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Towards an integrative approach for ecodesign principles and sustainable material selection. A systematic literature review to explore scholarly contributions at the intersection of materials, sustainable design and household appliances

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Abstract: Through a systematic literature review the scholarly contributions at the intersection of ecodesign, sustainable material selection, and the household appliance sector are explored. A comprehensive search was conducted on the Scopus database, yielding 181 initial results, which were narrowed down to 52 relevant documents for in-depth analysis. Notably, the review revealed a growing research interest in these areas, particularly since 2015, reflecting broader industry trends towards circular and sustainable production models. Key findings include the identification of eco-innovation drivers, approaches for sustainable product design and assessment, and the importance of validating research outcomes through real-world case studies. The analysis also pointed out an evolution in sustainable design strategies and material selection focus, shifting from sole materials recycling towards durability, repair and life-extension. Some overarching themes emerged across the reviewed documents, including the application of Life-Cycle-Thinking approaches together with LCA-based methods and a general push to foster the implementation of ecodesign strategies in early design phases to maximize their effectiveness. The review also allowed to identify and visualize a network of scholars focused on appliance-related research works. A significant finding is the relative scarcity of research that effectively aim at integrating ecodesign and material selection specifically for the appliance industry.

Introduction

Sustainable development and transition towards circular economy require a synergistic action of multiple actors such as governments, local authorities, companies, practitioners and consumers. For this reason, bridging academic knowledge and business realities can be a win-win opportunity: on one hand, it allows companies to gain innovative and long-termed insights from privileged observers into research issues; on the other hand, allows universities to become aware of real-world challenges that industries must face. To foster the creation of such bridges, the Italian Ministry of University and Research (MUR) has co-financed – together with Italian companies – innovative PhD scholarships framed within the National Recovery and Resilience Plan initiative "From research to business" to relaunch the Italian economy after the COVID-19 pandemic (MUR, 2023). One of these doctoral scholarships in Design entitled "*Towards a New Approach for a Holistic Integration of Sustainable Material Selection and Ecodesign in an Appliances Company*" was initiated by Politecnico di Milano together with the Italian cooking and washing appliances manufacturer Smeg S.p.A.

The rationale in which the research is rooted is the will to define a comprehensive approach to holistically integrate sustainable use of materials with Design for Sustainability-related strategies for household appliances projects to be applied within the Italian context. The proposed approach will address design innovation across multiple scales, ranging from the product and material lifecycle (ecodesign) to more comprehensive approaches (systemic design). This multi-tiered innovation strategy is guided by two key elements: design strategies that promote sustainability and circularity, and established material selection methods and tools, with a particular focus on environmental

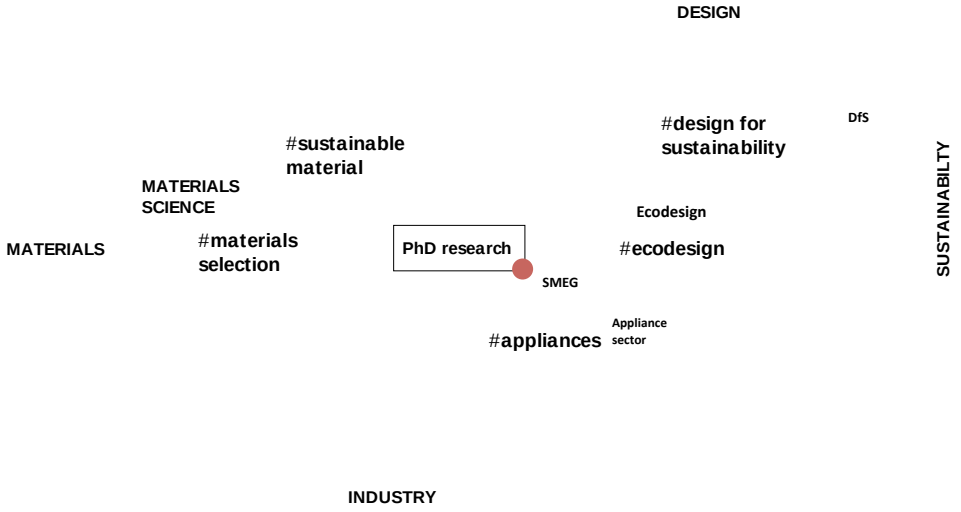

Figure 1. PhD research areas.

materials characteristics. Furthermore, the household appliance sector, with its regulatory landscape and industry-specific features, is taken into account to ensure the practical applicability and transferability of the research outcomes. Figure 1 depicts the three overlapping areas and disciplines involved in the PhD research: product design, materials and the household appliances industry with sustainability that runs across them all. Thus, the final aim of the doctoral research will be the harmonic integration of ecodesign principles into material selection for household appliances companies. Referring to broader sustainability theories, the PhD research primarily focuses on the "Product and Material" dimensions of the organizational circular economy (Uhrenholt, J. N. et al., 2022). Dialogue with companies in the development of doctoral theses in Design has been common practice at Politecnico di Milano for some years now and has always proven to foster better grounding of research results and to inform research based on concrete case studies (Italia, M., 2024; Papile, F., 2022; Piselli, A., 2018).

