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ISSN 2720 - 9644 (print)
ISSN 2721 - 0871 (online)
IJESSS
INTERNATIONAL JOURNAL OF ENVIRONMENTAL, SUSTAINABILITY AND SOCIAL SCIENCE
Indexed By : GARUDA Google doi Crossref ROAD INDEX COPERNICUS oneSearch ISJD sinta 4 EBSCO Clarivate Analytics WEB OF SCIENCE
Volume: 5
Number: 4
Page: 1126 - 1139

CLIMATE ADAPTATION IN CONSTRUCTION TOWARDS ZERO EMISSION: CASE STUDY IN VIETNAM

Thi Song LE[1], Cao Chien LE[2], Jae Yoon SHIN[3], Tea Gyun YUN[4], Sung Uk JOO[5], Sang Moon LEE[6], Trung Thanh LE[7], Thi Tam NGUYEN[8]

[1,2,7,8]Vietnam Institute for Building Materials, Ministry of Construction, Hanoi 100000, Vietnam

[3,4,5,6]Korea Conformity Laboratories, 107, Seongbonsandan 2-Ro Geumwang-eup, Eumseong-gun, Chungbuk, 27679, Korea

Corresponding author: Thi Song Le

E-mail: lesong1986@gmail.com

Article History:
Received: 2024-06-17
Revised: 2024-07-03
Accepted: 2024-07-16

Abstract:

Low energy consumption significantly contributes to new and retrofitting buildings when emphasizing energy efficiency. Although the mandatory requirements for U-factor and R-value are described in the Vietnamese National Technical Regulation on energy efficiency buildings - QCVN09:2017/BXD, these values have yet to be widely published, leading to designers' difficulties in choosing suitable materials at the design stage. The research involved a literature review, selection of criteria from global energy programs, developing a building materials labeling program in Vietnam, and a case study on insulation products to test its applicability. This paper focuses on the method of declaring heat transfer values of building materials based on the energy-labeling process. The study aims to build an energy labeling program for building materials. Criteria and labeling procedures for windows, doors, walls, and building roofs have been developed to accomplish these objectives. In addition, a case study for labeling insulation products was researched to evaluate the applicability of the developed labeling program in the implementation phase.

Keywords: Energy Label, Building Materials, Energy Efficiency, Labelling Program, Sustainable Building

INTRODUCTION

Buildings use about 40% of global energy and emit approximately 30% of global emissions (Payam Nejat et al., 2015). The ambitious goal of carbon neutrality by 2050 can be achieved by improving building energy efficiency. It is widely known that energy consumption in the building can be reduced by adequately selecting building energy-saving materials (Amani & Hosseini, 2011). In most developed countries, the energy rating and labeling system for building materials was introduced to help consumers make the right decisions about the products they procure and whether they are energy-saving building materials (Harrington & Damnics, 2004).

In general, the energy labeling system for building materials will provide the following benefits: (1) Allow consumers directly compare the energy performance of a product from different manufacturers; (2) Allow consumers and designers to choose the suitable materials based on their actual energy performance; (3) Provides 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, assess energy efficiency buildings, or green buildings; (5) Encourage construction material manufacturers to capture the market's use of products, to improve technologies that are suitable for consumption needs and practical use; (6) Encourage designers to come up with ideas on how to use materials to make the most of energy saving benefits to minimize construction and

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operation costs and to reduce CO2 emissions from energy consumption and specifies a product that meets the code.

Several energy labeling programs for building materials were issued around the world, including Nordic Ecolabels, New Zealand, Canada, Australia, Korea Ecolabels, Taiwan GreenMark, UK Energy Saving Recommended Logo and U.S. programs (Economidou et al., 2011; Evans et al., n.d.; Harrington & Damnics, 2004; Sujiman, 2024; Park et al., 2015). The implementation of green buildings and energy-saving buildings is carried out very effectively in countries where labeling programs are widely implemented.

