

CREATING AN ECOSYSTEM CONCEPT FOR SCALABLE GREEN MORTGAGES

SAARI, Anniina, JUNNILA, Seppo and HOLOPAINEN Maria

Aalto University School of Engineering

ABSTRACT

Decarbonising the real estate sector per the Paris Agreement requires rapid and significant renovation of existing buildings, targeting half the stock by 2040, with an annual global investment of USD 700 billion. Green mortgages offering financial incentives for environmentally compliant homes, are a promising tool to encourage renovations, but have seen slow uptake and remain underdeveloped. This paper uses an explorative research approach with participatory workshops to create an initial ecosystem concept for green mortgages, addressing the challenges of slow adoption and inefficiency. We identify the necessary network of participants for effective green mortgage implementation and describe value-creation mechanisms for ecosystem participants. Our tentative green mortgage ecosystem concept presents value-creation opportunities with significant implications for practitioners, the public sector, and society. Next steps involve developing a shared logic and governance system for the ecosystem. Future research should explore whether introducing decentralised technologies, like blockchain, could add value, as literature suggests, and validate the concept across varying contexts.

Keywords: decarbonisation, green mortgage, ecosystem, participant network, value creation, built environment, real estate

INTRODUCTION

The real estate sector accounts for around 30 % of global carbon emissions, making its decarbonisation crucial for meeting global climate goals. Decarbonising the real estate sector per the Paris Agreement requires rapid and significant renovation of existing buildings, targeting half the stock by 2040. This requires an annual global investment of USD 700 billion (IEA, 2020) – the green investment gap.

The increasing importance of Environmental, Social, and Governance (ESG) mandates and tightening of green building and carbon regulation requirements are reshaping investment priorities in the real estate sector. Recent studies (Lee et al., 2024; Lee and Liang, 2024) highlight a growing appetite among investors for green buildings and sustainable financial products, driven by their alignment with climate goals and risk mitigation strategies. Green mortgages offering financial incentives for environmentally compliant homes, are a promising tool to encourage renovations and close the green investment gap in the residential real estate sector by providing preferential financial terms to homeowners for purchasing, constructing or retrofitting energy-efficient properties (Akomea-Frimpong et al., 2022). However, despite these market and regulatory developments, green mortgage uptake remains slow and underdeveloped (Saari et al., 2024).

While promising research suggests the benefits of green mortgages for both originators and consumers (Dell'Anna et al., 2022), there has been limited academic exploration of how these financial instruments can be implemented and scaled in practice. Addressing these challenges—such as the needs for standardised financial products and regulatory guidance, high upfront costs, and limited awareness among institutions and borrowers (EBA, 2023)—requires a comprehensive understanding of the ecosystem in which these products operate. Mortgage loans, given their significant share in banks' assets and their environmental impact due to high fossil fuel consumption, present a critical area for intervention (Schuetze, 2020).

This paper adopts an explorative research approach with participatory workshops to create an initial ecosystem concept for green mortgages, addressing the challenges of slow adoption and inefficiency. The main research question is 'How can a green mortgage ecosystem create value for the participants', focusing on identifying key participant network and value creation mechanisms within the ecosystem.

To explore this question, we first utilised Thomas and Aitio's (2014) ecosystem theory, later adapted by Pulkka et al. (2016) to the real estate industry. However, a key finding from the participatory workshops was that no organisation had the power or incentives to coordinate ecosystem development – critical success factors identified in ecosystem theories (Iansiti and Levien, 2004; Stonig and Müller-Stewens, 2019) and that transparency of data, i.e. shared logic and governance system, is a key value driver in green financing. These observations led us to explore distributed ecosystem theories as a fitting approach, ultimately guiding us to adopt participants' value creation aspects from Toufaily et al.'s (2021) framework on blockchain adoption for our data analysis and concept development.

Toufaily et al.'s (2021) framework, grounded in strong theoretical foundations, integrates key ecosystem stakeholders—such as private organisations, end-users, public sector entities, and startups—into a model that emphasises the reinforced mutual interactions driving socio-economic value. Additionally, it incorporates crucial blockchain features (e.g., scalability, transparency, interoperability, security, and privacy) and the role of public-private partnerships, along with theories on externalities and network effects. This framework is particularly relevant as it allows for the examination of complex networks to collaborate to create value, which is essential for understanding and scaling the green mortgage ecosystem.

This paper contributes to the growing body of literature on green finance by addressing a significant gap: the slow adoption of green mortgages and the lack of scalable ecosystem models. Grounded in participatory workshop data and ecosystem theories, the framework identifies value-creation mechanisms for stakeholders such as financial institutions, end-users, public sector entities, and startups. By highlighting the public sector's role in creating incentives and fostering ecosystem development, the paper offers actionable insights for scaling green mortgages and supporting residential decarbonisation efforts aligned with global climate goals.

