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The interplay of policy and energy retrofit decision-making for real estate decarbonization

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Abstract

Retrofitting existing buildings is critical for meeting global and institutional net-zero CO₂ emissions goals. Prominent energy and climate policy strategies are aiming to increase notoriously low retrofitting rates by triggering energy efficient and/or decarbonized real estate investments. Although many real estate assets are owned by large-scale investors (LSIs), the interplay of their retrofit decision-making and policies are under researched. Relying on interviews with four major owner types, industry experts, and policymakers, we unpack the ‘black box’ of retrofit investment and demonstrate how LSIs can transform retrofit decision-making processes to meet emissions goals. We show that to accelerate deep retrofits, policymakers should focus on integrated policy mixes, and consider the cross-impacts of policy instruments from various domains on the value-driven retrofitting decision. Instruments indirectly influencing retrofits, such as those targeting affordability or densification, represent a critical avenue for improving the retrofitting policy mix by moving away from single instruments directly targeting energy or emissions aspects. This policy mix should specifically target asset management budgetary decisions, which mainly drive investment planning relevant for deep retrofits.

1. Introduction

The building sector accounts for 30% of final energy use and 28% of energy-related CO₂ emissions globally, speaking to the necessity—and potential—to decarbonize the sector [1]. While new building regulations are approaching net-zero energy in progressive jurisdictions [2], notoriously low retrofitting rates (<1%) at insufficient depth threaten decarbonization targets [3]. In Europe, buildings existing today will constitute around 90% of the stock until 2050 [4, 5], necessitating deep retrofitting rates of ~3% annually—as demanded by long-term climate change mitigation strategies [6–9].

In industrialized countries, large-scale investors (LSIs), or institutional investors, account for a large share of annual building investments and stock ownership, of which real estate is a significant asset class in LSIs’ investment portfolios [10]. LSIs are experiencing increasing pressure from financial markets to incorporate environmental, social, and governance (ESG) criteria in general, and CO₂ performance criteria specifically, into their investment strategies [11, 12]. Further, policies to trigger ‘renovation waves’ at both city [13] and transnational [5] levels are focusing political attention on retrofits as a vital means of achieving climate goals. Considering LSIs’ crucial leverage in decarbonizing real estate, we need to better understand the interplay of their retrofitting decisions and policies.

Most previous research in this area has either largely focused on private homeowners or residential buildings [14–20] rather than professional owners’ mixed portfolios, or it has analyzed individual policy instruments from the energy domain [21–24] such as financial incentives [25], energy performance certificates (EPC) [26–28], voluntary labels [29, 30], and mandatory energy audits [31] instead of the overarching retrofitting policy mix.

The few studies with a specific focus on LSIs [32–36] provide valuable insight into LSIs' retrofitting behavior but typically treat decision-making as an economically rational 'black box'. For example, a stream of LSI retrofitting research has focused on economic decision-support models [37–39] which incorporate aspects like weighing-criteria to determine profitable renovations [40], risk management [41], and meeting triple-bottom-line objectives [32]. While findings suggest energy efficiency (EE) awareness and monitoring has become the norm for LSIs [36], nonetheless their retrofitting strategies have a scope beyond just energy aspects, varying between LSI types and real estate markets [33].

We know little of the *processes* behind retrofitting *decisions* of LSIs, especially considering the relatively new phenomenon of integrating non-economic aspects (i.e. ESG or CO₂ emissions) into real estate [42] which would affect which retrofitting technologies they invest in [43]. Furthermore, the EE paradox predicates that non-economic factors such as organizational structures and management practices [44, 45] can hinder economically attractive retrofitting investments [46, 47]. Since each building's context is unique, overcoming the technical, economic, and organizational barriers to profitable retrofits requires significant efforts from LSIs [33]. By neglecting decision-making processes, studies at more aggregated levels of analysis fail to uncover important managerial mechanisms relevant to policy response [45, 48].

Concerning building-sector energy and climate policy, while prominent policy instruments such as increasingly stringent building energy codes (BECs) and progressive financial incentive programs have been effective for new buildings in many countries [21, 49], their impact on the speed of deep retrofits (>60% energy savings) is largely insufficient [2, 5, 50]. Moreover, policy instruments from other domains might conflict with those that directly target the EE and renewable energy (RE) aspects of deep retrofits, and therefore should be taken into account, since they frame investment decisions [51–53]. Consequently, understanding the interactions between instruments from various domains with respective policy objectives—referred to as 'policy mixes' [54, 55]—will be relevant for accelerating deep retrofits [52, 56–59].

In this paper, we address these gaps by (i) uncovering firm-level retrofit decision-making processes of LSIs to (ii) better understand their interplay with the overarching retrofitting policy mix. We adopt an institutional perspective by investigating how LSIs' internal strategies and retrofit decision-making processes support or hinder decarbonization.

2. Case and method

2.1. Research case

To better understand the mechanisms between policies and real estate retrofitting decisions, we conducted an in-depth qualitative case study based on semi-structured interviews. We utilize semi-structured interviews as the core methodology, relying on a sample of 32 interviews based mainly on 'deep dives' into the four cases of Swiss-domiciled real estate LSIs supplemented by a diverse set of stakeholders. The four LSIs hold a collective assets under management (AuM) of over EUR 158 billion (table 1), placing two in the top five and two in the top 60 of European real estate LSIs in 2019 [60]. They are divided into one public LSI (entirely Swiss investments) and three private LSIs, typified as bank (globally distributed investments), insurance (predominantly European investments), and insurance (globally distributed investments).

The Swiss LSI setting is particularly interesting for global applicability due to Switzerland's (i) high tenancy rate (over 58% [61]), (ii) large volume of LSI investment in buildings (total 72% of investments in 2016, split by 16% public and 56% commercial [62]), (iii) large LSI ownership share (20% of residential and 10% of commercial property in Switzerland [62, 63]), and (iv) a mix of national and international financial investment infrastructure and experience, along with (v) a complex building-sector policy mix with significant overlap and goals to those of Europe. From the policy side, Switzerland has stringent building regulations in the form of BECs, tenant laws, and incentives, along with a high CO₂ tax and a national net-zero CO₂ climate goal by 2050, as well as a federalist regulatory structure that provides heterogeneity in cantonal retrofitting policy mixes such as real estate regulations.

As three of the four studied LSIs (all private) generally have globally diversified assets, we discussed the prominence of international market and regulatory settings while also comparing the LSIs' at Swiss settings. The majority of the points (i) to (v) above also apply in other countries where LSIs hold real estate assets, as a large portion are in Europe. Tenancy rates in Europe span a broad range between countries [61] while real estate LSIs also play a significant role in building investments and ownership share. Nonetheless, in Europe both energy and non-energy policy instruments can vary between countries, cantons/states, and even cities, with prominent differences affecting LSIs drawing attention in the interviews.

