The Scottish Government

Western Isles IoT Rural Community Trials

End of Trials Report

Contents

Executive Summary

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Trials Background & Approach

The use of Internet of Things (IoT) technology is expanding globally and touching multiple sectors with many different use cases. In Scotland, there have been several trials of sensors and related technologies which have contributed to the growing understanding of how smart devices can benefit the community through supporting socio-economic activity, improving public service delivery and evidencing the need for environmental conservation. However, a large proportion of these use cases have taken place within urban settings.

FarrPoint was commissioned to conduct a programme of trials focused on rural IoT use cases. The objective of these trials is to investigate and develop the aggregation of use cases that are determined to be important to rural local communities and organisations. The approach taken for these rural community trials focussed around five key stages:

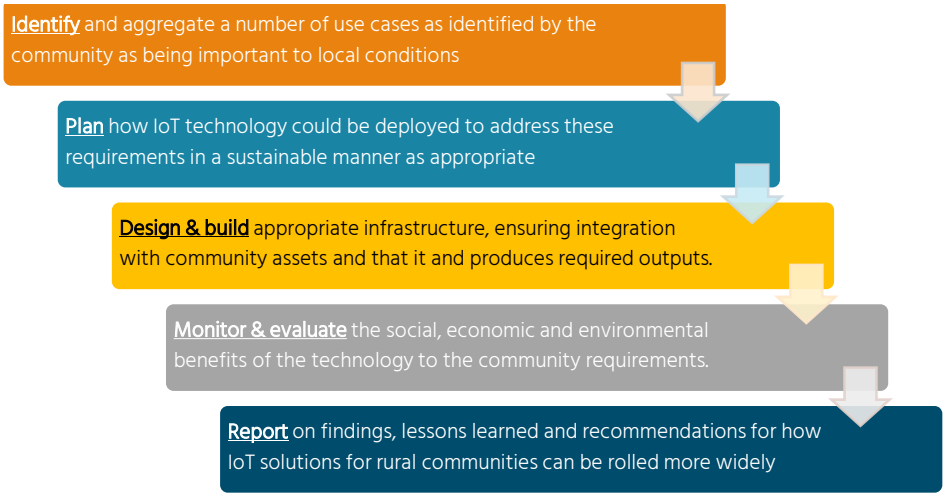


Figure 1.1: Approach to developing Western Isles IoT Rural Community Trials

Through the identify stage, discussions were held with key stakeholders to identify the IoT use cases that would be of most potential benefit to the community. From this, three initial use cases were taken forward for using IoT technology to remotely monitor:

- conditions within a historical community Document Store;
- speed of Road Traffic at specific places in the Pairc Estate; and,
- the water table within a local Peatland restoration site.

At this stage, several other use cases were discounted including examples in Health, Energy, Seafood, and local Road Conditions. This was done for a variety of reasons, including: gaining approval for use of IoT technology in a health setting, limited budgets and infancy of use case specific sensors development., or resource prioritisation from other key stakeholders and issues applying current commercial approaches.

At the planning stage, two alternative IoT connectivity solutions were considered: LoRaWAN and NB-IoT (through a mobile network operator, MNO). Ultimately all the solutions were delivered using a LoRaWAN network, given its suitability for rural settings, its lower cost and longer sensor battery life as well the MNO discussions not progressing at pace. Initially it was assumed that FarrPoint would manage the development of the supporting infrastructure (e.g. gateways, sensors, and server and data management devices and software), with partner organisations aiding in the implementation of the technical aspects of the network. Ultimately, FarrPoint carried out all the technical work.

In the development of the sensor solution for the Road Traffic use case, several issues arose with the performance and durability of the sensor technology. As a result, the project team agreed to cease this particular use case and focus on the remaining two use cases.

Two dashboards were created to enable the community and other key stakeholders to monitor and make the most of the information/ data provided by the IoT solutions.

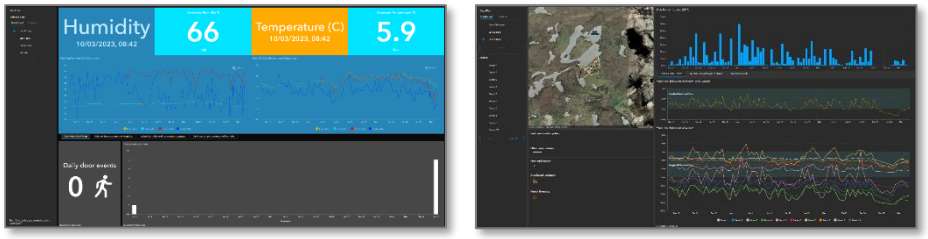


Figure 1.2: Monitoring Dashboards for Document Store and Peatland Use Cases

Evaluation Approach & Assessment

The project aims included an evaluation of the project impact and to learn lessons on how IoT technology could be rolled out within remote and rural communities elsewhere across Scotland.

To do this, a framework was established to ensure that outcomes from the project were aligned to the wider strategic objectives of the key stakeholders involved.

Figure 1.3: Western Isles IoT Trial Accountability Framework

This approach led to the development of six project objectives:

- Objective 1: Support local community to overcome local challenges;
- Objective 2: Support a green recovery through developing and promoting nature-based investments to protect and enhance Scotland's natural capital;
- Objective 3: mobilise investment in digital infrastructure;
- Objective 4: work closely with the local community to build on local assets;
- Objective 5: bring Scottish Government and a number of key stakeholders together to work supportively;
- Objective 6: explore practical uses of IoT technology for wider adoption across Scotland.

The evaluation of how the trials performed against these objectives was split into:

- Impact Evaluation – answering the question: *what were the outcomes and impact of the Western Isles Rural Community IoT Trials?*
- Process Evaluation – answering the question: *how has the behaviour of individuals/ organisations influenced these outcomes?*

The key conclusions and lessons learned from both the impact and process evaluations of the project, have been:

- Taking the 5-stage approach (Identify, Plan, Design & Build, Monitor & Evaluate and Report) trialling the use of IoT technology in remote and rural settings has been successful and has ensured that a wide variety of use cases have been considered.
- Stakeholder engagement is key for the successful use of IoT in remote settings, in particular to ensure the local communities are on board with the solution and that it helps them deliver their ambitions. This collaborative working is also key to ensuring that all stakeholders get something out of the approach.
- The success of the Document Store Use Case has shown that IoT technology can be used to provide solutions to rural communities, helping them to meet their objectives. The feedback from the community suggested that the use of IoT in this solution provided critical information for the safe storage of historical documents, and that other local museums have also signalled that they would be interested in using this solution at their sites.

- The use of IoT as a solution for Peatland Monitoring has proved to be viable in certain situations and NatureScot are considering the potential to roll this out to other sites across Scotland as a mechanism for understanding changes in the peatland conditions. The benefits it brings around providing good quality real time data without the need for costly in-person monitoring trips has proved a significant success.
- However, it is important to note the challenges that remain. For example, challenges around the technology itself often being in its infancy – such as the case with the Traffic Speed Sensor – means that viability in more remote locations can be difficult due to the amount of ongoing testing required, which also hindered the ability to stack use cases for the use of this technology and therefore truly prove viable for wider roll out in a local community.
- In addition, some of the project's initial assumptions around the pace of development of the wider IoT ecosystem may have been slower than expected – for example, there still remains a gap in the market for a 3rd party low-cost data dashboard which could be used by local communities or smaller organisations, thus making the use of IoT a more viable option for wider adoption across Scotland's rural communities.

