Engineering Heating Systems

Reducing energy use by up to 25%

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Agenda

- Background
  - Heat sources & Thermodyamics
  - Building Regulations – L1
  - Practialities – Domestic Hot Water & Legionella
  - System Layouts
- System Designs
  - Physical improvements
- What can the new tech do?
  - Home Automation recap
  - Control & monitoring
  - Automation tech, Matter etc

Background

Vaillant ecoTEC plus

- Sources & Thermodyamics
- Building Regulations – L1
- Practialities –
  Hot water and Legionella
- System Layouts

"A Practical Zero-Carbon Home"
Vaillant aroTherm+ heat pump

Gas prices are up 75% in the last 5 years (BBC "More or Less" Jan 26)
A Dec 2025 survey of 21,000 neighbourhood watch members showed that 81% have a smartphone, 20% had a "smart heating system"

UK installation industry woes!

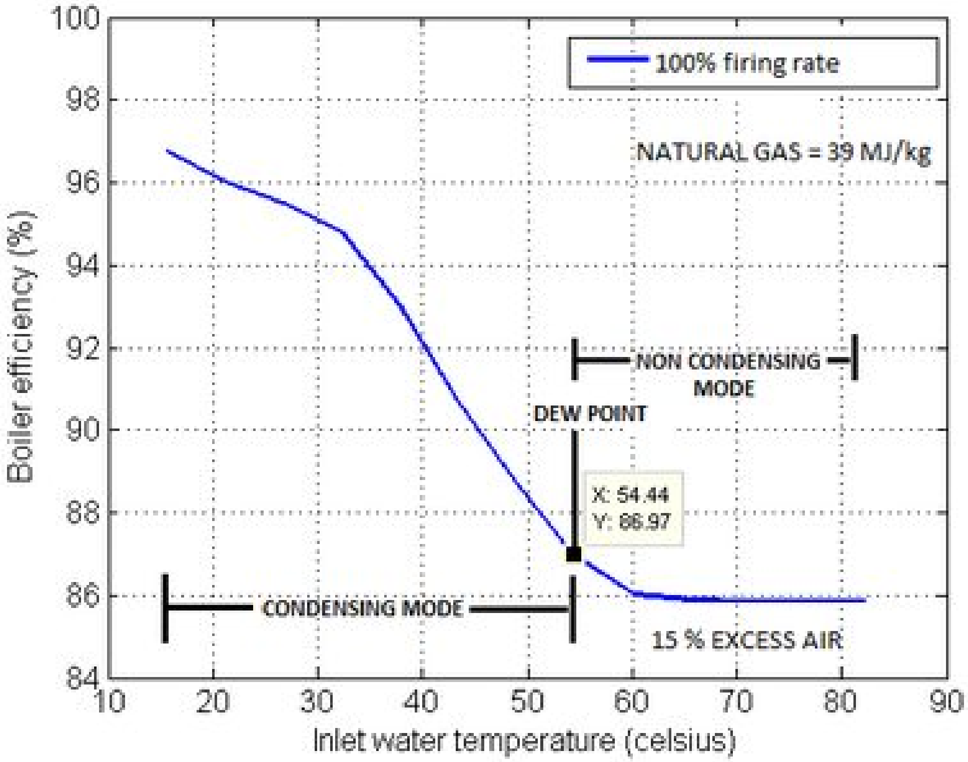
- UK boilers have typically been grossly oversized historically
- UK Boiler life 10-15 years Germany 20+ years
- A boiler should last 22 years (Heathub)
- UK: 1.7 Million boilers / yr (7%)
- Germany: replacement: 4%
- “Over a quarter of homes (27%) have a boiler that is 3 years old or less and 48% are between 3-12 years old. German heating systems are on average 17 years old and 40% are more than 20 years”

- *“Radiators not heating up properly”* *(local Fulham co. May 2026, +boiler flow set to 75^{o}C!)*
- *“The UK Situation: Rushed Jobs and Falling Standards”*
- *“...approaching the end of its life...”* *(at 7-9 years)*

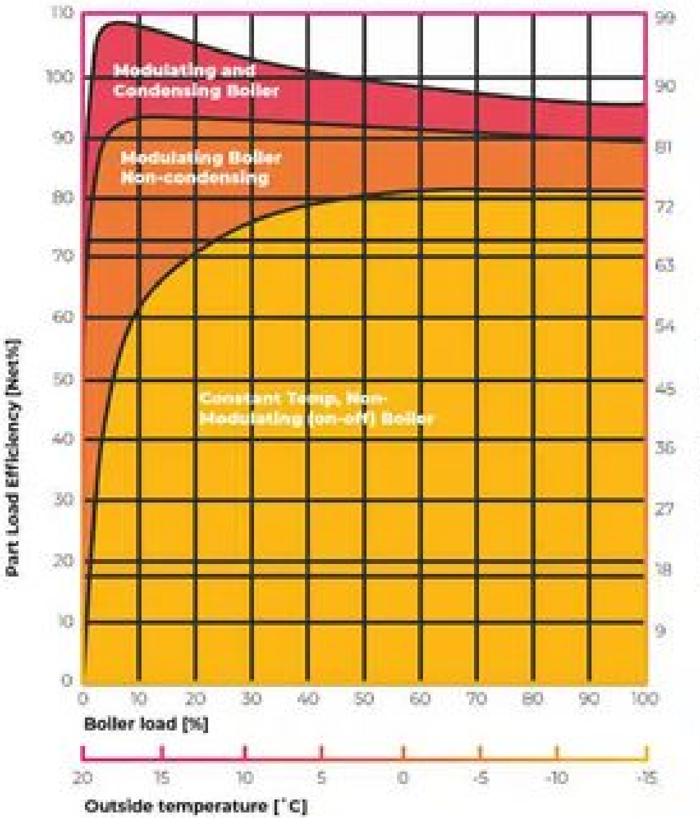
2023: https://committees.parliament.uk/writtenevidence/125976/pdf

Boiler Thermodynamics

Efficiency vs Return temp

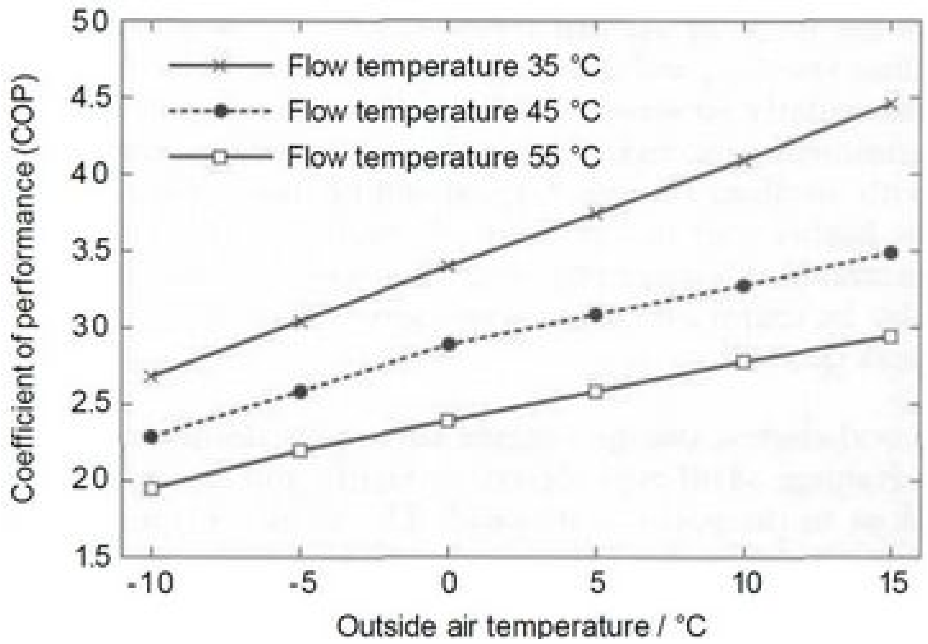


Efficiency vs load

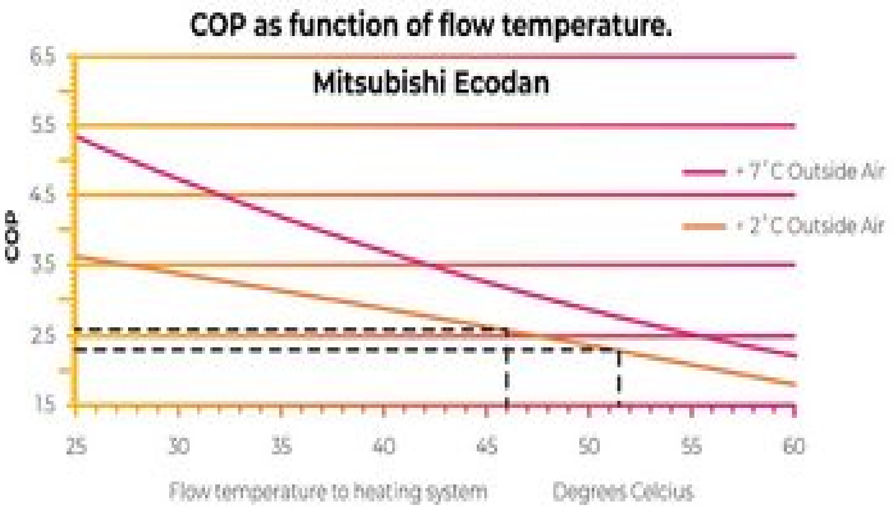


Heat Pump Thermodynamics

COP vs external temp at various flow temps



COP vs. flow temp



Building Regs Part L1 (2021)

- Revision of 2010 regulations
- 5.10 Where a wet heating system is either:
  - a. newly installed
  - b. fully replaced in an existing building, including the heating appliance, emitters and associated pipework
    - all parts of the system including pipework and emitters should be sized to allow the space heating system to operate effectively and in a manner that meets the heating needs of the dwelling, at a maximum flow temperature of 55°C or lower.
    - Where it is not feasible to install a space heating system that can operate at this temperature (e.g .where there is insufficient space for larger radiators, or the existing distribution system is provided with higher temperature heat from a low carbon district heat network), the space heating system should be designed to the lowest design temperature possible that will still meet the heating needs of the dwelling.