The four LSIs generally diversify portfolios across: (i) real estate market geographies, (ii) various building types (e.g. residential, commercial, mixed, etc), (iii) uses (e.g. multi-family residential, nursing home, office,

Table 1. Four studied LSI cases with portfolio details.

LSI type	Assets under management (billion EUR)	Portfolio investment vehicles	Real estate market focus
Bank—global	46	Stock-market listed funds	Global scope (over 20 countries in five continents) with particular focus on European assets Portfolios generally clustered into building types, uses, and/or ages. Specific green buildings portfolio
Insurance—Europe	66	Proprietary assets managed portfolio along with stock-market listed funds and third-party managed assets from foundations	European geographic scope (over 20 countries) Portfolios generally clustered into building types, uses, and/or ages
Insurance—global	35	Proprietary assets managed portfolios from subsidiary corporations along with stock-market listed funds	Global scope (in over four continents) with particular focus on European assets
Public—Swiss	11	Portfolios clustered into self-managed and rented properties	Portfolios generally clustered into building types, uses, and/or ages Swiss geographic scope Many different building types, uses, and/or ages within the two portfolios

retail, industrial, logistics, etc.), and (iv) ages. While the private LSIs' AuM is expressed in real estate market value, the public LSI listed the buildings' insurance or replacement value, which can diverge from market value.

The three private LSIs are strongly rooted in real estate markets, with some portfolios in operation for over a century. Their assets are clustered in various portfolio investment vehicles (sometimes referred to as 'products'), which can be categorized as proprietary, internal client-focused, stock-market listed funds, and third-party-focused. The public LSI manages two large portfolios—self-used (e.g. hospitals, schools, sports halls, administration, etc.) and rented (e.g. multi-family residential, office, retail, etc.).

2.2. Interviews

Within each LSI, we interviewed four to six members of real estate teams at all hierarchical levels to gain an in-depth understanding of their processes and role priorities, such as portfolio, asset, and construction management—along with strategic decisions relating to ESG (18 total interviews with LSIs). This was supplemented by 14 interviews with property managers, real estate consultants, and retrofit developers, along with heads of relevant associations and federal/cantonal policymakers (32 total interviews). Policymakers were split based on the structure of Swiss energy regulation, focusing on interviewees in administrative roles rather than political appointees to leverage technical regulatory expertise. A list of the interviewees with company sector, subsector, and role are provided in table 2, with all quoted evidence from interview results with further supporting discussion provided in the supplementary material (<https://stacks.iop.org/ERIS/1/035006/mmedia>).

Qualitative interviews provided in-depth narratives within each LSI type and explored relevant actors' views on strategic orientations, decision-making processes, and individual role priorities, along with the most meaningful policy mixes which would influence retrofitting. Such a qualitative approach allows for an integrated analysis of the interplay between policy and institutional efforts towards decarbonization, highlighting the roles that both policymakers and real estate owners play in the transformation towards a decarbonized building stock [64]. We refined the insights from our interviews until a saturation level for additional insights was reached, as suggested for case-specific interview studies [65–67]. While this does not allow us to comment on the efficacy of a particular policy instrument as in a quantitative study [24, 31], it does allow for a high-level narrative about the influence of policy on LSIs' retrofit decision-making processes.

While main interview questions focused on incorporating aspects from the relevant sector, subsector, and roles, they can be categorized in the following:

- Real estate department budgetary and decision-making workflows, with considerations for organizational structure, processes, and role involvement.
- Within portfolios, describing processes for budgetary distributions across various interventions (i.e. transactions, new construction, replacements, retrofits).

Table 2. Interview campaign data sources across sectors, company types, and roles.

Sector	Company type	#	Role
Large-scale investors	Bank—global	6	1. Head of real estate ESG 2. Head of construction management 3. Head of portfolio management & portfolio manager—ESG fund 4. Portfolio manager—traditional fund 5. Asset manager 6. Construction manager
	Insurance—Europe	4	1. Head of real estate ESG 2. Portfolio manager—fund 3. Portfolio manager—foundation 4. Construction manager
	Insurance—global	4	1. Head of construction management 2. Head of transaction management & portfolio manager 3. Senior asset manager with sustainability focus 4. Construction manager with sustainability focus
	Public—Swiss	4	1. Project leader of sustainable building department 2. Portfolio manager—rented properties 3. Portfolio manager—self-used properties 4. Group leader—construction management (renovation)
Energy	Energy developer & consultancy 1	2	1. Senior consultant for real estate sustainability 2. Building & district energy systems engineer
	Energy developer & consultancy 2	2	1. Leader of integrated energy & mobility solutions 2. Product manager of strategic solutions
Real estate	Property management company	3	1. Head of project management & sustainability 2. Property manager for LSI portfolios 3. Construction manager
	Real estate consultant	1	1. Head of sustainability services
	Real estate valuator	1	1. Director of valuation with sustainability specialization
Association	Building owner	1	1. Director of building & energy department
	Tenant	1	1. Head of tenant association
Regulatory	Federal	1	1. Program manager for building energy
	Cantonal	2	1. Head of cantonal energy department 1 2. Head of cantonal energy department 2
Total		32	October 2019–November 2020

- (c) How buildings are selected from the portfolio to be retrofitted, and how decisions are made about specific component investments and deep retrofits.
- (d) Project-level retrofit decision-making workflow, with specific focus on internal/external stakeholders' involvement, tools, and regulatory considerations.
- (e) Which policy instruments and potential regulatory scenarios impact the level of investment into retrofits on a speed and depth basis, specifically relating to technology choice.

The interview campaign was conducted from October 2019–November 2020. Each interview lasted about one hour (± 10 min) and was audio recorded (for both in-person and phone interviews) to enable full transcription for scientific accuracy and ethics.

