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Review of Barriers and Drivers for an Ageing Society in Low-Carbon Transition

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ABSTRACT

The global shift toward a low-carbon economy presents both challenges and opportunities for ageing societies. As the proportion of elderly individuals increases, it becomes crucial to understand the complex interplay between demographic change and sustainable energy transitions. This paper reviews the multifaceted barriers—economic vulnerability, behavioral inertia, digital exclusion, and institutional rigidity—that impede low-carbon adoption among older populations. At the same time, it explores key drivers including long-term cost savings, enhanced energy awareness, smart technology uptake, and inclusive policy innovation. Based on systematic literature review and policy document analysis, the study synthesizes empirical and theoretical insights across economic, technological, social, and governance domains. It identifies a suite of policy responses—from revenue-recycled carbon pricing and participatory governance to infrastructure modernization and digital literacy programs—that not only address specific barriers but also reinforce enabling drivers. The paper proposes a policy framework that aligns institutional reforms with environmental justice and ageing-inclusive development. This integrated approach is essential to ensure a just, inclusive, and effective transition to a low-carbon future for ageing populations.

INTRODUCTION

The transition toward a low-carbon economy has become a critical objective for many nations in light of global warming, environmental degradation, and increasingly stringent climate targets (Lin, Li, 2023; Karpavicius, Balezentis, 2025). This transition is multifaceted, involving complex interactions between technological innovation, economic restructuring, and socio-cultural change. In this context, the demographic shift toward an ageing society introduces a unique set of challenges and opportunities (Streimikiene et al, 2022a). Older populations, which are projected to grow significantly in many regions, present both barriers—such as financial constraints, limited digital literacy, and inertia in consumption patterns—and drivers including increased energy awareness and a heightened focus on quality of life and environmental health (Long et al, 2023).

The sustainability transition literature emphasizes the importance of identifying and addressing key barriers and drivers to facilitate effective policy and institutional responses (Andrews-Speed, 2015). Barriers such as inadequate infrastructure, high initial capital costs for retrofitting existing housing stock, institutional rigidity, and behavioral resistance can significantly impede the adoption of renewable energy technologies and energy efficiency measures among older populations (Streimikiene et al., 2022b). At the same time, drivers such as the potential for long-term cost savings, improvements in energy security, and the growing societal emphasis on environmental justice and well-being provide a strong impetus for change (Pearson et al., 2024).

This dynamic interplay between challenges and opportunities calls for integrated policy frameworks that not only mitigate adverse obstacles but also leverage existing drivers to promote a sustainable, low-carbon future (Li, 2020). In addition, the policy measures must be tailored to account for the heterogeneity of ageing societies including education and variuos capacities of population (Streimikiene, Bathaei, 2025). Innovative policy instruments—including carbon pricing models with revenue recycling, targeted subsidies, and participatory governance mechanisms—are essential to ensure that the low-carbon transition does not exacerbate existing economic and social inequities. The integration of environmental, social, and governance (ESG) principles into national sustainability strategies further provides a holistic framework for aligning economic development with climate objectives, while also addressing the unique needs of ageing populations (de Souza Barbosa et al., 2023).

There is the gap in sicnetific studies providing comprehensive review of barriers and drivers of low carbin transition by taking into account the ageing society of developed countries. This paper aims to synthesize the current body of literature on the barriers, drivers, and policies relevant to low-carbon transitions within the context of an ageing society, drawing on empirical and theoretical studies to offer comprehensive insights and guide future research and policymaking and future research in this area.

By analyzing the transition pathways of emerging economies to innovative policy regimes in developed countries—and by analyzing the socio-technical and institutional dimensions of the transition, this review seeks to contribute to the understanding of how ageing societies can navigate the multifaceted journey toward a low-carbon, sustainable future (Ogbonna et al., 2023). In doing so, it will reveal the importance of a coordinated, multi-level approach that integrates technical, economic, and social measures to overcome barriers while reinforcing the drivers of change.

1. METHODS AND DATA

To examine the barriers, drivers, and policy measures for enabling a low-carbon transition in ageing societies, we adopted a mixed-methods triangulation approach. This approach integrates insights drawn from a systematic literature review, document analysis thereby establishing a robust theoretical, historical, and empirical foundation for the enquiry (Nunes, ICatalão-Lopes, 2024).

First, we conducted a systematic literature review to identify and synthesize existing academic research on low-carbon transitions with a particular focus on ageing populations. This review allowed us to critically assess theoretical frameworks, recount empirical findings, and map the research landscape across economic, technological, social, and policy dimensions, following approaches similar to those outlined by Nunes and Catalão-Lopes (2024). Second, we performed a comprehensive document analysis of policy reports, governmental documents, and case studies from regional and international organizations. This phase in our study helped to uncover policy trends, assess policy instruments, and identify successes and shortcomings in current energy transition practices.

Data for this study were collected from multiple sources to ensure a comprehensive understanding of the research problem. The literature review involved systematic searches in academic databases such as Scopus, Web of Science, and Google Scholar. Keywords such as "low-carbon transition," "ageing society," "barriers," "drivers," and "policy measures" were used to retrieve relevant publications from 2000 to 2025. In parallel, key policy documents and technical reports were retrieved from governmental agencies, international organizations (e.g., UN, International Energy Agency), following methodologies similar to those employed in data-driven policymaking studies.

