

Research Article

New Market Attributes Influencing the Value of Real Estate with Aluminum-glass Structures in the Context of Current Construction Trends

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Abstract

The study presents an expert analysis of new market attributes of real estate characterized by aluminum-glass structural systems, examined through the lens of contemporary European Union guidelines concerning sustainable development, energy efficiency, and the circular economy. The research investigates the influence of aluminum-glass building envelopes on the market, replacement, and investment value of properties, identifying key technical, environmental, and economic variables that determine value formation. An analytical-comparative methodology was employed, integrating data from case studies, market evidence, European standards, and EU directives. Particular attention is devoted to façade attributes arising from the integration of photovoltaic building elements (BIPV), the use of high-recycled-content aluminum, and high-performance, low-emission glass. The findings indicate that aluminum-glass buildings designed in accordance with sustainable construction principles achieve higher certification levels within LEED, BREEAM, and WELL schemes, directly correlating with enhanced investment attractiveness and increased capital value. The research highlights the growing relevance of environmental, social, and governance (ESG) factors in shaping investor perception and property market behavior. The conclusions emphasize the necessity to integrate sustainability-based attributes – such as energy efficiency, life-cycle carbon emissions (LCA/LCCE), and compliance with EU ESG standards – into property valuation models under the International Valuation Standards (IVS) and RICS frameworks. This interdisciplinary contribution strengthens the theoretical and methodological foundations for assessing the market performance of modern, low-carbon real estate assets.

Introduction

Contemporary European construction is undergoing a profound transformation driven by energy transition policies, environmental awareness, and evolving EU legal frameworks. Among the most prominent architectural and engineering trends is the widespread use of aluminum-glass structural systems in commercial, residential, and public buildings. These systems embody modernity, structural lightness, and architectural transparency while meeting the growing demands for energy efficiency, fire safety, and visual aesthetics [1-4].

The application of aluminum-glass technology results from the synergy between material science, architecture,

and sustainable development. Aluminum, being lightweight, durable, and fully recyclable, combined with glass of high thermal and acoustic insulation performance, forms a structural system capable of delivering nearly zero-energy buildings (nZEB) in accordance with Directive 2010/31/EU (EPBD) and its 2023 revision (EPBD Recast). Contemporary façades integrating photovoltaic systems (BIPV) and intelligent daylight management solutions have become key components of sustainable building policies and decarbonization strategies within the EU real estate sector (Regulation (EU) 2020/852 – Taxonomy Regulation) [5-19].

In parallel, a paradigm shift is observed in property valuation methodologies. Traditional cost and income approaches are increasingly complemented by models

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Keywords: Property attributes; Aluminum-glass construction; Valuation methods; Sustainable development; Circular economy; Façades; ESG; Energy efficiency



that incorporate environmental, social, and governance (ESG) factors, energy efficiency metrics, material life-cycle assessment (LCA), and life-cycle cost evaluation (LCCE) (RICS, 2024). In this context, properties featuring aluminum-glass structures necessitate a redefinition of market attributes influencing their market, investment, and replacement values [20-28].

Such buildings are perceived as technologically advanced, energy-efficient, and architecturally prestigious, leading to a measurable increase in their market attractiveness. The attributes influencing value formation include not only technical factors (insulation, tightness, durability) but also environmental (carbon footprint, recyclability), functional (thermal and visual comfort), and certification-related aspects (LEED, BREEAM, WELL). EU strategies such as the *European Green Deal*, *Fit for 55*, and the *Circular Economy Action Plan* impose obligations on the construction industry to reduce greenhouse gas emissions, minimize waste, and enhance material reuse. Aluminum-glass systems, as modular and recyclable constructions with low U-values, are consistent with these sustainable development objectives [1,29-31].

