Construct Innovate
Built Environment Research Ireland

AHARDD Programme Final Report

Sustainable living houses and apartments performance data

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Revision	**Date**	**Modifications**
R00	28/11/2023	1st version
R01	04/02/2024	Revised based on peer review

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1 Introduction

1.1 Objective of Report

This report focuses on the outcomes of the Accelerated Housing Applied Research, Dissemination and Demonstration (AHARDD) Programme funding to support the project 'Sustainable Living Houses/apartments-Performance Data'.

1.2 Project Aims

This AHARDD programme funding was to support the development of an open source IOT platform for monitoring building operational energy and indoor environmental quality performance levels.

This project builds on the work of HEAT-CHECK, an SEAI funded project, which is examining the energy demand and indoor environmental quality levels of 100 new and retrofit homes with the overall objective of improving the DEAP energy compliance procedure. The project has focused on establishing the hardware and database of an IOT platform with the AHARDD funding accelerating the development of the cloud infrastructure and system API. The adaptable and scalable IOT based platform will provide services to stakeholders in the building and construction industry including:

- Performance level monitoring of building technologies installed in both new build and retrofit properties, including those constructed with MMC based methods.
- Monitoring, and analysis of energy and indoor environmental quality KPIs and benchmarking for a growing number of buildings, sites, and facilities.
- Identification of abnormal energy demand and indoor environmental quality patterns to allow stakeholders to act proactively.
- Insights of energy demand and indoor environmental quality of homes through customizable reports.
- Occupant's guidance documents for how to best use their home and appliances for optimum energy consumption and indoor environmental conditions (thermal comfort, ventilation, etc.)
- Measure operational GHG emissions for homes to inform progress against the Climate Action Plan.

This project is in partnership with Land Development Agency who co-funded the project to monitoring the performance levels of over 90 homes.

The project will therefore also deliver a database of energy performance and indoor environmental quality data to de-risk any potential energy performance gaps (i.e. the difference between measured and expected) associated with building technologies and assist in accelerating their delivery to market. The database of information will provide a benchmark of the performance of existing market solutions to assist in establishing a path forward for the industry.

1.3 Report Structure

The report begins by outlining its purpose, and the project aims. Section 2 presents how each of the project aims were addressed as part of the project with Section 3 providing conclusions.

2 Deliverables of Project

2.1 Performance level monitoring of building technologies

94 apartments were identified by the Land Development Agency (LDA) for monitoring. Negotiations with the contractor for the installation of IOT system hardware for building performance monitoring delayed the project. A trial installation of one apartment was conducted on 17th November with agreement established between LDA, University of Galway and contractor for installation of IOT system hardware for remaining 93 apartments. The installation of remaining IOT hardware will be conducted in December 2023 with monitoring to be conducted throughout 2024. Table 1 provides the equipment forming the physical layer of IOT system for LDA requirements.

Table 1: Equipment forming physical layer of IOT system for LDA requirements.

Equipment	Purpose	LDA requirements
ELSYS ERS CO2 	Measure indoor environmental quality of buildings (Temperature, Carbon Dioxide, Relative Humidity, Brightness)	• Measurement and verification of building indoor environmental performance • Feedback to householders • KPI tracking and analysis • Sustainability reporting
Electricity Consumption- 17 Electricity Circuits (	Measure electricity consumption of 17 electrical circuits (including total) .	• Energy auditing • Measurement and verification of building performance • KPI tracking and analysis • Sustainability reporting • Feedback to householders on their energy use patterns and energy saving tips
Outdoor Gateway 	Gateway for LoRaWAN Network	Establishing wireless network for building portfolio energy management system

The IOT hardware forms the physical layer of the overall HEAT-CHECK platform architecture which is a flexible middleware comprising of three layers. To support the functioning of the physical layer to provide the desired insights into the data, there are the virtualized layer, and the application layer, as illustrated in Figure 1. The IOT equipment also includes LoRaWAN gateways and broadband devices that deliver the data from the sensors to the virtual layer which acts as a database for the energy performance and indoor environmental quality data.

