Marko Cosic
Technical Director

marko@coheat.co.uk
+44 7774 524 114

Actively managed heat networks

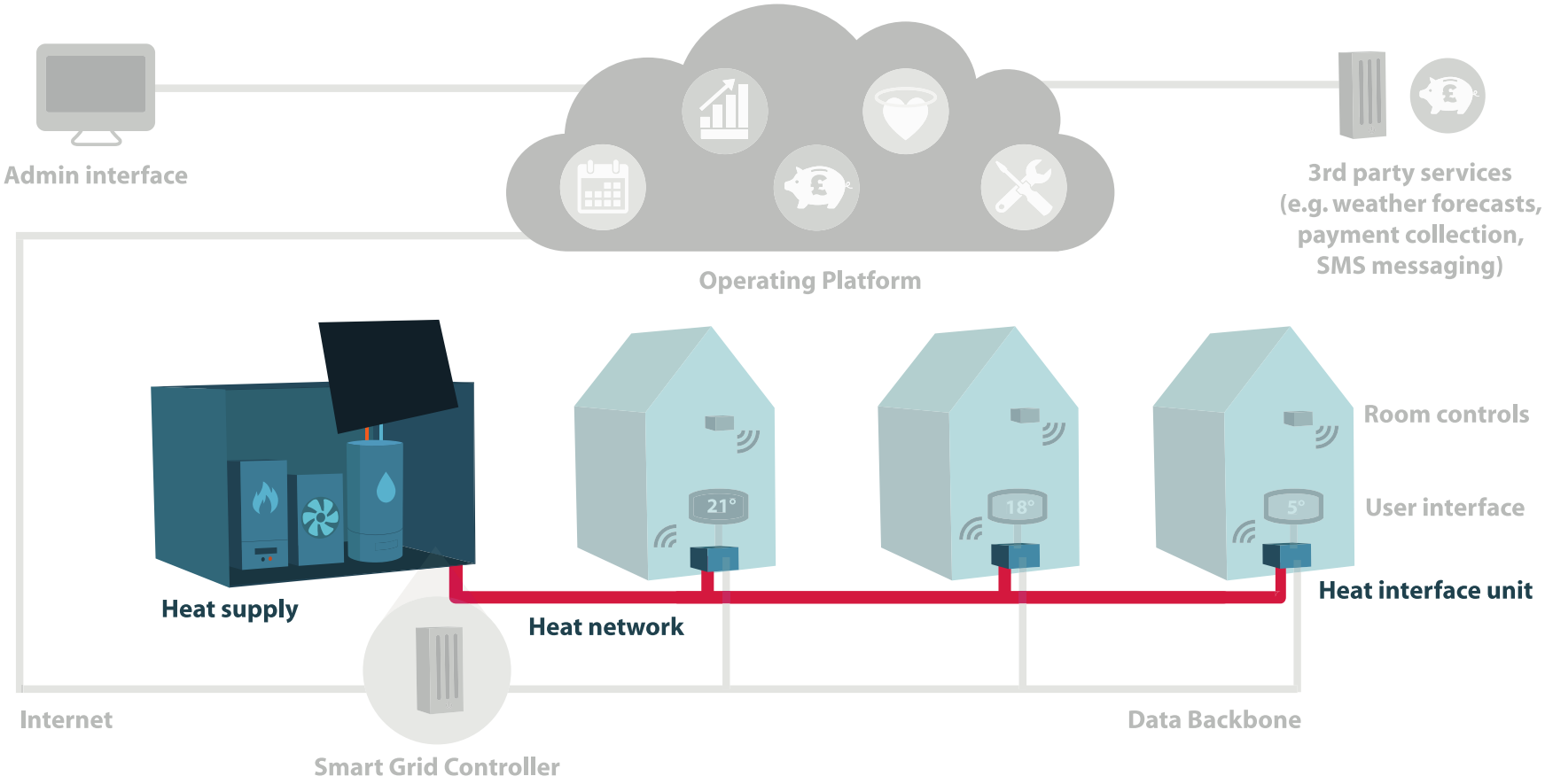
2nd International Conference on Smart Energy Systems and 4th Generation District Heating
27-28 September 2016

AALBORG UNIVERSITY
DENMARK

4DH
4th Generation District Heating
Technologies and Systems


The competition (€350 + €30/MWh)

A heat network



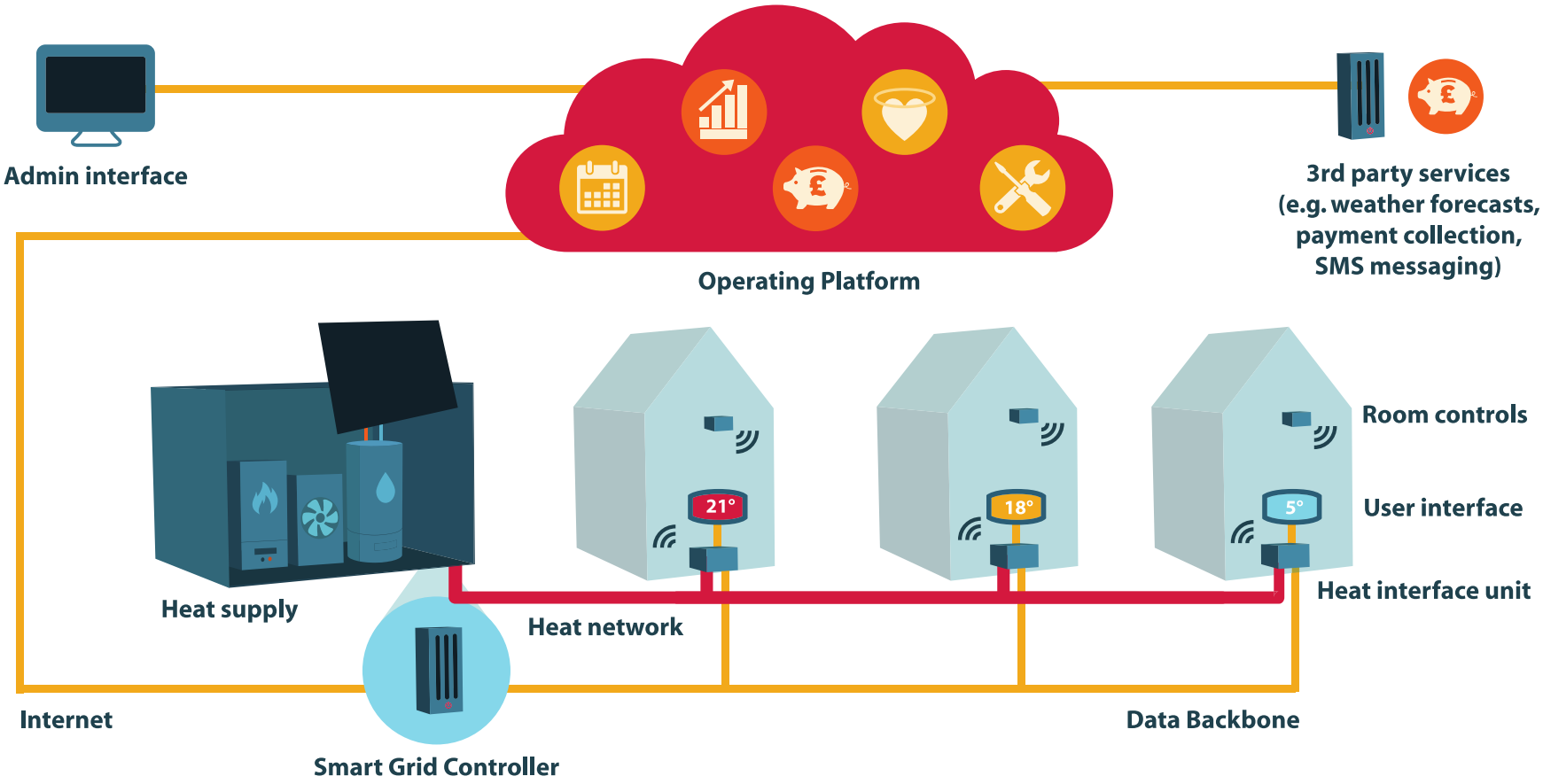
COHEAT


Traditional instrumentation and control

How do we improve heat networks?

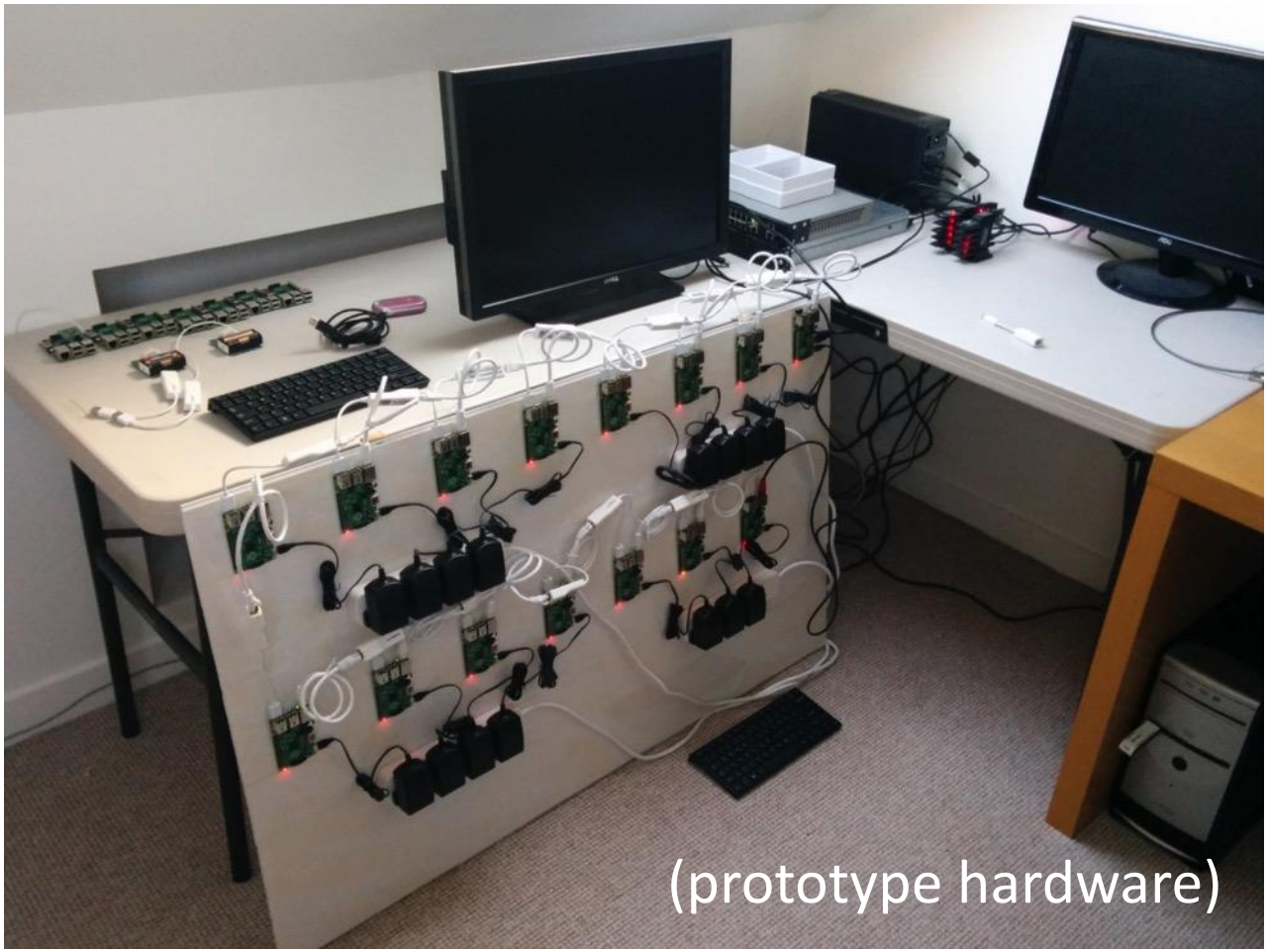
- Know what customers are asking for
- Know what the whole system is doing
- Know what customers are receiving
- Control how the whole system operates

