

Thermal Integration Ltd.

SBRI Project No: 10032027

Open Digital Solutions for Net Zero Energy

Open Source Plumbing Controller

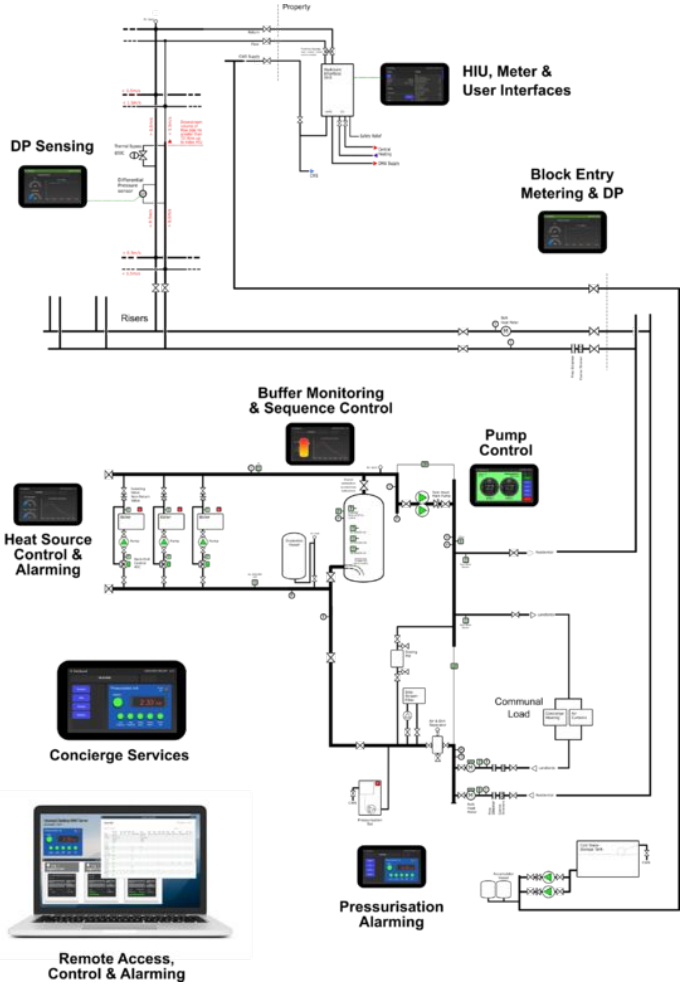
Our solution: An Open-Source Plumbing Controller

Our open-source plumbing controller can connect to almost all HVAC sensors/devices and provides an open-source software environment for control and communications

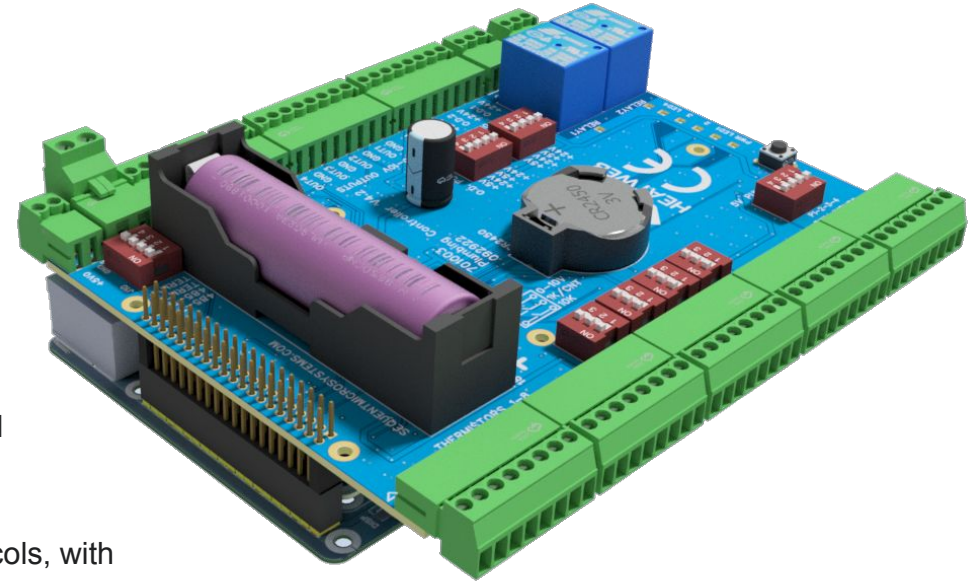


We will further develop our current Version 1 prototype, which has the following characteristics:

- **Hardware** – Heating Interface Unit
- **Software** – Node-RED
- **Communications** – MQTT open protocol



Plumbing Controller I/O Board (Version 4)



- 8 x dedicated NTC temperature sensor inputs
- 4 x universal inputs for volt-free contacts, 100Hz pulse signals, 0-10V signals, and 1k/10k NTC thermistors
- 4 x volt-free / 100Hz pulse inputs
- 2 x 10A change-over relay outputs
- 4 x PWM inputs with jumper switched pull-up resistors and voltage comparators
- 4 x PWM sinking outputs with jumper switched pull-up resistors in both 5v and 24v
- 4 x 0-10v analogue outputs
- 2 x RS485 lines for Modbus or bespoke protocols, with jumper switched terminating resistors
- On-board Modbus for daisy chaining multiple I/O boards
- M-Bus meter communications
- On-board battery supported uninterruptible power supply to all equipment
- Real time clock
- General purpose input button
- 3 x user definable LEDs

- Fan control and connector
- Runs from a 12v power supply
- 24v uninterruptable output power for valves generated on-board
- 5v uninterruptible output power for sensors generated on-board
- 36v uninterruptable output power for M-Bus generated on-board

