



From Commitment to Sustainability: GIC's Role in Carbon Emission Mitigation

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ABSTRACT

Climate change and its negative environmental impacts have prompted many companies to adopt more environmentally friendly policies, including carbon emission mitigation. In this context, Top Management Green Commitment (TMGC) is a key factor in encouraging companies to integrate sustainability practices focusing on carbon emission reduction into their business strategies. This study aims to analyze the role of TMGC in supporting carbon emission mitigation and sustainability, the impact of GIC in reducing carbon footprints to create sustainability and to understand how Green Intellectual Capital (GIC) can mediate the relationship between TMGC and sustainability. This study involved 220 respondents from energy and manufacturing sector companies in Indonesia, with analysis using PLS second order to test the relationship between variables. The study results indicate that TMGC significantly encourages carbon emission mitigation practices that contribute directly to sustainability. GIC has been proven to significantly affect sustainability and mediates the impact between TMGC and sustainability. The study's findings generally support the Upper Echelon Theory (UET), which states that top management's strategic decisions are influenced by their commitment to sustainability. The study also supports the Natural Resource-Based View (NRBV) theory, which emphasizes the importance of GIC in creating sustainable competitive advantage. TMGC and GIC are important elements in reducing carbon emissions and increasing long-term sustainability for companies.

Keywords: Top Management Green Commitment, Sustainability, Green Intellectual Capital, Carbon Emission Mitigation

JEL Classifications: Q01

1. INTRODUCTION

The world has been facing environmental problems, especially climate change, a trend of CO₂ that continues to increase and is global. Human-caused greenhouse gas emissions contribute around 76% of global emissions (Sylvia and Sunitiyoso, 2023). As a result, virtually every nation agrees to address the climate catastrophe (Sylvia and Sunitiyoso, 2023). Moreover, carbon emissions are considered one of the most dangerous environmental problems in the world (Kurular, 2020). Businesses and other sectors are paying more attention to carbon reduction techniques due to the pressing need to address climate change. Carbon emissions contribute significantly to global warming and pose risks to long-term sustainability, such as regulatory penalties,

reputational damage, and increased operating costs. As a result, integrating carbon mitigation into business strategies has become imperative. In this context, sustainability in business is no longer limited to profit considerations but must also encompass social and environmental aspects (De Giovanni, 2012). Businesses that actively mitigate their carbon footprint are better positioned to meet regulatory requirements, enhance stakeholder trust, and achieve competitive advantage in an increasingly environmentally conscious marketplace.

Top management commitment is one of the important factors that drives the transition to sustainable business practices. Top management has an important role in shaping the organization (Tzempelikos, 2015). Upper echelon theory states

that top management commitment determines the direction of organizational priorities, resource allocation, and integration of corporate sustainability goals (Hambrick and Mason, 1984), including sustainability in minimizing environmental impacts, significantly reducing corporate carbon emissions.

Study on the influence of Top Management Green Commitment (TMGC) on sustainability from the perspective of carbon emission mitigation is critical considering the pressure from stakeholders that encourage companies to adopt environmentally friendly practices, especially in reducing carbon emissions (Yunus et al., 2020). This study offers a more specific construct, namely TMGC, in the context of carbon mitigation. In addition, businesses are increasingly aware that climate change can significantly change the business landscape, creating a more competitive environment (Howard-Grenville et al., 2014). Therefore, it is necessary to design a more effective carbon policy, which includes top management commitment to sustainability (Lee and Lee, 2018). Top management commitment to carbon mitigation can encourage the adoption of environmentally friendly practices, such as the use of renewable energy and waste management (Xie et al., 2019), which ultimately contributes to improving the company's positive image and economic and non-economic performance (including social and environmental aspects (Panzo et al., 2023). In today's era, where sustainability is a significant focus for stakeholders (Magness, 2009), study on TMGC on sustainability is becoming increasingly relevant because it is a goal that companies want to achieve in the long term.

Top Management Green Commitment (TMGC) is needed in every company to ensure effective and efficient environmentally friendly operations. The commitment of competent leadership in a company can provide adequate human resources, technology, and financial resources and allocate these resources appropriately for the company's survival Luthra et al., 2015, including in the form of Green Intellectual Capital (GIC) allocation. Commitment to reducing carbon emissions will encourage management to provide and utilize company resources, including GIC, as a strategic effort to reduce carbon emissions. GIC is a form of operationalizing top management's commitment to supporting carbon emission mitigation. Top management's objectives, especially in the context of sustainability, will be realized by allocating appropriate resources, including intangible assets such as GIC, to support carbon emission reduction. In today's era, when sustainability is the company's primary goal, management needs to operationalize its commitment by strategically organizing and allocating owned resources to achieve sustainability, including practical carbon emission mitigation efforts.

Di Vaio et al., 2024 stated that the company can focus on intellectual capital (IC) to reduce carbon emissions. Companies can leverage IC dimensions, namely human, structural, and relational capital, as important sources of economic growth towards low-carbon environmental transformation and sustainable development (Goklany, 2007). However, there is minimal empirical study that discusses the role of GIC as a tool that companies can use to carry out carbon emission mitigation efforts. Previous study is still limited to discussing the four dimensions of GIC: Green

human capital, green relational capital, and green structure capital (Shah et al., 2021; Sohu et al., 2024; Wang and Juo, 2021a; Yong et al., 2019) and green social capital (Chen, 2008). The concept of classifying IC with 4 dimensions, namely human capital, structure capital and, relational capital, social capital, was criticized by several experts.

Inkinen et al. 2017 State that one criticism of the previous IC dimension model is that it offers a categorization that is not comprehensive enough since the number and diversity of intellectual elements would allow for a more accurate separation between IC dimensions (Inkinen et al., 2017) classifying IC into human, structural, relational, entrepreneurial, renewal, and trust capital. Kianto, 2007 state that one of the elements of IC is renewal capital.

