A step to clean energy - sustainability in energy system management in an emerging economy context

Abstract: Due to high consumption of energy, its associated concerns such as energy security and demand, wastage of resources, and material-energy recovery are leading to the importance of sustainable energy system development. This is a high time to assess the sustainability in energy systems for meeting the requirements of energy with an enhanced economic, ecological, and social performance from a nation context. The energy system plays a significant role in deciding the economic progress of emerging economies such as India, China, Brazil, and Africa. In this paper, an original attempt has been made to list and evaluate important indicators for sustainability assessment of energy systems development and management in an emerging economy especially India. Firstly, based on the analysis of the extant literature and then followed by expert opinion, potential key sustainability assessment indicators for energy systems development and management were identified. Further, grey based Decision-Making Trial and Evaluation Laboratory technique to understand the causal interactions amongst indicators and segregate them into cause and effect groups, is used. This work can provide useful aids to decision making bodies, sustainability practitioners and business organisations in selective implementation, monitoring and control of sustainable strategies in energy systems development and management and meeting sustainable development goals of clean energy in a nation context.
Keywords: Energy System Development and Management; Sustainability assessment indicators; Grey DEMATEL; Clean Energy; Sensitivity analysis; Emerging economy.

1. Introduction

Energy management has become a vital area of research due to increasing importance of conservation of energy resources and fossil fuels (Ng and Hernandez, 2016; Byravan et al., 2017). On a different note, approximately 80% of the global energy demand is still fulfilled by the fossil fuels, which is estimated to grow exponentially in the future (Parajuli et al., 2015; Child et al., 2018). In this sense, it is increasingly becoming important for policy makers to have sustainable development of energy systems in its usage and managing energy consumptions and energy demand related issues in emerging and emerged economies (Drake and Spinler, 2013; Santoyo-Castelazo and Azapagic, 2014). To get to know the concept of sustainable development in energy systems, the energy development and management needs to meet the requirements of the current and upcoming generations (WCED, 1987; Shortall et al., 2015). Thus, it is crucial to understand the concept of sustainability in Energy System Development and Management (ESDM) to substitute energy from fossils with suitable sustainable energy sources (Bilgili and Ozturk, 2015; Kumar et al., 2017). Further, including sustainability in energy usage and energy systems management not only help to enhance energy consumption efficiency but also assist to recover the energy from waste using various advanced and innovative methods and processes in modern industrialisation. Electricity is the most significant form of energy for fulfilling the needs of industrial systems and improving the quality of human life (Szakonyi and Urpelainen, 2013; Al-Falahi et al., 2017; Sindhu et al., 2017). Besides this, different sources of renewable sources of energy such as hydropower plants, wind energy and solar plants may also be explored to fulfil the needs of society. Emerging economies such as India, Brazil, South Africa and China etc. seeking to explore a reliable and affordable source of energy to meet their economic growth. Hydropower plants are essential for the sustainable development of renewable energy resources (Kuriqi et al., 2017a, b). In most emerging economies such as India, there exists a large amount of hydropower potential. Since 2000, China is doing remarkably well in its hydropower growth and reaches to a hydropower capacity of 341 GW in 2017 (IHA Hydropower Status Report, 2018). Small Hydro Power (SHP) is one of the most cost-effective and environment friendly choices to generate electricity (Luthra et al., 2015a) and may be used for rural electrification in the emerging economies including India (Khan, 2015).

In energy systems, sustainability assessments generally seeks to provide an integrated understanding of aspects related to environment, economic, societal, security and safety, operational and technological conditions to make the society more responsible and sustainable (Proskuryakova, 2018). In order to access sustainability in ESDM, various sustainability indicators need to be explored and required subsequent analysis for exact information on various aspects of energy systems and performance management from a country perspective.

The energy requirement is more in emerging economies such as India, China, Brazil and South Africa is much higher than the developed countries (Bellos, 2018; Fernando et al., 2018). The population of India is growing at an exponential rate. In order to cater the needs of growing population, India's energy consumption is also growing at a higher rate. Concurrently, India is meeting its most energy needs using coal and fossil fuel, which is environmentally unsustainable (Kanitkar et al., 2019). Furthermore, due to high emission into environment, the health issues related to air pollution are also raking up. In this sense, India is positioned at the 4th position in CO_2 emissions in the world (Dawn et al., 2019). Currently, India is at crossroad because on the one had there is growing need of energy for economy to grow to meet the basic needs of the larger population. On the other hand, issues related to environment pollution are causing distress. India needs to provide access to reliable sources of energy in a sustainable way. In fact, the world moving away from non-renewable source of energy to renewable sources likes wind, solar, biogas etc. Tropical countries, including India, are richly endowed with these renewable sources (Sindhu et al., 2016; Sharma and Balachandra, 2018). Indian Prime Minister, Mr. Narendra Modi, with his policies is aiming to give global recognition to the country as Innovation hub for renewable energy technology. This will further boost energy security, associated with reduced import dependence. Based on above discussed aspects, it is becoming increasingly important to conduct study to address sustainability in ESDM in India (Bhattacharyya, 2010; Srikanth, 2018).

Briefly, this work has three objectives, as follows:

i. To identify the indicators relevant to the effective sustainability assessment of ESDM;

ii. To understand causal interactions among the identified ESDM sustainability focused indicators; and

iii. To develop a research framework to organise the ESDM sustainability focused indicators for a practical applicability.

In order to meet above stated research objectives, firstly the extant literature for the topic proposed under study is explored. Later, the indicators are refined with the expert feedback to access their applicability in Indian context. Finally, Grey-DEMATEL (Decision-Making Trial and Evaluation Laboratory) technique is used to explore the deeper casual interactions among the indicators. The listed indicators are further organised into cause and effect categories. This work combines grey approach with DEMATEL to incorporate the inherent uncertainty that exists due to lack of information and/or human bias.

The remaining work in this study is placed as: Section 2 illustrates the theoretical development of the study. The sustainability indicators are presented in section 3. The methodology along with framework of present investigation is proposed in section 4. An application part of this framework is covered in section 5. Section 6 is provided with the discussion and implications of the study. Section 7 comprises of the sensitivity analysis followed by section 8 with concluding remarks and limitations.

2. Theoretical Background

Intensive literature review was performed using various key words e.g. Indicators/Drivers/Critical Factors/Metrics/Enablers/Variables and Sustainability Assessment and Energy Systems Management; Energy Systems Development, Planning and Management etc. for the collection of relevant data. In so doing, various databases including Emerald; ISI WoS; Science Direct; Taylor & Francis; Scopus; EBSCO; DOAJ; Inderscience and Wiley, were searched. Hence, this section contains the literature review on ESDM and Sustainability, indicators to ESDM for sustainability, and finally draws the knowledge gaps in following sub-sections.

2.1 ESDM and Sustainability

Energy is a must require component for satisfying the human daily routine needs or industrial based application tasks. Energy is also acting as a foremost player in economic and social growth, prosperity and ensuring sustainable growth of a nation (Nowotny et al., 2018). The concept of sustainable development in energy system is evolved recently; however, to trade-off between energy and economics is a very important aspect for nations in 1970. This was also due to the lack of understanding of association and importance between energy and the environment. Then, in 1980s, with the increase in ecological considerations and issues like climate change, ozone hole and depletion, the linkage and awareness for the balance between energy consumption and the ecological concern was also recognised (Dincer and Rosen, 2012; Bellos, 2018). Further, according to the Copenhagen meeting in 2009, the experts from various nations of the world were gathered and discussed on climate change related issues and showed an agreement to achieve a reduction of global warming temperature by 2 degrees in 2050 (Rogelj et al., 2016). Dealing with climate change related issues means transformation in the energy system through decarburisation in the generation of power with no compromise on energy efficiency (Verbruggen and Laes, 2015).

ESDM is an initiative that works on the development and management of new or existing energy plants and systems in a most sustainable way. In line with this, the suitable utilisation of energy definitely leads to grow sustainably by managing its energy resources. However, to achieve sustainability in energy, a balance between energy demand-supply is required and further to this, some efficient alternatives can also be preferred to meet global energy demand.

