Sustainable Energy Authority of Ireland

National Energy Research, Development & Demonstration Funding Programme

FINAL REPORT TEMPLATE

SECTION 1: PROJECT DETAILS – FOR PUBLICATION

Project Title	SMARTLAB (Smart Buildings Living Lab)
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Lead Grantee (Name)	Prof. Stephen Kinsella
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Project Summary

The Smart Building Living Lab (SMARTLAB) project installed wireless sensor technology (energy and indoor environment sensors) in 70 buildings in the Limerick city centre Decarbonisation Zone and worked directly with building owners and users. The project examined both the barriers (financial and technical) to the deployment of smart technologies, and the opportunities of increased smartness offered by the adoption of the EU Smart Readiness Indicator to enable the uptake of smart technologies and services in buildings across Ireland.

The project created frameworks for upgrading existing buildings to be smart using DIY toolkits and off the shelf components, identified the city-scale infrastructure that could be deployed to reduce the costs for building owners investing in their smart readiness, and investigated methods to encourage uptake of the Smart Readiness Indicator (SRI) and associated smart services

(energy and non-energy) to empower smart energy citizens. SMARTLAB's embedded activity offered a unique opportunity to evaluate the technical and financial challenges and benefits of increased smart readiness for a broad range of construction methods, use cases, and use patterns in typical Irish urban buildings. The project's adoption of a Living Lab approach allowed real impacts to be measured and quantified directly with citizens and stakeholders. The work may be used to inform policy (top-down) and disseminate the experiences of others (bottom-up) as the impact of the solution has been verified in a real-world environment over a 12–18-month monitoring period.	
Keywords (min 3 and max 10)	Smart Buildings, Living Lab, Smart Readiness Indicator, Smart Services, Smart Sensors, Energy Management, Co-Creation, Sustainable Heritage

SECTION 2: FINAL TECHNICAL REPORT – FOR PUBLICATION (max 10 pages)

2.1 Introduction to Project

The imperative to transform our building stock in readiness for a new energy system is clear. 85% of EU buildings were built before the year 2000, with 75% of those now demonstrating a poor energy performance. The path to full decarbonisation of building stock by 2050 must therefore involve significant action on energy efficiency to produce energy savings. EU planning, as detailed in the Energy Performance of Buildings Directive (EU/2024/1275) and Energy Efficiency Directive (EU/2023/1791), involves policies to support not only decarbonisation of buildings but a stable environment for investment and new services and business models to support the energy transition. The SMARTLAB project has sought to address a section of this challenge, by investigating the potential for increased building smartness to provide new opportunities for the energy transition in Irish buildings. A critical yet underexplored aspect of this transition is its social dimension. There is a scarcity of research on deep public engagement in energy innovation projects. Engaging citizens and integrating their buildings into the energy transition is essential for crafting policies and programs that address the complexities of building usage and the motivations of occupants, thereby uncovering opportunities for evolution in these areas. Creating a new services market to support the increased smartness of buildings, necessitated by energy flexibility demands must be done in collaboration with end users to ensure effectiveness and rapid implementation. Empowering energy users to become prosumers, with greater control over their energy use and generation, hinges on strategies that make energy and environmental sensor data accessible and understandable. The recent EU energy policy's community-focused, bottom-up approach will require new frameworks for collaborative energy communities.

The high-level framework objective of the SMARTLAB project is to feed into Irish approaches to the proposed Smart Readiness Indicator, an EU scheme introduced as part of the European Energy Performance of Buildings Directive (EPBD) in 2018. The latest recast of the EPBD EU/2010/31 and the Energy Efficiency Directive EU/2023/1791, revised in 2023, both promote policies to support the decarbonisation of European building stock by 2050 and are seen as crucial sections of the European Green Deal. Once ratified by the Council of the EU, implementation by member states will begin in 2026. The SRI is an ambitious attempt to both encourage and frame the energy transition in buildings, supporting the transformation of how buildings use energy and support inhabitant health and wellbeing with maximum efficiency. It seeks not simply a transfer of energy use from fossil fuels to renewables but a wholesale reorientation of the relationship between buildings, building users, and the energy system. This breadth of this ambition necessitates policy and implementation responses which can both spur and evaluate the multifaceted transitions which need to take place. The SMARTLAB project thus exists during a moment of transformation in European and Irish national policy implementation around energy. SMARTLAB is a wide-scale citizen sensing project which examines the financial and technical barriers to the deployment of smart technologies, and the opportunities that could arise from the uptake of smart technologies and services in buildings across Ireland. It worked to identify the city-scale infrastructure that could be deployed to reduce the costs for building owners investing in their smart readiness, and methods to encourage uptake of the SRI and associated smart services (energy and non-energy) that can empower smart energy citizens. SMARTLAB's adoption of a Living Lab approach allowed real impacts to be measured and quantified directly with citizens and stakeholders, and its position within the Citizen Innovation Lab fostered connection between communities and the wider innovation ecosystem.