In the United States, independent or non-profit associations mainly test, rate, and label building materials. Different building materials in the U.S. may undergo different processes to be tested, certificated and labeled. For example, the National Fenestration Rating Council (NFRC) managed the windows' rating and labeling system. At the same time, the American Society for Testing and Materials developed test methods for insulation products that were rated and labeled by the U.S. Federal Trade Commission. The Cool Roof Rating Council (CRRC) rated and labeled the radiative performance of roofing products. Indicators for each label are shown in Table 1 (National et al., 2016).

Table 1. Labelling Program and Criteria for Building Materials in the U.S

Type of label	Applicable product	Indicator
NFRC	Windows, doors, skylights	U-factor, SHGC, VLT, air leakage, condensation resistance
Energy Star	Wall insulation	R-values
CRRC	roofing products	solar reflectance, thermal emittance, solar reflective index (SRI)

(National Fenestration Rating Council, 2016).

In Europe, the Nordic Swan system has been known as one of the most comprehensive ecolabels for windows. It is a voluntary certification system that covers Denmark, Finland, Iceland, Norway and Sweden. It is designed to provide a guide for fixing and opening windows, window doors, and exterior doors, forming the boundary between accessible and heated areas. The main aspects of the Nordic Swan Ecolabel are shown in Table 2 (Economidou et al., 2011).

Table 2. Information on Nordic Swan Ecolabel in the EU

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

(Economidou et al., 2011)

In Korea, labeling and certification programs have been nationally implemented to reduce total energy consumption in buildings (Wang et al., 2019). As a result, many construction companies

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have paid attention to selecting more effective green and energy-saving building materials. It not only leads to an increase in the number of green buildings and energy efficiency buildings where the environmental impacts of buildings are reduced, but it also drives the development of the construction market in a sustainable direction. The benefits of labeling and certification standards for eco-friendly building materials are realized.

In Vietnam, using energy economically and effectively in buildings has gained much attention from government management and scientific research to ensure energy security and 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 and realize the energy-saving goal in buildings and towards a sustainable consumption culture. In 2006, The Ministry of Industry and Trade (MOIT) released the Vietnam National Energy Efficiency Program (VNEEP) from 2006 to 2015 (Decision 04/2017/QD-TTg List of Products under VNEEP, n.d.). The results show that the country saved 5.65% of total energy consumption from 2011 to 2015, equivalent to saving 16.1 million tonnes of oil equivalent (TOE). Four groups of equipment and vehicle subjects have been required for energy labeling under Prime Minister Decision No. 04/2017/QD-TTg in March 2017 (Decision 04/2017/QD-TTg List of Products under VNEEP, n.d.). These include household appliances, office and commercial appliances, industrial equipment, and means of transport. The Vietnamese National Energy Performance and Labeling program was begun in 2011 in the form of voluntary and became mandatory in 2023. There are two types of energy labels: endorsement and comparative labels, as shown in Figure 1. However, they have not yet been applied to building materials (phủ, n.d.-b, p. 3).

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 in the nine months of 2023 increased by 6.17% compared with the same period in 2022 (dựng, n.d.). With Vietnam's current economic development rate, the pollution rate is increasing, increasing housing demand. As a result, new building types that use new building materials are being developed. In parallel, the awareness of reducing embodied emissions and energy consumption by selecting suitable building materials is growing (Oktaviari et al., 2023). The regulations related to economic and energy requirements have been issued as a critical national strategy, working to reduce national energy consumption and greenhouse gas emissions in the building, as shown in Table 3. This effort is an urgent national issue implementing the 2050 national carbon neutrality declared at COP26.

However, the use of energy economically and efficiently in the building is being delayed due to insufficient mandatory design standards and quality certification standards for distribution technology. Furthermore, the lack of field practitioners for the implementation of building energy efficiency (BEE) has led to low awareness of BEE in the Vietnamese construction demand market and is acting as a factor delaying the implementation of mandatory BEE design standards. To solve

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these problems, the existing BEE design standards should be advanced to ensure clear BEE guidelines are maintained without confusion in the implementation process by the government and the demand industries. Second, a quality certification system for critical technologies for BEE implementation should be established to encourage the distribution of high-quality thermal insulation building materials.

