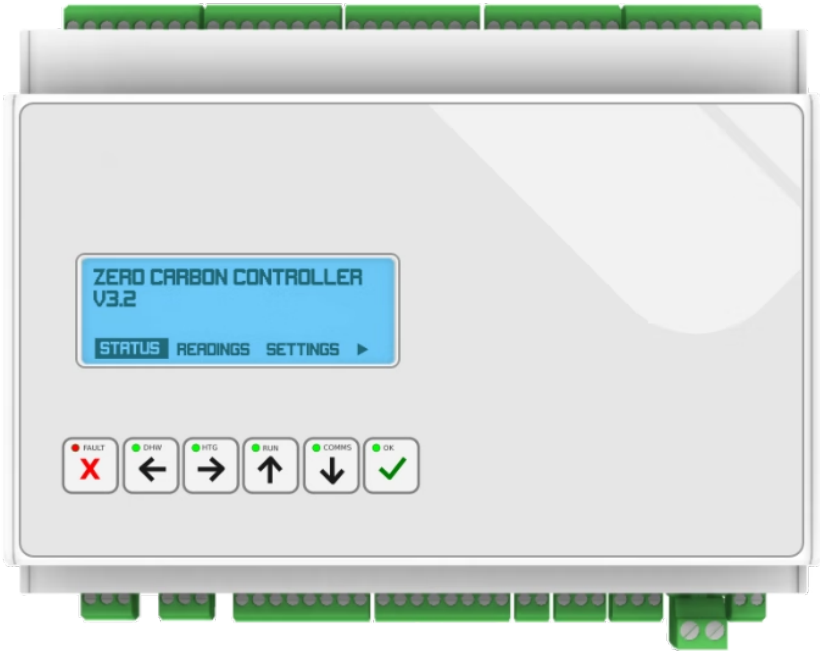
Zero Carbon Controller

The Zero Carbon Controller is an industrial grade general purpose controller designed to bring open-source control to plumbing and HVAC



The **Zero Carbon Controller** is a general purpose controller designed to bring the best standards of control to domestic heating and hot water, with the aim of improving efficiencies and accelerating the move to net zero.

Improving control and adding transparency to renewables (or fossil fuel) installations is one of the best ways to guarantee savings in energy costs and carbon emissions, ensuring that the latest controls strategies are in place, systems work as expected, and investments in low carbon technology translate to real savings.