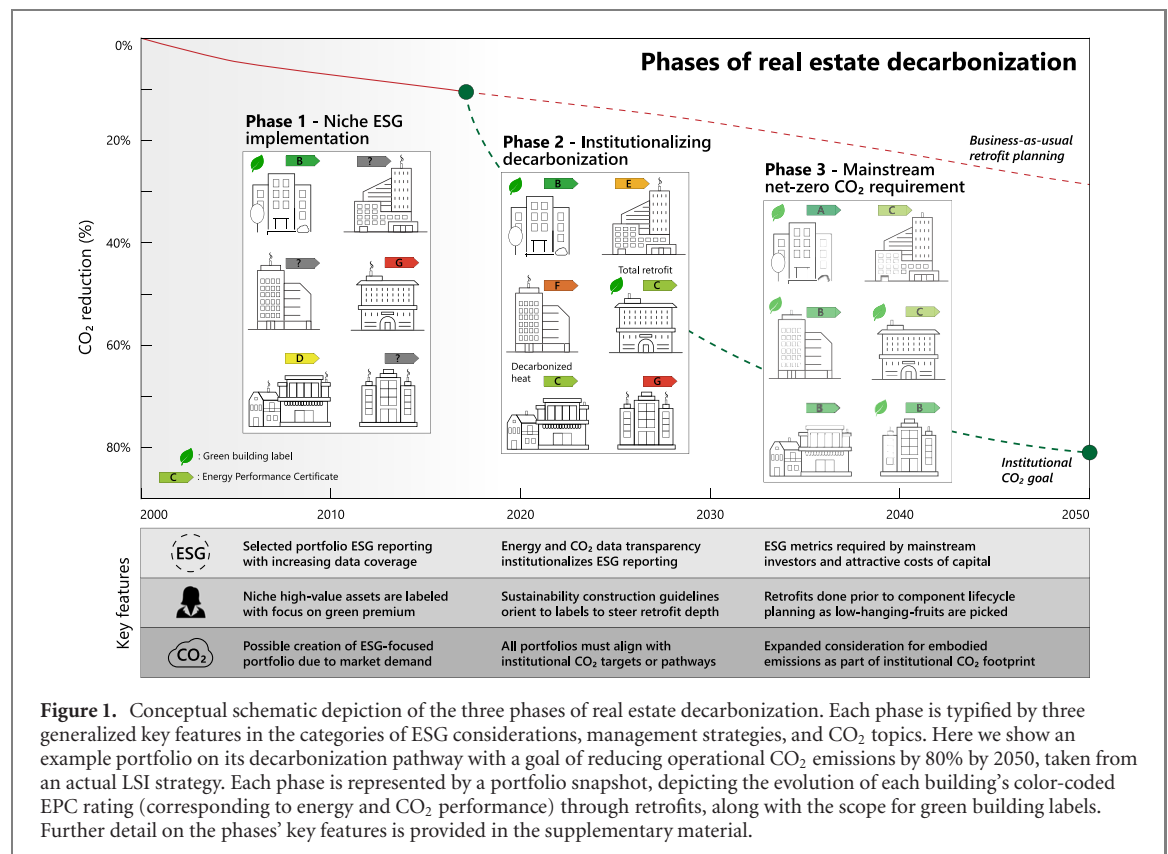
3. Results and discussion

3.1. Three phases of real estate decarbonization

All LSI interviewees affirmed that energy and emission reduction topics made their way on to business agendas in the 2010s, but with a recently observed step-change in their importance due to new net-zero CO₂ emissions goals. Presently, LSIs' integration of these topics into real estate decision-making is *observed* as two phases of decarbonization (figure 1), not unlike the transitional phases outlined by reference [68] for the energy sector: emergence followed by maturation. Interviewees also *envisioned* a third and final phase that will be necessary for achieving net-zero CO₂ in the long-term.

Phase 1 of decarbonized real estate investments is marked by symbolic, niche ESG implementation with (i) ESG reporting for selected portfolios, (ii) flagship niche labeled assets, and (iii) possible creation of ESG-focused portfolios for '*clear product differentiation*,' as the bank's ESG Manager put it. For private LSIs, selected portfolio reporting is typically done through the Global Real Estate Sustainability Benchmark (GRESB). While such ESG-focused portfolios require new asset management strategies, LSIs mostly integrated individual decarbonized assets into traditional portfolios, leaving overall strategies largely unchanged [69].

The transition towards phase 2 is marked by a substantive strategic reorientation to institutionalize CO₂ as the most prominent ESG criterion, driven by two key factors. All LSI interviewees pointed to sociopolitical



pressure as the main factor behind their increased attention to CO₂, particularly over the last two years. This has led to alignment towards science-based targets such as net-zero CO₂ by 2050 [70]. Multiple representatives from each LSI explicitly mentioned the recent public discourse around climate—for example, Fridays for Future, climate strikes, or Greta Thunberg.

Real estate market forces were labeled as the second most important factor for institutionalizing CO₂. These are seen partly as a response to sociopolitical pressure, but are also felt independently by both sides of the market—investors and tenants. Investors increasingly require high ESG ratings in general, or low-CO₂ certificates specifically, which are seen as a key differentiator in low financial interest rate and high-value markets. Green building labels are especially favored by commercial tenants, with LSIs mentioning a higher willingness-to-pay, but also pointing to the difficulty of labeling retrofitted buildings due to the contextuality and complexity of projects. While LSIs also moved to label 'high-value' residential properties [71], nevertheless the 'green premium' has been contradicted in some studies [72].

Phase 2 is marked by (i) an institutionalization of ESG reporting built on energy and CO₂ data transparency, (ii) the creation of label-oriented guidelines to steer retrofit decision-making, and (iii) an increased firm-level focus on decarbonization, trickling down to all portfolios [73]. Here, LSIs put predominant focus on CO₂ in ESG strategies through now common practice ESG monitoring, reporting, long-term CO₂ goals, and sustainable construction guidelines. While the year of transition between phases 1 and 2 can vary between LSIs, and thus cannot be established for the overall market, our interviews point to the emergence of phase 2 in the late 2010s with all LSIs demonstrating the key features of phase 2. Nonetheless, all LSIs recognized that phase 2 features will not be enough to meet internal or global CO₂ goals.

It was clear from interviews that inconsistencies in decision-making processes and policy in phase 2 must be ironed out to decarbonize a significant proportion of real estate. Interviewees envisioned a phase 3 that would be needed in order to transform real estate decision-making for decarbonization, representing the future achievement of net-zero CO₂ emissions goals—requiring low CO₂ ratings for all assets. This phase would prospectively be marked by (i) minimum standards for ESG and CO₂ performance, (ii) earlier-than-planned retrofits, and (iii) considering energy embodied in materials as part of the CO₂ footprint.

