Innovation Technology Report

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Contents

List of Abbreviations

WP	Work Package
HP	Heat Pump
BER	Building Energy Rating
NHRS	National Home Retrofit Scheme
MRS	Midland Retrofit Scheme
CEG	Communities Energy Grant
HLI	Heat Loss Indicator
DEAP	Dwelling Energy Assessment Procedure
O1	Objective 1: Technology evaluation process development
O1	Objective 2: Technology integration process development
SEAI	Sustainable Energy Authority Ireland
TOU	Time of Use
TGD	Technical Guidance Document
SPF	Seasonal Performance Factor
LCA	Life Cycle Analysis
ASHP	Air Source Heat Pump
PMI	Project Management Institute
PV	Photovoltaic
GWP	Global Warming Potential
SMAR	Substitution Modification Augmentation Redefinition
CEP	Clean Export Premium

Introduction

Technologies are constantly entering the marketplace and organisations such as Superhomes that are heavily reliant on technological solutions must have strategies for evaluation and integration of those technologies into their technical solutions.

The main objective of this report is to **develop an approach for horizon scanning to ensure Superhomes integrates relevant technical innovations coming to the market**. To achieve this main objective the following sub-objectives were created:

Objective 1. (O1) Technology evaluation process development

Objective 2. (O2) Technology integration process development

The report describes both the development and final completed process for both objectives in sections 1 and 2 of this report.

Furthermore, to support this report a worked example of the developed Superhomes technology evaluation process (O1) was carried out on technologies identified as being suitable for the domestic retrofit market during the period 19/04/21 to 14/07/21. This worked example can be found in Appendix 1 and will provide the reader:

How the 6 step Superhomes technology evaluation process is carried out including:

- The scope of the evaluation
- List of identified technologies from the technology horizon scan process
- Evaluation criteria and scoring methods
- Results and recommendations

For the purpose of this report, a technology can be classified as a material, collection of materials installed in a specific manner, a device or software that can be integrated into Superhomes retrofit solutions. The technological focus of this report will fit into 2 main categories:

I. Building Fabric and Air Tightness
II. Mechanical and Electrical Building Services

Prior to selecting a technology, the Superhomes engineering team must have a full understanding of the technical requirements (set out by current building regulations, SEAI and the BER & DEAP process) for the grant application for a retrofit project. The following section outlines the main technical requirements for the grant schemes that Superhomes is currently working within i.e. the National Home Retrofit Scheme (NHRS) [1], the Midland Retrofit Scheme (MRS) [2], and the Communities Energy Grant (CEG) Scheme [3], which are funded and managed by the SEAI.

Building Energy Rating (BER) and BER Uplift Targets

For all the schemes above the minimum post works BER target for each home is a B2 or between 100 and 125 kWh/m2/yr. A minimum primary energy BER uplift of at least 100 kWh/m²/yr is required. The starting BER needs to be a C2 or worse between 175 and 200 kWh/m2/yr.

Both the BER and uplift targets heavily influence the technology choice when designing the retrofit project as lower U values, higher renewable contributions and more advanced building controls all contribute to higher BERs.

Heat Loss Indicator & Heat Pump Systems

The Superhomes approach is a heat pump led retrofit and therefore must follow the associated technical guidelines set out by the SEAI in the Technical Assessment Process for Heat Pump System Grants Version 1.3 2020 [4] document. This document sets out guidance on how a heat pump system can receive SEAI grant support via the metric of the Heat Loss Indictor (HLI) of the building. The HLI sums up the dwelling's fabric & ventilation losses per metre square of floor area and if the resulting HLI figure meets either of the following 2 conditions SEAI grant support can be applied for:

1. HLI ≤ 2 W/m².K

2. Where the HLI is between 2 and 2.3 W/m².K, in some cases it may not be economically feasible to upgrade the home further. A HLI ≤ 2.3 can be accepted where the following requirements are met:
    - Maximum exposed wall U-value 0.37 W/m².K
    - Maximum roof U-value 0.16 W/m².K or 0.25 W/m2 K where not accessible (e.g., flat roof or rafters)
    - Maximum Window U value 2.8 W/m².K * (and double glazed)
    - Maximum Adjusted Infiltration Rate of 0.5 ac/h

* The maximum elemental u-value from Part L is 1.4 W/m2K, however a value of 2.8 W/m2K recognises that it may not be economically feasible to upgrade windows.

Part L

The 2019 Building Regulation Technical Guidance Document (TGD) Part L outlines rules and regulations on how major renovations must perform, which directly impacts the selection and application of technologies to achieve the required performance. Major Renovation: means the renovation of a building where more than 25 % of the surface of the building envelope undergoes renovation [4] which implies that the vast majority of deep retrofits will fit into this classification. The TGD Part L states that the performance of entire building should be improved to a cost-optimal level where technically, functionally, and economically are feasible. The cost optimal performance level is considered 125 kWh/m²/yr when calculated in DEAP.

Table 1 below is the result of an examination of the 2019 Building regulations through the lens of a deep retrofit and the technological considerations the regulations impose.

Table 1 2019 - Part L Max elemental U values for major renovations

Building Element	**Max. Elemental U-Value (Area weighted) W/M²K**	**Retrofit approach to achieve required U-Value**
Pitch roof – Insulation at ceiling	0.16	Addition of Insulation
Pitch roof – Insulation on slope	0.25	Addition of Insulation
Flat roof	0.25	Addition of Insulation

Cavity Walls	0.55	Addition of Insulation
Other Walls	0.35	Addition of Insulation
Ground Floor	0.45	Addition of Insulation
Other exposed floors	0.25	Addition of Insulation
External doors, windows, roof lights	1.4	Replacement of old doors, windows, roof lights

In this case Part L provides the maximum U-value (based on weighted area for insulation materials) for specific building elements and maximum U-values for doors, windows, and roof lights.

Table 6 for the building regulations part L describe the elements that trigger the Major renovation and upgrading over 25% of the thermal envelope of the dwelling, details can be found in Figure 1 below.

Items such as painting, tiling, cavity wall insulation and attic insulation on the ceiling are not considered major renovation.

Table 6

Elemental works that are included in the surface area calculation for major renovation[1,2,3]

External walls renovation • External insulation of the heat-loss walls • Replacement or upgrade of the external walls' structure • Internal lining of the surface of heat-loss walls
Windows renovation • Replacement of windows
Roofs renovation • Replacement of roof structure
Floors renovation • Replacement of floors
Extension • Extension works which affect more than 25 % of the surface area of the existing dwelling

Figure 1 TGD Part L- Table 6

Part L Table 7 below details than if the min B2 standard cannot be meet a cost optimal level can achieve compliance meeting the min back stops U values and heating efficiency.

Table 7 - Cost Optimal Works activated by Major Renovation

Major Renovation > 25% surface area[1,2,3,5]	Cost Optimal level as calculated in DEAP (Paragraph 2.3.3 a.)	Additional Works to bring dwelling to cost optimal level in so far as they are technically, economically and functionally feasible (Paragraph 2.3.3 b.)
External walls renovation	The cost optimal performance level to be achieved is 125 kWh/m²/yr.	Upgrade insulation at ceiling level where U-values are greater than in Table 5 & Oil or gas boiler replacement[6] & controls upgrade where the oil or gas boiler is more than 15 years old and efficiency less than 86% &/or Replacement of electric storage heating[7] systems where more than 15 years old and with heat retention not less than 45% measured according to IS EN 60531.
External walls and windows renovation		
External walls and roof renovation		
External walls and floor renovation		
New Extension affecting more than 25% of the surface area of the existing dwelling's envelope (see 2.3.6)	The cost optimal performance level to be achieved is 125 kWh/m²/yr	Upgrade insulation at ceiling level where U-values are greater than in Table 5 & Oil or gas boiler replacement[6] & controls upgrade where the oil or gas boiler is more than 15 years old and efficiency less than 86% &/or Replacement of electric storage heating[7] systems where more than 15 years old and with heat retention not less than 45% measured according to IS EN 60531 & Upgrade insulation at wall level where U-values are greater than in table 5.

Figure 2 TGD Part L Table 7

Dwelling Energy Assessment Procedure (DEAP)

DEAP is the official Irish methodology for calculating the energy performance and associated carbon dioxide emissions for the provision of space heating, ventilation, water heating and lighting in dwellings and the main output of DEAP is the BER rating which is key to the SEAI grant process. DEAP requires performance data for each type of technology that will be inputted, the most readily available sources and pertinent technology related to this report are found in Table 2 below.

Table 2 DEAP source information

Source	Technology	Information provided
HARP Database	Heat Pump	Manufacturer, model, type, SPF, rated capacity, EN test methods, F-gas name, F-gas quantity
NSAI Agrément Cert Database	PV systems	Product description, certification, technical specs and control data, technical investigations, conditions of certification
NSAI Agrément Cert Database	Mechanical extract ventilation	Product description, certification, technical specs and control data, technical investigations, conditions of certification

NSAI Agrément Cert Database	Thermal Insulation	Product description, certification, technical specs and control data, technical investigations, conditions of certification
NSAI Agrément Cert Database	External Insulation	Product description, certification, technical specs and control data, technical investigations, conditions of certification
NSAI Agrément Cert Database	Dry Lining Systems	Product description, certification, technical specs and control data, technical investigations, conditions of certification
DEAP internal library	Windows & Doors	

For technologies that are not listed in the above databases the SEAI have provided details on how to substantiate the technology for entry into DEAP in the DEAP manual Version 4.2.2 [6]. For example to enter an insulation system that has not got an NSAI Agrément Certificates the following is stated:

"Certified data from other sources can also be used, bearing the following text in mind (taken from Building Regulations 2019 TGD L):"For thermally homogeneous materials, declared and design values should be determined in accordance with I.S. EN ISO 10456: 2007. Design values for masonry materials should be determined in accordance with I.S. EN 1745: 2012. For insulation materials, values determined in accordance with the appropriate harmonised European standard should be used.""

It should be noted that the SEAI offer a Helpdesk where test certificates on products can be sent to see if they meet the DEAP requirements.

Macro Trends

Introduction

During the research of this report a number of macro trends relating to the domestic retrofit sector were identified via the following events:

- The 'Supporting the Retrofit Journey using Innovative Technologies' consultation event which was held on the 22nd of April 2021 and attended by more than 50 participants provided an opportunity for presentation, discussion and Q&A
- Interviews from individuals representing the supply side of the construction sector

The trends identified were the Grenfell tower fire, the carbon cost of material, retrofitting traditional buildings, indoor air quality & radon gas, heat pump refrigerants, micro generation feed in tariffs and fully electric homes. Further information on each trend is found below.

Grenfell tower fire

The 2017 Grenfell tower fire and subsequent public inquiry has shone a light on combustible insulation materials which a number of contributors to this report believe both consumers and specifiers for both residential and non-residential projects will opt for non-combustible insulation materials. To address this potential trend non-combustible insulation systems must be fully evaluated and included as a retrofit option if required.

Furthermore, increases in insurance for buildings that contain external insulation made from combustible materials is seen as threat to business [7].

Carbon cost of Materials

There is growing awareness to the amount of embodied carbon within construction materials and the need for Life Cycle Assessments (LCA) on buildings. Governments are creating policy and legislation in this area in an effort to achieve climate targets. Table 3 shows such examples:

Table 3 Policy / Legislation examples of LCA and embodied carbon actions

Country	Policy / Legislation Description
Denmark	The national strategy for sustainable construction is a government action plan which sets out a staged phasing in and tightening of targets combining embodied CO2 emissions and operational CO2 emissions for buildings between 2023 and 2030. [6]
France	The National Low Carbon Strategy is the French roadmap to climate neutrality by 2050. Within the building section the strategy will promote construction and renovation products and equipment with a lower carbon footprint (from the circular economy or bio-based) and high energy and environmental performance throughout their life cycle. [7]
Netherlands	The 2012 National Building Regulations introduced mandatory LCA for new buildings [8]

There is currently no legislative approach in Ireland that deals with the carbon cost of material or life cycle analysis in new residential building or retrofitting. In an Irish context the decision to opt for a low or zero embodied carbon material is ultimately down to the customer and specifier of the project and will involve the following questions:

- What is the embodied carbon of the material?
- What are the technical performance characteristics of the material?
- Has the material the correct certification
- Material cost
- Availability of the material
- Skill and capacity to install the material

Retrofitting Traditional Buildings

The 2018 Deep Energy Renovation of Traditional Buildings report [9] on behalf of the Heritage Council and ICOMOS Ireland state that one-sixth of Irish dwellings are traditionally built. These dwelling will require a different approach to retrofitting as there are risks to both the building and occupants if the same energy efficiency methods to modern construction are applied.