The paper is structured as follows: The next section provides a snapshot of green mortgage research, reviews the literature on the business ecosystem concept, and discusses data transparency needs in decarbonising the property sector. The following section describes the methodology, followed by the results which outline the preliminary concept for the green mortgage ecosystem, including the network of participants and value creation mechanisms. Finally, the results are discussed, and conclusions are provided.

LITERATURE REVIEW

Green Buildings and Green Mortgages

Recent studies emphasise the environmental, economic, and social benefits of green buildings. Environmentally, green buildings reduce energy use and carbon emissions, supporting global sustainability goals (Geng et al., 2019). Economically, they lower operating costs, increase property values, and reduce default risks (An and Pivo, 2020; Fu et al., 2021; Leskinen et al., 2020). Socially, they improve occupant health and satisfaction (Geng et al., 2019). While green buildings offer significant benefits, their adoption is hindered by high upfront costs (Darko et al., 2020; Geng et al., 2019) and financial accessibility issues. Green mortgages can provide a pathway to address these barriers by reducing the economic burden of green building investments (Akomea-Frimpong et al., 2022; Musić, 2021).

Debt financing remains the primary mechanism for global real estate transactions, with mortgage loans as the backbone of residential property markets. As such, integrating sustainability into these financial instruments is essential for achieving decarbonisation goals. The literature on green mortgages complements green building studies by addressing financial barriers to sustainable building practices (Musić, 2021). Green mortgages incentivise the constructing, purchasing, or renovating energy-efficient homes through lower interest rates and improved loan terms (Dell'Anna et al., 2022; Reid et al., 2019). However, challenges remain, including inconsistent definitions of qualifying green properties, limited consumer awareness, and the need for standardised market criteria (EBA, 2023; Saari et al., 2024). Aligning green mortgage programs with broader regulatory frameworks, such as the Energy Performance of Buildings Directive in the EU - can enhance adoption and support decarbonisation efforts (European Commission, 2024).

Historically, much attention in green real estate finance has focused on green bonds, which are used to finance large-scale sustainable projects. Green bonds have become popular due to their ability to attract institutional investors and fund significant initiatives. However, due to investment size constraints, they are accessible only

to a limited number of issuers. This creates a gap in the market for smaller-scale projects and individual homeowners who wish to contribute to environmental goals. (Saari et al., 2024).

To bridge this gap, scaling up green mortgages—typically featuring 30-80% debt-to-asset ratios—is essential for real estate decarbonisation efforts. Green mortgages can fill this gap, offering a scalable solution for residential real estate and targeting individual property owners with incentives for sustainable investments.

Green residential mortgages were first introduced in 2005 by major US banks like Wells Fargo and Bank of America. Over the years, the green mortgage markets have grown considerably. However, the exact market size remains unclear due to a lack of standardised disclosure requirements (Saari et al., 2024).

A noteworthy example of successful market penetration can be observed in Ireland, where green mortgages have gained substantial traction since their introduction in 2019. By 2022, green mortgages accounted for 30 % of all mortgages originated in the country 2022 (Lambert et al., 2023). This development has been strongly supported by Ireland's Climate Action Plan, which aims to retrofit 500,000 homes to meet the B2 Energy Performance Certificate standard. Irish consumers benefit from an average 30 basis point financial advantage with green mortgages, which can be applied to buying, building or retrofitting homes. (Lambert et al., 2023)

Despite this success, green mortgages still lag behind green bonds in terms of global market penetration. Standardisation and global data availability are imperative for scaling green mortgages effectively across different regions, each with its unique real estate practices and regulations.

Overall, bank lending is households' primary source of finance, yet tools supporting household access to green loans still need to be improved. The European Commission identifies challenges including the needs for standardised financial products and regulatory guidance, high upfront costs, and limited institutional and borrower awareness. Notably, low-income households are primarily excluded from the markets financing energy-efficient buildings (EBA, 2023). The European Banking Authority's 2023 survey results signal that European credit institutions expect green loans to grow in the coming years. The Energy Performance of Buildings Directive encourages increased lending to residential renovation (European Commission, 2024). However, no widely used common market standards or labels exclusively applicable to consumers' green loans exist (EBA, 2023). Although European financial institutions must disclose their green asset ratio, this is only an internal metric and does not mean the institution is offering green mortgages to consumers. Additionally, these European institutions face significant data availability issues, as energy efficiency data is not yet routinely collected from customers (Platform on Sustainable Finance, 2022).