In today's scenario, there is lack of sustainability initiatives and assessments in energy systems and their management. The reason behind this is intense power demands, growing population, lack of awareness and knowledge, increased economic growth. Sustainability assessment in ESDM can help in developing dynamics of energy system development (flexibility, adaptability) and finding challenges in management of new energy plants, and external and internal factors involved in development of new energy systems. Sustainability assessment in ESDM can be understood as the course of action to incorporate sustainability aspects into decision-making by recognising and analysing the ESDM focused sustainability impacts to encourage sustainable development goals (Holden et al., 2014). A concise summary of recent contributions in sustainability assessment in the ESDM is given in Table 1.

Table 1: Recent contributions towards sustainability assessment in ESDM

S. No.	Reference	Description of work	Research methods	Application (area)
1	Bhattacharyya (2010)	Discussed about the future of sustainable energy systems in India	Literature review	Energy sector
2	Carrera and Mack (2010)	Social aspects of sustainability of energy system are analysed. Various energy technologies are evaluated.	Literature review and experts opinions	Energy technologies
3	Winfield et al., (2010)	Proposed a model to assess environmental sustainability of energy industry of Ontario.	Literature review and Case study approach	Electricity system design
4	Doukas et al. (2012)	Evaluated the environmental emission of power sector in rural region and proposed energy sustainability index for European communities.	Principal Component Analysis	Sustainable energy patterns
5	Sovacool (2013)	Suggested a model to assess the performance of energy security as	Case study approach	Energy security

		well as developed an energy security index in Japanese context		
6	Dombi et al. (2014)	Analysed the environment emission for energy used for heat generation in Hungary.	Choice experiment (CE) survey	Renewable energy technologies
7	Liu (2014)	Assessed the sustainability of renewable energy technologies.	Literature review	Renewable energy systems
8	Mattiussi et al. (2014)	Proposed a decision model for sustainable technology selection	multi-objective and multi-attribute decision-making	Energy supply
9	Maxim (2014)	Assessed the sustainability of power generation technologies in Romania	Weighted multi-criteria decision analysis	Electricity generation technologies
10	Milutinović et al. (2014)	Proposed a framework for waste treatment along with energy recovery in Serbia.	Analytic hierarchy process	Waste treatment Scenarios
11	Santoyo-Castelazo and Azapagic (2014)	Based on life cycle approach, the sustainability of energy systems was assessed in Mexico	Multi-criteria decision analysis	Electricity production
12	Luthra et al. (2015b)	Assessed the environmental emission for planning and development of energy sector in India.	Fuzzy Analytic hierarchy process.	Energy planning and management
13	Verbruggen and Laes (2015)	Assessed the sustainability of nuclear power plants in Belgium	Disclosure analysis	Nuclear energy
14	Nie et al. (2016)	Developed a mathematical model for planning the renewable energy system under uncertainty	Interval type-2 fuzzy fractional programming method	Renewable energy planning
15	Bhowmik et al. (2017)	Literature review for green energy planning and scheduling	Literature review	Green energy planning
16	Kumar et al. (2017)	Made literature review on decision making methods towards sustainable renewable energy development.	Literature review	Renewable energy development
17	Ervural et al. (2018)	Prioritised various alternative energy strategies for effective energy planning and management.	ANP and fuzzy TOPSIS-based SWOT analysis	Energy planning

18	Liu et al. (2018)	Made literature review on forecasting techniques of energy demand resources, energy models and planning of energy systems especially in isolated areas.	Literature review	Energy systems planning
19	Wretling et al. (2018)	Examined current energy planning practice in Sweden.	mixed-methods (quantitative and qualitative approach)	Energy planning
20	Karunathilake et al. (2019)	Proposed renewable energy screening and energy selection framework by considering triple bottom line sustainability	Fuzzy TOPSIS	Energy planning

From the above Table 1, it can be concluded that sustainability assessment in ESDM is not much covered in the literature. Most of papers are on literature review as the concept is still in its early stages.

2.2 Related Indicators for Assessing the Sustainability of ESDM

Sixteen indicators were selected through literature and two indicators through experts' input for sustainability assessment in ESDM (for more details refer Section 4.1). These eighteen indicators were further classified into five dimensions of indicators (Social and security related indicators; Technology and operational related indicators; Political and legal related indicators; Economic related indicators; and Environmental related indicators) through expert feedback. The listed dimensions and indicators are provided (see Table 2).

Table 2: The indicators and dimensions for the sustainability assessment of ESDM with sources

Indicators	**Description**	**Sources**
Social and Security Related Indicators		
Energy security and safety (I1)	Energy security and safety concerns with consistent availability and safety in production, transmission and uses of energy. Energy safety and security is a key concern because of very high energy demands.	Santoyo-Castelazo and Azapagic 2014; Luthra et al. 2015b; Shortall et al. 2015; Banshwar et al., 2018

Societal equity and acceptance (I2)	Societal equity and acceptability is significant in implementation of sustainability in energy systems. For example, nuclear energy production is risky to locality. Generally it is believed that waste generated from plant will harm environment.	Santoyo-Castelazo and Azapagic 2014; Sovacool and Dworkin, 2015; Jenkins et al., 2018
Risk/uncertainty analysis and management (I3)	Risk/uncertainty analysis and management of the energy systems is very significant in knowing the economic and ecological costs associated with their deployment.	Ness et al. 2007; Winfield et al. 2010; Evans et al. 2012; McLellan and Corder 2013; Luthra et al. 2015b; Cardin et al., 2017
Employment generation and people welfare (I4)	The decisions of sustainable development in energy systems are important in improving the people living standards, societal developments, employment generation and people welfare and economy from a nation perspective.	Holden et al. 2014; Lorek and Spangenberg 2014; Terrapon-Pfaff et al. 2014; Bhattacharya et al., 2016
Technology and Operational Related Indicators		
Adoption and up-gradation of technological advancements (I5)	Technology plays a key role in reduction in environment emission and social development. The adoption of innovative technology in terms of knowledge, right applicability, up gradation will help to minimise its environmental footprint and reduce wastage of resources and energy consumptions as well.	Evans et al 2012; Singh 2015; Jamasb et al., 2018
Optimal resource allocation and utilisation (I6)	Resource allocation and its optimal use directly affect the issues related to energy consumptions and greenhouse gas emissions. Thus, in order to minimise non-renewable material source consumption and use them efficiently, there is a need to the development of intelligent hybrid energy systems for optimal resource allocation and utilisation.	Nema et al. 2009; Beloglazov et al. 2012; Lee and Zomaya 2012; Chauhan and Saini 2014; Siddaiah and Saini 2016
Developing system capabilities in terms of its resilience, reliability, flexibility and diversification (I7)	Development of innovative technologies in renewable energy sector can provide consistent and uninterrupted power supply. The new sustainable and energy efficient sources should be scalable and flexible. The new fuel cell technology, advance in battery technology and smart grid systems are key steps in this aspect.	Soriano and Mulatero 2011; Biresselioglu et al., 2017; Mazur et al., 2019
Political and Legal Related Indicators		

Political stability (I8)	Political stability is crucial in sustained (economic-ecological-social) growth. A stabilised political system can help policy makers in meeting energy requirements more sensibly, since the energy reservoirs are not evenly distributed.	Carrera and Mack 2010; Giampietro et al. 2013; Naser, 2015; Bakirtas and Akpolat, 2018
Democratic governance and legitimacy (I9)	It refers to development of sustainability focused energy management related guidelines, and constant supervising of their appropriate implementation, by the members of the governing body of an organisation (private and public).	Carrera and Mack 2010; Sala et al. 2015; Burke and Stephens, 2018; Martinico-Perez et al., 2018
Building a socio-ecological focused regulatory system (I10)	Socio-ecological focused regulatory system means regulations associated with many dimensions of system functioning and development of normative societal goals for higher sustainability	Experts' input
Economic Related Indicators		
Energy cost-in-time effectiveness (through Capital and energy levelised cost) (I11)	It represents the efficiency and effectiveness of energy system in meeting the energy requirements and consumption related issues with minimum costs during a period of time. This can be achieved through by taking into account the capital and energy levelised costs.	Boardman et al. 2014; Maxim 2014; Santoyo-Castelazo and Azapagic 2014; Wu et al., 2017
Higher return on investments and competitive advantages (through NPV analysis) (I12)	Feasible return on investment and sustained competitive advantages should be used to evaluate and select the suitable energy technology. For example, solar energy technology is considered costly as compared to coal in India. Generally, NPV analysis is used, which is significant in analysing the future of sustainable energy systems.	Evans et al. 2012; Aman et al. 2015; Lang et al. 2015; Jenkins et al., 2016; Ritzenhofen and Spinler, 2016
Investment opportunities and generation of funds (I13)	There are numerous opportunities of investment in energy sectors and their effects could be decreased energy consumption, lowered pollution and waste generation, managed time and traffic issues by investing in more compact cities. This will further leads to increase in energy efficiency, generation of funds and sustainable growth in ESDM.	Watson et al. 2010; Bhattacharya et al. 2015; Kursun et al. 2015; Paramati et al., 2016; Paramati et al., 2018
Cost benefits through reduction in emissions generation (I14)	Cost benefits in ESDM can be achieved through switching to alternative sources of energy like wind, solar. This would help in reducing carbon emissions.	Experts' input