The content of this contribution concerns a systematic literature review in which the areas of design for sustainability (especially focused on the ecodesign approach) and material selection have been correlated with the appliance sector to map the existing network of scholars and types of contributions, useful to inform the abovementioned PhD research. This was done to identify possible convergences between sustainable and circular design strategies (Bakker, C. A. et al., 2014; Bhamra, T., & Lofthouse, V., 2016; Bocken, N. M. et al., 2016; Clark, G. et al., 2009; Vezzoli, C. & Manzini, E., 2008) and material selection (Ashby, M. F., 2022; Ashby, M. F., 2012; Ashby, M. F., & Johnson, K., 2013), as both these very broad fields individually show a vast corpus of specific literature.

A final introductory clarification is necessary: although in recent years Design for Sustainability (DfS) approaches have evolved both in scope (form the sole product to socio-technical system) and in the breadth of design problem framing (from technocentric to human-centric) (Ceschin, F., & Gaziulusoy, İ., 2019), 'ecodesign' was selected as keyword for two main reasons: sustainability in the household appliances sector in Italy is still strongly related to product and material lifecycles addressed by ecodesign; secondly, selecting keywords related to other DfS approaches, no relevant results were returned.
However, the approach resulting from the doctoral research will reflect the holistic evolution that has characterized 'Design for X' – where 'X' stands for several design approaches – in recent years (Moreno, M. et al.,

Query string	Limits	Records
TITLE-ABS-KEY (("design for sustainability") AND (appliance OR "domestic appliance" OR "home appliance" OR "household appliance"))	Years: 2004-2024 Langauage: English, Italian	2
TITLE-ABS-KEY ((ecodesign OR eco-design) AND (appliance OR "domestic appliance" OR "home appliance" OR "household appliance"))	Years: 2004-2024 Langauage: English, Italian	142
TITLE-ABS-KEY (("material selection") AND (appliance OR "domestic appliance" OR "home appliance" OR "household appliance"))	Years: 2004-2024 Langauage: English, Italian	32
TITLE-ABS-KEY (("sustainable material") AND (appliance OR "domestic appliance" OR "home appliance" OR "household appliance"))	Years: 2004-2024 Langauage: English, Italian	13

TITLE-ABS-KEY ((Appliance OR "domestic appliance" OR "home appliance" OR "household appliance") AND ("design for sustainability" OR ecodesign OR eco-design OR "material selection" OR "sustainable material"))

Figure 2. Scopus query string.

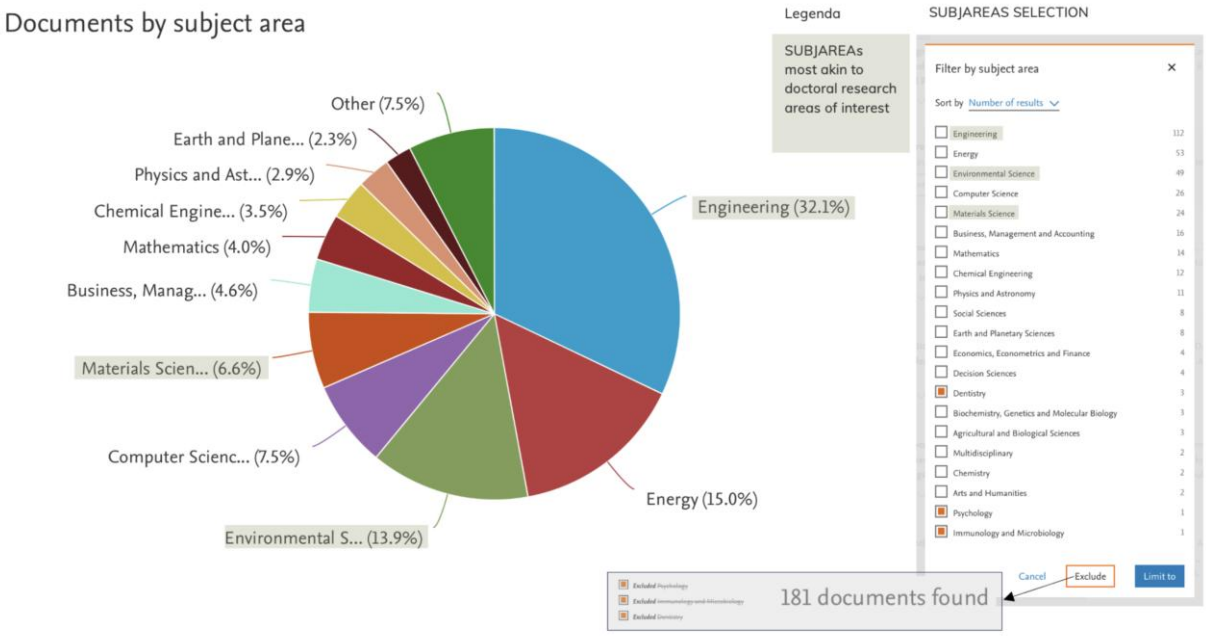

Figure 3. Subject areas exclusion limits and documents distribution.

2016), considering the relevance and importance of the further implications that go beyond the sole product level. In fact, holistic approaches seems to have the potential to pave the way to a wiser and more efficient use of materials (Allwood, J., 2011) for product design and for the implementation of circular economy principles (Bompan, E. & Brambilla, I., 2016).

Methods

Since the protocol adopted for conducting the literature review uses some items from PRISMA statement (Page, M. J. et al., 2021), but doesn't adopt it in full, the various steps followed will be described in detail to ensure maximum methodological transparency.

The review was conducted on Scopus database and the results are updated to June 2024.