One of the key characteristics of traditional buildings is that they are constructed of solid masonry walls that are 'breathable', i.e., the building fabric allows moisture to be absorbed and released cyclically. This form of construction relies on vapour permeable materials and higher levels of ventilation to ensure the well-being of the building fabric and the internal environment [9].

Traditional buildings are the buildings that form the core of our cities and towns and populate our countryside. In Ireland, they are typically built with solid, load-bearing masonry walls, single-glazed windows and timber-framed roofs. This type of construction was used in the majority of buildings built before 1940 and forms a key component of our built environment.

It is likely that Superhomes will have to deal with a growing percentage of this cohort of dwelling in the following years and bespoke retrofitting solutions will be created that will ensure the integrity of the building and comfort of the occupants.

Indoor Air Quality and Radon Gas

Contributions to this report via the 'Supporting the Retrofit Journey using Innovative Technologies' consultation event raised concerns about the impact of deep retrofitting in Ireland. Anecdotal evidence implied that in some houses there was an increase in radon post retrofitting.

A team from the National University of Ireland Galway school of Physics conducted one of the first studies of its kind to quantify the impact of improved energy-efficiency and airtightness on radon, this study showed that if appropriate ventilation measures were not considered during the retrofitting process there is a potential for radon levels to more than double [10].

The study titled 'Factors influencing radon concentration during energy retrofitting in domestic buildings: A computational evaluation' was carried out by Dr James McGrath and led by Dr Miriam Byrne. Dr McGrath said: "It is important that in our drive to make our buildings more energy efficient and reduce greenhouse gas emissions that we do not introduce additional risks of negative outcomes. The research findings highlight that radon, and indoor air quality overall, needs to be given due consideration as a key element of any proposed retrofitting works" [11].

Heat Pump Refrigerants

Refrigerants are vital aspects within the operation of HP's. We value them because they can easily evaporate and condense in a continuous cycle which is essential for achieving the thermal efficiency of HP's.

Refrigerants sold in HP's today can be classified as:

- Natural refrigerants – ASHREA states natural refrigerants occur in nature's biological and chemical cycles without human intervention. These materials include ammonia, carbon dioxide, natural hydrocarbons, water, and air [12].
- Fluorinated gases (F-gases)
    - Hydrofluorocarbons (HFC) – these are known as the 3rd generation of fluorine based refrigerants and include refrigerants such as R134a, R410A and R32
    - Hydrofluoro-Olefins (HFO) – these are known as the 4th generation of fluorine based refrigerants and differ from HFC in their molecular makeup in that HFO's are unsaturated HFC's with molecular double bonds.
    - HFC and HFO blends

One important challenge to climate change is the measure of a refrigerant's Global Warming Potential (GWP) which describes the global warming impacts of different gases. "Specifically, it is a measure of how much energy the emissions of 1 ton of a gas will absorb over a given period of time, relative to the emissions of 1 ton of carbon dioxide (CO2)" [13].

Table 4 below shows a comparison of the GWP of common refrigerants available.

Table 4 GWP of common refrigerants

Gas	Other Name	GWP	Natural Refrigerant	HFO	HFC
R717	Ammonia	0	√		
R744	Carbon Dioxide	1	√		

R290	Propane	3	√		
R1234yf	Opteon® YF	4		√	
R1234yf	Solstice™ yf	4		√	
R1234ze	Solstice™ ze	7		√	
R32		675			√
R4027c		1774			√
R410a		2088			√

Table 4 above illustrates the availability of lower GWP refrigerants, but the choice of refrigerant for a domestic heat pump must also consider requirements such as thermodynamic properties, flammability, toxicity, chemical stability, compatibility with materials and lubricants etc. The vast majority of HP's currently sold into Europe have Fluorinated gases (F-gases) required for their operation, but F-gases are powerful greenhouse gases with a range of medium to high Global Warming Potential (GWP) and the EU is taking regulatory action to control F-gases as part of its policy to control climate change.

The EU regulatory action is known as the F-Gas Regulation, it was adopted in 2006 and further updated in 2015. The goal of the regulation is by 2030 to cut EU F-gas emissions by two-thirds compared to 2014 levels. Figure 2 below demonstrates this goal by showing the annual HFC phased down schedule projected cut in F-gas emission between 2015 and 2030.

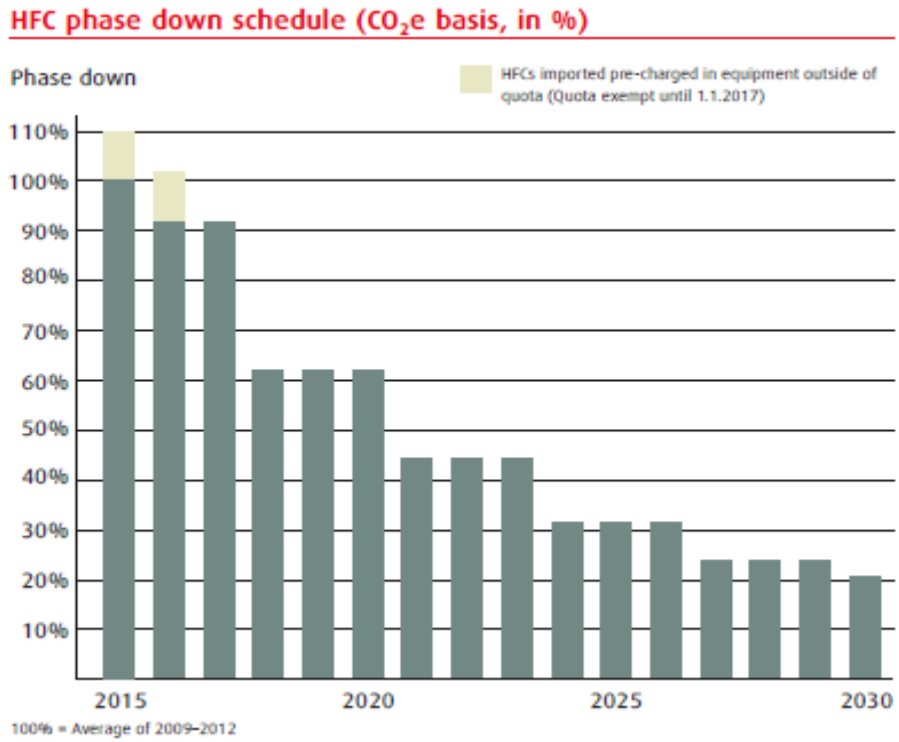


Figure 3 HFC phase down schedule [14]

The F-gas goal and regulation will further impact the HP equipment market by:

- Phased down of virgin HFC's – Reused HFC's are not subject to the phasing down;
- Reduced charge – Charge is the term that refers to the amount of refrigerant in a HP;
- Use of lower GWP refrigerants;
- Use of refrigerants with zero GWP;

- Refrigerant re-use at end of equipment life.

Superhomes needs to be mindful of this developing trend as the move towards natural and low GWP refrigerants will impact on the development and availability of commercially viable domestic heat-pumps. Issues considering the selection, design, and sizing of HP's along with skills and training of HP installers will need to be addressed.

Micro generation Feed in Tariffs

The Irish government's 2019 Climate Action Plan sets out a number of measures to support micro generation in Ireland. An announcement published on the 21st of December 2021 by the Department of the Environment, Climate and Communications had the following key points for the domestic market:

- The Clean Export Premium (CEP) tariff will be €0.135/kWh in 2022 and will reduce by €0.01 from 2024 and each year thereafter
- The Clean Export Premium (CEP) will be offered at a fixed rate for 15 years, and eligible volumes will be capped at 80% of generation capacity to encourage self-consumption
- The Clean Export Premium (CEP) will be paid by suppliers. The difference between the wholesale market rate (Clean Export Guarantee) and the Clean Export Premium (CEP) will be funded by the Public Service Obligation (PSO). It is expected that Clean Export Premium (CEP) supports for new installations, installed from 2028 on, will be phased out
- Grant amounts will be €900/kW up to 2kW and an additional €300/kW between 2kW and 4kW in 2022. The maximum total grant in 2022 will be €2,400 – in line with existing SEAI Solar PV grant rates
- The maximum grant will reduce by €300 on a pro rata basis from 2024 and each year thereafter

The emergence of smart meters, microgeneration feed in tariffs and the potentially TOU tariffs will provide the opportunity for optimisation of the Superhomes offering, for example when commissioning a heat pump system, it would be worthwhile liaising with the customer to set up the heat pump according to their tariff, e.g., to charge the hot water tank at times of low electricity price, etc. This has the potential to make the Superhomes offering more attractive to customers by reducing running costs, improving comfort or peace of mind regarding sustainability.

Fully electric home

The Irish government's climate targets will increase the percentages of an all-electric home by 2030. The plan to have 600,000 HPs installed and 1,000,000 EVs on the Irish roads will give rise to the fully electric home.

Currently they are a number of Superhomes that fit this bill, electric space heating and DHW supplied by an ASHP, PV panels on the roof, EV in the driveway, EV charging point installed and a smart meter to be installed very shortly. All this technology in tandem with the electrical consumer goods the home is using allows the opportunity for optimisation of the home via integrated controls. This type of home has the potential to save the most in energy from matching the solar output to the house load and availing from cheap energy rates during a specific time period for example matching the house load to the night tariff.

1. Technology evaluation process development

This section focuses on the first objective of the report, to create a technology evaluation process that Superhomes can use when considering technologies that may be suitable for their retrofit approach. Two key points drove the development process:

1. Evaluation consumes organisational resources, so therefore the process must be fit for purpose and efficient
2. The evaluation process must aim to remove bias, so all technologies are evaluated fairly

Prior to the development of the evaluation process, background research was undertaken to inform the development phase, this can be found in the next section.

1.1 Process development

Evaluation is integral part of every organisation and exists in many types from a teacher evaluating a student's work to a manufacturer evaluating an energy saving process. Table 5 lists the main evaluation types:

Table 5 Evaluation types

Evaluation Type	Description
Formative evaluation	Evaluative activities undertaken during the design and pretesting of programs to guide the design process [15]. This type of evaluation provides feedback that is designed to enhance and improve the program / project / process.
Summative evaluation	Evaluative activities undertaken when a project has been in existence for some time and looks at the outcomes from the initiative, as well as the process underpinning it [16].
Process evaluation	Evaluate the steps / sequence / processes through which an intervention generates outcomes. They are especially useful for interventions that include a number of interacting components operating in different ways and also when interventions address complex problems or seek to generate multiple outcomes [17].
Impact evaluation	Impact evaluation is an assessment of how the intervention being evaluated affects outcomes, whether these effects are intended or unintended [18].
Stage Gate	Stage Gate reviews are a form of process evaluation that focus on technology and market readiness. They determine when a technology or activity is ready to move to its next stage of development. Stage gate reviews involve use of a series of "Gates" to review projects before moving forward, typically using external experts to assess the technical and business cases. Each stage of the process is designed to reduce levels of uncertainty and risk. [19]
Technology Evaluation	A set of principles, methods, and techniques / tools for effective assessing the potential value of a technology and its contribution to company's competitiveness and profitability. A thorough evaluation assesses the technology and its device's value from technical, market and consumer perspectives and reconciles the results within a valid methodology. [20]

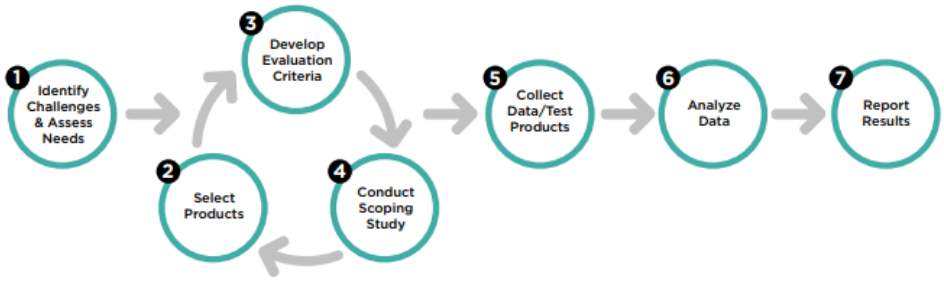
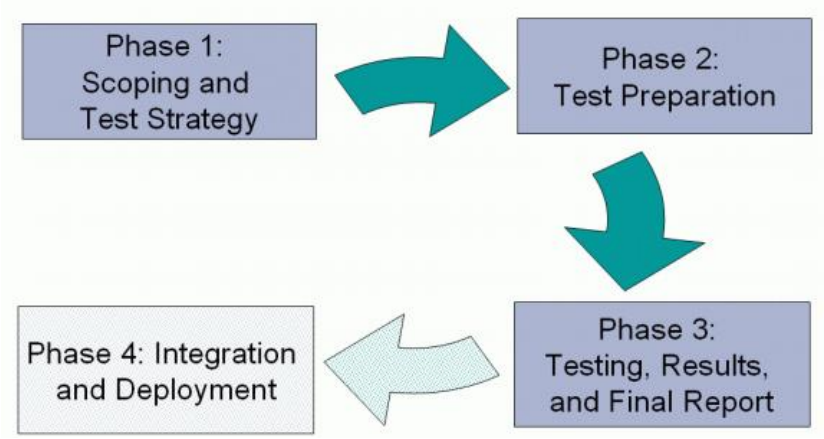
The '**technology evaluation'** type is further explored below as it is the most appropriate to answer the most fundamental question of 'why evaluate' in the context of technology and the Superhomes organisation. J. Green & J. South in their book *'Evaluation'* state "at its most basic, evaluation is concerned with assessing whether interventions are effective" [23] in the context of technology evaluation and Superhomes this can be re-stated as:

IS THE TECHNOLOGY EFFECTIVE FOR THE SUPERHOMES APPROACH?

