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The Role of Knowledge, Consumption Behavior and Adoption of Renewable Energy on Environmental Management: Concern about Environment as Moderator

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ABSTRACT

Environmental management has been the significant factor that effect the sustainable development around the globe and this aspect requires the focus of recent studies. Hence, the present study examines the impact of knowledge, consumption behavior and adoption of renewable energy on environment management of industrial sector in Germany. The study also investigates the moderating role of concern about environment among knowledge, consumption behavior and adoption of renewable and environment management. The study collect the data from the employees of industrial sector who are dealing with environmental protection activities using surveys. The study checks the validity, reliability and association among variables using smart-PLS. The outcomes revealed that the knowledge, consumption behavior and adoption of renewable energy have a positive association with environment management. The results also exposed that the concern about environment significantly moderates among knowledge, consumption behavior and adoption of renewable energy and environment management. The study helps the regulators in making regulations related to environment management using effective knowledge, reliable consumption behavior and adoption of renewable energy.

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1. Introduction

Germany has been ranked very high in environmental management and utilization of renewable energy. Hence understanding how knowledge, consumption behavior and the use of renewable energy produce the desired or better environmental impacts reinforces the study. Therefore, the purpose of this research is to examine the context of these factors in the environmental management of Germany and investigate how the level of environmental concern might influence these relationships. Importantly, in order to comprehend the leverage points of possible changes in the context of environmental management in Germany, it is necessary to note that the country has a number of clear objectives concerning the reduction of greenhouse gases emissions, increase of energy efficiency and transition towards low-carbon economy. The interviewed of Germany shows that the country has a long-term strategy, which can be characterized as rather ambitious

(Rechsteiner, 2021). If it fully implements all the plans, then the country will abandon nuclear energy and focus on using renewable resources.

The knowledge aspect of this study deals with the extent of awareness and comprehension that people and companies have with regard to the environmental question and renewable energy solutions. In Germany, people tend to respect the environment so much because the level of education is high together with the availability of information in regard to environmental issues (Braun & Dierkes, 2019). This awareness is an indication of State and non-State players' sensibility regarding climate change and sustainable development. The study also investigates how this knowledge plays out in terms of consumption and the choice of RE technologies. The population knowledge level is assessed in the study to determine to what extent informed citizens are more likely to use environmental products and support renewable energy sources.

Another area that should be considered in the management of this environment is the consumption behavior. Consumers in Germany have adapted the culture of consuming goods and services in more sustainably manner in the past decades (Ganglmair-Wooliscroft & Wooliscroft, 2022). This shift is apparent in many aspects of life such as the use of energy, disposal of wastes, and the mode of transport. For example, people currently demand energy-efficient devices or lightings in their homes, many people prefer to use public transport, move towards utilization of electrical cars. They will also change consumer behavior and the promotion of renewable energy within the framework of environmental management. It will also look into the enablers and constraints that characterize the consumers' decision-making process to get an understanding of the policy ways through which consumers can be influenced towards sustainable consumption. Implementation of renewable energy is one of the main focus issues in this study especially with a special reference to Germany. Wind and solar and biomass power have been made large investments in by Germany so as to diversify the type of energy mix that is used in the country (Michalak & Wolniak, 2023).

The research will also seek to establish various factors that trigger the use and implementation of renewable sources of energy at the individual and business level. It will involve the factors that make the decision to invest in renewable energy systems possible economically, technologically and socially. Also, the study will establish the effects of governmental policies and incentives in the promotion of renewable energy, and barriers to the complete transition to sustainable energy. One other characteristic of this study is the moderating factor of environmental concern. Environmental concern can therefore be described as the extent of awareness that people have for the environment and how willing they are to alter their behavior in order to prevent the degradation of the environment (Michalak & Wolniak, 2023). Thus, the level of environmental concern is relatively high in Germany due to cultural and educational factors as well as due to the presence of policies aimed at saving the environment. The research will seek to establish how environmental concern affects knowledge, the consumption behavior and renewable energy. In particular, it will also investigate whether people those who bear higher levels of environmental concern will patronize the goods and services outcomes of their concern and is ready to purchase renewable energy technologies and practice sustainable consumption.