Data analysis was performed in several stages. First, qualitative data obtained from the systematic literature review and document analysis were subjected to thematic coding. Key themes were identified and categorized into barriers, drivers, and policy responses. A narrative synthesis approach was subsequently applied to collate and integrate data, facilitating the identification of interconnections among various factors. In addition, insights from the document analysis were used to cross-validate findings from the academic literature and survey responses. The study provided a multidimensional perspective on the low-carbon transition in ageing societies and ensured that the conclusions drawn were substantiated by a variety of data sources.

2. REVIEW OF BARRIERS OF LOW CARBON TRANSITION OF AGEING SOCIETY

The low-carbon transition is fundamentally shaped by multifaceted barriers that impede its progress, particularly in ageing societies. Many barriers are interrelated, ranging from economic and technical limitations to social and institutional constraints. In ageing households, for instance, fixed or limited incomes hinder incremental investments in energy efficiency or renewable technologies, while policy measures often lack the specificity required to address the unique circumstances of elderly populations (Long et al., 2022, Streimikiene et al., 2022c).

Economic barriers play a central role in inhibiting the uptake of low-carbon technologies among ageing populations (Siciliano et al., 2021; Saikkonen, Ilmakunnas, 2024). Many elderly individuals rely on fixed incomes, making the costs associated with retrofitting homes, purchasing energy-efficient appliances, or investing in renewable energy installations prohibitively high (Blohm, 2021). The situation is further exacerbated by the high initial capital investments required for low-carbon infrastructure and the perceived risk in adopting novel technologies. Scholars have noted that in many cases, these economic burdens are compounded by energy poverty, where ageing households experience higher relative energy costs due to inefficient housing stock and the inability to access financial incentives or subsidies tailored to their needs (Streimikiene, Balezentis, 2019; Tian et al., 2023). This economic vulnerability is particularly significant in regions where the energy regime is dominated by fossil fuel dependencies, as highlighted by studies on transitional economies like Nigeria, where weak infrastructural bases and entrenched fossil fuel-based systems further restrict the availability of affordable renewable options (Ogbonna et al., 2023).

Social and behavioral barriers also critically influence the low-carbon transition in ageing societies. Elderly populations may have lower environmental awareness or exhibit resistance to changing long-established consumption habits, making the adoption of sustainable energy practices more challenging. Behavioral inertia is often observed when ageing individuals face difficulties in understanding or trusting new technologies that promise energy efficiency improvements (Pearson et al. 2024). Research has demonstrated that low levels of environmental literacy, compounded by limited exposure to modern digital information channels, can stymie efforts to disseminate knowledge regarding the benefits of low-carbon solutions (Stankuniene et al., 2020). As a result, the transition is not merely a matter of infrastructure or capital, but also of tailored communication strategies and community-based engagement initiatives that accommodate the cognitive and cultural contexts of ageing populations.

Institutional and policy-related barriers further complicate the transition process (Budde, 2013). Many existing policies and regulatory frameworks are designed with a “one-size-fits-all” approach that fails to recognize the particular needs and limitations of ageing demographics (Li, 2020). Institutional inertia, where long-established policies and practices resist rapid change, adds an extra layer of complexity. Formal and informal institutional rules—embedded in the economic, political, and social fabric—often obstruct the deployment of low-carbon technologies that could benefit an ageing society. As argued by institutional perspectives on low-carbon transitions, effective transformation requires not only technological change but also a reconceptualization of governance structures and policy instruments to facilitate adaptive and inclusive transitions (Andrews-Speed, 2015). In environments burdened with over-regulated energy frameworks and underinvestment in infrastructure, older populations are doubly disadvantaged because the policy support necessary to remove financial and technical barriers is often delayed or insufficient.

Moreover, these barriers tend to be context-dependent. For example, the challenges encountered in countries like Nigeria—where poor management of the energy regime and reliance on external financial support prevail—underscore that resource constraints and technological lag can outweigh the potential drivers of efficient low-carbon transitions (Ogbonna et al., 2023). In contrast, regions with advanced technical infrastructure, such as parts of the European Union, still face challenges in the transition for ageing households due to fragmented policies and low environmental awareness among older residents (Streimikienė, 2022). This divergence emphasizes the need for localized policy measures and tailored financial mechanisms that specifically address the vulnerabilities of ageing populations.

Therefore, the fundamental constraints—economic vulnerability, social inertia, and institutional rigidity—collectively complicate the path towards a low-carbon society for ageing populations. Overcoming these barriers requires integrated policy frameworks that acknowledge the heterogeneity of ageing households and provide comprehensive support through financial incentives, targeted educational programs, and adaptive regulatory measures. Only by addressing these barriers holistically can policymakers design transformative strategies that align the needs of an ageing society with the imperatives of a low-carbon future.

In addition to the economic, social, and institutional barriers previously discussed, several other factors further complicate the low-carbon transition for ageing populations. These additional barriers can be grouped into four main categories: technological literacy and digital divides, infrastructural and housing stock constraints, cognitive and cultural determinants, and regional as well as global contextual challenges.

An important barrier for ageing societies is related to technological literacy and the digital divide (Paul et al., 2024). Many modern low-carbon solutions require engagement with smart technologies and digital interfaces that offer energy monitoring, remote control of home appliances, and automated systems for energy efficiency. However, older individuals often have limited exposure to digital environments, which can hinder effective use and acceptance of these technologies. This limited digital competency not only affects the adoption of energy management systems but also restricts access to information about renewable energy incentives and support programs. Further, concerns related to cybersecurity and privacy may augment scepticism toward technology-driven solutions. The digital divide creates an information asymmetry that places ageing populations at a disadvantage, thereby perpetuating inequities in access to low-carbon innovations.