A smart heat network



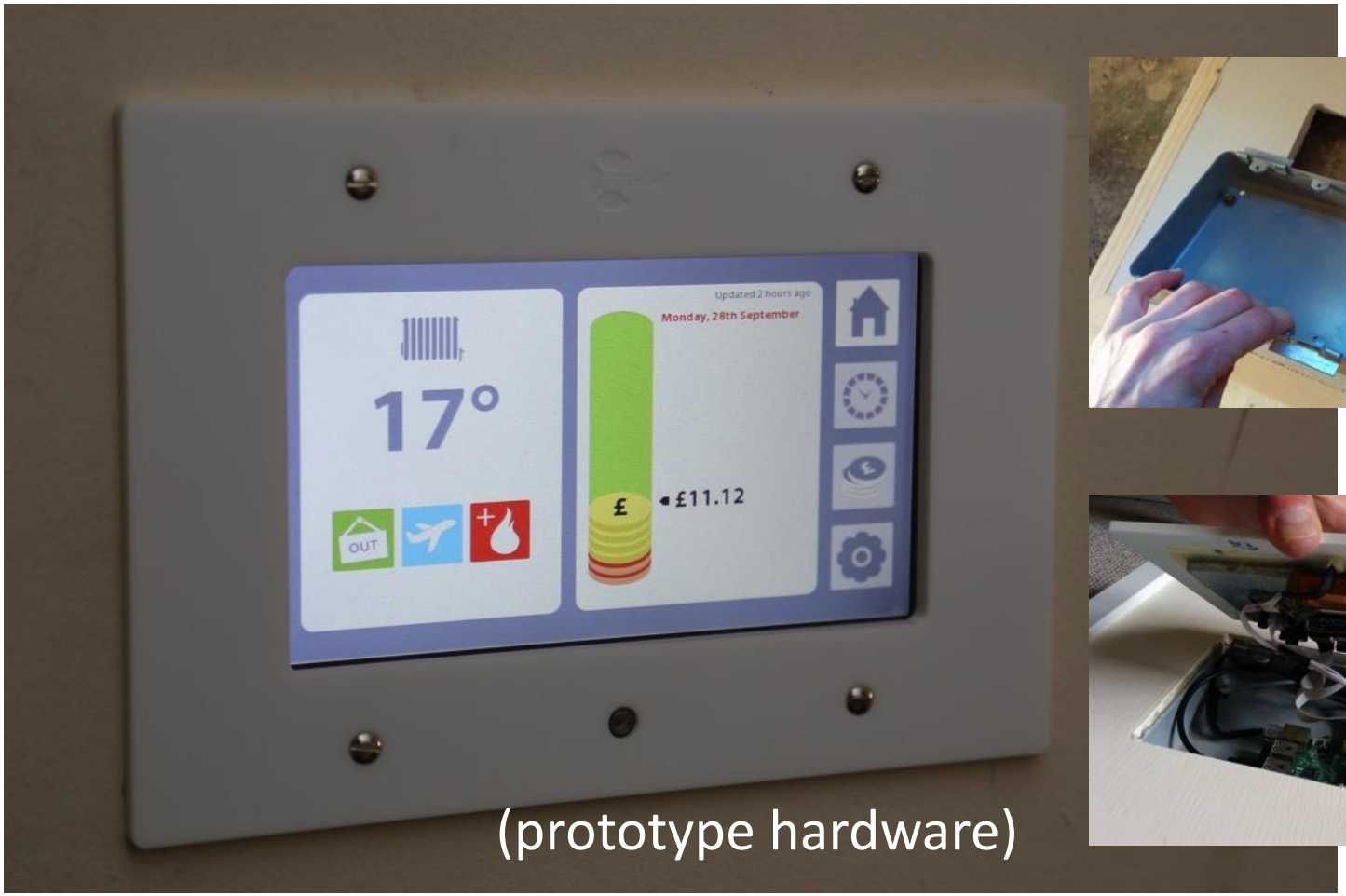
COHEAT

Ring Ethernet and Linux backbone



COHEAT

A user interface



COHEAT

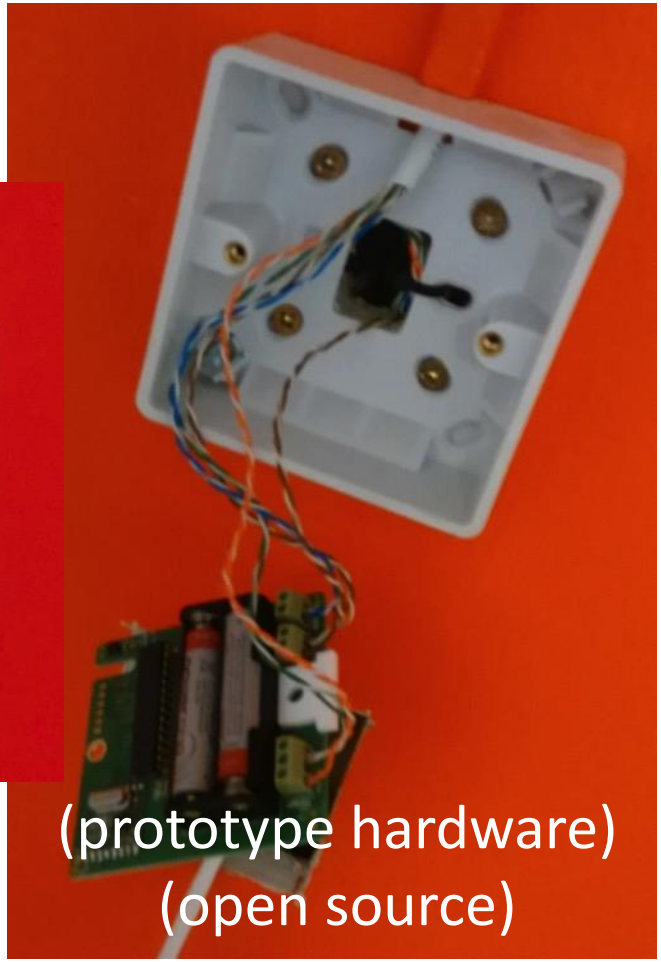
Networked heat interface unit (HIU)

COHEAT

Networked energy centre (heat supply)

COHEAT

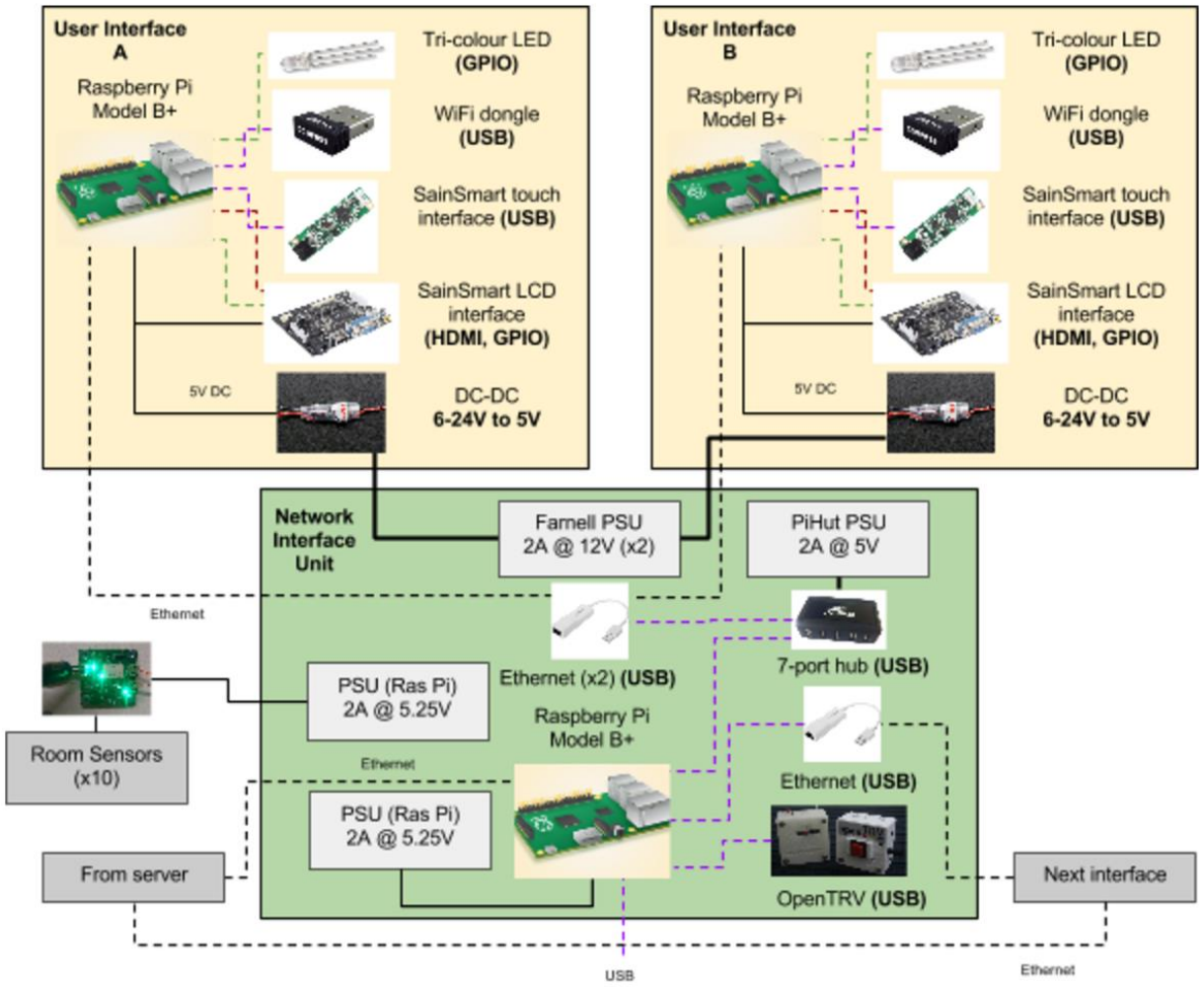
Networked radiators and room sensors



(prototype hardware)
(open source)

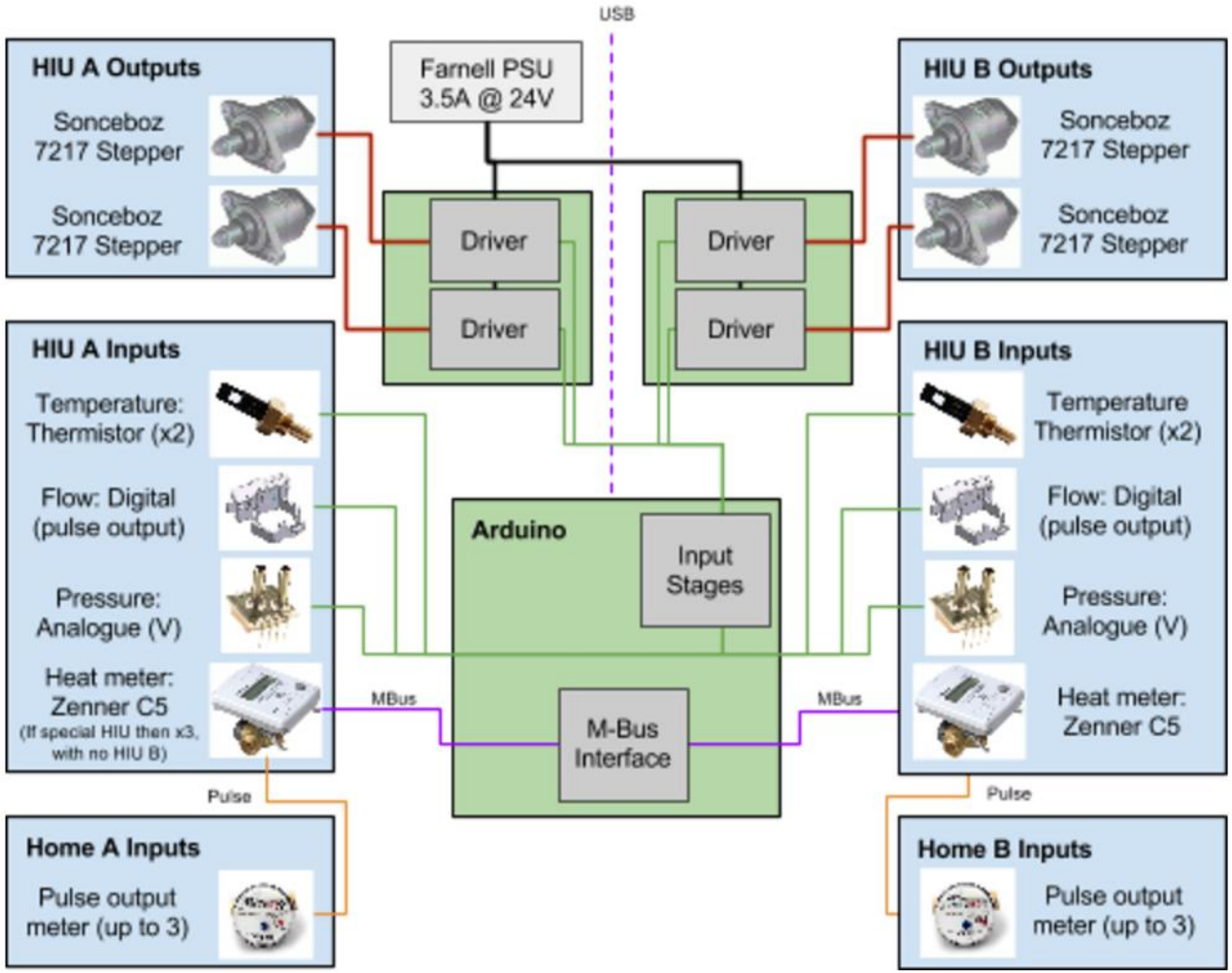
COHEAT

Network hardware (view later)



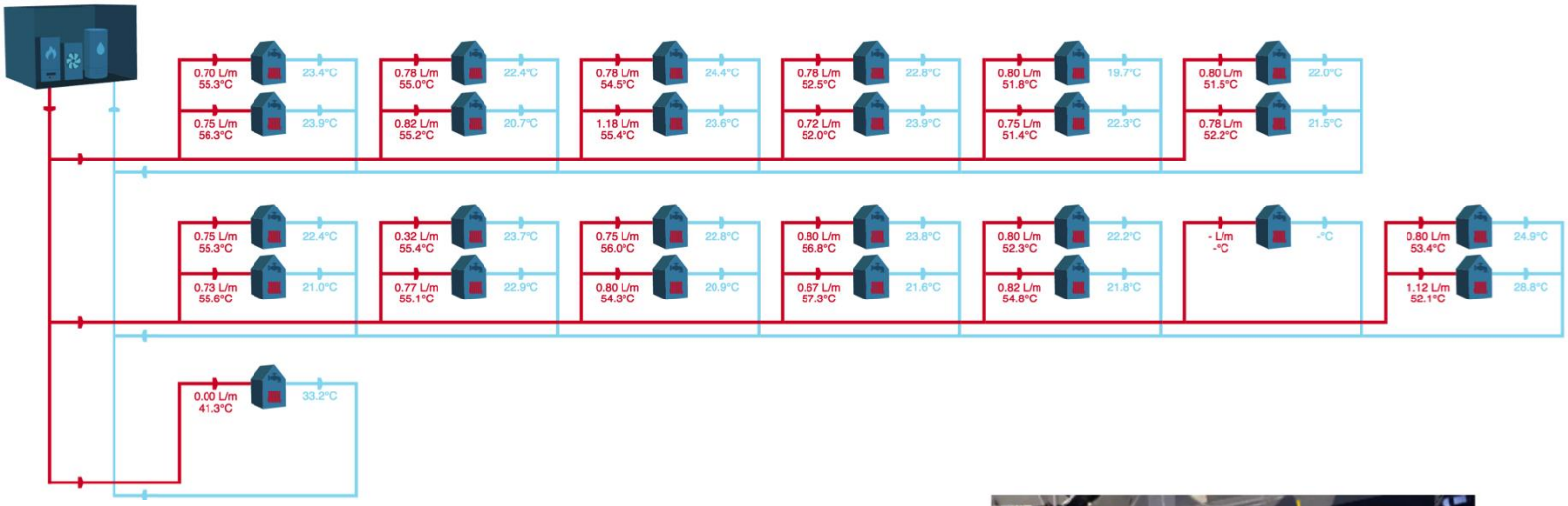
COHEAT

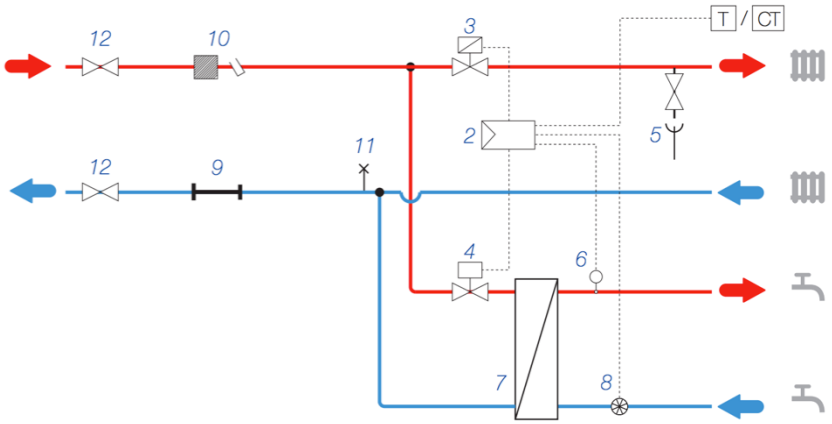
Low level hardware (view later)



COHEAT

Demonstration network





COHEAT

What do customers ask for? (space heat)