2.2 Project Objectives

2.2.1 SRI Potential

The SMARTLAB project conducted a review of smart certificates and assessed the potential of the EU Smart Readiness Indicator to support the transition of Irish buildings to a decarbonised energy system. The Smart Readiness Indicator (SRI) is a high-level key performance indicator of a building's ability to respond to external signals. The SRI Directive 2018 was incepted as part of the EPBD towards better energy-efficient buildings. Although EPBD introduced the energy performance certificate (EPC, 2010/31/EU) directive as a mandatory DEC for all European building stock to be implemented, the SRI is currently a voluntary scheme and is intended to support the EPC directive, not replace it (Commission, 2010; Verbeke, et al., 2020). Fundamentally, the SRI is a common scheme for rating the smart readiness of buildings, but in practice, the SRI serves as a tool to close the performance gap between estimated energy use based on the building thermophysical and system properties (EPC) and actual energy use based on occupants needs. The SRI serves a means of assessing a building's ability to adjust to exterior stimuli from the grid, climate, and its occupants by recording the actual energy flux of buildings towards better energy management leveraging novel technologies (Volkov & Batov, 2015; Verbeke, et al., 2020). The SRI is an important tool for transitioning current and future building stock towards a smart and more efficient future. More so, the SRI is designed to influence stakeholders such as "building occupants and owners, property managers, building designers and engineers, product manufacturers, technology providers, and policy-makers" towards smart and sustainable systems during the design and operational phase of existing and future buildings (Apostolopoulos, et al., 2022, pg. 2). More directly, the SRI supports the role in which building users, owners, tenants, and smart service providers play in improving building energy efficiency and liveability (Verbeke, et al., 2020).

Much like the original EPC certificate, the SRI will need to be assessed by an accredited assessor to evaluate the level of smartness for current and future building stock. However, even at member state scale, assessors may differ in opinion and expertise depending on their background. For example, a case study of a near-zero energy building (nZEB) in Bolzano, Italy found that assessors can interpret SRI technical solutions differently (Vigna, et al, 2020). Fundamentally, the assessment process in the SMARTLAB project should be agreed by project partners to help prevent any misunderstanding or misinterpretation by the designated assessors. Furthermore, a notable finding from this study illustrated the marginal score a modern building attained with an average score of C (61%) despite the modernity of the systems (Vigna et al, 2020). On average, the cost of increasing single family homes SRI score by 4% was €5,000 across these building type in this case study (Apostolopoulos, et al, 2022). Although less expensive smart solutions can improve a building's SRI, deep solutions (solutions that overhaul entire systems and sometimes fabric of the building) were the only solutions that had meaningful improvements to the SRI scores. As Ireland is situated in western Europe with a heating dominated climate, the weighting factors for SRI scoring primarily focus on space heating efficiency. Moreover, with roughly 40% of Irish building stock built before the introduction of building energy standards (pre-1980), a substantial amount of Irish building stock will need energy refurbishment to hit EU Green Deal 2030 and 2050 targets. Thus, building owners of old energy inefficient building stock will need consideration when adapting the new SRI framework so that SRI technical solutions can be appropriately applied. The project team performed a number of analyses to determine methods and costs for applying an SRI upgrade to different types of contemporary Irish housing stock. Eight Frameworks applied to heritage, apartment, and single-family homes common in Limerick. Prices were based on advertised equipment, excluding installation costs, and SRI tool version 4.4 was used. For other analyses see **WP3-D2 Framework for Upgrading the SRI of Existing Buildings**.

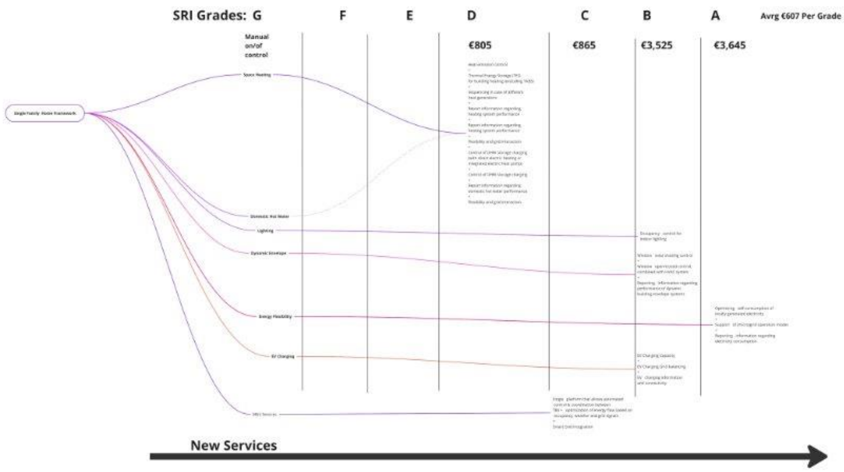


Figure 1 SRI upgrade analysis for Single Family Home With Existing Radiator/ HW tank/ Boiler Combo

2.2.2 Smart Energy Citizens

The project used a living lab approach, harnessing the ecosystem and experience of the UL/LCCC Citizen Innovation Lab in Limerick. The objective was to ensure the generation of actionable insights and robust data through carefully orchestrated interactions with the three main stakeholder groups – building owners and occupants, policy makers and other stakeholders. The figure below outlines the orchestration of the SMARTLAB living lab, including participant journeys (this figure compiles numerous journey steps) and learning loops across the project timeline. This work is set out in **WP1D1 Plan for Stakeholder Engagement and SMARTLAB Journeys** and **WP1-D6&7 SMARTLAB Playbook of Engagement Activities and Events (1&2)**.