Research across multiple countries like Belgium, Italy, and the Netherlands confirms that energy-efficient properties have substantially lower default risks (Energy Efficient Mortgages Action Plan, 2019; Guin and Korhonen, 2020; Kaza et al., 2014). In the US, green mortgages for LEED-certified buildings have benefited from lower interest spreads, resulting in annual savings for property owners (Eichholtz et al., 2019). According to the EBA 2023 survey, the main benefits of originating green mortgages stem from financial institutions meeting their sustainability targets, improving investor and borrower reputation, helping with regulatory requirements, and minimising climate change-related transition risks (EBA, 2023). The investor demand from insurers, banks, and asset managers for green mortgages on the secondary markets has been substantial, as evidenced in the US green residential mortgage-backed securities market (Greene et al., 2021). The growth is also fuelled by strong demand from global capital markets, with investors seeking safe and green assets. The International Finance Corporation estimates energy-efficiency improvement investments within the building sector to represent one of the most prominent investment opportunities by 2030, estimated to be around USD 24.7 trillion (International Finance Corporation, 2019).

Despite the market and regulatory developments and promising research confirming the benefits of green mortgages for originators and consumers, academic literature on creating green mortgage ecosystems has been limited. Burke's (2020) preliminary research assessed system-building for energy-efficient mortgage movement, highlighting the need for more comprehensive studies in this area. This study addresses this gap by proposing a framework to scale green mortgages through collaboration among financial institutions, regulators, and consumers.

The business ecosystem concept

Ecosystems are dynamic and purposeful networks where participants collaborate to create value that would be impossible for a single participant alone (Thomas and Autio, 2014). The primary ecosystem goal is joint value

creation (Bogers et al., 2019). The ecosystem construct is an analytical lens that can examine any network of actors collaborating to create value, as Pulkka et al. (2016) demonstrated in the construction industry. The three characteristics of a well-functioning ecosystem include a) value-creating networks b) a governance system, and c) shared logic (Thomas and Autio, 2014).

Value-creating networks aim for system-level value-creation through complementary asset providers. Participants' inputs must be complementary, synergistic, and supported by sufficient resources and capabilities (Pulkka et al. 2016). The network of participants consists of specialisation, complementariness, and co-evolution (Pulkka et al. 2016). Unlike traditional value chains, ecosystems encompass a broader network contributing to a customer-facing solution through mutual exchange, relation-specific assets, and non-market governance. This interconnectedness allows ecosystems to efficiently move information, innovation, and resources, facilitating continuous adaptation and co-evolution, regardless of location (Pulkka et al., 2016). Each ecosystem participant shares the network's fate as a whole, reacting to changing circumstances or requirements (Pulkka et al. 2016). Value co-creation dynamics mean opportunities are not necessarily equally distributed but often coordinated by a powerful hub, known as the ecosystem leader (Liu et al., 2023). This role is crucial, as the ecosystem leader orchestrates the ecosystem through different stages, co-vision, co-design, and co-creation, each requiring varying dynamic capabilities (Chen et al., n.d.). The key ecosystem participants include ecosystem complementors, who provide individual components of the value proposition and increase the overall ecosystem value through their aggregated presence and interactions (Stonig and Müller-Stewens, 2019). Customers also play a vital role, not only by passively engaging with the ecosystem's offerings but also by contributing to its attractiveness and at times, acting as complementors themselves, such as by creating content or services (Adner and Kapoor, 2010; Stonig and Müller-Stewens, 2019).

The governance system coordinates participant activities through regulatory and normative elements, defining participation, decision-making, and preferred inputs (Pulkka et al., 2016). It consists of authority structure, membership control, and task coordination. Authority structure describes power distribution among participants (Pulkka et al., 2016). Ecosystems rely on rules and standards to manage interactions and ensure smooth functioning and survival (Adner, 2012). Membership control, determining ecosystem openness, moderates the trade-off between increased value creation and competitive crowding. Task coordination ensures that participants serve a common purpose (Iansiti and Levien, 2004; Pulkka et al., 2016). Effective governance systems are essential for managing complex interdependencies and strategic games among participants.

The shared logic includes cognitive elements such as legitimacy, trust and mutual awareness, providing the foundation for coexistence with minimal friction (Pulkka et al., 2016). The shared logic is essential for creating stable ecosystems, defining the societal acceptability of value creation and guiding common goals (Pulkka et al., 2016; Thomas and Autio, 2014). An ecosystem gains legitimacy, and stakeholders, and the broader community recognise and support it, aligning with the ecosystem's goals (Thomas and Autio, 2014). Trust is fundamental to value creation, facilitating knowledge exchange and acting as an informal task coordination mechanism (Iansiti and Levien, 2004; Pulkka et al., 2016). Mutual awareness refers to participants' shared understanding and common purpose, guiding value creation and sharing (Thomas and Autio, 2014).