Renewal capital (RNC) is an organization's ability to acquire and generate new knowledge through learning new things and learning new abilities (Inkinen et al., 2017). Green renewal capital (GRNC) can be interpreted as the capacity of an organization to learn and create new knowledge related to the environment. Organizations that have knowledge resources will be able to identify environmental problems and find solutions to these problems. In an era of increasing environmental awareness, companies must also adapt to current challenges, such as the negative impacts of climate change on the destruction of natural resources, global warming, and pollution (Mirón et al., 2023). To overcome these challenges, companies use new methods, techniques, and new knowledge and skills to increase environmentally friendly productivity (Wei et al., 2023), significantly reducing climate change.

Entrepreneurial capital (EC) relates to the proactive efforts of business staff who have fresh chances to create goods and plans and gather market signals (Lumpkin and Dess, 1996). Green Entrepreneurial capital (GEC) refers to the ability of company employees to find new opportunities, develop new environmentally friendly products, and develop environmentally friendly strategies to achieve competitive advantage. When company employees can develop new products with a low carbon footprint, it will meet the expectations of environmentally conscious consumers, improve the company's image, and thus increase sustainability (Al Mamun and Fazal, 2018).

Another dimension of the proposed IC is trust capital. Trust will result in stronger relationships within internal and external networks (Mayer et al., 1995), considers Trust Capital (TC) as one of the key drivers of inter- and intra-organizational cooperation, knowledge sharing and transfer and joint creation of innovations. (Inkinen et al., 2017; Nahapiet and Ghoshal, 2009). Green Trust capital (GTC) is a psychological state where other companies have positive beliefs or expectations towards the company due to environmentally friendly practices and good ethics in managing the environment. This trust is based on environmentally friendly practices, companies find it easier to establish strategic partnerships with partners, suppliers, or even competitors to develop low-carbon solutions such as clean technology, environmentally friendly production processes, or renewable energy sources. GTC strengthens the company's reputation as an entity committed to

environmental sustainability. Trust from external stakeholders, such as consumers, regulators, and communities, makes it easier for companies to gain support through licenses, environmental incentives, or even market preferences. This reputation also helps companies maintain their competitive position in a market that increasingly demands environmental transparency.

This study investigates the relationship between top management commitment, Green IC, and business sustainability from a carbon emission mitigation perspective, with Green IC mediating the effect of top management commitment on business sustainability.

2. LITERATURE REVIEW

2.1. Upper Echelon Theory

The central premise of the upper echelon theory states that the company is a reflection of top management because the characteristics of managers as decision makers greatly influence the company's strategic decisions (Hambrick and Mason, 1984). This theory considers the concept of top management as the most important strategic decision-making in the organization. Thus, according to this theory, the organization is a reflection of top management.

Organizations in the current era must be adaptive to face stakeholder demands from both the government and consumers. Therefore, top management commitment is needed to adapt to current demands, namely that companies are not only required to generate profits but are also obliged to be environmentally friendly and pay attention to social (sustainability) and environmental aspects (Yusoff et al., 2019). Top management's commitment to sustainability will encourage implementing green initiatives, including low-carbon innovation, energy efficiency, and resource allocation for developing environmentally friendly technologies. This supports companies in reducing their carbon footprint effectively while strengthening their competitive position through regulatory compliance and reputation enhancement.

2.2. Natural Resources Based View

NRBV states that three primary strategic capabilities are sustainable development, product stewardship, and pollution prevention (Hart, 1995). (Hart, 1995) states recognizing the challenges that exist from the natural and social environment, is extensive so that it is likely that strategy and competitive advantage will be rooted in the company's ability to facilitate environmental activity responsibilities. To facilitate the company's environmental responsibility, management requires resources and strategy implementation. Green intellectual capital is a unique company resource that meets the criteria as a unique, valuable, rare, and difficult-to-imitate resource that can be used to fulfill environmental activity responsibilities.

Green intellectual capital (GIC) is a strategic resource that supports carbon emission mitigation. GIC, as a combination of knowledge, skills, and green innovation in an organization, meets the criteria of valuable, rare, difficult to imitate, and organized resources. Good GIC management allows companies to develop low-carbon technologies, improve energy efficiency, produce environmentally

friendly products, and comply with global environmental standards, thereby improving sustainability.

3. THEORY AND HYPOTHESIS

3.1. TMGC has a Positive Effect on Sustainability

Based on the upper echelon theory, top managers' characteristics and environmental orientation play an important role in influencing corporate environmental management strategies. The personal characteristics, vision, and experience of top management determine the strategies taken, including carbon emission mitigation, which have a significant impact on the company's environmental, social, and economic performance (Hambrick and Mason, 1984; Kitsis and Chen, 2021).

Top management that understands the potential benefits of carbon mitigation programs tends to take concrete actions to achieve them. Examples include investing in low-carbon technologies and adopting clean energy, which aligns with the demands of "going green" in modern business (Chen, 2008). These strategies reduce the company's carbon footprint and improve the health of employees and the community around the company, which ultimately strengthens the company's positive image and economic performance (Panzo et al., 2023). Previous studies have shown that TMGC contributes to the success of environmental initiatives such as Green Human Resource Management (GHRM) (Yong et al., 2022) and Green Supply Chain Management (GSCM) (Adusei et al., 2023).

Environmental commitment from top management ensures better carbon emission management and motivates the entire organization to play an active role in green initiatives. This supports the achievement of business sustainability that encompasses environmental, social, and economic impacts and creates a long-term competitive advantage for the company.

H₁: TMGC contributes positively to sustainability.

3.2. TMGC has a Positive Effect on GIC

Upper echelon theory stated that differences in managers' values and cognitive styles cause their decisions to differ (Hambrick and Mason, 1984), especially in complex situations (Bamber et al., 2010). Competent leadership commitment in a company can provide good human resources, technology, and financial resources for the company, as well as the proper allocation of these resources for the company's survival (Luthra et al., 2015) including GIC allocation. Thus, it can be concluded that commitment to reducing carbon emissions will encourage management to provide company resources including GIC to reduce carbon emissions. Previous research (Kanwal et al., 2017) found that top management support plays a role in the success of information system project implementation. Based on the description above, the following hypothesis is drawn:

H₂: TMGC contributes positively to sustainability to GIC

3.3. GIC has a Positive Effect on Sustainability

GIC represents the collective intellectual resources within an organization that enable it to address environmental challenges and implement sustainable practices. This includes human capital

with carbon mitigation expertise, structural capital supporting low-carbon processes, and relational capital strengthening ties with green suppliers, customers, and investors. Additionally, GIC fosters innovation through green entrepreneurial, green social capital and renewal capital, which allows companies to develop environmentally friendly products and solutions. Organizations that effectively leverage GIC can reduce their environmental impact, improve their operational efficiency, and enhance their reputation. This, in turn, supports long-term business sustainability by meeting the increasing demand for sustainable practices, addressing climate change, and gaining a competitive advantage.

