Assessing Green Technology Indicators for Cleaner Production and Sustainable Investments in a Developing Country Context

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Abstract

The United Nations proposed the Sustainable Development Goals (SDGs) to foster sustainable development, including tackling environmental challenges and adopting cleaner production practices worldwide. Green technology is crucial for the implementation of the SDGs. Currently, there is an urgent need to form a long-term sustainable investment mechanism for screening, evaluation, and promotion of appropriate green technology. Therefore, this study develops an integrated green technology framework to fill a gap in the literature by prioritizing green technologies' most critical attributes in Pakistan. Initially, we focus on eight leading green technology indicators: Environmental Quality, Resource Utilization, Agriculture & forestry, Green building, Energy utilization, Green Transport, Life Health, and Ecology Safety with the help of the fuzzy Delphi method. Fuzzy Analytical Hierarchy Process (FAHP) is employed to find primary and sub-indicators relative importance. Results reveal that Energy Utilization and agriculture & forestry are significant indicators. Supply chain and sustainable food security, Energy Recycling and Eco-Farming obtained the highest weight scores and are seen as essential among 43 sub-criteria. This study is among the first to assess the green technology indicators for cleaner production and sustainable investment to achieve sustainable development. This study's outcomes can help scholars, managers, government agencies, and decision-makers understand the importance of green technologies to achieve SDGs while simultaneously improving sustainability practices.

Keywords: Green technology; cleaner production; sustainable investment; sustainable development goals; Pakistan

1. Introduction

In 2015, the General Assembly of the United Nations (UN) adopted "The 2030 Agenda for Sustainable Development" and agreed upon the Sustainable Development Goals (SDGs). The SDGs represent a shared expression of stakeholder needs at a global level, balancing economic, social, and environmental development and provide an indication and measure of progress towards the main objective of sustainable development (Barbier and Burgess, 2017; Fonseca and Carvalho, 2019). Several technologies are essential to achieve the SDGs of the United Nations (UN) globally and locally. One of these is 'green technology,' aiming to mitigate the negative impacts from the linear/traditional economic development paradigm and improve living standards quality (Guo et al., 2020; UNCTAD, 2018). Considering the shift from a linear to a circular economy (Ferasso et al., 2020), green technologies are cutting-edge for building a sustainable future based on an economic balance for Pakistan as an emerging economy. This transition depends on interrelated factors to succeed, environmental and social resilience. It is essential to consider environmental and economic impacts when executing/implementing green technologies since this technology's effectiveness depends on these factors (Shaikh et al., 2017).

It is widely known that human activity through production function generated economic growth. However, the balance between satisfying the infinite needs via finite resources led to several environmental issues, e.g., climate change, water, air pollution, acid rain, impacting all living organisms on Earth (Durán-Romero et al., 2020). Thus, the transition to the green economy refers to targeting sustainable development through cleaner production practices, which must be addressed by any vulnerable country related to environmental issues, such as Pakistan – the fifth most vulnerable country globally (Abid et al., 2021). The fourth total productivity theory created by Solow (1957) became a widely recognized indicator to measure technology upgrade and the improvements on the management model, production quality, and companies' structure. Otherwise, the total green factor productivity increased the concerns related to sustainable development by bringing to light environmental and energy endowments due to their impact and constraints regarding economic growth (Coto-Millán et al., 2018; Liu et al., 2020). Technological innovations are considered critical not only because they provide economic development but also because they leverage society's development as a whole (Ganda, 2019; D'Attoma and Ieva, 2020). One such innovation is the green technology innovation. Green technology innovations are devoted to energy-saving and environmental-friendly innovations

(Deng et al., 2019). Then, green technology innovations can provide more significant results concerning the total factor productivity and contribute to decreasing the negative environmental impacts in several levels.

As known, different regions/countries have different economic growth rates and, as a consequence, different socio-economic development levels. This variation also affects the environmental challenges because countries that cause degradation to the natural resources/environment need sustainable innovations and investments to their implementation (UNEP, 2019; Zhang et al., 2019). Some countries recently created investment banks (national or state-owned ones) aiming the green development promotion, called 'green investment banks' to help address these issues. The main goal of a 'green investment bank' is to sustain economic resilience. Some successful initiatives are seen from emerging economies, such as the Brazilian *BNDES* (National Bank for Economic and Social Development), to established economies, such as Austria's Clean Energy Finance Corporation and the UK's Green Investment Bank (Mazzucato and Penna, 2016; Geddes et al., 2018). Currently, twelve green investment banks or similar organizations are operating in the world. The 'green investment banks' are already leveraging the private investments towards green infrastructure and green technological innovations (OECD, 2018). These banks and the country contexts within which they have been established provide a unique research opportunity.

Targeting green technology innovations and green technologies transfer promotion and support, the Pakistani government launched an initiative through the green technology investment program (World Economic Forum, 2019). Led by the Pakistani Ministry of Science and Technology, this program is associated with the Pakistani Ministry of Planning and Development and is aligned with UN's 2030 Agenda and Paris Agreement. Compared with the current technological investments in Pakistan, the investments in green technologies are comparable more to a platform than to a bank. The green investment banks can provide direct financial support to the companies classified into the green industries, in the same way as the UK's Green Investment Bank (Geddes et al., 2020). The green development investment has, as its primary function, to find the best green solutions to the customers, and green investment banks promote the green technologies implementation by their partners in association with financial institutions and green technology providers.

Although green technology benefits from financial support, its development and implementation face several barriers (Shah et al., 2019; Ikram et al., 2020). These barriers include supportive policies (Taghizadeh-Hesary and Yoshino, 2019; Darko et al., 2018), consumption market (Campiglio, 2016; Agyemang et al., 2018), green technology knowledge and awareness (Liao and Shi, 2018; Peng et al., 2020), and also financial constraints (Wakeford et al., 2017; Bhandari et al., 2019).

Despite promoting green technologies, a classification criterion at a world scale still lacks (WIPO, 2019). Moreover, the absence of a standardized green technology classification system may lead to uncertain decisions when selecting a specific green technology. Green technology is a complex and changing concept, and there is no consensus on its definition, covering several fields. This lack of standardized classification/guidance can confound our understanding of what green technology is. The existing attempts to classify green technologies at a regional scale normally are inconsistent, leading to constraints when transferring green technology to a large-scale level. An international scale of green technology transfer requires an efficient classification, which is achieved via a common framework composed of multiple stakeholders (going from technology providers to investors and end customers).

Green growths' goal is to enhance a country's ability to develop green products and reduce the environmental pollution of all forms (Hottenrott et al., 2016). It also wants to promote more knowledge on green technology adoption and the changes organizations need to face to enhance their energy resource issues. The European Center for Development of Vocational Training stated that "Public and private sectors should create the link between technological development, innovation and economic sustainability that provides benefits for economic productivity and economic growth to attain sustainable green growth"(UN, 2011).

Sustainable development includes procedures and activities that help organizations adopt cleaner production practices to reduce environmental impacts and manufacture eco-friendly products (Ikram et al., 2021). Meanwhile, the companies need to move on to green technologies that help develop sustainable development that provides social, environmental, and economic benefits to stakeholders. Thus, the companies must pay attention to multiple sustainability dimensions as enablers of technology investments.

Exploring the literature on green technology in association with sustainable development, cleaner production, and innovation (Table 1 and Figure 2), it is noticed that the field of research needs further development regarding some specific subjects. Results of systematic literature review (presented in section 2.1) evidenced that green technology evolved along with innovation and sustainable development. These two research topics are responsible for most of available research published in relevant journals. However, when focusing the cleaner production and green technology, the field of research plummet to less than 200 papers, and when focusing an emerging economy context (such as Pakistan), the studies are even more limited (only 86 papers). Associating all the key terms in Boolean searches, the results proved that there is no available research covering these topics as this research intends to do. Then, there is a lack of research addressing the integration between green technologies, cleaner production, and sustainable investment, as proposed in Figure 1. Then, this research intends to fulfil this gap in literature by addressing the integration of green technologies, cleaner production, and sustainable investment in the frame of an emerging economy as context, i.e., Pakistan.

Given recent developments in Pakistan, we find this country's context essential to review and further research their emerging programs. Pakistan's green technology program has three primary missions: a) to implement the assumptions described in UN's 2030 Agenda and Paris Agreement, b) to create a green technologies platform that supports their emergence and adoption, and c) to integrate Science & Technology (S&T) through financing in order to promote green technology transfer at national and international boundaries. The green technology bank created in 2017 was conceived to be part of the Pakistani Implementation Plan for the National Technology Innovation Initiative. Two years later, the Pakistani Ministry of Science and Technology published the first document prioritizing the green technology investment program's actions. The Pakistani government took these supportive activities due to the relevance in speeding up the market-oriented green technologies system.

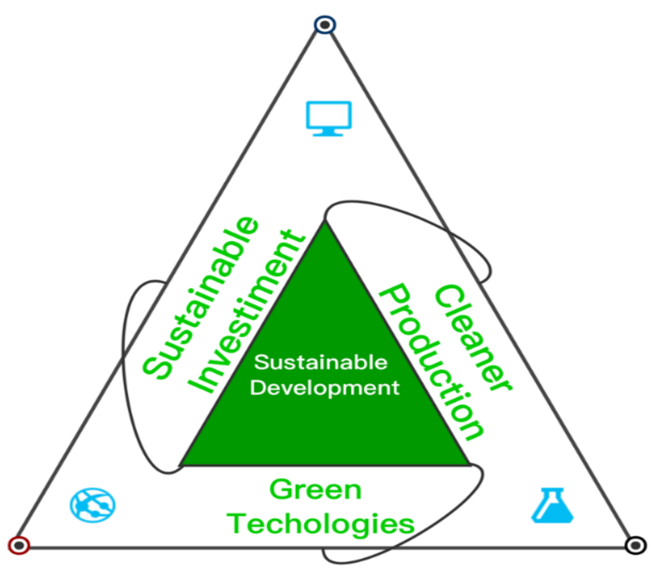


Fig. 1. The integration of sustainable investment, cleaner production, and green technology

As stated previously, green technology has a powerful influence on sustainable innovations and their investments. Although Pakistan is in a transition stage, shifting to green technologies, the proper classification of green technologies is still missing. This is a relevant research gap to be fulfilled regarding energy technologies classification in a country context. This research contributes to classifying green technologies using the Multi-Criteria Decision Analysis (MCDA) method. This research used the classification system of green technology in its development. This system allows classifying the green technologies and enhancing green technology transfer and helps examine Pakistani green cases. Moreover, this system allows access to information from the Pakistani government, investors, and several stakeholders to address green technologies concepts. Another contribution of this research is closing the literature gap by investigating a country-level context of green technologies and their classification.

One of the outcomes of this study is our identification of the most relevant classifications and our ranking them according to the importance degree for developing green technologies investments. This research contributes to policymakers when designing good policies by addressing the proposed green technologies classification. In this research, scholars may find an extensive survey of literature on green technologies and the developed framework that can assist future research on the subject and in other contexts. This research advises scholars that the number of green technologies and results may vary in other comparative studies. Additionally, this research contributes to coping with green technologies investments required to build a better future for Pakistan based on sustainable development principles.

Information in this study is organized as follows. Section 2 presents an extensive literature review on green technologies carried out from previous research. Section 3 presents the development steps of Fuzzy Delphi and FAHP methods. Section 4 presents the classification of green technology indicators and calculates the weights and ranking of the main green technologies according to criteria and sub-criteria in the major green technologies category sub-categories by using FAHP method. Finally, we discuss the results of the study along with theoretical and practical implications. In the conclusions, we review the limitations of the study and opportunities for future research.

2. Literature review

2.1 Systematic literature review methodology

We used a systematic literature review to help identify the current state of the art in the literature. The SCOPUS scientific database was used due to the extensive results it reported in exploratory searches. The main key terms used for Boolean searches were the following:

a) “Green technology” AND “innovation*” (including the possible variation of innovations);

b) “Green technology” AND “sustainable development”;

c) “Green technology” AND “cleaner production”; and

d) “Green technology” AND “Pakistan”.