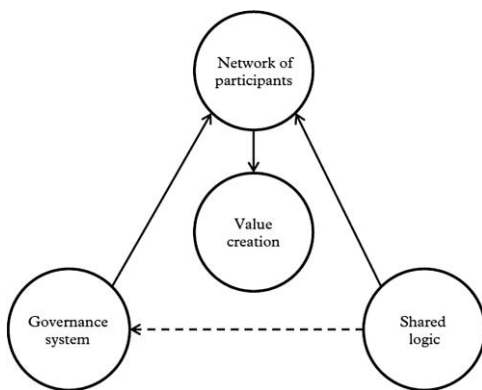


Figure 1. Primary connections between ecosystem characteristics and value creation. Adapted from Pulkka et al. (2016).

Figure 1 above, adapted from Pulkka et al. (2016), illustrates how shared logic drives network participation. Participants combine complementary inputs and competencies to create value. The governance system

coordinates activities and decisions, linking to value creation through the network of participants. The shared logic also connects to value creation through the network. Trust can substitute formal coordination. Both governance and shared logic ensure participants work synergistically towards shared objectives. (Pulkka et al., 2016)

Data Transparency in Decarbonizing Property Sector

Data transparency is promoted as the foundation of a well-functioning ecosystem. It ensures that all participants can see clearly, trust each other, and work together effectively. The significance of consistent, transparent, and comprehensive data in driving energy-efficient home investments is also evident. EeMAP (2017) highlights the need for consistent energy performance data to enhance property values, particularly in regions with high energy costs. Similarly, Sanderford et al. (2015) identify the flow of information to lenders as a critical obstacle – a market failure - to the broader adoption of energy-efficient housing. Banks, acting as "information gatekeepers," play a significant role in this process, making effective data orchestration essential to drive innovation in decarbonising the housing market (Sanderford et al. 2015).

Given these challenges, blockchain technology emerges as a promising solution to enhance data transparency and streamline information flows within the green mortgage ecosystem. Blockchain's decentralised ledger can enable real-time tracking of green finance transactions, ensuring consistent and verifiable energy performance data. Toufaily et al. (2021) highlight the broader applications of blockchain, particularly in the realm of "smart properties" such as real estate, where assets can be tracked or exchanged directly on the blockchain. This capability could revolutionise the green mortgage sector by integrating real estate and mortgage tracking with transparent energy performance data.

METHODOLOGY

This research employed an explorative research design to create a scalable green mortgage ecosystem. We used a two-step methodology. First, preliminary ideation meetings with the organisations discussed the initial research ideas and clarified organisational needs and expectations towards the theme. Second, participatory workshops engaged stakeholders in identifying the needs, preferences, barriers, and opportunities related to green mortgages. Workshops as a research methodology aim to produce reliable and valid data about the domain in question regarding forward-oriented processes, such as organisational change and design (Ørngreen and Levinsen, 2017), which suits the research aims well. This approach ensures that the developed conceptual green mortgage ecosystem concept is grounded in real-world insights and addresses varying aspects of green mortgages.

Participatory workshops

The three participatory workshops, lasting from 60 to 90 minutes, served as the primary data collection method. The participants were purposefully selected to represent key stakeholder groups in green mortgage ecosystems, including a financial institution, a property development company, and a real estate data provider. This purposive sampling ensured diverse perspectives and real-world applicability. The workshops were designed to cover the following themes: targets for the concept, value creation mechanisms, customer segments and value propositions, and ecosystem participants. Additionally, the workshops included discussions on relevant regulations and a case study of green mortgages in Ireland, providing practical examples to ground the discussion.

Data collection and analysis

The workshops were recorded and transcribed. Thematic analysis identified common themes, patterns, and insights. This method facilitated the systematic examination of the qualitative data, ensuring the analysis was comprehensive and nuanced.

A crucial initial observation from the workshops revealed that no single organisation had the incentives or power to dominate platform development or ecosystem formation – to be the powerful hub coordinating the ecosystem. Raising general awareness is crucial to scale green mortgages, requiring extensive advocacy and communication. This prompted us to explore distributed ecosystem theories as more fitting. Combining insights from blockchain features (e.g., scalability, transparency, interoperability, security and privacy), the

role of public-private partnerships, and theories on externalities and network effects, Toufaily et al.'s (2021) framework on blockchain adoption incorporates ecosystem stakeholders - private organisations, end-users and society, public sector and startups and entrepreneurs – emphasising the reinforced mutual interactions that drive socio-economic value in the ecosystem. The well-rounded basis led us to choose Toufaily et al.'s (2021) framework as the tentative framework for our data analysis and ecosystem concept development. We heavily relied on abductive research logic, where theory and empirical insights helped iteratively enrich each other.

Synthesis and Framework Development

Insights from the thematic analysis were synthesised by adopting Toufaily et al.'s (2021) framework to construct a tentative conceptual framework for the green mortgage ecosystem, concentrating on value creation aspects and the ecosystem participants. Several interviewee quotes are provided throughout the results to maintain a direct link with the framework and empirical findings. Here, we use workshops A, B and C to ensure the interviewees' anonymity while maintaining the researchers' chain of evidence.