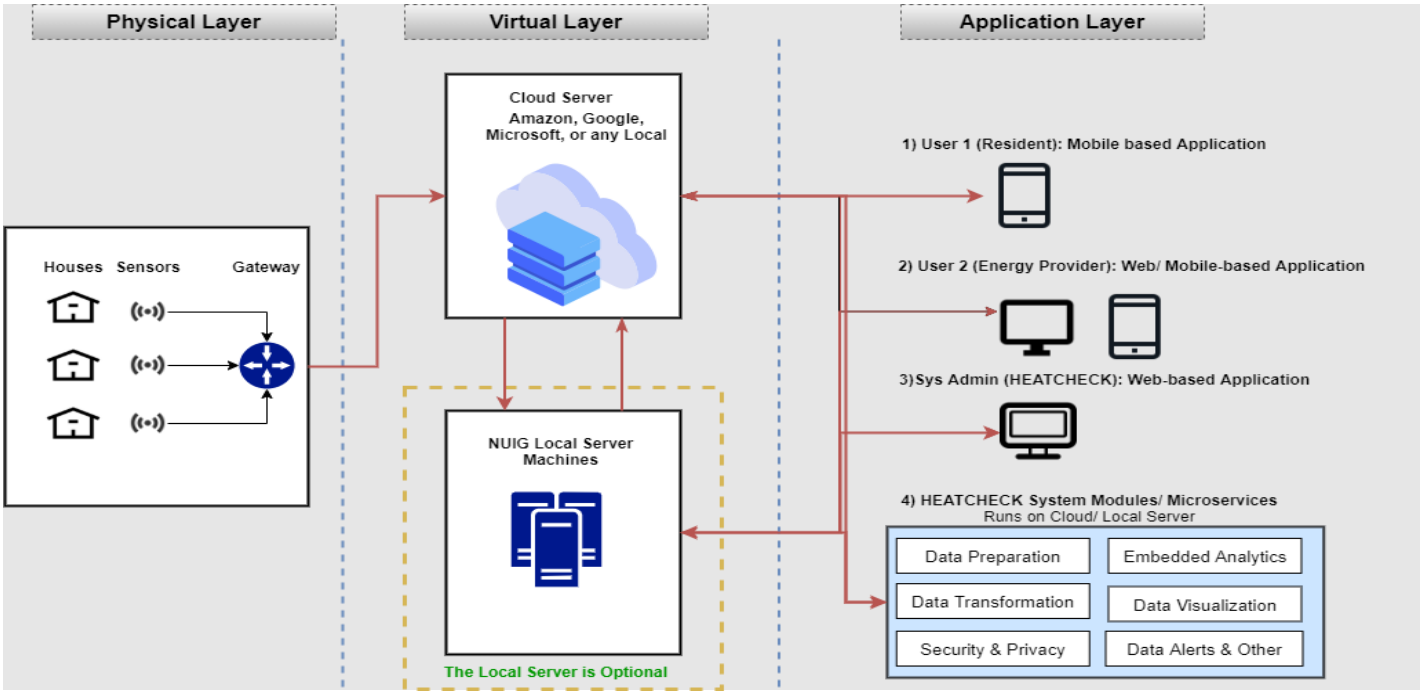


Figure 1: Overview of the technological infrastructure of HEAT-CHECK solution

2.2 Database of energy performance and indoor environmental quality

In the **virtual layer** the HEAT-CHECK network server is implemented, which collects reliable data over LoRaWAN based network server. The gateways push the data to the network server, which, in turn, pushes the data to the application server as necessary. A database of the data measured as part of the physical layer is stored and used in the services applied as part of the application layer.

2.3 IOT platform for monitoring, and analysis of energy and indoor environmental quality KPIs and benchmarking

In the **application layer**, the HEAT-CHECK system supports the provision of information to stakeholders. A beta version of the IOT platform application layer was developed with support of the AHARDD programme funding. More precisely the system is a hybrid system built over LoRaWAN based supported technologies (sensors, gateway, protocol, and others) and equipped with the flexibility of Wi-Fi-based devices. Amazon Web Services Infrastructure and services (as shown in Figure 2) is used to ensure the hardware and software flexibility, security, privacy, and availability of the system for different end users.