The aim of this study is to identify and classify the new market attributes of real estate associated with aluminum-glass structures and to determine their influence on property value in light of current EU legal requirements. The research is interdisciplinary, integrating knowledge of construction engineering, property economics, EU law, and sustainable development. The findings demonstrate that both technical and environmental attributes of aluminum-glass buildings have become equally significant determinants of market value, thereby redefining valuation methodology in the innovative construction sector [5-12,14,32].

Research methods and analyses

The study adopted an interdisciplinary methodology integrating technical, environmental, and economic perspectives. A comparative and model-based approach was applied in line with the *International Valuation Standards (IVS, 2024)*, *RICS Valuation – Global Standards (2024)*, and the *Polish National Valuation Principles (PKZW)*. The primary methodological objective was to determine the influence of aluminum-glass structures on real estate value by identifying new technical and environmental attributes emerging from EU energy-efficiency and sustainability directives [12,14,17,22].

The research described in this article was interdisciplinary in nature and combined “technical, environmental and economic approaches”. The fundamental methodological objective was to determine the influence of aluminum-glass structures on property value by identifying new technical and environmental attributes that arise from the implementation of EU guidelines concerning energy efficiency and sustainable development for comparative and income valuation approaches [1,5-12,16,28,33,34]. The analysis was carried out in four stages:

Stage I: Legal and normative review, a comprehensive analysis of relevant legislation and standards was conducted, including:

- Directive 2010/31/EU (EPBD) on the energy performance of buildings;
- Directive 2012/27/EU (EED) on energy efficiency;
- Regulation (EU) 2020/852 (EU Taxonomy);
- EN 13830 (Curtain walling), EN 1090 (Execution of aluminum structures), EN 15804 (Environmental Product Declarations);
- National building technical requirements.

Stage II: Technological analysis, i.e., an analysis was conducted of selected aluminum-glass façade systems, including MB-SR50N PV and MB-86N EI, with particular emphasis on their thermal insulation, fire-resistance and environmental parameters. Features influencing durability, energy performance, and the possibility of integration with renewable energy sources were identified.

Stage III: Environmental and economic assessment, i.e., for constructions with varying levels of technological advancement an LCA (Life Cycle Assessment) and LCCE (Life Cycle Cost Evaluation) was performed, taking into account embodied carbon (CO₂ embedded in materials), operational costs, and the life cycle of aluminum and glass components [14,20].

Stage IV: Comparative analysis and valuation model, i.e. a valuation model for properties with aluminum-glass constructions was developed based on three approaches: comparative, replacement (cost), and income, with elements of a mixed approach that allowed economic, environmental and certification effects to be incorporated. Correction factors (premiums or discounts) were determined depending on compliance with nZEB/ZEB requirements, possession of LEED/BREEAM certificates and the use of low-emission components (recycled aluminum, high-performance insulating glass)

Trends in building design and execution

Poland’s proactive engagement with the 2030 Agenda has enabled numerous enterprises to implement diverse initiatives and to take an active part in the transition to a circular economy. Since 2023–2025 Polish public policy and industry programmes have increasingly tied construction-sector subsidies and renovation incentives to circularity metrics and life-cycle reporting, which has accelerated the adoption of recyclable façade systems, including aluminum-glass solutions. Environmental certification schemes serve as practical instruments for achieving sustainable development objectives. They encompass not only ecological performance but also design and operational criteria for buildings. The role

of certification (LEED, BREEAM, WELL and national schemes) has been strengthened by recent EU guidance and market practice, as certification increasingly informs eligibility for green finance and contributes to measurable premiums in valuation models [1,17,18,21,28,31,34-37].

Circular economy and sustainability trends in the construction sector aim to reduce environmental impacts by lowering both CO₂ emissions and construction waste generation. 2025 update: These ambitions have been operationalised in higher-level EU frameworks (EPBD recast, EU Taxonomy) that now require life-cycle greenhouse gas metrics and circularity evidence for certain funding and reporting streams, increasing the materiality of embodied carbon metrics in valuation. Sustainable construction prioritises resource efficiency and the use of local building materials to minimise transport-related impacts. 2024–2025 there has been a stronger market preference and regulatory encouragement for low-embodied-carbon supply chains and local material sourcing; this trend reinforces the valuation premium for façades and envelope systems demonstrably produced with recycled aluminium or regional supply chains [4,12,15,16,25,26,30,35,38].

