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A NARRATIVE REVIEW OF ENERGY LABEL TOWARDS SUSTAINABILITY

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Abstract: Energy labels are crucial for promoting energy efficiency and sustainability in modern consumer markets. The labels provide transparent information about the energy efficiency of appliances, buildings, and vehicles, to name a few. Furthermore, they promote numerous benefits to the people and environment by reducing energy costs. Notably, the energy label emerged during the post-1970s oil crisis to address global energy insecurity and conservation measures. It now encompasses diverse products, standardises metrics, and facilitates consumer comparability in purchasing decisions. Despite their potential, a significant issue lies in the inconsistent global adoption and enforcement of energy labelling standards, which creates barriers to widespread consumer understanding and market impact. In addition, limited research addresses the long-term effectiveness of energy labels in driving actual consumer behaviour change. Thus, this study employs a narrative review methodology to explore the historical development, evolution, impacts, and challenges of energy labels as a catalyst for sustainability, focusing on their significance and limitations. The study reveals that implementing energy labels is a significant step towards promoting energy efficiency and sustainability, potentially reducing energy costs. However, challenges such as a lack of consumer awareness about the benefits of energy labels hinder their effective implementation. In summary, energy labels are crucial in promoting sustainable energy by empowering consumers, incentivising innovation, and promoting environmental stewardship. This includes reducing greenhouse gas emissions and promoting informed decisions for climate change mitigation, thereby contributing to a greener, more resilient planet.

Keywords: Energy efficiency, energy label, review, sustainability.

Introduction

Energy labels, ubiquitous in modern consumer markets have emerged as a powerful tool to promote energy efficiency and sustainability (Koskimäki, 2012; Oskouei *et al*., 2020; Polverini *et al*., 2022). It is a vital mechanism that fosters sustainable practices and serves as a visual indicator that presents transparent information related to the energy efficiency of appliances, buildings, and vehicles, amongst others (Brunzell & Renström, 2020; Razali *et al*., 2022). This empowers consumers to make informed decisions about their energy consumption habits (Heinzle & Wüstenhagen, 2012; Kamaludin *et al*., 2021). Rooted in transparency and consumer awareness, these energy labels provide valuable insights into the environmental footprint associated with various products and services. It ultimately drives demand toward more sustainable options (Verplanken & Weenig, 1993; Elsen & Leenheer, 2022).

Historically, the post-1970s oil crisis was when the energy label began to emerge in the market, calling for an urgent need for conservation measures and an effort to curb the threat of global energy insecurity. Since then, the usage and significance of energy labels have evolved. In particular, it encompasses a diverse array of products in the market, allows industries

to employ standardised metrics and facilitates comparability for consumers to make sound decisions when exercising their purchasing power. In response, governments and regulatory bodies began implementing labelling schemes to incentivise energy efficiency and curb wasteful consumption patterns (Sorrell *et al*., 2000).

Energy label, other than encouraging consumers towards energy-efficient choices, also contributes to reducing greenhouse gas emissions and raising awareness about the interconnection between individual consumption patterns and global environmental challenges (Palkowski *et al*., 2019; Sorrell *et al*., 2000; Boyano & Moons, 2020a). Accordingly, the advancement of energy-efficient technologies and the abundance of smart devices can be accurately reflected through the recalibration of the labelling scheme. In this sense, efforts to combat greenwashing and ensure the integrity of label information are paramount to maintaining consumers' trust and optimising the efficacy of sustainability interventions (Delmas & Montes-Sancho, 2011; Lin *et al*., 2020). In essence, energy labels represent a key player in transitioning towards a more sustainable energy future. Moreover, by empowering consumers, incentivising innovation, and fostering environmental stewardship, these labels constitute a vital tool in the collective pursuit of a greener, more resilient planet.

Despite these benefits, energy labels face critical challenges that hinder their effectiveness, including inconsistent regulatory standards across regions, limited consumer understanding of label information, and varying levels of enforcement. This article addresses these issues by providing a comprehensive narrative review of energy labels, exploring their historical development, evolution, impacts, and limitations as a catalyst for sustainability. Additionally, this study seeks to bridge existing gaps in the literature by analysing how energy labels influence consumer behaviour and their role in promoting sustainable practices.