RESULTS

This section introduces the results by exploring the value-creation mechanisms within the green mortgage ecosystem, organised by participant groups, as shown in Figure 2. The participants in the figure are adapted from Toufaily et al. (2021). Still, we separated specific joint categories (e.g., Organisations & industries, end-users and society) into distinct headings based on our empirical findings. This distinction was necessary, as organisations and industries, despite some similarities, do not entirely share the same value logics. The values shown in bold in Figure 2 are directly from our workshop findings, while the non-bolded values are from Toufaily et al.'s framework corroborated with our empirical findings.

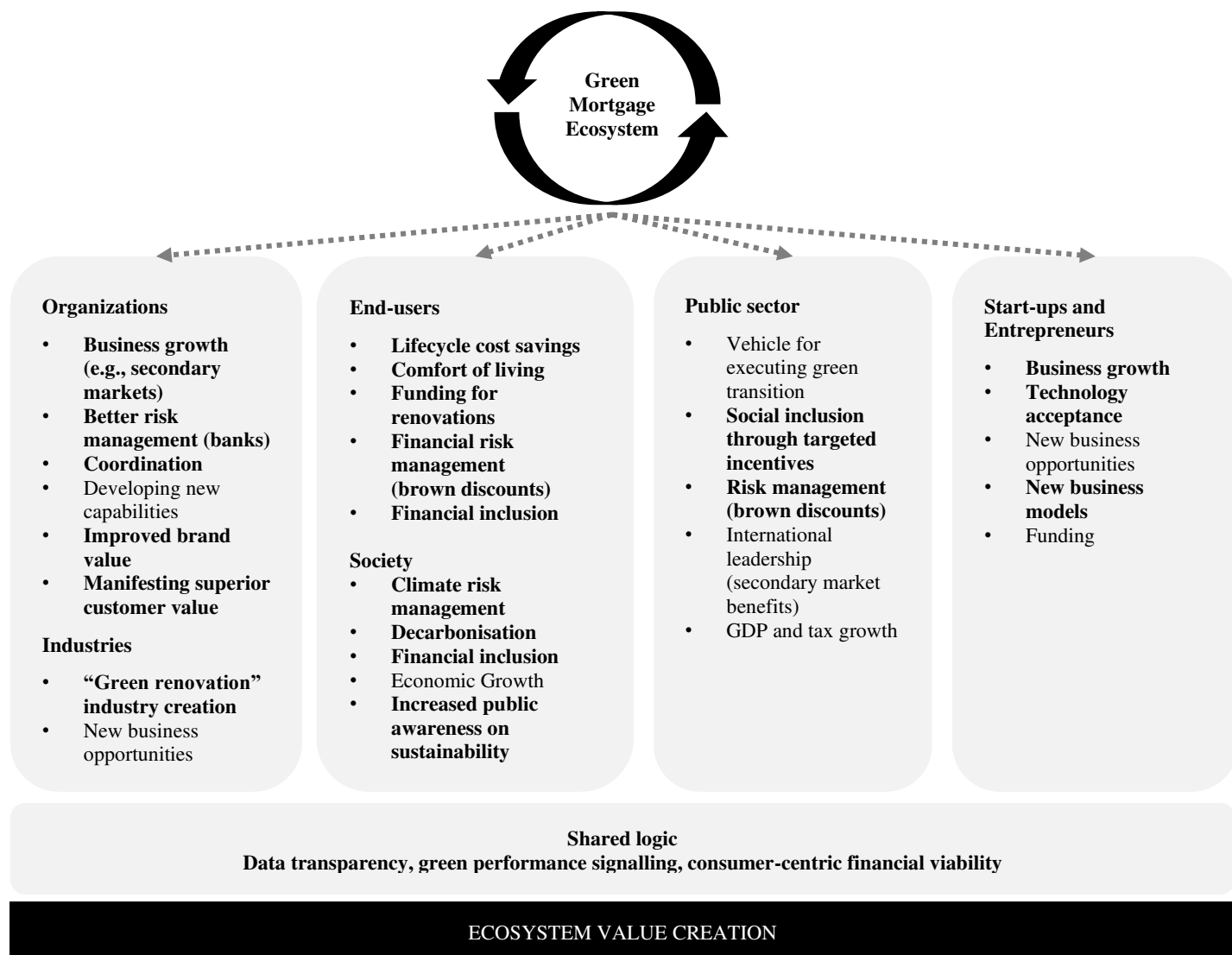


Figure 2: Green Mortgage Ecosystem: Network of Participants and Value Creation Mechanisms. The values shown in bold are directly from our workshop findings, while the non-bolded values are from Toufaily et al.'s (2021) framework corroborated with empirical findings.

