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Analysis of social inequality factors in implementation of building energy conservation policies using Fuzzy Analytical Hierarchy Process Methodology

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ABSTRACT

Because residential buildings consume significant reserves of energy, they are among the largest contributors to climate change. Carbon and greenhouse gas (GHG) emissions from buildings have negatively impacted the environment. In response, institutions around the globe have issued policies and regulations to minimize climate change problems. While these policies have succeeded to some extent, additional factors are present that need greater attention. Among these other factors are social inequality and environmental injustice in society, both of which must be analyzed thoroughly before solutions can be suggested. This research seeks to examine these factors and their effects; we analyze the factors that cause social inequality and injustice and correlate those factors to the implementation of energy policies. We then pursue how these actions have consequences in civil society. Results show that some 15 social inequality factors are omnipresent, but the top three include: i) the limited participation of women in environmental campaigns, ii) variances in the adoption of building energy regulations across the globe, and iii) ethnic/racial discrimination with regard to how environmental safety is prioritized. We analyze these factors through the Fuzzy Analytical Hierarchy methodology (AHP), and our results are statistically validated through sensitivity analysis and a consistency check.

Keywords:

Social inequality;
Environmental injustice;
Gender discrimination;
Energy Consumption;
Residential Buildings;

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1. Introduction

While climate change affects everyone, certain minorities – including children, the elderly, and women – are more vulnerable than others [1]. Social inequality occurs in a society when its resources are not accessible or available to all inhabitants. Ideally, resources should be distributed regardless of race, social status, gender, wealth, or religion. In this research, our emphasis is on factors that generate social inequality due to buildings' energy conservation policies and result in climate change. According to a United Nations report, over 1.2 billion people still have no access to electricity, and 40% of the world always rely on solid fuels for cooking. Compared to wealthier individuals, the poor have to spend a much larger percentage of their income to get electricity. A study notes that more than half of the population in 41 countries of Sub-Sahara African region have no access to power, and over 95% of households in this region rely on wood, waste, and charcoal for cooking [2]. Moreover, the equipment available to more miserable persons is much less efficient, thus creating a further burden [3].

The increasing concern about macro energy variables such as GDP, household income, and energy consumption has been an emerging topic. The GDP of a country affects the energy inequality, as it is linked with macro variables like economic activity, energy consumption, and development of a country [4]. In all these three macro energy variables, energy consumers play a major role. The distribution and access to energy resources

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may lead to significant social inequalities. Measuring energy equality is a good way of monitoring and a tool for reducing it. Wu et al., showed in his research that perfect energy equality would be achieved if the GDP and cumulative energy consumption is linear and directly proportional [5]. The total world electricity consumption in 2017 was 23.696 PWh, representing an increasing trend in electricity consumption globally [6].

The relation between the macro energy variables can be summarized into two scenarios: The first scenario portrays energy as a hurdling factor for economic growth and is necessary for industrial production, which involves labor and capital. The second scenario depicts a neutral stand on energy as neutral to economic development; this is because the energy that constitutes a small part of GDP cannot have huge impact [4]. However, considering that GDP and economic development are linked with labor and people, the inequality in energy distribution and access should be reduced. Buildings consume approximately one-third of all energy produced, and because they emit large quantities of GHG [7] they are a major contributor to climate change. Buildings do not utilize energy equally, and these inequalities may be classified into two types: (i) Inequalities that arise due to a building's distribution of energy; (ii) After effects of energy distribution that result in climate change.

The energy use of a building is a resource that is vital for the activities of daily life, such as cooking, washing, and transportation [8, 9]. Therefore, it should be distributed without any discrimination towards the building's or dwelling's inhabitants. If discrimination occurs with regard to resources, inequalities may be noted. For example, some countries provide tariffs that result in inequality in society. In Addis Ababa, Ethiopia, wealthy people receive a greater subsidy than poorer people for residential electricity [10]. Peak pricing with electricity tariff is unfair from the perspective of disadvantaged residents [11]. Great Britain and Queensland have been sharply criticized due to their pricing policies regarding electricity tariffs in residential sectors [12]. Those with a higher social status and greater wealth enjoy more privileges with lower energy prices; further, no cap or limit in the quantity of usage is placed on affluent customers so they demand and consume more electricity. To meet the greater energy demand, strategies such as power layoff, load shifting, demand response, load shedding are enacted in specific low-income areas. The result is social inequality concerning essential utilities. In the U.K., the energy sector has become privatized. That business model allows energy costs to accelerate, restrict energy usage by low-income groups, and creates assets at the expense of low-income households [13]. The result enforces the occurrence of unjust economic discrimination and inequality for British communities.

The aftereffects of energy distribution, including overall impact and social inequality, can be seen on a global scale. Goal 13 of the Sustainable Development Goals of the United Nations states that the poorest and the most vulnerable are the most affected. Emissions from one country may have a profound impact on neighboring countries. One country's CO_2 and GHG emissions are not proportionate to the disastrous climate change effects endured by the same country. Most countries that produce low emission levels are more vulnerable to climate change. In Figure 1, we can see quantiles showing that countries that produce high emissions (dark red) exhibit less vulnerability. Similarly, countries with high vulnerability (dark green) produce lower emissions. Countries in yellow represent balanced cases of emissions and vulnerability.

The less intense colors show gradually decreasing or increasing levels of inequality among countries. The few countries with no data are depicted in grey. Since global emission stakeholders cause climate change inequality, the solution to eradicate these inequalities should emerge from the leaders of GHG emissions, the strongest polluters. Those nations that release the most emissions should shoulder the responsibility of eradicating inequality globally. Figure 2 shows a perpetual cycle where climate hazards add to the burden of social inequalities. Multidimensional inequalities expose disadvantaged groups to climate hazards, which, in turn, leads to income loss and a loss in other human, physical, or social assets.

In 2005, Hurricane Katrina that occurred in the U.S. presented an example of the role of inequality in society. For example, the areas where wealthy households lived were better fenced and had protective infrastructures, whereas poorer neighborhoods had no preventive measures. Due to omnipresent economic and racial inequalities, African Americans lived in low-lying, poverty-stricken, vulnerable areas of New Orleans that bore the brunt of the floodwaters. In contrast, the more affluent, privileged homes populate the high areas of the city. This spatial distribution is the result of socio-political and discrimination inequality in society. As a result, the impact of Hurricane Katrina was felt disproportionately [16].

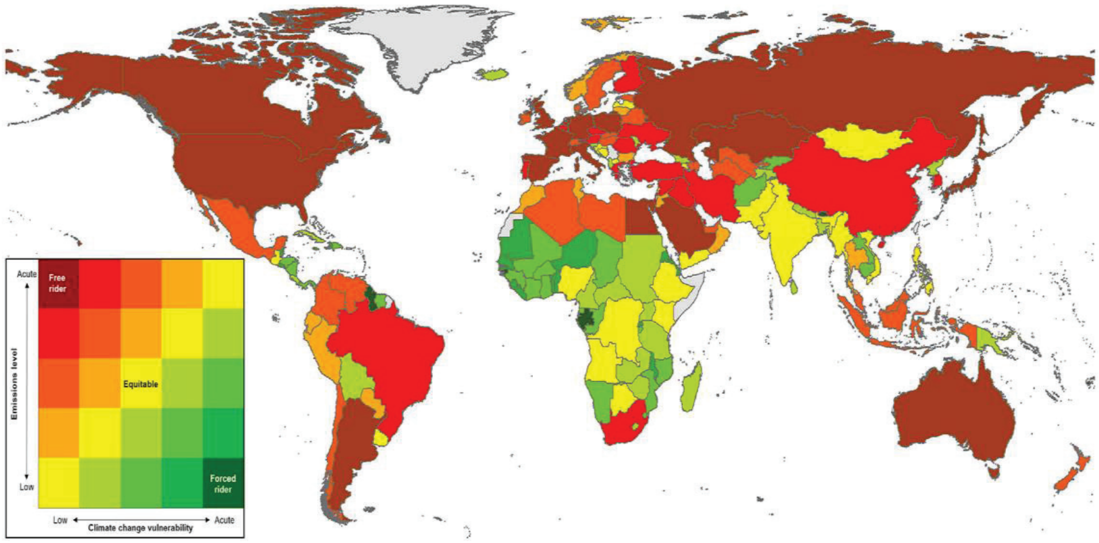

Figure 1: Inequality in GHG emissions by country (2030) (Source: [14])