The purpose of this research is to examine the knowledge, consumption behavior and renewable energy in the management of the environment within Germany. In particular, it analyses how environmental concern acts as the moderator in these relationships. Based on the economic awareness index, electricity consumption and people's willingness to use renewables, this study aims to determine the success of these variables in enhancing positive environmental behaviors. Thus, the study seeks to contribute to the existing literature as well as inform policymakers in a bid to improve on the management of the environment in Germany. Regarding the purposes of this study, the present research also fills several vital gaps in the literature on environmental management in Germany. First of all, it unites the fragmented concepts of knowledge, consumption behavior, as well as renewable energies encompassing all their interconnected effects. Second it rises the

separated and independent variable known as environmental concern most of the time neglected by the researchers. Finally, the study targets Germany, one of the most progressive countries in the production and utilization of renewable energy sources, but few adequate researches investigating these types of interactions and their consequences on policy have been conducted.

In the next section of this study, we will look into the relevant literature review, provide a research methodology, and conduct a full empirical analysis to test the proposed hypotheses.

2. Literature Review

The subject on renewable energy pervasively transforms environmental management by creating awareness on sustainable development and curbing climate change and depletion of the environment. Renewable sources of power include solar, wind, hydro, and geothermal and they have very little impact on the emission of greenhouse gases unlike the fossil fuels (Chien et al., 2021; Mohsin et al., 2021; Rahman et al., 2022). Familiarizing ourselves with the uses of these energy sources gives the policy makers, business men and even consumers the necessary knowledge to champion for the environment. For example, Tan et al. (2021) points that great theoretical understanding of renewable energy systems advances the development of energy generation and storage leading to better technologies. This in the long run cuts on the amount of non-renewable energy resources and hence decreasing pollution levels and conserving ecosystems. Additionally, educational projects and awareness raising activities in connection with renewable energy foster participation of the community and people's changes in their behavior focusing on conservation and sustainability (Ardoin et al., 2020; Baloch et al., 2021; Liu et al., 2022). Sharing of information through research papers, survey, and government papers guarantee the culture of partnership in environmental management. It enhances the voice of multiple interest groups in advancing green processes- from giant renewable power plants to various grassroots processes. Thus, the envisaged cumulative consequences of these efforts include better quality of air and water in the environment, increased bio-diversity and overall improvement in the quality of the environment (Chien et al., 2022; Shair et al., 2021; Wang et al., 2023). Therefore, the growth of knowledge regarding renewable energy is a vital instrument for attaining environment objectives that sustain the health of the living environment in future generations. Therefore, we propose that,

H1: Knowledge about renewable energy have positive impact on environmental management.

Everyone's perception, belief or opinion about the use of renewable energy sources has a great impact on its management through promotion of policies, encouraging research and development as well as practicing environmental management (Hanif et al., 2022; Nawab et al., 2021; Shafiq & Zafar, 2023). According to Almulhim (2022), a positive attitude towards renewable energy entails more spending on such energy resources by the public and private sector organizations and hence the adoption of the green-energy sources like the solar, wind, hydro, and geothermal. Whenever people and communities buy renewable energy, it creates a culture of sustainable power; this inspires local and national authorities to come up with policies that encourage environmental conservation (Goggins et al., 2022; Hussain et al., 2021). This societal encouragement of renewable energy systems may lead to improvements in the funding for researches so as to come up with new technology that makes the renewable energy systems efficient and cheap. Besides, positive attitudes towards renewable energy enhance behavioral alterations on energy use at the individual level, energy-efficient appliances, and environmental conservation and recycling (Shah et al., 2021; Yang et al., 2024; Zainudin et al., 2022). Altogether, such behaviors help reduce emission of greenhouse gases, smog, and pollutants in the air and water, as well as save ecosystems. Karasmanaki and Tsantopoulos (2019) Says that the attitudes mainly originate from educational and awareness programs that are useful to promote the

use of renewable energy since it is more environmental conscious and economical. Due to the increasing awareness of the general public on the impacts of climate change and the quest to use clean energy sources, there is a focus towards sustainable practices to realize a sustainable environment (Almulhim, 2022; Farooq et al., 2024). Hence, this study established that promoting the attitude toward the utilization of renewable energy sources is essential in efficient environmental management and sustainable development. Therefore, we make a hypothesis that,

H2: Attitude towards renewable energy adoption have positive impact on environmental management.