Testing, certifying, and labeling are essential in selecting material from the design stage. It will also facilitate the expansion of Vietnam's BEE market and strengthen industrial capacity. Building owners, architects and construction companies need help accessing information relevant to the energy performance of materials due to the lack of an energy labeling program. Consequently, it must be directly requested information from manufacturers or can be re-searched using the manufacturer's website. It limits the implementation of energy-saving, green, and sustainable buildings that meet the national building code and other Vietnamese regulations in the building sector. The labeling program for building materials will bring many benefits to promoting and implementing energy-saving activities. Especially, Decision No.280/QĐ-TTg set a target up to 2030. At least 50% of insulating building materials available in the market must be labeled (LawNet, n.d.-a). Therefore, the implementation of research for the development of energy labeling for building materials is necessary, consistent with actual needs and national strategies on energy saving in the building. It 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.

Table 3. Policy for Energy Efficiency in Buildings in Vietnam

Policy	Detail contents	When	Reference
Energy Efficiency and Conservation Law	Obligations of Key Energy Users: - Appoint an energy manager Perform Energy audits every three years - Apply Energy management system - Develop and implement a 5-year energy efficiency plan	2010	(*Law No. 50/2010/QH12 of 2011 2010.*)
Decree No. 21/2011/NĐ-CP Implementation of the Energy Efficiency and Conservation Law	Definition of the Key Energy User Entities: a) Industrial, agricultural, production establishments and transport units consuming > 1000 TOE per year. b) Tertiary buildings (office, residential, educational, medical, entertainment and sports facilities; hotels, supermarkets, restaurants, shops) consuming > 500 TOE per year	2011	(Decree No. 21/2011/NĐ-CP, 2021)
Construction Law	The Law on Construction (amended in 2020) regulates incentives for assessing and certifying energy-efficient and green buildings. Article 10, Clause 4: The state has a policy incentive for investment activities, certification of energy savings and efficiency, and natural resource consumption in buildings while ensuring environmental requirements.	2014 amended in 2020	(Construction Law, 2014)

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National regulation on energy efficient buildings-QCVN09:2017/BXD	Article 162, Clause 2: Ministry of Construction: "Promulgating and organizing the implementation of criteria for buildings using efficient energy and natural resources This regulation provides mandatory technical standards for designing, constructing or retrofitting buildings with a gross floor area of 2,500 m^2 or more, including offices, hotels, hospitals, schools, commercial buildings, and residential buildings. The requirements of this regulation apply to the building envelope, ventilation and air conditioning systems, lighting systems and other electrical equipment.	2017	(*Energy Code, 2017.*)
Decision No.280/QĐ-TTg: Approving the National Program on Economic and Efficient Use of Energy from 2019 to 2030	Deploy and implementation of QCVN09:2017/BXD At least 50% of insulating building materials must be labeled up to 2030	2019	(Decision No.280/QĐ-TTg, 2019)
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 2021 - 2030, which emphasizes implementing activities to develop standards, sets of criteria and guidelines for assessing and certifying building materials that are energy-saving, green, environmentally friendly and low carbon emission.	2020	(*Decision No. 1266/QD-TTg, 2020.*)
Decree No. 15/2021/NĐ-CP: Regulations detailing construction investment management content (specifying some Construction Law contents).	Article 7. Energy-efficient constructions, resource-saving constructions, and green constructions: When investing in construction, technical solutions and management measures must be available that aim at energy efficiency, resource conservation, and environmental protection. The state encourages constructing, developing, evaluating, and certifying energy-efficient, resource-saving, and green buildings. - The development of the buildings mentioned in clause 2 of this Article will be implemented according to the policies, plans, and application roadmaps stipulated by the Prime Minister.	2021	Decree No. 15/2021/NĐ-CP, 2021)