Technology Evaluation

Research in this area, has identified a number of reports, guides, frameworks and processes for technology evaluation, table 6 below identifies some examples and provides a brief description.

Table 6 Technology evaluation examples

Resource	Description
A Practitioner's Guide for Technology Evaluation in Global Development at a Glance [21]	The Practitioner's Guide offers a user-friendly, step-by-step framework for conducting comparative product evaluations. No matter the size of your organization or resources available, this guide will help you make evidence-based procurement decisions through the following process: 
Standardized Technology Evaluation Process (STEP) User's Guide and Methodology for Evaluation Teams [22]	STEP outlines a rigorous process for technology evaluations of one or more commercial off-the-shelf products. It applies to a variety of areas of technology and provides substantial benefits for evaluation teams and their organisations. STEP contains phases as shown below: 

TECHNOLOGY EVALUATION report [20]	A report published as part of the EU funded INNOREGIO project provided a comprehensive examination of the subject of Technology Evaluation and provided a 7-step methodology for organisation to use, the 7 steps are as follows: 1. Work Team Establishment for a Preliminary Assessment 2. Selection or Rejection of the proposed technology, on the basis of the pre-evaluation made in step1. 3. Identification of Areas where Additional Information is required. 4. Comparison of New Information arising from step 3 with that used in the initial decision (step1). 5. Assessment of possible Conflicts 6. Decision to Terminate or to Proceed, repeating steps 3-5. 7. Detailed Evaluation considering: Corporate objectives, strategy, policies, and values Marketing Financial criteria Production & Manufacturing criteria.

A detailed examination of the examples in table 6 resulted in the development of a technology evaluation process suitable for Superhomes, figure 2 outlines the steps of this process.

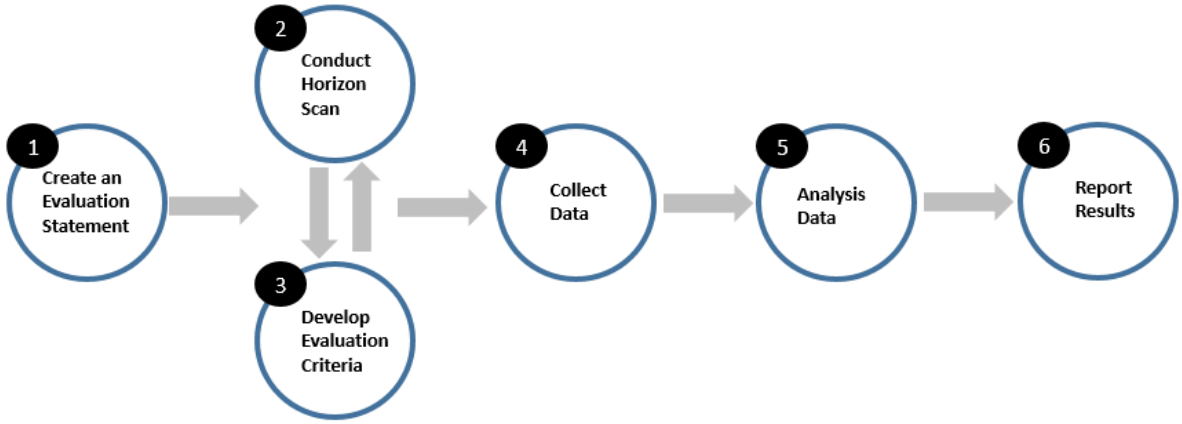


Figure 4 Superhomes Technology Evaluation process

This process will be defined in more detail in section 1.2 of this report.

1.2 Technology Evaluation Process for Superhomes

The 6-step evaluation process developed (as seen in figure 3 below) is defined in table 7 below and a worked example using this process can be found in Appendix 1.

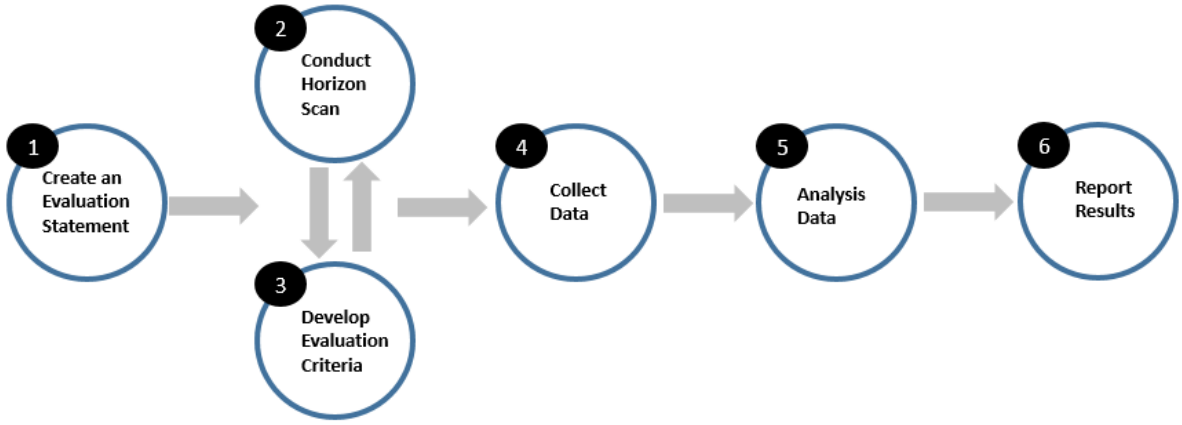


Figure 5 Superhomes Technology Evaluation process

Table 7 Superhomes Technology Evaluation Process

1	Create an Evaluation Statement	This step allows for a focused approach to evaluation through clear and concise goals, objectives and understanding. It should clearly define: • Evaluation task description • Evaluation Start and end dates • Goals and objectives • Evaluator For example: **Evaluation task description**: To respond to the consumer trend towards low embodied carbon building materials. **Evaluation Start date and period**: Start date 02/02/21 and complete within 4 weeks. **Goals & Objectives**: To identify and evaluate low embodied carbon building materials for the retrofit market in Ireland. **Evaluator**: Superhomes engineering team member.
2	Conduct Horizon Scan	This step requires the evaluator to identify technologies that fit within the scope of the evaluation statement. Note: This step can follow step 1 or step 3, as in some situations step 3 the development of the evaluation criteria made be known. Suggested methods for identification are: • Trade events such as the annual SEAI energy show provide the opportunity for manufacturers and suppliers to show case technologies / measures • Consultation events with market actors (building contractors, technology suppliers, EU associations, Standards Authorities) such as the 'Supporting the

		Retrofit Journey using Innovative Technologies' which was an online event held on the 22nd of April 2021 and attended by more than 50 participants provided an opportunity for presentation, discussion and Q&A. • Manufacture / supplier information session. Numerous manufacture / suppliers offer expert information sessions and training opportunities, generally free and online on a specific technology or measure • Trade Publications such as Passive House plus provide quarterly publications which include technology / specific building measure reviews and signposts to more information. • Desktop research in the form of published reports, case studies, manufacture / supplier websites etc can provide a myriad of performance data, installation guides, case studies etc
3	Develop Evaluation Criteria	This step has 2 parts: 1. Evaluator identifies the stakeholders that will be impacted by the technology. For Superhomes it is expected the following stakeholders will be included: • Superhomes designers • Homeowners • Contractors 2. Evaluator defines the evaluation criteria and scoring method as per the scope of the evaluation statement and in relation to the viewpoints of the stakeholders. If the scope of the evaluation is broad and incorporates many different categories of technologies, it is key to select the most appropriate criteria for the technology that will result in an evaluation outcome that is fit for purpose for Superhomes. For further information please see: Appendix 1 – provides a list of technologies and appropriate evaluation criteria and scoring methods
4	Collect Data	This step requires the evaluator to collect detailed data about the technology from independent sources such as certifications, technology experts, case studies, research papers etc. The specific data required will be directly linked to the evaluation criteria, for example in the evaluation of an insulation system the technical performance data will be available in product certifications, whereas the installed cost per m^2 will require a combination of real time pricing associated with a specific example.
5	Analyse Data	This step requires the evaluator to combine the information from steps 2, 3,4 and 5 (the viewpoints of the stakeholders, the identified technology, the evaluation criteria, and data) and accept or reject the technology. The key to this step will be the selection of the evaluation criteria and associated scoring methods chosen for the technology evaluation.

6	Report Results	This step requires the evaluator to report the results of the evaluation along with any recommendations or further tasks. The following methods of reporting are recommended for the key stakeholders: Superhomes Team: A report incorporating the evaluation results and supporting information such as: The evaluation statement, list of identified technologies from the horizon scan, evaluation criteria and scoring methods, data sources and analyse details. Homeowner: A factsheet outlining the recent technology/s that have undergone evaluation that will benefit the homeowner. Contractor: A factsheet outlining the recent technology/s that have underdone evaluation that will impact the contractor

In order to ensure that the 6-step evaluation process is fit for purpose, efficient and non-bias, the following recommendations on the process should be followed:

Communication throughout the evaluation process

Effective communication between the evaluator, stakeholders, subject matter experts, and vendors throughout the evaluation process will ensure the evaluation process is fit for purpose as the evaluator will gain both positive and negative insights about the technology/s from multiple viewpoints.

Evaluation Integrity

To ensure that bias is reduced / removed from the process the evaluator must document each step and include all 3rd party information. This allows for the process to be scrutinized which may led to the identification of change in the process or training for the evaluator.

Resources

A time schedule must be applied to this process to ensure the evaluation process doesn't consume more resources than it needs. Step 1 of the process the creation of an evaluation statement will help inform the scope and thus the schedule.

Evaluator

The evaluator is expected to have experience with the principles of effective evaluation, a comprehensive understanding of the Superhomes technical approach and appreciation of the viewpoints of various stakeholders that will be impacted by the technology. It is envisaged that an experience Superhomes engineer will be the evaluator.

2. Technology integration process development

This section focuses on the second objective of the report, to create a technology integration process that Superhomes can implement after a specific technology/s has successful gone through the evaluation process and is recommended for integration into the Superhomes standards.

The Superhomes standards are a set of working documents that require reviewing and updating as per the complex changing environment of the domestic retrofit sector. The standards have many functions and objectives, most notable in relation to this specific task:

'Reflect the most current information available such as funding schemes, building regulations, retrofit design guidance, and retrofit solutions for a range of housing typologies.'

Prior to the development of the integration process, background research was undertaken to inform the development phase, this can be found in the next section.

2.1 Process Development

Integration is defined as the action or process of combining two or more things in an effective way [23] or the quality of collaboration which exists among organisational departments and units that are required to achieve a common purpose, through unity of effort as dictated by the demands of the environment [24]. In other words, integration requires organisational collaboration to effectively combine two or more things to achieve a common purpose.

Technology integration is further defined as the approach companies use to choose and refine the technologies employed in a new product, process, or service [25].

In the June 2010 edition of the International Journal of Operations & Production Management an article titled *Integrating new technology in established organizations* [26] lists a number of factors that influence the process of managing technology integration. Table 8 below lists the most appropriate factors in relation to the Superhomes organisation.

