OVERVIEW OF ECO-INNOVATION ASSESSMENT INDICES AT THE ENTERPRISE LEVEL

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Summary:

Eco-innovation (EI) is a type of innovation that contributes to generating new solutions, providing added value to consumers and businesses by significantly reducing environmental impacts. It is also the key to transitioning traditional linear production and consumption systems to circular economic practices. Measuring eco-innovation is crucial and is part of implementing circular economies. An overview of studies related to eco-innovation assessment indices at the enterprise level indicates that the indices currently focus on four forms of eco-innovation (product, process, organization, and marketing). Furthermore, the overall results show that research on eco-innovation in general and the assessment of eco-innovation at the enterprise level in Vietnam is currently limited. Therefore, this study recommends that Vietnam may consider referring to a set of 30 comprehensive indices for measuring eco-innovation within enterprises. Additionally, there is a need for additional and updated research on a suitable set of eco-innovation assessment indices at the enterprise level that aligns with the conditions in Vietnam.

Keywords*: Innovation; Eco-innovation; Assessment criteria; Enterprise.*

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1. Introduction

In the current context, due to sustainability requirements at both international and national levels, measuring the effectiveness of business operations in the context of global business is gradually shifting from simple performance metrics based solely on business results to metrics that consider sustainable goals in social, economic, and environmental aspects. Therefore, businesses are increasingly focusing on more sustainable

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production methods and integrating sustainable processes into core business activities. Success in addressing environmental issues will create new opportunities for businesses to achieve sustainable development values and new competitive advantages. This leads to eco-innovation, a special form of innovation, being considered as a strategic tool to achieve these goals.

As recommended by researchers and policymakers, one of the most effective techniques for businesses to minimize pollution while maintaining their competitiveness is eco-innovation *(Jun & colleagues, 2019; Yang & Roh, 2019)*. However, this tool will not be effective without practical research on eco-innovation, specifically without a suitable tool for assessment and measurement that can be applied. The assessment and measurement of eco-innovation at the business level help understand the extent to which businesses practice eco-innovative activities and enhance social awareness, especially encouraging businesses to strengthen these activities. It also helps policymakers understand the motivations and barriers, thereby helps designing effective policies and framework conditions promote eco-innovative practices. Eco-innovation can be measured at various levels: international, national, regional, sectoral, and business levels, playing a crucial role as a part of the implementation of circular economies.

At the national level, the ASEM Eco-Innovation Index and the Eco-Innovation Scoreboard (Eco-IS) are two prominent sets of indices used to measure and compare eco-innovation performance among countries. In addition, there are other indices that measure eco-innovation at the national or regional level, such as those used by the European Union *(Kemp & Pearson, 2007; Smol et al., 2017),* China *(Chen et al., 2017)*, and others.

In Vietnam, at the national level, the ASEM SMEs Eco-Innovation Center (ASEIC) has used the ASEM Eco-innovation Index to assess the national-level eco-innovation in Vietnam and compare it with 10 countries in the region. Based on this index, Nguyen Ngoc Tu (2021) developed a set of indices for Vietnam at the provincial/city level with 23 component indicators grouped into three categories: eco-innovation-supportive environment, eco-innovation activities, and eco-innovation results, in line with national statistical indicators, and applied as a pilot in Quang Ninh province. Additionally, some other sets of indices are used to assess the "green" level at the national level, such as the Green Growth Statistical Index, Provincial Environmental Protection Results Index, and Provincial Green Index.

However, at the enterprise level, research on the measurement and assessment of eco-innovation is still relatively limited. Currently, only a

few studies have constructed general eco-innovation indices at the business level, such as the study by Dinh Tuan Minh et al (2018), a set of indices used to investigate eco-innovation in businesses conducted by the Ministry of Science and Technology, or the most recent one, the set of eco-innovation business assessment indices for Vietnam developed by NIC & GIZ (2021), which is currently in the testing phase to evaluate the eco-innovation status of businesses.

