

May 2026 - C02

Living Lab 4: Smart Housing, Smart Communities
Digital Blueprint for a Smart Home of the Future

ENVISION: the digital blueprint for a smart home of the future



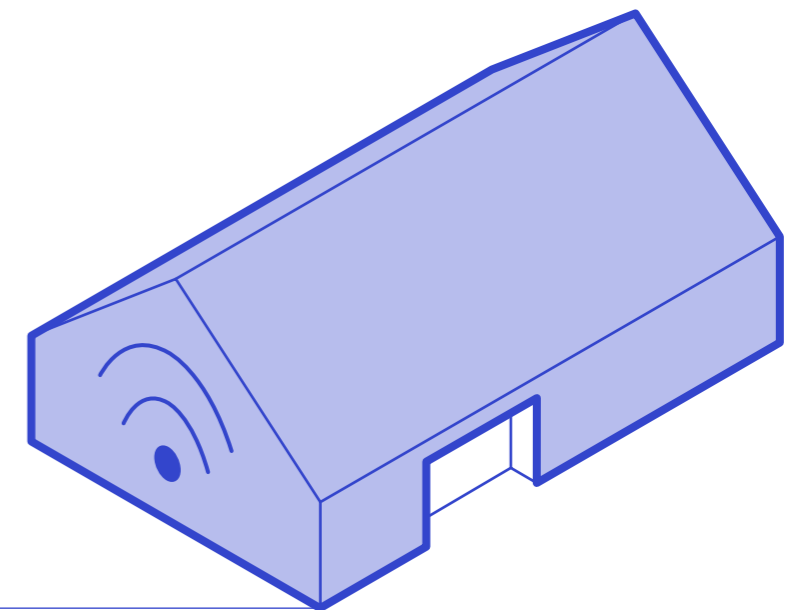
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DHI supports innovation between academia, the public and third sectors, and businesses in the area of health and social care.

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Envision, the digital blueprint for a smart home of the future is a practical blueprint and guidance for delivering the next generation of homes, that are affordable to run, aligned with net zero, and designed to support the health and wellbeing of their residents.

The blueprint is a bold rethinking of the home as a living system: one that generates energy, supports wellbeing, anticipates need, and evolves with its occupants over time. Designed for rural Scotland but relevant far beyond, it combines low-carbon construction, digital health, and adaptive design into a single, integrated blueprint. The model is structured across three horizons (short, medium and long term), allowing housing providers and policymakers to act immediately while planning for future integration and ambitions.

It isn't about smart gadgets, at its core, Envision reframes the home as part of our national infrastructure, reducing demand on health and care services, tackling fuel poverty, and supporting independent living and wellbeing. It's a scalable, evidence-led approach to building homes that are not only sustainable, but sustainable to live in and ensure future proofing.

Contributions note

The project has benefited from the guidance and oversight of a cross-sector Project Delivery Group comprising representatives from DHI, BE-ST and Moray Council, alongside input from a wider network of partners. The contribution of an Expert Advisory Group is also gratefully acknowledged in shaping the development and future application of the digital blueprint.

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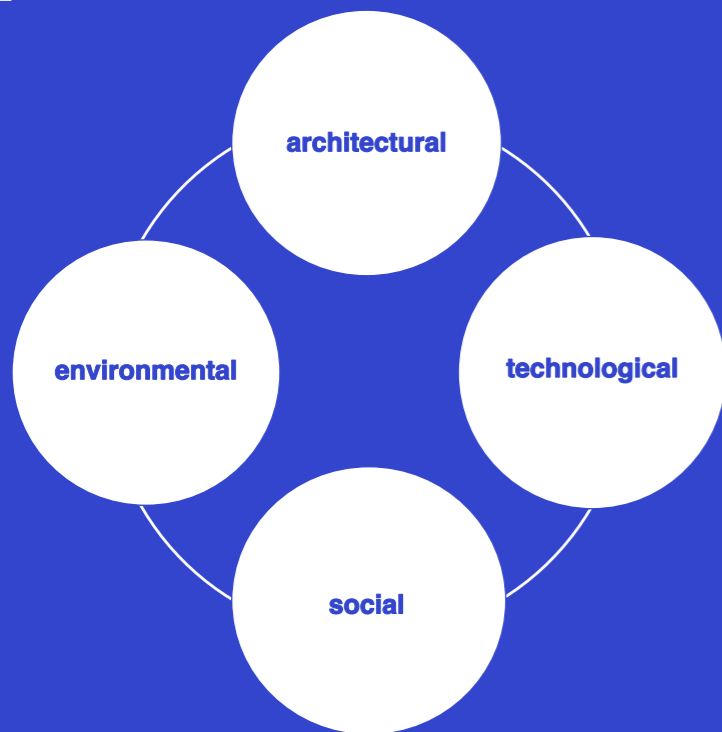
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Setting the scene



Across the United Kingdom, the home has become the front line of three converging global challenges: population health, technological transformation, and climate resilience.

We spend approximately 90% of our lives indoors¹, a statistic that alone underscores the profound influence of domestic environments on physical and mental well being. Yet many of those environments are ill-equipped for the realities of the twenty-first century. Around 55% of homes in the UK already overheat during relatively cool summers², a warning signal as climate volatility accelerates. At the same time, operational emissions from buildings account for roughly 19% of the UK's carbon footprint³, and the built environment as a whole is responsible for around 37% of global greenhouse gas emissions⁴. Critically, 80% of the buildings that will be occupied in 2050 already exist³, making the decarbonisation and adaptation of existing stock as urgent as the design of exemplary new homes.

Health and care systems are under equally acute strain. The NHS and social care services face rising demand driven by demographic change and increasing multi-morbidity, while resources have remained static or declined in real terms. Workforce gaps are persistent, unpaid carers shoulder growing burdens, and public satisfaction has fallen to historic lows. Nearly one million older people in the UK are often lonely, with loneliness and social isolation now recognised as serious public health risks, associated with increased morbidity and premature mortality⁵. Meanwhile, fuel poverty affects approximately 6.1 million households⁶, with many unable to heat their homes to a safe and comfortable level, exacerbating respiratory and cardiovascular conditions and compounding pressure on health services. The home, far from being a neutral backdrop, has become a determinant of health, resilience, and inequality.

Technology offers both disruption and opportunity. The rapid expansion of digital health and social care, remote monitoring, telecare, technology enabled care (TEC) and assistive technologies has demonstrated that care can be delivered differently—closer to home, more anticipatory, and more personalised. However, digital innovation has too often been layered onto a housing stock never designed to accommodate it. The prevailing model treats the home as a passive container for devices rather than an active, adaptive platform for lifelong

support. In rural contexts, where access to services is constrained by distance, workforce shortages, and infrastructure gaps, this misalignment is particularly stark. Service innovation at a system level needs to be activated. The potential for digitally enabled, low-carbon homes to act as distributed hubs of prevention, early intervention, and community connection remains largely unrealised.

The future-ready home must therefore be reconceptualised not simply as a shelter or asset, but as an integrated system—architectural, environmental, technological, and social. It must respond to the Human Givens framework of emotional needs: offering security through thermal comfort, structural safety, and reliable digital connectivity; enabling autonomy and control via accessible design and user-centred technologies; supporting emotional intimacy and community by facilitating social participation rather than isolating occupants; preserving privacy and dignity even as monitoring becomes more sophisticated; and sustaining status, competence, and meaning through environments that empower rather than diminish. A home that fails to meet these needs risks amplifying dependency and ill health; a home that fulfils them becomes a foundation for resilience across the lifespan.

Against this backdrop, the Smart Home of the Future is not conceived as a showcase of gadgets, nor as a speculative prototype detached from policy and market realities. It is a digital blueprint for a flexible two-bedroom, single-storey, detached rural home, designed as a lifelong hub for digital-first health and social care, aligned with Scotland's Housing to 2040 ambitions and its statutory Net Zero commitments. It integrates sustainable construction, high-performance fabric, and renewable energy systems with embedded digital infrastructure capable of supporting remote diagnostics, virtual consultations, anticipatory care and community connectivity. In doing so, it contributes to addressing the housing crisis not only in terms of supply, but in terms of suitability, adaptability, and long-term value.

The proposition is deliberately systemic. By reducing operational energy demand and embedding low-carbon technologies, such homes contribute to national decarbonisation goals. By enabling people to remain independent for longer, they relieve pressure on acute and residential care services. By mitigating overheating and fuel

poverty, they protect vulnerable populations from climate-related harms, and by designing for emotional as well as physical needs, they reaffirm the home as a site of agency, belonging, and purpose.

The question is no longer whether our homes should change, but how rapidly and coherently we can reimagine them. In rural communities especially, where demographic ageing, service retrenchment, and climate exposure converge, the stakes are high. This report therefore advances not simply a demonstrator dwelling, but a strategic proposition for the next generation of rural living: one that positions the home as preventative infrastructure, capable of anticipating need, supporting independence, reducing carbon impact, and evolving over time alongside its occupants.

We have called the Smart Home of the Future - **Envision** - a forward looking but grounded framework for rethinking the home as an integrated platform for health, sustainability and lifelong adaptability.

- Envision a rural home that functions as a digitally enabled health node, reducing avoidable hospital admissions through embedded monitoring, seamless connectivity, and anticipatory design.
- Envision housing that measurably lowers operational carbon while actively protecting occupants from overheating, fuel poverty, and climate volatility.
- Envision a dwelling that evolves with its residents—supporting autonomy, dignity, and competence in later life rather than precipitating premature moves into institutional care.
- Envision communities where distance is mitigated by intelligent infrastructure, and where the home becomes a platform for participation, productivity, and meaning rather than isolation.

In setting out Envision, we invite policymakers, commissioners, designers, and researchers to treat the home as foundational civic infrastructure—an enabling platform for health, equity, and sustainability in a carbon-constrained, demographically ageing society.

1. The National Human Activity Pattern Survey (NHAPS): A resource for assessing exposure to environmental pollutants by Neil E. & others (2001).
 2. The UK Green Building Council (UKGBC) Innovation showcase (2025)
 3. The UK Green Building Council (UKGBC) Climate Change Mitigation
 4. Global Status Report for Buildings and Construction, UN Environment Programme (2024)
 5. Age UK - Loneliness Policy Report (2024)
 6. National Energy Action Group, Fuel Poverty Statistics (2025)



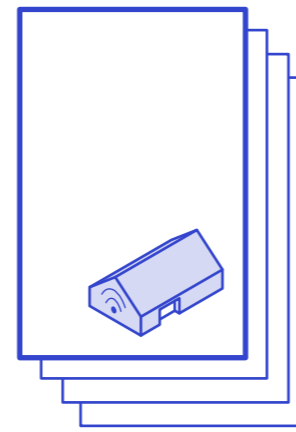
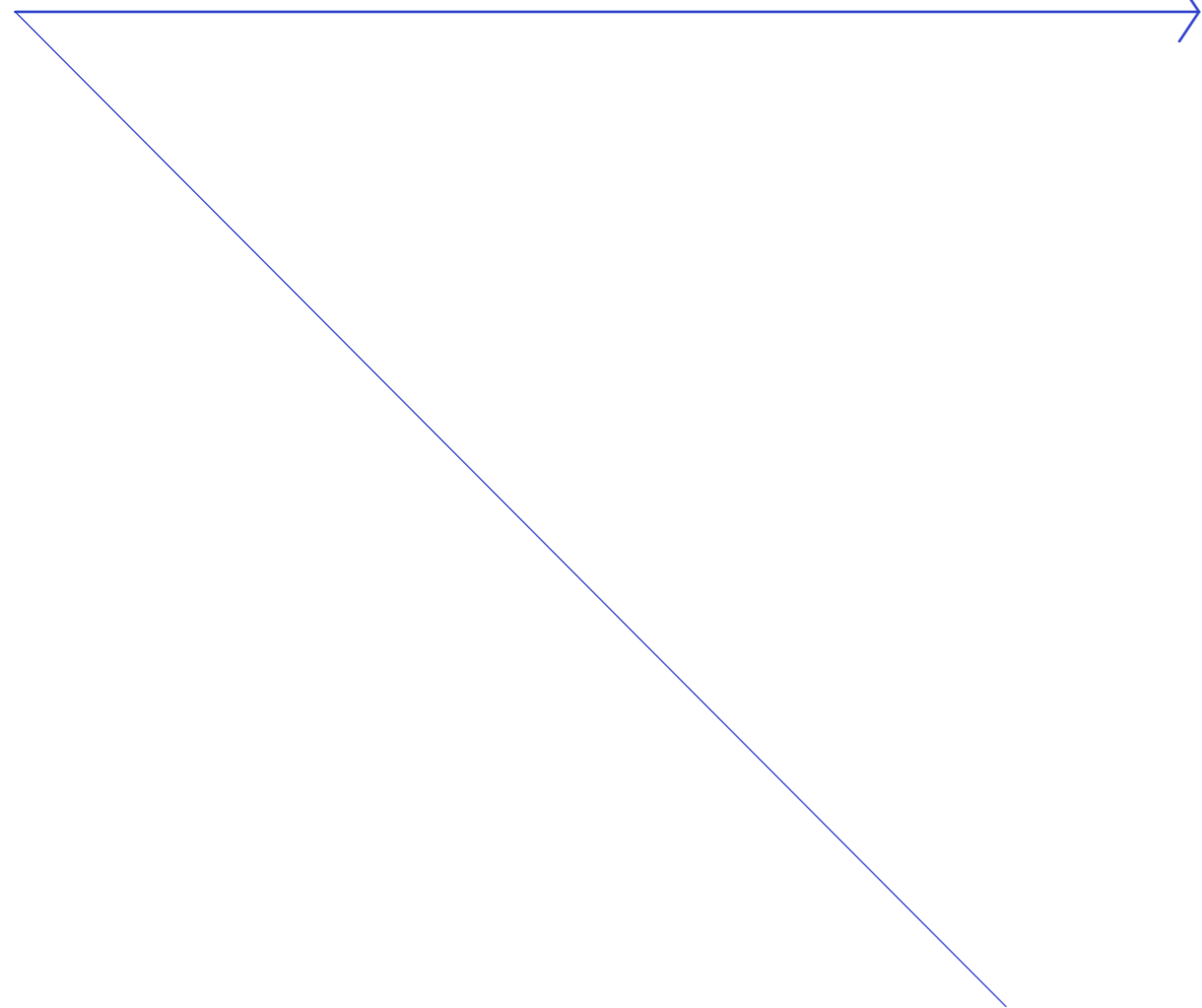
1.2 - Introduction

How to use the blueprint

The Envision blueprint is presented through two complementary tools: the **Guide** and the **Matrix**. Together, they translate a complex, systems-based proposition into something both understandable and actionable.

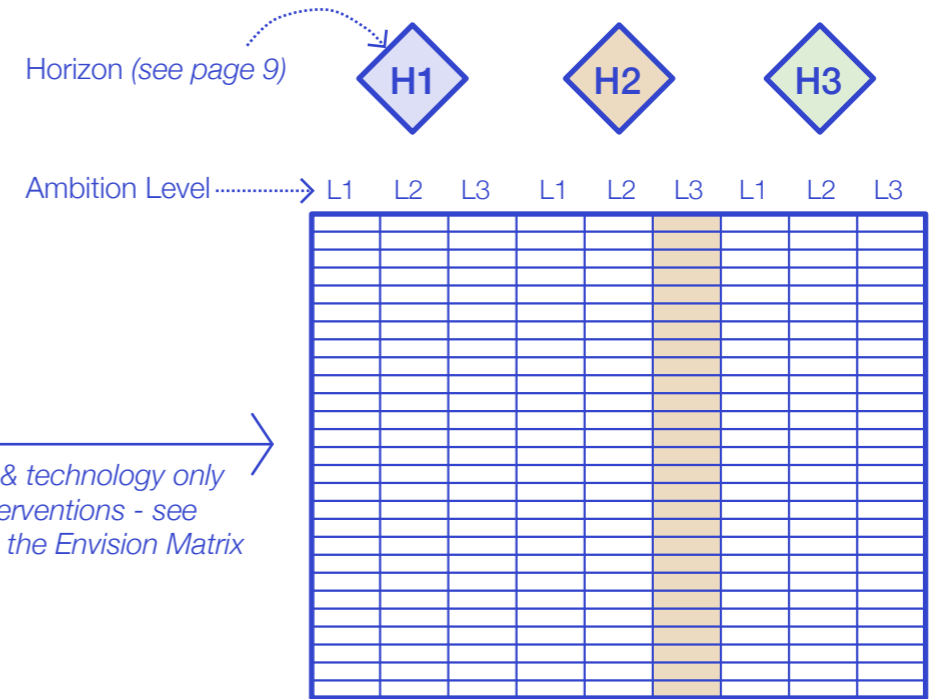
The **Guide** sets out the why and the how. It explains the thinking behind the project—linking health, housing, technology and design—and describes how a future-ready home can operate as an integrated system. It provides the narrative, evidence base and design principles needed to understand the ambition, from architectural concept through to digital technology stacks, infrastructure, governance and policy alignment.

The **Matrix** translates this into the what and the when. Structured across the three Horizons (see Page 9), and further broken down into three ambition levels within each, it acts as a practical toolkit. It shows how capabilities can be layered over time—from foundational, deployable elements through to more advanced, integrated and future-facing systems. Each “kit of parts” can be read independently or combined, allowing users to tailor ambition to context, budget and readiness.

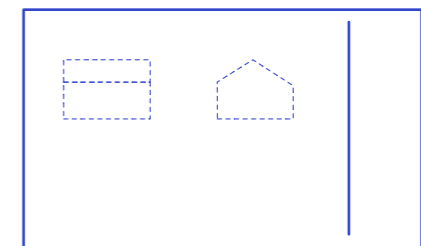


ENVISION: Guide

For Retrofit & technology based interventions - see section 4.6 & the Envision Matrix



ENVISION: Matrix



Future Design

Used together, the Guide and Matrix enable different entry points. A policymaker may use the Guide to understand system-level impact, while a designer or housing provider can use the Matrix to identify specific components and sequencing.

The intent is not to prescribe a single solution, but to provide a flexible framework—one that supports immediate action while maintaining a clear pathway toward longer-term transformation.

Glossary of terms

Built Environment & Construction

ASHP – Air Source Heat Pump: A low-carbon heating system that extracts heat from the external air to provide space heating and hot water.

BIM – Building Information Modelling: A digital process for creating and managing structured data about a building across its lifecycle.

LETI – London Energy Transformation Initiative: An industry-led network producing guidance and benchmarks for net zero carbon buildings, widely used to define best practice performance targets.

MVHR – Mechanical Ventilation with Heat Recovery: A ventilation system that extracts stale air and supplies fresh air while recovering heat, improving indoor air quality and energy efficiency.

PV – Photovoltaics: Solar panels that convert sunlight into electricity, typically installed on roofs to reduce operational energy demand.

RICS – Royal Institution of Chartered Surveyors: A professional body providing standards and guidance, including whole life carbon assessment methodologies.

RIBA – Royal Institute of British Architects: A professional body setting design standards and climate targets.

SBS – Scottish Building Standards: The statutory minimum requirements for building design and construction in Scotland.

VOC – Volatile Organic Compounds: Chemicals emitted from certain building materials and finishes which can negatively impact indoor air quality and occupant health

Digital & Technology Systems

AI – Artificial Intelligence: Computer systems capable of analysing data, identifying patterns and supporting decision-making or automation.

API – Application Programming Interface: a mechanism that allows different software systems to communicate and exchange data securely.

BLE – Bluetooth Low Energy: A short-range wireless communication protocol designed for low-power devices such as sensors and wearables.

DAO – Decentralised Autonomous Organisation: A digitally governed system where decisions and operations are managed collectively through rules encoded in software.

HOS – Home Operating System: The central digital platform within the home that integrates sensors, controls environmental systems, and manages data locally.

LoRaWAN – Long Range Wide Area Network: A low-power, long-range wireless network used to connect sensors across homes or communities, particularly in rural areas.

MQTT – Message Queuing Telemetry Transport: A lightweight communication protocol enabling efficient data exchange between devices within a smart system.

TRL – Technology Readiness Level: A scale used to assess the maturity of a technology, from early research to commercially proven deployment.

VR – Virtual Reality: A digital technology that enables immersive visualisation of spaces and systems, often used for design communication and engagement.

Health & Care

COPD – Chronic Obstructive Pulmonary Disease: A group of lung conditions often exacerbated by poor indoor air quality, damp and cold environments.

HRV – Heart Rate Variability: A measure of variation between heartbeats, used as an indicator of stress, recovery and overall health.

IAQ – Indoor Air Quality: A measure of air conditions within a building, including pollutants, humidity and carbon dioxide levels, with direct impacts on health.

NHS – National Health Service: The publicly funded healthcare system of the United Kingdom.

TEC – Technology Enabled Care: Digital tools and services, such as telecare and remote monitoring, that support independent living and health management.

Organisations & Programme Context

DHI – Digital Health & Care Innovation Centre: A Scottish innovation centre focused on advancing digital health and care solutions.

EAG – Expert Advisory Group: A panel of specialists providing strategic guidance and review for the project.

LL4A / LL4C – Living Lab 4A / Living Lab 4C: Components of the Rural Centre of Excellence programme supporting digital health innovation and system integration.

ONS – Office for National Statistics: The UK's official statistics body, providing population, demographic and economic data.

PDS – Personal Data Store: A resident-controlled digital system where personal data is stored securely and shared only with explicit consent.

RCE – Rural Centre of Excellence: A programme focused on advancing innovation, infrastructure and services in rural Scotland.

RSL – Registered Social Landlord: An organisation that owns and manages social housing, typically regulated and often not-for-profit

2.0 Executive Summary

Purpose scope intent

1. Introduction

Envision: the Digital Blueprint for a Smart Home of the Future forms a flagship component of Living Lab 4: Smart Housing, Smart Communities, within the Digital Health & Care Innovation (DHI) Centre Rural Centre of Excellence (RCE) in Moray, funded by the UK Government. The project responds to Scotland’s urgent need for integrated, preventative, digitally enabled rural homes (& beyond) that promote lifelong health and wellbeing, independence, and sustainability. As set out in the brief, the blueprint is not a finalised house design but a strategic, design-informed model that unites digital health and social care integration, low-carbon construction, and rural-appropriate innovation into a single coherent framework.

The project positions Moray as a leading international exemplar of future global communities, demonstrating how modest homes can operate as preventative health and social care platforms that continuously support wellbeing across the life course. Digital technologies are embedded as core infrastructure, not retrofitted accessories, enabling early risk identification, proactive care, and seamless integration with RCE assets such as Living Labs 4A and 4C. The Living Labs provide the wider infrastructure for Envision: 4A supports the shift from reactive telecare to proactive, preventative Technology Enabled Care (TEC), while 4C develops an AI-based stratification platform using citizen-controlled data and social determinants of health to enable earlier intervention and community-scale wellbeing planning.

Led by Evolve Capex by Gordon Bain, a chartered Construction Manager with a Masters in Psychology, and Architype under Christina Gaiger’s low-carbon architectural leadership, the project is delivered by a multidisciplinary team with deep expertise in rural resilience, digital health, passive architectural design principles, and cultural change. Strategic contributors Pat Kane and Indra Adnan from The Alternative ensure the blueprint is grounded not only in technical excellence but in ethical local identity, cultural readiness, and lived experience.

Together, the team have evolved a blueprint that is practical, scalable, and inspiring—a model uniquely suited to remote and rural Scotland but holds wider applicability, aligning fully with Net Zero targets, Housing to 2040, and future policies.

2. Scope of Work

Core Deliverables: Drawing from the brief and our tender proposal, our scope encompassed four interconnected streams:

A. Digital Health & Care Infrastructure

- Integration of high-TRL (>7) technologies including ambient activity sensors, environmental monitoring, and early-warning health and social care analytics
- AI-enabled data interpretation linked to a citizen-controlled Personal Data Store (PDS), with clear privacy, consent, and data governance protocols.
- Open APIs and interoperable architectures ensuring compatibility readily available platforms
- Connectivity-resilient systems designed for low-bandwidth environments with edge computing and offline-first functionality.

B. Sustainable, Inclusive, Low-Carbon Construction

- Specification of mass timber, natural insulation, low-VOC finishes, and circular material pathways, aligned with RICS Whole Life Carbon Assessment and LETI benchmarks
- Designs incorporating renewable energy, microgeneration, battery storage, and integrated smart resource management.
- Inclusive spatial strategies supporting accessibility and life-stage transitions.

C. Rural-Appropriate Design

- Construction thinking suited to microclimates,

exposed landscapes, and infrastructure gaps (e.g., off-grid capability, water harvesting, autonomous operation during outages)

- Modular communications infrastructure bridging variable connectivity.

Why rural, why now?

Rural households in Scotland typically face:

- higher energy costs and greater exposure to fuel poverty
- older, harder-to-treat building stock
- patchy broadband and mobile coverage
- reduced access to local health and social care services
- persistent risks from cold, damp, mould and loneliness
- more single-occupancy living driving up energy use and costs

At the same time, rural communities often have stronger social ties, access to land and a culture of self-reliance. The project treats these homes as testbeds for integrating energy, health and digital infrastructure in ways that could later be scaled to other settings.

The Envision blueprint is framed against the Scottish Building Standards, net-zero and digital health and care policy, with the growing recognition that housing is a key determinant of health and social care. The focus is on design and interventions that are grounded, deliverable, technically realistic, ethically sound and financially defensible.

D. Immersive & Interactive Outputs

- VR walkthroughs, interactive models, and annotated diagrams illustrating spatial layouts, digital systems, and material performance
- Customisable toolkit supporting adaptation for different sites, budgets, and scenarios.

2.0 - Executive Summary

What this blueprint is – and what it is not

It is A conceptual and technical scaffold for adoption – aligning energy systems, health-enabling technology and connectivity.

- A three-horizon guide that shows how today's proven solutions (Horizon 1) can evolve into predictive systems (Horizon 2) and, eventually, ambient intelligence (Horizon 3).
- A way to organise discussion between architects, engineers, digital teams, health and social care, housing delivery partners and government around a shared set of capabilities.

It is not A fixed specification, product catalogue or procurement list or;

- A commitment to deploy every proposed technology in every home.
- A clinical safety case or a substitute for detailed business modelling.
- A fully developed architectural proposal but a strategic, design informed model

3. Brief Development

Our approach was built on engagement, iteration, and cross-sector integration to create a forward-thinking yet grounded digital blueprint.

The average demographic, and need – demonstrates how homes can actively support health, social care, wellbeing, and sustainability.

It's not a fixed design or tech showcase; it's a framework for integration, where good design, digital systems, and care innovation meet.

It's purpose is to:

- Demonstrate Convergence: Demonstrate how design, technology, health and social care can converge through housing in rural Scotland.

- Create Repeatability: Create a repeatable conceptual outline of a smart, sustainable, inclusive living.

- Balance Ambition: Balance ambition with deliverability via practical information and guidance for real world application.

4. Conclusion

The process demonstrates a coherent, integrated, and future-ready approach fully aligned with the scope requirements.

The blueprint aims to:

- Advance Moray, the RCE and DHI's position as a global leader in rural digital health and social care innovation;
- Embed sustainability, circularity, and inclusivity from first principles;
- Provide a visually compelling, technically robust model for widespread adoption
- Strengthen rural resilience, community wealth, and long-term wellbeing;

The resultant guide and assets act as a beacon and a roadmap—a visionary yet pragmatic blueprint that sets a new standard for rural housing, digital care integration, and sustainable living across Scotland and beyond.



DIGITAL - Health, Wellbeing & Independence

What: Integrate digital systems at build stage to generate useful data for health and social care, wellbeing, and independence.

How: Embedded in schematic and plan development. Human-first, outcomes-led, vendor-neutral. Open protocols aligned with RCE assets such as the Personal Data Store (PDS). Connectivity and privacy modelled across horizons to ensure reliability and trust.



SUSTAINABLE Construction - Inclusive design & low carbon fabric

What: Show how sustainable, inclusive construction supports Scotland's Net Zero and wellbeing goals.

How: Benchmarked against Building Standards and carbon targets; matrices show embodied & operational performance. Draws on Architype research and exemplar homes. Designs in flexibility from the start – spaces, lighting, and controls work for everyone without retrofit adaptations or clinical add-ons. Considers retrofit potential and future compliance.



RURAL Application

What: Reflect rural conditions – limited connectivity, variable utilities, climate volatility and dispersed care networks.

How: Stress-tested against outage scenarios; aligned with national infrastructure plans.

Development of a resilience hierarchy (connectivity → power → autonomy) to build trust in technology.



AFFORDABILITY & Local Economic Impact

What: Ensure affordable smart living that stimulates local economies.

How: Benchmarked to government funding bands; technology as core capital not add-on.

Uses local materials and skills to build community wealth. Horizons show feasible commercial models and long-term investment potential.



COLLABORATION & Delivery

What: Integrate design, construction, and digital health expertise in one process.

How: Core delivery team team (Architype / Evolve Capex / Alternative) supported by RCE and beyond, captures lessons for future multi-sector delivery.

Horizons align construction and tech timelines, engaging clinical and community partners for real-world validation.

3.0 The Horizons

Accessible actionable inspiring diverse

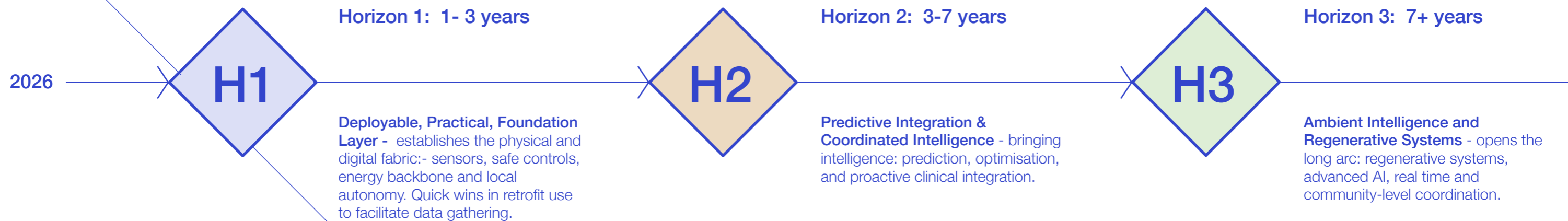
The Horizons - An Introduction

The blueprint is structured across **three Horizons** to reflect both the realism, intent and ambition of the project.

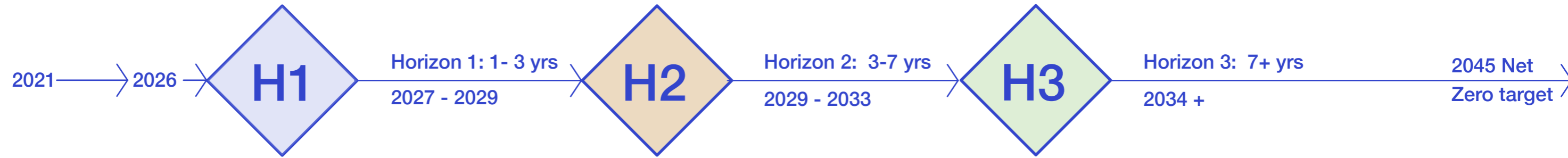
The horizons recognise that innovation in housing, health, social care and energy systems will not occur overnight; it unfolds through staged adoption, regulatory alignment, data maturity, supply chain readiness, and public trust.

By setting out Horizon 1 (1–3 years), Horizon 2 (3–7 years), and Horizon 3 (7+ years), they anchor the ambition to deliverable timeframes. This model creates clarity about what can be implemented immediately using proven technologies and established construction methods; what becomes viable as integration, interoperability, and analytics mature; and what properly belongs in the longer-range innovation space where governance, ethics, and infrastructure must evolve in parallel.

The horizon framework also mitigates risk. It allows commissioners, housing providers, and delivery partners to invest in foundational measures that yield immediate benefits and quick wins — thermal performance, indoor air quality, safety, and basic digital implementation— while ensuring that today’s decisions do not foreclose tomorrow’s capabilities. Each horizon therefore builds deliberately upon the previous one: fabric-first design enabling predictive optimisation; local data stewardship enabling federated civic intelligence; passive resilience enabling regenerative systems. In doing so, the programme avoids the common pitfalls of technological determinism and stranded assets. Instead, it establishes a sequenced pathway in which architectural design, construction systems, and digital infrastructure co-evolve, ensuring that the steps towards Envision - the Smart Home of the Future is both immediately actionable and strategically future-proofed.



3.2 - The Horizons



2021–2026: the strategic direction is set.