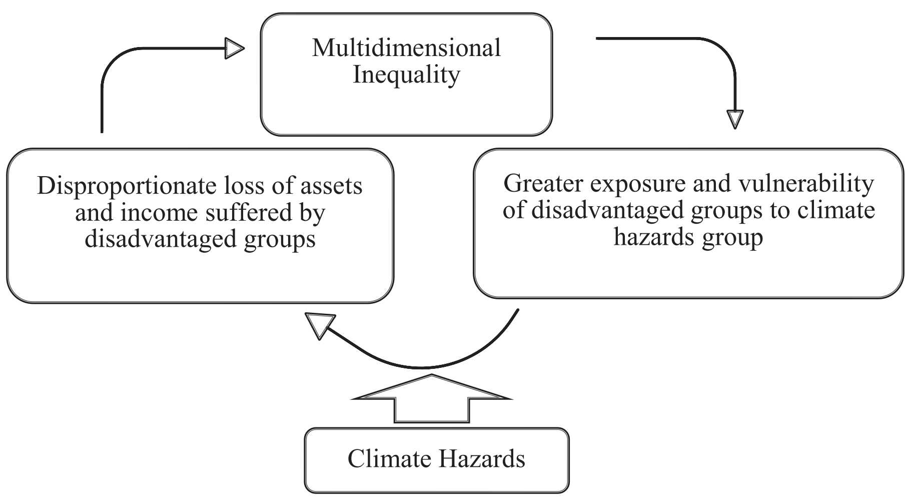

Figure 2: Climate change – a vicious cycle of inequality (Source: [15])

This research aims to provide the factors that are responsible for leveraging social inequality and social injustice, in energy usage predominantly at the domestic and residential level. The main objective of this research is to rank the factors based on the relevance of importance obtained by applying the Fuzzy Analytical Hierarchy Process method. This paper tries to answer the following questions:-

a) What are the factors responsible for inducing social inequality and injustice in society due to energy usage?
b) Which factor are the most and the least influential in imparting social inequality in society due to energy usage?

2. Literature Review

The role of gender, geographical location, and ethnicity play a significant role in imparting energy inequality. Therefore for better understanding, these topics are discussed in this section with practical examples by reviewing research works in the field of energy inequality. The research problem is also discussed in section 2.2.

2.1 Experiencing energy inequality by different scenarios

Goal # 13 from the 2030 agenda of sustainable development on climate action seeks to achieve a more equitable world by reducing inequalities among countries [17].

In developing countries, the availability of energy resources in domestic households is central, whereas, in developed countries, the affordability of all households is a core issue [18]. In both cases, these issues go beyond reducing environmental impacts and point to the inequalities in society. Federal institutions should act and frame policies to reduce inequalities in energy consumption.

According to a research by Shi (2019), inequality in China's energy consumption is due to circumstances beyond the control of individuals: their gender, family status, family background, and region of birth. Shi also declares that the most disadvantaged group facing the most inequality in energy consumption are females born in rural areas with low-income family background [19]. Mader states in his research that if the rich and the poor are given an equal distribution of wealth, the social costs of climate change and its mitigation could be accrued, thereby reducing inequality in energy consumption related to climate change [20].

To understand energy inequality, it is essential to clear ambiguity between energy poverty and income poverty. It is because energy poverty and income poverty are linked to energy inequality leading to social injustice in society. One good example of interlinking the inequalities is that the poor households spend a larger percentage of their income on energy than their wealthier counterparts. This larger percentage of spending by the poor deprives them of other necessary household expenses [21]. The minimum amount of energy consumption that is required to sustain a living is termed as energy poverty. Alternatively, it can be defined as the level of energy consumed by a household below the determined expenditure or income poverty. Whereas, the income poverty is based on the food and non-food items essential in daily routine to sustain a living or livelihood [21]. In the present contemporary society, there is a lack of precise definition of energy poverty. The research work by Doughlas et al., has defined and successfully applied the poverty line that can be used as a standard benchmark of energy consumption necessary to nurture life [22]. If there exists an energy inequality and income inequality in a society, it is evident that it would eventually result in social injustice. This is because both inequalities are part of a large society. Therefore, through this research work, the determinants of social injustice and energy inequality in society are introduced.

Inequality in energy consumption must be measured correctly to reduce it. For example, in some cases, inequality is measured by taking the country's GDP as a weighted variable. That approach may show decreasing trends in inequality, whereas when inequality is measured using population distribution as a variable, it will show an even distribution. Consequently, precise and detailed research is needed to determine how to reduce such inequality [23]. A major geographical cause of energy inequality is the regional imbalance of energy resources, and that energy consumers are situated at different geographical locations. For example, 80% of energy resources are concentrated in the northern or southern parts of China, but the majority of consumers are situated in different geographical areas. Moreover, a region's heterogeneity and its socioeconomic transformation strongly affect its energy inequality [24]. In India, an area's social castes and religions present varying degrees of access to electricity. Marginalized sections of the society receive unequal accessibility to electricity and cooking gas [25]. In Zambia, an increase in electricity tariffs generated greater inequality with 0.7% or 0.5% (108,000 or 90,000) people ranking below moderate or extreme poverty lines. Additionally, 60% of the electricity subsidy was taken by the richest quantiles; only about 1% was taken by the 20% poorest households [26]. South Korea also displays an example of social injustice in electricity dissemination, consumption, and disposal. Some residents are excluded from the decision-making process; their opposition to certain policies is simply neglected, which creates an environment of social injustice. Certain regions produce 200% more electricity than they consume, but the resource is not transmitted to other metropolitan areas because of environmental and infrastructural disturbances [27].

The energy reforms and policies framed by the governments should not be driven only by political or economic pursuits, but also take into account the social ills, uneven distribution of wealth in society and poverty [28]. A study in Kenya revealed that a rise in energy prices could lead rich people to invest in energy-efficient appliances and poorer people to cut down on energy consumption [29]. Income is considered as one of the impact indicators of household energy use, and this energy use is responsible for driving the socioeconomic situation of homes and access to electricity [30] by removing energy access discrimination. According to a study conducted in Hungary revealed that energy poverty in the region forced the inhabitants to illegal use of burning biomass for heating homes [31]. In the European Union, energy liberalization is shown to have an impact on energy distribution, particularly in the residential sector. One of the aims of liberalization is to provide affordable prices to all energy users to bring energy justice [32].

2.2 Problem Description

The energy utilized for daily routine purposes in society is an example of social injustice. In high-income countries, wealthy households enjoy subsidies in electricity bills, whereas poorer households could benefit even more if grants were offered to them [33]. Research shows examples of societies in which one portion receives electricity, and a different portion of the society is deprived of electricity usage. Even with the same energy provider, the same distribution network, and the same usage pattern, there is a vast gap in the price of electricity, which creates social inequality [34]. This research seeks to determine what factors lead to these discriminations in energy utilization and why some groups suffer social inequality and are deprived of energy accessibility. If a society is offered with electricity at the same price and with the same level of access, with no differences among the rich or poor, male or female, and with no regard to the consumer's religion, then energy would be provided fairly and equally. India's Schedule caste, Schedule tribes, and Muslims are among the most disadvantaged groups in terms of receiving LPG gas for household cooking [25].

Different types of inequality exist in society due to socioeconomic, regional, ethnic, and political reasons. But in a just society, all individuals should have access to daily routine actions such as having utilities to provide hot water in the early morning and the ability to travel to an office or other destination in a vehicle. Successful routine activities are linked to energy utilization. If the daily routine's energy usage is disturbed, then the common man's life is concerned because he has fewer alternatives. Something as basic as one's access or not to energy is the foundation for social inequality and injustice.

3. Methodology

This section explains the importance of the Analytical Hierarchy Process and the various steps associated with it. The application of the model to the research work, its validation, and sensitivity analysis is also discussed. In this research, to minimize vagueness and imprecision in human judgments, a fuzzy set theory with Multiple Criteria Decision Making (MCDM), first developed by Zadeh in 1965 [60], was chosen. Fuzzy set theory can handle more complex problems when compared to classical set theory, and Fuzzy AHP has been derived from fuzzy set theory [35, 36]. Although there are many tools in MCDM methodology, the Fuzzy Analytical Hierarchy Process (Fuzzy AHP) has been used in this paper because it can handle multiple criteria of factors with ease. Both qualitative and quantitative data can be effectively processed, so it is one of the most commonly utilized tools for MCDM methods [37]. Fuzzy AHP, introduced by Thomas L. Saaty in 1980, is a technique that can accommodate both subjective and objective functionalities, and it can include dynamic expert participation while relatively evaluating problems [38]. In Fuzzy AHP, a decision problem is decomposed into decision criteria, and a hierarchy decision model is constructed. The decision criteria are compared pairwise with the criterion preceding them in the hierarchy [39, 49].

Compared to other Multi-criteria decision making (MCDM) Methods, AHP is extensively used and widely accepted method. AHP method handles multiple criteria with extreme simplicity comparably with other methods. In contrast with other Fuzzy MCDM methods, AHP is easier to understand and easily handle qualitative and quantitative data. Some of the characteristics that make it a good candidate for analysis are, the method does not need complicated mathematics for analysis. It consists of principles of decomposition, pairwise comparison, priority vector generation, and synthesis [40]. AHP methodology provides an opportunity for analysis of a system rather than concluding it true or false. It tries to provide a solution that fits the goal and objectives of a solution [41] when compared with ANP and TOPSIS. Still, AHP is preferred because of its worldwide acceptance [38; 61]. Therefore, AHP is used in this research.

The steps involved in Fuzzy AHP are as follows.

