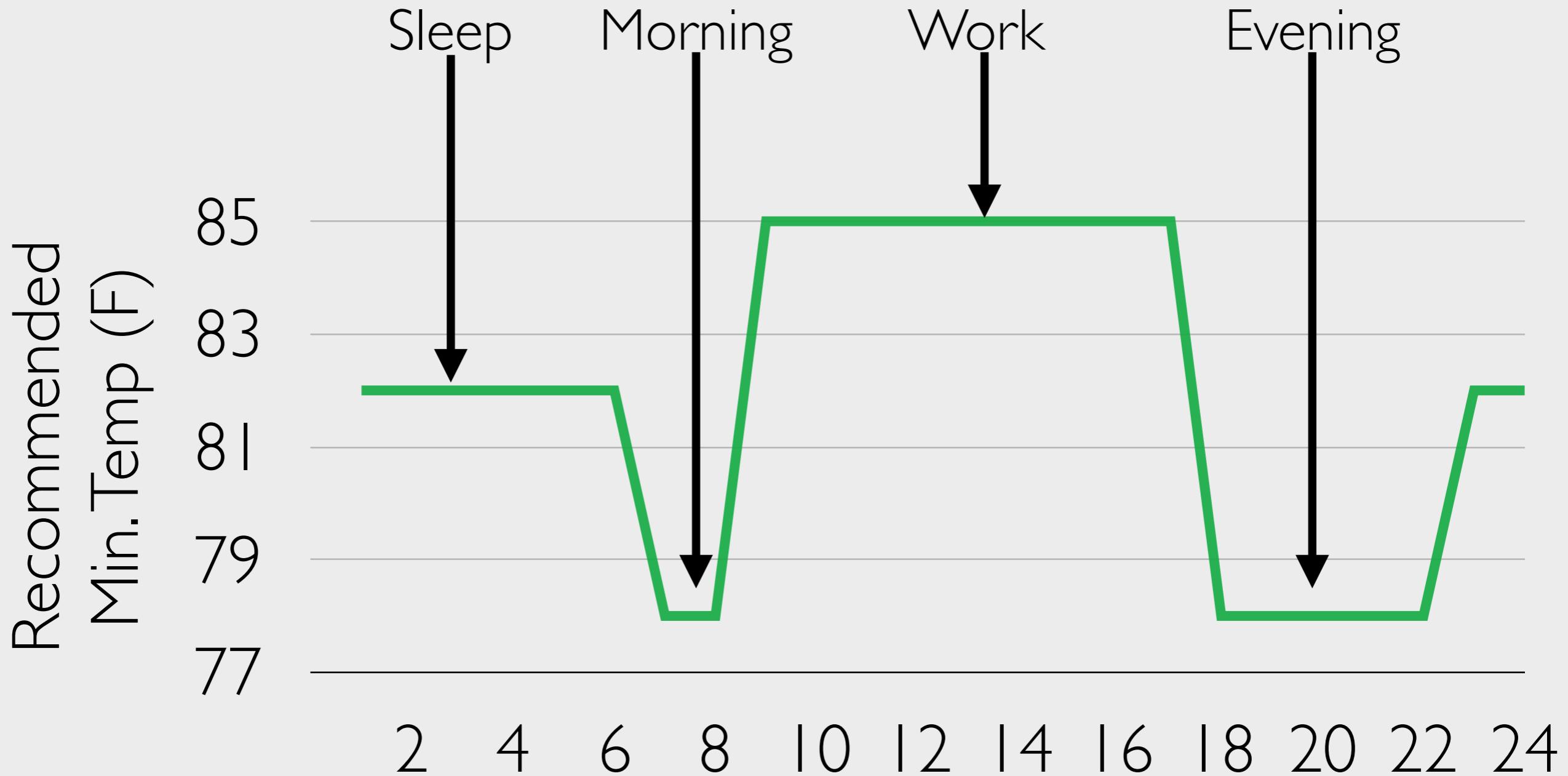
As temperature increases during the day,
more energy required to cool the home