The consumption behavior is very helpful in environmental management to eradicate the use of fossil energy, declining the emission rates of greenhouse gases and the unsustainable usage of resources. Rechsteiner (2021) Says that if individuals, businesses and governments decide to rely on cleaner sources of energy like solar energy, wind energy, hydro energy and geothermal energy, this in a sure way means a reduction in air and water pollution since most of these energy forms produce little pollution to the surrounding environment. It also assists in avoiding climate change and in maintaining the Bio-diversity as well as Organic systems from the harm that is caused by energy generating processes in the conventional method. Moreover, changing behaviors in relation to the consumption of renewable energy creates awareness of this resource-conserving and technology-promoting measure (Ma & Fan, 2023). Demand for any particular energy type has a positive effect on research and succeeding build-up for an enhanced, efficient and cheaper energy production. This, in return, increases the availability and affordability of renewable energy sources thus expanding its market at a faster rate. More consumption rates also help increase the level of commitment of the people towards environmental awareness and promotion of renewable energy sources (Irfan et al., 2021). Also, when coupled with a significant improvement in the prevalence of renewable power sources, large-scale energy conservation likewise minimizes the exploitation of natural assets. Through this, effective utilization of energy and management of the environment is achieved and natural sceneries and health of the planet maintained. Thus, the favorable attitude towards the consumption of renewable energy is crucial for the sustainable development of the energy sector in the long run and efficient management of the environment. Therefore, we propose that,

H3: Consumption behavior of renewable energy have positive impact on environmental management.

These three, namely, concern for the environment, the level of knowledge about the renewable energy and environmental management, are the tripod on which sustainable development is predicated. Concern for the environment also enforces the relationship between context familiarity of renewable energy and efficient management of the environment (Nguyen et al., 2022). Levenda et al. (2021) Says that those with a higher level of environmental sensitivity are likely to search for additional information and become involved in applying the acquired knowledge of renewable energy sources, thus converting theoretical knowledge into practical actions. It also contributes to the enhancement of the firm's sustainability agenda as well as availing opportunities for renewable energy to buoy environmental consciousness. Therefore, the escalating concern of people about environmental consequences turns out to be an effective driver for the practical application of renewable energy sources and technologies in everyday practices and businesses (Gazzola et al., 2019). This in return enhances the chances of making better decisions and planning in managing the environment. Through patronizing renewable energy, such people help in checking emissions and other impacts of climate change. This way, knowledge and concern interact to provide a stronger and more efficient system of environmental management, which guarantees that as all the measures taken are supported by the data obtained, the main motivation behind them comes from the desire to protect the environment. Therefore, enhancing people's environmental concern appears to be critical in

narrowing the awareness-application gap concerning renewable energy and extensive environmental management (Nguyen et al., 2022).

H4: Concern about environment works as a moderator between knowledge about renewable energy and environmental management.

The protection of the environment is an essential variable which acts as a mediator between adopting the use of renewable resources and implementing efficient environmental management (Nazir et al., 2023). Thus, when it comes to the subject of environmental concern, the findings of Yacob et al. (2019) also reveal that respondents with a high score have favorable attitudes towards implementing renewable energy, an indicator suggesting that they are proactive in their endeavors when it comes to environmental management. This concern increases the congruence between the self-anchored values and the environmental solutions, which places the utilization of renewable power as an imperative more than a choice. Towards the environmental activism, the positive attitude on the renewable energy act as a self-Driving force that prompts a set of activities in the management of environment (Vivi & Hermans, 2022). This pertains to issues such as renewable energy, climate change policies, and practicing sustainable measures within homes, workplaces and even schools. The improvement of the certain environmental concern brings assurance that these individuals are not only aware of the aspects of renewable energy but also want to adopt these aspects in their certain environmental management (Ikram et al., 2019). Therefore, it becomes easier to have enhanced and broad preventive measures to minimize the effects of carbon footprints and other related causes of environmental degradation. The combination of concern and attention, along with a favorable attitude and active behavior is beneficial to the enhancement of sustainable attitudes where the focus is put on the acceptance and implementation of renewable energy sources that produces valuable results manifested through strictly environmental measures (Nguyen et al., 2022). Therefore, we say that,

H5: Concern about environment works as a moderator between attitude towards renewable energy adoption and environmental management.