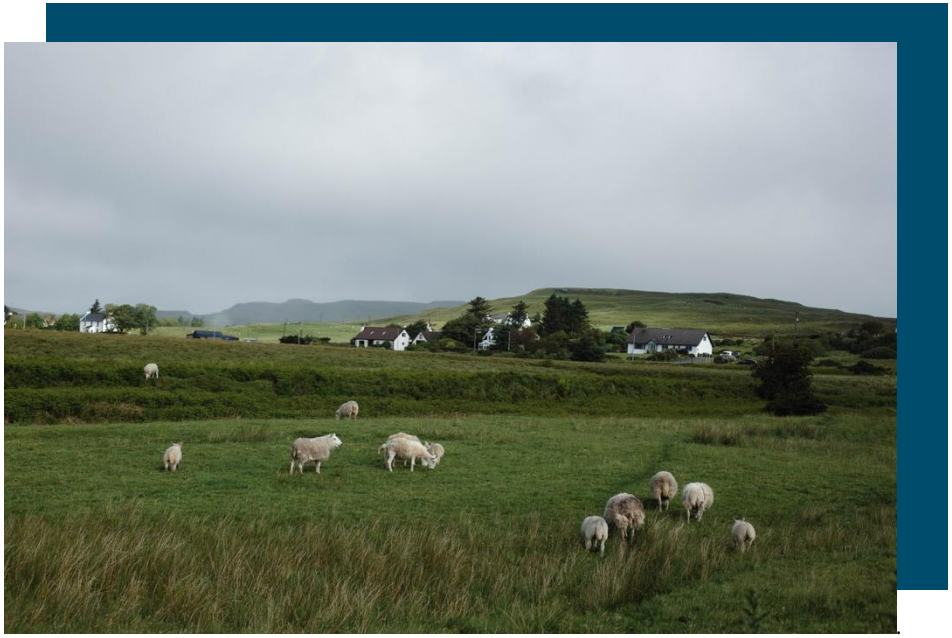
Recommendations

From this work several key recommendations become apparent:

Recommendation 1: Wider work should be undertaken to help rural and remote communities to consider using IoT technology as a solution to help them overcome key local challenges. This should focus on use cases, which can deploy proven technology so as to avoid costly testing.

Recommendation 2: The public sector should consider funding a low-cost data dashboard to be made available to local bodies to enable them to manage IoT solutions at a more viable cost.

Recommendation 3: The use of digital communications infrastructure for environmental monitoring (incl. peatland monitoring) should be considered more widely given the capability from good quality, relatively low cost, real-time data.



Introduction

1. Introduction

1.1 Background

The use of Internet of Things (IoT) technology is expanding globally and touching multiple sectors with many different use cases. In Scotland, there have been several trials of sensors and gateway rollouts which have contributed to the growing understanding of how smart devices can benefit the community through supporting socio-economic activity, improving public service delivery and evidencing the need for environmental conservation. However, a large proportion of these use cases have taken place within urban settings.

FarrPoint was commissioned by Scottish Futures Trust, and subsequently Scottish Government, to conduct a programme of trials focused on rural IoT use cases. The objective of these trials is to investigate and develop the aggregation of use cases that are determined to be important to rural local communities and organisations.

As part of this project, FarrPoint was tasked with delivering a full evaluation of the trials, including whether it achieved what it set out to do and what lessons were learned which could be applied in rolling out similar uses cases/ projects elsewhere. The purpose of the trials was not to just test the IoT technology, but to also build knowledge of the following:

- understanding the community requirements and engagement;
- determining how IoT could be best implemented within the community;
- understanding whether stacking multiple use cases can make rural IoT solutions more viable;
- delivering the solutions alongside the community;
- understanding the potential for mobile operator facilitation;
- identifying key benefits;
- refining the model for wider adoption.

This report provides a detailed assessment of the costs and benefits associated with developing IoT use cases in the remote rural community of Pairc on the Western Isles, and the lessons that have been learnt along the way.

1.2 About FarrPoint

FarrPoint is an independent technology consultancy that specialises in digital connectivity. We provide independent advice on the commercial and technical considerations of the design of national and regional connectivity strategies, economic assessment, technical planning and modelling, use case development, procurement support, and implementation assurance.

Our team comprise a mix of consulting technologists, economists and data scientists who work together to provide experience, expertise, and complementary resource to clients in the public and private sectors.

Our approach is unlike many other consultancies; what clients get from FarrPoint is pragmatic guidance from a team that understands both the commercial, regulatory and policy considerations, plus how these connectivity and technology solutions can be delivered on the ground to deliver the desired benefits.

As trusted advisers, we build strong relationships with our clients based on empathy, flexibility, and independence.

With decades of experience advising clients on connectivity, telecoms and enterprise IT, we continue to evolve and innovate. We believe that connectivity is the underlying mechanism to bringing social and economic benefits to societies and communities.

1.3 Document Structure

1.3.1. Trials Approach

This section outlines the approach taken to the trials - centred around identifying use cases, planning, design and build, and monitoring and reporting. This will also establish the key objectives of the trials against which its success will be determined.

1.3.2. Evaluation Methodology

The methodology for evaluating the trials as well as the lessons learned is set out in a clear and robust way, and will focus on two key aspects:

- Impact - *What were the outcomes and impact of the Western Isle Rural Community IoT Trials?*
- Process - *How has the behaviour of individuals/ organisations influenced these outcomes?*

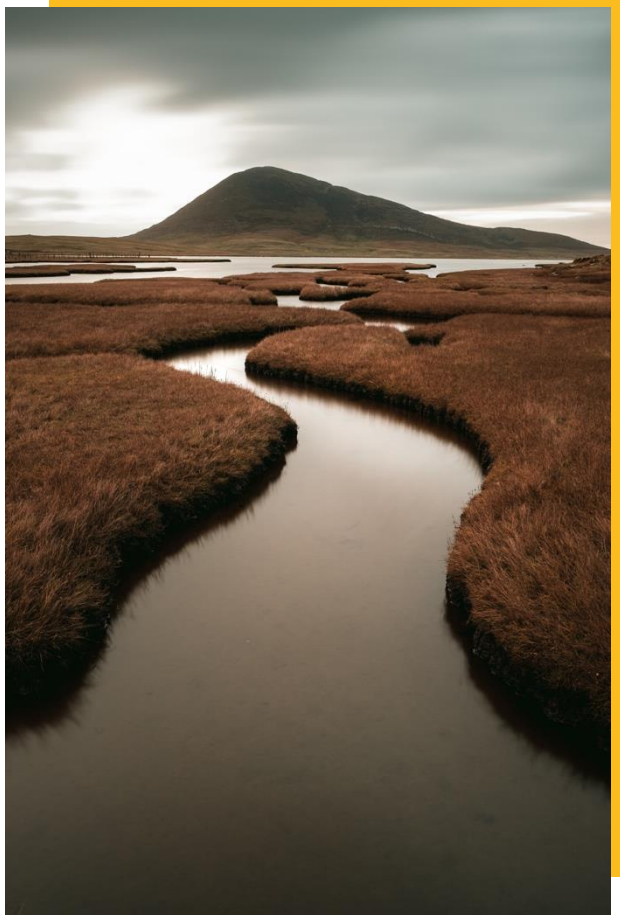
In line with HM Treasury Magenta Book guidance, the project's impact evaluation follows a logic model Theory of Change approach. Alongside the process evaluation, this approach enables the outcomes and lessons learned from this evaluation to be used in exploring the adoption of similar use cases within remote and rural communities/ areas elsewhere across Scotland. In particular, it will provide information required to weigh up the costs and the benefits to understand if the approach to using IoT in remote and rural communities is an effective one. This assessment can be used as a basis for an HM Treasury Green Book style business case options appraisal, in line with the Digital Appraisal Manual for Scotland (DAMS).

1.3.3. Evaluation of Use cases

This section is focussed largely on answering the questions established within the Evaluation Methodology Section.

1.3.4. Conclusion and Recommendations

This final section summarises the main findings and lessons learned of the trials and develops a clear set of recommendations.



2. Trials Approach

2.1 Introduction

The proposal for the trial programme stated that it will identify and aggregate a number of use cases as identified by the community as being important to local conditions.

The trial will plan how IoT technology could be deployed to address these requirements in a sustainable manner so there is life after the trial and pulling in elements of other IoT initiatives as appropriate.

The trial will design and build the appropriate infrastructure, working to ensure the technology integrates with the community and produces the outputs required.

The trial will monitor and evaluate the benefits of the technology to the community requirements in respect to the commercial and/or social benefits.

The trial will then report on the findings, lessons learned and recommendations for how similar requirements could be addressed within other communities.

2.2 Identify

2.2.1. Process to Identify Potential Use Cases

Discussions were held with the local community representatives (Pairc Trust) and other stakeholders such as Western Isles Mussels, Peatland ACTION, CENSIS, University of Edinburgh and the Scottish Association for Marine Science (SAMS) to identify potential use cases. The Local Authority was also engaged with at this stage, via the local community representatives. In addition to this, discussions were also held with a MNO as a potential technology partner and Scottish Water as a facility provider.

The discussions were to identify the IoT use cases that would be of most potential benefit to the community, to agree a mechanism for the provisioning of an IoT network, and to engage with the community to realise the potential benefits. The initial use cases were identified through community discussion on the local issues together with FarrPoint's explanation of the potential for technology to address specific requirements that were raised.

Subsequently, FarrPoint has developed a simple to use IoT Use Case Template (**Table 2-1**) to assist in the process of identifying future use cases, for which IoT could provide a measurable benefit.

