From Market Value to "Climate Value": Quantifying EU ETS-2 Risks in Real Estate Valuations within the Austrian Real Estate Market and its Mitigation through Carbon Neutral Heating and Cooling

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1 ABSTRACT

In 2023, the European Union's second Emissions Trading System (EU ETS-2) was launched and is planned to take effect in 2027 (EUROPEAN PARLIAMENT, 2023).This scheme will cover buildings and road transport sector and represents a fundamental shift in how decarbonization in real estate economics operates. This regulatory framework is the second step, after EU-ETS 1, of the EUs ambition to reduce carbon emissions through a market-based pricing approach. This strategy introduces a market-based carbon pricing mechanism that differs significantly from the existing national fixed-price systems, which is in Austria currently under use (Republic of Austria, 2022), known as "Nationales Emissionszertifikatehandelsgesetz 2022" (NEHG 2022).As the existing legislation in Austria governs currently no cost-sharing between landlords and tenants, all carbon costs have to be carried by the tenant through their energy spending due to NEHG 2022 as of yet and EU ETS-2 in future. This most likelywill impact rental levels, no matter what future legislation exactly will look like, as energyefficiency is already influencing property pricing, as other research indicates (Chegut et al, 2020). Property valuers, investors and lenders potentially face with this transition a future challenge, as established and accepted valuation methods in Austria do not adequately take potentially rising carbon costs currently into account. As a consequence, carbon neutral heat and cooling production from renewables on site currently does not get fully awarded, as property valuerscurrently don't distinguish between carbon intense and less carbon intense heating and cooling.By analyzing a comprehensive set of real estate valuations and the focusingon their current integration of environmental aspects, we will understand how Austrian real estate appraisers currently are considering environmental issues as of today in the real estate valuation process. Further, by employing a sophisticated Discounted Cash Flow (DCF) model, as used in other studies (de Joung et at, 2025), we can project carbon price scenarios what introduces a new metric, the "Climate-Adjusted Market Value" (Carbon Delta AG, 2017) as discussed in the recent past (MSCI, 2024) to quantify the spread between a building's current market price and its value after accounting for future carbon obligations.The findings demonstrate that the mitigation provided by carbon-neutral heating and cooling systems, prevents existing assets from facing a "brown discount, " rendering them economically obsolete – or "stranded" – long before their physical lifespan ends.Consequently, this study give evidence if integrating carbon-neutral technology is no longer merely of an ecological choice but a fundamental financial imperative to secure long-term property income streams and avoid asset stranding in the wake of EU ETS-2.

Keywords: EU ETS-2, Real Estate Valuation, Stranded Assets, Climate-Adjusted Market Value, Carbon neutral heating