User Interface History

User Interface History - b8:27:eb:2f:d2:1a

Timestamp	Screen	Control	x	y
April 24, 2016, 10:17 p.m.	schedule (Popup: none)	temp-block-8	572	101
April 24, 2016, 10:17 p.m.	schedule (Popup: none)	navbar-button-schedule	719	168
April 24, 2016, 10:17 p.m.	home (Popup: none)	navbar-holder	712	129
April 24, 2016, 10:17 p.m.	home (Popup: none)		662	134
April 24, 2016, 7:56 p.m.	schedule (Popup: none)	temp-block-9	605	85
April 24, 2016, 7:56 p.m.	schedule (Popup: none)	navbar-button-schedule	766	170
April 24, 2016, 7:56 p.m.	home (Popup: none)		281	248

(prototype hardware)

Demand profile from Sun Apr 24 00:00:00 2016 to Sun Apr 24 23:30:00 2016

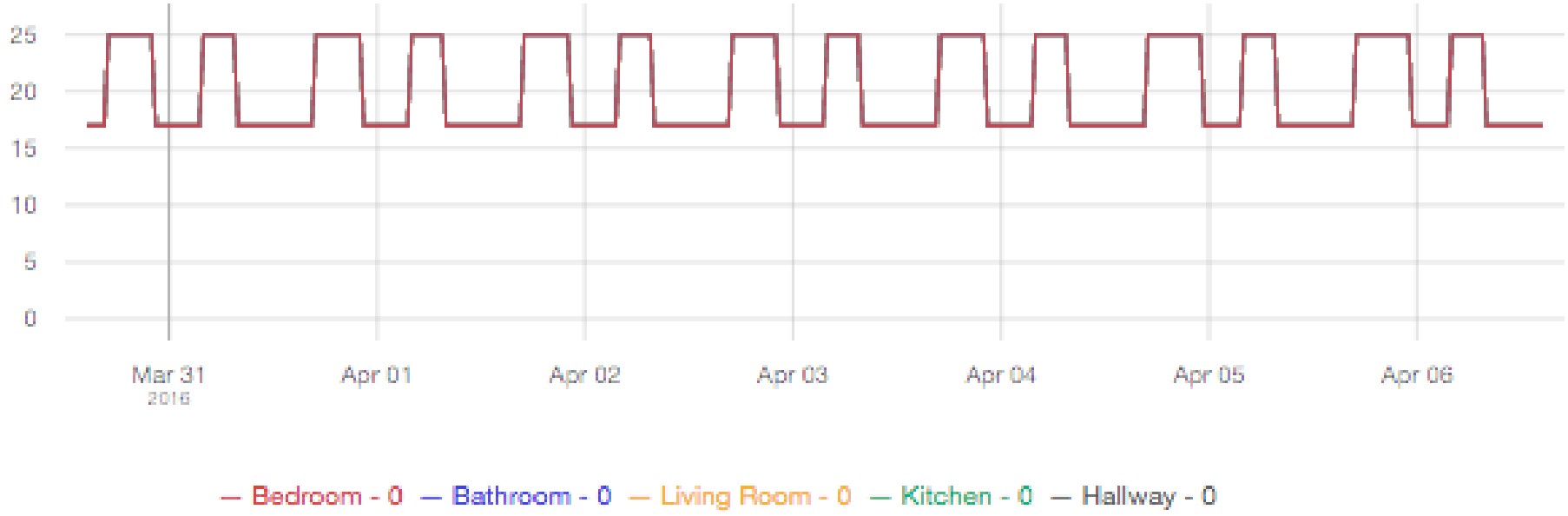
Period of 30 minutes

Scheduled Boost Away Out No Demand Off

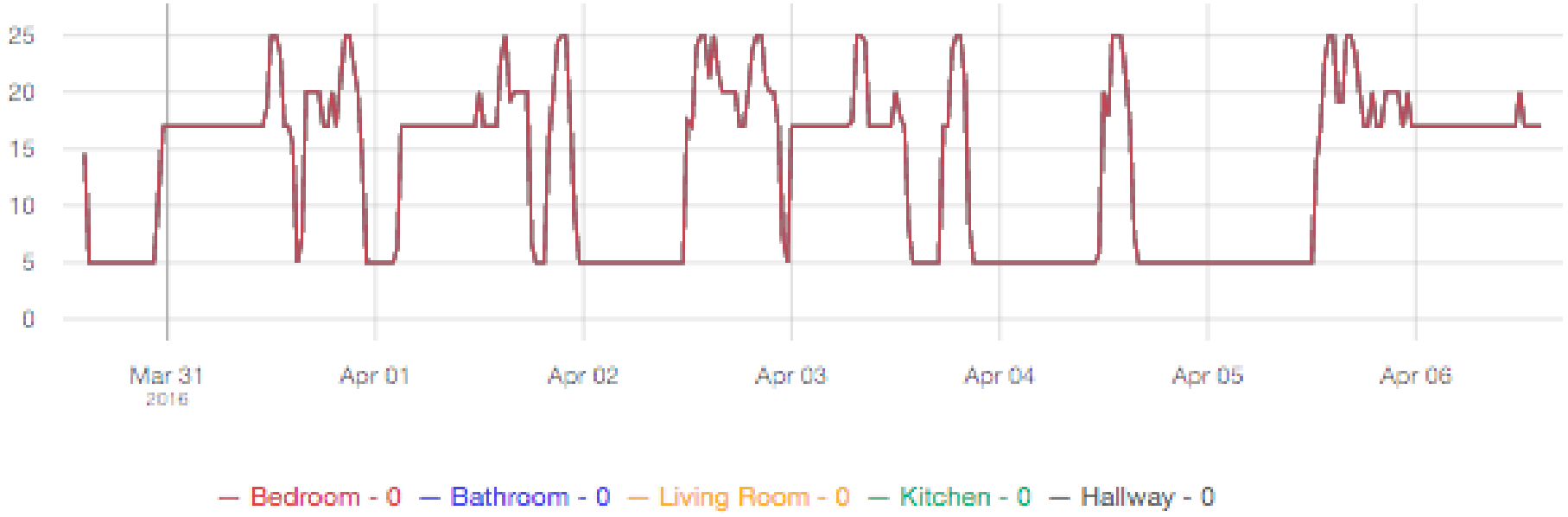
+24hr +Zoom
-24hr -Zoom

Property	HeatZone	RoomZone	0:00	0:30	1:00	1:30	2:00	2:30	3:00	3:30	4:00	4:30	5:00	5:30	6:00	6:30	7:00	7:30	8:00	8:30	9:00	9:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	1
1 - Flat 12	4	Kitchen_Kitchen - 0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	1
1 - Flat 12	1	Bedroom_Bedroom - 0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	1
1 - Flat 12	5	Hallway_Hallway - 0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	1
1 - Flat 12	2	Bathroom_Bathroom - 0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	1
1 - Flat 12	3	LivingRoom_Living Room - 0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	1

Textbook heating schedule

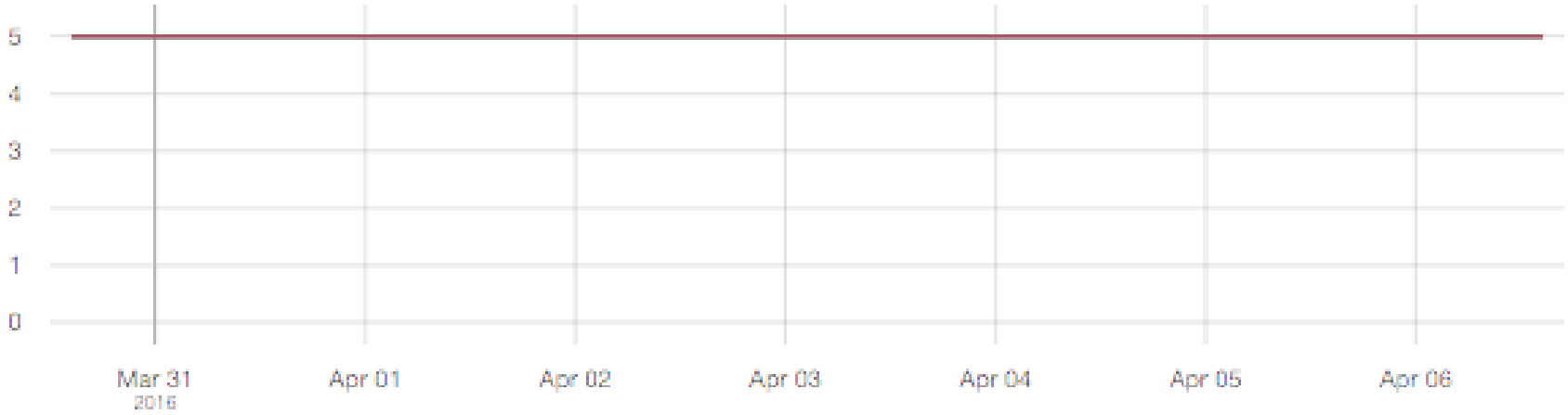


Consumer heating schedule



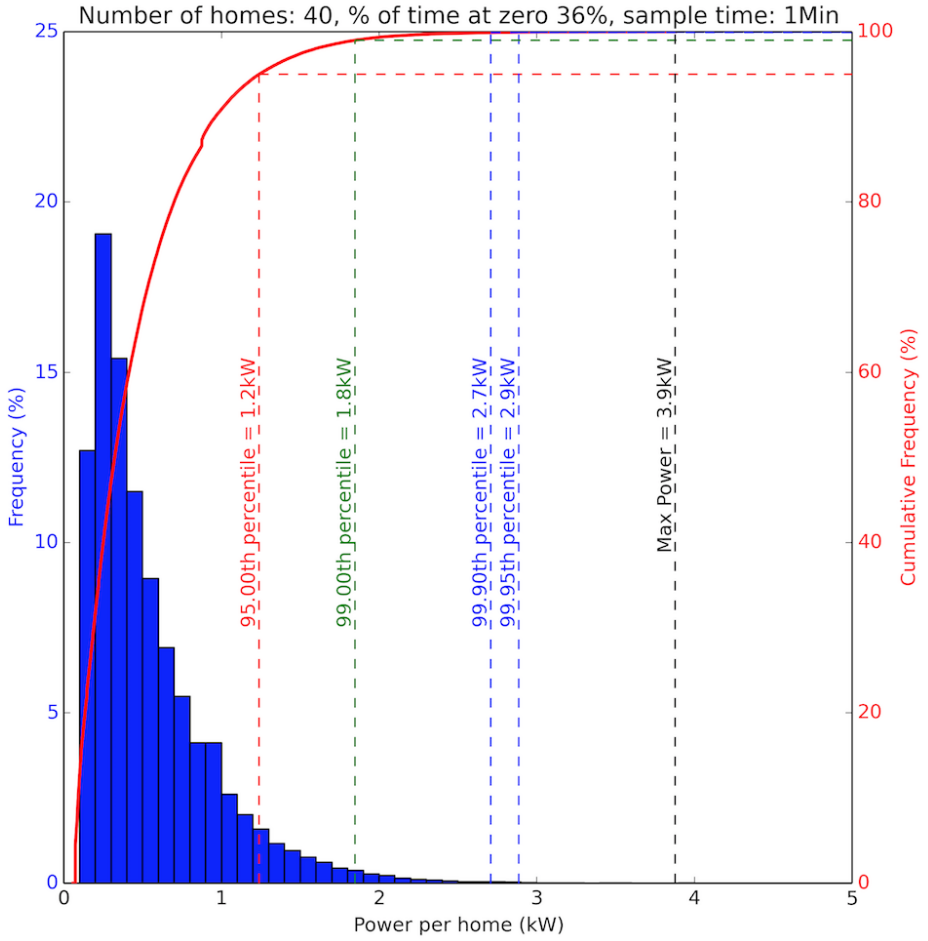
COHEAT

Empty home



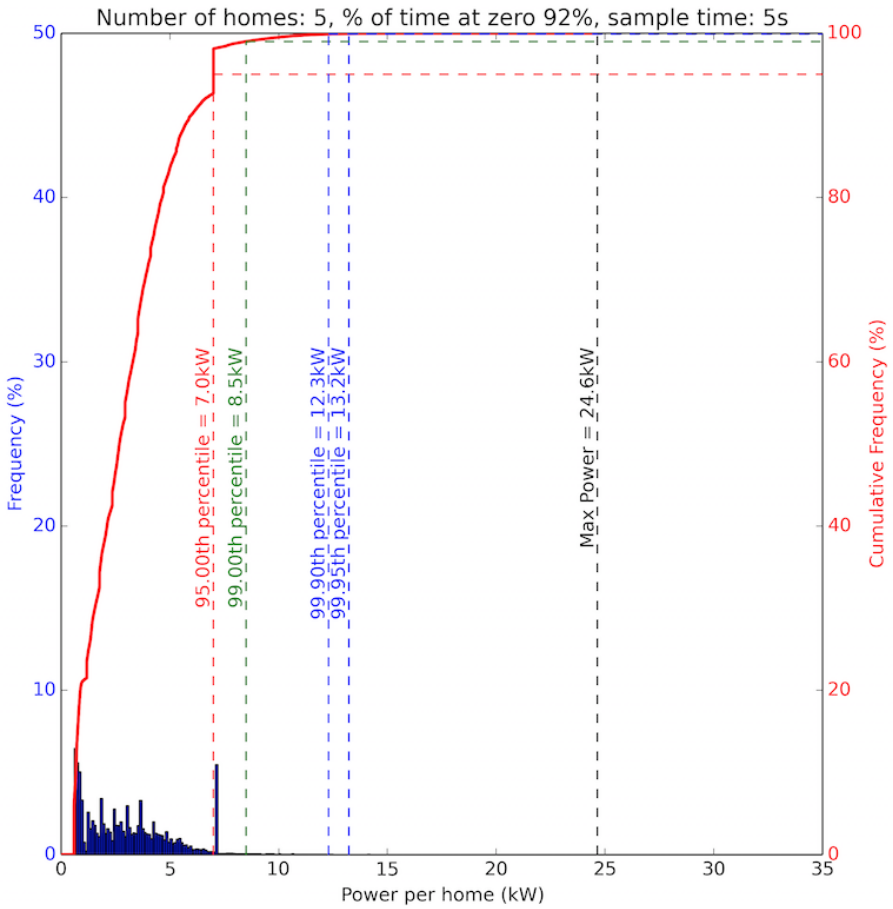
COHEAT

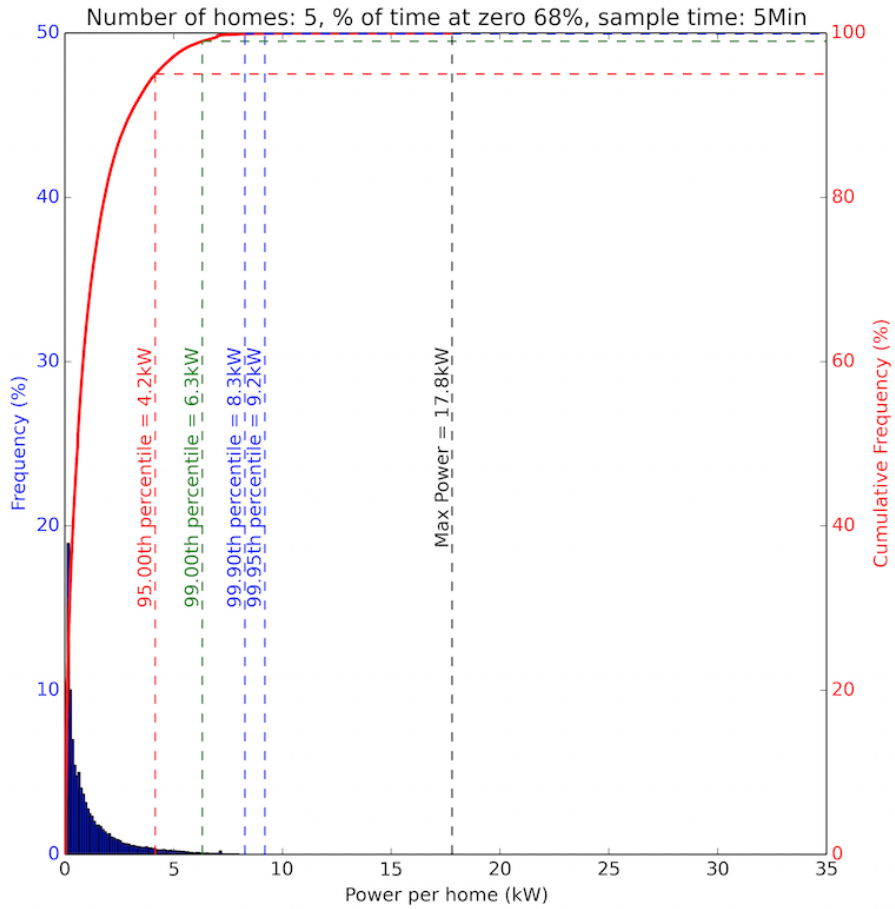
What do customers ask for? (hot water)



- Blue columns
  - "What % of the time is spent at this power output? (zero power not shown)
- Red curve
  - "What % of the time (when there is any hot water use) is the hot water power lower than X kW per home?