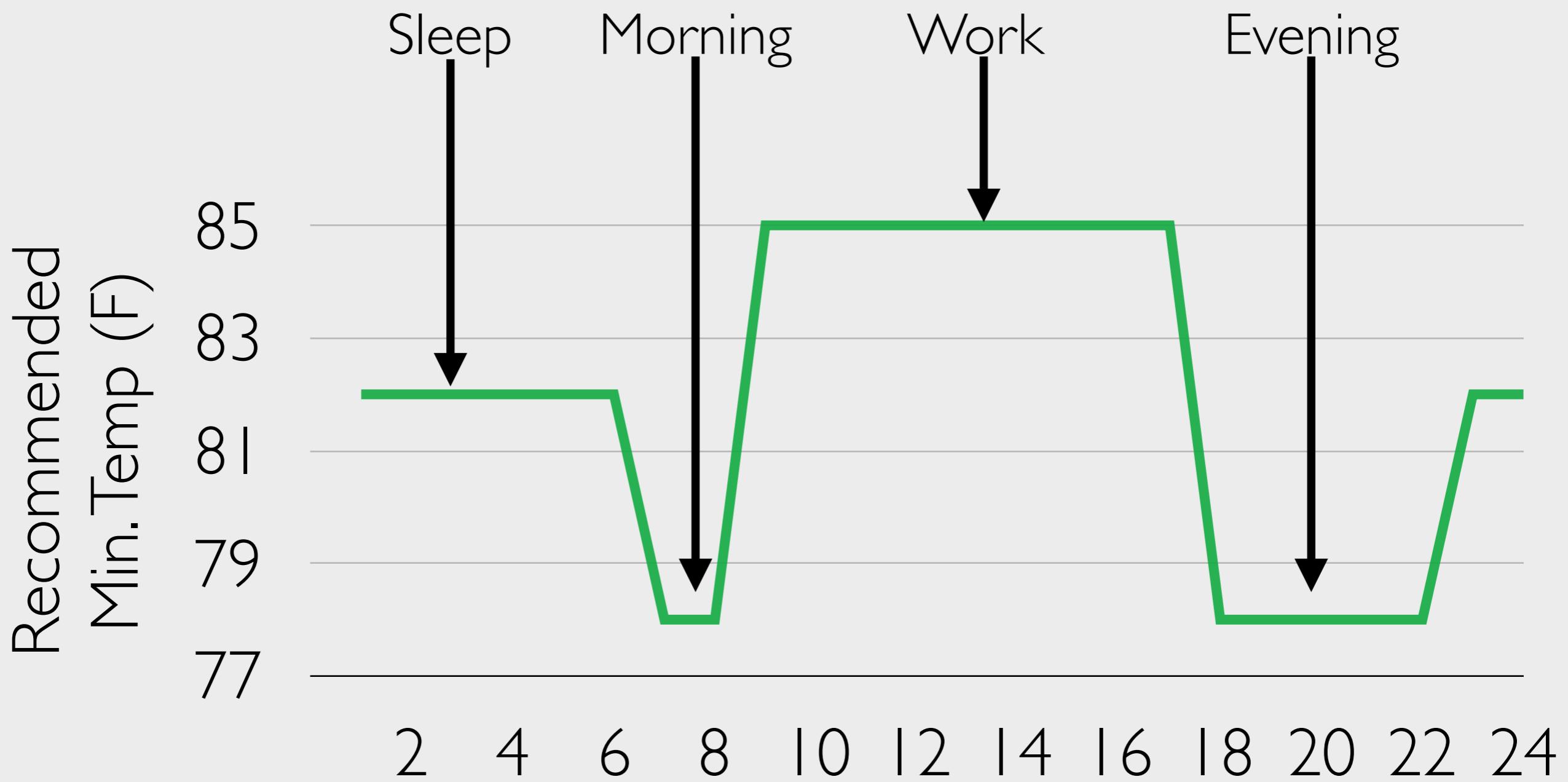
People typically turn up the temperatures when they leave home