Legionella & myths

- “The risk arises when legionella colonises a man-made water system under conditions that allow it to multiply, particularly temperatures between 20°C and 45°C, stagnation, biofilm, and sediment”
- Legionnaires' disease is notifiable under the Public Health (Control of Disease) Act 1984. ACOP L8 and HSG274 guidance (part 2, 75pp), BS 8580-1:2019 *Water quality. Applicable to non-domestic properties*
- Max water temp 60C (Building regs, Part G)

HSG274 part 2

- Domestic Hot Water Tanks (Storage) Storage Temperature:
  ”Hot water should be stored at a minimum temperature of 60°C and distributed so it reaches a minimum temperature of 50 °C (55 °C in healthcare premises)”
- Calorifier Flow Temperatures: Thermostat settings should modulate as close to 60°C as practicable without going below 60°C.

Hot Water Conundrum

- We’re supposed to be running boilers/HP’s at 55C max.
- Yet hot water supposed to be 60C!

SCALD HAZARD

WATER TEMPERATURE (C)	TIME TO 3RD DEGREE BURN
68	1 second
64	2 seconds
60	5 seconds
56	15 seconds
52	1 minute
51	3 minutes
48	5 minutes
37	safe temperature for bathing

https://www.heatgeek.com/articles/legionella-and-water-temperature-what-you-need-to-know

Legionella practicalities

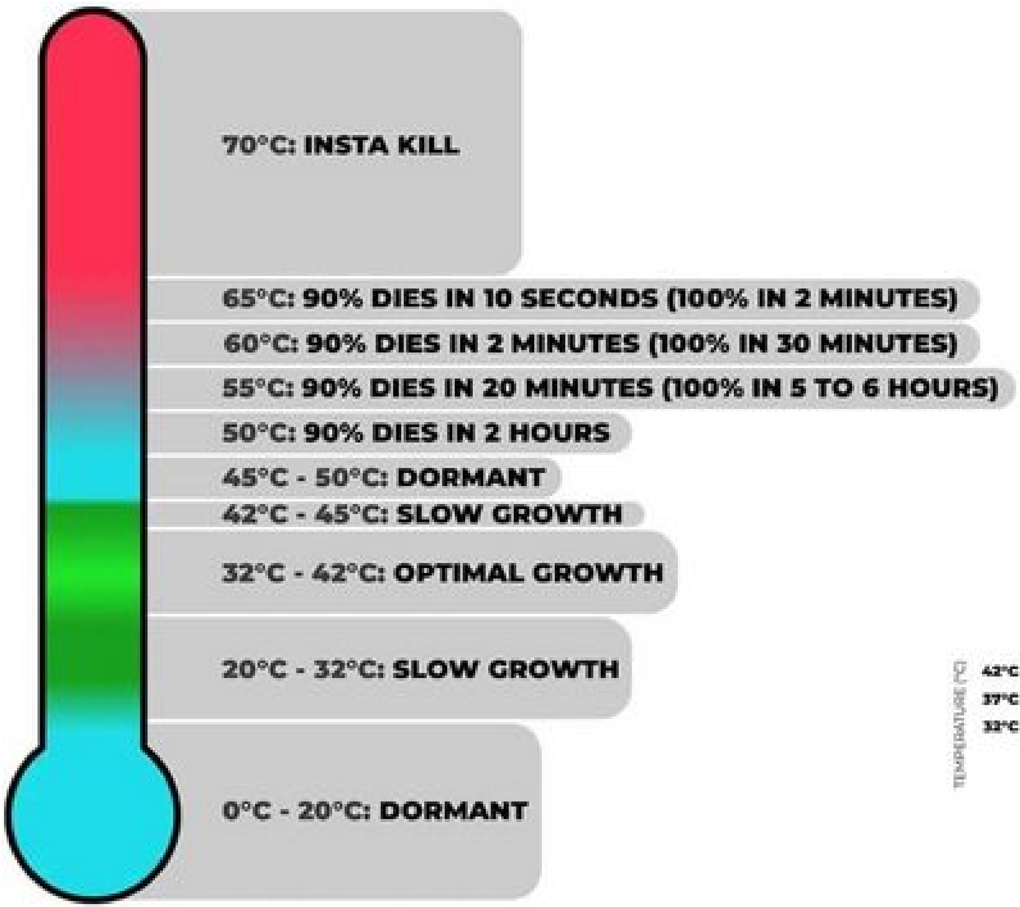
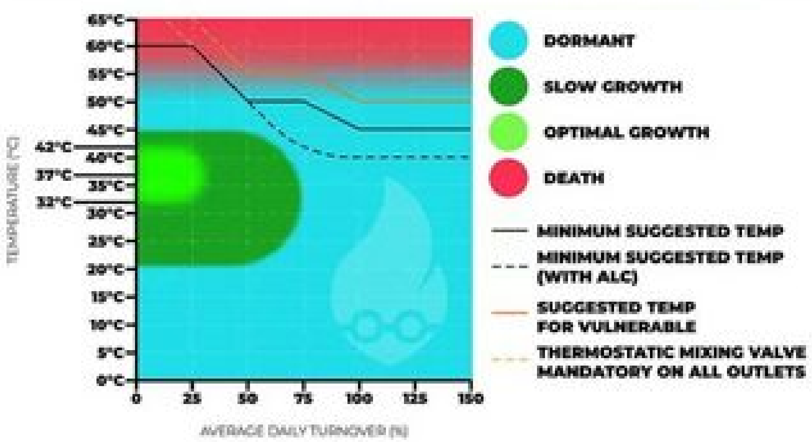


TABLE 1: NUMBER AND PROPORTION (%) OF CONFIRMED CASES OF LEGIONELLOSIS BY CATERGORY OF EXPOSURE FOR CASES WITH SYMPTOM ONSET FROM 1 JANUARY TO 31 OCTOBER 2020

EXPOSURE CATERGORY	SYMPTOM ONSET (JANUARY TO OCTOBER)	
	3 YEAR MEAN 2017 TO 2019 (%)	2020 (%)
COMMUNITY	216 (47.0)	220 (74.6)
NOSOCOMIAL	9 (1.9)	14 (4.7)
TRAVEL ABROAD	186 (40.6)	38 (12.9)
TRAVEL UK	48 (10.5)	22 (7.5)
UNASSIGNED	-	1 (0.3)
TOTAL	459	295



https://heatgeek.com/articles/articles-home?p=hot-water-temperature-scalding-and-legionella

Summary of aims

- Reduce flow temperature: target max 55ºC
- Keep return temp as low as is practical ("DT=20")
- Ensure load at least matches boiler's min output, then keep load as low as possible above min, to increase efficiency
- Reduce normal max Domestic Hot Water (DHW) temp to suit you, not the installer (48ºC enough?)
- Consider your risks and adjust any Anti-Legionnaires Cycles (ALC) accordingly (not required for combi's)
- Reduce dead paths
- Reduce DHW flow rate to a cylinder if it suits your lifestyle?