Regarding the assessment of the "green" level of businesses, the Small and Medium Enterprise Development Fund (SMEDF) and the Global Green Growth Institute (GGGI) have provided criteria related to green growth for small and medium-sized enterprises in two groups: processing and manufacturing industries and agriculture, forestry, and fisheries (SMEDF & GGGI, 2019. The research by Nguyen Ngoc Thia (2019) developed a set of 29 criteria, divided into seven groups: (i) energy and resource use, (ii) natural environment, (iii) economic results, (iv) labor, (v) products, (vi) recycling, and (vii) policies to assess the implementation of green growth for cement-producing businesses in Vietnam. The study by Pham Anh Nguyen (2022) on evaluating the impact of green innovation and environmental performance on the efficiency of manufacturing businesses in Vietnam, proposed nine criteria for assessing eco-innovation for products and 11 criteria for assessing eco-innovation for processes.

For these reasons, this paper is conducted to provide an overview of eco-innovation assessment criteria at the business level. The research results will be an important reference document for developing an eco-innovation assessment toolkit in Vietnam. This can help monitor the development of the eco-innovation level of businesses, provide a basis for policymakers to have suitable policy directions based on the current situation, and contribute to achieving the goal of building a circular economy in Vietnam.

2. Concept of eco-innovation

Innovation was first introduced by Schumpeter in 1934. Since Schumpeter's initial findings and theories, the concept of innovation has evolved and increasingly captured the attention of the research community. Baregheh and colleagues (2009) summarized over 60 different definitions of the innovation concept. The OECD report in 2005 provided a definition that states, "innovation is the introduction of a new or significantly improved product (goods or services), process, marketing method, or organizational method in business practices, workplace organization, or external relations" *(OECD, 2005).* The concept of innovation was further refined by OECD in its fourth edition in 2018. The definition proposed by OECD in 2005 is comprehensive, encompassing all activities of a business and is widely

cited and generalizable. According to this definition, innovation can be categorized into four types: product, process, organization, and marketing.

The concept of eco-innovation emerged in the 1990s, and from the early 2000s, research on eco-innovation has rapidly increased. Although expressed in various terms (green innovation, environmental innovation, eco-innovation, sustainable innovation) *(Takalo & Tooranloo, 2021),* these concepts share a common point, which is reflected in the consideration of the environmental impact in the context of innovation. There are three main factors driving eco-innovation: (1) Government pressure (e.g., taxes and subsidies); (2) Consumer and industry standards pressure; and (3) Innovation resources. Innovation resources are classified into internal R&D, external R&D, mixed resources (such as purchasing machinery, software, patents, and licenses), and R&D collaboration with relevant parties *(Rodriguez & Wiengarten, 2017).*

Documents on eco-innovation use various foundational theories for their arguments, including resource-based theory and stakeholder theory *(Doran & Ryan, 2014).* Resource-based theory emphasizes the role of resources (things that the business owns, such as physical assets, finances, employee skills, organizational secrets) and capabilities (things that the business can perform) in forming the basis for gaining a competitive advantage. Additionally, stakeholder theory shows that, to survive and grow, businesses must meet the needs of stakeholders. Doran & Ryan (2014) identify four types of stakeholders in eco-innovation: regulatory stakeholders (government, trade associations, informal networks, and competitors), organizational stakeholders (customers, suppliers, and employees), community stakeholders (community groups, environmental organizations, and other advocacy groups), and media. Stakeholders influence a business's activities through direct pressure and/or by conveying information.

Table 1. Some concepts related to eco-innovation

Author	Eco-innovation related concept
Fussier & James (1996)	The process of developing new products, processes, or services that provide value to customers and businesses but significantly reduce environmental impact.
Hemmelskamp (1997)	Innovations aimed at reducing negative environmental impacts caused by production methods.
Klemmer & partners (1999)	All measures by stakeholders (businesses, politicians, associations, churches, private households) to develop new ideas, behaviors, products, and processes, and contribute to reducing environmental burdens or ecological sustainability goals.
Vinnova (2001)	Innovations to prevent or reduce the burden caused by human activities on the environment, remedy environmental damage, or diagnose and