EnergyStar.gov recommended HVAC setpoint schedule

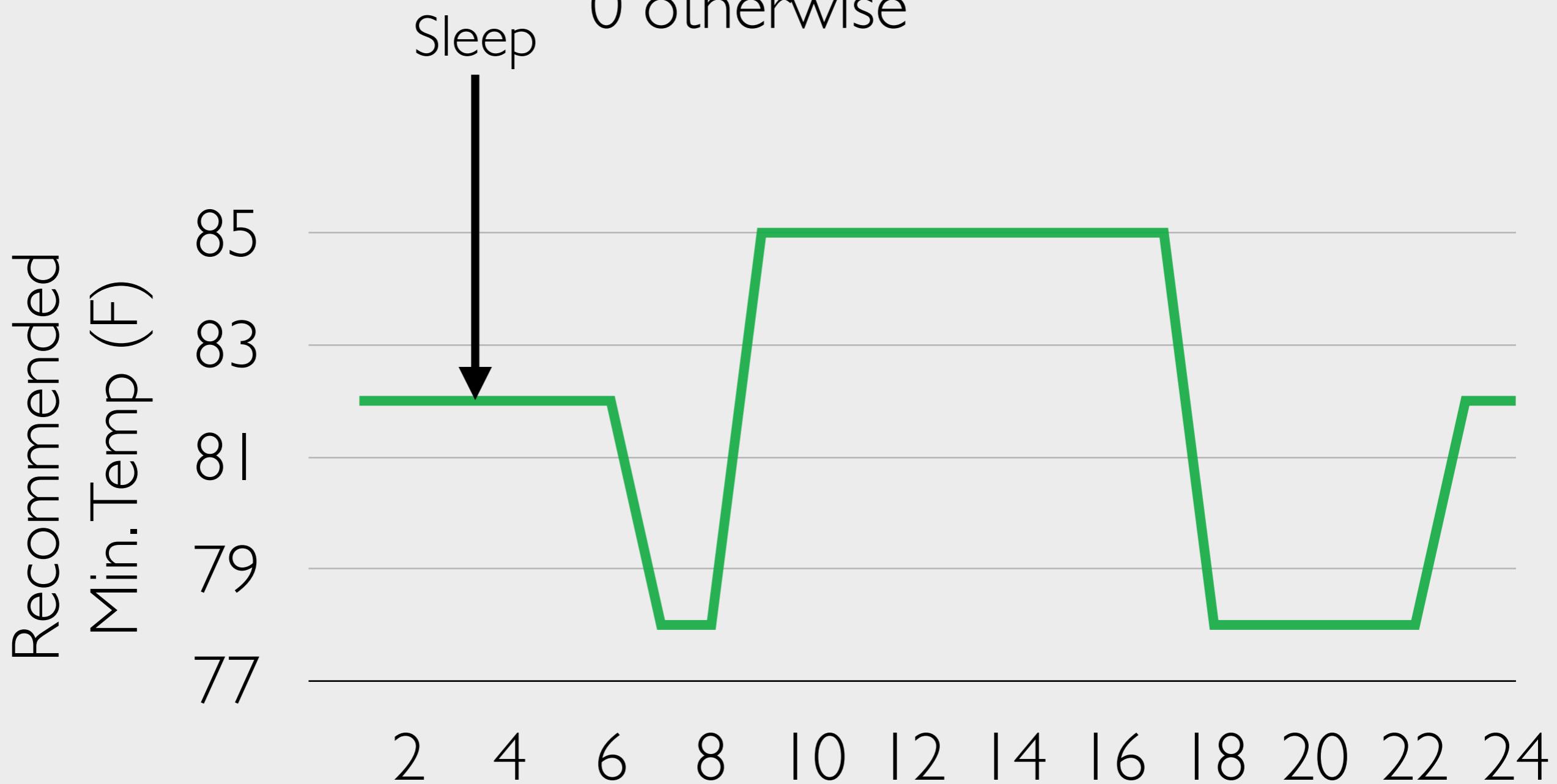


Setpoint schedule score



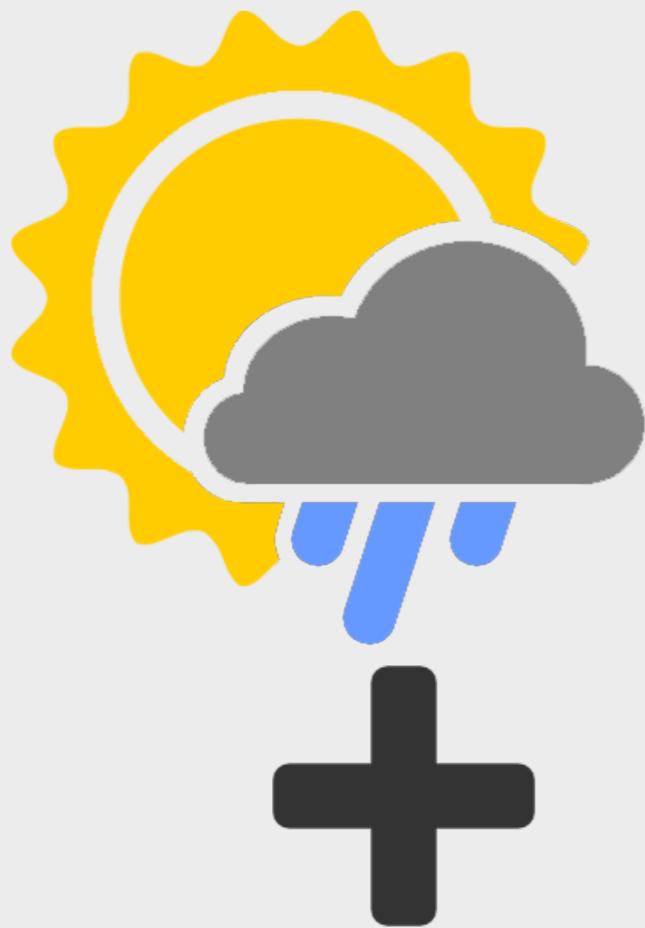