Unique characteristics of the housing stock common among ageing populations also present significant hurdles (Blohm, 2021). Many older households reside in housing built several decades ago, which often lack the design features necessary for energy efficiency (Davies, Osmani, 2011). Retrofitting older buildings to incorporate modern insulation, high-performance windows, and renewable energy systems (such as solar panels) tends to be both technically challenging and financially burdensome. Infrastructural inflexibility is aggravated by regulatory complexities, property ownership issues, and limited incentives for mortgage or rental modifications in ageing communities. Additionally, the dispersed geographical location of many elderly residents reduces economies of scale for retrofitting projects, further limiting investments from both public and private sectors.

Beyond the financial and technical aspects, cognitive and cultural factors among older adults can impede the low-carbon transition (Olazabal, Pascual, 2015) . Studies have shown that established routines and long-held beliefs may contribute to behavioural inertia. For instance, an ageing population might be more inclined to maintain familiar consumption patterns, showing a reluctance to adopt new practices even in the face of evidence on the long-term health and financial benefits of low-carbon strategies. This resistance is often linked to risk aversion and a lack of perceived personal benefit associated with transitioning to novel technological systems or changing daily habits. Furthermore, cultural traditions that frame energy use—such as longstanding practices in heating, cooking, or transportation—may not readily align with emerging low-carbon paradigms. This misalignment requires carefully designed educational and engagement strategies that consider the cognitive context and value systems of older adults (Moore et al., 2021).

The aforementioned barriers often interact with regional and global challenges that compound difficulties in initiating a low-carbon transition among ageing populations. For example, policy fragmentation at local levels and a lack of harmonization in statutory frameworks can inhibit the consistent rollout of energy-efficient programs (Matschoss, Repo, 2018). In regions where local governments have limited budgets or where regulatory environments lag behind technological innovations, older populations may experience both a lack of tailored support and delayed access to cutting-edge low-carbon technologies. Global economic pressures, such as fluctuating energy prices and reliance on imported technology or expertise, also affect the affordability and practical feasibility of investing in sustainable infrastructure. These challenges are particularly pronounced in developing countries, where both ageing populations and fossil fuel dependencies coexist with underdeveloped renewable energy sectors.

In Figure 1 the barriers to low carbon transition of ageing society are systematized.

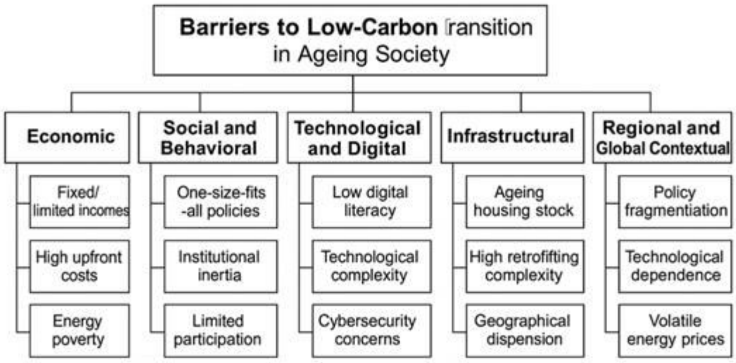

Figure 1. The barriers of low carbon transition of agening society

It is critical to stress that these all analysed barriers do not operate in isolation but are interwoven in a network of interconnected challenges. For instance, limited digital literacy not only affects the direct use of renewable energy technologies but also reinforces social and cognitive barriers by isolating older adults from mainstream communication channels that promote environmental awareness. Similarly, infrastructural constraints may escalate economic vulnerabilities by requiring expensive modifications that cannot be easily justified through traditional cost-benefit analysis. The cumulative effect of these multifaceted barriers demands an integrated policy response that simultaneously addresses technological, social, cultural, and infrastructural dimensions.

The low-carbon transition in ageing societies cannot be addressed solely through financial incentives or technological innovations. Instead, a holistic approach—one that integrates strategies to overcome digital divides, modernize infrastructure, shift cultural perceptions, and adapt policies to regional contexts—is essential. As ageing societies continue to reshape demographic landscapes, addressing these compounded barriers will be crucial in mobilizing the full potential of low-carbon pathways.

3. REVIEW OF DRIVERS OF LOW CARBON TRANSITION OF AGEING SOCIETY

Economic considerations are a primary force motivating low-carbon transitions, especially among ageing populations that are increasingly aware of long-term cost savings and energy security. For instance, environmentally conscious consumers—including seniors—tend to favor low-carbon products if the associated costs are competitive and translate into reductions in household energy bills (Dwivedi et al. , 2023). Moreover, the promise of improving energy efficiency and reducing operating costs can stimulate investments in retrofitting homes and adopting renewable technologies, particularly in regions undergoing economic transformation toward less carbon-intensive activities (Zhang et al., 2020). These economic incentives are amplified by a global trend toward decarbonisation, which creates market opportunities for green investments and promotes the reallocation of resources toward sustainable infrastructure (Das et al., 2021). Collectively, these factors create favorable conditions for ageing societies to embrace low-carbon options that enhance household financial security and align with broader sustainable development goals.

