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Barriers to Sustainable Development:

Toward a Hemp Economy

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Olena Larionova

Olena Larionova, 31 August 2025

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Abstract

This dissertation explores the barriers to sustainable development toward a hemp-based economy, with a specific focus on the use of hempcrete in the Irish construction sector. While hemp is increasingly recognised for its environmental, economic, and regenerative benefits, its implementation in building practices remains limited due to a range of regulatory, institutional, and economic challenges.

Adopting a qualitative research design, this study draws on literature and policy analysis, comparative case studies, and semi-structured interviews with stakeholders from industry, academia, government, ecology, and hemp-based households. The research identifies key obstacles, including legal ambiguity, lack of certification, insufficient policy integration, supply chain limitations, and the inadequacy of current energy performance metrics such as the U-value to fully capture hempcrete's thermal and environmental performance.

Worldwide and European experience in the implementation of industrial hemp, along with case studies from Ukraine, provide unique insights into the performance of hemp-based homes during prolonged blackouts and extreme climatic conditions, including sub-zero winters and hot summers, highlighting and advocating for hemp's superior performance and resilience.

To address these challenges, the dissertation proposes a set of targeted policy recommendations, including the introduction of the H-Value, a new metric for evaluating the circular, carbon-negative potential of natural building materials. The findings highlight the critical role of cross-sector collaboration and strategic policy innovation in scaling hempcrete and supporting Ireland's transition toward a low-carbon, circular construction economy. The study also emphasises hempcrete's capacity to enhance building energy performance through its high thermal mass and moisture regulation, reducing heating and cooling demand and enabling load-shifting benefits aligned with global strategies to lower energy use in buildings through improved insulation and thermal energy storage.

Ultimately, my research argues that unlocking the potential of hemp-based construction can make a meaningful contribution to achieving Ireland's 2030 emissions targets, net-zero by 2050, and compliance with EU climate commitments.

Table of Contents

1. Introduction

The built environment is under growing scrutiny as a key sector for achieving sustainable development and net-zero targets. Globally, it accounts for about 37% of energy-related CO_2 emissions and over one-third of total energy use (IEA, 2023). In Ireland, the construction sector contributes significantly through both operational energy and embodied carbon. National climate policy, anchored in the Climate Action and Low Carbon Development (Amendment) Act 2021*,* commits to a 51% emissions reduction by 2030 and net-zero by 2050 (Government of Ireland, 2021). Meeting these goals demands systemic change in building design, material choices, and regulatory frameworks.

Natural building materials, particularly hempcrete – a biocomposite of hemp shiv, lime, and water are increasingly recognised as viable solutions for climate-resilient, low-carbon construction (Arrigoni et al., 2017; Allin, 2021). Hempcrete exhibits a unique combination of environmental and functional benefits: it is carbon-negative over its life cycle, sequesters more CO_2 than it emits, and provides high thermal mass alongside moisture regulation. These properties contribute to reduced heating and cooling demand, improved indoor environmental quality, and long-term durability. Hempcrete aligns closely with circular economy principles, addressing both operational and embodied carbon in construction (Zhang et al., 2020).

The building sector is also the single largest global energy consumer, accounting for roughly 40% of total energy use (Sawadogo et al., 2022). In the context of climate change, this makes it a decisive arena for emissions mitigation. As Sawadogo et al. (2022) note, lowering the energy consumption of buildings particularly in heating and cooling is essential to reducing global demand. This can be achieved through a combination of better insulation and advanced thermal energy storage strategies, which offer multiple benefits: reduced total energy consumption, minimised heat losses, shifting electricity demand from peak to off-peak hours, and enabling greater integration of intermittent renewable energy sources (Basecq et al., 2013).

Hempcrete's high thermal mass and hygroscopic nature mean that it inherently functions as a form of passive thermal energy storage. It absorbs heat during periods of high temperature, stores it, and releases it slowly when conditions cool, while also regulating indoor humidity. These properties directly support demand-side energy management and peak load reduction – both critical priorities in Irish and EU energy policy. However, conventional building performance metrics, particularly the U-value, fail to capture these dynamic benefits. As Daly (2019) argues, such steady-state measurements undervalue hempcrete's performance, leading to its omission from incentive schemes and certification pathways.

Despite growing international momentum for bio-based construction, hempcrete adoption in Ireland remains constrained by regulatory, institutional, and market barriers.These developments underscore an important lesson: when strong policy alignment, targeted investment, and coordinated industry collaboration converge, hemp-based economies can scale rapidly, even under the most adverse conditions. In Ukraine, hemp is framed not only as a green material but also as a strategic tool for post-war reconstruction, rural economic regeneration, and integration into global low-carbon supply chains.

At the EU level, policy frameworks such as the Energy Performance of Buildings Directive and the Circular Economy Action Plan encourage the use of sustainable, low-carbon building materials. However, Ireland's implementation of these directives remains narrow, focusing on operational energy efficiency through the Nearly Zero Energy Buildings standard without specific provisions to address embodied carbon, or to incentivise materials that deliver thermal and environmental performance beyond conventional metrics.

Ireland has favourable agronomic conditions for industrial hemp cultivation, with temperate climate and suitable soils (Madden et al., 2022). Yet, domestic hempcrete production is constrained by fragmented regulation, the absence of National Standards Authority of Ireland certification, and insufficient processing capacity. Current building regulations prioritise U-values as the main measure of thermal performance (DHLGH, 2021), overlooking dynamic properties such as thermal mass and moisture buffering, thereby undervaluing hempcrete's benefits (Daly, 2019).

Hemp cultivation also faces economic barriers: it is excluded from most agricultural subsidies and green construction incentives, reducing its attractiveness to farmers and investors (Michels et al., 2025; Carus and Sarmento, 2016). Institutional knowledge of hempcrete remains limited, while persistent misconceptions linking industrial hemp to controlled narcotics create additional regulatory caution (Huijberts, 2023; Daly et al., 2012). Licensing remains restrictive, enforcement inconsistent, and hemp is absent from Ireland's strategic housing and climate plans (Government of Ireland, 2025; Department of the Environment, Climate and Communications, 2021).

The Irish market is further disadvantaged by a reliance on imported hemp shiv, which can increase costs by 25–30% compared to conventional materials (Allin, 2021). Without domestic decortication and processing facilities, the sector struggles to achieve price competitiveness or supply chain resilience. These combined factors result in a fragmented value chain and lost opportunities for rural economic development, climate action, and innovation in sustainable construction.

Integrating hempcrete into mainstream Irish construction aligns directly with both national and EU climate and energy objectives. The EU Renovation Wave strategy (European Commission, 2020) emphasises reducing building energy use not only through operational efficiency but also through materials with inherent thermal energy storage capacity. Hempcrete's thermal mass and humidity regulation can deliver operational energy savings of 60–70% (Allin, 2021), reduce peak energy demand, and enhance grid stability.

Experimental research on bio-based phase change materials confirms that optimising thermal mass can improve occupant comfort, reduce reliance on active heating and cooling, and enable better integration of renewable energy sources (Sawadogo et al., 2022). Yet, current Irish policy and certification systems do not account for these performance characteristics, leaving hempcrete undervalued and underutilised in both the housing and retrofit sectors.

A strategic shift combining policy reform, investment in processing infrastructure, and updated performance metrics such as the proposed H-Value is essential if Ireland is to unlock the potential of hempcrete as both a climate mitigation tool and a driver of rural economic regeneration (Larionova and ZWAI, 2025).

2. Literature Review

2.1 Overview of Sustainable Development in the Built Environment

The built environment accounts for around 37% of global energy-related CO_2 emissions and 30–40% of final energy demand (IEA, 2023; Sawadogo et al., 2022). As both a driver of climate change and a site for mitigation, it is central to climate policy. Sustainable development defined by the Brundtland Commission (WCED, 1987) and advanced through the UN SDGs, the European Green Deal, and Ireland's Climate Action Plan 2025 provides the guiding framework for balancing environmental, social, and economic goals in this sector.

At the global level, the UN Sustainable Development Goals (SDGs) call for sustainable cities (SDG 11), circular resource use (SDG 12), and urgent climate action (SDG 13), aligning with the Paris Agreement's aim to limit warming to 1.5–2°C (UNFCCC, 2015). These frameworks guide strategies to cut both operational energy demand and embodied carbon in construction (Trindade et al., 2022). Within the EU, the European Green Deal commits to climate neutrality by 2050, with the building sector central to this agenda (European Commission, 2019). Instruments such as the Energy Performance of Buildings Directive, the Renovation Wave, and the Circular Economy Action Plan drive efficiency, renovation, and sustainable material use, increasingly supported by life-cycle assessment approaches.

Ireland's Climate Action and Low Carbon Development (Amendment) Act 2021 commits to a 51% emissions cut by 2030 and net zero by 2050. The Climate Action Plan 2025 sets ceilings for the built environment through retrofits, heat pumps, and NZEB standards (Government of Ireland, 2025). Yet policy still prioritises operational energy, with little focus on embodied carbon or bio-based materials with sequestration potential (Daly and Barril, 2024). Closing this gap requires rethinking supply chains, regulation, and performance metrics to capture the wider impacts of construction. The next section situates this within the global hemp economy, exploring its history, markets, and role as a circular, low-carbon material.

2.2.1 Historical Context of Hemp Use

Hemp (*Cannabis sativa L.*) has been cultivated for over 10,000 years for fibre, textiles, cordage, food, and oil (Fike, 2016; Carus and Sarmento, 2016). Its versatility, rapid growth, and low input needs made it a key pre-industrial crop, particularly valued for rope, sails, and paper (Montford and Small, 1999). In Europe, it supported naval industries until the 19th century (Amaducci et al., 2015), before declining with the rise of synthetic fibres, timber paper, and narcotics legislation (Michels et al., 2025).

Industrial innovation nevertheless emerged, with Henry Ford's 1940s hemp-based composites and ethanol prototypes demonstrating hemp's industrial potential (Herer, 2000). Regulatory reforms in the 1990s such as EU rules permitting low-THC hemp (European Commission, 2023) spurred renewed research into agronomy and applications (Salentijn et al., 2015).

Today, hemp is recognised as a multipurpose crop spanning textiles, construction, bioplastics, paper, nutraceuticals, and biofuels. Its high yields and ability to sequester 9–13 tonnes of CO_2 per hectare (Allin, 2021; Michels et al., 2025) position it as a strategic resource for low-carbon, circular economies.

2.2.2 Global Trends: China, France, Ukraine, and Beyond

Industrial hemp is cultivated in more than 30 countries, with rapid expansion over the past decade driven by legislative reform, environmental awareness, and market diversification. China dominates, producing over 75% of global fibre and targeting 3.2 million hectares by 2030 under its Five-Year Plan, framing hemp as a sustainable alternative to cotton (Salentijn et al., 2015; CBI, 2024). Yet inconsistent THC limits, limited fibre processing infrastructure, and a lack of international benchmarks continue to constrain standardisation and global trade (Global Market Insights, 2024).

Europe contributes about 15% of global hemp cultivation, led by France, which grows more than 20,000 hectares annually – around 60% of EU production (European Commission, 2023). Farmer cooperatives such as La Chanvrière sustain high-value markets, while supportive standards and R&D underpin fibre and hurd applications (CannaReporter, 2025). Other European countries, including Germany, the Netherlands, and Spain, are expanding with EU funding support.

Ukraine illustrates resilience amid war, with projects like the Ma'rijanni Hemp Industrial Park establishing capacity to process 14,000 tonnes of stalks annually, with plans to expand alongside cultivation (Kyiv Post, 2024; Forbes, 2024). Once covering 150,000 hectares, Ukraine's hemp industry is being revived as part of rural economic regeneration, targeting textiles, packaging, and construction materials.

2.3.1 Material Composition and Properties

Hempcrete is a bio-composite made from hemp shiv (the porous woody core of *Cannabis sativa L.*), a lime-based binder, and water. The shiv provides lightweight insulation and moisture regulation, while the lime binder contributes durability, alkalinity, and pest resistance (Arnaud and Gourlay, 2012). Modern mixes often use hydraulic lime or pozzolanic additives to improve setting and performance (Nguyen et al., 2020).

