HANDIHEAT T2.1.1 & T2.3.1: Utilising curtailed wind energy for domestic use in rural homes and household pathfinder pilot through upgraded energy performance and a renewable energy supply with resulting greenhouse gas savings

Abstract: *The decarbonisation of domestic energy consumption in rural areas is a critical challenge for meeting carbon reduction targets in the Northern Periphery and Arctic (NPA) region and the wider EU. Simultaneously, there is a growing recognition of the need to tackle rural energy poverty, with recent estimates suggesting that as many as 1 in 5 rural households in the EU may be living in energy poverty.*

Dr Patrick Keatley

Senior Lecturer (HANDIHEAT Associate Partner)

Ulster University

Robert Clements

Head of Sustainable Development (HANDIHEAT Project Lead)

Northern Ireland Housing Executive

HANDIHEAT T2.1.1 & T2.3.1: Utilising curtailed wind energy for domestic use in rural homes and household pathfinder pilot through upgraded energy performance and a renewable energy supply with resulting greenhouse gas savings

Background:

The Northern Ireland demonstration was led by the Housing Executive aims to explore the potential benefits of hybrid electricity generation and storage solutions for six Housing Executive owned properties in Lisnaskea, Co Fermanagh.

This pilot evaluated a combination of hybrid installations in these properties, including oil/electric boilers; air source heat pumps; solar photovoltaic panels; and battery storage systems as well as energy efficient insulation measures. In the strategic context of the national carbon reduction policies, there is an imperative to find alternative energy sources to counteract the current high level of fossil fuel consumption, particularly in rural settlements that do not have access to alternative sources of low carbon heating.

The Fermanagh pilot is also being supported by associate partners, Electric Storage Company, which specialises in energy storage solutions (storage batteries) and staff from the Ulster University, who will analyse and monitor the effectiveness of the hybrid systems over a 24 month period. Data from the pilot will be analysed to assess the suitability of low carbon and hybrid options as alternatives to oil fired boilers, which are still the predominant fuel source currently being installed in Northern Ireland.

Wind Curtailment: The Opportunity:

Northern Ireland has world-leading levels of wind energy; however, when wind generation exceeds electricity demand, the output from wind turbines is dispatched down - 'turned off'. In 2020, 15% of available wind with a retail value of over £80m, was dispatched down.

The rejection (or dispatch-down) of wind energy because there is no demand when it is available is a growing concern, especially for member states and regions integrating high levels of variable renewable energy. Demand flexibility presents an opportunity to move consumer loads to periods of excess wind energy, which could provide significant value to the system.

Northern Ireland achieved 49.2% renewable electricity generation (85% of which is wind energy) in 2020, exceeding its target of 40%. It has set a new target of 80% renewable electricity by 2030. It also plans to handle at least 90% System Non-Synchronous Penetration (SNSP – instantaneous power generated by non-synchronous generators, primarily wind) by 2030. The system can currently handle up to 75% SNSP at any time.

However, without a parallel increase in flexible demand for wind energy when it is available, for example through electrification of heat, turn-down is likely to increase, leading to higher costs for consumers and poorer returns for operators.

Fig. 1 below shows the percentage of dispatch-down of wind energy in Northern Ireland between 2011 and 2020. There has been a steady increase in dispatch-down as the penetration of wind energy has increased. In 2020, about 15% of available wind energy was rejected. Without demand flexibility, there will be more curtailment and constraint of wind energy as Northern Ireland strives to reach its 2030 targets. Uniquely, in Northern Ireland more than 90% of wind generation is connected to the distribution network, presenting opportunities for consumer-owned flexibility to be used to manage the variabilities, curtailments, and constraints locally.