Table 8 Factors believed to influence the process of managing technology integration

No	Factor
1	The level of complexity inherent in the technology
2	Whether the new technology is competence-enhancing or competence-destroying: Competence-enhancing = A new technology refines and improve an existing technology therefore increases the organisations competence Competence-destroying = A new technology replaces an old technology and therefore renders the organisations competence of the old technology obsolete
3	The degree of market turbulence and market dynamism
4	The degree of risk aversion of the organisation
5	The firm's prior experience of managing technology integration
6	The strategic role of the new technology

These factors highlight the challenge to successful technology integration in an organisation and point to the key element, that integration is a management challenge which impacts on the success of the business as a whole [26].

Research identified two examples of technology integration approaches that support the development phase. Table 9 provides details of the SMAR model and Integrated Change Management Phases.

Table 9 SMAR model & Integrated Change Management Phases

SMAR Model	The Substitution Modification Augmentation Redefinition (SMAR) model was developed by Ruben Puentedura, an educational researcher. It was originally developed for helping teachers bring technology to the classroom but can be used for industrial applications too. The SMAR model identifies 4 tiers in which technologies can be integrated, these are: Substitution – Technology acts as a direct substitute, with no functional change Modification - Technology acts as a direct substitute, with functional improvements Augmentation – Technology allows for significant task redesign Redefinition – Technology allows for the creation of new tasks, previously inconceivable The benefit of this model is that it allows an organisation to frame a new technology into 1 of the 4 tiers mentioned above so further defining the roadmap for integration.
Integrated Change Management Phases	Change management is a systematic approach to dealing with change, both from the perspective of an organization and on the individual level [27]. The Project Management Institute (PMI) has a 4-phase approach of integrated change management which is appropriate for technology integration, the 4 phases are: 1. Prepare for the change 2. Plan the change 3. Manage the change 4. Reinforce and sustain the change These 4 phases allow an organisation to clarify the objectives of the change, develop formal steps, execute the change, and lastly embed the change within the organisation.

A detailed examination of the research conducted in this development phase resulted in the development of a technology integration process suitable for Superhomes, figure 3 below outlines the steps of this process.

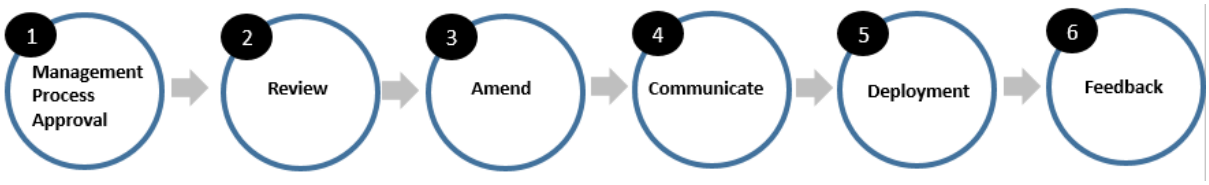


Figure 6 Superhomes Technology Integration P*rocess*

This process will be defined in more detail in section 2.2 of this report.

2.2 Technology Integration Process for Superhomes

The 7-step technology integration process developed (as shown in figure 5) is defined in table 10 below.

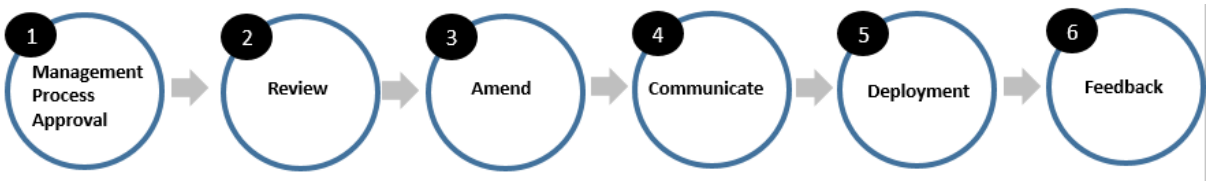


Figure 7 Superhomes Technology Integration P*rocess*

Table 10 Superhomes Technology Integration Process Overview

1	Management Process Approval	This step requires management to sign off on the Technology Integration Process for Superhomes i.e., the addition of technology into the Superhomes standards. Management approval is essential as the process will: 1. Consume organisation resources 2. Effect external stakeholders (contractors and Superhomes customers) 3. Involve risk – minor risk in the actual process and various risk levels when it comes to the actual technology
2	Review	This step requires a review of the in-house standards that require amendment due to the insertion of the technology. Depending on the technology a review of the Superhomes standards that effect the engineering team, customer journey team and contractors will be required.
3	Amend	This step requires the in-house standards that were identified in step 2 to be amended to reflect the technology. The degree of amendment will be based on the following: • Technology is added to an existing list of technological solutions for an identified problem • Technology allows for a significant solution redesign • Technology allows for the creation of a new task in the Superhomes approach All supporting document relating to the technology should be included in the appropriate appendixes of the relevant in-house standard.
4	Communicate	This step requires the communication of the amendments of the Superhomes standards to all stakeholders Where appropriate to support this step, the following methods should be considered: • Email updates to all internal staff • Training day to all internal staff • Focus groups or phone calls to contractors explaining the technology • Newsletter and social media campaign promoting the technology

5	Deployment	This step requires the newly entered technology to be supported by the Superhomes management and team as their will be apprehension from some stakeholders regarding the implementation of the technology. There will always be a certain level of resistance, and this must be countered by encouragement, training, and support.
6	Feedback	This step requires a monitoring and feedback mechanism such as an online survey or phone survey after a certain time period or number of units of the technology installed. All stakeholders impacted by the technology should be included in this step.

In order to ensure that the 6-step integration process is fit for purpose the following recommendations on the process should be followed:

Management

Technology integration into an organisation that has both functional departments and external stakeholders requires management buy in and support for the process including resource allocations.

Resources

A time schedule must be applied to this process to ensure the integration process doesn't consume more resources than it needs.

File Management

Care must be taken to ensure that detailed recording keeping is done when in-house standards are amended and only the most up to date standards are accessible to the stakeholders and the previous versions are securely archived.

Conclusion

This report has provided an insight into the complexity of deep retrofit through the lens of technology, advances in technology have led to the current Superhomes approach to deep retrofitting by providing high efficiency heating and hot water systems via ASHPs, excellent thermal performance via high performing insulation systems, air tight dwelling via membranes, tapes and paints, controlled ventilation that benefits both the building fabric and occupant via centralised or room only ventilation systems and were appropriate renewable generation via PV panels.

These technologies combined with proper design, correct installation and commissioning, excellent communication between the Superhomes team, contractor and homeowner provide a Superhome which is energy efficient, comfortable, and healthy.

New technologies enter the Irish marketplace every year, some will provide alternatives to the existing range of technologies, others will provide specific solutions to building element upgrades while other technologies will be re-examined in the light of their low embodied carbon credentials. Expanding the list of technologies that are suitable for deep retrofitting only adds to the list of possible solutions.

The first objective of this report was to develop a technology evaluation process that Superhomes can use for technologies that are not currently be used within the organisation including the Superhomes

contractors. Detailed research and engagement with members of the Superhomes Engineering team resulted in the **Superhomes Technology Evaluation Process**, shown below:

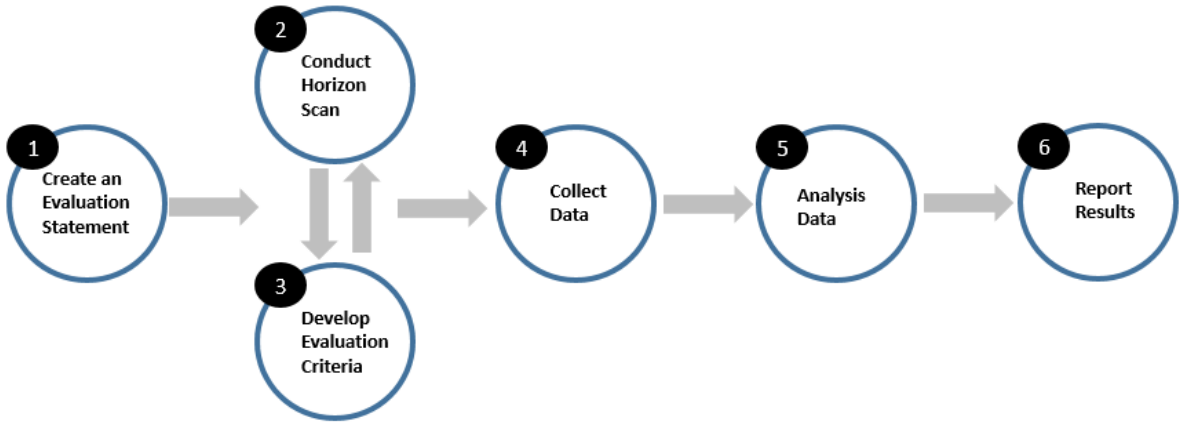


Figure 8 Superhomes Technology Evaluation process

This 6-step process is a roadmap for how Superhomes can effectively evaluate a technology. To further support this process a detailed worked example of this process was undertaken for a range of technologies identified during Q1 of 2021. The worked example is available in Appendix 1.

The second objective of the report was to develop a technology integration process that Superhomes can use for technologies have successful undergone the Superhomes Technology Evaluation Process and recommended for integration. Detailed research and engagement with members of the Superhomes Engineering and Management team resulted in the **Superhomes Integration Evaluation Process**, shown below:

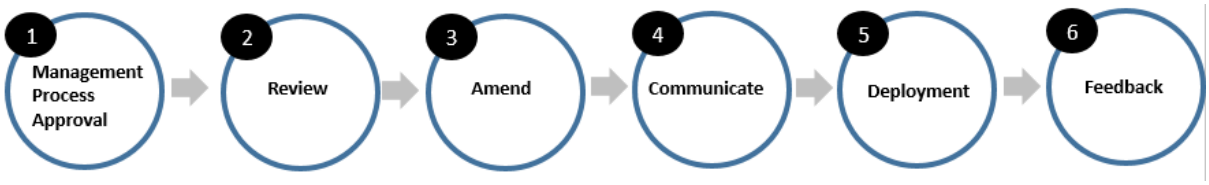


Figure 9 Superhomes Technology Integration P*rocess*

This 6-step process is a roadmap for how Superhomes can effectively integrate a technology into the Superhomes in-house standards while also considering the impact on external stakeholders such as homeowners and contractors.

The process of creating this report and especially the work done in producing the worked example in Appendix 1 of *an evaluation of technologies during Q1 of 2021* provided key insights into the area of training and quality control. These insights were captured during interviews and the 'Supporting the Retrofit Journey using Innovative Technologies' event which was held on the 22nd of April 2021.

Training

Contributors from the field of building fabric and airtightness stated that there is a need for all retrofitting contractors to be upskilled in the use of technologies that enhance the thermal performance and air tightness of all housing typologies without causing harm to the building element or occupants. Contractors should be confident to retrofit any building element, ensuring that the

essential issues like, thermal performance, thermal bridging, moisture and vapour control, breathability and condensation are all taken into consideration.

Quality Control

Quality control is also essential within a retrofit project and contractors need to implement systems to ensure the retrofit is of the highest standard. This can be assured by a quality assurance system that describes a systematic and controlled way of working. A QA system should cover both retrofitting process and maintenance, since experience shows that a successful energy improvement retrofit will be permanent only if the building is guided by effective routines and knowledge transfer. One such system is the air tightness control station as seen in figure 6 below:

Figure 10 Airtightness Quality Control Station

This system ensure that each stakeholder involved in the retrofit project is responsible for the integrity of the air tightness system installed.

To conclude, retrofitting the range of housing typologies in Ireland is a complex and necessary task and organisations like Superhomes need to have processes ready that can both evaluate and integrate technologies thus increasing the range of solutions for retrofitting.