Previous research (Omar et al., 2019; Wang and Juo, 2021b) found that green human capital impacts sustainability. (Omar et al., 2019) found that GRC has an impact on sustainable business. (Nguyen et al., 2018) found that social capital improves organizational performance. (Xie et al., 2022) find the mediating role of green social capital in the influence of green process innovation on financial performance. Based on the explanation above, the following hypothesis can be drawn:

H₃: GIC contributes positively to sustainability.

3.4. GIC Mediates the Influence of TMGC on Sustainability

In the NRBV paradigm, GIC as a resource must help implement strategies to achieve company goals (Hart, 1995). GIC is a form of operationalization of top management commitment. The objectives of top management will be implemented, one of which is by allocating appropriate resources to achieve goals, one of which is by allocating company resources (Luthra et al., 2015) including intangible assets, namely GIC. In today's era, where sustainability is the company's goal and carbon emissions are the most significant environmental problem, management will operationalize its commitment to managing and allocating its resources to reduce its carbon emissions. Thus, proper resource allocation helps reduce carbon emissions and ensures that the company achieves sustainability goals. So, this research tests GIC as a mediating variable between TMGC and sustainability.

H₄: GIC positively mediates the effect of TMGC on Sustainability

4. RESEARCH DESIGN

4.1. Sample and Procedure

This research employs a quantitative approach, utilizing a survey method to collect data through questionnaires. The questionnaire design was validated through content validity testing, which involved interviews, literature surveys, and Focus Group Discussions (FGD) with the Green Industry Center, academics, and practitioners from the energy sector. The survey was then distributed to environmental managers, environmental auditors, production managers, general managers, and accounting managers from manufacturing and energy companies that have received Green Certification, Green Awards from the Ministry of Industry, Green PROPER, Gold PROPER from the Ministry of Environment and Forestry, and ISO 14001 certifications.

4.2. Variable

Endogenous variables in this research sustainability, within the framework of carbon emission mitigation, represents a company's capacity to operate sustainably by embedding principles of sustainable development. It has three dimensions: Economic sustainability (Ali AlShehail et al., 2022; Androwis et al., 2018; Lin et al., 2021; Zhu and Sarkis, 2007)

The exogenous variables are top management green commitment in the perspective of carbon emission mitigation, it is the initiative of top management as the primary driving agent in formulating, implementing, and being responsible for carbon emission mitigation policies. The TMGC indicator is adopted from (Wijethilake, 2017).

GIC, from the perspective of carbon emission mitigation, consists of seven dimensions: GHC (Chen et al., 2019; Huang and Kung, 2011), GSC and (Chen, 2008; Huang and Kung, 2011; Nikolaou, 2019), Green Social Capital (Chen et al., 2019; Delgado-Verde et al., 2014) GRNC (Inkinen et al., 2017), GEC (Inkinen et al., 2017), and GTC, which is adopted from (Inkinen et al., 2017).

4.3. Model

This study employs a comprehensive research model that integrates several critical variables to explore the factors influencing sustainability within the context of carbon emissions mitigation and organizational commitment. The model has three key components: Top Management Commitment (TMGC), Green Intellectual Capital (GIC), and Sustainability. Through this conceptual framework, this study intends to advance the understanding of how strategic leadership and intellectual capital impact sustainability, particularly within industries critical to environmental management, such as manufacturing and energy.

4.4. Data Analysis

PLS-SEM with SmartPLS v. 4.0 software was used to test the hypothesis. SEM-PLS can still produce estimates even for small sample sizes and deviations from the normality assumption (Tenenhaus et al., 2005). PLS-SEM is suitable for studies in the early stages of theory development and for complex models with moderating and mediating variables (Lin et al., 2020). A small sample size of 220 is also acceptable for PLS-SEM analysis; a minimum sample of 10 times the true path is often used to determine the minimum sample size in the PLS-SEM approach (Lin et al., 2020). Therefore, with 220 responses, the sample size met the minimum PLS-SEM sample. Partial Least Squares (PLS) testing on variables with several dimensions or complex constructs often involves second-order models. Second-order constructs are constructs formed from several first-order constructs. PLS testing on second-order constructs mainly aims to test more complex relationships where a variable or construct includes several interrelated dimensions (Van Riel et al., 2017).

This study conducts a Confirmatory Tetrad Analysis (CTA) to determine whether the model is reflective or formative. To ensure the validity and reliability of the measurement model, validity is

evaluated using outer loading, Cronbach's Alpha (CA), Composite Reliability (CR), and Average Variance Extracted (AVE). Additionally, discriminant validity is assessed using the Fornell-Larcker criterion, ensuring that each construct is empirically distinct (Figure 1).

5. DATA

5.1. Sample Characteristics

This study categorized the sample based on key demographic and professional characteristics, including job position, work experience, company sector, and company size. Table 1 presents a detailed breakdown of these characteristics. Diversity in job position, work experience, industry sector, and company size provides a comprehensive picture of study participants.

5.2. Confirmatory Tetrad Analysis

In this study, before assessing the measurement model, we conducted a Confirmatory Tetrad Analysis (CTA) to determine

the most appropriate measurement model based on the collected data. CTA was performed to assess the fit between the proposed model and the empirical data, ensuring the validity and reliability of the constructs used in this research.