Item	Use Case
Description	A brief description of what the use case will cover
Why	Outline the reason(s) behind why this use case is needed. What is the issue that this use case will try to overcome?
Benefit	Set out the key benefits that this use case will realise
Sensor Requirements/ Data Capture	Detail what data needs to be collected and if known what sensors are needed
Visualisation	Set out which metrics need to be obtained and visualised from the sensor information

Table 2-1: IoT Use Case Template (Source: FarrPoint)

2.2.2. Use Cases Taken Forward

This template was used to engage with the community and other key stakeholders to identify possible use cases to be explored further. The three keys ones that were established during this stage are set out within **Table 2.2**.

Item	Description
Use Case 1 - Document Store	
Description	Use IoT technology to remotely monitor conditions within a historical community document store.
Why	Improve the security and monitoring of conditions in document store. The community has concerns about the potential longevity of historical documents currently housed. The environmental conditions are unknown and could be detrimental to the fabric of the documents that are of considerable importance and value to the community.
Benefit	• Improve security of community documents • Preserve community history • Record frequency of visits to the store
Sensor Requirements/ Data Capture	• Temperature and humidity sensor • Door open/closed sensor
Visualisation	Temperature, humidity and door open/close information provided within a dashboard.
Use Case 2 - Road Traffic	
Description	Use IoT technology to monitor speed of traffic at specific places in the Pairc Estate.
Why	Improve community safety through monitoring of potential speed to allow policy makers to improve road safety. The community had highlighted concerns around speed of vehicles, particularly in relation to the safety of children and animals.
Benefit	• Improve road safety • Improve safety for community and wildlife
Sensor Requirements/ Data Capture	LoRaWAN traffic radar sensor with solar panel. Collects data on vehicle numbers and speeds.
Visualisation	Road Traffic sensor information provided within dashboard, which provides visualisation of numbers of cars passing in each direction, broken down into speed categories.
Use Case 3 – Peatland Restoration Monitoring	
Description	Use IoT technology for water table monitoring for peatland conservation.
Why	Draining peatlands harms the environment through the release of carbon to the atmosphere. Sensors are used to measure the water table which is critical to evaluating the success and progress of peatland restoration..
Benefit	• Improve the quality/ timeliness of monitoring • Reduce requirement of in-person monitoring

Item	Description
	• Reduce degradation of peatlands -> Decrease CO2 emissions -> Reduce climate change
Sensor Requirements/ Data Capture	Water pressure sensor to capture water depth
Visualisation	Device has been set up on the LoRaWAN network and data flow provisioned to experimental dashboard. Calibration will be required to translate water pressure into depth and provide a direct visualisation of water depth.

Table 2-2: Western IoT Use Case Summaries

2.2.3. Discounted Use Cases

During the identify stage of the project, a number of additional potential use cases were discussed and subsequently discounted included examples in Health, Energy, Seafood, road icing and woodlands. These are detailed below, alongside the reasons why these use cases were discounted or not taken forward:

Health & Care

Two potential use cases using IoT technology in health care were initially highlighted through discussions with the community:

- Integrating the use of IoT technology in the NHS. However, discussions with the Western Isles NHS technology lead, highlighted that there would be a considerable amount of bureaucracy involved in getting devices approved for recognition within health care settings within the NHS. This was out of the scope of the trials and so this use case did not move to the planning stage.
- Care-related applications within normal domestic use, such as monitoring of kettles and other appliances for older/ vulnerable people to identify pattern changes. However, this use case was considered more complex than the others identified due to the potential need for significant application monitoring development and engagement with other stakeholders already involved with caring for vulnerable people. Therefore, due to the limited budget this was considered to not be viable to take forward to the next stage.

Renewable Energy

A potential use case surrounding monitoring of wind turbine operations was considered. However, the community turbines are some distance from the Pairc Estate and those that are nearby to the estate are owned by a separate organisation to which the community was not keen on engaging. Therefore, the development of this use case did not continue to the planning stage.

Seafood

Through discussions with the Scottish Association for Marine Science (SAMS), and Western Isles Mussels, a potential use case was suggested for using IoT for monitoring marine environment conditions in Loch Erisort. However, this was reliant on the development of an IoT solution by the team at SAMS as well as Western Isles Mussels obtaining additional funding for investment in the Loch, neither of which were developed in time with the project timelines.

In addition, discussions around some further environmental use cases were held with various stakeholders including the monitoring of sphagnum moss growth, monitoring/counting of wild animals and birds, and direct monitoring of harmful algal blooms in the marine environment. However, these all were specialist use cases that would require distinct development budgets and partnering with specialist organisations which could not be enabled within the project timelines and budget.

Road Icing

The local community highlighted a concern with ice on the roads, again development of technology stood as a barrier to the progression of this use case.

Woodland

The community identified a potential use case for the community owned Aline Woodland. Through engagement with the Erisort Trust, it became clear that there are a number of development areas required to better manage and enhance the facilities provided by the Woodland. The issues identified cut across key sectors and areas of interest, including:

- Economic Growth: Enable informed decisions to attract further funds into the development of the Woodland to make it more valuable and attractive, and to harness the potential as an income generator. The Woodland has the potential to be a magnet for the local area.
- Impact on jobs market and educational benefit: Possibility to employ full time staff members through income generation for ongoing management of the Woodland, utilising IoT technology to help inform decisions.
- Application of technology: Scope to demonstrate the benefit of existing and new applications of IoT technology to remote communities.
- Social/Recreational benefit: Informing how the Woodland is used and can be enhanced for multi-purpose use.
- Environmental: Understanding the Woodland's role in the local environment and Scotland's wider carbon neutral agenda.

From these current issues, three potential forestry use cases were identified around:

- Social/ recreational use of the Woodland - To inform how the Woodland is used and can be enhanced for increased/multi-purpose use through visitor counts, and capture of activities undertaken.
- Woodland health and impact on the environment/climate - To maintain good woodland health and understanding best conditions for tree planting and the overall contribution of the Woodland on the environment.
- Operational/ Maintenance of facilities - To monitor facilities for maintenance purposes to prevent issues going unnoticed that can make the facilities deteriorate faster and, in some instances, make unusable or dangerous.

Through discussions led by SFT with a mobile network operator (MNO), FarrPoint established that there was good coverage of their NB-IoT (Narrowband Internet of Things) network in the Aline Woodland area. This would provide a good opportunity to collaboratively test out how this alternative delivery of IoT could work in a rural setting.

However, at the stage of identifying the specific sensor solutions, data capture and visualisation options required for these 3 use cases identified by the local woodland trust, the collaboration with the MNO did not develop further. This was due in part to their internal resource prioritisation and issues applying their IoT methodology and platform to solve the specific challenges faced by the Aline Woodline. Therefore, these use cases were not carried forward.

Discussions around some further use cases were held with various stakeholders including the monitoring of sphagnum moss growth, monitoring/counting of wild animals and birds, and direct monitoring of harmful algal blooms in the marine environment. These are all specialists use cases that will require distinct development budgets and partnering with specialist organisations which unfortunately were outside the parameters of this project.

2.3 Plan, Design and Build

2.3.1. Alternative IoT technologies

The trial aimed to be technology neutral, and so as well as assessing the use of LoRaWAN (Long Range Wide Area Network), an MNO was also engaged to understand whether their NB-IoT technology could be used.

NB-IoT networks (and similar LTE-M networks) are operated by Mobile Network Operators (MNOs) using licensed frequencies. There is no opportunity therefore to

set up a private NB-IoT network and liaison is needed with an MNO to gain access. LoRaWAN networks can be set up entirely privately using unlicensed spectrum. The following table summarises the key differences between these technologies.

	LoRa	NB-IoT
Band	Unlicensed Band	Licensed Band
Cost	Low-cost device	Higher cost device
Gateway	Gateway required	No gateway required
Battery	Long battery life	Shorter battery life
Latency	High latency	Low latency
Distance	15-20Km Rural	20-25Km Rural
Rural or Urban	Better rural performance	Better Urban performance
Speed	Up to 50Kbps	Up to 200Kbps

Table 2-3: LoRa vs. NB-IoT

Discussions were held on a number of occasions with an MNO, who confirmed the operation of NB-IoT within the geographical area of interest in the Western Isles. Potential use cases were explored centring around the community owned forest area. However, these discussions did not reach fruition within the timescales required for this project. Therefore, it was decided that the preferred way forward for the Western Isles Use cases was to develop a LoRaWAN network given the benefits surrounding suitability for rural settings, its lower cost and the longer life of the batteries requires for sensors. So, a private LoRaWAN network was established by FarrPoint using two gateway sites.