Controller Board Options

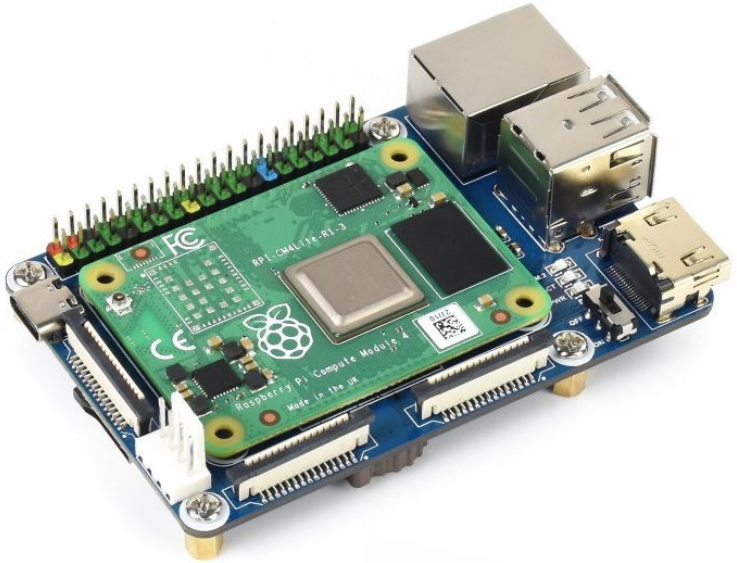
The primary processing unit used for the controller development is the **Raspberry Pi CM4 Compute Module**.

- Well developed and industrial grade
- Range of flash memory and processor sizes
- Advances feature set

The Compute module sits into a Controller Base Board, providing USB, Ethernet and display interfaces as standard.

The Compute module communicates directly with the I/O board using I2C and three UARTs.

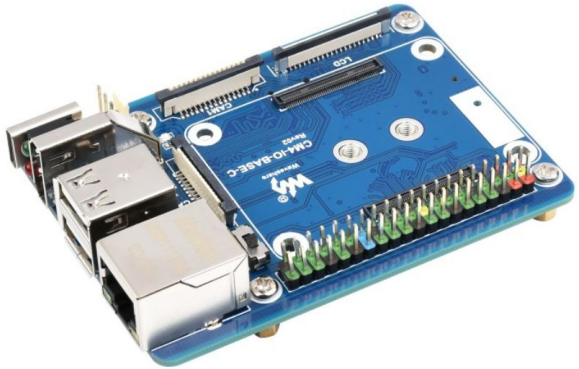
Alternatively, all models of the Raspberry Pi, and Beaglebone are compatible with the I/O board, as well as the ESP32 controller.



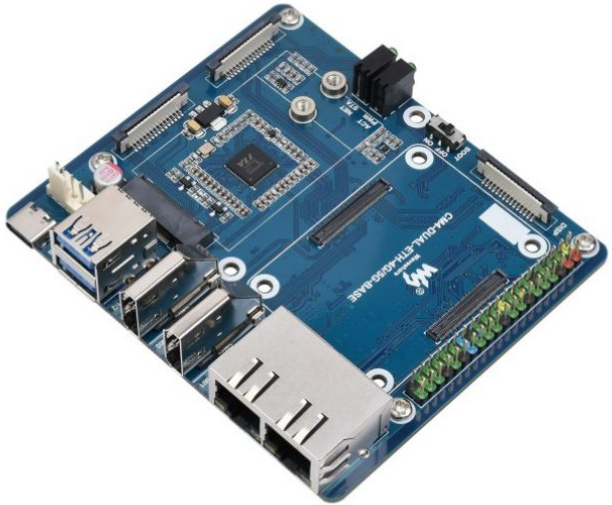


Controller Board Options

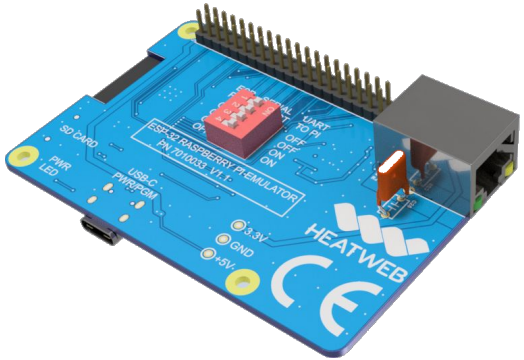
Variants on the Base Board allow for additional communications options, including GSM modules. These include the Minibase Board, Dual Ethernet base board & ESP 32.



Waveshare
Mini Base Board



Waveshare
Dual Gigabit Base Board



HEATWEB
ESP32 Raspberry Pi Emulator

Enclosure Design

The final enclosure design has nearly been completed, with the 2nd 3D rapid prototype in hand and tweaks being made to improve fit and function.

3D CAD has allowed us to model and assemble the controller in its final layout, before going into production.

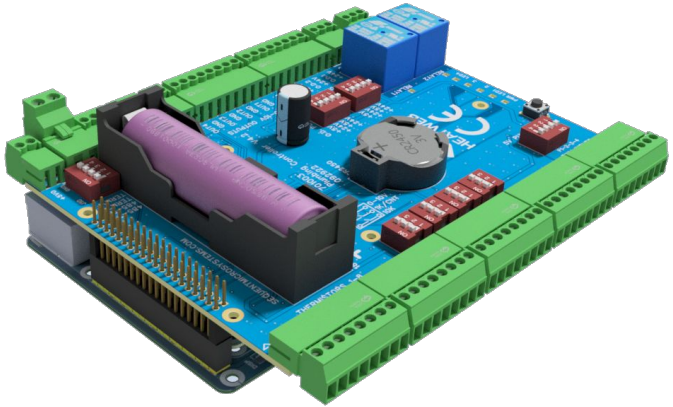
We are currently designing enclosure labels, with custom labels intended on terminals for different applications.