System designs & components

Underfloor heating

2 types:

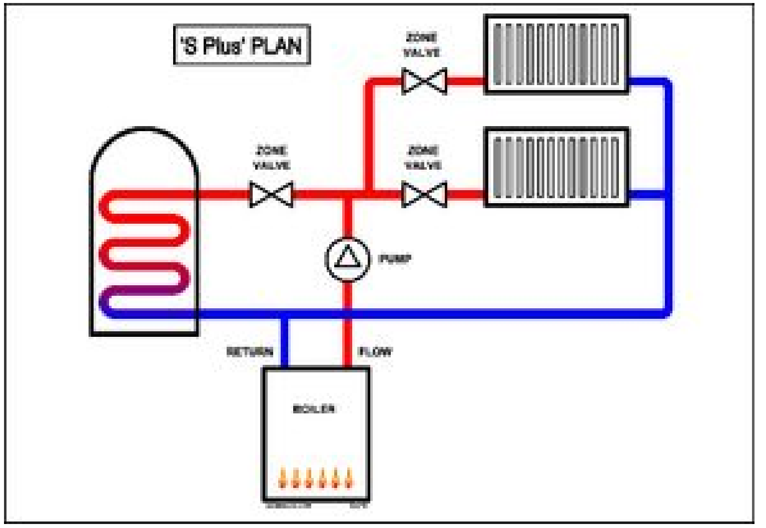
- Concrete slab (extension)

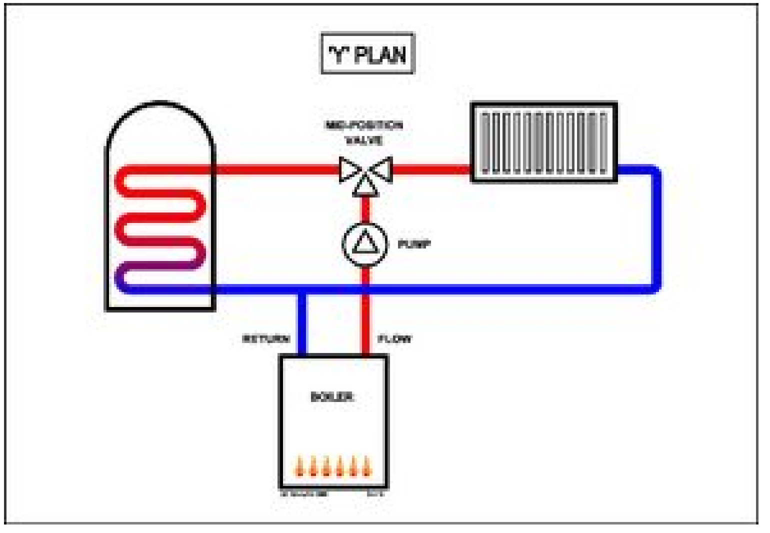
- Suspended wooden floor (as original)

+ **Conventional radiators**

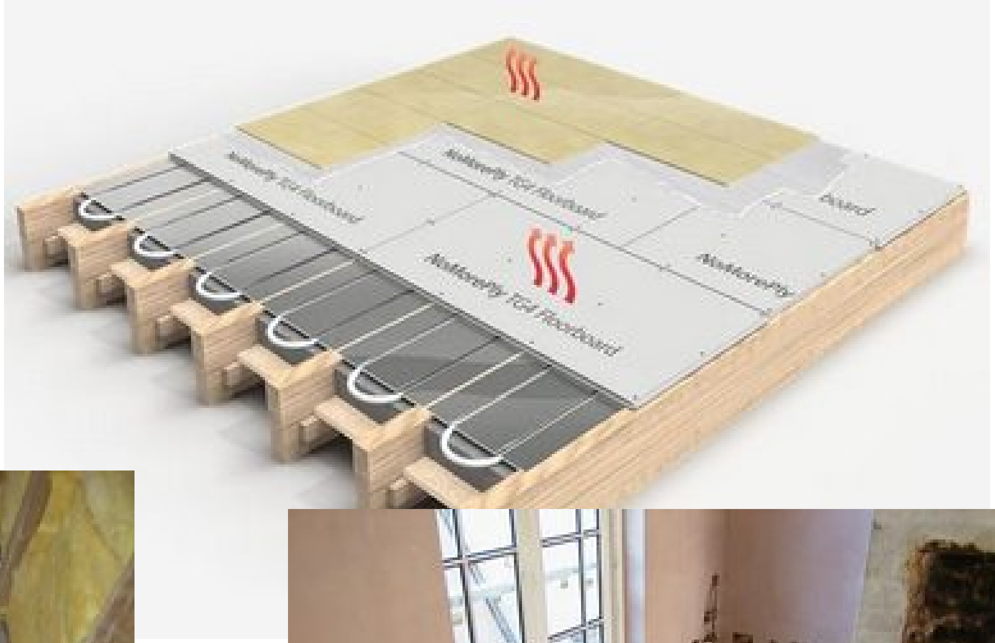
Typical System Layouts

- ‘S-Plan’/’S-Plan plus’ means separate zones, both DHW and heating are separately controlled
- ‘Y plan’ involves less plumbing, only 1 zone valve, lower flows, which may actually be preferable.
  ‘W plan’ is a variant: ‘either/or’, normally ‘DHW priority’





Under Floor – slab or timber



Manifold & Wilo electronic pump

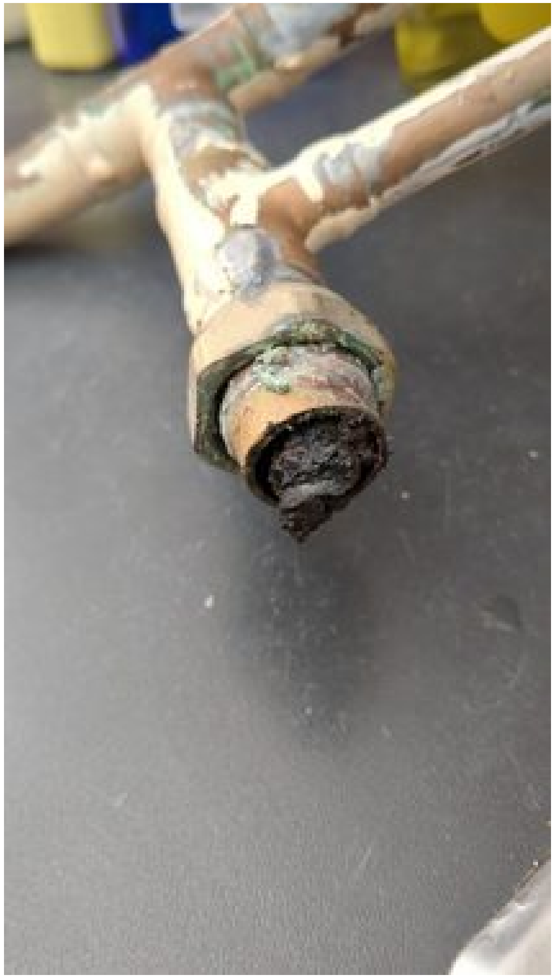
Physical Improvements

- The following are all straightforward DIY!

Double-up the radiators!

- Adjust the lockshield valves to reduce return temps
- Type 11 → Type 21 +45%
- Type 11 → Type 22 +70%
- Type 11 → Type 33 +140%
- Adapters for old-new metric spacings £4
- More output from larger rads → lower return temperature ☺

Plumbing Horrors!



Electronic pump

- Power consumption typ. 10-25% of an old pump (35/45/50W) ➜ 5-10W
- Regulations make it easy to swap!
- Cost ~£120
- Magnetic filter also essential, about same price

Watts

m^3/hr (x 16.66=l/m)
~ 6.7 l/m

Summary of mechanical improvements

- Minimal effort by anyone: Reduce radiator return temperatures by adjusting ‘lockshield’ valves
- DIY tasks:
  - Switch radiators to larger ones to reduce return temperatures
  - If possible, swap to a variable speed electronic pump to reduce running costs, better control flow rate + diagnostics
  - Keep primary water as “CLEAR AS GIN” – add a magnetic filter if none exists + clean it! Use inhibitor.

What’s new for boilers?

- Ion flame detection approximately halves previous min load to ~3kW
- Internal electronic pumps allow lower flows, better control, integration & performance
- Control & monitoring:
  - Since 2005, Vaillant boilers have had eBus
  - Vaillant Heat Pumps also use same eBus
  - Viesmann and Worcester Bosch mostly use a proprietary bus
  - Others have ‘OpenTherm’

Recent boiler Improvements

Manufacturer	Ion detection Technology Name	UK Introduction Date	Max Modulation Ratio	Lowest o/p for ~20kW boiler	Native Serial Bus Protocol	Bus Type
Vaillant / Gloworm	IoniDETECT	2021 (ecoTEC Plus)	1:10	2.7kW	eBUS	Proprietary
Viessmann	Lambda Pro / Pro Plus	2001 (Pro) 2019 (Pro Plus)	1:17	1.9kW (200W premium), 3.2kW for 50/100W models	PlusBus (Newer models) KM-Bus (Older models) (100-W range natively uses OpenTherm	Proprietary / Universal
Worcester Bosch	Air/Gas Ratio Control	2019 (Greenstar 8000)	1:12	3.1kW	EMS / EMS+ (Energy Management System)	Proprietary
Baxi	ACC (Adaptive Combustion)	2019 (600/800 Series)	1:10	4.8kW	OpenTherm	Universal / Standard
Ideal	Intelligent Combustion Control	2023 (Logic Gen 2 / Vogue)	1:13	3.7kW	OpenTherm	Universal / Standard

Control - what do we need?