Step 1. Framing a Pairwise comparison matric for Social inequality factors.

$$A = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix} \tag{1}$$

Step 2. Normalization of the pairwise comparison matrix.

$$A = \begin{bmatrix} a'_{11} & a'_{12} & \dots & a'_{1n} \\ a'_{21} & a'_{22} & \dots & a'_{2n} \\ \dots & \dots & \dots & \dots \\ a'_{n1} & a'_{n2} & \dots & a'_{nn} \end{bmatrix}$$

$$a'_{ij} = \frac{a_{ij}}{\sum_{1-n}^{2} a_{ij}} \text{for } i, j = 1,2,3...n \quad (2)$$

Step 3. Calculate the weight of each factor using equation 3.

$$Localweight = \frac{\sum_{i-n}^{n} a_{ij}}{n} \quad (3)$$

Step 4. Obtain the global weight of each factor by multiplying the local weight of each factor by the local weight of its respective main factor.

Step 5. Rank the factors based on weights to arrive at most influencing factors.

3.1 Application of the proposed model to the case illustration

Many government policies have been implemented to overcome energy conservation factors into present-day societies. Today's societies are comprised of different levels and classes of people, including wealthy and poor, laborers, expatriates, foreigners, immigrants, and so forth. Governmental implementation of these energy conservation policies tends to permit social inequality and discrimination among the inhabitants because they demonstrate ethnic, racial, and religious differences. To eradicate these social inequality factors, the first step would be to identify the factors responsible for inequality; in this research, the factors were collected through the Delphi technique with 13 climate experts in the first stage. The thematic analysis was applied to classify the comprehensive list of factors into three themes, as shown in Figure 4. When the number of opinions and decision-makers goes up, inconsistency and vagueness also increase [42]. To limit the impracticality and degrees of inconsistency, we chose a sample size of 13 experts. Figure 4 provides a classification of the factors and subfactors. Among the 13 climate experts, two are university professors with 15 years of experience; four are consultants with more than 15 years of post-graduation experience in a climate-related field. There are three policy makers possessing a postgraduate degree in a climate-related area from a government organization with over ten years of experience. The remaining four were engineers with a Bachelor's degree with over ten years' experience in design and the construction of building climate control systems.

Figure 3 shows the design of this research, where the identification of social inequality factors through the Delphi technique and thematic analysis. A model of factors is framed in a matrix for pairwise comparison. The next step is a pairwise comparison performed by the experts using the linguistic scale in Table 1. In this step, each factor is compared pairwise to know which factor is more important than the other. The pairwise comparison matrix is normalized, and local weights are calculated. The consistency is checked to understand whether the performed tests are consistent or not. In this research work, the survey results are consistent because the consistency ratio value obtained is within the acceptable limits. Now all the subfactors are compared, and global weights are calculated.

Table 1: Linguistic scale for difficulty and importance

Linguistic scale for difficulty	Triangular fuzzy Scale	Linguistic scale for importance	Triangular fuzzy Reciprocal Scale
Just equal	(1,1,1)	Just equal	(1,1,1)
Equally difficult (ED)	$\left(\frac{1}{2},1,\frac{3}{2}\right)$	Equally important (EI)	$\left(\frac{2}{3},1,2\right)$
Weakly more difficult (WMD)	$\left(1,\frac{3}{2},2\right)$	Weakly more important (WMI)	$\left(\frac{1}{2},\frac{2}{3},1\right)$
Strongly more difficult (SMD)	$\left(\frac{3}{2},2,\frac{5}{2}\right)$	Strongly more important (SMI)	$\left(\frac{2}{5},\frac{1}{2},\frac{2}{3}\right)$
Very strongly more Difficult (VSMD)	$\left(2,\frac{5}{2},3\right)$	Very strongly more important (VSMI)	$\left(\frac{1}{3},\frac{2}{5},\frac{1}{2}\right)$
Absolutely more difficult (AMD)	$\left(\frac{5}{2},3,\frac{7}{2}\right)$	Absolutely more important (AMI)	$\left(\frac{2}{7},\frac{1}{3},\frac{2}{5}\right)$

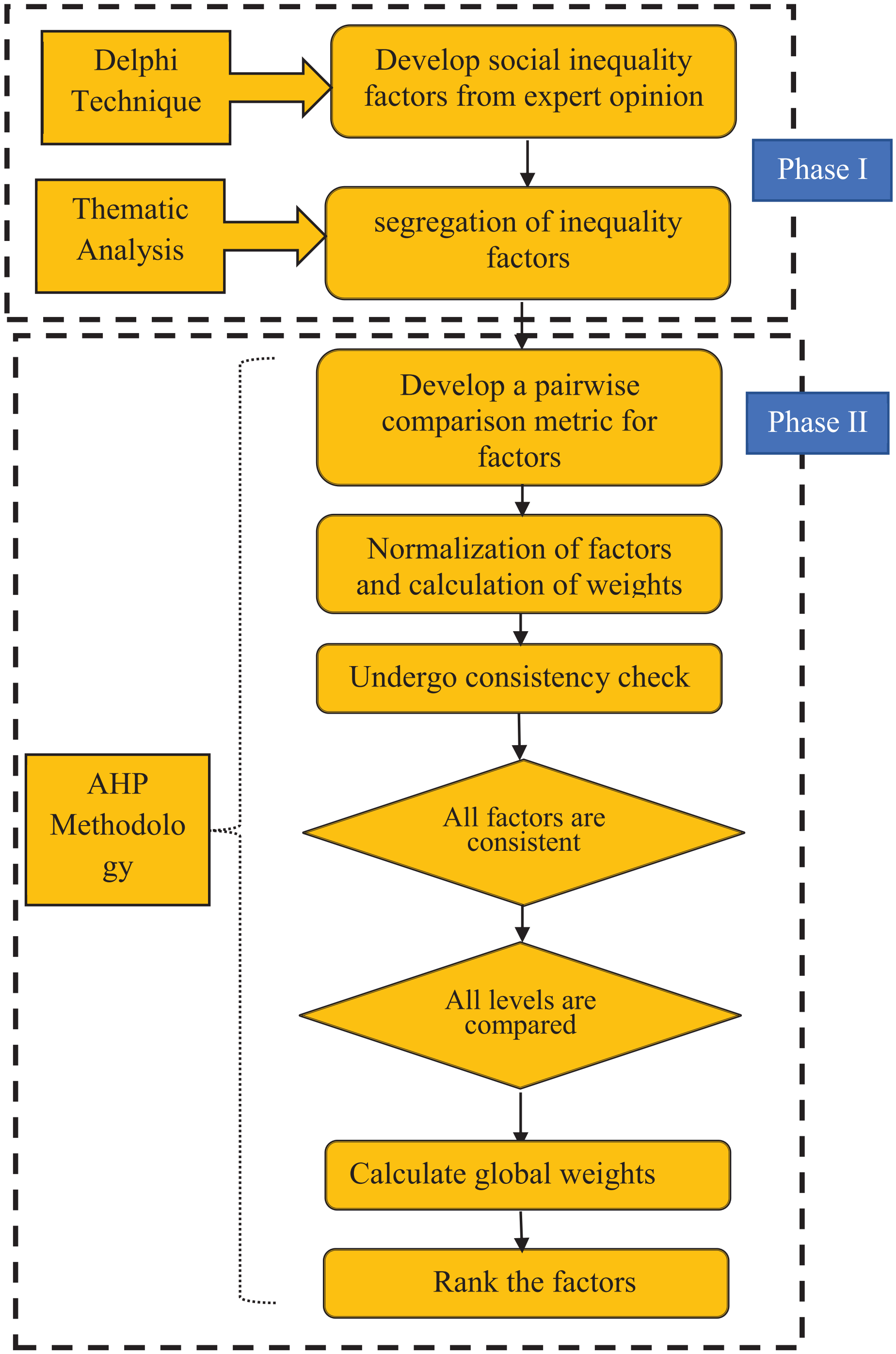

Figure 3: Analytical Hierarchy Process Flowchart

A pairwise comparison matrix constructed for main factors is provided in Table 2 using the fuzzy scale provided in Table 1. The local weight is obtained by using equations 2 and 3. The consistency check is conducted as explained in Section 6. The global weights of the main factors and subfactors are given in Table 6.

