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## SUSTAINABLE DEVELOPMENT: THE MEANING OF THE TERM AND CONCEPTUAL AMBITIONS IN THE CONTEXT OF DESIGN INNOVATION OF HOUSEHOLD ELECTRICAL APPLIANCES

*This study aims to investigate the sustainable concepts and their significance in the innovative design of household appliances in the context of sustainable development. From a design perspective, it presents the current status and emerging trends in sustainable design of household appliances, analyzes the various dimensions and directions involved in the innovation of consumer electronic products, and synthesizes their underlying implications. Furthermore, it identifies opportunities and challenges for future research in this field.*

*This research employs two methodologies, namely literature analysis and case study analysis, to comprehensively understand the sustainable concepts in innovative design of household appliances from both theoretical and practical perspectives. The literature analysis entails a systematic exploration of relevant academic literature through the utilization of the Web of Science database, aiming to uncover the theoretical foundations and academic focal points of sustainable design in household appliances. The case study analysis entails an examination of representative household appliance brands and products, enabling an understanding of their practical achievements and developmental directions.*

*The findings underscore the strategic value of incorporating sustainable principles into the design of household appliances, as it facilitates environmentally friendly practices, social harmony, and economic development. This study presents research perspectives and directions for sustainable design of household appliances, while addressing the challenges associated with implementing sustainable concepts in practice.*

*This study highlights the significance of investigating sustainable development in the home appliance industry, offering a comprehensive exploration of the role of sustainability in the process of innovative design for household appliances. It sheds light on the intricacies and complexities of sustainability in the domain of consumer electronics design, thereby providing valuable research recommendations within the context of sustainability.*

**Key words:** innovative design, sustainable concept, household appliances, brand research, design strategy.

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## СТАЛИЙ РОЗВИТОК: ЗНАЧЕННЯ ТЕРМІНУ ТА КОНЦЕПТУАЛЬНІ АМБІЦІЇ В КОНТЕКСТІ ІННОВАЦІЙ ДИЗАЙНУ ПОБУТОВИХ ЕЛЕКТРОПРИЛАДІВ

*У представленій роботі досліджено концепції сталого розвитку та їхнє значення в інноваційному дизайні побутової техніки. З точки зору дизайну в ньому представлено поточний стан і новітні тенденції сталого дизайну побутових приладів, проаналізовано різні аспекти та напрямки, пов'язані з інноваціями у сфері споживчої електроніки, а також синтезовано їхні основні наслідки. Крім того, у ньому визначено можливості та виклики для майбутніх досліджень у цій галузі.*

*У дослідженні використано дві методології, а саме: аналіз літератури та аналіз конкретних прикладів, щоб всебічно зрозуміти концепції сталого розвитку в інноваційному дизайні побутової техніки як з теоретичної, так і з практичної точок зору. Аналіз літератури передбачає систематичне вивчення відповідної наукової літератури за допомогою бази даних Web of Science з метою розкриття теоретичних основ та академічних фокусів сталого дизайну побутової техніки. Аналіз тематичних досліджень включає вивчення репрезентативних брендів та продуктів побутової техніки, що дає змогу зрозуміти їхні практичні досягнення та напрями розвитку.*

*Результати дослідження підкреслюють стратегічну цінність впровадження принципів сталого розвитку в дизайн побутової техніки, оскільки це сприяє екологічно безпечним практикам, соціальній гармонії та економічному розвитку. У цьому дослідженні представлені наукові перспективи та напрямки сталого дизайну побутової техніки, а також розглянуті виклики, пов'язані з реалізацією концепцій сталого розвитку на практиці.*

*У дослідженні підкреслено важливість вивчення сталого розвитку в індустрії побутової техніки, пропонуючи всебічне вивчення ролі сталості в процесі інноваційного дизайну побутової техніки. Воно проливає світло на тонкощі та складнощі сталого розвитку у сфері дизайну побутової електроніки, тим самим надаючи цінні рекомендації щодо досліджень у контексті сталого розвитку.*

**Ключові слова:** інноваційний дизайн, концепція сталого розвитку, побутова техніка, дослідження бренду, стратегія дизайну.