Pakistan was also included as key term in order to explore the available research on the combination of green technology studies within this country context. Results of this four-step search is presented in Table 1. Criteria for selecting the papers were: a) searching in title, abstract and keywords; b) only articles; c) source type: journal; d) language: English. Documents by year of selected key terms in Scopus scientific database is presented in fig. 2. We used following keywords such as (all time period) Keys: a) “Green technology” AND “innovation*”; b) “Green technology” AND “sustainable development”; c) “Green technology” AND “cleaner production”; d) “Green technology” AND “Pakistan”.

Table 1. Results of Boolean searching within the Scopus scientific database

Key terms	Searching procedures	Total of papers*	Top-5 journals (total of papers)	Top-5 most cited references [number of citations]**
"Green technology" AND "innovation*"	TITLE-ABS-KEY ("green AND technology" AND "innovation*") AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (SRCTYPE , "j"))	1,551	1) Journal of Cleaner Production (106) 2) Sustainability (99) 3) Energy Policy (35) 4) Technological Forecasting and Social Change (29) 5) Business Strategy and the Environment (28)	1) Feder, Just & Zilberman (1985) [1332] 2) Paish (2002) [560] 3) Menanteau, Finon & Lamy (2003) [493] 4) Shiferaw et al (2013) [276] 5) Ozaki & Sevastyanova (2011) [269]
"Green technology" AND "sustainable development"	TITLE-ABS-KEY ("green AND technology" AND "sustainable AND development") AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (SRCTYPE , "j"))	2,717	1) Journal of Cleaner Production (196) 2) Sustainability (140) 3) Environmental Science and Pollution Research (37) 4) Science of the Total Environment (37) 5) Wit Transactions on Ecology and the Environment (37)	1) Anastas & Kirchhoff (2002) [1595] 2) Sheldon & van Pelt (2013) [1412] 3) Cherubini (2010) [1070] 4) Duxson et al (2007) [965] 5) Rawat et al (2011) [657]
"Green technology" AND "cleaner production"	TITLE-ABS-KEY ("green AND technology" AND "cleaner AND production") AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (SRCTYPE , "j"))	183	1) Journal of Cleaner Production (55) 2) Environmental Science and Pollution Research (4) 3) Science of the Total Environment (4) 4) Business Strategy and the Environment (3) 5) Clean Technologies and Environmental Policy (3)	1) Zhang, Zhang & Deng (2011) [527] 2) Sharma (2002) [385] 3) Tseng et al (2013) [226] 4) Raghava Rao et al (2003) [118] 5) Messagie et al (2014) [107]
"Green technology" AND "Pakistan"	TITLE-ABS-KEY ("green AND technology" AND "pakistan") AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (SRCTYPE , "j"))	86	1) Environmental Science and Pollution Research (10) 2) Pakistan Development Review (8) 3) Journal of Cleaner Production (4) 4) Arab Gulf Journal of Scientific Research (2) 5) Biomed Research International (2)	1) Ali, Bakhsh & Yasin (2019) [77] 2) Murgai, Ali & Byerlee (2001) [77] 3) Monneveux, Jing & Misra (2012) [64] 4) Aized et al (2018) [62] 5) Abbas & Sağsan (2019) [59]

* Papers were inspected according to their adherence to this research and those most adherent were used in the literature review.

** These citations were not included in the references due they provide examples of most cited papers according to each key term searched.

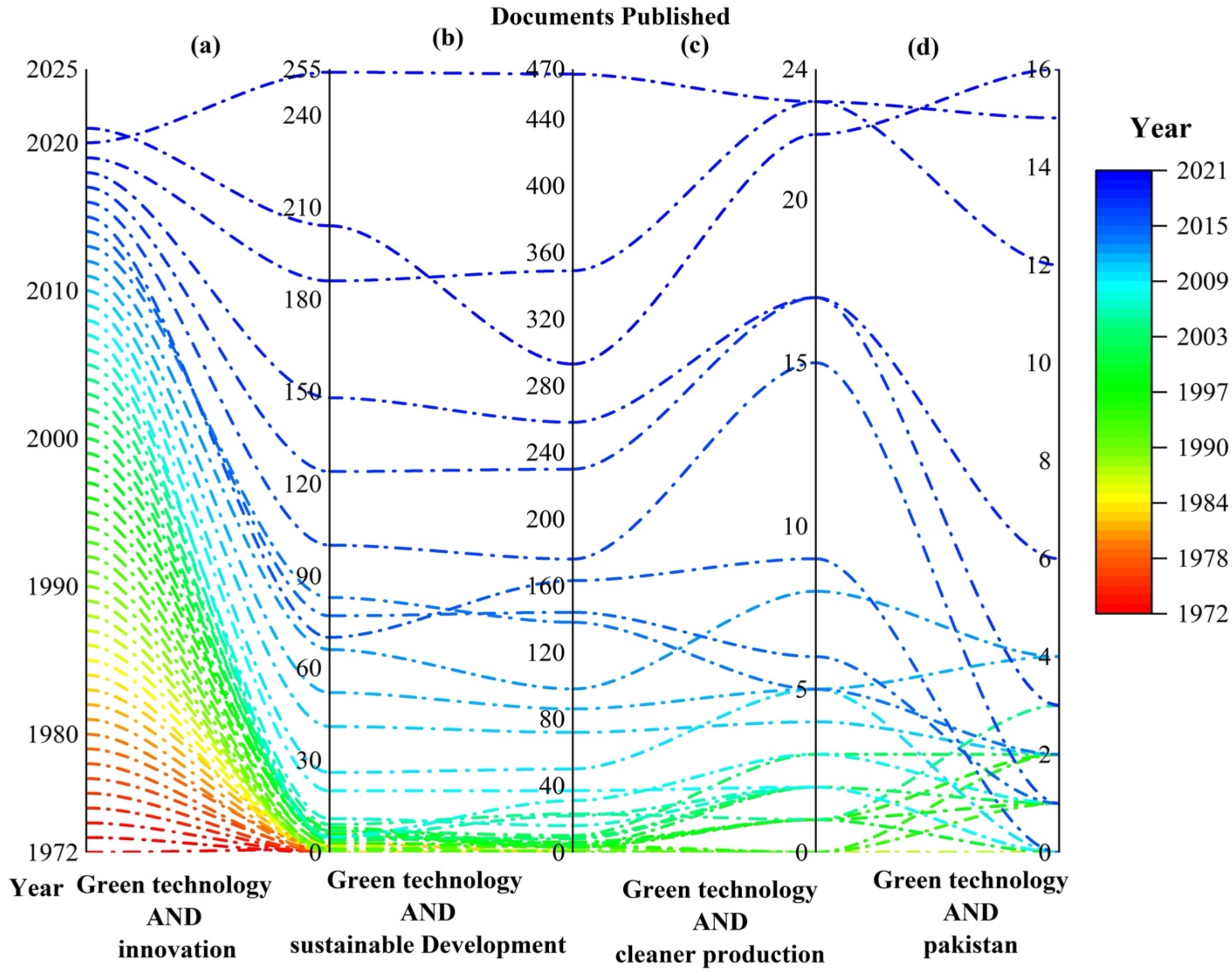


Fig. 2. Documents by year of selected key terms in Scopus scientific database (all time period) Keys: a) "Green technology" AND "innovation*"; b) "Green technology" AND "sustainable development"; c) "Green technology" AND "cleaner production"; d) "Green technology" AND "Pakistan"

Results from the exploratory phase of the literature provided interesting findings. In all themes, the Journal of Cleaner Production is proved to be the leading source in the field. Only in one of the studies dedicated to Pakistan (green technology & Pakistan), the leading journal was found to be Environmental Science and Pollution Research. The findings confirmed an initial assumption, that the green technology is a field well developed in association with innovation and sustainable development. However, when looking for combinations of green technology and cleaner production, the results proved that more research is needed in order to explore the connections between these thematic elements of the field. When looking at the country context of Pakistan, few studies address this country context in association with green technology (evidenced by 86 articles). After a careful examination of results, these articles comprise the foundation for the literature review of this study and information summarized in the following sections of this paper.

2.2 The Integrated Green Technology Framework

Countries with more significant environmental commitments can be best positioned to utilize green technologies investments, i.e., those technologies that promote energy savings, pollution prevention, and waste recycling (Chen et al., 2006; Asadi et al., 2020). These technologies have in common the focus on negative impacts on the environment and decreasing them. As examples, these impacts are those provoked by waste management, nutrient recycling via utilization of ecological processes, and the implementation of environmental solutions (Pretty, Toulmin, and Williams (Galdeano-Gómez et al., 2013; Mingaleva et al., 2020). The current environmental context is requiring a greater commitment from companies in order to achieve their environmental goals. Investing in green technologies is presenting as a way of these goals' achievements (Kim, 2013). Followed by several environmental challenges, the environmental regulations are considered to motivate different companies to invest in green technologies. In doing so, governments are creating measures to leverage sustainable development by including policies enacted by communities, political support towards sustainable development, and integral legislations (Mamede and Gomes, 2014; Ikram et al., 2019). In this matter, the government's motivation towards green technologies investments is related to compliance with regulations(Dangelico and Pujari, 2010). Beyond regulatory compliance, environmental regulations can also open risk minimization opportunities, preserve revenues and a companies' reputation, or even create new business.

There are major managerial concerns at the companies' side related to the motivation for investing in green technologies, which depends significantly on such managers' management styles and decision-making (Sulich, Sołoducho-Pelc, and Ferasso 2021). This is aligned with the findings of Qi et al. (2010) and Centobelli et al. (2020) regarding adopting green practices as one of the main managerial concerns. Among the definitions of green innovations, Li and Lin (2008) included the innovation in technologies. Chen's (2008) findings reported that companies with green processes and green product innovations performance-enhanced organizational learning and their capabilities towards green innovations and environmental management. Another finding from Huang et al. (2016) is related to organizational commitment and information flows to employees' training activities and is reported as critical enablers of green innovations.

Additionally, Chang and Chen (2013) identified that green innovations were considered critical in business management. Companies benefit and leverage their overall performance, competitive advantages if compared with competitors, and increased value-added thanks to an efficient management style. Hottenrott et al. (2016) added value to the field when identifying that green technologies' adoption can lead to productivity reduction. Their adoption is followed by critical changes at the organizational level leading to comprehensive and efficient use of green technologies adopted. In the medium to long term, the identified productivity reduction for adopting green technologies is compensated by subsequent efficiency levels that may be diminishing or reverted.

These technologies are optimized and integrated according to theoretical and practical experiences to fulfill stakeholder requirements. An integrated bottom-line (IBL) approach to understanding the phenomenon in this study is one way to look at environmental, social, and economic performance as multidimensional (Sroufe, 2018). At the initial level, categorizing these green technologies provided three sub-platforms: information, transformation, and finance. The information sub-platform involves the evaluation process of energy demand and energy supply. The transformation sub-platform presents the feasibility of energy trade and project implementation. Finally, the finance sub-platform promotes investment by providing funds, bank loans, and other financial instruments to improve green technologies' efficiency and accuracy.

Beyond managerial and human capital development concerns, companies in the business climate change related to societal expectations from several stakeholders (Cheng et al., 2014). These authors found that companies are struggling with increasing sustainability issues when attracting, satisfying, and retaining their consumers. Customers’ demands are considered one of the key drivers for companies to adopt green technologies since the payers are why these companies exist. In Diaz-Rainey and Ashton's (2015) study, reported findings revealed that the motivation for adopting eco-innovations are achieved when minimum societal requirements are satisfied. The relations between customers’ requirements and companies’ interests already showed that these companies are adopting measures to reduce energy consumption and waste generation in their services/products/processes and increase the efficient use of resources (Horbach et al., 2012). Thus, green innovations are presenting as a new strategic goal for companies. Green innovations are opening a vast array of opportunities to satisfy customers’ needs and preserve the environment simultaneously (Albort-Morant et al., 2016).

The central government of Pakistan proposed the comprehensive technology service center, which comprises three decision-makers, coordination services, and market operations. The ministries, the direct prime mister, and secretariat involvement in green technology decision-making and leading groups are included at the decision-maker level. The coordination organization level is further divided into three sub-levels of experts’ advisory groups, coordination, and administration centers. The market operation level comprises five sub-categories of evaluation, finance, conservation, international agencies, and Pakistan's provincial governments.