The results of the CTA indicate that the $P > 0.05$, suggesting that there is no significant difference between the theoretical model and the empirical data (Kassa and Worku, 2025). Based on these findings, the reflective measurement model was chosen for this study. This model was selected because the observed indicators are considered reflections of the latent construct, meaning that changes in the latent construct lead to changes in the indicators.

5.3. Measurement of Construct

In this study, the measurement of constructs for the first-order model was assessed using outer loading, Composite Reliability (CR), Cronbach's Alpha (CA), and Average Variance Extracted (AVE). For the first-order model, outer loadings were considered significant if they exceeded the threshold of 0.70, indicating that the indicators strongly represent their respective constructs. Composite Reliability (CR) and Cronbach's Alpha (CA) values above 0.70 confirmed satisfactory internal consistency. AVE values >0.50 indicated adequate convergent validity, meaning each construct explained more than half of the variance in its indicators. All constructs meet the recommended thresholds, confirming the reliability and validity of the measurement model for the first-order constructs, as shown in Table 2.

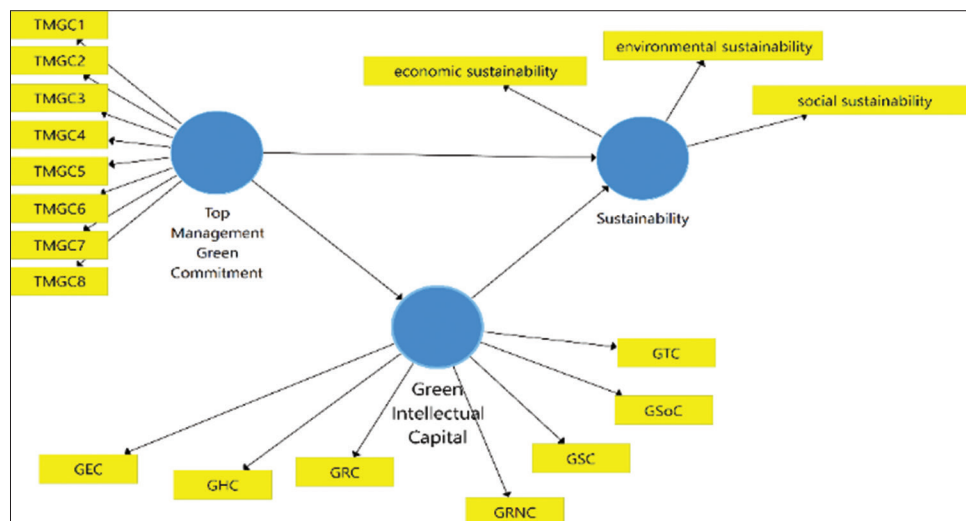
5.4. Fornell Larcker Criteria

The Fornell-Larcker Criterion is a widely used method in Structural Equation Modeling (SEM) to assess discriminant validity, ensuring that constructs in a model are sufficiently distinct. It is considered valid if the Average Variance Extracted (AVE) square root for each construct is greater than the correlations between that construct and any other constructs in the model. This criterion helps confirm that the constructs are not overly correlated, supporting the uniqueness and reliability of the measurement model. In this study, the Fornell-Larcker Criterion

Table 1: Company demographics

No	Item	Category	Frequency	%
2	Position	Middle management	146	67
		Senior staff	73	33
4	Work Experience	15 years	75	34
		6-10 years	63	29
		11-15 years	40	18
		16-20 years	19	9
		21-25 years	10	5
		26-30 years	7	3
		>30 years	5	2
3	Corporate sector	Manufacturing	162	74
		Energy	58	26
4	Number of employees	<100 people	23	10.5
		100-300 people	36	16.36
		300-1000 people	86	39
		1001-2000	41	18.63
		2001-5,000	29	13.18
		Above 5,000	5	2.33

Figure 1: Overall PLS Model (Reflective-reflective)



Source: Author (2025)

Table 2: Measurement construct (first order)

Construct and their measures	Item	Outer loading 1	Outer loading 2	CA	CR	AVE
Sustainability				0.967	0.970	0.572
Economic sustainability				0.906	0.924	0.604
Employees in our company have the necessary skills, knowledge, and expertise to perform tasks related to carbon emission mitigation. (Ali AlShehail et al., 2022)	ES1	0.723	0.723			
Companies have the infrastructure, human resources, or technology needed to reduce carbon emissions so that company profits increase (Ali AlShehail et al., 2022)	ES2	0.793	0.793			
Companies produce more environmentally friendly output using fewer resources. (Ali AlShehail et al., 2022)	ES3	0.755	0.755			
Companies can improve market performance, position or reputation in general due to efforts to reduce carbon emission mitigation. (Ali AlShehail et al., 2022)	ES4	0.833	0.833			
Investments made by companies related to carbon emission mitigation efforts provide adequate economic value for the company. (Ali AlShehail et al., 2022)	ES5	0.795	0.795			
The ratio of energy costs to the output produced in our company is very low (Zhu et al., 2008)	ES6	0.765	0.765			
The company gains cost efficiencies from the recycling process it carries out (Zhu et al., 2008)	ES7	0.785	0.785			
The cost of using raw materials in our company is very efficient (Zhu et al., 2008)	ES8	0.763	0.763			
Social sustainability				0.925	0.940	0.690
Stakeholders participate in the company's carbon emission mitigation program (Tasleem et al., 2019)	SS1	0.759	0.764			
The company's carbon emission mitigation program has led to stability in the employment market. (Ali AlShehail et al., 2022)	SS2	0.831	0.834			
The company contributes to non-profit organizations, especially in efforts to reduce carbon emissions (Ali AlShehail et al., 2022)	SS3	0.811	0.813			
Our company carries out many CSR activities, especially carbon emission mitigation programs in the community (Jusoh et al., 2023)	SS4	0.846	0.847			
Employees receive benefits from the company's carbon mitigation programs (exp: career development, education, and knowledge) (Lin et al., 2021)	SS5	0.842	0.844			
Organizations benefit from increased workforce capacity, capabilities, and skills, but also from increased workforce engagement, satisfaction, morale and loyalty through implementing carbon emission mitigation programs that demonstrate the company's commitment to environmental sustainability. (Tasleem et al., 2019)	SS6	0.871	0.871			
The company has had very minimal government complaints regarding carbon emissions (De Giovanni, 2012)	SS7	0.300				
Relationship building Our company with customers is powerful, can this happen because of the carbon emission mitigation program carried out by the company? (Ali AlShehail et al., 2022)	SS8	0.841	0.837			
Environmental sustainability				0.959	0.965	0.755
Our company is known for being environmentally responsible, especially in mitigating carbon emissions (Tjahjadi et al., 2023)	ENVS1	0.845	0.845			
Our company plays an active role in providing solutions to environmental problems, especially carbon emission mitigation. (Tjahjadi et al., 2023)	ENVS2	0.890	0.890			
Our company is committed to environmental sustainability, focusing on preventing carbon emissions (Tjahjadi et al., 2023)	ENVS3	0.882	0.882			
We are pioneers or implementers of innovative solutions to reduce carbon emissions and protect the environment.	ENVS4	0.792	0.792			
Our company sets aside funds to address environmental issues, especially carbon emission mitigation (Tjahjadi et al., 2023)	ENVS5	0.867	0.867			
The company has a good image in the field of carbon emission mitigation (Tjahjadi et al., 2023)	ENVS6	0.902	0.902			
HR in our company is aware of the importance of preventing carbon emissions (Tjahjadi et al., 2023)	ENVS7	0.853	0.853			
Our company has a culture of environmental conservation, especially in preventing carbon emissions (Tjahjadi et al., 2023)	ENVS8	0.881	0.881			
Our company has leadership in sustainability related to carbon emission prevention (Tjahjadi et al., 2023)	ENVS9	0.903	0.903			