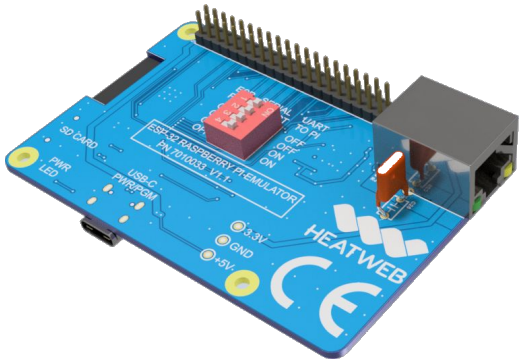
CE Certification

Each of the PCBs developed for this project has been tested and found in compliance with the council EMC Directive 2014,30,EU.

We also plan to apply for UKCA approval, with the same approvals body, on future production runs.



Heating Controller
Cert. No.
POCE230403637TCE



ESP 32
Cert. No.
POCE230403635BCE



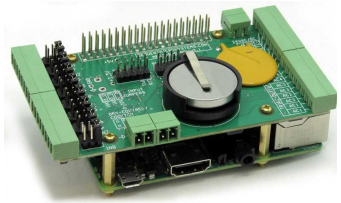
LCD Display
Cert. No.
POCE230403636YCE

Comprehensive Suite of Products to suit Applications



Plumbing IO Board

- Plumbing I/O
- 2 xRS485
- M-Bus
- Battery Backup



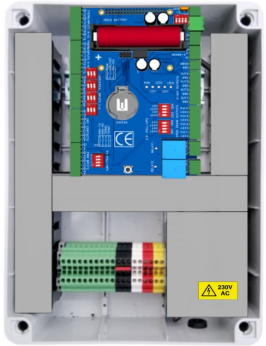
BA Board

- 8 x Universal Inputs
- 4 x 0-10v Outputs
- 3 x Triac Outputs
- 1 Wire
- RS485



Control Panels

- Standard & Custom
- Metal Cabinet
- Touch Screen



Application Enclosures

- Working Control Panel
- Customised to Application
- Pre-Wired
- Connected to Cloud and ready to turn on





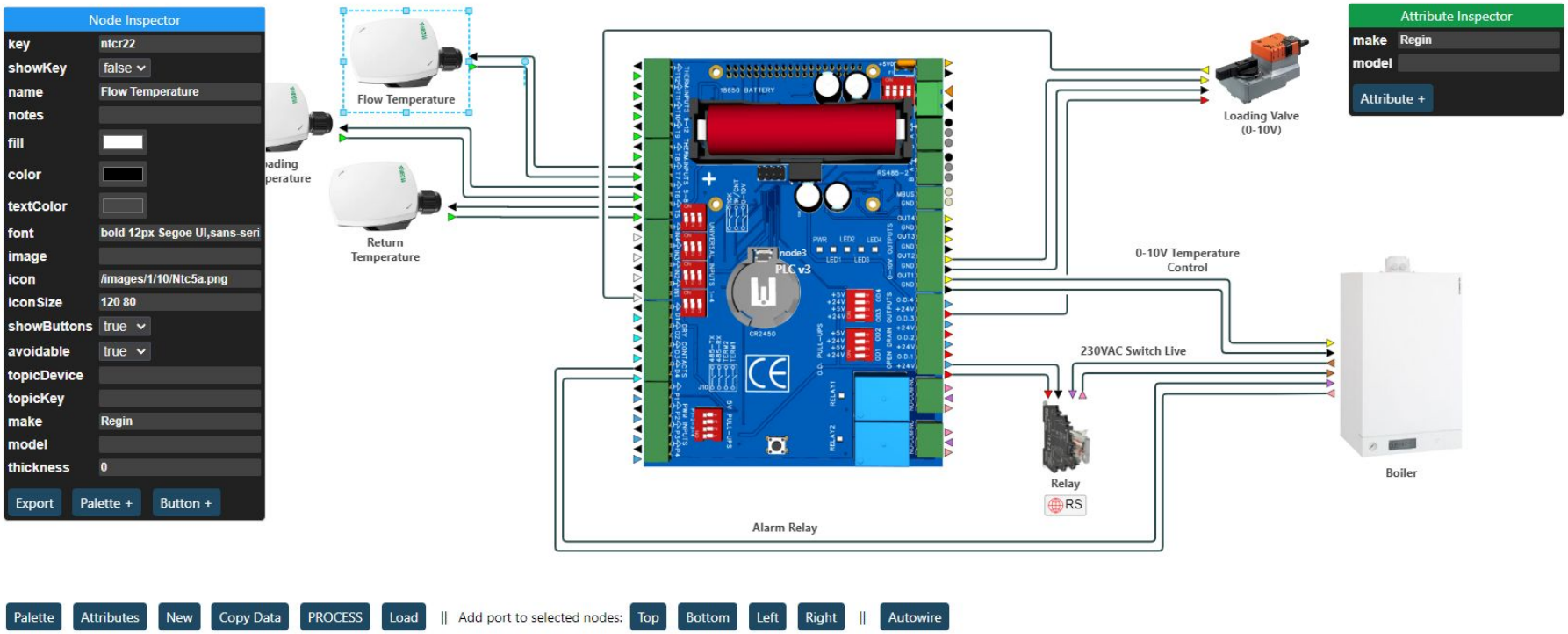


EnOcean Gateway & Wireless Sensors

- Ethernet, WiFi
- LTE Modem
- EnOcean Wireless
- Energy Harvesting
- CO2, Temperature, Humidity, Volt-Free Contacts, CT Current Clamps, & more

Wiring Editor

As part of the project we are delivering tools for generating application software from visual wiring diagrams based on drag-and-drop functionality and automatic wiring. https://hwwiki.ddns.net/index.php/Wiring_Editor



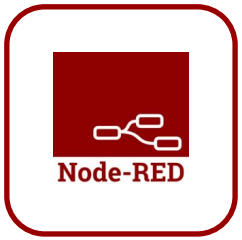
Software: Open Source Controls Stack

All software used on the controller is open-source and licence free. We have refined the software architecture to deliver a robust, modular framework, built on battle hardened core technologies.