Scotland's long-term housing direction is framed by Housing to 2040, which sets out the ambition that homes should be safe, good quality, affordable, meet people's needs, and support net zero and accessibility outcomes over the long term. Alongside this, the Scottish Government's affordable housing commitment was reset to 110,000 affordable homes by 2032, with at least 70% for social rent and 10% in rural and island communities. In parallel, the 2023 accessibility consultation proposed that the review of Housing for Varying Needs should directly inform a new Scottish Accessible Homes Standard applying to all new homes and to homes created through conversion, with implementation intended through changes to building standards and guidance from 2025–26.

On the carbon side, Scotland retains its statutory net zero by 2045 target, but the Climate Change (Emissions Reduction Targets) (Scotland) Act 2024 replaces the previous annual target framework with five-year carbon budgets, signalling a more delivery-oriented pathway to decarbonisation. In housing regulation, the New Build Heat Standard came into force in 2024 and was subsequently amended with changes taking effect from 1 January 2025; the direction of travel is clear: new buildings are expected to move away from direct emissions heating. On the care side, the Scottish Government's January 2025 statement on the National Care Service, alongside Scotland's population health framework (2025) shifted emphasis from a single structural overhaul toward a programme of reform focused on consistency, quality, fair work, and support for unpaid carers, while the Health and Social Care Service Renewal Framework published in June 2025 set out a wider programme to improve the sustainability, accessibility and integration of services.

2027–2029: the regulatory tightening phase for new homes. By 2030: voluntary best practice is ahead of regulation.

This is the period in which several strands begin to converge. The Scottish Government has continued work on a Scottish Passivhaus Equivalent, consulting in 2024 on the principles for new energy and environmental standards and then confirming an implementation date of 31 March 2028 in the enabling regulations. The intent is not simply a label, but a step change in delivered fabric performance, energy demand, comfort and robustness through building regulations. In parallel, the Scottish Accessible Homes Standard remains an important planned reform, intended to mainstream accessibility and adaptability across all tenures. For a project such as Envision, this period is especially significant: it is the window in which a rural smart home can align itself with the likely future baseline for energy performance, zero-direct-emissions heating, and more adaptable design.

While not policy, LETI and the RIBA 2030 Climate Challenge are highly relevant as they define the performance level that many leading clients and design teams now regard as best practice. RIBA's 2021 version 2 targets for domestic buildings call for operational energy below 60 kWh/m²/yr by 2025 and below 35 kWh/m²/yr by 2030, and embodied carbon below 800 kgCO₂e/m² by 2025 and below 625 kgCO₂e/m² by 2030; RIBA states these targets are voluntary and aligned with LETI on operational and embodied carbon. LETI's own guidance is explicit that buildings adopting its requirements now are leaders, and that by 2025 these approaches should have already be standard design practice if the sector is to stay on a credible climate trajectory.

UK and Scottish Net Zero Building Standards will also gain traction in this period, albeit still at a voluntary level.

2029–2033: delivery, not only standard-setting, becomes the test.

By this point, Scotland's housing policy expects measurable progress on the 110,000 affordable homes by 2032 commitment, including social rent and rural/island provision.

For social care and independent living, the policy trajectory points toward keeping more people at home or in homely settings with maximum independence, improving adaptations, strengthening support for unpaid carers, and aligning housing more closely with health and social care delivery. That makes the home increasingly visible as part of national care infrastructure, not just housing supply.

The Office for National Statistics (ONS) project the number of people of pension age increasing by around 1.7 million between 2022 and 2032, with an estimate that the UK will have over 15.5 million people aged 65 and over by 2030.

< Please note the Scottish Accessible Homes Standard was noted as intended for implementation from 2025–26, but from our research we could not confirm the commitment and direction of travel for a final date, therefore the introduction of this standard would need to be tracked.

Horizon 3: 7+ yrs

2034 +

2034 - 2045: the destination point.

The long end of the timeline remains Scotland's statutory 2045 net zero target.

By then, the expectation is not simply that homes emit less, but that housing, care, energy and accessibility policy have become materially more integrated: lower-energy, zero-direct-emissions, adaptable homes supporting prevention, independence and resilience across their life span.

While subject to greater uncertainty, ONS 2022-based projections suggest that the number of people aged 85 and over in the UK, already around 1.7 million, is projected to almost double to around 3.3 million by 2047. Concurrently, the overall share of the population of pensionable age is projected to grow substantially, increasing the proportion of older adults relative to working-age groups. By the mid-2040s, demographic change is expected to see significantly higher old-age dependency ratios as fertility remains below replacement levels and life expectancy continues to climb.

Projections portray a UK demographic landscape characterised by a rising absolute number of older people, growing numbers of 85+, and a larger share of the population in retirement ages by the 2040s. This intensifies pressure on health and social care systems, housing suitability, and the sustainability of intergenerational support ratios — forming a key backdrop for planning future-ready housing and support environments.

policy timeline

Defined phases clear milestones



Horizon 1 (1-3 Years) – Deployable, Practical, Foundation Layer

Horizon 1 focuses on technologies that are proven, commercially available and able to deliver clear gains in energy, safety, health and well being immediately. This horizon establishes the baseline digital and environmental infrastructure that later capabilities depend on.

Architecturally, it is underpinned by a fabric-first, single-storey design optimised for accessibility, thermal efficiency, and low operational energy demand. High-performance insulation, airtightness with mechanical ventilation and heat recovery (MVHR) readiness, and passive solar orientation form the core. Construction systems take the baseline case to a level that could achieve Passivhaus certification and the Gold Standard. Structural allowances are embedded for future PV expansion, battery installation, and internal reconfiguration, ensuring that the home can adapt without major retrofit disruption.

Characteristics:

- Low-risk, affordable, and fully achievable by 2030
- Works at Connectivity Tiers 1–2 (off-grid autonomy and local LoRa/mesh)
- Direct impact on comfort, IAQ, damp/mould, safety and routine care
- Requires minimal behaviour change and minimal digital training

Typical inclusions:

- ASHP + PV-ready electrical backbone, battery readiness
- CO₂, humidity and damp detection with automated ventilation cues
- Leak sensors, smoke/CO extensions, movement sensing
- Basic Technology Enabled Care (TEC): panic buttons, voice control
- Circadian lighting, nudges for sleep and activity
- Local edge hub for transparent, resident-controlled data

3.3 - The Horizons

Living Lab 4: Smart Housing, Smart Communities
Digital Blueprint for a Smart Home of the Future

H2

HORIZON 2 (3-7 Years) – Predictive Integration and Coordinated Intelligence

Horizon 2 marks the transition from monitoring to prediction. Systems begin to anticipate health and well being alongside environmental issues, optimise energy flows, and coordinate between homes. This is where the home develops a deeper “memory” of patterns.

Architecturally, homes evolve toward greater system integration: enhanced envelope performance verified through in-use performance monitoring; modular internal layouts capable of accommodating changing mobility or care needs without structural alteration. Construction approaches increasingly integrate digital twins at design stage, linking BIM models to live operational data to refine maintenance cycles and performance tuning.

Characteristics:

- Predictive, personalised, cross-system orchestration
- Requires Connectivity Tier 3 (edge + cloud hybrid)
- Benefits accrue to residents, housing delivery teams, alongside health and social care services
- Enables early interventions and reduced unplanned maintenance

Typical inclusions:

- Home Operating System integrating heat, ventilation, lighting and comfort
- Digital twin models forecasting heat loss, moisture and energy
- Ambient health and well being analytics combining sleep, HRV, movement and IAQ
- Predictive damp/mould algorithms and maintenance triggers
- Community energy loops and peer-to-peer balancing pilots

H3

HORIZON 3 (7+ Years) – Ambient Intelligence and Regenerative Systems

Horizon 3 signals the longer-term direction once data maturity, civic governance and energy systems stabilise. It focuses on ambient intelligence - homes and communities that adapt dynamically to residents, environments and collective needs.

Architecturally, this horizon anticipates regenerative design principles: buildings operating as energy-positive assets within micro-grids; materials selected for circularity, bio-based carbon sequestration, and responsive performance; and spatial configurations that flex seamlessly between living, care, and community functions. Construction becomes increasingly platform-based and circular, with components designed for disassembly, reuse, and continuous upgrade rather than obsolescence.

Characteristics:

- Deep integration of net zero energy, health and care focused support, innovative materials and AI
- Requires Connectivity Tier 4 (secure civic mesh and federated data)
- Strong ethical, regulatory and governance requirements
- Community-level optimisation and regenerative cycles

Typical inclusions:

- Regenerative micro-grids with seasonal thermal and electrical storage
- Bio-reactive materials modulating light, humidity and heat
- Home-embedded digital clinics and multi-modal biosensing
- Advanced assistive robotics and embodied AI companions
- Federated data cooperatives for community health and social care, carbon and resilience

4.0 Technology blueprint

(New Build + Retrofit)

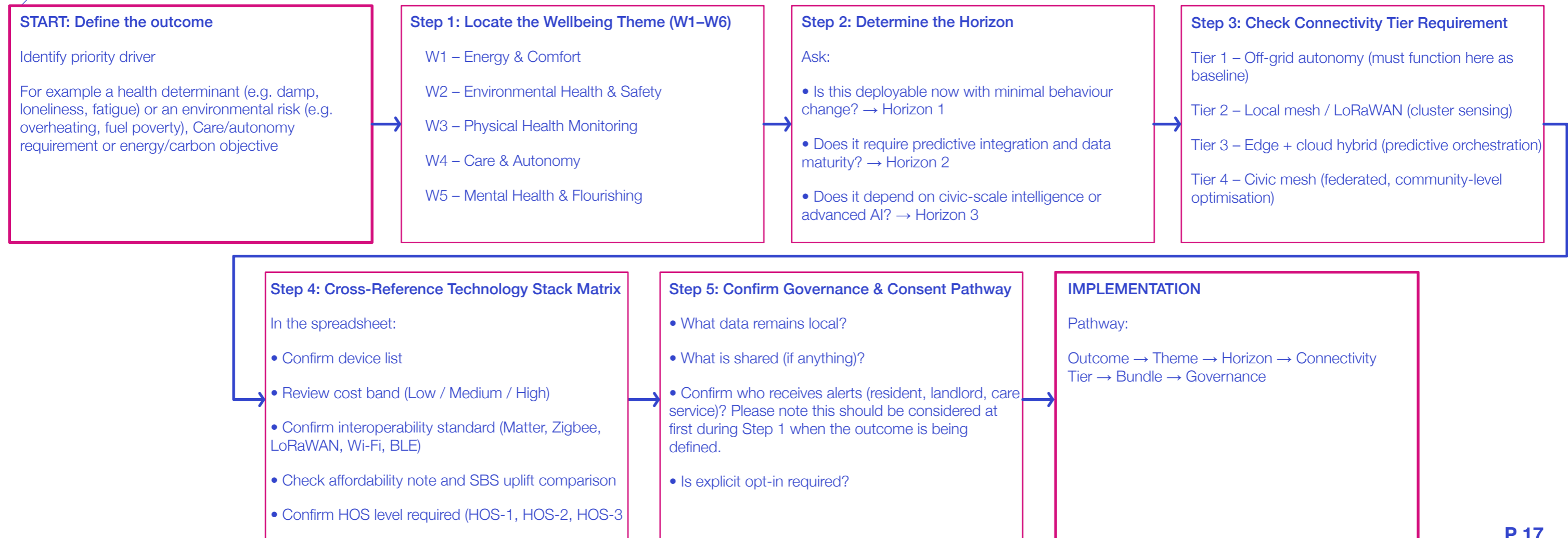
Technology workflow

The Technology section sets out how the Smart Rural Home of the Future operates as an integrated, resilient and ethical system rather than a collection of devices.

The technology stacks are organised across the three horizons and four connectivity tiers, and structured around six interdependent wellbeing themes. This section should therefore be read as a layered architecture: environmental systems underpin health and well being; health and care insights support autonomy; autonomy reinforces dignity and community participation; and governance safeguards trust throughout.

The accompanying Technology Stack Matrix, as part of the Envision Matrix Toolkit, functions as the operational register behind this narrative. It itemises devices, bundles, cost bands, connectivity dependencies and horizon alignment, allowing commissioners, designers and delivery partners to trace each capability from strategic intent through to component level. Readers are encouraged to navigate between the narrative (why the capability exists), the horizon model (when it becomes viable), the connectivity hierarchy (how it functions in rural contexts), and the Technology Stack Matrix (what it consists of and what it costs).

Taken together, this section and the Technology Stack Matrix form the technology approach for the blueprint: policy-aligned in ambition, technically grounded in deployment reality, and structured to support phased implementation from Horizon 1 foundations through to Horizon 3 regenerative intelligence. This workflow ensures every technological element can be traced from strategic objective through to physical component and ethical control, maintaining coherence between narrative vision and deliverable specification.



A guide to defining the outcome

Health and Well Being Context, Priority Conditions & Predictive Use Cases

The Smart Rural Home of the Future is built on a simple premise: many of the factors that drive long-term illness begin at home. The leading causes of death in the UK - dementia and Alzheimer’s disease, ischaemic heart disease, and chronic lower respiratory diseases - all have strong links to daily routines, indoor environments and the subtle behaviours shaped by the spaces we live in.

The home cannot diagnose or treat disease, but it can influence the determinants that precede them: sleep, stress, movement, loneliness, air quality, damp, routine drift, cold homes, sensory under-stimulation, and the slow accumulation of environmental strain.

To frame this clearly, we align each priority condition with its modifiable determinants and the relevant Human Givens domains, then translate these into predictive use cases the home can support.

1. Dementia & Cognitive Decline

Key determinants: sleep instability, inactivity, loneliness, low daylight, poor air quality, routine drift.

Human Givens domains: security, attention, emotional intimacy, community, privacy, competence, meaning & purpose.

Predictive use cases:

- Cognitive Drift Detection: early pattern changes (routine delays, reduced engagement) trigger gentle prompts.
- Daylight & Sensory Support: home encourages outdoor micro-bouts when daylight is optimal.
- Stability of Routine: detects disrupted circadian rhythm and offers calming evening cues.
- Connection Nudges: identifies sustained social withdrawal and offers ways to re-engage.

2. Ischaemic Heart Disease

Key determinants: physical inactivity, poor sleep, chronic stress, poor IAQ, diet patterns, alcohol/tobacco use.

Human Givens domains: security, autonomy & control, privacy, competence & achievement.

Predictive use cases:

- Fatigue & Recovery Drift: home spots declining HRV/sleep and offers recovery-focused nudges.
- Movement Support: identifies long sedentary streaks and encourages micro-bouts of activity.
- Stress Pattern Detection: evening routines plus environment data reveal stress cycles; home responds with calming light/sound.
- Circadian Eating Prompts: detects late-night kitchen spikes and supports healthier timing without judgement.

3. Chronic Lower Respiratory Diseases

Key determinants: damp/mould, cold homes, humidity extremes, poor ventilation, pollutants.

Human Givens domains: security, autonomy & control, privacy.

Predictive use cases:

- Damp & Mould Prevention: humidity + temperature profiles predict condensation before it forms.
- Respiratory Strain Flags: home connects worsening sleep/CO₂ with potential respiratory flare-ups.
- Cold-Home Risk Detection: identifies fuel-poverty under-heating and alerts residents/support teams.
- Ventilation Optimisation: boosts airflow automatically during high-risk periods (cooking, sleep, showering)

4. Flourishing, Purpose & Emotional Health and Well Being

Key determinants: loneliness, emotional flatness, lack of purpose, irregular routines, low creativity.

Human Givens domains: emotional intimacy, attention, community, competence, meaning & purpose, privacy.

Predictive use cases:

- Mood Drift Detection: voice tone + activity + light exposure reveal flattening; home offers gentle reorientation.
- Creativity Prompts: environmental cues encourage small acts of creativity or reflection.
- Social Withdrawal Signals: reduced community-app engagement or movement patterns trigger connection nudges.
- Nature & Calm Anchors: the home suggests garden/outdoor moments when weather and mood align.

How These Use Cases Connect Back to Health and Well being Outcomes

These predictive loops don’t treat disease: they lower the behavioural and environmental load that contributes to it.

- Better sleep, cleaner air and more daylight support brain health.
- Micro-activity, reduced stress and consistent routines protect heart health.
- Ventilation, humidity control and warm, dry rooms protect lungs.
- Connection, creativity and meaning support mental resilience and reduce decline across all domains.

Together, these use cases turn a rural home into a quiet, continuous form of preventative health and well being infrastructure - one that supports safety, emotional needs, purposeful living and long-term well being.

Top Predictive Use Cases

Use Case 1 – Damp & Mould Risk Prediction

What the home sees:

Rising humidity, cooler surfaces, poor overnight ventilation, bathroom moisture not dissipating, weather conditions that increase condensation risk.

Predictive insight:

Identifies damp and mould formation days before visible signs, using humidity–temperature interaction patterns.

Action:

H1: Boosts ventilation automatically; prompts resident (“Bathroom is taking longer to dry, would you like more airflow?”).

H2: Adjusts whole-home ventilation and heating cycles; flags persistent patterns to landlord or support teams.

Outcome:

Reduced respiratory symptoms, fewer damp-related repairs, improved sleep and comfort stability.

Use case narratives

Use Case 2 – Cognitive Drift & Routine Stability

What the home sees:

Delayed morning routines, irregular sleep timing, reduced movement, fewer kitchen events, less engagement with community prompts.

Predictive insight:

Detects early cognitive drift or withdrawal before noticeable decline, an early signal of dementia pathway risk.

Action:

H1: Offers stability nudges (“Your bedroom light was late last night, want help resetting tonight?”).
H2: Generates routine summaries and, with consent, shares concerning patterns with carers or family.

Outcome:

Earlier support, stabilised circadian rhythm, stronger cognitive engagement, reduced risk of rapid decline.

Use Case 3 – Fatigue, Stress & Low Recovery

What the home sees:

Low HRV, short sleep duration, fragmented sleep, high overnight CO₂, late-night screen or kitchen use.

Predictive insight:

Identifies deteriorating recovery and rising stress load, a precursor to cardiovascular strain.

Action:

H1: Suggests recovery cues (cooler bedroom, earlier wind-down).
H2: Weekly personalised feedback (“Your recovery improves when bedtime is before 23:00 and CO₂ stays low.”).

Outcome:

Reduced cardiovascular stress, improved sleep, more stable mood, lower cumulative strain.

Use Case 4 – Sedentary Patterns & Mobility Change

What the home sees:

Long seated periods, reduced gait speed, fewer room-to-room transitions, night-time wandering or restlessness.

Predictive insight:

Detects declining mobility or early frailty, relevant for both dementia and heart disease risk.

Action:

H1: Micro-movement prompts (“You’ve been still for 90 minutes, want a 2-minute reset?”).
H2: Trend reporting (“Your gait is slowing slightly, consider a mobility check-in.”).

Outcome:

Better mobility, fewer falls, preserved independence and cardiovascular health.

Use Case 5 – Respiratory Stress & Air Quality Signals

What the home sees:

High CO₂ overnight, humidity spikes, persistent damp corners, poor airflow, cooking/cleaning particulates not clearing.

Predictive insight:

Recognises patterns that precede chronic respiratory flare-ups (COPD, asthma, chronic bronchitis).

Action:

H1: Auto-vents environment; prompts window/fan use.
H2: Predictive alerts (“Your air quality trend may affect breathing - adjustments made.”).

Outcome:

Fewer flare ups, more stable breathing environment, better sleep quality.

Use Case 6 – Fuel-Poverty Under-Heating Detection

What the home sees:

Consistent low temperatures, delayed morning heating, sudden drops in appliance use, patterns of self-rationing.

Predictive insight:

Identifies risk of under-heating due to cost anxiety or lack of awareness - an early sign of winter stress.

Action:

H1: Suggests safe heating cycles (“Bedroom is cold - a short warm-up is low cost right now”).
H2: Alerts support teams when patterns consistently indicate risk (with consent).

Outcome:

Reduced cold-related illness, strengthened thermal stability, protection for vulnerable residents.

Use Case 7 – Loneliness & Social Withdrawal

What the home sees:

Reduced engagement with community apps, fewer kitchen or shared-space routines, diminished voice tone, flat evening behaviour.

Predictive insight:

Identifies sustained social withdrawal - a precursor to depression and dementia acceleration.

Action:

H1: Provides soft prompts (“Community gardening tomorrow - want the details?”).
H2: Flags patterns for community support teams (with resident approval).

Outcome:

Greater connection, prevention of loneliness, stronger emotional resilience.

4.2 - Technology blueprint

Living Lab 4: Smart Housing, Smart Communities
Digital Blueprint for a Smart Home of the Future

Use Case 8 – Mood Drift & Emotional Flatness

What the home sees:

Low daylight exposure, inconsistent routines, reduced activity bursts, quieter tone, decreased creative engagement.

Predictive insight:

Identifies emotional flattening, early burnout or low mood drift.

Action:

H1: Micro-nudges (“Light is good outside - would you like a short break?”).

H2: Weekly wellbeing summaries highlighting stability supports.

Outcome:

Better mood regulation, improved motivation, reduced risk of escalation to crisis support.

Use Case 9 – Appliance / System Failure Prediction

What the home sees:

Irregular power draw, short-cycling, silent circuits, failing heating cycles.

Predictive insight:

Forecasts appliance failure before breakdown - the kind of failure that causes cold homes, food spoilage or condensation.

Action:

H1: Alerts resident directly.

H2: Sends predictive maintenance flags to landlord/asset manager.

Outcome:

Fewer crises, reduced maintenance cost, stable home environment.

Use Case 10 – Heat Stress & Dehydration (Summer Peaks)

What the home sees:

High indoor temperatures, low water-usage signals, reduced movement, poor sleep.

Predictive insight:

Recognises dehydration or heat stress risk - especially in older adults.

Action:

H1: Hydration reminders and cooling adjustments.

H2: Predictive alerts and routines to manage sustained heat stress.

Outcome:

Safer summer periods, reduced hospitalisations, better sleep and hydration.

These predictive use cases quietly support the major determinants behind dementia, heart disease and respiratory illness - turning the home into a living, preventative and caring environment without ever becoming clinical.

Health & well-being stack overview

The Smart Rural Home of the Future treats the home as a living ecosystem - one that shapes physical health, mental well-being, safety, comfort and the ability to flourish. The technology stack is organised into six themes, each representing a different dimension of what it means for a home to support a healthy life.

These themes are not standalone. They overlap, reinforce and influence one another. Better air quality improves sleep; good sleep improves mood; positive mood supports autonomy. The stack is therefore designed as an integrated system rather than a collection of gadgets.

How the Themes Fit Together

Each theme supports the others:

- Energy affects sleep; sleep affects health; health and well being affects autonomy.
- Movement data informs safety; safety patterns inform care pathways.
- Environmental sensing supports mental health; mental health influences activity and social connection.
- Data governance underpins trust across all interactions.

The technology stack is therefore a coherent, layered system - not six disparate categories.

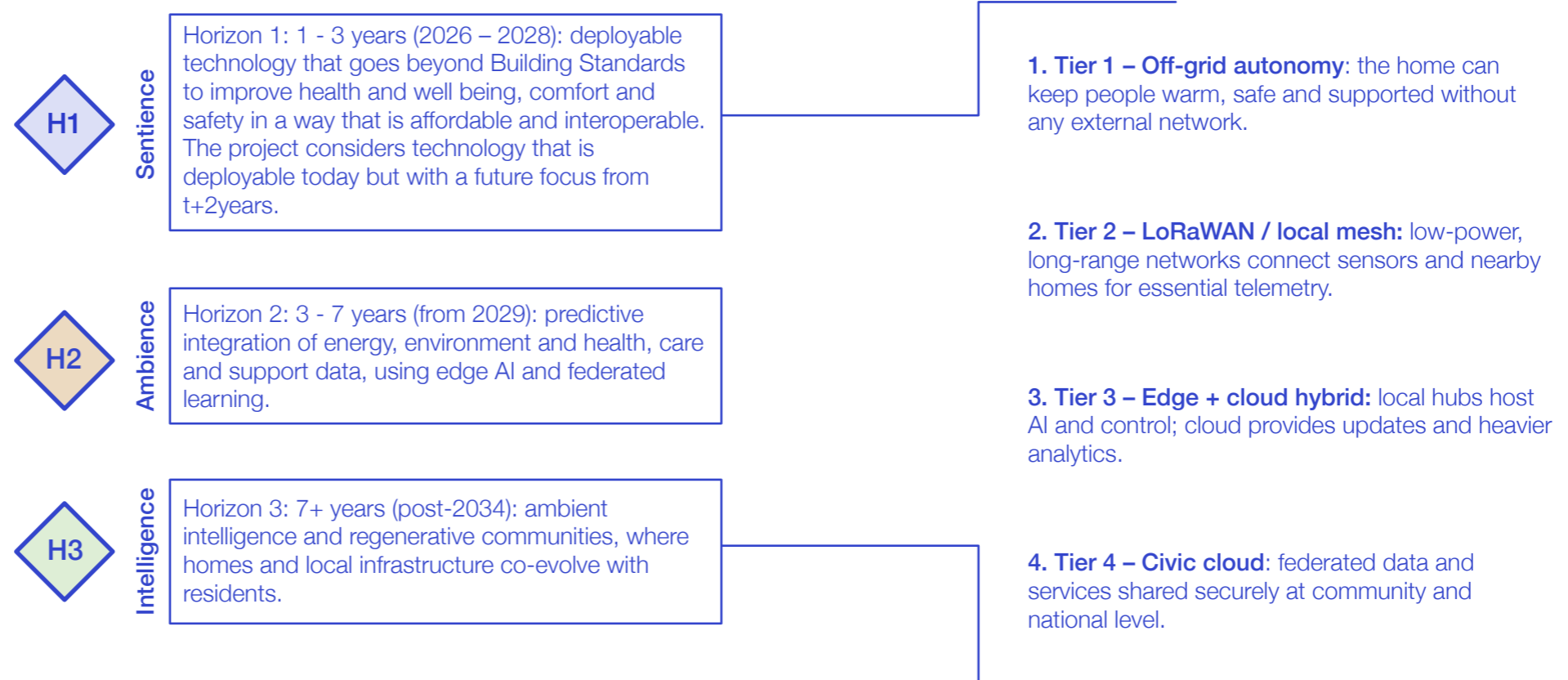
| | | | |
|--|--|--|---|
|  | <p>W1 - Energy & Comfort</p> <p>Warmth, ventilation and light underpin every other health outcome. This theme covers the systems that keep the home thermally stable, breathable and affordable to heat, while providing the data and</p> | <p>What this includes:</p> <ul style="list-style-type: none"> • Low-carbon heating (heat pumps) and intelligent emitters • CO₂ and humidity sensing for healthy air • PV integration, battery readiness, circuit-level visibility • Circadian lighting and comfort-driven automation | <p>Why it matters:</p> <p>Stable temperature, good air quality and low running costs directly reduce respiratory illness, stress and fuel-poverty impacts. A warm, dry, quiet home is a health and well being intervention</p> |
|  | <p>W2 - Environmental Health & Safety</p> <p>Environmental hazards drive some of the worst outcomes in rural and low-income housing - damp, mould, falls, leaks, cold spots, poor ventilation. This theme focuses on detecting and preventing these issues early.</p> | <p>What this includes:</p> <ul style="list-style-type: none"> • Leak, freeze, damp and mould sensors • Temperature gradients and airflow monitoring • Door, motion and pressure sensors for night-time safety • Smart ventilation and building-physics models | <p>Why it matters:</p> <p>A small change in humidity can prevent a hospital admission. A leak sensor can prevent thousands in damage. Night safety lighting reduces falls. The preventative value here is large and immediate.</p> |
|  | <p>W3 - Physical Health Monitoring</p> <p>The home becomes a gentle health companion, not a clinic. This theme supports early identification of deterioration, better self-management and low-friction communication with health services.</p> | <p>What this includes:</p> <ul style="list-style-type: none"> • Wearables, sleep sensors and basic vitals stations • Hydration and nutrition cues • Bathroom-integrated monitoring (future) • Patterns of activity and rest | <p>Why it matters:</p> <p>Sleep regularity, HRV, movement and hydration are early signs of physical decline or increased stress. Tracking these unobtrusively supports prevention and timely help.</p> |
|  | <p>W4 - Care & Autonomy</p> <p>Homes should support independence at every stage of life. This theme focuses on the technology that assists daily living, reduces risk and supports ageing in place without institutionalising the home.</p> | <p>What this includes:</p> <ul style="list-style-type: none"> • Panic buttons, voice control, scheduled check-ins • Movement-linked lighting for safe navigation • Early assistive robotics and retrieval tools • Later: embodied AI companions | <p>Why it matters:</p> <p>Independence is a health and well being outcome. Reducing risk and enabling autonomy preserves dignity and reduces the burden on formal health and care.</p> |
|  | <p>W5 - Mental Health & Flourishing</p> <p>Mental wellbeing is shaped by the environment: light, sound, connection, routines, and opportunities for creativity and purpose. This theme focuses on nurturing those aspects.</p> | <p>What this includes:</p> <ul style="list-style-type: none"> • Circadian and mood-responsive lighting • Simple voice-based reflection and mood check-ins • Community mesh apps, local events and social touchpoints • Biophilic design prompts, garden-tech, creative interfaces | <p>Why it matters:</p> <p>Loneliness, stress and a lack of meaningful engagement are major contributors to poor health. Homes that foster connection and creativity improve resilience and prevent decline.</p> |
|  | <p>W6 - Data & Governance</p> <p>Everything in the home only works if residents trust it. This theme sets the rules for privacy, autonomy, data flow and ethical use, alongside the edge-cloud architecture that keeps data safe and local.</p> | <p>What this includes:</p> <ul style="list-style-type: none"> • Local edge hub and resident dashboard • Consent controls, data minimisation, privacy UX • Federated learning for predictive analytics • Civic-scale data models for community benefits interfaces | <p>Why it matters:</p> <p>Strong governance ensures that the home serves the resident, not the other way around. Without clear data ethics, nothing in the stack is acceptable at scale.</p> |

Horizons + connectivity tiers

Three horizons and four connectivity tiers

The programme uses three time horizons, anchored to where we are now (March 2026):

Beneath these horizons sits a connectivity hierarchy tailored to rural reality:



Horizon 1 must be fully viable at Tiers 1–2, with optional Tier 3. Horizon 2 depends on a robust Tier 3. Horizon 3 adds Tier 4 for population-level optimisation while preserving local autonomy.

Connectivity hierarchy

Connectivity Hierarchy - Connectivity in rural Scotland is uneven, fragile and often expensive. A home that relies entirely on cloud services or uninterrupted broadband is a home designed to fail. The Smart Rural Home of the Future therefore uses a resilience-first connectivity hierarchy. Each tier builds on the one below it, ensuring essential functions work even when the wider network does not.

This hierarchy underpins all technology decisions across Horizons 1–3.

How the Tiers Interact

- Tier 1 ensures that no home becomes unsafe when connectivity drops.
- Tier 2 provides rural-range sensing and cross-property awareness.
- Tier 3 brings intelligence, prediction and integration.
- Tier 4 extends the home into a community-scale wellbeing and energy system.

The hierarchy ensures resilience at the bottom and innovation at the top.

Tier 1 (T1)

Off-Grid Autonomy

Definition:

The home can operate its essential systems without any external data or power connection.

Typical components:

- Battery + PV or micro-grid input
- Local Wi-Fi, Bluetooth, Zigbee/Matter, direct sensor → hub links
- Local automation for heat, ventilation, lighting and safety

Supported functions:

- Heating and ventilation control
- CO₂/humidity responses (boost, vent, damp prevention)
- Panic buttons, fall alerts, leak alarms
- Basic local health and well being nudges (sleep, comfort)

Design principle:

Essential functions must continue for at least 72 hours even if broadband fails.

Horizon alignment:

Mandatory foundation for H1 (2–5 years); persists through all horizons.

Tier 2 (T2)

LoRaWAN / Local Mesh

Definition:

A low-power, long-range network that connects sensors within the home, across a cluster of homes, or within a rural community.

Typical components:

- LoRaWAN gateways (single dwelling or shared)
- Sub-GHz mesh networks
- Basic telemetry routing and redundancy

Supported functions:

- Damp/mould monitoring across dispersed rooms or buildings
- Movement sensors, door sensors, temperature nodes
- Environmental sensing in outbuildings, gardens and shared spaces
- Community signalling (alerts, maintenance triggers)

Design principle:

Low bandwidth, high resilience. Prioritise reliable telemetry over speed.

Horizon alignment:

Core infrastructure for H1 (2–5) and extended across H2 (5–10) for predictive maintenance.

Tier 3 (T3)

Edge + Cloud Hybrid

Definition:

Local edge compute hosts automation and privacy-sensitive logic. Cloud is used only for storage, updates and heavier analytics.

