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Case Report

Research on the Effective Use of Energy-Saving Building Materials in Vietnam

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Abstract: Low energy consumption is a significant contribution of new and retrofitted buildings that place an emphasis on energy efficiency. Although the mandatory requirements of the U-factor and R-value are described in the Vietnamese National Technical Regulation on the energy efficiency of buildings—QCVN09:2017/BXD, these values are not widely publicized, leading to designers facing difficulties when choosing suitable materials at the design stage. This study focuses on the method used to declare the heat transfer values of building materials based on the energy labeling process in order to create an energy labeling program for building materials. To accomplish this objective, criteria and labeling procedures for windows, doors, walls, and building roofs have been developed. In addition, a case study of insulation product labeling was used to evaluate the applicability of the developed labeling program in the implementation phase.

Keywords: energy label; building materials; energy efficiency; labeling program; sustainable building

1. Introduction

Buildings use about 40% of global energy while emitting approximately 30% of global emissions [1]. The likelihood of achieving carbon neutrality by 2050 can be increased by improving the energy efficiency of buildings. It is widely known that building energy consumption can be reduced through the use of energy-saving materials [2]. In most developed countries, energy rating and labeling systems for building materials have been introduced to help consumers make the right decisions about the products they procure and to determine whether they will save energy [3].

In general, an energy labeling system for building materials should provide the following benefits: (1) allow consumers to directly compare the energy performance of products from different manufacturers; (2) allow consumers and designers to choose the right materials based on their actual energy performance; (3) provide a set of general tools and methodologies, avoiding the development of a multitude of separate and incompatible systems; (4) provide a basis for an energy ranking system to assess the energy efficiency of buildings; (5) encourage construction material manufacturers to capture the market's use of products in order to improve technologies that are suitable for consumer needs and practical use; and (6) encourage designers to come up with ideas on how to use materials in order to make the most of energy-saving benefits, minimize construction and operation costs, reduce CO_2 emissions from energy consumption, and create products that meet the requirements.

Several energy labeling programs for building materials have been issued around the world, such as Ecolabels in Nordic countries, New Zealand, Canada, Australia, and Korea; GreenMark in Taiwan; the Energy Saving Trust Recommended logo in the UK; and various programs in the U.S. [3–6]. It is clear that the implementation of green and energy-saving buildings is most effective in the countries where labeling programs are widely implemented [3,4,6].

In the United States, the testing, rating, and labeling of building materials are mainly performed by independent or non-profit associations, with different testing, certification, and labeling processes used depending on the specific material. For example, the rating and labeling system for windows is managed by the National Fenestration Rating Council (NFRC), test methods for insulation products

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were developed by the American Society for Testing and Materials and are rated and labeled by the U.S. Federal Trade Commission, and the radiative performance of roofing products is rated and labeled by the Cool Roof Rating Council (CRRC). The indicators for each label are shown in Table 1 [7].

Table 1. Labeling programs and criteria for building materials in the U.S [7].

Type of Label	Applicable Product	Indicator
NFRC	Windows, doors, skylights	U-factor, Solar heat gain coefficient (SHGC), visible light transmission(VLT), air leakage, condensation resistance
Energy Star	Wall insulation	R values
CRRC	Roofing products	Solar reflectance, thermal emittance, solar reflective index (SRI)

In Europe, the Nordic Swan system is one of the most comprehensive window ecolabels. This is a voluntary certification system that covers Denmark, Finland, Iceland, Norway, and Sweden. It is designed to provide a guide for fixed and opening windows and window-doors, as well as exterior doors forming the boundary between free and heated areas. The main aspects of the Nordic Swan Ecolabel are shown in Table 2 [4].

Table 2. EU Nordic Swan Ecolabel system [4].

Country	Labeling organization	Status	Indicator
Denmark	Vindues	Voluntary	Uw, g, AU/Aw
Finland	Energy	Voluntary	Uw, L
France	Union des	Voluntary	Uw, Sw
Portugal	ADENE	Voluntary	Uw, G, L
Slovakia	Energakma	Voluntary	Uw, G, L
Spain	ASEFAV	Voluntary	Uw, G, L
Switzerland	EQ	Voluntary	Uw, L
Great Britain	BFRC Certass BSI	Voluntary	Uw, G, L AU/Aw

In Korea, labeling and certification programs have been nationally implemented to reduce total building energy consumption [8]. As a result, many construction companies actively aim to select more effective green and energy-saving building materials. This not only leads to an increase in the number of green and energy-efficient buildings, consequently reducing their environmental impact, but also drives the sustainable development of the construction market. The benefits of the labeling and certification standards for eco-friendly building materials have been clearly realized.