Open Source Plumbing Controller

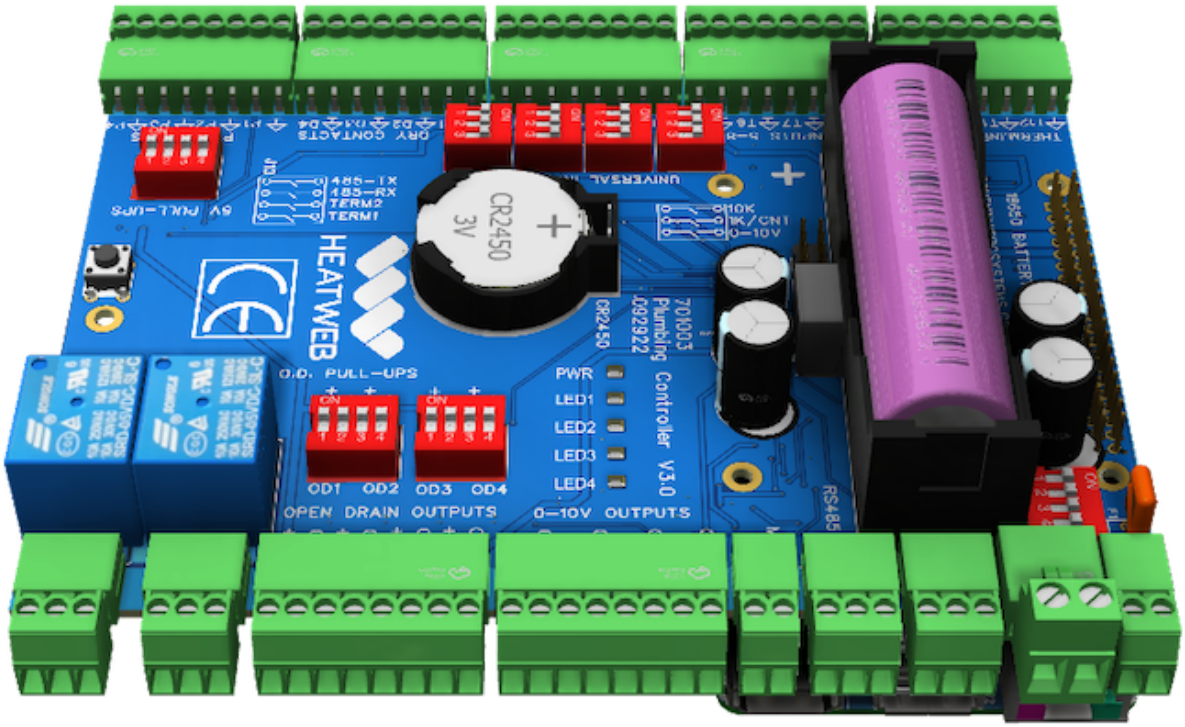
Open Digital Solutions for Net Zero

A UKRI funded project

Development have been funded through UK Innovate, as part of an SRBI scheme to provide Open Digital Solutions for Net Zero, including deliver a number of fields trials to demonstrate a range of applications.

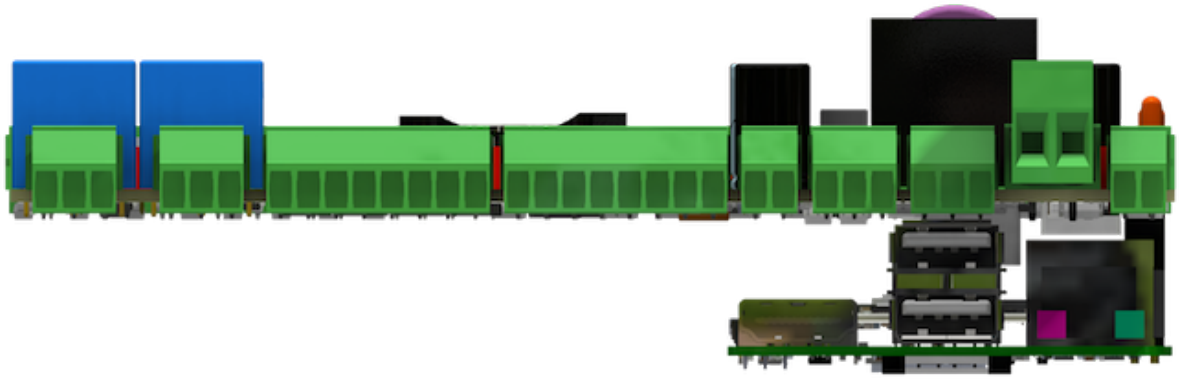
The Hardware

At the heart of our project is the design and testing of a **Zero Carbon IO Board** that enable OEM and industrial levels of control in domestic systems, including common signal types as well as 0-10V and PWM to drive modern pumps and valves, pulsed inputs up to 100Hz, dry contacts, relays, M-Bus to talk to meters, two lines of RS485 for Modbus communications, real-time clock, on-board backup power, and more.