Environmental Related Indicators		
Lowering resources consumptions and related impacts (such as material, fuel, land etc.) (I15)	Sustainable development in ESDM can help in lowering the resources (raw material) consumption and managing their negative ecological impacts such as fossil fuel conservation, land management etc.	Santoyo-Castelazo and Azapagic 2014; Terrapon-Pfaff et al. 2014; Bhattacharya et al., 2016; Dermody et al., 2018
Managing carbon emissions and climate related issues (I16)	Implementation of sustainable initiatives in ESDM can help in managing the carbon emissions and climate change related issues such as global warming, greenhouse gas emissions, ozone layer depletion.	Olivier et al. 1998; Pervanchon et al. 2002; Kang and Banga 2013; Prakash et al. 2014; Fernando and Hor, 2017; Fernando et al., 2018
Waste minimisation and management (I17)	Sustainable development in ESDM is important in waste generation and management. Waste management policy promotes minimisation, sorting, disposal, recycling and energy recovery from non-dangerous solid wastes.	Buytaert et al. 2011; Eriksson et al. 2014; Samolada and Zabaniotou 2014; Zhang et al., 2017
Adoption of energy management systems (ISO 50001:2011) (I18)	Adoption of energy management system in terms of certifications like ISO 50001 serves as a model of continuous improvement of energy systems.	Chiu et al. 2012; International Standard Organisation (ISO) 2016; McKane et al., 2017; Fernando et al., 2018

2.3 Knowledge Gaps

In order to manage the issues of climate change, the sustainable energy development is a well opted choice to use (Blanco et al., 2017; Fernando et al., 2018). Considering the case of developed nations, the sustainability seeks to address environmental concern while, in case of developing nations, the issues related to society like prosperity and poverty need to be addressed in assessing the sustainability of ESDM (Sarkar, 2010; Muhumuza et al., 2018). Although, some researchers have addressed the issues of energy sustainability assessment in developed nations; yet there is lack of studies in addressing the subject in developing nations, particularly in India (Bhattacharyya, 2010; Manju and Sagar, 2017; Rathore et al., 2019).

Among emerging national economies, with GDP of 6.2% in fiscal 2014, India has emerged as a significant global economy. Simultaneously, the issues related to energy security and demand are also emerging due to considerable change in price structure of fossil fuels and imported energy and continuous depletion in the energy reserves (Chu and Majumdar, 2012; Sebri and Ben-Salha, 2014; Jana et al., 2018). Thus, country is forced to meet their energy demands through energy imports and lower their negative environmental impacts (Hadian and Madani, 2015; Kumar and Madlener, 2016). In this scenario, ESDM becomes necessary for a country to distinguish its economic growth and industrial development along with its climate change impacts and environmental risk (Evans et al., 2012; Shahbaz et al., 2016; Ansell and Cayzer, 2018). In addition, there is an urgent need for affordable, environmentally friendly and sustainable energy systems and sustainable energy development in Indian context (Rathore et al., 2019).

ESDM is a group of processes, methods and initiatives that can helps industrial plants, governmental facilities, and business organisations to either develop the new energy systems or manage the energy requirements in existing system on a continuing basis for higher control and improvement in energy performance. ESDM represents an important prospect for organisations to reduce their energy use while improving the overall performance and productivity (Mertzanis, 2018). It has also been anticipated that energy consumption could be decreased up to 10% to 40% after the effective implementation of ESDM in an industrial viewpoint. This is clearly an indication that how important could be the initiatives of ESDM in managing the energy issues in modern industrialisation.

Further, the sources of energy production vary from one country to another. Similarly, the available options for renewable sources also vary. Furthermore, sensitivity and priorities with environment and social aspects of sustainability is also different among developed and developing countries. An effort has been made in this study to address key questions with respect to consideration of sustainability criteria in ESDM in India. Firstly, the sustainability measures for ESDM are identified from the available literature. Later, the indicators are refined with the expert feedback. Then, the cause and effect relationship between indicators are revealed using grey-DEMATEL approach. The combining of grey theory with DEMATEL aids in incorporating uncertainties into causal analysis. This study is an original effort to propose a sustainability assessment and implementation framework ESDM in Indian context.

3. Solution Methodology

In this paper we have used grey based DEMATEL approach as solution method. The proposed research framework is provided in below Figure 1.

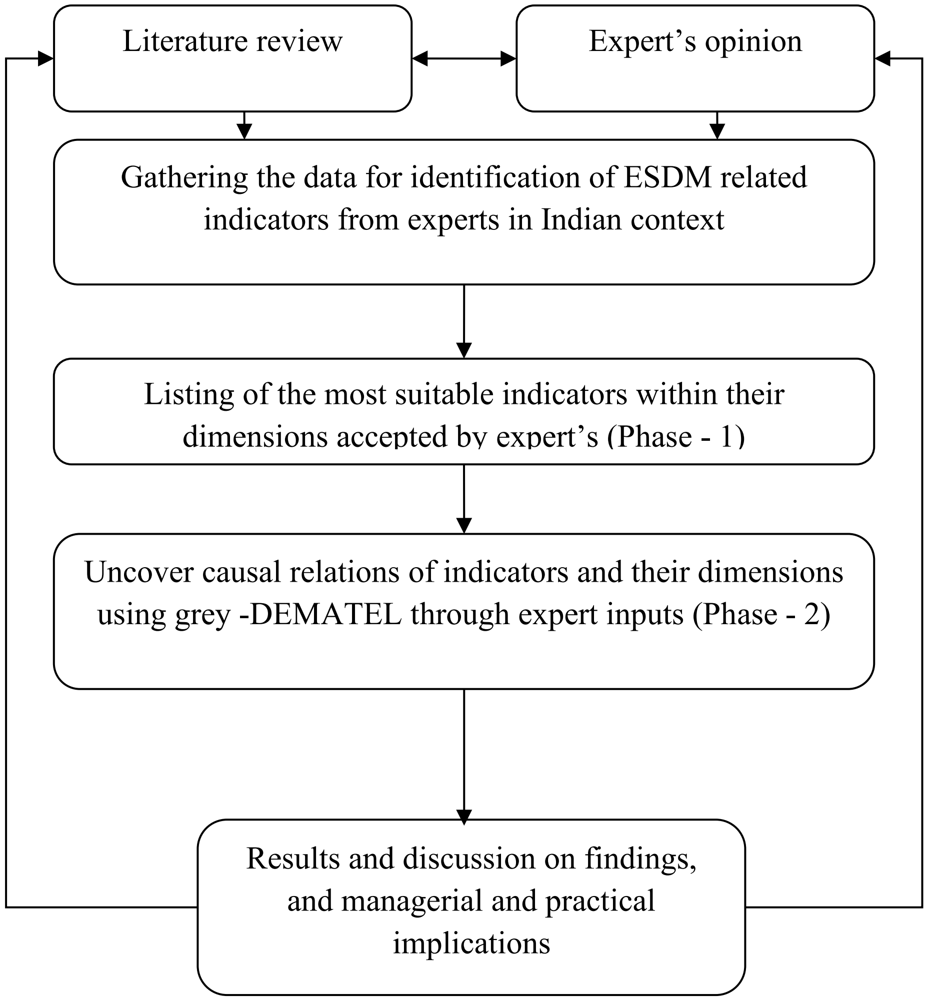

Figure 1: Research framework

DEMATEL can examine the inter-relationship between the factors (Gandhi et al., 2016; Thankur and Mangla, 2019). As compared to other decision making techniques, viz. ANP (Analytic Network Process), which is used to analyse criteria and alternatives that have very strong interactions and may also have a high effect in the decision making (Jharkharia and Shankar, 2007). However, the ANP is also not preferred by decision makers due to i) complexity in use, ii) problem in understanding. On the other hand, DEMATEL gains a significant recognition, as it assists having a sensible idea of the causal interactions among decision criteria (Falatoonitoosi et al., 2014; Mangla et al., 2016).