	monitor environmental issues.
Andersen (2002)	Innovations which can promote green economics (green rents) in the market.
European Commission (2004)	Environmental technology includes all technologies that, when used, cause less harm to the environment than similar substitute technologies.
Little (2005)	"Sustainability-oriented" innovation involves creating new market spaces, products, and services or new processes driven by social, environmental, or sustainability issues.
Chen và partners (2006)	Involves product and process innovations related to energy conservation, pollution prevention, waste recycling, green product design, and corporate environmental management.
Europe INNOVA (2006)	Creating new competitive goods, processes, systems, services, and procedures designed to meet human needs and improve the quality of life for everyone, with minimal use of natural resources (including energy and surface area) per unit output and minimal discharge of hazardous substances.
European Commission (2007)	Any form of innovation aimed at significant progress and demonstrably geared toward sustainable development, reducing environmental impact, or achieving efficient and responsible use of natural resources, including energy.
Kemp & Pearson (2007)	Producing, absorbing, or exploiting a new product, production process, service, or management or business method (being developed or applied) that reduces environmental risks, pollution, and other negative impacts of resource use (including energy) compared to related alternative solutions.
European Commission (2008)	Introducing novelty into products, production processes, services, or management and business methods with the aim (throughout its lifecycle) of preventing or significantly reducing environmental risks, pollution, and other negative impacts of resource use (including energy).
Reid & Miedzinski (2008)	Innovating production processes, business operations. This innovation is carried out by minimizing the use of natural resources throughout the product lifecycle (including energy and surface area), on a per-unit output basis, and limiting the release of hazardous substances into the environment, aiming to create competitively priced goods, services, and management systems that meet consumer needs and improve the quality of life.
EIO (2010)	Introducing any new or significantly improved product (goods or services), changing processes, organization, or marketing solutions to reduce the use of natural resources (including materials, energy, water, and land) and minimize the release of hazardous substances throughout the lifecycle.
Oltra & Saint Jean (2009)	Broadly, environmental innovations can be defined as innovations involving new or improved processes, practices, systems, and products that benefit the environment and thus contribute to environmental sustainability.
Kammerer	Includes all eco-innovations that have a beneficial impact on the

(2009)	natural environment, regardless of whether this is the primary goal of eco-innovation or not.
OECD (2009)	Implementation of the production of new products (goods and services) or significant improvements in processes, marketing activities, organizational structures, and institutional arrangements to improve the environment and minimize adverse effects on the environment.
Bos-Brouwers (2010)	Eco-innovation in which the innovation or improvement of products, services, technological processes, or organization not only brings economic improvement but also enhances environmental and social performance, creating short- and long-term positive impacts on society and the environment.
Boons & Lüdeke-Freund (2013)	A process in which considerations of sustainability (environmental, social, and financial) are integrated into the company's systems from idea formation to research and development (R&D) and commercialization.
Calik & Bardudeen (2016)	Any significant or new improvement in product, service, technological process, or organization, commercially deployed or internally implemented, not only bringing economic benefits but also creating positive social and environmental impacts.
Yang & Roh (2019)	New or improved processes, technologies, systems, and products designed to minimize or avoid environmental issues.

Source: Updated based on Salvador & colleagues (2012)

An overview of the various concepts and definitions of eco-innovation above reveals several commonalities, including the improvement or innovation of products, processes, management practices, and marketing to reduce environmental impact. Therefore, in this study, eco-innovation for businesses is understood as the implementation of new or significantly improved products, or goods, or services, the development and implementation of processes, marketing methods, and new organizational methods with the aim of minimizing negative impacts on the environment, to achieve eco-innovation goals.

3. Measuring eco-innovations for businesses

The implementation of eco-innovations may or may not lead to an absolute reduction in environmental harm. In the case of replacing a technology that is more environmentally friendly, the environmental impact may decrease. However, in cases of increased productivity or increased capacity utilization, the environmental impact may rise, as each technology has some environmental impact in the production chain and during usage. Energy-saving outdoor lights are an example. Cost-saving innovations often have a "rebound effect" through increased spending. Therefore, the relevant criterion to determine whether an innovation is indeed an eco-innovation is whether its use is less harmful to the environment than using similar alternative solutions *(Kemp & Pearson, 2007).*

There are several notable studies on measuring eco-innovations. Chen & colleagues (2006) divided eco-innovations into "Green Product Eco-Innovations" and "Green Process Eco-Innovations" and developed a scale to assess technology and electronics companies in Taiwan. The green product innovation performance scale includes indices such as: (1) Companies choose materials for products that cause the least pollution for development or design; (2) Companies choose materials for products that consume the least energy and resources for development or design; (3) Companies use the least amount of material to make a product for development or design; (4) Companies carefully consider whether the product is recyclable, reusable, and disposable for development or design. Meanwhile, the green process innovation scale includes four indices: (1) The company's production process efficiently reduces emissions of hazardous substances or waste; (2) The company's production process recycles waste and emissions for processing and reuse; (3) The company's production process reduces the consumption of water, electricity, coal, and oil; (4) The company's production process reduces the use of raw materials.