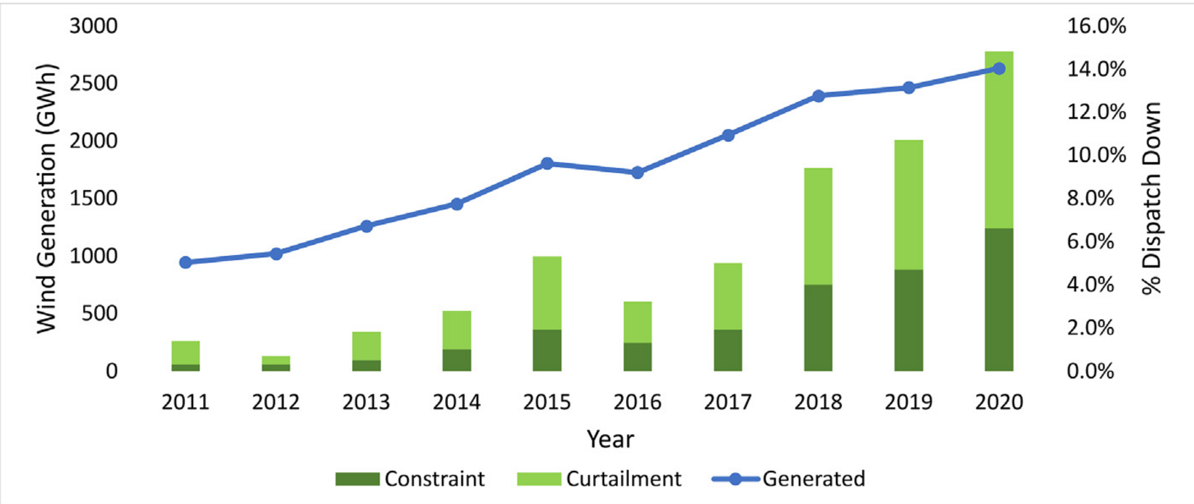
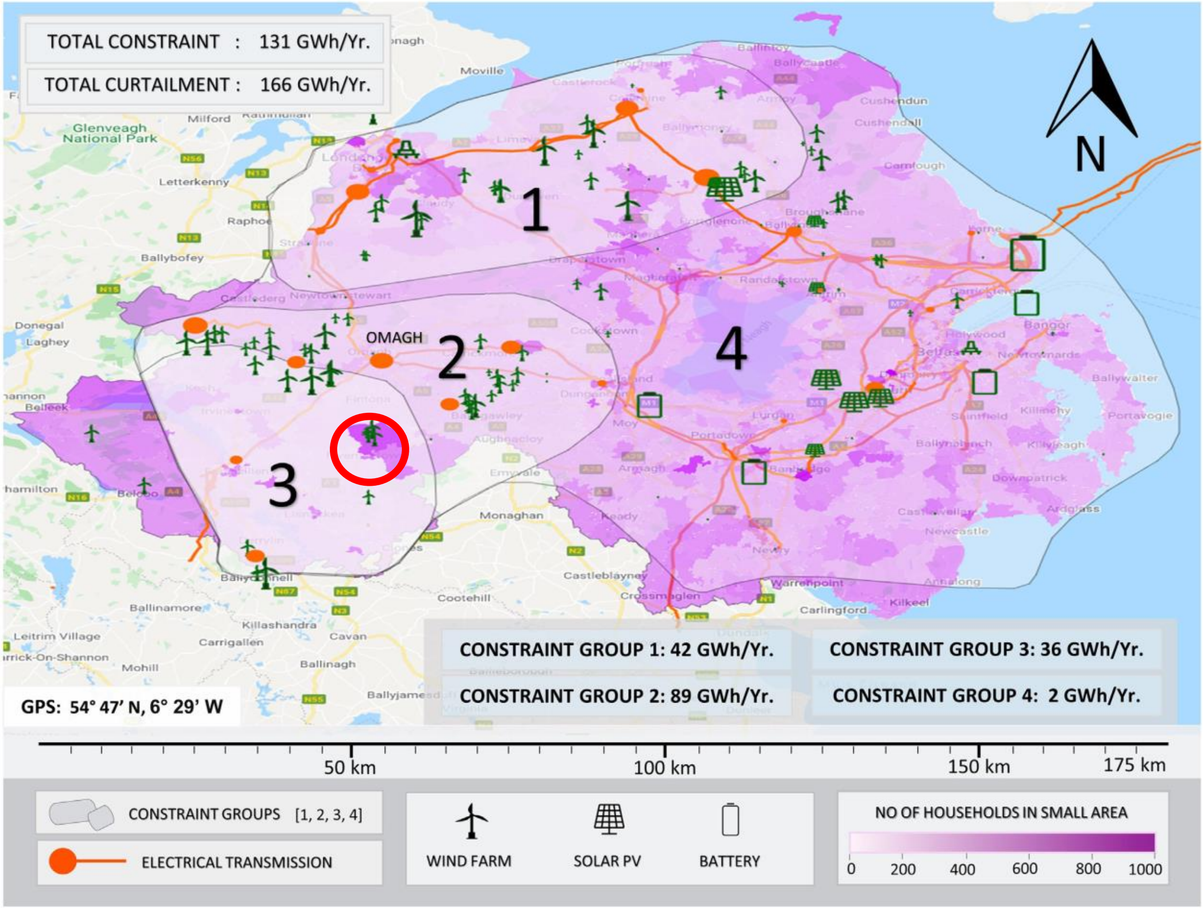


Figure 1 Wind Energy Turn-down in Northern Ireland 2011-2020

There are four constrained zones (known as constraint groups) in Northern Ireland in which wind generators are routinely dispatched down because local wind generation exceeds demand. These, along with the volumes of wind energy dispatched down in each group, are shown in Figure 2.



Constraint group 3 is a subset of constraint group 2; hence, the total constrained wind energy for constraint group 2 is 89 GWh/Yr (53 GWh/Yr plus 36 GWh/Yr). The location of Lisnaskea, the area selected for the Handiheat trial is highlighted in red in constraint group 3 in Figure 2.

Household Pathfinder Pilot

As part of the **Handiheat** project, NIHE designed and implemented a trial to assess how electrical heating, energy storage and smart control technologies could increase the uptake of wind energy in highly constrained rural areas.

The project involved a field trial of a range of domestic energy systems provided by project partners Climote, Grant Boilers and the Electric Storage Company. The trial incorporated hybrid heating and electric generation and storage installations, including hybrid oil boilers with air source heat pumps, solar photovoltaic panels, and battery storage systems as well as improved energy efficiency measures. The aims of the trial were to improve thermal comfort for householders, reduce energy bills and to reduce greenhouse gas emissions by displacing oil heating with locally generated clean electricity. In parallel with the field trial, NIE Networks and SONI were able to assess the impacts of the uptake of flexible electrical heating systems in NIHE's dwellings; in particular, in off-gas grid homes in areas of high wind penetration.

Context for Domestic Renewable Heat in Northern Ireland

The Northern Ireland Renewables Obligation (a feed in tariff) and the NI Renewable Heat Incentive (RHI) have been the main support mechanisms for installing renewable technologies in homes and businesses (DECC, 2016a). Though these schemes were not developed specifically for social housing, some social housing providers (including the NIHE) have taken advantage of them to install solar panels and renewable heat technologies in some of their houses. They had hoped it would provide significant fuel savings for their tenants. However, it is not clear whether tenants are reaping the full benefits of these technologies. For example, solar PV would generate electricity during the day when the sun is shining. However, if tenants are not at home, they may not make use of the energy generated and hence installing solar PV may not provide the intended benefit to the tenants (such as reducing electricity cost and tacking fuel poverty) (Clark & Hay, 2012).