To define the search string, four keywords were selected, two related to the design discipline (i.e. design for sustainability, ecodesign) and two related to the materials field (i.e. material selection, sustainable material). In order not to miss results, when necessary, keywords were associated with their synonyms through the Boolean logic operator 'OR'. The four keywords were then associated with the household appliances domain through the logical conjunction operator 'AND'. A search was then launched on the Scopus database to retrieve documents containing the required keywords combination within the article title, abstract or keywords; two further limits were also applied to the research results regarding the year of publication (2004-2024) and the language of the documents (English and Italian). Figure 2 summarizes the steps described above to shape the query string used to launch the advanced search on Scopus; in addition, the number of records for each keywords combination is also provided in the figure.

In order to narrow down the search results, an exclusion limit was applied to subject areas: dentistry, psychology, immunology and microbiology were thus excluded (Fig. 3). After some iterative verifications, based on records titles and keywords, it has been decided not to exclude certain disciplinary areas – such as computer science – distant from the main topics of interest of the doctoral research (Fig. 1) since they output relevant results (based on a preliminary screening carried out on the contribution titles).

The search, with these filters set, yielded 181 resulting documents. Figure 3 illustrates the distribution of records in the various subject areas: even if Scopus doesn't have subject area dedicated to design, others that returned the highest number of records are related to the areas of interest of the doctoral research: engineering (112), environmental science (49) and material science (24).

Afterwards, the 181 records were screened by title and abstract reading. Downstream this skimming process 52 documents were assessed for eligibility, 29 were left apart for further future information due to their minor relevance and 100 were discarded.

The following tools were used for data processing: OpenRefine for data extraction and refinement; Microsoft Excel for data systematisation; and RawGraphs for results visualization.

Findings and discussion

Table 1 in the Appendix provides key information on the 52 documents selected for analysis: contained search keyword(s); author(s); document title; publication year; author(s)'s keywords.

A first notable aspect to highlight is the substantial disparity between the results derived from the different keywords: in fact, 43 out of 52 of the eligible documents were retrieved since they contained the keyword 'ecodesign'; this is due to the fact that ecodesign is widespread in almost any project-based discipline (e.g. product design, packaging design, interior design, fashion and textile design, graphic design and visual communication, architecture and construction, urban planning and landscape architecture, industrial and manufacturing engineering, electronics and technology) to indicate design strategies that take sustainability-related criteria into account. At the same time, 'ecodesign' is a widely used term in standards and legislative acts, such as the Ecodesign for Sustainable Products Regulation (ESPR), which entered into force in July 2024 and will be

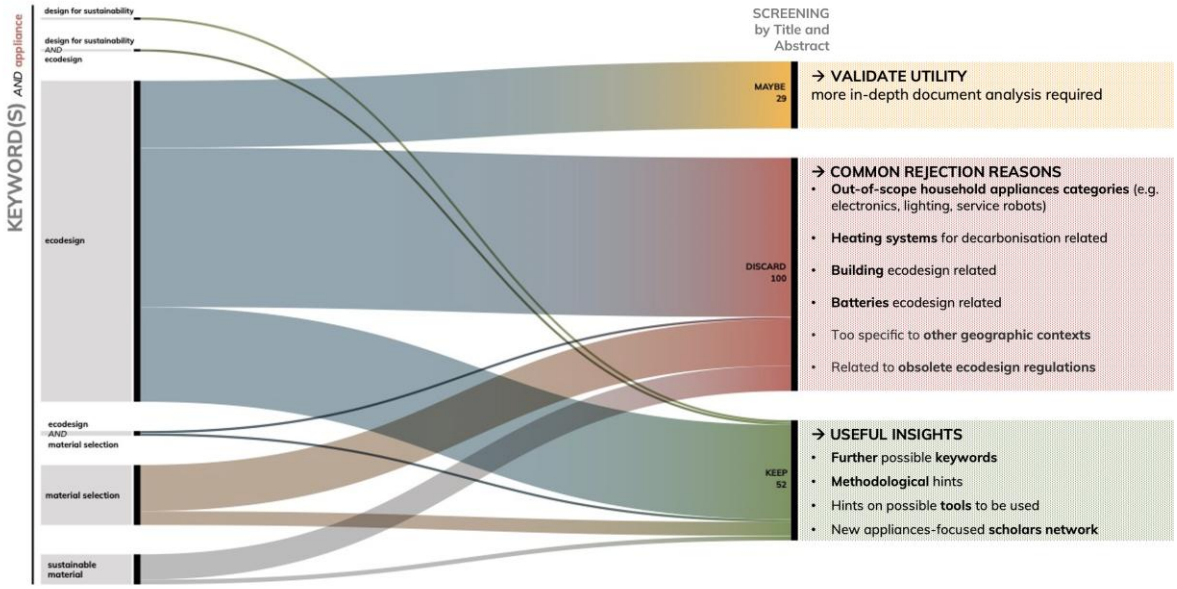

Figure 4. Rejection reasons and useful insights

the cornerstone of the European Commission's approach to more environmentally sustainable and circular products (European Commission, 2023). This interdisciplinary nature and the wide-ranging applications of the term 'ecodesign' make it an excellent umbrella term but, at the same time, it may produce many results outside the scope of a specific research. In contrast, the term 'material selection', is much more vertical and mainly used in the field of engineering and product design (Ashby, M. F., 2005) and it output fewer research results (7).

In this regard, an interesting exercise has been to analyze the reasons that led to the exclusion of several documents in the screening phase, many of which are precisely related to the broadness of the term ecodesign (Fig. 4).