(Contd...)

Table 2: (Continued)

Construct and their measures	Item	Outer loading 1	Outer loading 2	CA	CR	AVE
Top management green commitment				0.966	0.972	0.810
Top management in our company we are committed to supporting carbon emission mitigation practices (Wijethilake, 2017)	TMGC1	0.868	0.868			
Top management committed to reducing sustainability issues especially carbon emissions issues arising from company operations (Wijethilake, 2017)	TMGC2	0.898	0.898			
Top management in our company continuously assess the impact of carbon emissions (Wijethilake, 2017)	TMGC3	0.919	0.919			
Top management demonstrates behavior that demonstrates sustainability by mitigating carbon emissions as a competitive advantage (Wijethilake, 2017)	TMGC4	0.930	0.930			
Top management has a good understanding of competitors' carbon emission mitigation practices (Wijethilake, 2017)	TMGC5	0.889	0.889			
Top management knows a lot about sustainability requirements, especially regarding customers' desired carbon emissions (Wijethilake, 2017)	TMGC6	0.906	0.906			
The top management has good knowledge of applicable carbon emission requirements (Wijethilake, 2017)	TMGC7	0.902	0.902			
Top management communicates effectively about carbon emission mitigation practices with stakeholders (Wijethilake, 2017)	TMGC8	0.890	0.890			
Green Intellectual Capital				0.986	0.987	0.656
Green Human Capital				0.946	0.957	0.789
Employees in our company are actively taking steps to reduce the impact of carbon emissions produced by the company. (Chen, 2008; Huang and Kung, 2011)	GHC1	0.899	0.899			
Our employees are competent in the field of carbon emission mitigation. (Chen, 2008; Huang and Kung, 2011)	GHC2	0.917	0.917			
Employees in our company produce Products that produce minimal carbon emissions. (Chen, 2008; Huang and Kung, 2011)	GHC3	0.780	0.780			
Our company has reliable teamwork related to carbon emission mitigation efforts. (Chen, 2008; Huang and Kung, 2011)	GHC4	0.916	0.916			
Our company managers support employees regarding carbon emission mitigation efforts. (Chen, 2008; Huang and Kung, 2011)	GHC5	0.877	0.877			
Our company actively implements human resource development strategies in carbon emission mitigation (Nikolaou, 2019)	GHC6	0.933	0.933			
Green structure capital				0.963	0.967	0.712
Our company has an environmental management system related to carbon emission mitigation (Chen, 2008; Huang and Kung, 2011)	GSC1	0.866	0.877			
Our company innovates to support carbon emission mitigation programs (Chen, 2008; Huang and Kung, 2011)	GSC2	0.840	0.850			
The ratio of investment in carbon emission mitigation compared to overall R&D is quite large (Chen, 2008; Huang and Kung, 2011)	GSC3	0.814	0.814			
The ratio of employees who are experts in the field of carbon emission mitigation is quite large compared to the total number of employees in the company (Chen, 2008; Huang and Kung, 2011)	GSC4	0.740	0.726			
Investments supporting carbon emission mitigation facilities in companies are quite large (Chen, 2008; Huang and Kung, 2011)	GSC5	0.877	0.880			
Companies excel in creating innovative products that have a low carbon footprint (Chen, 2008)	GSC6	0.859	0.855			
The overall process regarding the company's carbon emission mitigation program worked well (Chen, 2008; Huang and Kung, 2011)	GSC7	0.902	0.906			
Environmental knowledge management systems in companies support the collection and sharing of knowledge to reduce carbon emissions (Chen, 2008; Huang and Kung, 2011)	GSC8	0.897	0.900			
The company has a reward system for achieving environmental goals related to carbon emission mitigation. (Chen, 2008; Huang and Kung, 2011)	GSC9	0.805	0.799			
Our company has a patent related to carbon emission mitigation efforts (Nikolaou, 2019)	GSC10	0.697				
The company has an organizational culture that supports good carbon emission reduction efforts (Nikolaou, 2019)	GSC11	0.864	0.864			
Companies will consciously consider having a trademark certificate regarding carbon (ex, SNI Carbon Footprint, etc.) (Nikolaou, 2019)	GSC12	0.780	0.779			
Implementing environmental control systems and environmental risk monitoring related to carbon emissions in our company is very good (Nikolaou, 2019)	GSC13	0.847	0.855			

(Contd...)