In Vietnam, the economical and effective use of energy in buildings has received much attention from both governmental and scientific perspectives to ensure energy security and to promote the development of the energy industry. Developing an energy labeling program is a state management measure to promote the use of high-performance equipment, thus achieving the goals of energy savings in buildings and a sustainable consumption culture. In 2006, the Ministry of Industry and Trade (MOIT) released the Vietnam National Energy Efficiency Program (VNEEP) for the 2006–2015 period [9]. The results show that the country saved 5.65% in total energy consumption from 2011 to 2015, equivalent to saving 16.1 million tons of oil equivalent (TOE). Currently, four categories of equipment and vehicles are required to undergo energy labeling as per Prime Minister Decision No. 04/2017/QD-TTg in March 2017: household appliances, office equipment and commercial appliances, industrial equipment, and means of transport. The Vietnam National Energy Performance and Labeling Program began in 2011 in a voluntary form and became mandatory in 2023, using both endorsement and comparative labels, as shown in Figure 1. However, these labels have not yet been applied to building materials [10].

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Figure 1. Energy saving label (**left**) and energy rating label (**right**) granted by the Ministry of Industry and Trade in Vietnam.

In the construction sector, the construction growth rate over nine months of 2023 increased by 6.17% compared with the same period in 2022 [11]. With the current rate of economic development in Vietnam, the population rate is also increasing, leading to higher housing demand. As a result, new types of buildings and building materials are being developed. In parallel, the awareness of the need to reduce embodied emissions and energy consumption by selecting suitable building materials is growing. The regulations related to economic and energy requirements are part of a key national strategy working to reduce the national energy consumption and greenhouse gas emissions of buildings, as shown in Table 3, in an urgent attempt to implement the goal of reaching national carbon neutrality by 2050 declared at COP26.

However, the economical and efficient use of energy in buildings has been delayed due to insufficient mandatory design and quality certification standards for distribution technology. Furthermore, the lack of field practitioners for the implementation of building energy efficiency (BEE) has led to the low awareness of BEE in the Vietnamese construction demand market and is delaying the implementation of mandatory BEE design standards. To solve these problems, first, the existing BEE design standards should be advanced to ensure that the government and relevant industries maintain clear guidelines in the implementation process. Second, to encourage the distribution of high-quality thermal insulation building materials, a quality certification system for key BEE implementation technologies should be established.

Table 3. Policies related to building energy efficiency in Vietnam.

Policy	Details	Year	Reference
Energy Efficiency and Conservation Law	Obligations of Key Energy Users: - Appoint an energy manager. - Perform energy audits every three years. - Apply an energy management system. - Develop and implement a 5-year energy efficiency plan.	2010	[12]
Decree No. 21/2011/NĐ-CP Implementation of the Energy Efficiency and Conservation Law	Definition of the Key Energy User Entities: (a) Industrial, agricultural, and production establishments and transport units consuming > 1000 TOE per year. (b) Tertiary buildings (offices; residential, educational, medical, entertainment, and sports facilities; hotels, supermarkets, restaurants, shops) consuming > 500 TOE per year.	2011	[13]
Construction Law	Incentives for the assessment and certification of energy-efficient buildings and green buildings are regulated by the Law on Construction (amended in 2020). Article 10, Clause 4: "The state has a policy incentive to carry out investment activities and certification of energy saving, efficiency, and natural resource consumption of buildings while ensuring environmental requirements…" Article 162, Clause 2: Ministry of Construction: "Promulgating and organizing the implementation of criteria for buildings using efficiency energy and natural resources".	2014, amended in 2020	[14]
National regulation on energy efficiency of buildings—	This regulation provides mandatory technical standards for the design, construction, or retrofitting of buildings with a gross floor area of 2500 m^2 or larger of the following types: offices, hotels, hospitals, schools, commercials buildings, and residential buildings. The requirements of this regulation apply to the building	2017	[15]