To achieve this, the scoping analysis for this review focused on peer-reviewed articles and reports published between 2000 and 2024. The sources were identified through systematic searches in reputable databases such as Scopus, Web of Science, and Google Scholar, using keywords such as "energy label", "sustainability", "consumer behaviour", and "energy efficiency". In addition, selection criteria included relevance to the objectives, methodological rigour, and geographical diversity to ensure a comprehensive understanding of the topic. This approach provides a foundation for the literature review and strengthens the analytical insights presented in this article.

Review of Study

The objective of this literature review is to delve into the knowledge, understanding, significance, and analysis of energy labels as a catalyst for sustainability according to three scopes: (i) Examining their historical development and evolution, (ii) their impacts, and (iii) the challenges and limitations of energy labels. Note that energy labels advocate numerous benefits for people, nations, resources, and the environment.

Historical Development and Evolution of Energy Label

Energy efficiency has become a paramount concern globally as nations grapple with the challenges of climate change and sustainable development. In pursuing more sustainable energy practices, policymakers and researchers have focused on the role of energy labels in influencing and shaping consumer behaviour. This includes driving innovation in energy-related products and systems. Notably, the first energy label was introduced in Sweden in 1975 (Apt & Eyre, 2008) as an effective way to raise environmental awareness and communicate product sustainability features to consumers (Zha *et al*., 2020).

Correspondingly, this literature review examines the key findings and insights from recent studies regarding the efficacy and implications of energy labels. This pertains

to various contexts focusing on the European Union (EU) and other developing countries as these nations have consistently emphasised the elements of energy labels, i.e., product efficiency, operational performance, and lifecycle consideration (Weiß *et al*., 2019). Similarly, Brunzell and Renström (2020) delved into the complexity of consumer behaviour and technical development in the context of energy labels for household appliances in the EU. The authors discovered dysconnectivity between energy-efficient technological advancement and consumer behaviour, particularly in the case of dishwashers. This finding called for energy labels concerning technical innovation, consumer preference, and the need for education and awareness related to environmentally friendly practices. Table 1 shows the classes on the energy efficiency of household dishwashers.

Table 1: Classes on the energy efficiency of household dishwashers

Energy Label	Energy Efficiency Index (EEI)
A^{+++}	EEI < 50
A^{++}	50 ≤ EEI < 56
A^{+}	56 ≤ EEI < 63

Source: Brunzell & Renström (2020)

Boyano and Moons (2020b) analysed the gap between energy-efficient programmes and consumer preferences in washing machines, emphasising the need for policy measures to align with consumer behaviour. Meanwhile, in China, its energy label follows the EU's energy label system (Zhang *et al*., 2021; Zhu & Thøgersen, 2023). As such, China established a voluntary certification system in 1998 to certify appliances that are energy-saving, water-saving, and ecologically beneficial. Following this, in 2005, China implemented an "energy-efficiency label management approach" to be used on refrigerators and air conditioners. Although it significantly reduced home power usage between 2007 and 2010, it deteriorated between 2011 and 2012 (Zhang *et al*., 2021). In the case of Malaysia, the country began to implement energy labels for air conditioning systems in the early 2000s (Mahlia *et al*., 2002). Figure 1 depicts the current energy label used in Malaysia. Kamaludin *et al*. (2021) asserted that the effectiveness of an energy efficiency label is mostly influenced by its ability to effectively communicate information and encourage energy conservation among the public. Accordingly, the energy-efficient label in Malaysia introduced by the Energy

Figure 1: The most recent implementation of Malaysia's energy label
Source: Kamaludin *et al*. (2021)

Commission (EC) provides information on the energy consumption of electrical equipment. The 1-to-5-star label used indicates the level of energy efficiency of the electrical equipment (Figure 1). In addition, the EC recommends that consumers utilise electrical equipment bearing the SIRIM-ST Label and Energy Efficiency Label. Figure 2 illustrates how to calculate top-loading washing machine operation costs.