Table 2: (Continued)

Construct and their measures	Item	Outer loading 1	Outer loading 2	CA	CR	AVE
Green relational capital				0.928	0.944	0.736
Our company's environmentally friendly product designs meet customer desires regarding carbon emission reduction (Chen, 2008; Huang and Kung, 2011)	GRC1	0.831	0.831			
Customer We are satisfied with the company's carbon emission mitigation efforts. (Chen, 2008; Huang and Kung, 2011)	GRC2	0.861	0.861			
Our company works with the government to reduce carbon emissions. (Chen, 2008; Huang and Kung, 2011)	GRC3	0.900	0.900			
Our company works closely with suppliers to build a sustainable supply chain. (Chen, 2008; Huang and Kung, 2011)	GRC4	0.844	0.844			
Our company has strategic partnerships with other companies to reduce carbon emissions. (Chen, 2008; Huang and Kung, 2011)	GRC5	0.888	0.888			
The company surveyed environmental complaints related to carbon emissions (Nikolaou, 2019)	GRC6	0.821	0.821			
Green social capital				0.926	0.948	0.820
Employees in our company share information and learn from each other in an effort to reduce carbon emissions in the company (Chen et al., 2019; Delgado-Verde et al., 2014)	GSOC1	0.924	0.924			
All employees participate in efforts to reduce carbon emissions (Chen et al., 2019; Delgado-Verde et al., 2014)	GSOC2	0.929	0.929			
Our company has norms (policies and procedures) such as energy management and waste management, which are the main guidelines related to efforts to reduce carbon emissions (Chen et al., 2019; Delgado-Verde et al., 2014)	GSO3	0.845	0.845			
Employees in our company share knowledge between employees regarding efforts to reduce carbon emissions in one group, which is actively shared with other groups.[2]	GSO4	0.922	0.922			
Green renewal capital				0.928	0.950	0.827
Our company has gained much new and important knowledge regarding carbon emission mitigation efforts. (Inkinen et al., 2017)	GRN1	0.878	0.878			
The company has important capabilities and expertise related to carbon emission mitigation efforts (Inkinen et al., 2017)	GRN2	0.930	0.930			
Our company can be described as a learning organization in its efforts to mitigate carbon emissions.(Inkinen et al., 2017)	GRN3	0.908	0.908			
Our company's operations related to carbon emission mitigation can be described as innovative, creative, and inventive (Inkinen et al., 2017)	GRN4	0.919	0.919			
Green entrepreneurial capital				0.931	0.948	0.572
Company employees are encouraged to try new and innovative ideas to reduce carbon emissions, even if the idea is likely to fail (Inkinen et al., 2017)	GEC1	0.913	0.913			
The company values employees who are proactive in seeking solutions to reduce carbon emissions (Inkinen et al., 2017)	GEC2	0.887	0.887			
The company's employees can find new business opportunities that are profitable for the company in the field of carbon emission mitigation (Inkinen et al., 2017)	GEC3	0.905	0.905			
Our company gives certain staff or departments autonomy to take the necessary initiatives and actions to reduce carbon emissions (Inkinen et al., 2017)	GEC4	0.878	0.878			
Employees in our company are accustomed to making urgent decisions regarding carbon emission mitigation (Inkinen et al., 2017)	GEC5	0.842	0.842			
Green trust capital				0.870	0.939	0/885
The company builds a work environment that fosters trust and integrity in carbon emission mitigation efforts (Inkinen et al., 2017)	GTC1	0.931	0.943			
Our company has experts in carbon mitigation who inspire stakeholder trust (Inkinene et al., 2017)	GTC2	0.923	0.938			
Our company has an image and reputation in the field of carbon mitigation that inspires stakeholder trust (Inkinen et al., 2017)	GTC3	0.450				

was met, and the results can be seen in Table 3.

5.5. Outer Loading Second Order

In the second-order model, constructs' measurements were evaluated using outer loading, Composite Reliability (CR), Cronbach's Alpha (CA), and Average Variance Extracted (AVE).

For second-order constructs, outer loadings above 0.70, CR and CA values exceeding 0.70, and AVE values >0.50 were considered acceptable, ensuring the reliability and validity of the model. All constructs meet these criteria, confirming the robustness of the second-order measurement model, as presented in Table 4.

Table 3: Fornell Lacker criteria (first order)

Construction	Env sustain	GEC	GHC	GRC	GRNC	GSC	GSoC	GTC	TMGC	Econ sustain	Soc sustain
Env sustain	0.869										
GEC	0.680	0.885									
GHC	0.720	0.828	0.889								
GRC	0.721	0.823	0.841	0.859							
GReC	0.726	0.862	0.838	0.865	0.892						
GSC	0.756	0.842	0.860	0.873	0.864	0.856					
GSoc	0.715	0.843	0.858	0.870	0.864	0.843	0.866				
GTC	0.749	0.858	0.882	0.827	0.879	0.842	0.854	0.847			
TMGC	0.842	0.757	0.825	0.818	0.817	0.832	0.843	0.798	0.876		
Eco Sustain	0.830	0.695	0.763	0.724	0.736	0.768	0.768	0.694	0.776	0.869	
Social Sustain	0.762	0.759	0.868	0.793	0.797	0.812	0.771	0.789	0.834	0.834	0.837

Table 4: Measurement construct (second order)

Construction	Outer loading	CR	CA	AVE
Green Intellectual Capital		0.956	0.946	0.759
Green human capital	0.896			
Green structure capital	0.924			
Green relational capital	0.773			
Green social capital	0.932			
Green renewal capital	0.919			
Green entrepreneurial capital	0.805			
Green trust capital	0.837			
Top management commitment		0.972	0.966	0.810
Sustainability	0.872	0.921	0.872	0.796
Economic sustainability	0.883			
Social sustainability	0.904			
Environmental sustainability	0.889			

Table 5: Fornell Lacker criteria (second order)

Construction	Green intellectual capital	Sustainability	Top management green commitment
Green intellectual capital	0.871		
Sustainability	0.846	0.892	
Top management green commitment	0.857	0.853	0.9

5.6. Fornell Lacker Criteria

In the context of second-order models, the Fornell-Larcker Criterion is used to assess discriminant validity by ensuring that the square root of the Average Variance Extracted (AVE) for each construct is more significant than its correlations with other constructs, including higher-order factors. This criterion is crucial for confirming that the dimensions of the second-order construct are distinct from each other and other first-order constructs in the model. In this study, the Fornell-Larcker Criterion was satisfied, as presented in Table 5.