Social attitudes and cultural values significantly influence low-carbon transitions. Older adults often prioritize quality of life and environmental well-being, with many increasing their awareness of the health benefits associated with cleaner air and reduced pollution. Such environmental concerns have prompted shifts in consumption behaviors toward sustainable practices (Sovacool et al., 2019). Furthermore, the emergence of new social values—focusing on sustainability, intergenerational equity, and community resilience—transforms traditional consumption patterns and encourages collective action for low-carbon initiatives (Webb, 2012). This transformation is supported by the active involvement of community groups, civil society organizations, and local leaders, who align public values with low-carbon objectives (Demski et al., 2015). The adoption of sustainable practices in daily life is further encouraged by information campaigns and peer networks, in which seniors play both roles as recipients and agents of change, illustrating the potential for normative shifts in an ageing society.

Technological advancements are vital enablers of the low-carbon transition. Innovations in renewable energy systems, energy storage, and smart home devices can facilitate reductions in carbon emissions and contribute to efficiency improvements that are particularly appealing for ageing households (Slameršak et al., 2022). For instance, studies indicate that rapid decarbonisation pathways, supported by reductions in net energy use and innovative energy management systems, can drive technological adoption (Slameršak et al., 2022). Additionally, the development of low-carbon materials and sustainable manufacturing processes has lessened the environmental footprint of products, reinforcing both consumer and corporate commitments to green practices (Das et al., 2021). In ageing societies with established energy consumption patterns, technological upgrades enhancing efficiency can yield noticeable long-term benefits both economically and environmentally. The integration of such innovations into everyday life not only reduces carbon emissions but also improves the quality of living for older residents by ensuring greater reliability and efficiency in energy use.

Structured policy frameworks and proactive governance are crucial to catalyzing low-carbon transitions. At the macro level, changes in regulatory environments and the introduction of specific incentives—such as subsidies for renewable energy installations, tax rebates, and low-interest financing options—are essential for making low-carbon options accessible to ageing populations (Matschoss & Repo, 2018). Policymakers have shown that governance experiments and internal reforms can foster a supportive policy climate by addressing socio-technical challenges and market failures (Matschoss & Repo, 2018). Data-driven approaches and stakeholder engagement further validate the legitimacy and acceptability of low-carbon policies, ensuring that public investments lead to effective outcomes. Recent studies emphasize the importance of participatory approaches in successful transitions, noting that including diverse actors—from government ministries to local advocacy groups—enables the co-production of policies tailored to the varied needs of demographic groups, including older citizens (Adabre et al., 2024). Institutional drivers such as these create robust frameworks that not only set targets but also provide the mechanisms necessary for sustained transitions toward a low-carbon society.

The drivers underpinning a low-carbon transition in ageing societies are multifaceted and interdependent. The main drivers of low carbon energy transition in ageing societies are systematized in Figure 2.

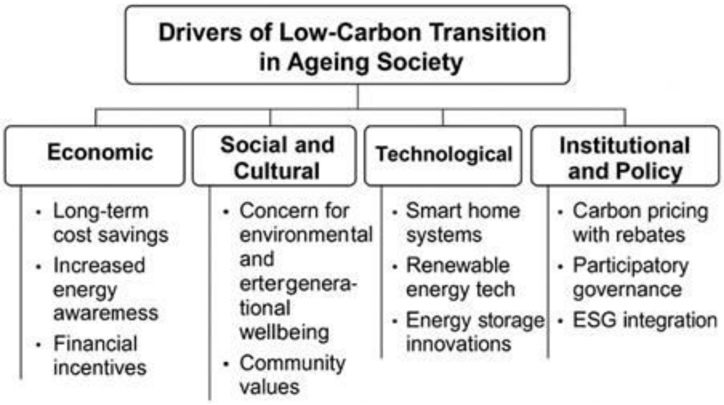

Figure 2. Drivers of low carbon transition of agening society

As one can see from figure 2 drivers as well as barriers of low carbin transition ar interrelated. An economic incentives yield immediate benefits for energy cost savings and investments in efficiency; social and cultural shifts encourage behavioral changes through increased environmental awareness; technological innovations provide practical solutions for reducing emissions; and solid policy and institutional frameworks foster an environment conducive to these changes. Together, these drivers interact to create a synergistic effect that can guide ageing societies toward sustainable, low-carbon futures. Understanding and leveraging these drivers is essential for designing integrated strategies that address the unique needs of older populations while advancing broader environmental and economic objectives.

4. REVIEW OF POLICIES TO PROMOTE LOW CARBON TRANSITION BY TARGETING BARRIERS AND ENABLING DRIVERS

The policies designed to overcome the barriers and leverage the drivers for a low-carbon transition in ageing societies are also interrelated. In order to address the multifaceted challenges—ranging from economic constraints and infrastructural limitations to social inequities and institutional inertia—a mix of targeted economic, regulatory, participatory, and technology-focused policies is needed.

Economic and Social Safety Measures are targeting mainly economic and fiancial barriers of low carbon transition of ageing society.

One of the most critical barriers to low-carbon transition among ageing populations is financial vulnerability. Older adults, particularly those on fixed incomes, face difficulties in affording retrofits, renewable technologies, or new low-carbon transportation solutions. In response, policy measures that combine carbon pricing with targeted protection schemes are recommended.