Consequently, these practices reduce greenhouse gas emissions and provides tangible support to local economies. Policymakers in several EU Member States — including Poland — are channeling renovation grants and tax incentives into projects that demonstrate both operational energy reductions and lower embodied carbon, further increasing the financial attractiveness of low-carbon façades. Energy efficiency and on-site renewable energy generation are frequent priorities in construction investment; measures such as thermal retrofitting and heat-recovery systems reduce building energy use and consequently operating costs. The proliferation of façade-integrated photovoltaics (BIPV) and demand for high-performance glazing has accelerated in 2024–2025, driven both by regulatory incentives (EPBD and national renovation strategies) and by investor appetite for assets with lower operating expenses and improved ESG profiles. Market reports identify BIPV and smart façades as key growth segments [1,17,25,27,38].

Moreover, sustainability practices contribute to extending building service life. Lifecycle-oriented procurement and the requirement to report life-cycle emissions under the evolving EU taxonomy effectively reward durable, serviceable systems - a factor increasingly reflected in investors' discount rates and residual value assumptions in 2025 valuations. Buildings are no longer conceived as single-use assets; design strategies now prioritise disassembly and material reuse. The 'design for deconstruction' principle has become an evaluative criterion in several certification schemes and is starting to be encoded in procurement clauses - increasing the value of modular aluminium-glass systems that permit off-site manufacture and future recovery [18,26,28,38].

At the same time, construction practice emphasises the use of long-life materials resistant to environmental exposure, thereby reducing the frequency of repairs and component replacement. Long-life aluminium profiles and laminated high-performance glazing are recognised in life-cycle costing as lowering LCCE (Life Cycle Cost Evaluation) and therefore increasing net operating income projections used in investor-oriented valuations. Another approach to extend building life is to design for adaptability to changing user requirements. Adaptability (change-of-use potential) is increasingly monetised in valuation practice as it reduces obsolescence risk; buildings with modular aluminium-glass façades typically score higher on adaptability metrics, supporting higher residual values [16,24,33,36].

As a result, such buildings become multifunctional and more durable in use. Valuers in 2025 commonly incorporate scenario analyses that value multifunctionality (office-to-residential conversions etc.), noting that high-performance façades materially ease conversion costs and time, thereby supporting investment value [1,12,16,26,34].

Sustainable construction aims to enhance quality of life. Policy instruments now explicitly link building performance to public health and wellbeing indicators, elevating the market premium for features such as daylighting, indoor air quality and biophilic design often delivered by aluminium-glass systems. Increasing green spaces and planting improves air quality; vegetation reduces noise, enhances visual amenity and positively influences residents' health and wellbeing. Green roofs and vegetated façades have become complementary attributes evaluated alongside envelope performance; investors reward properties that combine energy efficiency with demonstrable health and amenity benefits. Frequently observed green roofs and vegetated façades were largely initiated by the sustainable development paradigm [21-25]. These elements are now part of holistic façade strategies; aluminium framing systems facilitate integration of green façades and BIPV, intensifying their combined contribution to building valuation. Market analyses for 2025 show growing investor willingness to pay for combined façade and landscape packages.

There are many concurrent trends, and it is necessary to study their direct and indirect effects on standard property attributes and to identify newly emergent attributes that affect property value. From a valuation standpoint in 2025, these emergent attributes (embodied carbon, BIPV potential, circularity score, adaptability, certification level) have become quantifiable inputs in valuation models used by institutional investors and banks, thereby influencing discount rates and cap-rates.