Setpoint schedule score

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

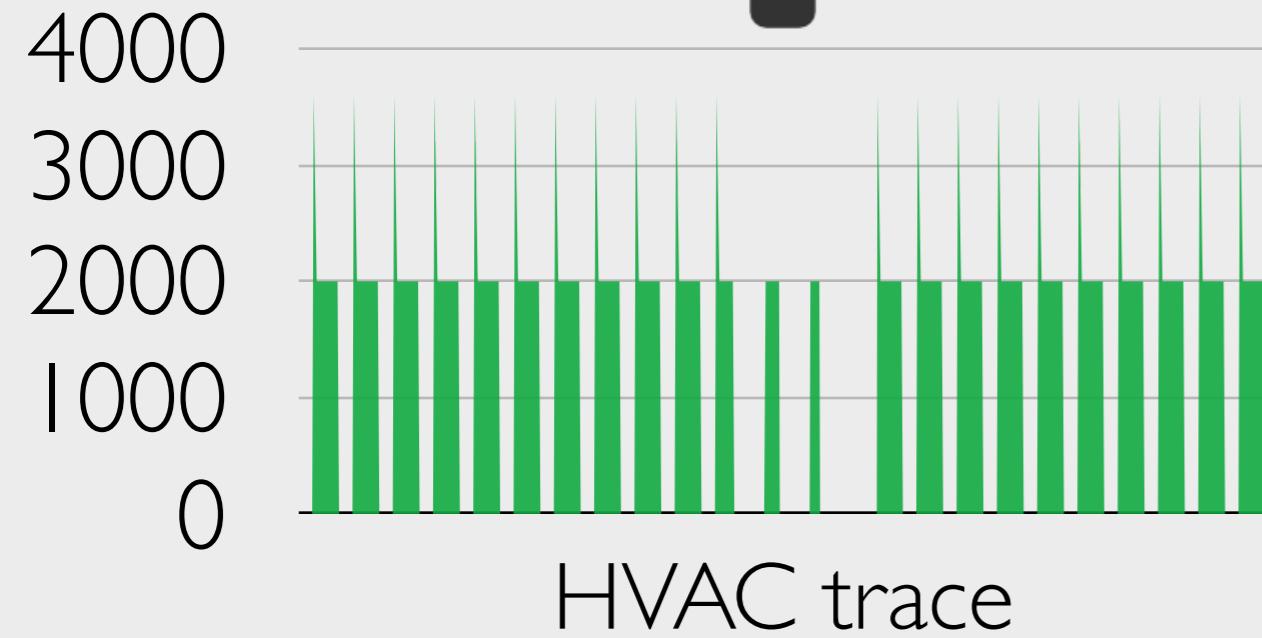
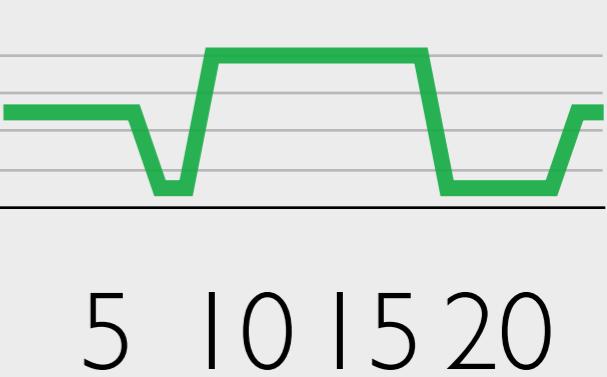