Tian et al. (2023) emphasize the need for carbon pricing policies that incorporate revenue recycling schemes—such as old-age pensions and subsidies—to ensure that low-income elderly populations are not adversely affected by increased energy costs. Additionally, welfare policies geared toward mitigating economic risks, as discussed by Saikkonen and Ilmakunnas (Saikkonen & Ilmakunnas, 2023), can help alleviate the burden of transition costs by providing direct support for energy efficiency upgrades and renewable energy installations in vulnerable households. This combination of targeted economic supports not only minimizes the risk of energy poverty among the elderly but also aligns with broader sustainability objectives by incentivizing investment in low-carbon technologies. Furthermore, incorporating just transition principles ensures equitable distribution of the benefits and costs of the transition, as highlighted by Siciliano et al. (2021) and supported by Blohm (2021) in their advocacy for an enabling framework that addresses the full range of economic and social barriers.

Effective governance structures and institutional reforms play a key role in overcoming systemic inertia and coordinating the multi-level response necessary for low-carbon transitions. Budde (2013) discusses how challenges in policy coordination and learning can be mitigated by adopting a sustainability transition approach, which emphasizes alignment between strategic goals and stakeholder interests. Complementary to this, governance experiments reported by Matschoss and Repo (2018) in the European Union illustrate that incremental regime changes—supported by transparent, evidence-based policy frameworks and computable general equilibrium models. Study byLi (2020) further underscores that tackling embedded obstacles such as decentralized control and political myopia requires long-term, multilevel strategies that integrate national, regional, and local policies. In designing these policies, selecting the appropriate mix of regulatory instruments is crucial; while command-and-control measures can yield immediate results, market-based instruments have demonstrated greater effectiveness when paired with mechanisms that support vulnerable groups (Zhou et al., 2023). Efforts to harmonize incentives, remove market distortions, and create adaptive regulatory frameworks can assist ageing societies in transitioning to renewable energy and low-carbon modes of production.

Low-carbon transitions in ageing societies benefit greatly from policies that embed principles of energy justice and inclusive decision-making. Siciliano et al. (2021) argue that recognition, distribution, and procedural justice must be central to the policy design process. This means creating mechanisms for open and democratic participation that ensure ageing populations are active participants in policy formulation. Sovacool et al. Sovacool et al. (2019) emphasize the importance of engaging a broad range of stakeholders—including civil society groups, advocacy organizations, and local leaders—to ensure that policy measures reflect shared values and address specific local needs. Just transition perspectives, as proposed by Mcilroy et al. (2022), insist on conflict transformation approaches in which policy design actively works to transform traditional "winner/loser" scenarios by including comprehensive social protection measures and ensuring equitable policy outcomes. Such participatory approaches not only empower older citizens but also contribute to the legitimacy and sustainability of low-carbon policies in a rapidly changing society.

An ageing society often faces additional challenges related to ageing housing stocks, limited digital literacy, and low adaptability to new technologies. Policies in this area must support investments to modernize infrastructure and promote technological upgrades. An enabling framework focusing on renewable energy technologies—as advocated by Blohm (2021)—can facilitate condition-based investments, ensuring that retrofitting measures and the introduction of smart energy management systems occur efficiently and equitably. Peng and Bai (2018) highlight the need for innovative policy evolution in urban contexts, which is critical for ageing cities facing rapid demographic change. Additionally, integrated approaches using economic and policy modelling, as seen in studies by An et al. (2023) and Omotoye et al. (2024), provide a robust basis for designing investments that yield both environmental benefits and improved quality of life for older citizens. Such policies must focus not only on technology transfer and infrastructure upgrades but also on training and educational programs to bridge the digital divide for elderly users—a necessary step to ensure that technological drivers translate into tangible low-carbon outcomes.

The diagram illustrating how targeted policies support specific drivers, which in turn help overcome barriers to low-carbon transition in ageing society is given in Figure 3.

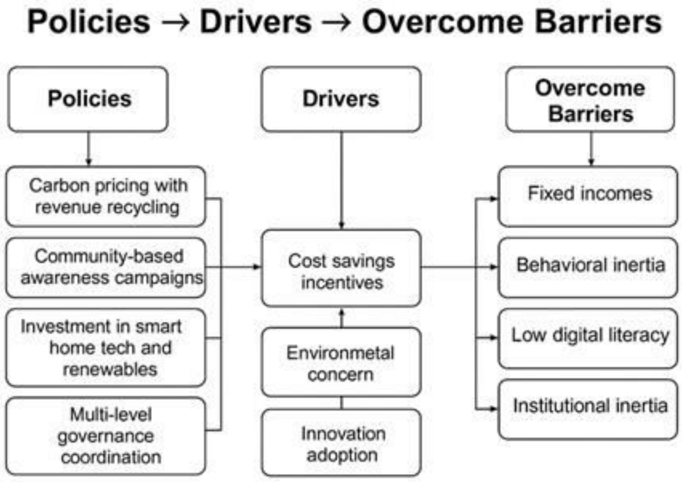

Figure 3. Barriers, drivers of low carbon transiiton and policies to suport low carbon transition of ageing society

This diagram presents a clear, stepwise causal model showing how targeted policy interventions lead to the activation of key drivers, which in turn help to overcome critical barriers in the low-carbon transition of ageing societies.

The flow begins with four main policy interventions positioned on the left. These include carbon pricing with revenue recycling, which is designed to redistribute financial resources to make clean energy more affordable for vulnerable populations; community-based awareness campaigns, which aim to educate and engage ageing citizens in sustainable practices; investment in smart home technologies and renewable energy, which enables technological accessibility; and multi-level governance coordination, which ensures that policy implementation is coherent and responsive at both local and national levels.