Details matter for small substations

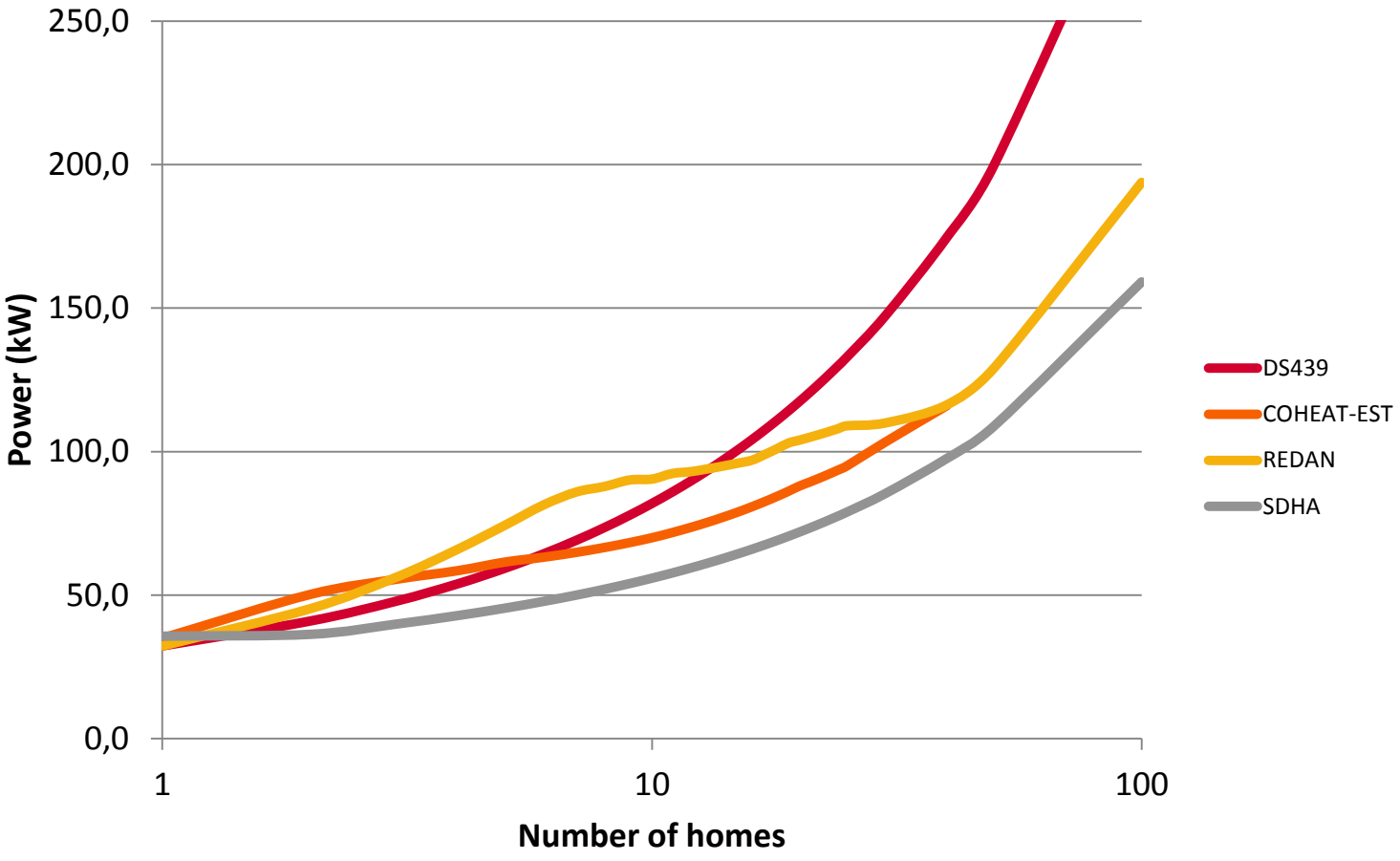




5 seconds or 5 minutes? 12.3 kW or 8.3 kW?

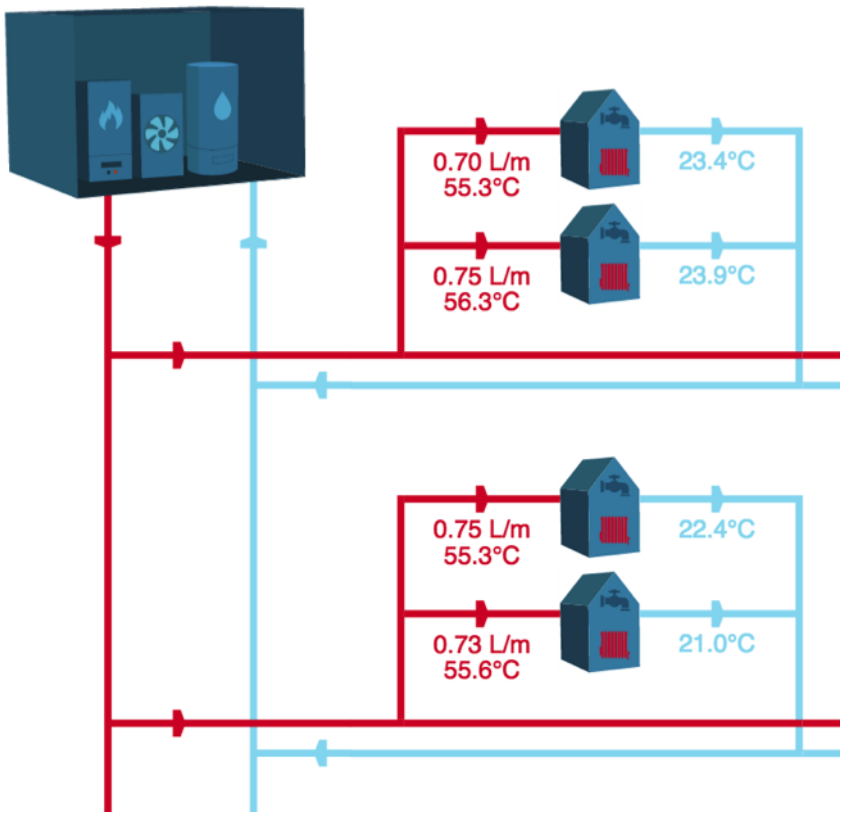
COHEAT

What are the real diversity factors?



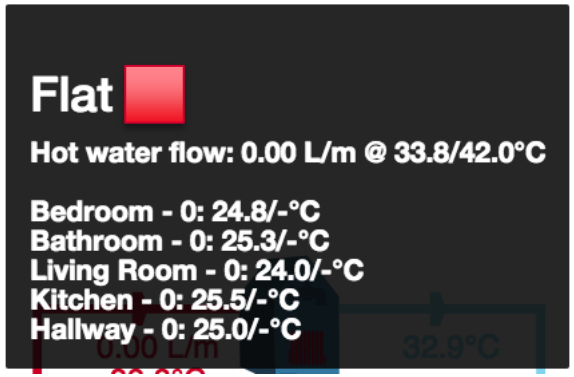
(chart smoothed – do not use as design reference)

What is happening? (real time)

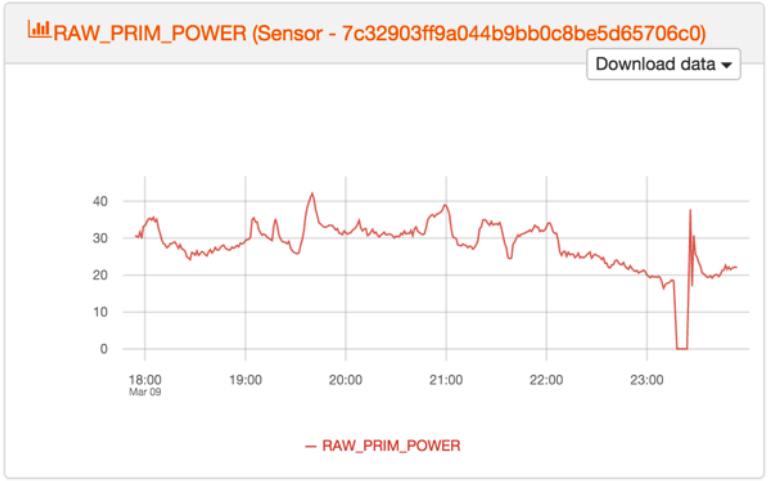


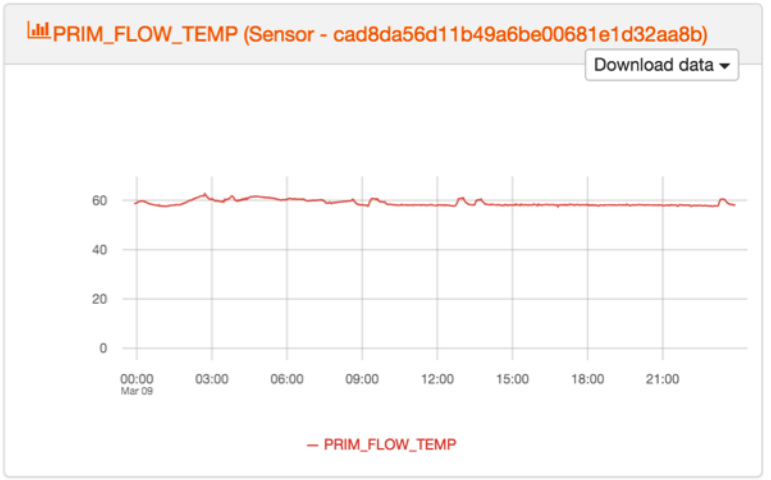
! Nodes in Error (Total: 3)

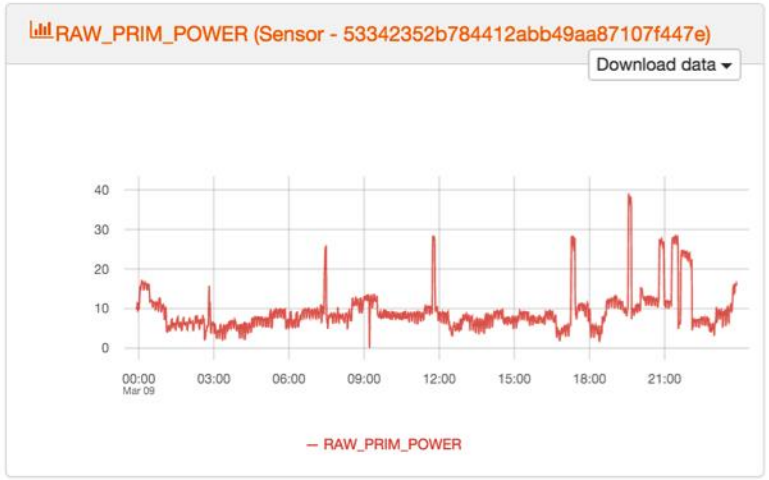
Equipment Node ID	Node Type	Node ID	Current State	Last Change
PiStat/Flat 14	COHEAT UX Screen Rev0.1	b8:27:eb:f6:ce:e4	unknown(20)	April 22, 2016, 1:33 p.m.