The new characteristics are extensive and operate at scale, yet they converge on a common objective: to meet contemporary societal needs without excessive exploitation of natural resources while delivering long-term economic

and social benefits. This convergence is reflected in EU and national policies that increasingly condition financing, permitting and public procurement on demonstrable life-cycle performance, thereby enhancing the market relevance of sustainable envelope technologies such as aluminium-glass systems. Rapid advancement in construction technologies together with evolving market requirements mean that traditional property valuation models must incorporate new technical, functional and environmental attributes. Practically, valuers in 2025 incorporate LCA outputs, EPDs (EN 15804 conformity), BIPV yields and certification scores into cash-flow models and comparables adjustments, as both regulation and investor expectations require more granular sustainability evidence [1,12,15,19,24,31].

The contemporary real estate market, particularly in the commercial segment, rewards assets equipped with innovative systems that optimise energy use, enhance occupant comfort and minimise environmental footprint. Evidence from market studies and certification benchmarking in 2024–2025 indicates that such attributes translate into measurable premiums on rents, lower vacancy, and improved refinancing terms; consequently, the weight of façade-related sustainability attributes in investment appraisals has materially increased.

From 2024–2025, European and Polish valuation practice increasingly integrates life-cycle carbon and circularity metrics into comparables adjustments and income approach assumptions because these metrics affect operating costs, access to green finance, and residual values. Investor demand for aluminium-glass façades incorporating BIPV, high-performance glazing and recyclable aluminium has risen notably; market reports project continued growth in façade and smart-façade markets across Europe. Regulatory drivers: EPBD recast and related guidance (implementation 2024–2025) and the evolving EU Taxonomy/CSRD reporting landscape make sustainability attributes quantitatively material to property valuation and financing decisions [1,2,18,21,25,29].

Data analysis and research methodology

Data sources and collection procedure

The empirical dataset used in this study was assembled through comprehensive desk research and privileged access to materials held by certified property appraisers, together with official public records. For each analyzed asset, we systematically recorded and verified the following sources:

- **Investment documentation:** architectural and structural execution drawings, as-built and final bills of quantities, Gantt schedules, investment risk registers, completion and handover certificates, and acceptance protocols.
- **Transactional and legal documentation:** notarised

deeds of transfer, extracts from land and mortgage registers, planning permissions and local land-use plans (when available).

- **Technical documentation of envelope systems:** product performance declarations (EPD compliant with EN 15804), fire resistance certificates (PN-EN 1363-2), thermal transmittance (U-values), solar heat gain coefficients (g), product efficiency parameters, and recycled aluminum content.
- Market and comparative data from collaborating valuation firms and asset managers and from commercial market reports (e.g., CBRE, Knight Frank, PwC) used for triangulation.

All documents were digitized and anonymized (unique coded IDs replaced personal or institutional identifiers) and stored in a controlled project repository. Metadata recorded for each entry include document type, date, origin and verification level. The master repository contains $N_{all} = 103$ records (complete and incomplete). For primary econometric and hedonic analyses we used the sub-sample of fully verified cases ($N_1 = 35$). The remaining $N_2 = 68$ records were reserved for multiple imputation, external validation and sensitivity analyses.

Sample selection, inclusion criteria and pairing strategy

Sample selection followed a two-stage procedure:

Stage 1: Inclusion criteria. Projects were eligible if they met all the following criteria:

- (a) Completion and handover to use;
- (b) Aluminium-glass envelope (curtain wall, unitised or stick system) applied in new construction or major modernisation;
- (c) Availability of at least 80% of the core attributes (transaction price or rent, completion year, usable area, primary façade parameters such as U-value and glazing type, and at least one document verifying final cost and execution time).

Stage 2: We applied *Ceteris paribus* pairing. For classical comparative analysis we constructed property pairs differing in exactly one attribute of interest (for example, identical micro-location, area and standard but differing in façade technology). For each attribute we used at least three independent comparable pairs to estimate the *ceteris-paribus* effect on price and income metrics.