These policies are linked by arrows to the central column, which identifies three essential drivers they aim to support. These drivers are: cost savings incentives, environmental concern, and innovation adoption. These are not outcomes themselves, but motivating or enabling factors that make the transition more attractive and feasible for older individuals. For instance, cost-saving incentives make energy-efficient retrofits financially appealing, while environmental concern can increase willingness to change established behaviors. Innovation adoption ensures older populations are included in technological transitions.

From the drivers, arrows then extend to the right-hand column, where the key barriers are listed. These include fixed incomes, which often prevent the elderly from investing in sustainable solutions; behavioral inertia, reflecting resistance to changing long-held habits; low digital literacy, which limits engagement with smart technologies; and institutional inertia, where outdated or misaligned governance systems hinder inclusive climate policy.

The diagram's structure highlights a logical and policy-relevant insight: barriers cannot be effectively addressed in isolation. Instead, targeted policies must activate the right drivers—economic, social, and technological—to unlock meaningful, lasting change. The central message is that policies must be designed not only to remove obstacles but also to empower the motivations and capabilities that make the transition possible for ageing populations.

5. DISCUSSION AND SETTING THE FUTURE RESAERCH GUIDELINES

The structured analysis of how specific barriers faced by ageing populations in the low-carbon transition can be addressed through tailored policy responses, and how these policies, in turn, support enabling drivers that promote sustainable change is presented in Table 3. The Table 3 establishes a logical linkage between three dimensions—barriers, policy interventions, and drivers—highlighting the complex yet actionable interplay among them.

Table 3. Barriers, policy respoce and supported drivers

Barrier (from the paper)	Policy Response (from the paper)	Drivers Supported
Fixed/limited incomes make retrofits and renewable energy unaffordable	Carbon pricing with revenue recycling; Targeted subsidies; Welfare-based transition support (Tian et al., 2023; Saikkonen & Ilmakunnas, 2023; Manate at al., 2023; Du et al., 2024)	Economic: Long-term cost savings; Improved energy security
Behavioral inertia and low environmental awareness among older populations	Tailored communication strategies; Community-based engagement initiatives (Stankuniene et al., 2020; Streimikiene et al., 2022a)	Social/Cultural: Environmental concern; Intergenerational equity; Community resilience
Low digital literacy limits access to smart energy tech and digital info	Training and educational programs to bridge the digital divide (Paul et al., 2024)	Technological: Smart home adoption; Innovation uptake
Outdated, inefficient housing stock is hard to retrofit	Infrastructure investment policies; Retrofitting support for old housing (Davies, Osmani, 2011; Blohm, 2021)	Technological/Economic: Energy efficiency; Lower long-term costs
Cognitive and cultural resistance to change established practices	Participatory governance and engagement; Gradual adoption models (McIlroy et al., 2022; Olazabal, Pascual, 2015)	Cultural: Norm change; Behavior adaptation; Quality of life focus
Institutional rigidity and one-size-fits-all policy frameworks	Regulatory and institutional reforms; Sustainability transition approaches (Budde, 2013; Li, 2020)	Institutional/Policy: Responsive institutions; Inclusion of older demographics
Fragmented or delayed local policies limit effectiveness	Multilevel governance and adaptive regulatory frameworks (Matschoss & Repo, 2018; Moore et al., 2021)	Institutional/Economic: Effective local implementation; Resource efficiency
Geographical dispersion of elderly makes infrastructure upgrades inefficient	Decentralized, community-scale retrofit incentives (Peng & Bai, 2018)	Technological/Social: Infrastructure modernization; Community empowerment
Energy poverty and lack of access to finance	Just transition policies; Direct economic supports for vulnerable elderly (Streimikiene, Balezentis, 2019; Siciliano et al., 2021; Blohm, 2021)	Economic/Social: Access equity; Financial resilience

Global tech dependence and fossil fuel dominance in some regions	Support for domestic renewable innovation and localization of technologies (Ogbonna et al., 2023; Blohm, 2021)	Economic/Technological: Green industry growth; Technological independence

Source: own

The first set of barriers addressed in the table are economic in nature. Many elderly individuals live on fixed incomes, making it difficult to afford home retrofits or invest in renewable energy technologies. In response, policies such as carbon pricing with revenue recycling, targeted subsidies, and welfare-based support mechanisms are proposed (Tian et al., 2023; Saikkonen & Ilmakunnas, 2023). These interventions aim to reduce the financial burden and increase the affordability of low-carbon options. As a result, they help unlock key economic drivers, particularly long-term cost savings and improved energy security, which can motivate older adults to participate in the transition.

Another significant challenge arises from behavioral inertia and low environmental awareness among elderly populations. These social and cognitive limitations often hinder the adoption of new technologies and sustainable practices. To overcome this, policies that promote community-based engagement and tailored communication strategies are recommended (Streimikiene et al., 2022a). These approaches are intended to raise awareness, shift perceptions, and encourage active participation. In doing so, they support social and cultural drivers, such as increased environmental concern, a sense of intergenerational responsibility, and stronger community resilience.

Technological barriers are also a major concern, especially those related to digital exclusion. Many elderly people lack the digital literacy required to operate smart home energy systems or access information about energy efficiency programs. To bridge this gap, educational and training initiatives are identified as essential policy responses (Paul et al., 2024). These programs enhance the technological readiness of the ageing population, thus enabling the uptake of innovations like smart home systems and digital energy platforms, which serve as critical technological drivers.