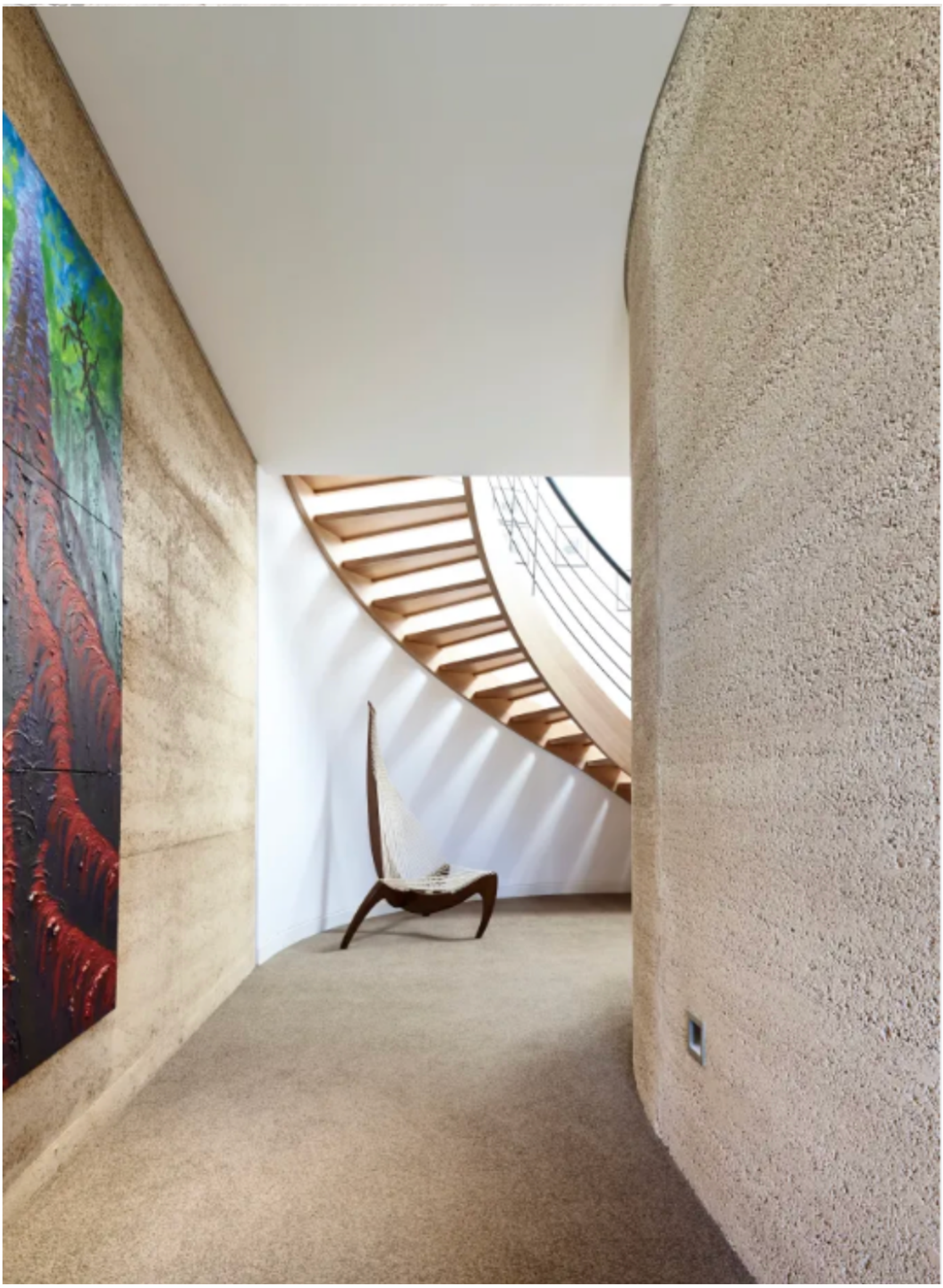

Figure 1: Interior performance of a hempcrete biophilic design passive house, demonstrating up to 70% energy savings.

With a density of 275–375 kg/m³ and porosity of 70–80%, hempcrete delivers excellent hygrothermal behaviour and indoor climate control (Walker and Pavía, 2014). Though non-structural, it functions effectively as insulating infill in timber or steel frames, with compressive strength (0.3–0.4 MPa) sufficient for its role. Its vapour-permeable, high thermal-mass composition further supports passive heating and cooling (Amziane and Arnaud, 2013).

2.3.2 Thermal Performance, Moisture Regulation, and Energy Efficiency

Hempcrete's thermal mass allows it to store and gradually release heat, stabilising indoor temperatures and reducing energy peaks (Walker and Pavía, 2014; Amziane and Arnaud, 2013). Its hygroscopic properties regulate humidity, preventing condensation and mould while improving indoor air quality (Shea et al., 2012; Walker and Pavía, 2014).

Field studies show hempcrete walls can cut heating and cooling demand by up to 60–70%, particularly in temperate climates, with resilience benefits demonstrated in off-grid contexts such as Ukraine during winter blackouts (Allin, 2021). However, standard U-value metrics overlook these dynamic behaviours, limiting recognition in certification schemes (Daly, 2019). To address this, holistic indicators like the proposed H-Value integrate thermal mass, moisture regulation, and life-cycle carbon performance (Larionova and ZWAI, 2025).

2.3.3 Carbon Sequestration and Circular Economy Benefits

Hempcrete combines rapid crop growth with strong environmental benefits. Hemp matures in 3–4 months, requires minimal inputs, and sequesters 9–13 tonnes of CO_2 per hectare (Allin, 2021; Michels et al., 2025). Its lime binder continues carbon uptake during use, and at end-of-life the material is recyclable or biodegradable, supporting closed-loop cycles. These features position hempcrete as both a carbon-negative material and a model for regenerative, circular construction aligned with climate goals.

Potential of the Hemp Economy as a Circular and Carbon Solution

CO_2 absorption between Peatlands, Hemp and Trees over a 3–4 month period

Criteria	Hemp (per hectare, 3–4 months)	Peatland (per hectare, 3–4 months)	Trees/Wood (per hectare, 3–4 months)
CO_2 Absorption	**8 to 15 tonnes** O_2 produced: 7–12 tonnes	**0.9 to 1.4 tonnes** (extrapolated from annual rates)	**1 to 2.5 tonnes** (varies by species and growth stage)
Growth Rate	**Fast** (harvested in 3–4 months)	**Extremely slow** (forms over millennia)	**Moderate** (trees take years to mature)
Carbon Storage	**Short to medium term** (used in products like hempcrete)	**Long-term** (stores carbon for thousands of years)	**Long-term** (sequesters carbon in biomass and soil)
Environmental Role	Reduces atmospheric CO_2 through photosynthesis	Acts as a carbon sink, preventing CO_2 release	Provides oxygen, absorbs CO_2, and supports biodiversity

Figure 2: Demonstrates a comparison of CO_2 absorption, growth rate, carbon storage, and environmental roles of hemp, and highlights how it can complement peatlands and forests in delivering both short-term and long-term climate benefits.

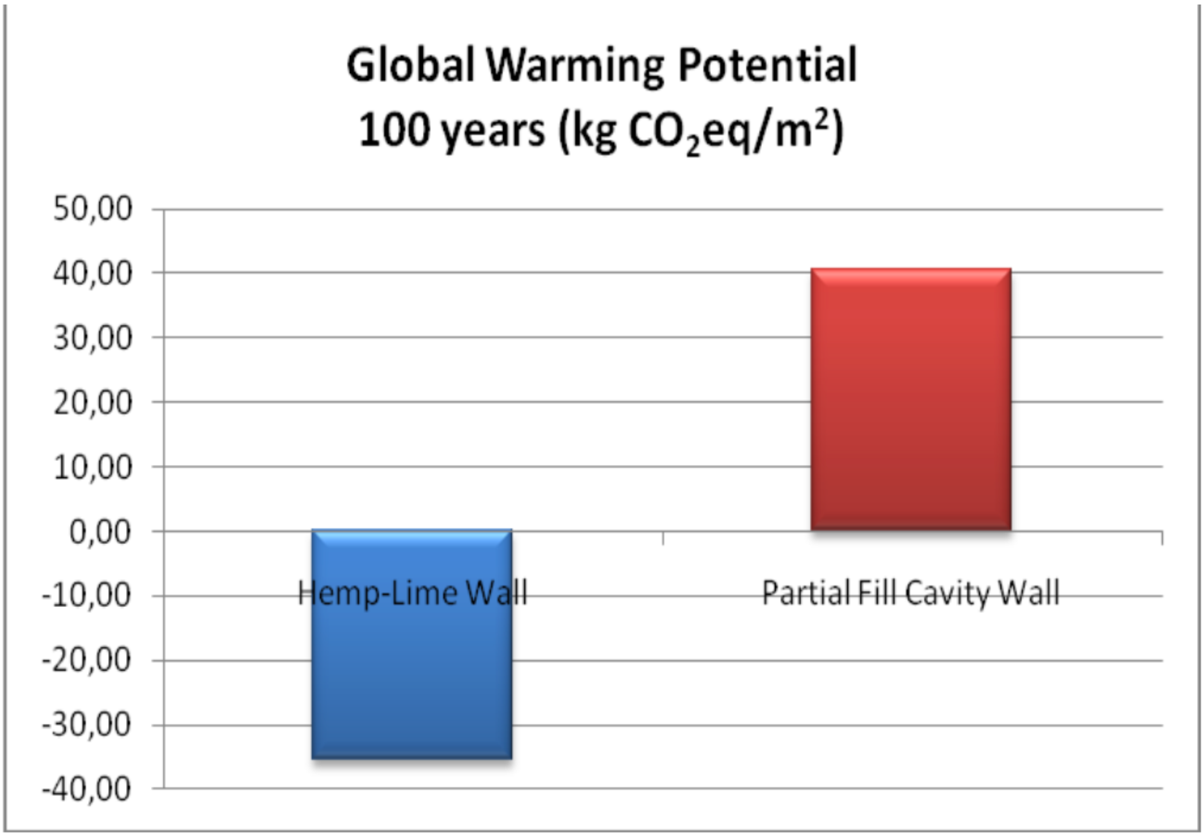

Figure 3: Comparison of the Global Warming Potential (GWP) of a hemp-lime wall and a partial fill cavity wall over a 100-year period (kg CO_2eq/m^2). The results, adapted from Daly et al. (2012), demonstrate hemp-lime's carbon-negative potential (–35 kg CO_2eq/m^2) due to biogenic carbon sequestration, in contrast to the carbon-positive profile of conventional cavity wall construction (+40 kg CO_2eq/m^2).

2.4 Barriers to Scaling Hempcrete

2.4.1 Regulatory and Legal Barriers

Despite its well-documented environmental, thermal, and health benefits, hempcrete adoption at scale remains constrained by regulatory, economic, institutional, and policy barriers. These challenges are interconnected, creating a fragmented value chain that limits investment, innovation, and mainstream construction uptake.

In Ireland, hemp cultivation is tightly regulated under the Misuse of Drugs Acts, with licensing administered by the Health Products Regulatory Authority. Although EU-approved varieties contain less than 0.3% THC, regulatory caution and uneven enforcement create uncertainty for farmers and processors (Huijberts, 2023).

Hempcrete adoption is further limited by the absence of National Standards Authority of Ireland certification. Without harmonised standards, demonstrating compliance with Building Regulations is difficult, discouraging its use. By contrast, France benefits from the NF DTU 26.2 hempcrete standard, published by AFNOR, which has facilitated mainstream adoption and enabled its inclusion in public procurement frameworks (Association Française de Normalisation, 2012).

Ukraine provides an instructive counterexample with its e-Hemp certification system, which streamlines traceability and quality assurance. This digital approach strengthens domestic market confidence, enhances export potential, and positions hemp for growth in post-war reconstruction (Kyiv Post, 2024).

2.4.2 Economic and Supply Chain Barriers

Ireland's hempcrete industry relies heavily on imported hemp shiv, which increases costs by 25–30% compared to conventional building materials (Allin, 2021). The lack of domestic decortication and processing facilities prevents the development of a vertically integrated supply chain, leading to higher transport emissions, longer lead times, and reduced price competitiveness.

Additionally, hemp cultivation is excluded from most Common Agricultural Policy subsidies and Irish green construction incentives. This exclusion makes hemp less economically attractive to farmers compared with subsidised crops. Limited processing capacity also constrains opportunities for rural job creation, regional economic regeneration, and the development of localised circular economies.

2.4.3 Institutional and Policy Barriers

Institutional knowledge of hempcrete's performance remains low within planning authorities, housing agencies, and the wider construction sector (Daly, 2024). Performance assessment frameworks rely heavily on steady-state thermal transmittance (U-values), which fail to capture hempcrete's dynamic benefits such as thermal mass and moisture buffering (Daly, 2019). This narrow measurement focus contributes to its exclusion from retrofit grants, energy efficiency incentive schemes, and national retrofit programmes.

Irish policy integration is also limited. While the *Climate Action Plan* (Government of Ireland, 2025) and National Retrofit Plan (Department of the Environment, Climate and Communications, 2021) aim to decarbonise the building sector, neither explicitly promotes bio-based materials or addresses embodied carbon in construction (Daly and Barril, 2024). In contrast, EU strategies such as the European Green Deal (European Commission, 2019) and *Renovation Wave* (European Commission, 2020) explicitly link building performance with sustainable materials, circular economy principles, and carbon accounting.