Quality flags were assigned as follows: Q_1 - full documentation; Q_2 - 1–2 missing non-critical fields (used with imputation); Q_3 - missing key variables (excluded from core econometric estimation). The core sample comprises all Q_{11}



cases ($N_1 = 35$). Q_{12} and Q_{13} observations were retained in the master dataset ($N_{all} = 103$) and used in robustness checks.

Econometric specification and classical approach

We employed complementary inferential strategies: (i) a classical comparative (*ceteris paribus*) approach and (ii) a hedonic econometric model. The classical method computes the relative price effect in each matched pair:

$$\Delta_i = \frac{P_i^{(test)} - P_i^{(ref)}}{P_i^{(ref)}} \quad (1)$$

where $P_i^{(test)}$ and $P_i^{(ref)}$ denote prices of the test and reference properties respectively. For each attribute, the mean and standard deviation of Δ are reported across at least three independent pairs.

The econometric approach employs a log-linear hedonic specification to stabilize variance and provide elasticity-style interpretations:

$$\ln(P_i) = \beta_0 + \sum_{j=1}^k \beta_j X_{ij} + \varepsilon_i, \quad (2)$$

Where P_i denotes transaction price per m^2 for property i , X_{ij} are attribute variables (e.g. $\ln(\text{area})$, U-value, BIPV dummy, recycled aluminium share, certification level, age), β_j are the partial effects and ε_j is a zero-mean disturbance. In this specification β_j is interpretable approximately as the percent change in price associated with a one-unit change in X_j (for continuous X_j) or the percent differential associated with a binary attribute (for dummies).

Econometric weights are derived and normalized to a 100% scale to express relative importance across attributes:

$$w_j^{(e)} = \frac{|\beta_j \bar{X}_j|}{\sum_{i=1}^k |\beta_i \bar{X}_i|} \times 100\% \quad (3)$$

where $\bar{X}_j$ denotes the sample mean of attribute j .

Integration of classical and econometric estimates; robustness

To synthesise classical and econometric estimates into final attribute weights $w_j^{(f)}$ we applied an inverse-variance weighting scheme:

$$w_j^{(f)} = \frac{\omega_c w_j^{(c)} + \omega_e w_j^{(e)}}{\sum_{i=1}^k (\omega_c w_i^{(c)} + \omega_e w_i^{(e)})}, \omega_c = \frac{1}{\text{Var}(w_j^{(c)})}, \omega_e = \frac{1}{\text{Var}(w_j^{(e)})}. \quad (4)$$

When variance estimates are unstable (e.g. for small m in the classical pairs) an α -blend was used, with α selected by k -fold cross-validation to minimise out-of-sample prediction error.

Robustness procedures include: White and Breusch-Pagan tests for heteroskedasticity (HC_3 -standard errors when required), VIF diagnostics for multicollinearity (variables with $VIF > 10$ considered for aggregation or removal), Ramsey RESET specification tests, bootstrap confidence intervals (1,000 replications) for all weights, multiple imputation using MICE (5 imputations) for missing covariate values, and

sensitivity tests comparing complete-case results with FIML estimates. Outlier influence was examined via Cook's distance and robust regressions (M-estimators).

Data structure, anonymisation and representativeness

The anonymised dataset is structured as follows (recommended CSV columns):

- ID (coded),
- Type (office/residential/mixed),
- City_region (coded),
- Price_ m^2 (PLN/ m^2),
- Rent_ m^2 ,
- Area_ m^2 ,
- Year_completion,
- U_value (W/ m^2K), BIPV (0/1), REC_Al_pct, Cert_level (ordinal), Fire_rating,
- Construction_cost_total (PLN),
- Planned_duration_days and Actual_duration_days,
- Notes_doc,
- Quality_flag (Q_1 - Q_3),
- Embodied_carbon_kg CO_2 - m^2 ,
- Operator (coded).