Chen (2008) continued to use this scale for another study with technology and electronics companies in Taiwan. Both studies focused on emissions, end-of-life management, environmental issues, and the use of energy, materials, and other resources. Additionally, many other studies, such as Huang & Jim Wu (2010), Yang & Roh (2019),... have also used the scale developed by Chen & colleagues (2006) to measure eco-innovations. Building on the scale of Chen & colleagues (2006), Chiou & colleagues (2011) extended the scale by adding the observation "Green Managerial Innovation" and readjusted the scale to evaluate businesses in Ireland. Accordingly, the green product innovation observation includes four indices: (1) Using environmentally friendly materials for products; (2) Improving and designing environmentally friendly packaging (e.g., using less paper and plastic) for existing and new products; (3) Recovering end-of-life products of the company and recycling; (4) Using eco-labels. The green process innovation observation includes three indices: (1) Low consumption of resources such as water, electricity, gas, and gasoline in the production/use/disposal process; (2) Recycling, reusing, and reproducing materials; (3) Using cleaner production technologies to save resources and prevent pollution (e.g., energy, water, waste). The green management innovation observation includes two indices: (1) Reviewing operating and production processes to ensure internal efficiency in the company can help implement green supply chain management (GSCM)[2]; (2) Redesigning and

[2] GSCM can be classified into internal environmental management and external environmental management. Internal environmental management focuses on internal support and commitment to GCSM, certification compliance and the existence of environmental management systems within the organization. External

improving products or services to meet new environmental criteria or goals. In addition, the observation "Greening Suppliers" is measured by indices, including: (1) Choosing environmentally criteria-based suppliers; (2) Requiring and supporting suppliers to achieve third-party environmental management system (EMS) certification; (3) Organizing seminars and training to raise environmental awareness for suppliers; (4) Providing environmental technical consulting for suppliers and contractors to help them meet environmental criteria; (5) Inviting suppliers to participate in the development and design phase; (6) Sending internal auditors to assess the environmental activities of suppliers.

The study by Tseng & Chiu (2012) measures eco-innovations through indices, including: (1) Reviewing operating and production processes to ensure internal efficiency can help implement green supply chain management; (2) Redesigning and improving products or services to meet new environmental criteria or goals; (3) Reducing hazardous waste, emissions, etc.; (4) Consuming less (e.g., water, electricity, gas, and gasoline); (5) Establishing an environmental management system; (6) Providing seminars and training to enhance environmental awareness for stakeholders; (7) Advanced green production technology; (8) Recycling, reusing, and reproducing materials; (9) Using cleaner technologies such as energy, water, and waste; (10) Sending internal auditors to assess the environmental activities of suppliers; Designing and innovating processes and enhancing R&D activities; (11) Green supplier with low costs: costs per unit compared to competitive counterparts; (12) Competitiveness of new green products understood by customer needs; (13) Evaluation of technical, economic, and commercial feasibility of new green products; (14) Retrieving and recycling the company's expired products; (15) Innovating green products and design measures; (16) Investing in green equipment and technology; (17) Implementing comprehensive resource-saving plans; (18) Managing documents and information.

The research conducted by Tseng et al. (2013) utilized a similar scale to that of Tseng and Chiu (2012) but divided it into four dimensions of eco-innovation, including: management, products, processes, and technology.