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	- The Minister of Construction is responsible for establishing standards and regulations on criteria, evaluation procedures, and certification for energy-efficient, resource-saving, and green constructions.		
Decree No. 06/2022/ND-CP Regulations to mitigate greenhouse gas emissions and protect the ozone layer	This Decree stipulates the minimum greenhouse gas emission reduction target for the period up to 2030 in the construction sector is 74.3 million tons CO2eq	2022	(Decree No. 06/2022/ND-CP, 2022)
Decision No.385/QĐ-BXD: Approving climate change action plan in the construction sector for the 2022 – 2030 period with a vision towards 2050 to fulfill Vietnam's commitments in COP 26	Exploiting and producing building materials: a) From 2022 to 2025: - 25% Of domestic construction materials are certified as green products - Reduce at least 25% GHG emissions in investment and operation of apartment buildings - 100% Of new and renovated buildings must be compliant with QCVN09:2017/BXD b) From 2030 to 2050: - Assess and conduct mitigation of GHG emissions for 100% of new buildings - > 50% of government projects meet green criteria - 100% of commercial buildings apartments are certified as low-carbon	2022	(Decision No.385/QĐ-BXD,2022)

This study researched the concept and design of an understandable labeling system for building materials to help professionals and other practitioners select performance-based support materials for energy-efficient and resource-efficient construction. The aim is to translate the complex information about building materials' energy consumption into a form easily understood by all relevant actors (e.g., skilled and unskilled construction workers and planners). Here, criteria, type of label, and labeling process for building envelopes and roofing products have been established following applicable conditions in Vietnam.

METHODS

This section describes the procedure followed while conducting this research. The study procedure is presented in Figure 2.

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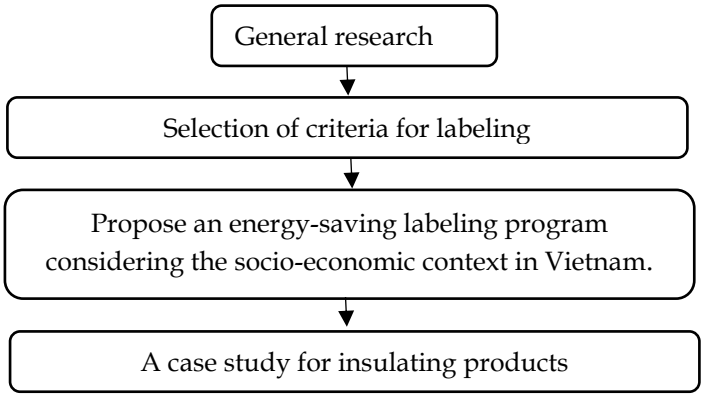

Figure 2. The study procedure

General Research. This part involved a literature review. Based on the observation of the overview, the authors proposed a labeling program for building materials applicable to Vietnam.

Selection of Criteria for Labeling. The criteria and technical parameters were determined through research of several energy labeling programs worldwide, mentioned in the Vietnam building energy code. These parameters were then used to develop a labeling concept suitable for Vietnam conditions.

Propose an energy-saving labeling program for building materials in Vietnam. In this part, a labeling program for building materials was developed based on the lesson learned from the world. The label type and the labeling process were proposed in this part.

It is a case study for insulating products. To evaluate the applicability of the selected criteria in practice, the developed labeling program was applied to autoclaved aerated concrete bricks supplied by Viglacera Joint Stock Company.

RESULT AND DISCUSSION

The requirements of the energy efficiency regulation in buildings of Vietnam - QCVN09:2017/BXD apply to (1) Building envelope; (2) Ventilation and air conditioning systems; (3) Lighting systems; (4) Other electrical equipment (electric motors, water heating systems). Among subjects, the building envelope has not been on the list of products under the VNEEP program according to Decision No. 04/2017/QĐ-TTg (Decision 04/2017/QĐ-TTg, 2017). Therefore, this research will focus on developing an energy labeling program for building envelopes which include light-transmitting materials (glazing, glass door, window), materials involved in making wall and roof covering structures (insulation materials), and finishing materials involved in making external covering structures, building roofs and exterior paving materials (such as paint, coating…).

Selection of Criteria for Labeling.

For Light-Transmitting Materials and Product Parts, according to building energy code QCVN 09:2017/BXD, maximum SHGC values for glazing shall be determined for the north-facing façade, the south-facing façade, and the other orientations (Christy et al., 2023). These values must comply with the values specified in Table 2.1 of the regulation (National Technical Regulation on Energy Efficiency Buildings, 2017).