**Problem Statement.** With the improvement of living standards, household appliances have become an indispensable part of modern homes. However, it is undeniable that the continuous updates and rapid iterations of household appliances have significant environmental impacts. The manufacturing and disposal processes of household appliances generate waste, leading to environmental degradation. Moreover, the usage of household appliances consumes a substantial amount of energy, resulting in the emission of greenhouse gases and other pollutants, exerting immense pressure on the environment.

The environmental impact, energy usage, and effects on consumer health and safety caused by household appliances have become important issues in contemporary product design, making sustainability a crucial consideration in innovative design of household appliances. However, the concept of sustainability remains complex and multifaceted, often leading to ambiguity and challenges in its interpretation. Therefore, this paper aims to contribute to the existing knowledge by studying the conceptual groundwork and implications of sustainability in the specific context of innovative design of household appliances, delving into a deep understanding of its concepts and meanings.

**Analysis of previous research.** Currently, “innovative design of home appliance products” is one of the research hotspots in both academia and industry. Zhang Linghao introduced the application and design paradigm of interaction design in smart home appliance products (张凌浩, 张顺峰 & 朱琪颖, 2021); Wang Tianjian explored the way to improve the market competitiveness of home appliance products from the perspective of modern home appliance product CMF design innovation (王天健, 2015); Yang Minglang discussed the characteristics of the “Internet+” concept and its impact on the traditional home appliance industry (杨明朗 & 胡雅婷, 2016); Wang Chunpeng determined the evaluation index set for elderly-friendly home appliance product design (王春鹏 & 许贞武, 2023), etc. Researchers focus on aspects such as home appliance product interaction experience, green design, modeling design, emotional design and intelligence, and propose innovative design concepts such as smart home systems, improvement of human-computer interaction interface, and satisfaction of user

personalized needs (为高质量发展指明科技创新方向, 2023). At the same time, they also emphasize the integration of home appliance products with other fields, propose theoretical frameworks, methods and ideas (郭宽荣 & 刘玮, 2019), and explore innovative design strategies for home appliance products.

Meanwhile, since the Club of Rome published *The Limits to Growth* in 1972, sounding the alarm to the world (张远, 2023), academia’s attention and dissemination of “sustainable design” has shown an upward trend, and scholars at home and abroad have achieved rich results and progress in different fields of sustainable design research. People try to find opportunities and methods for sustainable development, to balance nature and human survival and development. For example, Barry Dimson proposed the principles and challenges of sustainable design and architecture (迪姆森, 1997); WAEL RASHDAN considered the adverse impact of traditional interior design construction on the environment, and proposed a standard interior design solution for sustainable development (Rashdan, W., & Ashour, A. F., 2017). In terms of design dimensions, Professor Liu Xin from Tsinghua University Academy of Fine Arts and his team systematically sorted out the concept and development of sustainable design, and clearly defined and divided the stages of sustainable design research and development. He believes that product service system design is an opportunity and challenge for sustainable design (刘新, 2019); Zhang Jun from the perspective of ecological civilization, thought about the evolution and transformation of sustainable design, proposed a coordinated transformation path of ecological aesthetics, ecological vision, green design thinking and ecosystem design concept (刘新 & 刘吉昆, 2011; 张军, 徐畅, 戴梦雅 & 王茜婧, 2021); He Renke started from the five advantages of low technology, combined with environmental impact factors and their strategies, discussed sustainable design based on low technology, in order to serve people and communities under low resource consumption solutions (何人可, 唐啸 & 黄晶慧, 2009); Jeremy Faludi collected the results of previous literature reviews and analyses on sustainable design methods and tools, and produced a strategy to integrate sustainable design methods and tools more closely into mainstream product design and development (Faludi, J., Hoffenson, S. et al, 2020).