There have been more concerns regarding renewable heat technologies. For example, some tenants may not understand the new heat system or controls. Furthermore, renewable heat technologies making use of electricity (e.g., heat pumps, immersion heaters) are affected by electricity price fluctuations. Increase in variable renewable energy sources such as wind could lead to a higher cost of grid balancing services, electrification of heat could also lead to congestions in medium and low voltage networks, which would require additional network investments (Agbonaye et al., 2020). These factors may increase energy costs for tenants, and hence there has been some reluctance from social housing providers to install these technologies in their houses (Stockton & Campbell, 2011).

The NIRO and RHI are now suspended, and hence there is currently no mechanism for incentivising the uptake of these low carbon technologies. However, new mechanisms for funding renewable energy technologies have started to emerge. An example is demand flexibility, using energy storage devices to maximise self-consumption of solar generation, moving consumers demand to times of lower electricity prices and using these low carbon devices to provide services to the grid (the revenue received is then used to finance the system) (Agbonaye *et al.*, 2019). Tenants may opt into dynamic tariffs in the future, but without energy storage technology, such tariffs may lead to higher energy prices for tenants or may cause severe loss of comfort and quality of life (Agbonaye *et al.*, 2020).

However, it is important to know how tenants use low carbon technologies in order to develop an appropriate strategy for their mass adoption. The aim of this trial is to investigate how rural households use renewable energy technologies and provide learnings on how they could adopt these technologies without the risk of energy price fluctuations or loss of comfort. There has been a lack of data about how Northern Irish homes use low carbon heat technologies. The Handiheat project provided such data to aid analysis and provide a better understanding of the impact of renewable technologies in low-income homes. This could help to inform NIHE policy decisions regarding large scale implementation of low carbon heat solutions. Houses were retrofitted with energy efficiency measures (an estimated energy efficiency budget of £8K), various low carbon heat solutions and renewable generation technologies.

Tenant Offer

- Tenants were assured no increase in electricity bill. Hence, they were incentivised to use the devices normally as they would use with the traditional fossil-fuel heat technologies (1-2 hours boosts or longer).
- Houses were retrofitted with energy efficiency measures which would provide the tenants with improved thermal comfort.

Energy Efficiency Measures

Examples of Energy Efficiency measures provided to the houses include:

- Double Glaze A-rated window sealed with approved air tape and aerogel.

- Cavity wall insulation replacement
- Eaves treatment with PIR
- 300mm Loft Insulation
- PIV system with heat
- Houses were also tested for airtightness.

The figure below gives a breakdown of the trial houses and the list of energy efficiency measures and low carbon technologies installed.

ITEM	House No. 1	House No. 2	House No. 3	House No. 4	House No.5	House No.6
Solar PV 2.5Kw	☒	☒	☒	☒	☒	☒
Modern Oil Boiler	☒					☒
Hybrid Oil Boiler with Electric Immersion		☒				
Air Source Heat Pump (ASHP)			☒			
Hybrid Oil Boiler with ASHP				☒		
High Inertia Direct Acting Heating System					☒	
Electric Battery Storage (11kw, 10kW usable)					☒	☒
Utilise HWC as Thermal Store	☒	☒	☒	☒		☒
Climote timeclock zoned heating/water per storey	☒	☒	☒	☒	☒	☒
NIHE Standard GRP external doors x 2 with improved fitting	☒	☒	☒	☒	☒	☒
Triple Glazed Windows sealed with approved air tape	☒	☒	☒	☒	☒	
Double Glaze A-rated windows						☒
Cavity Wall Insulation replacement	☒	☒	☒	☒	☒	
Eaves treatment with PIR	☒	☒	☒	☒	☒	
300mm Loft Insulation	☒	☒	☒	☒	☒	☒
Partial Airtightness Strategy (confirm with NIHE)	☒	☒	☒	☒	☒	
Demand Controlled MEV system	☒	☒	☒	☒	☒	
Air-tightness testing	☒	☒	☒	☒	☒	☒

Six homes were investigated.

- Four of the houses were fitted with Various low carbon heat Solutions: House H1 – H4
    - House 1 (H1): Modern Oil Boiler
    - House 2 (H2): Hybrid Oil Boiler with Electric Immersion
    - House 3 (H3): Hybrid Oil Boiler with Air-Source Heat Pump
    - House 4 (H4): Hybrid Oil Boiler with Air-Source Heat Pump
- Two of the Houses were fitted with solar PV and battery: House P1 and P2

❖ **<u>House H1</u>**

House H1 is a mid-terraced building with an SAP value of 58, EPC Band D. A Modern Oil Boiler was installed in this house.

❖ **<u>House H2</u>**

This is a two-storey mid-terraced building built in the 1960s. The house had an SAP value of 57 (EPC Band D). The house was retrofitted with energy efficiency measures and a hybrid oil boiler with an electric immersion heater was installed. However, the tenant in this house passed away during the project and data monitoring was terminated.

❖ **House H3**

This is a two-storey, three-bedroom mid-terraced building occupied by a young family who had a new baby in December 2020, and a subsequent increase in heat demand. The house had an SAP value of 57 (EPC Band D). This house was fitted with energy efficiency measures and heated by a Grant hybrid heat pump/ oil boiler (see below).