Environment concern fully mediates the link between consumption behavior of renewable energy and environmental management. Environmental concern as a personal characteristic is more likely to see the consumption behavior of renewable energy sources turning into environmental management outcomes (Trudel, 2019). This concern provides a motivation, strengthens the efforts towards implementation of sustainable energy use so that people consume energy not because they know, or it is convenient to do so, but because they are willingly involved in the protection of the environment. This implies that when people have higher levels of concerns towards environmental issues, their patterns and trends of consumption of renewable energy are more conscious and long lasting thus enhancing the levels of effecting the environmental management (Khan et al., 2020). This involves carrying out solar and or wind energy and or any other natural sources of energy, less usage of the non-renewable sources of energy, and emissions reduction impacts. It is interesting to learn how the consumption of renewable energy in matters of daily life, as well as in organizational apparatus, presents a positive attitude towards environmental management, as a result of a genuine concern over the fate of planet earth. Shittu (2020) Says that in this synergistic effect of environmental concern and individual consumption behavior of renewable energy, there is a heightened culture of sustainable practices and policies, resulting to positive impacts on the environment. Thus, increasing environmental awareness is important for guaranteeing that the purchase and utilization of renewable energy are reflected in adequate and efficient measures of environmental management to support the sustainable preservation of ecosystems. Therefore, we make a hypothesis that,

H6: Concern about environment works as a moderator between consumption behavior of renewable energy and environmental management.

3. Research Methods

The study examines the impact of knowledge, consumption behavior and adoption of renewable energy on environment management and also investigates the moderating role of concern about environment among knowledge, consumption behavior and adoption of renewable and environment management of industrial sector in Germany. The study collect the data from the employees of industrial sector who are dealing with environmental protection activities using surveys. The items are used to measure variables such as knowledge about renewable energy has four items (Wall et al., 2021), attitude towards renewable energy adoption has three items (Bang et al., 2000), consumption behavior of renewable energy has for items (Khalid et al., 2021), concern about environment has five items (Gârdan et al., 2023) and environment management has six items (Brammer et al., 2012). These items are given in Table 1.

Table 1
Variables and Measurements

Items	Questions	Sources
Knowledge about Renewable Energy		
KRE1	I am familiar about notion of renewable energy.	(Wall et al., 2021)
KRE2	I knew that renewable energy-based solutions are available.	
KRE3	I am aware about the benefits of the renewable energy.	
KRE4	I have a high interest in technology such as renewable energy.	
Attitude towards Renewable Energy Adoption		
ARE1	I think renewable energy utilization is safe.	(Bang et al., 2000)
ARE2	I think renewable energy utilization is reliable.	
ARE3	I like to adopt renewable energy because of environmental protection.	
Consumption Behavior of Renewable Energy		
CBRE1	I enjoy using renewable energy.	(Khalid et al., 2021)
CBRE2	I have plan to consume renewable energy in future.	
CBRE3	I belief that I continue to receive benefit from renewable energy.	
CBRE4	I perfect to use renewable energy in comparison with other energy.	
Concern about Environment		
CAE1	I am concerned about environment while purchasing.	(Gârdan et al., 2023)
CAE2	I am concerned about the way of using environment.	
CAE3	I am concerned about pollution in the environment.	
CAE4	I am concerned about environmental problems due to energy usage.	
CAE5	I am concerned about energy resources and environment.	
Environment Management		
EM1	Our firm invests in research and development for cleaner products and technologies.	(Brammer et al., 2012)
EM2	Our firm evaluates our products and processes based on their environmental impact.	
EM3	We conduct environmental audits at regular intervals within our firm.	
EM4	Our firm has a mission statement that explains our commitment to the environment.	
EM5	Our firm sets specific environmental goals every year.	
EM6	Our firm has cross-functional teams whose main responsibility is to improve our environmental performance.	