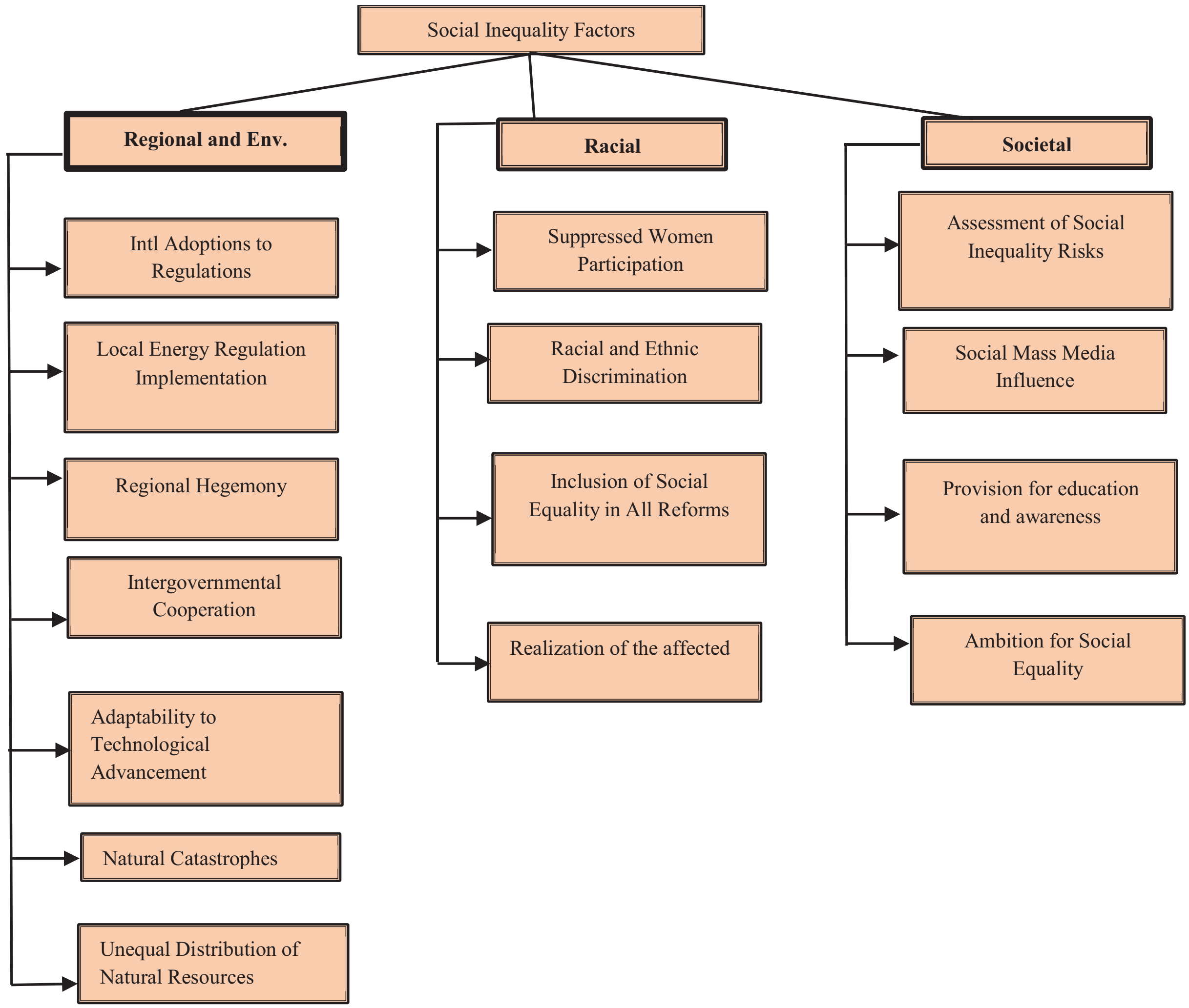

Figure 4: Classification of Social Inequality Factors

Table 2: Pairwise comparison of main factors

Main factors	Regional and Environmental (RE)	Racial (RA)	Societal (SO)	Local Weight	Rank
RE	1,1,1	3/2,2,5/2	2,5/2,3	0.4991	1
R	2/5,1/2,2/3	1,1,1	5/2,3,7/2	0.3444	2
SO	1/3,2/5,1/2	2/7,1/3,2/5	1,1,1	0.1564	3

3.2 Validation of the Model

In this research work, the validation of the research model is done by two methods: a consistency check and a sensitivity analysis. Because the inputs to this model come from human judgments, it requires a certain level of consistency [43]. If the value of the Consistency Index (CI) is equal to zero, then the matrix is perfectly consistent. However, the suggested value of Consistency Ratio (CR) should not be greater than 0.1 [43, 49]. In this study, the proposed matrix is consistent with a CR value of 0.0965 (i.e., less than 0.1). The CR can be checked as follows.

Table 3: Local weight and pairwise comparison of Regional and Environmental (RE) Subfactors

	IAR	LERI	RH	IC	ATA	NC	UDNR	Local weight
International Adoption to Regulations (IAR)	1,1,1	5/2,3,7/2	2,5/2,3	3/2,2,5/2	3/2,2,5/2	1,3/2,2	1,3/2,2	0.2378
Local energy legislation implementation (LERI)	2/7,1/3,2/5	1,1,1	1/2,1,3/2	1,3/2,2	5/2,3,7/2	1/2,1,3/2	1,3/2,2	0.1429
Regional hegemony (RH)	1/3,2/5,1/2	2/3,1,2	1,1,1	5/2,3,7/2	2,5/2,3	1/2,1,3/2	1,3/2,2	0.1674
Intergovernmental cooperation n (IC)	2/5,1/2,2/3	1/2,2/3,1	2/7,1/3,2/5	1,1,1	3/2,2,5/2	1,3/2,2	5/2,3,7/2	0.1425
Adaptability to technological advancements (ATA)	2/5,1/2,2/3	2/7,1/3,2/5	1/3,2/5,1/2	2/5,1/2,2/3	1,1,1	1,3/2,2	1/2,1,3/2	0.0897
Natural catastrophes (NC)	1/2,2/3,1	2/3,1,2	2/3,1,2	1/2,2/3,1	1/2,2/3,1	1,1,1	1/2,1,3/2	0.1174
Unequal distribution of natural resources (UDNR)	1/2,2/3,1	1/2,2/3,1	1/2,2/3,1	2/7,1/3,2/5	2/3,1,2	2/3,1,2	1,1,1	0.1028

Table 4: Local weight and pairwise comparison of Racial (R) subfactors

	SWP	RED	ISE	ROE	Local weight
Suppressed Women participation (SWP)	1,1,1	3/2,2,5/2	3/2,2,5/2	1,3/2,2	0.3487
Racial and ethnic discrimination (RED)	2/5,1/2,2/3	1,1,1	5/2,3,7/2	2,5/2,3	0.3111
Inclusion of social equality in all reforms (ISE)	2/5,1/2,2/3	2/7,1/3,2/5	1,1,1	5/2,3,7/2	0.2037
Realization of effected (ROE)	1/2,2/3,1	1/3,2/5,1/2	2/7,1/3,2/5	1,1,1	0.1367

Table 5: Local weight and pairwise comparison of Societal (SO) Subfactors

	ASER	SMMI	PEA	ASE	Local weight
Assessment of Social Inequality Risks (ASER)	1,1,1	3/2,2,5/2	2,5/2,3	2,5/2,3	0.4138
Social Mass media Influence (SMMI)	2/5,1/2,2/3	1,1,1	3/2,2,5/2	1,3/2,2	0.2487
Provisions for education and awareness (PEA)	1/3,2/5,1/2	2/5,1/2,2/3	1,1,1	2,5/2,3	0.2008
Ambition for justified social equality (ASE)	1/3,2/5,1/2	1/2,2/3,1	1/3,2/5,1/2	1,1,1	0.1369

Table 6: Global rank and global weight of subfactors

Main factors	Weight	Rank	Sub Factors	Local Weight	Local Rank	Global Weight	Global Rank
Regional and Environmental (RE)	0.4991	1	RE1	0.2377	1	0.1187	2
			RE2	0.1428	3	0.0713	5
			RE3	0.1673	2	0.0835	4
			RE4	0.1424	4	0.0711	6
			RE5	0.0896	7	0.0448	12
			RE6	0.1173	5	0.0586	9
			RE7	0.1027	6	0.0513	10
Racial (RA)	0.3444	2	RA1	0.3486	1	0.1201	1
			RA2	0.3110	2	0.1071	3
			RA3	0.2036	3	0.0701	7
			RA4	0.1366	4	0.0471	11
Societal (S)	0.1564	3	SO1	0.4137	1	0.0647	8
			SO2	0.2486	2	0.0389	13
			SO3	0.2007	3	0.0314	14
			SO4	0.1368	4	0.0214	15

$$Calculate = \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix} and \quad W_i = \frac{\sum_{i-1}^{n} a'_{ij}}{n} and \quad W = AW = \begin{bmatrix} W'_1 \\ W'_2 \\ \vdots \\ W'_n \end{bmatrix} \tag{4}$$

$$\lambda_{\max} = \frac{1}{n}\left[\frac{W'_1}{W_1} + \frac{W'_2}{W_2} + \ldots \frac{W'_n}{W_n}\right] \tag{5}$$

In equation 4, W is the eigenvector, W_i is the eigenvalue, and λ_{max} corresponds to the largest eigenvalue of the pairwise comparison matrix.

The consistency index is given by $CI = \left(\frac{\lambda_{\max} - n}{n-1}\right)$ (6)

and n in this equation is the rank of the matrix.

Consistency Ratio CR is given by $CR = \frac{CI}{RI}$ (7)

Table 8 shows the consistency ratio by applying equation 4 to equation 7. Table 7 provides the Random Index ratios to calculate consistency ratio.