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Appendix

Appendix 1 – Superhomes Technology Evaluation Process Worked Example

Note: As multiply technologies required evaluation the structure of the worked example is as follows: a master document was created called 'SH_E10' which provides details of all 6 steps but directs the reader to sub documents for each of the technologies. Table 11 provides an overview of the documents

Table 11 Superhomes Technology Evaluation Process Worked Example Document Structure

Master document name	Sub document name and technology
SH_E10	SH_E10_subsection MSS – Microgeneration Support Scheme
	SH_E10_subsection SM_TOU – Smart Metering & Time of Use Tariffs
	SH_E10_subsection EVHC – Electric Vehicle Home Charging
	SH_E10_subsection GWP – Low GWP refrigerant for HPs'
	SH_E10_subsection RM – Radon monitoring
	SH_E10_subsection SIM – Super Insulation Materials
	SH_E10_subsection LECI – Low Embodied Carbon Insulation

Superhomes Technology Evaluation Process (STEP)		
Document Name		SH_E10
Start Date		19/04/21
End Date		14/07/21
Evaluator Name		M.O.S.
Technology/s		For list of technologies see step 2
No	**Step Name**	**Details**
1	Create an Evaluation Statement	**Evaluation task description:** Implement STEP to: a) identify technologies that fit inside the scope of domestic retrofitting during the period of 19/04/21 to 14/05/21 that are **not** in the existing Superhomes in-house standards / database b) evaluate and report the findings of the identified technology

<table>
<tr><td></td><td></td><td>Goals & Objectives:
Implement STEP with consideration of all stakeholders:
Superhomes organisation
Contractors
Homeowners</td></tr>
<tr><td>2</td><td>Conduct Horizon Scan</td><td>Methods Used:
A consolation event titled ‘Supporting the Retrofit Journey using Innovative Technologies’ with market actors (building contractors, technology suppliers, academics, standards authorities members etc) was held on the 22nd of April 2021 and attended by more than 50 participants provided an opportunity for presentation, discussion and Q&A
Interviews with stakeholders in the supply side of the retrofit market were held
Desktop research in the form of published reports, case studies, manufacture / supplier websites etc
Identified Technologies
The table below shows a) technology b) the source and c) if the technology is currently in the Superhomes technology database. Of the 18 technologies / technology themes identified, 3 were outside the scope of this evaluation process, 8 were on the Superhomes technology database and 7 were not on the Superhomes database and therefore continued to step 3.
<table><tr><th>Technology</th><th>Source</th><th>Superhomes technology database (Y/N)</th></tr><tr><td>Microgeneration Support Scheme</td><td>Consultation event</td><td>N</td></tr><tr><td>Smart Meters & Time of Use tariffs (TOU)</td><td>Desktop</td><td>N</td></tr><tr><td>Electric Vehicle Home Charging</td><td>Desktop</td><td>N</td></tr><tr><td>Low GWP refrigerant for HPs’</td><td>Consultation event</td><td>N</td></tr><tr><td>Radon monitoring</td><td>Consultation event</td><td>N</td></tr><tr><td>Super insulation material</td><td>Consultation event</td><td>N</td></tr><tr><td>Natural insulation</td><td>Consultation event & Interviews</td><td>N</td></tr><tr><td>District Heating</td><td>Consultation event</td><td>N – feasibility study required for this technology so outside the scope of this evaluation process</td></tr></table></td></tr>
</table>

Ammonia district heat pumps	Consultation event	N - feasibility study required for this technology so outside the scope of this evaluation process
Energiesprong factory build retrofit model	Consultation event	N - feasibility study required for this technology so outside the scope of this evaluation process
Home Energy Management	Desktop	Y
Multifunctional balanced ventilation systems	Desktop	Y
Construction membranes	Interview	Y
Insulation and airtightness systems for specific building element	Interview	Y
Airtight structural boards	Desktop	Y
Battery Storage	Desktop	Y
PV + Battery demand response systems (solo energy system)	Consultation event	Y
I boost system for excess PV energy storage	Consultation event	Y
Decentralised ventilation system	Consultation event	Y

3	Develop Evaluation Criteria	This step has 2 parts: 1. Evaluator identifies the stakeholders that will be impacted by the technology. For Superhomes it is expected the following stakeholders will be included: • Superhomes designers • Homeowners • Contractors 2. Evaluator defines the evaluation criteria and scoring method as per the scope of the evaluation statement and in relation to the viewpoints of the stakeholders. If the scope of the evaluation is broad and incorporates many different categories of technologies, it is key to select the most appropriate criteria for the technology that will result in an evaluation outcome that is fit for purpose for Superhomes. **See additional documentation for details on specific technology identified from the horizon scan**

4	Collect Data	This step requires the evaluator to collect detailed data about the technology/s from independent sources such as certifications, technology experts, case studies, research papers etc. The specific data required will be directly linked to the evaluation criteria, for example in the evaluation of an insulation system the technical performance data will be available in product certifications, whereas the installed cost per m^2 will require a combination of real time pricing associated with a specific example. **See additional documentation for details on specific technology identified from the horizon scan**
5	Analyse Data	This step requires the evaluator to combine the information from steps 2, 3,4 and 5 (the viewpoints of the stakeholders, the identified technology/s, the evaluation criteria and data) and accept or reject the technology/s. The key to this step will be the selection of the evaluation criteria and associated scoring methods chosen for the technology/s evaluation. **See additional documentation for details on specific technology identified from the horizon scan**
6	Report Results	This step requires the evaluator to report the results of the evaluation along with any recommendations or further tasks. The following methods of reporting are recommended for the key stakeholders: Superhomes Team: A report incorporating the evaluation results and supporting information such as: The evaluation statement, list of identified technologies from the horizon scan, evaluation criteria and scoring methods, data sources and analyse details. Homeowner: A factsheet outlining the recent technology/s that have undergone evaluation that will benefit the homeowner. Contractor: A factsheet outlining the recent technology/s that have underdone evaluation that will impact the contractor **See additional documentation for details on specific technology identified from the horizon scan**

Microgeneration Support Scheme

<table>
<tr><th colspan="3">Superhomes Technology Evaluation Process (STEP) steps 3 to 6</th></tr>
<tr><td colspan="2">Document Name</td><td>SH_E10_subsection MSS</td></tr>
<tr><td colspan="2">Start Date</td><td>19/04/21</td></tr>
<tr><td colspan="2">End Date</td><td>14/07/21</td></tr>
<tr><td colspan="2">Evaluator Name</td><td>M.O.S.</td></tr>
<tr><td colspan="2">Technology</td><td>Microgeneration Support Scheme</td></tr>
<tr><th>No</th><th>Step Name</th><th>Details</th></tr>
<tr><td>1</td><td>Create an Evaluation Statement</td><td>As per master document SH_E10</td></tr>
<tr><td>2</td><td>Conduct Horizon Scan</td><td>As per master document SH_E10</td></tr>
<tr><td>3</td><td>Develop Evaluation Criteria</td><td>
<table>
<tr><th>Technology</th><th>Stakeholder</th><th>Evaluation Criteria</th><th>Scoring Method</th></tr>
<tr><td>Microgeneration Support Scheme</td><td>>Superhomes Engineering and customer journey team
>Homeowners
>Contractors</td><td>Scheme fully defined? i.e. includes export unit price, and all terms & conditions

Scheme adds value to the Superhomes offering from a homeowner point of view?

What is the risk level associated with the scheme for the stakeholders identified?</td><td>Binary method (Yes / No)

Binary method (Yes / No)

Range (None - Low – Medium – High)</td></tr>
</table>
</td></tr>
<tr><td>4</td><td>Collect Data</td><td>>2019 Climate Action Plan - This initiative is called out in Action 30 [28]
>Public Consultation on a Micro-generation Support Scheme in Ireland 2021 document [29]</td></tr>
<tr><td>5</td><td>Analyse Data</td><td>Analysis of the data has shown that the scheme is not fully defined as there is no official launch date announced or specific details regarding export unit price, eligibility rules etc. Therefore the evaluation criteria Scheme fully defined scores a NO</td></tr>
</table>

		Regarding whether the scheme adds value to the Superhomes offering from a homeowner point of view, the data identifies the scheme has clear ambitions stated such as: *'provide a route to market for citizens and communities to generate their own renewable energy and receive a fair and efficient price for doing so'* The ability for the homeowner with a PV system to receive a payment for excess PV energy will be positive for the homeowner as it will reduce the payback years on the system, remove the frustration that PV energy is being wasted due to circumstances where self-consumption of PV is not viable due to low occupancy due to work etc. Due to the lack of specific details about the scheme the evaluation criteria pertaining **to adding value to the Superhomes offering** scores a **NO** Regarding the risk level associated with the scheme, this cannot be answers due to lack of specific detail about the scheme
6	Report Results	The scheme is currently not fully defined so detailed evaluation is not possible with consideration of the impact of the scheme on Superhomes, contractors and homeowners. **It is recommended to re-do this evaluation upon the scheme officially launching later this year.**

<table>
<tr><th colspan="3">Superhomes Technology Evaluation Process (STEP) steps 3 to 6</th></tr>
<tr><td colspan="2">Document Name</td><td>SH_E10_subsection SM_TOU</td></tr>
<tr><td colspan="2">Start Date</td><td>19/04/21</td></tr>
<tr><td colspan="2">End Date</td><td>14/07/21</td></tr>
<tr><td colspan="2">Evaluator Name</td><td>M.O.S.</td></tr>
<tr><td colspan="2">Technology</td><td>Smart Meters & Time of Use (TOU) tariffs</td></tr>
<tr><th>No</th><th>Step Name</th><th>Details</th></tr>
<tr><td>1</td><td>Create an Evaluation Statement</td><td>As per master document SH_E10</td></tr>
<tr><td>2</td><td>Conduct Horizon Scan</td><td>As per master document SH_E10</td></tr>
<tr><td>3</td><td>Develop Evaluation Criteria</td><td>
<table>
<tr><th>Technology</th><th>Stakeholder</th><th>Evaluation Criteria</th><th>Scoring Method</th></tr>
<tr><td>Smart Meters & Time of Use (TOU) tariffs</td><td>>Superhomes Engineering and customer journey team
>Homeowners
>Contractors</td><td>Completion rate of Smart Meter roll out

Time of Use tariff fully defined?

Adds value to the Superhomes offering?

What is the risk level associated with the scheme for the stakeholders identified?</td><td>Range (1=≤25% 2= >25%&<50% 3 = >50%&<75% 4=≥ 75%)

Binary method (Yes / No)

Binary method (Yes / No)

Range (None - Low – Medium – High)</td></tr>
</table>
</td></tr>
<tr><td>4</td><td>Collect Data</td><td>>2019 Climate Action Plan – The smart meter program is called out in Action 32 [28]
>Commission for Regulation of Utilities – Smart metering & smart services for example TOU tariffs [30]
>ESB – Smart metering [31]
>Electric Ireland – Smart Meter TOU tariffs [32]
>Bordgais Energy – Smart Meters TOU tariffs [33]
>Electric Ireland – Heat pump price plan [34]</td></tr>
</table>

5	Analyse Data	Analysis of the data has shown that the ESB has installed more than 250,000 smart meters with the aim of replacing all 2.4 meters in homes, businesses and farms by the end of 2024 [32]. Based on these figures approximately 10% of all meters have be replaced with smart meters. Assuming all these were for domestic homes this is still very low. Therefore the evaluation criteria **completion rate of Smart Meter roll out** scores **1 on a scale of 1 to 4**. Regarding the criteria **TOU tariff fully defined** the data has shown that a number of energy suppliers have a TOU products available for homes with smart meters installed. The TOU tariff is structured around bands for example day, night, peak and free time. There are defined terms and conditions for the TOU products so the score for this criteria is **YES.** Regarding whether the Smart Meters & TOU tariffs **add value to the Superhomes offering**, the data identifies may benefits including: • Lower carbon footprint by moving to off peak times • Accurate electricity readings as the smart meter collects data every 30 minutes which will allow the homeowner to make more informed choices such as shifting loads to off peak periods • No costs associated with the installation of the smart meter • TOU products available for Heat pump applications [34] Based on the above points the score for this criteria is **YES** Regarding the risk level associated with a) the smart meter and b) the TOU tariffs the score would be **LOW** due to the following identified risks: • Commissioning the HP system in a home that can avail of a TOU tariff may be a challenge and require carefully monitoring to ensure comfort levels are maintained while been cost optimal.

<table>
<tr>
<td>6</td>
<td>Report Results</td>
<td>The data has shown that smart meter deployment is underway and TOU products are available in the market and the associated risks are low. As the Superhomes approach to space heating and DHW is HP led, the smart meter + TOU products will make HP's more attractive to customers by reducing running costs, improving comfort or peace of mind regarding sustainability, this will serve to make the Superhomes proposition more appealing.

It is recommended to integrate smart metes and TOU product offerings into the Superhomes technical and customer journey standards.