Companies need to consider two essential measurements related to sustainability's economic dimension when considering investing in green technologies. The first is the company's stakeholders' economic interests, and the second is the company's financial performance (Sheth et al., 2011). The economic dimension of sustainability already proved that green innovations are drivers of cost savings (del Río et al., 2017; Abid et al., 2021). Additionally, (Takashima, 2020) and Koçak et al. (2021) have demonstrated that the cost savings go beyond the main expected benefit and are considered drivers for environmental R&D investments. Horbach and Rammer (2020) underlined that cost savings are the main reason for reducing resources and energy consumption. Then, the taxation role on raw materials and energy prices is critical for leveraging eco-innovations adoptions. Another benefit of eco-innovations is that green technologies investments may be motivated a company's productivity improvement level (Du and Li, 2019). Hottenrott et al. (2016) stated that by improving productivity standards through investing in green technologies, a company might enhance its economic performance. The analytic design of green technologies is based on top-down and bottom-up approaches.

Table 2. Methods/Approach used in green technology research

NO	Green Technologies research conducted	MCDM Methods/Approach	Year	Author(s)
01	The selection of clean technologies in uncertain data.	AHP, ANP	2018	(Promentilla et al., 2018)
02	Assessment of clean technologies investment for supply chain management in a competitive management: A case of one manufacturer and two retailers.	DEMATEL and MOORA	2021	(Haiyun et al., 2021)
03	The development of a comprehensive evaluation technique for assessing the various battery energy storage systems	Fuzzy-Delphi, Best-Worst method (BWM)	2019	(Zhao et al., 2019)
04	Prioritizing the Waste-to-energy (WtE) technologies based on energy trilemma energy security, energy equity, to develop environmental sustainability	Fuzzy ANP and Fuzzy DEMATEL	2020	(Ali Shah et al., 2021)
05	To evaluate the green building technologies for retrofitting to existing buildings by using the decision-making approach.	AHP	2016	(Si et al., 2016)
06	The evaluation of of hospital sites' suitability by spatial information technologies to improve technical, social and environmental issues, and standard healthy life.	AHP and GIS	2020	(Halder et al., 2020)
07	Developing the integrated framework to assess and prioritize the bioenergy technologies (BETs) from agriculture residue.	Fuzzy AHP-VIKOR	2019	(Wang et al., 2019)

08	To establish a framework of ecotourism technologies indicators from a comprehensive list to develop a sustainable ecotourism in Philippines.	Fuzzy Delphi Method	2018	(Ocampo et al., 2018)
09	The assessment of forest green technologies indicators that affect the success of innovations in the context of forest machinery manufacturing.	AHP	2020	(Blagojevic et al., 2020)
10	The construction of multi-criteria comprehensive clean energy technologies model for environmental protection, economy and social benefits.	Fuzzy AHP	2020	(Si et al., 2020)
11	The selection of optimal strategies to improve the sustainable management practices in industry.	SWOT, AHP	2016	(D'Adamo and Rosa, 2016)
12	Identification of policy actions and initiatives to reduce the amount of food wastage.	Fuzzy inference	2019	(Morone et al., 2019)

The main goal of green technology design comprises three main phases: mitigate environmental issues, initiatives of green technology in Pakistan, and fulfill the agenda 2030. The first phase involves green technology orientation, green technology design, comparison, and integration. The second phase of the 2030 agenda comprises SDGs, fulfill stakeholders' requirements, and implant green technologies at Plan-Do-Check-ACT (PDCA) process approach. The final phase of environmental challenges represents renewable energies' production to achieve zero percent CO_2 emission level, effective waste management agenda, recycling and reuse strategies, and electric vehicles' adaptability. The integrated framework of analytical design, organizational structure, and three layers platform of green technologies is in Figure 3. The detailed summary of the eight green technologies decision sub-criteria such as Environmental Quality, Resource Utilization, Agriculture & forestry, Green building, Energy utilization, Green Transport, Life Health, and Ecology Safety are in Table 3.

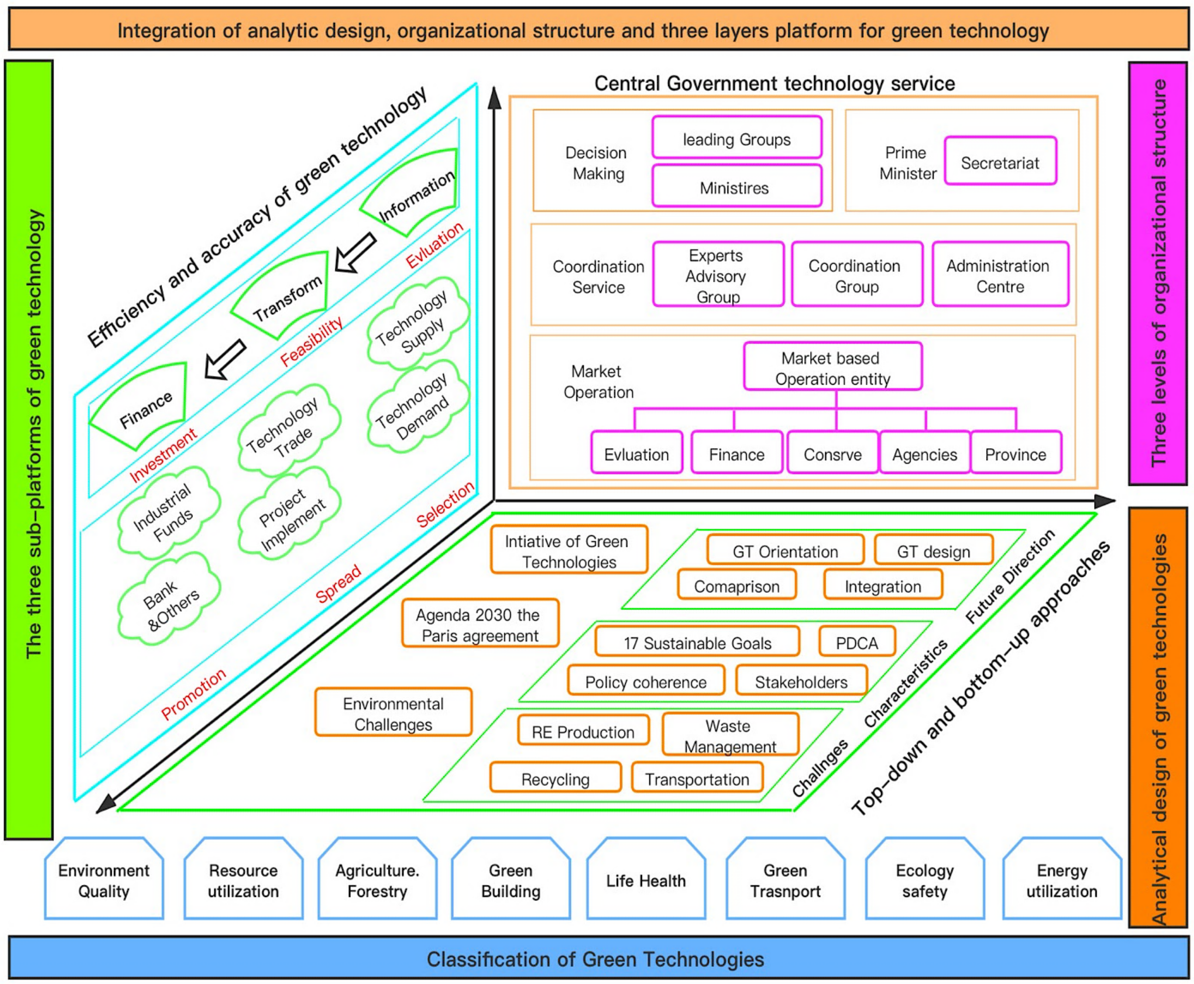


Fig. 3. Integration of analytic design, three-layer platform, and three-level organizational structure

Table 3. Decision sub-criteria of green technologies

Main Criteria	Main Criteria Code	Sub-Criteria	Sub-Criteria Code	References
Environmental Quality	ENV	Quality of Environmental Management System	ENV1	(Ikram et al., 2019), (Alam and Qiao, 2020), (Ma et al., 2020), (Du et al., 2021)
		Solid waste treatment and Management	ENV2	
		Drinking Water quality and wastewater Management	ENV3	
		Air Quality	ENV4	
		Noise Pollution	ENV5	
		Radiation Pollution and Ozon Depletion	ENV6	
		Analyzing and controlling of Environmental Risk	ENV7	
Resource Utilization	RES	Resource Exploitation and Utilization	RES1	(Zeng et al., 2021)
		Resource/Material Recycling	RES2	(Gu et al., 2020)
		Resource/Material/Conservation	RES3	(Wu et al., 2018)
		Resource/Material management	RES4	
		Energy efficient vehicles	TRA1	(Liu et al., 2018)

Green Transportation	TRA	Less Polluted Vehicles	TRA2	(Sharma and Chandel, 2020)
		Vehicles Interior voice reduction	TRA3	
		Interior air improvement	TRA4	(Langemeyer et al., 2020)
		Green roof solution at parking facility to reduce maintenance cost	TRA5	
Energy Utilization	ENG	Implementation of Energy Management System	ENG1	
		Energy Efficient Appliances and cost reduction strategies	ENG2	(Ali Shah et al., 2021)
		Energy Storage mechanism	ENG3	(Dieu-Hang et al., 2017)
		Energy Recycling	ENG4	
		Energy Conservation	ENG5	(Metson et al., 2021)
		Barriers of Renewable Energy to adopt cleaner technologies	ENG6	(David, 2018)
		Reduction of Fossil Energy to mitigate the CO2 emission	ENG7	
Life Health	LFE	Ecotourism and eco system	LFE1	(Ren et al., 2021)
		Rural living environment	LFE2	(Mukhopadhyay et al., 2021)
		Urban living environment	LFE3	
		Environmental health management system	LFE4	(Brousmiche et al., 2021)
Green Buildings	BLD	Sustainable site selection	BLD1	(Yadegaridehkordi et al., 2020)
		Innovative, energy efficient material for construction	BLD2	(Mondal et al., 2019)
		Occupants health, safety, and comfort	BLD3	
		Increase ventilation efficiencies	BLD4	
Agriculture and Forestry	AGR	Sustainable forest management	AGR1	(Köhl et al., 2020)
		Ecosystems conservation and restoration	AGR2	(Gonzalez-Roglich et al., 2019)
		Biodiversity conservation and Land degradation prevention	AGR3	(Li et al., 2021)
		Ecological animal husbandry	AGR4	(Sbragaglia et al., 2020)
		Ecological Fishery	AGR5	
		Eco friendly farming	AGR6	(Sharma et al., 2018)
		Supply chain and sustainable food security	AGR7	
Ecology Safety	SFT	Natural disaster prevention	SFT1	(Khan et al., 2020)
		Waterland and lake protection	SFT2	
		Ecological safety emergency plan	SFT3	(Shvartsburg et al., 2017)
		Ecological safety monitoring	SFT4	

3. Research Methods

3.1 Fuzzy Delphi Method

Hsu et al. (2010) proposed a fuzzy Delphi method widely used in the MCDM field to classify the criteria. Fuzzy Delphi's main benefit is that the latter is a detailed process to obtain the expert's feedback, making it superior to the conventional Delphi approach. Moreover, the conventional Delphi method is complicated and constantly suffers from low convergence, which causes error in experts' consensus and consumes more time by consulting the experts repeatedly to revise their feedback to reach on possible consensus (Ikram et al., 2020a). Conversely, the Fuzzy Delphi technique needs only one round of investigation to obtain the experts' consensus. The Fuzzy Delphi method adopts the function of membership to characterize the experts. Previous studies used the Triangular Fuzzy Number (TFN), Gaussian fuzzy number, and trapezoidal fuzzy number to develop the degree of fuzzy membership. Therefore, this study used the TFNs in the construction of the membership degree function. The geometric mean is used to solve the TFNs to find the converging point of the experts' group. The process of the Fuzzy Delphi method comprises three steps as follows.