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Policy	Details	Year	Reference
QCVN09:2017/BXD	envelope, ventilation and air conditioning systems, lighting systems, and other electrical equipment.		
Decision No. 280/QĐ-TTg: approving the National Program on Economic and efficient use of energy in the period 2019–2030	- Deployment and implementation of QCVN09:2017/BXD. - At least 50% of insulating building materials must be labeled up to 2030.	2019	[16]
Decision No. 882/QĐ-TTg: National Action Plan on Green Growth for the period 2021–2030	This Decision approves the National Action Plan on Green Growth for the period 2021–2030, which emphasizes the implementation of activities to develop standards, sets of criteria, and guidelines for the assessment and certification of building materials that are energy-saving, green, environmentally friendly, and produce low carbon emissions.	2020	[17]
Decree No. 15/2021/NĐ-CP: Regulations detailing some content on construction investment management (specifying some contents of the Construction Law).	Article 7. Energy-efficient, resource-saving, and green construction: - When investing in construction, there must be technical solutions and management measures aimed at energy efficiency, resource conservation, and environmental protection. - The state encourages the construction, development, evaluation, and certification of energy-efficient, resource-saving, and green construction. - The development of the buildings mentioned in clause 2 of this Article will be implemented according to the policies, plans, and application roadmaps as stipulated by the Prime Minister. - The Minister of Construction is responsible for establishing standards and regulations of the criteria, evaluation procedures, and certification for energy-efficient, resource-saving, and green construction.	2021	[18]
Decree No. 06/2022/ND-CP: Regulations to mitigate greenhouse gas emissions and protect the ozone layer	This Decree stipulates that the minimum greenhouse gas emission reduction target for the period up to 2030 in the construction sector is 74.3 million tons CO2eq.	2022	[19]
Decision No. 385/QĐ-BXD: Approving a climate change action plan in the construction sector for the 2022–2030 period, with a view to fulfilling Vietnam's commitments based on COP26 by 2050	Exploiting and producing building materials: (a) From 2022 to 2025: - Twenty-five percent of domestic construction materials must be certified as green products. - GHG emissions must be reduced by at least 25% in the investment and operation of apartment buildings. - One hundred percent of new and renovated buildings must be compliant with QCVN09:2017/BXD. (b) From period of 2030 to 2050: - Assess and conduct the mitigation of GHG emissions for 100% of new buildings. - >50% of government projects must meet green criteria. - One hundred percent of commercial buildings and apartments must be certified as low-carbon.	2022	[20]

Testing, certifying, and labeling play an important role in the selection of materials at the design stage while facilitating the expansion of Vietnam's BEE market and strengthening industrial capacity. In fact, building owners, architects, and construction companies may experience difficulty in accessing information relevant to the energy performance of materials due to the lack of an energy labeling program. Consequently, this information must be directly requested from manufacturers or researched using the manufacturer's website. This limits the implementation of energy savings in

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green and sustainable buildings that meet the national building code and other Vietnamese building sector regulations. It is clear that the implementation of a labeling program for building materials will have many benefits for the promotion and implementation of energy-saving activities. In particular, Decision No. 280/QĐ-TTg set the target of labeling at least 50% of insulating building materials available in the market until 2030 to promote the energy-saving materials market and increasing the number of green buildngs [16]. Therefore, the implementation of an energy labeling system for building materials is necessary, consistent with actual needs and national strategies on energy saving in the construction sector. This also indicates the responsibility of the Vietnamese government to reduce energy consumption and greenhouse gas emissions, respond to climate change, and move towards sustainable development.

In this study, the concept and design of an understandable labeling system for building materials were investigated to support professionals and other practitioners in the industry when selecting materials for energy- and resource-efficient construction. The aim of this study was to translate the complex information related to the energy consumption of building materials into a form that can be easily understood by all relevant actors (e.g., skilled and unskilled construction workers, planners). Herein, the criteria, label types, and labeling process for building envelopes and roofing were established in accordance with the conditions applicable to Vietnam.