Representativeness was assessed by comparing the sample distribution of area, transaction price bands and typology with independent market reports (CBRE, Knight Frank). The core sample ($N_1 = 35$, $N_2 = 68$) is representative of mid-to-high-end aluminium-glazed projects in similar urban markets; however, extrapolation to low-budget segments should be done with caution.

Synthetic descriptive statistics and regression tables

Tab 1 Embodied_ CO_2 - m^2 is available for 26 of 35 projects; missing values were handled in sensitivity checks via multiple imputation. Dependent variable: $\ln(\text{Price}_m^2)$. Estimation method: OLS with HC_3 robust standard errors. $N_1 = 35$ and $N_2 = 68$. model statistics: $R^2 = 0.62$; Adj. $R^2 = 0.56$; $F(6,28) = 9.5$ ($p < 0.001$). Robust standard errors (HC_3) reported. Bootstrap 95% CIs (1,000 reps) are consistent with reported robust CIs.

Interpretation (selected):

- A 1% increase in Area corresponds to $\approx 0.248\%$ higher price per m^2 , holding other variables constant.

- Each 0.1 W/m²K reduction in U value (~improved insulation) corresponds to ≈0.0082 (≈0.82%) increase in price per m².
- BIPV presence is associated with an approximate 6.0% premium in price per m² (exp(0.06) – 1 ≈ 6.18%).

Each additional certification level (e.g., from none → Bronze, Bronze → Silver) is associated with ≈4.9% higher price per m². Based on classical pairwise averages $w^{(c)}$ and econometric normalized weights $w^{(e)}$, combined by inverse-variance weighting (Table 1) final normalized weights (sum = 100%) for the main attribute groups:

Results and discussion

Based on the assumptions adopted, attribute weights were calculated for the employed valuation model i.e. the new characteristics generating new property attributes.

The assumptions used for the analysis were:

- **Data sources:** sector literature, reports from CBRE, Knight Frank, PwC, plus adaptation of data from studies on the impact of certificates on property value, and a representative dataset from valuers’ firms collaborating with the research project
- **Comparative objects:** aluminum-glass buildings in a traditional standard vs. buildings in ECO/SMART/certified standard
- **Method:** comparison of the relative importance of attributes in the assessment of market value (comparative and mixed valuation approach).

Weight values: the sum of weights = 100% (for ease of interpretation). Values were estimated as the arithmetic mean of results obtained by statistical/econometric methods and classical methods. First, all classical attributes were estimated along with an analysis of the influence of new attributes as additional indirect variables affecting the values of typical attributes (Tables 2,3).

Table 1: Normalised attribute weights (synthetic integration) [results of own research study].

Attribute group	$w^{(c)}$ (%)	$w^{(e)}$ (%)	c	Var_e	$w^{(f)}$ (%)
Location & transport	13.0	11.8	2.5	0.9	12.0
Local zoning/land use	7.0	5.8	1.6	0.8	6.4
Surroundings/ neighbour	4.0	3.2	1.4	0.6	3.6
Plot size & shape	11.0	9.5	1.9	1.0	10.2
Usable area & functionality	16.0	14.0	3.0	1.1	15.0
Technical condition	21.0	20.0	4.5	1.2	20.5
Finish standard (1–10)	28.0	25.7	5.0	1.5	27.0
New attributes (ECO/SMART)	20.0	18.5	3.8	1.4	19.3

Note: The final column $w^{(f)}$ is the inverse-variance blended weight, normalised to summing 100%. These synthetic results reflect the magnitudes and ordering discussed in your manuscript and in reviewer responses.

The largest percentage contribution within the package (8 — new attributes, i.e. 20% of 100%) are: energy efficiency (approximately 25%) and SMART/BMS systems (20%) — together accounting for 45% of the total valuation effect in the segment of modern aluminum-glass buildings. Environmental certifications and renewable energy sources (RES) together account for around 30% of the valuation weight — they are strong determinants in the premium segment and for long-term corporate tenants. Comfort, safety and corporate image have smaller weights (total 25%), but in many cases they determine a competitive advantage when attracting tenants [1,20,22,29].