A fully cloud-based virtual and application layer based on AWS environment (shown in Figure 2) has been defined, designed and partially developed during the AHARDD project. This used to manage and monitor remote devices and gateways with an elaborate toolset, using the AWS rules engine. Data confidentiality, data integrity, data availability, data encryption, infrastructure security, configuration management, identity, and access control, monitoring and logging, and multiple account access are features that the system provides to secure cloud infrastructure.

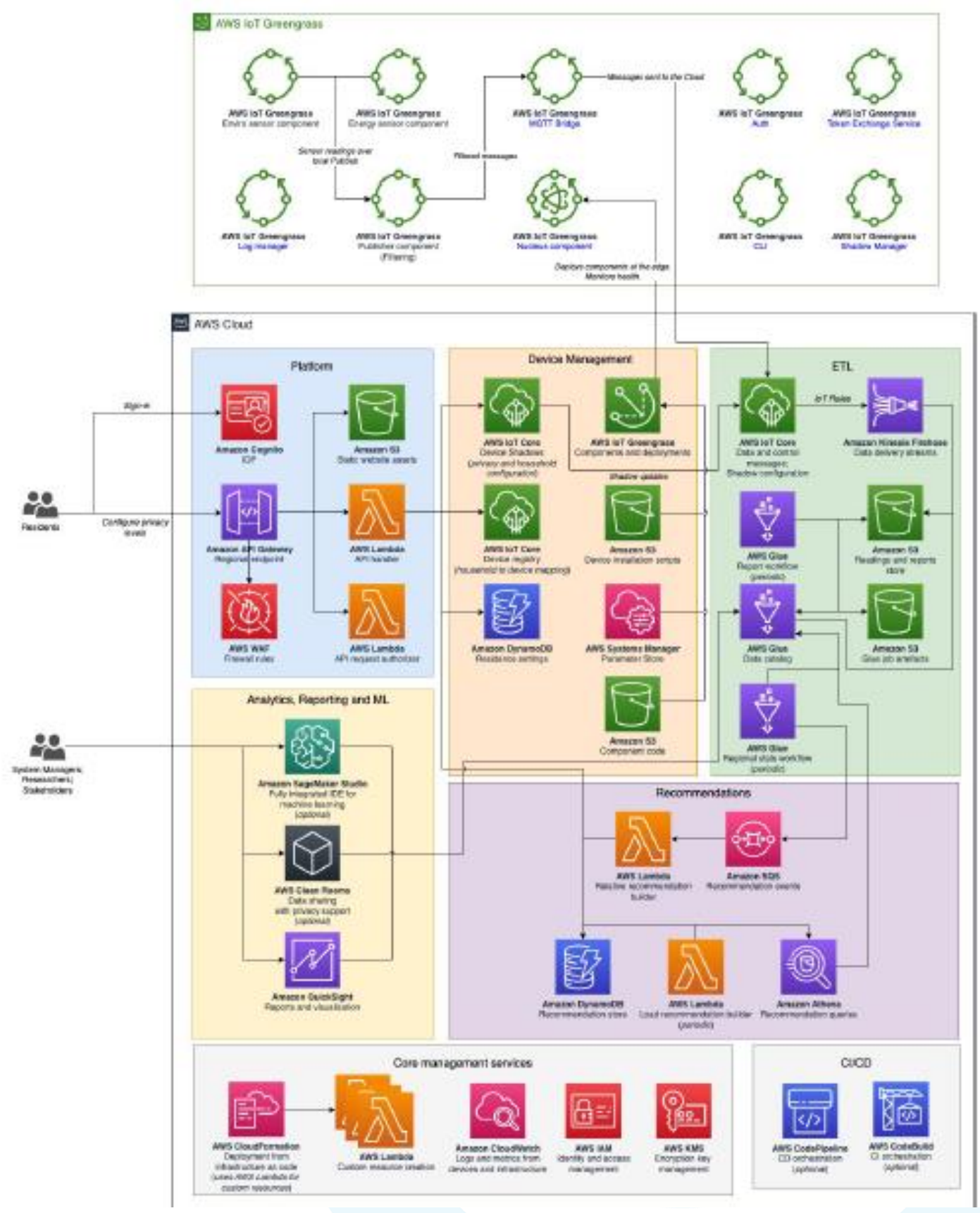


Figure 2: Full cloud-based infrastructure of HEAT-CHECK solution under development