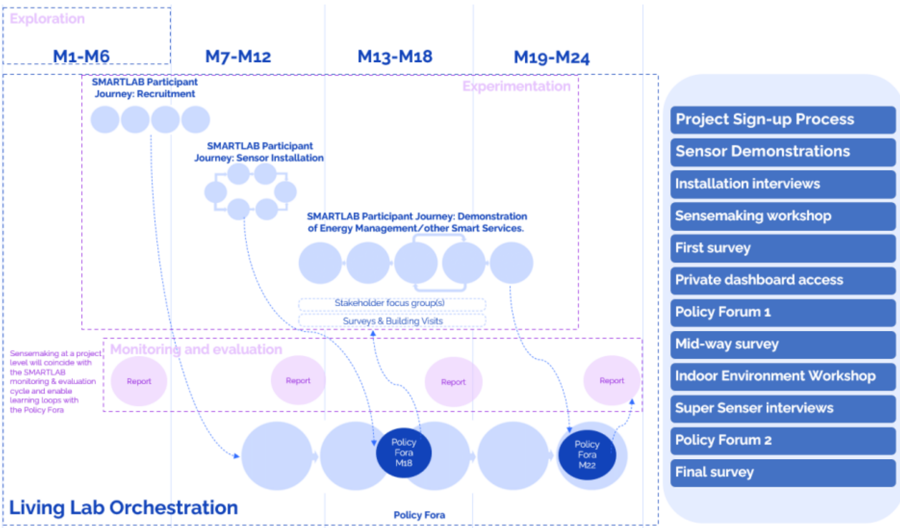


Figure 2 SMARTLAB living lab orchestration including core activities

2.2.3 Smart Infrastructure

At the heart of the SRI framework is the assumption that data streams from buildings can be made available affordably and reliably to feed data models and underpin services. One of the major milestones required to bring the building set up to a minimum SRI is to establish a flow of data between the building and the internet. A flow of data is the cornerstone of the SRI and a two-way data flow allowing for control and delivery of services remotely is at the top of the performance criteria for the SRI. In order to achieve this, we needed to evaluate the connectivity layer that lies between buildings themselves and the internet to evaluate the optimal route to enable smarter buildings. Collection of building data is ultimately a physical endeavour and depends on a link between the data point within the building e.g. a meter and the internet of services that are supported. We thus evaluated of technologies to implement streaming sensor data, using criteria including: wireless transmission, wide area coverage, two-way communication, wide device support, long battery life, blackspot resolution and commercial models. It was decided that LoRaWAN technology offered the most promising solution for the project and offered the most opportunity for delivery at scale if required by a local provider under the SRI. See **WP2D1** for further information.

A process of evaluation and tendering was also used to identify the optimal sensors to be used in the project. The sensor requirements for the project were for monitoring of energy use at the main incoming meter and monitoring of environmental conditions within the building to report comfort and other relevant data for taking action and offering services. The sensor selection process yielded a smart energy meter based on a LORAWAN network, the Vutility Hotdrop. This device is simple to install and requires no access to power or electrical works to install. It is ideal for data collection in this context and will transmit data independently of the tenants' own internet provision. Environmental sensors were evaluated against a matrix of requirements and a tender process. The final selection yielded the Milesight AM307 as the environmental sensor of choice. It provides in-building feedback via large e-ink screen as well as granular data to the digital twin model. Further, exploration of the potential for a DIY approach to sensor development was carried out, and although these sensors were not installed in participant buildings, they were harnessed for demystification and capacity building among participants. A detailed account of this process is found in **WP2D2 Approved List of Sensor Devices**.

2.2.4 Smart Buildings

Along with creating a framework for 'smart' building upgrades for broad application (as detailed above), the project devised a set of Use Cases to define 'smart' for a range of experiences identified through end user engagement and analysis of building types and patterns of use. This involved the definition of a project boundary (below).

Figure 3 Official boundary map of the SMARTLAB project.

SMARTLAB Use Case typologies as agreed by partners are defined in relation to three core categories – period of construction, current use of the building, and estimated smartness level (see **WP1D4 Catalogue of Use Cases**). These Use cases draw on available statistics and data sources, but the team did not attempt to exactly replicate particular quotas within Use Cases. The greater range of buildings within Use Cases is also reflective of the partner expertise in determining which building types (age, use, smartness) are most valuable for research purposes. The below Table 5 gives a resume of SMARTLAB Use Cases within each category:

Use Case #	Date	Use Type	Smartness
1	Pre-1940 Heritage Buildings	Mixed Use	G
2		Residential – House	G
3		Residential – house	G
4	1941-75 Post-war building	Residential – house	G
5	1976-91 Oil Crisis	Residential - house	G
6	1992-2007 Celtic tiger building	Institutional	G
7		Commercial / Mixed Use	F
8		Residential	G
9	2008-present	Residential – apartment	F

Table 1 SMARTLAB Use Cases by date, use, and smartness level.

Assessment of the particular requirements of heritage buildings, which made up approximately 40% of SMARTLAB participant buildings, was led by project partner Carrig Conservation with a selection of u-value assessments of heritage buildings across Use Cases 1, 2, and 3. The results of this are discussed below and in **WP4D2 Report on Outcomes of Service Provision**.

2.2.5 Smart Services

Exploring the potential for uptake of smart services required in the first instance the development of the SMARTLAB digital twin. An initial model was adapted from Limerick's EU H2020 +CityXChange project digital twin. This served as the starting point for the 3D modelling of the SMARTLAB pilot site. A 3D visualization of buildings in Limerick city within the boundary was manually assigned with their height and number of storeys. The total pilot area is 2,448,560.35m. The Digital Twin is hosted on the IES site, and was mirrored on the SMARTLAB project website.