Organisations

Multiple organisations are required to form a scalable green mortgage ecosystem. **The financial institutions** were regarded as the critical players in the ecosystem: Banks get to define which properties get financed and are the other direct party in the green mortgages in addition to the mortgagees. This finding is aligned with the literature, as previous research has presented financial institutions as innovation gatekeepers for highly energy-efficient homes (Sanderford et al., 2015)

"I believe banks will play a critical role in the green transition, particularly in risk management. They will determine which properties are worth renovating. This presents a huge opportunity for banks, especially with new loan products and profit generation. However, this mechanism won't work if banks don't profit from it." Workshop C

The other organisations needed in the ecosystem include **energy performance certificate issuers** that can act as the banks' partners. Even if mandatory by law, energy performance certificates are not always available. This partnership can help banks gather and update their collateral portfolio's energy performance certificate data. Banks have incentives to have up-to-date EPCs when negotiating mortgages (and generally).

*“We need energy certificate data for financing negotiations. Especially in renovation projects, it would be ideal if the customer updated or obtained a new energy certificate. It could be convenient to have an energy certificate partner from whom customers could easily obtain the certificate.”
Workshop A*

Naturally, for existing properties’ green mortgages, a pool of (preferably verified) **renovation contractors** for the bank to recommend and customers to choose from is essential. The bank may regard it as risky to recommend just one. A fluent customer renovation journey can support the overall ecosystem. An important question to solve is how to ensure that the anticipated cost and CO2 savings are realised through the renovations. Here, standardised local renovation solutions can play a key role in easily predictable savings.

“From the bank’s perspective, recommending specific renovation contractors or repair firms could be risky. If the recommended company doesn’t deliver high-quality service, it could negatively impact the bank’s reputation. However, from the customer’s perspective, it would be very beneficial to have a ready-made package offered to them.” Workshop A

Energy companies (utilities) in the green mortgage ecosystem can provide online energy consumption data, and data-driven energy and carbon performance services for buildings. They can also verify the impact of all energy performance improvements in the building stock, and account for emission factors and origin of energy. This role is crucial, especially when progressing from basic energy certificate indicators to more sophisticated life-cycle emission indicators in green financing.

For banks, green mortgage ecosystem can enable **business growth**. Banks can seize many types of opportunities through green mortgage ecosystem: largest financial institutions may tap on 1st mover opportunities. Challenger banks, i.e., local banks with smaller market shares, can invent novel, highly attractive green mortgage products for the local markets and challenge the local bank to win market share in more remote areas while reducing their collateral risks. Here, a green mortgage product that is barely profitable without subsidies could be the winning combination.

Banks’ business growth potential in green mortgages lies especially on secondary markets where there is a substantial demand for green (covered) bonds (ECBC, 2023). Currently, the lack of green mortgages limits banks’ opportunities to originate green (covered) bonds on the secondary markets; a functioning green mortgage ecosystem would remove this significant bottleneck and contribute to business growth.

“The main bottleneck is the limited number of green loans available—it’s a scarce resource. For green bonds, we’ve never had an issue with demand from investors, and we can usually secure good prices. The real challenge is that not enough energy efficiency renovations are being done to meet climate goals, which means there’s not enough green framework-compliant material to sell to investors. That’s the biggest bottleneck.” Workshop A

Green mortgages can also allow banks to **manage credit risks** better than they do currently. Currently, banks lack an understanding of their mortgage stock’s green aspects, which hampers their risk management efforts.

“In fact, even now, we still need to find out exactly what properties we have. Not all banks have even this basic property data figured out yet. Even among the large Finnish banks, there are still significant gaps. For example, there are gaps in knowing exactly what collateral properties we have.” Workshop C

The better the bank’s collateral stock performs in environmental terms, the smaller its risks.

“When consumers make these renovations, the condition and value of the property improve, which is reflected in our mortgage portfolio and indirectly reduces credit risk. Such a product also inevitably supports the bank’s image as a responsible actor in society and as a financier, which we aim to be and have been for probably 100 years.” Workshop A

As the above interview quote illustrates, banks and organisations in the green mortgage ecosystem can attract **improved brand value** by presenting themselves as a socially responsible company.

Overall, the organisations participating in the green mortgage ecosystem can receive **coordination** benefits through the ecosystem’s shared logic. For banks, the green mortgage ecosystem can also mean **developing new capabilities**. For instance, in loan granting, the advisors should expand their current primarily economic-

focused expertise to property renovations. Renovation companies would likely need to develop new capabilities to leverage the ecosystem for successful business growth.

“In various EU-level working groups, it’s become clear that offering green mortgage services to mortgage customers would require new technical skills from the bank staff involved in the loan sales process.” Workshop A

For property developers offering newly built properties, green mortgages can be used as tools to communicate the green values embedded in the properties, which are already highly environmentally friendly by regulatory standards. Thus, green mortgages can help organisations **manifest superior customer value**.