Firstly, some papers were excluded because they focused on the ecodesign of artefacts not relevant to the doctoral research (e.g. building, batteries, heating systems); others, although more focused on industrial product design, involved appliances outside the cooking and washing scope. A further reason for exclusion concerned a geographical issue: some papers in fact concerned issues closely related to specific contexts (e.g. Asian) that are not consistent for the Italian one on which the doctoral research is focused. Finally, given the use of the term 'ecodesign' in legislative acts, several excluded documents addressed design issues aimed at ensuring compliance with regulations or standards that are now obsolete or replaced by updated versions.

In Figure 5, the distribution of documents over time is plotted. This timeline clearly visualizes and increasing research interest on topics related to ecodesign and sustainable material selection for appliances. In particular, the growth is more pronounced from 2015 onwards, and this is consistent with the results of other reviews on adjacent topics (Rotondo, B., & Arquilla, V., 2024). This result also reflect a more general trend towards the uptake of more circular and sustainable models in various industries (Bocken, N. M. et al., 2016; Ellen MacArthur Foundation, 2015; Pigosso, D .C. A. et al., 2013) and a materials landscape increasingly rich in new sustainability-oriented solutions and attentive to eco-informed selection (Genovesi, E., & Pellizzari A., 2021; Italia, M. et al., 2023; Papile, F. et al., 2020; Poblete, S. S. D. et al., 2024).

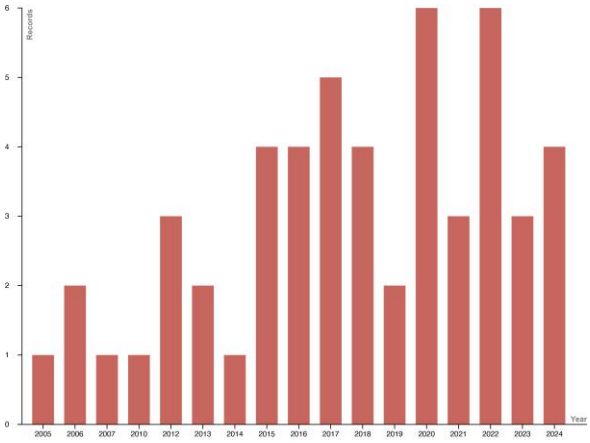

Figure 5. Distribution of documents by publication year

Insights from selected documents review

The documents selected for analysis offered several useful insights including further possible search keywords, hints on ecodesign methods and tools and material selection strategies.

Below, the main insights derived from the in-depth analysis of the documents are reported and discussed.

• *Eco innovation drivers*
Many authors have pointed out which drivers in the appliances sector give momentum to the sustainable transition. There are mainly two forces, one from the top down, and one from the bottom up: the first is connected to regulations imposing requirements for sustainable design, circular use of resources and proper end-of-life management; the second one is the ever-increasing consumers demand for responsibly designed products (Papetti, A. et al., 2017; Ardente, F. et al., 2015; Dostatni, E. et. al., 2015b; Karagiannopoulos, P.S. et al., 2024; Landi, D. et al., 2016; Kara, S. et al., 2006).

• *Approaches and tools for (re)design and assessment*
Common outcomes of appliance-related applied research consist in approaches or tools aimed at enabling more circular or sustainable (re)design of existing and/or new products; or tools aimed at obtaining environmental assessment of such products. Often, these research works make use of digital tools (e.g. virtual prototyping) and aim – whenever possible – to be interoperable with the design tools used in industry (e.g. CAD, CAE, CFD, FEM, etc.) (Germani, M. et al., 2015; Dudkowiak, A. et al., 2021; Favi, C. et al., 2018; Peters, H. A., et al., 2012; Kara, S. et al., 2006; Germani, M. et al., 2013).

• *Validation on real cases*
A recurring aspect is that the abovementioned approaches or tools that are developed in research undergo a validation process through applicability tests in firms or pilot projects (Germani, M. et al., 2015; Papetti, A. et al., 2017; Landi, D., & Cicconi, P., 2022; Favi, C. et al., 2018; Piselli, A. et al., 2016).

• *Guidelines extraction*
Furthermore, it is often the case that the main takeaways derived from applied research activities, case study tests and literature reviews are then translated into guidelines or other forms knowledge base to foster eco-informed design and materials choices (Favi, C., et al., 2024; Zong, J. et al., 2019; Rodríguez, N. B., & Favi, C., 2022; Rodríguez, N. B., et al., 2023; Favi, C., et al., 2016; Peters, H. A., et al., 2012).

• *Household appliances and packaging*
The analyzed papers, in most cases, focus on large or small cooking or washing appliances (dishwashers, extractor hoods, hobs, electric kettles, etc.). However, in some cases, packaging becomes the subject of research, since acting on the materials that constitute the packaging systems and ensuring their proper management, it is possible to reduce the overall impacts associated with the household appliance itself (Landi, D., & Cicconi, P., 2022; Postacchini, L., et al., 2021; Landi, D., et al., 2020)

• *Consumers behavior*
An assumption underlying some of the documents analyzed concerns the recognition of the key influence of consumer behavior on sustainability and the importance of working on it through Design for Sustainable Behaviour-related interventions (Withanage, C., et al., 2016). Household appliance usage patterns, as well as food habits and diets (Favi, C., et al., 2020), can greatly influence the related impacts. Therefore, if design takes the user into

consideration, it is possible to reduce the impacts related to the use phase by increasing energy efficiency (Boyano, A., et al., 2020) and to evaluate different end-of-life options (Pérez-Belis, V. et al., 2017).