2.3 Summary of Key Findings/Outcomes

SMARTLAB harnessed Use Cases within its project timeline, methodology, and dissemination strategy, and the final Use Cases synthesis is perhaps the most effective way to encapsulate project findings. Use Cases were designed first to ensure solutions were designed with the end user in mind (T1.4), as well as guiding the identification of technical and financial challenges to the development of city-scale infrastructure, SRI-driven upgrades, and smart data governance. One of the strengths of the SMARTLAB project was its work across a wide range of buildings and building users, building a picture of a contemporary Irish city in the midst of an energy transition. But this strength is also a challenge – the complexity of the project test area and participant group has generated highly varied results. The project team has therefore harnessed project Use Cases to streamline and encapsulate project findings across project work packages, including results of analysis in energy, indoor environmental and u-value data for each building typology as well as highlights from engagement data for each building user type. The Use Case summation also includes tailored insights on SRI potential, smart services, and smart infrastructure.

The original Use Cases Deliverable D1.4 included nine project typologies, arranged into five temporal eras (see colour coding of User Case numbers). For final depiction and analysis, the project team chose the six Use Cases with the most significant data findings across all categories. All six of the final Use Cases also draw on "Super Senser" building data with extensive internal sensoring, and the Use Cases referring to historic buildings have had u-values read. It should be noted that there is no final Use Case from the original #9, buildings dated 2008-present. In Limerick city, this building stock is predominantly large-scale apartment rentals, and it is one finding of the project that accessing the users of this building type is particularly challenging. The final six Use Cases are developed from real examples from within the SMARTLAB cohort. For reasons of data privacy, the Use Case buildings and building users are pseudonymized. Energy and environment data are collated from typical readings within the Use Case typology, while engagement data (including direct quotations) refer to one particular building within the typology. Below are two of the six Use Cases (1 & which were designed and printed for dissemination of results at the Citizen Innovation Lab in Limerick city. As an encapsulation of key project analysis across multiple strands of enquiry, the Use Cases are a powerful communication tool. All Use Cases can be found in **WP5D3 Final Report on Impacts.**

SMART LAB

USE CASE 1: PRE-1940 HERITAGE BUILDING - OFFICE USE

USE TYPE

Office building, open plan, used during office hours and quiet on weekends.

EXISTING SRI RATING

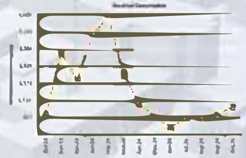
G

TYPOLOGY

Terraced house, solid brick wall, Pre 1900. Georgian brick terrace house found in Limerick from late 1700s up to mid-1800s. These 3 storey dwellings often have a parapet wall to the front which disguises the pitched roofs behind to retain the aesthetic of the streetscape. Found in Limerick on O'Connell St & surrounds.

This project has been funded by the Sustainable Energy Authority of Ireland under the SEAI Research, Development & Demonstration Funding Programme 2021 Grant number [illegible]

ENERGY DATA



This graph shows average monthly electrical consumption for this sampled building from November 2023 to October 2024. The building uses electrical radiators for heating. The highest average electrical consumption was in February 2024 and lowest was in June 2024. The electrical consumption pattern indicates that more energy was used during the winter period, the usual consumption pattern in a building situated in a heating climate. This is an office building , so there was an energy dip in December 2023 over the holiday period before consumption increased until February 2024. After that,consumption continued to decrease until June 2024. There's a gradual energy consumption increment from July 2024 onwards, as a poor summer in Ireland meant radiators were switched on earlier.

INDOOR ENVIRONMENTAL DATA

This graph shows the correlation between humidity and indoor temperature in the building, with low temperatures matching low humidity. The building's humidity level stayed between 60% to 72% which is at the outer range for the optimum indoor humidity levels. When temperatures drop, the air can't hold as much moisture, and this moisture begins to settle on indoor surfaces, potentially causing trouble with damp and mould.

U-VALUE DATA

U-value is a measurement of the thermal insulation properties of a building element. The in-situ measured U-value for this type of wall was 0.8 W/m2K which means that the wall is performing considerably better than national benchmarks would predict. The traditional construction of this building with lime mortar and plaster is breathable and anti-microbial meaning that it can absorb and release some moisture and is resistant to mould, helping to regulate the internal environment. Heritage buildings such as Limerick's Georgians are more resilient than expected and may manage future climate transitions more successfully than buildings of modern construction.

BUILDING USER ENGAGEMENT - IMPACT & INSIGHT

The users of this sample building, which is owned by an association and used for offices of multiple businesses, joined SMARTLAB to gain "insight on how older buildings perform in a commercial context possibly give us an evidence base for advocating for change." Once sensors were installed, examination of their energy use showed patterns of cumulative heating - their building is cold each Monday, then too warm by Friday. They plan to use this information to change their heating schedules, and are interested in further smart tech that could control these functions. Air quality results were also impactful, with the participant telling the team, "particularly in terms of airborne particulates and quality of air for staff. I think becoming familiar with the tech and how to understand it was critical." The living lab approach allowed for both translation of technical information about the sensors and peer-to-peer discussions of their use and application.

IMPLICATIONS FOR SRI POLICY

This sample building is solid and well maintained, but its indoor humidity is regularly above recommended levels. Any transition plan for Irish buildings should take into account the need to mitigate humidity issues, whether through consistent heating programmes or comprehensive ventilation strategies. However, given building age, there will likely be limitations on what alterations can be made to the building envelope to support ventilation strategies and will thus depend on less intrusive interventions. This will limit the building's ability to achieve the higher SRI grades. However, there is some potential to improve the buildings smartness via HVAC systems that do not require intrusive work on the building fabric such as features leveraging the existing fabric with mechanisms such as smart glass and automated window frames to regulate thermal gains as well as natural ventilation at optimal times throughout the day.