Industries

A thriving green mortgage ecosystem can bring to life a **‘green renovation’ industry** that provides several **novel business opportunities**. Especially, regions with good energy certificate data, smart metering in buildings and high adaption of ICT technology, such as Finland, can benefit from the fast adaption green financing ecosystem in the international green financing markets.

End-users

The end-users in the green mortgage ecosystem – mortgage borrowers - can be divided into three larger subgroups: 1) those who are buying new builds that already fulfil the green criterion needed for green mortgages (“buyers of new green property”) and those 2) mortgage borrowers with existing apartments or single-family houses that either already fulfil the green criterion (“owners of existing green properties”) or that will 3) fulfil the green criterion after a renovation or retrofit (“renovators”).

All interviewees regarded environmental reasons as secondary motivation for green financing and highlighted pursuing profitable green mortgages as the primary motivation for end-users.

“I don’t really believe in the concept of a “green consumer”—there aren’t many people making highly informed environmental choices. However, I do believe that if all the basic needs are met, like buying a home or renovating a long-term residence, and improving the energy efficiency comes as an added benefit, people are likely to invest a bit more in such upgrades.” Workshop C

Instead, the end-user value comes through **lifecycle cost savings** (Sanderford et al., 2015) and the **comfort of living** that environmentally competitive properties provide. The buyers of new green property can be divided into green value advocates (still valuing lifecycle cost efficiency), cash flow monitorers, and the general public that needs an understanding of green property benefits. On the other hand, the renovators can be divided into “frugal guardians”, valuing long-term cost savings, long-term residents valuing the comfort of living, and profit seekers looking to increase their property’s sales price through the renovation. Interestingly, Anttonen et al. (2023) et al. demonstrated that frugality behaviour is more consistently associated with lower consumer carbon footprints than conscious pro-climate behaviour. This finding emphasises the importance of targeting frugal behaviour in promoting green mortgages, as it not only aligns with the goals of long-term cost savings but also significantly contributes to reducing carbon footprints.

From a bank’s perspective, it may be wise to upsell current customers first rather than attract new mortgage customers. For existing mortgage borrowers, the trick would be to improve EPC without increasing the consumer’s monthly costs.

“Yes, I think cost reduction is a strong factor for everyone if it can be achieved. It becomes a key element if customers can indirectly influence costs through their choices. Especially if we can demonstrate cost efficiency, and ideally cost reduction, over the investment’s lifecycle, even within a certain timeframe, that’s a powerful aspect in all of this.” Workshop B

Naturally, end-users receive **funding for renovations** from green mortgages. This can also allow the end-users to **manage financial risks** (asset value depreciation) related to environmentally non-performing, illiquid assets, i.e., better manage the brown discount risks. When the green mortgage product is designed so that even low-income homeowners can access it (likely requiring governmental subsidies), the green mortgage ecosystem can also **increase financial inclusion** by allowing disadvantaged populations to enjoy the lifecycle cost savings from renovations.

Society

Societal value from the green mortgage ecosystem stems from better **climate and credit risk management** (Esposito et al., 2022), **decarbonisation** (Greene et al., 2021), and **financial inclusion**, primarily through providing a viable financial debt tool to help young households enter the sustainable real estate market (Dell'Anna et al., 2022). It would also contribute to **economic growth** and increase public **awareness of sustainability**.

Public sector

The public sector is required in the green mortgage ecosystem, especially to create incentives for owners of illiquid properties who would not otherwise have access to renovation financing. In addition to incentives, improving regulatory clarity and schedules of upcoming environmental regulations are key.

“I see the biggest value proposition coming from the combination of improving the current situation while keeping monthly costs the same or even reducing them, and at the same time, addressing potential future regulations. In Finland, there isn't yet a clear picture of when certain things will become mandatory, but it's already being discussed.” Workshop C

For the public sector, a green mortgage ecosystem can be an **effective vehicle for executing the real estate sector's green transition**. Targeted incentives can improve **social inclusion**, while the renovations could **reduce brown discount risks**. As past research has confirmed the existence of brown discounts in European residential markets (Marmolejo-Duarte and Chen, 2019; McCord et al., 2020), this risk-reducing potential of green mortgages is significant. **International leadership**, especially on secondary markets (e.g., green-covered bonds), can contribute to **GDP and tax growth**.

Start-ups and entrepreneurs

The green mortgage ecosystem can open **novel business growth** opportunities for startups and entrepreneurs. Scaleups offering crucial environmental risk and energy data for banks' mortgage granting process can **grow their business** aligned with banks' business growth. Establishing their role as essential data and platform providers in the ecosystem can improve **technology acceptance**.