These barriers reinforce one another: regulatory uncertainty limits investor confidence, weak supply chains keep costs high, and institutional oversight reduces market visibility (Michels et al., 2025). Overcoming them will require a coordinated policy approach that integrates certification reform, targeted subsidies, processing infrastructure investment, and performance metric modernisation.

2.5 Existing Performance Metrics and the Case for the H-Value

Current building performance assessment frameworks both in Ireland and internationally rely heavily on steady-state metrics such as the U-value, which measures thermal transmittance under fixed conditions. While U-values provide a standardised benchmark for heat loss, they fail to capture the dynamic thermal and hygrothermal properties of bio-based materials like hempcrete (Daly, 2019).

HEMP BUILD U Value Study	For HEMP BUILD LTD							by Patrick Daly April 2019			
CONSTRUCTION TYPE	EXISTING	IMPROVEMENT MEASURE									
FLOOR	Baseline	Replacement Hemp Lime floor						Upgrade Hemp Lime Floor			
		120mm	% Diff	150mm	% Diff			60mm	% Diff	90mm	% Diff
Floor											
Lime Screed - Earth Floor	0.6	0.4	33	0.34	43						
Uninsulated Concrete Slab	0.64	0.4	38	0.34	47			0.39	39	0.33	48
WALL	Baseline	Upgrade Wall									
		60 mm	% Diff	90 mm	% Diff	120 mm	% Diff	150 mm	% Diff	210 mm	% Diff
Stone											
Limestone Wall 20% Plaster Lath	1.35										
Limestone Wall 40% Lime Earth	1.72										
Limestone Wall 20% Lime Earth	*1.85*	*0.63*	*66*	*0.5*	*73*	*0.42*	*77*	*0.36*	*81*	*0.28*	*85*
Brick											
230mm Brick Wall	*2.12*	*0.65*	*69*	*0.52*	*75*	*0.43*	*80*	*0.37*	*83*	*0.28*	*87*
340mm Brick Wall	1.63										
Concrete Wall											
200mm Conc Wall	*2.59*	*0.69*	*73*	*0.54*	*79*	*0.44*	*83*	*0.36*	*86*	*0.29*	*89*
Masonry Wall											
250mm Hollow Block	*1.93*	*0.68*	*65*	*0.53*	*73*	*0.44*	*77*	*0.38*	*80*	*0.29*	*85*
325 mm Cavity Wall	*1.74*	*0.62*	*64*	*0.49*	*72*	*0.41*	*76*	*0.35*	*80*	*0.28*	*84*
							TGD	*New 11*	*New 18*	*Exist MA & CoU*	
ROOF	Baseline	Upgrade Roof					Wall	0.21	*0.18*	0.35	*0.55 cv*
		100 mm	% Diff	240 mm	% Diff		Floor	*0.21*	*0.18*		0.45
Uninsulated Roof	2.5	0.4	84	0.17	93		RoofCl	*0.16*	*0.16*		0.16

Figure 4: U-value study by Daly (2019) showing that hemp-lime upgrades to floors, walls, and roofs can reduce heat loss by up to 70–90%, bringing traditional constructions close to modern regulatory standards.

Hempcrete's high thermal mass enables it to store and release heat gradually, while its hygroscopic behaviour regulates indoor humidity levels, reducing the need for mechanical heating, cooling, and ventilation (Walker and Pavía, 2014; Shea *et al.*, 2012). These qualities contribute to improved comfort, peak-load reduction, and resilience in energy outages—benefits that remain invisible under conventional metrics. Consequently, hempcrete often underperforms in regulatory energy models, leading to its exclusion from building certification schemes, retrofit grants, and policy incentives.

To address this gap, Larionova and ZWAI (2025) propose the H-Value – a holistic performance metric for natural building materials. Unlike the U-value, the H-Value integrates:

Thermal mass capacity (heat storage and release)

Moisture buffering index (humidity regulation)

Life-cycle carbon balance (including sequestration and end-of-life impacts)

Circularity score (potential for reuse, recycling, and biodegradation)

The adoption of the H-Value would align performance assessment with life-cycle thinking and EU climate policy trends, including the Whole Life Carbon Roadmap and the Circular Economy Action Plan (European Commission, 2020). It would enable materials like hempcrete to be evaluated not solely on steady-state energy performance but on their overall contribution to climate resilience, health, and circularity. (Larionova and ZWAI, 2025).

2.6 Identified Research Gaps

The literature review highlights several critical gaps in knowledge and policy frameworks that this research seeks to address:

Performance Metrics Bias – Current building performance assessments, dominated by U-values, fail to capture the dynamic properties of bio-based materials. While hempcrete's hygrothermal and carbon-sequestering benefits are documented, few studies have translated these into policy-ready metrics (Daly, 2019; Larionova and ZWAI, 2025).

Ireland-Specific Evidence – There is a shortage of empirical, in-situ performance data on hempcrete in Irish climatic conditions, limiting its credibility with policymakers, insurers, and industry stakeholders (Madden et al., 2022; Daly et al., 2010).

Regulatory and Market Integration – Although EU frameworks such as the European Green Deal and the Circular Economy Action Plan promote sustainable materials, Ireland lacks pathways to integrate hempcrete into building codes, procurement rules, housing policy, or retrofit incentives (European Commission, 2019; European Commission, 2020; Huijberts, 2023).

Supply Chain and Processing Capacity – Research on strategies to develop a vertically integrated hempcrete supply chain in Ireland is scarce. Without local processing infrastructure, the sector remains dependent on imports, undermining cost competitiveness and rural development opportunities (Carus and Sarmento, 2016; Michels et al., 2025).

Resilience and Crisis Contexts – There is little academic exploration of hempcrete's contribution to resilience in scenarios such as extended energy outages, extreme weather, or post-war reconstruction, despite emerging lessons from Ukraine (Allin, 2021; Forbes, 2024; Kyiv Post, 2024).

Addressing these gaps will require not only technical studies but also interdisciplinary research linking material science, socio-technical transitions, and policy analysis. The H-Value framework proposed in this dissertation aims to bridge these divides, offering a holistic tool to connect performance research with actionable policy reform.

3. Methodology

3.1 Research Design

The aim of this research is to examine the barriers to sustainable development toward a hemp economy in Ireland, with a particular focus on hempcrete in the construction sector, and to identify potential policy and practice pathways that could support its wider adoption.

The central research question guiding the study is:

What are the key regulatory, economic, and institutional barriers to the use of hempcrete in Ireland's construction sector, and how might these be addressed to advance a sustainable hemp economy?

This dissertation employs a qualitative research design to examine barriers to sustainable development toward a hemp economy in Ireland, focusing on hempcrete's role in construction. Qualitative methods enable in-depth exploration of lived experiences, stakeholder perspectives, and institutional barriers in an emergent context, offering insights into socio-institutional dynamics that quantitative metrics cannot capture (Lim, 2024)

Comparative sustainability studies also support qualitative methods for examining barriers to sustainable materials. For instance, research on residential construction in Tanzania identified regulatory, financial, and cultural obstacles through expert interviews, an approach mirrored in this dissertation (Mahame et al., 2024).

The study adopts a case study approach combining semi-structured interviews, literature and policy analysis, and international comparisons. Case studies of hempcrete homes were integrated with interviews across policymakers, industry leaders, architects, ecological experts, and homeowners, enabling data triangulation across household, institutional, and policy levels in Ireland and Ukraine.

Semi-structured interviews were used to capture in-depth insights from a small but expert group of stakeholders, offering flexibility with comparability (Kakilla, 2021). This method is well-suited to analysing niche innovations like hempcrete within broader sustainability transitions.

The framework draws on sustainability transition theory and circular economy perspectives to highlight systemic, regulatory, and cultural barriers facing hempcrete. Combining fieldwork with policy analysis, the study identifies structural challenges and potential pathways forward.

3.2 Data Collection Methods

3.2.1 Literature and Policy Analysis

A desk-based review of literature and policy documents was undertaken to situate hempcrete within broader debates on sustainability, circular economy, and climate policy. Key sources included the Irish Climate Action Plan, the EU Green Deal and a range of authoritative peer-reviewed publications in order to achieve a high quality review of available knowledge in the scientific and policy fields.

3.2.2 Comparative Case Studies

The study incorporated international case studies to highlight the potential of hempcrete in different contexts. In Ireland, case studies focused on retrofitted and newly built hempcrete homes. Comparative material from Ukraine was included, illustrating the role of hempcrete under wartime and crisis conditions. This contrast helps to identify both universal properties of hempcrete and localised barriers to its adoption.

3.2.3 Semi-Structured Interviews

The primary empirical material for this study was generated through 10 semi-structured interviews conducted between May and August 2025. These interviews engaged a diverse range of stakeholders.

3.3 Sampling and Participant Selection

The interview sample was deliberately diverse to capture a wide range of perspectives across the hempcrete sector. Four householders were interviewed: two who had retrofitted their homes in Ireland, one who had built a new hempcrete house in Ireland, and another who had constructed a hempcrete home in Ukraine. Industry voices included the CEO of one of Ireland's leading hemp-based construction companies and the founder of a Ukrainian enterprise pioneering hempcrete technologies. Policy and advocacy perspectives were represented by a Green Party Senator, actively engaged with agricultural and sustainability policy and hempcrete working groups, and the Vice-Chair of Zero Waste Alliance Ireland, who emphasised hempcrete's potential to reduce construction and demolition waste. Expertise from the built environment was provided by an architect who led a hempcrete restoration project in Dublin, offering insights on conservation and regulatory acceptance. Ecological perspectives came from a consultant with a background in agroforestry and soil health, who assessed hemp's role in regenerative land use and biodiversity. Interviews lasted between 15 and 35 minutes and were conducted in person or online via Zoom and Microsoft Teams.

Semi-structured interviews were chosen because they provide a balance between comparability across cases and the flexibility to explore unexpected themes. The interview guides were tailored to each category of stakeholder but broadly covered the following domains.

The interviews were structured around five broad thematic areas.

First, ecological and technical aspects were explored, focusing on the material performance of hempcrete, its impact on indoor air quality, energy efficiency, and its biodegradability compared to conventional materials. Second, participants discussed economic and institutional barriers, including construction costs, certification and insurance challenges, and the limited availability of hemp processing infrastructure. Third, the policy and regulatory environment was examined, particularly the role of planning permissions, building codes, and agricultural frameworks in shaping the viability of hempcrete. Fourth, householders were asked to reflect on their lived experience and wellbeing, offering insights into comfort, health, and lifestyle changes associated with living in hempcrete homes. Finally, attention was given to future opportunities, such as the potential to scale hempcrete in Ireland, lessons from international contexts, and participant recommendations for enabling policy and practice. This ensured a consistent thematic framework while allowing respondents to narrate their own experiences.

3.4 Data Analysis Approach

All recordings were transcribed manually and anonymised where necessary to protect privacy. Notes were used to support transcription and to highlight non-verbal aspects such as emphasis, tone, or hesitation.

The analysis employed thematic coding based on Braun and Clarke's (2006) method, beginning with descriptive codes (e.g., 'energy performance,' 'insurance barriers,' 'political perception') and progressing to interpretive categories aligned with the dissertation's three core research themes.

Regulatory and institutional barriers

Economic and infrastructural challenges

Ecological and social benefits

NVivo software was not employed due to the relatively small sample size; instead, coding was conducted manually to maintain closeness to the material. Extracts from the interviews were integrated with documentary sources (policy reports, academic studies, and industry publications) to build a comparative understanding.

To strengthen the reliability of findings, data from the Irish context were compared with Ukrainian case studies. Ukraine provided a contrasting context in which hempcrete has been applied under wartime and crisis conditions, emphasising resilience, autonomy during blackouts, and safety benefits. This international comparison highlights both the universal properties of hempcrete and the locally specific barriers to its adoption.

3.5 Ethical Considerations

This research adhered to the ethical standards of Trinity College Dublin. Participants were informed of their right to withdraw at any time and to request deletion of their data. Consent was obtained verbally and in writing. Sensitive data such as wartime experiences in Ukraine were handled with particular care, ensuring respect and confidentiality.

To minimise researcher bias, reflective notes were kept after each interview. The research process also acknowledged positionality: as a displaced student from Ukraine, my personal background and motivations could both facilitate rapport with participants and introduce subjective perspectives. Transparency about this positionality is part of maintaining ethical rigour.

3.6 Limitations of the Methodology

The interview sample, while diverse, is relatively small (10 participants). It cannot claim statistical representativeness but instead offers rich qualitative insights. Another limitation lies in access: hempcrete remains a niche sector in Ireland, so the pool of available interviewees was restricted.