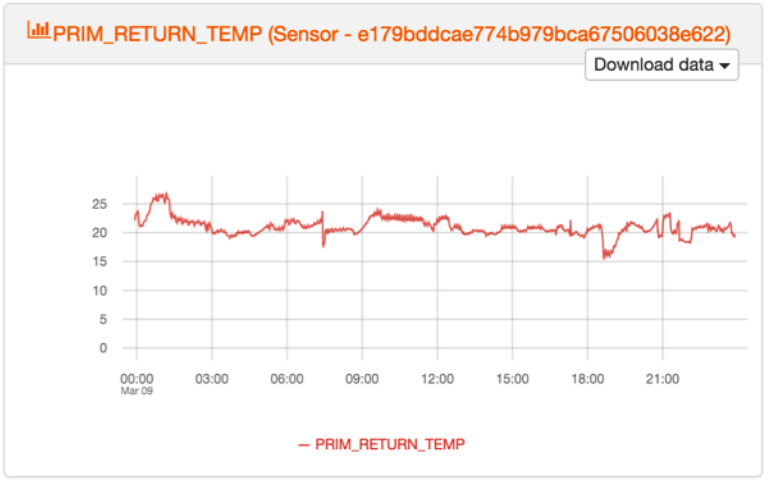


What happened before? (engineers)









COHEAT

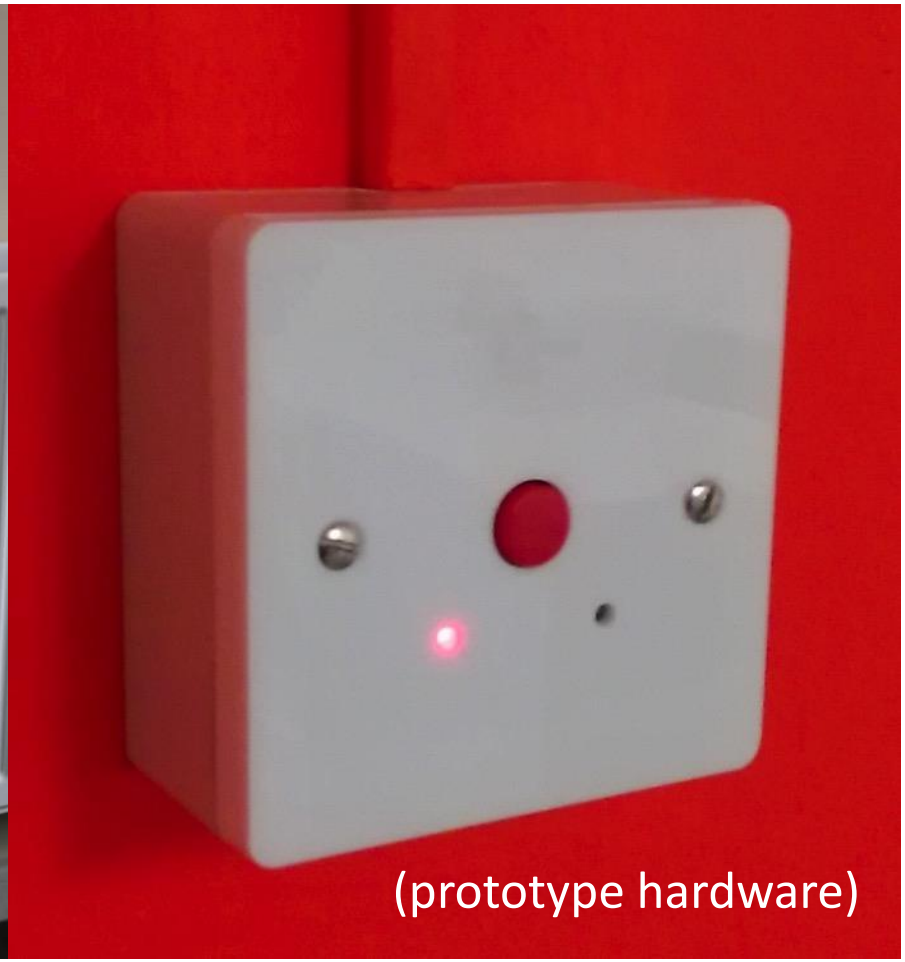
What happened before? (accountants)

Statement: Period: 2nd May 2016 to 5th May 2016 (4 days) monthly

Your balance at Mon 2nd May 00:00						**£-10.94**
Charges during this period	**Hot water**		**Heating**		**Daily charge**	**Total**
Mon 2nd May	8kWh	£0.48	24kWh	£1.44	£0.00	£1.92
Tue 3rd May	4kWh	£0.24	11kWh	£0.66	£0.00	£0.90
Wed 4th May	1kWh	£0.06	10kWh	£0.60	£0.00	£0.66
Thu 5th May	1kWh	£0.06	7kWh	£0.42	£0.00	£0.48
TOTAL	**14kWh @ 6.00p =**	**£0.84**	**52kWh @ 6.00p =**	**£3.12**	**£0.00**	**£3.96**
Credits during this period						
Thu 5th May @ 10:00			Allpay(AllPayTDCH0353.PP)			£20.00
TOTAL						**£20.00**
Your balance at Thu 5th May 23:59						**£5.10**

COHEAT

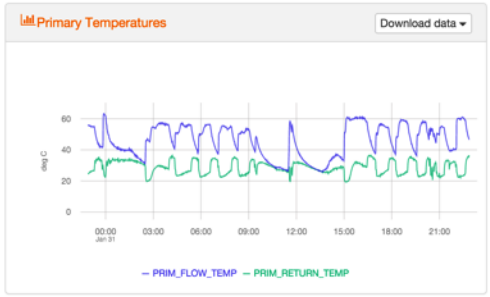
What did we deliver? (space heat)

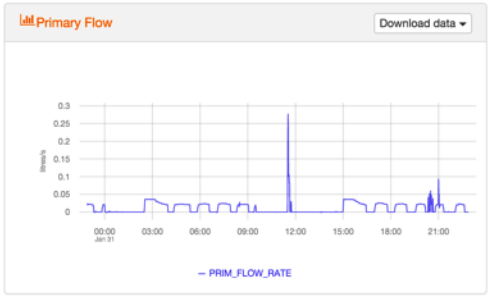


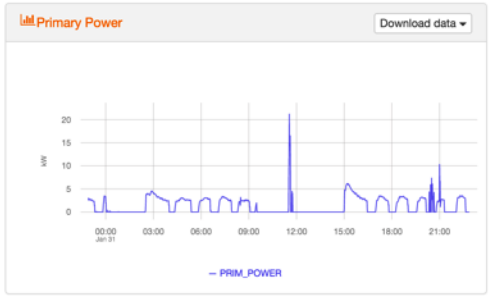
(prototype hardware)