The evaluation score is:
<table>
<tr><th>Evaluation Criteria</th><th>Method</th><th>Score</th></tr>
<tr><td>Completion rate of Smart Meter roll out</td><td>Scale (0=100%)</td><td>1 out of 4 (1=≤25%)</td></tr>
<tr><td>Time of Use tariff fully defined?</td><td>Binary method (Yes / No)</td><td>YES</td></tr>
<tr><td>Adds value to the Superhomes offering?</td><td>Binary method (Yes / No)</td><td>YES</td></tr>
<tr><td>What is the risk level associated with the scheme for the stakeholders identified?</td><td>Scale (None to High)</td><td>LOW</td></tr>
</table>
</td>
</tr>
</table>

<table>
<tr><th colspan="4">Superhomes Technology Evaluation Process (STEP) steps 3 to 6</th></tr>
<tr><td colspan="2">Document Name</td><td colspan="2">SH_E10_subsection EVHC</td></tr>
<tr><td colspan="2">Start Date</td><td colspan="2">19/04/21</td></tr>
<tr><td colspan="2">End Date</td><td colspan="2">14/07/21</td></tr>
<tr><td colspan="2">Evaluator Name</td><td colspan="2">M.O.S.</td></tr>
<tr><td colspan="2">Technology</td><td colspan="2">Electric Vehicle Home Charging</td></tr>
<tr><th>No</th><th>Step Name</th><th colspan="2">Details</th></tr>
<tr><td>1</td><td>Create an Evaluation Statement</td><td colspan="2">As per master document SH_E10</td></tr>
<tr><td>2</td><td>Conduct Horizon Scan</td><td colspan="2">As per master document SH_E10</td></tr>
<tr><td>3</td><td>Develop Evaluation Criteria</td><td colspan="2">
<table>
<tr><th>Technology</th><th>Stakeholder</th><th>Evaluation Criteria</th><th>Scoring Method</th></tr>
<tr><td>Electric Vehicle Home Charging</td><td>>Superhomes Engineering and customer journey team
>Home owners
>Contractors</td><td>Available to every home?

Cost per purchase and install

Grant available?

Adds value to the Superhomes offering?

What is the risk level associated with the scheme for the stakeholders identified?</td><td>Binary method (Yes / No)

Range (None, Low, Medium, High) where low = <€1,000, Medium = between €1000 and €2,000, High => €2,000)

Binary method (Yes / No)

Binary method (Yes / No)

Range (None - Low – Medium – High)</td></tr>
</table>
</td></tr>
<tr><td>4</td><td>Collect Data</td><td colspan="2">>SEAI – electric vehicle home charger grant [35]
>Wallbox – supplier [36]
>Electric Ireland – supplier [37]</td></tr>
</table>

5	Analyse Data	Analysis of the data has identified that all homes are not suitable for EV home charging as all homes don't have off-street parking that can be connected back to the fuse board. Apart from the parking, the homes electrical wiring status is also a factor, homes may have: • Old wiring that would need upgrading • High electrical loads with no more capacity An electrical survey will provide the answer as to whether the home is suitable or not. Furthermore it was found in the terms and conditions of some suppliers that there will be extra costs for the installation of the charging unit on EWI. The evaluation criteria, **available to every home?** Scores a **NO** There are a number of suppliers selling home charging solutions, the final cost of the solution will be based on a number of options available such as: • kW output of the charger, popular options available are 3.7kW, 7.5kW, 11kW, 22kW • Tethered vs Untethered charging units • Length of charging cable • Smart features • Installation included in price or not Table 10 below was created from data available from the market for an EV charging solution based on a 7kW output, tethered solution with and without standard installation. Specific details regarding the criteria for standard installation can be found at the supplier's websites. *Table 12 Cost of EV Home Charging*

Manufacture / supplier	EV charging Unit	EV charging Unit Cost (€)	EV charging Unit + standard installation Cost (€)	Reference
Electric Ireland	EC Mini Pro 2		€1,099	[37]
SSE Airtricity & Epower	7.4 kW EO Mini		€1,199	[38]
Epower	7.4kW Garo		€1,299	[39]
Epower	7.4 kW Zappi		€1,330	[39]

		<table><tr><td>Wallbox</td><td>7.4 kW Pulsar Plus</td><td>€959</td><td></td><td>[36]</td></tr><tr><td>Myenergi</td><td>7 kW Zappi</td><td>€875</td><td></td><td>[40]</td></tr></table> All prices are inclusive of VAT Based on the above data the score for this criteria is **Medium** ie the Cost per purchase and installation lies between €1,000 and €2,000. Regarding the criteria **Grant available?** the data identified that SEAI offer a grant up to €600 [35] towards the purchase and installation of a EV charging unit, so this scores a **YES.** The addition of the grant would bring the overall cost of the EV charger and installation below €1,000 therefore putting the evaluation score of cost to low. Note: There are eligibility criteria associated with the grant, including the type and year of EV, off street parking requirements, work done by an electrician who is registered with Safe Electric Ireland etc. Full details can be found on the SEAI website. Regarding whether the EV home charging **add value to the Superhomes offering**, the data identifies the following benefits: • Enhance the attractiveness of PV installations as some EV home charging products are pre-configured to harness PV energy • Add additional features to the Superhomes customer journey for those customers that have EV's such as: guidance on how to benefit from TOU tariffs that support both HP usage and EV charging. Based on the above points the score for this criteria is **YES** Regarding the risk level associated with EV home charging the score would be **LOW** due to the following identified risks: • Additional costs may have to be incurred by the homeowner if the home has an existing EV charger located on an external wall that may need EWI added to meet the retrofit design • Additional work or delay in work may be experienced by the contractor is trying to relocate an existing EV charger on an external wall that requires a retrofit intervention. • Where a home has an existing home charger and EV and plans to undergo a complete retrofit including ASHP, this additional electricity load may trigger repeating trips on the distribution board if the kW capacity is not sufficient for the HP, EV and general home loads to operate together.
6	Report Results	EV home charging is becoming more common place and will continue to gain traction as consumers opt for EV's, the analysis has shown that while home charging will not be an option for all homes due to the lack of off-street parking and electrical limitations within certain homes the actual cost of the technology including the installation is low when the SEAI grant is taken into account.

Like all technologies the consumer needs to select the right home charger for their specific needs as there are many options and additional features as previously discussed in the analysis section.

As the Superhomes approach to space heating and DHW is HP led and the installation of PV systems is commonly done, a home that has an existing EV and home charger will need to be considered in the design of the Superhomes retrofit due to an increase in overall peak demand of the house in kW and the potential of advising the homeowner on how to optimise systems based on day/night tariffs or TOU tariffs.

It is recommended that EV home charging should be integrated into the Superhomes technical standards so the risks associated with the technology can be avoided or reduced.

The evaluation score is:

Evaluation Criteria	Method	Score
Available to every home?	Binary method (Yes / No)	NO
Cost per purchase and installation	Range (None to High)	MEDIUM – (LOW if grant included)
Grant available	Binary method (Yes / No)	YES
Adds value to the Superhomes offering?	Binary method (Yes / No)	YES
What is the risk level associated with the scheme for the stakeholders identified?	Scale (None to High)	LOW

<table>
<tr><th colspan="3">Superhomes Technology Evaluation Process (STEP) steps 3 to 6</th></tr>
<tr><td colspan="2">Document Name</td><td>SH_E10_subsection GWP</td></tr>
<tr><td colspan="2">Start Date</td><td>19/04/21</td></tr>
<tr><td colspan="2">End Date</td><td>14/06/21</td></tr>
<tr><td colspan="2">Evaluator Name</td><td>M.O.S.</td></tr>
<tr><td colspan="2">Technology</td><td>Low GWP refrigerant for Heat Pumps</td></tr>
<tr><th>No</th><th>Step Name</th><th>Details</th></tr>
<tr><td>1</td><td>Create an Evaluation Statement</td><td>As per master document SH_E10</td></tr>
<tr><td>2</td><td>Conduct Horizon Scan</td><td>As per master document SH_E10</td></tr>
<tr><td>3</td><td>Develop Evaluation Criteria</td><td>
<table>
<tr><th>Technology</th><th>Stakeholder</th><th>Evaluation Criteria</th><th>Scoring Method</th></tr>
<tr><td>Low GWP refrigerant for HPs'</td><td>>Superhomes Engineering and customer journey team
>Home owners
>Contractors</td><td>Availability of low GWP refrigerants in domestic HP's

Adds value to the Superhomes offering?

What are the risk level associated with GWP refrigerants for the stakeholders identified?</td><td>Binary method (Yes / No)

Binary method (Yes / No)

Range (None - Low – Medium – High)</td></tr>
</table>
</td></tr>
<tr><td>4</td><td>Collect Data</td><td>>BOC gases - HFC cap and phase down [14]
>WOLF propane (R290) HP's [41]
>Vaillant Group propane (R290) HP's [42]
>NIBE Exhaust Air HP with propane [43]
>ECOFOREST ASHP with propane [44]
>2019 PwC Irish Retail and Consumer report [45]</td></tr>
</table>

5	Analyse Data	Of great importance to the challenge of climate change is the refrigerant metric of Global Warming Potential (GWP), it was developed to allow comparisons of the global warming impacts of different gases. Specifically, it is a measure of how much energy the emissions of 1 ton of a gas will absorb over a given period of time, relative to the emissions of 1 ton of carbon dioxide (CO2) [13]. The larger the GWP, the more that a given gas warms the Earth compared to CO2 over that time period. Table 11 below shows a list of refrigerants and their GWP number, their classification and if domestic HP applications were found in this horizon scan. *Table 13 Common Refrigerants and their GWP* **Gas** | **Other Name** | **GWP** | **Natural Refrigerant** | **HFO** | **HFC** | **Domestic HP Applications found in this horizon scan** R717 | Ammonia | 0 | √ | | | No R744 | Carbon Dioxide | 1 | √ | | | No R290 | Propane | 3 | √ | | | Yes R1234yf | Opteon® YF | 4 | | √ | | No R1234yf | Solstice™ yf | 4 | | √ | | No R1234ze | Solstice™ ze | 7 | | √ | | No R32 | | 675 | | | √ | Yes R4027c | | 1774 | | | √ | No R410a | | 2088 | | | √ | Yes Table compiled using data from BOC gas HFC cap and phase down document [14] The table shows that while there is a number of refrigerants that have low GWP values only R290 is available in domestic HP applications in the natural refrigerant category while R32 is the best of the HFC's. R290 is a natural refrigerant with a GWP of 3, it is widely used in industrial applications but is now emerging as a viable solution for homes and businesses in Europe. Table 12 below shows 4 manufacturer using R290, the HP type and reference.

Table 14 Low GWP HP's for domestic applications

Manufacturer	HP type	Refrigerant (GWP)	Reference
WOLF	ASHP monobloc	R290 (3)	[41]
Vaillant Group	ASHP monobloc	R290 (3)	[42]
NIBE	Exhaust Air HP	R290 (3)	[43]
ECOFOREST	ASHP monobloc	R290 (3)	[44]

Regarding the criteria 'availability of low GWP refrigerants in domestic HP's' the analysis shows that R290 is the most available so the score for this criteria is **YES**.

Regarding whether low GWP refrigerants **add value to the Superhomes offering**, the data identifies the following benefits:

- Consumers are prepared to pay a premium for sustainable products. The 2019 PwC Irish Retail and Consumer report stated that 41% of respondents said they would pay a premium for sustainable products [45]. As there is no data available on consumer decisions making when it comes to heat pumps and specifically what refrigerant it contains, the evaluator can only speculate that if the consumer was given the knowledge and choice he/she would choose the more sustainable heat pump refrigerant.
- Superhomes brand could be further enhanced by adding low GWP HP's to their retrofit solutions technology database

Based on the above points the score for this criteria is **YES**

Regarding the risk level associated with Low GWP refrigerant for HPs' the score would be **MEDIUM** due to the following identified risks:

- The risk is LOW when considering the use of R290 (propane) provided product guidelines are followed regarding the location of equipment and the associated ventilation requirements, and the insistence that only properly qualified technicians work on the equipment.

6	Report Results	The integration of Heat Pumps that contain low GWP refrigerates into the Superhomes standards requires a more detailed analysis of the products currently available on the Irish market. A product specific analysis is recommended that identifies key aspects such as: • Range of HP capacity • Cost

- Ease of use
- Ease of installation
- Technical Support
- Commissioning service
- After sales
- Training
- Cost vs environmental benefits

The evaluation score is:

Evaluation Criteria	Method	Score
Availability of low GWP refrigerants in domestic HP's	Binary method (Yes / No)	YES
Adds value to the Superhomes offering?	Binary method (Yes / No)	YES
What is the risk level associated with the scheme for the stakeholders identified?	Scale (None to High)	MEDIUM

Radon Monitoring

<table>
<tr><th colspan="4">Superhomes Technology Evaluation Process (STEP) steps 3 to 6</th></tr>
<tr><td colspan="2">Document Name</td><td colspan="2">SH_E10_subsection RM</td></tr>
<tr><td colspan="2">Start Date</td><td colspan="2">19/04/21</td></tr>
<tr><td colspan="2">End Date</td><td colspan="2">14/07/21</td></tr>
<tr><td colspan="2">Evaluator Name</td><td colspan="2">M.O.S.</td></tr>
<tr><td colspan="2">Technology</td><td colspan="2">Radon Monitoring</td></tr>
<tr><th>No</th><th>Step Name</th><th colspan="2">Details</th></tr>
<tr><td>1</td><td>Create an Evaluation Statement</td><td colspan="2">As per master document SH_E10</td></tr>
<tr><td>2</td><td>Conduct Horizon Scan</td><td colspan="2">As per master document SH_E10</td></tr>
<tr><td>3</td><td>Develop Evaluation Criteria</td><td colspan="2">
<table>
<tr><th>Technology</th><th>Stakeholder</th><th>Evaluation Criteria</th><th>Scoring Method</th></tr>
<tr><td>Radon monitoring</td><td>>Superhomes Engineering and customer journey team
>Home owners
>Contractors</td><td>Is radon testing recommended pre and post retrofitting?