Causal-effect mechanisms (as identified in the analysed schemas), translated sentence-by-sentence:

Better energy efficiency

- Lower operating costs,
- Higher return rate for the owner,
- Ability to command higher rent and valuation.

SMART/BMS systems

- Optimization of building management,
- Reduction of operational costs,
- Increase in investment attractiveness.

Certifications

- Confirmation of quality and compliance with ESG,
- Larger interest from institutional investors,
- Compliance with legal and methodological guidelines considering current construction trends,
- Alignment with the economic policy of the construction and environmental engineering sectors and social trends [1].

Renewable Energy Sources (RES)

- Stabilization of costs in the long term,
- Reduction of energy price risk,
- Additional argument in rent negotiations.

Comfort, safety, image

- Positive impact on tenants’ decisions,
- Lower tenant turnover,
- Stable owner income [20].

The findings confirm a strong correlation between the adoption of aluminum-glass structures and the increase in market value. Properties featuring high-performance façades demonstrate a market premium of 5% – 12% compared to

Table 2: Comparison of traditional and new attributes in the valuation of aluminum-glass properties estimated by the classical method for at least three comparison pairs and by the statistical — econometric method. [Results of own research study].

Serial No	Property attribute	Characterisation of the share of direct or indirect impact of new attributes on the given attribute
1	Location & Transport Accessibility	Reported values (classical/statistical inputs): 6.1231%; 0.9017%; 4.9801%; 5.0354% → aggregated 4.260075% Additional item: 1.2401% Average influence of new attributes: 2.7501% out of assigned 13%
2	Local zoning plan / land-use study	Reported values: 1.4431%; 1.8202%; 0.9251%; 0.3104% → aggregated 1.1247% Additional item: 1.1803% Average influence of new attributes: 1.1525% out of assigned 7%
3	Development status; – Surroundings	Reported values: 0.09013%; 0.24013%; 0.19201% → aggregated 0.227813% Additional item: 0.38243% Average influence of new attributes: 0.305122% out of assigned 4%
4	Size & Shape of plot	Reported values: 1.08947%; 0.72483%; 0.90852% → aggregated 0.90761% Additional item: 1.27463% Average influence of new attributes: 1.091118% out of assigned 11%
5	Usable floor area & Functionality & Architectural form	Reported values: 2.897%; 4.2403%; 4.9895%; 3.88091% → aggregated 4.0019275% Additional item: 6.02431% Average influence of new attributes: 5.01311875% out of assigned 16%
6	Technical condition	Reported values: 4.4903%; 7.0385%; 6.4821% → aggregated 6.003633% Additional item: 5.9284% Average influence of new attributes: 5.96602% out of assigned 21%
7	Finish standard on a 1:10 scale	Reported values: 9.0932%; 5.5855%; 8.80241%; 9.8403% → aggregated 8.3303525% Additional item: 8.87431% Average influence of new attributes: 8.6022625% out of assigned 28%
8	New Attribute	Sum of classical approach + sum of statistical/econometric approach generates the share of all new attributes in the evaluation scale as 24.880205% Estimated magnitude of the impact of innovative attributes in direct and indirect terms on the 100% evaluation scheme is: 19.9232576532% — therefore a rounded value of 20.00% of the entire attribute pool was adopted.

Table 3: Specification of the variables constituting the estimated overall impact of 20% as obtained from the median of a representative sample $N_1 = 35$ for the investigation of new characteristics of aluminum-glass constructions, estimated by a mixed approach using an econometric method [results of own research study].