2 INTRODUCTION AND BACKGROUND

2.1 European Environment Legislation and Valuation Standards

Climate risksare financial threats caused or exacerbated by climate change. They impact companies and their value chains through physical risks (natural hazards) and transition risks (regulatory, technological, or social shifts), both of which often interact (FMA, 2025a). At the EU level and, consequently, at the national level, climate regulation affects real estate through building rules, carbon pricing, and disclosure requirements, all of which can be captured as transition risks. The recast of the Energy Performance Buildings Directive (EPBD) tightens requirements for new buildings and renovation policy, and it expands data and compliance obligations across the stock (European Commission, 2024). The first European carbon emissions system was introduced in 2005 to meet the Kyoto Protocol targets and is defined by the EU Emissions Trading System (ETS), which applies to emissions frompower generators and energy-intensive industries. The scope of the ETS was enlarged by a second emissions trading system, the EU-ETS2, which was created to cover emissions from buildings, road transport and additional sectors (EUROPEAN PARLIAMENT, 2023). The new system will become operational in earliest in 2027, latest in 2028, which is expected to raise the cost of fossil heatingas part of the “Fit for 55” progam (European Commission, 2023b).The EU Taxonomy defines when building-related activities qualify as environmentally sustainable and sets technical criteria through delegated acts. (European Union, 2021).The Sustainable Finance Disclosure Regulation (SFDR) requires standardised disclosures on sustainability risks and adverse impacts for financial products with real estate exposure (European Parliament, 2019).The Corporate Sustainability Reporting Directive (CSRD) and the European Sustainability Reporting Standards (ESRS) make climate risks, transition plans and metrics part of mandatory corporate reporting (European Commission, 2024) (European Commission, 2023a) Further, the Corporate Sustainability Due Diligence Directive (CSDDD) adds due diligence duties across supply chains, which matters for development, refurbishment and materials (Directive – EU – 2024/1760, 2024)] Since 2025, EU “simplification” proposals have targeted the scope and timing of the CSRD/CSDDD; final legal texts can shift thresholds and deadlines. (Reuters, 2025). In Austria, building and energy rules are implemented in compliance with EU policy at the national and provincial levels. Building energy requirements are harmonised via OIB Guidelines, especially OIB Guideline 6. (OIB, 2025) The Energy Performance Certificate (EPC) is mandatory for sale and letting under EAVG 2012. (Nationalrat, 2012) Federal energy-efficiency duties are set through the EEffG. (Nationalrat, 2024) Renewables expansion is anchored in the EAG (Nationalrat, 2021) and the EWG (Nationalrat, 2024). Austria’s Nationales Emissionszertifikatehandelsgesetz (Nationalrat, 2022) prices carbon nationally and explicitly links to the planned transfer into EU-ETS2 from 2027, which is central for carbon-intense heating cost trajectories. (Nationalrat, 2022) Climate governance runs through the KSG (Nationalrat, 2017). CSRD transposition has been prepared via a draft Nachhaltigkeitsberichtsgesetz (NaBeG) and remains linked to EU-level omnibus discussions (Bundesministerium für Justiz, 2025). The FMA consolidates supervisory expectations around sustainability disclosure for regulated entities. (FMA, 2025b)

2.2 Comparative Synthesis of Climate Risk Integration in Property Valuation

Traditional Austrian valuation, governed by the Liegenschaftsbewertungsgesetz (LBG) (Nationalrat, 1992) and ÖNORM B 1802-1, primarily treats climate factors as “special value-influencing circumstances” (Section 7 LBG). Physical climate risksare typically addressed through qualitative deductions – a climate risk assessment is not specifically required. However, these norms lack a standardised quantitative framework for internalising transition risks, such as the carbon-pricing impacts of the EU ETS 2. The recognition of EPCsduring the valuation process is highly recommended – if missing, valuers should state "No EPC available, " assess the building's energy efficiency (consulting an expert if necessary), and incorporate these findings into the final market value determination to limit the valuer’s liability (Allerstorfer et al., 2009). The same logic accounts for the recognition of ESG features of buildings when surveilling “sustainable” or “non-sustainable” buildings (Martin M. Roth, 2022)

In contrast to the Austrian valuation frameworks, the RICS Valuation – Global Standards mandate the proactive identification of ESG factors as core value drivers. Valuers must analyse how climate-related sustainability influences marketability and investor behaviour, ensuring these factors directly inform capitalisation rates (yields) and market value. (RICS, 2024).Similarly, requirements were identified in The European Valuation Standards (TEGOVA, 2025), which align valuation practices with the European Green Deal, which addresses the impact of the EU Taxonomy and mandatory renovations on long-term value stability (TEGOVA, 2025) A critical innovation is the “Property Value”, introduced to comply with the Capital Requirements Regulation (European Banking Authority, 2024). This value is based on “prudently conservative valuation criteria”, excluding speculative elements and cyclical price increases to provide a stable basis for mortgage lending.Article 229 clearly states that the property revaluation may exceed historical values if improved energy efficiency or greater resilience, protection, and adaptability to physical climate risk areachieved (European Banking Authority, 2024).The EBA Guidelines further integrate ESG risks into the prudential supervision of financial institutions. Banks must incorporate environmental factors into credit risk appetites and collateral monitoring throughout the entire loan lifecycle (EBA/GL, 2020). This regulatory pressure drives a shift from point-in-time appraisals to continuous risk assessments, especially to identify potential "stranded assets" as the economy transitions to a low-carbon, climate-resilient economy. (EBA/GL, 2020).