According to this regulation, the SHGC value should be a mandatory parameter on the label applied for light-transmitting materials. As a result, the SHGC value was selected as an indicator on the product's label, together with typical information such as the manufacturer's name, the product name, the product code and other needed information. It is important to note that a designated laboratory must provide the SHGC value.

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For Materials Involved in Making Wall and Roof Covering Structures. Table 4 of the building energy code, QCVN09:2017/BXD, specifies the building envelope design requirements.

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

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

Therefore, the label indicator for materials involved in making wall and roof covering structures should include standard information like the company's name and product code and must include thermal conductivity, λ, the standard laboratory gives that.

For Finishing Materials: Involved in Making External Covering Structures, Building Roofs and Exterior Paving Materials. Vietnam's current urbanization process faces the "Heat Island Effect" phenomenon, in which the central city area will have higher temperatures than the outlying area. Combined with greenhouse gas emissions, the city area absorbs and re-emits the sun's heat more than natural landscapes such as forests and water bodies. In order to measure the ability of roofs to reject solar heat, as shown by a slight temperature rise, the solar reflectance index (SRI) is usually used.

The value of the SRI index has been required in current green building certification systems in Vietnam, such as LOTUS and LEED (LEED Rating System | U.S. Green Building Council, n.d.; "LOTUS Rating Systems," n.d.). In the LOTUS evaluation system, the requirement of 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 the SRI greater than 29 or block the sun with existing tree canopies or place the building in a planned tree planting area within 10 years (tree shade must cover the roof and paving surface); (2) use paving materials with the SRI values greater than 29; (3) use roofing materials with the SRI value greater than 78 for roofs with small slopes (height to length ratio less than 2:12) and roofing materials with an SRI value greater than 29 for roofs with steep slopes. The SRI index is required in the LEED certification system, as shown in Table 5.

Table 5. The Requirement for SRI Index in the LEED Evaluation System

Material	Initial SRI value
Roofs with a slight slope (≤ 2:12)	≥ 78
Roofs with large slopes (> 2:12)	≥ 29
Parking lot	≥ 29
Road, sidewalks, yards	≥ 29

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

Proposed Labeling Format. Through an overview of the programs, the types of labels used for construction materials around the world and the selected criteria which complied with building energy code and the requirement in the green building evaluation systems, the author proposed a form of energy label that declares the energy properties of products and materials to help customers choose suitable products in keeping with their responsibility to the environment and society. This

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label applies to building envelopes and roof structures such as wall panels, wall structures, glazing, windows, and doors. The labels include two main aspects: basic information about materials/ or products (product name, company), the certificate number of products that the designed certification organization gives, and its information on energy-saving properties, as follows:

- For building materials or construction products used as external covering structures (including walls and rooftops), the thermal conductivity of materials λ (W/m. K) must be declared, except for wall paint.
- Building materials or construction products applied to external enclosures and building roofs, including the finish coating, must provide information on the SRI of materials or construction structures.
- 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 of glass doors or glass walls must be declared.

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

Proposed a Labeling Program. The labeling program is proposed to be implemented on an incentive basis for the first two years and becomes mandatory in subsequent years. The labeling program is applied to all types of products and materials involved in the building envelope and roof structures. The size of the proposed label can be enlarged or reduced, imprinted, embossed or integrated with the background of the product's label on the products or materials to ensure it does not cause confusion, 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, packaging, or instructions. Organizations and individuals using energy labels on products must be responsible according to the Law and promulgated regulations if the information on the label does not meet the product's declared value. The product owner must bear all testing costs related to handling and overcoming errors and other additional costs when participating in the labeling program.

The testing, evaluating, and labeling system to publish the thermal properties of construction materials will help users clearly and consistently understand the thermal properties of materials. The construction materials labeling program also ensures manufacturers have incentives to produce materials with good thermal insulation properties, making it easier to comply with national regulation QCVN 09:2017/BXD and evaluation programs for green and energy-saving buildings. The development of an energy labeling program for building materials supports the implementation of energy efficiency in the building, making it more effective and following the trend of sustainable development.