Zero Carbon IO Board

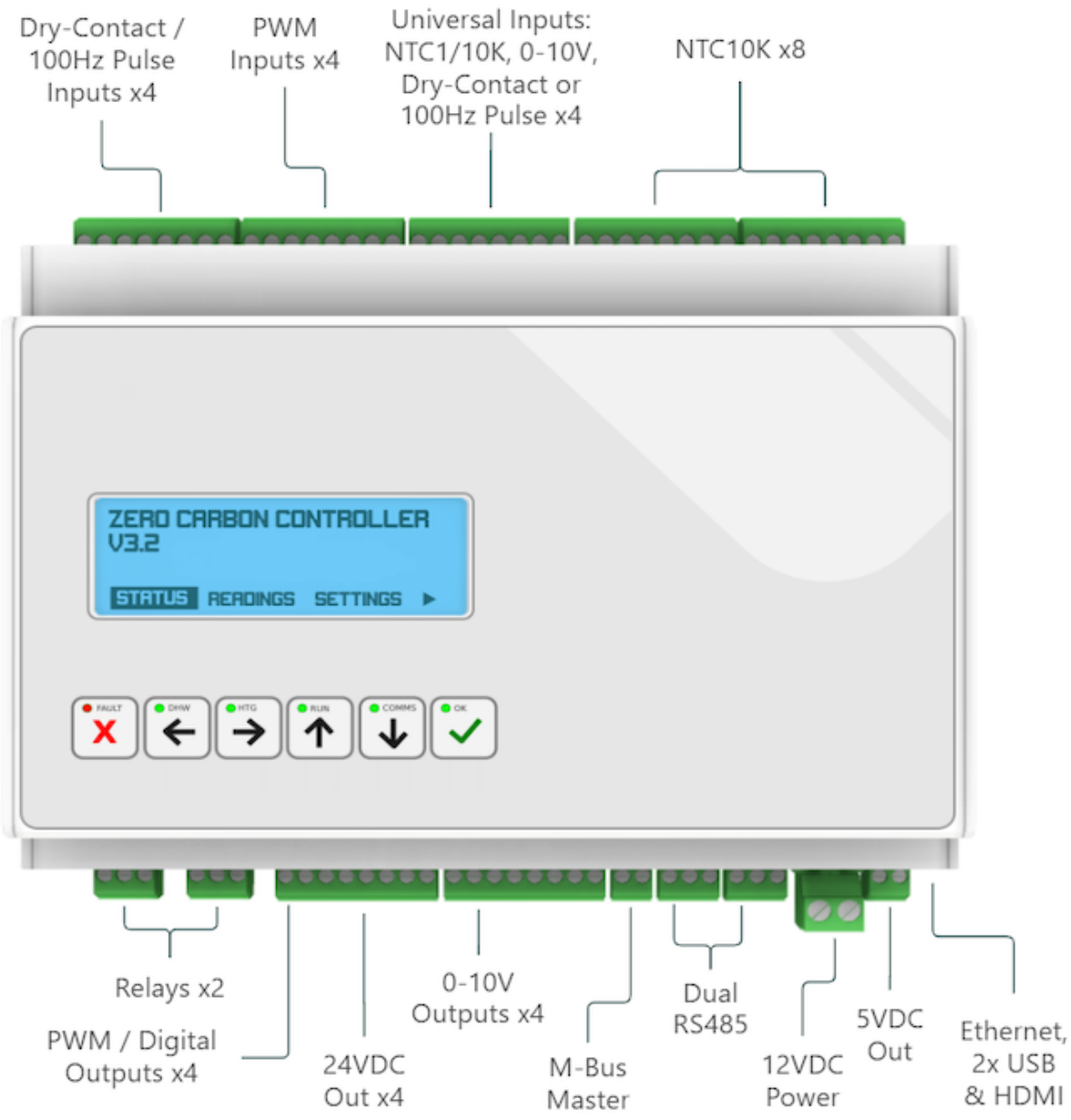
The IO board is driven entirely through I2C and UART making it compatible with a range of main controller boards, including the Raspberry Pi, Beaglebone Black, and ESP32. The ESP32 option provides a lower cost route as well as a more robust line of controller supply for OEM applications.



