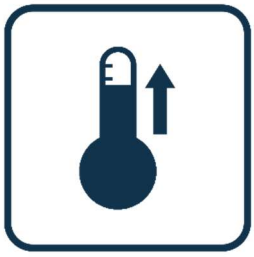
Graphene-Enabled Direct Heating for a Net Zero Future.

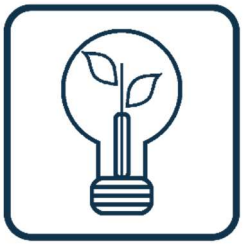
White Paper

Powered by haydale

JustHeat Benefits



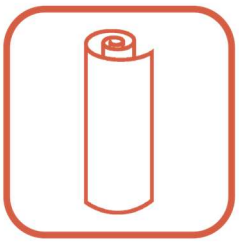
Rapid Heat-Up
Reaches Room Temperature in Minutes, not Hours



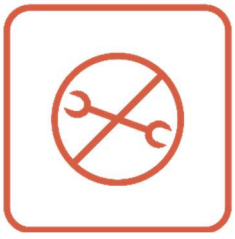
Energy Efficient
Delivers Exceptionally High Energy Conversion Efficiency

Low Voltage
Compatible with Renewable and Low-Carbon Power Sources

High Emissivity, No Hot Spots
Provides a Large, Uniform Heating Surface for Even Comfort



Durable and Easy to Install
Supplied in Flexible Rolls for Simple Fitting



Easy Maintenance
No Moving Parts, No Wear Components

Executive Summary

Decarbonising heat in buildings is one of the greatest challenges and opportunities of our time. In the UK, heating our homes and commercial buildings accounts for around 40% of total carbon emissions. Achieving Net Zero means we urgently need smarter, cleaner ways to keep buildings warm without burning fossil fuels. **JustHeat** –an advanced underfloor heating system developed by Haydale – offers a breakthrough solution to this challenge. Powered by Haydale's patented HDPlas® functionalised graphene technology, JustHeat delivers comfortable warmth with dramatically improved energy efficiency and a low-carbon footprint.

JustHeat panels convert electricity to heat with over 90% efficiency, providing radiant warmth that heats rooms in minutes, not hours. The system operates at safe low voltage (48 V DC), making it uniquely suited for use with renewable power sources like solar. Real-world tests and independent studies show that JustHeat can achieve the same comfort levels as conventional heating systems while using significantly less energy. This white paper presents the data and design behind JustHeat – demonstrating how its cutting-edge materials and engineering yield rapid heat-up, even heat distribution, and major energy savings.

"In short, JustHeat offers a new way to cut carbon and costs without compromising comfort or reliability, making it an ideal heating solution for Net Zero strategies." – Simon Turek (Chief Executive, Haydale Graphene Industries plc)

JustHeat: Graphene-Enabled Direct Heating for a Net Zero Future

Introduction

The JustHeat Low Power Direct Heating System represents a new generation of efficient electric heating, powered by Haydale's patented HDPlas® plasma functionalisation technology. Using functionalised graphene inks, JustHeat panels combine exceptional energy efficiency, rapid response, and even heat distribution with low-voltage, renewable-ready operation – delivering comfort and sustainability in one system.

Developed by Haydale's Technical Team, the latest generation of JustHeat panels applies our proprietary graphene formulation expertise to transform everyday heating. The result is a lightweight, flexible, and durable underfloor system that reaches operating temperature in minutes, maintains uniform warmth without hot spots, and uses significantly less energy than traditional heating systems.