Time constraints also meant that interviews were conducted within a narrow timeframe (May–August 2025). Seasonal effects on hempcrete performance (e.g., extreme winter cold) could not be observed directly, although they were reported by participants.

The scope of the literature also presented a limitation. While there is a growing international body of work on bio-based construction materials, academic research on hempcrete particularly within the Irish context remains narrow, with limited empirical evidence and policy analysis available. This constrained the extent of direct comparison with broader construction debates and required reliance on grey literature, policy documents, and practitioner accounts to supplement peer-reviewed sources.

Nonetheless, these limitations are balanced by the depth and variety of perspectives gathered, which together provide valuable insights into the barriers and opportunities for hempcrete adoption.

This dissertation employs a qualitative, case study methodology centred on semi-structured interviews with ten stakeholders, supported by policy and literature analysis. The approach captures the complexity of barriers to hempcrete adoption in Ireland while situating them in a wider European and Ukrainian context.

By combining lived experience with institutional perspectives, the methodology identifies not only the barriers but also potential pathways for developing a sustainable hemp economy.

4. Findings

4.1 Regulatory and Legal Barriers in Ireland.

Interviews with architects, industry representatives, and policymakers highlighted the absence of regulatory recognition for hempcrete in Ireland's building code. Although international research demonstrates that hempcrete is a low-carbon, breathable, and durable material (Walker, 2019), Irish standards remain tied to concrete and synthetic insulation. Without formal certification, insurers and developers remain reluctant to adopt hempcrete, an example of the 'lock-in' effect described by Geels (2002).

These findings highlight the urgent need for regulatory innovation, perhaps through pilot schemes, recognition in the National Building Regulations, or alignment with EU bioeconomy directives.

4.2 Economic and Supply Chain Challenges

Across interviews, economic barriers were seen as central. Hempcrete's higher upfront cost stems from Ireland's lack of processing infrastructure, forcing reliance on imports that raise transport costs and weaken circularity. This reflects EPA (2024) findings on the challenge of scaling bio-based solutions amid fragmented supply chains.

Irish construction industry actor, emphasised that

'With no grants or government financial support, even simple measures such as reduced VAT, tax relief, or carbon credits could tip the balance and provide the confidence to scale. However, the sector also struggles with its niche status and reliance on imports, which can lead to potential delays.'

CEO of Irish Construction Company, respondent A5

These insights mirror academic findings that niche innovations struggle without infrastructural support (Kivimaa & Kern, 2016).

Economic barriers could be reduced through targeted subsidies, grants for processing facilities, or public procurement favouring hempcrete in retrofits. This would align with EU Green Deal ambitions for circular materials (European Commission, 2019).

4.3 Institutional and Policy Gaps

Policy and advocacy perspectives further underscore the challenges facing hempcrete in Ireland. One Green Party Senator interviewed, highlighted the absence of hempcrete from the Climate Action Plan (Government of Ireland, 2025), despite its acknowledged ambition to decarbonise construction. This omission, it is argued, reflects systemic inertia and cultural stigma.

'The main barrier in Ireland has been traditionally the association of hemp with cannabis … there needs to be greater awareness and understanding at a political level of the benefits of

hemp … we are not in a space, because of the climate crisis, that we can afford the luxury of slowness'

The Green Senator also highlighted the political influence of farming organisations.

'Nobody can influence government quicker than farmer organisations,'

'I think we have good growing conditions in Ireland.'

This is supported by Teagasc, which notes that hemp grows 'surprisingly well in an Irish maritime climate.' The Hemp Federation Ireland also highlights the suitability of Ireland's loamy, moisture-retentive soils for hemp cultivation. In addition, Madden et al. (2022) demonstrate that industrial hemp in Ireland offers significant environmental and economic benefits under existing agro-climatic conditions (Teagasc, n.d.; Hemp Federation Ireland, n.d.; Madden, Ryan & Walsh, 2022).

As the Green Senator suggested,

'So, the Agricultural Committee, the Climate Committee, the Housing Committee, and perhaps committees like Finance as well. So it's about trying to socialise that at a political level among the politicians.'

called for government-supported exemplar projects to legitimise hempcrete:

'we need exemplar projects that government can see and touch before it will be taken seriously.'

Green Party Senator (Ireland), respondent A7

These political insights were complemented by the perspective of the Vice-Chair of Zero Waste Alliance Ireland (ZWAI) a former chair of the Environmental Executive Committee, who situated hempcrete within broader debates on circular economy and construction waste management. The Vice-Chair emphasised that Ireland continues to send between 13–18% of mixed construction and demolition waste to landfill (EPA, 2024), much of it concrete, and argued that natural alternatives such as hempcrete could play a decisive role in reducing this burden. As has been observed,

'…hemp has the potential to change the end-of-life problem in construction because it is biodegradable, reusable, and carbon negative.'

The Vice-Chair of Zero Waste Alliance Ireland, *respondent A8*

arguing that hempcrete could play a role in reducing waste streams if end-of-life policies recognised its biodegradability. This echoes literature framing waste policy as a missed lever in supporting natural materials (Allin, 2020).

These interviews underscore a critical policy gap: although hempcrete's ecological and technical merits are widely acknowledged, it remains excluded from state frameworks due to cultural stigma, regulatory inertia, and a lack of demonstration projects. Both political and civil-society advocates stress the need for institutional recognition and proactive government support to unlock hempcrete's potential as a mainstream material for decarbonisation and circular economy strategies (Nesterenko, 2024).

As one architect involved in a Dublin hempcrete restoration project noted,

'…this creates a chicken-and-egg situation – without certification we cannot scale, but without scale no one will invest in certification.'

An architect recalls replacing failing concrete infill in a timber-frame kiosk with hempcrete, marking their first step toward a more sustainable solution.

'The original building was essentially a timber-frame structure with poured concrete infill – somewhat like a hurdy-gurdy version of concrete. Inside, it had a lime plaster finish but lacked any real insulation. It was built as a simple kiosk. When the concrete started to fail, we asked: What infill product could provide better performance and make the structure more sustainable? That's how we arrived at hempcrete.'

Figure 5: Demonstrates the architects' first experience of a conservation project using hempcrete, in the Restoration of An Bothán Tae Café, Blackrock Park

'We work in conservation, and the council was receptive to our approach because it was sensitive to the building's original character. The conservation officer supported our recommendation. The fact that hempcrete was a good technical and environmental fit helped, even if its carbon benefits were a secondary bonus.'

Architect (Dublin Hempcrete Restoration Project), respondent A10

As an ecological consultant noted, this represents a 'policy silo' problem, consistent with sustainability transitions literature (Meadowcroft, 2011).

'Because the farming lobby in Ireland is very strong. So, if you can frame hemp as something that actually benefits the beef and dairy sector, it's more likely to be accepted.'

Ecological Consultant (Agroforestry and Soil, UCC Background), respondent A9

Interviewees also pointed to a policy disconnect: hemp cultivation is permitted in Ireland but hampered by complex licensing and poor coordination with construction policy. This gap hinders integration of agricultural and housing strategies. Policy research emphasises that cross-departmental collaboration between agriculture, housing, and environment ministries is vital to overcome these barriers and unlock hempcrete's potential in sustainable retrofit strategies (Vierling, 2024).

4.4 Insights from Comparative Case Studies

<u>Comparative Analysis of an Irish and Ukrainian Construction Company</u>

The comparative analysis of an Irish construction company and a Ukrainian one illustrates how national contexts and regulatory frameworks shape both the opportunities and the barriers to hempcrete adoption. While both companies operate in niche markets for bio-based construction, their struggles and strategies reveal important insights for scaling sustainable materials.

In Ireland's relatively stable economy, development is constrained by regulatory and institutional barriers. A key challenge is the absence of domestic hemp processing facilities, which forces reliance on imported hurd thereby increasing costs, extending lead times, and exposing vulnerabilities in sustainable construction supply chains. As the CEO already noted,

'Materials are not grown locally and need to be shipped, which adds to overall costs and delays.'

This lack of vertical integration limits the capacity of the sector to scale and compete economically with conventional materials.

Certification and performance assessment present another obstacle. Existing U-value–based regulatory standards fail to account for hempcrete's hygrothermal properties and carbon-sequestering potential. *U-value refers to the rate of heat transfer through a building element, with lower values indicating better insulation.* As a result, insurers and building regulators remain unconvinced of its reliability, leading hempcrete projects to be classified as experimental rather than mainstream. As the CEO emphasised,

'The U-value is too simple. It can't reflect the true performance of hempcrete; it ignores thermal mass and hydric regulation. When a material absorbs heat and slowly releases it back as the environment changes, the U-value cannot calculate the effect.'

This regulatory mismatch creates a significant barrier to wider acceptance (Daly, 2019).

Economic constraints compound these technical barriers. According to the CEO, *'The biggest current disadvantage and challenge in hempcrete construction is the higher cost – about 25% to 30% more expensive than traditional building.'*

Without targeted government support, hempcrete must compete directly with heavily standardised materials such as concrete and synthetic insulation, which benefit from decades of policy support, subsidies, and institutional familiarity. Furthermore, hempcrete continues to be perceived as a niche product requiring specialist skills, with the CEO noting that

'Hempcrete remains a niche material, requiring specialist knowledge to produce and apply.'

CEO of Irish Construction Company, respondent A5

These findings from the Irish case demonstrate how regulatory misalignment, infrastructural gaps, and limited policy support collectively constrain the expansion of bio-based construction. They also reinforce the broader literature on socio-technical transitions, which highlights how incumbent standards and institutional inertia hinder the diffusion of sustainable innovations (Geels, 2002; Farla et al., 2012).

The Ukrainian construction company, in contrast, operates in a highly unstable wartime context but demonstrates resilience through localisation and innovation. From its foundation, the company adopted two guiding principles: all materials must be 100% natural and of Ukrainian origin. As the founder explained,

'We established two principles for our materials: they had to be 100% natural and of Ukrainian origin. Thanks to these principles, we managed to withstand earlier challenges, including the COVID-19 pandemic.'

This localisation strategy has not only ensured supply chain resilience during war but has also reduced reliance on imports; unlike Ireland, Ukraine does not import hemp hurd. All raw material is grown and processed domestically, which both minimises logistic costs and strengthens national autonomy in material supply.

This commitment to local sourcing underpins company involvement in the Maryzhany Industrial Hemp Park, an ambitious closed-loop initiative integrating hemp cultivation, processing, design, construction, and research. According to the founder,

'The idea of the park is to create a closed-cycle production that minimises logistics costs and simplifies communication between all participants. This is crucial, as logistics costs are increasing not only in Ukraine but worldwide. Thus, the project could become a striking example of local economy development focused on hemp production and has significant potential.'

If fully realised, the park has the capacity to position Ukraine as a European leader in hemp production. However, expansion into European markets remains constrained by EU quotas, as the founder noted:

'Due to the constant quotas imposed by the EU, we cannot yet fully supply the European market. Nevertheless, our potential is enormous. The Maryzhany plant and Industrial Park, in which we are also involved, could become a key platform for this growth.'

In parallel, the founder of the Ukrainian construction company has advanced sectoral organisation through the creation of the Association for Hemp Construction in Ukraine, which brings together processing enterprises, architects, builders, research institutes, farmers, and developers. As the founder explained,

'Last year, we established the Association for Hemp Construction in Ukraine, which I lead as president. Within its framework, we unite processing enterprises, architects, builders, research institutes, farmers, and developers to develop the industry comprehensively.'

Founder of the Ukrainian construction company, respondent A6

This represents a deliberate strategy to integrate the supply chain and build institutional legitimacy for hempcrete in national and international contexts.

The Ukrainian hempcrete experience has demonstrated tangible resilience under wartime conditions. The founder stated that hempcrete walls retained heat significantly longer than conventional materials, enhancing comfort and safety during prolonged blackouts. However, limited recognition by EU regulators continues to restrict broader market access, reflecting wider tensions in cross-border regulatory harmonisation (D'Eusanio et al., 2024).

Despite differing contexts, both the Irish and Ukrainian cases face barriers rooted in political and institutional inertia. In Ireland, slow regulatory adaptation, outdated U-value standards, and limited investment in bio-based supply chains constrain progress. In Ukraine, despite advanced certification mechanisms and a strong local ecosystem, challenges arise from fragmented standards and trade restrictions. Collectively, these cases demonstrate how conservative regulatory systems hinder the mainstreaming of hempcrete, even where its ecological and social benefits are evident (Folke, 2006).

The comparison underscores reciprocal lessons. Ireland could adopt Ukraine's proactive local sourcing strategies and digital certification systems both effective at enhancing transparency and resilience. Conversely, Ukraine might benefit from Ireland's access to EU research and innovation networks to help accelerate standardisation and integration into European markets. Broadly, both cases illuminate that without strong political commitment and cross-sector collaboration, hempcrete risks remaining a niche innovation rather than becoming a cornerstone of climate and housing strategies (Shaping Bio, 2024).