Learning HVAC setpoint

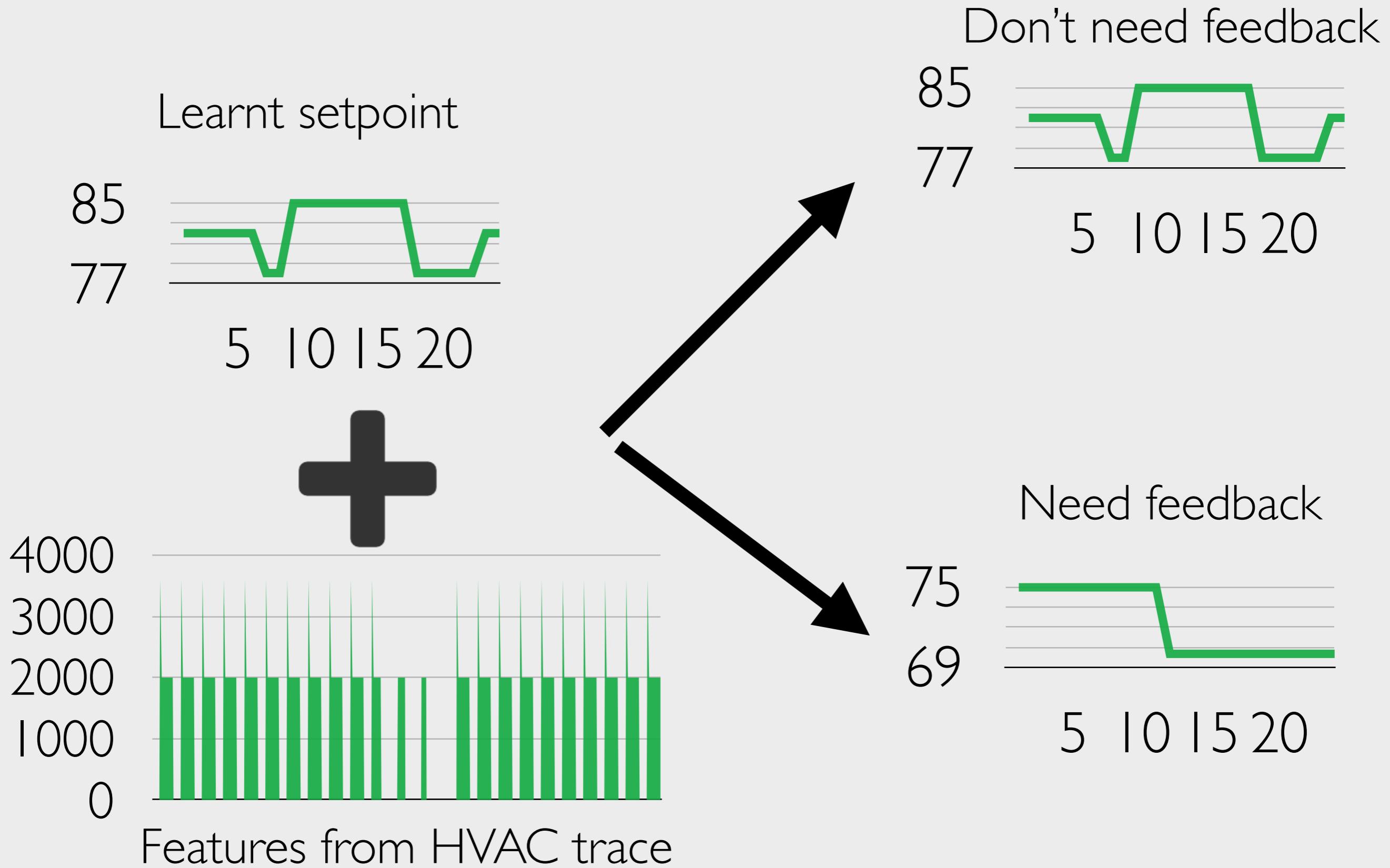
Weather



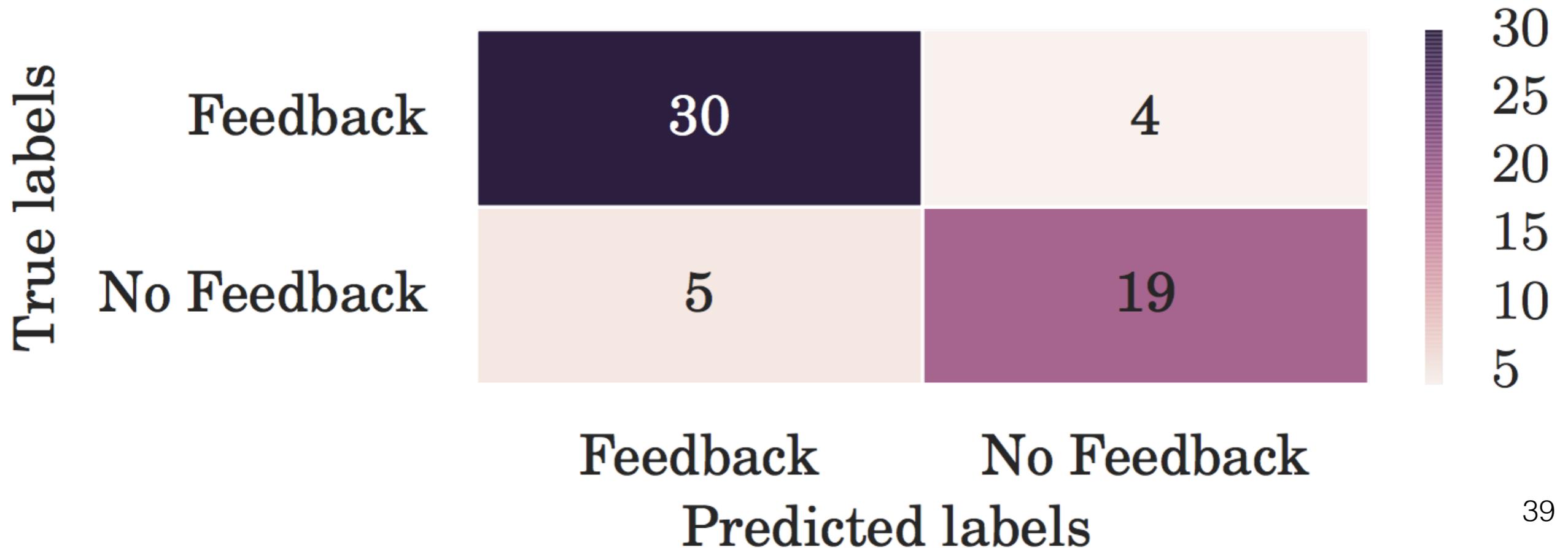
Learnt setpoint