A number of supporting infrastructure elements are required in order to provision a LoRaWAN network. The basic building blocks are gateways to which sensor devices connect, a network server that facilitates the communication with gateways and sensor devices and an application server that allows data manipulation, dashboards and end user access. Initially it was assumed that FarrPoint would manage this process and partner organisations would aid in the implementation of the technical aspects of the network. Ultimately, FarrPoint carried out all the technical work. A network server was established on a private AWS cloud and a combination of node-red for data manipulation and dashboards form the application server.

2.3.2. Gateways

For the use cases covering vehicle counting, and temperature, humidity and security sensing, these were implemented using a LoRaWAN gateway installed at a community hub building at Ravenspoint. The Ravenspoint centre is near the shore of Loch Erisort estuary and provides good coverage of a significant portion of the Pairc area. It also covers the area where mussel farms operate, and although not direct line of sight, it also provides coverage to the community-owned document store.

For the Peatland Monitoring use case, a LoRaWAN gateway was installed at the Loch Orasaigh water pumping station following extensive negotiation with Scottish Water. This has been negotiated by FarrPoint so that there is no charge to the community by Scottish Water. This gateway covers the peatland conservation project area interest. Coverage from the two gateways is shown in the Figure 2.2.

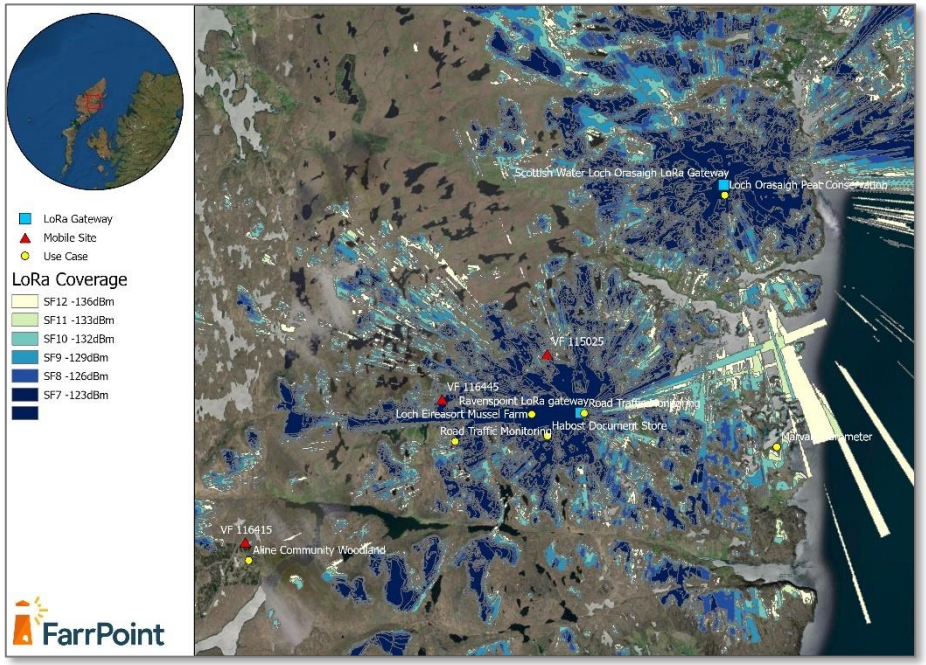


Figure 2.2: Local LoRa Coverage for the two gateways

2.3.3. Sensors

Use Case 1 – Document Store

A temperature/humidity sensor was installed in the document store along with a door open/closed sensor. These devices send data through the Ravenspoint gateway every ten minutes. Initially, the temperature/humidity sensor provided data intermittently and it was found that the signal level from the gateway inside the document store was insufficient. Therefore, an alternative sensor was sourced with an external antenna port. This was swapped for the original sensor and an antenna was installed on the outside of the building. This has now proved to be reliable.

Use Case 2 – Road Traffic

An IoT traffic counter, which collected data on number of vehicles in certain speed bands, was set up on the B8060 near the village of Habost. This device connects to the Ravenspoint gateway and sends summary data for traffic flow every ten minutes. However, in the deployment of this sensor, several issues arose. Firstly, the sensor was reporting a very small number of vehicles passing only in one direction. Despite support from the sensor supplier, this issue remained. Installation at different locations was considered but none could be found that did not involve installing additional poles and obtaining permission from the roads department, which would be a lengthy process. The sensor comprised a solar panel and internal battery so that data can be recorded and sent in the hours of darkness. The solar charging mechanism failed on two occasions and the device was again returned to the supplier for repair. Ultimately, high winds caused the solar panel to be wrenched from its mount and the electrical connections were broken. The device was returned to FarrPoint and a temporary repair was made to carry out tests at a location where it was installed close to the A7 in the Scottish Borders. Again, the numbers of vehicles reported did not match those observed and at this point it was decided to abandon this device. Therefore, at this stage it was recommended that due to there not being a suitable sensor solution at this present time, then development of this use case should be halted.

Use Case 3- Peatland Restoration Monitoring

As part of the initial developments of this use case, a water pressure sensor was sourced and evaluated by Peatland ACTION for installation in the peatland to monitor water content. The pressure sensor is installed at the bottom of a dip well and the pressure reading (alongside temperature) is used to derive the depth of water in the dip well, thereby providing an accurate water table level measurement at the location of the dip well. The sensor requires careful installation and calibration by a specialist hydrology contractor to record the depth of the sensor below the closed vegetation canopy. This can be contracted through NatureScot's existing supplier framework. To provide the most meaningful measurements, around 10 sensors need to be deployed and monitoring conducted for as many months before and after restoration as possible.

2.4 Monitoring and Reporting

A key part of this project is delivering solutions that are useful to the community and other stakeholders, and so a mechanism to monitor and make the most of the information/ data that is provided by the IoT sensors is required. To enable this, two dashboards were developed by FarrPoint in collaboration with the relevant stakeholders.

2.4.1. Use Case 1 - Document Store

The dashboard for the Document Store (**Figure 2.1**), enables the community to monitor the two sensors (Temperature & Humidity sensor and Door open/closed sensor). This currently displays information from the last 24 hours and enables exploration of historical data over selectable date ranges.

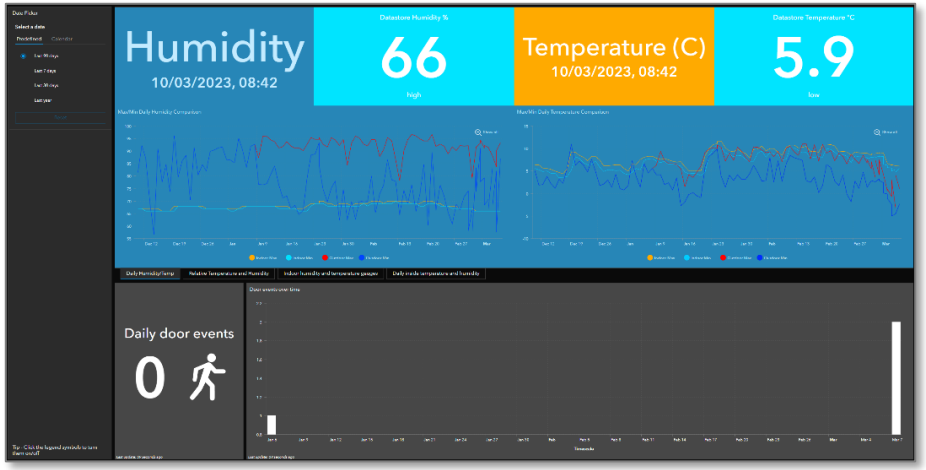


Figure 2.1: Document Store Dashboard (Source: FarrPoint)

Through the development of the dashboard, a key capability that was identified and implemented, was a notification system, where the dashboard sent an email alert to several members of the community when temperature and humidity tolerance thresholds (agreed with the community) were breached. This means that the community does not need to be constantly monitoring the dashboard.

2.4.2. Use Case 3 - Peatland Restoration Monitoring

Following the installation of the Loch Orasaigh peatland sensors, a workshop was held with the key stakeholders including: Peatland ACTION (with engagement from the local estate owner), Scottish Water and the Scottish Government to identify the key attributes that would be useful for the Peatland Monitoring dashboard. This would include a map showing sensor locations, time series of the data (with selectable time ranges e.g. month, year etc.) as well as an aggregated daily average of the water depths.