Irish Retrofit Case Studies

The two Irish retrofit case studies illustrate how hempcrete can directly address household challenges of health, energy use, and indoor comfort.

In one case study of a 1980s bungalow retrofit, the Irish homeowner reported that chronic mould allergies, which had previously been a significant health concern, were effectively resolved following the installation of hempcrete. Dehumidifiers were required only during the initial drying phase of the lime-hemp plaster, after which, as the resident explained,

'…no need anymore, we don't use the dehumidifier at all.'

The occupant emphasised a marked improvement in thermal comfort, describing how

'In the winter, when it's very cold outside, it is warm in here, even when we have very little heat on. And in the summer, it stays cool inside when it's hot outside. So it works in both directions.'

Houseowner of 1980s bungalow retrofit, *respondent A1*

In the Galway City retrofit of a mass-concrete semi-detached home, the household affected by asthma and multiple chemical sensitivities reported significant improvements in indoor air quality and wellbeing following the installation of hempcrete and natural plaster. The homeowner described an immediate change in living conditions, noting that

'Immediately after hemp and plaster was installed the house no longer made my husband sick.'

The family observed a marked reduction in dampness and enhanced air freshness, with one participant highlighting the

'…lack of comparable dampness and excellent air quality.'

These improvements had direct health outcomes, with asthma flare-ups becoming rare and the general health of family members improving, thereby reducing reliance on medical services. As demonstrated by Levy, Nishioka and Spengler (2003), insulation retrofits can generate significant public health gains alongside energy savings.

The retrofit also delivered substantial energy efficiency gains. As the homeowner explained,

'Our heating needs have dramatically changed after all works were completed. We cut our heating oil amount: before, we filled the tank more than once a year; now we go through maybe ¾ tank.'

Although electricity consumption was more difficult to compare due to changes in family living arrangements, heating oil savings indicate a significant reduction in ongoing costs.

Beyond technical performance, the retrofit underscores the social and policy relevance of natural-material housing. Despite clear evidence of health improvements and reduced strain on public health systems

'My son and I both have asthma but rarely have flare-ups due to the healthy nature of our house … our health being better means no doctor's visits, no hospital beds being taken up.'

The homeowner noted the absence of state support:

'We also don't understand why there are no government supports available for such products … the cost for us was all out of pocket, and we're a very low income family.'

Houseowner semi-detached home, respondent A2

These cases highlights a critical gap between the potential public health and environmental benefits of hempcrete retrofits and the absence of supportive financial mechanisms in Ireland's retrofit schemes. Evidence from occupants experiences suggests that hempcrete reduces reliance on mechanical systems, enhances a home's ability to regulate temperature and humidity, and lowers heating demand, thereby cutting energy bills while providing a drier and healthier living environment. These outcomes demonstrate hempcrete's capacity to deliver both economic and health co-benefits, aligning with international findings on the multiple advantages of bio-based building materials (Collet & Pretot, 2014).

Fully Built Hempcrete Homes in Ireland and Ukraine

A comparative perspective between a new-build hempcrete home in Ireland and a hemp-based house in Ukraine demonstrates how national contexts shape both the performance and perceived value of bio-based construction.

In Ireland, the resident of a full hempcrete home described energy savings of approximately 70% compared with conventional houses, attributing this to the synergy between hempcrete's thermal mass, airtightness, and integrated energy systems such as underfloor heating and mechanical ventilation. The homeowner reported year-round thermal comfort, explaining that the house

'…remains warm in winter with minimal heating.'

Irish Homeowner new build hemp house, *respondent A3*

The homeowner is considering the implementation of solar panels to achieve full energy independence. With the potential integration of a smart metering system, surplus energy could be sold back to the grid.

These lived experiences align with international research showing hempcrete's strong hygrothermal regulation and energy-saving potential. Simulation studies demonstrate superior temperature and humidity control compared to conventional materials (Kaboré et al., 2024) while life cycle assessments confirm substantial reductions in energy demand and environmental impact (Tong et al., 2025).

In Ukraine, the interviewee emphasised the role of hempcrete as a material of resilience under crisis conditions. During wartime blackouts, the standalone hempcrete house demonstrated a capacity to retain heat three to four times longer than conventional masonry, while maintaining a cool indoor climate during hot summers. The resident explained that this thermal stability allowed the family to endure prolonged periods without electricity

'…even when there was no power, the house stayed warm enough in winter and cool in the summer, so we could manage without external energy for longer.'

Beyond thermal performance, the respondent highlighted the material's acoustic properties, noting that the thick hempcrete walls

'…reduced outside noise and helped the children feel less afraid during frequent air raid sirens.'

Resident of a Hemp-Based House in Ukraine, respondent A4

This testimony underscores hempcrete's value not only for sustainability but also within resilience frameworks, offering both physical protection and psychological reassurance during instability (Folke, 2006).

These case studies underscore hempcrete's multifaceted relevance. In Ireland, it is valued for energy savings, cost efficiency, and alignment with climate policy; in Ukraine, it delivers autonomy, safety, and resilience amid war and infrastructural collapse. Despite these differing priorities, both respondents affirm hempcrete's ecological and social co-benefits illustrating its potential to serve policy objectives from carbon reduction to human security (Steyn, de Villiers & Babafemi, 2025).

4.5 Hempcrete's Performance

As figure 6 outlines the wide-ranging performance benefits of hempcrete, illustrating how its thermal, environmental, and health advantages align with Ireland's climate targets and EU circular economy policies, positioning it as a strategic alternative to conventional construction materials.

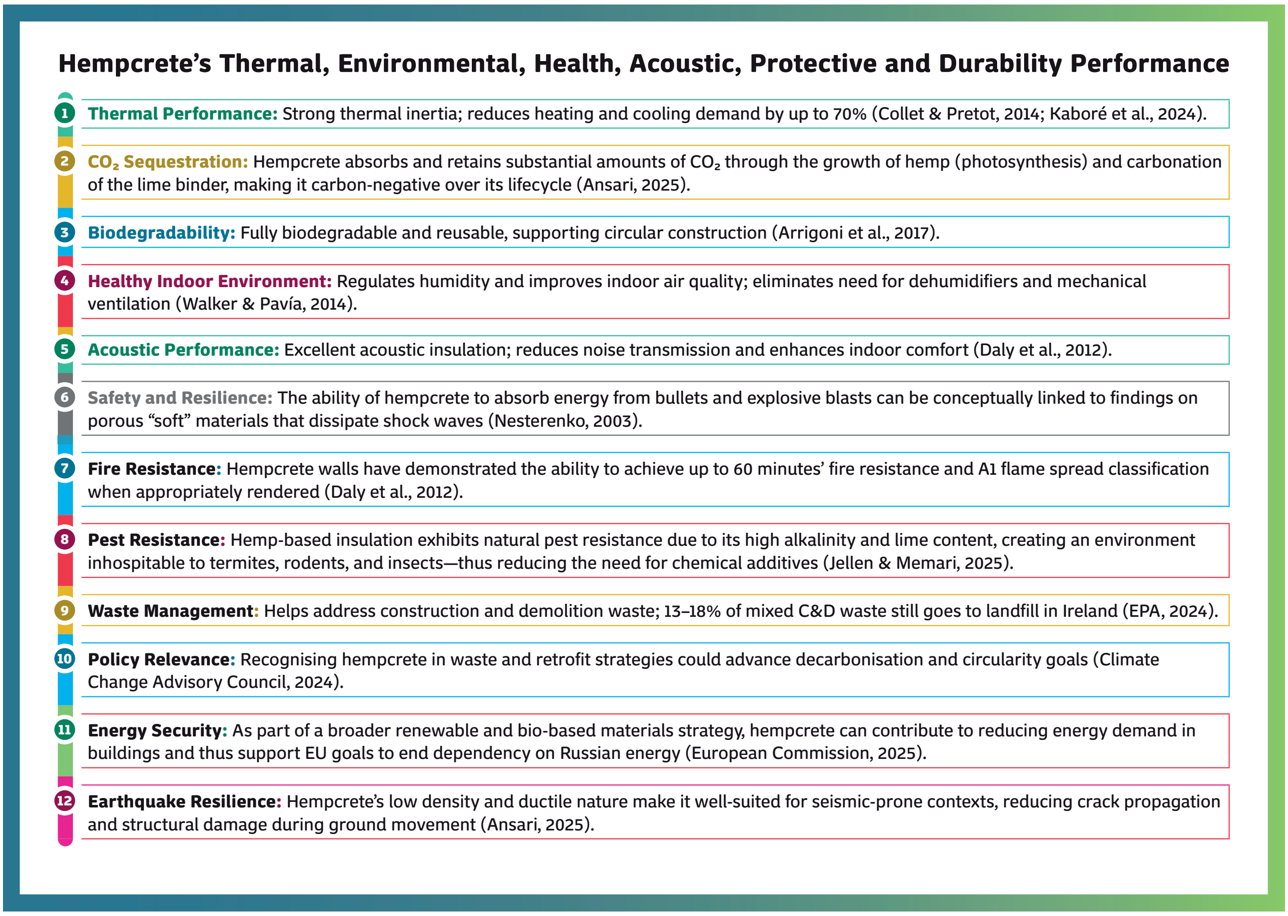

Figure 6: Hempcrete's Thermal, Environmental, Health, Acoustic, Protective, and Durability Performance

4.6 The H-Value Proposal and Its Potential Impact

Patrick Daly's Hemp Lime Block U-Value Study (2019) demonstrated that hemp lime upgrades – retrofitting or improving existing building elements with hemp lime materials – can deliver U-value improvements of up to 85–93% in Irish pre-regulation walls, floors, and roofs. Certification and performance assessment present another obstacle. Existing U-value based regulatory standards fail to account for hempcrete's hygrothermal behaviour and carbon-sequestering potential.

Daly also highlighted a fundamental limitation of the U-value method, noting that it represents only steady-state conductive heat loss and fails to capture thermal mass, moisture regulation, and dynamic energy storage (Daly, 2019). This highlights the need for more holistic evaluation methods. One such proposal is the H-Value metric, which extends beyond thermal conductivity to integrate indicators of embodied carbon, biodegradability, and indoor environmental quality. By addressing the performance gaps identified in Daly's study, the H-Value offers a more comprehensive framework that can align natural materials like hempcrete with national decarbonisation and circular economy targets, reframing them from 'alternative' options to recognised mainstream low-carbon solutions (Larionova and ZWAI, 2025).

5. Discussion

5.1 Interpretation of Findings in Relation to Research Questions

This dissertation set out to investigate the barriers and opportunities for the adoption of hempcrete within the Irish construction sector, framed within a sustainability transitions perspective. The findings confirm that while hempcrete demonstrates multiple ecological, health, and performance benefits, its integration into mainstream construction in Ireland is significantly constrained by regulatory inertia, infrastructural deficiencies, and policy fragmentation.

Regulatory exclusion emerged as one of the most consistent barriers across interviews, with stakeholders emphasising that hempcrete's absence from the national building code and certification schemes prevents insurers, developers, and builders from recognising it as a reliable material. This confirms Geels' (2002) socio-technical 'lock-in' argument: incumbent regimes reinforce stability around dominant materials such as concrete and synthetic insulation, making it difficult for alternatives to scale. Interviewees also pointed to the inadequacy of U-value metrics in capturing hempcrete's dynamic performance, echoing earlier critiques of reductionist thermal assessment methods. (Daly, 2019; Sawadogo et al., 2022).

The finding that residents of hempcrete homes experienced significant improvements in health and comfort, while reducing reliance on mechanical heating and ventilation, challenges conventional definitions of building efficiency and suggests the need for broader evaluation criteria.

Economically, the findings reveal that hempcrete's higher upfront cost, exacerbated by the absence of domestic processing infrastructure, remains a structural barrier. This aligns with Kivimaa and Kern's (2016) insights that niche innovations require targeted infrastructural and policy support to overcome market disadvantages. However, the Ukrainian case provides an alternative model: through localisation and integrated supply chains, hempcrete producers there have reduced reliance on imports and created resilient circular ecosystems. This suggests that economic barriers are not inherent to hempcrete, but contingent on infrastructural and policy design.

Unexpectedly, the retrofit case studies in Ireland highlighted the public health potential of hempcrete more strongly than anticipated. Interviewees reported reduced asthma flare-ups, alleviation of mould-related allergies, and improved indoor air quality. These findings are consistent with Levy, Nishioka and Spengler (2003), who found that insulation retrofits can generate direct public health benefits alongside energy savings. The social relevance of these outcomes underscores that hempcrete adoption has implications not only for climate and energy policy but also for public health strategies an area largely absent from Irish retrofit frameworks.