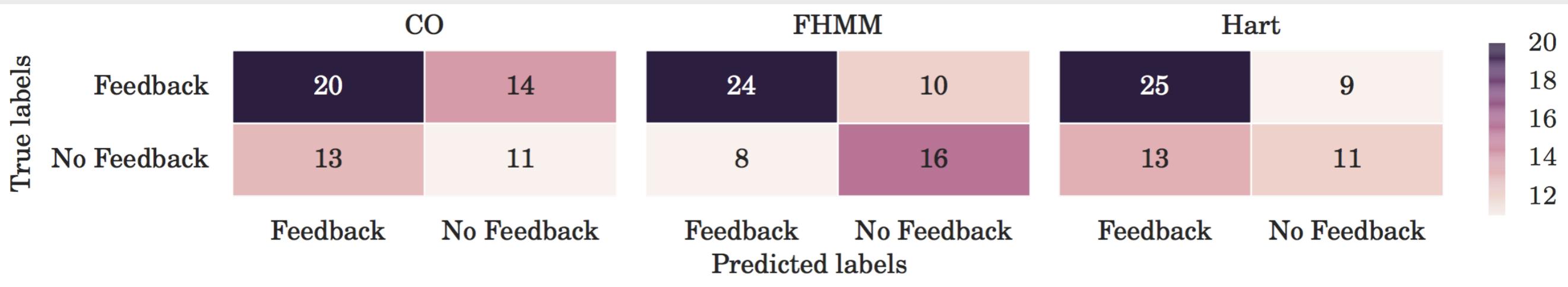


Giving feedback

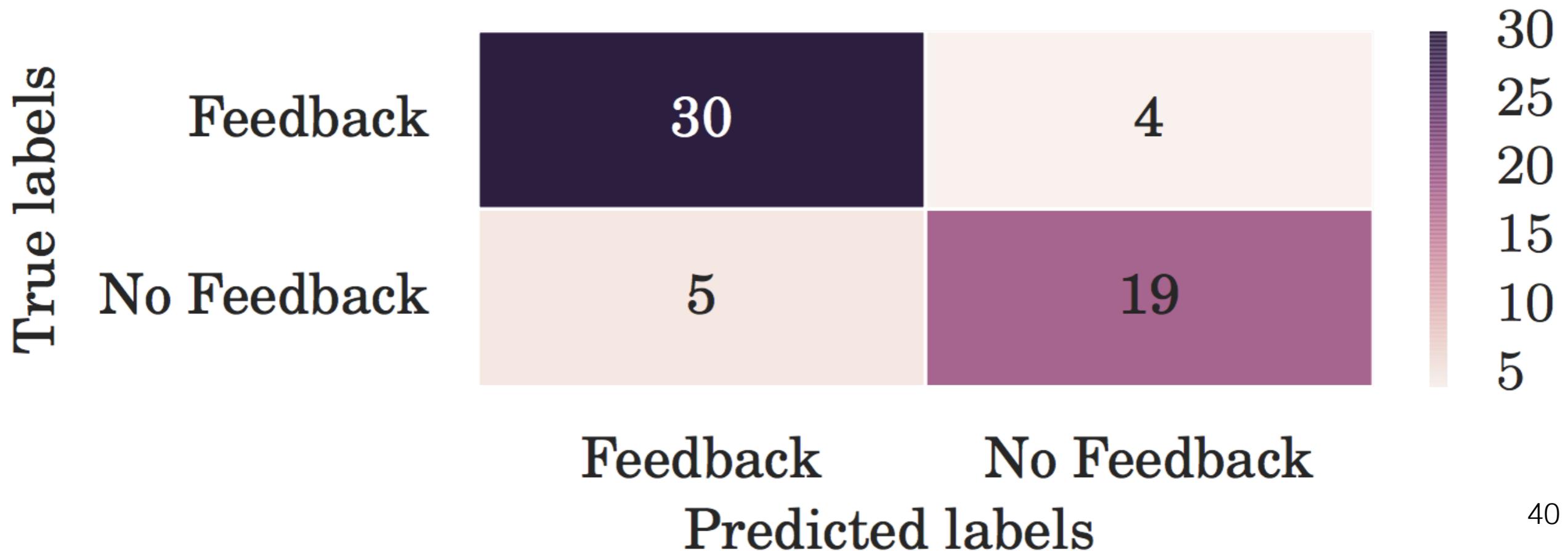


84% accuracy on giving feedback using
submetered traces