It was also considered useful to have a local weather station installed to give area specific rainfall data at the site to enable those monitoring the sensor data to understand if fluctuations in the water table are being caused by deterioration of the peatland or local weather conditions. Taking this into account, the Loch Orasaigh Peatland Monitoring dashboard was created and published (**Figure 2.3).**

Figure 2.3: Peatland Monitoring Dashboard (Source: FarrPoint)

Evaluation Approach

3. Evaluation Approach

3.1 Introduction

This section describes the methodology used for evaluating the impact of the trials as well as the lessons learned which will be set out in a clear and robust way. In line with HM Treasury Magenta Book guidance, the project evaluation follows a logic model theory of change approach.[1]

This approach enables the outcomes and lessons learned to be used to explore the roll out of similar use cases within remote and rural communities elsewhere across Scotland.

3.2 Evaluation Scoping

3.2.1. Establishing rational and objectives of the trial

Prior to the Western Isles IoT Rural Community trials commencing, it is important to ascertain the rationale for the intervention. To do this, requires an understanding of the relevant policy and strategic framework at the time of the trial initiation, and to assess if there have been any notable changes in government policy since then. In addition, it is important to also consider any strategic aims of the stakeholders involved, for example: the Pairc Community Trust and NatureScot. [2]

This approach is set out within a high-level framework (**Figure 3.1**), which shows the high-level policy to programme alignment. Taking this approach ensures that the outcomes of this evaluation take into account the relevant objectives all the stakeholders involved within the projects This framework overview demonstrates how they create a clear chain back to primary Government policy.

Figure 3.1: Western Isles IoT Trial Accountability Framework

Scottish Government

Reviewing the relevant Scottish Government's strategic policy documents [3] emphasises several key policy themes based around delivering a strong place-based

[1] Source: *Magenta Book: Central Government guidance on evaluation*, UK Government

[2] It is also worth noting the priorities of Scottish Futures Trust (SFT) who lead on the programme in its initial stage. Being at the forefront of improving public sector infrastructure across Scotland, SFT focus to facilitate opportunities to enhance digital infrastructure investment and its delivery throughout Scotland. This means exploring how new technologies can be used to transform the way businesses, public sector bodies, citizens and visitors interact to enrich their respective digital experience.

[3] Sources: Scotland's National Strategy for Economic Transformation (2022), Scotland's National Performance Framework (2018), A stronger and more resilient Scotland: Programme for Government 2022-23 (2023), and A changing nation: how Scotland will thrive in a digital world (2021)

green recovery and wellbeing economy for Scotland. This is focussed on 3 main ambitions:

- Fairer – Ensuring that work pays for everyone through better wages and fair work, reducing poverty and improving life chances;
- Wealthier – Driving an increase in productivity by building an internationally competitive economy founded on entrepreneurship and innovation;
- Greener – Demonstrating global leadership in delivering a just transition to a net zero, nature-positive economy, and rebuilding natural capital.

The Scottish Government recognise the importance of ensuring that digital is at the heart of inclusive sustainable economic growth, public services reform, creating the future workforce and reaching Net Zero. It also recognises the profound challenges that digital poses for the nature of work, for society, and the myriad of local economies within Scotland. Digital as a policy theme, is a key driver of economic productivity, innovation, job creation and internationalisation.

Other Key Stakeholders

When assessing how the project has delivered for the local community it is important to consider some of the key objectives of the local trust (The Pairc Trust). Several of the key objectives of the Trust[4] are relevant to this project:

- Develop/ promote the infrastructure for the benefit of the public and the community to improve communications and related facilities;
- Advance community development, including rural or urban regeneration;
- Improve educational opportunities in the Community relating to environment/ culture/ heritage/ history;
- Further environmental protection including preservation, sustainable development and conservation of the natural environment;
- Preservation of buildings or sites of architectural, historic or other importance to the Community.

For NatureScot[5], Nature must be the first choice in helping people in Scotland to deal with the impacts of climate change and other challenges in society. Nature-based solutions to climate change - like tree planting and rewetting peat bogs - are nature positive and bring many other benefits. NatureScot have three priorities:

- Protecting Nature by expanding protected areas, regulating species management, and delivering effective planning advice on land and at sea
- Restoring Nature through a new biodiversity strategy, restoring peatlands, aiding nature's recovery and transforming farming.
- Valuing Nature so that the many benefits it provides to society can in turn attract public, private and social enterprise financing for both protection and restoration.

Trials Objectives

The Western Isles IoT Rural Community Trials programme itself fits firmly within the objectives of Scottish Government as well as those of the key stakeholders involved. At the beginning of the project several key objectives were outlined to ensure that the trials deliver the key ambitions of the wider policy narrative. They were:

- Objective 1: Support local community to overcome local challenges;

[4] Source: Articles of Association of the Pairc Trust (2009)

[5] Source: A nature-rich future for all - Corporate Plan 2022-2026

- Objective 2: Support a green recovery through developing and promoting nature-based investments to protect and enhance Scotland's natural capital;
- Objective 3: mobilise investment in digital infrastructure;
- Objective 4: work closely with the local community to build on local assets;
- Objective 5: bring Scottish Government and a number of key stakeholders together to work supportively;
- Objective 6: explore practical uses of IoT technology for wider adoption across Scotland.

3.3 Purpose of Evaluation

In choosing the most suitable evaluation approach(es), it is important to consider the type of evaluation and question(s) to be answered, alongside an understanding of the intervention itself, the context in which it is being implemented, and the information/data available. It is important to recognise that – in line with the outputs within this project – this evaluation has been conducted at a high level.

With that in mind, the aims of this Western Isles IoT Rural Community Trials evaluation are focussed largely on delivering:

- Impact Evaluation – answering the question: *what were the outcomes and impact of the Western Isles Rural Community IoT Trials?*
- Process Evaluation – answering the question: *how has the behaviour of individuals/ organisations influenced these outcomes?*

Section 5 of this report will look to answer: *what can we learn for wider adoption of IoT technology across Scotland?* This approach will enable the outcomes and lessons learned from this evaluation to be used in exploring the adoption of similar use cases within remote and rural communities/ areas elsewhere across Scotland. It will provide information required to weigh up the costs and the benefits to understand if the approach to using IoT in remote and rural communities is an effective one. This assessment can be used as a basis for an HM Treasury Green Book style business case options appraisal, in line with the Digital Appraisal Manual for Scotland (DAMS).

3.4 Evaluation Methodology

3.4.1. Impact Evaluation

What were the outcomes and impact of the Western Isles Rural Community IoT Trials?

The impact evaluation will focus on assessing whether the first three objectives of the Trials Project have been achieved:

- Objective 1: Support local community to overcome local challenges
- Objective 2: Support a green recovery through developing and promoting nature-based investments to protect and enhance Scotland's natural capital
- Objective 3: mobilise investment in digital infrastructure

Impact evaluations can be particularly challenging to design and implement. Impact evaluations aim to assess what changes have occurred and the scale of those changes. They also assess the extent to which the changes can be attributed to the intervention, over and above what would have happened had the intervention not taken place.

Given the 'pilot' nature of this project and the early stage at which this evaluation is being undertaken, a theory of change-based approach has been taken to identify the key outcomes and impacts of the project, reinforced where possible with evidence from the trials themselves.

For the purpose of this evaluation, this Theory of Change will establish an understanding of how the trials project was expected to work in practice, starting

from the problem the intervention aims to address; the change it aims to bring about; the causal chain of events that are expected to bring about the change; the main stakeholders expected to affect change and be impacted; and the expected conditions required for the intervention to succeed. It will expose any assumptions upon which the intervention is based and the strength or weakness of the evidence supporting these assumptions. A linear Theory of Change approach structured as in Figure 3.2 will be followed.

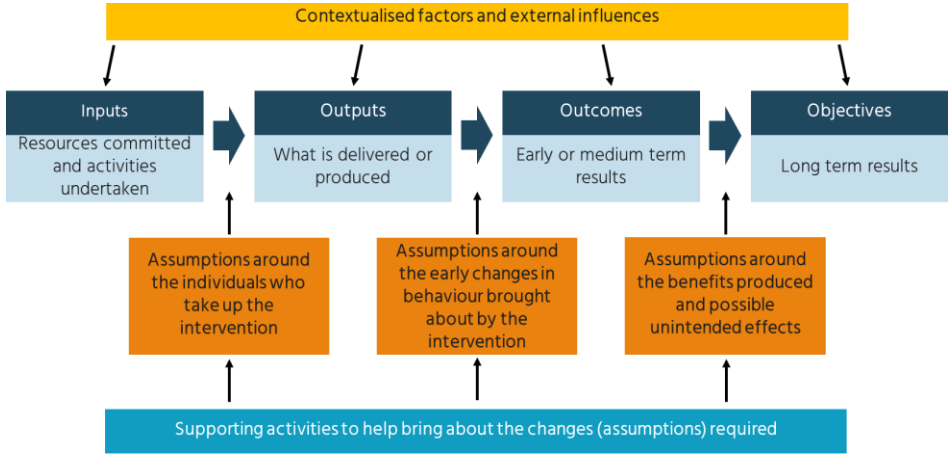


Figure 3.2: A Linear Theory of Change (Source: Magenta Book)

Given the nature of the trials process, this impact evaluation will only focus on the two successful use cases demonstrating the impact that these use cases have on the various project objectives and wider policy narrative. Whilst it will not evaluate the road and woodland use cases as they did not reach a sufficient stage of deployment, these two use cases will be assessed as part of the subsequent process evaluation, to understand why these use cases were unsuccessful.