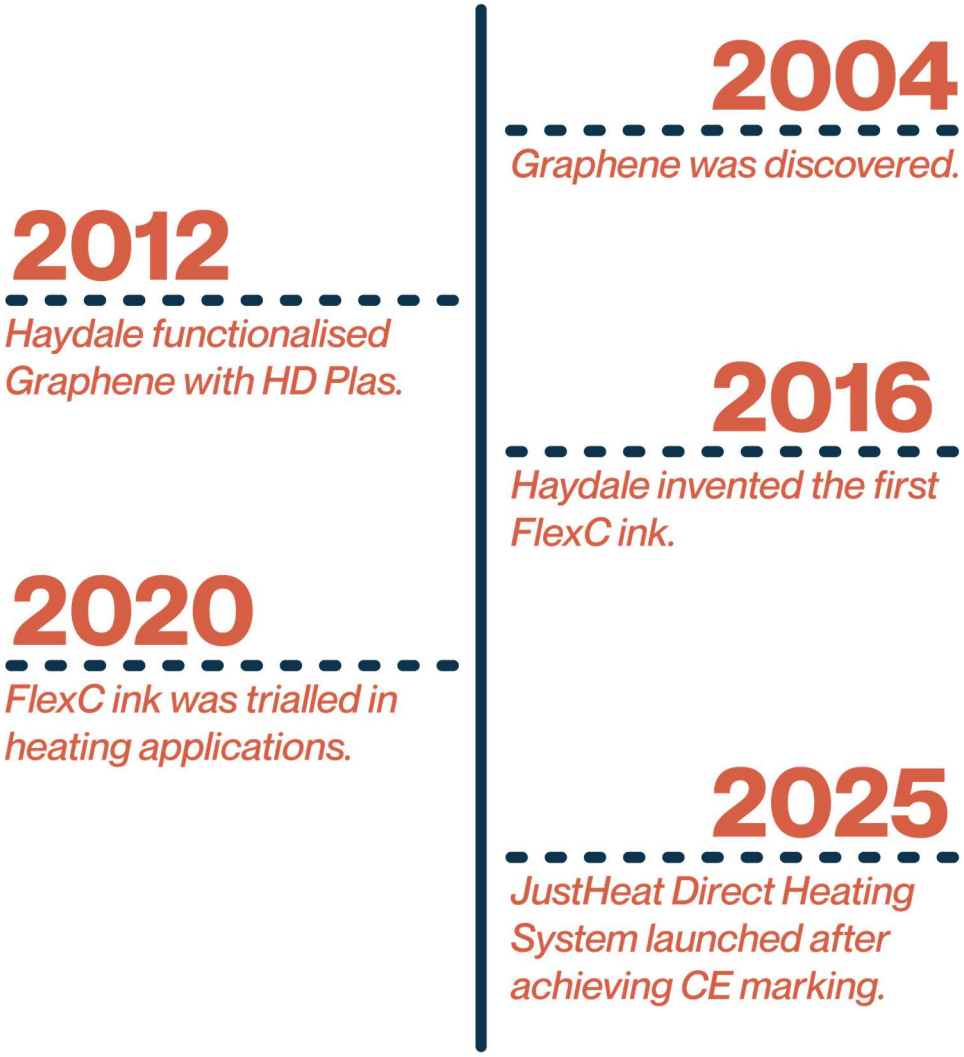


Figure 1: Roadmap of the development of JustHeat Low Power Direct Heating System

How It Works

Each JustHeat panel is printed using Haydale's FlexC electrically conductive ink, a proprietary formulation based on Few Layer Graphene (FLG) enhanced through HDPlas® plasma functionalisation. This process "scrubs" the graphene surface and attaches chemical groups that increase electrical conductivity and lower thermal resistance. When current passes through the printed layer, heat is emitted evenly across the surface, creating a large surface area, radiant heater that's thin, safe and efficient.

The panels consist of four precision-engineered layers:

1. A **flexible polymer substrate** providing electrical insulation and stability.
2. The **graphene-based conductive layer** (FlexC), forming the active heating surface.
3. **Metallic busbars** (silver/copper) along each edge, ensuring even current distribution and temperature uniformity.
4. A **transparent protective coverlay**, encapsulating the system for durability and safety.

Supplied in roll format up to 250 m, JustHeat mats can be cut to modular panel lengths and installed rapidly by qualified electricians. The low-voltage 48 V DC design allows for direct integration with solar PV and battery systems, making JustHeat inherently compatible with renewable energy and decentralised microgrid setups.

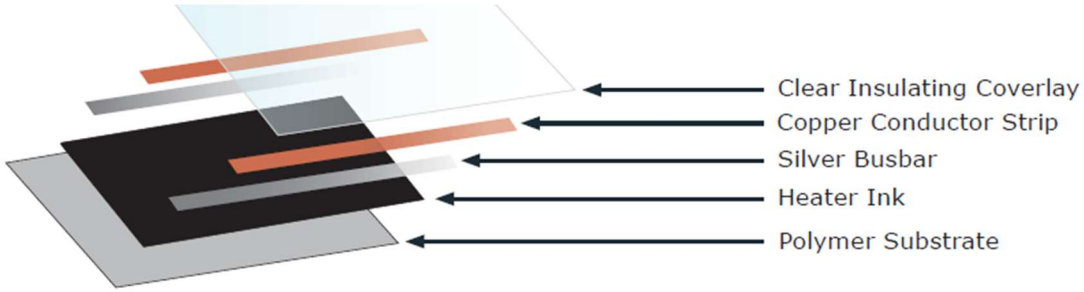


Figure 2: Diagram of the composition of a JustHeat Panel

Product Accreditation and Compliance

The JustHeat Direct Heating System has achieved full CE and UL accreditation, independently validated to the following standards:

1. **EU Low Voltage Directive** 2014/35/EU (EN 60335-1:2012 +A15:2021; EN 60335-2-96:2021 +A11:2021)
2. **UL 499 / CSA C22.2 No. 72-10** (R2019) – CU US + Canada Certificate

3. **Flammability Resistance** (EN 60335-1 + A16:2023, Clause 30.2 Glow Wire)
4. RoHs and
5. REACH compliant
6. EMF Safety verified (IEC 62233:2005)
7. WEEE Registered (No. WEE/MM1598AA)

Performance and Durability

Laboratory and real-world testing confirm JustHeat's rapid warm-up, steady heat retention, and exceptional emissivity. Panels reach operational temperature (30 °C) in around 75 seconds, while maintaining uniform surface temperatures and continuing to radiate gentle warmth for over an hour after power is switched off.

Even with physical damage — such as a nail hole through the panel — testing demonstrated continued functionality, with localised cold spots having minimal impact on performance. This resilience highlights the robustness of the printed graphene layer and its redundancy against localised faults.

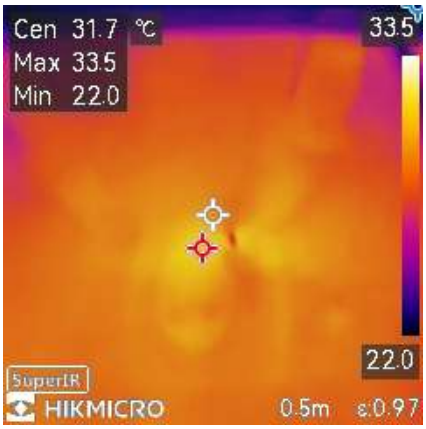


Figure 3: Nail Hole having a minimal impact to the heating up of the panel

Figure 3 shows a cold spot where the hole is, however the temperature of the panel is above 30°C, showing that the panel is still operational (as if the hole wasn't there).

High Radiant Efficiency (Emissivity ≈ 0.95)

Independent thermography (Thermography Services UK, 2025) confirmed that JustHeat panels have an emissivity of ≈ 0.95 — nearly a perfect black body.

In contrast, typical painted metal radiators emit only 0.77–0.84. This high radiant efficiency means JustHeat transfers more of its heat as useful radiant energy rather than wasted convection. The result is greater comfort at lower air temperatures — for example, users can feel equally warm at 19 °C air temperature with JustHeat as at 21 °C using a radiator. Reducing indoor temperature by just 1–2 °C can save ~10 % in heating energy annually (UK Energy Saving Trust, DESNZ).

Rapid Response and Extended Heat Retention JustHeat panels combine the best of both worlds: **fast warm-up and slow cool-down.**

- **Heat-up**: From 16 °C to 30 °C in ≈ 75 seconds (room temperature rise in ≈ 30 min).