Controller applications and services are deployed in docker containers.

- **Easy to manage and update software**
- **Version control** - with public and private repositories
- **Reliable** - applications isolated from host system



Applications are built using Node-RED for logic, control and data routing.

- **Open source** – completely unlicenced and open with extensive community support
- **Powerful, but user friendly** – a visual programming interface combined with code
- **Customisable** – custom functions can be refined and published as Nodes

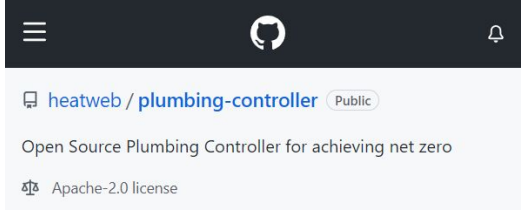


Communications are driven through MQTT protocols.

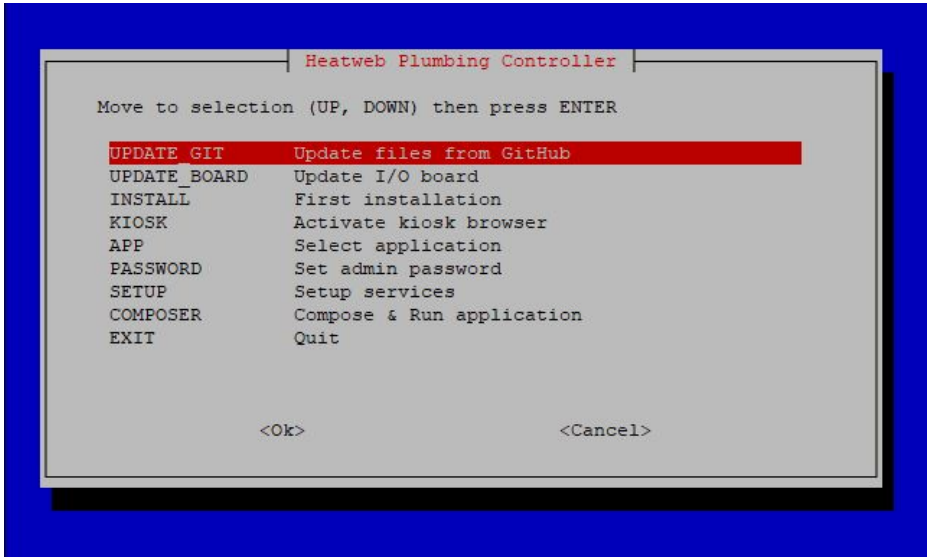
- **Open standard** – completely unlicenced and used by millions of systems
- **Publish/Subscribe operation** – using topics and values to describe data
- **Fast & Secure** – built in user management and topic/user based rules systems

Software: Getting Started

We have made getting started with open source controls as easy as running a single command to install from GitHub.




```
bash <(curl -sL https://raw.githubusercontent.com/heatweb/plumbing-controller/main/scripts/start.sh)
```



Installation is automated via a user friendly menu system that can be run over SSH.

The menus allow one to:

- Install and manage services
- Update I/O board firmware
- Build and update applications based on Node-RED and Docker building blocks
- Update passwords on all services using a single command

Cloud Systems

We have completed the design and implementation of our open cloud infrastructure, built around an Influx database and Grafana for visualisation.

influxdb
Time series database for holding historic timestamped data

+

Grafana
Graphing and dashboarding

The same components that run in the cloud, also run in controllers, unifying the architecture across all systems.

The choice allows for a completely open source approach to implementation, licence free, or to switch over to hosted commercial services where additional support is required.

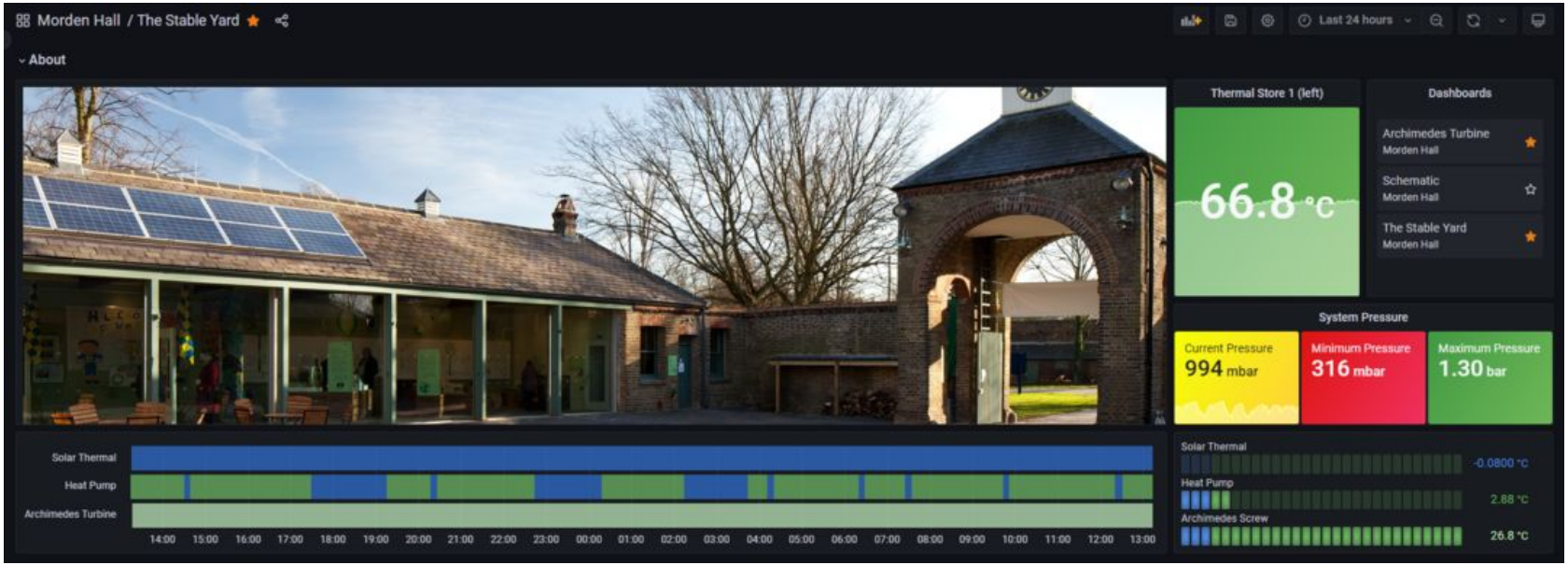
The project establishes both the open-source DIY on-ramp, as well as a fully hosted turn-key solution, leveraging the Grafana Infrastructure, that meets all the required security standards and holds certificates required by commercial organisations and local authorities.