3.4.2. Process Evaluation

How has the behaviour of individuals/ organisations influenced these outcomes?

The process evaluation will focus on assessing whether two of the objectives of the Trials Project have been achieved:

- Objective 4: work closely with the local community to build on local assets
- Objective 5: bring Scottish Government and a number of key stakeholders together to work supportively

The evaluation will understand and evaluate how the process of setting up and running the IoT use cases worked, and how the behaviour of those within the trial impacted upon its overall success. This assessment will be based on interviews of key stakeholders within the trial, as well as a detailed look into each of the use case studies.

3.4.3. Overall Conclusions

This final part of the Evaluation gives some overall conclusions, as well as the extent to which this approach delivers good value for money. This will identify the key learnings from the process and assess whether or not this approach to the use of IoT technology in remote and rural settings can be adopted more widely across Scotland and elsewhere. Therefore, these conclusions will be used to assess whether the final objective has been met:

- Objective 6: explore practical uses of IoT technology for wider adoption across Scotland

Evaluation Assessment

4. Evaluation Assessment

4.1 Impact Evaluation

This impact evaluation aims to answer the question:

> *What were the outcomes and impact of the Western Isle Rural Community IoT Trials?*

To assess the impact of the Document Store and Peatland Monitoring Use Cases this the evaluation will use a Theory of Change approach. It is important to note at the start of this impact evaluation, that due to the scale of the project, it is not possible to provide a quantitate assessment of the magnitudes of each benefit the project has given.

4.1.1. Document Store Use Case

The main aims of this use case were to improve the security and monitoring of conditions in document store. The community had concerns about the potential longevity of historical documents that are currently housed in this store. Prior to the establishment of this use case, the environmental conditions within the document store were unknown and could have been having a detrimental impact on the fabric of documents that were of considerable importance and value to the community.

As demonstrated by the Theory of Change model for the Document Store use case (outlined in Figure 4.1, with more detail contained within Appendix A), it is evident that the two main outputs of using IoT technology for this purpose is to provide both real-time data which the community can manage via a dashboard, but subsequently to have a system in place to notify the community liaison team when a certain humidity threshold is crossed.

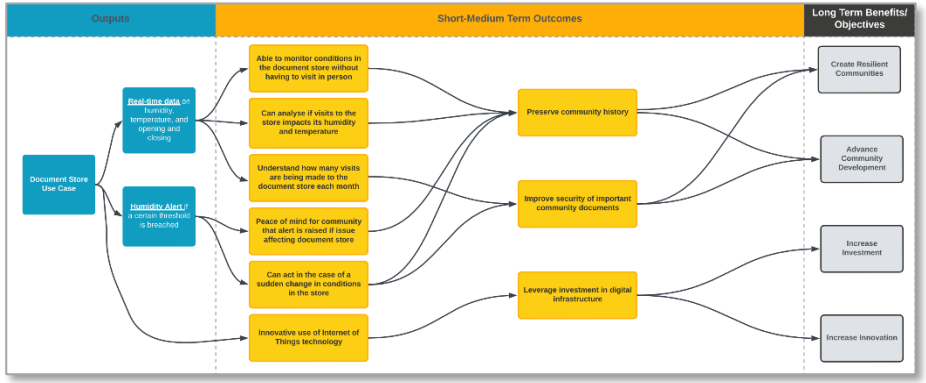


Figure 4.1: Impact of Document Store Use Case (Source: FarrPoint)

These two key outputs from the Document Store Use Case lead to a range of short-medium term outcomes including:

- Improved ability to monitor conditions in the document store in real time without the need for an in-person visit.
- Improved ability to analyse the impact that visits to the store have on humidity and temperature conditions within it.
- Improved ability to understand how many visits are made to the document store each month.
- Increased peace of mind for the community who can be alerted to any significant changes in conditions
- Improved ability to react to any sudden changes in conditions within the store
- Increased innovation through using the IoT technology in an innovative way

These short-term benefits lead to several medium-term ones surrounding:

- Increased ability to better preserve the community's history through IoT monitoring and notifications.

- Improved security (both in terms of access to and reducing impact of dampness) of the documents within the store.
- Increased ability to leverage investment and innovation for further growth

This will have enabled the stakeholders, including the local community, to achieve their long-term objectives, surrounding creating resilient communities, advancing community development and increasing investment & innovation.

This is backed up by the community, who stated that:

> *"The ability to monitor humidity in our document store has been invaluable. With the site being unmanned and remote from our main archive and museum the IOT sensors provide us with door access data and continuous environmental stats which in our climate is the most critical factor for the safe storage of historic heritage documents. It's an excellent low running cost solution and means we don't need more expensive internet connectivity." – **Pairc Trust***

Furthermore, this was further reinforced at the end of the project where the local community identified several other museum sites at which they want to take a similar approach to monitoring the environmental conditions within a community asset.

Impact on Trial Objectives

Given the community nature of this use case, it focusses on addressing:

- **Objective 1:** Support local community to overcome local challenges - Through the engagement with the community, they highlighted that improving the monitoring and management of the document store was a key priority and would help them to achieve some of the Pairc Trusts' objectives surrounding improving preservation and opportunities with their cultural and heritage assets.
- **Objective 3:** mobilise investment in digital infrastructure - In line with Scottish Government goals and those of the local community this project has invested in digital connectivity infrastructure and helped develop an IoT network within the community

4.1.2. Peatland Monitoring Use Case

Scottish peatlands store 1.7 billion tonnes of carbon, but with 80% of Scotland's peatland being damaged, maintaining and improving the quality of peatland is essential to avoid carbon emissions. This use case was designed to capture reliable real time information around the quality of peatlands before, during and after its restoration. This innovative IoT solution has helped to monitor the water table and help improve the understanding of the impact of peatland restoration, as well as cutting down on the resource and emissions costs of sending people to the remote peatland locations to collect measurements.

As demonstrated by the Theory of Change model for the Peatland Monitoring use case (outlined in **Figure 4.2**, with more detail contained within Appendix A), this IoT solution has delivered a viable methodology for delivering peatland monitoring needs. It is evident that the two key themes that need to be considered when thinking about the benefits of using IoT for peatland monitoring purposes:

- The reduction in the need for costly in-person monitoring (in terms of financial and environmental costs).
- The longer-term improvement in the quality and timeliness of the peatland monitoring data.

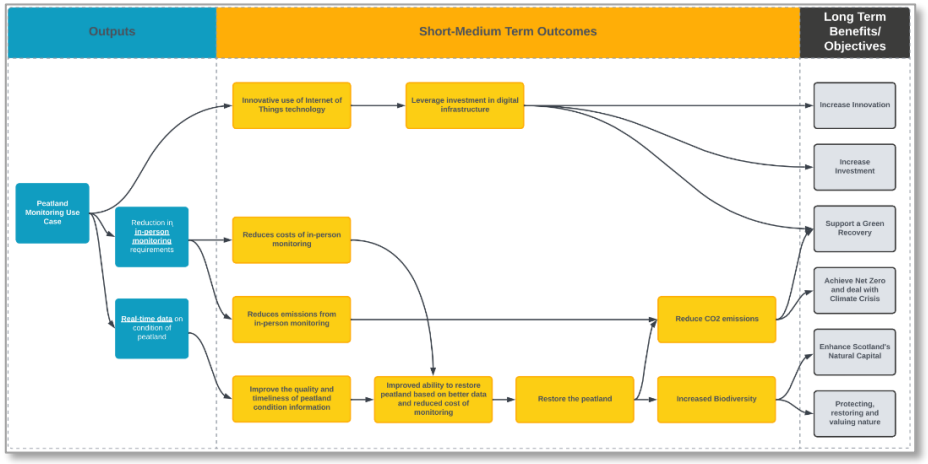


Figure 4.2: Impact of Peatland Monitoring Use Case (Source: FarrPoint)

For the reduction in in-person monitoring, this reduces the financial cost of monitoring for a peatland site, which could make monitoring viable in the longer run and lead to better quality of data etc. It also decreases the environmental impact of monitoring, as the peatland sites are mostly in remote and rural locations meaning that it is likely that a significant amount of travel would be required. This is especially the case with sites such as the one used within this trials project on the Western Isles, where travel for monitoring could also involve ferry travel.