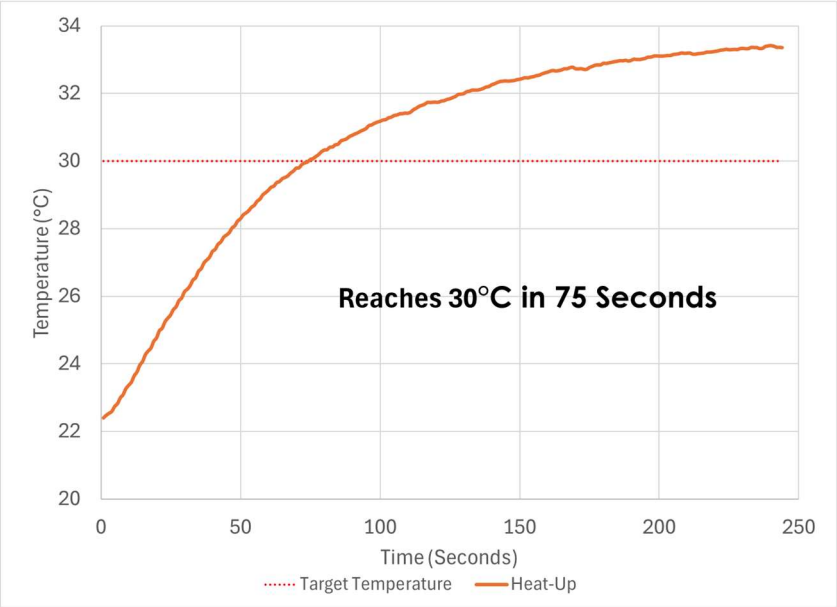


Figure 4: Heat up rate of JustHeat Panel without flooring

Figure 4 was recorded using thermocouples spaced evenly across the panel, with a 48V power supply. The average of these results shows 3 panels taking 75 seconds to warm-up from 22°C to 30°C.

- **Cool-down**: Retains heat for **≈ 75 minutes** after switch-off, continuing to radiate warmth.

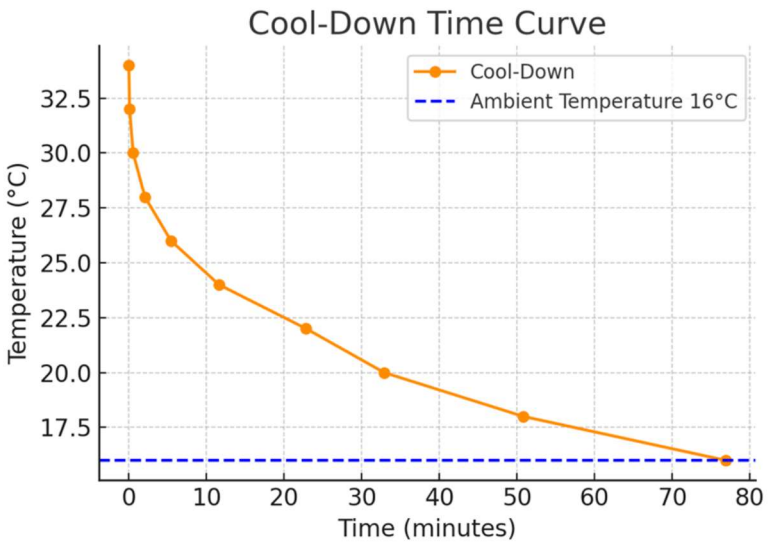


Figure 5: Cool down rate of JustHeat Panel without flooring

Figure 5 shows the cool-down rate as measured by a thermographer (Thermography Services (UK) Limited). This shows that heat is emitted into the room over a 75-minute period, meaning the panels perform as a radiator after the electrical power has been removed, ensuring a higher proportion of the heat energy created is used to keep the room at the desired temperature. This is partially due to the effective emissivity of the panel (as described above).

Compared with conventional systems:

- Wet underfloor heating can take hours to respond as concrete slabs heat up and cool slowly.
- Gas radiators heat unevenly and waste energy via convection and hot-water circulation losses.

By contrast, JustHeat responds as quickly as a radiator but delivers the comfort and efficiency of radiant flooring, avoiding the slow responsiveness of traditional underfloor heating.

Uniform Heat Distribution (No Hotspots)

Thermographic imaging shows no critical hotspots or cold streaks, with surface temperature variance under ± 2–4 °C during operation. The even distribution of the graphene ink ensures consistent warmth and safety, preventing local overheating and improving flooring longevity.

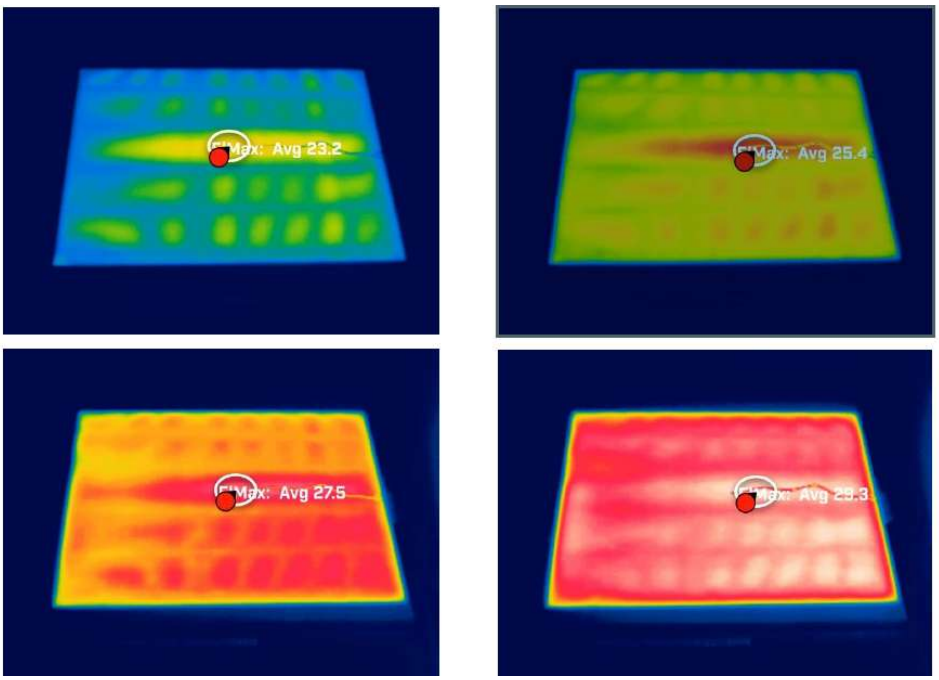


Figure 6: Heat Distribution of JustHeat Panels as electrical energy is applied over time

Figure 6 shows the heat progression, with the centre of the panel heating first before heat spreading across the entire panel.