Zero Carbon IO Board, Raspberry Pi CM4 and Carrier Board

The selection of IO (inputs and outputs) allows the controller to be used to control and/or monitor any type of domestic heating system, from a basic boiler installation through to the most complex of renewables systems integrating heat pumps, solar panels, thermal storage and biomass. Common applications include:

- Solar controller
- Boiler and heat pump sequencing
- Thermal store control
- Fan coil control
- Remote sensing
- Plate heat exchanger systems
- General monitoring, dashboarding and alarming



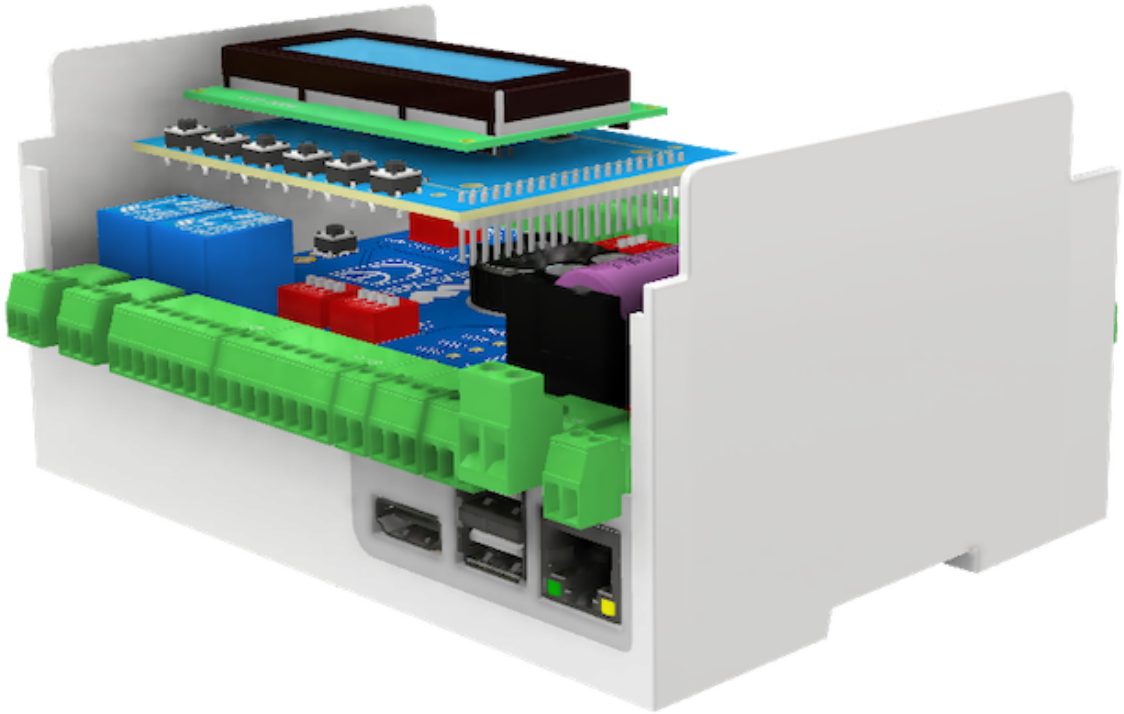
A significant amount of development time has gone into ensuring the IO works with HVAC equipment properly. The board now includes a variety of DIP switches to adapt digital and PWM signals with pull-up resistors, voltage differentiators are built into the inputs to account to ground offset, and IO (including M-Bus) is protected against accidental short-circuit.

Backup power was important to us, with many applications requiring continued functionality, such as valves to be closed following a loss of power, or an alarm to be sent out. All controller functions can continue following loss of power, with enough

storage to maintain 24v supplies to power valves and move them to appropriate shut-down position, before the system goes into hibernate.

M-Bus was also important, with the ability to read heating or cooling meters a core function of any energy system. This also open the system to use in metering applications as well a means of reporting both performance and usage data to operators.

Two lines of RS485 enable both Modbus master and slave functionality to run in parallel, and as the standard BMS protocol, allows the connection to a vast array of equipment. An IO card can even be run without a main controller, with one line of RS485 acting as a Modbus slave, exposing all the IO as registers.



The addition of an LCD screen and button module provides a 4 line display, as well as 6 buttons with RGB LEDs, all application definable. We have gone with a flat enclosure front with an under-surface printed graphic overlay, that can be customised to suit applications, and branded as required.

An HDMI connection, and USB, allows direct connection to a full size touch screen display, to show dashboards and provide customised kiosk user interfaces. Wired or wireless mouse and keyboard may be added if needed via USB.