Infrastructure-related barriers further compound the problem. Many older adults live in ageing or inefficient housing that is difficult to retrofit. To address this, infrastructure investment policies and targeted support for retrofitting are needed (Blohm, 2021). These initiatives not only help modernize the housing stock but also contribute to enhanced energy efficiency and reduced long-term costs, reinforcing both technological and economic drivers.

Cognitive and cultural resistance is another barrier that emerges prominently in the analysis. Older individuals may be reluctant to change familiar routines or adopt unfamiliar technologies. In response, policies that emphasize participatory governance and gradual, pilot-based adoption models are recommended (McIlroy et al., 2022). These approaches promote cultural adaptation and support a shift in norms, improving quality of life and fostering greater acceptance of sustainable practices.

Institutional rigidity, including one-size-fits-all policy designs and entrenched regulatory systems, presents additional challenges. Regulatory and institutional reforms are thus proposed to make governance structures more adaptive and inclusive (Budde, 2013; Li, 2020). Such reforms can enable more responsive institutions and broaden the scope of participation, activating institutional drivers necessary for sustained progress.

Fragmentation and misalignment of local policies is another barrier, particularly in regions where local governments lack capacity or resources. Policies that promote multilevel governance and adaptive regulatory frameworks are seen as essential to improve local effectiveness and coordination, enhancing institutional efficiency and economic outcomes (Matschoss & Repo, 2018).

In geographically dispersed areas, the spatial distribution of elderly populations makes infrastructure upgrades less efficient. Decentralized, community-based retrofit schemes are identified as a promising solution (Peng & Bai, 2018). These policies support infrastructure modernization and empower communities, reinforcing both technological and social drivers of change.

Energy poverty and financial exclusion are also key barriers that disproportionately affect the elderly. To mitigate this, the table recommends just transition frameworks and direct economic support mechanisms targeted at vulnerable populations (Siciliano et al., 2021; Blohm, 2021). These efforts ensure that older adults are not left behind in the transition and support drivers related to financial resilience and equitable access.

Finally, the global dependence on imported technologies and entrenched fossil fuel systems presents a structural barrier. Policies that promote domestic innovation in renewable energy and the localization of clean technologies are proposed as a remedy (Blohm, 2021). Such strategies can reduce reliance on global supply chains and foster local economic growth, advancing both technological independence and green industry development.

Therefore, the Table 3 demonstrates that a successful low-carbon transition in ageing societies requires a comprehensive and integrated policy approach. It highlights that addressing barriers is not enough on its own—policies must also activate specific economic, social, technological, cultural, and institutional drivers that empower older populations to participate in and benefit from the transition. This three-part logic—barrier, policy, and driver—provides a practical roadmap for designing inclusive and effective sustainability strategies.

The scheme presented in Figure 3 bellow visually represents the current limitations in research on the low-carbon transition in ageing societies and directly links each limitation to a recommended future research focus. It is designed to guide scholars, policymakers, and practitioners toward more targeted and impactful research that responds to the specific needs of ageing populations.