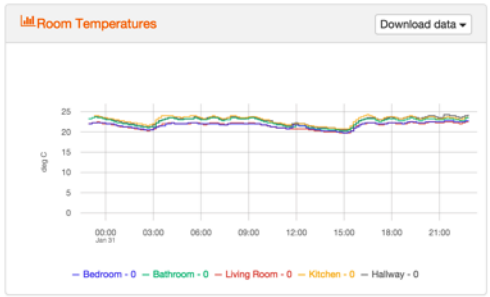
COHEAT

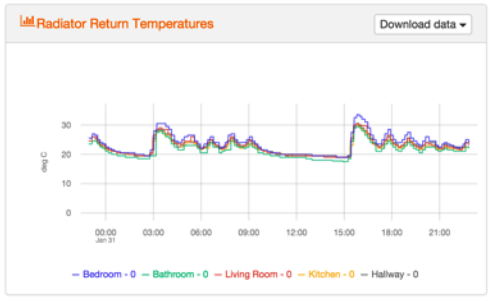
In-home data

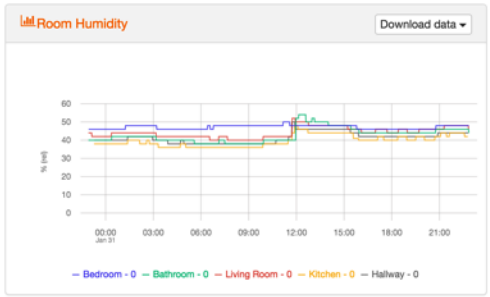


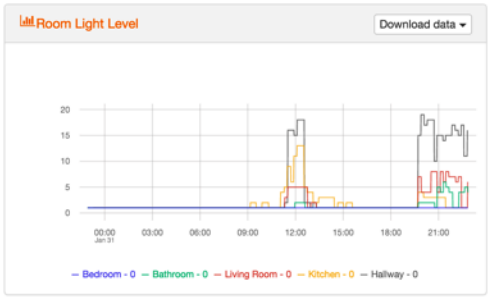






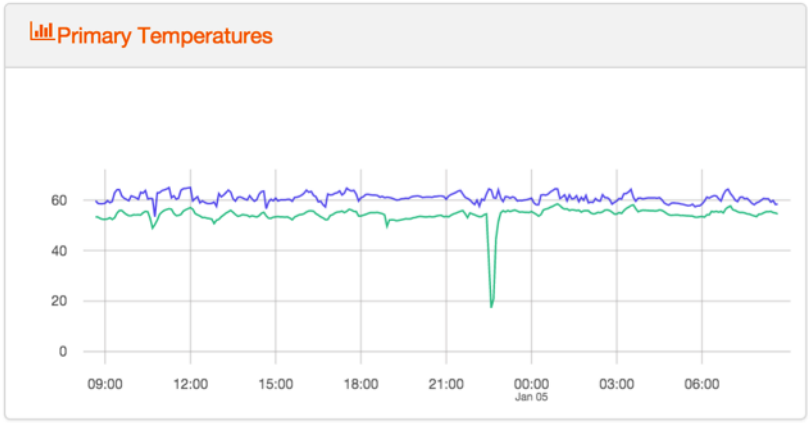


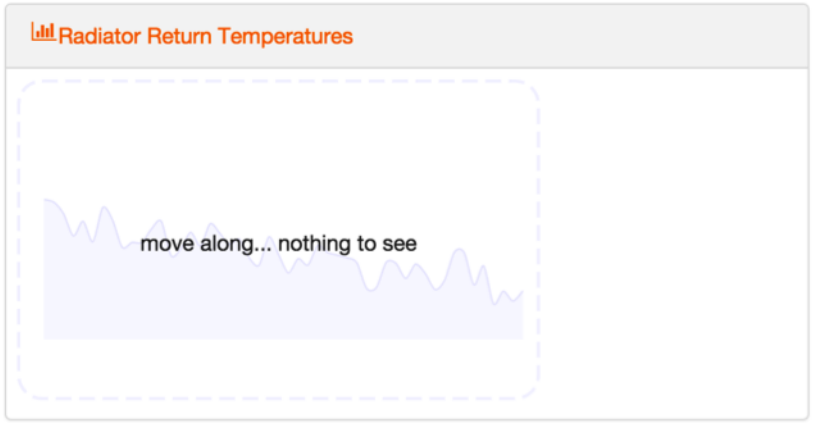




COHEAT

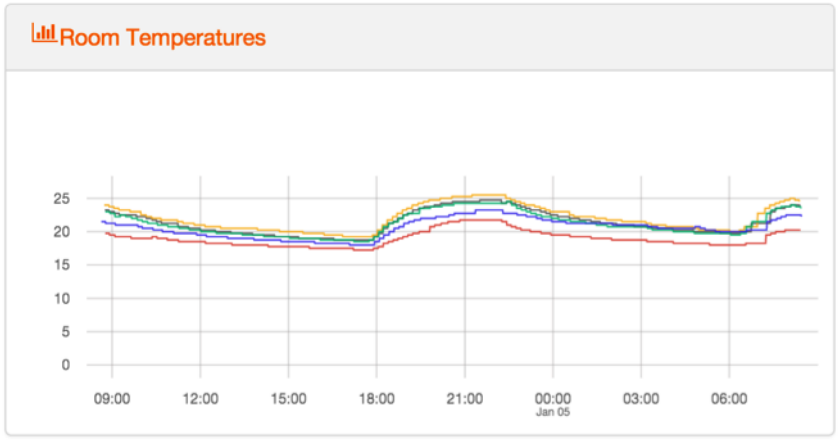
Heat meters see that there is a problem

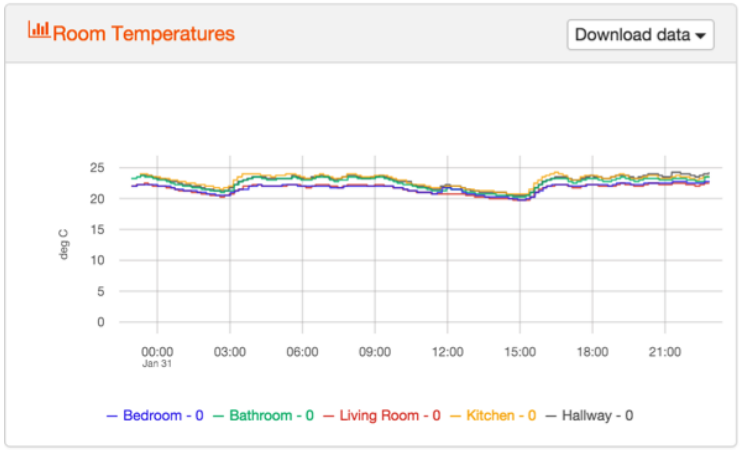


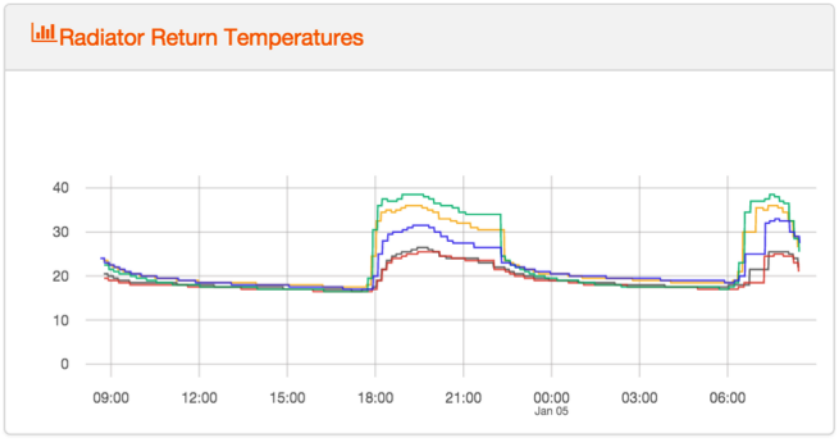


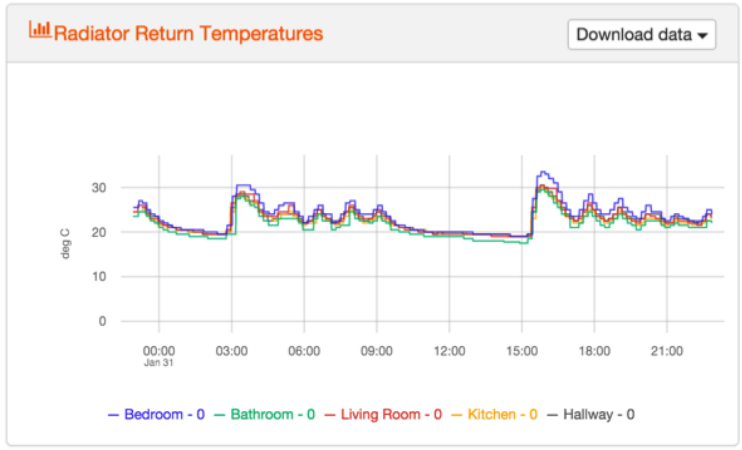
COHEAT

Secondary sensors show the problem



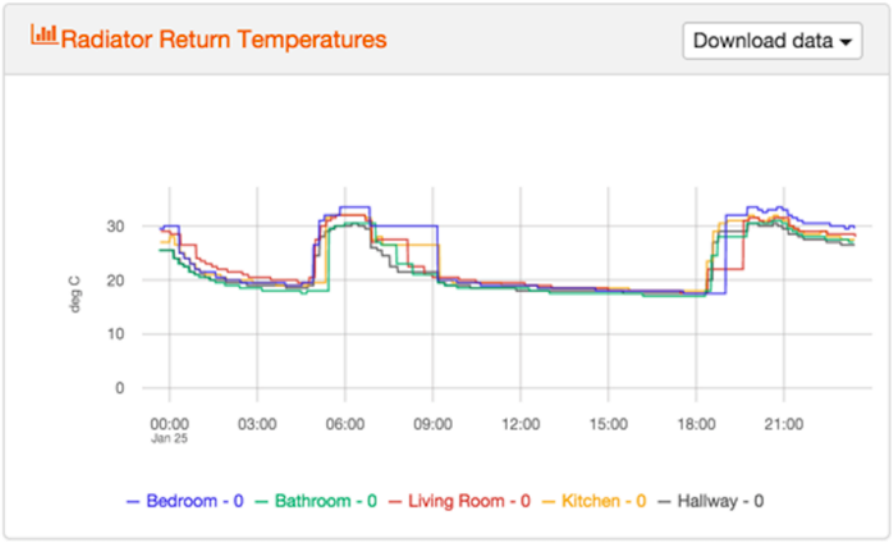




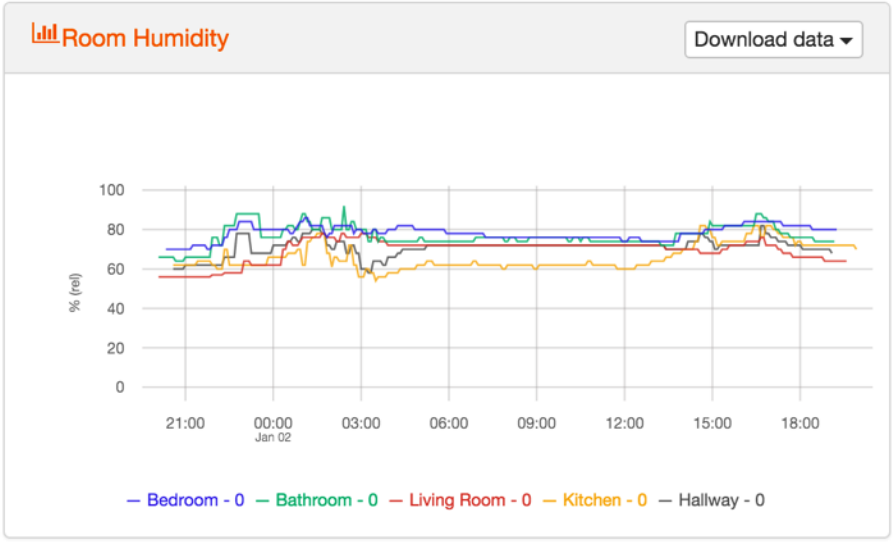


COHEAT

Secondary sensors show other things



Towels/underwear on radiator

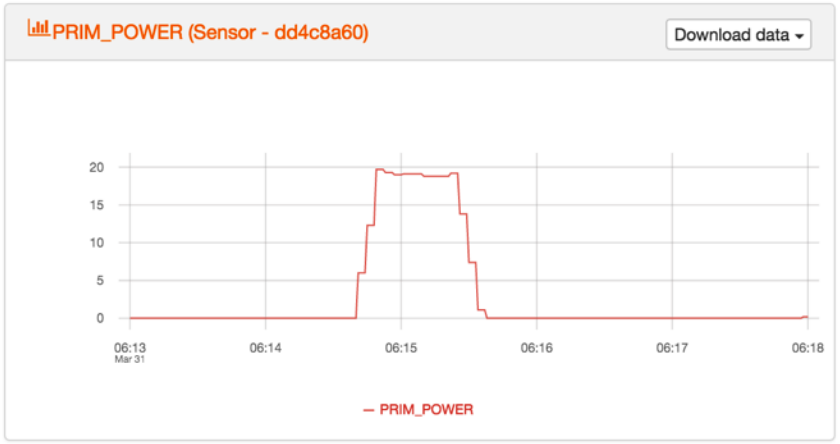


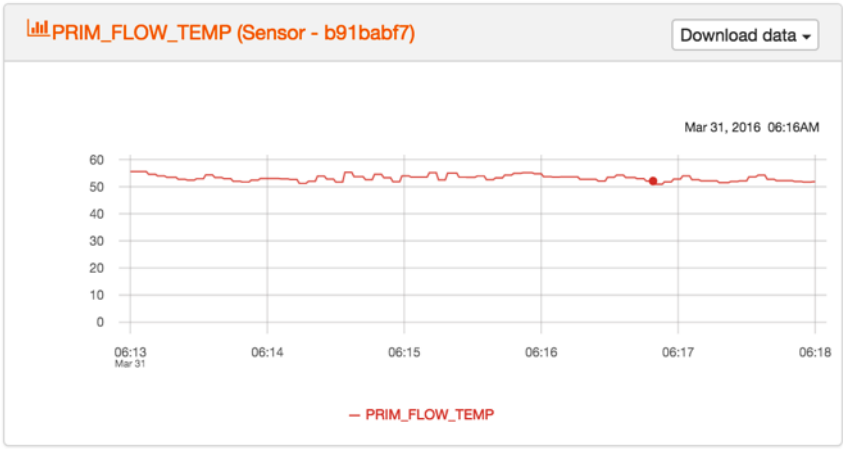
House party

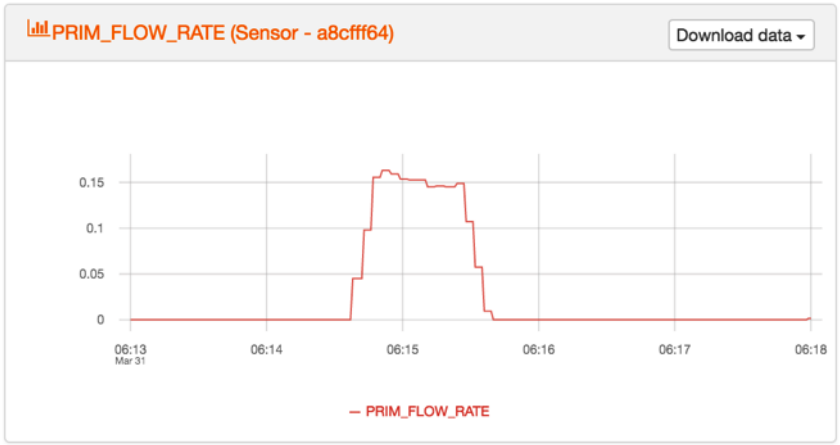
“I’m cold”

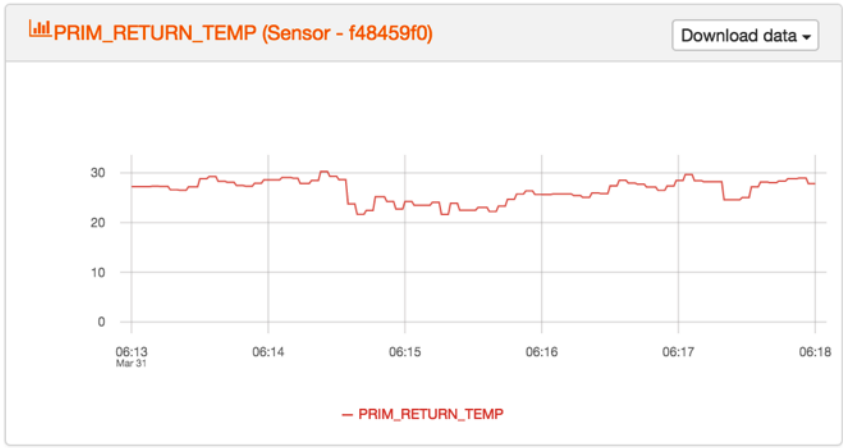
“We can’t rent out this home”

What did we deliver? (hot water: meter)



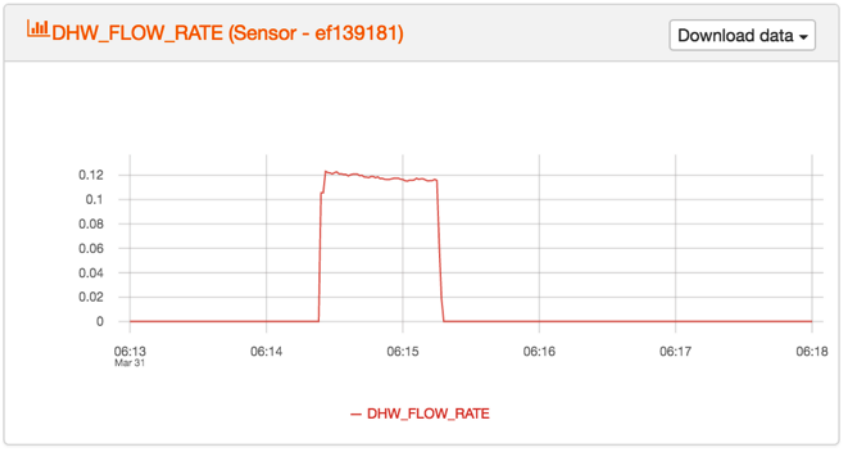


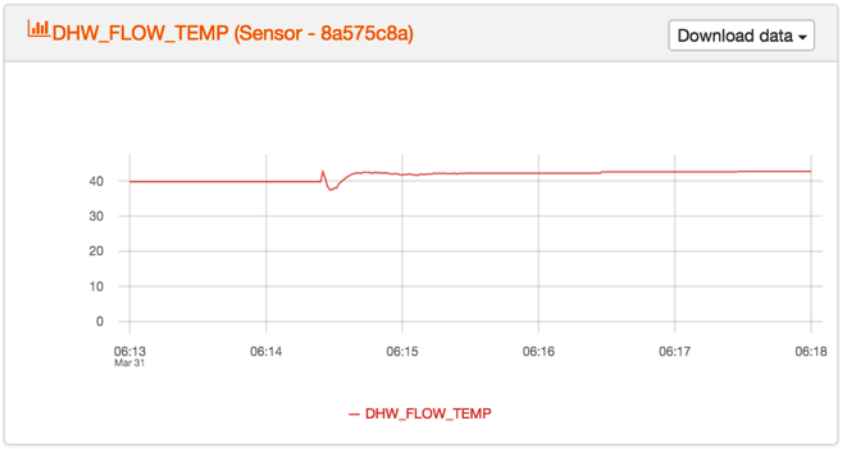


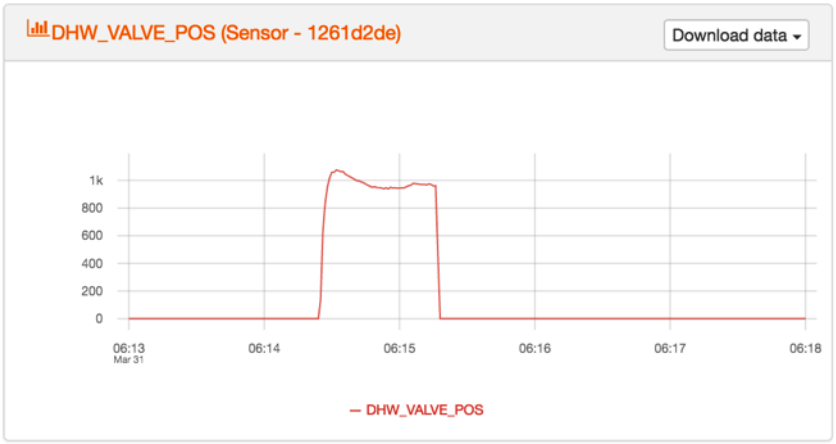


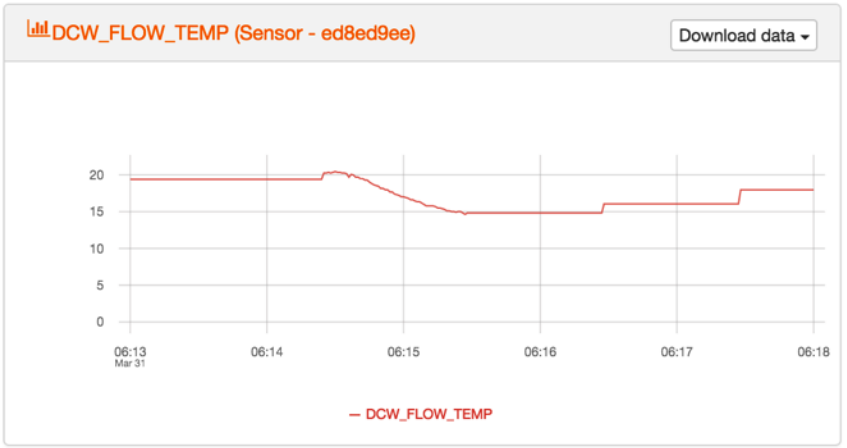
COHEAT

What did we deliver (hot water: actual)