2. Materials and Methods

In this section, a detailed account of the procedure that was followed while conducting this research is described. The overall procedure is presented in Figure 2.

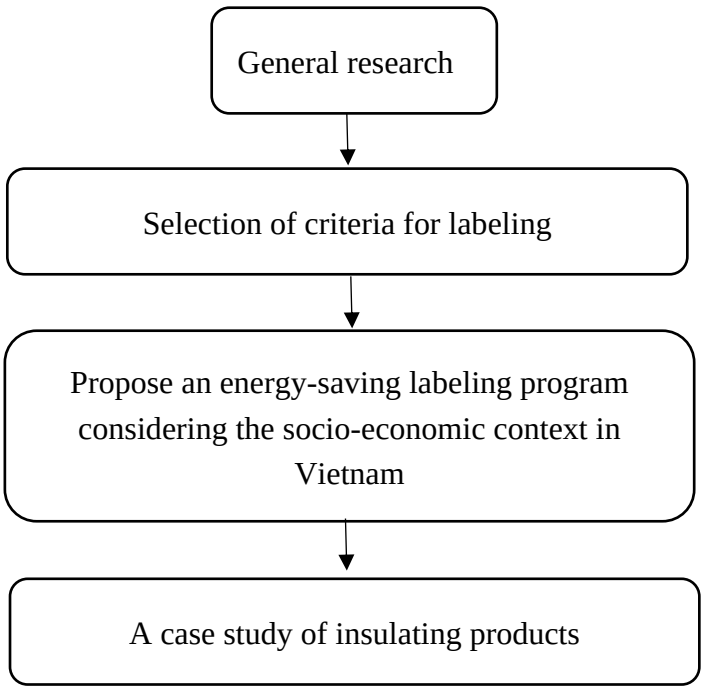

Figure 2. The study procedure.

(i) General research

In this stage, a literature review was performed. Based on the overall observations, the authors proposed a labeling program for building materials applicable to Vietnam.

(ii) Selection of criteria for labeling

The criteria and technical parameters were determined through research into energy labeling programs used in different parts of the world and those that have been mentioned in the Vietnamese regulations. These parameters were then used to build a labeling concept that was suitable for the conditions of Vietnam.

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(iii) Proposal of an energy-saving labeling program for building materials in Vietnam

In this stage, a labeling program for building materials was developed based on the lessons learned from global research. The types of labels and the labeling process were proposed in this stage.

(iv) Case study of insulating products

To evaluate the applicability of the selected criteria in practice, the developed labeling program was applied to autoclaved aerated concrete bricks that were supplied by the Viglacera Joint Stock Company.

3. Results and Discussion

The requirements of the regulation on the energy efficiency of buildings in Vietnam—QCVN09:2017/BXD apply to the following aspects: (1) building envelopes; (2) ventilation and air conditioning systems; (3) lighting systems; and (4) other electrical equipment (electric motors, water heating systems). Of these, building envelopes are not included in the products listed under the VNEEP program according to Decision No. 04/2017/QĐ-TTg [21] . Therefore, this research focuses on developing an energy labeling program for building envelopes, which include light-transmitting materials (glazing, glass doors, windows), materials involved in the construction of wall- and roof-covering structures (insulation materials), and finishing materials involved in the construction of external covering structures, building roofs, and exterior paving materials (such as paint and coatings).

3.1. Selection of Criteria for Labeling

3.1.1. Light-Transmitting Materials and Product Parts

According to the building energy code QCVN 09:2017/BXD, the maximum SHGC values for glazing must be determined for the north-facing façade, the south-facing façade, and all other orientations. These values must comply with the values specified in Table 2.1 of the National Technical Regulation on Energy Efficiency Building [15]. According to this regulation, the SHGC value should be a mandatory parameter of the labels applied to light-transmitting materials. As a result, the SHGC value was selected to be an indicator on product labels, together with typical information such as the name of the manufacturer, product name, product code, and other needed information. It is important to note that the SHGC value must be provided by the designated laboratory.

3.1.2. Materials Involved in Wall- and Roof-Covering Structures

In the building energy code QCVN09:2017/BXD, the requirements for the design of building envelopes are specified as in Table 4.

Table 4. The insulation requirements for building envelopes in the Vietnamese building energy code.