Unlike wire mats or hydronic radiators – which can show large gradients (e.g. 40 °C to 70 °C across a radiator) – JustHeat provides uniform warmth across the entire surface and an even temperature gradient through the room. Heat starts where it's needed most: at floor level, reducing stratification and wasted ceiling heat.

Efficient Energy Transfer (Low Thermal Resistance)

JustHeat panels exhibit an exceptionally low thermal resistance (~0.12 °C/W), meaning heat moves quickly through the panel and floor.
This allows the system to operate at lower surface temperatures (≈ 30–35 °C) while still providing full comfort, avoiding the 60–70 °C of traditional radiators or wire UFH.

Every watt of electricity is converted into heat directly in the room, without the distribution or standby losses of boilers, pumps, or pipework. With smart zonal control, each area heats only when needed, minimising idle consumption.

Haydale has constructed a demonstration room within an office building to simulate real world conditions, allowing a realistic heat up rate to be illustrated. The orientation of the room is shown in Figure 7, with the floor having a full coverage of JustHeat panels on top of foil insulation. The floor is covered in 1cm thick MDF floorboards, to represent the standard floor in a residential home.

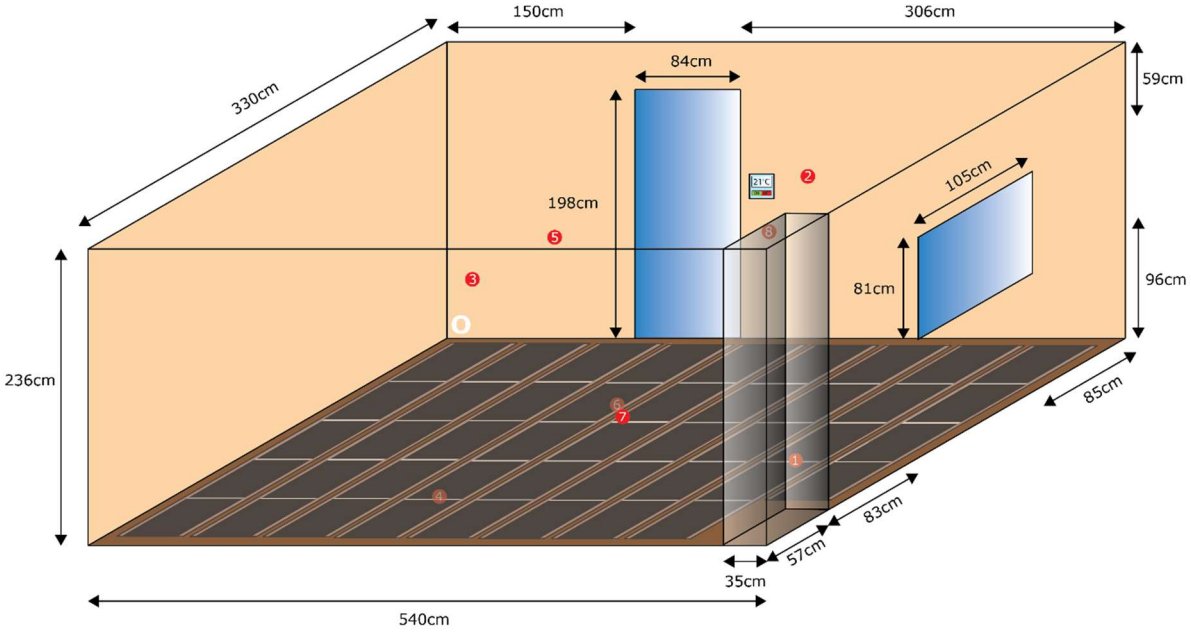


Figure 7: Demonstration Room Layout with Thermocouple Locations

Thermocouples are placed in the locations shown in Figure 7, allowing the temperature of the panels, floor and air to be measured. The electrical energy inputted into the system is also measured.

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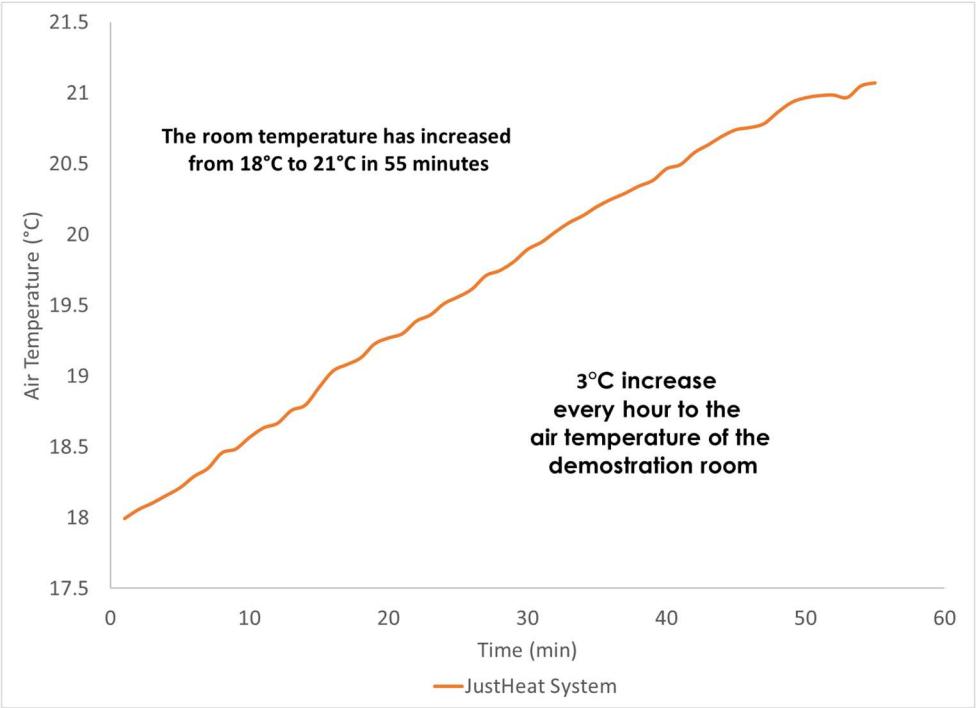