5.2 Comparison with International Best Practice

The comparative analysis of Ireland and Ukraine demonstrates how national contexts shape the trajectory of hempcrete adoption. In Ireland, hempcrete is framed primarily through energy savings and climate alignment, yet struggles with regulatory misalignment, fragmented supply chains, and limited policy support. By contrast, in Ukraine, hempcrete is positioned as a material of resilience, valued for its autonomy during wartime blackouts, its capacity to maintain comfort without electricity, and its role in strengthening local economies.

These findings resonate with Folke's (2006) framing of resilience as both a material and social attribute. Hempcrete in Ukraine contributes to human security by offering both physical protection and psychological reassurance during instability. This extends the debate on bio-based materials beyond climate mitigation, situating them within broader resilience and security discourses.

International best practice also points to the importance of certification and demonstration projects. In France and the UK, government-supported exemplar projects and technical standards have legitimised hempcrete and facilitated its market entry (Steyn et al., 2025). Ireland's absence of such state-backed demonstration projects reflects a policy inertia that contrasts with these more proactive approaches.

5.3 Opportunities for Cross-Sector Collaboration

A recurring theme across interviews was the disconnect between agricultural and construction policy. While hemp cultivation is permitted in Ireland, licensing complexity and poor coordination with housing and retrofit strategies hinder integration. As Vierling (2024) argues, cross-departmental collaboration linking agriculture, environment, housing, and finance is essential to unlock hemp's potential.

The findings suggest clear opportunities for cross-sectoral synergies:

Agriculture and Construction. Positioning hemp as a diversification crop would align with national commitments to support farmers while also supplying a sustainable raw material for the built environment. Evidence shows that hemp cultivation improves soil health, biodiversity, and carbon sequestration while offering farmers new income streams (Madden et al., 2022; Michels et al., 2025). A domestic processing network would close a critical supply-chain gap, linking Irish agriculture with eco-construction demand (Daly et al., 2012; Teagasc, 2019).

Health and Housing. Incorporating hempcrete into retrofit schemes has direct co-benefits for public health through improved indoor air quality, hygrothermal stability, and reduced heating needs. These benefits justify targeted subsidies and grant support, as healthier housing reduces healthcare system pressures while accelerating Ireland's retrofit targets (Sawadogo et al., 2022; Climate Change Advisory Council, 2024).

Climate and Waste Policy. Hempcrete's biodegradability offers a circular solution to Ireland's C&D waste challenge, where 13–18% of mixed waste still ends up in landfill (EPA, 2024). Embedding hempcrete into C&D waste strategies would reduce landfill reliance, cut embodied carbon, and accelerate the shift to low-carbon building practices.

International Lessons. The Ukrainian Maryzhany Hemp Industrial Park provides a model of systemic innovation by integrating cultivation, processing, construction, and research within a closed-loop industrial ecology. Such approaches demonstrate how cross-sectoral collaboration can deliver resilience, scale economies, and innovation capacity offering Ireland a roadmap for building a hemp-based circular economy. (Geels, 2002; Carus & Sarmento, 2016; Michels et al., 2025).

5.4 Policy Implications and Strategic Pathways

The findings carry several implications for Irish policy. First, regulatory recognition of hempcrete through inclusion in the building code and development of certification pathways is essential. Without this, hempcrete will remain a niche product regardless of its proven ecological and health benefits. Daly's (2019) U-value study underlines the urgency of updating performance metrics to capture holistic benefits, strengthening the case for the proposed H-Value (Larionova and ZWAI, 2025), which offers a more holistic framework by integrating indicators of embodied carbon, biodegradability, and indoor environmental quality. Embedding such a metric in Irish regulation would not only validate the unique advantages of hempcrete but also align national building standards with circular economy and decarbonisation targets. In doing so, Ireland could position itself as a leader in mainstreaming bio-based construction, providing both climate benefits and healthier living environments.

Second, financial mechanisms must be reformed to level the playing field. While concrete has benefitted from decades of subsidies and infrastructural support, hempcrete is expected to compete without comparable backing. Introducing grants for processing facilities, subsidies for retrofits, or public procurement requirements could dramatically alter its competitiveness.

Third, Ireland's Climate Action Plan should explicitly integrate hempcrete and other bio-based materials as part of decarbonisation and circular economy strategies. As the Climate Change Advisory Council (2024) has argued, industry and waste remain critical areas of untapped potential for emission reductions.

Finally, international collaboration is vital. Ukraine could benefit from Ireland's access to EU research and innovation networks, while Ireland could learn from Ukraine's localisation and digital certification strategies. Such cross-national exchanges would accelerate standardisation, enhance transparency, and expand markets for bio-based materials.

5.5 The Role of Hempcrete in Achieving Ireland's Climate Targets

The evidence presented in this dissertation demonstrates that hempcrete can make meaningful contributions to Ireland's climate and housing targets. Its strong thermal inertia reduces heating demand by up to 70% (Collet & Pretot, 2014; Kaboré et al., 2024), while its carbon-negative lifecycle through both hemp growth and lime carbonation further strengthens its decarbonisation profile (Ansari, 2025). Hempcrete's biodegradability also addresses Ireland's end-of-life construction waste challenge, offering a pathway to reduce the 13–18% of C&D waste that still goes to landfill (EPA, 2024). This aligns with recent scholarship highlighting the need for circular, carbon-negative materials that minimise waste streams and extend building life cycles (Daly et al., 2012; Sawadogo et al., 2022; Michels et al., 2025). By substituting conventional concrete with biodegradable hempcrete, Ireland can move closer to EU circular economy targets while reducing its reliance on landfill disposal.

Beyond energy and carbon, hempcrete contributes to co-benefits often overlooked in policy frameworks: improved indoor air quality, mould resistance, pest resistance, and resilience under extreme conditions such as war or natural disasters. These dimensions highlight hempcrete's relevance not only for climate mitigation but also for adaptation and human wellbeing.

The introduction of the H-Value metric builds directly on these findings. By integrating embodied carbon, biodegradability, and indoor environmental quality alongside thermal performance, the H-Value addresses the shortcomings of U-values identified by Daly (2019). Interviewees confirmed that such a metric could help reframe natural materials from 'alternative' to mainstream, incentivising policymakers to expand beyond narrow efficiency measures and align material standards with climate and circularity goals (Larionova and ZWAI, 2025).

Ultimately, hempcrete can be seen as a silver bullet, and its systemic integration into Irish policy, regulation, and supply chains would represent a decisive step towards meeting Ireland's 2050 net-zero targets. The findings of this dissertation suggest that with political will, institutional recognition, and cross-sector collaboration, hempcrete could move from niche innovation to a cornerstone of sustainable construction.

6. Conclusions and Recommendations

6.1 Summary of Key Findings

This dissertation examined the barriers and opportunities for scaling hempcrete in Ireland, within the context of sustainable development, socio-technical transitions, and circular economy policy. The findings show that hempcrete combines thermal, environmental, health, acoustic, protective, and resilience benefits, making it a strong low-carbon material. Yet its adoption remains limited by systemic barriers that entrench conventional construction materials.

The research highlighted four central challenges. First, regulatory inertia most notably the absence of hempcrete from the Irish building code and certification schemes prevents developers, insurers, and regulators from recognising it as a mainstream material. Second, economic and infrastructural barriers limit scalability: the lack of domestic processing facilities forces reliance on imports, increasing costs and undermining circularity. Third, policy fragmentation between agriculture, housing, and climate agendas means hempcrete is left outside key state frameworks, such as the Climate Action Plan. Finally, cultural stigma and lack of demonstration projects reinforce perceptions of hempcrete as niche or experimental.

At the same time, the case studies and interviews illustrated hempcrete's transformative potential. Retrofit households in Ireland reported improved indoor comfort, reduced heating demand, and substantial health co-benefits such as reduced asthma and mould-related illnesses. In Ukraine, hempcrete has demonstrated resilience in wartime conditions, providing thermal stability during blackouts and psychological security during air raids. Comparative analysis shows that while Ireland struggles with regulatory and infrastructural gaps, Ukraine's localisation strategies have enabled greater autonomy and resilience. Together, these insights suggest that with targeted support, hempcrete can advance Ireland's climate, health, and housing goals simultaneously.

The introduction of the H-Value metric represents an important conceptual contribution to this dissertation. Building on Daly's (2019) critique of U-values, the H-Value incorporates embodied carbon, biodegradability, and indoor environmental quality alongside thermal performance. Interviews indicated strong support for such a holistic metric, which could reframe hempcrete from an "alternative" to a mainstream in low-carbon construction (Larionova and ZWAI, 2025).

6.2 Policy Recommendations

The findings point to several urgent policy priorities:

Regulatory Recognition – Hempcrete should be formally included within the Irish building code and supported through Agrément certification. This would remove a major barrier to insurance and financing, as earlier research identified third-party certification as a prerequisite for mainstream adoption of hemp lime products in Ireland (Daly et al., 2012).

Demonstration Projects – State-funded exemplar retrofits and new builds should showcase hempcrete's benefits. International experience shows that visible demonstration is crucial to shifting institutional perceptions, with projects in France, the UK, and Ireland proving decisive in establishing hemp lime as a credible construction material (Daly, 2019).

Financial Mechanisms – Grants, subsidies, and public procurement requirements should support the establishment of hemp processing facilities and incentivise the use of hempcrete in retrofits. Evidence from Germany shows that financial stability and secure markets are essential to encourage adoption of hemp as part of the European Green Deal (Michels et al., 2025).

Cross-Sectoral Collaboration – Policy frameworks must integrate agriculture, housing, and climate. Hemp can be promoted as a diversification crop, while its role in health and waste policy should also be recognised. Systems analysis of hemp cultivation in Ireland demonstrates how aligning agricultural and climate policy can unlock environmental and economic co-benefits (Madden et al., 2022).

Integration into National Climate Strategies – Hempcrete should be explicitly included in the Climate Action Plan as part of Ireland's pathway to net zero, in line with EU bioeconomy and circular economy directives. Its integration would support Ireland in meeting its 2030 and 2050 climate targets more effectively and potentially at lower compliance costs, reducing the risk of fines for missed obligations (Climate Change Advisory Council, 2024).

Energy Independence – In addition, hemp and hempcrete should be incorporated into EU and national energy security strategies as a means of reducing reliance on Russian energy sources, thereby linking material innovation with geopolitical resilience. Implementing the proposed H-Value metrics represents a smart strategy in this new geopolitical and environmental reality, as it not only captures hempcrete's holistic performance but also reinforces its role in advancing energy security (Climate Change Advisory Council, 2024).

Education of Policymakers – Targeted education and training programmes should be developed for politicians, ministers, and civil servants to raise awareness of hemp's ecological, economic, and strategic benefits. Increasing institutional knowledge is essential to overcoming regulatory inertia and ensuring informed decision-making in support of bio-based construction materials (Daly, 2019)

6.3 Recommendations for Industry and Academia

For industry, the priority lies in building credibility and supply chain resilience. Irish hempcrete companies could emulate Ukraine's localisation strategies by investing in domestic cultivation and processing, reducing reliance on imports and strengthening circularity. Collaboration across the supply chain including farmers, processors, builders, and designers will be critical to achieving scale.

For academia, the development of holistic performance metrics such as the H-Value should be advanced through interdisciplinary research, combining engineering, environmental science, and public health perspectives. Academic institutions can also play a key role in training architects, engineers, and trades in the use of hempcrete, helping to overcome the knowledge barriers identified in this study. Partnerships with international research networks would accelerate the establishment of performance standards and comparative data across climates and contexts.

6.4 Areas for Further Research

While this dissertation has provided new insights, further research is needed in several areas. First, quantitative studies on health outcomes of hempcrete retrofits would strengthen evidence for its public health co-benefits and provide justification for state support. Second, life-cycle assessments specific to the Irish context are needed to validate hempcrete's carbon-negative profile and quantify its contribution to national climate targets. Third, further work is required to refine the H-Value metric into an operational tool that can be tested, validated, and eventually integrated into building regulations. Fourth, research on seismic and protective properties of hempcrete would deepen understanding of its role in resilience frameworks. Finally, longitudinal studies of economic viability and market development would help identify pathways for scaling within Ireland's construction sector.

In conclusion, this dissertation shows that hempcrete can be a 'silver bullet' for Ireland's construction sector – simultaneously tackling energy demand, carbon sequestration, waste, health, and resilience. Its potential, however, is held back by regulatory inertia, infrastructure gaps, and policy silos. With holistic metrics like the H-Value, stronger cross-sector collaboration, and investment in supply chains and demonstration projects, hempcrete could move from the margins to the mainstream becoming a cornerstone of Ireland's path to climate neutrality, healthier homes, and sustainable housing by 2050.