Wong's study (2012) measures eco-innovations for electronic businesses in China through 02 observation variables with 10 indices. According to this, the observation variable "Green Innovation for Products" includes 5 indices: (1) New products use materials that cause little or no pollution/toxicity; (2)

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environmental management involves "greening" supplier, so they engage with the organization in achieving environmental goals. It also includes green procurement, customer collaboration, environmental requirements, capital recovery and eco-design practices or green product innovation *(Chiou & et al, 2011).*

New products use environmentally friendly packaging; (3) When designing new products, the company considers recycling and disposal when they reach the end of their life; (4) New products use recycled materials; (5) New products use materials that can be recycled. The observation variable "Green Innovation for Processes" includes indices: (1) The production process consumes fewer resources (e.g., water, electricity,...) compared to competitive counterparts; (2) The company's production process allows recycling, reusing, and reproducing materials or product parts; (3) The company's production process uses cleaner or regenerative technologies to save (e.g., energy, water, and waste); (4) The company redesigns production and operation processes to improve environmental efficiency; (5) The company redesigns and improves products or services to meet environmental criteria or goals (e.g., WEEE Directive, RoHS Directive,...). This scale is also used by Wong (2013) in his study measuring eco-innovations for electronic businesses in China.

The study by Horbach & colleagues (2012), Castellacci & Lie (2017)[3], etc., utilizes the results of the European Community Innovation Survey (CIS) conducted in 2009. The survey comprises 10 sections: (1) General information about the business; (2) Measurement of innovation in products (goods or services); (3) Measurement of innovation in processes; (4) Ongoing or abandoned innovation activities for process and product innovation; (5) Innovation activities and budgets for process and product innovation; (6) Information sources and collaboration for eco-innovation activities; (7) Eco-innovation objectives; (8) Organizational innovation; (9) Marketing innovation; (10) Innovation with environmental benefits. Regarding "Innovation with environmental benefits," it can be divided into "Eco-innovation in products" with 03 indices: (i) Reduction in energy use; (ii) Reduction in emissions of air, land, water pollution; (iii) Improvement in recycling of used products. "Eco-innovation in processes" includes 07 indices: (i) Reduction in material use per output unit; (ii) Reduction in energy use per output unit; (iii) Reduction in CO_2 emissions; (iv) Reduction in emissions of air pollution; (v) Reduction in emissions of land pollution; (vi) Reduction in emissions of water pollution; (vii) Reduction in noise pollution.

Thus, the environmental issues addressed by the EU Community Innovation Survey are not specific and separate. In this survey, they are addressed along with health and safety issues. The EU Community Innovation Survey also includes questions about whether innovation helps comply with regulations and asks about impacts related to reducing resource and energy use for improvements made in the past three years. However, there are no

[3] Castellacci & Lie (2017) use the Korea Innovation Survey scoreboard 2010, which is very similar to European CIS.

questions about waste and pollution. However, in the most recent version (2018), the survey no longer includes content related to "Eco-innovation with environmental benefits[4].

Additionally, Kemp & Pearson's study (2007) is one of the prominent studies on measuring eco-innovation. The study was carried out in collaboration with Eurostat, the European Environment Agency (EEA), and the Joint Research Centre (JRC) of the European Commission. The authors measured eco-innovation using four observations: input through R&D expenditure, intermediate output through the quantity of patents and scientific publications, direct output through the quantity of innovations, describing specific innovations and data on the sales volume of new products, and indirect impact through the efficiency of resource use. The study also developed an eco-innovation survey for small and medium-sized enterprises with 19 questions, including 9 questions about eco-innovation in organizations, including: (1) Environmental certification such as ISO 1400; (2) Conducting internal environmental audits; (3) Conducting external environmental audits from outside organizations; (4) Issuing written environmental policies; (5) Developing publicly available environmental reports for the organization; (6) Environmental objectives/indicators for organizational activities; (7) Environmental training programs for employees; (8) Using environmental criteria to evaluate/pay employees; (9) Conducting assessments of the environmental effectiveness of the organization. The study also provides an overview of measurement scale used for measuring eco-innovation, such as R&D expenditure related to the environment, expenditure on eco-innovation activities, the application of pollution control technologies, implementation of recycling programs, deployment of new or improved products or services that are more environmentally friendly than those already on the market, implementation of new or improved processes that result in environmental benefits, organizational eco-innovation like environmental reporting, audits, or environmental management programs, new distribution and transportation systems for the organization's products or services that create environmental benefits, and evaluation of the environmental impact of eco-innovation activities.