The study select the employees of industrial sector who are dealing with environmental protection activities as respondents. The study select these employees by applying purposive sampling. The researchers distributed the surveys by personal visits. The researchers distributed 604 surveys but only 357 valid surveys were received that shows around 59.11 percent response rate. Moreover, the study checks the validity, reliability and association among variables using smart-PLS. this tool deals with primary data.

It provides best results even though the researchers used complex models or large data sets (Hair Jr et al., 2020). The three predictors were used such as knowledge about renewable energy (KRE), attitude towards renewable energy adoption (ARE) and consumption behavior of renewable energy (CBRE), while the study also used one moderating variable named concern about environment (CAE) and one dependent variable named environment management (EM). Figure 1 shows these variables.

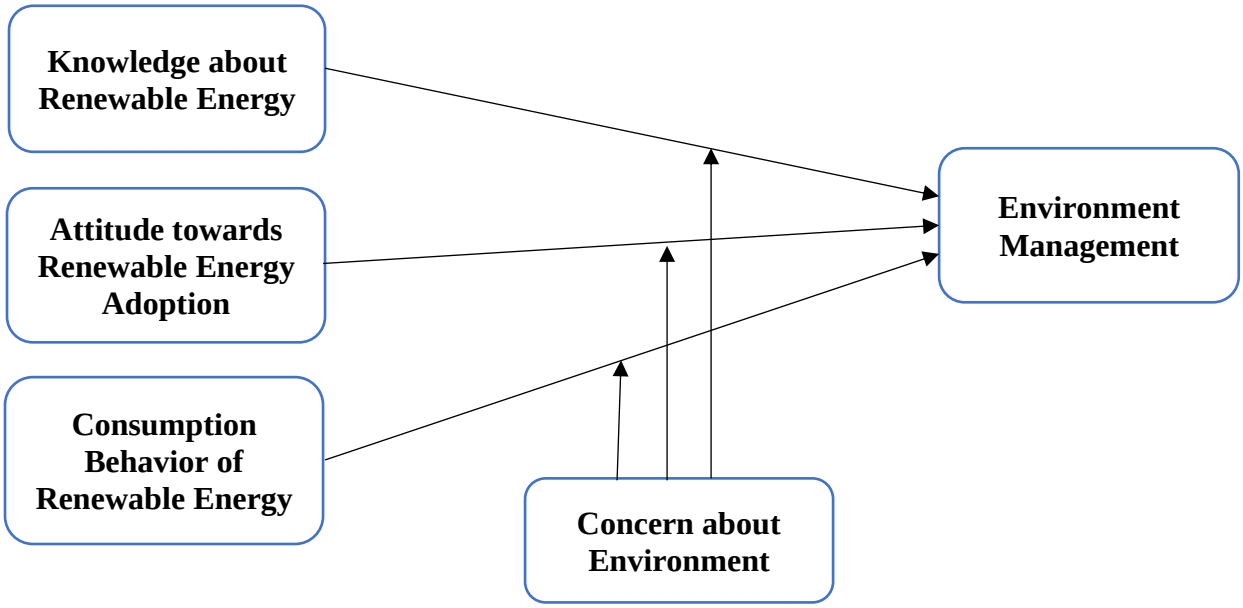

Figure 1: Research Model

4. Research Findings

The study shows the convergent validity that exposed the correlation between the items. The results exposed that composite reliability (CR) and Alpha values are bigger than 0.70. The outcomes also exposed that the average variance extracted (AVE) and factor loading values are bigger than 0.50. These values exposed a high correlation among items. These values exposed valid convergent validity. Table 2 shows these values.

The study shows the discriminant validity that exposed the correlation between the variables. The results exposed that Heterotrait Monotrait (HTMT) values are less than 0.85. These values exposed a low correlation among variables. These values exposed valid discriminant validity. Table 3 shows these values.

The outcomes revealed that the knowledge, consumption behavior and adoption of renewable energy have a positive association with environment management and accept H1, H2 and H3. Finally, the results also exposed that the concern about environment significantly moderates among knowledge, consumption behavior and adoption of renewable energy and environment management and accept H4, H5 and H6. Table 4 shows these results.