GRANT
AERONA³

- **House H4:**

  This is a two-storey, three-bedroom, end-terraced building occupied by a young family. The house was fitted with energy efficiency measures and heated by a hybrid heat pump/oil boiler.

- **House P1**

  This is a single storey two-bedroom, mid-terraced house. It is a single person occupancy. This house was fitted with energy efficiency measures, solar PV, electric battery, electric heating (see below)

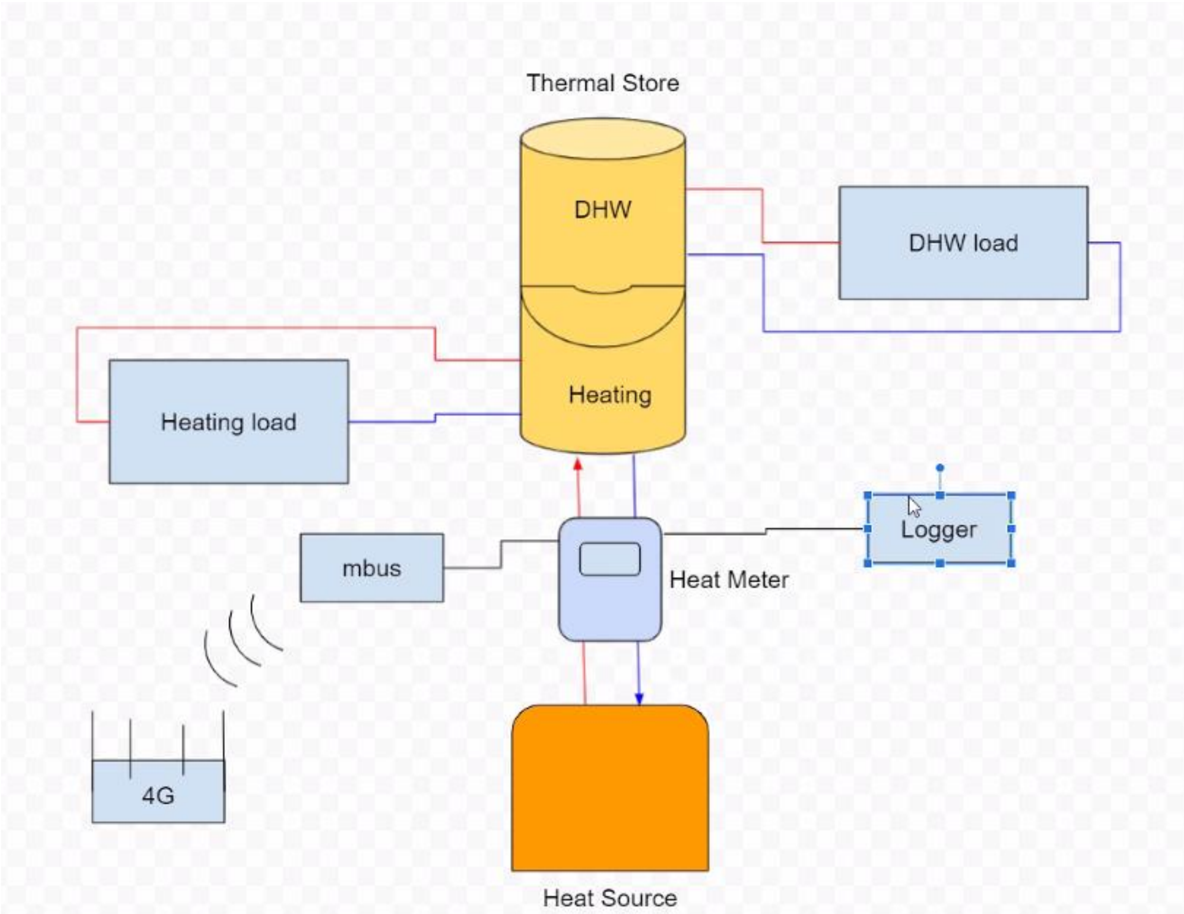
❖ **House P2**

This house was fitted with energy efficiency measures, solar PV, electric battery, electric heating

Data Monitoring

Ulster University oversaw monitoring and analytics for the project. Handiheat involved several industry partners, who collaborated at various levels, particularly with data monitoring. The project also assessed the viability of low-cost data monitoring equipment.

The figure below provides an overview of the data monitoring. The trial initially started with passive monitoring but later switched to an active monitoring system due to several challenges faced with passive monitoring.



<u>You Generate CIC</u>

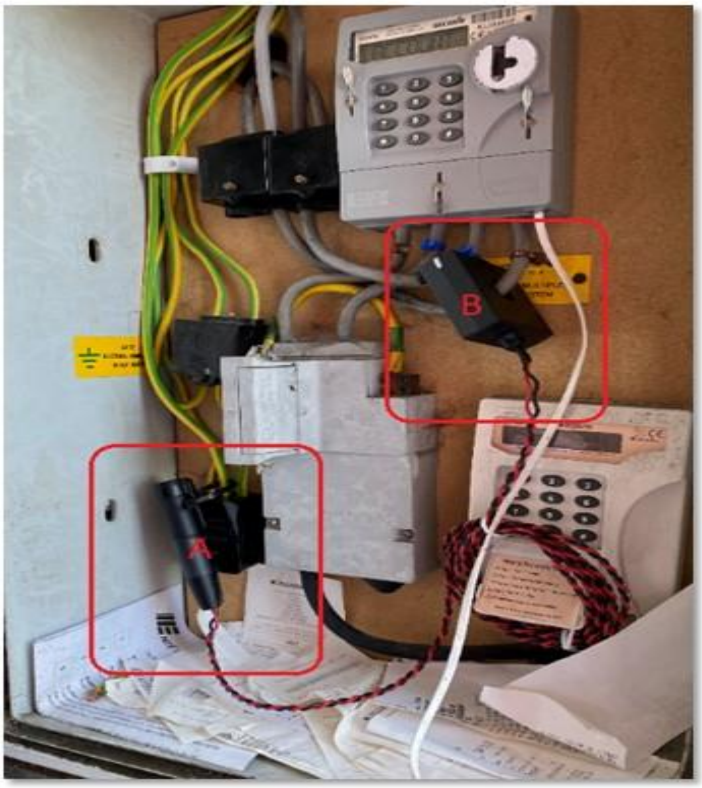
You Generate CIC provided heat metering for the wet heating systems and the record of the amount of the energy generated for both domestic hot water (DHW) and heating combined. You Generate also monored electrical energy imported from the grid.