- Setup of key parameters, local and/or remote
- Visibility of how the system is running – KPI's
- Remote control of flow temperature (automation: load, mode [heating/water], weather) via the bus
- Energy data

Boiler fixed settings: summary of suggsted improvements

- ‘Range Rate’ a boiler to reduce max output, 10-12kW is often enough! Will prevent boiler running at max when starting or in DHW cycles
- Set max flow to suit (65^{o}C?)
- Set your system to target DT if possible (on Vaillant via pump mode - ‘spread DT’) – reduce pump speed

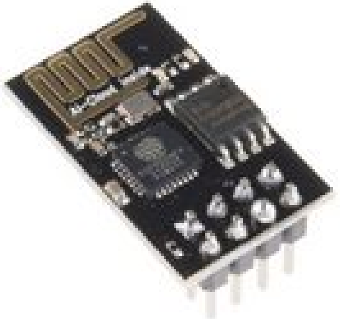
Home Automation Recap

From 2022…

Adding eBus

Setting the Scene : Enabling Technologies

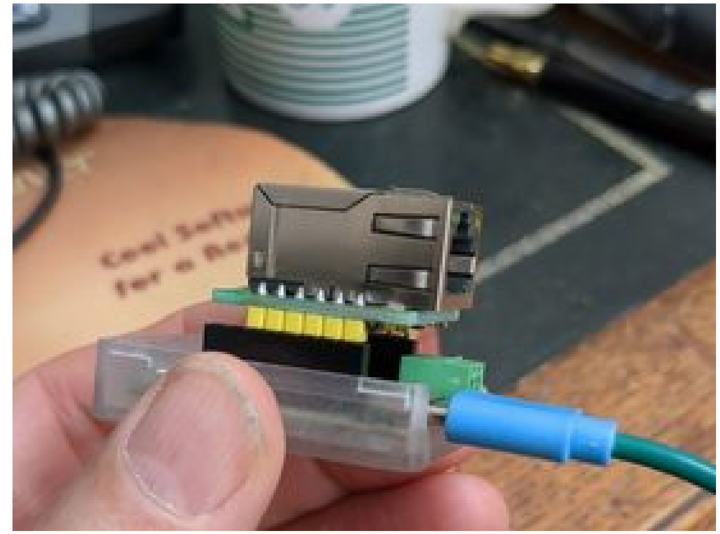
- Networking – wired & wireless
- Re-purposing / recycling / upcycling of existing products and hardware by open-source enthusiasts ♻
- Cheap, reliable PC's, with low-*ish* energy consumption
- Raspberry Pi ♻
- Low cost modules like ESP2866: ~~TASMOTA~~*
- ~~Wake-On-LAN, Sleep-On-LAN, Intel AMT~~
- Internet/RSS data feeds (e.g. weather)
- XML
- ~~IBM's MQTT*~~
- eBay and similar marketplaces ♻

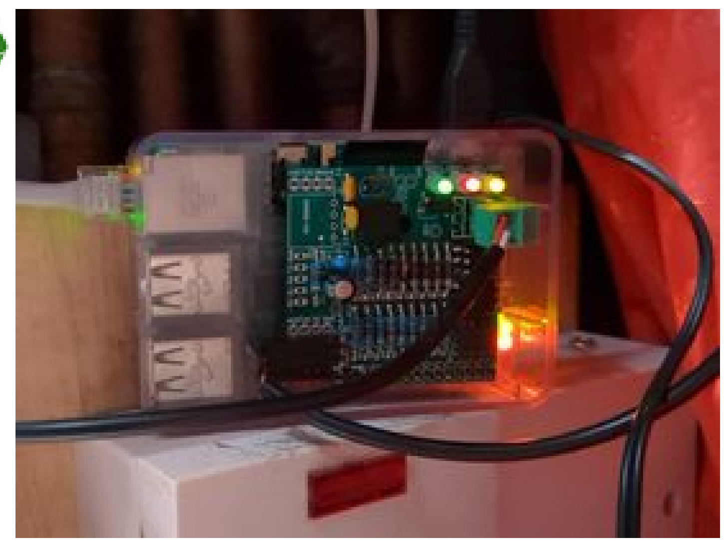


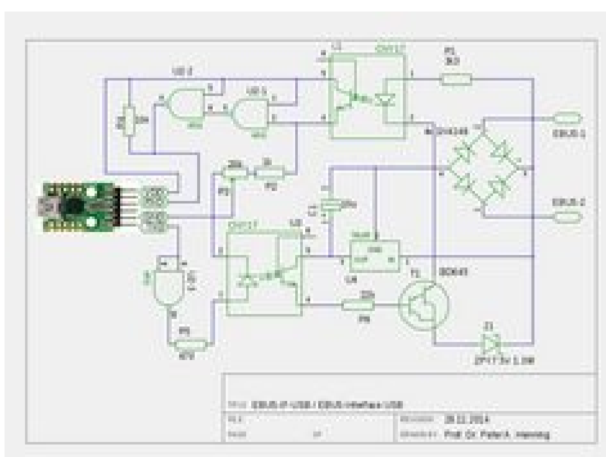
* Not used

eBus adapters

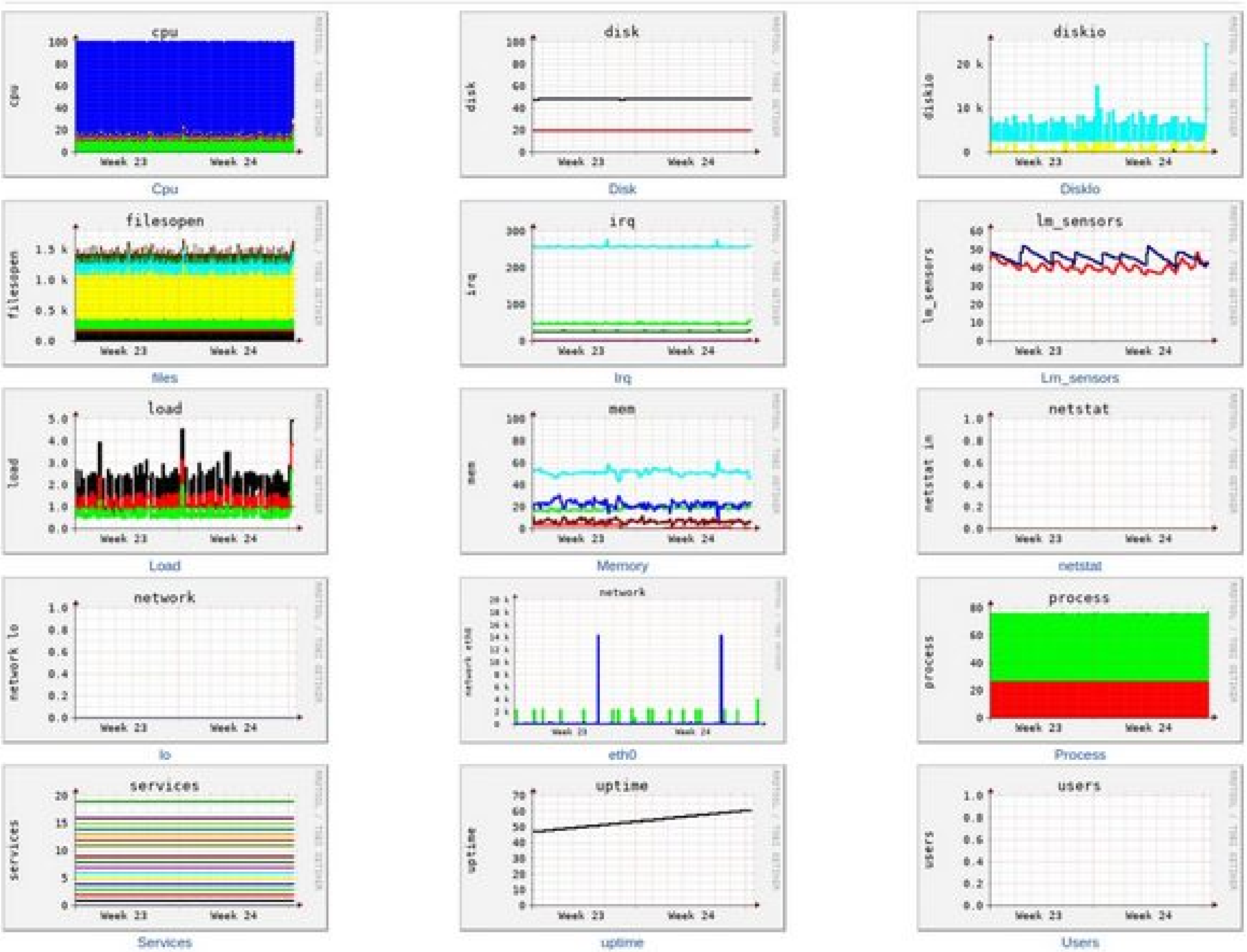
- ESP32 vs. Raspberry Pi 1 with adapter
- Same functionality, but Rpi significantly more reliable (~1yr uptime)
- Plenty of Commerical & DIY options (https://wiki.fhem.de)
- Need a machine to run ebusd & owfs (temp measurement) from Github. A recycled Rpi1 can do both easily, as shown







Raspberrypi monitoring - Webmin



eBus complete data!