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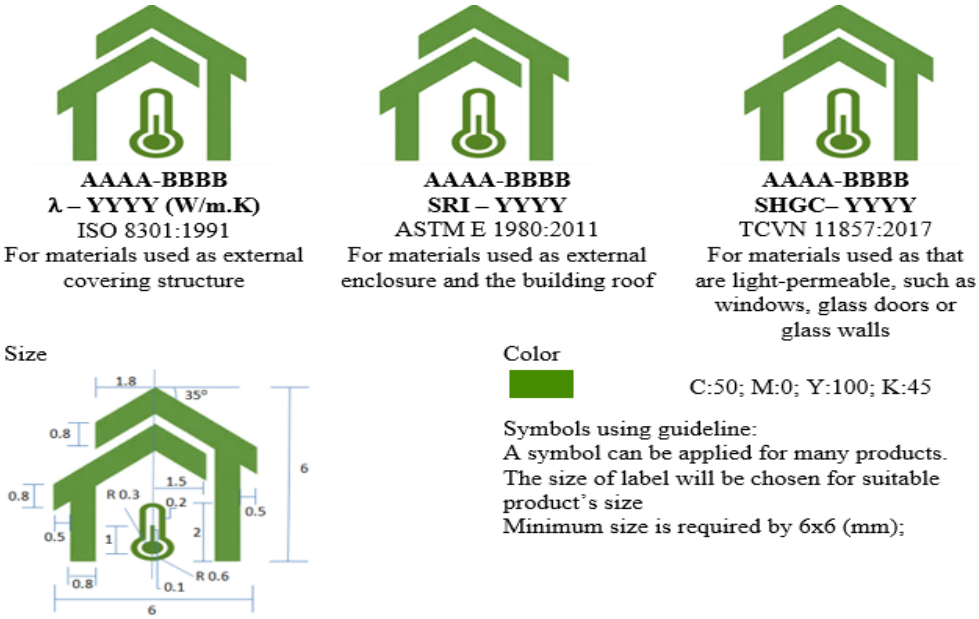

Figure 3. A proposed energy label for construction materials

Proposed a Labelling Process. A labeling process was proposed, as shown in Figure 4. According to this process, enterprises with certification and labeling requirements for their products must prepare all necessary documents (including application form, manufacturer dossier, report on environmental implementation, and product testing results…) and send them to a designed certification and labeling organization. In the second step, this organization will evaluate and consider if the submitted documents meet the requirements for issuing the energy label. After the evaluation step, enterprises will receive their certification and information on the label and self-label their certificated product. The detailed steps are shown in Table 6.

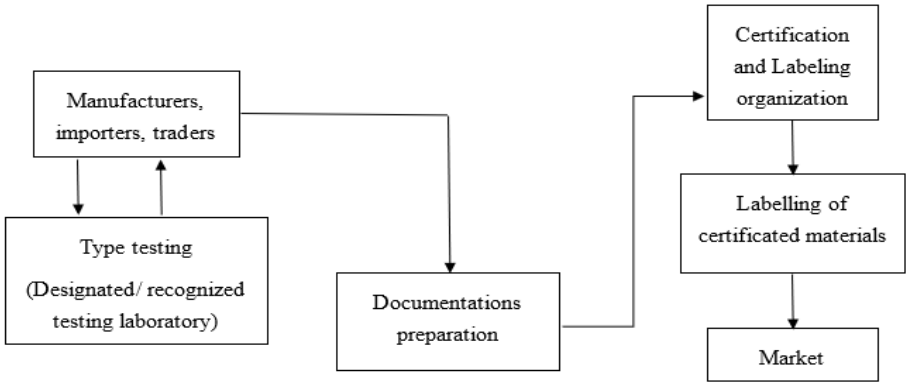

Figure 4. A Proposed Labelling Process

Table 6. Proposed a Labelling Procedure

Step	Operations
Step 1	Application as guided by certification organization
Step 2	Type- test conducted at designated/ recognized laboratories (ISO/ IEC 17025 accredited)
Step 3	Prepare documentation and send it to the certification organization

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Step 4 Labeling and putting labeled products into the market