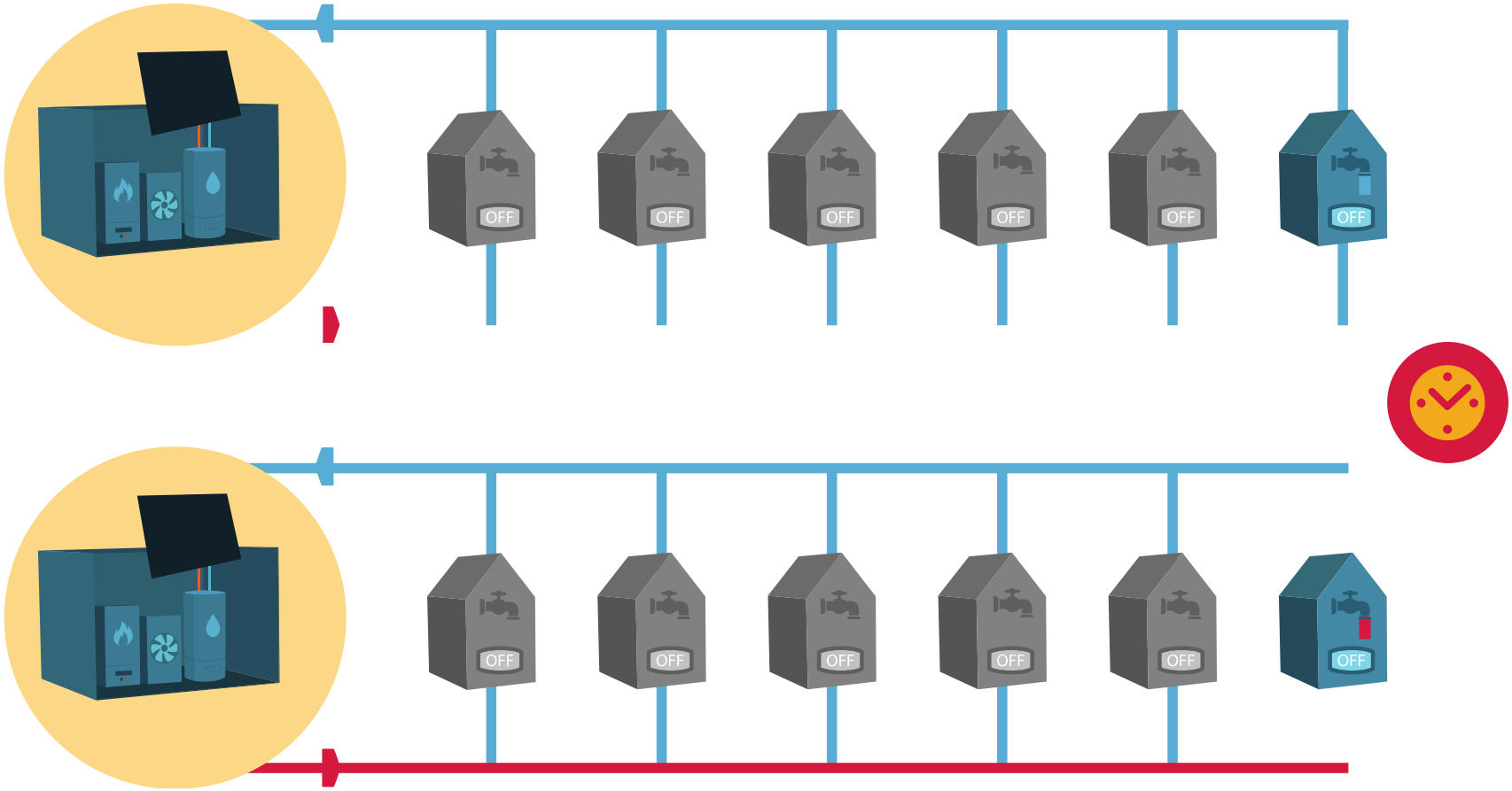






COHEAT

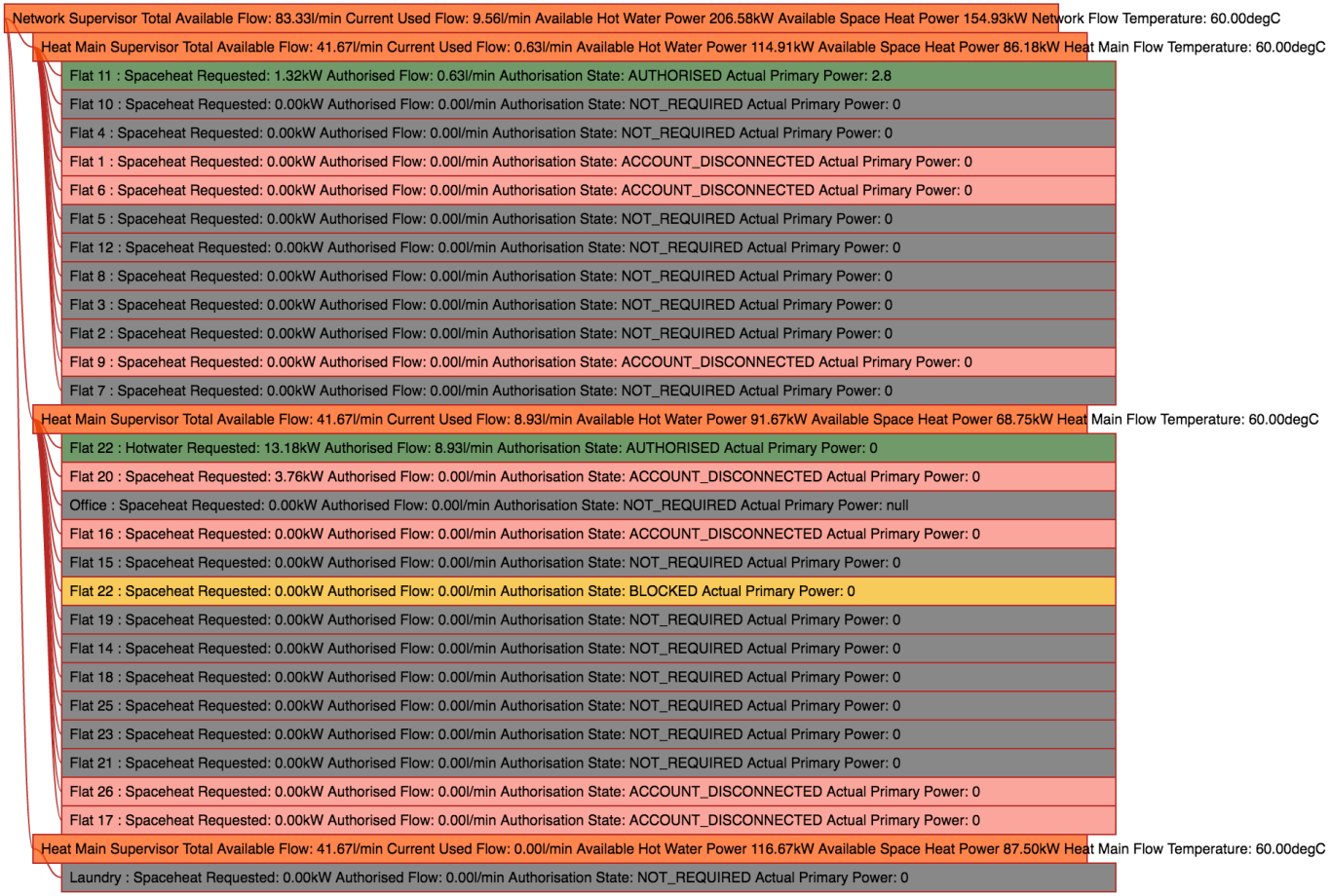
Why might we care? (bypass)



Real time control

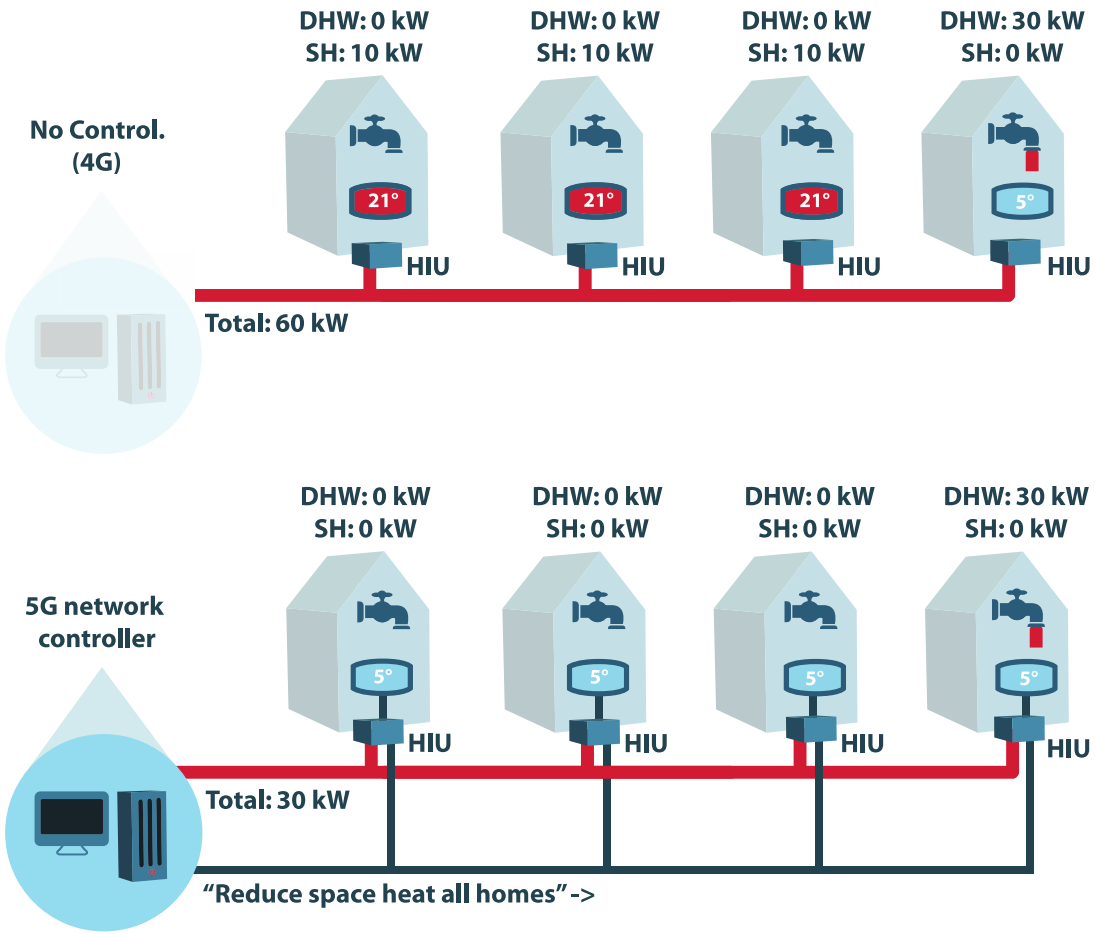
- What is the system being asked for now?
  - Interrupt driven
  - Integrated with service level policy
- Create a plan
  - Quickly and reliably
  - Handles constraints
- Implement the plan
  - Delegates control authority

Real time planner

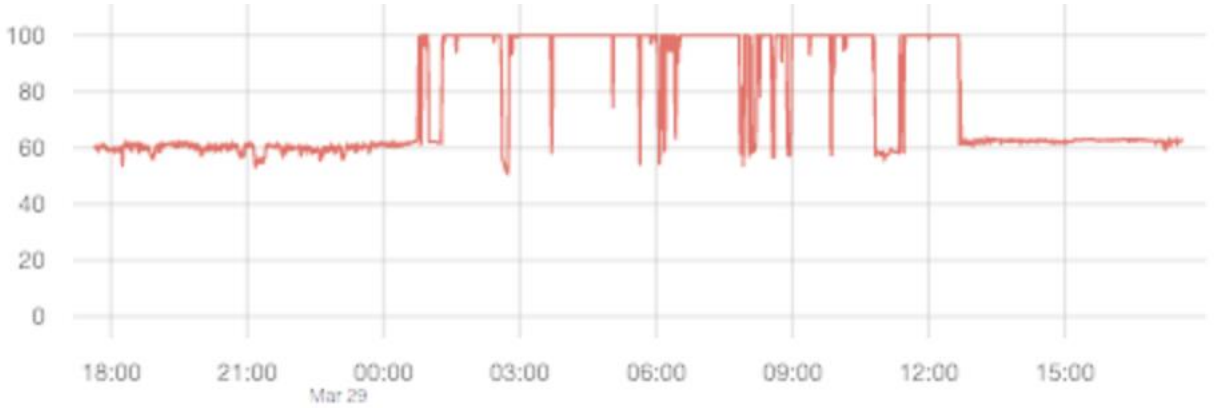


COHEAT

Real time service priority



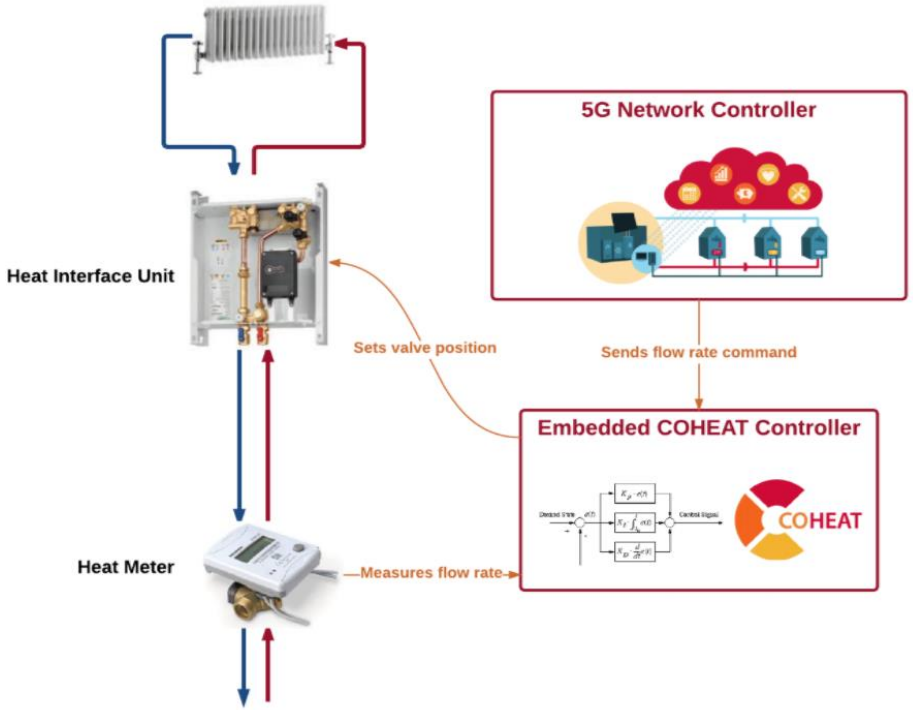
Aggressive dP control

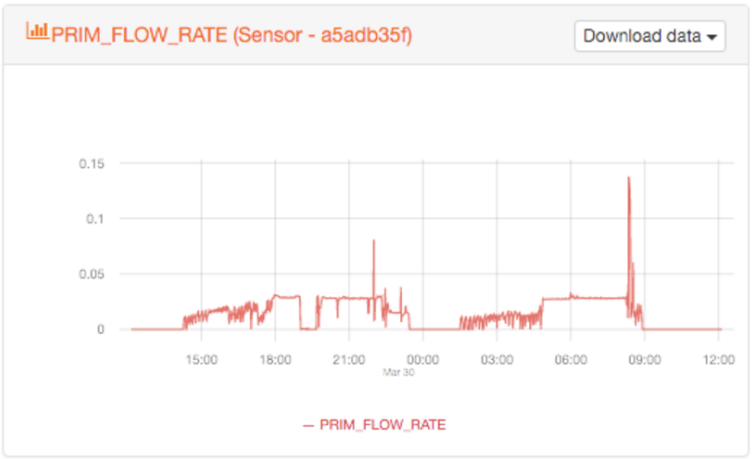


Available pump capacity (%)

(differential pressure = 0 kPa for 12 hrs/day)