Step 1: Suppose the importance given to ith component (i = 1,2,3, ..., m) by jth expert (j = 1,2,3, ... ,n) is denoted by wij = (aij,bij,cij). Then, the fuzzy weight of ith element (i = 1,2,3, ..., m) is represented as wi = (ai, bi, ci) where ai, bi, and ci components are computed respectively as:

$$a_i = Min\{a_{ij}\} = b_j = \frac{1}{n} = \sum_{i=1}^{n} b_{ij}, \;\; c_i = Max\{c_{ij}\} \tag{1}$$

Step 2: This step involves the transformation of fuzzy weights to actual weights Si, by using the center of gravity technique. It can be defined as follows:

$$S_i = \frac{\sum a_i, b_i, c_i}{3} \tag{2}$$

Step 3: In the last step, the selection of green technologies criteria are finalized by comparing each barrier’s weight with threshold $\tilde{a}$. The mean value of all the green technologies criteria’s weights represents the value of threshold $\tilde{a}$. If the weight value of green technology criteria is more than or equal to $\tilde{a}$, then the criteria are selected. Otherwise, it is rejected. In taking this approach, a FAHP methodology was used for computing the weights of the main and sub-attributes of corporate sustainability, supported by decision-makers, using a pairwise comparison matrix.

To the best of the author's knowledge, there is no standard available for how many experts should be involved in this analysis. Prior studies used a different number of experts for data analysis to obtain reliable results. For example, Solangi et al. (2021) selected ten experts for data analysis for the assessment of renewable energy barriers for sustainable energy planning in Pakistan Whereas, Wang et al. (2019) selected five experts by using the FAHP to select the strategic renewable energy resources in Pakistan to improve sustainable development. Therefore, we utilized eight academic and industrial experts to help with this analysis. Their details are in supplementary information (see Table S1).

3.2 Fuzzy Analytical Hierarchical Process (FAHP)

Analytical Hierarchical Process (AHP) has been widely used in various fields of research and has considered the most adaptable multi-criteria decision making (MCDM) technique to solve complicated decision-making problems. The fundamental of AHP is designed on a ratio scale to compute the decision-makers feedback for a different set of alternatives. The AHP is one of the most adaptable multi-criteria decisions making (MCDM) approaches to solve complex decision-making problems and has been used across various fields (Solangi et al., 2019).

This technique quantifies the decision maker's instinctive feedback and evaluates the consistency to provide the optimal solution during the decision-making process. The AHP technique can be combined with other methods such as fuzzy set theory, grey system theory, linear programming, and data envelopment analysis. Although AHP can compute the decision maker's opinions, this approach has some limitations regarding human biases. Hence, the conventional method has some deficiencies such as (a) it cannot deal with the unbalanced and inconsistent experts' feedback (b) It does not process the expert's uncertain judgment number s and uncertain and system relationship (c) lack of precision in results (d) It prefers the decisions makers subjective opinions.

Therefore, the AHP method was improved by the application of fuzzy set theory known as Fuzzy AHP. The FAHP is more accurate than traditional models and is widely used to provide optimal solutions for complex decision-making problems (Shah et al., 2019).

FAHP is the advanced modified form of AHP combined with fuzzy set theory, in which membership functions represent each membership element. Moreover, each membership element further divided into membership degree has a value between 0 and 1, which implies that the element with value "1" has the membership. On the other hand, an element with 0 value has no membership. Similarly, the elements that have a value between 0 and 1 have the membership to a certain degree. There is a need to replace the linguistic membership function with fuzzy numbers to remove uncertainties during the estimation process. Therefore, TFN has represented the linguistic values in FAHP.

There are numerous benefits of FAHP application and has been widely used in different research fields such as prioritizing social dimensions of corporate sustainability (Ikram et al., 2020), identifying the groundwater potential in semi-arid zones (Shao et al., 2020), the selection of advanced manufacturing systems (Mathew et al., 2020), evaluating the criteria in the fog computing system (Ogundoyin and Kamil, 2020), decision making for ecotourism sustainability (Zabihi et al., 2020), selection of renewable energy sources in Pakistan (Shah, 2020), identifying the risk factor involved in the transmission of COVID-19 (Ghorui et al., 2021), or the selection of aircraft (Kiracı and Akan, 2020).

To prioritize the green technologies in Pakistan, the construction of FAHP involves in six following stages:

Stage 1: This step involves the designing of the hierarchical structure of the problem.

Stage 2: Development of relative importance scale employed in pairwise comparison matrix. After developing the hierarchical problem structure, the next stage is finalizing the relative importance scale for the pairwise comparison of the matrix. The TFN based scale of relative importance from 1 to 9 is presented in Table 4, in which five TFNs ($\tilde{1}$, $\tilde{3}$, $\tilde{5}$, $\tilde{7}$, $\tilde{9}$) are used for experts' qualitative evaluation relative to their correspondence number to prioritize Pakistan's green technologies investment. The advantage of FAHP, it's removed the uncertainties and vagueness during the evaluation process. Figure 4 represents the fuzzy membership for main criteria' and sub-criteria.

Table 4. TFNs for criteria with Linguistic variables

Linguistics variable	Triangular fuzzy numbers	Fuzzy number	AHP Equivalent
Extreme importance/preference	(7,9,11)	$\tilde{9}$	9
Very strong importance/preference	(5,7, 9)	$\tilde{7}$	7
Strong importance/preference	(3,5,7)	$\tilde{5}$	5
Moderate importance/preference	(1,3,5)	$\tilde{3}$	3
Equal importance/preference	(1,1,3)	$\tilde{1}$	1

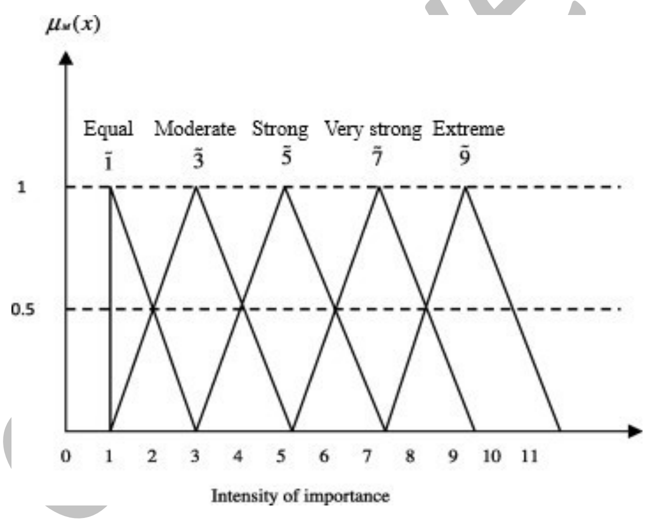


Fig. 4. Fuzzy membership function for linguistic variables

Stage 3: It involves the development of a fuzzy comparison matrix. The experts were asked to pairwise comparison based on TFNs for prioritizing the green technologies in Pakistan. To assess the pairwise comparison, the arithmetic mean-based fuzzy comparison matrix Z was constructed from the experts is presented in equation 3.

$$Z = \begin{bmatrix} 1 & \tilde{a}_{12} & \dots & \dots & \tilde{a}_{1n} \\ \tilde{a}_{21} & 1 & \dots & \dots & \tilde{a}_{2n} \\ \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \dots & \dots & 1 \end{bmatrix} \quad (3)$$

Where $\tilde{a}_{ij} = 1$, if $i = j$, and $\tilde{a}_{ij} = (\tilde{1}, \tilde{3}, \tilde{5}, \tilde{7}, \tilde{9})$ or $(\tilde{1}^{-1}, \tilde{3}^{-1}, \tilde{5}^{-1}, \tilde{7}^{-1}, \tilde{9}^{-1},)$ if $i \neq j$. The reciprocal of scores has been obtained by reversing the Z matrix comparison to compute each pair's score. Suppose if $\tilde{Z}_{ij}$ is the value of matrix Z represents the relations of components i and j, then $\tilde{Z}_{ij} = \frac{1}{\tilde{z}_{ij}}$.

Stage 4: This step involves the construction of a crisp comparison matrix in which the α-cut method is used to make the expert's decision-making feedback more accurate. Adamo (1980), proposed the α-cut method by prioritizing the fuzzy numbers, in which the interval between the fuzzy number yields a value. If the value of α=0.5 on TFN will yield $a_{0.5} = (2,3,4)$ is presented in Figure 5.

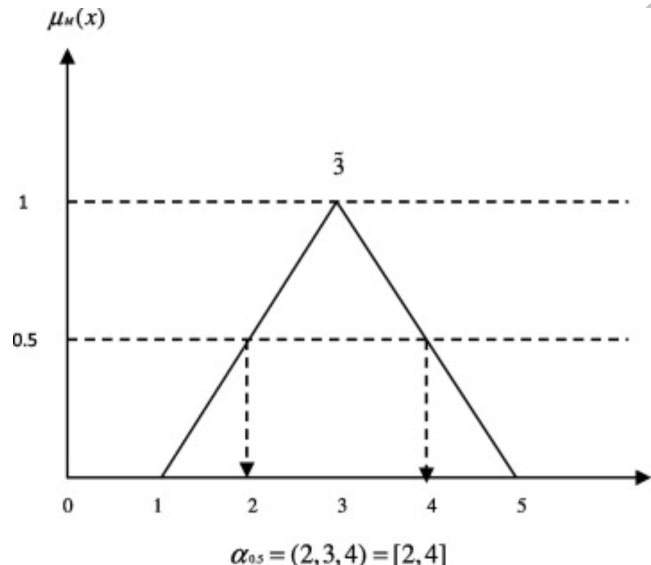


Fig. 5. α-cut operation on TFN (shah et al., 2019)

By considering the optimism index μ based on the fuzzy comparison matrix, the value of the a is fixed and set to the degree of estimation to satisfy Z matrix conditions. The following α-cut comparison matrix can be constructed.

$$\tilde{Z}^{\alpha} = \begin{bmatrix} 1 & \tilde{b}_{12}^{\alpha} & \dots & \dots & \tilde{b}_{1n}^{\alpha} \\ \mathrm{b}_{21}^{\alpha} & 1 & \dots & \dots & \tilde{b}_{2n}^{\alpha} \\ \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots \\ \tilde{b}_{n1}^{\alpha} & \tilde{b}_{n2}^{\alpha} & \dots & \dots & 1 \end{bmatrix} \quad (4)$$

The μ represents the index of optimization in the preference matrix, and its value is computed by the opinion of decision-makers depend on the degree of confidence. The larger the value of μ indicates the higher degree of satisfaction/confidence. The concept of the index of optimism μ is the combination of linear convex proposed by (Lee et al., 1999) represented follow as:

$$\tilde{b}_{ij}^{\alpha} = \mu b_{iju}^{\alpha} + (1-\mu) b_{iju}^{\alpha} \text{ where } 0 < \mu \leqslant 1 \tag{5}$$

The conversion of the fuzzy comparison matrix with α-cut into crisp comparison matrix Z by adding the value of μ into equation 5. The new form of matrix z is presented as follow:

$$Z = \begin{bmatrix} 1 & b_{12} & \dots & \dots & a_{1n} \\ b_{21} & 1 & \dots & \dots & \mathrm{b} \\ \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots \\ b_{n1} & \mathrm{b} & \dots & \dots & 1 \end{bmatrix} \tag{6}$$

Stage 5: Checking the Consistency

To validate the expert's opinion, a consistency ratio (CR) was used to calculate the consistency of each matrix as well as the overall consistency of hierarchical structure. Hence, it converts the consistent crisp comparison matrix Z into a consistent fuzzy comparison matrix denoted by $\tilde{Z}$.

The largest Eigenvalue of the matrix calculated by the following formula is in Equation 7.

$$X_v = \lambda_{\max} v \tag{7}$$

Where v indicates the principle Eigenvector value of the matrix.

To validate the feedback obtained by the expert's judgment approach, the CR is then used for pairwise comparison. The calculation formula of CR is in Equation 8.

$$CR = \frac{CI}{RI} \tag{8}$$

$$CI = \frac{\lambda_{\max} - k}{k-1} \tag{9}$$

CI indicates the consistency index, whereas the random index is presented by RI (shown in Table 5), and the size of the matrix is presented by k.

Table 5. Random Index

k	1	2	3	4	5	6	7	8
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.40

If the CR value of any matrix records less than 0.10, that matrix falls in the acceptability area; otherwise, the experts' process needs to repeat in the pairwise comparison matrix until the results improve.

Stage 6: Computation of criteria's weights

The last step of the FAHP development process involves the computation of green technology weights by normalizing any of the columns or rows of matrix Z. The methodological framework operationalized in this study is presented in figure 6.