Typical components:

- Edge server or advanced home hub
- MQTT/HTTPS bridges
- Local processing of AI models
- Periodic syncing to cloud

Supported functions:

- Home Operating System coordinating heat, IAQ, energy and lighting
- Ambient health analytics combining environment, sleep and behaviour
- Early predictive maintenance (moisture models, heat loss patterns)
- Local digital twins for comfort/energy optimisation

Design principle:

Local first, cloud second. Sensitive data (movement, health and care, routines) should be processed on the edge, not streamed.

Horizon alignment:

Becomes essential for H2 (5–10) as predictive intelligence comes online.

Tier 4 (T4)

Full Cloud / Civic Mesh

Definition:

Federated, secure data-sharing across homes, communities, local authorities and health systems. Designed for collective outcomes, not individual device control.

Typical components:

- Federated data platforms
- Secure APIs to health, care, energy and housing partners
- Civic data cooperatives or DAOs
- Regional energy markets and digital twins

Supported functions:

- Community energy optimisation
- Population-level damp/mould and IAQ risk prediction
- Virtual wards and home-based clinical pathways
- Collective wellbeing analytics and local resilience planning

Design principle:

Cloud and civic data must serve communities and residents - not replace local autonomy or create new vulnerabilities.

Horizon alignment:

Required for H3 (10+) once the foundations of H1 and H2 are stable.

Capability evolution summaries

The Smart Rural Home evolves in layers. Horizon 1 establishes the baseline: the sensors, safety systems and energy core that make the home healthier from day one. Horizon 2 adds intelligence; systems that learn, anticipate and coordinate. Horizon 3 extends the home into a regenerative, community-scale ecosystem.

These can be applied across both the Blueprint example and to existing properties.

In Short

- H1 makes the home smarter and healthier.**
- H2 makes the home intelligent.**
- H3 makes the home part of a regenerative community.**



1. Energy & Comfort

H1: Low-carbon heat, CO₂ and humidity sensing, PV-readiness, simple automation. Homes actively prevent damp and maintain comfort with minimal resident effort.

H2: A Home Operating System coordinates heating, ventilation, lighting, PV and battery. Digital twins predict comfort, running costs and thermal behaviour.

H3: Regenerative micro-grids, seasonal storage and adaptive materials that modulate light, heat and moisture. Homes become contributors to local resilience.



2. Environmental Health & Safety

H1: Leak, damp, mould and IAQ sensors catch issues early. Movement and door sensors improve night safety.

H2: AI moisture and airflow models forecast problems days or weeks ahead. Buildings self-adjust in response to risk.

H3: Bio-reactive and self-healing materials become part of the home fabric, continuously managing moisture, temperature and building fabric health.



3. Physical Health Monitoring

H1: Basic vitals (sleep, HRV), simple wearables, hydration prompts, and movement patterns to detect early decline.

H2: Ambient analytics fuse environment, behaviour and physiology into early warnings. Virtual care pathways integrate directly with health services.

H3: Home-embedded digital clinics: biosensing surfaces, continuous monitoring, autonomous triage tools that support clinicians and residents alike.



4. Care & Autonomy

H1: Panic buttons, scheduled check-ins, voice control and movement-linked lighting for independence.

H2: Assistive robotics support mobility and daily tasks. Early warning systems flag functional decline.

H3: Embodied AI companions combine physical assistance with emotional presence, supported by strong safeguarding and ethics frameworks.



5. Mental Health & Flourishing

H1: Circadian lighting, local prompts, simple voice reflection, community-mesh apps and garden-tech nudges.

H2: Emotion-aware lighting, sound and environment; skill-exchange platforms and adaptive biophilic design.

H3: Collective AI companions and experiential creation hubs allow communities to grow, learn and socialise through shared digital and creative spaces.



6. Data & Governance

H1: Local edge processing and resident dashboards ensure privacy and transparency.

H2: Federated learning enables prediction without centralising sensitive data.

H3: Civic data cooperatives allow communities to share value securely - from energy flexibility to wellbeing insights.

Retrofit + monitoring

While the Smart Rural Home of the Future is presented as a new-build blueprint, its underlying architectural and digital principles are equally applicable — and arguably more urgent — within existing housing stock. Given that around 80% of the buildings that will be occupied in 2050 already exist, retrofit is not a parallel agenda but a primary area for immediate focus. The challenge is to translate a systems-based, health and care-informed and digitally enabled approach into the complexity of diverse, lived in, and ageing buildings.

PAS 2035, a Publicly Available Specification guide to energy retrofit of domestic buildings, provides the essential framework. Whilst not formally adopted in Scotland, its whole-dwelling, fabric-first methodology, underpinned by risk assessment, condition surveys, occupancy evaluation and medium-term retrofit planning, aligns closely with our overarching preventative ethos. Rather than prescribing standardised measures, PAS 2035 requires the Retrofit Coordinator to understand how a home is actually used: occupancy patterns, heating behaviours, moisture loads, ventilation routes, vulnerabilities and constraints. This is critical. Two visually identical homes can perform very differently depending on construction, orientation, previous maintenance, household composition, fuel poverty risk, an occupants health status and daily routines within the home.

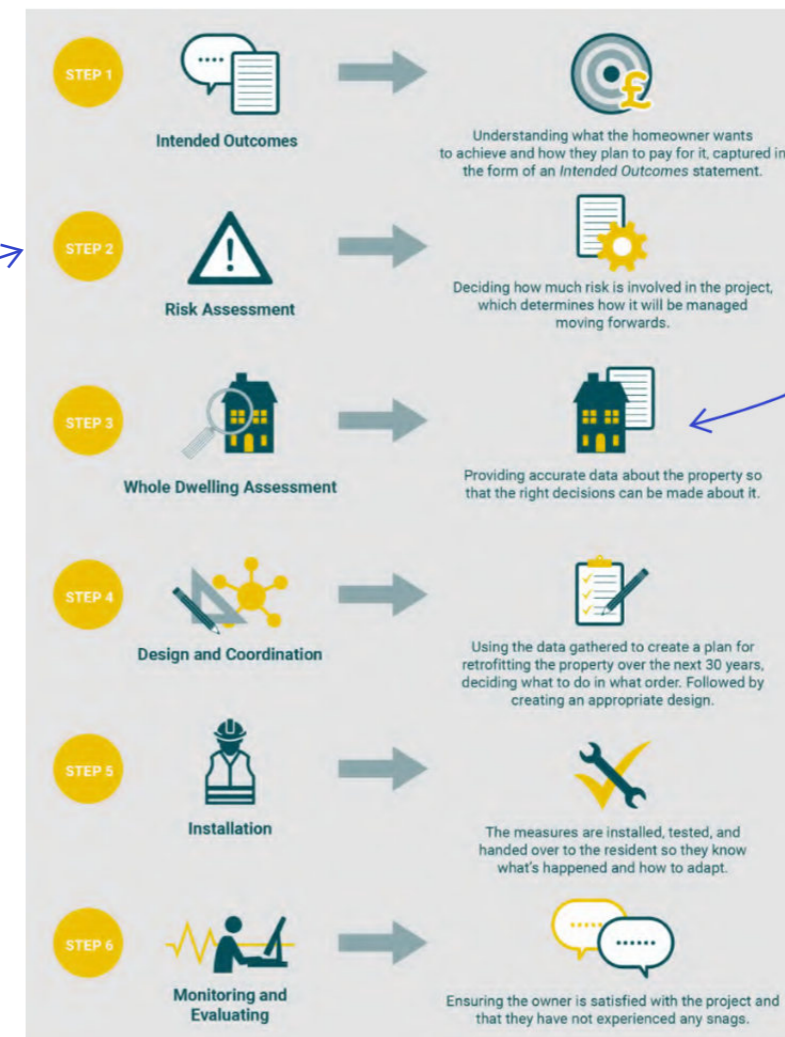
In this context, environmental monitoring becomes a diagnostic tool rather than an add-on. Continuous sensing of temperature gradients, humidity, CO₂, appliance loads and movement patterns enables the identification of targeted interventions: a ventilation upgrade in one dwelling, insulation measures in another, heating controls optimisation elsewhere. It supports strategic sequencing — addressing moisture risk before insulation, improving airtightness alongside ventilation and avoiding unintended consequences.

Industry best practice increasingly recognises that retrofit must be iterative, measured and resident-centred. A one-size-fits-all specification risks under performance or harm. By embedding local-first digital infrastructure and governance within a PAS 2035 workflow, retrofit can become adaptive: homes learn from use, coordinators adjust pathways, and investment could be directed to where it has the greatest health and well being, carbon and resilience impact.

Utilised in this way, the blueprint's approach methodology and technology stacks evolve from a model home into a scalable methodology for upgrading Scotland's existing housing stock.

Technology stack solutions and Retrofit ease assessment (please refer to Envision Matrix for the Technology Stacks and the Retrofit Ease score)

Tech stack monitoring



PAS 2035 Workflow Diagram

Affordability + standards

Affordability is central to the Smart Rural Home blueprint. The aim is not to create a high-spec concept home, but a repeatable, scalable, financially realistic approach that improves health and well being outcomes without inflating build costs or excluding low-income households.

A key design constraint is affordability. Horizon 1 is explicitly defined as:

The minimum range of coherent smart stacks above Scottish Building Standards that clearly improve health and social care, and is financially defensible.

Technologies are grouped into bundles (e.g. “Safety+”, “Comfort & IAQ”, “Basic TEC”) with indicative cost bands and high-level payback views. Some bundles – such as leak and damp sensors, improved controls and basic TEC – fall in the “low” cost band and are expected to pay back quickly through avoided repairs and reduced crises. Others, such as circadian lighting or wearables, are treated as optional enhancements or more likely to be funded from health and care budgets.

Horizons 2 and 3 are framed not as mandatory hardware upgrades but as service layers and R&D pathways, building on the infrastructure laid down in Horizon 1.

We therefore compare each major capability bundle against the minimum Scottish Building Standards (SBS) baseline. The question is always the same:

What are we adding, why does it matter, and does it pay for itself in health and well being or maintenance outcomes?



1. Energy & Comfort Bundles

E1 – Low-Carbon Energy Core

Heat pump, smart controls, PV-ready wiring.

SBS: Low-carbon heat expected; PV optional.

Incremental cost: Medium–High depending on PV/battery.

Value: Lower bills, better EPC, reduced fuel poverty risk.

Affordability view: Strong case for social landlords, self-build, SME developers; supported by grants.

E2 – IAQ & Damp Prevention

CO₂ + humidity sensors, automated ventilation.

SBS: No IAQ sensors; basic ventilation only.

Incremental cost: Low–Medium.

Value: Prevents damp/mould, reduces respiratory harm, cuts repairs.

Affordability view: High ROI; essential for social landlords and retrofit.

E3 – Demand Visibility

Circuit-level metering, smart plugs.

SBS: Not required.

Incremental cost: Low.

Value: Behavioural energy savings; supports budgeting and fuel-poverty reduction.

Affordability view: Easy inclusion across all segments.



2. Environmental Health & Safety Bundles

S1 – Safety Plus

Leak sensors, damp/mould alerts, enhanced smoke/CO.

SBS: Smoke/CO required; leak/damp alerts not required.

Incremental cost: Low.

Value: Avoids major damage and repairs; improves safety.

Affordability view: Strongest cost–benefit of the entire stack.

S2 – Movement & Falls Prevention

Door/motion/pressure sensors; linked night lighting.

SBS: No requirements.

Incremental cost: Low–Medium.

Value: Falls prevention, safer night-time movement.

Affordability view: Essential in supported housing; optional in general needs.

4.7 - Technology blueprint



3. Physical Health Bundles

H1 – Everyday Health and Well Being

Sleep sensors, basic vitals, hydration cues.

SBS: Not addressed.

Incremental cost: Medium.

Value: Early detection of decline; improved self-management.

Affordability view: Best funded jointly with health/care budgets.



4. Care & Autonomy Bundles

C1 – Basic TEC

Panic buttons, voice control, scheduled check-ins.

SBS: Not addressed.

Incremental cost: Low.

Value: Maintains independence; reduces emergency risk.

Affordability view: Standard in social landlord supported housing; easy inclusion in new build.



5. Mental Health & Flourishing Bundles

M1 – Light & Sound

Circadian lighting, calming soundscapes.

SBS: Illuminance only.

Incremental cost: Medium.

Value: Better sleep, reduced stress, improved mood.

Affordability view: Optional upgrade; targeted use in retrofits and small developments.

F1 – Community & Nature

Community mesh app, garden-tech prompts, local events.

SBS: Not covered.

Incremental cost: Low.

Value: Tackles loneliness; strengthens social connection.

Affordability view: Low cost, high social value; strong fit for rural pilots.



6. Data & Governance Bundles

D1 – Local Edge Hub

Local compute, privacy controls, resident dashboard.

SBS: No requirements.

Incremental cost: Low–Medium.

Value: Enables all other digital capabilities; protects privacy; future-proofs the home.

Affordability view: Foundation investment; cost spread across multiple bundles.

Affordability Summary in One View

- Low-cost, high-value bundles: IAQ/damp prevention, leak detection, safety+, movement sensors, local edge hub.
- Medium-cost but essential for future horizons: smart controls, circadian lighting, basic TEC, sleep/vital sensing.
- High-cost, high-return: PV + battery (where viable), advanced edge hardware (Preparation for H2).
- Best funded centrally: predictive analytics (H2), connectivity upgrades, health-support features for high-risk groups.

Why Statutory Standard Comparison Matters

Scottish Building Standards describe a minimum viable home.
The Smart Rural Home describes a minimum healthy home.

The gap between the two is where health inequalities can either be entrenched or reduced. The additions proposed in Horizon 1 are low-cost, high-return and immediately deployable. They represent a pragmatic uplift, not a technology-heavy leap.

Sensor list example

Lists for schematic based on Tier 1 / 2 connectivity



W1. Environmental & Energy

- CO₂ sensors (bedrooms + living room)
- Temperature sensors (all rooms)
- Humidity sensors (bathroom, kitchen, cold spots)
- Surface temperature probes (optional but recommended for mould accuracy)
- External temp/humidity sensor
- Ventilation event sensors (extractor, room pressure, door contact)
- Smart meter integration
- Circuit-level metering
- Appliance load monitoring (fridge, cooker, washing machine)
- ASHP temperature monitoring
- Hot water outgoing temp sensor



W2. Safety

- Smoke / CO alarms
- Leak sensors (kitchen sink, bathroom, hot water

cylinder, washing machine)

Movement & Behaviour

- Motion sensors (living room, hallway, bedrooms)
- Door/contact sensors (front/back doors)
- Night-path lighting triggers
- Gait-change detection (higher sampling motion in hallway)
- Kitchen event signatures (via appliance load)



W3. Physical Health

- Sleep sensor (non-contact radar or bed sensor)
- HRV-capable wearable (integration, not provided)
- Bathroom vitals station (weight, BP)
- Wearables / mobile sensors



W4. TEC / Autonomy

- Panic button(s)

- Voice interface device
- "I'm OK" check-in device or voice cue



W5. Mental Health & Flourishing

- Circadian lighting (tunable white)
- Light-level sensor (daylight exposure)
- Ambient sound device
- Home tablet / community engagement endpoint
- Garden-tech sensor (soil moisture/plant care)
- Creative interface device (tablet, MIDI, etc.)



W6. Data & Network

- Edge compute hub (Wi-Fi, BLE, Thread/Zigbee built-in)
- Optional LoRaWAN gateway (for clusters or outbuildings)

Digital architecture

Digital Blueprint Architecture

The Smart Rural Home of the Future depends on a digital ecosystem that is resilient, private, simple to operate and capable of evolving across the three Horizons. The architecture follows a “local-first, cloud-optional” model: the home retains its essential functionality even when broadband fails, and only higher-order intelligence reaches the cloud.

This section describes the layers, data pathways and architectural principles that allow sensors, predictive models, care features and energy systems to act as one coherent system.

4.9.1 The Home Operating System (HOS)

The Home Operating System is the quiet brain of the house. It sits on a low-power edge compute hub in a central cupboard, orchestrating the home’s environment, safety and wellbeing data.

Roles of the HOS

- Unifies all sensors (IAQ, movement, damp, sleep signals)
- Runs local automation (ventilation boosts, night lighting, temperature stability)
- Applies H2 predictive models locally without exporting raw data
- Manages device interoperability (Matter, Zigbee/Matter-over-Thread, LoRaWAN, Wi-Fi)
- Handles consent and privacy at the edge, not in the cloud

Why this matters

A rural home must continue to operate if connectivity fails. The HOS ensures:

- Heating still works
- Damp prevention still runs
- Safety still triggers
- Sleep/air-quality routines still optimise
- TEC and check-in functions remain available

This is the foundation of Horizon 1 and the enabler of Horizons 2–3. See appendix A of this document for a comparative affordability analysis.

4.9.2 Data Flow & Privacy Model

Data is treated like water: it should flow only where needed and no further.

Local-First Model

All sensitive data (movement, sleep patterns, routines, IAQ, sentiment cues) stays on the edge device. The HOS performs:

- Raw signal ingestion
- Feature extraction
- Predictive modelling
- Pattern recognition
- Automation & nudging decisions

Cloud as a Service Layer

Only non-sensitive, aggregated or anonymised data is sent to secure cloud endpoints for:

- Software updates
- Model improvements
- Asset management (leak events, damp alerts)
- Optional resident dashboards
- Community-level wellbeing insights (H3, fully consented)

Federated Learning (Horizon 2–3)

Models improve across many homes without sharing raw data. Only model weight updates move upward — keeping the home private while enabling collective intelligence.

Consent & Control

Residents see:

- What data is collected
- What stays local
- What can be shared with landlord / community / health and care services

Every flow is opt-in, transparent and reversible.

4.9 - Technology blueprint continued ...

4.9.3 Integration & Device Layer

A smart home fails when it becomes a collection of incompatible products. The SRHoTF solves this through interoperability:

Device Standards Supported

- **Matter** (mainstream devices, lighting, plugs, switches)
- **Zigbee** / Thread (low-power local mesh)
- **LoRaWAN** (long-range environmental sensors)
- **Wi-Fi** (high-bandwidth devices, HOS connectivity)
- **Bluetooth LE** (sleep sensors, wearables)

Integration Principles

- Avoid vendor lock-in
- Use open, well-adopted standards
- Keep device logic simple; intelligence sits on the HOS
- Allow drop-in replacements without re-engineering the home

The integration layer ensures that a £12 humidity sensor and a £500 environmental monitor both plug into the same system without friction.

4.9.4 Community & Provider Interfaces

The home never broadcasts raw data. Instead, it offers **three controlled interfaces**:

1. Resident Dashboard (H1–H3)

Shows the simplest possible view:

- Air quality
- Temperature & energy use
- Sleep environment
- Routines & small nudges
- Device management

2. Landlord / Asset Management View (H1+)

(Only when resident opts in)

- Damp/mould alerts
- Leak detection
- Under-heating signals
- Appliance failure prediction
- Long-term ventilation profiles
- Stock-level patterns for maintenance planning

3. Health & Care Pathways (H2–H3)

(Strict consent required; never automatic)

- Recovery patterns
- Sleep quality
- Respiratory risk signals
- Mobility trends
- Cognitive engagement drift

This enables virtual wards, community wellbeing programmes, and cost-effective early intervention in Horizon 3.

4.9.5 Safeguarding, Security & Resilience

The architecture is designed around the assumption that rural connectivity can fail and that vulnerable residents need a fail-safe baseline.

Edge-Level Resilience

- Local automation continues with no broadband
- Panic buttons work locally
- Heating and ventilation controls stay active
- Local logs stored for up to 72 hours

Security Model

- Hardware-level encryption on the HOS
- Tamper detection for key devices
- Secure boot & signed firmware
- Separate networks for guest Wi-Fi and home control
- LoRaWAN secured with AES-128/256

Emergency Fallback Behaviour

If the system detects:

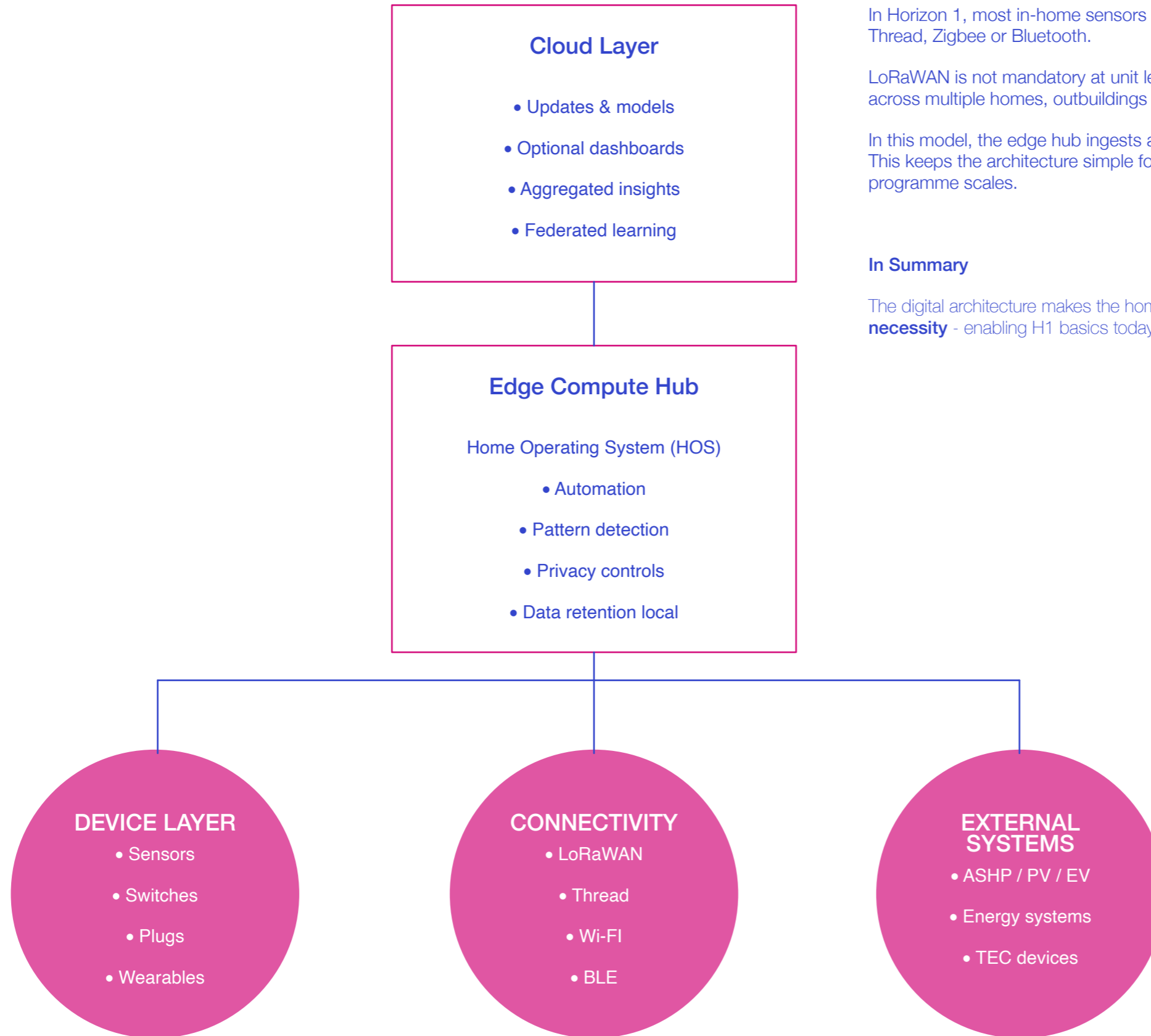
- Broadband loss
- Power fluctuations
- Sensor anomalies
- High-risk environmental patterns

It shifts into **Safe Mode**:

- Minimal automation continues
- Heating/ventilation moves to safety presets
- Battery backup engages (if fitted)
- Tenant is notified via light or speaker

4.9 - Technology blueprint continued ...

4.9.6 Architecture



4.9.7 Connectivity Rationale

In Horizon 1, most in-home sensors can be served by Wi-Fi and low-power short-range protocols such as Thread, Zigbee or Bluetooth.

LoRaWAN is not mandatory at unit level. It is introduced where it clearly adds value: shared sensing across multiple homes, outbuildings and external environments, or where multi-year battery life is critical.

In this model, the edge hub ingests all signals via a single local bus, abstracting away the underlying radio. This keeps the architecture simple for single homes, while still allowing estate-scale resilience when the programme scales.

In Summary

The digital architecture makes the home **private by default, intelligent by design**, and **resilient by necessity** - enabling H1 basics today and H3 regenerative care ecosystems tomorrow.

4.9 - Technology blueprint continued ...

Home Operating System (HOS) - Comparative Affordability Analysis

The HOS uses a single internal event bus (e.g. MQTT) with a capability-based topic structure. All radios (Wi-Fi, Thread/Matter, BLE, Zigbee and optional LoRaWAN) publish normalised sensor events onto this bus, allowing automations and predictive models to remain independent of device brand or protocol.

| Option | Horizon Fit | Typical Use | CPU / RAM | Storage | Radios | Power | Cost Band | What it Enables |
|--|--------------------------------|---|--|---------------|---|---------|-----------|---|
| HOS-1: Affordable Edge | H1 (H2-ready for light models) | Single rural home, core sensing spine | Quad-core ARM (1.5–2.0 GHz), 4 GB RAM | 16–32 GB eMMC | Wi-Fi, BLE, Thread/Matter border router (optional Zigbee) | < 10 W | £120–£250 | All H1 automations (IAQ, damp, falls, sleep env), basic predictive loops, local privacy, OTA updates |
| HOS-2: Enhanced Edge | H1 - H2 | Clusters of homes, more complex predictive models | 6–8 core ARM (A76/A55 class), 8 GB RAM | 32–64 GB eMMC | Wi-Fi, BLE, Thread/Matter, Zigbee, optional LoRaWAN gateway | 10–20 W | £250–£400 | Richer behavioural inference, multi-home analytics, estate-level damp/fuel-poverty monitoring, federated learning client |
| HOS-3: Intelligent Edge | H2 - H3 | Pilot 'lighthouse' schemes, heavy local AI | ARM/x86 with NPU or accelerator, 16 GB RAM | 128 GB+ | Wi-Fi, BLE, Thread/Matter, Zigbee, LoRaWAN | 20–40 W | £400–£700 | Local voice processing, small on-device LLMs, advanced mood/behaviour modelling, multi-home orchestration, strong H3 path |

Governance principles

The Smart Rural Home of the Future requires a governance model that is ethical, transparent and human-centred. These principles ensure technology enhances, rather than replaces, human agency; supports both individual and community wellbeing; and remains practical, repairable and resilient in rural contexts. The model distributes responsibility across residents, local care networks, housing providers and formal services, ensuring that no single actor holds undue power and that all interventions remain grounded in consent.

Resident Agency and Consent

Residents are the primary authority within the governance model. All data generated in the home is owned by the resident, processed locally wherever possible, and shared externally only through explicit, informed consent. The Home Operating System (HOS) enforces consent boundaries through local data handling, privacy dashboards and transparent permissions.

Residents may adjust or withdraw permissions at any time. No organisation - housing provider, care service, or technology partner - receives personal or behavioural data without deliberate opt-in.

Local-First Processing and Data Minimisation

To maintain privacy, resilience and autonomy, the home uses a local-first architecture. Environmental sensing, routine analysis and predictive pattern recognition are executed on the edge hub inside the home. Raw behavioural data does not leave the building unless the resident opts into sharing.

When aggregated insights are shared (for example with an RSL or telecare service), they are limited to

what is strictly necessary - such as a damp alert, a plant failure notification or a request for contact. This reduces risk, avoids surveillance dynamics, and keeps oversight proportionate.

Defined Roles and Responsibilities

Each stakeholder has a clearly bounded role:

- Residents lead decisions on data use, automation levels and external support.
- The Home Operating System acts as a coordination layer, not an overseer. It supports residents through gentle prompts, risk detection and environmental optimisation but cannot enforce behaviour or escalate without consent.
- Housing providers act only on building-related signals - damp, heating failures, leaks, ventilation issues - and do not receive personal wellbeing data.
- Health and social care services receive information only when residents explicitly choose to connect them, typically through summarised wellbeing signals rather than detailed behavioural logs.
- Community networks provide social support but have no access to individual digital records.

These boundaries ensure that governance remains relational, not supervisory.

Repairability, Resilience and Local Capability

Rural homes demand reliability and repairability. The system is therefore built on open standards, modular hardware and components that can be serviced or replaced locally. A distributed model of maintenance - using local trades, community repair hubs and simple component swaps - reduces dependency on large corporate platforms.

When digital systems fail or connectivity is lost, the home enters a safe mode: heating remains stable, ventilation continues, environmental safety alerts function and essential TEC features are preserved. The system must fail safe, not fail closed.

Cultural and Community Integration

Governance must reflect the cultural context of rural Scotland. Concepts such as ceilidh (convivial gathering) and dùthchas (belonging rooted in place) inform the design of community integration. Technology supports connection rather than isolation, encouraging participation in shared routines, mutual aid and local activity.

As the horizons progress, homes strengthen - not replace - the care networks already present in rural communities. Governance therefore incorporates both formal structures (telecare, social work, local health teams) and informal ones (neighbours, community hubs, mutual support groups).

Ethical Use of Artificial Intelligence

AI within the home must remain transparent, restrained and aligned with resident values. Systems are designed to:

- Support, not substitute, human connection
- Enhance emotional wellbeing without creating dependency
- Avoid impersonation or simulated relationships that could displace real social ties
- Provide clear explanations for prompts or automated decisions
- Keep critical functions local and under resident control

Any expansion of AI capability, especially in Horizon 3, must undergo ethical scrutiny and community review to ensure it strengthens social cohesion rather than diminishing it.

Continuous Governance Through the Horizons

As technology evolves, so must governance. Each horizon introduces increased capability alongside strengthened safeguards:

- Horizon 1: Focus on environmental safety, affordability and local consent.

- Horizon 2: Introduction of community micro-networks, shared repair culture and early collective wellbeing approaches.

- Horizon 3: Community-embedded intelligence, advanced support tools and deeper integration into local care structures - always governed by resident agency and community values.

Governance evolves at the pace communities can live with, not at the pace technology enables.

Commitment to Transparency and Trust

Every participating organisation commits to:

- Clear communication
- Open reporting of data use
- Transparent update mechanisms
- Accountable escalation pathways
- Regular co-design with residents and communities
- Published ethical standards

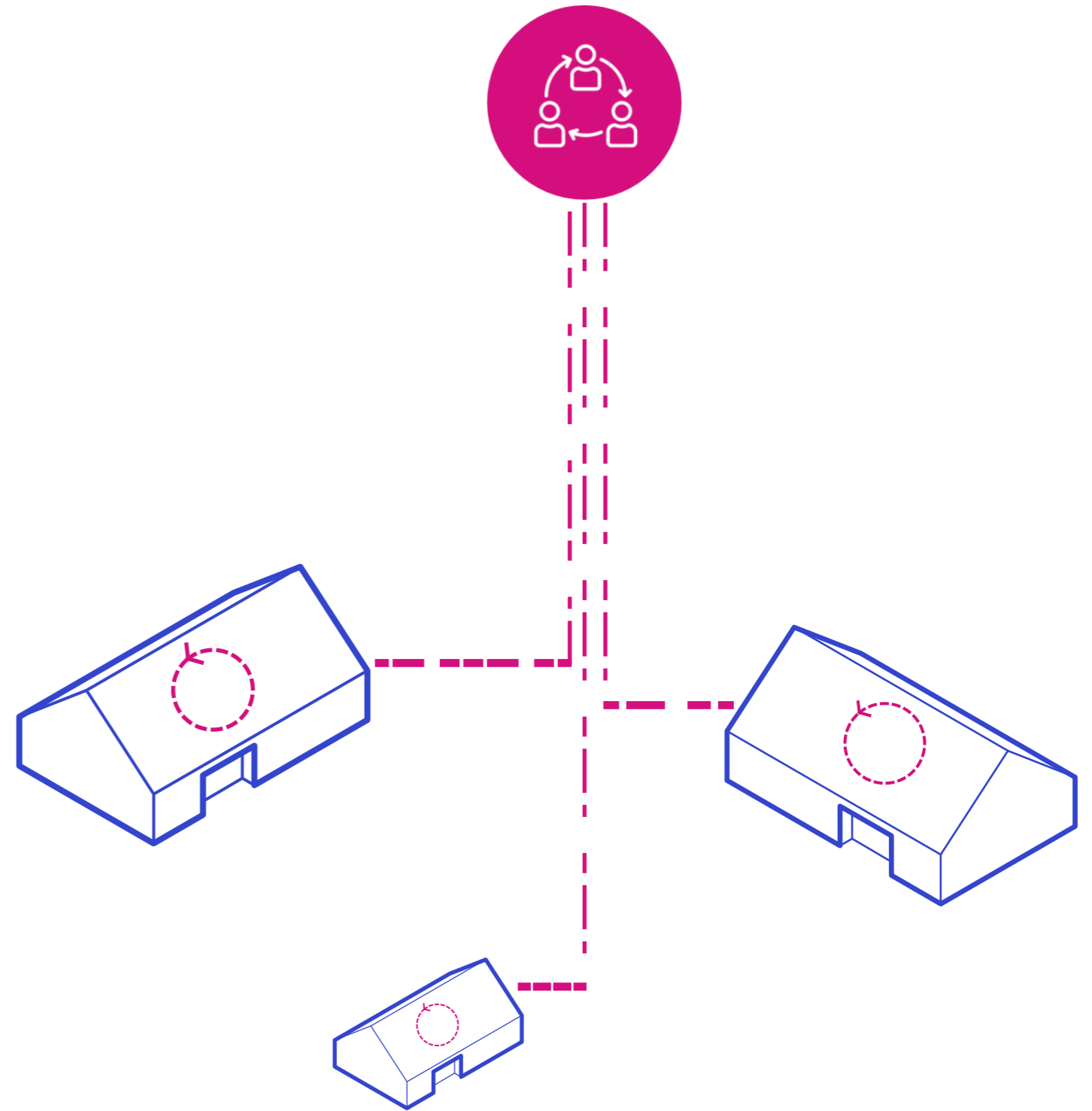
Trust is the foundational currency of the system; governance protects it.