Open Source ebusd (ebus daemon) uses a set of config files, talks proprietary eBus protocol to the heat pump or boiler, and produces the JSON above on demand via http/terminal client. Also other network transports (MQTT, KNX...)

ebusd Important JSON data

Type (Boiler/HP/SW/HW...)
ConsumedElectricalEnergyHeating
ConsumedElectricalEnergyHW
ConsumedPrimaryEnergyHeating
ConsumedPrimaryEnergyHeatingLastYear
ConsumedPrimaryEnergyHeatingThisYear
ConsumedPrimaryEnergyHW
ConsumedPrimaryEnergyHWLastYear
ConsumedPrimaryEnergyHWThisYear
DateTime
FanHours
FanSpeed
FanStarts
Flame
FlowTemp
FlowTempDesired *


```
"scan.08": {
"messages": {   "": {
  "name": "",
  "passive": false,
  "write": false,
  "filename": "",
  "level": "",
  "lastup": 1780613864,
  "zz": 8,
  "fields": {
   "MF": {"value": "Vaillant"},
   "ID": {"value": "BAI00"},
   "SW": {"value": "1104"},
   "HW": {"value": "7603"}
  },
```


HcHours
HcPumpMode
HcPumpStarts
HcStarts
HwcStarts
HwcTemp
ModulationTempDesired *
PumpHours
PrimaryCircuitFlowrate *
PumpPower
ReturnTemp *
SetmodeOverride *
TargetFanSpeed
WaterPressure
WP
datetime
error


```
"WaterPressure": {
 "name": "WaterPressure",
 "passive": false,
 "write": false,
 "filename": "vaillant/bai.0010015600.inc",
 "level": "",
 "lastup": 1780613863,
 "zz": 8,
 "fields": {
  "press": {"value": 0.992},
  "sensor": {"value": "ok"}
 }
},
```

Heating control

Radiators are easy!

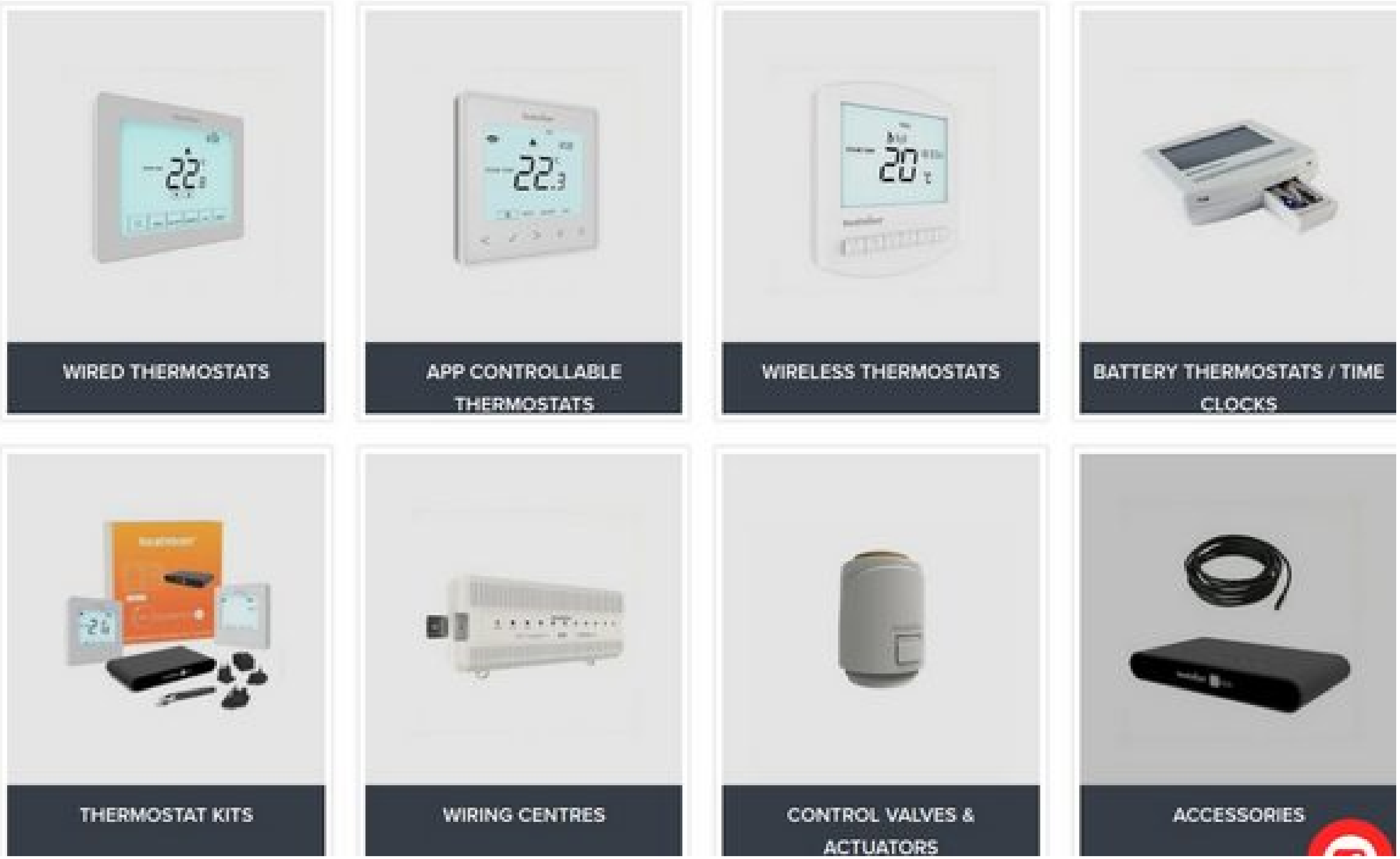
Under Floor Heating may require complex control, few refs!

Radiator control strategies

- Inputs:
  - Typical rate of rise*
  - Current weather and external temp
  - Internal temp
- Outputs
  - Start time
- (separately: Flow temperature based on external temp)

* was 1°C / 25 min. Now 1°C / 40-45 min, a result of improvments:
- lowering of flow temp
- reduction of flow through radiators as a result of measuring return temps and setting lockshield valves
- Same room temp

Simple Controls



Typical Vaillant controls

- External temp sensor and VRC430 weather compensator
- Set schedules, set room temp and DHW temps, heating curve

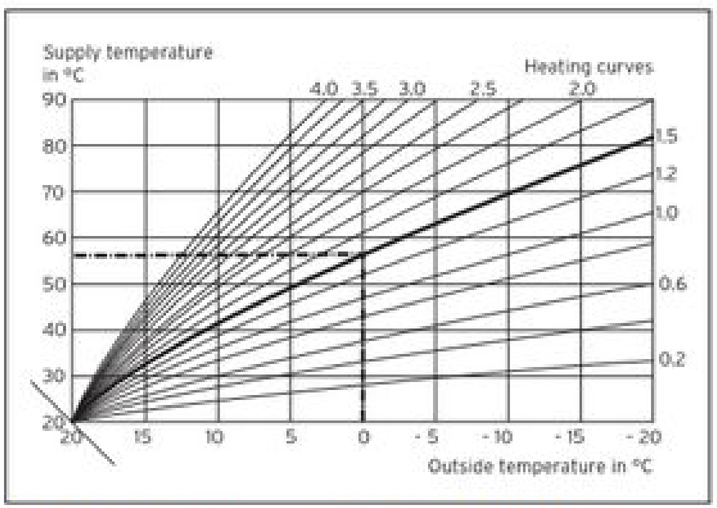


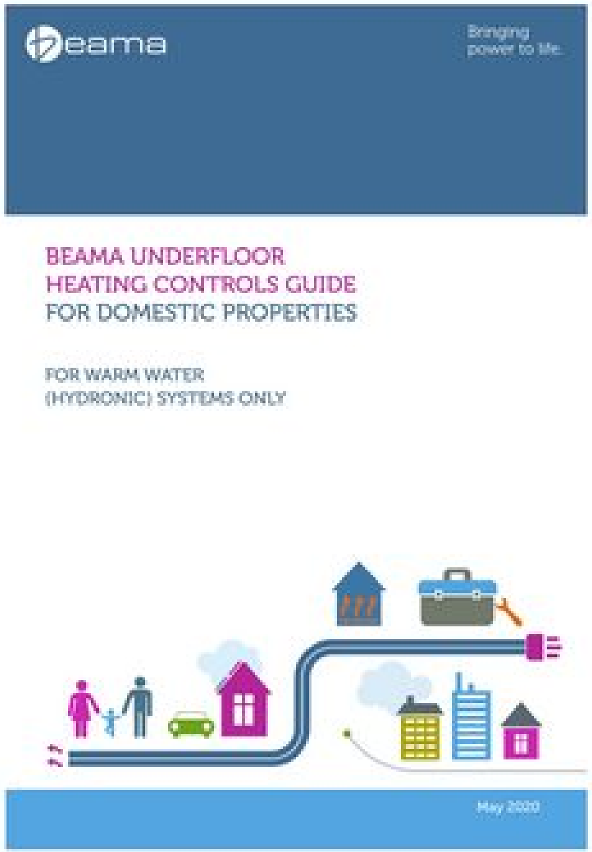
Fig. 4.15 Diagram with heating curves for a target room temperature of 20 °C