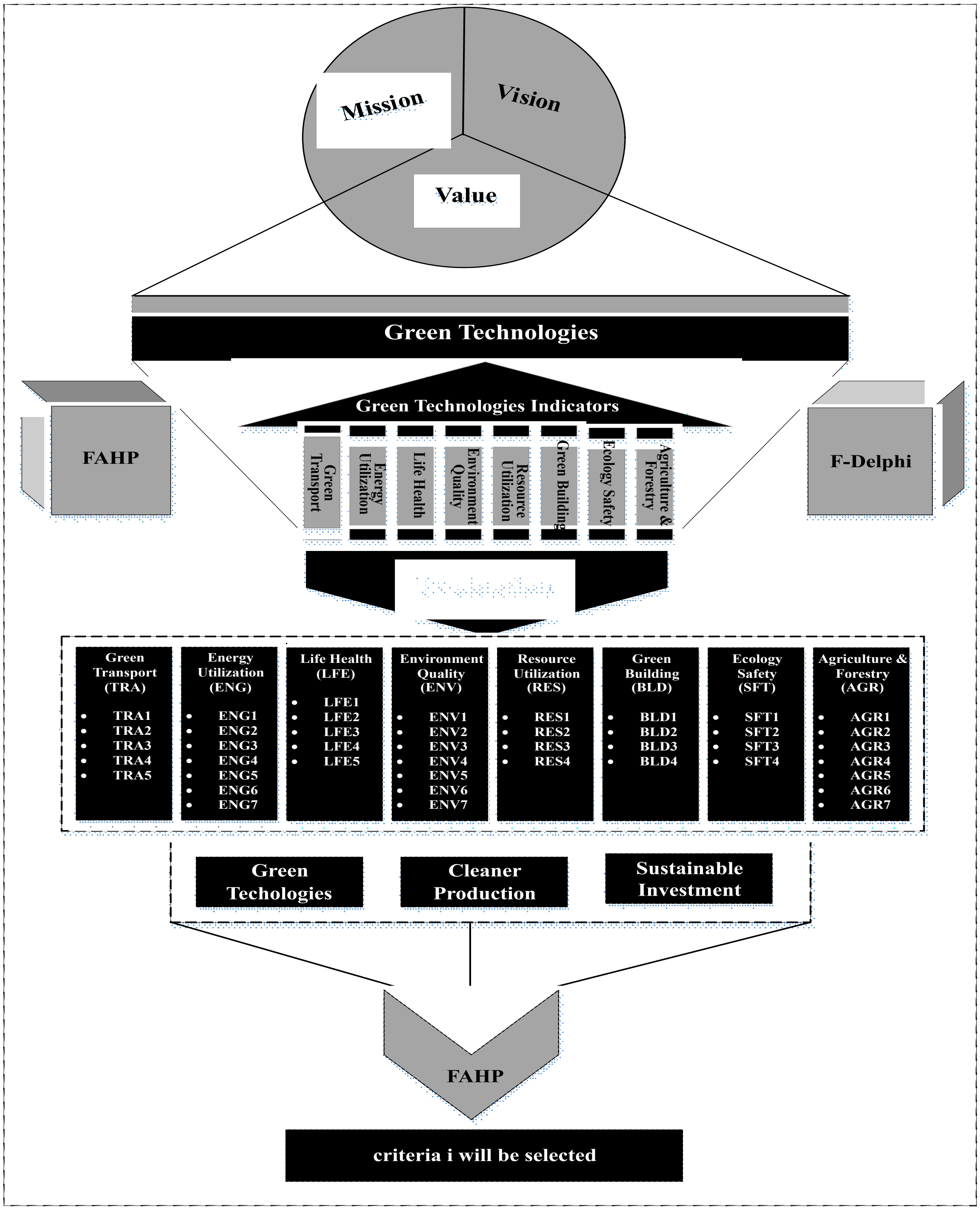


Fig. 6. Methodological framework operationalized in this study

4. Results

The results of this study comprise two parts. The first part of the results presented the fuzzy Delphi in which the selection of green technologies indicators is finalized on the experts' evaluation. In the second part, results of FAHP are illustrated in which main criteria and sub-criteria of green technology were ranked as per relative importance given to them by experts.

4.1 Fuzzy Delphi Results

The fuzzy Delphi scores are calculated as 5.335 to set the threshold value by obtaining the mean of green technologies criteria. The green technologies criteria that obtained scores more than or equal to 5.335 are retained while others are dropped out. Table 6 presented the detailed description of the total eleven green technologies attributes, whereas the rest of the three criteria were rejected due to fewer scores than the threshold value. The rejected criteria are nepotism, location, institutional corruption, and lack of institutional capacity. Rejection of these criteria does not imply that they do not place significant importance. It implies that these indicators are not within the objective of the study. For instance, lack of institutional cooperation is an important indicator and has been discussed in several studies. However, experts have rejected this indicator, keeping in view the context of this study. If coordination lacks between the institutions, then there shall be an impartial and overall effect on all the green technologies investment in Pakistan. It can be considered irrational to measure the proportional effect on individual technologies.

Table 6: Result of Fuzzy Delphi

Indicators	a	b	c	Fuzzy Delphi Scores	Selected √/ Rejected ×	Indicator code
Environmental Quality	3	6.79	10	6.65	√	ENV
Resource Utilization	3	6.70	10	6.54	√	RES
Location	0	2.72	5	2.83	×	
Transportation	3	5.90	10	5.77	√	TRA
Energy Utilization	3	7.85	10	7.71	√	ENG
Life Health	3	6.72	10	6.40	×	LFE
Nepotism	0	2.10	7	2.67		
Green Buildings	3	5.88	10	5.44	√	BLD
Agriculture/Forestry	3	7.70	10	7.60	×	AGR
institutional corruption	1	3.79	9	4.02		
Ecological Safety	3	6.33	10	6.10	√	SFT

4.2 Fuzzy AHP Results

In the second phase of our analysis, we used the FAHP technique based on a pairwise comparison matrix. This matrix was developed to compute the expert's score individually by using the geometric mean approach. The group-based decision-making technique was used to calculate the green technologies' main attributes and sub-attributes. Based on the extensive literature review and expert opinion, eleven green technology indicators were selected. The fuzzy Delphi method is employed to classify the main attributes into eight important categories: Environmental Quality, Resource Utilization, Transportation, Energy Utilization, Life Health, Green Buildings, Agriculture/Forestry, and Ecological Safety. The FAHP section is further divided into two parts. In the first section of the AHP method, we calculated the weights of the eight most influencing green technologies' main criteria. The second section of FAHP comprises the computation of sub-criteria weights. The hierarchal structure of green technologies' main indicators and sub-indicators are in Figure 7.

4.3 Prioritizing green technology main attributes

The FAHP technique was used to calculate the weights of green technologies hierarchically. Table 6 shows the weights of the main criteria's results in which Energy Utilization recorded the most influencing criteria among the other seven main criteria's by receiving the highest weight (23.75%). At the same time, Agriculture/Forestry come in a row on second place by obtaining the second heights weights (22.23%) after utilization of energy followed by Environmental Quality (15.81%), Life Health (13.75%), Resource utilization (11.57%), Ecology Safety (10.93%), Transportation (6.13%) and the least influencing criteria of green technology Green Building (5.54%) respectively.

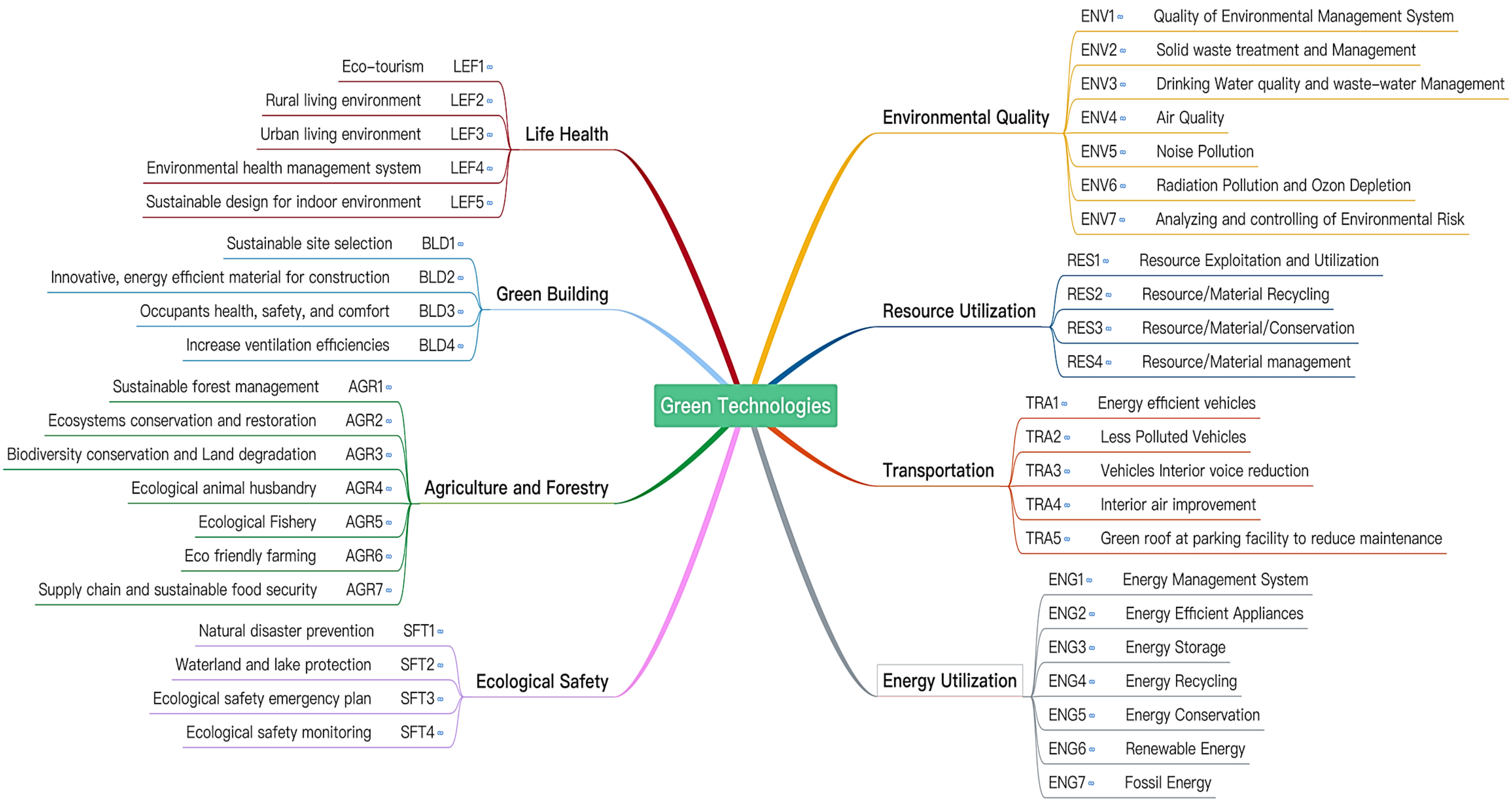
Energy utilization appeared the most critical green technologies criterion because Pakistan is facing severe energy crises due to eighteen hours of electricity load shedding daily, which harms the economy. To develop economic sustainability and socio-economic prosperity like other developing countries, Pakistan needs more evident energy technologies to produce uninterrupted, clean, affordable, and renewable energy supplies to improve well-being and living standards. However, a severe electricity crisis is a barrier that hinders economic growth. Despite, high rate of electricity access, people are failed to get reliable and affordable electricity. There is an emergent situation of loading shedding in Pakistan. The urban is suffering 8-10 hours and 18-20 hours of electricity shortage in rural areas (Mirjat et al., 2018). This nationwide power shortage has been caused substantial economic loss and does not go down due to interrupted and less production of electricity supply in Pakistan.

Agriculture & Forestry is the second most important criteria in the green technology paradigm. In Asia, the green revolution brings agriculture prosperity by improving the production quality in agriculture, effective irrigation control system, the adaption of modern crop technologies, and application of fertilizers and pesticides. The strong public influence boosts the adaptability of these technologies (Hazell, 2014). However, these technologies could not give many benefits to all farmers. Due to sufficient financial resources, the large and medium farmers have more access to these technologies, such as easy access to seeds, irrigation water, fertilizers, and modern cultivation equipment. They have achieved high productivity and income levels.

Environmental quality, life health, resource utilization, ecological safety, and transportation come in a row after the agriculture & forestry criteria. At the same time, green buildings took its place as the criteria receiving the lowest weight. According to the pairwise matrix, the 43 green technologies sub-criteria were assessed through the expert's critical approach.