3.3 Sensitivity Analysis

According to Chang et al. (2007), the final rankings may change if there is a minute change in the factor's relative weights [45]. Since most of the analysis is based on the experts' subjective judgments, the stability of the ranking should be tested. To accomplish the proposed model, a sensitivity test is conducted, and the results are tabulated in Table 9. Table 10 provides the ranks of main factors.

From the pairwise comparison Table (Table 2), the relative weight of the Regional and Environmental (RE) factor is 0.4991, providing the highest weight among all three main factors. The weight of the RE factor is varied to check the performance on the other two factors. The results, seen in Tables 9 and 10, show that the RE factor maintains its first position and the Societal (S) factor maintains last position in ranking after the normalized value of 0.4991. Therefore, according to the results in Tables 9 and 10 and the ranks gained by the factors, the Regional and Environmental (RE) factor is the most significant factor.

Table 7: Random Index (RI) and recommended consistency ratio values [44, 50]

Size (n)	3	4	5	6	7	8	9
RI	0.58	0.90	1.12	1.24	1.32	1.41	1.45

Table 8: Calculation of Consistency Ratio

Main Factors	W	W'	λ	λ_{max}	CI	CR
RE	0.4991	1.5790	3.1636			
R	0.3444	1.0742	3.1190	3.113	0.056	0.0965
S	0.1564	0.4783	3.0581			

Table 9: Sensitivity analysis of main factors when varying Regional and Environmental (RE) factors

Main factors	Values of Main Factors when Regional and Environmental (RE) value changes from 0.1 to 0.9									
RE	RE = 0.1	RE = 0.2	RE = 0.3	RE = 0.4	RE = 0.4991 (Normal)	RE = 0.5	RE = 0.6	RE = 0.7	RE = 0.8	RE = 0.9
RA	0.6189	0.5502	0.4814	0.4126	0.3445	0.3439	0.2751	0. 2063	0.1375	0.6888
S	0.2811	0.2498	0.2186	0.1874	0.1565	0.1561	0.1249	0.0937	0.0625	0.0312

Table 10. Rank of main factors when varying Regional and Environmental (RE) factors

Main factors	Rank of main factors when Regional and Environmental (RE) value changes from 0.1 to 0.9									
	RE = 0.1	RE = 0.2	RE = 0.3	RE = 0.4	RE = 0.4991 (Normal)	RE = 0.5	RE = 0.6	RE = 0.7	RE = 0.8	RE = 0.9
RE	3	3	2	2	1	1	1	1	1	1
RA	2	1	1	1	2	2	2	2	2	2
S	1	2	3	3	3	3	3	3	3	3

Similarly, in Figure 5 and Table 11 the weights of the subfactors under varying RE values of 0.1 to 0.9 are presented. The subfactor RA1- Suppressed women participation has maintained the first rank between the RE values of 0.1 and 0.5, and RE1-International Adoption to Regulation has gained top rank with RE values from 0.6 to 0.9. However, factor S4-Ambition for social equality has consistently maintained the last rank for the values of RE between 0.4 to 0.9. Thus, Tables 11 and 12 clarify that RA1-Suppressed women participation and RE1-

Table 11. Global weights of subfactors when RE changes from 0.1 to 0.9

Sub Factors	RE = 0.1	RE = 0.2	RE = 0.3	RE = 0.4	RE = 0.4992 (Normal)	RE = 0.5	RE = 0.6	RE = 0.7	RE = 0.8	RE= 0.9
RE1	0.0238	0.0476	0.0713	0.0951	0.1187	0.1189	0.1427	0.1665	0.1902	0.2140
RE2	0.0143	0.0286	0.0428	0.0571	0.0713	0.0714	0.0857	0.1000	0.1143	0.1285
RE3	0.0167	0.0335	0.0502	0.0669	0.0835	0.0837	0.1004	0.1171	0.1338	0.1506
RE4	0.0142	0.0285	0.0427	0.0570	0.0711	0.0712	0.0855	0.0997	0.1140	0.1282
RE5	0.0090	0.0179	0.0269	0.0359	0.0448	0.0448	0.0538	0.0628	0.0717	0.0807
RE6	0.0117	0.0235	0.0352	0.0469	0.0586	0.0587	0.0704	0.0821	0.0938	0.1056
RE7	0.0103	0.0205	0.0308	0.0411	0.0513	0.0514	0.0616	0.0719	0.0822	0.0924
RA1	0.2158	0.1918	0.1678	0.1439	0.1201	0.1199	0.0959	0.0719	0.0480	0.0240
RA2	0.1925	0.1711	0.1497	0.1284	0.1071	0.1070	0.0856	0.0642	0.0428	0.0214
RA3	0.1260	0.1120	0.0980	0.0840	0.0701	0.0700	0.0560	0.0420	0.0280	0.0140
RA4	0.0846	0.0752	0.0658	0.0564	0.0471	0.0470	0.0376	0.0282	0.0188	0.0094
S1	0.1163	0.1034	0.0904	0.0775	0.0647	0.0646	0.0517	0.0388	0.0258	0.0129
S2	0.0699	0.0621	0.0544	0.0466	0.0389	0.0388	0.0311	0.0233	0.0155	0.0078
S3	0.0564	0.0501	0.0439	0.0376	0.0314	0.0313	0.0251	0.0188	0.0125	0.0063
S4	0.0385	0.0342	0.0299	0.0256	0.0214	0.0214	0.0171	0.0128	0.0085	0.0043
	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 12: Ranking for subfactors by sensitivity analysis when RE factors changes from 0.1 to 0.9

Sub-factors	RE = 0.1	RE = 0.2	RE = 0.3	RE = 0.4	RE = 0.4991 (Normal)	RE = 0.5	RE= 0.6	RE = 0.7	RE = 0.8	RE = 0.9
RE1	9	8	5	3	2	2	1	1	1	1
RE2	11	11	10	7	5	5	4	3	3	3
RE3	10	10	8	6	4	4	2	2	2	2
RE4	12	12	11	8	6	6	6	4	4	4
RE5	15	15	15	14	12	12	10	9	7	7
RE6	13	13	12	10	9	9	7	5	5	5
RE7	14	14	13	12	10	10	8	7	6	6
RA1	1	1	1	1	1	1	3	6	8	8
RA2	2	2	2	2	3	3	5	8	9	9
RA3	3	3	3	4	7	7	9	10	10	10
RA4	5	5	6	9	11	11	12	12	12	12
S1	4	4	4	5	8	8	11	11	11	11
S2	6	6	7	11	13	13	13	13	13	13
S3	7	7	9	13	14	14	14	14	14	14
S4	8	9	14	15	15	15	15	15	15	15

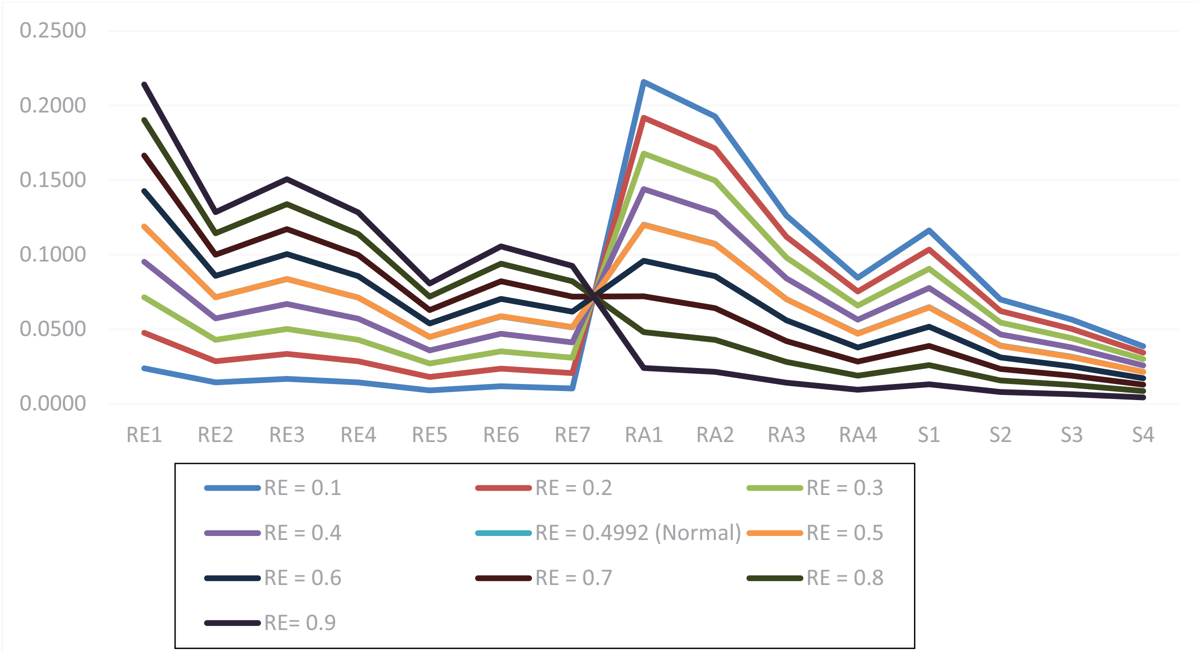

Figure 5: Sensitivity Analysis: Performance of social inequality subfactors (by global weight)