Cheng & Shiu's study (2012) developed an eco-innovation measurement scale and tested it on 1,000 businesses in Taiwan. This scale is the first study that assess the reliability. The study categorized eco-innovation implementation into 3 groups: eco-innovation for the organization, eco-innovation for products, and eco-innovation for processes. They developed 6,

[4] See European CIS at: <https://ec.europa.eu/eurostat/cache/metadata/en/inn_cis11_esms.htm#annex1675764022213>

7, and 4 indices respectively for these observations. Cheng & colleagues (2014) continued to use the scale to assess the relationship between eco-innovation and business performance. The scale used is presented in Table 2.

Table 2. Eco-innovation Measurement Scale by Cheng & Shiu (2012)

Measurement Scale	Indices
Eco-innovation for the Organization	1. Business leaders often use new systems to manage eco-innovation
	2. Business leaders regularly gather information on eco-innovation trends
	3. Business leaders actively participate in eco-innovation activities
	4. Business leaders frequently exchange information on eco-innovation with employees
	5. Business leaders often invest a high R&D percentage in eco-innovation
	6. Business leaders regularly exchange experiences among departments related to eco-innovation
Eco-innovation for the processes	1. Businesses frequently improve production processes to combat pollution.
	2. Businesses frequently enhance production processes to meet environmental law standards.
	3. Businesses regularly integrate new technologies into the production process to save energy.
	4. Businesses frequently upgrade equipment during the production process to save energy.
Eco-innovation for the products	1. Businesses often focus on developing new environmentally friendly products through new technologies to reduce product packaging.
	2. Businesses often concentrate on developing new environmentally friendly products through new technologies to reduce product structure.
	3. Businesses often focus on developing new environmentally friendly products through new technologies to facilitate the recycling of their components.
	4. Businesses often concentrate on developing new environmentally friendly products through new technologies for easy decomposition of their materials.
	5. Businesses often focus on developing new environmentally friendly products through new technologies using natural materials.
	6. Businesses often concentrate on developing new environmentally friendly products through new technologies to minimize damage from waste.
	7. Businesses often focus on developing new environmentally friendly products through new technologies to use as little energy as possible.

Source: Cheng & Shiu (2012)

Besides that, to measure eco-innovation, some studies use the quantity of patents focusing on technology factors related to sustainability, such as Aguilera-Caracuel & Ortiz-de-Mandojana (2013), Markatou (2012),... or the citation count of these patents over a period, as in Messeni Petruzzelli & colleagues (2011), Berrone & colleagues (2013),...

Shuaib & colleagues (2014) proposed a set of indices to assess the sustainability of a product, which is considered one of the important studies. Based on the life cycle assessment (LCA) approach in four stages: (i) pre-production; (ii) production; (iii) use; and (iv) post-use. The study evaluated the sustainability of the product in three dimensions: economic, social, environmental. In particular, the environmental sustainability of the product was assessed through 5 groups, 21 criteria.

Table 3. Set of indices for the sustainability assessment of the product by Shuaib & colleagues (2014)

Groups	Criteria	Indices
Efficiency and Use of Materials	Raw materials for products	- Total amount of materials used to produce the product - Recycling rate of product materials - Total amount of restricted/hazardous materials - Total amount of materials used for packaging - Recycling rate of materials used for packaging
	Use of materials	- Use of materials
	Regulations and certification	- Compliance with regulations/certifications
Efficiency and Energy Use	Renewable energy sources	- Wind - Hydro - Solar - Other
	Non-renewable energy sources	- Coal - Oil - Nuclear - Natural gas - Other
	Energy regulations and certification	- Compliance with energy regulations - Energy certification
	Energy efficiency	- Energy efficiency
Efficiency and Use of Other Resources	Water use	- Amount of water used
	Use of recycled water	- Amount of recycled water
	Use of other resources	- Use of other natural resources
	Regulations and certification related to natural resources	- Compliance with regulations on natural resources - Certification of natural resources