All interviewees believed that turnkey and one-stop shop renovation service providers can speed up and simplify the renovation of existing properties, providing many **novel business opportunities and models** for start-ups and entrepreneurs that can combine digital platforms into their traditional contractor business. Past research has supported the importance of one-stop shops (Dell'Anna et al., 2022). Additionally, (Brown, 2018) identified four other business models for residential decarbonization, ranging from the traditional approach to more innovative energy service contracts, including the atomised market model, market intermediation model, energy services agreement, and managed energy services agreement.

“I see that if we can solve the complexity of renovations through packaging solutions, there's potential for banks to offer repair loans as easily as ordering a pizza. You'd select from a range of predefined options, and the process would kick off smoothly without the usual hassle of having a contractor come by to assess. Even with good models, there's always a gap between the calculated improvements and what actually happens. As contractors develop more standardised methods for these renovations, we'll eventually reach a point where we can consistently predict the impacts on different properties.” Workshop C

Interviewees also agreed that a seamless customer journey is crucial for encouraging consumers to invest in energy efficiency and green initiatives. (Milin and Bullier, 2021) support this view, noting that scaling home energy renovations requires the implementation of appropriate supply-side services, to decrease the burden of renovation on homeowners. They propose three models for delivering integrated home renovation services: an advice model focused on the initial stages of the customer journey (providing information and basic guidance without delving into project specifics), a support model where homeowners receive assistance with the detailed design of their energy renovation project, and an implementation model, where the service not only offers detailed advice but also carries out the renovation itself.

As the business need for such services is clear, startups and entrepreneurs in this space have opportunities to **attract funding**.

Shared Logic

The workshops also provided insights for establishing the ecosystem's initial shared logic. First, the importance of data transparency was emphasised, particularly regarding energy performance certificates, which was a recurring theme in the workshops. Second, the discussions acknowledged the potential of green mortgages as a powerful tool for signalling and communicating environmental performance. However, it became clear that superior environmental performance alone might not incentivise consumers to undertake green investments and opt for green mortgages. Therefore, it is recommended that the design of green mortgage products begins with a strong focus on consumer financial viability, ensuring that these products are not only environmentally beneficial but also financially accessible and appealing to consumers.

DISCUSSION AND CONCLUSIONS

Our tentative green mortgage ecosystem concept outlines the primary participants needed for a scalable green mortgage ecosystem and the expected value for each participant group. Empirical findings support adopting elements from Toufaily et al.'s (2021) framework, to understand value creation through network in the green mortgage ecosystem. This adaptation makes our concept more applicable to the financial and environmental context of green mortgages, particularly by emphasising how different participants in the ecosystem can benefit from adopting and scaling green mortgages.

While our ecosystem concept retains core elements like coordination, capability development, and business growth, it introduces new value-creation aspects such as risk management, financial inclusion, platform provider and the development of the green renovation industry. We also highlight the potential for improved brand value and the importance of manifesting superior customer value through green mortgages. These additions address specific challenges in the green mortgage market, providing a more tailored approach compared to the broader blockchain-focused framework of Toufaily et al (2021). Blockchain technology offers transformative applications in real estate, particularly in enhancing data transparency, enabling smart contracts, and facilitating asset tokenization (Saari et al., 2022). As suggested in Toufaily et al.'s (2021) framework, these features align closely with the ecosystem's need for improved collaboration, scalability, and stakeholder trust.

Our tentative green mortgage ecosystem concept emphasises the public sector's role in coordinating efforts and driving industry creation, with its potential to achieve international leadership within the ecosystem. Additionally, the concept acknowledges the critical role of startups and entrepreneurs in finding new business opportunities, developing new business models, and securing funding to support innovation. Regarding end-users, our framework details benefits, such as lifecycle cost savings, comfort of living, and financial risk management related to brown discounts. We also strongly emphasise financial inclusion within the green mortgage context. At the societal level, we add elements like climate risk management, decarbonisation, economic growth, and increased public awareness of sustainability—reflecting broader environmental and social goals.

The next steps for this research involve refining the green mortgage ecosystem's network of participants by defining specialisation, complementariness, and co-evolution, as proposed by ecosystem theories (Pulkka et al., 2016; Thomas and Autio, 2014). Further developing the shared logic encompassing the ecosystem's legitimacy, trust, and mutual awareness will ensure its scalability. Additionally, future research should explore whether integrating blockchain technology into the green mortgage ecosystem could enhance its value, particularly regarding transparency, speed, and data management, as suggested in Toufaily et al.'s (2021) original framework. Previous research has indicated that blockchain can provide benefits over centralised systems in the real estate sector (Saari et al., 2022). Furthermore, recent research confirms blockchain's benefits in fostering collaboration and shared innovation during early-stage, cross-industry digital transformations (Saari et al., 2024a), which can similarly support the formation of green mortgage ecosystems. Finally, future research should validate and refine the preliminary green mortgage ecosystem concept across varying regulatory and market contexts.

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