Area	U_{0max} (W/m²·K)	R_{0min} (m²·K/W)
Building envelopes	1.8	0.56
Flat roofs	1	1

Therefore, the labels for the materials used in wall- and roof-covering structures should include the normal information like the company's name and product code, but must also include the thermal conductivity, λ, that is provided by the designated laboratory.

3.1.3. Finishing Materials Involved in External Covering Structures, Building Roofs, and Exterior Paving Materials

Vietnam's current urbanization process has led to the "Heat Island Effect", in which a central city area reaches higher temperatures than the outlying area. Combined with greenhouse gas emissions, the city area absorbs and re-emits the sun's heat to a greater extent than natural landscapes

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such as forests and water bodies. In order to measure the ability of roofs to reflect solar heat as shown by a small temperature rise, the solar reflectance index (SRI) is usually used.

The SRI is required in current green building certification systems in Vietnam, such as LOTUS and LEED [22]. In the LOTUS evaluation system, the requirement to provide the SRI of materials is stipulated in Section LE-4 on reducing the urban heat island effect caused by buildings as follows: (1) use sun-blocking structures with SRI values greater than 29, block the sun with existing tree canopies, or place the building in an area in which trees are planned to be planted within 10 years (tree shade must cover the roof and paving surface); (2) use paving materials with SRI values greater than 29; and (3) use roofing materials with SRI values greater than 78 for roofs with small slopes (height-to-length ratio less than 2:12) and roofing materials with SRI values greater than 29 for roofs with steep slopes. In the LEED certification system, the SRI requirements are as shown in Table 5.

Table 5. The requirement for the SRI in the LEED evaluation system [22].

Material	Initial SRI Value
Roofs with small slopes (≤2:12)	≥78
Roofs with large slopes (>2:12)	≥29
Parking lots	≥29
Road, sidewalks, yards	≥29

Based on these criteria, to support the selection of materials in the design stage in the construction of energy-efficient and green buildings, the SRI of materials needs to be declared. This can be implemented through a labeling program for the finishing materials involved in making external covering structures, building roofs, and exterior paving materials. The label should include the product's information, product code, etc., and must indicate the SRI value that is given by a valid testing laboratory.

3.2. Proposed Labeling Format

Through an overview of the programs, the types of labels used for construction materials around the world, and the selected criteria that comply with building energy codes and green building evaluation system requirements, the authors propose an energy label that declares the energy properties of products and materials to help customers make choices that are in keeping with their responsibility to the environment and society. This label can be applied to building envelopes and roof structures such as wall panels, wall structures, glazing, windows, and doors. The labels should include several main aspects: the basic information of the materials and/or products (product name, company…), the certificate number of the products given by a designed certification organization, and information on the energy-saving properties of the products, as follows:

- For building materials or construction products used as external coverings (including walls and rooftops), the thermal conductivity λ (W/m·K) must be declared.
- For building materials or construction products applied to external enclosures and the building roof, including the finish coating, information on the SRI must be provided.
- For building materials and construction products that are light-permeable, such as windows, glass doors, or glass walls, information on the SHGC of the product must be declared.

No benchmark energy consumption data for similar materials are available for comparative evaluation at the moment. Therefore, these labels are proposed to be implemented as a type of informative label, providing information for investors, designers, consultants, construction contractors, and consumers so that they can choose suitable energy-efficient materials according to QCVN09:2017. This might accelerate the development of energy efficiency technology in buildings. The recommended symbols are presented in Figure 3.

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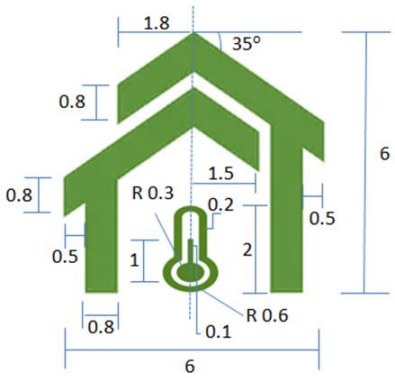
AAAA-BBBB
λ—YYYY (W/m·K)
ISO 8301:1991
For materials used as external covering structures

AAAA-BBBB
SRI—YYYY
ASTM E 1980:2011
For materials used as external enclosures and the building roof

AAAA-BBBB
SHGC—YYYY
TCVN 11857:2017
For light-permeable materials, such as windows, glass doors, or glass walls

Size



Color

C:50; M:0; Y:100; K:45

Symbol guidelines:
A symbol can be applied to many products. The size of the label will be chosen based on the size of the product
The minimum required size is 6 × 6 mm.