Initial analysis has suggested that this reduction could be as much as 70kg CO2 equivalents per monitoring visit[6].

The improved quality and timeliness of data should improve the overall restoration of peatland, with better data and reduced cost meaning the sector can better understand the impact that restoration has in a timely manner so as to replicate at other peatland sites. Improved restoration of peatland not only reduces CO2 emissions but also increases the biodiversity of the degraded peatlands themselves.

This will have contributed towards the environmental ambitions including:

- Achieving Net Zero and dealing with the climate crisis;
- Supporting a green recovery
- Enhancing Scotland's natural capital
- Protecting, restoring and valuing nature

This is backed up by NatureScot, who stated that:

> *"Using these sensors in a remote area has enabled us to gather real-time live data, which is important to monitoring the response of water table dynamics to peatland restoration. Projects like this help us explore how emerging technologies can be used to meet the challenges of monitoring peatland restoration work which is often in remote locations". –*
>
> ***NatureScot***

In addition to those environmental benefits, this use case also contributes to increasing innovation through using the IoT technology in a new and innovative way. This will also enable these more remote and rural settings to leverage investment and further innovation.

[6] Based on the technician having to travel from Inverness to the peatland site at Loch Orasaigh), each made up of 190km car journey each way by car at 123.6g CO_2 per KM (source: Scottish Government) plus Ullapool-Stornoway ferry 86km each way at 129.5g CO_2 per KM per driver and car (source: DEFRA)

Comparison with alternative methods for monitoring Peatlands

When considering the impact of using IoT technology for monitoring the condition of peatland it is important understand what differences and benefits this brings over and above that of other methods.

The current solution being used for peatland monitoring, most widely across Scotland, uses devices that are designed to send data directly over normal 2G/ 4G mobile services using an in-built modem. This solution therefore was supposed to deliver remote monitoring, via data downloads. However, the rural nature of the peatlands meant that the 2G/ 4G connectivity was not reliable and had issues due to battery life to provide the power required for using 2G/ 4G. As a result, costly manual in-person site visits to collect and download data all still necessary.

Taking this into account the three key benefits of this IoT technology over the current solution that need to be considered within any further cost benefit analysis are:

- Reduced need for costly in-person monitoring: By being able to monitor the sensor output remotely instead of routine manual in-person visits to download sensor data, this will have substantial financial savings as well as environmental ones (e.g., reduced carbon emissions from travel). It will also reduce the negative disruption impact of visits on the natural peatland.
- Improved quality and timeliness of the peatland monitoring data: Given this solution provides the monitoring organisation with real-time data dashboard (as well as data to download) this will enable them to analyse and make decisions on the need for restoration works (or to change current approaches to restoration) based on much more up-to-date information.
- Enhanced ability to remotely monitor issues with the sensors: An alarm/ notification system can be established to alert the monitoring organisation if there was an issue with the sensor failing to send data – allowing them to assess whether there is an issue with the sensor itself or with the backend servers etc. This is a significant benefit compared to the current sensors/ loggers, via which an issue with sensor/ data would only be known about at an infrequent monitoring/ maintenance visit.

Impact on Trial Objectives

Given the environmental and climate change nature of this use case, it focusses on addressing:

- Objective 2: Support a green recovery through developing and promoting nature-based investments to protect and enhance Scotland's natural capital – As shown through the trailing, the use of IoT technology can represent a viable solution for improving the timeliness and quality of environmental monitoring
- Objective 3: mobilise investment in digital infrastructure – In line with Scottish Government goals this project has invested in digital connectivity infrastructure and helped develop an IoT network at the Loch Orasaigh peatland site.

4.2 Process Evaluation

The process evaluation aims to answer the question:

How has the behaviour of individuals/ organisations influenced these outcomes?

To review how the behaviours of the various stakeholders influenced the outcomes of this project, feedback has been sought from the key stakeholders throughout the period of the trials project. The key lessons learned are set out below.

FarrPoint was engaged as a managing agent for this project in 2020, and it was envisaged that other organisations would contribute to technical implementation and provisioning work. Whilst multiple initial talks were held with other organisations who engaged in a limited advisory capacity due to competing internal resource

priorities. To expedite the project, FarrPoint carried out the network design, implementation, and provisioning for the use cases to date. In addition to this, engagement with stakeholders was hindered due to Covid-19 which has affected elements of the overall timeline.

Key to ensuring the success of the Pairc use cases, was to ensure that the local community were engaged and that the IoT use cases provided solutions for local issues. This was why Objective 1 and Objective 4 were so important to the trials.

- Objective 1: Support local community to overcome local challenges – Through the engagement with the community, they highlighted that improving the monitoring and management of the document store was a key priority and would help them to achieve some of the Pairc Trusts' objectives surrounding improving preservation and opportunities with their cultural and heritage assets.
- Objective 4: Work closely with the local community to build on local assets – By engaging with the local community, this project was able to ensure that it prioritised the assets available to the community. For digital connectivity infrastructure, the project utilised the current mobile connectivity within the area to backhauled the information to the data server. In addition to this, the cultural and historical assets (such as the document store) were seen as important for the local community, therefore the project ensured that it helped to improve the sustainability of these assets.

However, one challenge that became apparent, and is important to consider in the roll out of IoT solutions to remote and rural locations, is ensuring that there is a local contact within the community who can lead on engagement and has some basic technical ability. Given the viability testing of some of the IoT solutions – for example the traffic sensor in particular – which needed to utilise a 3rd party contractor to return sensors/ reattach sensors, this could quickly become relatively costly. If the local engagement lead was able and willing to do some of this more routine work then this would reduce the costs and thus make the solution more viable for the community. In part this is an issue that would only appear in the testing phase of a technology solution., For example, the Document Store Use Case has proved to be viable, and there has been minimal need for additional technical support for the sensors/ gateway.

The Pairc use cases enabled engagement between the key stakeholders from Scottish government, and the community to assess where key priorities were. Beyond this, however, the Peatland Monitoring use case has offered the best opportunity for collaborative working across a number of key stakeholders including multiple workshops with representatives from Scottish Government (and SFT at the start), Scottish Water (who have a local interest and experience of peatland restoration), as well as the Peatland ACTION team within NatureScot and the Carloway Estate Trust (who acted as experts from the Peatland monitoring side). This engagement and collaborative working ensured that there was buy-in across the project and ensured that the technical solutions developed achieved the objectives of the community or other key stakeholders.

- Objective 5: Bring Scottish Government and a number of key stakeholders together to work supportively – Engaging a range of stakeholders has been key to the success of this trials project and as shown has enabled the project to achieve its wider social, economic and environmental ambitions.

At the outset of the project, one key aspect that was going to be explored was the long-term sustainability of the use cases.

- Peatland Monitoring Use Case: the medium to long term sustainability of the monitoring at the Loch Orasaigh site has been relatively straightforward as Peatland ACTION have been keen to continue with their involved from the beginning in testing this innovative solution. Therefore, they are going to be taking over the ownership of the use case equipment and dashboard at the end of the Pilot.
- Document Store Use Case: Initially it was believed that the community would take ownership to sensors at the pilot's end and they would get access to a data

dashboard hosted by a 3rd party at a low enough cost to make it worth their while and off they go. However, due to some of the issues highlighted earlier, through the process of the pilot, it has not been possible to source this low-cost hosted dashboard solution. Moving forward this may be one area that the sider public sector should consider, for example: funding a low-cost data dashboard to be made available to local bodies to enable them to manage IoT solutions at a more viable cost.

4.3 Summary

This final part of the Evaluation provides overall conclusions, considers the extent to which this approach delivers good value for money, and assesses the impact on Objective 6. This identifies the key learnings from the process and assesses whether this approach to the use of IoT technology in remote and rural settings can be adopted more widely across Scotland.