5.7. Hypothesis Testing Results

The results of the analysis indicate that top management green commitment (TMGC) significantly influences Sustainability with a path coefficient of 0.469 ($T = 6.149$, $P = 0.000$), explaining 77.2% of the variance in sustainability ($R^2 = 0.772$) (Table 6). Additionally, TMGC positively impacts green intellectual capital

(GIC) with a strong path coefficient of 0.857 ($T = 36.908$, $P = 0.000$), accounting for 73.3% of the variance in GIC ($R^2 = 0.733$). GIC also plays a significant role in enhancing sustainability, with a path coefficient of 0.444 ($T = 5.759$, $P = 0.000$). Moreover, GIC mediates the relationship between TMGC and sustainability, as indicated by a significant mediation path coefficient of 0.381 ($T = 5.479$, $P = 0.000$). The Standardized Mean Group Ratio (SMGR) for the TMGC to sustainability relationship is 0.048, which suggests that the variation in the effect of TMGC on sustainability across different groups is relatively small. This implies that the influence of TMGC on sustainability is consistent across various company categories, confirming the robustness of the relationship. In the context of Partial Least Squares (PLS) analysis, the SMGR value of 0.048 meets the standard threshold of consistency, suggesting that the results are stable and reliable across different groups.

6. DISCUSSIONS

6.1. TMGC has a Positive Effect on Sustainability

Based on the results obtained from the four hypotheses, it can be concluded that top management commitment (TMGC) plays an important role in supporting sustainability and mitigating carbon emissions through two main mechanisms: direct and indirect effects. First, TMGC is proven to have a significant effect on Sustainability, with a path coefficient of 0.469 and a very small P-value (0.000). This shows that top management's commitment to green initiatives has a significant direct impact on sustainability practices in the organization. Sustainability itself is measured by three main dimensions: Economic, social, and environmental.

This is in line with the Upper Echelon Theory, which states that strategic decisions and policies taken by top management are greatly influenced by their experience, values, and commitments. In this context, top management who have a strong understanding and commitment to environmental issues tend to adopt policies that support sustainability practices, especially those focused on reducing carbon emissions. Top management who support sustainability more broadly—both in economic, social, and environmental aspects—will facilitate the integration of policies that support carbon emission reduction into the central business strategy, improving the company's overall sustainability performance. In the environmental sustainability dimension, top management commitment plays a significant role in designing policies that focus on reducing carbon footprints,

Table 6: Hypothesis testing results

Hypothesis	Path coefficient	T-value	SD	P-values	R-square	SMGR
TMGC>>sustainability	0.469	6.149	0.077	0.000	0.772	0.048
GIC>>>Sustainability	0.444	5,759	0.077	0.000		
TMGC>>>GIC>>>Sustainability	0.381	5,479	0.069	0.000		
TMGC>>GIC	0.857	36,908	0.023	0.000	0.733	

Significant level of 1% ***

waste management, and adopting environmentally friendly technologies. For the economic sustainability dimension, support from top management will encourage companies to have environmentally friendly infrastructure (technology), produce environmentally friendly output with fewer resources, improve market performance, efficiency in the use of raw materials, etc., which leads to reduced operational costs related to carbon emissions and increased company profits. Meanwhile, in the social sustainability dimension, top management commitment will influence relationships with stakeholders to ensure fair and environmentally friendly business practices while paying attention to social welfare within and around the organization. In the context of TMGC's environmental performance, it has resulted in effective carbon emission reduction policies, increasing the company's reputation in the eyes of the public and stakeholders.

This study supports both relevant theories, namely the Upper Echelon Theory and the Natural Resource-Based View (NRBV). Upper Echelon Theory explains the importance of top management commitment and decisions in driving strategic change towards sustainability. At the same time, NRBV emphasizes the importance of green resource management and intellectual capital as resources that can provide sustainable competitive advantage, including in mitigating carbon emissions.

6.2. TMGC has a Positive Effect on GIC

Top management green commitment (TMGC) has a significant influence on green intellectual capital (GIC) in a company, and this is in line with the upper echelon theory (UET). UET states that strategic decisions taken by top management are greatly influenced by their values, experiences, and views on specific issues, including sustainability. In this context, top management's commitment to sustainability, reflected in TMGC, will shape and influence the company's management of various dimensions of green intellectual capital (GIC). Top management with a strong commitment to sustainability will encourage investment in Green Human Capital by improving employee skills and knowledge related to environmentally friendly practices. The sustainability views and values held by top management will create a proactive culture in seeking green solutions, in line with the UET idea that the background and values of top management shape the company's strategic direction. In addition, TMGC ensures that green structure capital—such as infrastructure and systems that support energy efficiency and carbon emission reduction—is integrated into the company's strategy. This decision is influenced by the views and priorities of top management. Top management commitment also strengthens Green Relational Capital by building mutually beneficial relationships with partners and suppliers focusing on sustainability. This reflects how top managers' experiences and views on sustainability influence external relationships that can accelerate the adoption of green technologies.

In addition, TMGC influences the formation of Green Social Capital by encouraging a collaborative culture and employee involvement in sustainability initiatives. Within the UET framework, top management's commitment to sustainability influences patterns of social interaction within the organization that support sustainability and green innovation. TMGC also strengthens Green Entrepreneurial Capital, which enables the company to recognize and develop new business opportunities in environmentally friendly products and services. This suggests that top management decisions focused on sustainability can open up pathways for innovation and entrepreneurship toward environmental sustainability. TMGC strengthens Green Trust Capital, which builds trust with stakeholders, including consumers and investors who are increasingly concerned about the company's environmental impact. This suggests that top management's values and commitment to sustainability not only shape internal policies but also strengthen external relationships that support the company's credibility in terms of sustainability.