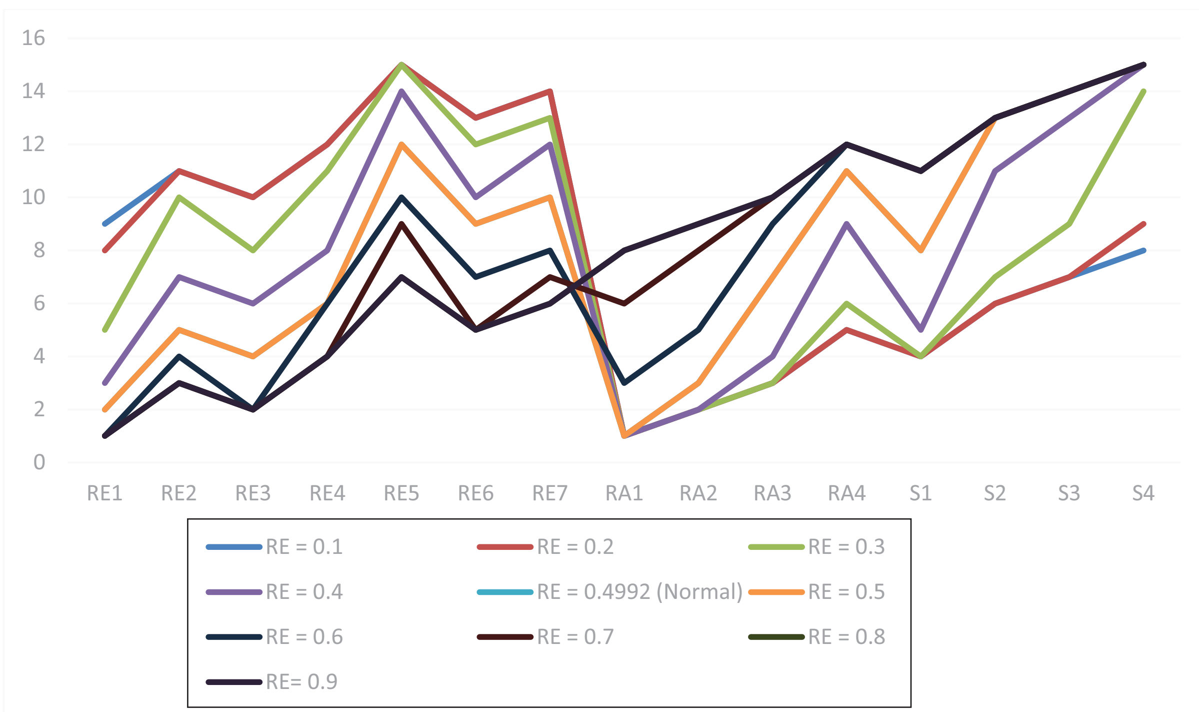

Figure 6: Ranks of subfactors under varying RE values of 0.1 to 0.9 (global weights)

International adoptions to regulations are the most significant factors that can impact social inequality in a greater way. Both Table 12 and Figure 6 provide detailed ranks under varying RE values of 0.1 to 0.9.

4. Results and Discussions

The application of the Fuzzy AHP to main factors shows the order of priority as RE > RA > SO: the Regional and Environmental factors exhibit the highest weightage followed by Racial and Societal factors. Environmental injustice impacts residents across all geographical regions. In the U.S., the concept of environmental injustice has been influential in many sectors, including transportation, urban planning, energy development, food justice, and a variety of indigenous cases [46]. In 2017, 51 nations ratified the Paris agreement [47], which brings positive benefits to climate change. This ratification by 51 countries shows the significance and weightage a region plays in bringing social equality and climate justice to a specific area.

The Racial (RA) factor attains the second-highest weightage with a weightage of 0.344. Ethnic and racial factors are a major challenge that creates examples of social injustice and inequality. For example, in Myanmar, minority farmers lost lives, property, and other assets due to the lack of a weather warning system during 2008's Cyclone Nargis [48]. Climate change affects men and women differently. Gender inequality has heightened due to weather-related circumstances and climate changes. Most of the time, women have been the victims, and the feminization of responsibilities has added burdens in creating social inequalities. Due to socially accepted roles in the family, women must do more work than men [51].

The last priority in the main factors is the societal influence with a weightage of 0.156. If a society reflects an inequality and practices social injustice, then the effects of climate change are endured and force some communities and societies to migrate for survival. It is a challenge for society to adapt to a new geographical area, which leaves open the possibility of continuing inequality and prevalent climate change [51].

Table 6 shows the global rank of each subfactor. The order of priority for ranking is RA1 > RE1 > RA2 > RE3 > RE2 > RE4 > RA3 > S1 > RE6 > RE7 > RA4 > RE5 > S2 > S3 > S4.

RA1-Suppressed women participation" ranks highest among all subfactors. Current studies report that female participation is vital in minimizing social inequalities; women participate more in climate change mitigation programs, and they support related policies. Their engagement in programs inspires more efficient outcomes, and their suppression and non-involvement will lead to severe consequences [52]. Moosa & Tuana stress the importance of feminist philosophy for climate change mitigation. Because women are more concerned with the environment and climate, they involve themselves more easily in mitigation activities, and their knowledge and commitment will help minimize social inequalities and climate change [53].

RE1-International Adoption to regulation achieves the second most significant weightage in Table 6. Adoption of international climate control policies and agreements, such as the Kyoto Protocol, Montreal Protocol, and the Paris Agreement, help to attain social justice and motivate international agreement among the nations. Such agreements serve as a global platform to bring justice to communities globally. Economic benefits might be shared with poorer income countries on the African continent, and environmental resources from these countries could be passed on to developed nations to balance social inequality and climate change.

With a weight of 0.311, RA2-Racial and Ethnic discrimination is the third most important factor. A survey conducted in the U.S. in 2014 showed that 43% of white Americans, 71% of Hispanic Americans, and 57% of black Americans were concerned that climate change would impact them negatively [54]. According to the differential vulnerability hypothesis, non-whites considered that climate change to be more of a vulnerable challenge due to their less privileged position in society [55]. RE3-Regional hegemony ranks four in subfactors with a weightage of 0.835. Regional hegemony can create indifference and promote social inequality and injustice among nations and communities. One of the best examples of regional hegemony is the withdrawal of the U.S., from the Paris Agreement on 1 July 2017. The U.S. is one of the top GHG-emitting nations of the world and a huge contributor to climate change. International pressures for the U.S to lower their GHG emissions were brought to bear as part of the ratifying Paris Agreement, but the U.S withdrew from the Agreement and continues to emit GHG gases, resulting in bad climate change consequences in other nations of the world. In short, through its withdrawal from the Paris Agreement, the U.S took advantage of its strategic influence to emit GHG gases at its liberty [56].

RE2- Local energy legislation implementation stands in fifth place among the subfactors. The implementation of local energy regulations will normalize the rules in a civil society for everyone, regardless of their social or financial status. A positive example of attaining social equality in society is, for instance, a region's local energy tariff that is equally applicable to all. RE4-Intergovernemental Cooperation ranks in sixth position in Table 6. Intergovernmental cooperation is necessary to mitigate climate change and to provide support to eradicate bias among residents of a community. One of the best examples of Intergovernmental cooperation is the political agreement attained by different governments to limit global temperature increases to 2 degrees Centigrade [57].

The findings of this research brings in significant lessons for policy makers. First and foremost is fair income distribution should be an element of energy policies, one of the core element of energy policy should reduce income inequality. One of the ways to achieve this is making the energy price affordable to all sections of the society without discrimination [58]. Access to energy in a rural area should be provided to bring equal access on par with urban counterpart. Secondly, the empirical findings of this research work has shown that suppression of women has high weightage in causing social injustice; therefore, women participation in framing policy should be encouraged to mitigate social injustice in society [59]. Third, the policymakers and energy policy should not yield to political influence that might give rise to a bias in energy distribution. Instead, policymakers should bring in the policy to create energy equality and environmental justice for users of energy [28].

5. Conclusions, Limitations and Further Scope

Among the 15 subfactors, the top five belong to RE-Regional and Environmental main factor and the RA-Racial main factor; the Fuzzy AHP establishes that the Societal main factor has the least weight. Hence, the Regional and Environmental (RE) and Racial (RA) factors should be given greater priority. This is because international, intergovernmental cooperation helps to formulate effective and more practical climate change policies. The effective implementation and execution lie with the end-user and, specifically, with the participation of women and ethnic minorities committed to eradicating inequality among society. The results in Table 6 also show that education and awareness, ambition for justified social equality, and social mass media has less impact in achieving social inequality when compared with other given factors.