Conceptually, the cloud deployment can be separated into:

- **Platform** - These are the resources to support the web application that allows users to sign in, configure their household privacy level and view recommendations.
- **Device Management** - Resources that help with edge device provisioning, management, configuration and monitoring.
- **Extract, Transform, Load (ETL)** - Resources that ingest data from edge device, that transforms and stores it in a centralised location that offers multiple integration points.
- **Recommendations** - Automated pipeline for producing recommendations that are sent to users.
- **Analytics, Reporting and Machine Learning (ML)** - Tools to allow users with access to data to run analytics queries, produce and visualise reports or train and run machine learning models.
- **Continuous Integration / Continuous Delivery (CI/CD)** - Tools that allow the building and deployment of software components (this is not deployed by default, but can be optionally set up).
- **Core management services** - Services that track the resources that make up the solution or enables core functionality like access control and the use of encryption keys. Also contains a centralised repository to record all the events and metrics that are produced by the solution and its deployment for monitoring purposes. All other services rely on these for their operation.

The functionality of the application layer allows for the monitoring, and analysis of energy and IEQ data which can be applied to a number of buildings, sites, and facilities with applications provided in the following sections.

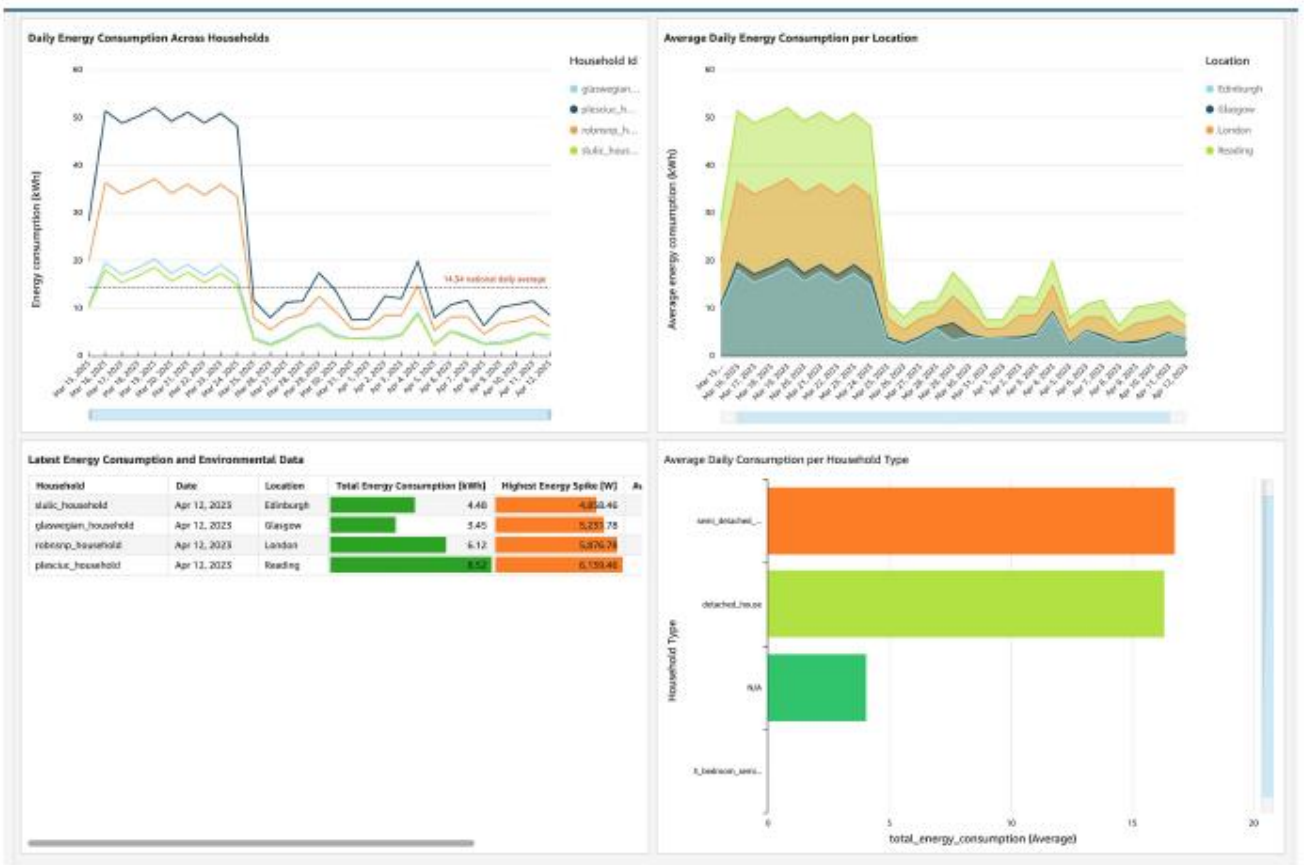


Figure 3: Example application layer of HEAT-CHECK solution for end-user

2.4 IOT platform Identification of abnormal energy demand and indoor environmental quality patterns

The developed application layer allows for identification of abnormal energy demand and indoor environmental quality patterns through:

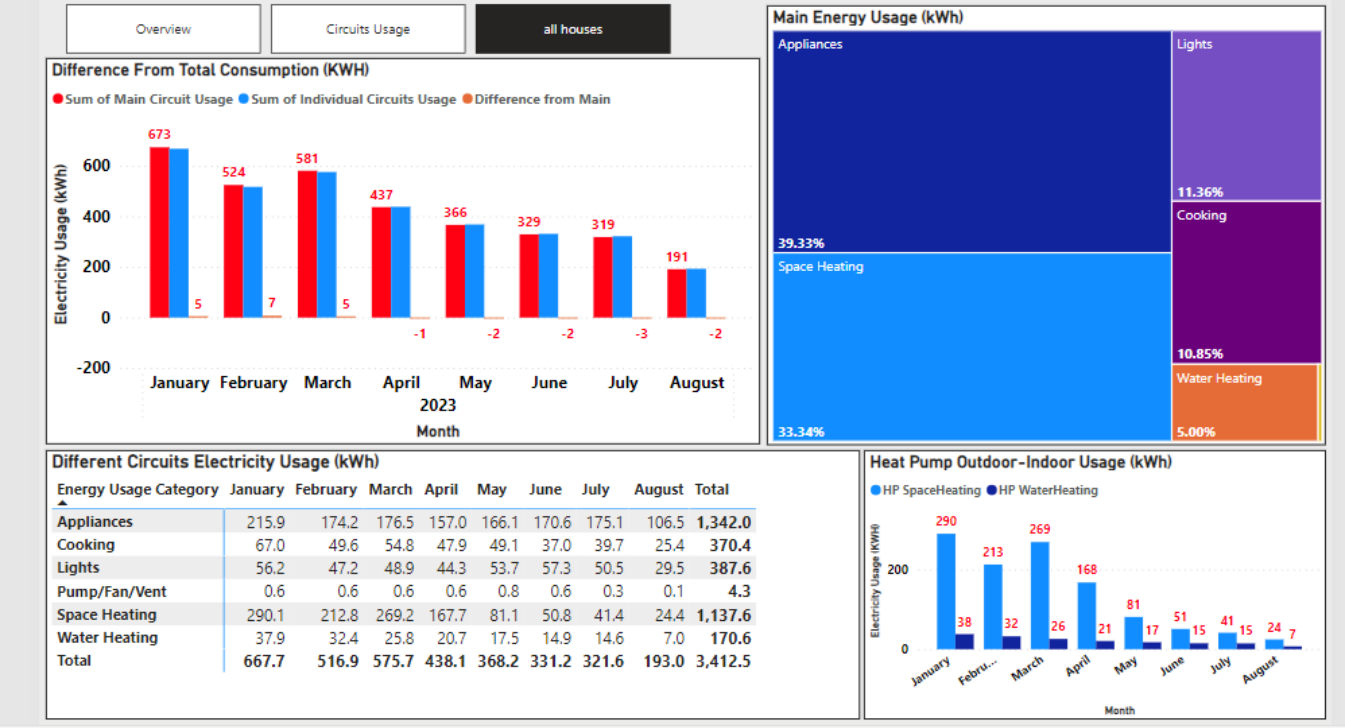
- Benchmarking of data against recommended/expected performance parameters (e.g. recommended indoor IEQ levels, maximum and minimum electricity consumption levels, etc.)
- Benchmarking of performance data against other buildings (see Figure 4 for comparison of cooker energy consumption across several houses)