Table 7. Ranking of Green Technologies main criteria's

Main Criteria	Code	Weight	Rank
Energy Utilization	ENG	0.237468	1st
Agriculture/Forestry	AGR	0.222268	2nd
Environmental Quality	ENV	0.158150	3rd
Life Health	LFE	0.137504	4th
Resource Utilization	RES	0.115731	5th
Ecological Safety	SFT	0.109280	6th
Transportation	TRA	0.061312	7th
Green Buildings	BLD	0.055446	8th



Green Technologies
Life Health
Eco-tourism LEF1
Rural living environment LEF2
Urban living environment LEF3
Environmental health management system LEF4
Sustainable design for indoor environment LEF5
Green Building
Sustainable site selection BLD1
Innovative, energy efficient material for construction BLD2
Occupants health, safety, and comfort BLD3
Increase ventilation efficiencies BLD4
Agriculture and Forestry
Sustainable forest management AGR1
Ecosystems conservation and restoration AGR2
Biodiversity conservation and Land degradation AGR3
Ecological animal husbandry AGR4
Ecological Fishery AGR5
Eco friendly farming AGR6
Supply chain and sustainable food security AGR7
Ecological Safety
Natural disaster prevention SFT1
Waterland and lake protection SFT2
Ecological safety emergency plan SFT3
Ecological safety monitoring SFT4
Environmental Quality
ENV1 Quality of Environmental Management System
ENV2 Solid waste treatment and Management
ENV3 Drinking Water quality and waste-water Management
ENV4 Air Quality
ENV5 Noise Pollution
ENV6 Radiation Pollution and Ozon Depletion
ENV7 Analyzing and controlling of Environmental Risk
Resource Utilization
RES1 Resource Exploitation and Utilization
RES2 Resource/Material Recycling
RES3 Resource/Material/Conservation
RES4 Resource/Material management
Transportation
TRA1 Energy efficient vehicles
TRA2 Less Polluted Vehicles
TRA3 Vehicles Interior voice reduction
TRA4 Interior air improvement
TRA5 Green roof at parking facility to reduce maintenance
Energy Utilization
ENG1 Energy Management System
ENG2 Energy Efficient Appliances
ENG3 Energy Storage
ENG4 Energy Recycling
ENG5 Energy Conservation
ENG6 Renewable Energy
ENG7 Fossil Energy

Fig. 7. The hierarchical structure of green technology indicators and sub-indicators

5. The assessment of green technology sub-criteria

The classification of green technologies' sub-criteria is in Figures 8(a) to 8(h).

5.1 Energy Utilization

Fig.8(a). Ranking of Energy Utilization sub-criteria

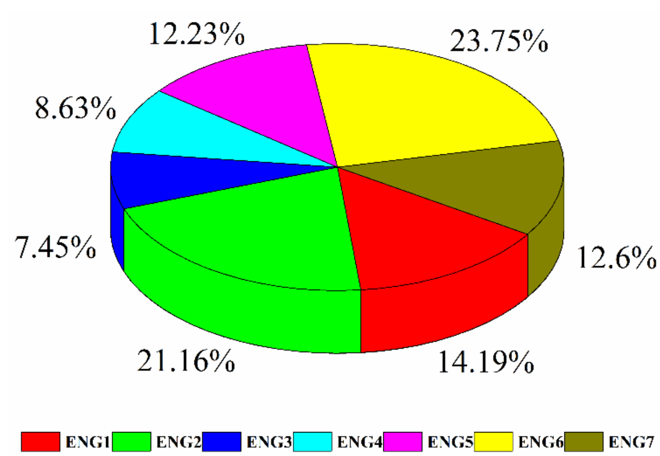


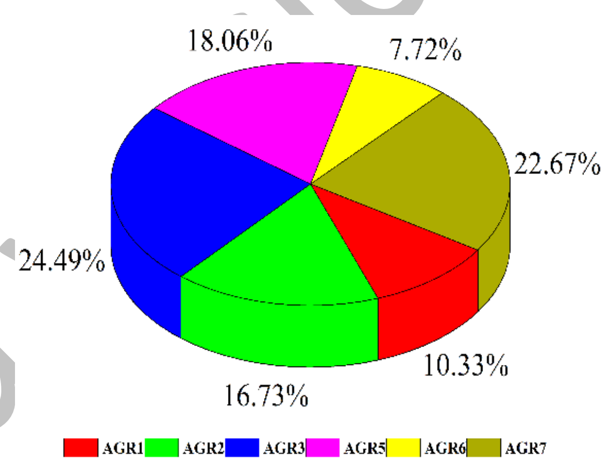
Figure 8(a) presents the following ranking of sub-criteria within the energy utilization category: ENG6>ENG2>ENG1>ENG7>ENG5>ENG4>ENG3. Here we see Renewable energy’s (ENG6) weight at (55. 77%) whereas Energy Efficient Appliances (ENG2) is ranked at the second position in the row with weight (49.69%). Pakistan has enormous renewable energy sources that can be used to fulfill the demand for electricity and wipe out the massive loading shedding issues that have drastic effects on Pakistan’s economy. RE's present potential is estimated to be 171.10 GW, which is predicted to be 290.4 GW by the end of 2050. In contrast, the current demand for electricity in Pakistan is only 27000 MW, which will be increased up to 65,000 by 2030 due to an increasing population (Rafique and Rehman, 2017). The adoption of RE has numerous benefits social, environmental, and economic benefits. It helps increase energy self-sufficiency and has sound effects on the environment and economic growth, i.e., control emissions and tackle climate-vulnerable issues (Lin and Raza, 2019). The new employment opportunities will be created by utilizing RE in local industries for manufacturing renewable energy equipment.

Energy Management System (ENG1) and Fossil Energy (ENG7) is recorded the third and fourth position within the energy utilization category by optioning the weight score of (33.20%) and (29.59%) respectively. Companies need to align their daily operations, business strategy, and organizational structure with an energy management system to improve carbon efficiency and energy performance. In this regard, the adaptability of ISO 50001 is a systematic tool that provides a blueprint for an organization to transform business processes into a sustainable environment. The government should start awareness programs for companies about the importance of the energy management system and how it helps develop sustainability.

Energy Conservation (ENG5) and Energy recycling (ENG4) weigh (28.70%) and (20.27%), whereas Energy Storage (ENG3) is recorded as the least influencing sub-criteria within the energy utilization category by receiving (17.48%) weight score. The industrial sector's low carbon development promotion to develop the industrial energy and low-carbon system more efficiently. There is a need to take specific steps to effectively control industrial emissions by conservation of energy storage of energy, recycling, improving efficiency, strengthening carbon emission management, and mitigating greenhouse gases during industrial production processes.

5.2 Agriculture/forestry

Fig.8(b). Ranking of Agriculture & Forestry sub-criteria



Under the agriculture and forestry category, the outcome in figure 8(b) presents the sub-criteria in the following sequence of importance: AGR3>AGR6>AGR7>AGR4>AGR2>AGR1>AGR5. Biodiversity conservation and Land degradation prevention (AGR3) received the highest weight of (56.61%) within the category. Climate vulnerability harms agriculture and forestry and causes land degradation, production challenges, and food insecurity. The 25% of global land area (38.52 million km) has been affected due to land gradation in soil quality reduction, physical and chemical changes, and erosion, and lower economic and biological productivity (ELD Initiative 2015).

Eco-friendly farming (AGR6) and Supply chain and sustainable food security (AGR7) got the second and third position by obtaining the score weight (51.92%) and (42.02%) respectively. The absence of green agricultural technologies in Pakistan turned to low production. Soil fertility leads to high agricultural production, whereas growing crops gained a different amount of nutrients from the soil. Eco-friendly soil fertility practices improve soil structure, reduce irrigation issues, high productivity, and enhance green manuring. The Pakistan food supply chain sector suffers from a lack of cold food storage technologies during transit due to temperature variation. Protecting the product's chain of custody is the main requirement for sustainable food security nowadays. Product monitoring, for example monitoring the temperature, most extended shelf life, has become a significant challenge during the transit of product supply (Tostivint et al., 2017).

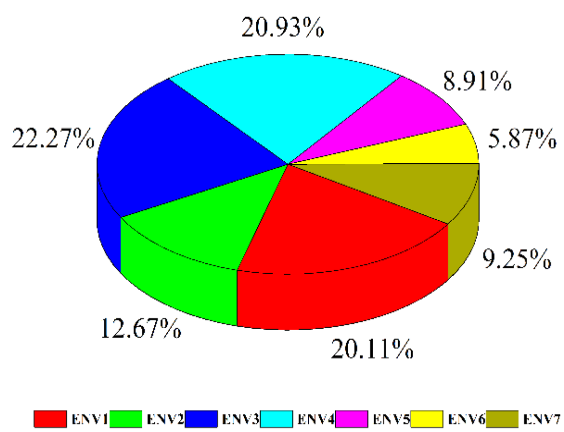
Ecological animal husbandry (AGR4) and ecosystem conservation and restoration (AGR2) come in a row at the fourth and fifth positions by receiving the weight score (41.36%) and (38.31%) respectively.

Due to the high population growth rate, the food demand for meat, eggs, milk, and other dairy products has been increased. Although animal husbandry has a high growth rate and is considered a pillar for economic development, if it is not managed correctly, it is a threat to environmental sustainability. Animal husbandry produces substantial pollutant discharge, which causes water pollution (Yang et al., 2019).

According to experts' feedback, Sustainable forest management (AGR1) and Ecological fisheries (AGR5) are evaluated as the least essential sub-criteria within the agriculture and forest category by obtaining the weight of (23.67%) and (17.68%) respectively. Significant losses of forest biodiversity and, conversely, the need to restore millions of hectares of degraded forest are two of the most significant issues challenging forest managers globally (Crouzeilles et al., 2016). To meet these challenges, some general principles can help guide forest biodiversity conservation and the restoration of forest ecosystems. Fisheries represent a significant basis for the world's food production and are a significant income source in many coastal regions. Due to unsustainable fishing practices and rapid improvements in fishery technology, many fishery resources are declining despite numerous attempts to improve scientific understanding and management practices (Bastardie et al., 2017).

5.3 ***Environmental Quality***

Fig. 8(c). Environmental Quality sub-criteria ranking



The following ranking of Environmental Quality (ENV) sub-criteria was obtained:

ENV3>ENV4>ENV1>ENV3>ENV7>ENV5>ENV6 can be seen in figure 8(c). Drinking-Water quality and wastewater Management (ENV3) received the heights weight score (44.21%) and is recorded as the most vital sub-criteria within the environmental quality category. The availability of clean water is essential for developing a better human society and progress in good environmental health and economic and welfare UN Water (2018). In this scenario, unnecessary delayed or failure to achieve SDG6 can disrupt the 2030 agenda. According to the Secretary-General of the UN report, the world is not on track to achieve this goal. This is because the world leaders do not have much information about this issue. There is a lack of coordination between the countries

(Independent Group of Scientists appointed by the Secretary-General, 2019; Nilsson et al., 2015). Therefore, 1.8 billion people still had no access to clean drinking water facilities and fecally contaminated drinking water. The more alarming point is that 80% of wastewater produced by human activities is still discharged directly into public areas and water-related ecosystems, which cause environmental diseases (United Nations, 2015). Consequently, 801,000 children below age 5 die every year due to stomach diseases such as diarrhea in developing countries (Liu et al., 2012). Air Quality (ENV4) received the second position within the category and obtained the weight score (41.56%). Quality of Environmental Management System (ENV1) showed the weight score (39.93%) and appeared in the third position.

Air quality is another important environmental factor with the highest public perception, and a long-range of scholars have studies the hazards of air pollution from multiple perspectives. Air quality plays an essential role in the life expectancy of residents. Due to uprising industrial processes and high non-renewable energy sources, the ratio of hazard pollutants is tremendously increasing, which causes respiratory and cardiac problems. To handle these environmental air quality issues, the implementation of environmental management systems (EMS) is a useful tool internally for organizations (Fonseca and Domingues, 2018; Sroufe, 2003, along wtih Melnyk, Sroufe, and Calentone, 2003) to reduce waste, mitigate the hazardous substances from the air and improve overall environmental performance, while reducing pollution and mortality rates that (Ebenstein et al., (2015) found in prior work in China.