Figure 8: Heat-up rate from 18°C and 21°C (readings taken from thermocouples with 100% floor area (13.2m2) covered with JustHeat Panels

Figure 8 shows the rate of temperature increase from 18°C to 21°C to illustrate a realistic heat up rate of the air in the room, provided by the Justheat panels.

Using this demonstration room, the energy usage throughout the day can be measured.

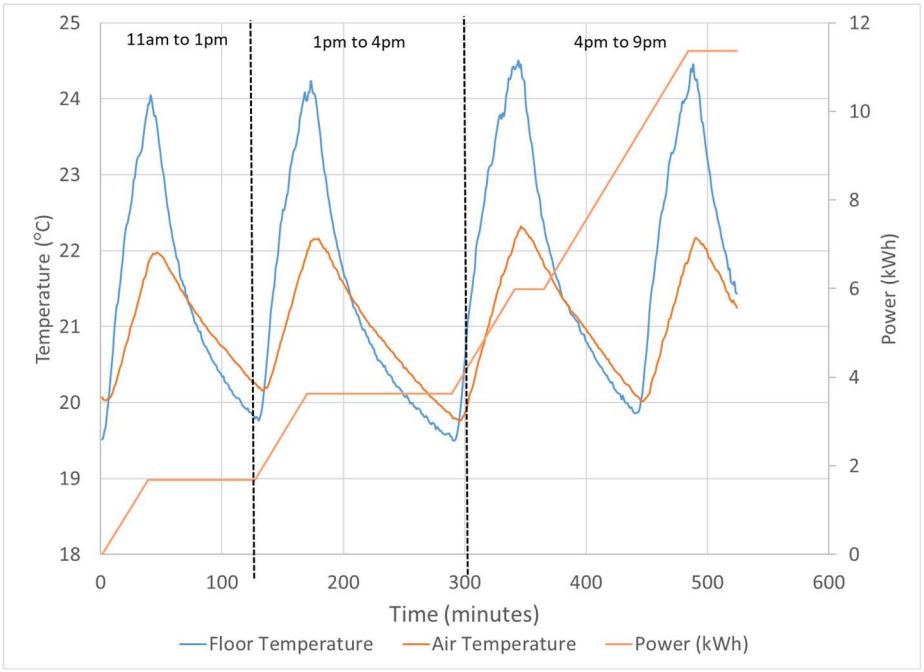

Figure 9: Energy usage when the temperature is cycled between 21°C and 20.5°C (temperature readings are taken from thermocouples) using 100% area covered (13.2m²) of JustHeat Panels

Figure 9 shows that, because JustHeat panels use the entire floor as a large radiant surface, they can deliver the same comfort at a lower operating temperature than standard systems. Lower temperatures cut losses and reduce circuit resistance, improving overall efficiency. Here energy efficiency is defined as the share of input electricity that becomes useful heat along the intended path – from panel to floorboard to room air. In set 1, 85% of input energy warmed the room air; by lowering the minimum setpoint and using 50% of the panel area (Set 2), efficiency increased to ~95%, with on-off cycling translating roughly to **1 minute of heating ≈ 6 minutes of comfortable room temperature**. Similar to this, Figure 8 shows the room's temperature rise from 18 °C to 21 °C, illustrating a realistic heat-up rate.