Table 2
Convergent Validity

Constructs	Items	Loadings	Alpha	CR	AVE
Attitude towards Renewable Energy Adoption	ARE1	0.798	0.839	0.904	0.759
	ARE2	0.928			
	ARE3	0.884			
Concern about Environment	CAE1	0.873	0.857	0.899	0.642
	CAE2	0.865			
	CAE3	0.633			
	CAE4	0.807			
	CAE5	0.807			
Consumption Behavior of Renewable Energy	CBRE1	0.777	0.850	0.899	0.691
	CBRE2	0.885			
	CBRE3	0.794			
	CBRE4	0.865			
Environmental Management	EM1	0.711	0.845	0.886	0.564
	EM2	0.705			
	EM3	0.764			
	EM4	0.779			
	EM5	0.752			
	EM6	0.791			
Knowledge about Renewable Energy	KRE1	0.847	0.872	0.912	0.722
	KRE2	0.848			
	KRE3	0.853			
	KRE4	0.851			

Table 3
Discriminant Validity

	ARE	CAE	CBRE	EM	KRE
ARE					
CAE	0.523				
CBRE	0.652	0.533			
EM	0.763	0.725	0.852		
KRE	0.624	0.509	0.536	0.691	

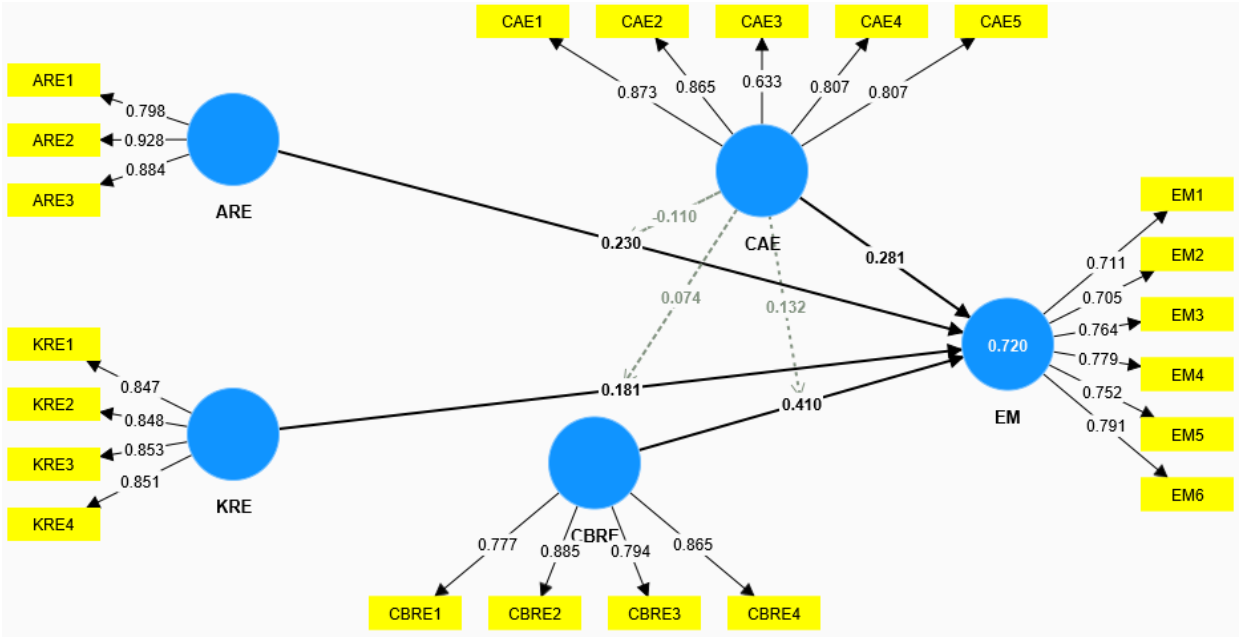

Figure 2: Measurement Assessment Model

Table 4
Path Analysis

Relationships	Beta	Standard deviation	T statistics	P values
ARE -> EM	0.230	0.045	5.103	0.000
CAE -> EM	0.281	0.041	6.877	0.000
CBRE -> EM	0.410	0.049	8.316	0.000
KRE -> EM	0.181	0.035	5.124	0.000
CAE x KRE -> EM	0.074	0.036	2.043	0.042
CAE x CBRE -> EM	0.132	0.043	3.087	0.002
CAE x ARE -> EM	-0.110	0.046	2.397	0.017