• *Design for X*
In recent years, we witnessed a product development process with an increasingly holistic approach, able to consider multiple aspects of the product in design decisions and capable of integrating circularity and sustainability issues. This resulted in the development of several 'Design for X' (DfX) techniques (Holt, R., & Barnes, C., 2010), each one with a specific focus and many aimed at fostering more sustainable design choices (e.g. Design for Remanufacturing, etc.). As evidence of this trend, several DfX strategies are implicitly or explicitly referred to in the reviewed documents. The most cited are Design for Assembly, Design for Energy Efficiency, Design for Disassembly and Design for Repair (Rodríguez, N. B., & Favi, C., 2022; Bracquené, E., et al., 2021; Favi, C. et al., 2018; Postacchini, L., et al., 2021; Wichniarek, R. et. al., 2018; Favi, C., & Germani, M., 2012; Collado-Ruiz, D., et al., 2007). In particular, with respect to the last mentioned strategy, some papers (Rodríguez, N. B., et al., 2023; Boix Rodríguez, N., & Favi, C., 2022) also refer to possible metrics to measure repairability – the so-called 'repairabilty index' – a very topical issue given the recent European debate around the 'Right to Repair' legislation aimed at making repair easier and more appealing to consumers (European Parliament, 2024). In general, especially in more recent documents, the trend is towards strategies to favor reuse, upgrading, repair and product life extension.

• *Material selection*
Analyzing material selection-focused documents, it can be observed that in older records reference is made mainly to materials recycling (Peters, H. A., et al., 2012; Luttropp, C. et al., 2010; Johansson, J., & Luttropp, C., 2006). In more recent papers, the focus shifts to durability and longevity (Bakırlıoğlu, Y., & Doğan, Ç., 2020) which are recognized as preferable solutions to recycling. Other issues related to sustainability in the use of materials for appliances are the following: importance of incorporating eco-properties in material selection (Guo, A. H., 2014); crucial role of material selection to ensure durability, considering requirements such as heat (Kaushik, D., et al., 2024) and chemical resistance (Basso, M. et al., 2017); and evaluating alternative material solutions to those already in use ('material replacement') (Piselli, A. et al., 2018; Anjumol, K. S. et al., 2022). Finally, Skorup, D. (2022) study demonstrates the impact that material selection can have on environmental impact through Life-Cycle-Assesment (LCA) studies.

As a concluding remark of this section, two aspects appear in most of the documents: the widespread application of Life-Cycle-Thinking (LCT) approach supported by Life Cycle Assessment method; and the will to implement ecodesign strategies since the early design phases to maximize the impact reduction.

Appliances-focused scholars

By extrapolating data on authors and co-authors of the selected articles, it was also possible to map a network of appliances-focused scholars.

Figure 6 offers a comprehensive view of authors and co-authors of the documents that passed the screening phase. Based on the results, it is possible to highlight scholars who authored or co-authored more contributions. In ecodesign-related publications the most prolific are Germani M. (15 records), Favi C. (14), Dostatni E. (9), Landi D. (8), Cicconi P. (7), Grajewski D. (7). Notably, can be noticed a co-authorship on multiple contribution (Tab. 1) by Germani, Favi, Landi and Cicconi, affiliated to different Italian research institutions (respectively UNIVPM, UniPr, UniBg and UNIVPM).

Regarding material selection, the main authors identified are Simonato M. (3 records), Del Curto B. (2) and Piselli A. (2) who co-authored of publications focused on the approach to materials selection in the professional appliances industry (Piselli, A. et al., 2018; Piselli, A. et al., 2016).

A further aspect of interest to highlight is that only two scholars – namely Ng C.Y. and Chuah K.B. – co-authored a contribution which