The new controller finally lets us apply the logic we have developed without many of the hardware complexities and costs caused by numerous circuit boards to achieve a specific combination of IO.

"The Zero Carbon Controller gives us a single low cost board for any application, rather than having to combine numerous industrial PLCs in a BEMS controls panel. It allows us to apply industrial levels of logic control at a domestic price point. "

The Software

The greatest barrier to efficiency in the HVAC industry is software license costs. All commercial control systems implement layers of licenses to get anything to work, and every additional feature comes at a cost. It is therefore no surprise that very few commercial systems have the additional layers of software and visibility required to properly monitor, fault find and tweak efficiencies. Recent government funded studies have shown most communal heating systems to be terribly inefficient, with poor control and a lack of visibility at the core. Domestic systems have never been able to afford any form of monitoring, and schemes such as the RHI have failed to realise proper carbon savings as a result.

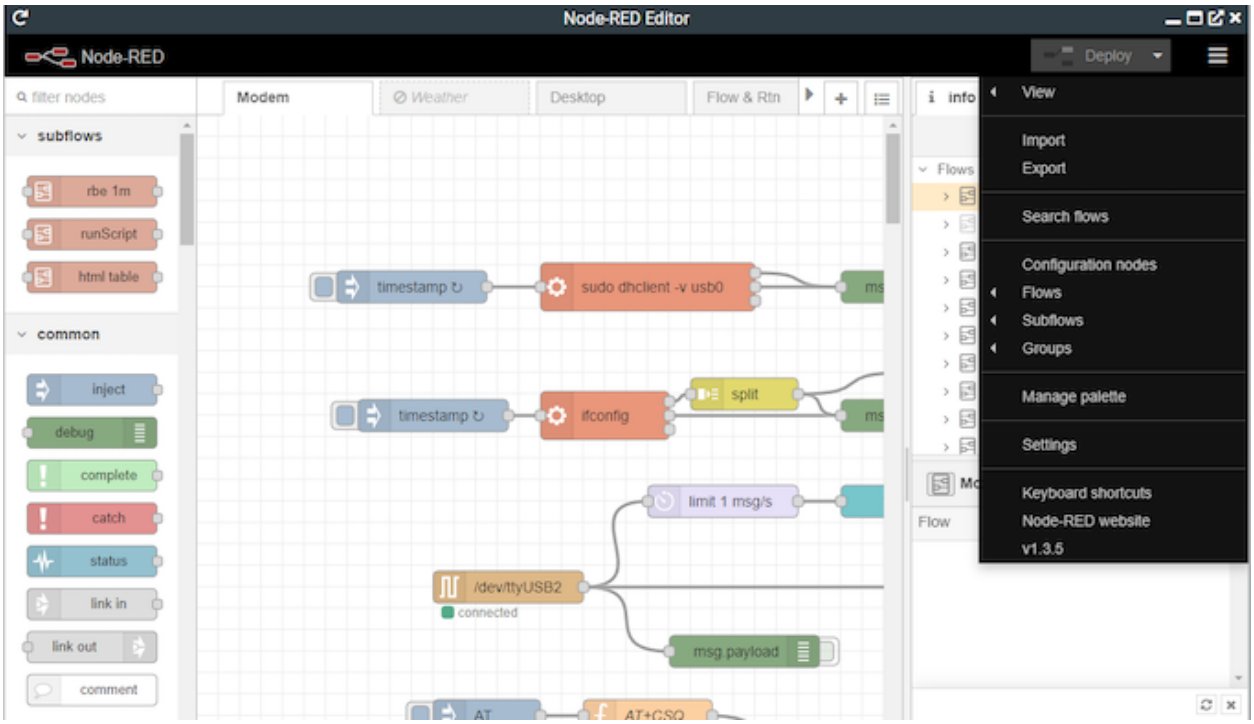
Our fully open approach allows one to implement the very highest standards of monitoring and control without a single license, in a domestic or commercial setting. There are no barriers to improving performance of systems and the results are a world apart.