In practical situations, decision making may involve inconsistent surroundings due to human bias and unclear information (Xia et al., 2015). In this sense, fuzzy concepts can be integrated with the DEMATEL; however, fuzzy based DEMATEL also fails in mapping a membership function. As a result, this work attempts to integrate grey set theory (Ju-Long, 1982) with DEMATEL to make more sensible decisions and deal with human bias (Liu and Forrest, 2010). Thus, this work applied the grey DEMATEL approach (Bai and Sarkis, 2013; Zhu et al., 2015) to study the interrelationships between the indicators and represent the same in the form of causal diagram. Further, the application of Grey-DEMATEL methodology in various areas is shown in Table 3.

Table 3: Studies on Grey-DEMATEL as reported in literature

S. No.	Sources	Description
1	Luthra et al. (2018)	Modelled critical success factors for supply chain sustainability
2	Lin et al. (2018)	Analysed risk to new energy power system
3	Ren et al. (2017)	Analysed critical barriers to the sustainable development of sludge-to-energy industry
4	Shao et al. (2016)	Analysed the gap in consumers' purchasing intention of green products
5	Asad et al. (2016)	Modelled supply chain flexibility in information technology enabled supply chain
6	Rajesh and Ravi (2015)	Analysed the cause effect relationship between the enablers to mitigate risk in electronic supply chain.
7	Özdemır, and Tüysüz (2015)	Analysed the strategies of universities

The steps included in grey–DEMATEL method are explained as follows.

Step 1: Developing initial relationship matrix (R): Let "c" be the number of identified factors and "n" be the number of respondents. Each respondent is requested to evaluate the factors (x vs. y) on a scale of 0 to 5, where 0 signifies no influence and increases gradually to 5 signifying very high influence respectively. Same is represented in Table 4.

Table 4: Grey scale used for his work

Linguistics assessment	Crisp values	Assigned grey numbers
No Influence (N)	0	(0, 0.1)
Very Low Influence (VL)	1	(0.1, 0.3)
Low Influence (L)	2	(0.2, 0.5)
Medium Influence (M)	3	(0.4, 0.7)

High Influence (H)	4	(0.6, 0.9)
Very High Influence (VH)	5	(0.9, 1.0)

Step 2: Calculation of corresponding grey matrices ($\otimes A_{xy}^{l}$): In this step, the initial relationship matrix is converted into equivalent grey matrices, i.e.

$$\otimes A_{xy}^{l} = \left(\underline{\otimes} A_{xy}^{l}, \overline{\otimes} A_{xy}^{l}\right) \tag{3.1}$$

Step 3: Determination of average grey matrix ($\otimes \check{A}_{xy}$) using equation (5.2).

$$\otimes \check{A}_{xy} = \left(\sum_{l} \frac{\underline{\otimes} A_{xy}^{l}}{n}, \sum_{l} \frac{\overline{\otimes} A_{xy}^{l}}{n}\right) \tag{3.2}$$

Step 4: Calculation of crisp relationship matrix (B): Modified-CFCS (Converting Fuzzy data into Crisp Scores) method is used to concert the grey number into crisp number (Please check supplementary file for more details of CFCS method). Further, the method had been explained by (Luthra et al., 2018) in their work.

Step 5: Develop the normalised direct-relation matrix (N).

$$L = \frac{1}{\max_{1 \le x \le c} \sum_{y}^{c} a_{xy}} \tag{3.3}$$

$$N = L * R \tag{3.4}$$

where, L is the normalisation factor and R is initial relationship matrix.

Step 6: Calculation of total relation matrix (T).

$$T = N(I - N)^{-1} \tag{3.5}$$

I – Identity matrix.

Step 7: Obtaining causal parameters 'D' and 'R'. These are calculated through equations (3.6) and (3.7):

$$R = \left[\sum_{y=1}^{c} a_{xy}\right]_{c \times 1} \tag{3.6}$$

$$D = \left[\sum_{y=1}^{c} a_{xy}\right]_{1 \times c} \tag{3.7}$$

Step 8: Plot the causal diagram. The values (R+D) denotes 'Prominence', on the other hand, the values (R-D) signifies 'Relation'. The value (R-D) also assists in dividing the factors into cause and effect groups.

4. Data Analysis and Results

The proposed framework was employed in Indian context. In order to analyse the issue; an expert panel of five experts was formed. Among five experts, two are senior project managers; one academician; one forest ministry environmental representative; and one statistics implementation and climate change allied representative. Luthra et al. (2018) used 5 experts in their research and suggested that more number of experts in Grey- DEMATEL may increase the data handling complexity. The individuals with on-job experience in the field of Energy Systems Management and Sustainability and Managing Environmental issues in Energy systems were considered. Also, the selected experts are highly experienced in this domain. After the formation of the expert panel, the proposed framework is applied.

4.1 Phase 1 - Finalisation and Validation of the Indicators

From literature, this work listed 16 key indicators. To appraise their applicability in Indian context, the expert panel rated these factors on 5-point Likert scale. Furthermore, these experts were requested to add any other relevant indicator as well.

The feedback received was evaluated and 2 more indicators were added to the initial literature identified 16 indicators. The two indicators added were 'Building a socio-ecological focused regulatory system' and 'Cost benefits through reduction in emissions generation'. The finalised 18 common indicators were then again confirmed to experts' feedback for categorising into five main indicators based on the meaning and similarities among the indicators.

4.2 Phase 2 - Analysis of Final Listed Indicators to Uncover Causal Relations

The Likert scale is used to capture expert opinion on role of identified indicators. The experts rated the indicators on five scale points. Firstly, the initial direct matrices were formulated. For instance, the direct matrix of expert 1 is shown in supplementary file. Further, the reported response from expert panel may contain human judgment bias. In order to capture this biasness, the initial relationship matrices need to transform into grey valued matrices. The equal weightage has been assigned to all five experts (0.2 each expert) while calculating the average grey relationship matrix$\left[\otimes \breve{A}_{xy}\right]$. The same is shown in supplementary file. The modified-CFCS method to obtain the crisp relationship matrix (shown in Table 5) from average grey relationship matrix is used.