3.2. Transforming real estate retrofit decision-making

Integrating decarbonization considerations into real estate decision-making presents different challenges in each phase of the transition. Based on our interviews, we generalize the traditional retrofit decision-making

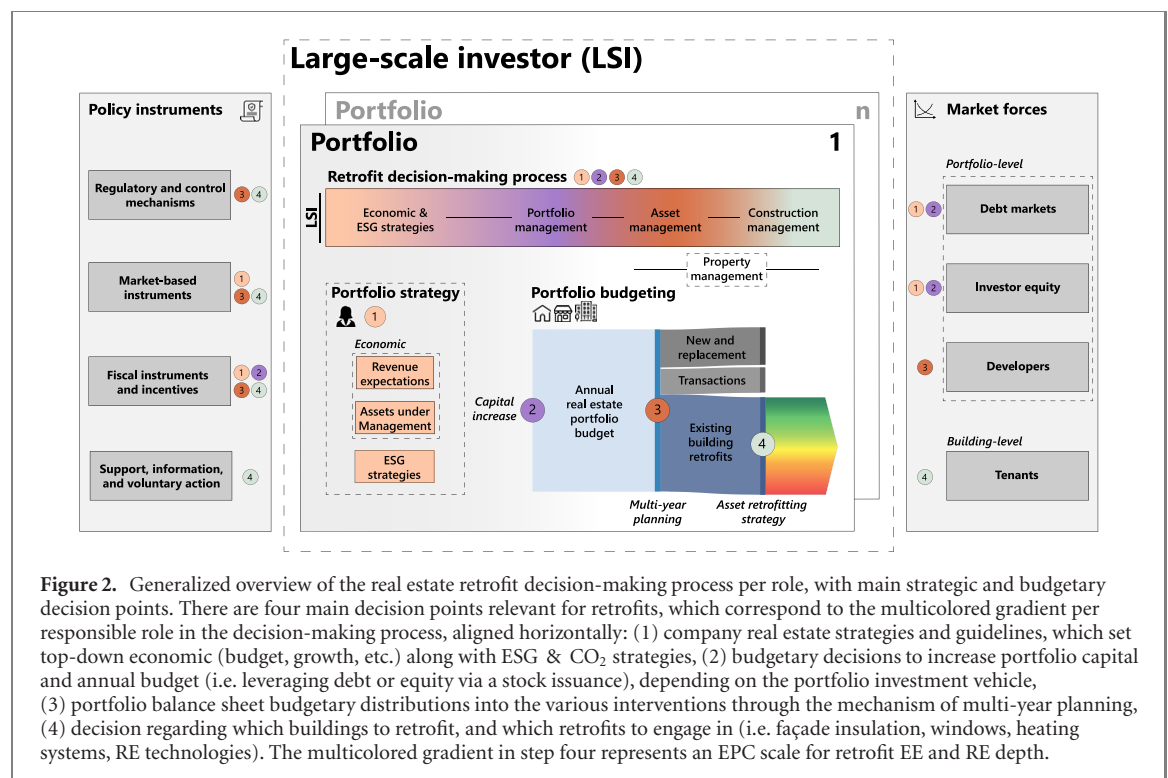


Figure 2. Generalized overview of the real estate retrofit decision-making process per role, with main strategic and budgetary decision points. There are four main decision points relevant for retrofits, which correspond to the multicolored gradient per responsible role in the decision-making process, aligned horizontally: (1) company real estate strategies and guidelines, which set top-down economic (budget, growth, etc.) along with ESG & CO₂ strategies, (2) budgetary decisions to increase portfolio capital and annual budget (i.e. leveraging debt or equity via a stock issuance), depending on the portfolio investment vehicle, (3) portfolio balance sheet budgetary distributions into the various interventions through the mechanism of multi-year planning, (4) decision regarding which buildings to retrofit, and which retrofits to engage in (i.e. façade insulation, windows, heating systems, RE technologies). The multicolored gradient in step four represents an EPC scale for retrofit EE and RE depth.

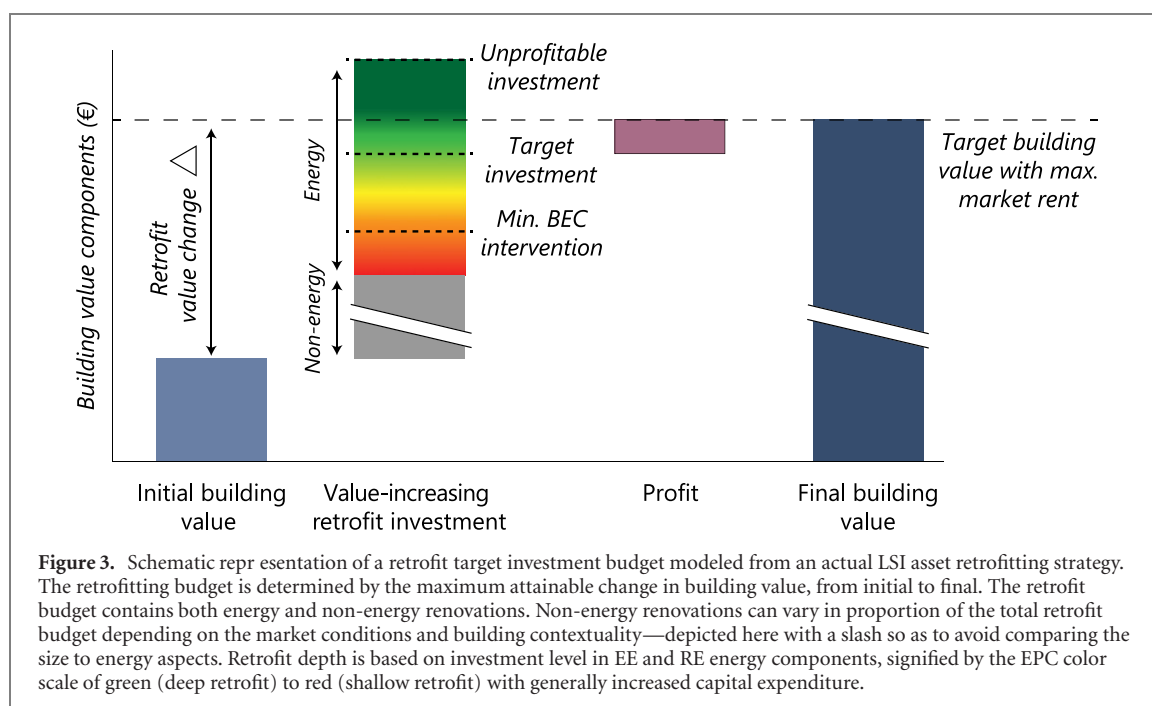
process in figure 2, highlighting four main decision points for all real estate team members ranging from high-level real estate strategies to portfolio budgeting and asset-level strategies.

First, we provide a brief explanation of the involved roles in real estate teams and their main responsibilities, with further details in appendix A. LSI real estate teams comprise three main internal roles (portfolio, asset, and construction management) and one typically externalized role (property management). Portfolio management are primarily responsible for implementing both sustainability and economic portfolio strategies (assisted by the ESG team), while asset management determine individualized strategies in collaboration with property management. For specific retrofitting projects, portfolio and asset management iteratively collaborate with internal construction managers and finance as well as external developers, architects, and planners. Next, we describe how these roles interact in the retrofit decision-making process.