By addressing the barriers of social and energy inequality, equitable economic development could be achieved, which unlocks the full developmental potential of local society. Lack of sufficient access to rural and poor energy may lead to a reduction in production and opportunities in society; in specific women, children and poor are more affected. On the contrary, providing energy equality may bring in the benefits of income equality, gender equality, and socioeconomic development of the society. It is mandatory to eliminate persistent energy and income poverty in households. Providing equal access to energy without bias reduces the gap between rich and poor, this reduces social injustice in society by distributing the economic advantages equally.

Although this research has been conducted using experts' input, the results are purely dependent upon their judgment and experience. As every individual judgment and perception is unique, this research reflects the experiences of these experts. A different set of experts may provide a different emphasis and priority. Furthermore, a comparative study could be accomplished, and characteristics of factors could be studied by extending this research work to various MCDM tools such as DEMATEL, ISM, and TOPSIS. The concept of energy inequality has widened over time and stills lacks clarity on mitigating factors that could bring in a change in energy distribution and access. There lies a need for urgent research to address the factors that could enable these inequality changes in society, particularly in rural areas. Further research could be extended to address energy inequality issues with specific gender groups and in different socioeconomic consequences.

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References

[1] Gender inclusive climate action in cities, Women for climate change, February 2019 https://w4c.org/sites/default/files/2019-02/W4C_REPORT_Gender%20Inclusive%20Climate%20Action%20in%20Cities_BD.pdf

[2] Ebhota, W. S. (2019). Power accessibility, fossil fuel and the exploitation of small hydropower technology in sub-saharan Africa. International Journal of Sustainable Energy Planning and Management, 19, 13–28. https://doi.org/10.5278/ijsepm.2019.19.3

[3] Accelerating SDG 7 Achievement Policy Briefs in Support of the First SDG 7 Review at the UN High-Level Political Forum, 2018. https://sustainabledevelopment.un.org/content/documents/22877UN_FINAL_ONLINE_20190523.pdf

[4] Bollino, C. A., Asdrubali, F., Polinori, P., Bigerna, S., Micheli, S., Guattari, C., & Rotili, A. (2017). A note on medium-and long-term global energy prospects and scenarios. *Sustainability*, *9*(5), 833. https://doi.org/10.3390/su9050833

[5] Wu, Q., Maslyuk, S., & Clulow, V. (2012). Energy consumption inequality and human development. *Energy Efficiency-A Bridge to Low Carbon Economy*, 101–116. https://DOI: 10.5772/38338

[6] IEA. (2019). Data & Statistics. Retrieved May 22, 2020, from https://www.iea.org/data-and-statistics?country=WORLD&fuel=Energy%20consumption&indicator=Electricity%20final%20consumption%20by%20sector

[7] Levesque, Antoine, et al. "How much energy will buildings consume in 2100? A global perspective within a scenario framework." *Energy* 148 (2018): 514–527. https://doi.org/10.1016/j.energy.2018.01.139

[8] Qarnain, S. S., Muthuvel, S., & Bathrinath, S. (2020). Review on government action plans to reduce energy consumption in buildings amid COVID-19 pandemic outbreak. *Materials Today: Proceedings*. https://doi.org/10.1016/j.matpr.2020.04.723

[9] Qarnain, S. S., Muthuvel, S., & Bathrinath, S. (2020). Analyzing factors necessitating conservation of energy in residential buildings of Indian subcontinent: A DEMATEL approach. *Materials Today: Proceedings*. https://doi.org/10.1016/j.matpr.2020.02.039

[10] Cardenas, H., & Whittington, D. (2019). The consequences of increasing block tariffs on the distribution of residential electricity subsidies in Addis Ababa, Ethiopia. *Energy Policy*, 128, 783–795. https://doi.org/10.1016/j.enpol.2019.01.033

[11] Neuteleers, S., Mulder, M., & Hindriks, F. (2017). Assessing fairness of dynamic grid tariffs. *Energy Policy,* 108, 111–120. https://doi.org/10.1016/j.enpol.2017.05.028

[12] Simshauser, P. (2018). Price discrimination and the modes of failure in deregulated retail electricity markets. *Energy Economics*, 75, 54–70. https://doi.org/10.1016/j.eneco.2018.08.007

[13] Alston, Philip. 23 April 2019, Visit to the United Kingdom of Great Britain and Northern Ireland, Report of the Special Rapporteur on extreme poverty and human rights, Human Rights Council, General Assembly, United Nations. https://undocs.org/A/HRC/41/39/Add.1

[14] Althor, G., Watson, J.E., & Fuller, R.A. (2016). Global mismatch between greenhouse gas emissions and the burden of climate change. Scientific reports, 6, 20281. https://doi.org/10.1038/srep20281

[15] UN/DESA Policy Brief #45: The Nexus between climate change and inequalities, United Nations Department of Economic and Social Affairs, September 2016. https://www.un.org/development/desa/dpad/publication/wess-policy-brief-the-nexus-between-climate-change-and-inequalities.

[16] United Nations, World Economic and Social Survey, September 2016, Climate Change Resilience: an opportunity for reducing inequalities. https://wess.un.org/wp-content/uploads/2016/06/WESS_2016_Report.pdf

[17] Zimm, C., & Nakicenovic, N. (2019). What are the implications of the Paris Agreement for inequality?. *Climate Policy*, 1–10. https://doi.org/10.1080/14693062.2019.1581048

[18] Aristondo, O., & Onaindia, E. (2018). Inequality of energy poverty between groups in Spain. Energy, 153, 431–442. https://doi.org/10.1016/j.energy.2018.04.029

[19] Shi, X. (2019). Inequality of opportunity in energy consumption in China. *Energy policy*, 124, 371-382. https://doi.org/10.1016/j.enpol.2018.09.029

[20] Mader, S. (2018). The nexus between social inequality and CO2 emissions revisited: Challenging its empirical validity. Environmental science & policy, 89, 322–329. https://doi.org/10.1016/j.envsci.2018.08.009

[21] Barnes, D. F., Khandker, S. R., & Samad, H. A. (2011). Energy poverty in rural Bangladesh. *Energy Policy*, *39*(2), 894–904. https://doi.org/10.1016/j.enpol.2010.11.014

[22] SHAHID KHANDKER. (2013, May 30). Why energy poverty may differ from income poverty. Retrieved May 22, 2020, from https://blogs.worldbank.org/developmenttalk/why-energy-poverty-may-differ-income-poverty

[23] Bianco, V., Cascetta, F., Marino, A., & Nardini, S. (2019). Understanding energy consumption and carbon emissions in Europe: A focus on inequality issues. *Energy*, *170*, 120–130. https://doi.org/10.1016/j.energy.2018.12.120

[24] Zhou, Q., & Shi, W. (2019). Socio-economic transition and inequality of energy consumption among urban and rural residents in China. *Energy and Buildings*, *190*, 15–24. https://doi.org/10.1016/j.enbuild.2019.02.015

[25] Saxena, V., & Bhattacharya, P.C. (2018). Inequalities in LPG and electricity consumption in India: The role of caste, tribe, and religion. *Energy for Sustainable Development*, 42, 44–53. https://doi.org/10.1016/j.esd.2017.09.009

[26] Maboshe, M., Kabechani, A., & Chelwa, G. (2019). The welfare effects of unprecedented electricity price hikes in Zambia. *Energy policy*, *126*, 108–117. https://doi.org/10.1016/j.enpol.2018.10.041

[27] Kim, J.D.Y., Choi, E., & Lee, E. (2019). Social justice, fairness and exclusion in the South Korean electricity sector. Energy Research & Social Science, 51, 55–66. https://doi.org/10.1016/j.erss.2018.12.002

[28] Abdallah, S. M., Bressers, H., & Clancy, J. S. (2015). Energy reforms in the developing world: sustainable development compromised?. *International journal of sustainable energy planning and management*, *5*, 41–56. https://doi.org/10.5278/ijsepm.2015.5.5

[29] Kwakwa, P. A., Adu, G., & Osei-Fosu, A. K. (2018). A time series analysis of fossil fuel consumption in Sub-Saharan Africa: evidence from Ghana, Kenya and South Africa. *International Journal of Sustainable Energy Planning and Management*, *17*, 31–44. https://doi.org/10.5278/ijsepm.2018.17.4

[30] Groth, A. (2019). Socio-economic impacts of rural electrification in Tanzania. *International Journal of Sustainable Energy Planning and Management*, *21*. https://doi.org/10.5278/ijsepm.2019.21.6

[31] Munkácsy, B., Csontos, C., Soha, T., Harmat, Á., Campos, J., & Csüllög, G. (2020). Spatial analysis of renewable-based hybrid district heating possibilities in a Hungarian rural area. *International Journal of Sustainable Energy Planning and Management*, 17–36. https://doi.org/10.5278/ijsepm.3661

[32] García-Álvarez, M. T. (2020). An assessment of supply-side and demand-side policies in EU-28 household electricty prices. *International Journal of Sustainable Energy Planning and Management*, *26*, 5–18. https://doi.org/10.5278/ijsepm.3417