Table 5: The crisp relation matrix (B) for indicators

Indicators	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	L12	I13	I14	I15	I16	I17	I18
I1	0.00	0.48	0.53	0.32	0.41	0.70	0.51	0.51	0.70	0.42	0.46	0.29	0.48	0.53	0.51	0.29	0.29	0.48
I2	0.51	0.00	0.53	0.27	0.51	0.51	0.51	0.75	0.27	0.51	0.75	0.53	0.53	0.53	0.27	0.53	0.13	0.29
I3	0.70	0.34	0.00	0.51	0.75	0.51	0.27	0.27	0.27	0.47	0.51	0.53	0.29	0.13	0.12	0.29	0.29	0.34
I4	0.28	0.29	0.13	0.00	0.27	0.27	0.12	0.12	0.12	0.19	0.27	0.29	0.29	0.29	0.12	0.29	0.13	0.13
I5	0.51	0.53	0.29	0.51	0.00	0.27	0.51	0.75	0.46	0.51	0.51	0.44	0.29	0.53	0.51	0.48	0.53	0.29
I6	0.42	0.53	0.48	0.27	0.51	0.00	0.51	0.32	0.27	0.51	0.51	0.44	0.48	0.53	0.75	0.53	0.48	0.29
I7	0.37	0.29	0.29	0.51	0.46	0.51	0.00	0.46	0.75	0.70	0.75	0.53	0.48	0.53	0.51	0.29	0.29	0.34
I8	0.47	0.53	0.53	0.51	0.51	0.75	0.75	0.00	0.51	0.51	0.51	0.48	0.29	0.53	0.27	0.29	0.29	0.34
I9	0.51	0.53	0.29	0.32	0.27	0.27	0.27	0.51	0.00	0.47	0.51	0.29	0.29	0.34	0.46	0.53	0.53	0.53
I10	0.47	0.53	0.53	0.51	0.27	0.51	0.51	0.51	0.46	0.00	0.32	0.34	0.29	0.48	0.51	0.53	0.29	0.29
I11	0.28	0.29	0.29	0.12	0.19	0.12	0.12	0.27	0.27	0.28	0.00	0.29	0.29	0.29	0.27	0.13	0.29	0.29
I12	0.12	0.13	0.29	0.12	0.27	0.27	0.27	0.27	0.12	0.12	0.12	0.00	0.34	0.29	0.12	0.13	0.13	0.29
I13	0.28	0.34	0.29	0.27	0.12	0.12	0.12	0.12	0.27	0.32	0.27	0.13	0.00	0.13	0.12	0.29	0.29	0.13
I14	0.32	0.34	0.13	0.12	0.12	0.18	0.15	0.12	0.32	0.28	0.27	0.29	0.16	0.00	0.15	0.13	0.20	0.13
I15	0.37	0.20	0.29	0.41	0.35	0.35	0.35	0.27	0.27	0.28	0.27	0.45	0.36	0.28	0.00	0.34	0.36	0.34
I16	0.37	0.53	0.34	0.27	0.27	0.43	0.38	0.27	0.27	0.30	0.32	0.31	0.31	0.28	0.27	0.00	0.34	0.34
I17	0.37	0.29	0.29	0.51	0.43	0.27	0.27	0.27	0.35	0.28	0.51	0.36	0.36	0.29	0.27	0.36	0.00	0.29
I18	0.51	0.48	0.53	0.75	0.27	0.27	0.27	0.46	0.27	0.51	0.51	0.53	0.53	0.29	0.51	0.48	0.39	0.00

Using above values, Normalised direct relation matrix (N) is calculated and represented in supplementary file.

Thereafter, the total relation matrix (T) is determined as shown in Table 6.

Table 6: Total relationship matrix for indicators

Indicators	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	L12	I13	I14	I15	I16	I17	I18
I1	0.20	0.25	0.24	0.22	0.22	0.27	0.23	0.24	0.26	0.25	0.27	0.22	0.23	0.25	0.23	0.21	0.19	0.21
I2	0.26	0.19	0.24	0.21	0.23	0.24	0.23	0.27	0.21	0.25	0.30	0.25	0.24	0.25	0.20	0.23	0.17	0.18
I3	0.25	0.20	0.15	0.21	0.23	0.22	0.18	0.19	0.18	0.22	0.24	0.22	0.18	0.17	0.16	0.18	0.16	0.17

I4	0.12	0.12	0.09	0.08	0.11	0.11	0.09	0.10	0.09	0.11	0.13	0.12	0.11	0.12	0.09	0.11	0.08	0.08
I5	0.26	0.25	0.21	0.24	0.17	0.22	0.23	0.27	0.23	0.25	0.27	0.24	0.21	0.25	0.22	0.23	0.21	0.18
I6	0.24	0.25	0.23	0.21	0.23	0.18	0.23	0.21	0.20	0.25	0.26	0.23	0.23	0.24	0.25	0.23	0.20	0.18
I7	0.24	0.22	0.21	0.23	0.22	0.24	0.17	0.23	0.26	0.27	0.29	0.25	0.23	0.24	0.23	0.20	0.19	0.19
I8	0.26	0.26	0.24	0.24	0.24	0.28	0.26	0.19	0.24	0.26	0.28	0.25	0.22	0.25	0.21	0.21	0.19	0.19
I9	0.23	0.23	0.19	0.20	0.19	0.20	0.19	0.22	0.15	0.22	0.25	0.20	0.19	0.20	0.20	0.21	0.20	0.19
I10	0.24	0.24	0.23	0.23	0.20	0.23	0.22	0.23	0.22	0.18	0.24	0.22	0.20	0.23	0.22	0.22	0.18	0.17
I11	0.14	0.13	0.13	0.11	0.11	0.11	0.10	0.13	0.12	0.13	0.11	0.13	0.13	0.13	0.12	0.10	0.11	0.11
I12	0.10	0.10	0.11	0.09	0.11	0.11	0.11	0.11	0.09	0.10	0.11	0.08	0.12	0.11	0.09	0.09	0.08	0.10
I13	0.12	0.13	0.12	0.12	0.10	0.10	0.09	0.10	0.11	0.13	0.13	0.10	0.08	0.10	0.09	0.11	0.10	0.08
I14	0.12	0.12	0.09	0.09	0.09	0.10	0.09	0.10	0.11	0.12	0.13	0.12	0.10	0.08	0.09	0.09	0.09	0.08
I15	0.18	0.16	0.16	0.17	0.16	0.17	0.16	0.16	0.15	0.16	0.18	0.18	0.16	0.16	0.12	0.16	0.15	0.14
I16	0.19	0.20	0.17	0.16	0.16	0.18	0.17	0.16	0.16	0.18	0.19	0.17	0.17	0.17	0.15	0.12	0.15	0.15
I17	0.18	0.17	0.16	0.19	0.17	0.16	0.15	0.16	0.16	0.17	0.21	0.18	0.17	0.16	0.15	0.16	0.11	0.14
I18	0.24	0.23	0.22	0.25	0.19	0.20	0.19	0.22	0.19	0.24	0.25	0.23	0.22	0.20	0.21	0.21	0.18	0.14

The sum of row $[r_x]_{n\times 1}$ and column $[d_y]_{1\times n}$ elements of the overall relation matrix T is given by vectors R and D respectively. The sum of the row elements (vector R) presents the direct and indirect effect of an indicatory x towards other indicators. The sum of the column elements (Vector D) presents the effects (direct and indirect) as received by an indicator y from all other indicators. This work obtained the 'Prominence' by adding the vector R and D whereas, the 'Relation' is obtained by subtracting the vector D from vector R. The calculated values are given in Table 7.

Table 7: Prominence' (R+D) and 'Relation' (R-D) for indicators

Indicators	R	D	R+D	R-D
I1	4.20	3.56	7.76	**0.63**
I2	4.13	3.48	7.62	**0.65**
I3	3.51	3.19	6.70	**0.32**
I4	1.87	3.24	5.11	-1.38
I5	4.13	3.14	7.27	**0.99**
I6	4.05	3.32	7.36	**0.73**
I7	4.11	3.11	7.21	**1.00**
I8	4.26	3.29	7.55	**0.98**
I9	3.67	3.14	6.81	**0.53**
I10	3.87	3.47	7.35	**0.40**
I11	2.16	3.83	5.98	-1.67

I12	1.82	3.40	5.22	-1.57
I13	1.92	3.18	5.10	-1.26
I14	1.82	3.31	5.13	-1.50
I15	2.87	3.02	5.89	-0.14
I16	3.01	3.08	6.09	-0.08
I17	2.96	2.74	5.71	**0.22**
I18	3.84	2.70	6.54	**1.14**

The diagram presenting causal effects of indicators is obtained from table 7 column 4 (sum of R+D) and column 5 (subtraction R-D), other details are given in Figure 2.