Data & Governance

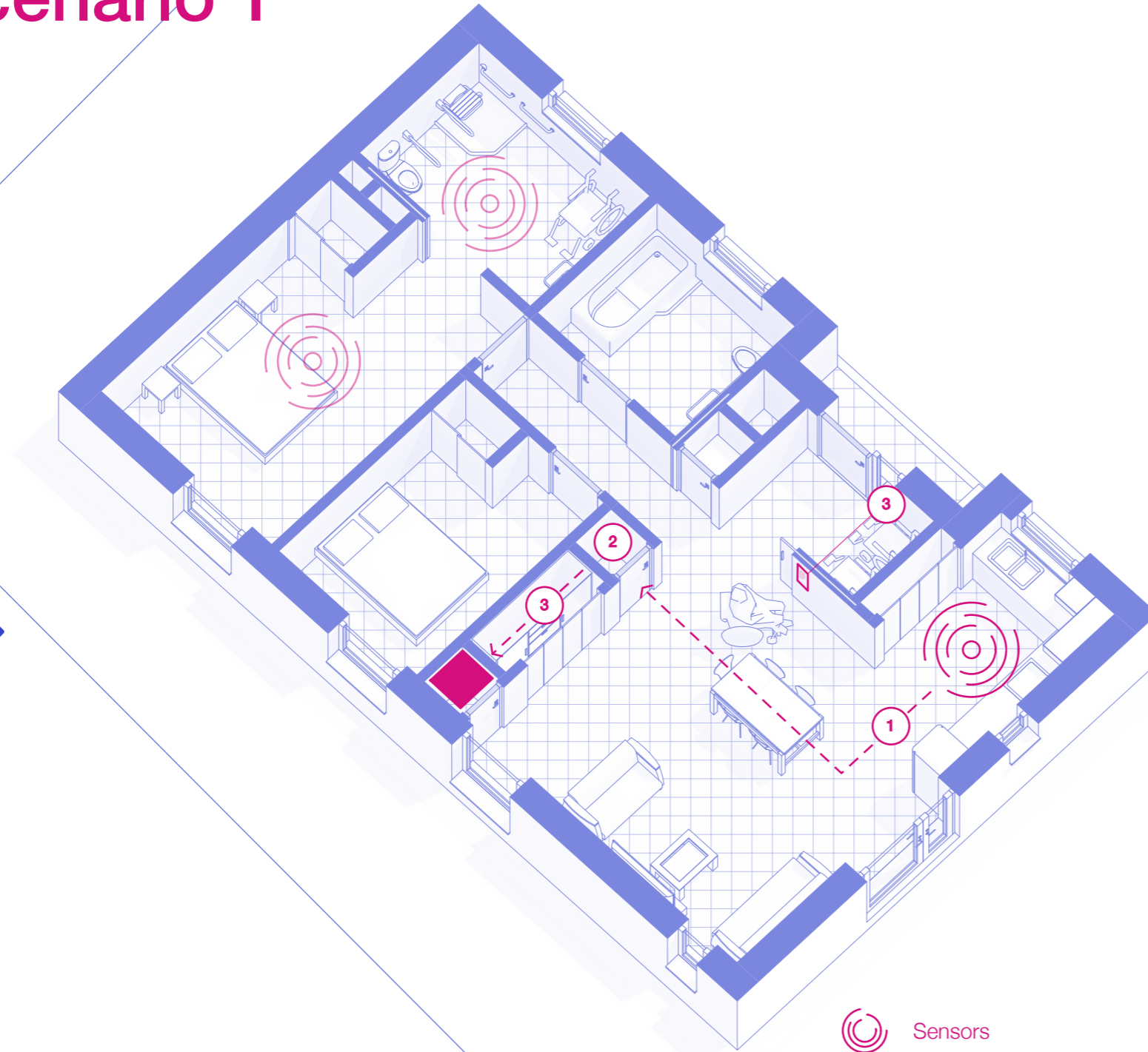
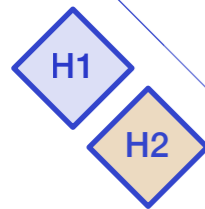
Each home starts as a self-managing environment—optimising comfort, safety, health and well being, and energy for its resident.

But at scale, these homes become a distributed intelligence layer across society. Homes evolve from passive spaces into intelligent, self-managing environments that support comfort, safety, and wellbeing in everyday life. At scale, they form a connected network that learns continuously from patterns of behaviour, health, and environment—while preserving individual privacy through consent and anonymisation. This enables a shift from reactive services to early, preventative support: identifying risks such as declining mobility, social withdrawal, or poor air quality before they escalate.

Connected homes can act as a front door to health and care systems, enabling earlier, lighter-touch interventions and supporting longer independent living. At a community level, they reveal emerging needs, strengthen local support networks, and enable more responsive services. Over time, housing becomes more than shelter—it becomes active infrastructure that contributes to public health, community resilience, and system-wide efficiency, improving quality of life not just for individuals, but across society.



Adaptive Intelligence Scenario 1



Indoor Air Quality & Moisture Risk Management

- 1 What the home sees**

Rising humidity, cooler surface temperatures, high overnight CO₂, poor ventilation, and airborne particles from cooking/cleaning that are slow to clear.
- 2 Predictive Insight**

HOS detects early patterns of moisture imbalance and air stagnation that increase risk of damp/mould formation and respiratory stress—days before visible mould or breathing issues occur.
- 3 Action**

Air and moisture levels are staying high—shall I boost airflow to improve comfort and breathing?

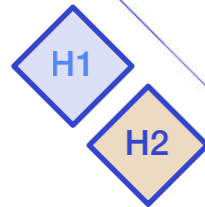
H1 - Automatically increases ventilation and airflow; prompts resident

Your air quality trend may affect breathing - adjustments made.

H2: Adjusts whole-home ventilation and heating cycles; Predictive alerts; flags persistent patterns to landlord or support teams (with residents permission).
- 4 Outcome**

Reduced respiratory symptoms, fewer damp-related repairs, improved sleep and comfort stability.

Adaptive Intelligence Scenario 2



Routine Stability & Independent Living

- 1 What the home sees**
Irregular sleep and wake times, delayed morning routines, reduced movement between rooms, longer sedentary periods, fewer kitchen interactions, and increased energy uses of appliances being left on longer than usual.
- 2 Predictive Insight**
HOS detects early routine instability—a combined signal of cognitive drift, declining mobility, and behavioural change—before noticeable health or safety issues emerge.
- 3 Action**

"Your routine shifted last night—shall I help reset your evening?"

"You've been still for a while—would you like a quick stretch?"

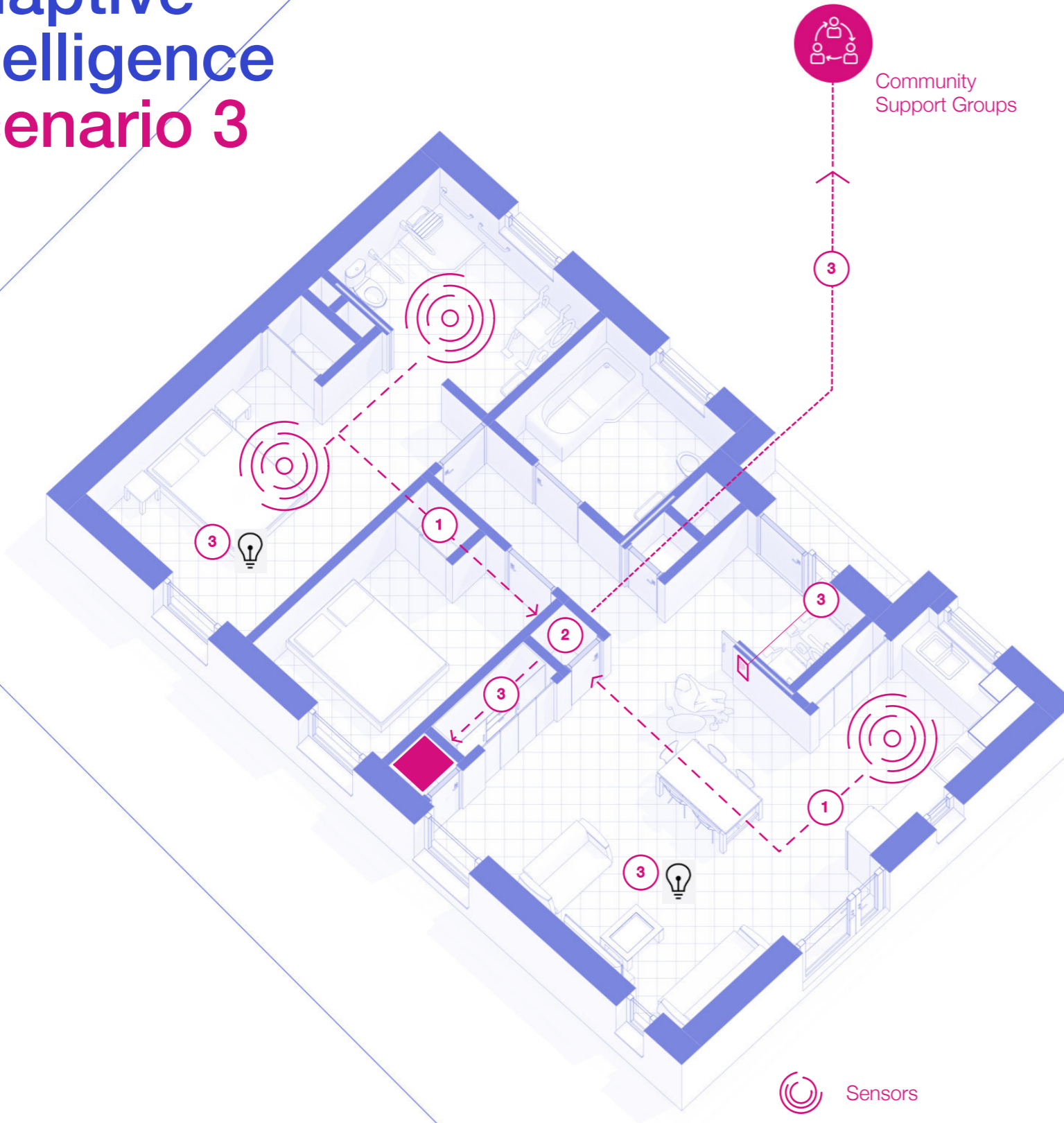
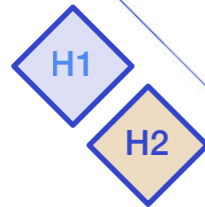
H1 - Prompts resident with gentle stabilising nudges; Adds light-touch safety awareness ("The oven has been on longer than usual—everything okay?").

"We've noticed changes in routine and movement—consider a well-being or mobility check"

H2 : Adjusts whole-home ventilation and heating cycles; Predictive alerts; flags persistent patterns to landlord or support teams.
- 4 Outcome**
Earlier support, improved routine stability, reduced safety risks, better mobility, fewer falls, and prolonged independent living.

Sensors

Adaptive Intelligence Scenario 3



Engagement Decline & Mental Health

- 1 **What the home sees**
Long sedentary periods, reduced movement between rooms, fewer trips outside, declining engagement with community or shared spaces, lower daylight exposure, quieter or flatter tone, and reduced daily activity bursts.
- 2 **Predictive Insight**
Detects early engagement decline—a combined signal of reduced mobility, social withdrawal, and mood drift—linked to increased risk of depression, cognitive decline, and loss of independence.

3 **Action**

"You've been still for a while—fancy a quick stretch?"

H1 - Provides gentle, human nudges to re-engage ("It's bright outside—would you like a short walk?" || "There's a community activity tomorrow—want the details?")

Subtly adapts the environment to support wellbeing:

- Gradually increases morning light to support natural wake cycles
- Softens lighting and reduces noise when stress signals appear
- Encourages outdoor and purposeful activity (e.g. gardening prompts)

Adds a light-touch safety layer; "I haven't seen much movement today—just checking everything is okay."

"We've noticed a sustained drop in activity and engagement—consider a wellbeing check or support option."

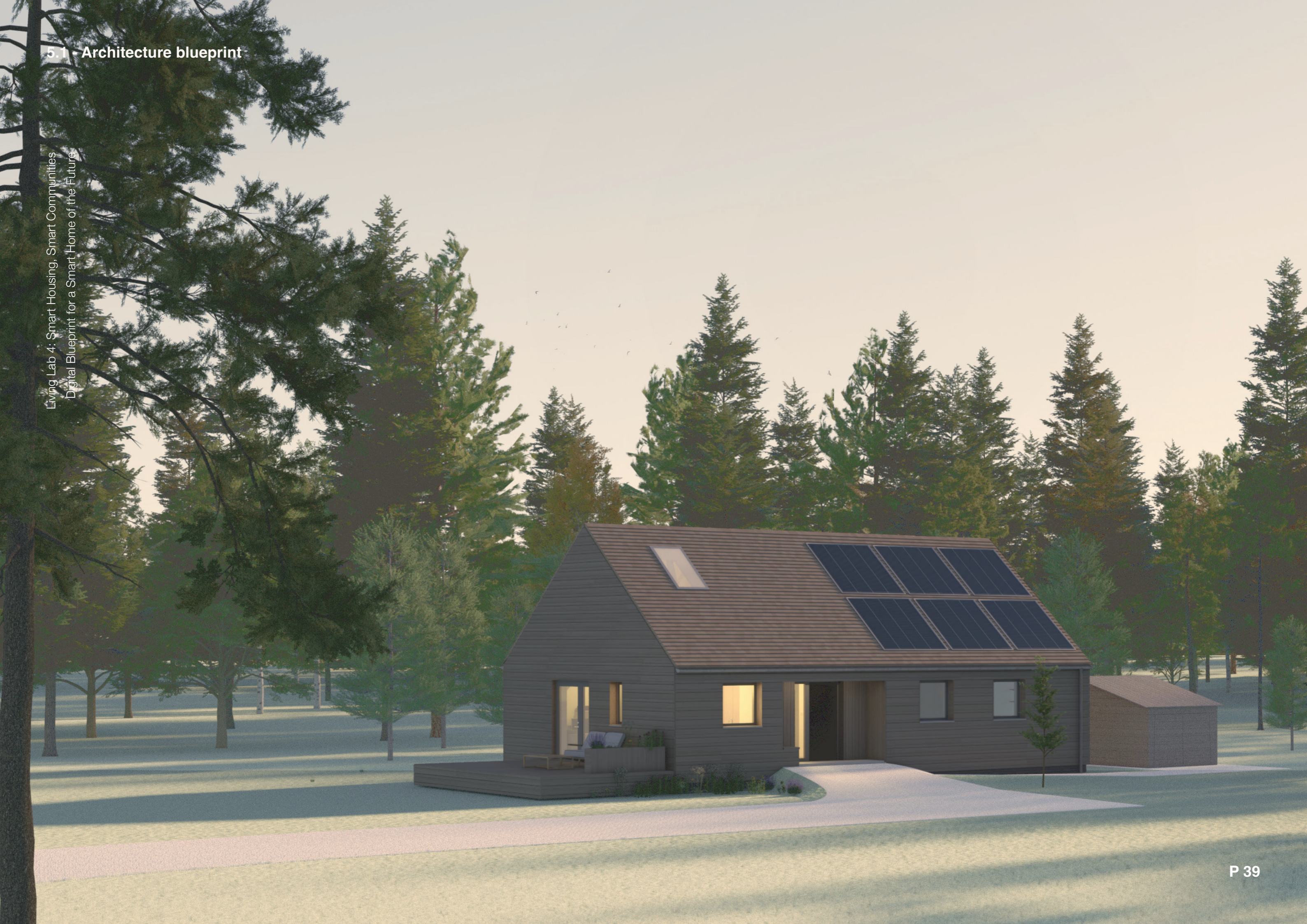
H2: Builds a longitudinal wellbeing profile: tracking mobility trends (movement, transitions), identifying social withdrawal patterns, detecting mood drift signals (low activity, low light, behavioural flattening)

With consent connects residents to wider support; prompts residents to engage "We've noticed a sustained drop in activity and engagement—consider a wellbeing check or support option"; recommends community activities and peer support opportunities; shares summaries with carers or health services (e.g. NHS pathways).

4 **Outcome**

Improved mood and motivation, stronger social connection, better mobility, reduced risk of depression and cognitive decline, and sustained independent living.

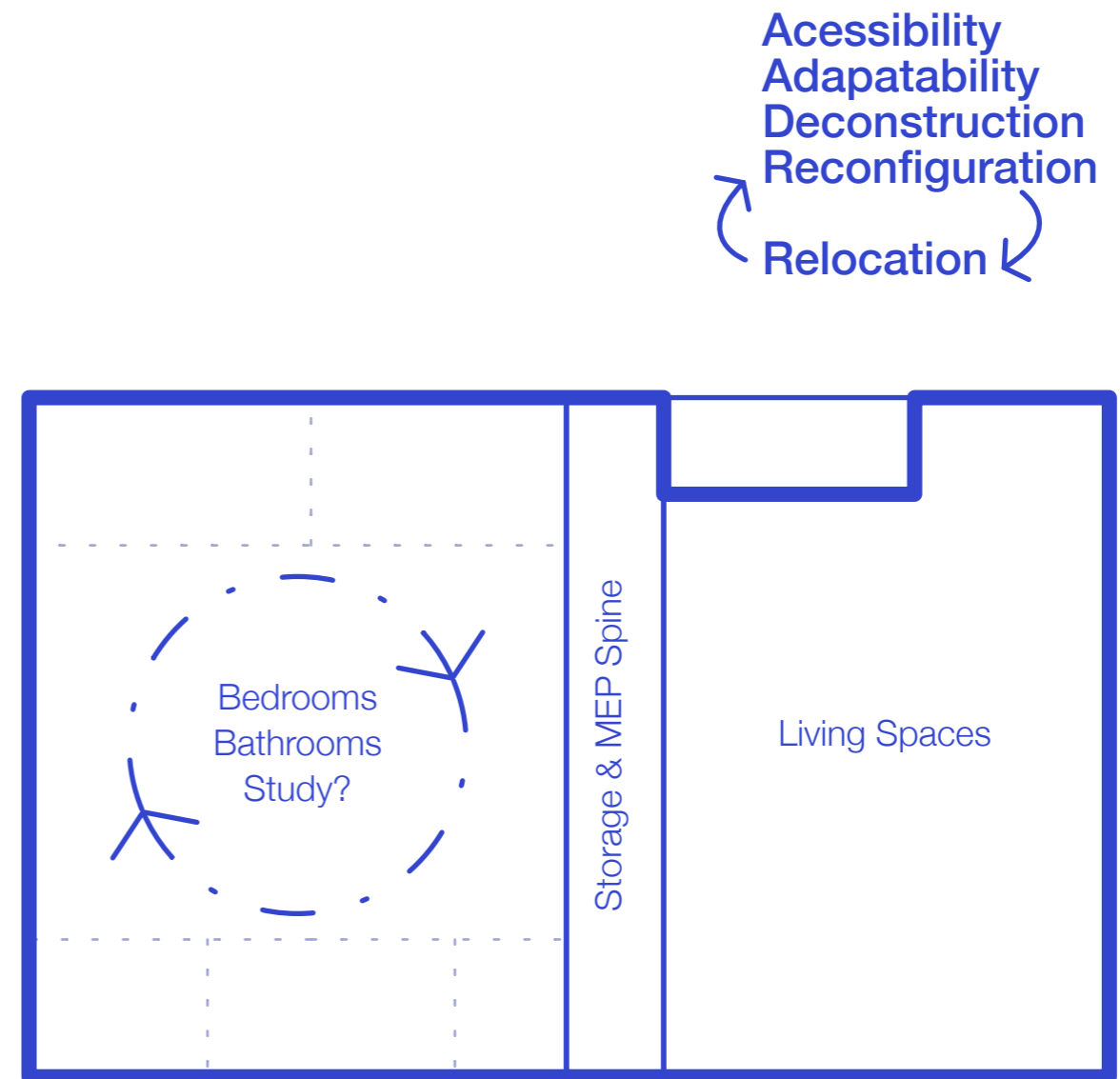
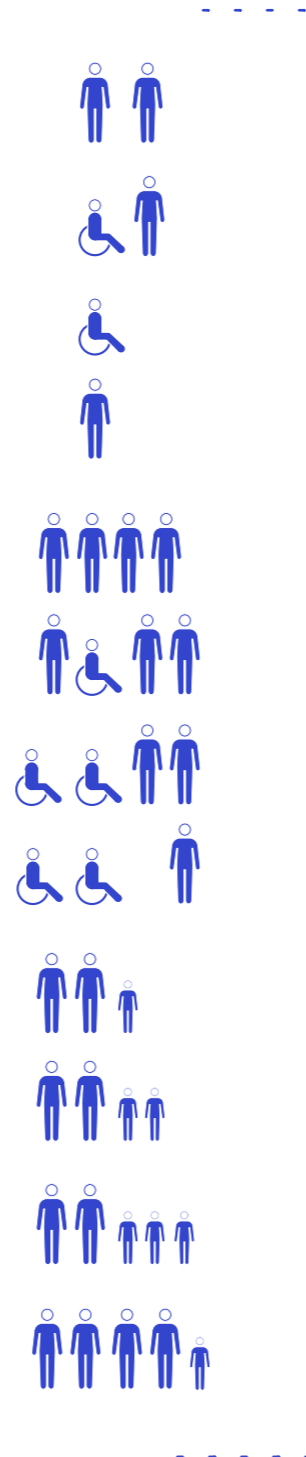
5.0 Architecture blueprint



Architectural concept

The architectural concept for the Smart Rural Home of the Future is rooted in a simple proposition: the building itself must function as an adaptable infrastructure. It is not a neutral container for technology, nor a fixed response to a single life stage or individual. It is a flexible, fabric-first structure designed to support changing physical, emotional and social needs across its lifespan, whilst meeting the environmental targets and net zero goals.

The home is conceived as a site agnostic, single-storey, two-bedroom dwelling that is inherently adaptable. Its structure anticipates internal reconfiguration, future assistive technologies, maintenance and evolving patterns of care without major retrofit disruption. Generous circulation, level thresholds, accessible bathrooms, and structural flexibility ensure alignment with emerging accessibility standards. At the same time, orientation, high-performance envelope design, and environmental control establish comfort, energy use reduction and resilience as architectural fundamentals rather than technological add-ons.



Flexibility operates at multiple scales: spatially within the plan, technically within the services strategy, and socially in how the home supports autonomy, privacy, community connection and purpose. In this way, architecture becomes the stable platform upon which digital intelligence, low-carbon systems and lifelong care can coherently evolve. Material flexibility and horizon options can be seen within the Envision Matrix Toolkit.

5.1 - Architecture blueprint

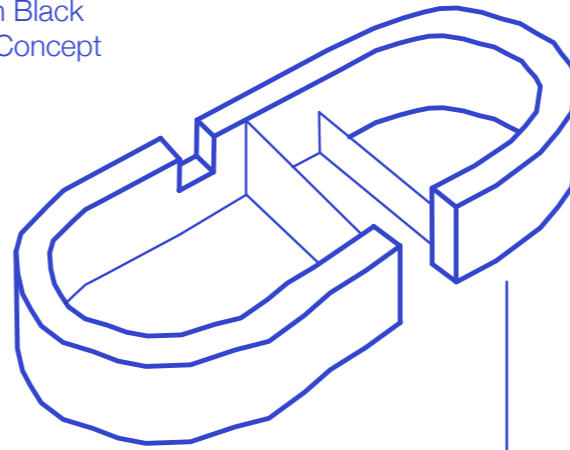
The blueprint draws on a long lineage of rural dwelling in Scotland, where architecture has historically been shaped by climate, material availability and patterns of living rather than abstract form-making. The Scottish Black House offers a clear precedent: a compact, materially grounded structure, embedded in the landscape, organised around shared function, and constructed from what was locally available. Its strength lay not in permanence of form, but in its capacity to respond—to weather, to use, and to the rhythms of everyday life.

Contemporary Scottish architecture is increasingly revisiting these principles. As explored in *New Scottish Houses: Contemporary Architecture and Living in the Landscape* by Isabelle Priest, there is a renewed focus on buildings that sit quietly within their context—working with topography, orientation and climate, and drawing on natural and locally sourced materials to reduce embodied carbon and strengthen a sense of place. Projects such as those illustrated here demonstrate a shift away from standardised suburban typologies toward more elemental forms: robust, legible volumes; simple material palettes; and a close relationship between inside and out.

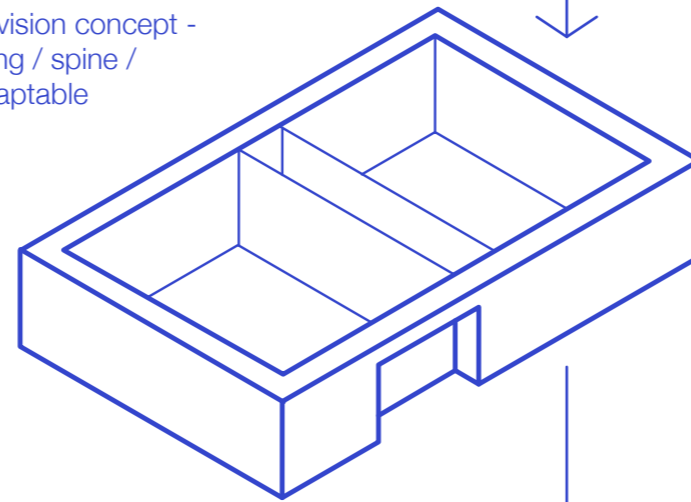
The Envision blueprint builds on this trajectory. Its form is deliberately restrained and archetypal, allowing it to be adaptable across sites while remaining responsive to local conditions. Material strategies prioritise timber, bio-based insulation and low-carbon finishes, not only for environmental performance but for their tactile and sensory qualities. The architecture is conceived as a continuation of landscape rather than an imposition upon it—anchored, sheltering, and resilient.

Therefore the proposal is not a departure from tradition, but an evolution of it: combining the spatial intelligence and material pragmatism of vernacular Scottish forms with the performance, adaptability and technology required for contemporary living.

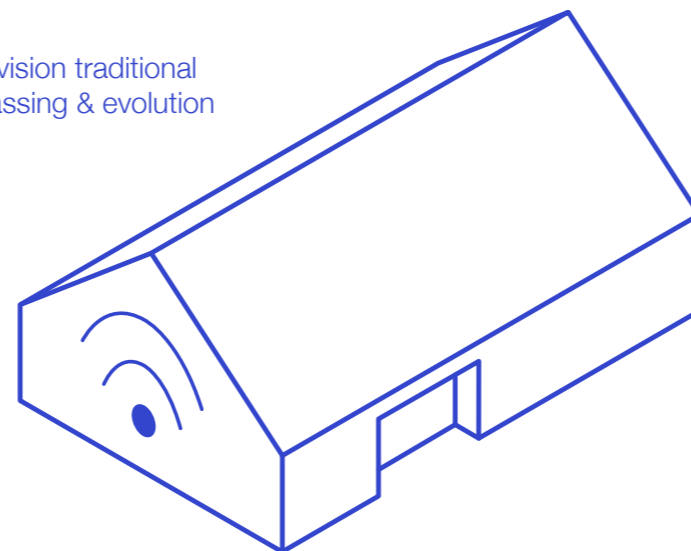
Scottish Black House Concept



Envision concept - living / spine / adaptable



Envision traditional massing & evolution



Dallas Dhu Distillery Building, Moray. Photo by Christina Gaiger



Cuddymoss by Ann Nesbit Studio

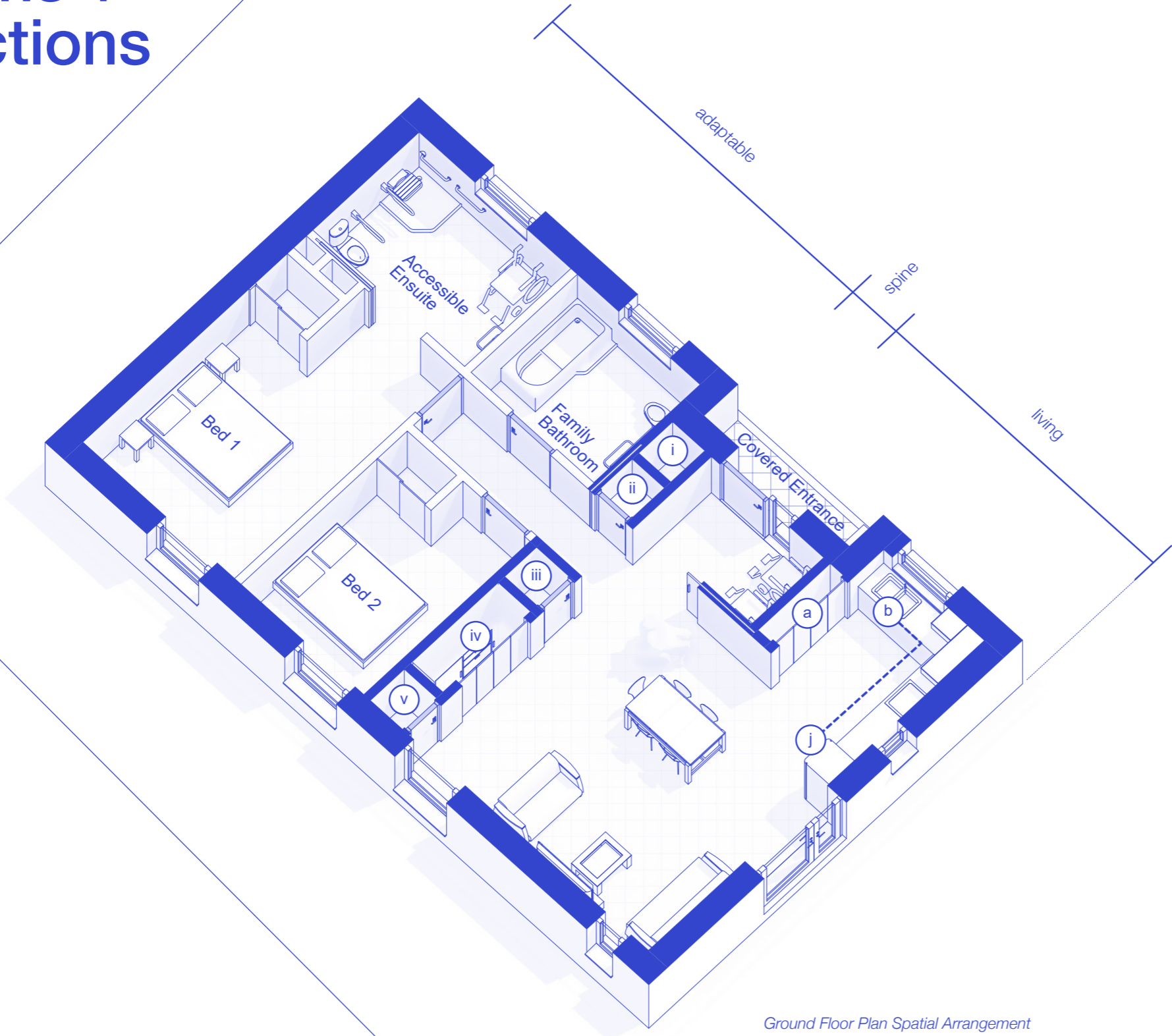


Heritage House by Ment Architecture



Low embodied carbon material palette by Archetype

Plans + sections



- i Electrics Distribution Board + Storage (Hoover + Household)
- ii Washing machine
- iii HOS + associated kit
- iv 2000x750 storage
- v EAHP+ MVHR Combi-Unit
- vi Linen Cupboard

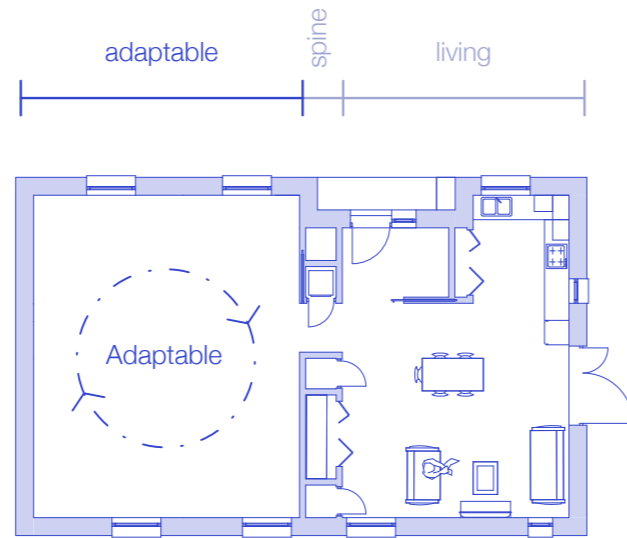
- a cleaning cupboard/pantry
- b sink+drainer
- c dishwasher
- d pull out corner unit
- e 4 ring hob + oven
- f base/drawer unit
- g recycle/refuse base
- j fridge freezer

BED 2 Showing Double Bed. Also suitable for two single beds (good for flexibility)

BED 3/STUDY Silver/gold standard providing a desk space (see section 7 of the technical handbook)

Ground Floor Plan Spatial Arrangement
Example layout option

5.2 - Architecture blueprint

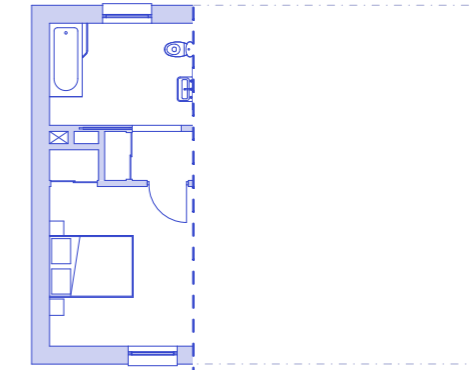


The sleeping quarters utilise a non-load-bearing partitioning system, allowing the floor plan to remain fluid. This structural strategy alongside tactically located SVPs This enables the seamless reconfiguration of bedrooms, nurseries, offices, or ensuites.