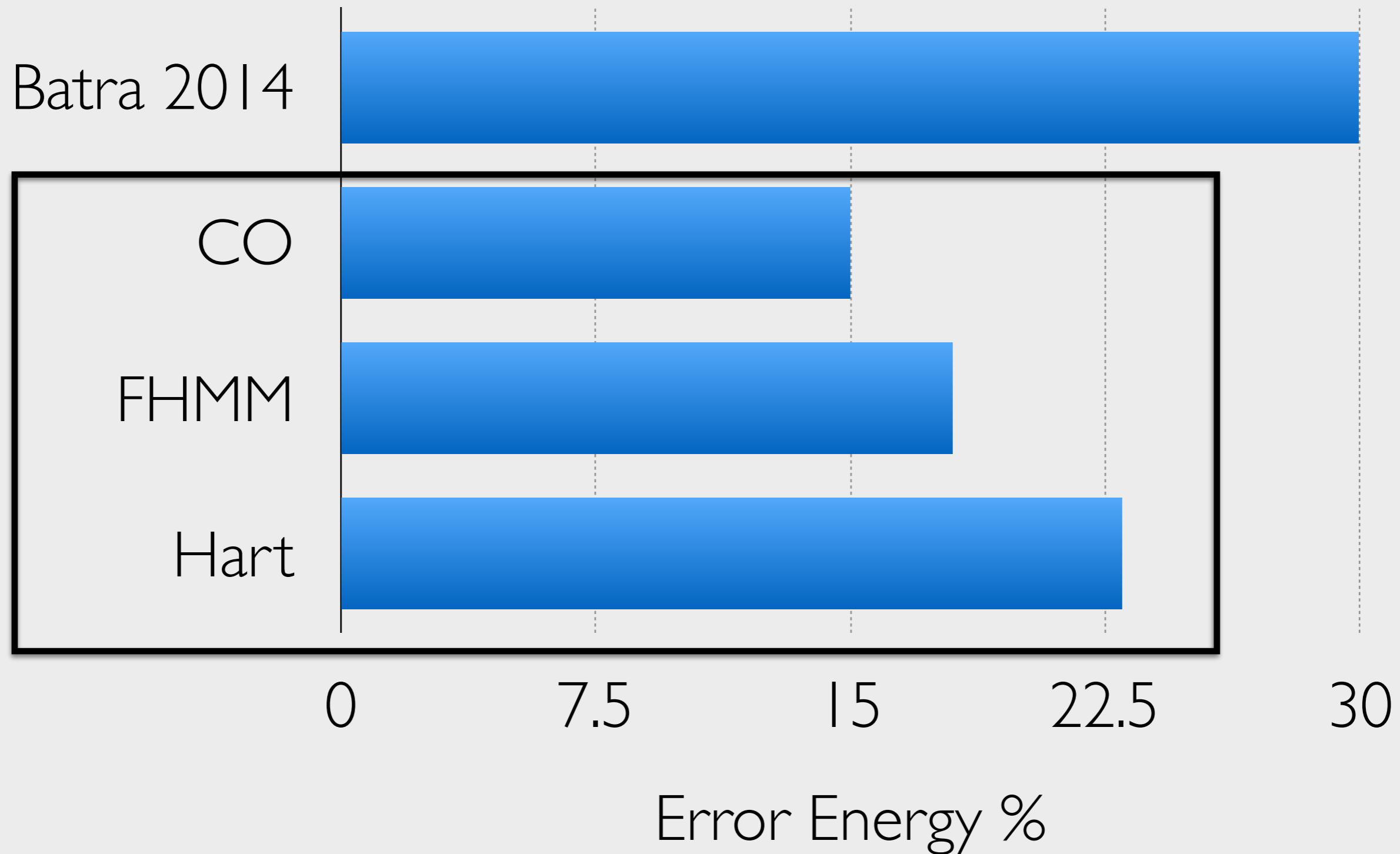




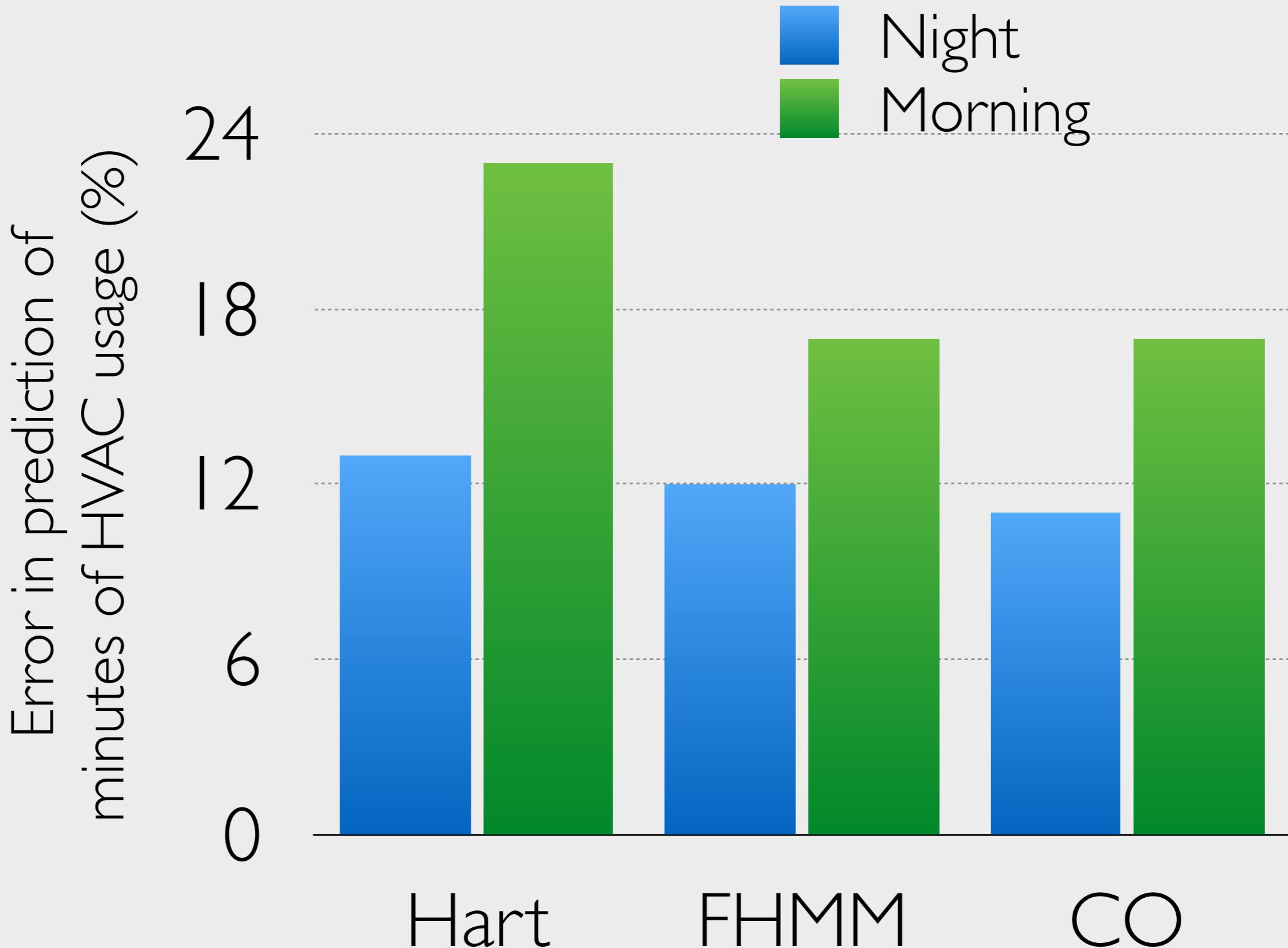
NILM methods give 15-30% worse accuracy for feedback



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

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

BUT

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