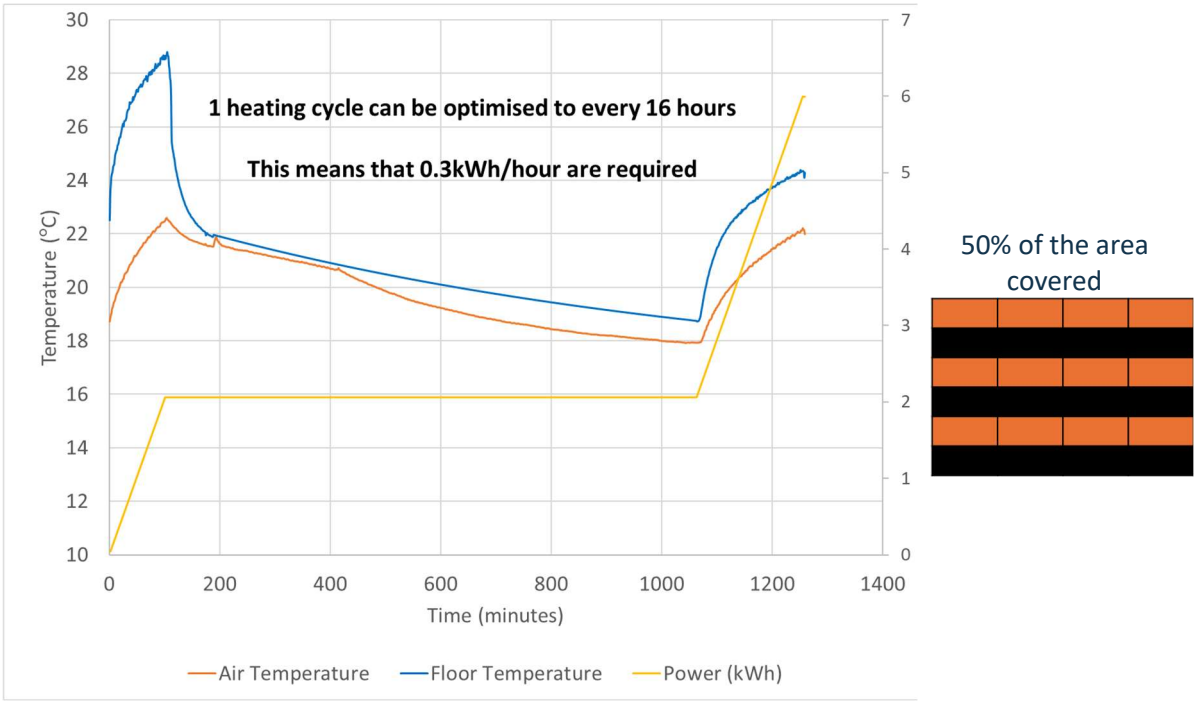

Figure 10: Energy usage when the temperature is cycled between 21°C and 18°C, with 50% of the panels (6.6m²) being utilised (temperature readings are taken from thermocouples)

Figure 10 shows the optimised temperature cycle for the JustHeat system, maintaining room temperatures between 18°C and 21°C. The initial heat-up peak reflects the artificial cooling of the room at the start of the test, while subsequent cycles stabilised naturally. Compared with Figure 9, the slower temperature decrease demonstrates higher thermal efficiency and improved heat retention. Energy balance measurements confirmed that 95% of the input electricity was converted into useful heat within the room. In practical terms, this means **each minute of active heating delivers around six minutes comfortable room temperature.**

Real-World Energy Savings

A comparison study was carried out on a commercially available wire mat based underfloor heating system against the JustHeat Low Power Direct Heating System.

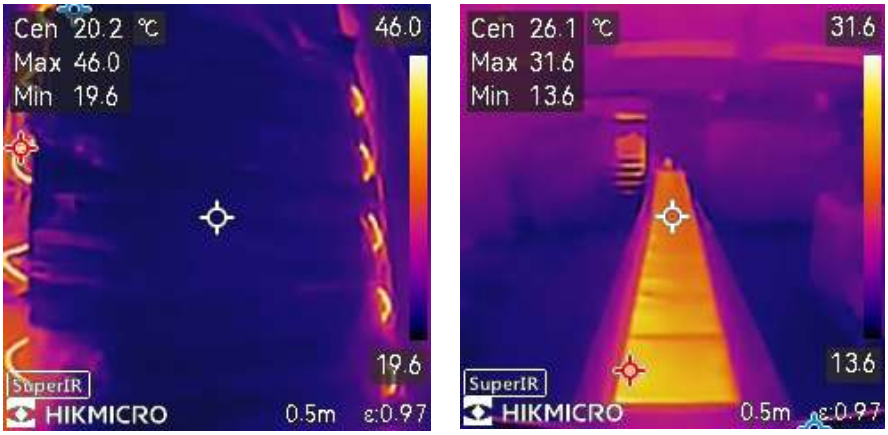

Figure 11: Wired UFH Infrared Image Temperature Profile (Left) vs JustHeat Panel Infrared Image Temperature Profile (Right)

Figure 11 compares a conventional wire-based underfloor heating system with the JustHeat panel. The wired UFH shows localised hotspots reaching 46 °C but minimal infrared emission, indicating low emissivity and uneven heat distribution. In contrast, the JustHeat panel maintains a uniform surface temperature of around 32 °C with strong, consistent infrared output.

Thermocouple data confirms that JustHeat panels heat up faster and more evenly, converting more of their energy into usable radiant heat within the room.