2.3 Analytical Synthesis of EU ETS 2 Pricing Scenarios and System Dynamics

The implementation of the second European Union Emissions Trading System (EU ETS 2) in 2028 represents a decisive regulatory shift within the “Fit for 55” framework. Unlike the established EU ETS 1, which primarily targets price-elastic industrial and power sectors, the EU ETS 2 focuses on buildings, road transport, and small industrial installations. These sectors are historically characterisedby high marginal abatement costs, path dependenciesand various structural market failures. The current scientific literature (2023–2025) emphasises that price formation in this market is not merely a function of internal supply and demand but is deeply contingent on the broader European policy landscape and technological replacement cycles.The predictability of price trajectories within the EU ETS 2 is subject to substantial variance due to the diverse modelling frameworks employed across the research community. Rickels et al. (2023) utilise the Computable General Equilibrium (CGE) model “DART” to quantify the efficiency gains of EU-wide trading, particularly in the context of the Effort Sharing Regulation (ESR). Conversely, the PRIMES model, utilised by Günther et al. (Günther et al., 2025), provides a high-resolution simulation of technological substitution – such as the adoption of heat pumps and electric vehicles – in response to marginal cost signals. Market-oriented simulations, such as BloombergNEF’s EUCPM 2.0 (Bloomberg NEF, 2025), further refine these projections by incorporating the anticipation and hedging behaviours of fuel distributors, which are expected to drive significant price premiums during the system’s initial phase. Finally, other research identifies macroeconomic consequences at the Eurozone level, which links carbon pricing directly to GDP and inflation metrics (Džubur&Pointner, 2024).A fundamental consensus emerging in contemporary research is the conceptualisation of the carbon price as a “residual variable” (Günther et al., 2025). This theory posits that, since the emissions cap is fixed, the equilibrium price is inversely related to the efficacy of non-pricing energy efficiency policies (EPs). For instance, ambitious enforcement of the Energy Performance of Buildings Directive (EPBD) and stringent CO_2 fleet standards for vehicles reduce the residual volume of emissions that must be addressed via the price signal. In a “Weak Policy” scenario, the carbon price must bear the overwhelming burden of abatement, with projections indicating a rise to approximately € 261/tCO_2 by 2030. Conversely, a “Strong Policy” scenario, characterised by high renovation rates and rapid electrification, could stabilise the price at a more manageable € 71/tCO_2.

The institutional architecture of the EU ETS 2 is uniquely intertwined with the Effort Sharing Regulation (ESR). Rickels et al. (2023) note that, until 2030, the trading system primarily serves as a cost-efficient vehicle for Member States to meet their binding national targets. However, the reliance on the Market Stability Reserve (MSR 2.0) as a price-containment tool is viewed with scepticism. While the current legislation aims to trigger allowance releases if prices exceed a threshold of roughly € 45 (in 2020 prices), simulations demonstrate that the limited volume of the reserve – capped at 150 million allowances – is insufficient to neutralise fundamental scarcity. Further, they conclude that maintaining a € 45 cap through 2030 would necessitate the release of 415 million additional allowances, a move that would fundamentally compromise the EU’s ecological integrity and 2030 climate targets.

A major challenge identified by Kalkuhl et al. (2023) is the inherent price inelasticity of the heating and transport sectors. Structural barriers, most notably the “split incentives” in the rental market, decouple the carbon price signal from investment decisions; tenants bear the carbon costs while landlords control the capitalfor retrofitting. This inelasticity suggests that prices may need to reach extreme levels to achieve the mandated cap without supportive measures. Consequently, the fiscal dimension of the ETS 2 becomes critical. Researchers unanimously argue for comprehensive revenue recycling mechanisms, such as the Climate Dividend (Klimageld) or the EU Social Climate Fund (SCF), to offset the regressive nature of carbon pricing and maintain public support (Agora, 2023; Džubur&Pointner, 2024). Looking beyond the 2030 horizon, the EU ETS 2 is expected to transition into a high-price paradigm as it approaches the 2050 neutrality target. Following the “Hotelling Rule”, the price of finite emission allowances is projected to rise in line with real discount rates as the cap approaches zero. Long-term modelling via PRIMES suggests that sectoral prices will converge toward € 475/tCO2 by 2050 to eliminate the most recalcitrant residual emissions. The evidence suggests that while carbon pricing is a necessary signal, its effectiveness depends entirely on its integration into a comprehensive policy mix. The research underscores that the “cost of neutrality” will be felt either through high carbon prices or through the direct costs of stringent energy efficiency regulations, the latter offering a more predictable and socially manageable transition path.