Applications and Field Trials

Our focus has been on delivering an open controls architecture that is ***capable*** of running ***any HVAC application***, ***licence-free***, ***forever***.

The applications of this control system are secondary, with a number of examples included in software, and demonstrated in the field.



Applications and Field Trials

The project focuses on three main applications in order to demonstrate complete examples of how the system may be applied in general.

- Buffer & Thermal Store Controller
- HIU Monitoring and Controls Refurbishment
- Fan Coil Monitoring and Control

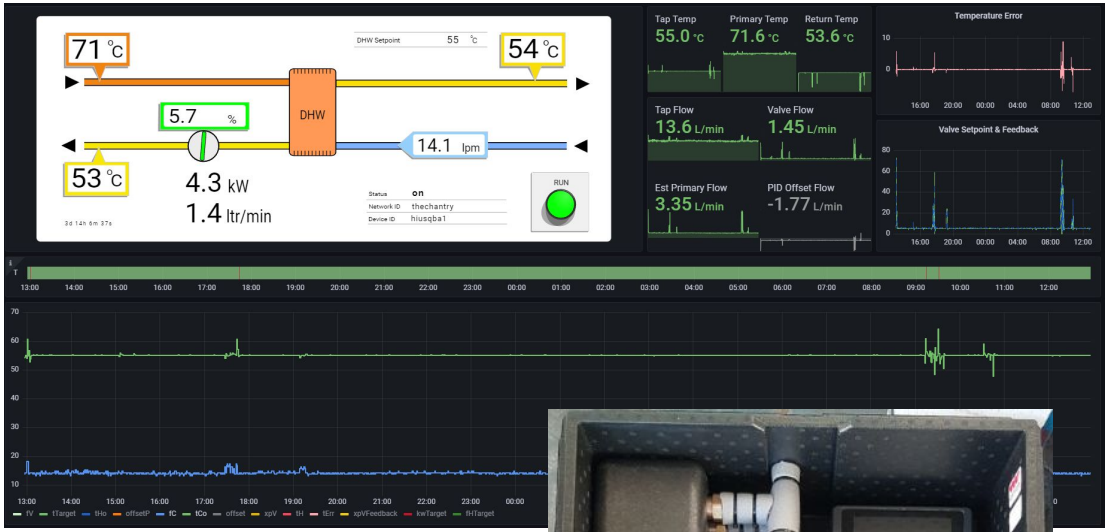
Each application is to be demonstrated and refined using field trials, where controllers are to be installed to both monitor and improve the efficiency of real world systems. Field trials include:

- The Barbican - cooling and heating circuits
- The Excel Centre - improving control of fan coils in main halls
- The National Trust - revisiting Morden Hall, a BRIAM design using a mixture of renewables including heat pumps and solar
- Swansea University SHED - the first installation in the UK of a heat network driven by CO2 heat pumps

Application:
HIU Monitoring & Control

Not only have we been able to monitor all types of HIU, from simple mechanical units through to RS485 enabled electronic systems, we have also manufactured a new HIU from scratch using our open source software and hardware.

Systems are GSM enabled as standard, sending HIU data to the cloud database where performance can be checked via statistical analysis, graphs and graphics.





Our controls have enabled us to deliver a next generation of hot water HIU, achieving exemplary performance and reliability, along with remote commissioning and alarming.

Application:
Fan Coil Monitoring & Control

We are in the process of conducting three field trials relating to Fan Coils and Air Handling Units.

- The Barbican
- The Excel Centre
- The SHED

Between them we are covering everything from domestic room temperature control through to the largest exhibition spaces in the UK.



Adding some basic visibility to existing systems has resulted in some huge CO2 and energy savings. For example, the graph above shows how a space was shown to be continuously heated (orange) and cooled (blue) at the same time due to a simple error in control. This had gone unnoticed for years, wasting up to 400kW of energy (enough to power 100 properties). **Estimated payback time of the monitoring equipment is under 48 hours !**