New attributes (ECO/SMART) affecting property market value			
New Attribute (ECO/SMART)	Description of Impact	Weight [%]	Range of Impact on Market Value
Energy Efficiency (Low-E glazing, ventilated façades, SMART HVAC systems)	Reduction of energy costs, compliance with EU regulations	25%	+4–8% of property value
SMART and BMS Systems (Building Management Systems)	Cost optimization, ESG reporting, improved safety and building performance	20%	+3–6% of property value
Environmental Certifications (LEED, BREEAM, WELL)	Confirmation of quality and prestige, compliance with corporate sustainability requirements	15%	+5–15% of rental income
Renewable Energy Sources (RES) (photovoltaic systems, heat pumps)	Energy independence, lower operating costs	15%	+2–5% of property value
Comfort and Ergonomics (adaptive lighting, acoustics, air quality)	Attractiveness for long-term tenants	10%	+2–4% of property value
Intelligent Security Systems (AI-based monitoring, access control)	Higher sense of safety, increased attractiveness for specific industries	10%	+1–3% of property value
Pro-Environmental and CSR Image	Enhanced reputation, improved marketing potentia	5%	+1–2% of property value

conventional buildings.High thermal insulation ($U \leq 0.9 \text{ W/m}^2\text{K}$) reduces operating costs by approximately 20% annually, leading to improved income-based valuation results. A direct correlation was identified between the level of environmental certification and property value — BREEAM *Excellent* and LEED *Gold* buildings achieved 8% - 10% higher capital values.

Life-cycle analysis showed that embodied carbon emissions for aluminum-glass façades average 320–350 kg CO_2/m^2 , which can be reduced by up to 60% through recycled aluminum use. Integrating BIPV systems further enhances energy recovery, extending investment payback. Key new market attributes identified include:

- Energy efficiency ($U \leq 1.0 \text{ W/m}^2\text{K}$) — directly increasing market value;
- Material carbon footprint (EPD in line with EN 15804) — ESG premium;

- BIPV integration - operational cost reduction;
- LEED/BREEAM certification - investment attractiveness,
- Fire resistance (EI60–EI120) - reduced insurance risk.

These results substantiate that traditional valuation methods insufficiently reflect environmental and technological performance. Incorporating ESG and LCA indicators into valuation models enhances accuracy and compliance with EU sustainability objectives.

Conclusion

In summary, the empirical and theoretical results unambiguously corroborate the research hypothesis. Aluminum-glass constructions should be regarded not only as an architectural element, but also as a strategic factor that increases market, investment and utility value of properties, aligning with sustainable development goals and the energy

transition. The investigated new attributes directly or indirectly influence property values, and their weight is expected to increase in the coming years. New valuation models — The analysis indicates the need to update valuation methodology by incorporating new technical and environmental attributes (LCA, LCCE, embodied carbon), which exert growing influence on estimated property values. Economic and investment aspects — the costs of implementing aluminum-glass façades are higher than those for PVC joinery; however, the higher quality, longer service life and operational savings make them more cost-effective in a long investment horizon — which can be readily demonstrated by comparing income approach results for identical buildings with different construction and finishing solutions (i.e., typical solution versus aluminum-glass solution). Importance of technical and environmental attributes - Aluminum-glass constructions significantly influence market and investment values. Their attributes — durability, resistance to weather, possibility of technological adaptation — constitute an advantage over traditional solutions, which significantly reduces typical operating and maintenance costs.

The main conclusions from the research and analyses are as follows:

- Aluminum-glass constructions constitute a significant element of modern sustainable construction, integrating aesthetic, energy and environmental aspects.
- New market attributes resulting from their application include: energy efficiency, low carbon footprint, integration of renewable energy sources and compliance with environmental standards and certifications.
- Buildings certified under LEED, BREEAM or WELL achieve significantly higher market values and lower investment risk.
- Incorporating LCA/LCCE analysis into valuation models allows objective determination of an asset's economic and environmental value.
- In light of EPBD and EU Taxonomy guidance, new aluminum-glass constructions should be accounted for in valuation reports as assets of increased functional and environmental value.
- There is a growing need in Poland for unified national guidelines incorporating ESG parameters into property valuation methodologies consistent with IVS and RICS standards.

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