Delegating control and linking equipment



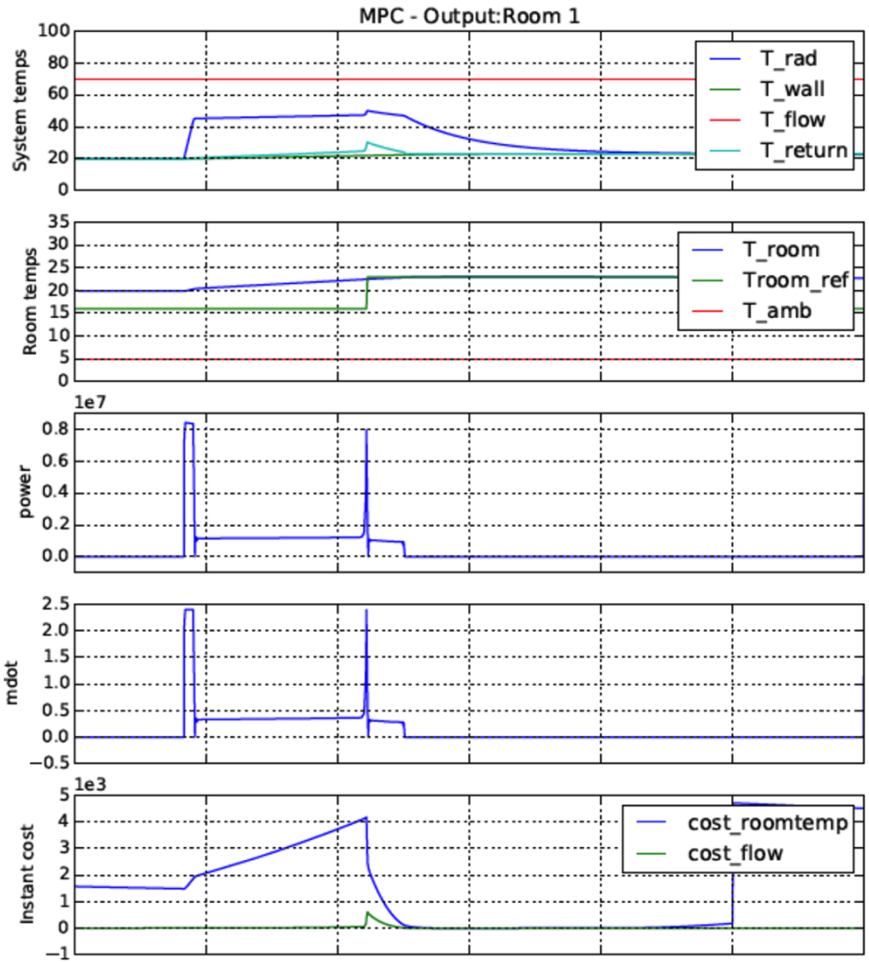


COHEAT

Predictive control

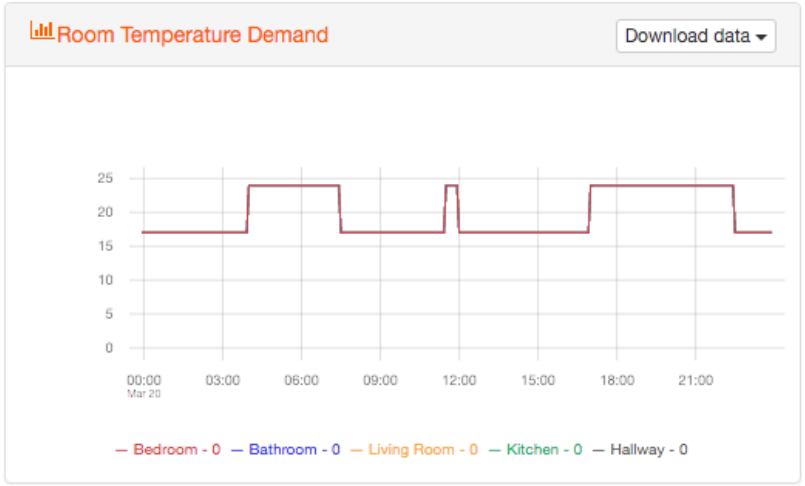
- Where am I now?
  - Historic data, physics model, state estimator
- What am I being asked for next?
  - Heating schedule, keep-hot schedule
- What else matters?
  - Weather forecast
  - Hot water demand forecast
  - Cost model for consumer comfort / tapping delays
  - Cost model for operating the network
- What should I do next?
  - Calculate a plan for the real time planner to implement
  - Share the plan with other services on the platform

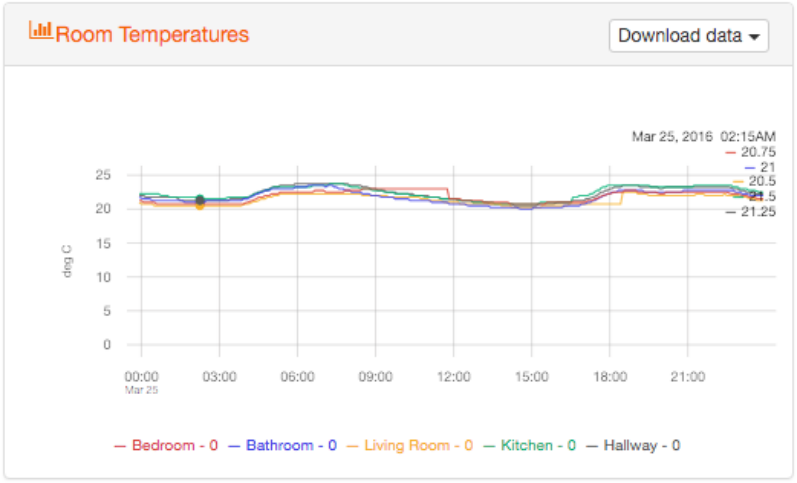
Model predictive control implemented

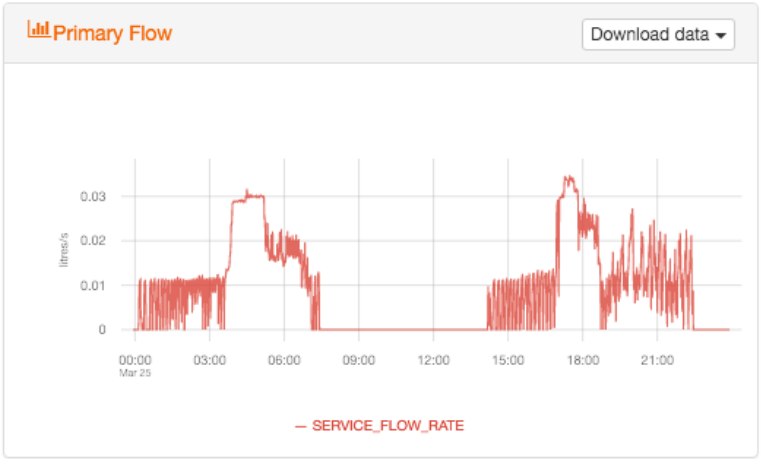


COHEAT

Model predictive control in action

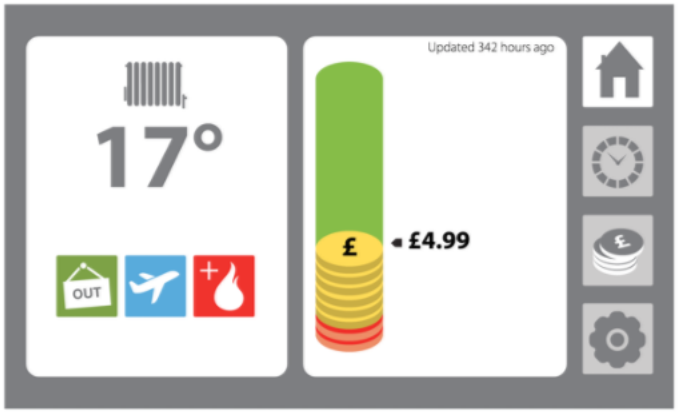


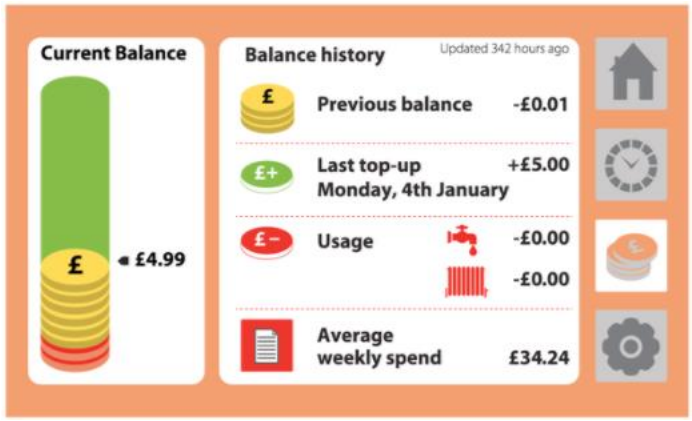


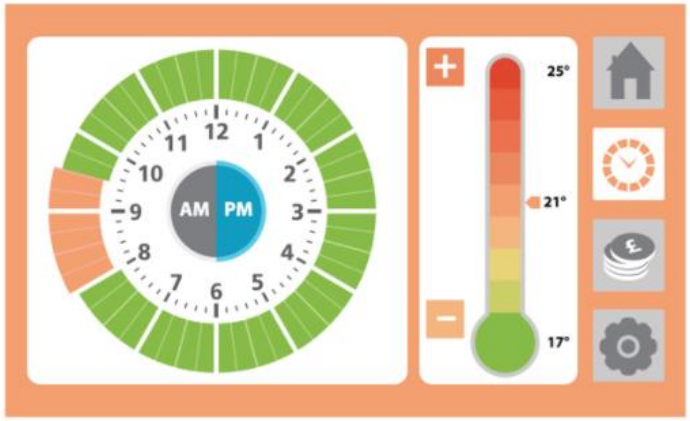


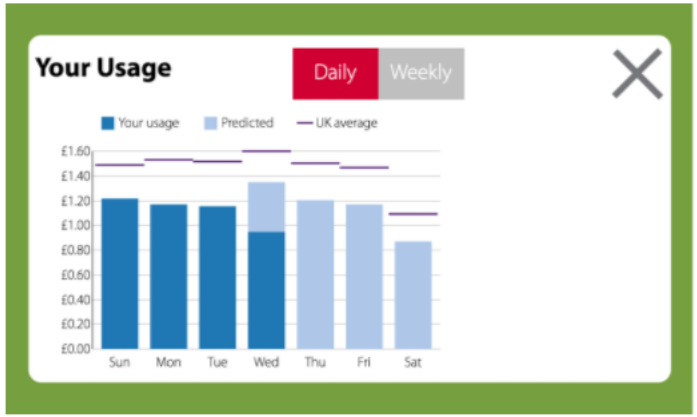
COHEAT

Sharing information with the consumer



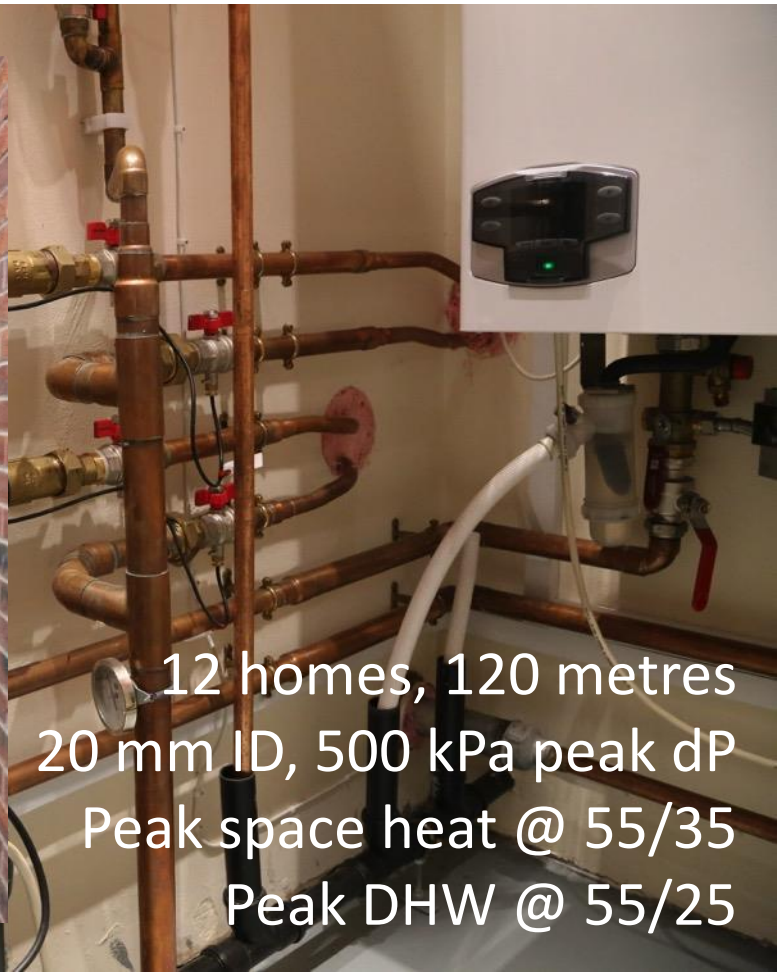






COHEAT

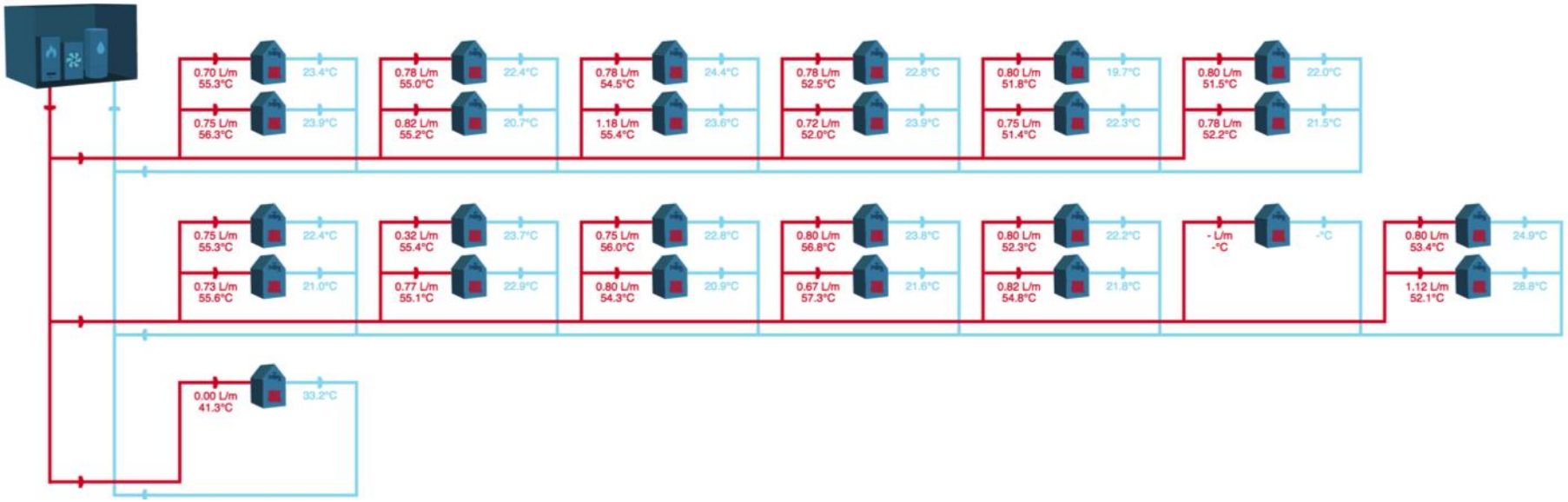
Implication for system sizing



12 homes, 120 metres
20 mm ID, 500 kPa peak dP
Peak space heat @ 55/35
Peak DHW @ 55/25

COHEAT

Implication for system performance



- Interim figures:
- (usage: 3 MWh/home/yr)
- (losses: 0.3 MWh/home/yr)

Gas boiler efficiency	**89.5% gross**	(40 kW @ 60F/45R)
Heat pump COP	**3.6**	(10 kW @ 35F/30R to 45F/40R)
Distribution losses	**11%**	
Pumping cost	**0.4%**	

COHEAT

Learnings?

- You can build a secure, resilient, real time control system all the way down to individual homes using an internet derived platform and low cost hardware.
  - Wireless solutions for individual rooms and radiators proved less suitable for commercial deployment (maintenance liability)
- The monitoring information is useful for improving the design and operation of standard heat networks.
  - You can use less sensors and infer what is happening once you know what to look for (we are developing this next)
- Basic real time (reactive) control reduces the impact of overload, and makes it more acceptable to overload a network regularly.
- Advanced (predictive) control is promising but truly self-commissioning, self-optimising networks need more work
  - We have the platform (and want to work with others on algorithms)