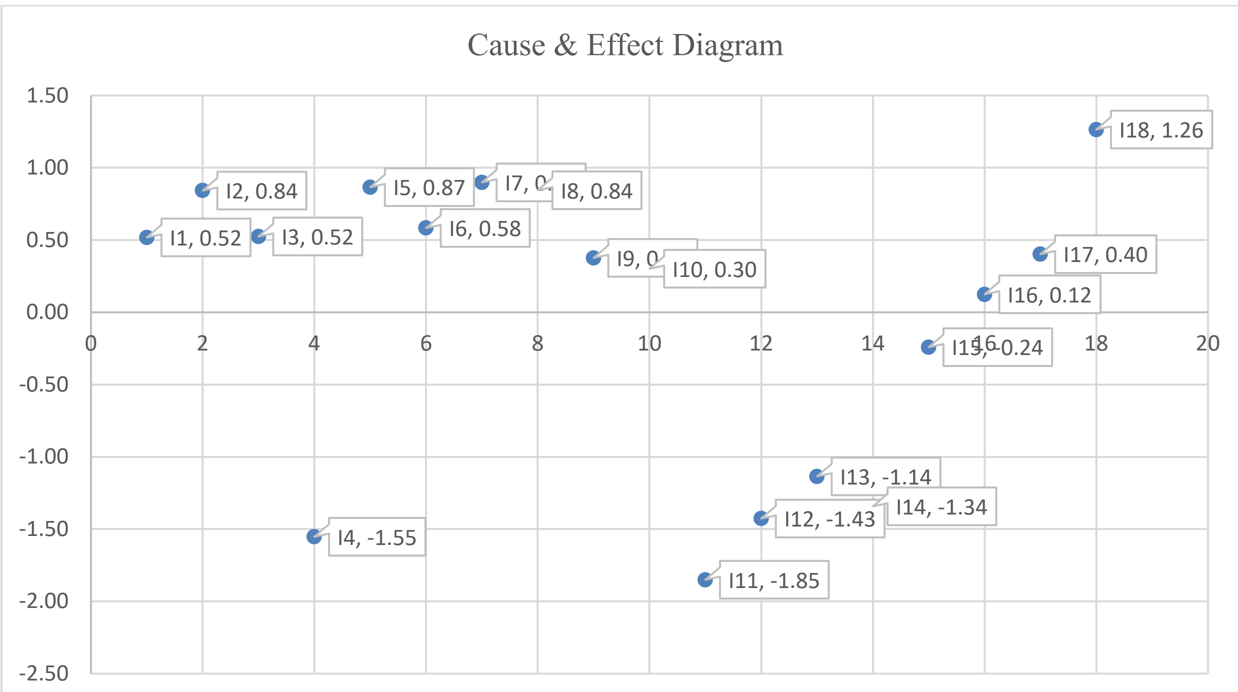

Figure 2: Cause and effect diagram

From Figure 2, it can be deduced that eleven indicators are fitted to cause group and seven indicators fitted to the effect group for effective sustainability assessment of ESDM.

5. Discussion of Findings

The findings of this work are discussed with the expert panel to explore and understand the contemporary energy management and development hurdles encountered by them during the process. The findings further give valuable insights in understanding the different critical indicators, their causal interactions and the preferences in decisions of implementing ESDM.

5.1 Influencing Indicators

The cause/influencing group indicators are vital, so it is important to concentrate on them. Among all the influencing group indicators, 'Adoption of energy management systems (ISO 50001:2011) (I18)' with highest relation (R–D) score represents that I18 has more influence on the overall system, however, its prominence(R+D) score, which is relatively low, could be understood by the justification that awareness of ISO 50001:2011 is quite low among Indian industries. The fact is that an organisation must implement monitoring and targeting energy management systems measures to get better energy efficiency (Vikhorev et al., 2013; McKane et al., 2018). The second highest relation score indicator is 'Developing system capabilities in terms of its resilience, reliability, flexibility and diversification (I7)', which also suggests that it is influencing other indicators. Energy system must develop system capabilities in terms of its resilience, reliability, flexibility and diversification to meet energy requirements in India (Harish and Kumar, 2014). 'Adoption and up-gradation of technological advancements (I5) is next important indicator. It shows its tendency in influencing other indicators in implementing ESDM initiatives; while its R score is 4.13, which is greater than the score of Developing system capabilities in terms of its resilience, reliability, flexibility and diversification'. India needs smart technologies and technological up gradations towards sustainability energy systems development (Garg et al., 2017). Next, Political stability (I8)' obtain fourth rank in terms of their influence with R-D score of 0.98. It means that the political stability is the main indicator that affects the selection of appropriate energy technologies (Naser, 2015). Next, important indicator based on R-D score is 'Optimal resource allocation and utilisation (I6)'. This indicates the proper allocation of resource for development of renewable energy sources should be key consideration in adopting ESDM concepts (Woldeyohannes et al., 2015; Siddaiah and Saini 2016). Further, the indicators 'Societal equity and acceptance (I2)' and 'Energy security and safety (I1)' hold sixth and seventh ranks respectively in terms of their influence on the other indicators. It means that societal equity and acceptance; and energy security and safety are key concerns that must be considered in adopting ESDM concepts and policy development. However, the influential impact (R) score of 'Energy security and safety (I1)'is higher than the 'Societal equity and acceptance (I2)'. It means that a proper care of huge demands and health issues arising from energy systems should be in developing energy systems (Luthra et al., 2015b). In addition to this, ‘Energy security and safety (I1)’has the highest R+D score (7.76), indicates the importance of availability of consistent supply of energy for long run and its safety during production, transmission and usages. Contemporary economies depend on a consistent and sufficient energy supply, and developing countries require securing this as a requirement for industrialisation (Mohsin et al., 2018). Next, is the indicator ‘Democratic governance and legitimacy (I9)’, it plays a significant role in achieving energy security along with development of sustainability energy systems (Sovacool and Dworkin 2015; Burke and Stephens, 2018). The indicator ‘Building a socio-ecological focused regulatory system (I10)’ is also imperative. This will further helps in creating synergies between economic and technological development (Hodbod and Adger, 2014; Hildingsson and Johansson, 2016). Next, ‘Risk/uncertainty analysis and management (I3)’ is essential in framing the mitigating strategies to manage the societal and ecological issues during the project development stages in the implementation of ESDM. Finally, the indicator ‘Waste minimisation and management (I17)’ helps organisations to obtain gain of a strategic approach in energy systems development with the objective of landfills minimisation and encouraging to more sustainable ways of using resources (Zhang et al., 2017).

5.2 Influenced Factors

The effect group indicators have tendency to get influenced by other indicator. ‘Managing Carbon emissions and climate related issues (I16)’ with the highest R-D score (-0.08) is significant in the management of energy systems related activities. This means that governmental institutions and industrial managers must work to address to climate related issues in energy systems to achieve successful low carbon industrial development (Geng et al., 2016). ‘Lowering resources consumptions and related impacts (I15)’ indicator comes next suggesting that ESDM helps in optimising the resource consumption related issues and their negative impacts in an efficient way (Liu et al., 2015). The other indicators in the effect group, include ‘Investment opportunities and generation of funds (I13)’with R-D score (-1.26) and ‘Employment generation and people welfare (I4)’ with R-D (-1.38). From a nation perspective, ESDM implementation initiatives can generate investment opportunities, which will enhance the living standards, employment generation, people welfare and reducing poverty (Bhattacharya et al., 2016). The other indicator, ‘Cost benefits through reduction in emissions generation (I14)' with R-D (-1.50) can help to improve the reducing costs related to carbon emissions and raises opportunities for economic and social development by implementing ESDM sustainable initiatives (Luong et al., 2012). The next indicator, 'Higher return on investments and competitive advantages (through NPV analysis (I12)' has an R-D score (-1.57) presents that regulating the other indicators can assist in integrating the economic and competitive advantages in ESDM adoption, and therefore, may assure sustainable development (Van Eijck et al., 2014; Ritzenhofen and Spinler, 2016). Finally, 'Energy cost-in-time effectiveness (through Capital and energy levelised cost) (I11)' has the smallest R-D score (-1.67), which suggests that this indicator receives the highest influence from all other indicators. It is necessary to put directed efforts to improve energy efficiency in cost-in-time effective way in support of good energy management systems (Luthra et al., 2015a).

5.3 Research Implications

The policy makers, decision experts and specialists as well as practitioners with the help of this work will find it easy to identify and assess sustainability of ESDM initiatives. Grey-DEMATEL technique distinguishes the mechanism that how the various indicators are interrelated through their causal interactions. Understanding of causal interaction among and between various indicators can improvise the efficiency of sustainability decisions in ESDM from Indian viewpoints. The cause and effect classified indicators will help to frame policies more oriented towards performance and results. The findings obtained will assist policy makers to identify several means to diminish the ecological and social impacts associated with the traditional energy systems. This work further proposes several policy measures for effective sustainability assessment for ESDM in Indian perspective, as follows:

- ✓ *Regulatory support in sustainability focused initiatives in ESDM*: Regulatory support and motivation is important for adoption of sustainability focused activities in ESDM. This may encourage the ESDM related sustainability oriented initiatives and results in enhanced performance.
- ✓ *Understanding energy requirements and educate society for ESDM*: The work provides grounds to educate people about sustainability in ESDM. Seminars and training programs may be conducted to enhance the performance of sustainability oriented activities in ESDM.