The progress of human thinking and the enhancement of sustainability awareness have promoted the advancement of design on the path of sustainable development. Academic research no longer stays at the level of “objects” but breaks through tangible constraints to internalize into intangible dimensions such as “non-objects”, to educate and guide humans to build a sustainable society from their subconsciousness. The transformational design for future vision is the direction and vane for future development.

**Setting objectives.** This article will undertake an analysis from two distinct angles: namely the examination of academic perspectives and the analysis of empirical cases. Firstly, it aims to investigate the prevailing trends and current state of research in this field through a comprehensive analysis of scholarly literature. Secondly, by scrutinizing the practical instances of three prominent brands and their respective products, namely BOSCH Home Appliances, Haier Smart Home, and Samsung Electronics, this study will conduct an in-depth exploration and discourse on the multifaceted concepts and implications of sustainability within the domain of household appliance design.

**Problem statement.** While sustainability is a universally recognized concept, its specific connotations and values in the context of innovative household appliance design lack definitive elucidation and comprehensive investigation. Given that household appliances have assumed a significant role as substantial consumers of energy in daily life, there exists a pressing need to undertake a thorough examination and exploration of the concept of sustainable development within the realm of innovative household appliance design.

### Results of the research.

1. *Academic dynamics of sustainable design of home appliances based on CiteSpace.* Using Web of Science database as the data source, using “sustainable” and “home appliance” as the search terms, searching in the topic field, limiting the time range to June 2023, limiting the document type to journal articles, a total of 120 relevant documents were retrieved. After deduplication, excluding irrelevant documents and supplementing missing information, 98 valid documents were obtained as analysis samples.

Visual analysis was performed to explore the current situation and development trend of academic research in this field. Using the clustering analysis function of CiteSpace, the related documents were divided into 10 research topics, as shown in Figure 1. Each topic has a label, representing the core content



Fig. 1. Status of international research on sustainable design of home appliances (by author)

of that topic. These labels are: 0-energy management, 1-building performance, 2-energy management system, 3-i-energy, 4-energy efficiency, 5-purchase intention, 6-water supply, 7-cost-time profiles, 8-energy behaviour, 9-need for uniqueness.

“Energy management” refers to a management method that improves energy utilization efficiency and reduces energy consumption and waste by taking various measures; “building performance” refers to a comprehensive evaluation indicator of the impact and effect on people, things, energy, environment and other aspects under the premise of meeting functional requirements (Tu, J. C., Nagai, Y., & Shih, M. C., 2018); “energy management system” refers to using advanced information technology and network communication technology to achieve intelligent control and management of energy; “i-energy” refers to an energy management platform based on Internet technology and big data analysis, which can realize intelligent monitoring, optimization and scheduling of energy production, transmission, distribution and consumption; “energy efficiency” refers to an efficiency indicator that reduces energy consumption or increases unit energy output; “purchase intention” refers to a psychological state of purchase willingness or tendency that consumers show when buying a certain product or service (Li, Y., Siddik, A. B., Masukujjaman, M., & Wei, X., 2021); “water supply” refers to obtaining water resources through treatment, transmission, distribution, storage and other links to achieve the goal of water saving; “cost-time profiles” are used to evaluate the cost and time required for projects or activities at different stages; “energy behaviour”

refers to the characteristics of energy use habits, preferences, modes and so on that consumers show in their energy consumption activities; “need for uniqueness” refers to the psychological need of consumers to pursue difference and show personality when buying home appliance products or services.

From the perspective of energy consumption, these research topics all involve improving the energy utilization efficiency of home appliance products, reducing the energy consumption and carbon emission of home appliance products, protecting energy resources and environment. “Energy management” “energy management system” “energy efficiency” and other topics are methods to improve the energy efficiency and save energy consumption of home appliance products by taking various measures from the demand side or supply side. While “i-energy” “cost-time profiles” and other topics are ways to use advanced information technology and data analysis technology to evaluate and optimize the energy performance and operation cost of home appliance products.