While top-down economic and ESG strategies (point 1) along with macroeconomic portfolio considerations (point 2) set the framework conditions, the final retrofitting investment decision is taken in an iterative process between budgeting in multi-year portfolio planning (point 3) and each asset's individual retrofitting strategy (point 4). As the bank's Head of Construction Management explained, '*the decision about sustainable things is basically on the (asset retrofitting strategy) level,*' but when accounted for in multi-year planning, it can be '*very ad hoc,*' as critiqued by the Head of ESG at a property management company. Developed over decades, this complex process is typified by fragmented role priorities and externalization from the LSI, which some interviewees describe as hindering a definitive retrofitting decision, making it difficult to align retrofits towards top-down CO₂ goals. Property managers have significant influence on retrofitting options, as stated by the Construction Manager at a property management company, '*ninety to ninety-five percent of our recommendations are followed [...] our recommendation is very decisive.*'

Due to the recent adoption of top-down CO₂ goals in phase 2, LSIs have begun screening portfolios for deep retrofit potential to align with internal CO₂ goals but also to increase awareness of stranded asset risks in light of future financial and regulatory uncertainties [74, 75]. As a consequence, all LSIs have found incongruencies related to the necessity to budget for deep retrofits, considering the scarcity of 'low-hanging fruits'. All LSIs agree that although CO₂ metrics are becoming more relevant for retrofits, economic considerations such as asset value and return targets, market positioning, and vacancy are still dominant. As one bank Portfolio Manager acknowledged, '*I am thinking sustainable. Absolutely. But sometimes I have to say, for the investors, is it really the best thing to do?*' In phase 2, LSIs are starting to reconsider short-term economic prioritizations and established management strategies to systematically integrate CO₂ considerations into the retrofit decision-making process.

To achieve net-zero CO₂ emissions in phase 3, LSIs will have to retrofit buildings where deep retrofits are not economically viable in current regulatory and market conditions. Here, interviewees stated that considering CO₂ presents new challenges to the economically focused retrofit decision-making process, culminating in the



adjustment of both asset strategies and portfolio multi-year plans. From an organizational perspective, this entails questioning the engrained tacit real estate industry knowledge (e.g., an attitude of ‘We always do it this way’) and aptitude (e.g. achieving a key performance indicator (KPI)). Our results show significant potential to align top-down CO₂ goals and LSI retrofit decision-making processes in three ways: (i) integrating multi-year planning with extended time horizons beyond five years to align with long-term CO₂ goals and building component lifetimes (30 + years), (ii) benchmarking CO₂ metrics for assets to consider ‘transferring’ costs between assets based on an internal CO₂ tax at portfolio level, and (iii) establishing adequate deep retrofitting KPIs (energy or CO₂) at role-levels.

Integrated multi-year planning is a crucial mechanism for aligning investment planning processes with CO₂ goals and subsequent decarbonization pathways, requiring an expanded time horizon alongside clear metrics, strategies, and risk management under uncertainty [11]. On the asset management level, teams would use these plans to evaluate retrofitting options on a cost vs emissions basis long before technical plans are available. Further, the fragmented influence of each role over various retrofitting decision points implies that the CO₂ emissions of the final investment decision will depend heavily on the aptitude of the individual role. Consequently, the lack of deep retrofitting KPIs on a role-level has a significant influence on both retrofitting speed and depth. An ‘all hands on deck’ approach of tying individual role KPIs to benchmarked emissions-savings possibly with an internal CO₂ tax, could incorporate decarbonization into investment decisions as a direct objective.

The retrofitting strategy for each asset is highly contextual and value-driven, depending on the maximum possible attainable value (at the market rent), the potential value increase through retrofitting, and the profit margin (figure 3). Real estate teams negotiate retrofitting options with a focus on maximizing (or preserving) building value and smoothing portfolio capital expenditure budgets, aligning with the land value theory for the highest and best use [10] (further detail is provided in appendix A). This explicitly contradicts academic studies utilizing payback periods or returns (ROI) on energy retrofits as the sole economic decision-making metrics [36].

When retrofitting energy-relevant components such as windows, façade/roof insulation, and/or heating systems, asset management aim to couple value-increasing non-energy renovations in the same project, such as possible extensions and interior renovations (e.g. kitchens, floors, and bathrooms, etc.) which constitute a non-trivial part of the budget. This is done mainly to reduce disturbance to tenants along with reduce management and project costs. Further, the landlord-tenant split-incentive [76] was not a major concern for most interviewees, due to a focus on maximizing value—that is, increases in net rents more than offset tenants’ energy savings due to retrofits.

Interviewees agree that if value-driven economic criteria remain the key decision-making metrics, deep retrofits will never become feasible for some properties—especially in low-value markets. This raises questions about how policies from the energy domain and beyond influence retrofitting decisions.

3.3. Limited impact of direct policy instruments

An overarching retrofitting policy mix relevant for LSIs has both direct (energy and emissions-focused) and indirect (not energy and emissions-focused) instruments, as presented in table 3. Paradoxically, our interviews revealed that direct instruments have only limited impact on the retrofitting decision itself. For example, many interviewees agreed that BECs are not decisive for altering retrofitting options, and are instead perceived as boundary conditions for depth. Furthermore, LSIs did not see potentially more stringent BECs as a threat, since their orientation towards green building labels in construction guidelines puts them ‘ahead of the game’ from a regulatory risk perspective. Thus, BECs are mostly relevant for low-value markets as minimum thresholds for EE and RE. As an energy policymaker observed, ‘*(The current BEC) reflects the technical state of the art [...] I think beyond a certain point, there’s only so far we can go*’ in terms of technical stringency approaching net-zero energy buildings.

Our findings suggest that instruments tied to CO₂ benchmarks have the most influence on retrofit decision-making. All LSIs agreed that high CO₂ taxes accelerate the switch to emission-free heating, but presently have little influence on EE investments. Further, interviewees mentioned the influence of high-level investment taxonomies on portfolio budgeting through reduced interest rates [77]. Financial incentives related to building components or general retrofit depth were deemed indecisive for retrofitting depth and speed; most LSIs considered them a ‘*nice to have*,’ due to their minimal influence on budgeting. Most interviewees expressed strong aversion to more restrictive types of direct instruments, such as technology mandates and retrofitting obligations.

In contrast to direct instruments, indirect policies from other domains crucially impact retrofitting decisions. Interviewees primarily pointed to the influence of affordability, tenant security, and urban planning instruments as influencing real estate valuations that are critical to asset retrofitting strategies and multi-year planning.

Both private and public LSI interviewees expressed particular concern over the influence of affordability policies such as rent controls—but not over tenant security laws such as eviction notices and component pass-on rates. Local jurisdictions’ rent controls were deemed the most influential indirect instrument, directly decreasing residential retrofitting investments through the mechanism of distorting building value, further prolonging the retrofitting trigger, possibly increasing CO₂ emissions, and decreasing living quality.