Source	PolicyContext& Drivers	2030 Price Proj.	Long-Term / 2050 Proj.
Rickels et al. (2023)	ESR Target Compliance	~€ 300	n/a
Günther et al. (2025)	Minimal Regulatory Support	€ 261	~€ 475
BloombergNEF (2025)	Base Case (Incl. Hedging)	€ 122	n/a
EWI (2025)	Multi-Model Consensus	€ 100–€ 200	> € 300 (by 2040)
Günther et al. (2025)	Maximum Efficiency (EPBD)	€ 71	~€ 475
Agora (2023)	PlannedSubsidy/Price Mix	~€ 100	n/a
OeNB (2024)	Price Only (NoSubsidies)	€ 668	>€ 800
EU-COM (2021)	Initial Impact Assessment	~€ 48	n/a

Table 1: Range of ETS-2 Scenario Pricing based on literature research

3 PROBLEM STATEMENT

In Austria, approximately 26% of households use carbon-intensive heating systems, with a similar proportion using biomass heating systems (Statistik Austria, 2025), which are currently regarded as low-carbon technologies. As residential tenants in Austria typically pay rent in addition to other occupational costs, such as energy consumption and service charges, the cost of heating has been a particular concern raised by the Austrian Labour Union in recent times, exerting pressure on rents (ÖGB, 2025). Therefore, the introduction of EU-ETS 2 is expected to put further pressure on rents, as energy costs already seem to doAmaral et al. (2025), and this is currently not taken into accountas climate risk by valuers. As institutional investors and lending banks have to recognise physical and transition climate risks within their risk management and policy frameworks and assess those risks with accepted tools, e.g., the CREEM assessment, private house buyers currently have no assessment method to assess their full climate risk exposure, aside from EPC assessments and natural hazard maps.Unclear private investment decisions may result from this opaque situation.

3.1 Defining the research question and methodology

The quantitative methodology of this study is based on an integrative valuation model that bridges traditional real estate appraisal with forward-looking carbon accounting frameworks. The methodological approach aligns with the recent findings of Jonge et al. (2025), who emphasise the needto embed both Operational Carbon Costs (OCC) and maintenance-related capital expenditures (CapEx) directly into cash flow projections. As investors usually prefer the IRR as an investment metric, the analysis will be enriched by a valuer's view of the Explicit Discounted Cash Flow (DCF) (TEGOVA, 2025), which assesses value change and reflects financial performance through the IRR amid decarbonization.

3.2 Data Acquisition and Portfolio Selection

The primary empirical basis consists of 84 individual real estate valuations systematically extracted from the Austrian Ediktsdatei (the official judicial auction database). These judicial appraisals have high methodological validity, as they are legally required to comply with the strict standards of the Austrian License Valuation Act (LBG). A structured content analysis was conducted to identify key parameters and performance indicators, including heating systems, energy performance indicators (EPCs), and assessments of natural hazard risks, such as using the HORA (Natural Hazard Overview & Risk Assessment) system. To ensure a consistent data baseline, missing energetic parameters were enriched with reference values from the TABULA Building Typology (Austrian Energy Agency, 2010) and the technical benchmarks of OIB Guideline 6 (OIB, 2025).

3.3 EU ETS 2 Simulation and Transition Modelling

The core of the methodology involves simulating the financial impact of the EU ETS 2 on cashflows and, consequently, on IRR and property values. Consistent with current regulatory projections, the model assumes the commencement of market-based carbon pricing liabilities in 2028. From this point forward, the portfolio is subjected to various price scenarios while adhering to a regulatory transition path (Phase-Out) :

- Phase-Out Schedule: The scheduled decarbonization of Austria's economy by 2040 (Jensen &Roniger, 2024), which foresees the full decarbonization of the tested assets before 2040.
- Operational Carbon Costs (OCC) : Following the framework established by Jonge et al. (2025), annual operationalcarbon liabilities (costsunder the EU ETS-2) are modelled until the expected end of the fossil system's regulatory lifecycle in 2040. The EU ETS-2 pricing scenario is aligned with

the scenario simulations of Günter et al (Günther et al., 2025), in a Weak EP, Limited EP and Strong EP as shown in Table 1.