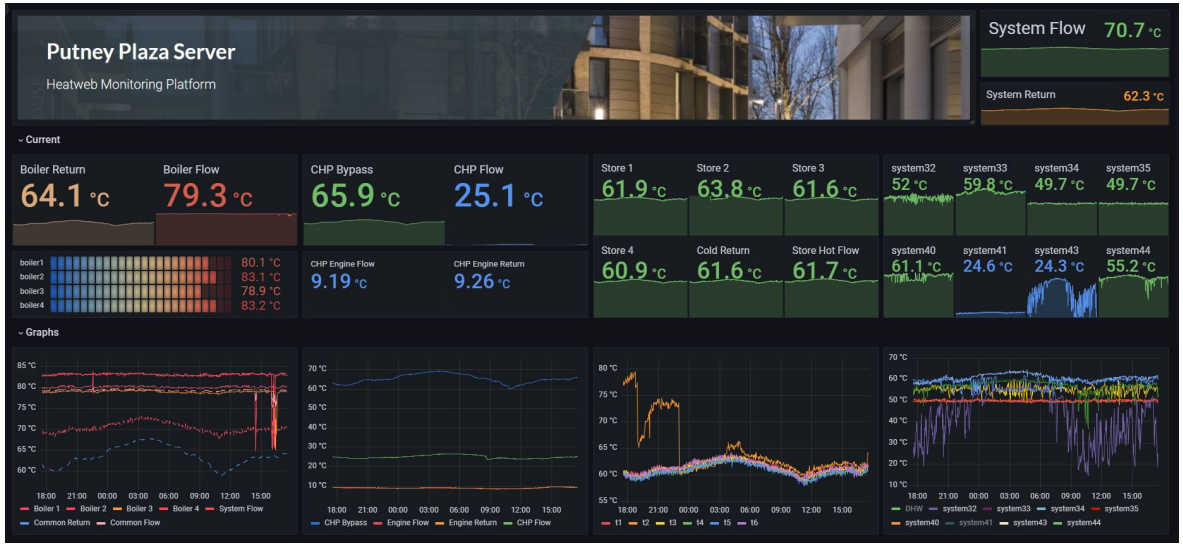
Application:
Buffer Store Control

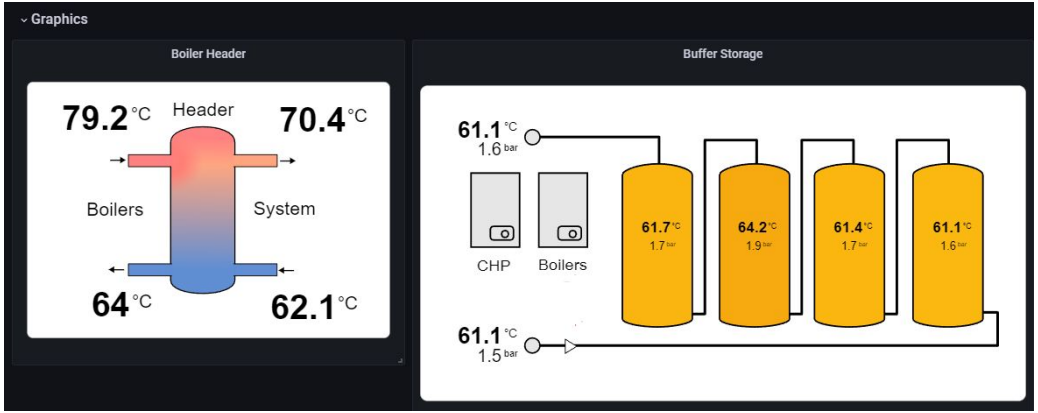
Buffer store control covers a lot of functions, from simple heater control through to boiler or heat pump sequencing.

Buffer applications are built up using function blocks, selected during installation, to arrive at the desired combination overall functionality.

The Putney Plaza field trial, for example, is upgrading a number of functions to control boilers, CHP, heat pumps and circulating pumps, around a number of buffer stores and a common header on the boiler.

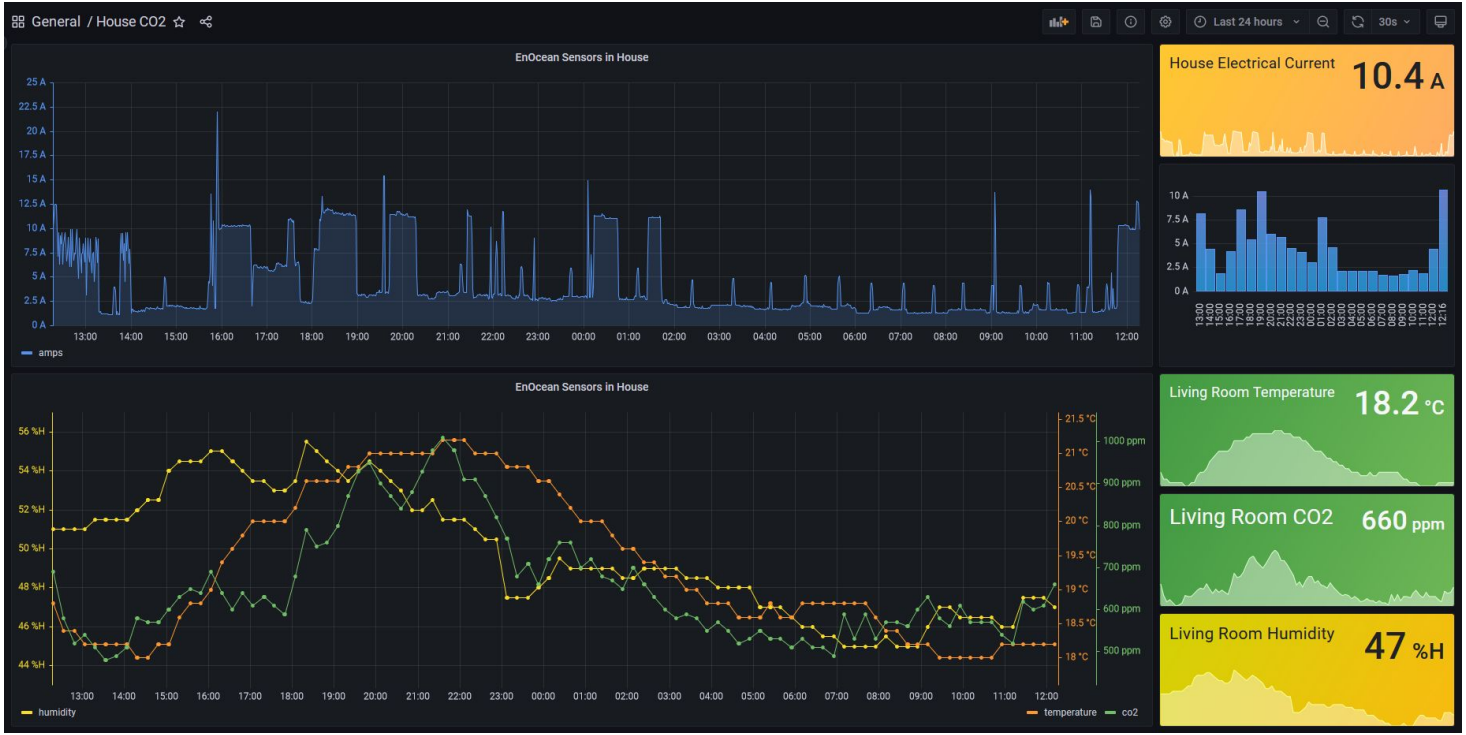
Other field trials cover functions concerning solar thermal and domestic biomass.