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List of Figures

List of Abbreviations

AFNOR – Association Française de Normalisation (French Standardisation Association)
CAP – Common Agricultural Policy
CBD – Cannabidiol
CCAC – Climate Change Advisory Council
C&D – Construction and Demolition (waste)
CO_2 – Carbon Dioxide
DAFM – Department of Agriculture, Food and the Marine (Ireland)
DCCAE – Department of Communications, Climate Action and Environment (Ireland)
DHLGH – Department of Housing, Local Government and Heritage (Ireland)
EPA – Environmental Protection Agency (Ireland)
EPBD – Energy Performance of Buildings Directive
EU – European Union
GHG – Greenhouse Gas
GWP – Global Warming Potential
HPRA – Health Products Regulatory Authority (Ireland)
IEA – International Energy Agency
LCA – Life Cycle Assessment
LEU – Large Energy User (industry classification)
NF DTU 26.2 – French National Standard for Hempcrete Construction
NZEB – Nearly Zero Energy Buildings
SDGs – Sustainable Development Goals (United Nations)
THC – Tetrahydrocannabinol
UCC – Urban Consolidation Centre (logistics) / University College Cork (context-dependent)
U-value – Thermal transmittance coefficient (rate of heat transfer through a building element)
UNFCCC – United Nations Framework Convention on Climate Change
WCED – World Commission on Environment and Development (Brundtland Report)
ZWAI – Zero Waste Alliance Ireland
H-Value – Holistic building performance metric (proposed by Larionova & ZWAI, 2025)

Glossary

Agroforestry – A land-use system that integrates trees, crops, and/or livestock on the same land to enhance biodiversity, resilience, and sustainable production.

Bio-based materials – Construction materials derived from renewable biological resources such as plants, including hemp, flax, or timber, offering low embodied carbon and biodegradability.

Biophilic – Relating to design that connects people with nature, often through natural materials, light, plants, or patterns that promote wellbeing.

Carbon sequestration – The process by which plants, soils, and materials capture and store carbon dioxide (CO_2) from the atmosphere, reducing greenhouse gas levels. Hempcrete continues to sequester carbon during both hemp growth and the carbonation of lime.

Circular economy – An economic model focused on minimising waste and keeping materials in use for as long as possible through reuse, recycling, and biodegradability.

Climate Action Plan (Ireland) – The national policy framework that sets sectoral carbon budgets and pathways to reduce greenhouse gas emissions by 51% by 2030 and achieve net-zero by 2050.

Construction and Demolition (C&D) Waste – Waste generated during construction, renovation, and demolition of buildings. In Ireland, 13–18% of mixed C&D waste still goes to landfill, much of it concrete.

Decortication – The mechanical process of separating the outer fibre (bast) from the inner woody core (hurd or shiv) of the hemp stalk, typically the first step in processing hemp for construction, textiles, and other industrial uses.

Embodied carbon – The total greenhouse gas emissions generated during the production, transport, installation, maintenance, and disposal of a building material or product.

Energy Performance of Buildings Directive (EPBD) – An EU directive requiring member states to improve energy efficiency in buildings through regulations, retrofits, and Nearly Zero Energy Building (NZEB) standards.

H-Value – A proposed holistic metric for assessing natural building materials, which includes thermal mass, moisture regulation, life-cycle carbon, and biodegradability — going beyond the traditional U-value.

Hempcrete – A non-structural bio-composite material made from the woody core of hemp (shiv), lime-based binder, and water. It is breathable, carbon-negative, and provides excellent thermal and moisture regulation.

Holistic performance – An approach to building evaluation that considers ecological, health, social, and economic impacts across the entire lifecycle, rather than only operational energy use.

High thermal-mass composition – A material characteristic that enables absorption, storage, and gradual release of heat, helping stabilise indoor temperatures and reduce energy demand.

Hydraulic lime – A type of lime that sets and hardens upon reaction with water, offering higher strength and durability than non-hydraulic lime while retaining some breathability.

Hurd – The woody inner core of the hemp stalk, used in hempcrete and other biocomposites for its absorbent and lightweight properties.

Hygrothermal – Refers to the combined effects of heat (thermal) and moisture (hygro) transfer in building materials and indoor environments.

Life Cycle Assessment (LCA) – A method of evaluating the environmental impacts of a product or system across its entire life, from raw material extraction to end-of-life disposal or recycling.

Lime-based binder – A binding material made primarily from lime, used in hempcrete to hold hemp shiv together while providing breathability and flexibility.

Lime carbonation – The chemical process where lime (calcium hydroxide) reacts with carbon dioxide in the air to form calcium carbonate, contributing to strength and long-term carbon sequestration in hempcrete.

Lock-in effect – A concept from socio-technical transition theory (Geels, 2002), referring to how existing regulations, institutions, and industry standards reinforce reliance on conventional materials (e.g., concrete), making it difficult for sustainable alternatives like hempcrete to gain market entry.

Nearly Zero Energy Building (NZEB) – A highly energy-efficient building standard mandated in the EU, where the very low amount of required energy is largely supplied by renewable sources.

Pozzolanic additives – Materials containing siliceous or aluminous compounds that, when mixed with lime and water, form cementitious properties, enhancing strength and durability.

Resilience – The capacity of systems, communities, or materials to adapt to shocks and stresses such as climate change, war, or energy crises. Hempcrete enhances resilience by maintaining indoor comfort without external energy supply.

Retrofit – The process of upgrading existing buildings with new materials or technologies to improve energy efficiency, comfort, and durability. Hempcrete retrofits in Ireland have demonstrated health and comfort benefits.

Socio-technical transitions – The study of how technological innovations interact with social, institutional, and cultural systems, influencing whether sustainable alternatives can replace dominant practices.

Thermal mass – The ability of a material to absorb, store, and slowly release heat, which stabilises indoor temperatures and reduces energy demand. Hempcrete's high thermal mass is a key feature overlooked by U-values.

U-value – A traditional metric for measuring heat transfer through a building element (wall, floor, roof). Lower U-values indicate better insulation. However, this metric does not account for hempcrete's dynamic properties like thermal mass and moisture regulation.

Vapour-permeable – A material property that allows water vapour to pass through, helping regulate indoor humidity and prevent condensation or mould.

Zero Waste Alliance Ireland (ZWAI) – An advocacy group promoting sustainable waste management and natural materials, highlighting hempcrete's biodegradability and potential to reduce landfill reliance.

Appendix 1: Interview Questions – Hemp Home Experience

Project 1: Retrofit of a 1980s Bungalow

Summary: The property underwent a deep retrofit using hemp-based materials. Measures included the installation of 100 mm hempcrete blocks applied internally to exterior walls, 20 mm hemp plaster on interior walls, hemp-fibre roof insulation, and a 5 mm hemp underlay beneath wooden flooring**.** The retrofit was particularly significant because the homeowner suffered from a severe mould allergy, making indoor air quality a priority.

1. How has your home's energy performance changed since the retrofit, and have your electricity or heating costs dropped? Do you use electricity, gas, or both?
2. How well does your home retain heat now, especially during the winter months?
3. Do you think it might be more effective if underfloor heating were installed?
4. Have you encountered any issues with mould or dampness since moving into the house?
5. Have you ever needed to use a dehumidifier in your hemp-retrofit home? If so, in what situations?
6. Has living in a hemp-retrofit home led to any noticeable improvements in your or your family's health?
7. How would you describe the overall impact of your home environment on your physical and mental wellbeing?
8. Have you experienced any psychological or emotional benefits from living in a chemical-free, natural-material retrofit home?
9. Some research suggests that stable indoor temperatures can lead to healthier eating habits—have you noticed any such changes in your daily life or routines?
10. Have you observed any changes in mood, sleep quality, or behaviour among household members?
11. Would you consider increasing the wall thickness to improve insulation and efficiency, or do you feel the current structure meets your needs?
12. Reflecting on the experience, is there anything you would do differently if you were starting again?
13. Would you consider retrofitting another property using hemp-based materials?
14. What would you say to other homeowners in Ireland who are thinking about retrofitting with natural materials like hemp?
15. Do you think the government or local authorities should do more to support natural-material retrofits?

Appendix 2: Interview Questions – Hemp Home Experience (Galway City Retrofit)
Project 2: Retrofit of a Semi-Detached Mass Concrete Home

Summary: This project involved the interior retrofit of a mass concrete semi-detached home in a Galway City housing estate. The retrofit used 70 mm hempcrete applied to walls, clay boards on ceilings, and natural plaster throughout**.** The project was undertaken with health considerations in mind, as the husband has multiple chemical sensitivities, while both the wife and son suffer from asthma.

1. How has your home's energy performance changed since the retrofit, and have your electricity or heating costs dropped? Do you use electricity, gas, or both?
2. How well does your home retain heat now, especially during the winter months?
3. Did the retrofit have any noticeable impact on keeping the house cooler in the summer?
4. Are you using any additional energy-saving systems (e.g., solar panels, smart thermostats)?
5. Do you think it might be more effective if underfloor heating were installed?
6. Have you noticed any improvements in indoor air quality or humidity levels since the retrofit?
7. Have you had any issues with damp, mould, or condensation before or after using hempcrete and clay boards?
8. Have you ever needed to use a dehumidifier in your hemp retrofit home? If so, in what situations?
9. Has living in a hemp- and clay-based home led to any noticeable improvements in your or your family's health ?
10. How would you describe the overall indoor comfort and freshness of the air?
11. What has been the most noticeable change in how the house feels to live in, day to day?
12. Have you or your family experienced any changes in wellbeing, such as better sleep, mood, or energy levels?
13. Do you feel more connected to the natural materials in your home, and has that influenced your lifestyle in any way?
14. Would you do anything differently if you were starting the retrofit again?
15. Would you recommend hempcrete and clay boards to other homeowners living in mass concrete homes?
16. Do you feel the 70 mm hempcrete was sufficient for insulation, or would you consider increasing it in future projects?
17. What advice would you give to someone considering a natural-material retrofit in a similar type of home?
18. Do you think there should be more public awareness or government support for retrofits using natural materials?

Appendix 3: Interview Questions – Full Hemp Home Experience (Ireland)
Project 3: New-Build Hempcrete Home

Summary: This project is a new-build hempcrete home constructed with 360 mm hempcrete walls, 240 mm hemp-fibre ceiling insulation, and modern underfloor heating systems**.** The design incorporates a ground-source heat pump powering a low-temperature underfloor heating system and a hempcrete floor upstairs**,** alongside a heat recovery ventilation (HRV) unit that maintains consistent indoor air quality and reduces heat loss. The structure was built using the Hemp Pro Structural System with the following finishes:

Interior: 15 mm interior hemp plaster, 5 mm PLS finish plaster
Exterior: 25 mm lime and sand traditional plaster
Total wall width: 400 mm

1. Your passive house design and implemented efficiency measures allow you to save up to 70% on electricity. Could you share more about your energy consumption over the past two years, and where you believe the main savings have come from?
2. How effective have you found the heated floor and recuperator system in maintaining thermal comfort and energy efficiency? (Do you rely primarily on electricity, gas, or both?)
3. Have you noticed any seasonal differences in performance, particularly regarding temperature regulation or heating needs (as mid-season performance)?
4. You are planning to install solar panels and aim to become fully energy-independent. Will your system include battery storage?
5. If you generate surplus energy (energy-plus performance), would you consider selling it back to the grid via a smart meter?
6. Have you encountered any issues with mould or dampness since moving into the house?
7. Have you ever needed to use a dehumidifier in your hemp home? If so, in what situations?
8. Have you experienced any psychological or emotional benefits from living in a chemical-free, natural-material home (e.g. noise reduction, improved air quality, reduced allergies)?
9. Some research suggests that stable indoor temperatures can lead to healthier eating habits. Have you noticed any such changes in your daily life or routines (e.g. mood, sleep quality, lifestyle habits)?
10. Were there any challenges in securing insurance for your hempcrete home? How did insurers respond, and did it affect your premium? (If insured, which company?)
11. Did you face any planning or regulatory hurdles during the building process, particularly regarding compliance with U-values or building codes?
12. What advice would you give to others in Ireland (or elsewhere) considering building a hemp-based home?
13. Based on your experience, is there anything you would do differently if you were building again?
14. Would you consider increasing the wall thickness to improve insulation and efficiency, or do you feel the current structure meets your needs?

Appendix 4: Interview Questions – Resident of a Hemp-Based House in Ukraine (Relocated Person)

Project 4: Hempcrete House Constructed After Forced Relocation

Summary: This case study concerns a resident who constructed a hempcrete home in Ukraine following displacement during wartime. The house was built under crisis conditions, with hempcrete chosen for its resilience, thermal stability, and natural health benefits. The interview explores motivations, lived experiences, safety performance, social perceptions, and future recommendations.