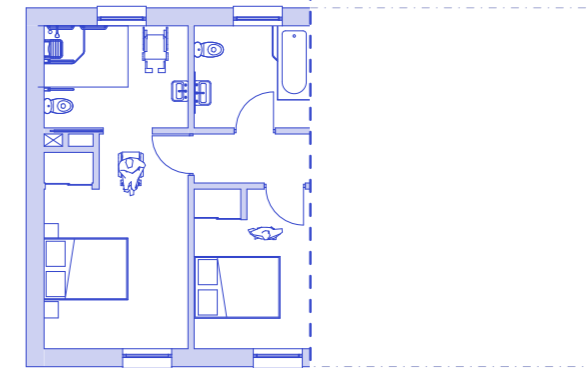
By treating internal walls as temporary, the home effortlessly adapts to evolving needs—from family growth to wheelchair-accessible living—without structural disruption.



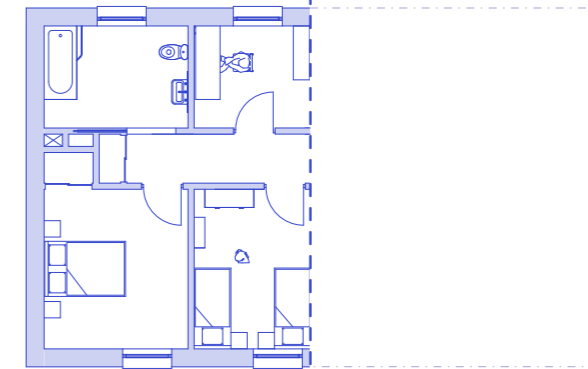
Reduced 75m2 Floor plan Option:
1 Accessible Double
+ Bathroom



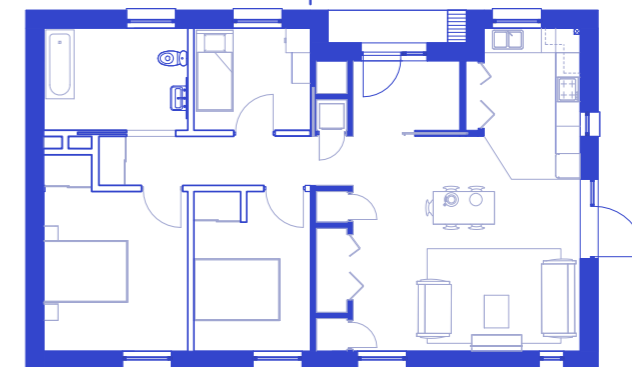
1 Accessible Bedroom
& En-suite
+ Twin Room



2 Bedroom
+ Office
+ Family Bathroom



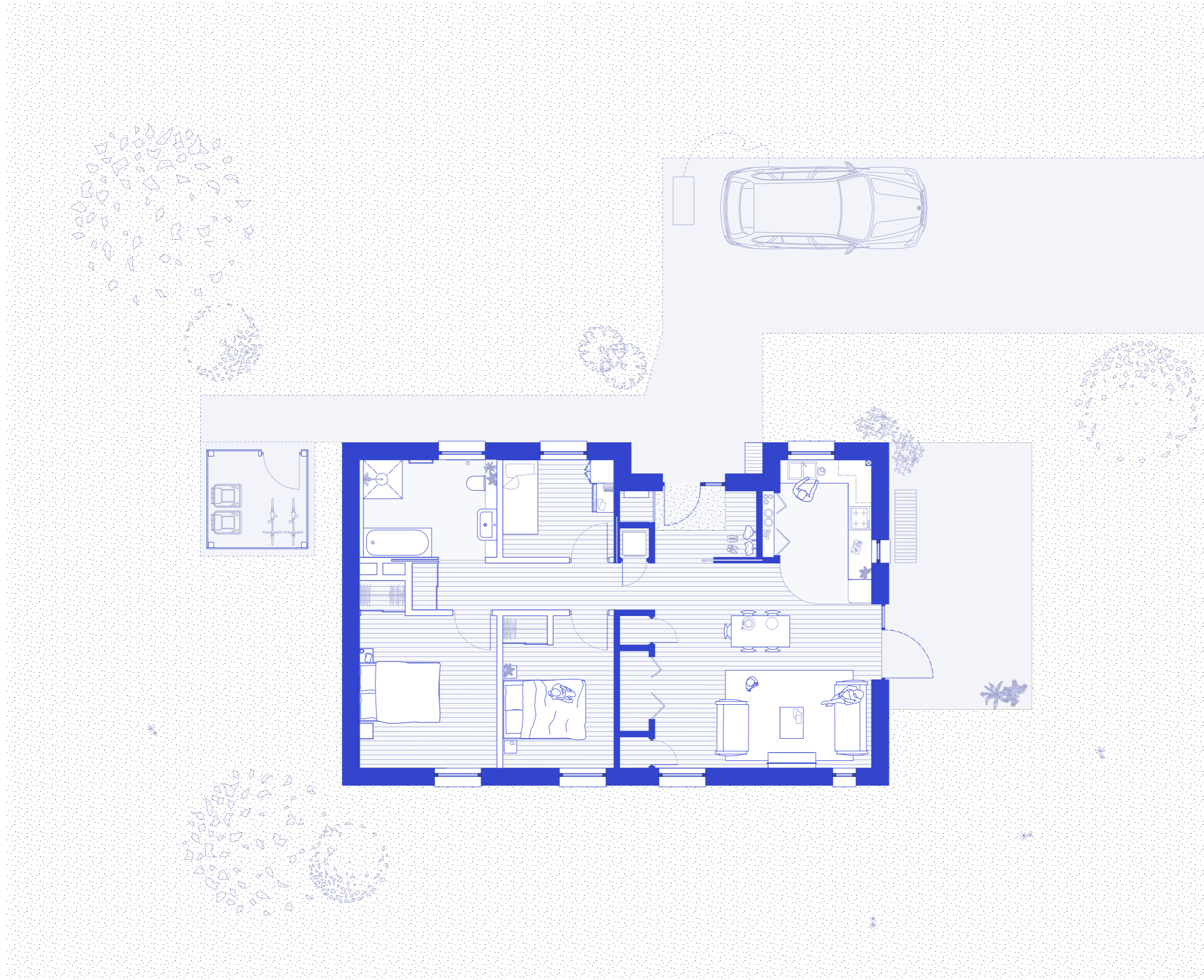
3 Bedroom
+ Family Bathroom



Adaptable Floorplan Diagrams

5.2 - Architecture blueprint

Living Lab 4: Smart Housing, Smart Communities
Digital Blueprint for a Smart Home of the Future



0 1 2 2.5m

Site Plan

5.2 - Architecture blueprint

Living Lab 4: Smart Housing, Smart Communities
Digital Blueprint for a Smart Home of the Future

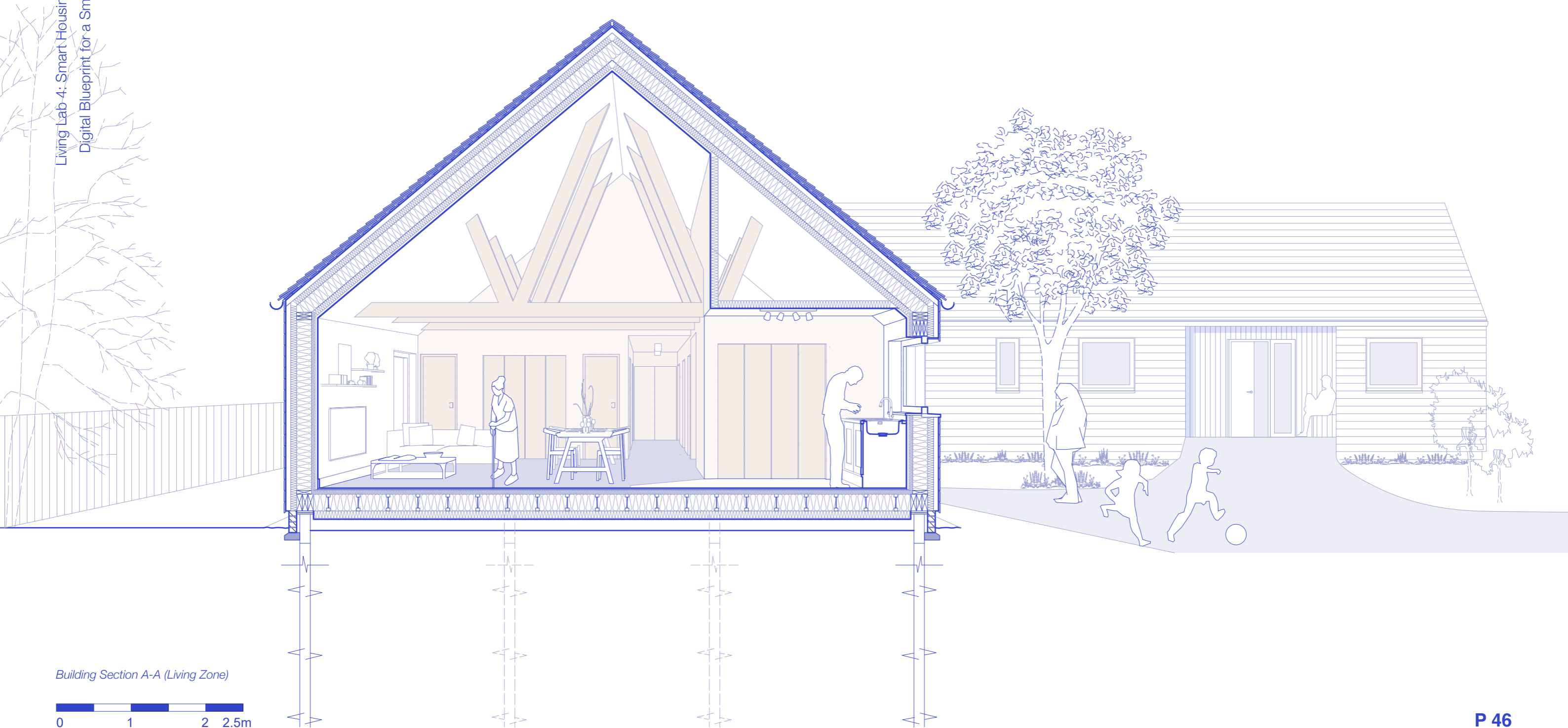


0 1 2 2.5m

Ground Floor Plan

5.2 - Architecture blueprint

Living Lab 4: Smart Housing, Smart Communities
Digital Blueprint for a Smart Home of the Future

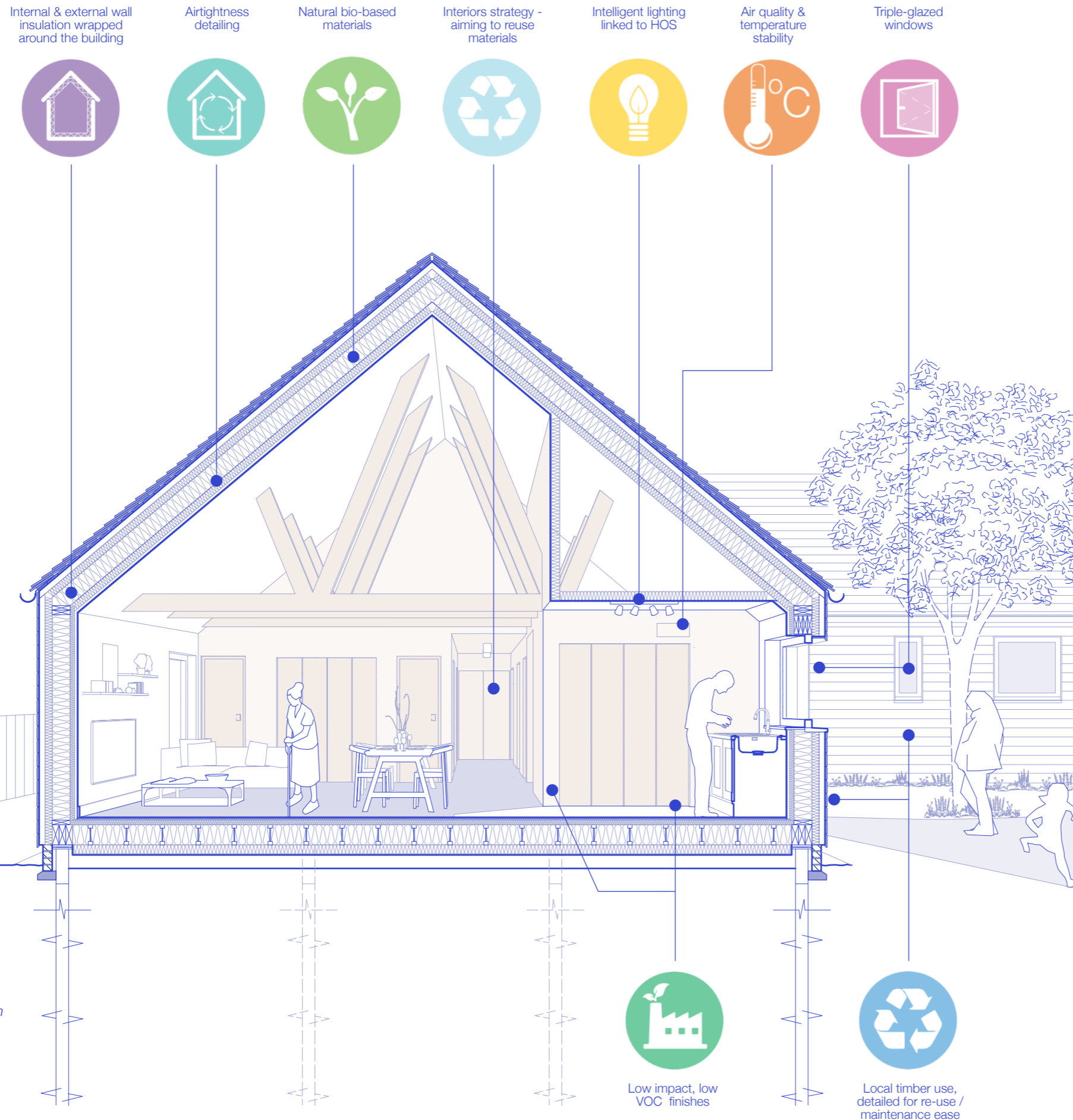


Building Section A-A (Living Zone)

0 1 2 2.5m

5.3 - Architecture blueprint

Living Lab 4: Smart Housing, Smart Communities
Digital Blueprint for a Smart Home of the Future



HORIZON 2 (3 - 7 years)

Level 3 (highest) Ambition Level

| Key Operational Ambitions | | |
|--------------------------------------|----|--|
| Heating Demand | or | Heating Load |
| 15 kWh/m ² a | | 10 W/m ² |
| Cooling Demand | or | Cooling Load |
| 15 kWh/m ² a | | 10 W/m ² |
| Airtightness | | Frequency of Overheating |
| 0.6 ACH | | 10% ideally < 2% |
| Renewable Energy Generation | or | Renewable Primary Energy |
| > 60 kWh/m ² (footprint)a | | < 45 kWh/m ² a |
| Upfront Carbon Target (A1 - A5) | | 260 kgCO ₂ e/m ² GIA |

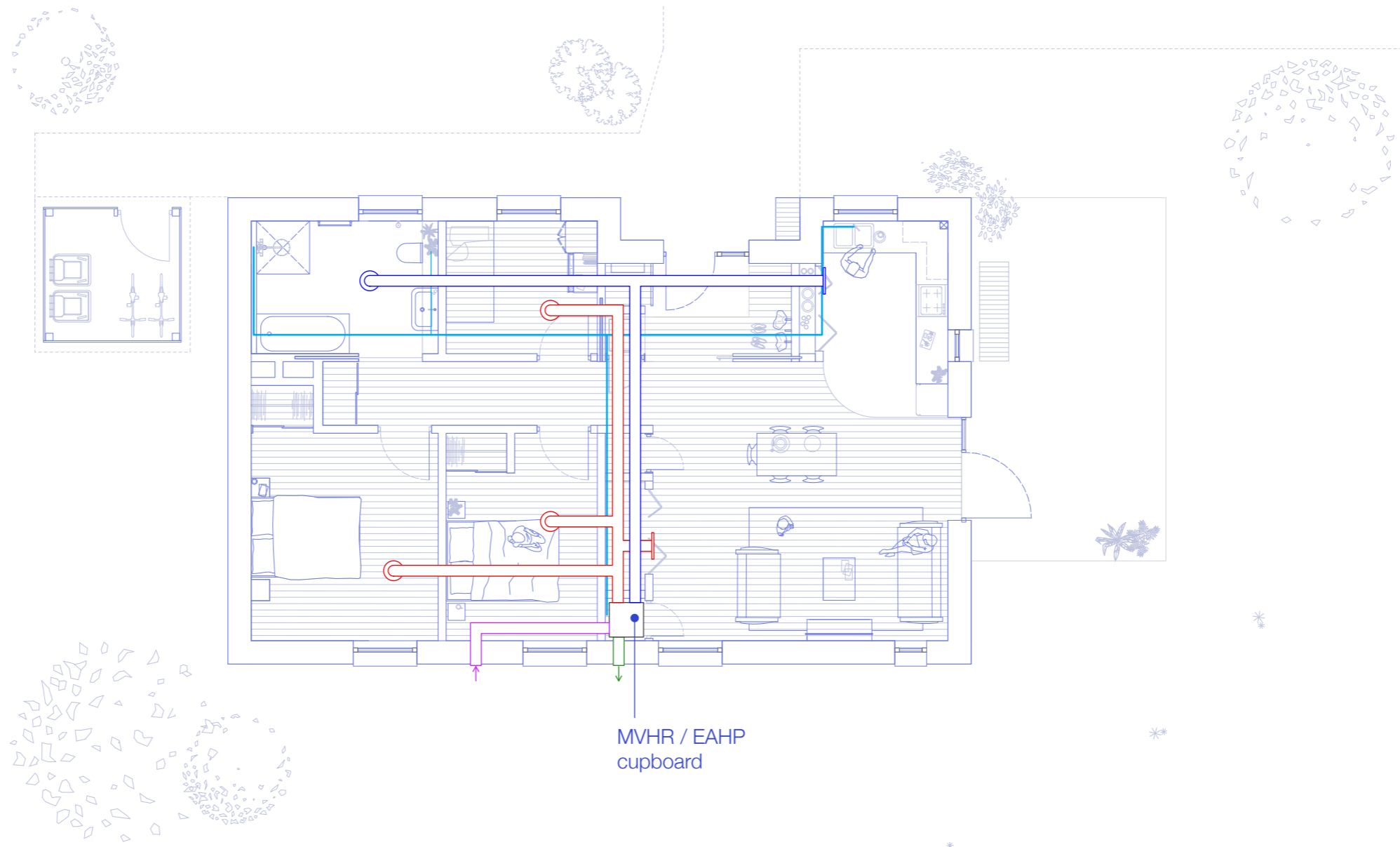
Building Section A-A (Living Zone) with architectural matrix features & targets



Mechanically enabled strategy

KEY:

- Exhaust Air Duct
- Fresh Air Duct
- Supply Duct
- Supply Duct
- Route for hot and cold water pipework



Operational Carbon

The reduction of operational carbon (ie the energy used to operate a building e.g. heating, lighting and small power) from the current baseline level has been an important consideration in the development of the blueprint. The Envision Matrix identifies targets for operational carbon performance for each horizon point. Commentary on the proposed targets is provided below.

The Scottish climate, rural localities and modest sized dwellings can present particular challenges for operational carbon performance and so, alongside the setting of ambitious targets, in acknowledgement that these targets may be challenging to meet, we have identified a number of key considerations and opportunities for operational carbon optimisation below. We've ordered these from region/site scale down to the scale of individual units.

Operational energy performance

The operational energy performance of a building is dependent on a number of factors, which include (but are not limited to): building fabric, quality of construction, orientation, climate, number of occupants and occupant behaviour. As such, the operational energy calculated as part of the Whole Life Carbon assessment is a generic figure. The operational energy performance would need to be calculated on a project specific basis.

Passivhaus is proposed as a proven and documented methodology for the reduction of heating demand and operational energy. For illustration purposes, the image below shows a comparison carried out between a 'best practice' home and a home designed to meet the Passivhaus standard (not site specific to Scotland). The Passivhaus home has a heat demand of 15kWh/m².a, whereas the 'standard best practice' home has a heat demand of 80kWh/m². An increase in heat demand not only represents increased energy use, but it also represents a risk of residents under heating homes, additional financial cost, and risk to health. An energy efficient home can represent a cheaper to operate, warmer, more comfortable living environment, with benefits to health and well being.

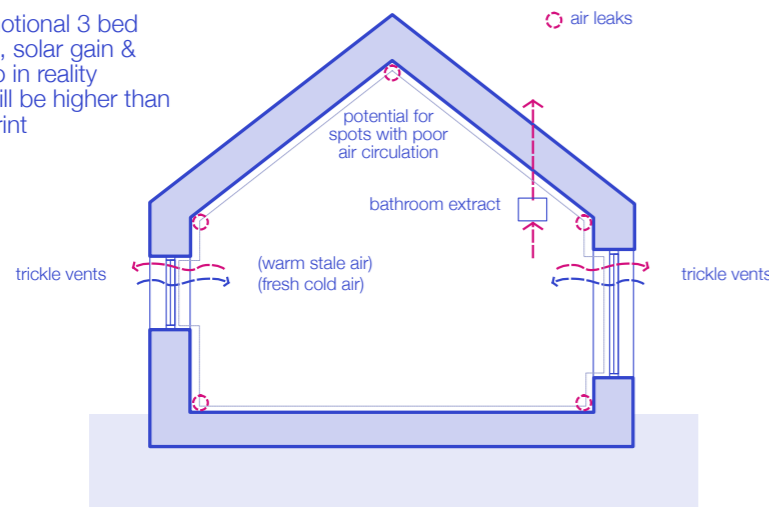
Target Setting: Passivhaus Design



With Scottish building regulations moving towards the adoption of a 'Passivhaus equivalent' (1) the Passivhaus standard has been identified as the methodology to benchmark operational carbon performance for H1L2 onwards. It should be noted, however, that achieving a Passivhaus level of performance is not always straight forward, particularly for smaller buildings in northerly regions. The blueprint has been created to be 'site agnostic' and therefore the design would need to be reviewed and potentially optimised to meet the requirements of Passivhaus compliance for of any specific site (in terms of orientation, latitude, climate data and shading) that was selected.

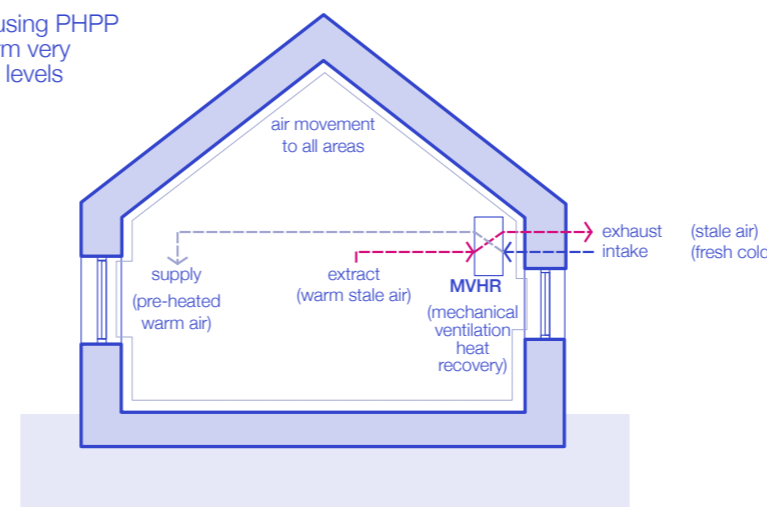
1 - <https://www.gov.scot/publications/scottish-building-regulations-proposed-changes-energy-environmental-standards-determining-principles-scottish-equivalent-passivhaus-standard-scottish-government-stage-1-consultation-response-part-2-onward-review/>

+ Based on notional 3 bed house design, solar gain & form factor so in reality energy use will be higher than for this blueprint



Heating Demand: 80 kWh/m² +
Primary Energy: 94 kWh/m² +

*Home designed using PHPP will typically perform very close to predicted levels



Heating Demand: 15 kWh/m²
Primary Energy: 41 kWh/m²

Operational Carbon

Opportunities for optimisation to improve operational energy efficiency:

Locality / site selection:

Where there is a choice available, sites which enable the principal elevation to face south will allow passive solar gain to be maximised. Good access to the site would enable the maximisation of off-site manufacturing.

Density:

If sites are developed with multiple units, opportunities are opened up for a shared approach to building services, such as heat networks. In addition, if units are built as semi-detached rather than detached units, this provides efficiency in the building envelope, and could improve performance.

Single storey, one off houses intrinsically have a poor 'form factor' (the ratio between the external 'envelope' and the heated air volume within), which has an impact on heat loss through the fabric (ie. there is more envelope for heat to escape out of). The blueprint has been designed to provide a highly efficient form with minimal corners, but an improved form factor could be achieved by developing pairs of semi-detached units.

Repetition:

If sites are developed with multiple units, off-site manufacturing could be used to achieve efficiency and enable quicker installation on site.

On site renewables:

It has been assumed for Horizon 2 and Horizon 3 that roof mounted photovoltaics (PVs) would be provided. The efficiency of PVs will be highly dependent on the location and orientation of the roof. In a multi-unit development, it's possible that a shared non-roof located PV array might be more efficient (e.g. on a community building).

Other factors to consider:

Operational energy/embodied energy "trade off" for particularly challenging sites

There will be some sites for which it is particularly challenging to achieve the Passivhaus standard. This might include north facing sites, or those in a particularly northerly location. For these locations it may be necessary to consider whether operational carbon or up front carbon should be prioritised. For example, in order to reduce up front carbon, the blueprint for horizon 2 assumes a concrete free substructure. However, a more traditional insulated raft foundation could enable improved u-values where necessary (at the cost of increased up front carbon).

Emergent technologies, materials and systems

It is anticipated that over the coming years, new technologies, materials and systems will provide improved performance for both embodied and operational carbon. Insulations will be developed with improved performance and materials will come to market which have lower embodied carbon.

Retrofit

The sustainability and performance targets and proposed construction methodologies identified in the Envision matrix are primarily structured around a new-build scenario. However, the operational performance of existing housing stock is also of critical importance. The setting of targets and identification of an appropriate approach to the retrofit of existing buildings will be highly dependent on a number of factors, including:

- Budget
- Potential listing or heritage status
- Construction type
- Whether a home is to remain occupied during construction work
- Potential for ventilation improvements

However, the general new-build principles of low embodied carbon, natural materials will, in many cases, be highly relevant to a retrofit scenario as they can provide breathable, hygroscopic solutions. There are various existing resources available which can provide guidance to clients and building owners. A list of current resources is provided within Appendix E.

Practical checklist

The blueprint architectural design has been developed to provide a flexible, single storey, two bedroom dwelling with the potential for adaptation to provide a fully accessible dwelling. In developing the blueprint, reference has been made to various standards and guides (see p48 for a summary list). A practical checklist has been prepared, which identifies key items to enable design flexibility and universal accessibility.

SITE + NEIGHBOURHOOD + LANDSCAPE + DESIGN

| Item | High Level Design Checklist | Blueprint Incorporation |
|------|--|---|
| 1 | Site and Approach <ul style="list-style-type: none"> • Gradient from street to entrance (ideally level, or gentle ramp ≤1:20 where possible). • Potential for on-plot parking bay(s) close to entrance; space to widen or allow side transfer. • Level or ramped path min 1050–1200 mm clear; gate & thresholds. | <p>The blueprint is site agnostic. Site specific accessible routes would need to be designed to suit each individual site</p> <p>Indicative parking bay shown (with EV charger). Exact location would need to be determined to suit site and / or community development.</p> |
| 2 | Entrance and Circulation <ul style="list-style-type: none"> • 1500x1500 mm clear landing externally and internally. • Hall widths 1050–1200 mm; internal doors 850 mm clear. | <p>Clear (covered) landing space externally, and clear space internally within entrance area.</p> <p>Hall width is 1200mm. All internal doors 850mm clear.</p> |
| 3 | Bedrooms Principal bedroom sized for lateral transfer + 1500 turning circle; obvious wall reinforcement areas | <p>The plan has been developed to enable flexibility within the layout of bedrooms and bathrooms for a range of potential future scenarios.</p> <p>In the main option illustrated, the principal bedroom has a 1500mm turning circle and 1200mm to each side of a standard double bed. Wall reinforcement not detailed within the blueprint - this would be added at detailed design stage.</p> |
| 4 | Bathroom and WC 1500 turning circle, level access shower 1200x1200, future-proofed services, hoist routing if needed. Obvious wall reinforcement areas | <p>The plan has been developed to enable flexibility within the layout of bedrooms and bathrooms for a range of potential future scenarios.</p> <p>In the main option illustrated, a family bathroom provides a 1500mm turning circle and level access shower. The plan is designed to enable this space to be converted into a fully accessible en-suite bathroom, should this be an occupant requirement.</p> |
| 5 | Kitchen and social spaces Clear crossing space 1200–1500 mm, one accessible worktop and sink, reachable controls. Open plan layout aids manoeuvrability | <p>The kitchen is open to the living dining space, aiding manoeuvrability, whilst maintaining some separation.</p> <p>The clear crossing space is 1700mm.</p> |
| 6 | Storage and mobility equipment 1100x1700 wheelchair store/charging space near entrance; extra general storage beyond NDSS minima. | <p>1100 x 1700mm space is provided within the main entrance area. It is anticipated that this space could be used flexibly for storage of coats, shoes, pram or other family items, or as a wheel chair storage space if required.</p> |
| 7 | M+E, services and safety Plug for powered door opener; provision for tracked hoist wiring (bedroom / bathroom); alongside any tech stack option requirements. | <p>At this stage, MEP design is at a schematic level. Requirements should be incorporated at advanced concept & detailed design stage. Technology requirements are incorporated in the tech stack options.</p> |
| 8 | External amenity Accessible garden routes, turning circles, accessible bin/cycle stores, access to outdoor areas with level access. | <p>The blueprint is site agnostic. Site specific external amenity spaces would need to be designed to suit each individual site. The blueprint indicates a level access external decked area adjacent to the main living space.</p> |
| 9 | Documentation Furnished plan layouts at 1:100 showing access zones and furniture; specification for fittings/ heights; schedule of adaptable elements (reinforced walls, wiring, spare capacity). | <p>1:100 furnished plans provided to illustrate the blueprint.</p> <p>Specification for fittings/heights and schedule of adaptable elements would be developed at detailed design stage.</p> |
| 10 | Holistic thinking When considering the design of a dwelling one must consider the envelope and the contents, but also the context, the opportunity for shared amenity spaces and shared service to enhance physical connectivity alongside the digital provision noted in section 6.0. For the potential site we understand that items already under consideration are: <ul style="list-style-type: none"> • Denser street patterns + 20 minute neighbourhoods • Pedestrian + active travel friendly / prioritisation • Enhanced public realm with a biodiversity focus • Choice of density / flexibility / adaptability • Shared EV charging or renewable energy • Community allotments + external amenity space • Tenure innovation | <p>The blueprint is site agnostic. Site specific holistic thinking should be applied to each site and tailored to the site alongside statutory needs for the local area.</p> |

Policy + guidance

Linking to Section 3.2 Policy Timeline, the list below identifies key reference policies and metrics for the Horizon development & blueprint.