(a) Passive monitoring

Pulse data loggers were initially used to monitor the heat generated, while a USB logger was used to measure the electrical input to the heat pump. Both loggers had to be manually read on site and reset when the memory is full. While the heat loggers could store up to a year's worth of data, the electrical loggers has to be read at most every 40 days, and ideally every month. Data recording had to be stopped before downloading stored data and then restarted to record new data. This resulted in errors in device configurations and missing datasets.

The figure below shows the setup for the heat data monitoring. (A) is the heat meter installed on the return flow from the heat source, which is connected to the heat logger (B) for easy access. The heat meter measures the flow rate, flow and return temperature.

The figure below shows an example of the electrical monitoring. The USB loggers only give a snapshot of the watts being used at the time of measurement (every 2 minutes).



(b) Active monitoring

Due to the challenges with the passive data monitoring, a more active approach (remote monitoring) was implemented. The pulse data logger has been upgraded with an EMON monitor, which includes an MBUS with 4G data to automatically send data to improve data reliability and improve data access.

The following devices were installed.

- 4G with Wi-Fi
- EmonTX for electrical measurement. The emonTX would also allow for more granular (10sec) real-time data gathering. The data is relayed back to the monitoring platform via WIFI.
- Mbus reader for heat meter. It pulls the data using mbus from the heat meter and transmits it via WIFI and stores it locally.

Grant Monitoring

Grant is the manufacturer of the hybrid air source heat pump (ASHP) used in the trial. The device is intended to reduce the cost of energy efficiency measures needed to be installed. Heating is provided by a 6kW ASHP which runs in conjunction with the oil boiler. The boiler fires only when the ASHP can no longer meet the demand. The ASHP is controlled by a smart ‘Evolink’ monitor, which also records thermal data for the devices.

Climote

Climote smart heating controllers (see below) were used to record the on and off times of the heat devices as well as recording the internal temperature of the houses. The schedule and internal temperature of the houses were recorded before the trial to understand how the houses use heat before the measures were implemented. The pre-trial data were collected between February 2020 – October 2020.

The Electric Storage Company

The Electric Storage Company installed Sonnen battery storage systems into two of the houses.

The various data sources were aggregated and compared to provide a holistic view of energy consumption and environmental conditions in the trial houses.

Data Monitoring Challenges

- Covid 19 disruption delayed the installation of monitoring devices in homes and significantly delayed carrying out air-tightness tests and in installing energy efficiency measures.
- One of the tenants passed-away (House H2).
- Missing timestamps due to loggers not being correctly reset after data was downloaded.
- Electrical data for heat was not separated from general electrical data.
- The heat pulse logger time resolution was too low. Hence sometimes, there was electrical demand but no corresponding heat demand.
- Space heating and DHW were not separated.

Scheduling

The heat devices were pre-set using the Climote smart thermostat as shown in the figure below.

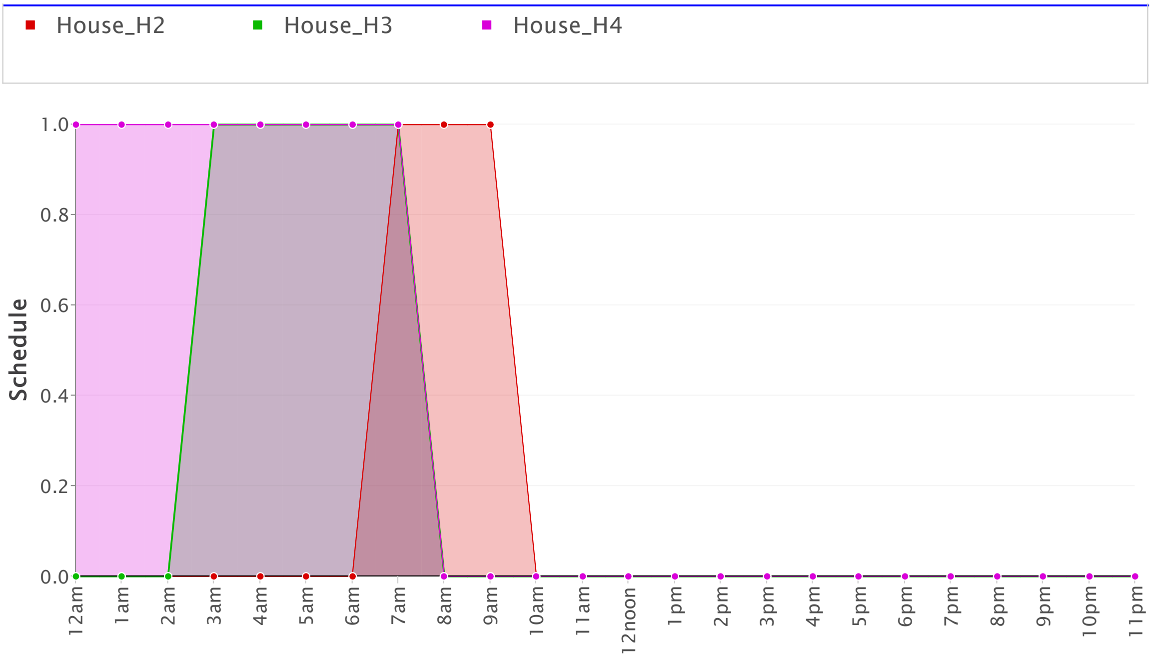


Figure: Schedule for the Heat Trial Houses

The figure below shows the number of 15 minutes on time for each of the houses. The devices were operated more frequently during the winter period.