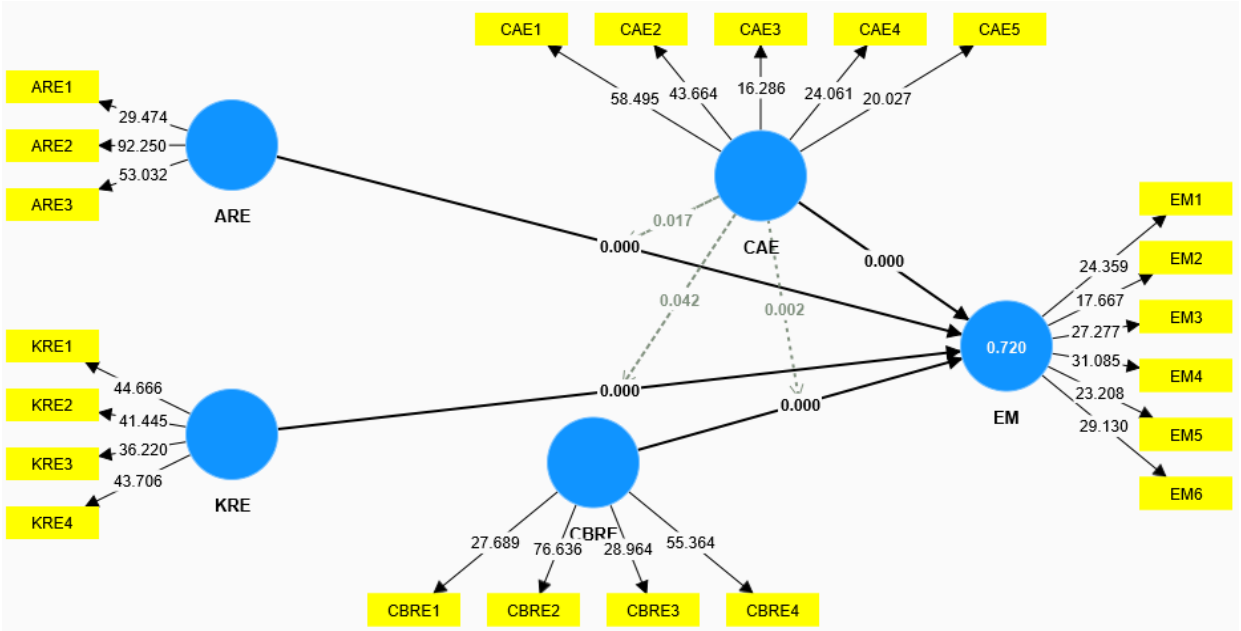

Figure 3: Structural Assessment Model

5. Discussions

The complexity of the interactions between knowledge, consumption behavior, and the use of renewable energy sources, and their effects on environmental management of Germany are the main focus of this research. Also, it explores the moderating effect that environmental concern has on these dynamics. This paper gives a wide-ranging view of how these elements feed into each other and it gives direction on how improvement to environment policies and practices can be made. In this case, it will be imperative to start by noting that the research underlines the centrality of knowledge when it comes to issues of environmental management. Since Germany is one of the most developed countries with a strong focus on education and huge attention paid to environmental issues, people have significant awareness of renewable energy sources and sustainability activities.

The findings of this study are such that awareness regarding environmental problems enhances the concern towards the usage of sustainable products and renewable energy systems. Al-Shetwi (2022) Says that this correlation can be interpreted to mean that efforts to commonly raise public consciousness and knowledge on environmental issues makes a massive difference in hopes to drive up the population's adherence to environmentally sustainable practices. It can therefore be argued that educational campaigns both in school settings and through television and other media can hence be used as a key tool in changing people's behavior sustainably. Furthermore, the facts regarding the potential of renewable energy and the overall positive effects of sustainable living may encourage people to become more conscious of the specific problems connected to the world's current state of affairs and ultimately, make them stick to environmentally friendly habits (Elahi et al., 2022).