From the perspective of circular utilization, these research topics all involve improving the recyclability and degradability of home appliance products, reducing waste generation and disposal, saving resources and protecting ecology. For example, “water supply” and other topics are from the perspective of water supply service, analyzing the impact and improvement ways of water supply service on consumers’ water resource utilization and saving. While “need for uniqueness” and other topics are from the perspective of consumers’ psychological needs and motivations, analyzing consumers’ purchase willingness or tendency for recyclable or degradable home appliance products or services.

From the perspective of social responsibility, these research topics all involve improving the social value and well-being of home appliance products, meeting users’ diversified needs and expectations, promoting social development and progress. For example, “building performance” and other topics are from the perspective of buildings, analyzing the impact and effect of buildings on people, things, energy, environment and other aspects, as well as improving the comprehensive performance of buildings by using energy-saving, environmental-friendly, intelligent home appliance products (Mostafa, N. A., Grida et al, 2022). While “purchase intention” “energy behaviour” and other topics are from the perspective of consumers’ behaviour and needs, analyzing consumers’ purchase behaviour and consumption patterns for energy-saving, environmental-friendly, personalized home appliance products or services.

2. *Case study of sustainable concept in household appliances.* In the context of increasingly prominent problems such as resource scarcity and environmental pollution, the concept of sustainable development has received more and more attention. Many home appliance enterprises participate in the wave of sustainable development, based on different home appliance product design transformation, showing the sustainable connotation of home appliance product design from multiple perspectives, as shown in Fig. 2. In order to discuss the application and practice of the concept of sustainability in home appliances more concretely, we will analyze from the perspective of actual cases, select 3 representative and innovative home appliance brands and their products as cases, which are Bosch, Haier Smart Home and Samsung



Fig. 2. Sustainable design for home appliance brands (by author)



Electronics. We will further interpret these 3 home appliance brands and their typical products, discuss the enlightenment and influence of each brand on the home appliance industry from a sustainable perspective, and summarize the concept and meaning of sustainable development in home appliance innovation design.

*The “Bosch sample” of sustainable development.* Bosch Home Appliances is an advocate and practitioner of green living. Through continuous innovation, it continuously launches energy-saving and water-saving home appliance products, committed to making practical contributions to energy saving and emission reduction and environmental protection while improving the high-quality home life experience for consumers. As shown in Figure 3, Siemens dishwasher under Bosch Home Appliances brand is equipped with patented Zeolite drying technology, which greatly shortens the drying time while saving energy; load sensing system can intelligently detect the number of dishes washing, automatically adjust the water consumption, achieve reasonable electricity and water consumption under the premise of ensuring washing effect; “energy saving wash” program can ensure low energy loss during washing process, achieving energy saving, environmental protection and efficiency. In addition, Bosch Home Appliances also contributes to carbon neutrality, circular utilization, water resource protection and social progress.

It can be seen that Bosch Home Appliances mainly focuses on: first, the energy consumption problem in the whole product life cycle, saving energy, reducing carbon footprint, achieving carbon neutrality; second, continuously researching and developing and innovating technology, improving product functionality and durability through intelligent and efficient technology; third, forming a sustainable development model, systematizing sustainable development from three dimensions: earth-human-prosperity.

*Haier Smart Home green development.* Haier Smart Home is a leader and practitioner of smart home ecosystem. In the context of the national implementation of the “dual carbon” strategy, Haier Smart Home established the first green recycling interconnection factory in China’s home appliance industry, as shown in Figure 4. At the same time, it actively explores a new model of green circular economy development in the whole industry, practices ESG (environmental, social and governance) concept globally, and uses smart IoT technology to promote automatic harmless dismantling, improve dismantling and recycling capacity efficiently and at low cost, promote efficiency improvement, energy saving and emission reduction. In addition, Haier Home Appliances is committed to the green design and manufacturing of products, using big data analysis and Internet of Things technology to achieve intelligent, flexible, and visualized production.