IMPLICATIONS FOR SMART SERVICES & INFRASTRUCTURE

This building's use of electric heating means that it is well positioned to transition to a smarter energy system in the coming years. Because of SMARTLAB, they have both the data and understanding they need to take the next step. But the building owners are expressing frustration at the difficulties they faced in applying for supports to retrofit their heritage building, citing "an extreme knowledge gap" in the application process. The experience of this building and these participants shows the urgency of an acceleration in financial supports, smart services markets, and collaborative actions.

SMART LAB

USE CASE 6: 1992-2007 CELTIC TIGER ERA BUILDINGS - RESIDENTIAL

USE TYPE

1992-2007 Celtic Tiger Era Buildings. Residential use.

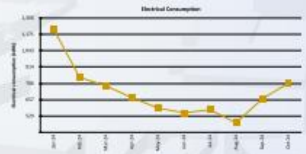
EXISTING SRI RATING

G

TYPOLOGY

Terraced house with cavity walls. Tabula states that "the part-filled cavity can be full-filled by pumping in additional insulation beads. The floors would most likely have been insulated during construction." These buildings typically found in Limerick in small developments such as Pennywell Gardens.

ENERGY DATA



The graph above shows the electrical consumption of a residential unit built during the Celtic Tiger Era. The building is using electric heaters for space heating. The data for the building's electrical consumption recorded from September 2023 to October 2024 but few data points from September 2023 to December 2023 available which then was omitted. The highest electrical consumption was in January 2024 while the lowest consumption was in August 2024. The energy trend kept decreasing every month until June 2024. There was a minor increase in consumption in July 2024 which then dropped in August 2024. The next couple of months saw a gradual increase in average energy consumption.

INDOOR ENVIRONMENTAL DATA

The graph above shows humidity and indoor temperature of the Celtic Tiger Era residential building. The indoor air temperature decreased from July 2023 to January 2024. There was a slight temperature increase in February 2024 before dipping again in March 2024. After March 2024, the temperature kept rising until August 2024. The next couple of months, the temperature gradually decreases every month. The humidity level of the building measured between 59% to 70% which is at the outer range of the optimum humidity level range for an indoor space.

BUILDING USER ENGAGEMENT - IMPACT & INSIGHT

The participants from this sampled building were motivated to learn more about their building to see what possibilities existed for improving their energy consumption. "We would just like to keep up to date and see what opportunities might be there to have an affordable and suitable heating/energy system." As "super senser" participants, the owners of this residential building received a significant amount of information about their indoor environment. They found that the insulation and temperature maintenance were good, but that ventilation was a problem – and a difficult one to solve, particularly in winter when opening a window isn't a viable option. Instead, they chose to use the heating more: "During the winter I probably put on the heater more often than I would have before because I was conscious of the room being too cold from the sensor." Although the participants do not see an obvious solution to their dilemma – strong insulation, low ventilation – they feel significantly more informed, and have adopted further smart technology with monitoring capability to manage their heating.

IMPLICATIONS FOR SRI POLICY

Use case 6 represents building stock that would need some minor upgrades to substantially improve its rating for smart readiness. However, a significant proportion of buildings like this sampled use case are still dependant on fossil fuel boilers - albeit a more energy efficient version of earlier boilers as seen in Use Cases 4 and 5. generally with a performance coefficient of 95%. Some newer buildings from this era have heat pumps installed which can be adapted with modern smart thermostats to greatly improve the SRI. They could use supporting smart energy use platforms that optimise energy use for the building occupants. However most Use Case 6 buildings would need to consider a heat pump, and its affiliated smart services to attain a high SRI grade.

IMPLICATIONS FOR SMART SERVICES & INFRASTRUCTURE

The strong engagement seen with these sampled building owners is reflected in the benefits they received from their sensors. Service markets will function best where trust between customers and vendors can be established. Ensuring the quality and safety of data while supporting service development and innovation are clear requirements observed from SMARTLAB's deployment.

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This project has been funded by the Sustainable Energy Authority of Ireland under the SEAI Research, Development & Demonstration Funding Programme 2021, Grant number 21/RDD/634.

2.4 Project Impact

2.4.1 User Engagement and Understanding

The impact of smart sensor installation was clearly observed within the SMARTLAB experiment, with particular impact seen in relation to the indoor environmental monitor. The electricity monitor, which fed data directly to a project server and had no live data stream within the building, was less impactful. 60% of SMARTLAB participants reported behaviour change among the residents and users of their building in response to the installation of smart sensors. Some participants noted constraints that prevent them from making certain changes, such as concerns about cold weather or limitations in rented buildings. In many cases, the sensors told them things about their building that they didn't know before, particularly in relation to established benchmarks. For many, this was access to a clear indicator of "normal" or "healthy" indoor environment for the first time. For those in non-residential settings, the information became directly actionable: participants changed how they managed their logistics and business operations in numerous ways. These changes resulted in more streamlined business processes, healthier outcomes and reported money savings, significant findings for a monitoring-only experiment.

A significant aspect of the SMARTLAB project remit – to assess the impact of increased smartness – is captured in project data around future intentions for participant buildings. 75% of SMARTLAB respondents reported impact to future planning for their building (see D1.2 Section 2.2.2). Where respondents indicated new intentions to make changes to their buildings, they plan to:

- continue to increase building smartness by installing more sensors to harness more building information,
- purchase dehumidifiers to address issues of humidity and damp in their building,
- install ventilation systems such as heat recovery ventilation units.