Cost associated with radon monitoring?

Adds value to the Superhomes offering?

What are the risk level associated with GWP refrigerants for the stakeholders identified?</td><td>Binary method (Yes / No)

Range (None, Low, Medium, High) where low = <€200, Medium = between €200 and €400, High => €400)

Binary method (Yes / No)

Range (None - Low – Medium – High)</td></tr>
</table>
</td></tr>
<tr><td>4</td><td>Collect Data</td><td colspan="2">>EPA – Radon [46]
>Alpharadon – Supplier of radon monitoring [47]
>theradonshop – Supplier of radon monitoring [48]</td></tr>
</table>

		>Aereco – Supplier of ventilation projects [49]
5	Analyse Data	Radon is a radioactive gas formed in the ground by the radioactive decay of uranium which is present in all rocks and soils. About 300 cases of lung cancer in Ireland every year can be linked to radon [46]. Every home has different amounts of radon so even if your neighbours have tested their home for radon, you should still test your home [46]. In 1990 the Irish Government set a national reference level of 200 becquerels per cubic metre (Bq/m^3) for radon exposure in the home. The reference level for homes is advisory. It represents a level of risk similar to other everyday risks such as fatal accidents on the road or deaths from accidental falls. [50] The only way to know if a home is above or below 200 Bq/m^3 is to test. In the context of retrofitting homes it is worth noting that the EPA state *If your radon results are below 200 Bq/m3 there is no need to re-test unless you carry out major refurbishment work to your home. For example:* • *fitting new windows* • *building an extension* • *insulation or any other work that could possibly open up new entry routes for radon or prevent radon escaping from your home.* To further support the EPA position regarding major refurbishments, Simon Jones in his article 'What is radon and why must we take it seriously in regard to retrofit in Ireland' concludes It is not unreasonable to suppose that without pre-retrofit tests for radon, we are already impacting homes with high levels and making it worse [49]. Based on the EPA advice the evaluation criteria Is radon testing recommended pre and post retrofitting? scores a **YES** Regarding the cost associated with testing, the 2 main methods are a 3 month passive test and digital monitor, table 13 below shows the cost associated with these 2 methods *Table 15 Radon monitoring methods* **Method** | **Cost** | **Reference** 3 month passive radon test | €40 | [47] Radon digital monitor | €199 | [48]

A further description of the monitoring method follow.

<u>3 month radon test</u>
There are a number of suppliers offering this long term test solution, it involves the placement of 2 small radon detectors in the home, 1 in the main bedroom and the other in the main living space. After three-months, you send the detectors back to the testing service for analysis and you'll then receive a report with your results. The cost of this service can be as low as €40.

The benefit of this long term testing solution is that radon levels vary day to day due to air pressure difference between the soil beneath the house and the house itself.

If air pressure in the house is lower than that of the soil, radon gas may actually be pulled from the soil into the house. Reduced air pressure results from the use of exhaust fans (such as those in clothes dryers, kitchens, and bathrooms), and some home heating devices (such as fireplaces or central heating burners). Natural shifts in air pressure, such as those associated with a storm or strong winds may also alter indoor air pressure enough to draw radon gas into the home. [47]

The negative side of this testing method is the length of time it would add to the Superhomes customer journey, if every retrofit had to be pre-radon and post radon tested this would take on average 4 months, 3 months for testing and 1 month for results to be issued for the pre and post testing.

<u>Radon digital monitor</u>
The radon digital monitor is a factory built device for the domestic market, it can be in the form of a hand-held device with a display or device that is linked to a mobile application. The monitor will output an indication of the radon level in the room in which it's located, the greater the number of days the monitor is active the more accurate the radon level reading will be.

The benefit of this method is you can get an indication level of the radon level in a short period.

Regarding whether radon monitoring will add value to the Superhomes offering, the data identifies the following:

- Adds an extra layer of peace of mind to the homeowner that testing was done as part of the retrofit experience
- Superhomes brand could be further enhanced by adding radon testing to each retrofit
- Avoid what Simon Jones concluded in his article 'What is radon and why must we take it seriously in regard to retrofit in Ireland' none of us want the headline "retrofit causes lung cancer" [49]

<table>
<tr><td></td><td></td><td>Based on the above points the score for this criteria is LOW

Regarding the risk level associated radon monitoring the score would be MEDIUM due to the following identified risks:

• Monitoring will add extra resources and lengthen the duration of a retrofit project

If radon levels are not acceptable, radon mitigation works must be carried out therefore increasing costs</td></tr>
<tr><td>6</td><td>Report Results</td><td>As Superhomes has the capacity to consider any domestic retrofit project in the country, there will be undoubtedly a percentage that will have radon levels above the reference value of 200 Bq/m^3 due to factors such as:
• Radon testing in homes is not required by law in Ireland so the vast majority of people don’t know the homes radon status
• Building regulations only required radon avoidance measures to be included in house building since 1998. Specific technical guidance published by the Department of the Environment, Community & Local Government (DECLG) requires that all homes built since July 1st 1998 must be fitted with a standby radon sump which can be activated at a later stage, to reduce any high radon concentrations subsequently found [51]
• Homes that have radon barriers and sumps installed may have defects in the barrier or the sump fan has failed over time

As high levels of radon can impact on the health of the occupants of the home and research has identified that retrofitting can both reduce and decrease the levels of radon depending on the specific house and the measures undertaken it is the view of the evaluator that radon monitoring should be integrated into the Superhomes standards.

It is recommended that a comprehensive risk analysis should be conducted taking the viewpoints of all stakeholders.

The evaluation score is:
<table>
<tr><th>Evaluation Criteria</th><th>Method</th><th>Score</th></tr>
<tr><td>Is radon testing recommended pre and post retrofitting</td><td>Binary method (Yes / No)</td><td>YES</td></tr>
<tr><td>Cost associated with radon monitoring?</td><td>Range (None, Low, Medium, High)
where low = <€200, Medium = between €200 and €400, High => €400)</td><td>LOW</td></tr>
</table>
</td></tr>
</table>

		Adds value to the Superhomes offering?	Binary method (Yes / No)	YES
		What is the risk level associated with the scheme for the stakeholders identified?	Scale (None to High)	MEDIUM

Super insulation material

<table>
<tr><th colspan="3">Superhomes Technology Evaluation Process (STEP) steps 3 to 6</th></tr>
<tr><td>Document Name</td><td colspan="2">SH_E10_subsection SIM</td></tr>
<tr><td>Start Date</td><td colspan="2">19/04/21</td></tr>
<tr><td>End Date</td><td colspan="2">14/07/21</td></tr>
<tr><td>Evaluator Name</td><td colspan="2">M.O.S.</td></tr>
<tr><td>Technology</td><td colspan="2">Super insulation material</td></tr>
<tr><th>No</th><th>Step Name</th><th>Details</th></tr>
<tr><td>1</td><td>Create an Evaluation Statement</td><td>As per master document SH_E10</td></tr>
<tr><td>2</td><td>Conduct Horizon Scan</td><td>As per master document SH_E10</td></tr>
<tr><td>3</td><td>Develop Evaluation Criteria</td><td>
<table>
<tr><th>Technology</th><th>Stakeholder</th><th>Evaluation Criteria</th><th>Scoring Method</th></tr>
<tr><td>Super insulation material (SIM)</td><td>>Superhomes Engineering and customer journey team
>Homeowners
>Contractors</td><td>Are there products available in Ireland?

Cost associated with the product?

Is there training available for contractors in this product?

Adds value to the Superhomes offering?

What are the risk level associated with SIM’s for the stakeholders identified?</td><td>Binary method (Yes / No)

Range (None, Low, Medium, High) where low = <€10 per m^2, Medium = between €10 and 20 per m^2, High => €20 per m^2)

Binary method (Yes / No)

Binary method (Yes / No)

Range (None - Low – Medium – High)</td></tr>
</table>
</td></tr>
</table>

4	Collect Data	>What are SIM's [55] >What is a Vacuum Insulation Panel? [56] >Kingspan – developer / suppliers of VIP system called Optim-R [56] >Optim-R certification – BDA Agrément Cert [57] >Proctorgroup - developer / suppliers of Aerogel system called Spacetherm [57] >Spacetherm performance specification [58] > Spacetherm certification – European Technical Assessment (ETA) 11/0471
5	Analyse Data	BUILD UP – The EU portal for Energy Efficiency of Buildings has identified the importance of Super Insulating Materials (SIM) to the building industry and has noted that SIM's are suited for the retrofitting market due to their high thermal performance and low material thickness [55]. There are two types of SIM's that have achieved market maturity: 1. Vacuum Insulated Panels (VIP) 2. Aerogels <u>VIP</u> VIP are specially designed panels that use the insulation of a vacuum in a board shape. A vacuum, or the absence of air, has no thermal conductivity. Only radiation can pass through a vacuum. These boards give outstanding thermal conductivity for the thinnest possible solution [56]. Advantages • Thermally and dimensionally efficient • Available in a range of sizes and thicknesses Disadvantages • Can't be cut as this may penetrate the vacuum <u>Aerogels</u> Aerogels are very low density solids created by a process called super critical drying which results in a gel where all the liquid is replaced by a gas. The resulting structure is 97% air entrapped in small pores. This makes for a material which is a super insulator but very brittle. Companies have overcome the brittleness by embedding the aerogel into a fibrous blanket which provides high thermal performance with robustness.

Aerogels can be used for floors, walls, roofs and specific element detailing for example window reveals.

Advantages

- Thermally and dimensionally efficient
- Vapour permeable
- Available in a range of sizes and thicknesses

Disadvantages

- Aerogels are brittle, but this can be overcome with the addition of other materials

<u>SIM's available to the Irish market</u>

This horizon scan has shown there are 2 main SIM's available in the Irish market:

1. Vacuum Insulated Panels (VIP) system created by Kingspan called Optim-R
2. Aerogel system created by the Proctor Group in the UK called Spacetherm

<u>Optim-R flooring system overview and performance details</u>

The Optim-R flooring system can provide an ultra slim insulation solution for retrofitting a solid ground floor. The old floor screed layer is removed and replaced with a thinner, modern alternative including a VIP insulation layer [59]. The BDA Agrément Cert associated with this product states that the thermal conductivity is 0.007 W/m.K and a 20mm thick panel can achieve a R-Value of 2.857 m^2.K/W [60] which equates to a U-value of 0.35 W/m^2.K. The Agrément Cert also states that a condensation risk analysis shall be completed at design phase to limit the risk of interstitial condensation.

Product specific Youtube videos are available on 'How to install vacuum insulation panels below a floor screed' [61] which provide a good overview of the Optim-R flooring system. However pricing is unavailable and requires communication directly with the suppliers, this was attempted but unfortunately no information was received in time for this case study.

<u>Spacetherm Directfix system overview and performance details</u>

Spacetherm Directfix is a high performance laminate which is specifically designed to be fixed directly to the wall. It consists of Spacetherm Aerogel insulation blanket with an additional pre-bonded plywood reinforcement to the plasterboard. With a thermal conductivity of 0.015 W /m.K [58] it is ideal for use in applications where low U-values are required but space is at a premium.