A Case Study for Insulating Product. All 4 specimens of AAC panel were cut with the size of 300 x 300 x 100 (mm) from AAC products supplied by Viglacera joint stock company. The specimens were dried at 105oC for 72h to reach stable conditions. Then, the specimens were measured in size and bulk density. After that, thermal conductivity measurement was taken using a guarded hot plate GHP 900. As a result, the equation that presented the relationship between thermal conductivity and bulk density was given (equation 1). Finally, the nominal thermal conductivity of the product following TCVN 7959:2011 - Lightweight concrete: autoclaved aerated concrete blocks were calculated from equation 1.

Table 7 presents the measured results of each specimen's density, size, and thermal conductivity.

Table 7. Technical Specifications of Measured Specimen

Property	Value			
	Specimen 1	Specimen 2	Specimen 3	Specimen 4
Nominal density (kg/m3)	600	600	600	600
Measured density (kg/m3)	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 thermal conductivity and measured density, which was determined from the results shown in Table 7.

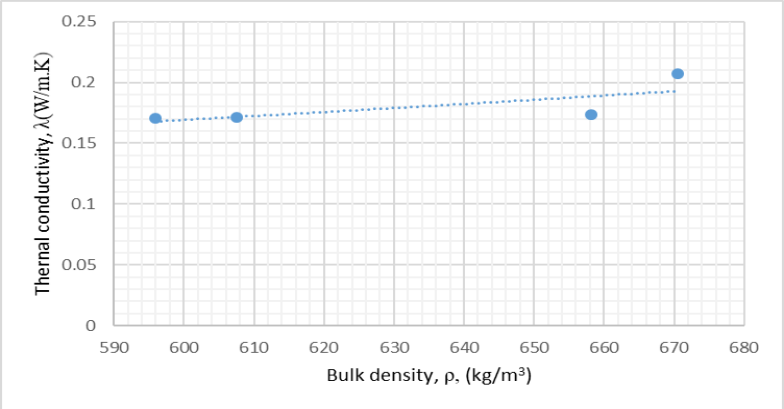

Figure 5. The Relationship Between Thermal Conductivity and Bulk Density

Table 8 presents the calculation results following TCVN 7959:2011, and Figure 6 shows the final label for the AAC product.

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	$\lambda_{23}^{650} = 0.191$

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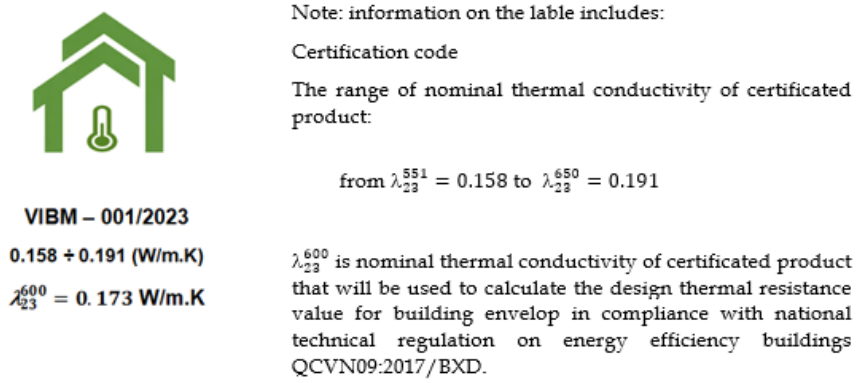

Figure 6. The Energy-Saving Label for AAC Block in Vietnam

CONCLUSION

In this study, the labeling system for building materials was developed with complete information about criteria, form and labeling process. It 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. The authors have labeled AAC insulation products to verify the suitability of this developed labeling program in practical use. The results show that the developed labeling program suits Vietnam's demand, testing and certifying conditions. This research is essential in evaluating building materials and construction products suitable for the present and future generations of energy-efficient and sustainable buildings. This primary research will significantly contribute to developing new energy-saving building materials to push the construction materials market toward using energy-saving materials to achieve the goal of zero emissions by 2050. Other countries that aim to improve energy efficiency in the building may also learn from the example of Vietnam.

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