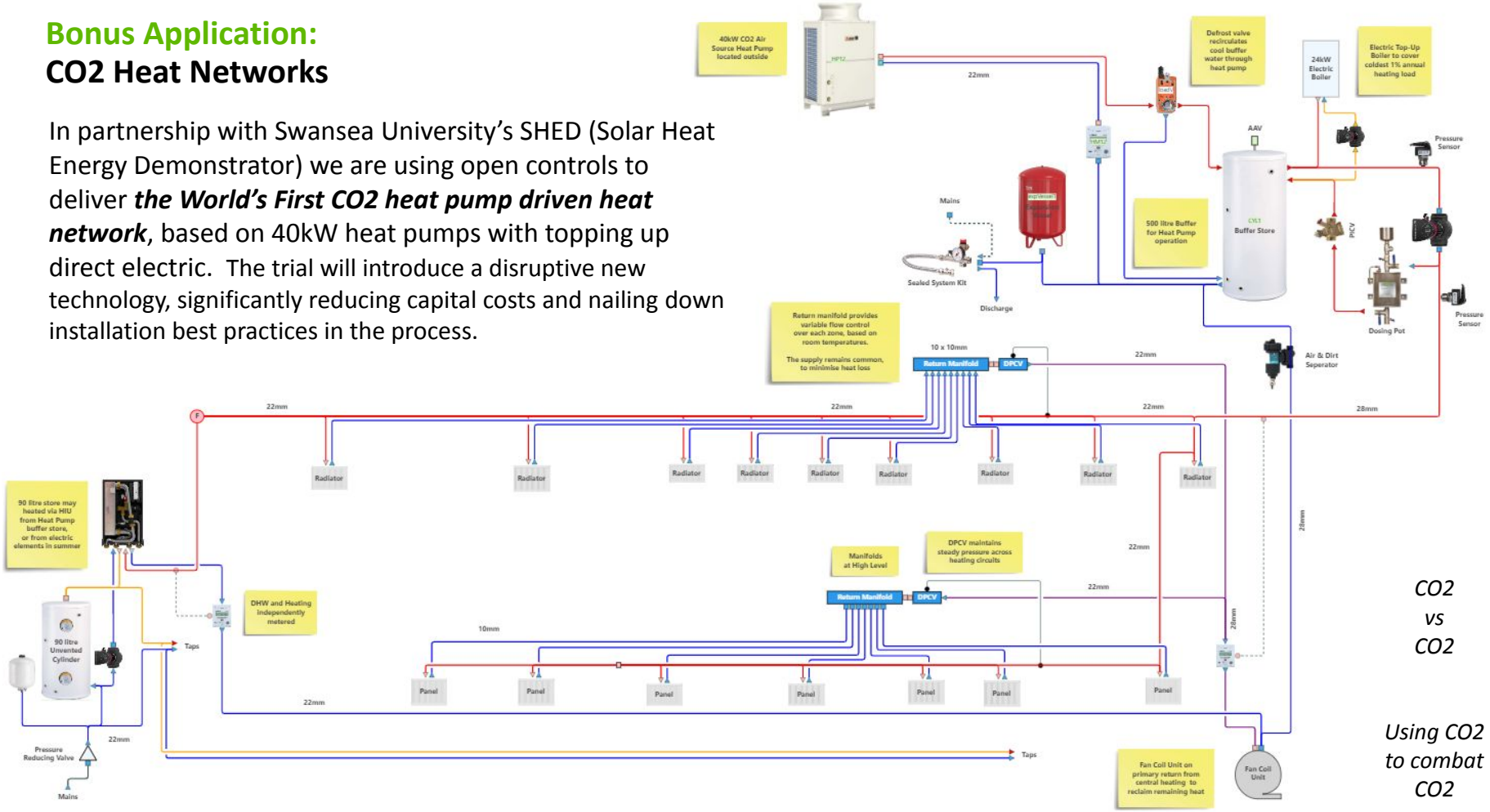
Bonus Application: Domestic Electrical Consumption, CO2, Temperature & Humidity

Wireless sensing, installed in ***under 5 minutes***, providing detailed historic data on household metrics that allows users to work out where energy is being used, and to track the effect of changes they make to ***save energy*** and ***improve air quality***.



Bonus Application:
CO2 Heat Networks

In partnership with Swansea University's SHED (Solar Heat Energy Demonstrator) we are using open controls to deliver ***the World's First CO2 heat pump driven heat network***, based on 40kW heat pumps with topping up direct electric. The trial will introduce a disruptive new technology, significantly reducing capital costs and nailing down installation best practices in the process.



CO2 vs CO2

Using CO2 to combat CO2

Wiki Project Site https://hwwiki.ddns.net

All advances made during the project are recorded on a newly created wiki site, including software, hardware designs, instructions, and records from field trials.