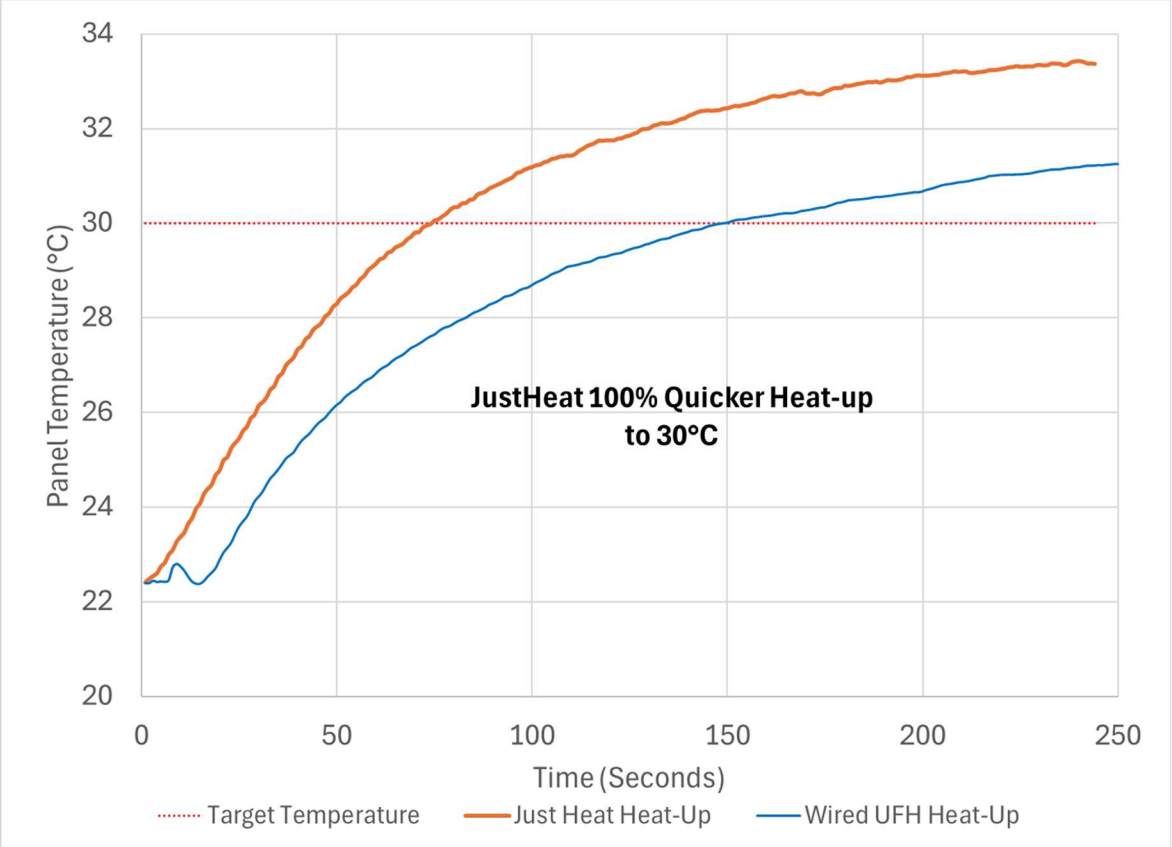

Figure 12: Comparison of the average heat-up rates for wired UFH and JustHeat low powered systems

The energy consumption for both systems was compared over a 4-day period, with the demonstration room air temperature cycling by 3°C.

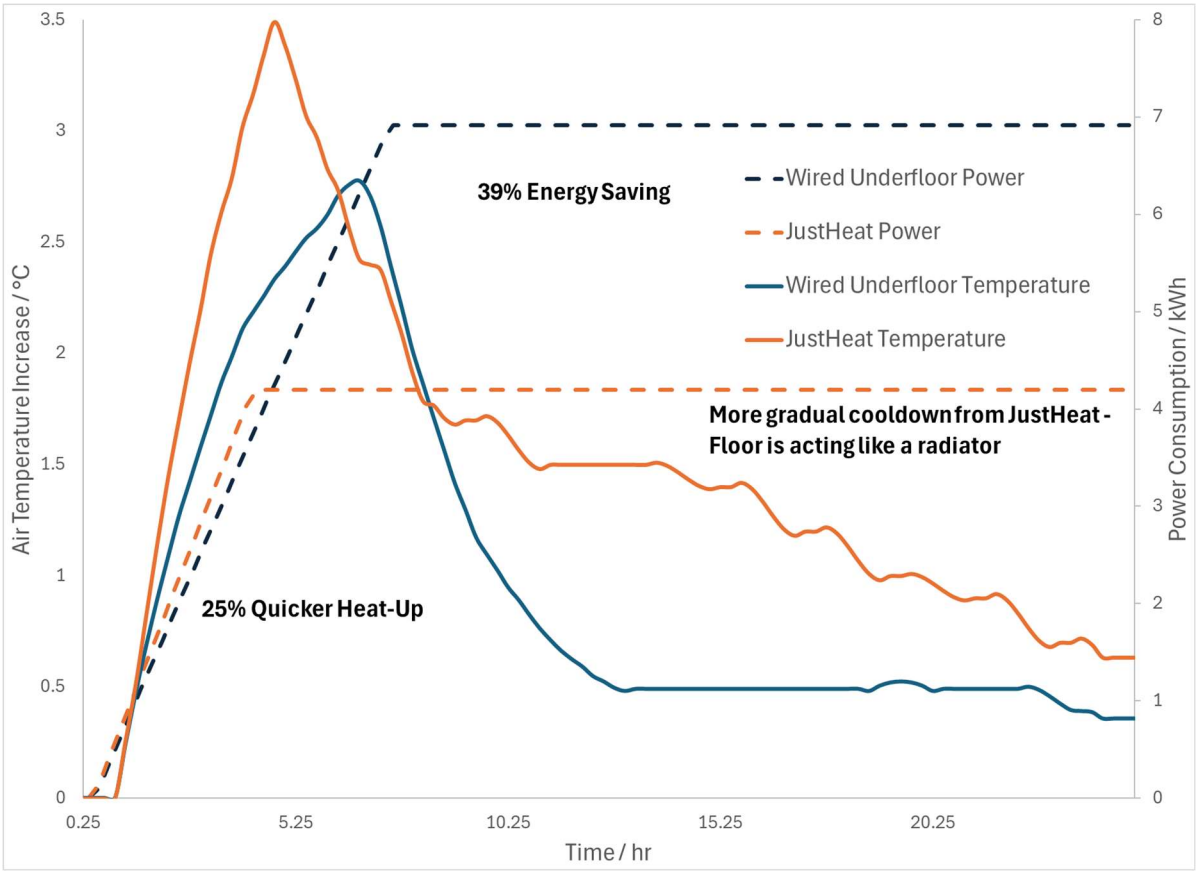

Figure 13: Comparison of energy consumption when the temperature is cycled by 3°C for wired UFH and JustHeat low powered systems (data for both curves has been smoothed using Savitsky-Golay method)

Figure 13 compares a single heating cycle of the JustHeat system with a conventional wired underfloor system. While both completed a similar number of cycles, JustHeat **achieved a 25% faster air temperature rise,** demonstrating higher energy efficiency. This improvement results from its lower operating temperature, which minimises wasted energy, and its larger radiant surface area, which raises the overall floor temperature and retains more residual heat after each cycle.