Abas and Mahlia (2018) tackled the rising electricity consumption in Brunei Darussalam, mainly due to air conditioning systems, with a suggestion to use energy labels to guide consumers and encourage manufacturers to improve energy efficiency. The authors used an online survey to design a suitable label that emphasises the importance of context-specific labelling in driving sustainable energy practices in developing countries. Figure 3 illustrates the proposed flow procedures for enforcing the energy efficiency standard and label.

In short, the literature reviewed highlights the significance of energy labels in promoting energy efficiency, influencing consumer behaviour, and driving innovation in energy-related products and systems in EU, China, Malaysia, and Brunei Darussalam towards a more sustainable energy future. Furthermore, addressing the complexities of consumer behaviour, technological advancement, and other contextual factors poses substantial challenges. This, ultimately, underscores the need for holistic approaches to energy label policy and intervention.

The Energy Efficiency Label helps the consumer to estimate the operation cost of the equipment before making a decision to purchase

Energy Cost = Average Energy Consumption (AEC) x Average Tariff

Average Tariff = RM 0.3945

STAR Rating	Capacity (kg)	Average Energy Consumption (AEC) kWh/Year	Percentage Energy saving compared to the lowest 2-Stars rating	Estimated energy bill AEC x Average Tariff
2★	12	83.95	14.81	RM33.12
3★	12	65.70	27.70	RM25.92
4★	12	29.35	71.41	RM11.58
5★	12	21.21	78.50	RM8.37

Figure 2: An example of operation cost calculation for a top-loading washing machine
Source: Energy Commission of Malaysia (2021)

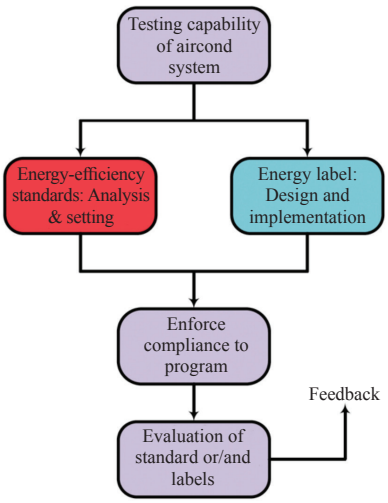

Figure 3: The operation routine of the programme for energy labels and energy efficiency standards
Source: Abas & Mahlia (2018)

The Impacts of Energy Label on Consumer Behaviour in a Dynamic Market and its Environmental Benefits

Consumer Behaviour in a Dynamic Market

The integration of energy labels into sustainability initiatives represents a critical step toward achieving environmental conservation and promoting energy efficiency. Sammer and Wüstenhagen (2006) studied the influence of eco-labels on consumer behaviour and purchasing decisions. Eco-label, which is widely used in European countries serves as an informational tool that empowers consumers to make informed decisions. At the same time, a dynamic market contributes to many environmental benefits. This section examines the multifaceted interactions between energy labels, consumer behaviour, market dynamics, and environmental benefits. In addition, energy labels help consumers make sustainable choices. Nevertheless, their effectiveness is hindered by consumer heterogeneity and preferences. For example, Zha *et al*. (2020) posited that some consumers may prioritise price and brand over energy efficiency. It was also revealed that consumers with low cognitive reflection value energy efficiency less and respond strongly to grade-like classes. This, in turn, disregards detailed information on annual energy use while those with high reflection value it more (Andor *et al*., 2019). Figure 4 shows the refrigerator appliances with EU energy label.

Understanding consumer behaviour in real-life scenarios is crucial for enhancing household operations, especially in cooling appliances like refrigerators (Geppert & Stamminger, 2010). Despite the advancement of energy-efficient technology, consumer behaviour often deviates from optimal practices, leading to energy inefficiency and environmental impacts. Therefore, addressing gaps in consumer information and promoting sustainable usage practices are essential for maximising the environmental benefits of energy-efficient appliances. Heinzle and Wüstenhagen (2012) analysed the revised EU energy label and indicated that expanding the existing seven-point A-G grading scale could reduce the significance of energy efficiency in customer choices. This, however, could lead to market failure as the label's effectiveness in addressing information imbalances is weakened by the inclusion of new categories in the rating system. While much attention has recently been directed towards changing consumer behaviour to combat issues such as food waste, technological advancement, particularly in household refrigeration, offers promising avenues for sustainability improvements based on energy labels (Holsteijn & Kemna, 2018). In this sense, optimising refrigerator designs for food preservation can

Figure 4: Refrigerator appliances with EU energy label
Source: Andor *et al.* (2019)

significantly reduce waste due to loss in quality and spoilage, thereby enhancing resource efficiency and sustainability.