- Technology Substitution:Firstly, for properties currently utilising fossil fuels, a full substitution with air- and ground-source heat pumps is assumed before the respective phase-out date, transforming theminto zero-carbon assets. Secondly, the properties shall receive a full thermal upgrade, pushing them toward a NetZero standard through serial retrofit, following the Energiesprong principles (including geothermal energy generation and façade heating/cooling, as defined by AEE (Weiss, 2025). Electrical Heating shall consume electricity from renewable sources only;district heating from renewable sources and biogenic fuels are treated asneutral within the ETS 2 framework.

3.4 Risk Quantification: Climate Value at Risk (CVaR)

To quantify the financial vulnerability, arising from carbon pricing (EU-ETS 2) and retrofittingneeds tobe calculated. According to MSCI (MSCI ESG Research, 2024) theClimate Value at Risk (CVaR) is a forward-looking financial metric that translates the present value of projected transition costs and physical damages into a percentage-based assessment of an asset's total valuation.Rebonato et al., argue that this metric captures a critical inverse relationship where aggressive carbon abatement policies increase near-term transition expenses but significantly reduce the long-term economic burden of physical climate impacts (Rebonato et al., 2024). In our context, this could involve improved thermal insulation, driven by future regulatory requirements under the "Fit for 55 package" energy efficiency policies. When combined with geothermal heating and cooling, it can help mitigate the effects of weather extremes on occupants, such as heat waves or cold winters. From an investment standpoint, this metric considers the present value of future carbon costs and the discounted Replacement Costs (RC) for climate-neutral heating systems and retrofitting measures at the end of the transition period, relative to the initial market value of an asset as in the CRREM model. Since transition risks are likely to impact cash flows unevenly, income-based valuation methods like DCF are most practical for estimating CVaR. Additionally, beyond CVaR, a second metric was developed: the Climate Value at Opportunity (CVaO), which accounts for rental and market opportunities from retrofitted upgrades, enhancing the asset's ability to generate market rents without discounts. The model employs the following deterministic formulas:

$$CVaR_i = \frac{\sum_{t=T+1}^{T}\left(\frac{R_{i,t}^{carb} - E_{i,t} * p_{ETS2,t}}{(1+r)^t}\right) - \frac{RC_{i,T} + Capex_{i;T}}{(1+r)^t} + \frac{TV_{i,N}^{carb}}{(1+r)^t}}{V_{i,0}}$$

and

$$CVaO_i = \frac{\sum_{t=T+1}^{N}\left(\frac{R_{i,t}^{carb}}{(1+r)^t} - \frac{RC_{i,T} + Capex_{i;T}}{(1+r)^t} + \frac{TV_{i,N}^{decarb}}{(1+r)^t}\right)}{V_{i,0}}$$

$\boldsymbol{E_{i,t} * p_{ETS2,t}}$:Annual operational carbon costs (OCC) derived from the building's emission profile and projected EU ETS 2 prices.
$\boldsymbol{R_{i,t}^{carb}}$: Rent based before decarbonization
$\boldsymbol{RC_{i,T}}$: Discounted Replacement Costs for a climate-neutral heating system (e.g., air-source heat pump) at the phase-out year *T*.

$\boldsymbol{Capex_{i;T}}$:(Median) Capital expenditures for mandatory building envelope retrofitting measures required to reach decarbonization targets.
$\boldsymbol{V_{i,0}}$: The initial (median) indexed market value of the asset as determined by the judicial appraisal.
$\boldsymbol{TV_{i,N}^{carb}}$: Terminal Value based on the carb rent before decarbonization.
$\boldsymbol{TV_{i,N}^{decarb}}$: Terminal Value based on the decarbed rent after decarbonization.

Fig. 1: Formula describing Climate Value at Risk (CVaR) and Climate Value at Opportunity (CVaO).

4 RESEARCH FINDINGS

4.1 Recognition of Climate Risks in the Valuation

Only 33% of all valuations included energy performance certificates toaccount for transition risks; the remaining did not take them into consideration, stating that the property's energy performance is to be expected based on the building's age or comparable buildings. Meanwhile, 61% identified physical climate risks through the HORA assessment (and others) during their evaluations. Further, about 60% of those who commissioned real estate appraisals were banks.