We have spent a number of years perfecting the selection of software to provide a system that allows us, as equipment manufacturers, to control and monitor complex plumbing systems with industrial reliability, but at the same time provide customers with license free transparency and the ability to adapt logic to needs.

Together with the Raspberry Pi CM4 Compute, the controller provides a completely open-source control environment based around Node-RED and Docker, with additional services loaded through containers.

Node-RED and Docker

The use of Node-RED has proven to be a game changer, allowing us to provide data routing, system administration and container management, as well as run custom applications in a separate Node-RED container that are easily updated and shared.



Node-RED

We have built the core software stack using the best open-source projects that are available, delivering a robust environment that allows us to take on any project using tools that others can learn and develop independently. In turn this lets us, as a manufacturer, focus more on applications and functions.

The core stack includes:

- Raspbian operating system, as the third best selling computer platform of all time, and one of the best long term supported with patches and updates required for an industrial system.
- Node-RED for control logic and data routing, developed by IBM to provide a wiring system for IoT. Now universally accepted as one of the most powerful and user friendly methods to implement and share logic.
- Docker provides a mechanism to run all other services in isolated containers, including Mosquitto MQTT, MySQL and InfluxDB databases, and Grafana for data visualisation.

Containerised Software

Applications & Tools

Each project using a Zero Carbon Controller is applied to can be saved as an application for installation onto other controllers.

We are providing a number of standard applications and functions in a form that can be easily installed from GitHub or Docker.

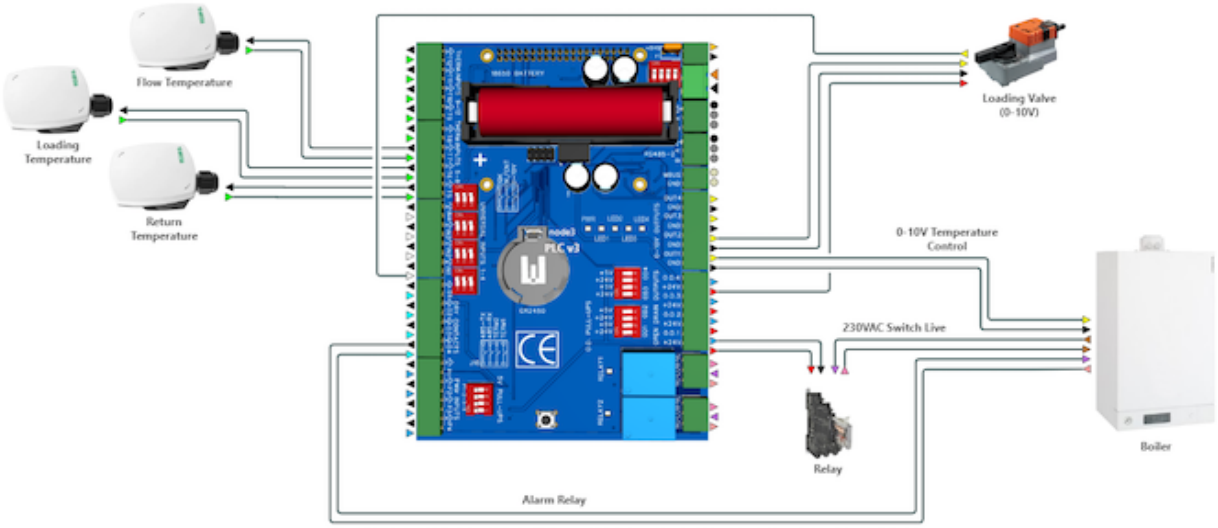
This allows us to develop a suite of professional control functions and applications that can be collaboratively evolved, with a continuously growing number of libraries to support specific devices.

Our funded project covered the deliver of the following applications:

- Fan coil monitoring and control
- HIU (Heat/Hydraulic Interface Unit) monitoring and control
- Buffer store l monitoring and control

They are delivered as Docker images that can be spun up on a controller.

The wiring diagram below has been generated using an online open-source software tool we have developed to make application development as easy as possible. Follow the link to view others.