At the other extreme, the consequential rising rents from LSIs’ short-term pursuit of value maximization—partly due to high-value ‘green’ buildings—could lead to ‘green gentrification’ [78] processes and, in the long run, to political initiatives for rent controls. LSIs are clearly aware of this potential negative feedback loop: ‘*Now, cheaper housing is being sacrificed for the sake of the environment,*’ as one bank Portfolio Manager noted. All LSIs reiterated their fear of the regulatory uncertainty of politically driven rent controls on multi-year planning processes. As the real estate Director of Valuation explained, rent control uncertainty is ‘*changing how much to invest in the properties [...] pushing renovations a few years back.*’

The policymakers we interviewed struggle with this dilemma of how to regulate real estate markets in light of various policy objectives. Significant affordability-friendly policies counteract market drivers for deep retrofits, endangering the (planned) retrofitting rate and future profits. In contrast, over-liberalized real estate markets allow disproportionate rent increases from (potentially deep) retrofits. Considering this, interviewees called for policy instruments from various domains to be aligned in order to meet CO₂ goals.

3.4. Integrated policy mixes for retrofits

Direct and indirect instruments potentially interfere at various leverage points in LSIs’ value-driven retrofitting decisions. Direct instruments act as framework conditions for the energy and emissions aspects of the value-increasing retrofit investment, with BECs setting minimum standards and financial (dis)incentives reducing costs for deep retrofits. In contrast, indirect instruments generally affect the profit margin and final building value.

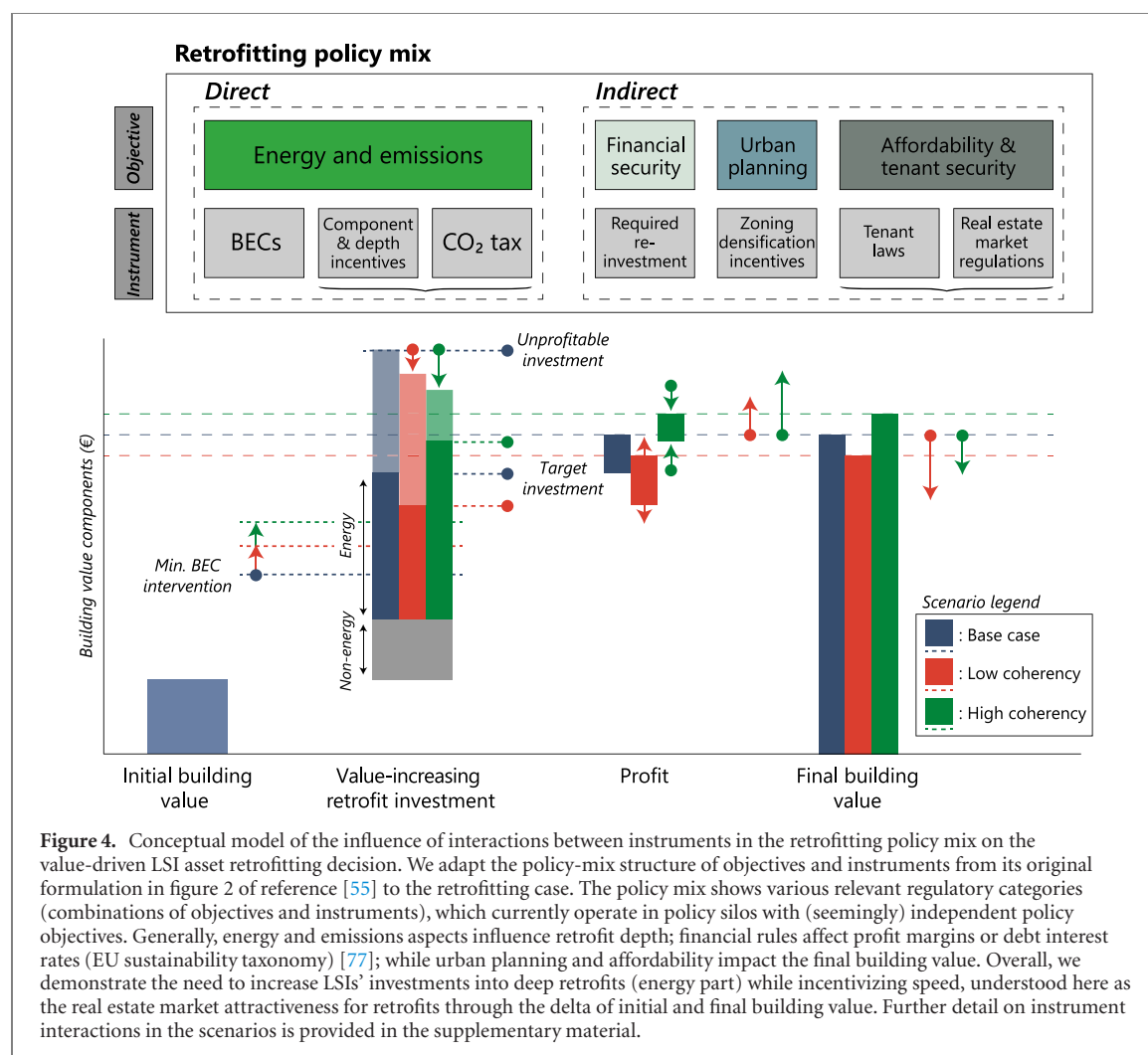
In figure 4, we conceptualize two example scenarios mentioned in the interviews related to the coherence of the policy mix for multiple social objectives. We compare the scenarios to the base-case presented in figure 2 to show how various instrument interactions influence the speed of deep retrofits.

Possible constellations of policy instruments can result in shallow or deep retrofitting decisions through interactive mechanisms. If the policy mix has low coherence, shown in the red scenario, the target (deep) retrofitting investment could be reduced mainly by distorting the final building value. In such a situation, stringent real estate market regulations constrain the final building value to a greater degree than densification incentives lift it. If little financial portfolio reinvestment¹ is required, this could lead to a reduced depth of

¹ Portfolio reinvestment requirements differ between portfolio investment vehicle types (e.g. foundations, stock-market, insurance funds), strongly influencing annual capital expenditure on retrofits (approximately 2% of portfolio value) and subsequently the available profit margin.

Table 3. Retrofitting policy mix comprised of direct and indirect policy instruments.