One very significant finding is that most intended changes expressed in the surveys are designed to improve indoor environmental conditions, specifically air quality. This finding has potential implications for future smart services provision, SRI policy in Ireland, and SEAI public engagement. It suggests that indoor air quality is an under-explored aspect of the energy transition in Ireland and a powerful potential asset in encouraging people to reassess their buildings' future.

Working with SMARTLAB participants through the living lab, it has become clear that the appetite for further adoption of smart technology is strong, and that people are open to not only the smart monitoring carried out in this project but also for more advanced smart controls.

Overall, there is little evidence of scepticism towards such technologies in either monitoring or control – a very positive finding. Several respondents also stated that the experience of the SMARTLAB project has impacted their attitude to smart technology, telling us that "it has made me more aware of what's possible." Through the evaluation of the project's living lab approach (see D1.7 SMARTLAB playbook of engagement activities) the project team identified a number of project impacts and outcomes which were attributable to this approach.

Smart infrastructure objectives:

- Access to participant buildings secured and maintained through relationships built through LL embedded networks;
- Impact of project insights on smart infrastructure potential in municipality magnified by LL co-creation methods.

Smart energy citizen objectives:

- Participant engagement instigated project learning loops, producing actionable insights which project team could act upon mid-timeline for greater impact;
- Participant-led engagement activity fostered city-based connections between participants (expertise sharing, building-level collaborations) which may continue beyond project timeline.

Smart building objectives:

- Use Cases, drawn from living lab ecosystem knowledge, streamlined research process from data gathering to policy development coherently;

- Living lab systemic approach identified building-level opportunities beyond smartness – new retrofit intentions, support for heritage buildings, alignment with future municipality planning.

Smart services objectives:

- Living lab approach captured evolution of participant motivations towards building smartness, generating valuable insights for future services market.

SRI potential objectives:

- Development of policy recommendations rooted in analysis of extensive sensor data filtered through participant sense-making.

The analysis and evaluation of the project's living lab indicates significant potential for supporting the acceleration of climate transition activity in Irish contexts.

2.4.2 Smart Energy System

Collection of building data is ultimately a physical endeavour and depends on a link between the data point within the building (e.g. a meter) and the internet of services that are supported. The explorations carried out by the project point to some of the challenges and opportunities required to advance our transition to a new energy system. At city scale the primary technical insights were derived from the testing of a Low Range Wide Area Network (LoRaWAN) to transmit sensor data, as well as the installation process for 200+ sensors in circa. 70 buildings. The local political and social infrastructure required to advance city-scale innovation projects was also tested in SMARTLAB.

The characteristics of a LoRaWAN network with capacity to upscale city-scale smart infrastructure were outlined. The network should be wireless, with wide area coverage and two-way communication capabilities. There's a need for long battery life of devices and blackspot resolution capacity. There should be a large body of supported devices in an ecosystem of multiple vendors. A commercial model would allow procurement of services by local government or utilities, allowing also for flexible capital investment. This is in line with local government planning around communication networks, which focuses on upgrading networks to allow for high quality services but does not envisage the development of data platforms for use by the service market in the Irish context.

At a very high level the streaming of data such as that in the SMARTLAB projects creates massive opportunity for better market performance. It facilitates the matching of buyers and sellers with better information quality while reducing the cost and time involved in developing a transaction. This is a crucial enabler of innovation and can create a cycle of innovation whose outcomes are ultimately hard to predict. This usually requires the adoption of a system by a significant number of people, kicking off a network effect flywheel and further attracting market entrants and solution providers.

The project identified a number of potential service supports which respond both to the needs and interests of SMARTLAB participants and to the current state of the Irish energy transition.

- Data Clearinghouse: Within SMARTLAB, our 200+ sensors streamed data to a private server hosted by project partner IES. Private dashboards facilitated access to private sensor data, and a live digital twin showed aggregated data. But participants were not able to query the datasets themselves, as there was no GDPR-compliant mechanism for widespread access to identifiable sensor data. This stopped the project from further investigating community data potential – for use, for example, to analyse geographical clusters of participant buildings to assess data usage towards forming an energy community, or to analyse environmental sensor data across a particular building type such as red-brick Georgian buildings common within Limerick city centre. A data clearinghouse might address these gaps. In considering a potential energy market, the sharing of data with potential vendors and digital applications is a privacy risk and potentially open to abuse. Therefore it is called out in this deliverable as a key discussion point. Cities or countries considering implementing a deployment of sensors to support SRI objectives need to consider their role in maintaining a credible, safe and protected data sharing environment.

- Peer-to-peer services: Delivery of more efficient housing stock is a key ambition of European policymakers, and the SRI can enable that ambition. SMARTLAB's sensor analysis identified valuable data flows from even the most basic of sensor interventions in stock. When the building type and location is aligned with real time data on energy use, thermal performance and humidity or mould risk, it becomes possible to identify a suite of interventions that might improve the energy performance (e.g. BER) of a unit. Service providers in this sector, such as consultancies, designers, builders, system integrators and energy transition contractors should be able to access these data sets to craft tailored, data-backed proposals for occupiers. The project findings indicate the need for a developed peer-to-peer facility for energy services trading in Ireland. These could include over-the-grid trading, as well as partly or fully independent microgrids.
- Intelligence-led insights: Another level of service enabled by the deployment of building sensors is for applications offering 'intelligence-led' insights and assistance to occupiers. These applications may utilise AI technologies in order to interrogate the sensor telemetry and offer ongoing support to improve quality of life for occupiers. Reviews of the efficacy of different kinds of techniques for prompting behaviour change - in residential settings in particular – pre-date the current intelligence capacity of smart building technology, but the principles from earlier surveys demonstrate promising avenues of intervention which may be updated in line with new analytical and generative capacity. A potential benefit in some of these services is community development whereby those with common behaviours or those with physical proximity can be brough together to share experiences and deepen their experience of this technology. There were clusters of buildings within the SMARTLAB cohort which demonstrated the potential for this kind of community or proximity-based approach (see D5.3 Final Report on Impacts for detail).