Figure 3. The proposed energy label for construction materials.

3.3. Proposed Labeling Program

The labeling program is proposed to be implemented on an incentive basis for the first two years (expected time is from 2024 to 2025), before becoming mandatory in subsequent years. The labeling program can be applied to all types of products and materials involved in the manufacturing of building envelopes and roof structures. The size of the proposed label can be enlarged or reduced, or imprinted, embossed, or integrated with the background of the product or material's label to ensure it does not cause confusion or obscure or affect the ability to observe mandatory information according to the law on product labeling. This energy label can be attached directly to products or on packaging or product instructions. Organizations and individuals using energy labels on products must be held responsible according to the law and promulgated regulations if the information on the label does not meet the declared value of the product. The product owner must bear all testing costs, costs related to handling and overcoming errors, and other additional costs when participating in the labeling program.

It is clear that this system for testing, evaluating, and labeling the thermal properties of construction materials will help ensure the clear and consistent understanding of their users. The program will also ensure that manufacturers have incentives to produce materials with good thermal insulation properties, making it easier to comply with national regulation QCVN 09:2017/BXD and the evaluation programs for green and energy-saving buildings; in turn, this will support the effective implementation of energy efficiency in the building sector and also follow the trend of sustainable development.

3.4. Proposed Labeling Process

The proposed labeling process is shown in Figure 4. According to this process, enterprises with certification and labeling requirements for their products need to prepare all necessary documents (including the application form, manufacturer's dossier, report on environmental implementation,

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results of product testing, etc.) and send them to a designated certification and labeling organization. Then, this organization will determine whether the submitted documents meet the requirements for issuing the energy label. After the evaluation step, the enterprise will receive the certification, the information on the label, and the self-labeled certificated product. The detailed steps are shown in Table 6.

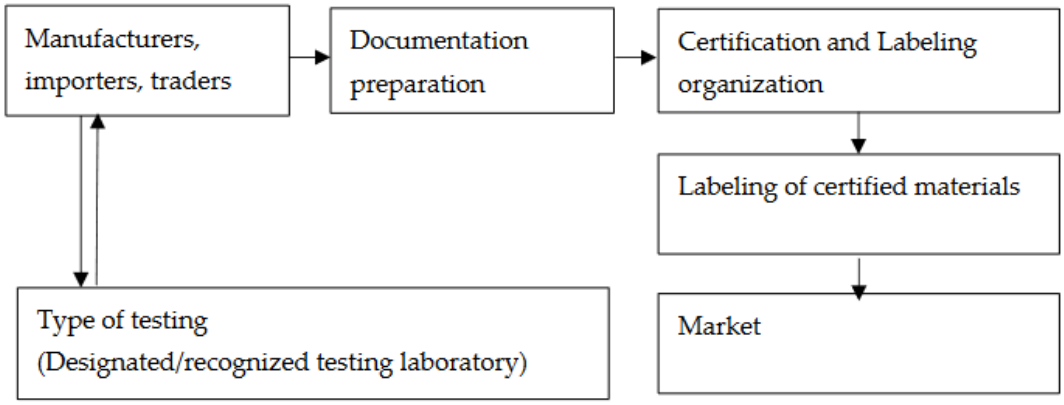

Figure 4. The proposed labeling process.

Table 6. Proposed labeling procedure.

Step	Operations
Step 1	Prepare application guided by certification organization
Step 2	Conduct type testing at designated/recognized laboratories (ISO/IEC 17025-accredited)
Step 3	Prepare documentation and send to certification organization
Step 4	Label products and add them to the market

3.5. Case Study of Insulating Product

All four AAC panel specimens were cut to the size of 300 × 300 × 100 (mm) from the AAC product that was supplied by the Viglacera Joint Stock Company. The specimens were dried at 105 °C for 72 h to reach a stable condition and were then measured to determine their size and bulk density. After that, thermal conductivity measurements were performed using a guarded hot plate GHP 900 (NETZSCH TAURUS Instruments, Germany) for measurement. The equation that presents the relationship between thermal conductivity and bulk density is given below (Equation (1)). Finally, the nominal thermal conductivity of the product in accordance with TCVN 7959:2011 [23], autoclaved aerated lightweight concrete blocks, was calculated using Equation (1).