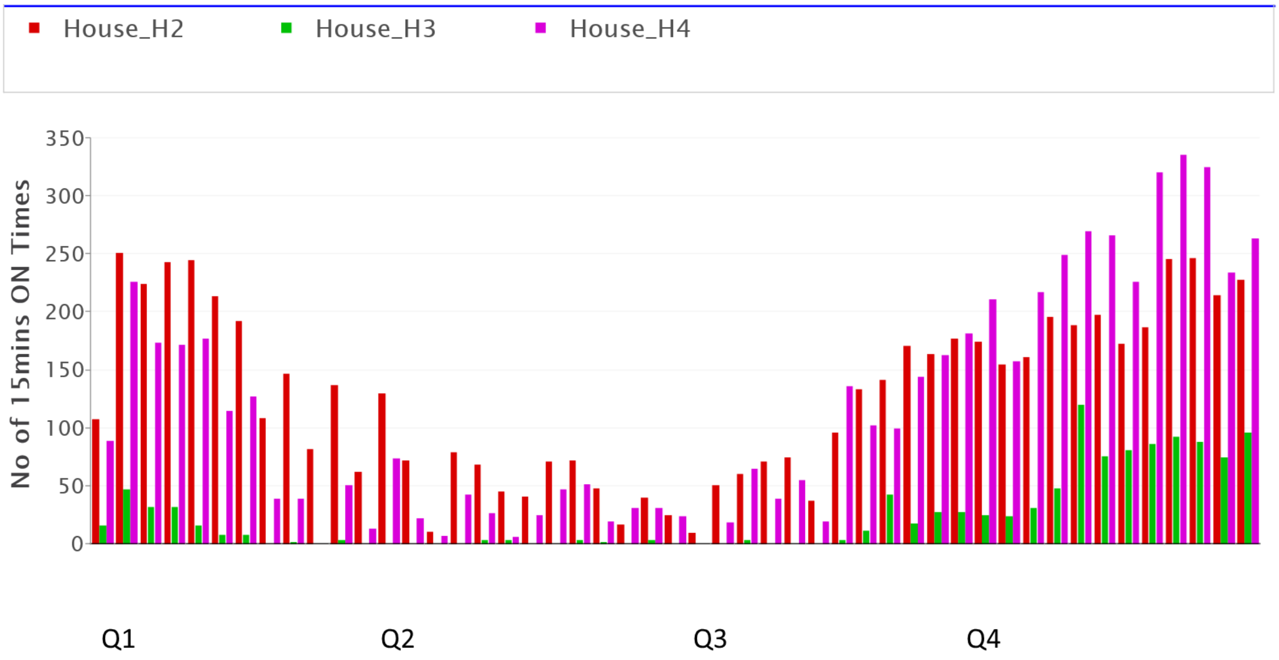


Figure: No of 15minute ON Times per week for the Heat Trial Houses

The heat in House H2 was turned on for up to 63 hours a week during the peak winter period (a yearly average of 32 hours/week). The heat in House H3 was turned on for up to 30 hours a week during the peak winter period (yearly average of 6 hours/week). The heat in House H4 was turned on for up to 84 hours a week during the peak winter period (yearly average of 30 hours/week), as seen in the table below.

Table 1: Summary of ON times for the heat trial houses.

	House H2	House H3	House H4
Average ON Hours/Week	32	6	30
Maximum ON Hours/Week	63	30	84

Internal Temperature

The figure below shows the average hourly internal temperature of the houses. The internal temperature for the houses seems to peak in the evening (between 6 – 11 pm) and dip during the day.