Construction Standards Policy:

Building Standards Technical Handbook: Bronze, Silver or Gold

Passivhaus Standard (The Scottish equivalent to the Passivhaus standard is a new regulatory framework being developed by the Scottish Government, with a target date for mandatory implementation in 2028)

UK Net Zero Carbon Building Standard

The Scottish Net Zero Public Sector Building Standard

LETI Targets

NZEB - Nearly Zero Energy Building

BREEAM

LEED

WELL Standard (V2)

Housing Standards Policy & Guidance:

Building Standards Technical Handbook, particularly facilities in dwellings (3.11)

Nationally Described Space Standard (NDSS)

Affordable Housing Standards: Affordable Housing Supply Programme (AHSP)

Scottish Accessible Homes Standard: Consultation - Enhancing the accessibility, adaptability, and usability of Scotland's homes

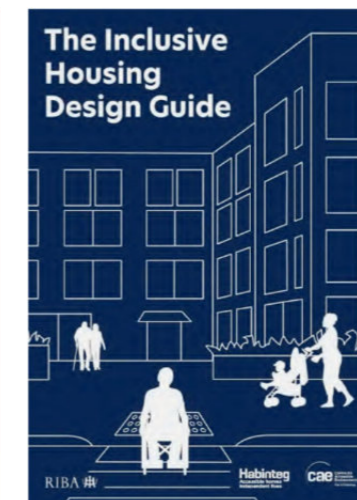
Centre for Accessible Environments: Lifetime Homes Concept

Housing for varying needs design guide (HfVN)

The Inclusive Housing Design Guide, RIBA

Stage 2 and Stage 3 adaptation categories

Scotland's Wheelchair Accessible Housing update (Scotland's Housing Network)



Place & wider sustainability

The architectural concept exists at the scale of an individual dwelling which is necessary but insufficient. The long-term health, resilience and sustainability of (rural) communities depends equally on the quality of place. Scotland has articulated this clearly through the work of Architecture & Design Scotland and the Place Standard Tool, which frames place not simply in terms of buildings, but in relation to movement, identity, safety, natural space, social interaction and civic participation. The underlying premise is that the environments we shape in turn shape our health, opportunity and collective wellbeing.

This placemaking agenda is reinforced in National Planning Framework 4 (NPF4), which positions climate mitigation, adaptation, biodiversity recovery and local living at the heart of spatial planning. NPF4 moves beyond growth-led development models toward outcomes that embed quality, climate responsibility and community wealth building. Within this context, Scotland’s ambition to realise 20-minute neighbourhoods—where daily needs can be met within a short walk, wheel or cycle—takes on particular significance in rural settings. While density patterns differ from urban Scotland, the principle remains: services, green space, community infrastructure and mobility must be intentionally structured to reduce car dependency, social isolation and carbon intensity.

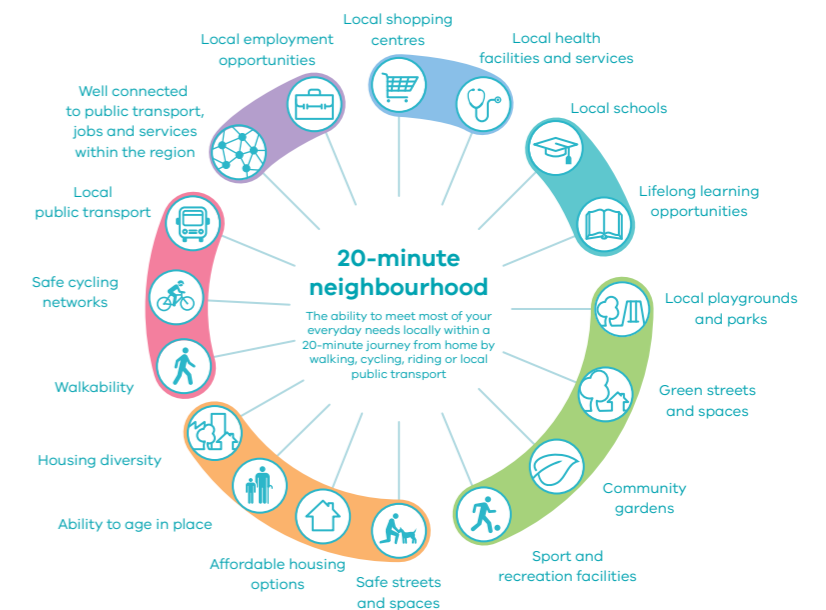
For Envision, the Smart Rural Home of the Future, neighbourhood design becomes an extension of the architectural and digital strategy. Shared infrastructures—communal EV charging hubs, micro-grids, battery storage clusters and district heat opportunities—enable collective carbon reduction that exceeds what any single dwelling can achieve. Allotments, community gardens and productive landscapes strengthen food resilience, promote physical activity and support mental wellbeing. Shared amenity spaces—designed for reflection, quiet gathering, intergenerational play and informal care networks—build the social capital that underpins preventative health.

Such spaces must not be residual or value engineered out of schemes; they are foundational civic assets. In an era of climate volatility and service retrenchment, the neighbourhood itself becomes part of the care system and the energy system. Thoughtfully designed shared landscapes moderate heat, manage surface water and enhance biodiversity. Community hubs support digital inclusion, skill exchange and mutual aid. EV infrastructure, when planned collectively, reduces cost burdens and future-proofs mobility transitions.

Delivering this ambition requires moving beyond minimum standards and fragmented procurement towards integrated, place-led development models.

The aspiration is not simply compliant housing, but regenerative neighbourhoods—where environmental performance, social cohesion and collective resilience are designed in from the outset. In this framing, place is not backdrop; it is active infrastructure for climate action, community wellbeing and long-term rural vitality.

Extract of the 20 minute neighbourhood from 'Plan Melbourne 2017-2030'



5.6 - Architecture blueprint

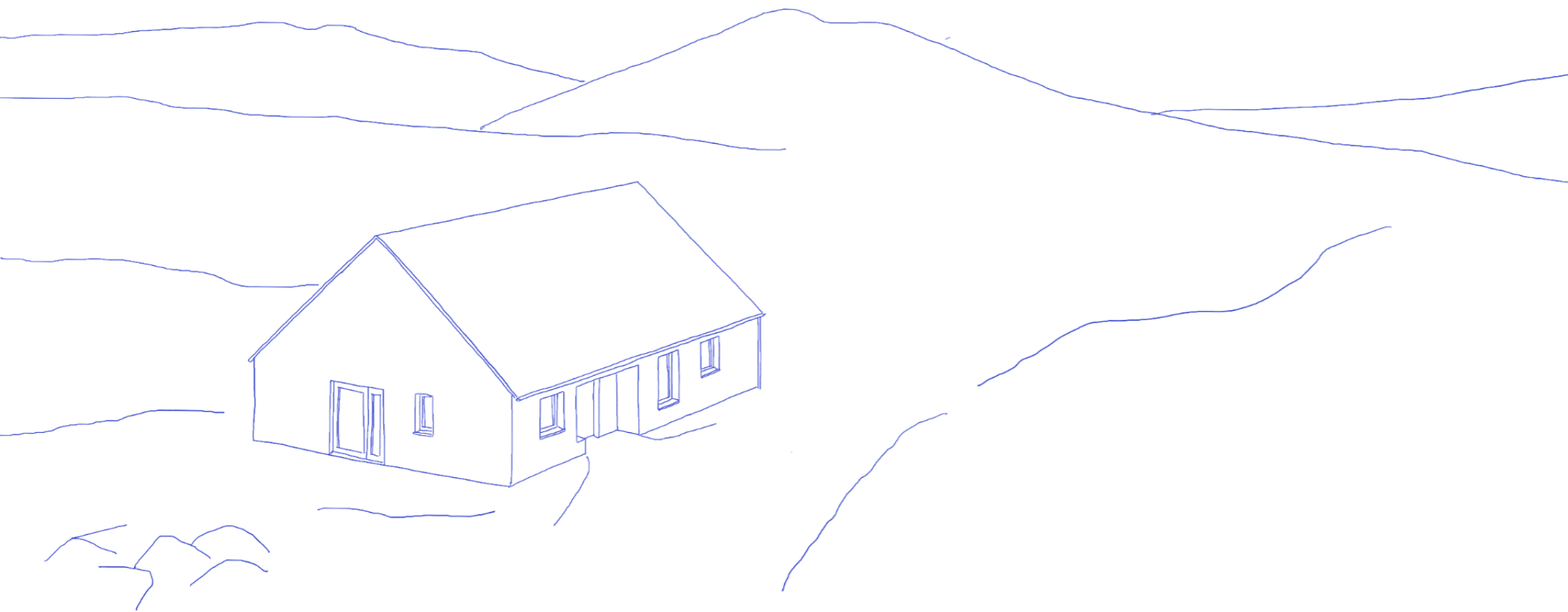
While place-making establishes the physical and social framework for rural living, the long-term viability of these environments depends equally on the strength and integration of health and social care systems. In rural Scotland, where populations are ageing and services are increasingly stretched, the home becomes a critical interface between individuals and the care ecosystem.

Access to timely, appropriate care is often shaped less by distance alone than by coordination—between primary care, social services, community support and informal networks. In this context, housing must be conceived as part of that system: not only as a setting for care, but as an active enabler of it. Homes that support remote monitoring, virtual consultation and early intervention can extend the reach of services, but only where they are embedded within trusted local pathways of care.

Crucially, patterns of occupancy and need vary significantly between households. A one-size-fits-all model is insufficient. Instead, homes must be capable of responding to differing levels of independence, vulnerability and support over time.

This reinforces the importance of aligning housing delivery with local service provision, workforce capacity and community networks. When effectively integrated, the home becomes a point of continuity within a fragmented system—supporting independence, reducing avoidable escalation, and strengthening resilience at both individual and community scale.

Rural site sketches: the reality



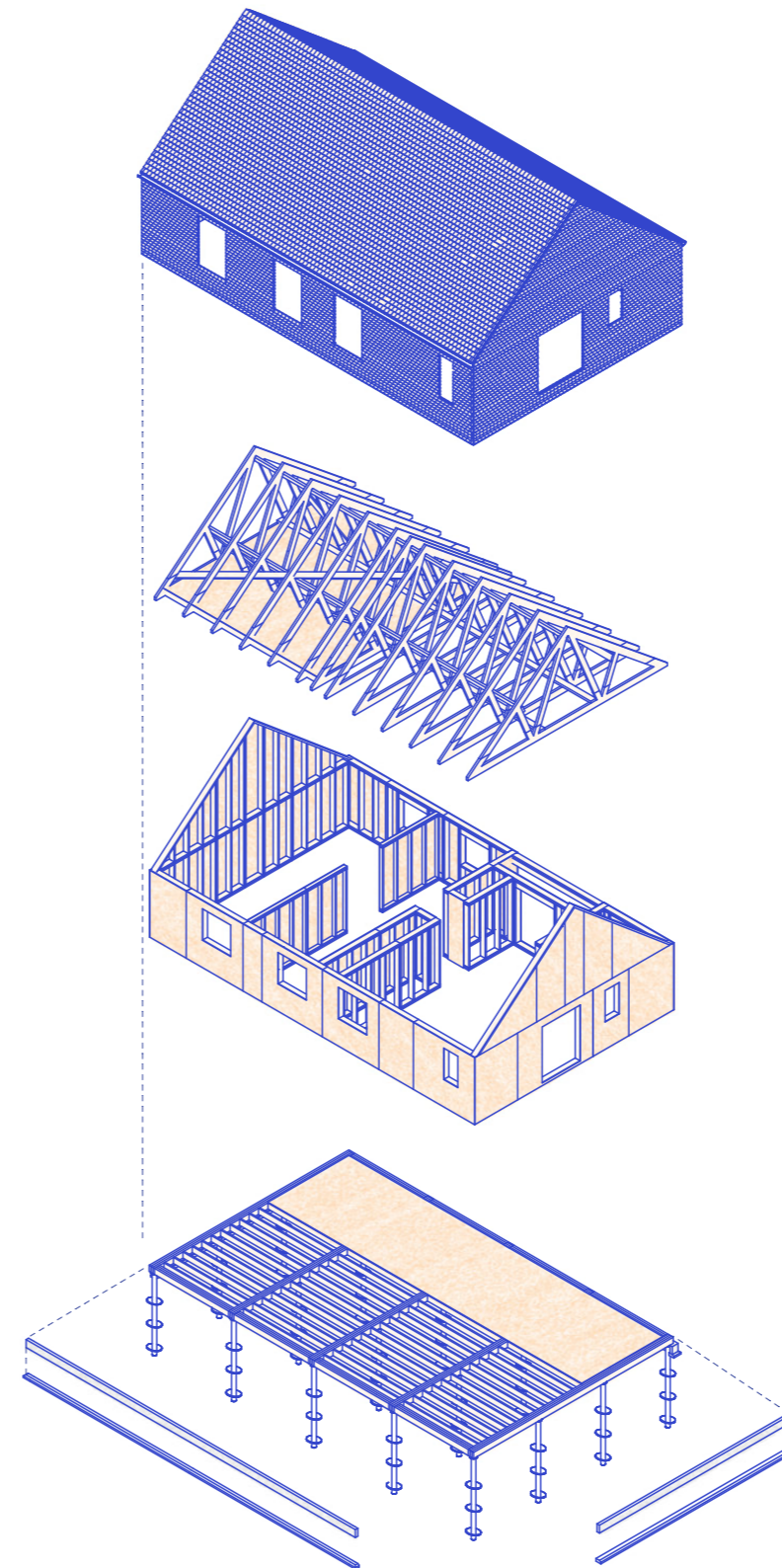
Construction

The construction approach set out within the Envision Matrix translates high-level sustainability ambitions into a sequenced, buildable methodology. Rather than prescribing a single solution, it establishes a direction of travel across the three Horizons—moving from low-risk, readily deployable construction systems towards more advanced, low-carbon and regenerative approaches. Each horizon and ambition level within the Matrix represents a deliberate calibration between performance, supply chain readiness, cost and scalability.

At its core is a commitment to a fabric-first, low embodied carbon strategy, prioritising materials and systems that reduce both operational energy demand and lifecycle emissions. As illustrated in Horizon 2 Level 3 (right), this includes a transition toward Scottish-grown timber structures, increased off-site manufacture, and bio-based insulation, alongside exploration of concrete-free substructures such as screw pile foundations. These choices reflect not only carbon reduction goals, but also a broader ambition to support local supply chains, reduce construction waste, and enable precision in delivery.

The Matrix enables this evolution to be understood and applied in practice. Early Horizon solutions focus on proven, compliant systems aligned with current standards, while later stages introduce greater integration of circular materials, adaptable components and disassembly-ready construction. Importantly, each step is designed to remain compatible with the next—avoiding stranded assets and enabling incremental upgrade over time.

Through this, construction is reframed as a progressive system rather than a fixed specification: one that can respond to changing technologies, material innovation and regulatory shifts, while consistently advancing toward net zero, resilience and long-term adaptability.



Envelope

Roof Finish: Scottish timber shingles or shakes

External Cladding; Scottish timber cladding or shingles (with consideration of local sourcing)

Super-Structure

Roof structure: Constructed from Scottish grown timber, C-16 grade with consideration of use of roof space and readily available truss systems.

Structural Strategy: Timber frame or I-Joist with increased offsite manufacturing, use of Scottish timber.

Insulation: Natural / by-product bio-based insulation (such as cellulose, wood fibre or hemp).

Sub-Structure

Ground Floor Structure: Suspended timber or I-Joist ground floor

Foundations: Concrete free sub-structure, galvanized steel screw piles.

Materials + embodied carbon



Whole Life Carbon Assessments

Whole life carbon refers to all of the green house gas emissions that are emitted as a result of the construction, use, and de-construction of a building. The majority of these emissions are currently unregulated in construction, but the industry is able to proactively reduce these through considered design, construction, and use. A fully detailed description of the Whole Life Carbon assessment and methodology can be found in Appendix E.

An assessment has been carried out for the baseline house built in 2026, and for **Horizon 2 Level 3** built in 2030. For each assessment, a comparison has been made with the most relevant available industry targets.

Terminology

We have used the industry-standard methodology to assess Whole Life Carbon as set out in RICS Whole Life carbon Assessment. Whole Life Carbon Assessment is a specialist field and use a number of specialist terms. For clarity of the readers of this guide we have provided a simplified description of the terms used in Table 01 (please see Appendix E for full descriptions).

Targets

At the current time, there are a number of voluntary targets (e.g. UK Net Zero Carbon Building Standard, LETI, RIBA 2030) but neither embodied carbon or whole life carbon are regulated. Regulation has been introduced in several European countries and is scheduled for regulation EU-wide. It is possible that Scottish regulation will come into place in the future, within the timeframe of horizon 2 or 3. The UK Net Zero Carbon Building Standard UKNZCBS has been used as a baseline with an ambitious reduction projected for H2L3 as per figures in Table 02. It is worth noting that the targets that are indicated above are fairly onerous, and present a challenge to the industry.

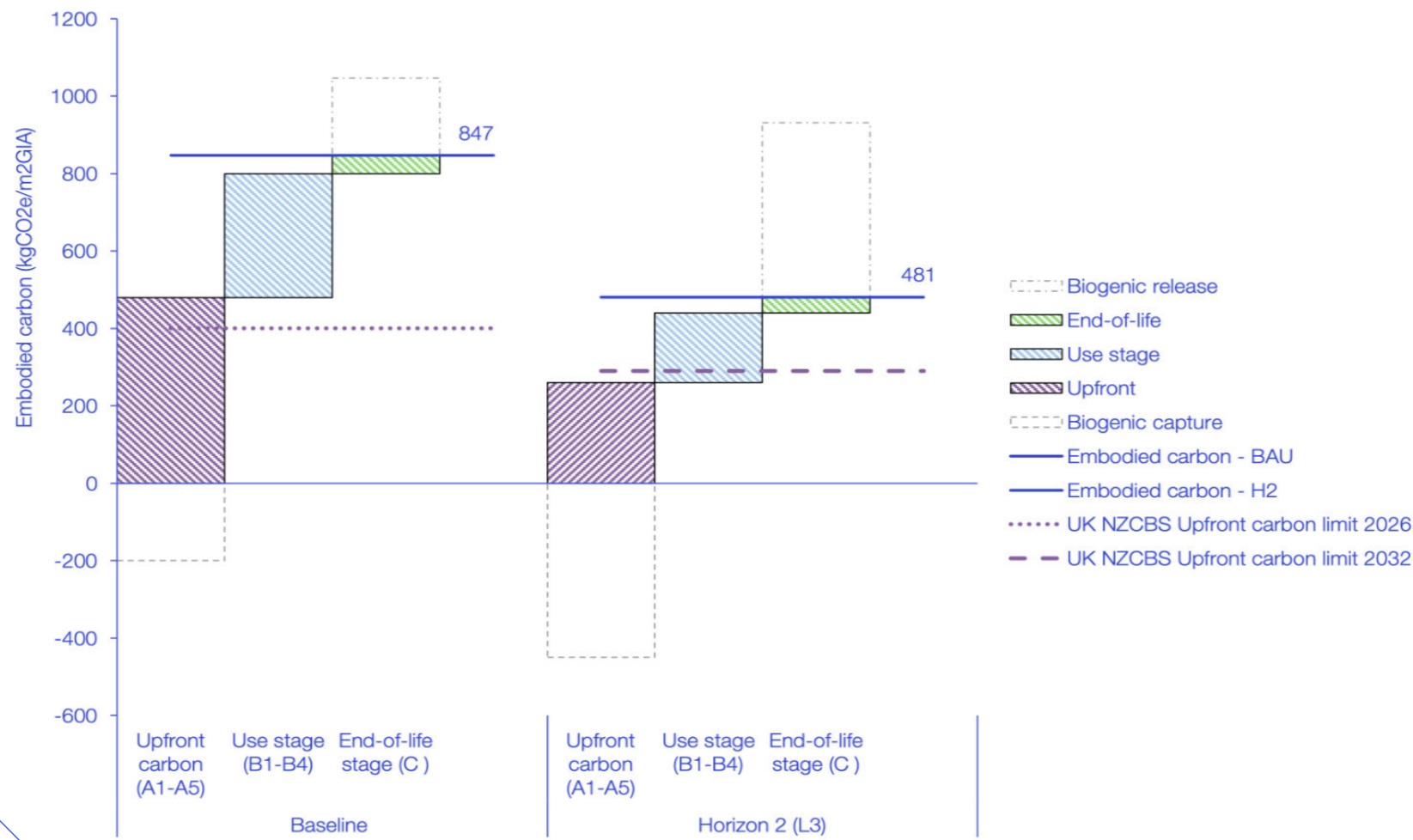
| Item | High Level Design Checklist |
|-----------------------------------|---|
| Whole life carbon | The carbon emissions associated to a building for its whole life, ie including material sourcing, construction, energy in use, in maintenance and replacement and demolition/deconstruction. (cradle to grave) |
| Upfront carbon | The carbon emissions that result from constructing a building |
| Embodied carbon | Upfront carbon, plus the carbon emissions from maintaining, repairing and replacing elements of the building through its life, plus the carbon emissions from its deconstruction and disposal at the end of the building's life |
| Lifecycle embodied carbon | Term used interchangeably with embodied carbon with the same scope. |
| Operational carbon | The carbon emissions resulting from the operation of a building (heat, light, ventilation, small power etc) in the course of its life |
| Sequestered carbon | Carbon 'locked up' in biogenic materials used in the building's construction which are removed from the atmosphere for the life of the product or building. |
| Environmental Product Declaration | An EPD is a 'passport' or certification of a product's climate impacts through its production, installation, maintenance, and end of life scenario. These impacts are multiplied by the volume of its use to inform the project totals. |

Table 01. Carbon Assessment Terminology Table

| Horizon | Targets | | Source of targets notes |
|-------------------|-----------------|---|---|
| | Up-Front Carbon | Lifecycle Embodied Carbon Whole Life Carbon | |
| Baseline | 400 kg CO2e/sqm | Not set | UK NZCBS |
| Horizon 2 level 3 | 290 kg CO2e/sqm | Not set | Progression to align with the 2033 UK NZCBS limit |

Table 02. Carbon Targets

Materials + embodied carbon



| Option | Upfront (A1-A5) | Use (B1-B4) | End of Life (C1-C4) |
|-------------------|-----------------|-------------|---------------------|
| Baseline | 480 | 320 | 47 |
| Horizon 2 Level 3 | 260 | 180 | 41 |

Headlines

Baseline / Business as usual

The baseline model has a total upfront carbon figure of 480kgCO2e/m2GIA, which is in excess of the current voluntary target figure of 400kgCO2e/m2GIA (from UK NZCBS). The baseline model is based on a typical construction specification which would meet the current Building Regulations in 2026. Please refer to the Envision Matrix for the indicative construction.

The total figure calculated for embodied carbon for the baseline model is 847 kgCO2e/m2GIA. RIBA published embodied carbon targets for the industry in 2021, suggesting the business as usual approach to construction for domestic buildings was 1200 kgCO2e/sqm, with a 2025 target of 800 kgCO2e/sqm. The calculated figure of 847 kgCO2e/m2GIA for embodied carbon is therefore higher than the current 'target'. In practice it would not be unexpected for this figure to be even higher.

Horizon 2 Level 3

The Horizon 2 L3 model has a total upfront carbon figure of 260kgCO2e/m2GIA. This represents a significant improvement on the baseline figure and is within the target of 290 kgCO2e/m2GIA (from UK NZCBS for work commencing on site in 2030).

The total figure calculated for embodied carbon for Horizon 2 L3 is 496 kgCO2e/m2GIA. This sits below the RIBA 2030 target of 625 kgCO2e/m2GIA.

The Horizon 2 model is based on a construction type with increased thermal insulation (to enable the reduction of operational energy) whilst achieving the reduction of embodied carbon, which is realised through the specification of natural and low embodied carbon materials. See the Envision Matrix for a description of the proposed construction principles assumed for both options.

Materials + embodied carbon

Commentary

It is striking that, despite a prioritisation of low carbon materials within the Horizon 2 design, it is still challenging to meet the targeted figure for up front carbon. When developing a design which is targeting both low embodied and low operational carbon there is often a tension between the two (e.g. to reduce operational carbon we increase the level of insulation and the increase of insulation results in an increase in up front carbon). This tension is particularly apparent when looking at a relatively small, one-off projects, due to their form factor. Optimisation of the design to ensure efficiency, off site manufacturing of multiple units and combining units to form clusters of semi-detached units could all be potential opportunities to reduce both operational and up front carbon.

Whilst there is a balance to be optimised between the insulation levels for operational and embodied impacts, the fundamentals for good building design for low energy also support low carbon construction. These principles include a good form factor, a sensible storey height, and avoiding unnecessary glazing.

As we move towards a future in which carbon targets become more stringent, a focus on reduction of embodied carbon, including close consideration of maintenance and replacement cycles, is vital in order to meet the requirements of a net zero future.

Business as usual is simply not going to get close to the necessary targets.

Other factors to consider

Decarbonisation of the grid

Future carbon targets have been set with a built in adjustment for the anticipated continued decarbonisation of the grid (ie in addition to becoming more ambitious generally, targets are also adjusted to acknowledge that the embodied carbon of building materials will become lower as the grid is decarbonised). Therefore, if assessing a future built scenario at the current time (such as the horizon 2 scenario in this publication), the calculations are being undertaken based on current carbon figures from the current Environmental Product Declarations, but being assessed against a future target which assumes a decarbonised future. This means the Horizon 2 figures in this report are conservative and likely to be lower with future data.

It is not all about carbon.

Whilst the reduction of embodied carbon is undoubtedly of critical importance to abate the climate and biodiversity crises, it is not the only impact for consideration. Many low carbon materials carry a mutual benefit of being low in volatile organic compounds (VOCs), and can contribute to a healthy indoor environment through good internal air quality. Natural materials can also play a part in regenerative design principles, providing a space which is pleasant to be in and feels natural and calming. In addition, an EPD also maps the other ecological impacts that a construction product or material has, such as ozone depletion and ocean acidification. Currently the industry has been focused on green house gas emissions, but is now expanding its considerations to encompass these other impacts.

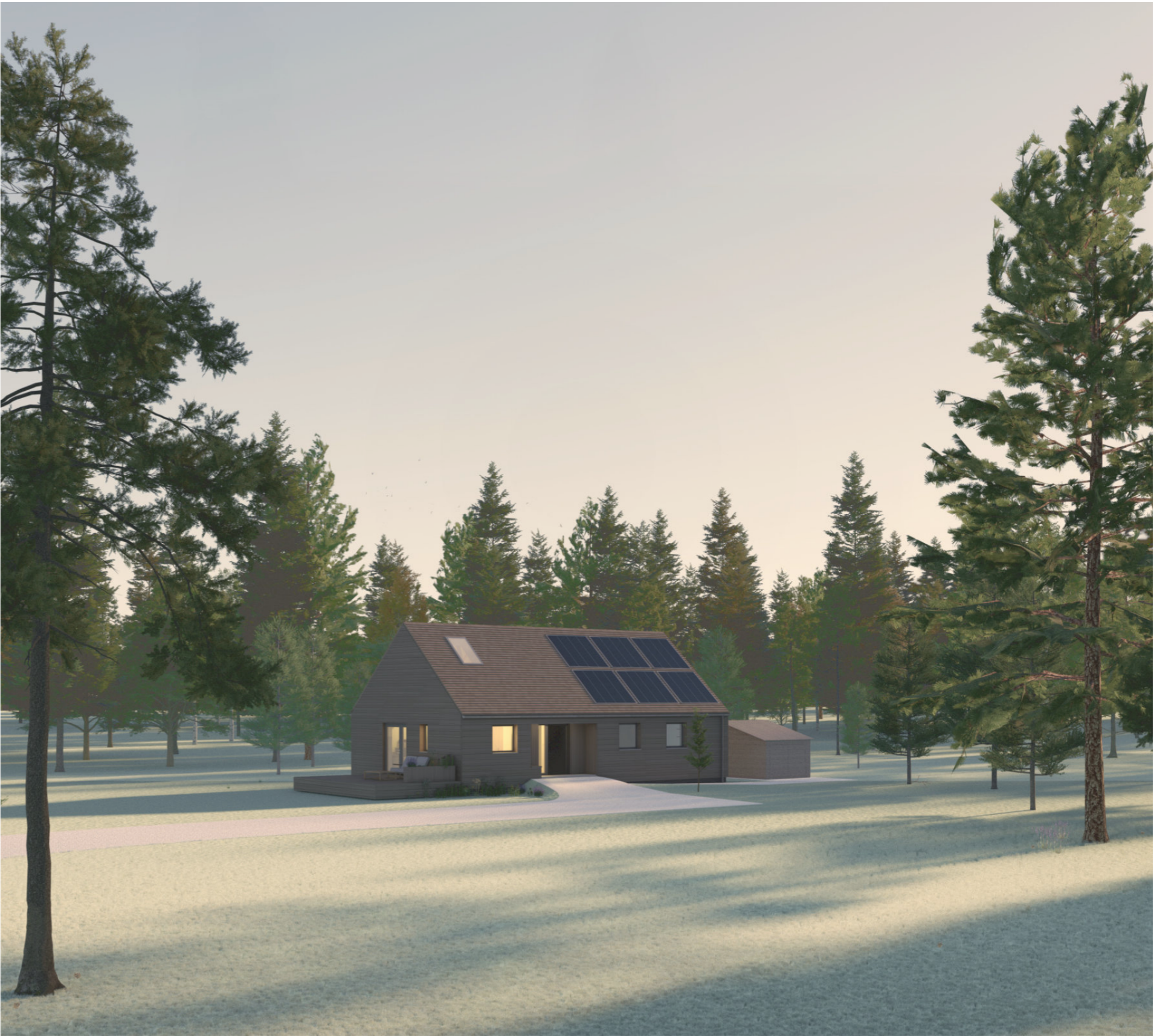
Stored carbon

Bio-based materials have a co-benefit in that they store sequestered carbon within the material, which is removed and kept from contributing to green-house gas emissions for the duration of a product or building's life. Whilst the UK industry has principally focused on reducing embodied carbon emissions in construction, increasing attention is being paid to the climate benefits of stored carbon, as recognised by the Carbon Removal and Carbon Farming taxonomy which enables stored carbon to be valued and traded, bringing financial value to projects that use bio-based materials.