Policy instrument type	Policy objective	Policy category	Policy instrument examples
Direct	Energy and emissions	Regulatory and control mechanisms	Building Energy Codes (BECs): heating efficiency performance (kWh m^{-2}), CO_2 performance ($\text{kg CO}_2 \text{ m}^{-2}$), renewable heat production requirements (W m^{-2} or %), on-site RE production requirements (W m^{-2} or %) Retrofitting obligations (kWh m^{-2} or EPC-level by certain year) Technology bans (e.g. electric resistance heaters, oil boilers) or mandates (e.g. solar PV) Energy Performance Certificates (EPCs) Green building labels (e.g. LEED, BREEM, DGNB, etc.) Energy performance contracting
		Market-based instruments	
		Fiscal instruments and incentives	Component-based financial incentives: Insulation, windows, RE heating generation systems (e.g. heat pumps, biomass boilers) and electricity generation systems (e.g. solar PV) Retrofit depth-based financial incentives (e.g. based on EPC-level or label achievement) Electricity self-consumption-based incentives CO_2 taxes on fossil heating and process fuels (EUR/tonCO_2) Fiscal instruments for sustainable investments (e.g. lower debt interest rates, tax benefits)
		Support, information, and voluntary action	Informational and education campaigns Mandatory energy audits and disclosures
Indirect	Affordability and tenant security	Regulatory and control mechanisms	Tenant laws: eviction notice periods (years), component or retrofitting pass-on rates (%—vary by intervention) Real estate market regulations: rent controls and caps Permitting processes
	Urban planning	Fiscal instruments and incentives	Zoning densification financial incentives (%)
	Financial security	Fiscal instruments and incentives	Required annual reinvestment in portfolios (e.g. $\sim 2\%$, depends on on portfolio investment vehicle type such as insurance, pension, or stock-market listed funds)



retrofitting. LSIs referred to the low-coherency scenario as characteristic of highly regulated real estate markets, demonstrating reduced rates of deep retrofits through staged projects (i.e. façade only, heating system only). Conversely, in liberalized markets with weak real estate market regulations (e.g. rent controls), LSIs demonstrated (or merely claimed) higher rates of deep, value-maximized retrofits. In a high-coherency scenario, shown in the green, real estate market regulations would need to be counteracted by zoning densification incentives. In combination with support from higher financial reinvestment requirements and direct financial (dis)incentives, this could lead to an increased target investment for energy aspects. However, increased investments also increase values and, in turn, rents, through tenant amortization. Such a scenario would necessitate an instrument to alleviate rising rents to assure tenant affordability. This brings other objectives, such as affordability, into the frame.

An integrated retrofitting policy mix must strive for improved coherence between policy objectives by considering the inconsistencies between (direct and indirect) policy instruments [55, 79] to effectively address LSI value-driven decision-making. Growing literature on *integrated* policy mixes—investigated, for example, for the case of road transport [80]—argues that only a multi-pronged approach will achieve mutual policy objectives. Such an approach requires an in-depth understanding of instrument interactions to meet multiple 'holistic sustainability' objectives from different policy domains and involved real estate stakeholders [81].

Improving coherence between objectives that are currently seen as divergent would address socioeconomic and political questions regarding affordability in the context of deep retrofits. Further, policymakers must break down policy silos at various jurisdictional levels in order to align affordability (local) and decarbonization (national) objectives. This would provide clarity for LSIs and alleviate organizational tensions in real estate markets with different instruments at play.

On the instrument level, we urge policymakers to reduce interference between instruments, or otherwise move towards instruments that can address multiple objectives [59, 79]. For example, jurisdictions have already been using multi-objective instruments such as density bonus incentives to promote affordable housing

[82, 83], as well as relaxing zoning laws for densification if a green building label is achieved (i.e. exaction) [84]. In terms of rent controls for affordability, limited evidence suggests that other instruments may be better suited to incentivize affordability without unintended consequences—for instance, through rent subsidies [51].

However, in terms of real estate market regulations, we need instruments that address multiple objectives such as affordability and retrofitting depth. One potential innovative example of such an instrument, paired with existing CO₂ taxes which have been shown to be insufficient when used in isolation [23], could be a rent subsidy linked to achieving a green label or EPC. In such a case, LSIs could still charge the market rate (at a controlled return on investment), while CO₂ tax revenue would be redistributed to low-income tenants. This combined direct and indirect instrument would directly target multi-year planning, allowing LSIs to effectively budget for deep retrofits.

4. Conclusions

Our results show the increased decarbonization pressure on real estate LSIs, moving from niche implementation (phase 1) to institutionalized decarbonization (phase 2). By unpacking the LSI retrofitting ‘black box,’ we observe that this phase transition has generated incongruencies around integrating decarbonization into the value-driven retrofit decision-making process. Findings point to the importance of asset managers’ planning decisions as a key institutional mechanism for setting building-sector policy in the framework of real estate management [85]. Despite better-integrated policy mixes, LSIs’ current phase 2 strategies might not be sufficient to meet both internal and global CO₂ goals. LSIs have the ability to transform decision-making processes to integrate decarbonization with (i) integrated multi-year planning, (ii) internal CO₂ tax transfers, and (iii) deep retrofitting role KPIs.

Paradoxically, the traditional energy and climate policy focus on single, direct instruments has limited impact on the retrofitting investment decision itself. This highlights the importance of instruments that target retrofits indirectly, such as those with different policy objectives. We outline an initial attempt at a pathway for an integrated policy mix to encourage broader market penetration of deep retrofits, while accounting for various policy objectives such as affordability, densification, and decarbonization. This is important because linking climate policies with socioeconomic issues in bundled policy mixes can increase public support [59, 86, 87], bringing supplementary benefits such as health and job creation [5, 88].

There are still open questions for policymakers as to what kind of policy mixes are needed and how they should evolve, along with the role of various regulatory domains in coordinated real estate market decarbonization. Transitioning to net-zero CO₂ emissions (phase 3) underlines the importance of the cross-impacts of policy silos and conflicting social goals, particularly on LSIs’ value-driven retrofit decision-making process. When political action is taken to assure affordability through rent controls, policymakers could reduce instrument interference by moving towards multi-objective instruments which provide some sort of financial incentive that will maintain the pace of deep retrofitting.

While we shed light on the depth of retrofits specifically, the retrofitting trigger was generally found to be based on component lifetime, presenting an avenue for future research [89]. Further, understanding varied retrofit decision-making processes between different types of owners (non-professional, owner-occupiers) and investors is vital. From a policy perspective, stronger emphasis should be placed on the interplay of direct and indirect policy instruments relating to other ‘sustainable’ investments, along with the distributional effects at various levels of policymaking [87, 90].

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Data availability statement

The data generated and/or analysed during the current study are not publicly available for legal/ethical reasons but are available from the corresponding author on reasonable request.

Appendix A. Extended description of real estate retrofit decision-making and theory

Here we present further detail on interview results related to real estate retrofit decision-making. First, real estate team structures are discussed, followed by a detailed description of how the various roles interact in the retrofit decision-making process with respect to the real estate theory of highest and best use and modern portfolio theory.