2.4.3 An Irish Smart Readiness Indicator

The SRI could be a valuable tool for the proliferation of smart technologies in Irish building stock; however, its success in Ireland will depend on overcoming technical and economic barriers associated with adapting nascent energy efficient technologies. Smart heating, smart meters, and automation should be prioritized for maximum impact in improvement for SRI scores in Ireland, but better infrastructure and supports should be given for the adaptation of these technologies which are often invasive, expensive, and difficult to implement. The below points summarise the application of the SRI in the Irish context during the research activities of the SMARTLAB Project:

1. **Smart Heating Solutions Have the Greatest Impact on SRI**

Smart heating solutions have high potential for improving energy efficiency and thermal comfort.

Challenges: These solutions can be expensive to implement, especially in older buildings. They often require professional installation.

Outcome: Prioritize deployment in buildings with compatible heating systems.

2. **Smart Energy Meters Improve Grid Flexibility & Demand Response**

Smart energy meters enable real-time energy monitoring, demand-side management, and grid interaction.

Challenges: Cost varies based on features; professional installation is required for advanced capabilities.

Outcome: The ability of an SRI certificate to inform grid operators (DSOs) of a building's demand response potential is not well-defined and needs alignment with Ireland's DS3 grid service markets.

3. **Environmental Sensors Improve Comfort but Have Limited Energy Impact**

Benefits:

Environmental sensors can support improvements in indoor air quality, thermal comfort, and occupant wellbeing.

Challenges: They require additional control systems (e.g., smart automation for ventilation). Multiple sensors are needed in large/multi-zone buildings, increasing cost.
Outcome: The potential of environmental sensors is limited unless combined with building automation (BACs) or AI-driven solutions, although their impact on building user behaviour and motivation is significant.
4. **Other Smart Technologies Have Varying Cost-Benefit Ratios**
Dynamic Building Envelopes, for example, adapt to outdoor conditions for better efficiency but are costly and require expert installation. Smart Lighting is easy to install but less impactful than LEDs in energy efficiency unless paired with automation.

2.5 Recommendations

Recommendation 1: SRI Policy in Ireland should target efficiency in heating systems

- **Acknowledge the upfront capital cost involved with improving SRI** in Ireland for almost all its building stock built pre-2010. Although, old heating and energy systems smartness can be improved, the overall smartness depends on the buildings ability to automate its operations towards energy efficiency which is often an expensive undertaken for older building stock in the current market.
- Although the SRI demonstrates a buildings level of smartness, moderate to medium SRI grades does not necessarily indicate that the building can receive and act on signals from the grid. Either a new SRI indicator or another means of certifying or indicating via other databases should be considered for **mapping building stock capable of complex demand side management on the grid**. Perhaps this could be achieved via the local census or a more sophisticated SRI score that indicates the buildings capabilities of receiving and acting on external signals.
- **The most cost-effective way for Irish building stock to improve its SRI grade is targeting the heating systems** towards energy efficiency via smart technologies that automate the energy use towards optimal operational use and thermal comfort for each property.
- The most impactful SRI criteria for optimal building indoor air quality and thermal comfort are domains related to the buildings HVAC, specifically heating and ventilation **as cold and damp conditions were most prolific in Limerick cities** building stock which is generally representative of Irish urban building stock.

Recommendation 2: Irish Smart Services Markets are ready and waiting

- It is clear that **non-energy services will be a driver in the smart energy transition**. It was a striking project finding that most intended changes expressed by participants are designed to improve indoor environmental conditions, specifically air quality. The study found that indoor air quality is an under-explored aspect of the energy transition in Ireland and a powerful potential asset in encouraging people to reassess their buildings' future.
- **Smart services should be designed for ease of use**. Engagement data in SMARTLAB showed far greater interest in those monitoring services which provided clear and accessible information with definite impact pathways (indoor environment sensing) than in services which required multiple steps to access and drive action (energy sensing).
- **Developing high-trust market scenarios will accelerate uptake**. Among the SMARTLAB cohort, there was little evidence of concern for energy and environmental data privacy. This likely reflects the efforts of the SMARTLAB team, notably including the Local Authority, to establish trust between participant and service provider. As Irish policy is moving towards a market-driven model of smart services, the evidence of the project's success through relationship and reputation building should be noted.

- **As launching customer, the power of local government has significant potential**. This role could be more strongly set out in policy documents or city charters – an example would be the City of Gothenburg Climate Charter. The opportunity is for city authorities to facilitate the development of smart markets as orchestrator and facilitator. This balance of upgraded city-scale communication networks alongside new commitments and mandates from local governments on energy transition initiatives would offer cities a real opportunity to accelerate progress to a decarbonised energy system.
- Cities or countries considering implementing a deployment of sensors to support SRI objectives need to consider their role in maintaining a credible, safe and protected data sharing environment. **A data clearinghouse is a required next step** to allow for the development of smart services in this context.
- The project findings indicate the need for a developed peer-to-peer facility for energy services trading in Ireland. These could include over-the-grid trading, as well as partly or fully independent microgrids. **When the building type and location is aligned with real time data on energy use, thermal performance and humidity or mould risk, it becomes possible to identify a suite of interventions** that might improve the energy performance of a unit. Service providers in this sector, such as consultancies, designers, builders, system integrators and energy transition contractors should be able to access these data sets to craft tailored, data-backed proposals for occupiers.
- Once sensors are deployed within buildings, **applications offering 'intelligence-led' insights and assistance to occupiers will become valuable**. These applications may utilise AI technologies to interrogate the sensor telemetry and offer ongoing support to improve quality of life for occupiers. A potential benefit in some of these services is community development whereby those with common behaviours or those with physical proximity can be brough together to share experiences and deepen their experience of this technology. There were clusters of buildings within the SMARTLAB cohort which demonstrated the potential for this kind of community or proximity-based approach.