6.0 Visualisations

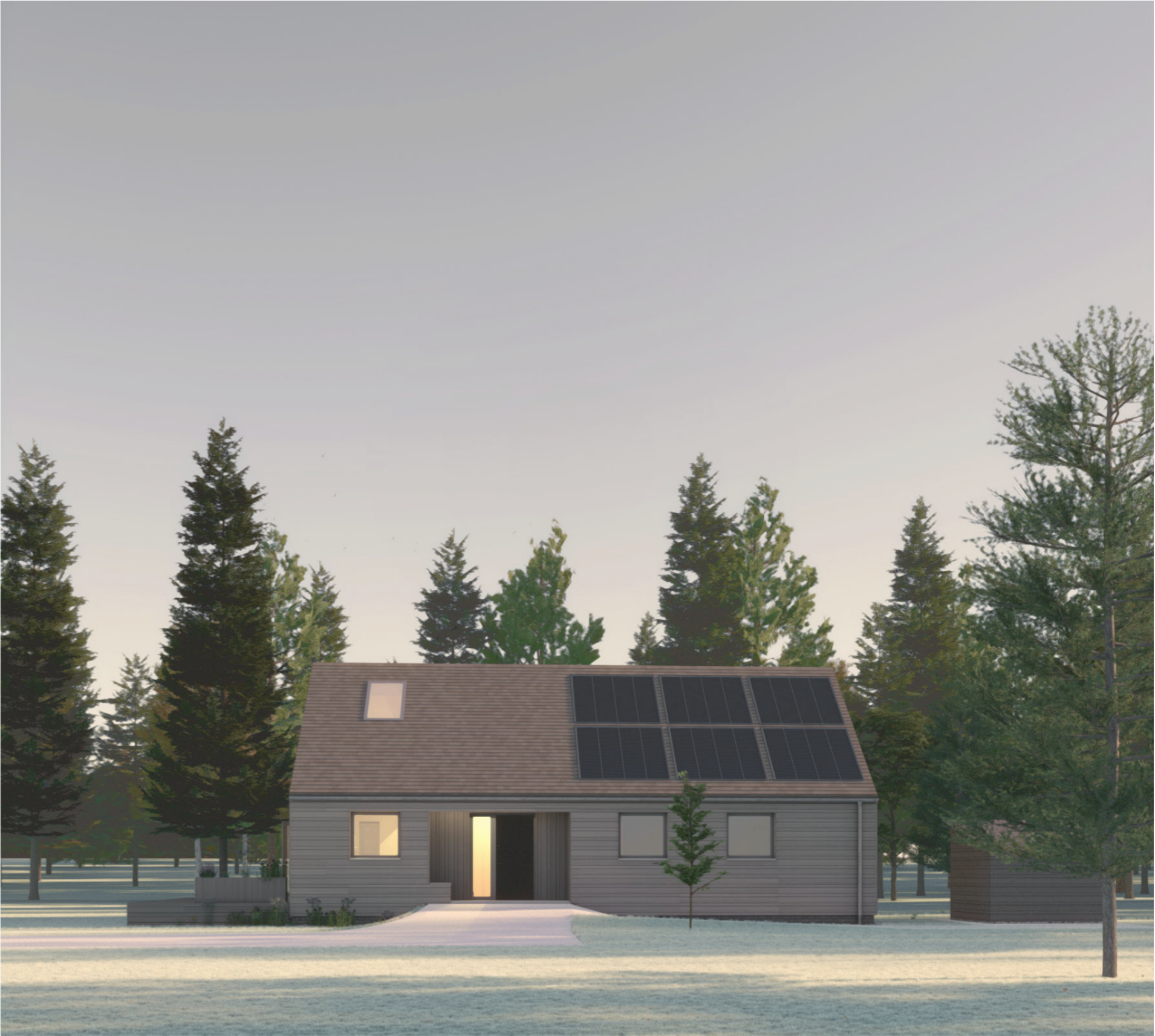
6.1 - External Visualisations

Living Lab 4: Smart Housing, Smart Communities
Digital Blueprint for a Smart Home of the Future



6.1 - External Visualisations

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Digital Blueprint for a Smart Home of the Future



6.1 - External Visualisations

Living Lab 4: Smart Housing, Smart Communities
Digital Blueprint for a Smart Home of the Future



6.2 - Interior Visualisations

Living Lab 4: Smart Housing, Smart Communities
Digital Blueprint for a Smart Home of the Future



6.2 - Interior Visualisations

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6.2 - Interior Visualisations

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6.2 - Interior Visualisations

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6.2 - Interior Visualisations

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7.0 Holistic Value

Glossary

(Holistic Value Chapter)

Funding, Policy & Delivery

AHSP – Affordable Housing Supply Programme:

The Scottish Government's primary funding mechanism for delivering affordable housing, providing capital grant support to Registered Social Landlords and local authorities.

BCIS – Building Cost Information Service: A construction cost benchmarking service used to provide location-adjusted cost data, including rural comparators for accurate project appraisal.

RSL – Registered Social Landlord: An organisation that owns and manages social housing, typically reliant on public funding and regulated to deliver affordable rent homes.

Digital & Care Integration

TEC – Technology Enabled Care: Digital tools and systems, such as remote monitoring and telecare, that support independent living and preventative care.

Hybrid Platform Model: A digital delivery approach that combines national-scale systems with local control, enabling interoperability while maintaining flexibility.

Cost & Financial Metrics

CAPEX – Capital Expenditure: The upfront cost of delivering a building, including construction, materials, and installed systems.

OPEX – Operational Expenditure: The ongoing cost of running and maintaining a home, including energy use, repairs, and servicing.

Extra-over Cost: The additional capital cost required to upgrade from a baseline specification to a higher-performing standard, such as Passivhaus or enhanced fabric.

Policy Baseline Cost: A benchmark cost used for appraisal and comparison, reflecting typical delivery expectations within funding frameworks.

Above-Benchmark Funding: Additional funding beyond standard grant levels, justified through evidence of higher costs or enhanced performance outcomes.

Digital Capex: The upfront cost associated with installing digital infrastructure, including sensors, connectivity and technology-enabled care systems.

Operating Surplus / Deficit: The net financial position of a dwelling when comparing rental income against operating and maintenance costs

Performance, Economic & Strategic Concepts

H1L1 / H1L2 / H1L3 – Horizons & Levels: Defined specification packages within the Matrix, representing increasing levels of performance, cost and integration.

Passivhaus (Passivhaus Standard): A high-performance building standard focused on ultra-low energy demand, airtightness and thermal comfort, reducing operational costs and improving long-term viability..

Whole-Life Cost: The total cost of a building over its lifecycle, including capital, operational, maintenance and replacement costs.

Cross-Sector Public Value: The wider economic and social benefits generated beyond housing, such as reduced healthcare costs or improved wellbeing.

Procurement Efficiency: Cost savings achieved through aggregation, standardisation or improved purchasing strategies across programmes or sectors.

Modular Delivery: A construction approach using off-site manufactured components, often improving cost certainty, programme speed and quality.

Holistic value summary

This section and associated appendix should be read as a decision-support tool, not a static cost comparison.

The analysis reflects the structural cost pressures associated with delivering high-performance built assets in constrained funding environments, using rural affordable housing as the primary reference case.

While capital costs exceed benchmark assumptions, the modelling demonstrates that a fabric-first specification, combined with targeted digital and energy systems, produces materially improved whole-life outcomes.

These outcomes include:

- Reduced ongoing maintenance burden
- Lower energy-related risk exposure
- Improved asset performance and longevity

While the analysis is grounded in the Registered Social Landlord (RSL) context, the underlying dynamics are applicable across other asset-intensive sectors, including:

- Local authorities
- Healthcare estates
- Institutional and portfolio landlords
- Private developers

The implication is consistent across all sectors. Affordability cannot be assessed on capital cost alone. Where assets are held and operated over the long term, the balance between upfront investment and operational stability becomes a primary driver of value. This appendix therefore presents a structured view of both capital and operational dynamics to support informed investment decisions.

Smart Home of the Future Affordability: Standalone affordability assessment for rural affordable housing in Scotland prepared in March 2026. For more information on this section please also refer to the 'Affordability Annex' document.

Executive Summary

Rural delivery costs are materially above national averages, the AHSP benchmark structure only partly covers the performance uplift required, and the combination of Passivhaus-grade fabric plus a targeted digital package produces the strongest operating case for rural affordable housing.

Interpretation

The affordability challenge is not simply a question of lowering capex. In rural Scotland the decisive issue is whether the specification produces a home that remains operable within rent constraints, reduces maintenance burden, and can justify above-benchmark funding through a clear public-value case.

1. Cost Reality and Policy Baseline

The rural cost baseline used in this assessment is deliberately more demanding than national headline averages.

AHSP out-turn data indicates an average total cost per home of £207,387 and an average social-rent cost per home of £197,708. BCIS-adjusted rural comparators rebased to Moray indicate a materially higher delivery range of £322,649 to £373,205 per dwelling. For business case modelling, this report uses a blended policy baseline of £301,080 per dwelling.

That matters because the above-benchmark case is structural, not cosmetic. If appraisal starts from a benchmark that understates real rural delivery conditions, even a well-designed scheme can appear artificially marginal before performance improvements are considered.

| Headline finding | Updated position |
|--------------------------------|--|
| Rural cost reality | BCIS-adjusted Moray comparators indicate £322,649 to £373,205 per dwelling, against a model policy baseline of £301,080 and AHSP 2024-25 average cost per home of £207,387. |
| Grant structure | Current AHSP grant averages 61.6% of cost, with £21,278 per home available through standard quality measure uplifts. |
| Preferred specification | H1L2 remains the strongest balance of performance and cost: £28,771 building-element extra-over and £4,350 digital capex, or £33,121 combined. |
| Operating model | Annual maintenance falls from £3,810 to £2,340, a saving of £1,470 per dwelling per year. |
| Critical viability test | At 100% grant, standard build still shows a £1,320 annual deficit, while Passivhaus H1L2 moves to a £403 surplus. |
| Digital opportunity | An illustrative 15% procurement and standardisation opportunity on national TEC spend could fund about 1,278 H1L2 digital packages per annum, covering 26% of recent AHSP approvals. |

Table 01: Holistic Value Headline Findings Table

| Metric | Value | Why it matters |
|---|----------------------|--|
| AHSP average total cost per home | £207,387 | Useful national reference point, but not a reliable rural cost proxy. |
| Average social-rent cost per home | £197,708 | Tender-stage benchmark from recent AHSP out-turns. |
| BCIS-adjusted rural comparator range | £322,649 to £373,205 | Represents the more realistic construction environment for Moray-style rural delivery. |
| Policy baseline used in this report | £301,080 | Blended rate used for viability modelling and package comparison. |

Table 02: Cost Reality and Policy Baseline Table

2. Grant Funding and Funding Implications

Current AHSP grant levels cover a substantial share of cost, but not the full performance uplift required for a rural future-ready home.

Recent out-turns indicate an average grant rate of 61.6%. Standard quality measure uplifts can add £21,278 per dwelling, with the largest components linked to zero direct emissions heating, updated energy performance, automatic fire suppression and, where justified, space for home working or study. Digital enabling contributes only £351 within the standard structure.

The practical implication is blunt. The grant system can partly absorb the shift to better fabric and low-carbon services, but higher-performing rural schemes still require either above-benchmark justification or blended funding routes.

3. Specification Packages and Preferred Horizon

The horizon framework separates building-element extra-over from digital infrastructure, then recombines them into total package cost. This makes the trade-offs visible rather than burying them in a single blended uplift.

| Funding Route | Implication for this report |
|--|--|
| Standard AHSP benchmark and quality measures | Provides the core baseline and can support £21,278 per home of standard uplifts. |
| Above-benchmark appraisal | Primary route for justified additional cost linked to Passivhaus-grade fabric, rural abnormal cost and other evidence-backed enhancements. |
| Rural and Islands Housing Fund / Key Workers Fund | Potential supplementary routes where the project geography or housing need aligns. |
| TEC, health and innovation funding | Relevant for digital and preventative technology elements that create cross-sector value rather than pure housing value. |

Table 03: Grant Funding Implications Table

| Package | Building Extra-Over | Digital Capex | Summary |
|--------------------------|---------------------|---------------|--|
| HORIZON 1 Level 1 | £14,219 | £2,000 | Entry package. Low complexity, but weaker long-term operating proposition. |
| HORIZON 1 Level 2 | £28,771 | £4,350 | Preferred balance of cost, performance and deployability. |
| HORIZON 1 Level 3 | £47,961 | £5,100 | Stronger environmental ambition, but a sharper capex step-up. |
| HORIZON 3 Level 1 | £23,752 | £6,600 | Integrated systems begin to scale, but reliance on digital coordination rises. |
| HORIZON 1 Level 2 | £48,528 | £13,050 | Mid-term coordinated package with much higher digital cost. |
| HORIZON 1 Level 3 | £92,627 | £18,050 | Demonstrator-level proposition rather than mainstream affordable housing baseline. |

Table 04: Horizon 1 and Horizon 2 Cost Table

4. Whole-Life Operating Case

The strongest argument for the preferred specification is operating performance under rent constraint.

5. Market Applicability and Modular Delivery

The preferred package is most transferable where the buyer can benefit from either operating savings, asset premium, or long-term resilience. The analysis indicates three distinct conclusions.

- For volume builders, H1L2 is commercially credible at scale, provided supply chain capability is available.
- For self-builders, H1L2 and H1L3 both work, with the more ambitious package becoming progressively values-led rather than purely commercial.
- For RSL social rent, any enhanced specification remains grant-dependent, but Passivhaus is the only route that materially improves operating viability.

Modular delivery becomes more attractive once rural realities are priced properly. With Moray and Highlands factors included, modular is effectively cost-neutral on construction alone and becomes cost-positive once programme benefits are recognised. The final adjusted comparison indicates approximately £262,189 for traditional rural delivery against £256,404 for modular delivery, a saving of about £5,785 per dwelling in favour of modular.

| Measure | Standard Build | Passivhaus H1L2 / H1L3 | Result |
|--|------------------------------------|---------------------------------|--|
| Annual maintenance and repair | £3,810 | £2,340 | £1,470 annual saving per dwelling |
| Net annual position at current average grant | £(6,620) | £(6,399) | Passivhaus performs better but both remain deficit positions |
| Net annual position at 100% grant | £(1,320) | £403 | Passivhaus H1L2 reaches operating surplus |
| Cross-sector public value | Not fully captured by the landlord | C. £3,650 per dwelling per year | Supports blended funding logic |

Table 05: Whole-Life Operating Case Table (compiled in and costs relevant to March 2026)

6. Digital Infrastructure and the Funding Opportunity

Digital infrastructure should be treated as a targeted enabling layer, not as speculative decoration. The H1L2 package focuses on practical systems: environmental sensing, targeted TEC, edge-based control and a light-touch data layer. On the current model, this costs £4,350 per dwelling, equivalent to roughly 1.4% of the policy baseline.

There is also a wider affordability opportunity. Scotland already supports a significant technology enabled care market. Using an indicative annual TEC spend equivalent of £37.05 million, a 15% procurement and standardisation opportunity would release about £5.56 million per year. At current package cost, that is enough to fund around 1,278 H1L2 digital packages, which include TEC, annually this is equivalent to 26% of recent AHSP approvals.

| Digital Finding | Implication |
|---|--|
| H1L2 digital package cost = £4,350 | Practical enough for deployment now; low enough to test at scale. |
| Hybrid platform model preferred | Balances national efficiency with local autonomy and open-protocol interoperability. |
| Illustrative procurement opportunity = £5.56m per year | Could fund about 1,278 H1L2 packages per annum. |
| This is an opportunity model, not a guaranteed saving | Requires programme design, aggregation and commissioning discipline. |

Table 06: Digital Infrastructures & Implications Table

7. Final Position and Recommended Use

- 1. Use H1L2 as the reference package for rural AHSP business cases.** It gives the strongest balance of deployability, performance uplift and cost discipline.
- 2. Anchor capital appraisal to a rural-adjusted baseline, not national averages alone.** The rural premium is material and should not be treated as a marginal exception.
- 3. Frame Passivhaus as an operating and risk strategy, not just an energy standard.** The maintenance and viability evidence is the strongest part of the case.
- 4. Treat digital as a targeted enabling package with separate cross-sector funding logic.** The housing budget should not be expected to carry the entire preventative technology layer.
- 5. Reserve H2 and H3 packages for strategic planning, demonstrators, innovation programmes and phased adoption.** They are strategically useful, but require economies of scale, national adoption and proven technology readiness to act as the mainstream affordable housing baseline today.

Appendix: Evidence Base

This report draws on AHSP out-turn data, BCIS rural benchmark comparators, Scottish Housing Regulator financial projections, Public Health Scotland technology enabled care data, and current policy benchmark documents. The main source groups used were:

- AHSP out-turn and benchmark guidance, including quality measure uplifts and rent benchmarks.
- BCIS rural residential cost comparators rebased to Moray and Q1 2026.
- Scottish Housing Regulator financial projections and loan portfolio data.
- Public Health Scotland and related evidence on technology enabled care usage and expenditure.
- Recent market evidence on energy-performance premiums, new-build premiums and retrofit avoidance.

Realising the vision

Envision began with a simple but urgent proposition: that the home must be understood not as a passive backdrop to life, but as active civic infrastructure, capable of supporting health, reducing carbon, enabling independence, and strengthening resilience across the lifespan. This project has demonstrated that this proposition is not speculative; it is practical, deliverable, and increasingly necessary.

The convergence diagram introduced whilst setting the scene for this guide, including architectural, environmental, technological, and social, was not intended as a conceptual illustration alone; it was a statement of method. Each circle represents a discipline too often treated in isolation; the value of Envision lies in proving that meaningful outcomes only emerge when these systems are designed together. Health outcomes cannot be separated from thermal comfort. Digital care cannot succeed without trust, governance, and resilient infrastructure. Low-carbon construction cannot be fully effective if it fails to support dignity, autonomy, and long-term adaptability. Rural and more widespread housing resilience depends on all four operating as one coherent system.

This is the firm position of the blueprint: the future-ready home should be commissioned, designed, and delivered as an integrated platform, not as a building with technology added later. The architecture must anticipate care. The environmental strategy must support a minimal footprint. The digital systems must be embedded

from first principles. The social model must preserve agency, privacy, and participation. Anything less risks repeating the fragmented delivery models that have created many of today's housing, health, and retrofit challenges.

The recommended use of this guide going forward is therefore as both a strategic framework and a practical decision-making tool.

For policymakers and commissioners, Envision should be used to inform procurement standards, funding models, and future housing policy, particularly where affordable rural housing, preventative health, and net zero delivery intersect. Envision provides a basis for reframing housing investment not as isolated capital expenditure, but as preventative infrastructure with measurable downstream value across health, care, and public service demand.

For housing providers, RSLs, and developers, the three-horizon structure offers a clear route to implementation. Horizon 1 should be treated as the immediate minimum standard: the coherent baseline above Scottish Building Standards that is financially defensible and operationally proven. This is where action should begin—not with experimental technologies, but with fabric-first performance, indoor air quality monitoring, safety systems, connectivity resilience, and basic Technology Enabled Care embedded as standard. Horizons 2 and 3 then provide the safeguarded pathway forward, ensuring today's decisions do not create tomorrow's stranded assets.

For designers and multidisciplinary delivery teams, the blueprint should function as a coordination tool. It creates a shared language between architecture, engineering, digital health, construction, and community stakeholders, allowing ambition to be balanced with deliverability. It is intentionally not a fixed specification or product catalogue; it is a repeatable methodology for convergence.

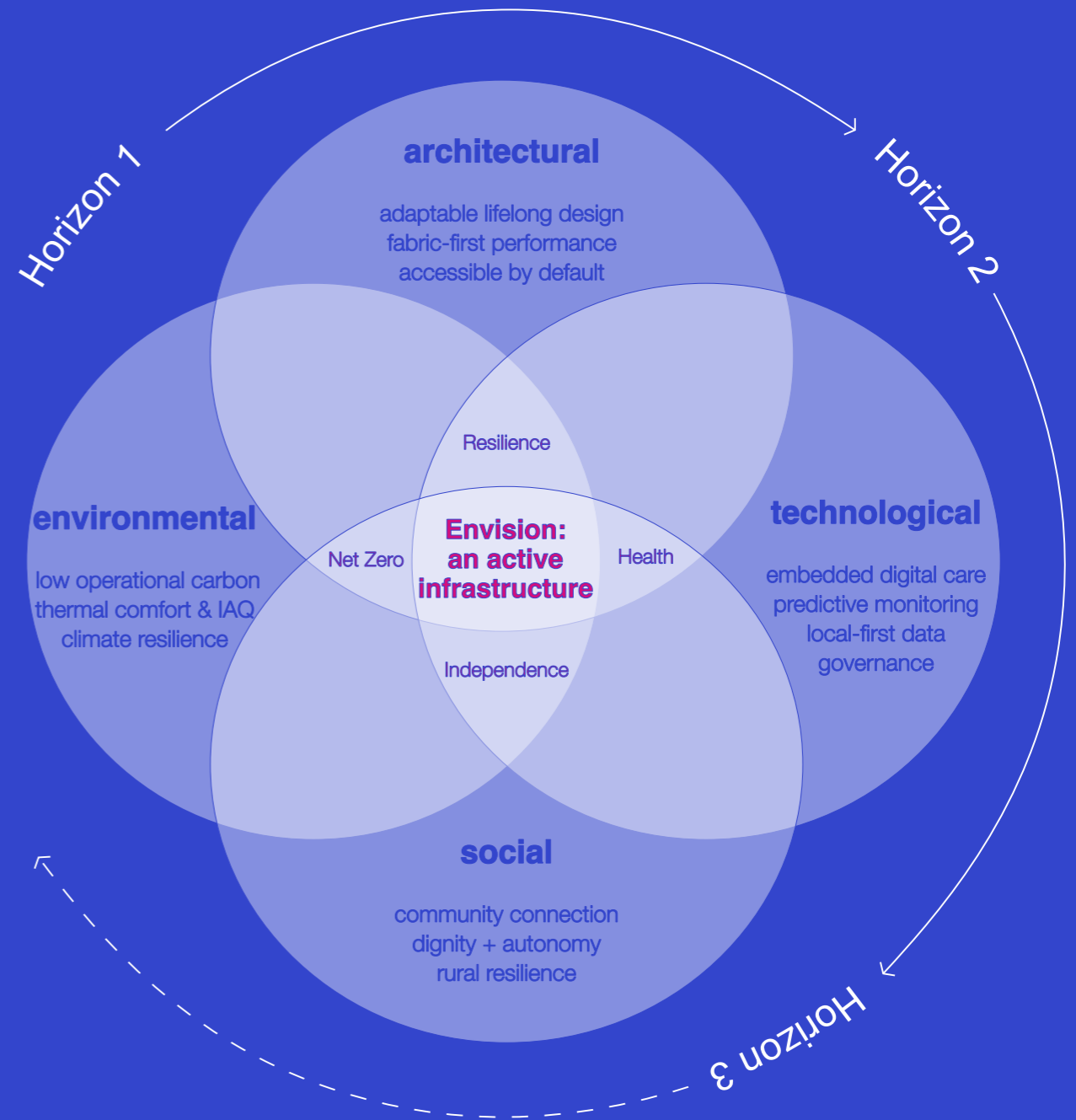
Most importantly, Envision should be understood as scalable beyond a single demonstrator home. Its principles apply equally to retrofit, to social housing programmes, to rural regeneration, and to future policy development across Scotland and beyond. Given that most of the homes of 2050 already exist, this is not simply a new-build agenda, it is a framework for transforming existing housing stock with precision, occupant health and well being, and long-term value at the fore.

We return, then, to the four circles: architectural, technological, environmental and social.

Architecture provides the physical foundation. Environmental performance ensures resilience and health. Technology enables anticipation, coordination, and autonomy. Social value gives the system purpose—community, dignity, belonging, and meaning. At their centre sits the true objective of the project: not a smarter house, but a better life.

Envision is therefore not the conclusion of a design exercise, but the beginning of a delivery model. It is a blueprint for how rural homes can become preventative infrastructure, how sustainability can become lived wellbeing, and how housing can once again be understood as one of society's most powerful public assets.

The question is no longer whether this convergence is required, but how quickly we choose to build it.



9.0 Appendices

| Appendix | Title |
|----------|----------------------------------|
| A | Envision Matrix** |
| B | Envision Video** |
| C | Affordability Research** |
| D | Plans & Sections |
| E | Carbon Report & Calculation Data |

** Seperate File - to be read alongside this report

Appendix A: Envision Matrix

APPENDIX A - Envision Matrix

Living Lab 4: Smart Housing, Smart Communities
Digital Blueprint for a Smart Home of the Future

| | Baseline | Horizon 1 (H1) | | | Horizon 2 (H2) | | | Horizon 3 (H3) | | |
|---|---|--|---|--|---|--|--|--|--|--|
| | 2026 | 1-3 years | | | 3-7 years | | | 7+ years | | |
| | | deployable, practical | | | integrated and coordinated | | | intelligent and regenerative | | |
| | | H1L1 | H1L2 | H1L3 | H2L1 | H2L2 | H2L3 | H3L1 | H3L2 | H3L3 |
| Internal definition | Assumed standard output, based on typical housing delivery in 2026. | Easy wins from the baseline - modest improvements to operational energy performance. | Taking baseline to potential for Passivhaus certification | Taking baseline to potential for Passivhaus certification and STHB Gold. | As per H1L2 | As per H1L3 | Mid point most ambitious approach. | As per H2L2 | As per H2L3 | Most ambitious future approach |
| | | Base level (L1) | Mid level ambition (L2) | Most ambitious (L3) | Base level (L1) | Mid level ambition (L2) | Most ambitious (L3) | Base level (L1) | Mid level ambition (L2) | Most ambitious (L3) |
| SUSTAINABILITY & PERFORMANCE TARGETS | | | | | | | | | | |
| STHBD Section 7: | Silver | STHB Silver and Gold Aspects 1 and 2 | STHB Silver and Gold Aspects 1 and 2 | Gold | STHB Silver and Gold Aspects 1 and 2 | Gold | Platinum (not yet defined) | Gold | Platinum (not yet defined) | Platinum (not yet defined) |
| Certification standard: "It is noted that the achievability of certification will be dependent on the siting of a house, and that this standard may be challenging to achieve in some locations. Nevertheless, the noted certification should form a target." | Not certified | Not certified | Passivhaus certified* | Passivhaus Plus certified* | Passivhaus certified* | Passivhaus Plus Certified* | Passivhaus Plus Certified* | Passivhaus Plus Certified* | Passivhaus Plus Certified* | Passivhaus Plus Certified* |
| Energy and carbon | | | | | | | | | | |
| Renewable energy generation | As required for SAP compliance | As required for SAP compliance | As required for SAP compliance | > 60kWh/m ² _(toopresent) | As required for SAP compliance | > 60kWh/m ² _(toopresent) | > 60kWh/m ² _(toopresent) | >60kWh/m ² _(toopresent) | > 60kWh/m ² _(toopresent) | > 60kWh/m ² _(toopresent) |
| Embodied Carbon - philosophy | Not prioritised | Not prioritised | Design in efficiency in structure and material use, specification of natural materials prioritised. | Design in efficiency in structure and material use, specification of natural materials prioritised. | Design in efficiency in structure and material use, specification of natural materials prioritised. | Design in efficiency in structure and material use, specification of natural materials prioritised. | Increased prioritisation of reduced embodied carbon, alongside reduction of operational energy. | Design in efficiency in structure and material use, specification of natural materials prioritised. | Increased prioritisation of reduced embodied carbon, alongside reduction of operational energy. | To follow UKNZCBS guidance of embodied carbon per kWh to ensure carbon investments are aligned with the national grid decarbonisation. |
| Carbon targets | | | | | | | | | | |
| Upfront carbon (A1-A5) | 400 kgCO ₂ e/m ² GIA | 400 kgCO ₂ e/m ² GIA (source: UK NZCBS (2026)) | 400 kgCO ₂ e/m ² GIA | 345 kgCO ₂ e/m ² GIA | 400 kgCO ₂ e/m ² GIA | 345 kgCO ₂ e/m ² GIA | 290 kgCO ₂ e/m ² GIA | 345 kgCO ₂ e/m ² GIA | 290 kgCO ₂ e/m ² GIA | 235 kgCO ₂ e/m ² GIA |
| Lifecycle embodied Carbon | Targets/limits not set - no formal/aligned targets available at the present time. | Targets/limits not set - no formal/aligned targets available at the present time. | Targets not set - no formal/aligned targets available at the present time. | Targets not set - no formal/aligned targets available at the present time. | Targets not set - no formal/aligned targets available at the present time. | Targets not set - no formal/aligned targets available at the present time. | Targets not set - no formal/aligned targets available at the present time. | Targets not set - no formal/aligned targets available at the present time. | Targets not set - no formal/aligned targets available at the present time. | Targets not set - no formal/aligned targets available at the present time. |
| Whole Life Carbon | Targets/limits not set - no formal/aligned targets available at the present time. | Targets not set - no formal/aligned targets available at the present time. | Targets not set - no formal/aligned targets available at the present time. | Targets not set - no formal/aligned targets available at the present time. | Targets not set - no formal/aligned targets available at the present time. | Targets not set - no formal/aligned targets available at the present time. | Targets not set - no formal/aligned targets available at the present time. | Targets not set - no formal/aligned targets available at the present time. | Targets not set - no formal/aligned targets available at the present time. | Targets not set - no formal/aligned targets available at the present time. |
| Offsetting | Not included | Not included | Not included | Not included | Not included | Not included | As required for net zero ambition - to include forestry and peatland projects | Not included | As required for net zero ambition - to include forestry and peatland projects | As required for net zero ambition - to include forestry and peatland projects |
| Approach to circular economy | Not prioritised | Not prioritised | Not prioritised | Specification of recycled products incorporated where possible. Design for deconstruction to meet the requirements of the Gold standard. | Not prioritised | Specification of recycled products incorporated where possible. Design for deconstruction to meet the requirements of the Gold standard. | Specification of recycled products incorporated where possible. Design for deconstruction to meet the requirements of the Platinum standard (not yet defined). | Specification of recycled products incorporated where possible. Design for deconstruction to meet the requirements of the Platinum standard (not yet defined). | Specification of recycled products incorporated where possible. Design for deconstruction to meet the requirements of the Platinum standard (not yet defined). | Fully considered - building designed to be deconstructed and materials tagged and recoverable as a material bank. To achieve ambitious re-use targets e.g. 50-75% of material by |

Appendix B: Envision Video

Living Lab 4: Smart Housing, Smart Communities
Digital Blueprint for a Smart Home of the Future

ENVISION: the digital blueprint
for a smart home of the future



Appendix C: Affordability Research

SECTION 1: THE COST REALITY — What It Actually Costs to Build in Rural Scotland

Evidence base from AHSP out-turn data, BCIS benchmarks, and SHR financial projections

| 1A. KEY COST & FUNDING FIGURES | | | | |
|---|----------|--|--------------|---|
| Variable | Value | Source | Year | Notes |
| Average total cost per AHSP home | £207,387 | Scotland's Housing Network DVfM Report | 2024-25 | National average; rural costs significantly higher |
| Average social rent cost/home | £197,708 | AHSP Out-turn Table 13a | 2023-24 | At tender approval stage |
| Average SG grant per social home | £121,737 | AHSP Out-turn Table 13a | 2023-24 | |
| Grant as % of total cost | 61.6% | AHSP Out-turn Table 13a | 2024 | 53% grant, 40% private finance, 5% other |
| Private finance / other facilities share | 33.4% | SHR Financial Projections | 2024 | RSL borrowing component |
| Weighted avg interest rate (new fixed) | 5.3% | SHR Annual Loan Portfolio 2025 | 2024-25 | Up from 5.0% in 2023/24 |
| Construction cost share of total | 74.0% | DVfM Report / SHN | 2022-23 adj. | |
| BCIS rural dev cost average project cost factored to Moray, Q1 2026) | £322,649 | BCIS factored to Moray | 2026 | 12 projects nationally, 7 rural - all rebased to Q1 2026, Moray, assuming average unit size 94m2 to comply with HfVN guidance |
| BCIS rural dev cost using closest equivalent project context factored to Moray, Q1 2026 | £373,205 | BCIS factored to Moray | 2026 | 1 project in a highland, rural context, North East Scotland |
| Policy baseline used in this model | £301,080 | Mid-point rural benchmark | 2026 | Simplified round figure for business case modelling |

COST RECONCILIATION NOTE

The BCIS-evidenced rural cost is £322,649. This model uses £301,080 as the policy baseline for business case calculations which is a blended rate of national AHSP average + BCIS mid + BCIS high point

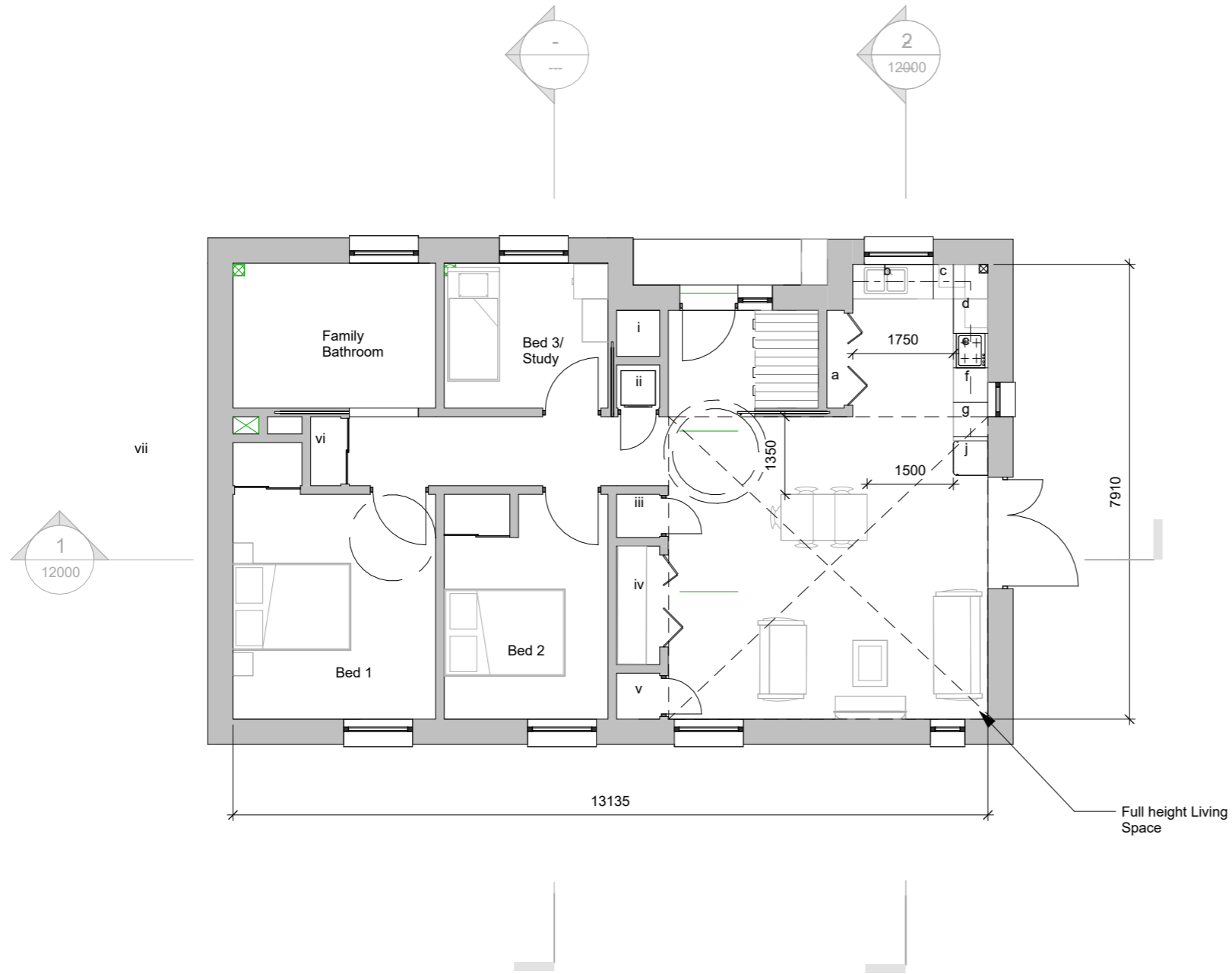
The gap between BCIS actual and policy baseline is the above-benchmark case rural Scotland costs more than the benchmark assumes and reflects inflationary pressure from '24-25 to Q1 '26

1B. AHSP HISTORIC TRENDS — RSL Social Rent (Out-turn Report 2023-24)

| Financial Year | Avg Cost/Home | Avg Grant/Home | Grant Rate | YoY Cost Change |
|----------------|---------------|----------------|------------|-----------------|
| 2019-20 | £157,811 | £87,994 | 55.8% | |
| 2020-21 | £158,262 | £85,553 | 54.1% | 0.3% |
| 2021-22 | £167,115 | £94,598 | 56.6% | 5.6% |
| 2022-23 | £195,077 | £116,601 | 59.8% | 16.7% |
| 2023-24 | £197,708 | £121,737 | 61.6% | 1.3% |

Source: AHSP Out-turn Report 2023-24, Table 13(a). Grant rate has risen from 55.8% to 61.6% over 5 years.