Groups	Criteria	Indices
Waste and Emissions	Gas emissions	- Gas emissions - Hazardous gases
	Solid waste	- Amount of solid waste landfilled - Reusable/recyclable solid waste - Hazardous solid waste generated
	Liquid waste	- Liquid waste discharged into the environment - Reusable/recyclable liquid waste - Hazardous liquid waste generated
	Other emissions and waste	- Heat - Noise - Light - Electromagnetic wave emissions
	Regulations and certification for waste management	- Compliance with waste management regulations - Waste management certification
End-of-life product	Recovery of end-of-life materials/products	- Ease of disposal of end-of-life products - Product disassembly capability - Rate of end-of-life products recovered
	Reuse of end-of-life products	- Capability to reuse end-of-life products - Rate of end-of-life products reused
	Remanufacturing of end-of-life products	- Capability to remanufacture end-of-life products - Product redesign - Rate of remanufactured products
	Recycling of end-of-life products	- Capability to recycle end-of-life products - Rate of products/materials recycled
	Regulations and certification for end-of-life products	- Compliance with regulations for end-of-life products - Certification for end-of-life products

Source: Shuaib & colleagues (2014)

The study by Calik & Bardudeen (2016) is based on an overview of various research. They employed a scale consisting of 10 observations to assess eco-innovation across three dimensions (economic, environmental, social) concerning both product and process eco-innovation.

Table 4. Eco-Innovation Assessment Index by Calik & Bardudeen (2016)

Dimension	Eco-Innovation Type	Form of Eco-Innovation	Questions
Economic	Product	New sustainable products	Over the past few years, our business has consistently developed and commercialized new products that benefit the environment and society.

Dimension	Eco-Innovation Type	Form of Eco-Innovation	Questions
Environmental		Energy Usage	Our new products consume less energy during use compared to competitors' products.
Environmental		Certification and Eco-Labeling	In recent years, the company has redesigned and improved products to meet new environmental criteria or directives (such as WEEE Directive, RoHS Directive, etc.).
Social		Quality and Durability	Over the past few years, the return and recovery rate of the company's products has continuously decreased.
Social		Design (Ergonomic)	Consumers rate the company's new products as more convenient than those of competitors.
Environmental	Process	Material Usage	Over the past few years, the company has improved the production process efficiently to reduce the use of raw materials.
Environmental		Waste, Emissions, and Pollution	The company's production processes effectively reduce emissions of hazardous substances or waste compared to competitors.
Environmental		End-of-Life Product Management	In recent years, the company has actively improved the production process for reusing and recycling parts.
Economic		Expenditure on Eco-Innovation	Over the past few years, the company has consistently increased spending on process innovations that benefit the environment and society.
Environmental		Safety and Health	Over the past few years, the company has actively designed and improved production processes to reduce injury, occupational illness, and work-related fatalities.

Source: Calik & Bardudeen (2016)

The study by García-Granero and colleagues (2020) developed a scale to assess eco-innovation for food businesses in Spain across 4 dimensions with 15 indices: product, process, organization, and marketing. According to this, Eco-innovation for products include 3 indices: (i) Ecological production (measured as a percentage); (ii) Use of biodegradable packaging (binary scale); (iii) Use of recycled packaging (measured as a percentage). Eco-innovation for processes includes 4 indices: (i) Packaging control system (binary scale); Investment in green technology (measured in

currency units); Number of green patents (measured in quantity); Material recycling rate (measured as a percentage). Eco-innovation for organizations includes 4 indices: (i) Implementation of environmental consulting (binary scale); Implementation of environmental audits (binary scale); Collaboration with stakeholders (binary scale); Environmental staff (measured by the number of people). Eco-innovation for marketing includes 4 indices: (i) Certification of environmental quality standards (measured by quantity); (ii) Certification of environmental management systems (measured by quantity); (iii) GlobalGap certification (measured as a percentage); (iv) GRASP certification (measured as a percentage).

Similarly evaluating eco-innovation across the 4 dimensions as García-Granero and colleagues (2020), Marcon and colleagues (2017) also developed a scale with 22 indices to assess eco-innovation practices for businesses in Brazil, as presented in Table 5.