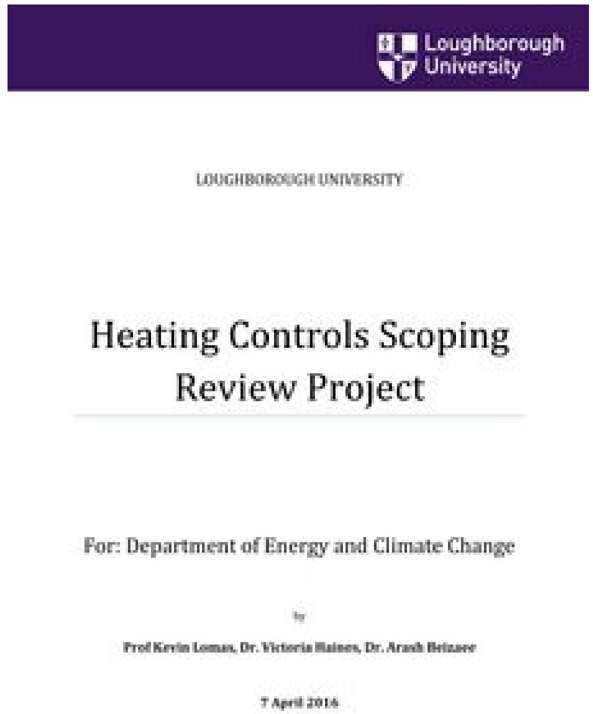
Heatmiser control

Good insulation, radiators

Good insulation but UFH means longer on time, spaced farther apart

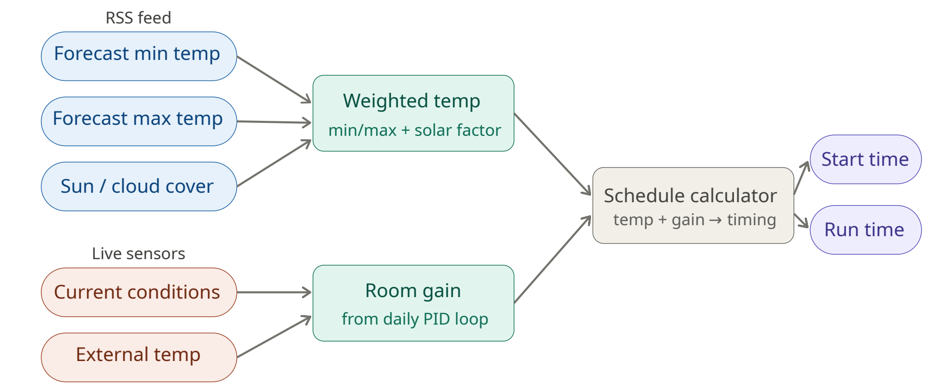
UFH Control refs - all recent

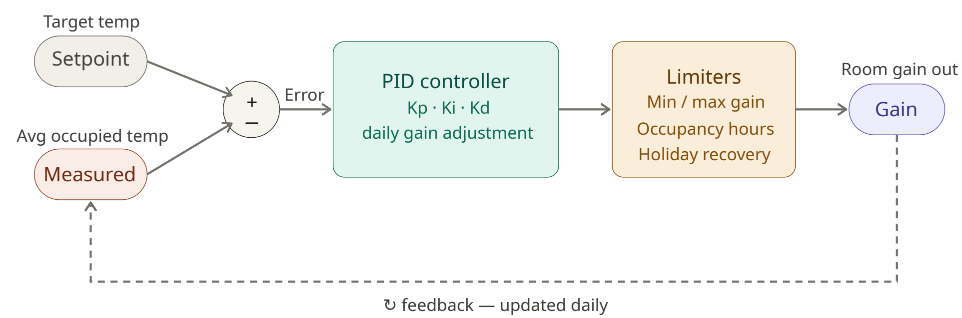




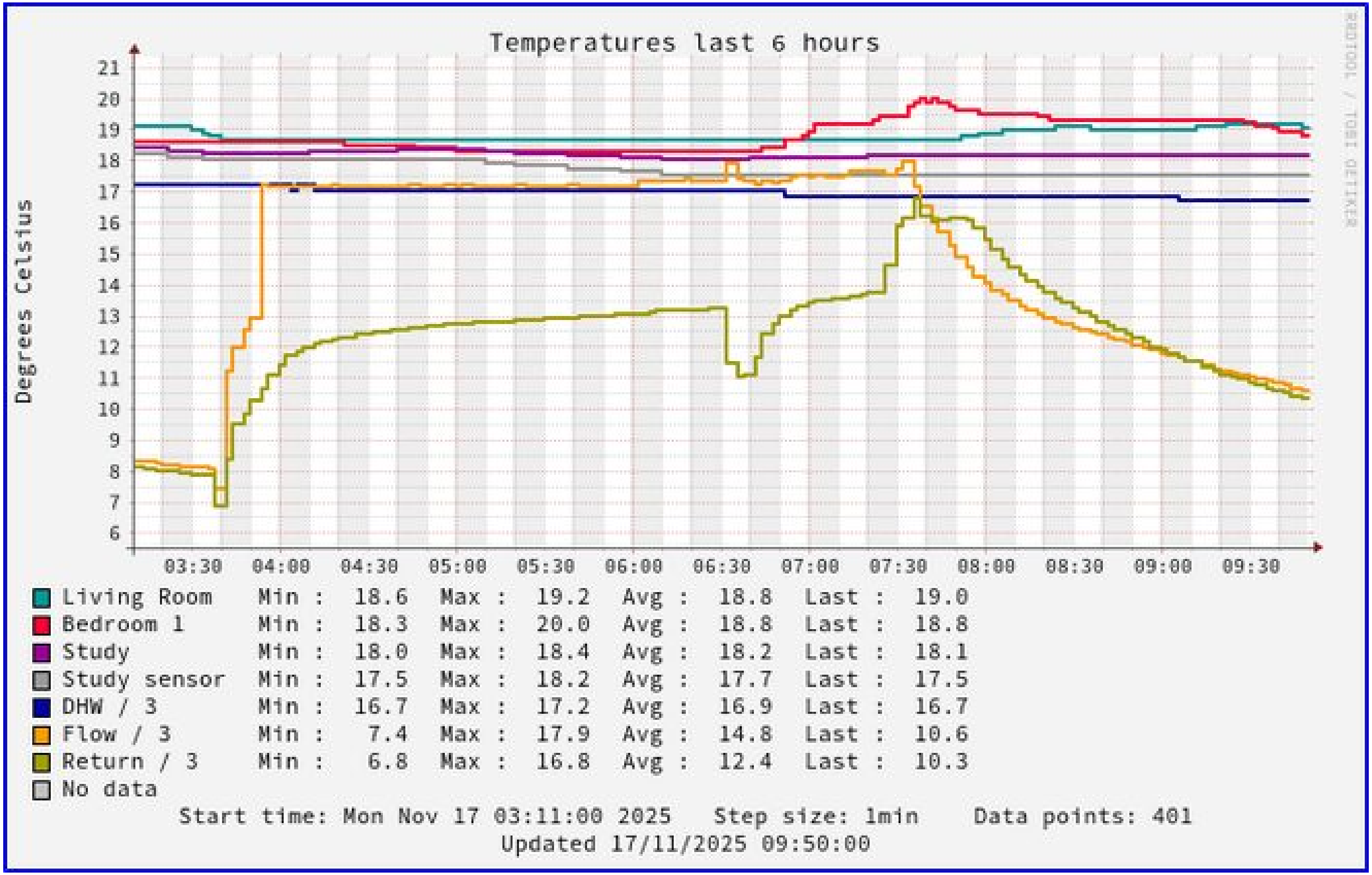
UFH Control strategy

- **Concept: “Offset Overnight Losses”**
- Inputs:
  - Prediction of min/max temp & sun via RSS weather feed, sunrise time
  - Current weather external temp
  - Room Gain (seasonally variable)
  - Occupancy
- Outputs
  - Run time
  - Start time
- Room temp is just a cutoff
- Learning: PID control loop for average temp over a day
- Error typ. 0.1...0.2°C
- (separately) Recent addition with ebus control Flow temperature based on avg external temp. Reduces seasonal room gain variation