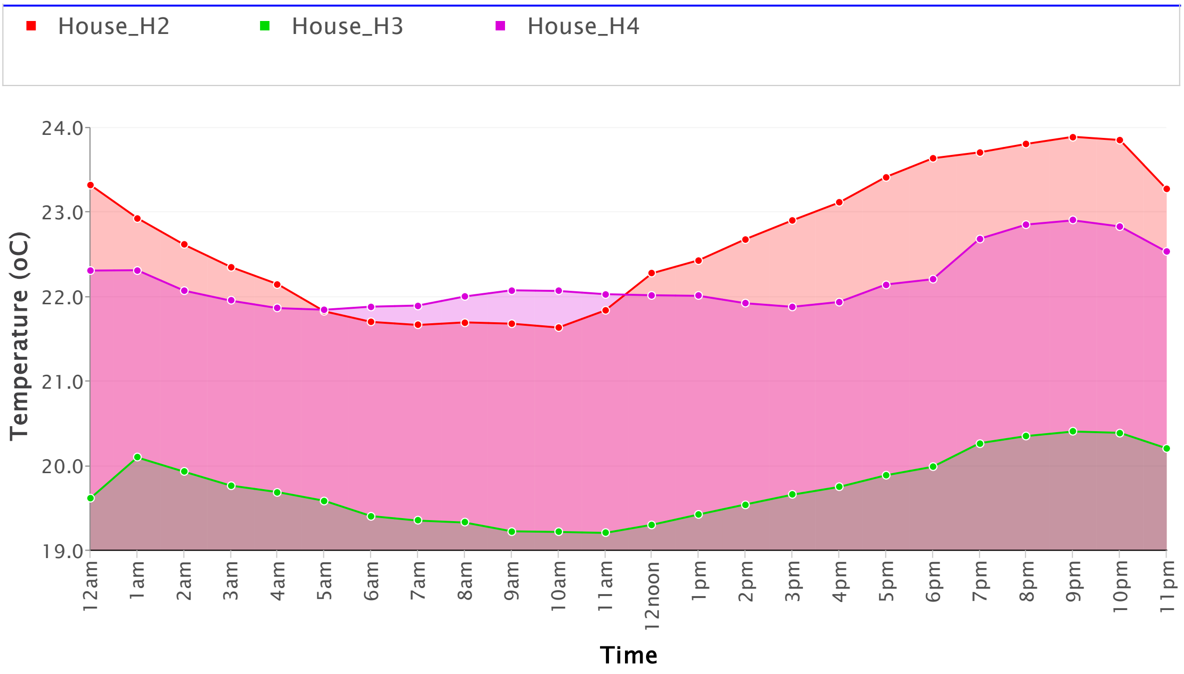


Figure: Average Hourly Internal Temperature for the Heat Trial Houses

The figure below also shows the average internal temperature for each month of the year. House H3 seem to be less concerned about adequate warmth. This is also evident from the table below as it shows that at certain times the house could be as cold as 10°C, as seen in Table 2.

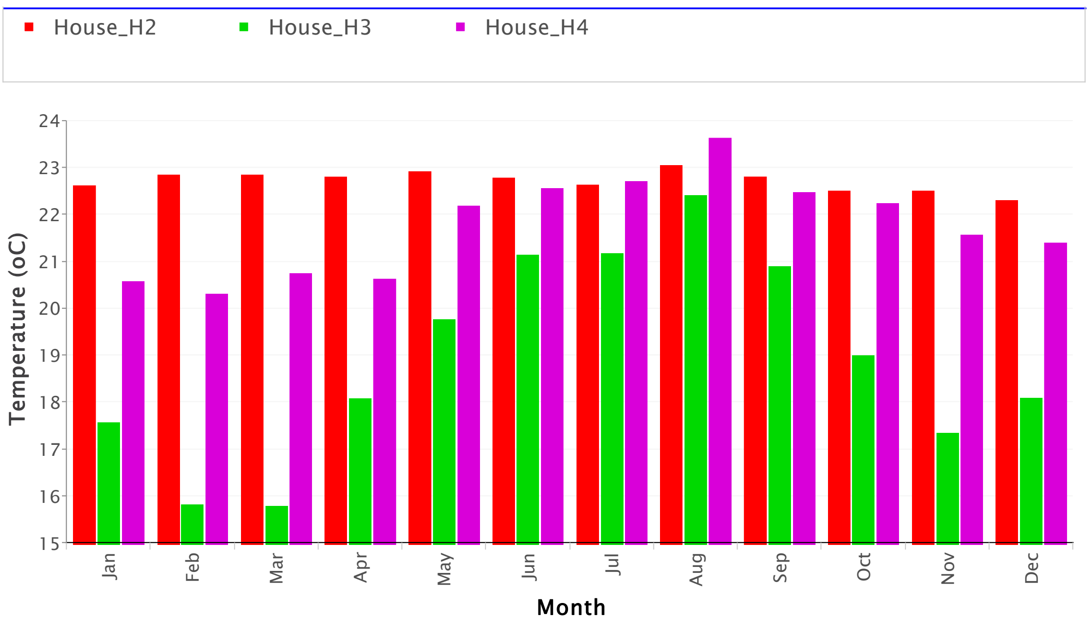


Figure: Average Monthly Internal Temperature for the Heat Trial Houses

Table 2: Summary of internal temperature for the heat trial houses.

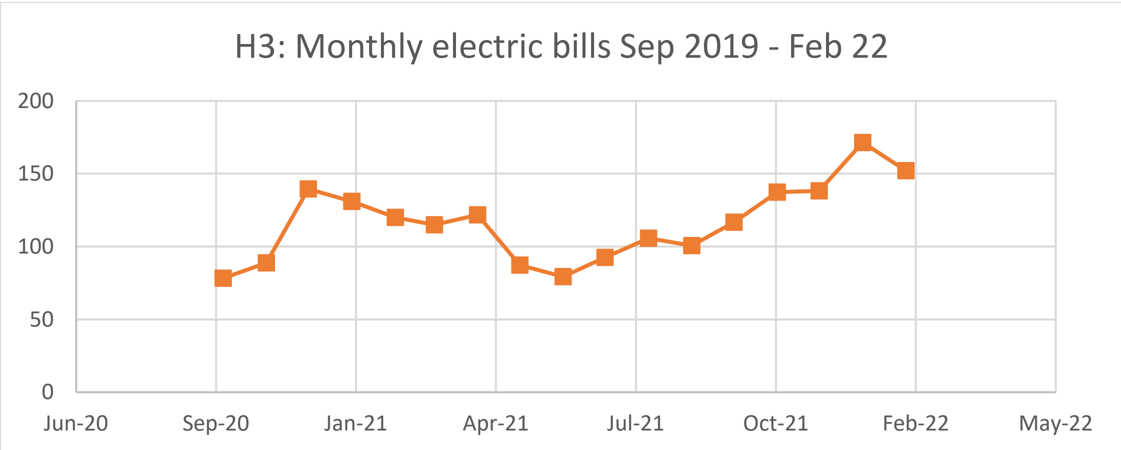
	House H2	House H3	House H4
Minimum Internal Temp (ºC)	19	10	16
Maximum Internal Temp (ºC)	25	26	26

Under the 10% methodology, a household is considered to be in fuel poverty, if in order to maintain a satisfactory level of heating (21ºC in the main living area and 18ºC in other occupied rooms), it is required to spend in excess of 10% of its household income on all fuel used. This metric will be reviewed under the energy cost analysis section (BEIS, 2010).