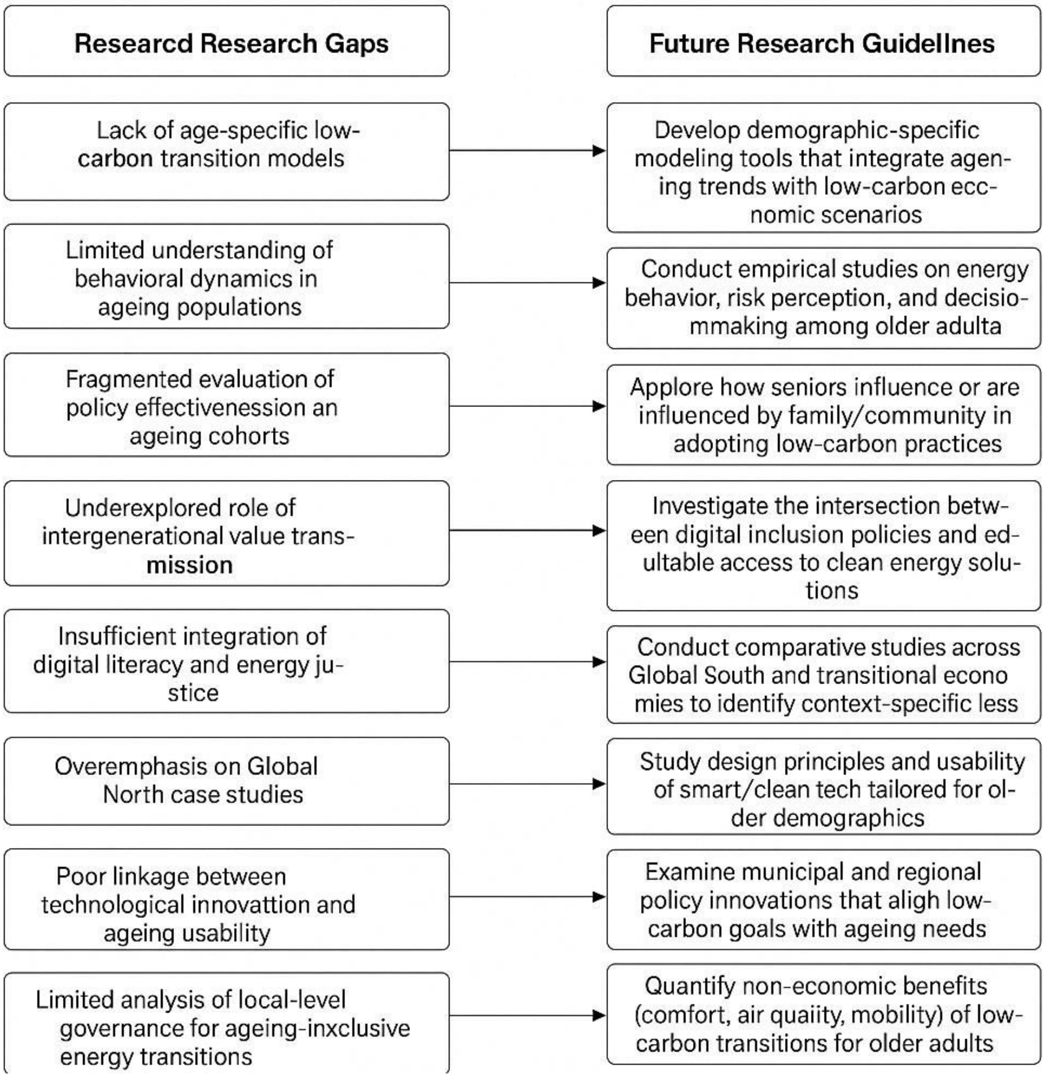

Figure 4. The key research gaps and corresponding future research directions for low-carbon transitions in ageing societies

The left side of the scheme lists ten key research gaps that hinder effective policy and practice. These include a lack of demographic-specific modeling tools, insufficient understanding of how older adults behave in relation to energy use, and weak evidence on how current policies affect ageing populations. Other gaps highlight the underexplored role of intergenerational dynamics, the digital divide, the dominance of Global North perspectives, and the need for better technology design tailored to seniors. Additionally, the scheme points out the need for local-level governance research, improved evaluation of co-benefits such as health and comfort, and more inclusive, long-term engagement with older citizens.

The right side of the scheme proposes corresponding future research directions to fill these gaps. For example, it suggests developing low-carbon economic models that account for demographic ageing, conducting behavioral studies that examine how seniors make energy-related decisions, and using participatory methods to evaluate policy effectiveness. It also calls for studying family and community influences, exploring how digital inclusion affects clean energy adoption, and expanding comparative studies to include underrepresented regions. Moreover, it recommends designing clean technologies that are accessible to older adults, investigating the role of municipalities in enabling age-friendly energy transitions, and quantifying the broader well-being benefits of low-carbon living for elderly populations.

Together, the two columns form a logical flow: each research gap is matched with a strategic research response. The arrows indicate that these proposed directions are not generic but specifically tailored to address each challenge. The scheme underscores the need for interdisciplinary, context-sensitive, and inclusive approaches to advance the low-carbon transition in a way that fully considers and supports ageing populations.

CONCLUSION

The review of the literature on ageing societies and low-carbon transitions reveals that the challenges and opportunities encountered during the transition are inherently multidimensional. On one hand, the literature consistently identifies barriers that are economic, social, technological, and institutional in nature. Ageing populations frequently face financial constraints, limited digital literacy, and infrastructural rigidity that hinder the adoption of renewable energy technologies and energy-efficient practices. In particular, fixed incomes and outdated housing stocks create conditions where retrofitting, modern energy management, and digitized solutions are both technically and financially challenging. Additionally, behavioral inertia and cultural resistance—as well as institutional rigidity manifested in inflexible policy regimes—compound these technical and economic barriers.

On the other hand, a range of drivers can propel the transition. Economic drivers such as long-term cost savings, enhanced energy security, and market opportunities in decarbonization are potent incentives for change. Advancements in technology—including smart energy systems and renewable energy innovations—are instrumental in overcoming traditional dependencies on fossil fuels. Furthermore, social and cultural drivers, such as heightened environmental awareness among older adults and community solidarity for intergenerational equity, support the diffusion of low-carbon practices. These drivers are further amplified by supportive policy environments wherein regulatory reforms, fiscal incentives, and participatory governance structures serve not only to mitigate the identified barriers but also to encourage broad-based market and behavioral shifts.

To bridge the gap between barriers and drivers, policy measures must adopt an integrated, multi-level approach. Economic and social safety measures—such as targeted subsidies, carbon pricing with revenue recycling, and direct financial support for energy efficiency upgrades—can cushion vulnerable ageing populations from the immediate impacts of transition costs. Complementary regulatory and institutional reforms that streamline policies across local, regional, and national levels are essential to overcome institutional inertia and promote adaptive policymaking. In addition, participatory governance models that integrate energy justice considerations ensure that the voices of older citizens are not sidelined, thereby fostering a more holistic transition process. Lastly, policies must encourage targeted investments in infrastructure and technology upgrades while also emphasizing education and digital inclusion to modernize ageing housing stocks and promote the widespread adoption of low-carbon technologies

Therefore, while ageing societies face significant barriers to low-carbon transitions, a convergence of targeted drivers and holistic policy interventions can effectively enable sustainable, inclusive, and resilient transitions. Addressing economic vulnerabilities, modernizing infrastructure, and harmonizing policy objectives with technological advances and social values are critical. Future policy designs should therefore be flexible, inclusive, and tailored to the unique characteristics of ageing populations to ensure that the transformation to a low-carbon economy is both equitable and effective.

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