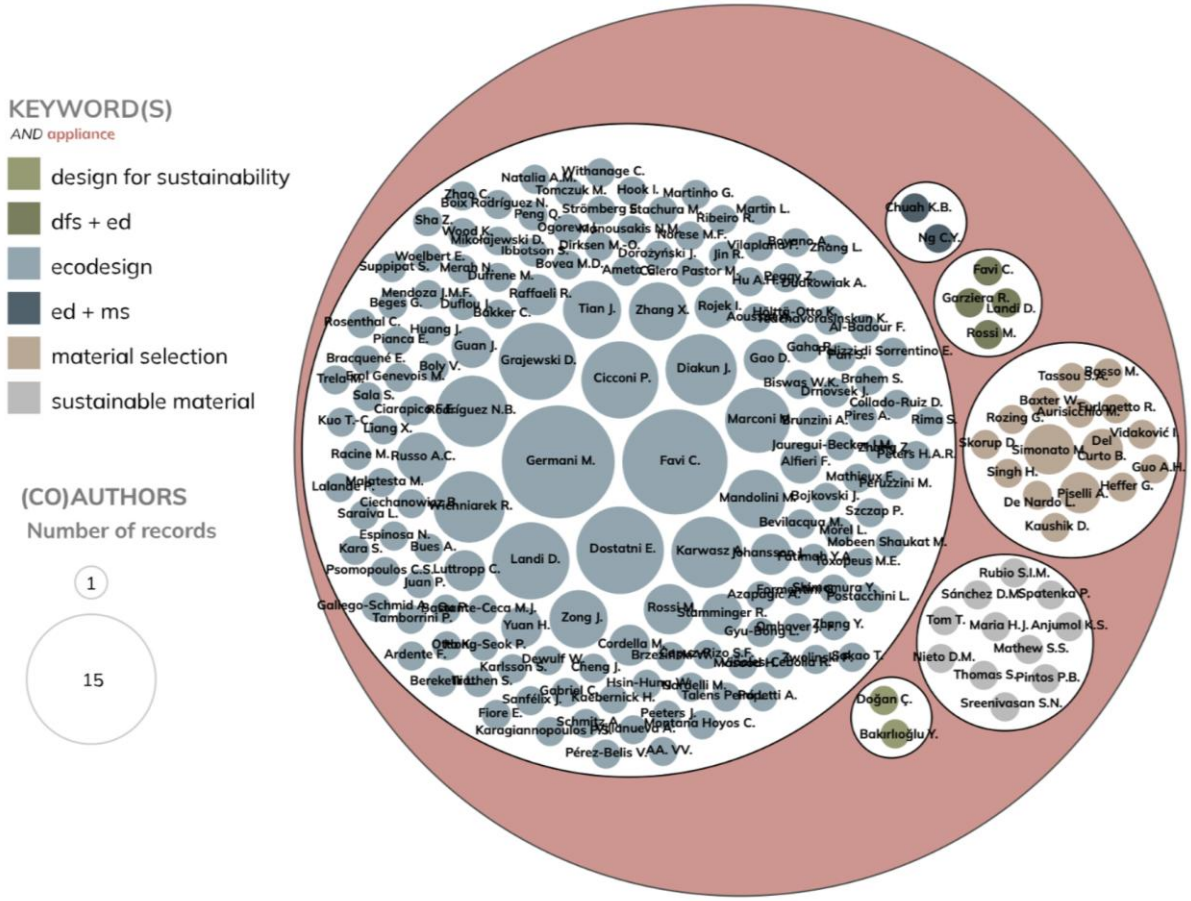

Figure 6. Appliances-focused scholars

combines the keywords ecodesign, material selection and appliance (Ng, C. Y., & Chuah, K. B., 2012). This evidence confirms that – at least limited to Scopus database – a substantial body of literature aiming at an effective integration of ecodesign and material selection for the appliances sector is still lacking.

Conclusions, perspectives and limitations

The systematic review has revealed several insights at the intersection of ecodesign, sustainable material selection, and household appliance sector. The analysis of 52 selected documents highlights a growing research interest in these areas, particularly since 2015, reflecting broader industry trends towards circular and sustainable production models. Through this in-depth analysis, common themes were identified such as eco-innovation drivers, approaches for sustainable (re)design and assessment, and the importance of validating research outcomes through real-world case studies. The review also highlighted the evolution of sustainable design strategies and material selection focus from recycling to durability and longevity, aligning with current sustainability paradigms. A notable remark is the relative scarcity of research products aimed at holistically integrating ecodesign and material selection tailored for the appliance industry, and this indicates a research gap that wants to be filled through the doctoral research described in the introduction.

A general suggestion for future Scopus searches using ‘ecodesign’ as a keyword is to narrow the search to the categories of artefacts in the scope of the research using the appropriate logical operators in the query string. Furthermore, if the research deals with topics

related to legal acts on ecodesign, it may be useful to limit the search to the last 10 years.

Finally, it is important to remark that the search is limited to publications indexed on Scopus database, thus contributions available on other databases have been excluded.

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Appendix

Table 1. Reviewed documents.

Contained keyword (s)	Authors	Title	Year	Author Keywords
design for sustainability	Bakırlıoğlu Y.; Doğan Ç.	Exploring Product/Part Longevity in Open Design of Small Kitchen Appliances	2020	co-design; design considerations; design for sustainability; open design; research through designing; small kitchen appliances
design for sustainability; ecodesign	Favi C.; Landi D.; Garziera R.; Rossi M.	Fostering Design for Sustainability through the Adoption of Computer-Aided Engineering Tools in the Development of Energy-Related Products	2024	ecodesign; life cycle engineering; virtual prototyping
ecodesign	Dostatni E.; Diakun J.; Grajewski D.; Wichniarek R.; Karwasz A.	Functionality assessment of ecodesign support system	2015	Agent technology; CAD; Eco-design; PLM; Product modeling
ecodesign	Martin L.; Morel L.; Boly V.	Integration of eco-products' criteria in project management	2020	EcoDesign; Green products; Sustainability
ecodesign	Peruzzini M.; Raffaeli R.; Malatesta M.; Germani M.	Toward a function-based IT platform for variants redesign of household appliances	2017	Computer-Aided Design; Design Methods; Function Modeling; Product Family and Platform; Product Modeling
ecodesign	Germani M.; Mandolini M.; Marconi M.; Rossi M.	Usability demonstration of the g.en.esi eco-design platform: The cooker hood case study	2015	n.a.