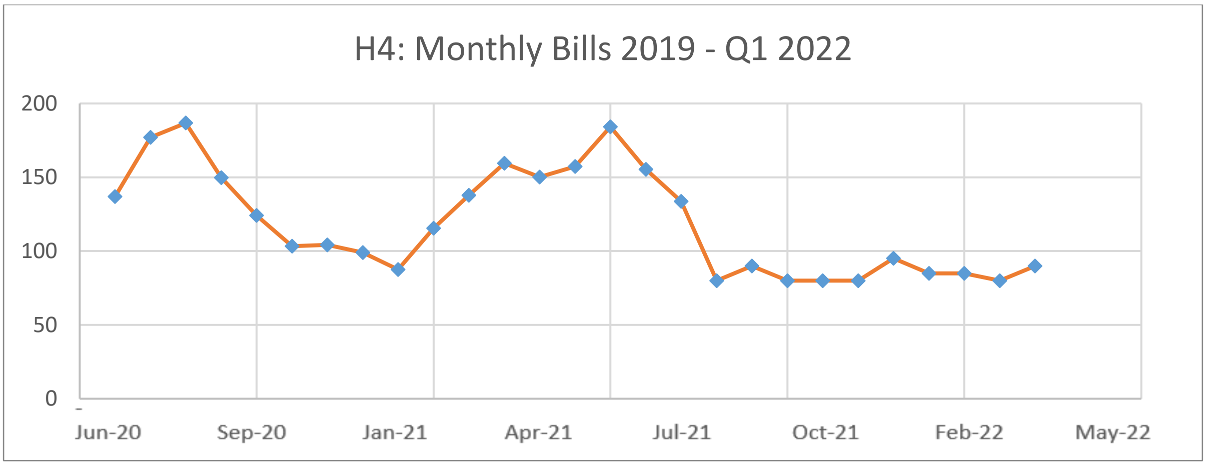
Energy Demand and Cost Data

As below, the householder's energy use and increased need for thermal comfort had a direct correlation with the household energy bills. A challenge going forward is to educate the householders that the increased electric costs are offset by savings in reduced home heating oil consumption.

Going forward a larger sample size is needed to provide clear learning points, which was severely disrupted with COVID 19.



HANDIHEAT
Northern Periphery and Arctic Programme 2014-2020
EUROPEAN UNION
Investing in your future
European Regional Development Fund



Summary and Next Steps

The HANDIHEAT Fermanagh pilot explored the potential benefits of hybrid electricity generation and storage solutions for six Housing Executive owned properties in Lisnaskea, Co Fermanagh.

This pilot evaluated a combination of hybrid installations in these properties, including oil/electric boilers; air source heat pumps; solar photovoltaic panels; and battery storage systems as well as energy efficient insulation measures. In the strategic context of the NI Energy Strategy and NI Climate Bill, there is an imperative to find alternative energy sources to counteract the current high level of fossil fuel consumption, particularly in rural settlements that do not have access to alternative sources of low carbon heating.

After the HANDIHEAT pilot, the Northern Ireland Housing Executive and Ulster University developed another pilot and learned from the key issues of improving monitoring, namely RULET pilot. The RULET builds on the work of the HANDIHEAT project (which tested low carbon heating and improved thermal performance). RULET is focused on making the full benefits of smart energy technology available to the most vulnerable households in the western counties of Northern Ireland, a wind energy hotspot. Other partners include Utility Regulator, NIE Networks, Energia/PowerNI, manufacturers Grant & Sunamp, and smart heating control developer Climote.

Learning points from the HANDIHEAT and RULET pilots as well as evidence from other pilots which the Housing Executive support (GIRONA) to scope out a low carbon programme of 300+

houses over 2023/25 to provide evidence for a future decarbonised heating policy, in line with national and local climate action plan targets. Without the initiation of pathfinder pilots via HANDIHEAT the Housing Executive as Northern Ireland's strategic housing authority with ownership of 12% of NI housing and impact across all the 800,000 houses we would not be on a trajectory toward decarbonisation.

Wind Curtailment: The RULET built on the research from HANIDHEAT to investigate the benefit of wind curtailment for rural households. With our network of partnerships across ROI and NI via HANDIHEAT, I successfully approached and negotiated an innovative second phase for the RULET pilot to use the Energy Cloud concept. This utilises the opportunity to capture surplus renewable wind energy (up to 15% annually - €50 million) and redistribute a proportion of this surplus energy to provide free hot water to the remaining 50 houses in this pilot. In ROI, this Energy Cloud concept is being trailed by Clúid Housing. With the key learning and negotiation during the HANDIHEAT project I am collaborating with the Energy Cloud ROI team to replicate this concept in NI and provide a scalable solution to reduce energy costs and carbon emissions for thousands of households, with an initial test of 50 houses in the RULET pilot, which is built upon the HANDIHEAT pilot.