A.1. Real estate teams and retrofit decision-making

All four LSIs situated real estate teams in matrix-oriented structures for each portfolio investment vehicle (otherwise referred to as ‘products’), shown in figure 5.² This organization is typically referred to as a product team, each having inherent decision-making structures and level of externalization. In such product teams, a clear split in retrofit decision-making was observed between roles from the top-down, led by portfolio management, to the bottom-up through mainly economic-focused support from asset management along with finance roles when necessary. More technical support related to the retrofitting project is provided by construction and property management. For private LSIs, property management or facility management is typically externalized but could also be a subsidiary of the main parent company, while for public LSIs is typically internalized. The ESG position is typically positioned as a high-level cross-cutting role with little budgetary decision-making power, although one LSI had various roles share ESG responsibilities. Acquisitions/transactions teams are involved especially for new buildings, but they are not described due to this study’s retrofitting scope.

The main four decision points and relevant roles of the retrofit decision-making process are shown in figure 2 of the manuscript. Here, we describe this process in more detail. As the product team leader, portfolio management is in charge of managing major economic decisions and strategic orientations which could come from the LSI institutional level. Under portfolio management, there are generally many asset managers who support in curating individual asset retrofitting strategies—invest, hold, or sell—based on building conditions, real estate market attractiveness, and tenancy conditions, among others. With regards to retrofitting, the asset-level decision-making process involves an iterative cycle between planning, budgeting, and valuation—specifically which type of retrofit depth to engage in. Internal construction management and finance roles along with (sometimes) external property management provide more detailed support for steering retrofitting projects in the form of planning, internal guidelines, and due diligence.

A.2. Theoretical background

The retrofitting decision is impacted by two main real estate theories: on the asset-level with the *theory of highest and best use*, and on the portfolio-level with *modern portfolio theory*. A fundamental aspect of real estate theory is that the lifecycle of buildings is based on land and structural value of properties, referred to as the theory of highest and best use which is explained in detail on page 96 in reference [10]. Here, the usage value of a property, depicted by U in exhibit 5–10, generally grows over time in real terms due to inflation or other macro-economic factors, while at the same time, the structural value decreases over time due to technical obsolescence and thus the total asset present market value (P) decreases as well [91].

When the property value deteriorates point equal to the plot/land value (C), the owner has the option to redevelop for the property’s ‘highest and best use’ (U) typically in 30–50 years cycles (R). This theory generally describes how the value of buildings evolves over their lifetime, and therefore how LSIs plan future retrofits (energy and non-energy aspects) based on timely retrofits (component lifetime) mainly to keep or maximize the value of the asset as shown in figure 3 of the manuscript.

Building valuation methodologies, typically done through DCF calculations, are vital tools to determine the maximum value potential at the market rate and thus the chosen retrofit scenario and budget. In contrast to energy retrofitting studies describing payback periods or ROI of energy retrofits as the main economic decision-making metrics [36], surprisingly these were not influential for the LSIs interviewed. Their focus instead was rather on aligning staggered component lifecycles balanced with urgency and potential to keep or increase building value. The payback or ROI of a retrofitting scenario, and thus asset performance, is calculated after the valuation considering both energy and non-energy components which ‘have to be done’ anyway (figure 3 of the manuscript). This has implications for retrofitting accounting measures and triggers, with the ‘improvement’ approach from reference [92] being confirmed as the most common although also including non-energy elements.

² One LSI was in the process of transitioning from a project-oriented structure with roles working across portfolios towards product-orientation. While neither product nor project-oriented structures can be argued to lead to particularly different approach to decision-making, LSIs with product-oriented structures were observed to have more autonomy at the portfolio-level compared to the LSI institutional level, potentially leading to more differentiation in portfolio strategies.

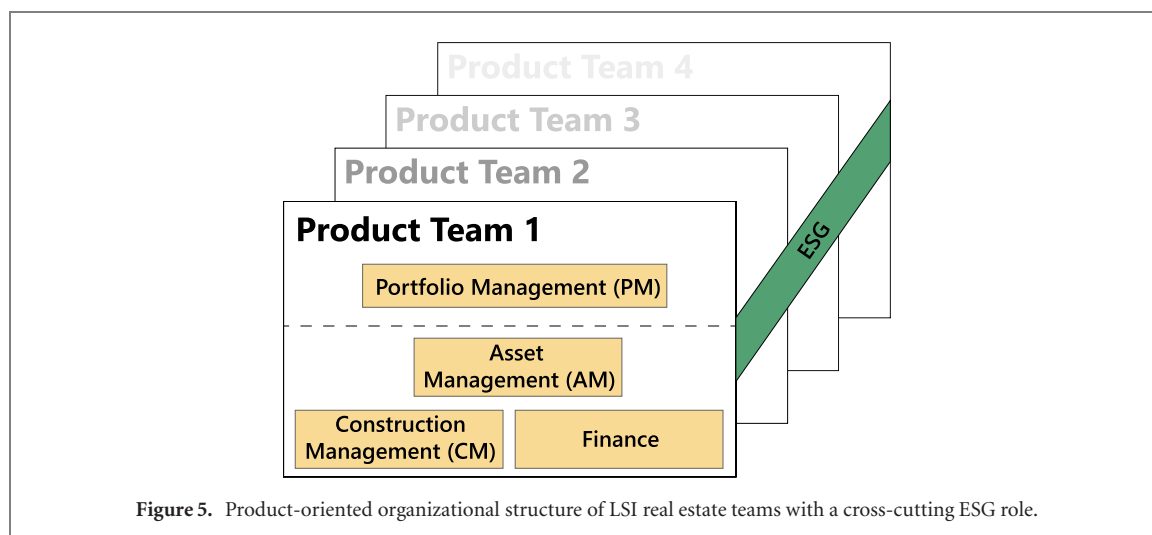


Figure 5. Product-oriented organizational structure of LSI real estate teams with a cross-cutting ESG role.

Modern portfolio theory, the traditional investment ideology in financial investment firms, suggests a balanced risk & return profile of a mixed-asset portfolio based on investor preference. Real estate is a natural part of a general LSI investment portfolio, typically accounting for 20%–30% of portfolio value [10]. LSIs' own real estate portfolios are generally 'packaged' into various investment products/vehicles based on building type (e.g. residential, commercial, industrial), geography (e.g. country region), or another specific aspect such as sustainability (e.g. ESG building portfolio).

Typically, the goal of real estate managers is to achieve a 'cash cow' strategy for assets which features 'long holding periods to magnify the importance of operational income generation in the overall investment return' [10]. The buy-and-hold versus redevelopment strategies can vary between LSIs depending on their risk tolerance, from less-risky (e.g. pension) to high-risk (e.g. private). The risk tolerance for redevelopment opportunities (retrofits) is taken into account through the theory for the highest and best use when redevelopment of the property is necessary in 30–50 years cycles. Further, risk is distributed across portfolio investment vehicles, implicating that both investment vehicle and ownership type can directly influence LSI retrofitting investment behavior. Most notably, their investments must take into account a risk-adjusted discount rate which relies on a risk-free cost of capital exposed to debt and equity markets.

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