It can be seen that Haier Home Appliances mainly contributes to sustainable design in: first, using various energy-saving technologies and materials in product design, providing diversified modes and programs to meet different users’ needs and expectations; second, focusing on product scrap and recycling solutions, efficiently improving product recycling dismantling work, significantly improving product recycling effect; third, innovating technology with the support of intelligent interconnection technology, thus reducing energy consumption, material consumption and labor cost.

*Samsung Electronics sustainable solutions.* Samsung Electronics is an outstanding contributor and leader in home appliance innovation design. With innovation as its core competitiveness, it continuously develops sustainable solutions that meet social needs and environmental requirements. As shown in Fig. 5, Samsung uses environmentally friendly packaging materials that can be upgraded and transformed on its Lifestyle TV series, incorporating aesthetic art paintings, aiming to encourage consumers to recycle



**Fig. 3. Siemens iQ700 dishwasher** (Siemens service, user manuals, spare parts, 2023)



**Fig. 4. Haier recycling interconnection factory (55英寸级三星画境艺术电视 LS01T, 2022)**



**Fig. 5. Samsung Lifestyle TV (55英寸级三星画境艺术电视 LS01T, 2022)**

and reuse the outer packaging box, to make small furniture such as cat climbing frames, TV cabinets etc. in an innovative way, to meet personalized user needs, and to strengthen users' awareness of packaging recycling reuse. In addition, Samsung Electronics focuses on the transition from linear economy to circular economy, improves product durability, strives to recycle, recycle and reuse after product life cycle ends, to ensure that resources can be optimized.

It can be seen that Samsung Electronics mainly emphasizes in sustainable design of home appliances: first, using eco-friendly home appliance packaging materials, paying attention to the use and upgrade of ancillary products other than home appliances; second, using environmental materials, controlling the selection of materials at the source of production, enhancing product life span, and giving value to products after repair; third, developing a closed-loop circular product development model, following the development concept of circular economy.

### *3. The concept and challenges of sustainability in the context of home appliance innovation design.*

The research on the concept of sustainability in the context of home appliance innovation design, on the theoretical level, studies the academic contributions of the global academic community in the sustainable design of home appliances; on the practical level, it takes 3 typical home appliance brands as representatives, and studies the direction of home appliance innovation development under the guidance of the concept of sustainability. In summary, the research results are integrated and summarized, and the semantic meaning of home appliance design in the context of sustainability can be summarized as: consumer demand, advanced technology, energy efficiency, recycling, and management mode.

**Consumer demand:** considering the impact of home appliance products on users' needs, preferences, experiences and satisfaction, starting from human-oriented, realizing humanization and socialization of products; meeting users' diversified needs, respecting differentiated needs of different groups and cultures, providing reasonable and efficient solutions; enhancing users' emotional connection with products, increasing users' use pleasure and loyalty, enhancing products' aesthetic value; improving users' well-being and quality of life by providing comfort, convenience, safety, health and functionality, enhancing users' comfort, satisfaction and trust.

**Advanced technology:** by using advanced information technology and data analysis technology to evaluate and optimize the energy performance and operation cost of home appliance products;

using intelligent and efficient technology to improve product functionality and durability to achieve higher efficiency, reduce resource consumption and environmental impact; at the same time, advanced technology can also monitor and manage energy consumption through intelligent control systems, sensors and automation technology to achieve accurate energy management and energy saving control.

**Energy efficiency:** it is the research focus in sustainable design of home appliances at present stage, and also a direct and effective way to control green development. Sustainable design of home appliances should consider the impact of products on natural resources and ecosystems, realize product circular utilization and low-carbon emission from source to end point, including energy consumption, energy efficiency improvement, carbon footprint reduction and so on. At the same time, it needs to pay attention to: selecting recyclable or degradable materials, reducing material usage and waste; optimizing product structure and function, reducing energy consumption and pollution emission in manufacturing process; using energy-saving mode, intelligent control and other technologies to improve product use efficiency and energy saving.