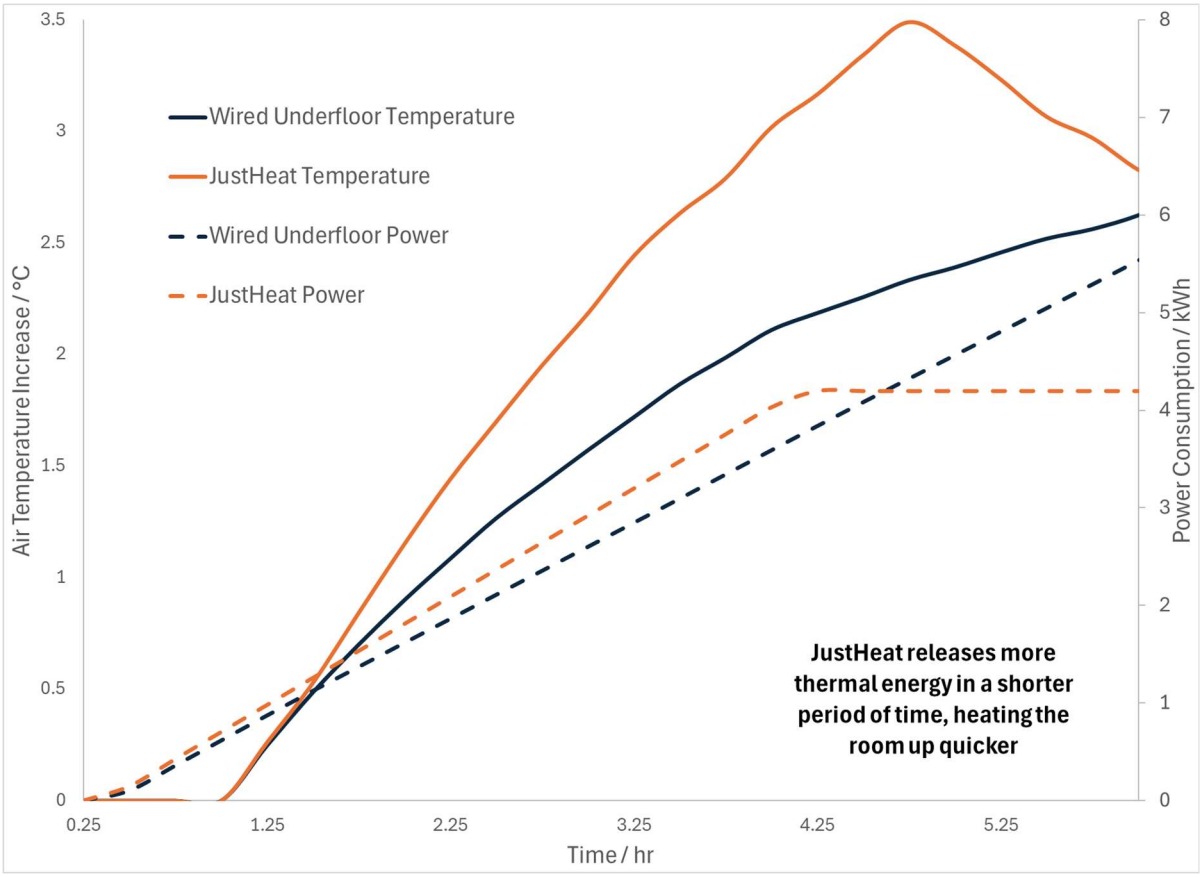

Figure 14: Initial heat up of the demonstration room by 3°C for JustHeat and Wire UFH (data for both curves has been smoothed using Savitsky-Golay method)

The JustHeat Direct Heating System delivers immediate warmth with exceptional energy efficiency. Its large radiant surface area ensures uniform heat distribution without hotspots, while operating at just 48 volts – a major reduction from conventional 240 V systems. This low-voltage design not only lowers energy consumption but also enables direct compatibility with solar and battery systems, supporting Net Zero objectives. Easy to install and cost-effective, JustHeat can transform any floor into a radiant heat source, making it ideal for both new builds and retrofits. Its rapid response also makes it suitable as a supplementary, battery-powered heating solution for vulnerable users or emergency applications.

The energy saving can then be applied to determine the annual energy savings, if 3 assumptions are made: the average house size is 100m^2, the unit price for electricity is 25.73p/kWh and the average household has their heating on for 168 days a year:

System Type	24 h Energy (kWh)	Annual Cost (£)	Savings vs Wire UFH
JustHeat	4.20	£1,019	–
Wire UFH	6.91	£1,679	39 % less energy used

In a standard 100 m² home, this equates to an **annual saving of ~£660** and a **reduction of 39 % in electrical consumption**.

Measured trials show **15–25 % lower energy use** versus gas radiator systems and **35–70 % less** than conventional electric underfloor heating or hydronic floors – with faster comfort response and better controllability.

Comparison to Other Systems

System	Energy Conversion	Response Time	Operating Temp.	Renewable Ready
JustHeat (Graphene UFH)	≈ 100 % (room-direct)	75 sec	30–35 °C	Yes (48V DC / PV-ready)
Wire UFH	60–70 % effective	>1 h	50–60 °C	No
Hydronic UFH	~85 % (delivery)	3–5 h	40–45 °C	Partial
Gas Radiator	~86 % (boiler efficiency)	30–60 min	60–70 °C	No
ASHP + Radiator	COP 2–3 but variable	45–90 min	40–55 °C	Yes (AC but slow)

Ongoing independent trials will further benchmark its performance against boiler and air-source heat pump systems to validate its superior efficiency and renewable readiness.

Comfort and Lifestyle Benefits

Beyond efficiency metrics, JustHeat enhances everyday comfort and flexibility:

- **Warmth in minutes** – perfect for intermittent use or fast recovery.
- **Comfort at lower air temperatures** – radiant heat warms people and surfaces, not just air.
- **Quiet, maintenance-free operation** – no pumps, fans, or moving parts.
- **Flexible and retrofit-friendly** – install under most flooring types.
- **Battery-ready emergency heat** – safe 48 V operation supports off-grid use.

Conclusion

JustHeat's graphene-based underfloor panels represent the next evolution of electric heating – combining the scientific rigour of plasma-functionalised nanomaterials with real-world performance and energy savings.

They deliver:

- Near-perfect emissivity for superior radiant efficiency.
- Fast warm-up, slow cool-down, and stable comfort.
- Uniform surface temperatures with no hotspots.
- Proven 35–40 % energy savings over legacy UFH systems.
- 48 V renewable compatibility for Net Zero heating.

In short, JustHeat provides radiant comfort, rapid response, and measurable energy savings, all in a safe, flexible, low-carbon system ready for today's Net Zero buildings.