Environmental Benefits

Energy labels have emerged as a powerful tool in promoting sustainability by guiding consumers towards more energy-efficient products, thus allowing them to make more informed decisions. As indicated through high ratings on the energy label, energy-efficient products contribute to mitigating climate change by reducing greenhouse gas emissions.

Sustainable development demands improving energy efficiency, reducing energy demand growth rates, and lowering CO_2 emissions (Schubert & Stadelmann, 2015). On the one hand, in the US, Heinzle and Wüstenhagen (2012) discovered that state-specific energy labs tailored to each household's state of residence lead to consumers making better choices in purchasing electronic items. Meanwhile, in European countries, D'Adda *et al*. (2022) reported that although consumers do not fully comprehend what energy labels are all about, they are still able to make better judgements when buying appliances online using the information they read on the label. Figure 5 shows the energy labels used in developed countries.

In line with this, He *et al*. (2022) discovered that providing information on environmental emissions does not significantly increase consumers' intention to invest in energy-efficient appliances. However, individuals with strong environmental concerns or postmaterialist values still display increased preferences for such appliances when presented with CO_2 emission information. Furthermore, Polverini *et al*. (2022) proposed an energy-labelling scheme for photovoltaic modules and systems to ensure environmental friendliness and the EU's commitment to reduce CO_2 emission. In addition, Boyano and Moons (2020a) revealed that energy labelling and regulatory frameworks effectively enhance energy efficiency and decrease CO_2 emissions in household appliances.

At the same time, Varman *et al*. (2005) examined Malaysia's televisions and noted that a one-watt standby power label has significantly reduced CO_2 emission and improved energy saving over two decades. In Brazil, the

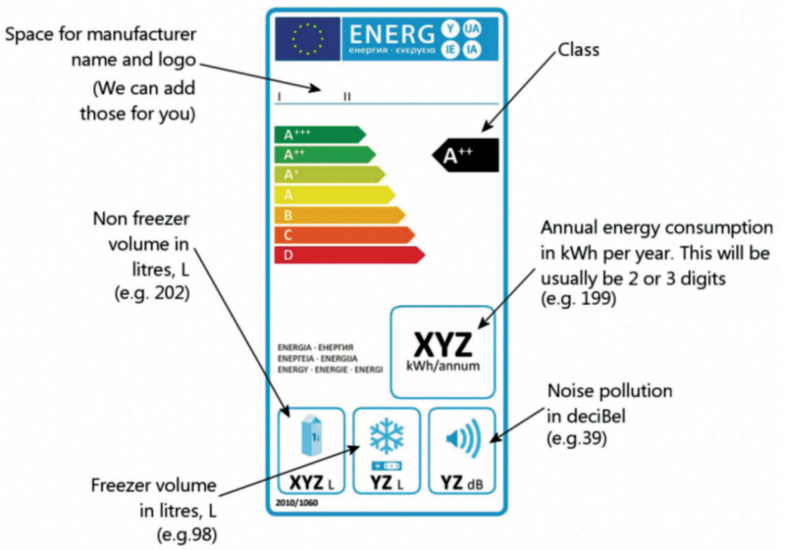

Figure 5: Energy labels used in developed countries; from left to right are EU, China, Australia, Japan, United States, and Canada
Source: Schubert & Stadelmann (2015)

Brazilian Labelling Programme, which was initiated in 1984 has resulted in substantial energy conservation equivalent to the yearly energy usage of around five million Brazilian families (Nogueira *et al*., 2015). Similarly, Yilmaz *et al*. (2019) demonstrated the impact of energy efficiency labelling on CO_2 emissions by indicating a potential 25% reduction in electricity consumption for white goods through improved efficiency technologies. This supports CO_2 reduction targets. In summary, energy labels are a catalyst for environmental sustainability by promoting energy-efficient technology, decreasing CO_2 emissions, and fostering sustainable consumption patterns.