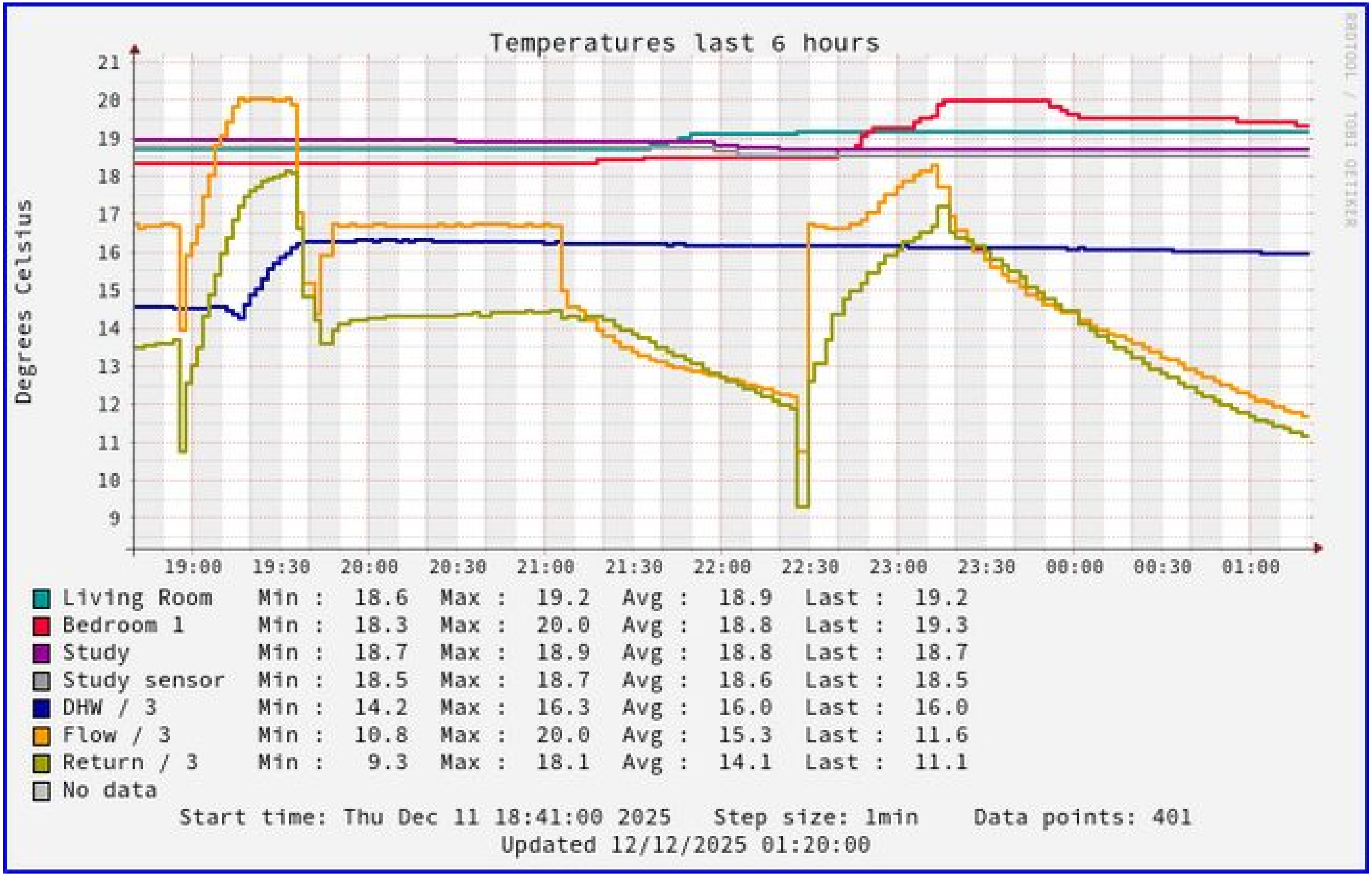




Graph 1 – flow temp control



Graph 2 +DHW cycle



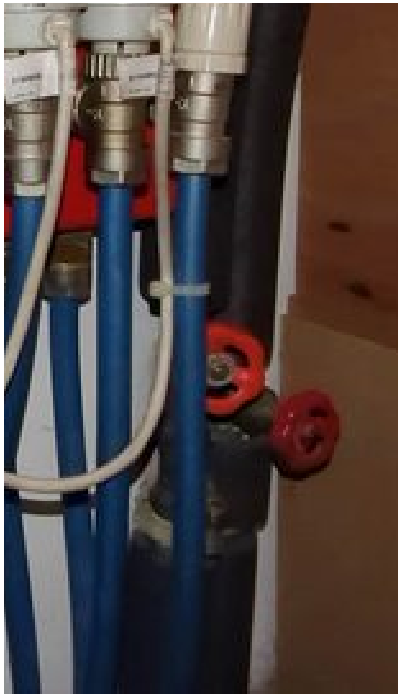
DHW control

A hot water tank as a known load is useful for testing control strategies.

Heating is too variable (weather, occupancy…) for meaningful results, except over extended periods

Increasing DHW efficiency

- Lower the losses, inc. pipework (insulation)
- Building regs Part L requirement: $0.85 \times (0.2 + 0.051\ V^{2/3})$
- For 210L shown, = 1.7 kWh / day max loss
- Megaflo (2004) spec without extra insulation jacket = 1.57kWh/ day
- Actual losses: 0.8 -1.2kWh / day with extra BS 5615 jacket over factory hard insulation
- Reduce flow temp (60/65 ALC)
- Reduce dead paths
- Limit return to 54°C
- Reduce coil flow rates with full flow lever valve (?)