[33] Galvin, R., & Sunikka-Blank, M. (2018). Economic inequality and household energy consumption in high-income countries: a challenge for social science based energy research. *Ecological economics*, *153*, 78–88. https://doi.org/10.1016/j.ecolecon.2018.07.003

[34] Byrne, D.P., Martin, L.A., & Nah, J.S. (2019). Price Discrimination, Search, and Negotiation in an Oligopoly: A Field Experiment in Retail Electricity. *Search, and Negotiation in an Oligopoly: A Field Experiment in Retail Electricity (March 15, 2019)*.http://dx.doi.org/10.2139/ssrn.3352209

[35] Moktadir, A., Rahman, T., Jabbour, C.J.C., Ali, S.M., & Kabir, G. (2018). Prioritization of drivers of corporate social responsibility in the footwear industry in an emerging economy: A fuzzy AHP approach. *Journal of Cleaner Production*, *201*, 369–381. https://doi.org/10.1016/j.jclepro.2018.07.326

[36] Wang, Q., Han, R., Huang, Q., Hao, J., Lv, N., Li, T., & Tang, B. (2018). Research on energy conservation and emissions reduction based on AHP-fuzzy synthetic evaluation model: A case study of tobacco enterprises. *Journal of Cleaner Production*, *201*, 88–97. https://doi.org/10.1016/j.jclepro.2018.07.270

[37] Kahraman, C., Cebeci, U., & Ulukan, Z. (2003). Multi-criteria supplier selection using fuzzy AHP. *Logistics information management*, *16*(6), 382–394. https://doi.org/10.1108/09576050310503367

[38] Mangla, S.K., Govindan, K., & Luthra, S. (2017). Prioritizing the barriers to achieve sustainable consumption and production trends in supply chains using fuzzy Analytical Hierarchy Process. *Journal of Cleaner Production*, *151*, 509–525. https://doi.org/10.1016/j.jclepro.2017.02.099

[39] Dağdeviren, M., & Yüksel, İ. (2008). Developing a fuzzy analytic hierarchy process (AHP) model for behavior-based safety management. *Information sciences*, *178*(6), 1717–1733. https://doi.org/10.1016/j.ins.2007.10.016

[40] Kahraman, C., Ertay, T., & Büyüközkan, G. (2006). A fuzzy optimization model for QFD planning process using analytic network approach. *European Journal of Operational Research*, *171*(2), 390–411. https://doi.org/10.1016/j.ejor.2004.09.016

[41] Govindan, K., Mangla, S.K., & Luthra, S. (2017). Prioritizing indicators in improving supply chain performance using fuzzy AHP: insights from the case example of four Indian manufacturing companies. *Production Planning & Control*, *28*(6-8), 552–573. https://doi.org/10.1080/09537287.2017.1309716

[42] Thanki, S., Govindan, K., & Thakkar, J. (2016). An investigation on lean-green implementation practices in Indian SMEs using analytical hierarchy process (AHP) approach. *Journal of Cleaner Production*, *135*, 284–298. https://doi.org/10.1016/j.jclepro.2016.06.105

[43] Saaty, T.L. (1977). A scaling method for priorities in hierarchical structures. *Journal of mathematical psychology*, *15*(3), 234–281. https://doi.org/10.1016/0022-2496(77)90033-5

[44] Zheng, G., Zhu, N., Tian, Z., Chen, Y., & Sun, B. (2012). Application of a trapezoidal fuzzy AHP method for work safety evaluation and early warning rating of hot and humid environments. *Safety science*, *50*(2), 228–239. https://doi.org/10.1016/j.ssci.2011.08.042

[45] Chang, C.W., Wu, C.R., Lin, C.T., & Chen, H.C. (2007). An application of AHP and sensitivity analysis for selecting the best slicing machine. *Computers & Industrial Engineering*, *52*(2), 296–307. https://doi.org/10.1016/j.cie.2006.11.006

[46] Schlosberg, D., & Collins, L.B. (2014). From environmental to climate justice: climate change and the discourse of environmental justice. *Wiley Interdisciplinary Reviews: Climate Change*, *5*(3), 359–374. https://doi.org/10.1002/wcc.275

[47] United Nations Climate Change. (2018). *UN Climate Change ANNUAL REPORT 2017* (ISBN 978-92-9219-175-7). Retrieved from https://unfccc.int/resource/annualreport/media/UN-Climate-AR17.pdf

[48] Islam, N., & Winkel, J. (2017). Climate change and social inequality. DESA Working Paper No. 152 ST/ESA/2017/DWP/152, U N, DESA https://www.un.org/development/desa/publications/working-paper/wp152

[49] Chang, D.Y. (1996). Applications of the extent analysis method on fuzzy AHP. *European Journal of Operational Research*, *95*(3), 649–655. https://doi.org/10.1016/0377-2217(95)00300-2

[50] Franek, J., & Kresta, A. (2014). Judgment scales and consistency measure in AHP. *Procedia Economics and Finance*, *12*, 164–173. https://doi.org/10.1016/S2212-5671(14)00332-3

[51] IPCC. (2014). *International Cooperation: Agreements & Instruments* (2014: International Cooperation: Agreements and Instruments. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change). Retrieved from https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_chapter13.pdf

[52] United national development programme UNDP Report 2013, Overview of linkages between gender and climate change. https://www.undp.org/content/dam/undp/library/gender/Gender%20and%20Environment/PB1-AP-Overview-Gender-and-climate-change.pdf

[53] Moosa, C.S., & Tuana, N. (2014). Mapping a research agenda concerning gender and climate change: A review of the literature. *Hypatia,* 29(3), 677–694. https://www.jstor.org/stable/24542024

[54] Jones, Robert P., Daniel Cox, and Juhem Navarro-Rivera. "Believers, Sympathizers, & Skeptics: Why Americans Are Conflicted about Climate Change, Environmental Policy, and Science." *PRRI*. 2014. http://www.prri.org/research/believers-sympathizers-skeptics-americans-conflicted-climate-change-environmental-policy-science/.

[55] Pearson, A. R., Ballew, M. T., Naiman, S., & Schuldt, J. P. (2017). Race, class, gender and climate change communication. In *Oxford research encyclopedia of climate science*. DOI:10.1093/acrefore/9780190228620.013.412

[56] Zhang, H.B., Dai, H.C., Lai, H.X., & Wang, W.T. (2017). US withdrawal from the Paris Agreement: Reasons, impacts, and China's response. *Advances in Climate Change Research*, *8*(4), 220–225. https://doi.org/10.1016/j.accre.2017.09.002

[57] IPCC (2014). Climate Change 2014: Impacts, Adaptation and Vulnerability. New York: Cambridge University Press. https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-Chap13_FINAL.pdf

[58] Khandker, S. R., Barnes, D. F., & Samad, H. A. (2012). Are the energy poor also income poor? Evidence from India. *Energy policy*, *47*, 1–12. https://doi.org/10.1016/j.enpol.2012.02.028

[59] Uzar, U. (2020). Is income inequality a driver for renewable energy consumption?. *Journal of Cleaner Production*, *255*, 120287. https://doi.org/10.1016/j.jclepro.2020.120287

[60] Zadeh, L. A. (1965). Fuzzy sets. *Information and control*, *8*(3), 338–353. https://doi.org/10.1016/S0019-9958(65)90241-X

[61] Bathrinath, S., Bhalaji, R. K. A., & Saravanasankar, S. (2020). Risk analysis in textile industries using AHP-TOPSIS. Materials Today: Proceedings. https://doi.org/10.1016/j.matpr.2020.04.722

[62] Østergaard, P.A.; Johannsen, R.M.; Duic, N. Sustainable Development using Renewable Energy Systems. Int. J. Sustain. Energy Plan. Manag. 2020, 29, http://doi.org/10.5278/ijsepm.4302.

Appendix A

Table A: Details of Focus group

Sl No	Designation	Experience	Qualification
1	Professor	16 years	PhD
2	Assoc. Professor	15 Years	PhD
3	Head of Department, Sustainability	17 years (Engineering Design consultancy)	Master's Degree
4	Head of Department, MEP Building Services	16 years (Engineering Design consultancy)	Master's degree
5	Project Manager- Execution of Energy Systems for Buildings	15 years (Engineering Design Consultancy)	Master's degree
6	Senior Designer, Mechanical	15 years (Engineering Design Consultancy)	Master's degree
7	Policy expert Energy conservation - Mechanical	10 years, Government organization	Master's degree
8	Policy expert Energy conservation - Electrical	12 Years government organization	Master's degree
9	Policy expert Energy conservation - HVAC	13 Years government organization	Master's degree
10	Engineer in Conservation and energy efficiency	14 years Design Consultancy Firm	Bachelor's Degree
11	Senior MEP Design Engineer	10 Contracting and Design Execution	Bachelor's Degree
12	Sustainability engineer-Mechanical	10 Contracting and Design Execution	Bachelor's Degree
13	Project Manager-MEP	12-Contractor construction and design execution	Bachelor's Degree