Solid waste treatment and Management (ENV2) obtained (25.15%) weight score in the environmental quality category and came in the fourth position. Analyzing and controlling environmental risk (ENV7) received the weight score (18.37%). Simultaneously, Noise pollution (ENV5) got the second last position by obtaining the (17.69%) weight score within the category.

The disposal of municipal solid waste has become a critical issue due to the rapid increase in population growth in urban areas (Singh, 2019). Due to the lack of solid waste treatment technologies, residents have health and environmental risks in developing countries. The level of noise pollution has increased due to an increasing population and transportation activities. The prior studies conducted by Yu and Kang (2017) observed a positive relationship between the number of building percentages and the road's width with the noise level. Conversely, the open area/space has a negative relationship with the level of noise.

5.4 Life Health

Fig.8(d). Ranking of Life Health sub-criteria

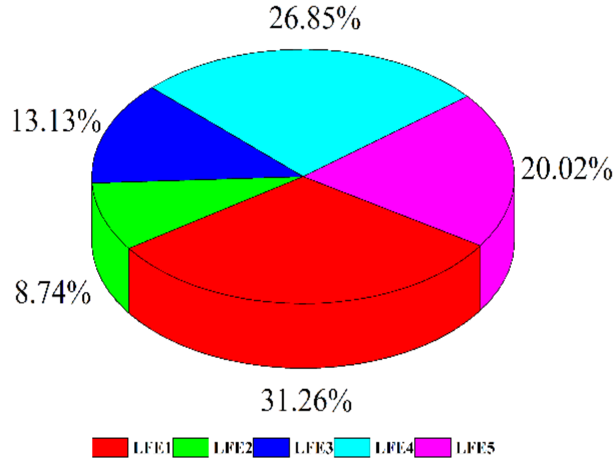


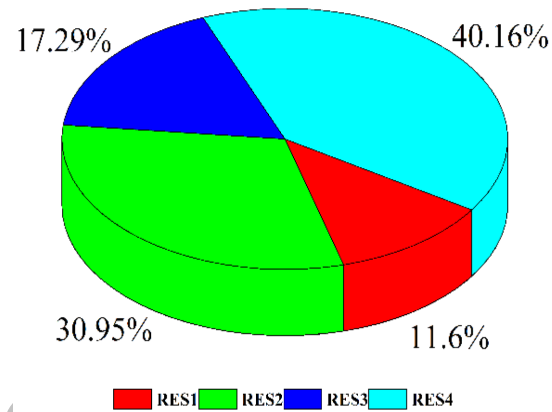
Figure 8(d) shows the outcomes with the following sequence of rankings: LEF1>LEF4>LEF5>LEF3>LEF2. Ecotourism (LEF1) has the highest weight score (42.12%) and recorded the most influencing sub-criteria within the category with a 0.0225 consistency ratio. The concept of Ecotourism has gained much popularity for the last several years, which requires protecting the natural environment from tourists during the visit in order to achieve sustainable development. Tourists can anticipate by their behaviors to make the environment clean and restrict to any damage. Chiu et al. (2014) conducted a study and investigated a positive relationship between the tourist responsible behavior perception and past traveling experiences. There are numerous social, environmental, and economic benefits of Ecotourism. It helps in community building, helps maintain biodiversity, protects the ecosystem, and encourages energy consumption. Moreover, Ecotourism motivates all stakeholders to focus on environmental awareness, which may ultimately contribute to sustainable investment in capacity-building efforts.

Environmental health management system (LEF4) and Sustainable design for indoor environment (LEF5) are ranked at third and fourth position, presenting the score of (36.18%) and (26.97%) respectively. Whereas Urban living environment (LEF3) and Rural living environment (LEF2) is the least influencing sub-criteria within the life health category by obtaining the weight (17.69%) and (11.78%) respectively.

The global environment's dynamic change exerts pressure on humans and other living organisms that are a severe threat and need to mitigate or cope with stressful conditions. These challenges have adverse effects on human health, our ecosystem, communities, and different sectors such as agriculture, forestry, water resources, and fishery(Agathokleous and Calabrese, 2020). On the other hand, the exploration and exploitation of oil also disrupt environmental sustainability plans. The excessive amount of tree felling and pipelines and equipment installation also disturb our ecology functions and severe environmental damage. Moreover, the explosive activities for mining have caused deforestation. The management of urban sewage sludge has become a server problem in developing countries due to lack of advanced sewerage technologies. The poor quality of wastewater treatment produces more solid sewage sludge, leading to many environmental issues (Chen et al., 2019).

5.5 Resource Utilization

Fig. 8(e). Resource Utilization sub-criteria ranking



Under the resource utilization criteria category, the following ranking sequence of sub-criteria obtained: RES4>RES2>RES3>RES1, as shown in figure 8(e). Resource and material management (RES4) has recorded the most important and challenging sub-criteria within the category by obtaining the weight score (35.28%).

Technical innovation and green technologies such as natural resources, efficiency, and environmental improvement capabilities have promoted new economic growth in many developed countries. Since the 4th industrial revolution, the human ecosystem and economy have a significant development that exploits the natural resources and has become a severe problem to achieve sustainability (Zhang et al., 2018).

The next sub-criteria that obtained the highest weight score (27.19%) within the category is Resource/Material Recycling (RES2). Various advanced strategies are required to develop a circular economy, such as closing the loop by recycling and reuse, a massive shifting of fossil energy to renewable and clean energy sources, and reducing resource consumption into efficient productivity (D'Adamo, 2019). However, recycling technologies are in practice in many countries for some material, e.g., glass, metal, paper, construction, and demolition waste, to achieve a circular economy. However, there is still a need for recycling green technologies for effective reduction of material consumption.

Following this, the Resource of Material and Conservation (RES3) comes in a row on the third position within the resource utilization category by obtaining the weight score (15.19%). In contrast, the least influencing sub-criteria within the category is Resource Exploitation and Utilization (RES1), with a weighted score (10.19%).
It is essential to have natural resources and conservation of ecosystems to make sustainable production economically feasible. Moreover, there is a need to control the overexploitation of renewable resource systems. Other options to consider include, but are not limited to, avoiding unsupportive environmental functions, the reduced use of non-renewable resources, and put a price on externalities like greenhouse gas emissions (Santibanez-Gonzalez, 2017).This,

in turn, will help to develop more environmentally sustainable systems, i.e., help the biosphere's stability, biodiversity maintenance, and other ecosystems, not ordinarily classified and economic resources.

5.6 Ecological safety

Fig.8(f). Ranking of Ecological Safety sub-criteria

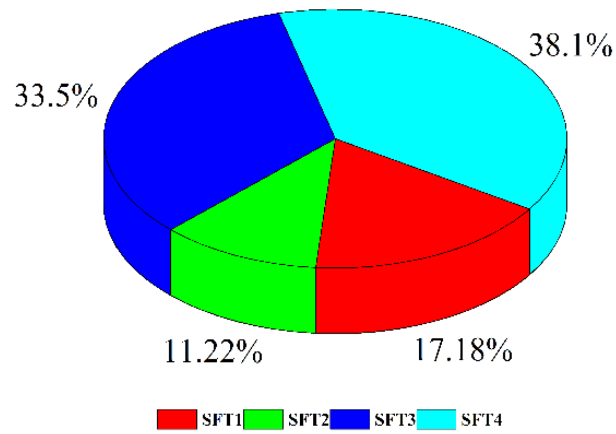


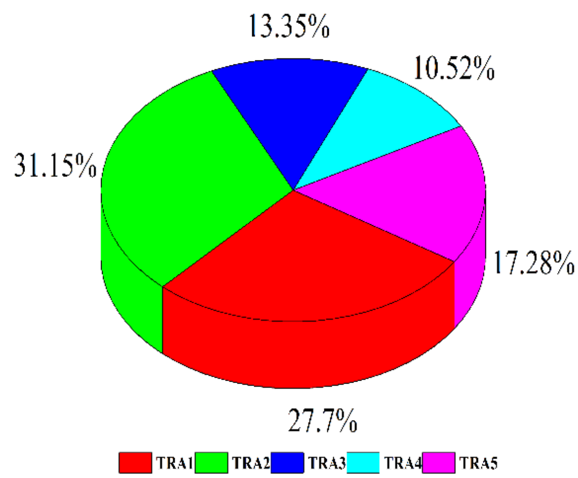
Figure 8(f) shows the ranking of sub-retribute related to ecology safety to classify the green technologies in Pakistan as follows: SFT4>SFT3>SFT1>SFT2 with consistency ratio 0.0141. Ecological safety monitoring (SFT4) holds the first position with the highest score (27.33%) within the ecological safety category.

Climate vulnerability, biodegradation, deforestation are the significant global ecological risks and challenges for human survival. Policymakers, environmentalists, and governments need to develop sustainable ecology safety monitoring programs at spatial and temporal scales to compete with these global challenges (Popkova et al., 2016). The second and third sub-criteria within the ecological safety are the Ecological safety emergency plan (SFT3) and Natural disaster prevention (SFT1), which obtained the weight of (24.03 %) and (12.32%) respectively. Whereas Waterland and lake protection (SFT2) holds the fourth position within the category by receiving the weight score (8.04%),

Climate change leads to natural disasters and has an alarming indication for environmental safety. In this regard, an effective emergency response plan can reduce the intensity of disaster and protect from any severe human loss. Therefore, the essential element of environmental emergency response is the early detection and reduction of ecological risks. Technical support and specialized expertise are required to tackle these environmental accidents to save human lives(Wu, 2020).

5.7 Transportation

Fig.8(g). Ranking of Transportation sub-criteria



As presented in figure 8(g), the ranking of sub-criteria within the transport category with a consistency ratio of 0.016261 is obtained as follows: TRA2>TRA1>TRA5>TRA3>TRA4. The highest weight score (41.95%), Less Polluted Vehicles (TRA2) sub-criteria, comes in at the first position. Energy-efficient vehicles (TRA1) reached the second position in the transportation category with (37.31%) weight.

There is a significant advantage of hybrid vehicles. They produced fewer emissions and consumed less fuel than conventional engines, and give similar performance. Green vehicles such as hybrid cars, electric cars other alternative source-based fuel vehicles can mitigate environmental problems through zero-emission and ultimately reduce oil dependency. The promotion of green and energy-efficient vehicles is a crucial measure to save energy and reduction of emissions.

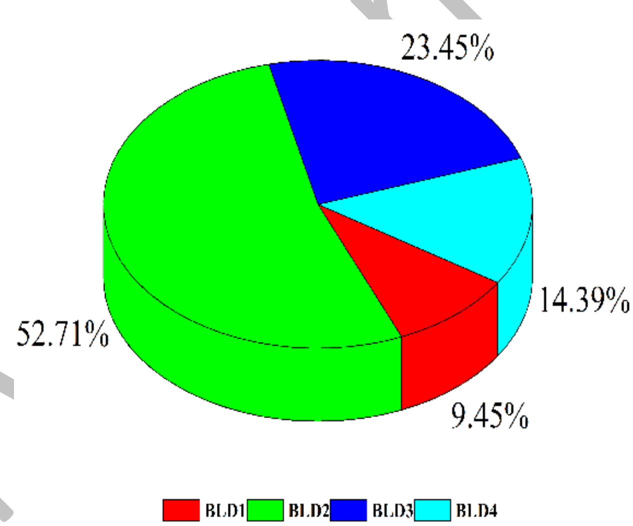
Green roof solution at parking facility to reduce maintenance cost (TRA5), and Vehicles Interior voice reduction (TRA3) ranked at third and fourth position within the transport criteria category by receiving the weight score 23.27 14.17% respectively. The green roof's adaptability has gained popularity worldwide and is considered a more sustainable practice (Yang and Wang, 2014). There are numerous social, environmental, and economic benefits of green roofs explored in prior studies. These benefits are stormwater management include but are not limited to: shielding against heat island effects, improving the water and air quality, lowering maintenance costs, a longer durability of the roof, wildlife habitat, less consumption of energy, controlling of noise pollution, saving the energy maintenance cost, increased urban plantation, boosts recreational activities, and enhanced the green area and protect the urban environment (Golbazi et al., 2020).