ecodesign	Dostatni E.; Mikołajewski D.; Dorożyński J.; Rojek I.	Ecological Design with the Use of Selected Inventive Methods including AI-Based	2022	automatic method—neural networks; eco-product; refrigerator; traditional method
ecodesign	Dudkowiak A.; Grajewski D.; Dostatni E.	Analysis of selected it tools supporting eco-design in the 3d cad environment	2021	3D CAD systems; Eco-design; Product design; Recycling
ecodesign	Dostatni E.; Rojek I.; Szczap P.; Tomczuk M.	Inventive methods in designing an environmentally friendly household appliance	2019	Eco-design; Eco-innovation; Household appliance; Inventive creation method
ecodesign	Zong J.; Tian J.; Gao D.; Zhang X.	Guidelines for green design of cooking appliances	2019	n.a.
ecodesign	Papetti A.; Germani M.; Marconi M.; Favi C.	Lifecycle tools as a support for the eco-design innovation of domestic appliances	2017	n.a.
ecodesign	Withanage C.; Hölttä-Otto K.; Otto K.; Wood K.	Design for sustainable use of appliances: A framework based on user behavior observations	2016	behavioral analysis; design for the environment; design methodology; living laboratory study; sustainable design; user behavior categorization
ecodesign	Rodríguez N.B.; Favi C.	Eco-design guidelines takeaways from the analysis of product repairability and ease of disassembly: A case study for electric ovens	2022	circular economy; cooking appliances; design for disassembly; design for repairability; disassemblability index; disassembly; eco-design; oven; repairability
ecodesign	Landi D.; Cicconi P.	An Approach for the Responsible Design of the Packaging Employed in Household Appliances	2022	Corrugated cardboard; Eco-design; EPS; Packaging
ecodesign	Bracquené E.; Peeters J.; Alfieri F.; Sanfélix J.; Duflou J.; Dewulf W.; Cordella M.	Analysis of evaluation systems for product repairability: A case study for washing machines	2021	Circular economy; Eco-design; Repairability; Scoring; Waste of electric and electronic equipment
ecodesign	Favi C.; Germani M.; Mandolini M.; Marconi M.	Implementation of a software platform to support an eco-design methodology within a manufacturing firm	2018	BoM; CAD; CAE; DfD: Design for Disassembly; DfEE: Design for Energy Efficiency; Eco-design methodology; eco-design software platform; EDIMS: EcoDesign Integration Method for SMEs; LCA; LCC; LCT
ecodesign	Pérez-Belis V.; Bakker C.; Juan P.; Bovea M.D.	Environmental performance of alternative end-of-life scenarios for electrical and electronic equipment: A case study for vacuum cleaners	2017	Ecodesign; Electrical and electronic equipment; Energy efficiency; INLA; LCA; Vacuum cleaner
ecodesign	Boyano A.; Espinosa N.; Villanueva A.	Rescaling the energy label for washing machines: an opportunity to bring technology development and consumer behaviour closer together	2020	Ecodesign; Energy Labelling; Washing machines
ecodesign	Favi C.; Formentini G.; Rodríguez N.B.	Eco-design of cooking appliances based on food habits and diets	2020	Cooking appliances; Ecodesign; Food habits; Product development; Sustainability
ecodesign	Postacchini L.; Cicconi P.; Ciarapica F.E.; Germani M.; Bevilacqua M.	A design method for improving assembly and environmental sustainability in packaging solutions: a case study in household appliances	2021	corrugated fibreboard; design for environment; design for manufacture and assembly; expanded polystyrene; Industrial packaging; life cycle assessment

ecodesign	Fiore E.; Tamborrini P.; Norese M.F.	Designing major appliances: A decision support model	2017	n.a.
ecodesign	Rodríguez N.B.; Gabriel C.; Gaha R.; Favi C.	Analysis of disassembly parameters in repairability scores: limitations for engineering design and suggestions for improvement	2023	Circular Economy; Cooking appliances; Design for Disassembly; Design for Repairability; Ease of repair; Repairability Index
ecodesign	Ardente F.; Calero Pastor M.; Mathieux F.; Talens Peiró L.	Analysis of end-of-life treatments of commercial refrigerating appliances: Bridging product and waste policies	2015	Ecodesign; Energy using products (EuP); Recyclability; Waste of electric and electronic equipment (WEEE)
ecodesign	Dostatni E.; Diakun J.; Grajewski D.; Wichniarek R.; Karwasz A.	Multi-agent system to support decision-making process in ecodesign	2015	Agent technology; Ecodesign; Product design; Product modelling
ecodesign	Rodríguez N.B.; Favi C.	Life Cycle Impact Assessment of Mechatronic Products: Towards Engineering Eco-Design for Hobs Technologies	2024	Cooking Appliances; Cooktops; Eco-Design; LCA; Sustainability
ecodesign	Dostatni E.; Diakun J.; Wichniarek R.; Karwasz A.; Grajewski D.	Product Variants Recycling Cost Estimation with the Use of Multi-agent Support System	2018	CAD 3D; Ecodesign; Recycling; Recycling cost
ecodesign	Boix Rodríguez N.; Favi C.	De-manufacturing Analysis for Product Repairability and Serviceability in Cooking Systems	2023	Cooking appliances; Design for repairability; Disassembly; Eco-design; Sustainable design
ecodesign	Landi D.; Rossi M.; Favi C.; Brunzini A.; Germani M.	A virtual design approach to simulate the hob energy performance	2020	Design methodology; Eco-design strategies; Virtual Prototyping
ecodesign	Landi D.; Cicconi P.; Germani M.	Analyzing the environmental sustainability of packaging for household appliances: A test case	2020	Molded pulp; Sustainable design; Sustainable packaging
ecodesign	Karagiannopoulos P.S.; Manousakis N.M.; Psomopoulos C.S.	"3R" Practices Focused on Home Appliances Sector in Terms of Green Consumerism: Principles, Technical Dimensions, and Future Challenges	2024	"3R" initiative; Green consumer; home appliances industry; technical dimensions
ecodesign	Rodríguez N.B.; Favi C.	Disassembly analysis of gas cooktops: towards eco-design rules for product repairability	2022	Cooking appliances; Design for Repairability; Disassembly; Eco-design; Sustainable design
ecodesign	Favi C.; Germani M.; Mandolini M.; Marconi M.	Includes Knowledge of Dismantling Centers in the Early Design Phase: A Knowledge-based Design for Disassembly Approach	2016	Design for disassembly; Disassembly Knowledge; Dismantling center
ecodesign	Wichniarek R.; Grajewski D.; Diakun J.; Dostatni E.; Karwasz A.	Automatization of the ecodesign process of small household appliances based on CAD 3D system	2018	Automatization; CAD 3D; Design for recycling; Ecodesign
ecodesign	Landi D.; Cicconi P.; Germani M.; Russo A.C.	A methodological approach to support the design of induction hobs	2016	n.a.
ecodesign	Favi C.; Germani M.	A method to optimize assemblability of industrial product in early design phase: From product architecture to assembly sequence	2012	Conceptual design for assembly; Interface connection; Product architecture
ecodesign	Kuo T.-C.; Hsin-Hung W.	Fuzzy eco-design product development by using quality function deployment	2005	Eco design; Green design; Life cycle analysis; Multi-objective analyses; Quality function deployment