		Direct communication with the technical team in Proctor Group in the context of the following retrofit example provided the following information about the Directfix system: Retrofit example: mid terrace single story house build in 1920's, solid brick (300mm) – plan is to retrofit internally as the brickwork outside must remain visible and the wall must achieve a U value of 0.35 W/m^{2}K. Solution: To achieve a final wall U value of 0.35 W/m^{2}K a 54mm Directfix laminate will be applied consisting of 12.5 mm plasterboard, 6mm ply and 35mm Spacetherm Aerogel insulation blanket. An indicative quotation of €657.67 for 20 sheets of Directfix (2400mm x 1200mm x 54mm) was provided for this project. Training Training is not required for the system, and it can be used by any competent installer. Installation guides are available and direct contact with the Proctor Group is welcome. Certification • No NSAI Agrément Cert is available • European Technical assessment is available for the Aerogel insulation blanket that provides technical performance details on the product • Declaration of Performance (DoP) is available for the Aerogel insulation blanket that provides technical performance details on the product Evaluation Criteria: Regarding the criteria are SIM's available to the Irish market the answer is **YES** Regarding the criteria of cost associated with SIM's it was only possible to receive an indicative price for the Spacetherm Directfix system and based on the quotation received of €11.41 per m^2 this falls in the **medium** range for cost. Regarding the criteria of training for installers, both Kingspan and Proctor offer a range of training and delivery formats on their products. If this training is specific for installers or can be modified for installers in relation to the Irish retrofit context will need to

		be confirmed. The answer to this criteria is **YES** but with the caveat that exact learning outcomes would need to be discussed and agreeed with both Kingspan and Proctor. Regarding whether SIM's add value to the Superhomes offering the answer is **YES** as they are both thermally and dimensionally efficient and will undoubtedly be suitable for some retrofits where internal space must be maximised and external solutions can't be used. Regarding the risk associated with SIM's this would score a **medium** due to: • As the products don't have an NSAI Agrément Cert which results in Superhomes engineers using resources to identify appropriate certified product data that will conform to the DEAP requirements • Insufficient case-studies of SIM's used in retrofits in Ireland • Contractors not familiar with the technology and thus may have an unwillingness to use it
6	Report Results	In the view of this evaluator SIM's have a place in the domestic retrofits, currently they may be appropriate for very specific, challenging elements of a project but the fact they have excellent thermal performance while be dimensionally efficient is very advantageous in the context of wide range of housing typologies that must be retrofitted in Ireland. Specially in relation to Kingspan's Optima-R and Proctor Group Directfix system, both these products are from very reputable companies with excellent technical teams, have supporting product certification and sell to the Irish market. Prior to the integration of SIM's into the Superhomes standards the following recommendations are recommended: • Product samples orders and distributed to Superhomes engineering team • Engagement with both Kingspan and Proctor Group on specific design details of their products in the context of the domestic retrofit market including themes such as: -thermal bridging -condensation risk -installation (handling, cutting, adhesion etc) -training -technical support -cost -Environmental Product Declaration status (Life cycle analysis) • Contractor engagement

<table>
<tr><th colspan="3">Superhomes Technology Evaluation Process (STEP) steps 3 to 6</th></tr>
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<tr><td colspan="2">Start Date</td><td>19/04/21</td></tr>
<tr><td colspan="2">End Date</td><td>14/07/21</td></tr>
<tr><td colspan="2">Evaluator Name</td><td>M.O.S.</td></tr>
<tr><td colspan="2">Technology</td><td>Natural insulation</td></tr>
<tr><th>No</th><th>Step Name</th><th>Details</th></tr>
<tr><td>1</td><td>Create an Evaluation Statement</td><td>As per master document SH_E10</td></tr>
<tr><td>2</td><td>Conduct Horizon Scan</td><td>As per master document SH_E10</td></tr>
<tr><td>3</td><td>Develop Evaluation Criteria</td><td>
<table>
<tr><th>Technology</th><th>Stakeholder</th><th>Evaluation Criteria</th><th>Scoring Method</th></tr>
<tr><td>Natural Insulation</td><td>>Superhomes Engineering and customer journey team
>Homeowners
>Contractors</td><td>Are there products available in Ireland?

NSAI Agrément Cert available?

Adds value to the Superhomes offering?

What are the risk level associated with Natural Insulation for the stakeholders identified?</td><td>Binary method (Yes / No)

Binary method (Yes / No)

Binary method (Yes / No)

Range (None - Low – Medium – High)</td></tr>
</table>
</td></tr>
</table>

4	Collect Data	>Information paper on natural fibre insulation [62] >List of manufacturers selling products into the Irish market – see step 5 >DEAP certification requirements for insulation materials [6] > GWP of insulation materials [63] > Supplier and training provider of natural insulation products – ecologicalbuildingsystems > Supplier and training provider of natural insulation products – roundtowerlime > Manufacturer of natural insulation products – ecocel
5	Analyse Data	Natural Insulation is derived from natural materials such as wood fibre, wool, hemp, and flax. The natural materials are processed to form a range of insulation products for the market, table 17 below shows the range of natural insulation materials, the thermal properties, and the available format available to the market. *Table 16 Properties of Insulation Materials [62]* ***Table 1:* Properties of insulation materials** **Material** / **Typical thermal conductivity (W/m/K)** / **Commonly available formats** **Natural materials** Wood fibre / 0.038–0.050 / Boards, semi-rigid boards and batts Paper (cellulose) / 0.035–0.040 / Loose batts, semi-rigid batts Hemp / 0.038–0.040 / Semi-rigid slabs, batts Wool / 0.038–0.040 / Semi-rigid boards, rolls Flax / 0.038–0.040 / Semi-rigid boards, rolls Cork / 0.038–0.070 / Boards, granulated The range of thermal conductivities for each type of insulation outlines the large variation between products available from various manufactures [62].

The evaluation of natural insulation products required the following to be established:

1. Product availability in Ireland
2. DEAP certification status of the products
3. Advantages of specifying natural insulation
4. Case Study example with solutions and costing from the marketplace

Product availability in Ireland

There is a very large range of products available in the Irish market that fall under the heading of natural insulation. Table 18 below shows the main manufactures that supply products into Ireland directly or via a supplier.

Table 17 Manufactures of natural insulation

Natural Insulation Type	**Manufacturer**
Wood Fibre	Steico
Wood Fibre	Gutex
Wood Fibre	Pavatex / Soprema
Paper (cellulose)	Ecocell
Paper (cellulose)	Dämmstatt
Paper (cellulose)	Isocell
Hemp	Isohemp
Hemp	Thermo Nature
Wool	Therma Fleece

Cork	Vipeq
Cork	Diasen

<u>DEAP certification status of the products</u>

If an insulation product or system is used in a major renovation, the DEAP manual version 4.2.2 outlines that one of the following certifications must be valid:

1. NSAI Agrément Cert or
2. For insulation products / systems that do not have a NSAI Agrément Cert the following is stated:

   "Certified data from other sources can also be used, bearing the following text in mind (taken from Building Regulations 2019 TGD L):
   "For thermally homogeneous materials, declared and design values should be determined in accordance with I.S. EN ISO 10456: 2007. Design values for masonry materials should be determined in accordance with I.S. EN 1745: 2012. For insulation materials, values determined in accordance with the appropriate harmonised European standard should be used."" [6]

As the vast majority of natural insulation products / systems available in Ireland do not have an NSAI Agrément Cert, other certified data must be found in the context of point 2 above. This presents a challenge for projects considering natural insulation products as extra resources must be allocated to ensure the correct documentation about the insulation product / system is valid and if doubts exist, communication with SEAI must be held about the specific product / system documentation.

<u>Advantages of specifying natural insulation</u>

The main natural insulation are not as thermally and dimensionally efficient in comparison to standard insulation but natural insulations have other benefits that can offset this barrier as outlined below.

			Low impact on the environment	With respect to the retrofitting of the Irish housing stock there are 2 types of carbon emissions: 1. **Operation carbon:** Operational carbon is the carbon emitted during the operation of the building over the building's life type, the better insulated the building the less heating and cooling will be required, and thus less operational carbon created. 2. **Embodied carbon:** Embodied carbon relates to the materials used in the manufacture, transport and construction / retrofit of a building. It is expected that post retrofit the operational carbon of the building will reduce due to all the retrofit energy reducing measures but considering the embodied carbon of materials when selecting materials for a retrofit can also contribute towards the fight against lower carbon emissions worldwide. To illustrate the impact of embodied carbon, the Centre for Industrialised Architecture in Denmark created the 'Construction Material Pyramid' tool [63]. Using this tool 4 common insulation materials were selected, and results were provided for embodied carbon in the unit of GWP (kg CO^2-Eq) from cradle to gate i.e., from the raw materials to the factory gate. Polyisocyanurate (PIR) insulation = 781.4 kg $C0^2$ Eq /m^3 Expanded polystyrene (EPS) insulation = 80.4 kg $C0^2$ Eq /m^3 Glass wool = 21.6 kg $C0^2$ Eq /m^3 Wood fibre = -173.1 kg $C0^2$ Eq /m^3
			Good vapour permeability / low water vapour diffusion resistance factor	The vapour resistance of a material is a measure of the material's reluctance to let water vapour pass through. The μ ("mu-value") of a material is also known as its "water vapour resistance factor". It is a measure of the material's relative reluctance to let water vapour pass through, and is measured in comparison to the properties of air. [64]
			Good hygroscopicity	A hygroscopic material is able to absorb vapour from the air and the water molecules within it into its pore structure without the material appearing to be 'wet'. [65]
			Capillary open	Capillarity is a moisture movement mechanism that occurs in materials via the materials pore structure, insulation materials that are capillary open have high water wicking abilities.

Protective clothing and masks not needed, more comfortable for installers and others coming into contact with it	

Case Study

In order to evaluate a selection of natural insulations available in the Irish market, the following retrofit case-study was created and sent to a number of suppliers of natural insulation in the market:

Mid terrace single story house built in the 1920's, solid brick (300mm)

- plan is to retrofit internally as the brickwork outside must remain visible and the wall must achieve a U value of 0.35 W/m^{2}K where possible
- exterior brickwork is in good condition and not prone to driving wind or rain, internally the old plaster and paint has been removed at it was in poor condition. Area of wall excluding openings is 20m^2.

Solutions 1 – Wood Fibre boards with lime plaster finish	- Adhesive to sticking wood fibre boards to the wall - RK70 Lime Base/Bonding Coat - 80mm of Steico Therm Wood Fibre with a thermal conductivity of 0.038 W/m.K - RK70 Lime Base plaster - Fibre glass mesh for the plaster work Indicative cost of the materials = 1.5 times standard internal insulation No specialist training required, competent retrofit contractor could install this system
Solution 2 – Cork based plaster with lime plaster finish	-85mm of Diasen Diathonite Thermactive with a thermal conductivity of 0.037 W/m.K -4mm internal lime plaster finish Indicative cost of the materials = 2.8 times standard internal insulation
Solution 3 – Cork based plaster with wood fibre boards and lime plaster finish	-25mm of Diasen Diathonite Thermactive with a thermal conductivity of 0.037 W/m.K -60mm of Gutex Thermoroom Wood Fibre with a thermal conductivity of 0.039 W/m.K -Internal lime plaster finish

		Indicative cost of the materials = 2 times standard internal insulation

Evaluation Criteria

Regarding the criteria **are there any products available in Ireland**? This scores a **YES**

Regarding the criteria are **NSAI Agrément Cert available**? This cannot be scored for the common theme of natural insulation and would need to be re-examined for individual products. However, after searching the NSAI database the vast majority of natural insulation products available in Ireland do not have an NSAI Agrément Cert.

Regarding the criteria **Adds value to the Superhomes offering?** This scores a **YES**, natural insulation have a place in the retrofitting of the Irish housing stock due to their low environmental impact and specific material properties which make them very suitable for both traditional and modern retrofits. The cost of natural insulation may be a barrier in some circumstances but providing the customer an option of retrofit materials including their environmental impact has a place in the Superhomes customer journey.

Regarding the risk associated with natural insulation this would score a **medium** due to:

- Extra resources needed by Superhomes to verify if specific natural insulation products that don't have NSAI Agrément Cert are suitable for DEAP
- Extra resources required to price a natural insulation retrofit vs standard non-natural insulation retrofit and present the options to the customer
- Contractor base not willing to change existing working practices i.e., move to an alternative product range
- Potential for the overall cost of the retrofit to increase

6	Report Results	In the view of this evaluator natural insulation materials have a place in the Superhomes solutions but further analysis is required in selecting the most appropriate natural insulation for the specific retrofit element. Prior to the integration of natural insulations into the Superhomes standards the following recommendations are recommended: • Product samples orders and distributed to Superhomes engineering team • Engagement with the technical team in SEAI on what natural insulation systems / products are valid for DEAP • Engagement with specialist in the area of traditional building retrofits • Engagement with specialist in the area of - Assessing Risks in Insulation Retrofits Using Hygrothermal Software Tools

		• Engagement with product manufactures / suppliers on specific design details of their products in the context of the domestic retrofit market including themes such as: -thermal bridging -condensation risk -installation (handling, cutting, adhesion etc) -training -technical support -cost -Environmental Product Declaration status (Life cycle analysis) • Contractor engagement