1. Am I correct in understanding that you built your house as a result of forced relocation?
2. Why did you decide to build a hempcrete house specifically?
3. What were the main factors influencing your decision in wartime conditions?
4. What advantages have you experienced living in a hempcrete house during extreme cold winters and hot summers?
5. How did the house perform during electricity outages and prolonged blackouts?
6. Have you noticed improvements in comfort, thermal stability, and indoor air quality compared to traditional buildings?
7. Have you observed any impact on your physical and psychological well-being while living in such a house?
8. How would you assess the fire resistance and moisture resistance of the house?
9. Do you feel that the hempcrete structure provides additional protection from noise, as well as from bullets or shrapnel, due to its fibrous composition that can absorb part of the kinetic energy and prevent sharp fragment formation unlike bricks or glass?
10. Have you experienced any issues with pests or rodents, especially in rural or semi-ruined areas where such problems are common, and how does hempcrete address this?
11. Did you have any prior experience or knowledge about hemp-based building technologies before constructing this house?
12. In your opinion, how has the war changed attitudes towards hemp technologies in Ukraine?
13. How do you assess the recent legislative changes regarding the cultivation and use of industrial hemp in construction?
14. What improvements or changes would you suggest for such houses in the future?
15. Would you recommend this type of house to others planning construction in conditions of instability or crisis?

Appendix 5: Interview Questions – CEO of Hemp Consrtuction Company (Ireland) Industry Stakeholder

Summary: This interview was conducted with the CEO one of Ireland's leading companies specialising in hemp-based construction materials and systems. The focus of the discussion was on material sourcing, economic feasibility, certification challenges, and the role of policy in supporting the development of hempcrete as a mainstream construction material.

1. Where do you currently source your technical hemp do you rely primarily on imports or domestic production?
2. In your assessment, would cultivating industrial hemp in Ireland be more cost-effective and environmentally sustainable than importing it?
3. If hemp were grown and processed locally, would that reduce the overall cost of hemp-based construction?
4. Do you consider it feasible that hemp-based housing could become less expensive than conventional construction in the future, and what conditions would enable this shift?
5. Beyond the cost of raw materials, what additional factors most significantly influence the affordability of hemp-based construction projects?
6. What are the principal challenges your enterprise faces in improving efficiency, and what forms of policy, financial, or institutional support would enable you to scale more effectively?
7. What regulatory or planning permission barriers have you encountered in promoting or delivering hemp-based housing projects?
8. In your view, how significant is the inaccuracy of U-value standards as a barrier to properly assessing the thermal and hygrothermal performance of hempcrete?
9. Certification is another major bottleneck problem. Does it significantly affect bio-based construction?
10. Do you currently receive any grants or government support for your contributions to zero construction waste practices and carbon sequestration through hempcrete?

Appendix 6: Interview Questions – Founder of Hemp Consrtuction Company (Ukraine) Industry Stakeholder

Summary: This interview was conducted with the founder of Ukrainian company pioneering the use of hempcrete in construction. The discussion focused on the resilience of hemp houses during wartime, the role of Ukraine's e-Hemp certification system, and the potential for scaling hemp production and exporting Ukrainian technologies to the European Union.

Block 1. Experience of Living in Hemp Houses During Wartime

1. How would you personally, or your clients, describe the experience of living in hempcrete houses during wartime conditions?
2. What were the main challenges and advantages experienced during electricity outages and prolonged blackouts?
3. Did you notice a significant difference in retaining heat in winter and maintaining coolness in summer compared to conventional materials?
4. Have these conditions influenced any subsequent improvements in the design or technology?
5. Based on your experience in both Ukraine and the USA, which country's legislation offers greater advantages for the hemp construction industry, and why?
6. Have you had experience working with Ukraine's e-Hemp system?
7. How effective do you find it in ensuring transparency, quality assurance, and market access for hemp-based products both domestically and internationally?
8. Which aspects of e-Hemp do you consider successful, and what, in your opinion, needs improvement or even a complete overhaul?
9. How do you assess the prospects of the Marižany Hemp Industrial Park does it have the potential to make Ukraine as significant in hemp production as France is for the European market?
10. What key conditions are necessary for scaling hemp production in Ukraine to match leading European players?
11. Do you see potential for developing a franchise model or exporting Ukrainian hempcrete technologies to the EU?

Appendix 7: Interview Questions – Green Party Senator (Ireland)

Summary: This interview was conducted with a Green Party Senator in Ireland, focusing on the political, regulatory, and policy dimensions of hempcrete adoption. The discussion addressed hemp's potential contribution to Ireland's Climate Action Plan, barriers in regulation and certification, and the scope for government incentives to support bio-based construction.

1. From your perspective, what are the main policy or regulatory barriers currently preventing the wider adoption of hemp-based materials in Ireland's construction and agricultural sectors?
2. Do you see a role for hemp within Ireland's national strategies on climate action, biodiversity, or rural development, and what kind of government support or incentives would be most effective in unlocking its potential?
3. How do you view the current level of public and political awareness around the benefits of hemp as a regenerative, carbon-negative material, and what could help drive broader acceptance and integration?

Appendix 8: Interview Questions – Vice-Chair of Zero Waste Alliance Ireland, Policy & Advocacy Stakeholder

Summary: This interview was conducted with the Vice-Chair of ZWAI, focusing on the intersection of hempcrete with waste management, circular economy strategies, and broader sustainability transitions. The discussion explored the potential of hempcrete to reduce construction and demolition (C&D) waste, policy gaps, and the advocacy needed to integrate natural materials into Ireland's regulatory frameworks.

1. From your perspective, what are the most pressing environmental issues associated with concrete production and use in Ireland?
2. Cement is highly carbon-intensive due to both energy use and process emissions. Do you see real potential for decarbonising cement in Ireland, or should policy focus more on alternatives?
3. According to the EPA, 13–18% of mixed C&D waste in Ireland still goes to landfill. Why is Ireland struggling to recycle more concrete and demolition materials compared to other EU countries?
4. What systemic barriers prevent widespread adoption of deconstruction over demolition?
5. How do you think regulation or financial penalties (e.g. fines for landfilling recyclable C&D waste) could shift developer behaviour?
6. Ireland relies heavily on natural aggregates from eskers and gravel pits, which has ecological consequences. Do you think stronger restrictions on quarrying are politically feasible?
7. Could a national strategy for recycled aggregates help reduce dependence on quarrying, and what would it take to implement such a strategy?
8. From your experience on the Environmental Executive Committee, do you think Ireland's building regulations and planning system incentivise or discourage circular practices in construction?
9. How can local authorities be empowered to promote reuse and recycling in construction projects?
10. What examples of international best practice in construction waste management should Ireland be looking to?
11. Hempcrete and bio-based materials are gaining attention for being carbon-negative and durable. From a policy and regulatory perspective, what needs to change to allow these materials to compete with concrete?
12. Do you think public procurement could play a stronger role in mainstreaming natural building materials?
13. If Ireland is to meet its 2030 and 2050 climate targets, what do you see as the most urgent interventions in the construction sector?
14. How do you envision the role of circular economy principles repair, reuse, recycling in reshaping Ireland's construction industry?
15. What advice would you give to young researchers and practitioners working on alternatives like hempcrete who want to influence policy?

Appendix 9: Interview Questions – Ecological Consultant (Agroforestry and Soil, UCC Background) Expert Stakeholder, ZWAI member.

Summary**:** This interview was conducted with an ecological consultant specialising in agroforestry and soil, with a background in Plant Biology at University College Cork (UCC**)**. The discussion explored the ecological implications of hemp cultivation in Ireland, opportunities for integration with agroforestry systems, and the potential of hempcrete to contribute to waste reduction and sustainable land management.

1. From your experience, what are the key ecological or regulatory barriers limiting the wider adoption of hempcrete in Ireland?
2. Are there other bio-based plants that offer similar or complementary benefits to hemp for use in natural building materials?
3. How often can hemp be cultivated in Ireland as a multiple harvest crop under certain conditions?
4. Hempcrete is a biodegradable and sustainable material for the construction sector. If its use were scaled up, to what extent could it significantly reduce construction and demolition waste going to landfills?
5. How can hemp-based construction systems, such as hempcrete, be integrated into agroforestry or regenerative land management practices?
6. Could such integration support the creation of closed-loop, localised, and sustainable building models that connect farming, materials production, and housing?

Appendix 10: Interview Questions – Conservation Architect (Dublin Hempcrete Restoration Project) Built Environment Professional

Summary: This interview was conducted with an architect specialising in conservation**,** who led a hempcrete restoration project in Dublin (An Bothán Tae Café). The focus was on technical and regulatory challenges, planning system responses, and the lessons that can be drawn for wider adoption of hempcrete in restoration and retrofitting.

1. Could you describe your experience working with hempcrete in the restoration of An Bothán Tae Café and how did you manage to convince the local authority to approve the use of hempcrete and other natural materials in a public project?
2. What challenges, if any, did you face in getting regulatory or planning permission for using non-traditional materials like hempcrete?
3. Was there any resistance from stakeholders (e.g. local council, conservation officers, contractors), and how was it addressed?
4. What led you to choose hempcrete material specifically for the infill of the old timber structure?
5. Could you talk through the reasoning behind the combination of 120 mm hempcrete blocks, 50 mm cork plaster inside, and 30 mm lime plaster with sand outside?
6. Do you see this project influencing other public or private developments in Ireland?
7. In your view, what are the key barriers to scaling up the use of hemp-based materials in architecture and construction more widely?
8. What advice would you give to other architects or local governments considering a similar approach?

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Template for Participant Information Form

School of Natural Sciences, Trinity College Dublin

"Barriers in Sustainable Development"

Details: The research is conducted by Olena Larionova, an MSc student in Smart and Sustainable Cities at Trinity College Dublin. The project, titled *"Barriers in Sustainable Development"*, explores challenges to implementing sustainable strategies in urban areas. It is self-sponsored with no external funding and involves no additional research assistants.

Introduction: The study involves a 20–35 minute interview. Additional details can be shared via email in advance, and a follow-up meeting can be arranged if requested.

Procedures: Participants will be selected based on their experience in sustainable development, urban planning, or related fields. Interviews will be conducted either online or in person, depending on availability.

Benefits: Although there may be no direct benefits to individual participants, your insights could help inform future urban sustainability policies and practices, which will be beneficial for the wider community and sustainability sector.

Risks: Because this study involves personal data, there is a small risk of identification. However, strict confidentiality measures will be in place, and the risk of a data breach is considered very low. See the confidentiality section for more details.

Exclusion from participation: Individuals with no experience or background in sustainable development, urban planning, or related fields will be excluded from the study.

Confidentiality: All data will be kept strictly confidential and handled in line with GDPR. Participants will be anonymised using unique codes, and identifying details will be removed. Data will be stored securely on password-protected, encrypted devices and accessed only by the researcher.

Voluntary Participation: Participation is voluntary. You may withdraw at any time without penalty and without losing any benefits.

Reimbursements*:* There are no reimbursements or additional incentives for participants, including for travel costs.

Stopping the study: The researcher may terminate your participation at any time without your consent, if necessary.

Permission: This study has been approved by the School of Natural Sciences Research Ethics Committee at Trinity College Dublin. No additional ethical approvals are required.

Access to data: Participants may access their personal data at any time under the Freedom of Information Act 2014.

Sharing the results: The research results will be shared with participants and the community before publication.

Further information: You can get more information or answers to your questions about the study, your participation, and your rights from Dr.Philip Lawton, who can be contacted at philip.lawton@tcd.ie.

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The University of Dublin

Template for Informed Consent Form

School of Natural Sciences, Trinity College Dublin

Title of research study: *“Barriers in Sustainable Development”*

This study and this consent form have been explained to me. I believe I understand what will happen if I agree to be part of this study.

I have read, or had read to me, this consent form. I have had the opportunity to ask questions and all my questions have been answered to my satisfaction. I freely and voluntarily agree to be part of this research study, though without prejudice to my legal and ethical rights. I have received a copy of this agreement and I understand that, if there is a sponsoring company, a signed copy will be sent to that sponsor.

Name of sponsor:
PARTICIPANT’S NAME:
PARTICIPANT’S SIGNATURE:
Date:
Date on which the participant was first furnished with this form:

Participants with literacy difficulties:
I have witnessed the accurate reading of the consent form to the potential participant, and the individual has had the opportunity to ask questions. I confirm that the individual has given consent freely and understands that they have the right to refuse or withdraw from the study at any time.

Print name of witness: ___________________________
Signature of witness: ____________________________
Date (Day/month/year) ___________________________
Thumbprint of participant:

Statement of investigator’s responsibility: I have explained the nature, purpose, procedures, benefits, risks of, or alternatives to, this research study. I have offered to answer any questions and fully answered such questions. I believe that the participant understands my explanation and has freely given informed consent.

Researcher’s signature: Date:
(Keep the original of this form in the project records, give one copy to the participant, and send one copy to the sponsor (if there is a sponsor).