- ✓ *Understand system requirements and allocation of financial aids for ESDM initiatives*: The financial aids form the basis of any new development or inculcating any sustainability oriented initiatives in the energy system. Therefore, adequate planning is essential to understand the system requirements in terms of funds to assess sustainability in ESDM.
- ✓ *Integrating ecological*-economic-societal concepts in implementing ESDM trends: Integrating ecological-economic-societal concepts together helps to analyses the success possibilities in implementation of sustainability in ESDM initiatives, and hence results in enhanced performance.
- ✓ *Investigate external and uncertain factors and align stakeholders' targets in ESDM initiatives*: This work gives better perspective of the external environment such as risks and uncertainties in energy systems, stakeholder behaviour and commitment for sustainability etc. It also helps practicing managers to align stakeholder actions to achieve sustainable development in energy system.

6. Sensitivity Analysis

Sensitivity analysis confirms the effectiveness of the pre-explained work. Different weights are assigned to experts for checking the consistency in the decision making process which in turn presents the variation in cause-effect.

To carry out the sensitivity analysis, all the five experts are weighted independently while keeping the weights identical for the other experts as shown in Table 8.

Table 8: Weights assigned to five experts during sensitivity run

Sensitivity Analysis	Run 1	Run 2	Run 3	Run 4	Run 5
Expert 1	0.4	0.15	0.15	0.15	0.15
Expert 2	0.15	0.4	0.15	0.15	0.15
Expert 3	0.15	0.15	0.4	0.15	0.15
Expert 4	0.15	0.15	0.15	0.4	0.15
Expert 5	0.15	0.15	0.15	0.15	0.4

In run 1 for sensitivity analysis; Expert 1 is given highest weightage (0.4) and other experts are provided with equal weightage (0.15). Then, the cause-effect relationship among the indicators (refer to Figure A.1 in Appendix A) are determined, and showed the indicators (I1, I2, I8 and I6) are most important causal indicators. In addition, the indicators I11, I12 and I14 are three highly influenced effect indicators (see Table 9).

Table 9: Result of Sensitivity analysis

Indicators	Analysis 1			Analysis 2			Analysis 3			Analysis 4			Analysis 5		
	R+D	R-D	Rank	R+D	R-D	Rank	R+D	R-D	Rank	R+D	R-D	Rank	R+D	R-D	Rank
I1	7.46	0.63	1	7.52	0.61	1	7.39	0.63	1	7.79	0.64	1	7.78	0.56	1
I2	7.28	0.64	2	7.47	0.57	2	7.33	0.63	2	7.59	0.64	2	7.55	0.69	2
I3	6.45	0.35	9	6.52	0.31	9	6.43	0.34	8	6.69	0.30	9	6.64	0.29	9
I4	4.86	-1.31	17	5.05	-1.33	16	4.92	-1.34	15	5.08	-1.38	18	5.08	-1.38	18
I5	7.02	0.93	5	7.01	0.97	7	7.08	0.94	5	7.19	1.02	6	7.26	0.98	6
I6	7.04	0.76	4	7.13	0.64	5	7.08	0.71	5	7.31	0.76	4	7.45	0.68	4
I7	6.90	0.98	7	7.06	1.04	6	7.01	1.01	6	7.10	0.87	7	7.20	1.00	7
I8	7.26	0.99	3	7.38	0.92	3	7.26	0.88	3	7.47	1.02	3	7.54	0.97	3
I9	6.52	0.50	8	6.62	0.51	8	6.60	0.53	7	6.80	0.52	8	6.75	0.51	8
I10	6.97	0.41	6	7.21	0.35	4	7.14	0.37	4	7.29	0.40	5	7.30	0.44	5
I11	5.71	-1.61	11	5.80	-1.63	12	5.79	-1.65	11	5.93	-1.66	12	6.00	-1.61	12
I12	5.03	-1.54	15	5.07	-1.49	15	5.03	-1.52	13	5.21	-1.60	15	5.17	-1.55	16
I13	4.80	-1.15	18	4.97	-1.11	17	4.95	-1.27	14	5.13	-1.33	17	5.09	-1.29	17
I14	4.87	-1.40	16	4.95	-1.52	18	4.90	-1.49	16	5.19	-1.45	16	5.18	-1.46	15
I15	5.60	-0.18	13	5.75	-0.12	13	5.79	-0.03	11	5.85	-0.15	13	5.80	-0.20	13
I16	5.65	-0.21	12	6.06	-0.05	11	5.84	-0.16	10	6.07	0.04	11	6.16	0.02	11
I17	5.51	0.16	14	5.53	0.20	14	5.56	0.26	12	5.63	0.22	14	5.68	0.26	14
I18	6.31	1.06	10	6.39	1.12	10	6.27	1.17	9	6.58	1.14	10	6.43	1.09	10

In run 2 of Sensitivity analysis, Figure C.2 indicates that I1>I2>I8>I10 are most important causal indicators and I11>I14>I12>I4 are the effect indicators. In run 3 of sensitivity analysis, is found that I1>I2>I8>I10 are most important causal indicators (see Table 9) and Figure C.3 denotes that I11>I12>I14>I4 are the effect indicators. In sensitivity run 4, I1>I2>I8>I6 are most important causal indicators (see Table 9) and Figure C.4 denotes that I11>I14>I12>I4 are the effect indicators. In sensitivity run 5, I1>I2>I8>I6 are the most important causal indicators (see Table 9) and Figure C.5 denotes that I11>I14>I12>I4 are the effect indicators. With reference to the sensitivity analysis results, it can be inferred that cause and effect diagrams are stable except a marginal variations (see Appendix A Figures A.1 – A.5). This can well justify the effectiveness of present work.

7. Conclusions

This work seeks to enhance the performance of sustainability focused ESDM initiatives, in terms of (i) listing the indicators relevant to sustainability of ESDM; (ii) assessing the causal interactions of the indicators through cause and effect diagram using a grey-DEMATEL approach. The grey-DEMATEL is helpful in in developing a structural framework of indicators that deals with uncertain situations, lack of information and human bias.

Based on the literature and expert inputs, this work offered 18 important indicators and five dimensions of indicators relevant to effective assessment of sustainability of ESDM from Indian perspective. The indicators recognised can lay down a foundation that can comprehensively cover probable success measures in assessing sustainability of ESDM. Indicators I18-I7-I5-I8-I6-I2-I1-I9-I10-I3-I17 are categorised into the cause group and suggested as focal indicators to have effective sustainable development in ESDM. The indicators I16-I15-I13-I4-I14-I12-I11 are classified into the effect group and suggested as the desired effects in assessing sustainability in ESDM initiatives. Finally, the present work is a proposal for the decision makers in managing the sustainability assessment issues of ESDM in an effective way.

This work has few limitations; therefore, this work can be extended in future studies. This work has been conducted in assessing sustainability in ESDM by taking a developing economy context like India. The findings may be extended to other developing nations, considering expert's views in particular context. The list of indicators may also be modified with innovations in technology and process domain in near future. The proposed method, grey-DEMATEL still depends on human judgment. The research findings can be elaborated through a case study (single/multiple case studies). In respect to the view point of extension of this work other MCDM techniques like ISM, AHP, ANP and TOSIS (Mangla et al., 2013; 2015) etc. can be used to further evaluate the relations between indicators. The identified indicators can also be ranked with regard to the expected performance outcomes associated with the implementation of ESDM initiatives. Further, this structural framework of indicators may be validated empirically with the help of SEM.