**Recycling:** in the design process, considering material selection and combination to facilitate dismantling and recycling treatment of home appliances; using detachable modular design to facilitate users to disassemble and clean products, improve product durability and maintainability; establishing a sound home appliance recycling system, providing recycling scrap solutions and services, encouraging users to participate in circular economy, promoting product recycling, reuse or regeneration, and dealing with product waste and hazardous substances, to reduce negative impact on environment.

**Management mode:** considering that home appliance products are affected by social, cultural and market changes, it is necessary to innovate product service mode and business mode, provide more value and convenience to users, promote social sustainable development; use circular economy concept, realize product remanufacturing, reuse, recycling, reduce waste generation, extend resource use; use systematic design method, analyze product life cycle and influencing factors, optimize product structure and function, realize product scaling and standardization; provide sharing, leasing and other services, meet users' diversified needs, reduce users' purchase cost, improve product use efficiency; create value and opportunities for users and society, provide innovative

solutions, improve efficiency and productivity, and support social and economic development.

Generally speaking, the semantics of sustainable home appliance design lies in meeting user consumption needs while reducing resource consumption, improving energy efficiency, promoting circular economy and adopting sustainable management mode. These aspects help to promote the development of home appliance industry towards a more sustainable direction, contributing to environmental protection and sustainable development. However, there are still challenges in this process.

**Consumer perception and choice:** Consumers are the ultimate users and evaluators of sustainable design of home appliances, and consumer perception and choice have a decisive impact on the success or failure of sustainable design. However, at present, many consumers do not have enough understanding of the concept and significance of sustainable design, nor do they have enough environmental awareness and sense of responsibility. They tend to choose products with low price, multiple functions and good brand, while ignoring the impact of products on environment and society. Therefore, in order to make consumers aware of the importance and value of sustainable design and choose sustainable design products, it is necessary to carry out publicity and education through various channels and ways, improve consumers' environmental awareness and sense of responsibility, and guide consumers to form green consumption habits and preferences.

**Balance between sustainability and other design elements:** Sustainable design is a design concept and strategy, but not the only design goal. While carrying out sustainable design of home appliances, we should also consider other design elements such as product function, quality, aesthetics, etc., to meet users' needs and expectations. However, there are often conflicts and contradictions between different design elements, such as improving product energy efficiency may reduce product performance, using environmental materials may increase product cost,

using simple style may reduce product aesthetics, etc. Therefore, in sustainable design, we need to balance and compromise between different design goals, find the best balance point and combination way, achieve multi-objective optimization and coordinated development.

**High cost of practice:** Sustainable design is an innovative and forward-looking design that requires breakthroughs and explorations in technology, market, policy and other aspects. This means that in practice of sustainable design, more human, material and financial resources are needed, more risks and uncertainties are to be borne. For example, in terms of technology, we need to constantly develop and apply new technologies and processes to improve product energy efficiency, durability, dismantling, recycling, etc.; in terms of market, we need to constantly promote and publicize the concept and value of sustainable design, change users' consumption habits and ideas, improve users' awareness and acceptance of sustainable products; in terms of policy, we need corresponding laws and regulations and supervision mechanisms, to provide support and incentives for sustainable design.

**Conclusion.** Incorporating "sustainability" into home appliance innovation design is a traditional and meaningful topic. In the face of the dual background of sustainable development and home appliance industry transformation, it is essential to define and clarify the context of sustainable home appliance innovation design. This paper starts from two perspectives: academic research status quo and empirical case analysis, and finally summarizes the concept embedding of sustainable development in the context of home appliance innovation design, including meeting consumer demand, using advanced technology, improving energy efficiency, paying attention to recycling, and improving management mode. These aspects help to promote the development of home appliance industry towards a more sustainable direction, contributing to environmental protection and sustainable development. However, there are still challenges in this process.

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