- 3d Heat Network v1
- About Heatweb
- Add MQTT Subscription
- Alarm and Notification Routing
- Block Editor
- Buffer Editor
- Buffer Store Control
- Building Automation Hat
- Circuit Design
- Commercial Services
- Controlling Belimo Valves
- Creating new pages on this Wiki
- Cylinder Editor
- Data Storage
- Data Tables
- Dual HIU dashboard example
- EMQX MQTT Broker
- Equipment Libraries
- Equipment Sound Analysis
- Fan Coil Monitoring and Control
- Floor Plan Designer
- HIU Monitoring and Controls Refurbishment
- HeatLossJS
- Heat Network Calculator v2
- Heat Network Designer v2.0
- Heat Network Management
- Heat Network Schematic Designer v1.6
- Heatweb BEMS Hat
- Hncalc
- Home Automation
- IPFS
- IP Camera
- Infoboxes
- Inkscape
- LoRaWAN
- M-Bus
- MQTT Brokers
- Main Page
- Methods of Viewing and Editing Data
- Monitoring Water Hammer
- Morden Hall
- Node-RED
- Node-RED:Hncalc
- Note 25-05-2022
- Open Control Architecture
- Open Source Plumbing Controller
- Overlaying 3D onto google maps
- Plotly.js
- Public MQTT Brokers
- Pushover
- Pushover1
- Putney Plaza
- Raspberry Pi Compute
- ReTerminal
- Remote Access
- Running Mosquitto in Docker
- SVG Files
- SVG Graphics
- Setting up this wiki
- Simple Floor Plan Designer
- Solar Heat Energy Demonstrator
- Specflue Training Centre Refit
- Telegram
- The Barbican
- Trevor
- Un y Berllan
- Updating the Building Automation Hat
- Web Colours
- WiFi
- Wireless Sensing
- Wiring Editor
- Wiring Editor Testing
- Wish List

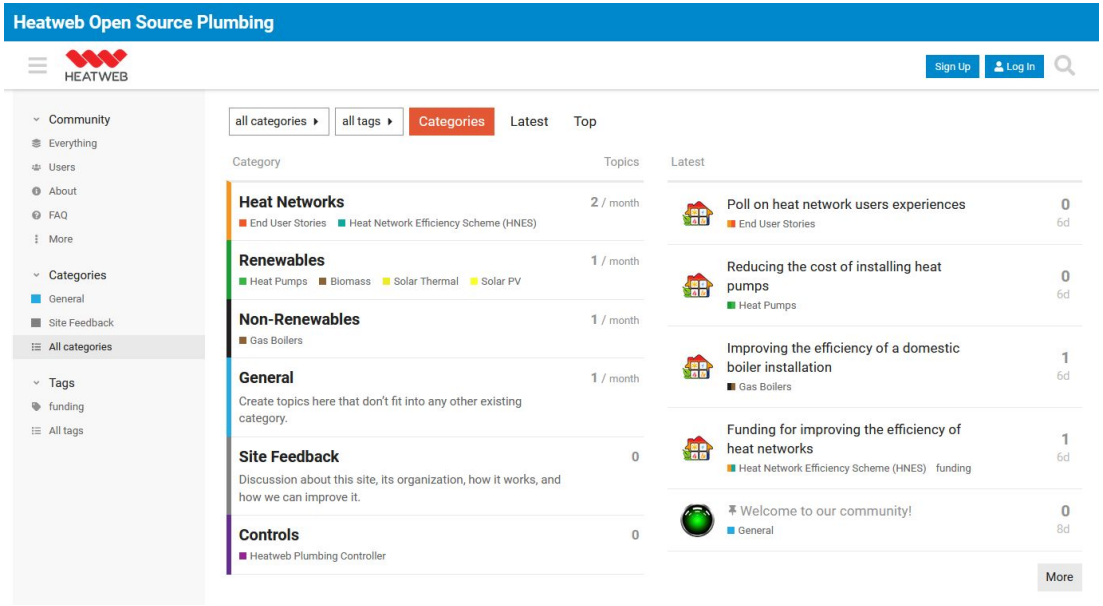
General Public On-Ramp: Discourse Forum https://heatweb.discourse.group/

We are trying to establish a thriving community centred around the use of data and open source control to achieve net zero.

We feel this is best approached by a combination of:

- A Discourse Forum
- A GitHub Project
- A Wiki

The forum allows newcomers to research what we are about, follow others, start dabbling, and find support.



The GitHub site provides any regulated source code, while the Wiki stores media and reference material.

Commercial Services arising from Our Project

Sales of Open Source Controls Hardware

IO Boards & Controllers
Control Panels
Sensors

HVAC and Heat Network Optimisation

Temporary installation of monitoring equipment
Data collection, storage and visualisation
Fault finding and reporting
HNES technical assistance and services

HVAC Asset Management

Permanent installation of monitoring and controls equipment
Data collection, storage and visualisation
Client portal with single sign-on, customised dashboards and reports
Alarming and alert escalation

BEMS Interventions

Analysis of existing BEMS logic and functionality
Remote access
Revision of controls logic
Data bridging

Wireless Sensing

Design, installation and visualisation of wireless sensor networks

Data Bridging

Routing signals and data from one system to another

HEATWEB
INTEGRATED THERMAL TECHNOLOGY

OEM Consultancy & Support

Support services to OEMs and Distributors of HIUs, substations, and equipment for heat networks.
Test rig design, control and commissioning
Field monitoring, fault finding, and alarm routing
HIU and Heat Network design and consultancy

Renewable Consulting

Detailed consultation on revision of existing hydraulic arrangements or new systems to improve existing performance and integrate renewable heat sources.
Data driven approach to design, with a lead taken from the measured performance in the field.
Specialist services in the integration of CO_2 heat pumps, biomass, and Exergy based management of networks.