Challenges and Limitations of Energy Label

Implementing energy labels is crucial in encouraging energy efficiency and sustainability across many sectors, as it can substantially reduce energy costs (Oskouei *et al*., 2020). Nevertheless, certain challenges and limitations hinder effective implementation. One of the primary challenges in implementing energy labels is consumers' lack of awareness and understanding of energy labels and their benefits (Mills & Schleich, 2010; Jornales, 2023). Accordingly, consumers may underestimate the significance of energy efficiency due to imperfect information, which can contribute to serious environmental issues like pollution and climate change (Andor *et al*., 2019).

In addition, energy labels can be relatively confusing and challenging to understand as they present complex information, varying standards, and inconsistent formats. Consequently, this makes it hard for consumers to make a purchasing decision (Steg & Vlek, 2009; Mills & Schleich, 2010; Stasiuk & Maison, 2022). Furthermore, products with new labels are viewed as less energy efficient than those with the old label, suggesting consumers' uncertainty about the new labelling system. In essence, enforcing energy labels can be challenging, especially in weaker countries. Additionally, their effectiveness in promoting energy efficiency can be limited by factors like consumer behaviour, market competition, and technological limitations (Koengkan *et al*., 2023).

Market dynamics and consumer behaviour also affect the effectiveness of energy labels. In this sense, consumers must be educated on environmentally friendly efforts to ensure they appreciate and realise the significance of choosing energy-efficient products (Brunzell & Renström, 2020; Boyano *et al*., 2020). Moreover, regulatory bodies face challenges ensuring compliance with energy labelling rules and enforcing standards. For example, Schuberth *et al*. (2024) proposed the EU front-runner approach. It involves expanding the energy label database and introducing legislative procedures to adjust energy-efficient requirements based on database findings. Correspondingly, manufacturers can manipulate test results to achieve favourable ratings. However, without a robust enforcement mechanism and monitoring system, the integrity of the energy label may be forfeited. Despite these challenges, energy labels remain an effective tool for promoting energy efficiency (Kama & Kaplan, 2013; Kamaludin *et al*., 2021; Zhang *et al*., 2021). Therefore, addressing these challenges requires collaborative efforts from policymakers, manufacturers, and consumers to enhance awareness, improve transparency, strengthen enforcement mechanisms, and adapt the labelling framework in the evolving market and technological advancement. Figure 6 shows the China's energy label with the energy-efficiency "top runner" label symbol.

Conclusions

This study reviews energy labels as instrumental in fostering sustainability across various sectors, from household appliances to renewable energy technologies. Transparency information on energy efficiency and environmental performance on the energy label allows consumers to make informed decisions aligning with sustainability goals. In relation to this, policymakers and researchers alike have turned their attention to the role of energy labels in influencing consumer behaviour and driving innovation in energy-related products and

Figure 6: China's energy label with the energy-efficiency "top runner" label symbol (Zhang *et al*., 2021)

systems. Nevertheless, consumer awareness, information accessibility, and the need for standardised labelling frameworks are among the challenges that must be addressed.

However, collaborative efforts are required among policymakers, industry players, and consumer advocacy groups to improve the effectiveness of energy labelling policies (He *et al*., 2022; Polverini *et al*., 2022). Therefore, ongoing research and innovation are essential to explore new labelling strategies, improve labelling designs, and evaluate the long-term impacts of energy labels on sustainability outcomes. Furthermore, the review of the study is in line with Sustainable Development Goal 12 (SDG12): Responsible Consumption and Production, whereas the energy label is indeed the essence of resource efficiency, sustainable energy, and consumer awareness. The energy labels contribute to achieving various targets under SDG12 and other related goals, ultimately advancing the global agenda for sustainable development.

Finally, by addressing these issues and leveraging the potential of energy labels as a catalyst for sustainable consumption and production, the world will become more resilient and environmentally sustainable. Overall, energy labels can be an effective tool for promoting sustainability and energy efficiency. However, education and awareness-raising efforts are also crucial to ensure that consumers understand and use the information provided by these energy labels.

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Conflict of Interest Statement

The authors declare that they have no conflict of interest.

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