The density, size, and thermal conductivity of each specimen are presented in Table 7.

Table 7. Technical specifications of measured specimens.

Property	Value			
	Specimen 1	Specimen 2	Specimen 3	Specimen 4
Nominal density (kg/m^3)	600	600	600	600
Measured density (kg/m^3)	595.86	670.46	607.56	658.11
Measured thermal conductivity, λ (W/m·K)	0.17038	0.20715	0.17154	0.17321

Figure 5 indicates the relationship between the thermal conductivity and measured density that was determined from the results shown in Table 7.

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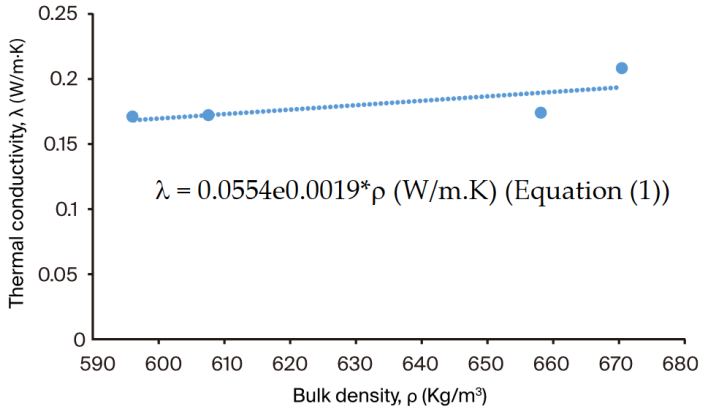

Figure 5. The relationship between thermal conductivity and bulk density.

$$\lambda = 0.0554e^{0.0019 \cdot \rho} \text{ (W/m·K)} \quad (1)$$

The calculation results in accordance with TCVN 7959:2011 are presented in Table 8, and the AAC product label is shown in Figure 6.

Table 8. Calculation results for nominal thermal conductivity according to TCVN 7959:2011.

No.	Nominal Bulk Density (kg/m³)	Nominal Thermal Conductivity (W/m·K)
1	600	$\lambda_{23}^{600} = 0.173$
2	551	$\lambda_{23}^{551} = 0.158$
3	650	$\lambda_{23}^{650} = 0.191$

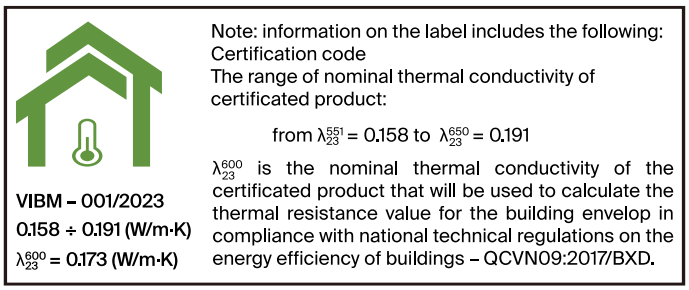

Figure 6. The energy-saving label for an AAC block in Vietnam.

4. Conclusions

In this study, a labeling system for building materials was developed using all available information about the criteria, form, and labeling process. This presents the Government of Vietnam with an opportunity to build an energy labeling system for building materials from the bottom up, learning from international and Vietnamese best practices. To verify the suitability of this developed labeling program in practical use, the authors used it to label an AAC insulation product. The results show that the developed labeling program is suitable for the demand, testing, and certification of building materials in Vietnam. This research is essential for evaluating building materials and construction products that are suitable for current and future energy-efficient and sustainable buildings and building materials and to push the construction materials market toward the use of these materials to achieve the goal of zero emissions by 2050. Other countries that aim to improve energy efficiency in the building sector may also learn from the example of Vietnam.

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Data Availability Statement: No new data was created in this study

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