Wiring diagram for controlling a boiler with loading valve

Using the online tool it is possible to generate a simple or complex wiring diagram using component palettes, and then export this to a controller in minutes. The components contain additional data such as NTC resistance charts, unit mappings, and topics used to describe data, the aim being that manufacturers can create their own palettes of components to use in the tool. Drag-and-drop wiring like this can help significantly in reducing errors during programming stages.

Our Progress So Far

Earlier versions have been in the field for approaching five years now, running services for hundreds of properties, with the majority on communal heating systems. The functions these systems provide include equipment control in properties, remote sensing, boiler and pump sequencing, BMS interfacing, and substation control. The remote visibility provided by these systems has allowed us to develop the Node-RED functions to achieve the best results in the industry, with our data even feeding into new standards.

The final version of the controller is currently in field trials, with EMC testing and approvals stages now been started.

The development and the funded project finishes in March 2022, after which we will be ramping up production and starting to supply the finished product.

The funded development project ran for 8 months, up until March 2023 and consisted of the following milestones:

- Build 10 of first prototype controller from new PCB design. Month 1.
- Successful testing of all additional functions. Month 2. (Milestone)
- Initial field trials Months 2-3. (Milestone)
- Complete redesign of PCB following initial trials. Month 4.
- Enclosure design completed. Month 4.
- Manufacture of 25 final units for field testing. Month 5-6. (Milestone)
- Publishing of beta versions of Node-RED Nodes for the three applications.
- Final field testing. Months 6-8.(Milestone)
- Documentation completed and published to Wiki. Month 8.
- Publishing of completed hardware designs. Month 8.
- Complete and publish production versions of Nodes for applications. Month 8. (Milestone)

Field Trials

The funded development included a number of field trials, aimed at demonstrating the potential of open source control, as well as performing field testing on the equipment leading up to the final production design.

In themselves, the field trials are quite revolutionary in terms of achieving zero carbon. The open control has enabled trials on systems never previously explored, including:

- The first ever CO2 heat pump installation in a communal heat network, aimed at significantly reducing costs of converting existing housing to renewables.
- Monitoring of an Archimedes Hydro-Electric Turbine installed in London, aimed at demonstrating how electricity can be generated in a suburban area with a low water head and low impact on wildlife.
- The complete overhaul of only the UKs only heritage BREEAM awarded renewables installation, one of five in Europe. Open controls are enabling a number of defects to be overcome and the systems to be reinstated to proper functionality, demonstrating an array of renewables including biomass, heat pumps, solar thermal and solar PV.
- Optimisation of fan coil units in the UKs largest exhibition halls.
- Working directly with residents, the comprehensive upgrade of a large communal system running on boilers, CHP and air source heat pumps. The system had been plagued with problems since before day one, but with no visibility it has taken the installation of open controls to improve the reliability of services and bring heat sources online.

All field trials, including The Barbican Centre, The Excel Centre, Battersea Power Station, and the National Trust, are documented in detail on the project wiki site at https://hwwiki.ddns.net/index.php/Category:Projects

Performance monitoring on communal heating systems as part of field trials to save energy

Environmental commitments

Visit our Environmental Resources Center to learn how Kickstarter encourages sustainable practices.

Long-lasting design

We have built the controller using the best established open hardware we know of, from the Raspberry Pi Foundation. Unlike most manufacturers, even the original RPi boards from ten year back are still supported with patches. As the third best selling computer platform of all time, the hardware is extremely reliable, and the circuit board forms are now being copied by others, providing alternative options for spares in the long term.
By building our system using exclusively open-source top-tier software we aim to ensure that the controller will be supported indefinitely. Nothing should go out of date.

Reusability and recyclability

A big problem with current control systems is that they are bespoke to a particular manufacturer and may run on closed protocols. This makes upgrading them almost impossible and generally old controls are replaced during upgrades. The general purpose nature of our controller makes it inherently reusable. A controller used as a boiler controller can be repurposed and used for running heat pumps and solar panels as one transitions to zero carbon. With a Zero Carbon Controller fitted, there is never a need to upgrade controls as a system changes - the versatility is built in.