Table 5. Eco-innovation assessment indices by Marcon & colleagues (2017)

Eco-innovation Type	Criteria
Eco-innovation in Product	Develop more efficient products
	Products with longer life cycles
	Products using recycled materials
	Products using environmentally friendly materials
Eco-innovation in Process	Increase process efficiency
	Save raw materials
	Reduce costs
	Clean technologies
	Reduce downtime in production lines
	Practices related to water
	Practices related to energy
	Reduce maintenance costs and material storage
	Renewable energy sources
Eco-innovation in Organization	Learning towards environmentally sustainable eco-innovation
	Explore new markets
	Collaborate with stakeholders
	Business model
	Invest in environmental expertise
Eco-innovation in Marketing	Improve/innovate distribution processes
	Innovations in packaging and design
	Innovations in communication

Source: Marcon & et.al (2017)

In addition, to measure the sustainability of an organization, a series of tools have been developed, such as the Global Reporting Initiative (GRI), AA1000, the Carbon Disclosure Project (CDP),… Among them, the GRI assessment framework is one of the most widely used frameworks to assess economic, environmental, and social issues of an organization. The GRI assessment framework (2013) comprises 149 indicators to evaluate the sustainability of an organization, divided into 3 dimensions: economic, environmental, and social. Specifically, the common standards include 57 indicators, the environmental dimension includes 34 indicators in 12 groups: materials (2 indicators), energy (7 indicators), water (3 indicators), biodiversity (4 indicators), emissions (7 indicators), waste and waste flow (5 indicators), products and services (2 indicators), compliance (1 indicator), transportation (1 indicator), overall (1 indicator), supplier environmental assessment (2 indicators), environmental grievance mechanisms (1 indicator).

Based on a review of 104 articles in the WoS and Scopus databases, García-Granero and colleagues (2018) identified 30 indicators commonly used in studies measuring eco-innovation across the 4 dimensions of eco-innovation: product, process, organization, and marketing.

Table 6. Summary of indicators in studies measuring eco-innovation

No.	Eco-innovation Practice Index
I	**Eco-innovation in Product**
1	Use clean or low-impact input materials
2	Use recycled materials
3	Reduce/restrict the use of raw materials
4	Reduce the quantity of materials per unit of product
5	Eliminate “dirty” components from product inputs
6	Products with longer life cycles
7	Product recyclability
II	**Eco-innovation in Process**
1	Reduce the amount of chemicals released into the environment
2	Reduce water consumption
3	Reduce energy consumption
4	Limit the generation of waste
5	Reuse components of the product
6	Recycle waste, wastewater, or materials
7	Environmentally friendly technologies
8	Renewable energy
9	Research and Development (R&D)
10	Purchase machinery and software
11	Purchase patents and licenses

No.	Eco-innovation Practice Index
III	**Eco-innovation in Organization**
1	Green human capital
2	Pollution prevention plan
3	Environmental goals
4	Environmental auditing
5	Environmental consulting
6	Investment in research
7	Collaboration with stakeholders
8	New markets
9	New systems (remanufacturing and transportation systems)
IV	**Eco-innovation in Marketing**
1	Packaging recovery/reuse
2	Environmentally designed packaging
3	Quality certification

Source: García-Granero & colleagues (2018)

4. Conclusion and recommendations

The overview of studies on eco-innovation in Vietnam shows that the assessment and measurement of eco-innovation by businesses are still relatively limited. In the future, assessments and measurements of eco-innovation need to be comprehensive and standardized in terms of evaluation classification, based on conformity with internationally standardized measurement methods. This raises a pressing need to have the research on specific assessment frameworks with measurement criteria, the level of eco-innovation capability development at the enterprise level. Subsequently, there should be comprehensive and tailored policy directions and solutions closely linked to the economic and social development conditions and development directions of each locality.

From the overview of studies on the assessment and measurement of eco-innovation by businesses, 4 forms of eco-innovation have been the focus of research, including: eco-innovation for products, eco-innovation for processes, eco-innovation for organizations, and eco-innovation for marketing. This study suggests considering the use of the 30 eco-innovation measurement indicators synthesized by García-Granero and colleagues (2018) to develop the eco-innovation measurement indices for businesses in Vietnam. However, one point to note is that the application needs to pay attention to the selection of indicators that bring more environmental value to each field. The overview of the above studies shows that current experimental studies on eco-innovation mainly focus on European countries, while research in the Southeast Asia region is still very limited.

Therefore, there is a need for more in-depth research to supplement and update the criteria for assessing and measuring enterprise-level eco-innovation to improve the existing research and practice gaps related to the identified eco-innovation indicators. This is especially useful when aiming to enhance the comprehensiveness and standardization of eco-innovation assessment and measurement in Vietnam./.

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