Overall, this evaluation has shown that:

- Stakeholder engagement is key for the successful use of IoT in remote and rural settings, in particular ensuring that the local communities are on board with the solution and that it helps them deliver their ambitions. This collaborative working is also key to ensuring that all stakeholders get something out of the approach.
- The success of the Document Store use case has shown that IoT technology can be used to provide solutions to rural communities, helping them to meet their community focused objectives. The feedback from the community suggested that the use of IoT in this solution provided critical information for the safe storage of historical documents, and other local museums have also signalled that they would be interested in using this solution at their sites.
- The use of IoT as a solution for Peatland Monitoring has proved to viable in certain situations and NatureScot are considering the potential to roll this out to other sites across Scotland as a mechanism for understanding changes in the peatland conditions. The benefits it brings around providing good quality real time data without the need for costly in-person monitoring trips has proved a significant success.
- However, it is important to note that challenges remain. For example, challenges around some of the technology being in its infancy – such as was case with the Traffic Speed Sensor – means that viability in more remote locations can be difficult due to the amount of ongoing testing required. This also hindered the ability to stack use cases for the use of this technology and therefore truly prove viable for wider roll out in a local community.
- In addition to this, some of the project's initial assumptions around the pace of development of the wider IoT ecosystem may have been slower than expected. For example, there still remains a gap in the market for a 3rd party low-cost data dashboard which could be used by local communities or smaller organisations, thus making the use of IoT a more viable option for wider adoption across Scotland's rural communities

Impact on Trial Objectives

- **Objective 6:** explore practical uses of IoT technology for wider adoption across Scotland – given the findings from the evaluation set out above, it is evident that there is a case to be made for the roll out of use cases such as the environmental peatland IoT monitoring elsewhere within Scotland given the significant benefits that it brings over the current solutions, representing a good value for money option for the monitoring organisation. Furthermore, once community IoT use cases (such as the Document Store Monitoring) have been proved to be technically viable in the rural settings, there is a strong case for them to be rolled out more widely to other local communities.

Conclusions and Recommendations

5. Conclusion and Recommendations

5.1 Conclusion

The key findings from the Western Isles IoT Rural Community Trials have been:

- Taking the 5-stage approach (Identify, Plan, Design & Build, Monitor & Evaluate and Report) to trialling the use of Internet of Things technology in remote and rural settings has been successful and has ensured that a wide variety of use cases have been considered.
- Stakeholder engagement is key for the successful use of IoT in remote settings, in particular to ensure the local communities are on board with the solution and that it helps them deliver their ambitions. This collaborative working is also key to ensuring that all stakeholders get something out of the approach.
- The success of the Document Store Use Case has shown that IoT technology can be used to provide solutions to rural communities, helping them to meet their objectives. The feedback from the community suggested that the use of IoT in this solution provided critical information for the safe storage of historical documents, and other local museums have also signalled that they would be interested in using this solution at their sites.
- The use of IoT as a solution for Peatland Monitoring has proved to viable in certain situations and NatureScot are considering the potential to roll this out to other sites across Scotland as a mechanism for understanding changes in the peatland conditions. The benefits it brings around providing good quality real time data without the need for costly in-person monitoring trips has proved a great success.
- However, it is important to note that challenges in using IoT technology in remote locations remain. For example, challenges around the technology itself being often in its infancy – such as was case with the Traffic Speed Sensor – mean that viability in more remote locations can be difficult due to the amount of ongoing testing required, which also hindered the ability to stack use cases for the use of this technology and therefore truly prove viable for wider roll out in a local community.
- In addition to this, some of the project's initial assumptions around the pace of development of the wider IoT ecosystem may have been slower than expected – for example, there still remains a gap in the market for a 3rd party low-cost data dashboard which could be used by local communities or smaller organisations, thus making the use of IoT a more viable option for wider adoption across Scotland's rural communities.

5.2 Recommendations

From this work several key recommendations become apparent:

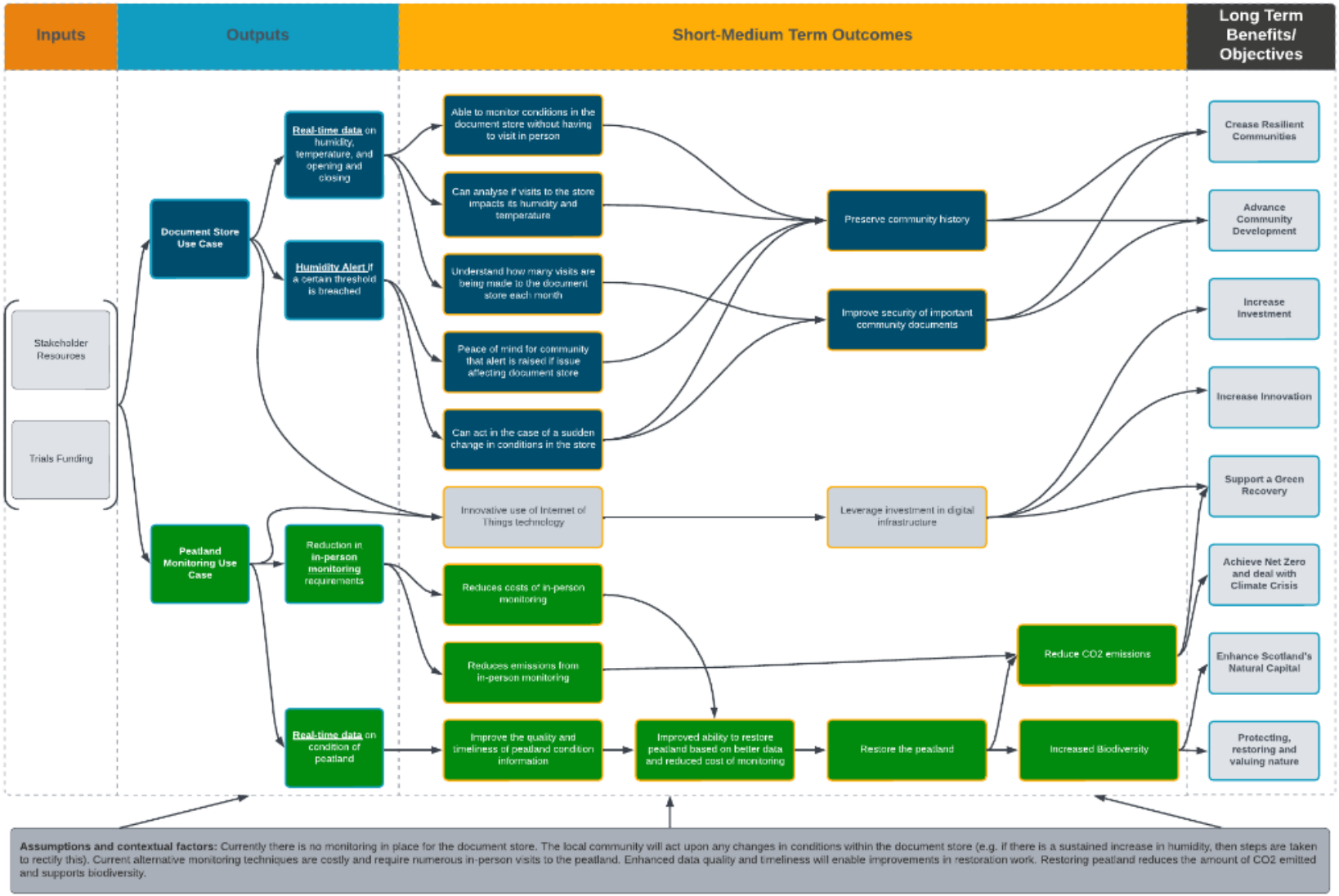
Recommendation 1: Wider work should be undertaken to help rural and remote communities to consider using IoT technology as a solution to help them overcome key local challenges. This should focus on use cases, which can deploy proven technology so as to avoid costly testing.

Recommendation 2: The public sector should consider funding a low-cost data dashboard to be made available to local bodies to enable them to manage IoT solutions at a more viable cost.

Recommendation 3: The use of digital communications infrastructure for environmental monitoring (including peatland monitoring) should be considered more widely given the capability from good quality, relatively low cost, real-time data.

Appendices

Appendix A: Western Isles IoT Trials Theory of Change Logic Model



Visit

farrpoint.com

Edinburgh
Exchange Place 2
5 Semple Street
Edinburgh
EH3 8BL
T: 0131 202 6018

London
1st Floor
99 Bishopsgate
London
EC2M 3XD
T: 020 3693 7310

Manchester
3 Hardman Square
Spinningfields
Manchester
M3 3EB
T: 0161 669 5821

Nova Scotia
1300-1969
Upper Water Street,
Halifax, Canada
NS B3J 3R7
T: +44 (0)131 202 6018