The Natural Resource-Based View (NRBV) perspective emphasizes that green innovation capability is a strategic resource that can create sustainable competitive advantage. Through TMGC, companies leverage various dimensions of GIC to manage resources sustainably. Green human capital enables companies to develop employee skills to support low-carbon technologies, while green structural capital ensures that innovation infrastructure is available for research and development. Green relational capital and green social capital support external collaboration with strategic partners and communities to accelerate green innovation, while green entrepreneurial capital helps companies create innovative solutions that are relevant to carbon emission mitigation. In addition, green renewal capital strengthens companies' adaptation to environmental changes, and green trust capital builds stakeholder trust to ensure the sustainability of green policy implementation. With the integration of NRBV, GIC serves as a strategic foundation driven by TMGC to reduce carbon emissions while creating a sustainable competitive advantage.

6.3. GIC has a Positive Effect on Sustainability

From the perspective of the Natural Resource-Based View (NRBV), sustainability is achieved through efficient and sustainable management of natural resources, as well as innovation in the use and development of these resources. Green Human Capital, which includes employee knowledge and skills related to sustainability, is essential in driving green innovation and more efficient management of natural resources. Employees skilled in sustainability can design and implement solutions that reduce resource waste, support energy efficiency,

and reduce environmental impact. Green Structural Capital involves the company's infrastructure that supports resource efficiency and waste reduction, such as green technologies and energy management systems. In the context of the NRBV, this infrastructure leads to more efficient use of natural resources and supports the company's long-term sustainability. Green Relational Capital, which includes the company's relationships with partners and suppliers who share sustainability values, enables the company to collaborate in the development and adoption of green technologies. This enhances the company's ability to share knowledge and innovation in managing natural resources more efficiently. Green Social Capital refers to the involvement of employees and communities in sustainability initiatives, which helps create a culture of collaboration within and outside the company, supporting social sustainability by raising awareness and action on natural resource management. Green entrepreneurial capital, which encompasses a company's ability to identify new opportunities for environmentally friendly products and services, focuses on developing innovations that can reduce dependence on limited natural resources and create new, more sustainable markets. Green Trust Capital strengthens a company's relationships with consumers and investors who care about sustainability, increasing access to external resources that support sustainability. Finally, Green Renewal Capital is a company's ability to adapt to changing environmental conditions by learning and creating new knowledge related to sustainable practices and carbon emission mitigation. In the context of NRBV, this leads to sustainable value creation and more efficient management of natural resources for the long term.

Overall, all dimensions of green intellectual capital (GIC) explained above support Sustainability by optimizing resource management more efficiently and innovatively, which leads to cost reduction, improved reputation, better stakeholder relations and environmental performance that minimizes carbon emissions.

6.4. GIC Mediates the Influence of TMGC on Sustainability

The relationship between top management green commitment (TMGC), green intellectual capital (GIC), and Sustainability is very important in the context of upper echelon theory (UET) and natural resource-based view (NRBV). Based on UET, strategic decisions made by top management are greatly influenced by their experiences, values, and views on specific issues, including sustainability. The mediating role of GIC is vital in the relationship between TMGC and Sustainability. Strong TMGC encourages companies to build and develop GIC, which in turn allows companies to be more efficient in managing natural resources and reducing carbon footprints, as well as encouraging innovation in environmentally friendly products and services. These dimensions of GIC serve as strategic assets that help companies achieve Sustainability. In other words, GIC acts as a bridge connecting TMGC with sustainability, strengthening the sustainability commitments that have been set by top management and directing companies to achieve long-term sustainability. In the context of NRBV, GIC enables companies to utilize natural resources in

more efficient and innovative ways, creating sustainable value and ensuring continued competitiveness in markets that increasingly prioritize sustainability.

7. CONCLUSION

Based on the research results, it can be concluded that Top Management Green Commitment (TMGC) plays a crucial role in supporting sustainability and mitigating carbon emissions through two main mechanisms, namely direct and indirect influences. This study shows that TMGC significantly influences sustainability through the mediation of green intellectual capital (GIC), which functions as a strategic asset that allows companies to be more efficient in managing natural resources and reducing environmental impacts.

TMGC has also been proven to influence GIC dimensions, such as Green Human Capital, Green Structural Capital, Green Relational Capital, and others, which overall strengthen the company's ability to innovate and develop environmentally friendly products and services. Through GIC, companies can create sustainable value, improve their reputation, and build better relationships with stakeholders, which ultimately support long-term sustainability.

Overall, this study supports both relevant theories, namely Upper Echelon Theory (UET) and Natural Resource-Based View (NRBV). UET explains that strategic decisions made by top management are greatly influenced by their experiences and values, which include a commitment to sustainability. On the other hand, NRBV emphasizes that green innovation capabilities obtained through GIC management can create sustainable competitive advantages. Therefore, TMGC becomes a key factor in creating sustainable value and reducing carbon footprint, which supports sustainability in the company.

7.1. Theoretical Contribution

This study makes a significant contribution to the development of Upper Echelon Theory (UET) and Natural Resource-Based View (NRBV). From the UET perspective, this study strengthens the argument that top management commitment to sustainability can influence the company's strategic direction, including in terms of adopting green policies and managing natural resources. In addition, through NRBV, this study highlights the importance of the Green Intellectual Capital dimension in creating sustainable competitive advantage by utilizing green resources and environmentally friendly innovation. The GIC dimensions related to HR, structure, external relations, entrepreneurship, and trust are proven to optimize resource management efficiently and sustainably.

7.2. Theoretical Contribution

In practice, the results of this study provide valuable insights for companies in formulating and implementing effective sustainability policies. Top management that has a strong commitment to green initiatives can encourage the creation of more efficient resource management. Companies can also utilize GIC, which includes green human capital, green structure capital, green relational capital, green social capital, GRnC, GEC, and GTC to achieve

sustainability. In addition, good GIC management can strengthen the company's reputation in the eyes of the public and increase stakeholder trust, which in turn will contribute to sustainability and the company's competitiveness in the long term.

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