Recommendation 3: Plan carefully for the challenges and opportunities of increased smartness in Irish heritage buildings

- **Consider building fabric:** Pre-1945 buildings are likely to be of a different construction type to modern buildings. Traditional construction of solid masonry, stone or brick with lime mortar, has different characteristics and any fabric interventions or heating regime need to take this into account as well as the comfort of the building occupants.
- **Plans should respect Heritage significance**: This relates to buildings of heritage significance, in an Architectural Conservation Area, or on the Record of Protected Structures or, if they are pre-1700, the national monuments service records. If a building has features of interest, then any smart technology interventions will need to be planned to coordinate with the things that give the building its character and not to detract from the character.
- Historic buildings may have been built before central heating or indoor plumbing. The integration of modern services into a historic building can be invasive and damaging if it is not well planned. The installation and integration of renewables is the next iteration of this, thus **we must use appropriate systems installed in ways that work along with the heritage features of the building**. For example, it would be an opportunity to learn from Segovia's historic centre project linking central heritage buildings to a PV source 2km away in a less sensitive area.
- **Wireless technology presents advantages in heritage buildings as it can reduce disruption to the building fabric**. Such non-invasive measures are of lower impact on the building. Care must still be taken in the appropriate location of any units. Some older buildings have thicker

walls of solid masonry and other features not seen in the modern buildings for which the technology is designed so it is advisable to test the wireless units in situ prior to final installation.
- **Use sensors to monitor baseline heat levels required in historic buildings**. Sensors can be used in combination with a timed heating system connected to a heat pump which keeps a low heat at a fairly constant level and then tops this up with a complimentary system, perhaps electric, infra-red, for when the room is in occupation.
- **Leverage the commitment and knowledge of heritage building owners.** SMARTLAB's heritage building owners demonstrated strong sense of responsibility towards their buildings, as well as strong concern for their future and frustration at the challenge of negotiating a complex funding and regulatory landscape. These owners should be supported as exemplars of a digital energy transition.

Recommendation 4: Harness the potential of living labs and embedded local action to accelerate the energy transition

As a living lab, the SMARTLAB project was highly effective at scoping the potential for technological and social transformation in the Irish energy transition. This is in part due to the embedded nature of the project in Limerick city, and to the work of community capacity building undertaken by the Citizen Innovation Lab. The recommendations below therefore focus on the specific potential of living labs and on the potential of other collaborative and engaged approaches, based on findings from SMARTLAB.

- **Living labs are well positioned to have impact in complex climate transition projects.** The combination of embedded position, network knowledge, and a methodology drawn from innovation processes, makes living labs particularly suited to the socio-technical challenges of the energy transition. Living labs, in bringing together representatives of the quadruple helix innovation approach, have been shown to accelerate energy retrofit objectives, even in complex historic environments.
- **The EU is embedding living lab approaches in its research agenda and the Irish research community should make the most of this opportunity**. As an example, one of the five EU Missions, focused on eradicating cancer, is to be enacted entirely through 100 living labs across Europe. The European Network of Living Labs has also signed an MoU with the European Research Council. Living labs appear with increasing frequency in funding calls, and Ireland is well positioned to benefit.
- Embedded living labs offer a methodological framework which can capture diverse datasets and encompass complex contemporary contexts (such as a city centre). **Irish national funding bodies should develop further awareness of the methodological capacities of certified living labs** as well as being wary of a rise in "lab-washing" as living lab approaches gain recognition as an impact pathway.
- **SEAI should support research and demonstration projects which are situated within localised contexts** for smart service and other grid decarbonisation development. The ability to develop and leverage public trust is an important resource in market scoping and other innovation activity.

2.6 Conclusions and Next Steps

SMARTLAB The SMARTLAB project, engaging across 70 buildings and their users/inhabitants, captured the evolution of attitudes and intentions towards the clean energy transition in ways directly relevant to future policy implementation across grid redevelopment, smart service design, and national retrofit. The engaged and multi-stakeholder living lab approach acted as a container and filtration mechanism for the multiple complexities of transition challenges across buildings, people, and technology. Its focus was necessarily broad, and future work could productively follow up on several promising areas. There was an obvious appetite among participants for additional smart technology within their buildings, both further monitoring and adding elements of control. There was clear interest in collaborative community approaches to energy efficiency, with several local clusters identified within the cohort, and this interest would be profitably leveraged for real-world testing of medium- and large-scale renewable installations, energy communities, and grid balancing/flexibility testing. The unexpectedly strong interest in indoor environment monitoring and its impact on behaviour change and future retrofit intent among participants was an important finding of the project, and a further piece of work to further capitalise on this interest in air quality in contemporary Irish urban buildings (and, potentially, their outdoor surrounds) would be very rewarding. Fundamentally, this experiment showed that although Irish energy infrastructure, regulatory environment and services markets are still in development, the appetite for transition has been well established by SMARTLAB.

2.7 References

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