Finally, Interior air improvement (TRA4) is considered the least essential sub-criteria within the transport category with (14.17%) weight score. In the recent decade, efficient engines have been developed with less waste heat, which mitigates the CO_2 emission an essential environmental sustainability element (D'Adamo et al., 2020). These combustion engines still waste roughly 81% of every gallon of gasoline as this goes to heat and friction, not movement of the vehicle (Lovins, Lovins, and Hawkins, 2013). Electric vehicles' popularity continues to increase as they cost

90% less when converting energy to movement, yet still have challenges, such as design systems for mobile climate control. The traditional gasoline engine produces 5kW heat used for cabin heating and de-icing the window in winter. Conversely, hybrid electric vehicle engines produced low heat, about 2kW, and when doing this, need more electricity from the battery, affecting the mileage performance (Das et al., 2020).

5.8 Green buildings

Fig.8(h). Ranking of Green Buildings sub-criteria



Under the green building category, results presented in figure 8(f) allowed the identification of the following ranking sequence: BLD2>BLD3>BLD4>BLD1. Innovative, energy-efficient material for construction (BLD2) is presented as the most influencing sub-criteria within the category by receiving the 37.05% weight.

The adoption of green building technologies such as ventilation and natural daylight, and energy-efficient material for construction involves 30-60% cost saving (Darko et al., 2017). The sustainable green construction processes and energy-efficient material help enhance the building's life and reduce the environmental impact (Sroufe, Stevenson, and Eckenrode, (2019).

Occupants' health, safety, and comfort (BLD3) and Increase ventilation efficiencies (BLD4) have received the second and third positions with weight scores (16.49%) and (10.12%) respectively. Interestingly, there is no such difference between the non-green building and the green building. However, green buildings' construction process is designed for environmental protection, energy efficiency, human safety and comfortability, better indoor air quality, saving cost, and reducing environmental risks. Therefore, green building's satisfaction level is higher than non-green buildings (Chan et al., 2018).

Sustainable site selection (BLD1) has recoded the less important sub-criteria within a green building having the weight score (6.64%) with a consistency ratio of 0.0009. Site selection is an essential issue in sustainable green building practices, which requires sustainable planning and design. Moreover, the most critical steps in sustainable planning are the layout of a suitable site, operations cost, and green building (Tsai et al., 2013). The during construction, problems can be dealt with at early stages, such as transportation, excessive energy and water consumption, and urban heat island effect due to the adaptability of sustainable green site design strategies.

5.9 Final Ranking of Sub-criteria

As shown in Figure 9, the final ranking of sub-criteria is determined by multiplying the sub-criteria of global weights by each respective category's weight. It has been recorded that the overall ranking of green technologies classification in based on final weights by the overall ranking of all the sub-criteria. The attributes of sub-criteria for the classification of green technologies in Pakistan is presented as follows:

AGR3>ENG6>AGR6>ENG2>ENV3>AGR7>LFE1>TRA2>ENV4>AGR4>ENV1>AGR2>TRA1>BLD2>LFE4>RES4>ENG1>ENG7>ENG5>RES2>LFE5>ENV2>SFT3>AGR1>TRA5>ENG4>ENV7>TRA3>LFE3>ENV5>AGR5>ENG3>BLD3>RES3>TRA4>SFT1>LFE2>ENV6>RES1>BLD4>SFT2>BLD1

For the classification of green technologies in this study, Supply chain and sustainable food security (AGR3) is the sub-criteria within agriculture criteria that recorded with the highest weight score 0.5609, followed by Energy Recycling (ENG6) with a weight (0.5577). Eco-friendly farming (AGR6) and Energy Efficient Appliances (ENG2) hold the third and fourth positions by receiving the weight score 0.5192 and 0.4969 is presented in Table 8. Finally, the last three positions of sub-criteria evaluated for the classification of green technologies in Pakistan are Increase ventilation efficiencies (0.1012), Waterland and lake protection (0.0804), and Sustainable site selection (0.0664) respectively.

Table 8. Final weights of sub-attributes

Main Attributes	Main Attribute Weights	Sub-attributes Codes	Consistency Ratio (CR)	Global Weight	Local Weight
Environmental Quality	0.1582	ENV1	0.010504	0.063173	0.399324
		ENV2		0.039796	0.251557
		ENV3		0.069944	0.442124
		ENV4		0.065746	0.415588
		ENV5		0.027980	0.176871
		ENV6		0.018433	0.116523
		ENV7		0.029064	0.183719
Resource Utilization	0.1157	RES1	0.010807	0.011785	0.101864
		RES2		0.031457	0.271887
		RES3		0.017576	0.151915
		RES4		0.040816	0.352779
Transportation	0.0613	TRA1	0.016261	0.022871	0.373109
		TRA2		0.025718	0.419547
		TRA3		0.011025	0.179860
		TRA4		0.008684	0.141668
		TRA5		0.014266	0.232725
Energy Utilization	0.2375	ENG1	0.000404	0.079134	0.333198

		ENG2		0.118017	0.496915
		ENG3		0.041524	0.174838
		ENG4		0.048131	0.202658
		ENG5		0.068181	0.287081
		ENG6		0.132459	0.557724
		ENG7		0.070265	0.295855
		LFE1	0.022523	0.057908	0.421152
		LFE2		0.016198	0.117807
Life Health	0.1375	LFE3		0.024334	0.176978
		LFE4		0.049742	0.361767
		LFE5		0.037090	0.269747
		BLD1	0.000909	0.003681	0.066447
Green Buildings	0.0554	BLD2		0.020533	0.370648
		BLD3		0.009134	0.164887
		BLD4		0.005607	0.101222
		AGR1	0.000808	0.052614	0.236684
		AGR2		0.085178	0.383167
		AGR3		0.124662	0.560787
Agriculture/Forestry	0.2223	AGR4		0.091933	0.413555
		AGR5		0.039294	0.176764
		AGR6		0.115412	0.519174
		AGR7		0.095643	0.430247
		SFT1	0.01414	0.013472	0.123264
Ecological Safety		SFT2		0.008794	0.080464
	0.1093	SFT3		0.026267	0.240322
		SFT4		0.029869	0.273278

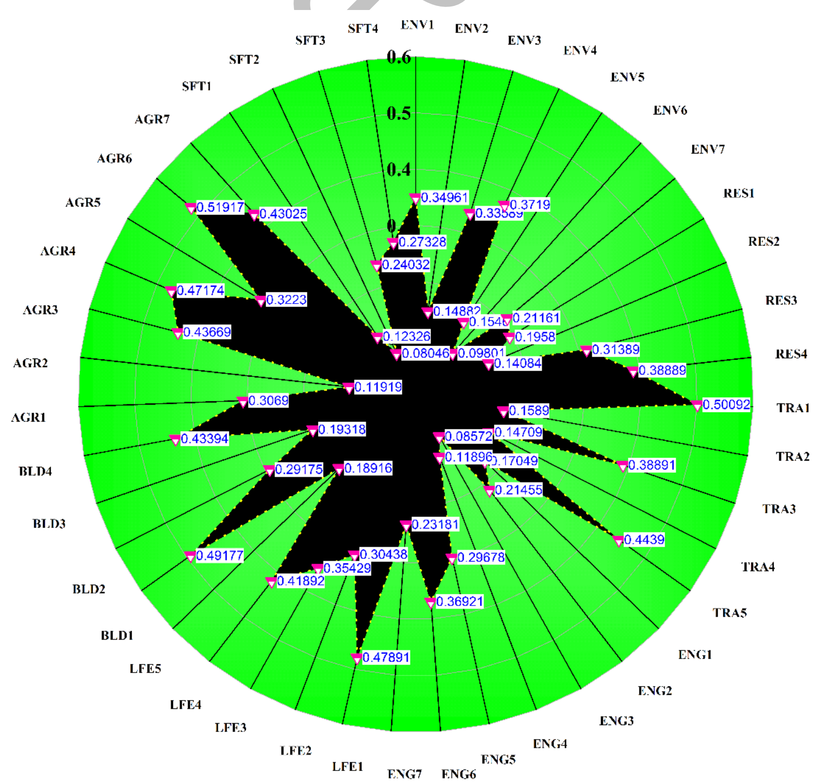


Fig. 9. Overall ranking of green technology sub-criteria

6. Conclusions

This study provides an opportunity to assess the green technology indicators for cleaner production and sustainable investment from a single country perspective. In meeting the objectives of this study, we have multiple contributions to the field and new insights regarding the relationships of green technologies, cleaner production, and sustainable investment to achieve an integrated approach to the global sustainable development goals (i.e., the UN SDGs). First, this study contributes to academic research by developing the integrated framework comprising the analytical design of green technologies, three layers of green technology platform, and organizational structure of green technologies in Pakistan. Further, this study identified the numerous green technology indicators for sustainable investment and cleaner production from the literature and refined with experts' help by using the fuzzy Delphi method. Forty-three green technologies indicators were finalized under eight significant categories: Environmental Quality, Resource Utilization, agriculture & forestry, Green building, Life health, Green Transport, Energy Utilization, and ecology safety. The application of Fuzzy AHP was used to compute the weights of all the indicators. The results reveal that Agriculture & forestry, and energy utilization are the most influencing criteria among the other six green technology indicators. Simultaneously, the Supply chain and sustainable food security (AGR3) 0.5609 weight score of the weight and Energy Recycling (ENG6) with a weight of 0.5577 is recorded as an essential green technology sub-indicator among the rest of the 43 sub-criteria lists. Finally, this study is also the first to assess the green technology indicators for cleaner production practices and sustainable investment from Pakistan's perspective.

Our research provides several contributions. The theoretical contributions include enriching the green technologies field of study by proposing a taxonomy of green technology indicators aiming at a cleaner production associated with sustainability investments. Moreover, this manuscript showed the interlinks among green technologies, sustainable investments, and cleaner production, having as context the country of Pakistan. Our study presented the two-way perspective (bottom-up/top-down) of sustainability dimensions by which companies may invest in green technologies. A practical and theoretical implication identified from the study is that our framework confirmed that the more a given company is engaged in promoting practices towards cleaner production, the more this company is willing to invest in green technologies. Our application of Fuzzy AHP provides new insights to the Pakistani industries related to agriculture and energy. It showed that green technologies most influence these two sectors because they face several energy crises and have a relevant potential for energy source transformation to renewables. Concerning the agriculture sector, the Pakistani economy, much like other developing economies, is highly dependent on this industry for its economic growth.

Practical implications include looking at how green technology investments create different forms of value for the country’s economy. The value that comes from investing in green technologies requires triggers related to tangible resources (e.g., financial capital). Our study contributed to the field by identifying how sustainability engagement can lead companies to invest more in green technologies. According to our findings, an integrated bottom line (Sroufe, 2018) understanding of investments' potential to impact environmental, social, and economic performance allows companies to invest in green technologies in practice through each studied sustainability dimension. Thus, the green technologies suppliers/providers must consider the sustainability dimensions stressed in our research when considering green technologies' development and trading.

Scholars can consider relevant criteria from the literature summarized in this study as a building block toward future research. Building on this study and leveraging insights from experts in future studies provides new opportunities for a multimethod approach to modeling. We also see opportunities to develop a new, more integrated approach to the green technologies’ classification process, scenario planning, and utilization of the UN SDGs as criteria for future research and assessment. Whole new sets of criteria, assessments, and rankings of subcriteria can be developed for other country contexts and then compared and contrast for effectiveness in pre and post-studies of infrastructure investments, cleaner production capabilities, and longitudinal studies of effectiveness. The methods used in this study support decision-making dynamically. These methods should be applied to future studies as countries and economies seek investment strategies in a post-pandemic world that will help make both developing and developed countries more stainable.

There are several limitations to this study. The first is the single country context in which we examine green technology, cleaner production, and sustainable investment opportunities. A developing country context was important to the researchers in this study for several reasons. First, develop and test multi-criterion decision analysis models within a context where there are immediate opportunities for application and impacts on decisions and near-term investments. Next, we believe the country context used in this study is representative of many developing countries, and therefore, the benefits of this study can be far-reaching. The approach taken to the development of the model is generalizable. Nevertheless, this approach will need to be applied to developed country contexts to help ensure the robustness of the methods employed in this study. The integration of fuzzy Delphi and fuzzy AHP methodologies makes this study both novel and complex. While the modeling approach was developed to accommodate complexity, the ease of use for any modeling tool can also cause limitations in its further application. While recognizing these limitations, there are several benefits from studies like this and opportunities for further research.

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