Device Name	Cooktop/Range/C
A2036A04B4AC67B25DB3A8	4.522
A2105A04B4AC67B2637AB8	3.884
A2106A04B410521CB896E0	3.709
A2106A04B44C11AEE63438	2.086
A2106A04B4B8F009A82D5C	1.788
A2107A04B440F5206A2780	3.526
A2107A04B44C11AEE60FD0	1.459
A2107A04B4AC67B2F5E390	1.139
A2107A04B4AC67B2F638F4	1.087
A2107A04B4B8F009A85180	2.642

Figure 4: Total weekly cooker electricity consumption (kWh)

2.5 Insights of energy demand and indoor environmental quality of homes through customisable reports

The application layer allows for the development of customizable reports on energy consumption and IEQ levels for different stakeholders depending on their requirements. This includes the use of tables and various different chart options (bar, pie, line, treemap, funnel, etc.) for conveying information to stakeholder. Figure 5 provides an example template for a homeowner which provides an aggregated and disaggregated breakdown of electricity use within the home.



Energy Usage Category	January	February	March	April	May	June	July	August	Total
Appliances	215.9	174.2	176.5	157.0	166.1	170.6	175.1	106.5	**1,342.0**
Cooking	67.0	49.6	54.8	47.9	49.1	37.0	39.7	25.4	**370.4**
Lights	56.2	47.2	48.9	44.3	53.7	57.3	50.5	29.5	**387.6**
Pump/Fan/Vent	0.6	0.6	0.6	0.6	0.8	0.6	0.3	0.1	**4.3**
Space Heating	290.1	212.8	269.2	167.7	81.1	50.8	41.4	24.4	**1,137.6**
Water Heating	37.9	32.4	25.8	20.7	17.5	14.9	14.6	7.0	**170.6**
Total	**667.7**	**516.9**	**575.7**	**438.1**	**368.2**	**331.2**	**321.6**	**193.0**	**3,412.5**

Figure 5: Energy consumption report template for homeowner providing an aggregated and disaggregated breakdown of their electricity consumption.

2.6 Occupant's guidance documents for how to best use their home and appliances for optimum energy consumption and indoor environmental conditions

Due to delays with installation of IOT equipment in LDA homes, guidance documents informing homeowners on their optimum use of the building was not developed. However, it is still planned to monitor the LDA homes throughout 2024. Using the functionality of the IOT platform, the current beta version of the platform will continue to be developed throughout 2024 to provide guidance to homeowners on how to optimise the performance of their homes from an energy consumption and IEQ perspective.

2.7 Measure operational GHG emissions for homes to inform progress against the Climate Action Plan

94 LDA homes will be monitored throughout 2024 with quarterly reports provided on building performance levels to LDA. Reports will also be shared with Cairn Homes and Enterprise Ireland.

3 Conclusions

The AHARDD funding supported the researchers in developing an adaptable and scalable IOT based platform. The beta version of the platform can provide services to stakeholders in the building and construction industry including:

- Performance level monitoring of building technologies
- Monitoring, and analysis of energy and indoor environmental quality KPIs and benchmarking for a growing number of buildings, sites, and facilities.
- Identification of abnormal energy demand and indoor environmental quality patterns to allow stakeholders to act proactively.
- Insights of energy demand and indoor environmental quality of homes through customizable reports.

Although delays in the installation of the IOT hardware resulted in no data collection during the funding period, the University of Galway and LDA have committed to monitoring the performance of 94 homes throughout 2024. The platform will continue to be developed throughout this period and will provide occupant's guidance for how to best use their home for optimum energy consumption and indoor environmental conditions and measure operational GHG emissions for homes to inform progress against the Climate Action Plan.