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4.2 Impact of Climate Value at Risk and Climate Value at Opportunity

The research confirms that properties with higher operational carbon intensity are more susceptible to negative price impacts, likely due to transitional climate risks. The simulation of the examined portfolio, based on Günther et al.'s pricing scenarios, suggests that the slow adoption of carbon reduction policies in some European countries – referred to as the "Weak Scenario" – could lead to a greater disparity in "Climate Risk at Value" for carbon-intensive properties, compared to those that are nearly or fully carbon neutral today.

		Gas < 2011		Gas >2011		Oil		Distric Heating		Elec		Biomass	
		IRR	Value	IRR	Value	IRR	Value	IRR	Value	IRR	Value	IRR	Value
Strong EP	$CVaR_i$	-0,84%	-7,75%	-0,89%	-8,27%	-1,97%	-17,23%	-0,04%	-0,37%	-0,06%	-0,40%	0,01%	-0,08%
	$CVaO_i$	0,42%	5,08%	3,65%	31,87%	4,84%	41,90%	0,23%	2,99%	1,62%	15,70%	1,81%	17,79%
Limited EP	$CVaR_i$	-1,00%	-9,00%	-0,98%	-9,02%	-2,42%	-20,46%	-0,07%	-0,65%	-0,13%	-0,87%	0,03%	-0,15%
	$CVaO_i$	0,28%	4,00%	3,58%	31,54%	4,68%	41,46%	0,20%	2,72%	1,57%	15,37%	1,82%	17,83%
WeakEP	$CVaR_i$	-1,12%	-9,90%	-1,05%	-9,54%	-2,80%	-22,69%	-0,10%	-0,85%	-0,20%	-1,19%	0,09%	-0,19%
	$CVaO_i$	0,16%	3,19%	3,52%	31,30%	4,50%	41,11%	0,18%	2,53%	1,54%	15,14%	1,82%	17,86%
Average	$CVaR_i$	-0,99%	-8,89%	-0,98%	-8,94%	-2,40%	-20,12%	-0,07%	-0,62%	-0,13%	-0,82%	0,04%	-0,14%
	$CVaO_i$	0,28%	4,09%	3,58%	31,57%	4,67%	41,49%	0,20%	2,75%	1,58%	15,40%	1,82%	17,83%

Table 2: Overview of the portfolio simulation under three ETS-2 scenarios

Transitional risks cause the simulated portfolio's cash flows and IRRs to decrease by 99 to 240 basis points, resulting in a CVaRi between -8, 89% and -20, 12% when compared to cash flow simulations that do not account for potential ETS2 and decarbonization costs. However, decarbonization also offers benefits. Particularly, the thermal refurbishment and upgrade of the heating system through the addition of a cooling system can bring rental levels closer to market rents. This reduces existing discounts on asset and rental prices, which might be viewed as brown or climate-related discounts.Not surprisingly, the CVaR-Upsides were also notable for the carbon-intensive assets, with a potential upside in value of up to 41, 49% identified in the analysed portfolio simulation.

5 CONCLUSION AND OUTLOOK

This study shows that, unlike physical climate risks, perceptions of transitional climate risks remain at a very early stage among real estate appraisers across Austria, and that the obvious benefit of carbon-neutral heating and cooling has not yet been realised. The potential qualitative Climate Value at Risk has yet to be discussed, as advised by organisationssuch as the ECB at the European level and the FMA in Austria, which are raising awareness. This creates uncertainty for investors, banks, and privatehomebuyers when making investment and lending decisions. The results of the quantitative analysis indicate that older properties in weaker real estate markets are more exposed, and that newer ones in stronger markets. Stakeholders should be aware of this fact when buying or lending in certain regions. However, an open dialogue among them is strongly recommended to foster a more holistic approach, especially as climate risks are expected to have stronger impacts on properties than in the past. To achieve a more complete understanding of this emerging topic, the study should be expanded to include a larger sample of valuations, including commercial properties, and future research should track developments toward a more comprehensive valuation approach in the context of climate change and evolving regulations.

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