Consumption behavior, another important factor under analysis in the framework of the given study, is revealed to be highly dependent on the level of knowledge found in individuals. Such findings are observed in Germany where people are relatively conscious of the environment as the above result illustrated the relationship between informed consumers and sustainable consumption behavior. This paper shows that people who possess knowledge in relation to environmental consequences of their purchases are more likely to patronize green services and goods as Amoako et al. (2020) also found and stated. Parajuly et al. (2020) States that such a behavior is very useful for avoiding a larger amount of detrimental effects on the environment and for encouraging the usage of raw and renewable resources. This insight can be used by the policymakers, and the business by ensuring that it gives information on the environmental consequences of products and results in the consumer being able to make his/her decision. Positive incentives for sustainable use of products for instance mentioning of incentives of environmentally friendly products or discouragement of high-carbon products could further heighten this behavior.

The use of renewable energy sources is one of the main strategies, which outlines Germany as the world's leader in the share of renewable energy sources (Aleixandre-Tudó et al., 2019). The results reveal that factors such as knowledge and consumption behavior further affirm the preparedness to accept renewable energy sources. People who learn the tangible positive aspects about the renewable energy technologies enabling them to comprehend the relevance attached to them show intentions to incorporate the renewable energy technologies into their daily life. Also, the respondents using resources in a sustainable manner are also more receptive to the utilization of the renewable energy solutions. This interplay implies that increasing citizens' awareness of the shift to a sustainable lifestyle and promoting rational consumption can facilitate the shift to renewable sources. The effectiveness of such measures as the interviewed, the stated goal of phasing out Germany's atomic power plants and gradually reducing the consumption of fossil fuels as well, cannot be managed without the people's support to renewable energy.

The purpose of this study is another in that it explores environmental concern as a moderating variable. The study establishes that one's attitude towards the environment can either enhance or reduce the relationship between knowledge and consumption behavior on renewable energy. For instance, Dawkins et al. (2019) state that the higher Environmental Concern means you would incorporate your green knowledge as well as sustainable consumption reflected by your uptake of renewable energy products. On the other hand, people with low level of environmental concern might not follow the same level of adoption despite having awareness and sustainable consumption (Saari et al., 2021). This finding suggests that increasing environmental concern in the population can improve the outcomes of educational and behavioral modification procedures designed to support the use of renewable energy. To potentially enhance environmental concern could also entail stressing positive self-gains such as economic effects of using renewable energy and effects on people's health in addition to environmental impacts.

6. Implications

The findings of this research are quite important for policy makers and social activists in Germany, specifically looking at the realm of environment. Unearthing the vital parts of knowledge, consumption behavior, and the utilization of renewable energy sources, the study postulates that ranging and focused educational campaigns and information releases as the ways to improve sustainable practices. The results also highlight the fact that one's environmental concern can act as a moderator, suggesting that increasing the populace's concern for the environment, through awareness campaigns, can strengthen these effects. Thus, the interaction of these approaches can contribute to the more effective management of environmental projects, preserving a leading position in the field of renewable energy sources in Germany and serve as an example for other countries. The study helps the regulators in making regulations related to environment management using effective knowledge, reliable consumption behavior and adoption of renewable energy.

6.1 Limitations

The study also contains certain limitations. It is entirely based on the German normative data for children, which might reduce the external validity of the results in regard to other countries with different cultural or economic characteristics. The work mainly relies on the respondents' answers, which can involve the social desirable response bias and recall bias. Moreover, the most apparent methodological weakness is the cross-sectional research design which provides the information at one point in time and, therefore, does not allow for assessing causality. The study should in future include follow-up investigation and different geographical regions in an effort to confirm and build up these dynamics.

Authors Contribution

Wasif Ali Khan: study design, data analysis, write-up
Seerat Hussain: data collection, literature review
Inzimam Ur Rahman: critical revision, data interpretation, drafting

Conflict of Interests/Disclosures

The authors declared no potential conflicts of interest w.r.t the research, authorship and/or publication of this article.

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