Appendix D: Plans & Sections



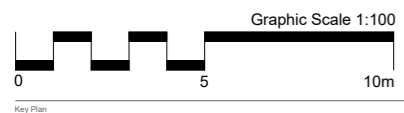
- i Electrics Distribution Board + Storage (Hoover + Household)
- ii Washing machine
- iii HOS + associated kit
- iv 2000x750 storage
- v MVHR 750x750
- vi Linen Cupboard
- vii ASHP + Internal 300x450mm Service Riser

- a cleaning cupboard/pantry
- b sink+drainer
- c dishwasher
- d pull out corner unit
- e 4 ring hob + oven
- f base/drawer unit
- g recycle/refuse base
- j fridge freezer

BED 2 Showing Double Bed. Also suitable for two single beds (good for flexibility)

BED 3/STUDY Silver/gold standard providing a desk space (see section 7 of the technical handbook)

1 Proposed Ground Floor Plan
1 : 100



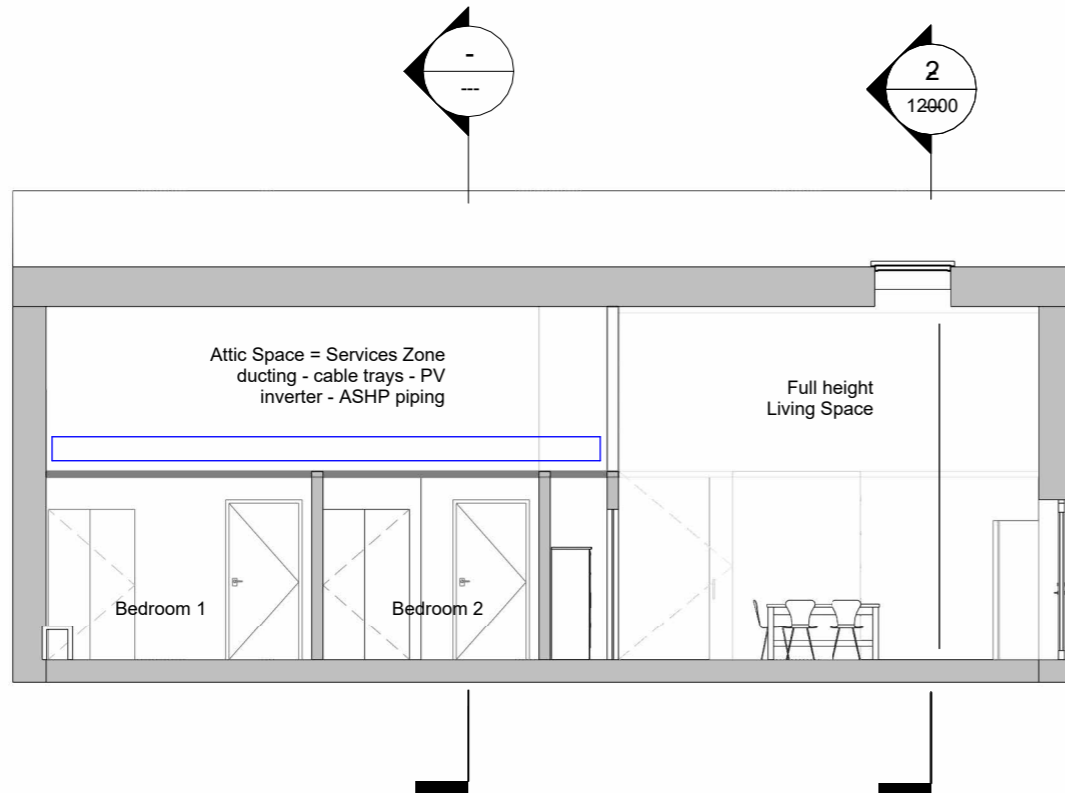
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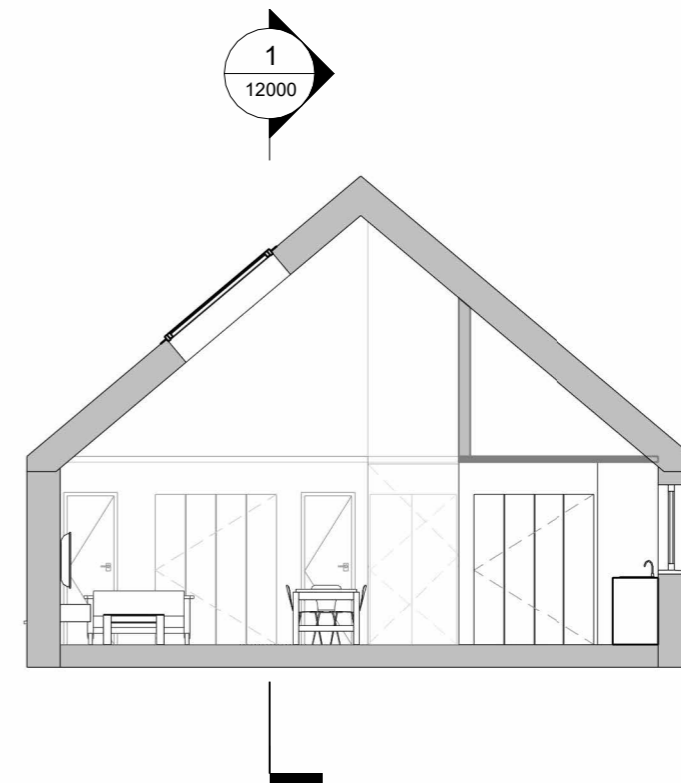


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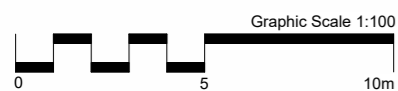
Project: Smart Home Digital Blueprint
Client: Architype
File ID: SDB - ART - XX - 00 - D - A - 11000
Drawing Title: Ground Floor Plan
Revision: **P02**
Date: 31/03/2026
Scale: 1 : 100 @ A1
Internal Project Reference: 10629



1 Section 1
1 : 100



2 Section 2
1 : 100



Key Plan

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Project
Smart Home Digital Blueprint
Client
Architype

File ID
SDB - ART - XX - ZZ - D - A - 12000
Drawing Title
Building Sections

Revision
P02

Date
31/03/2026

Scale
1 : 100 @ A1

Internal Project Reference
10629

Appendix E: Carbon Calculation Data

WLC for Smart Homes Prototype
Using ECCOlab

Appendix E: Embodied Carbon Calculations

Scope of analysis

Table E.1 outlines which Whole Life Carbon Assessment (WLCA) information modules were included in the calculations for this report (section 5.8 Materials + Carbon). The scope and methodology are in broad alignment with the current industry standard RICS Professional Standard Whole Life Carbon Assessment (WLCA) for the built Environment, Global, 2nd edition (RICS PS v2, 2024). With research and available data on embodied carbon at its infancy aligning with RICS PS v2 helps achieve comparability and consistency. The scope and calculation methodology was adapted to the Concept Design Stage and available information in this study.

The aim was to compare the Embodied carbon of two scenarios:

- The Business-As-Usual 2026 baseline, and
- The Horizon 2 (H2), assuming the highest level of ambition (Level 3).

Each of these are described in the main part of the report.

Figure E.1 (obtained from the RICS PS v2 document) is a visualisation of which modules are included in subsets of Whole Life Carbon and how these are reported.

Life-cycle embodied carbon (also Embodied carbon) includes the total greenhouse gas emissions and removals, associated with construction products and construction processes, over the whole life cycle of a building, including its disposal (life cycle modules: A0–A5, B1–B5 and C1–C4, with life cycle module A0 assumed to be zero for buildings).

Upfront carbon is a subset of life-cycle embodied carbon and includes emissions associated with construction products and construction processes, up to practical completion.

Biogenic carbon includes Greenhouse gas removals associated with carbon sequestration into biomass, as well as any emissions associated with this sequestered carbon, is separately reported.

APPENDIX E - Carbon Calculation Data

Table E.1 Whole Life Carbon Assessment Modules and reporting requirements in RICS v2.

| Stage | Module | Description | Included | Notes for concept stage small dwelling |
|---|-------------------------------|---|-------------------------------|--|
| Stage A: Products and Construction | A0 Pre-construction | Non-physical pre-construction activities: surveys, ground investigations, design-related travel. | No | A0 is assumed to be zero (RICS PS v2 s.5.1.1 for small buildings) |
| | A1 – A3 Product Stage | Raw material extraction, transport to factory, manufacturing of all construction products, components and MEP. | Yes | Data source: generic or specific product EPDs in existing datasets or desktop research |
| | A4 Transport to Site | Carbon from transporting construction products from factory gate to site, including return journeys and interim depots. | Yes | Standardised assumptions from RICS PS v2 for distances / emission factors applied on material categories. |
| | A5 Construction Process | All on-site construction activities: energy use, water, waste, temporary works, and any demolition of existing structures. | Yes | A5.1 Pre-construction demolition: Omitted / assumed 0 A5.2 Construction activities: RICS PS v2 benchmark 40 kgCO ₂ e/m ² GIA A5.3 Construction Waste Management defaults based on selected approach to construction waste management and default percentages by material category. A5.4 Worker transport – omitted. |
| | Biogenic carbon sequestration | Carbon sequestered in sustainably sourced timber and other bio-based materials (e.g. FSC/PEFC-certified timber). Recorded as a removal in A1–A3 and | Included. Reported separately | Biogenic carbon removals in A1–A3 must be reported separately from upfront carbon (RICS v2 s.4.11.1). They cannot be claimed as a net benefit within the WLC total. |
| Stage B: Use Stage for 60 years (included in life-cycle embodied carbon) | B1 Use | Direct emissions/removals from products in use: e.g. refrigerant leakage from heat pumps, carbonation of concrete, off gassing from insulation. | No | Omitted |
| | B2 Maintenance | Carbon from routine maintenance of all construction products and components over the RSP (cleaning, repainting, servicing). | Yes | Default of 10 kgCO ₂ e/m ² GIA or 1% of A1-A5 whichever is greater (RICS PS v2) |
| | B3 Repair | Carbon from repair of construction products and components over the RSP. | Yes | Default 25% of B2 (maintenance). At this stage separately accounting for building fabric elements and MEP was not possible due to dependencies on project level estimates. |
| | B4 Replacement | Carbon from like-for-like replacement of products whose service life is shorter than the RSP (e.g. boiler, windows, kitchen, roof covering). | Yes | Calculated for each material / product from number of replacements in 60 years reference period and A1-A5. Allowances for selected types. |
| | B5 Refurbishment | Carbon from any planned refurbishment or change in performance during the RSP. If no refurbishment is planned, this may | No | Default assessment assumes no planned refurbishment. |

APPENDIX E - Carbon Calculation Data

Living Lab 4: Smart Housing, Smart Communities
Digital Blueprint for a Smart Home of the Future

| Stage | Module | Description | Included | Notes for concept stage small dwelling |
|--------------------------|--|--|------------------------|---|
| | | be zero or excluded with justification. | | |
| | B6 Operational Energy | GHG emissions from energy use over the in-use stage (heating, hot water, lighting, cooking, appliances, ventilation). | Separately | From benchmarks and prof. judgement, compliance with Section 6 (Scotland) (RICS v2. S.3.8) |
| | B7 Operational Water | GHG emissions from water supply and wastewater treatment over the in-use stage. | No | Omitted. |
| | B8 User Activities | Emissions from user activities not covered elsewhere, e.g. commuting to an office, vehicles using a road. Not applicable to a private dwelling. | No | Not applicable – omitted. |
| Stage C End of life | C1 Deconstruction / Demolition | Carbon from dismantling or demolishing the building at end of the RSP: plant, equipment, energy use. | Yes | Included, with standardised assumptions at material category level and at project level. |
| | C2 Transport of Waste | Carbon from transporting waste materials from site to waste processing or disposal facilities. | Yes | |
| | C3 Waste Processing | Carbon from processing of waste for reuse, recycling or recovery, including sorting and treatment. | Yes | |
| | C4 Disposal | Carbon from landfill or final disposal of materials not recovered or recycled. | Yes | |
| | Biogenic Carbon release | Carbon sequestered in sustainably sourced timber and other bio-based materials is emitted at the end of life and recorded as emission in C3/C4. Net effect across A-C is approximately zero. Not a net benefit within WLC total. | Reported separately. | Biogenic carbon removals cannot be claimed as a net benefit within the WLC total. |
| D Beyond system boundary | D1 Material Reuse / Recycling / Recovery | Potential carbon benefits from reuse, recycling, energy recovery or landfilling of materials arising from A4–A5, B2–B5, or C1–C4. For a timber-frame house this can show significant benefit. | Qualitatively assessed | D1 must be assessed and reported separately. Per RICS v2, it does not form part of the WLC total but must not be omitted. (Sequestration benefits beyond A–C may be noted in Module D or supplementary information.) |
| | D2 Exported Utilities | Carbon benefits from utilities exported from the asset during B6–B8 (e.g. electricity from PV panels exported to the grid). | Qualitatively assessed | D2 included if PV or other export is incorporated in the design. To be confirmed at detailed design stage. |
| Offsetting | Forestry & Peatland Offsetting | Offsetting of residual emissions. As required for net zero ambition. Residual emissions only, after all feasible reduction measures applied. Offset through certified UK forestry and peatland restoration projects. Must follow RICS v2 guidance on offset reporting and be additional to WLCA results. | Qualitatively assessed | Offsets are not a RICS WLCA module. They are reported separately alongside (not within) the WLCA result, per RICS v2 s.6 reporting requirements. Only residual emissions after reduction hierarchy is exhausted should be offset. |

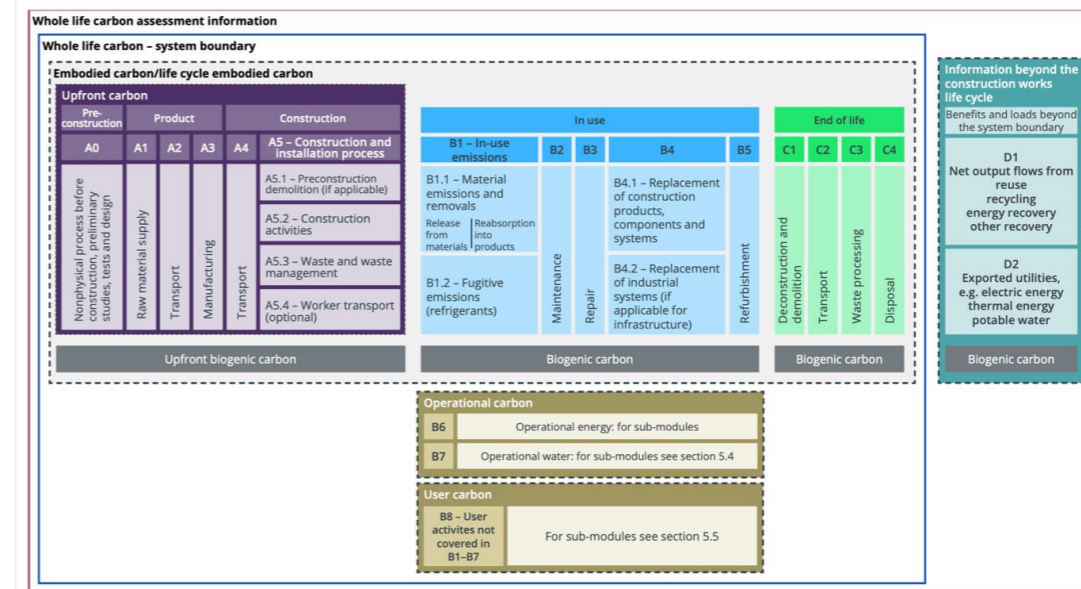


Figure E.1 (Image Source: RICS v2) Modular diagram showing which modules are included under Whole Life Carbon vs. Life cycle embodied carbon.

Analysis period: The analysis covers the standard reference period of 60 years (RICS aligned), which is also assumed to be the life span of the building.

The main elements of the building included in the embodied carbon assessment, aligned with industry-standard elemental classifications, included:

- **Substructure:** foundations and ground floor construction
- **Superstructure:** external walls, roof, windows and doors
- **Internal elements:** internal walls, floors, ceilings and finishes
- **Building services:** heating, ventilation, water systems and associated pipework
- **Fitted elements:** kitchen units, sanitaryware and fixed appliances (e.g., oven, microwave and dishwasher)

Loose furniture, IT equipment, non-fixed equipment / freestanding appliances (e.g., washing machine) were excluded.

Limits and targets

Existing targets or limits of upfront, life-cycle embodied and whole life carbon are also limited by the lack of data, as noted in the UK Net Zero Carbon Buildings Standard v1 (2026). Standardisation of the WLCA methodologies and potentially making assessment a regulatory requirement (Part Z, 2026) are likely to support the creation of a dataset, increasing the reliability of such analyses in the future.

APPENDIX E - Carbon Calculation Data

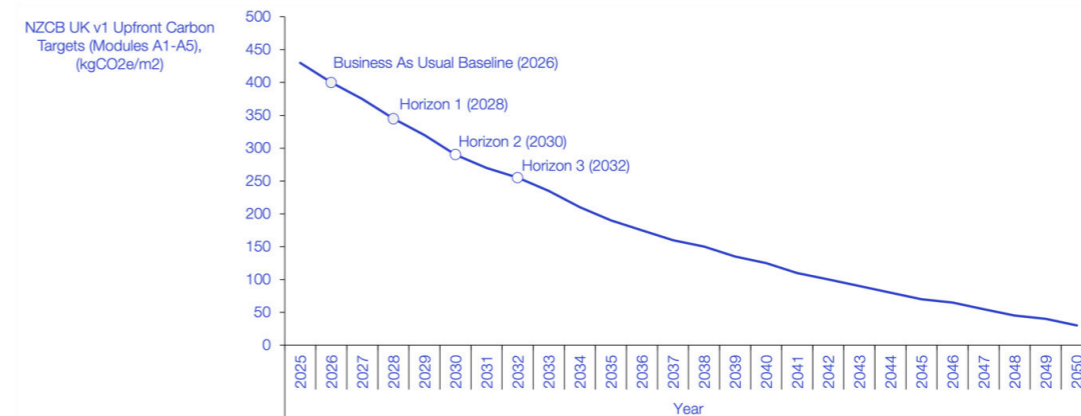


Figure 2 NZCB UK Upfront Carbon Target progression from 2025 to 2050 (Modules A1-A5 for new-build single family dwellings).

Existing limits of upfront carbon: The UK NZCBS sets limits for upfront carbon (A1-A5, kgCO₂e/m²GIA) of new-build single-family dwellings based on the year starting on site. The proposed limits are reduced year-on-year from 2025 to 2050, reaching a tenfold decrease compared to 2025 levels: from 400 kgCO₂e/m²GIA (2026 start onsite) to 40 kgCO₂e/m²GIA for works starting in 2049. The different targets selected for the “Business-as-usual” baseline option and the “Horizon 2” option, are shown in Figure 2:

- 400 kgCO₂e/m²GIA for the 2026 business-as-usual baseline (considerably lower than the LETI 2020 target of 500 kgCO₂e/m²GIA (LETI, 2024).
- 290 kgCO₂e/m²GIA for the 2030 Horizon 2 scenario (broadly aligning with the LETI 2030 target of 300 kgCO₂e/m²GIA) (LETI, 2024).

Lifecycle embodied carbon limits are not yet determined in the UK NZCBS (2026). For reference, the RIBA 2030 target for embodied carbon for residential buildings is **625 kgCO₂e/m² GIA** (incl. sequestration) in the RIBA 2030 (v2) Climate Challenge (RIBA, 2021). The life-cycle embodied carbon targets provided in Part Z Blog by the authors of the UK NZCB standard v1 (Part Z Blog, 2026), broadly align with the RIBA 2030 value of 625 kgCO₂e/m² GIA.

From this benchmark value for embodied carbon excluding upfront is 143 kgCO₂e/m² GIA assuming current forecasts of grid decarbonisation (Part z blog, 2026). Adding this to the above limits for the baseline and horizon 2 scenarios, the lifecycle embodied carbon targets become:

- 543 kgCO₂e/m² GIA (2026 BAU baseline)
- 433 kgCO₂e/m² GIA (2030 Horizon 2).

Table 2 Lifecycle embodied carbon target and scope

| Framework | Scope | Residential target |
|-----------|-------|--------------------|
|-----------|-------|--------------------|

APPENDIX E - Carbon Calculation Data

| | | | |
|---------------------------------|----------------------------|---|---|
| RIBA 2030 (RIBA, v2, 2021) | Life cycle embodied carbon | A1-A5, B1-B5, C1-C4 incl. sequestration | < 625 kgCO ₂ e/m ² (2030 goal) |
| Part Z Blog based on UK NZCB v1 | | A1-A5, B1-B5, C1-C4 | 717 kgCO ₂ e/m ² – without grid decarbonisation 573 kgCO ₂ e/m ² – with grid decarbonisation (assuming 430 upfront carbon) |

Additional notes on Modules A1-A3

Carbon information for most materials was based on existing library of EPDs within the ECCOlab software developed by Architype. Where product specific EPDs were unavailable or where there was not enough sizing/quantity information at concept design stage an alternative approach was selected:

- Benchmarks and defaults from industry standards and other publications (e.g., for heating and ventilation systems) – moderate uncertainty.
- Allowances per m² Gross Internal Floor Area (GIFA) from order of magnitude estimates (e.g., drainage and cold-water pipes, lighting) – high uncertainty.

High uncertainty estimates were acceptable where the percentage contribution of the element to the overall lifecycle carbon was expected to be small.

Quantities estimation at early-stage design: The quantities of materials were calculated directly from the BIM model (Revit). Where quantities were not possible to calculate, allowances based on professional judgement were made, or defaults were used, in line with existing standards.

For MEP upfront carbon, the RICS v2 MEP supplementary tables give typical kg quantities per m² GIA for residential MEP systems. These are then multiplied by a kgCO₂e/kg factor from TM65 or the CIBSE MEP database.

Benchmarks beyond embodied carbon – interpretation note

The current methodology includes lifecycle embodied carbon (A1–A5, B1–B5 and C1–C4), thus excluding operational carbon, in line with current industry standards recommendations for small scale residential buildings at concept design stage. Whole life carbon assessments at more detailed stages can include operational carbon (energy and water) which is expected to be significantly less for the Horizon 2 scenario compared to Baseline option. Indicative benchmarks for whole life carbon are just over 1000 kgCO₂e/m² and over 600 kgCO₂e/m² without and with decarbonisation respectively (Part Z Blog, 2026).

An existing benchmark/target of operational energy carbon (B6) exists from the Part Z Blog: 56 kgCO₂e/m² and 346 kgCO₂e/m² with and without decarbonisation respectively. As RICS v2 suggest using time-dependent (decarbonising) factors for Module B6, a target of 56 kgCO₂e/m² can be assumed (over 60 years of operation).

Assuming however Total energy use intensity (EUI) targets from the *UK Net Zero Carbon Buildings Standard (2026)* the following benchmarks are selected:

For the baseline, an EUI of 100 kWh/m²GIA.yr, based on the limit for existing dwellings following stepped retrofit (2025).

For the Horizon 2 option, an EUI of 46 kWh/m²GIA.yr aligns with the 2031 new-build target for single-family dwellings.

Time-averaged emission factors over the 60-year reference period assuming grid decarbonisation, were assumed to be 0.07 kgCO₂e/kWh for electricity and 0.19 kgCO₂e/kWh for gas. For the BAU baseline, 40 kWh/m²GIA.yr of the total EUI was assumed to be met by gas, with the remaining demand met by electricity. The Horizon 2 option was assumed to be fully electrified.

Greenhouse gas emissions from operational energy over the study period was calculated at:

- For the baseline: **876 kgCO₂e/m²** (87,600 kgCO₂e total)
- For Horizon 2: **193 kgCO₂e/m²** (19,320 kgCO₂e total).

Additional results: breakdown by elemental classification

In addition to the results presented in the main report, Figures E.3 and E.4 show a breakdown of embodied carbon across the information modules for each of these classifications for the baseline (left) and Horizon 2 Level 3 (right). The white boxes above the axis line represent biogenic carbon released at the end-of-life stage, and it is excluded from the total, per RICS v2, i.e., reported separately. The biogenic carbon captured at product stage is shown as a negative value below the axis.

The analysis shows that the superstructure in the business-as-usual scenario is responsible for a considerable part of embodied carbon across both options, but that upfront carbon is the highest in the baseline option only.

APPENDIX E - Carbon Calculation Data

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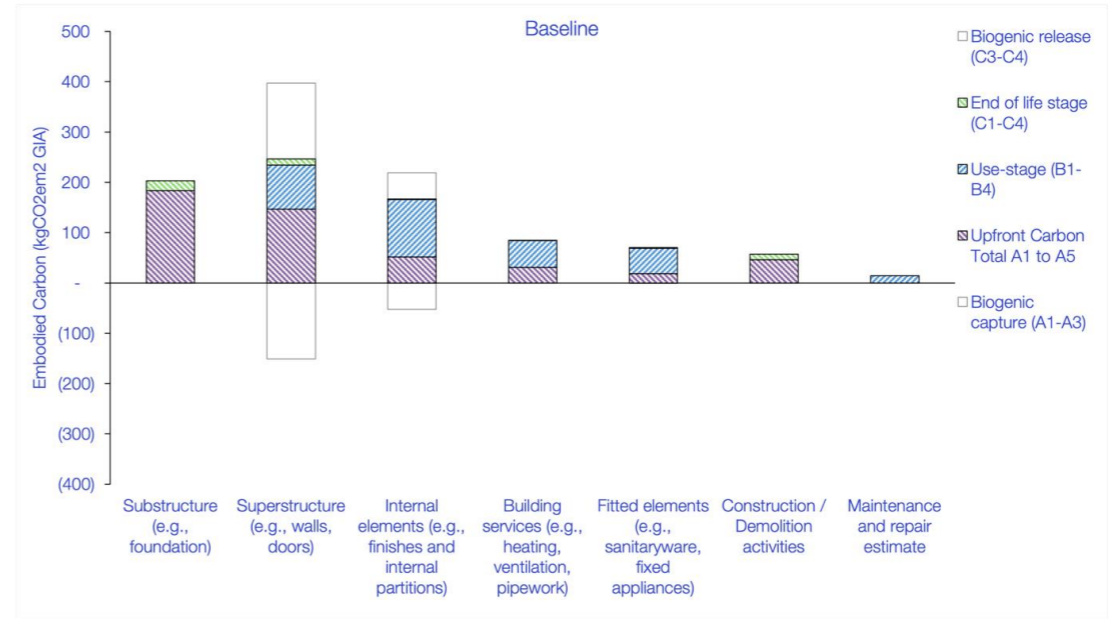


Figure 3 Elemental classification breakdown of embodied carbon for the Baseline scenario.

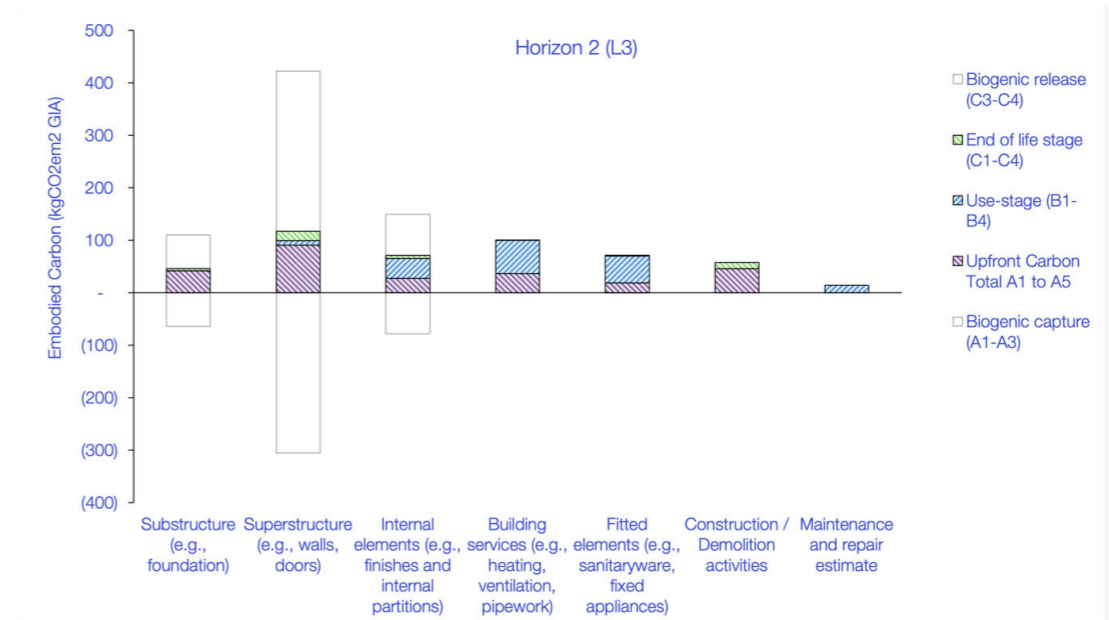


Figure 4 Elemental classification breakdown for the Horizon 2 Level 3 scenario.