ecodesign	Zhao C.; Peng Q.; Gu P.; Zhang Z.	Module development method for open-architecture product using extended QFD	2013	Design for product life cycle; Modular design; Open-architecture product (OAP); Quality Function Deployment (QFD)
ecodesign	Peters H.A.R.; Toxopeus M.E.; Jauregui-Becker J.M.; Dirksen M.-O.	Prioritizing 'design for recyclability' guidelines, bridging the gap between recyclers and product developers	2012	Design; Recyclability; Tool
ecodesign	Collado-Ruiz D.; Bastante-Ceca M.J.; Viñoles-Cebolla R.; Capuz-Rizo S.F.	Identification of common strategies for different electric and electronic equipment in order to optimize their end-of-life	2007	Design for Disassembly and Recycling; Ecodesign; End of life strategies; Waste electric and electronic equipment
ecodesign	Kara S.; Kaebernick H.; Ibbotson S.	Using Design for Environment for redesigning a household appliance	2006	Cost impact; Design for environment; Environmental impact; Redesign
ecodesign	Luttropp C.; Johansson J.; Vilaplana F.; Strömberg E.; Karlsson S.	Design for material hygiene - An ecodesign strategy for improved recycling of polymers	2010	Polymer recycling; Recyling process; Technological innovation for material recycling
ecodesign	Johansson J.; Luttropp C.	Material hygiene, an ecodesign mindset for optimized material use	2006	Disassembly; Material hygiene; Recycling
ecodesign	Germani M.; Dufrene M.; Mandolini M.; Marconi M.; Zwolinski P.	Integrated software platform for green engineering design and product sustainability	2013	Design for environment; Eco-design; Product development process
ecodesign; material selection	Ng C.Y.; Chuah K.B.	Effect of material selection on the Life Cycle Assessment of environmental impact	2012	Eco Design; Electrical Appliances; Life Cycle Assessment
material selection	Kaushik D.; Singh H.; Tassou S.A.	Vacuum insulation panels for high-temperature applications – Design principles, challenges and pathways	2024	Appliances; Core material; Energy efficiency; High temperature; Thermal conductivity; Vacuum Insulation Panels (VIPs)
material selection	Skorup D.; Rozing G.; Heffer G.; Vidaković I.	Product Life Cycle Analysis on the Example of a Home Appliance	2022	Industrial production; Life cycle analysis; Reduction of environmental impact
material selection	Piselli A.; Baxter W.; Simonato M.; Del Curto B.; Aurisicchio M.	Development and evaluation of a methodology to integrate technical and sensorial properties in materials selection	2018	Aesthetics; Human factors; Materials selection; Metal replacement; Product design; Sensory perception
material selection	Basso M.; Simonato M.; Furlanetto R.; De Nardo L.	Study of chemical environments for washing and descaling of food processing appliances: An insight in commercial cleaning products	2017	Chemical environments; Commercial cleaning products; Detergents; Durability; Food processing
material selection	Guo A.H.	Research and exploration on green design of household electrical appliances	2014	Green design; Household electrical appliances; Material; Recycling; Structure

material selection	Piselli A.; Simonato M.; Del Curto B.	Holistic approach to materials selection in professional appliances industry	2016	Design process; Design tools; Interdisciplinary collaboration; Product development; Research methodologies and methods
sustainable material	Nieto D.M.; Pintos P.B.; Sánchez D.M.; Rubio S.I.M.	Large Format Additive Manufacturing in Furniture Design with Novel Cork Based Polymeric Materials	2023	Additive manufacturing; Design for additive manufacturing; Furniture design; Product design; Sustainable materials
sustainable material	Anjumol K.S.; Sreenivasan S.N.; Tom T.; Mathew S.S.; Maria H.J.; Spatenka P.; Thomas S.	Development of natural fiber-reinforced flame-retardant polymer composites	2022	Fire retardancy; Fire retardants; Flammability; Natural fiber polymer composites; Polymer combustion