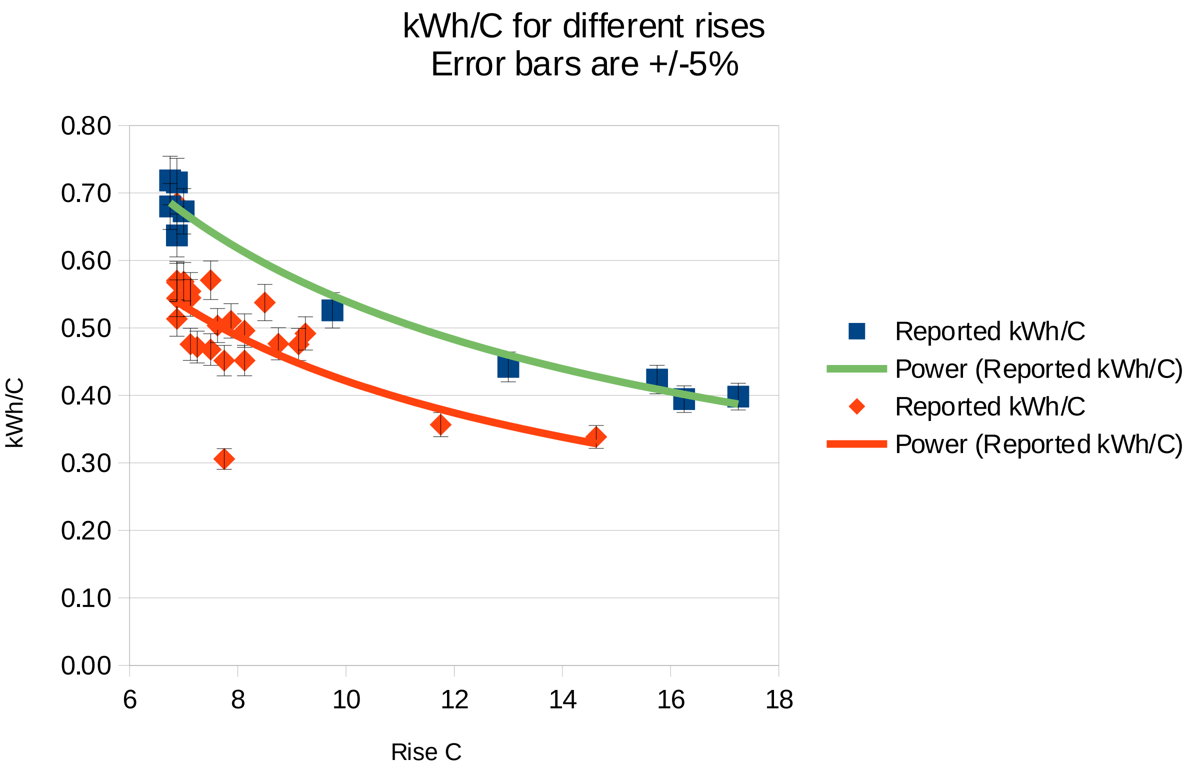
A typical DHW cycle

Automation: Flow Temp Target

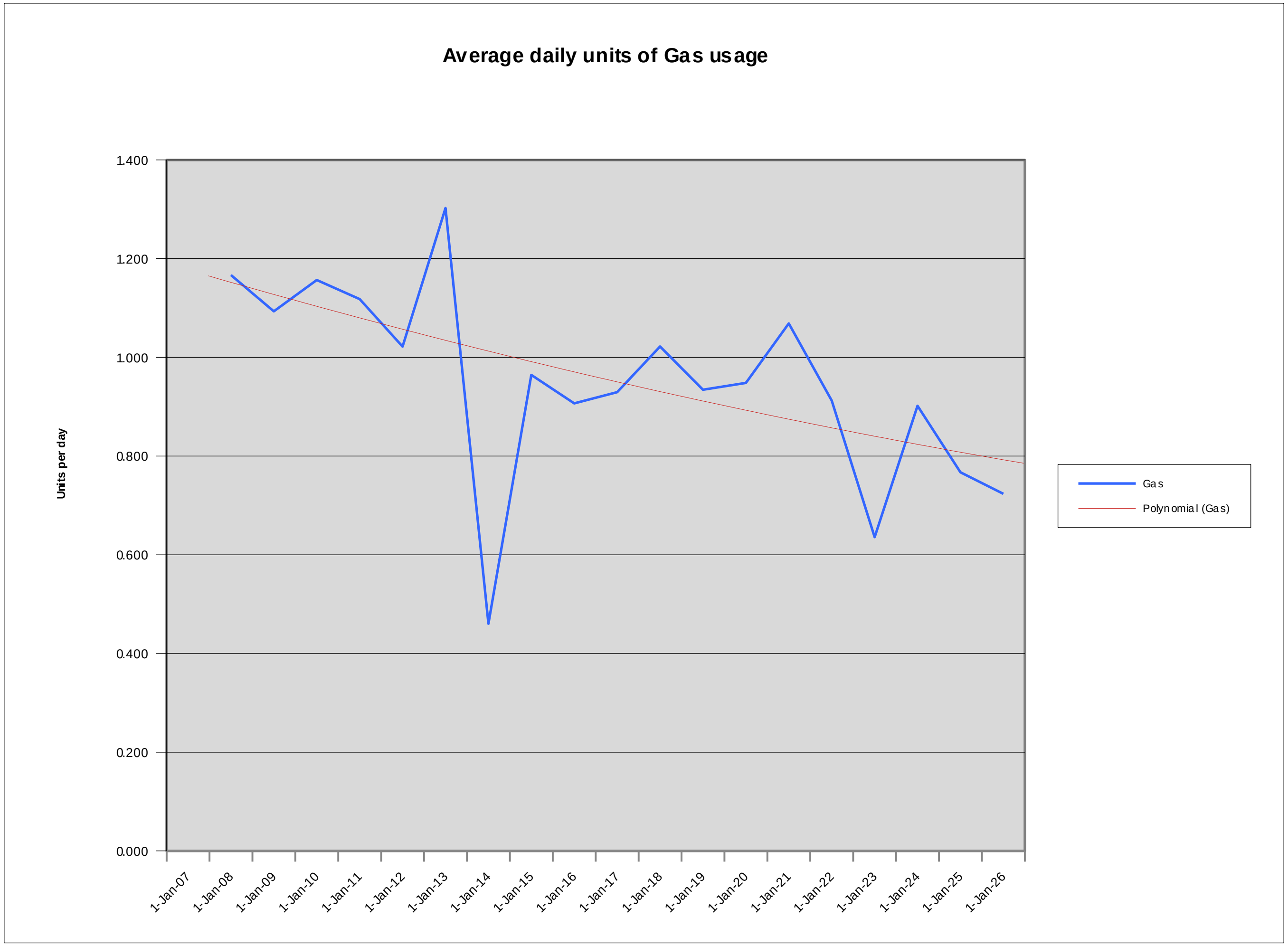
```
13/06/2026 07:00:11 60.0 set_by=DHW

13/06/2026 07:27:16 59.2 set_by=DHW, limited (return over 54 by 0.4)

13/06/2026 07:29:13 60.0 set_by=DHW

13/06/2026 07:31:15 58.4 set_by=DHW, limited (return over 54 by 0.8)

13/06/2026 07:33:15 59.3 set_by=DHW, limited (return over 54 by 0.1)

13/06/2026 07:34:43 59.6 set_by=DHW, limited (return over 54 by 0.1)

13/06/2026 07:35:17 58.0 set_by=DHW, limited (return over 54 by 1.0)

13/06/2026 07:37:17 58.4 set_by=DHW, limited (return over 54 by 0.7)

13/06/2026 07:39:17 58.0 set_by=DHW, limited (return over 54 by 1.0)

13/06/2026 07:45:10 45 set_by=DHW-ended
```

DHW efficiency savings

- Eliminate a dead path (UFH leg in this case)
  = 24% saving here (normal cycles - red vs green shown)
- 54°C return temp limiting = 12%
- Coil flow restriction
  = 11% (ALC cycles)
  = 3% (normal cycles?)
- Note that a larger range for same target temp is overall more efficient per °C, may explain above differences for restricted coil flow
- Theoretical for this tank is 0.23 kWh/°C



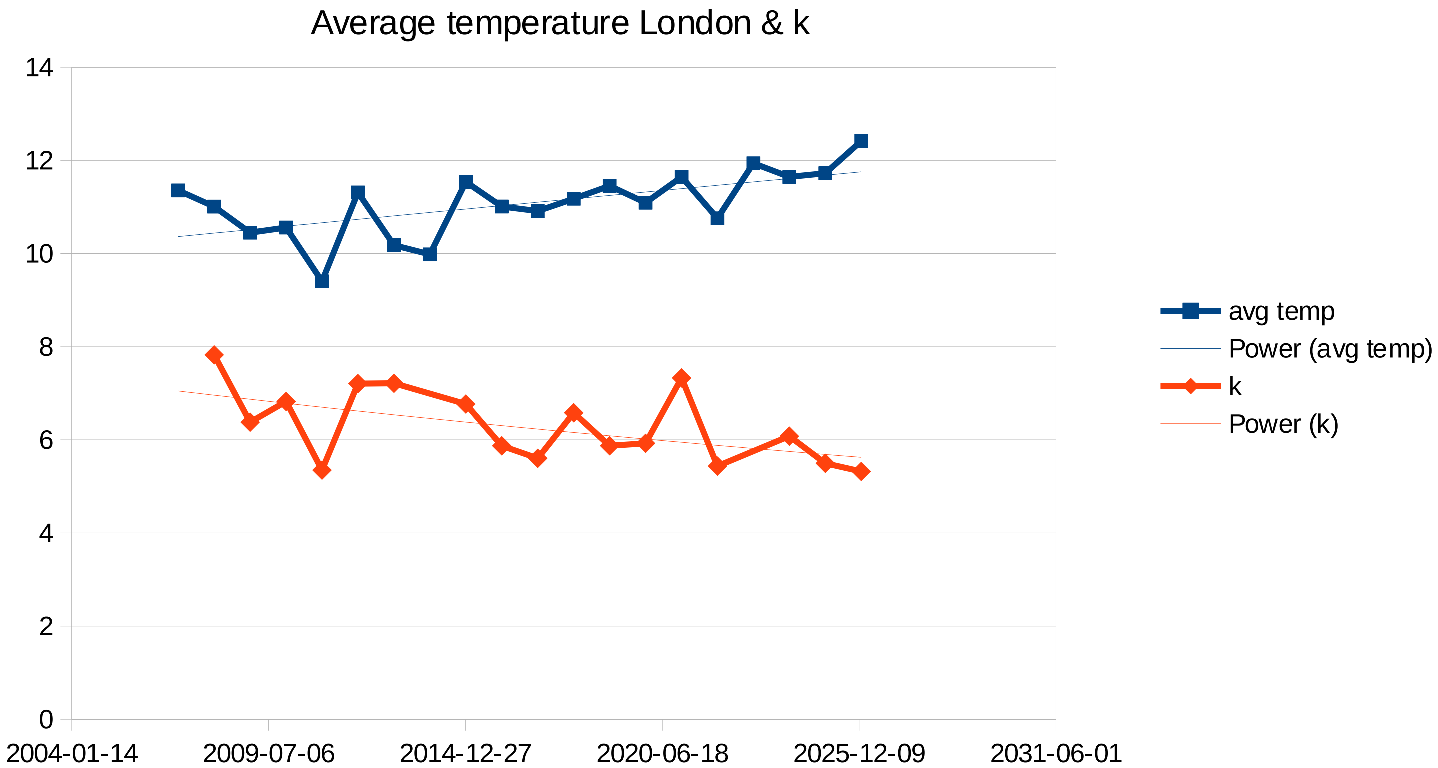
Actual Gas usage 2006-2026: ~35% reduction



Average of last 2 yrs (since new boiler) vs. representative sample of previous 10 yrs = 22.5% reduction

2008: 13536 kWh
2026: 8369 kWh

Climate will have had an impact!



Average k
last 2 yrs
(since new boiler)
vs.
representative
sample of
previous 10 yrs
= 12% reduction
Unclear if HDD is representative in this case

Heating Degree Days (HDD) is the UK standard metric — it measures how far daily mean temperature falls below a baseline (typically 15.5°C in the UK) and correlates strongly with gas/heating consumption.

Gas consumption (kWh) ≈ k × HDD, where k is your home's heat loss coefficient. A typical UK semi-detached uses ~12,000–15,000 kWh/yr for heating. Plotting annual gas bills against annual HDDs should give a near-straight line.