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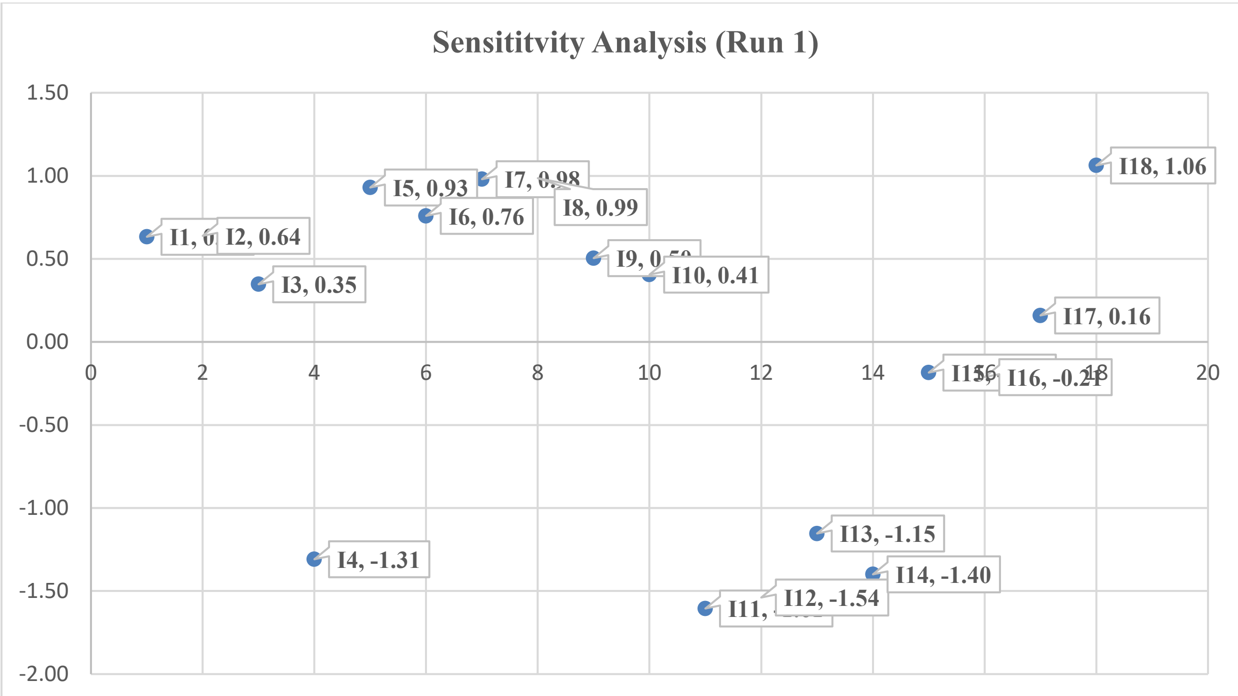
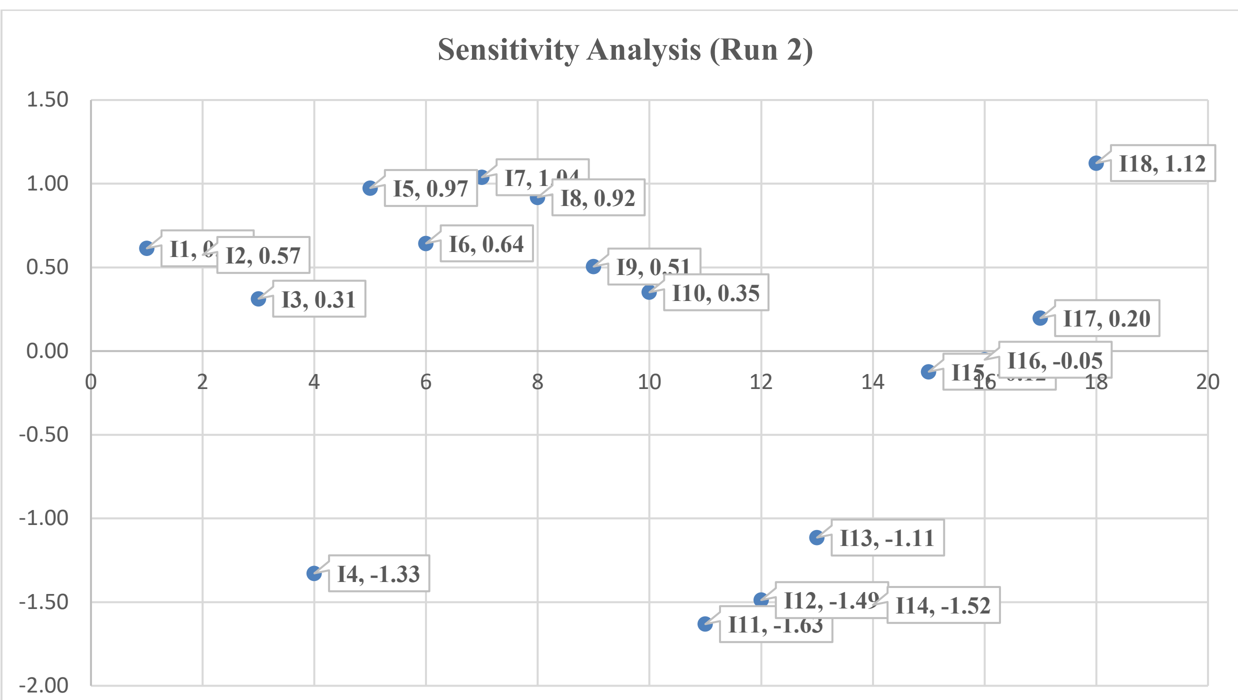


Figure A.1: Causal relationship diagram for Sensitivity Analysis 1



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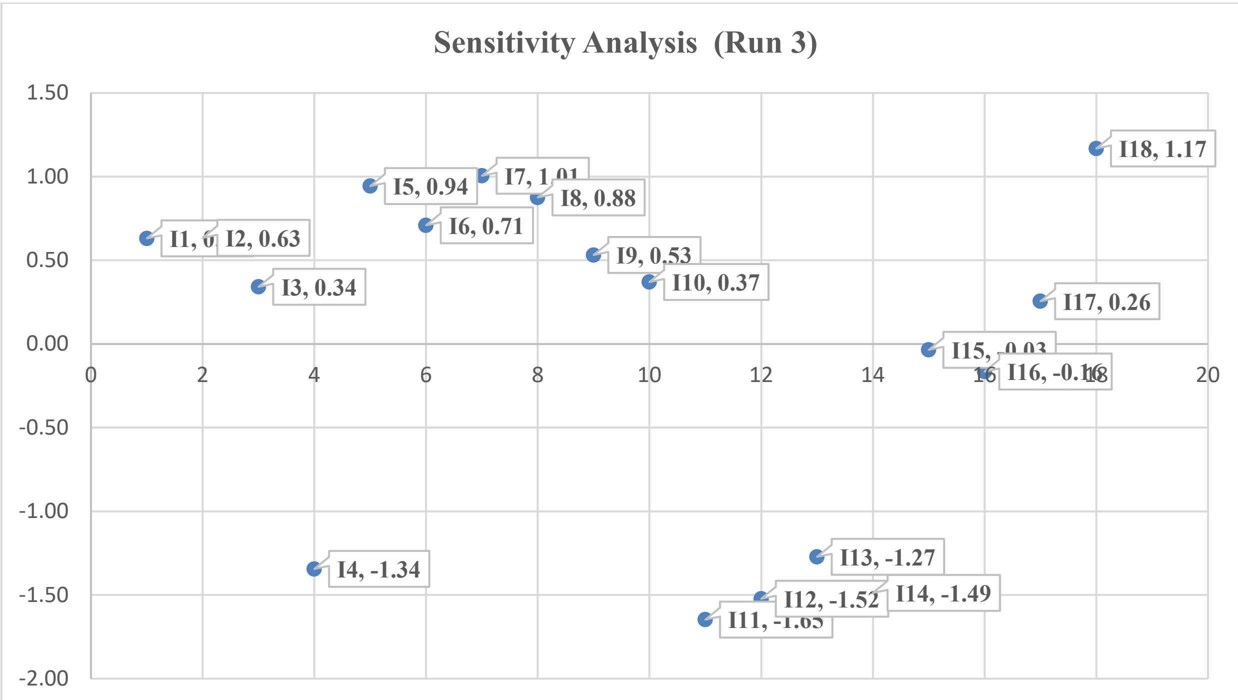

Figure A.3: Causal relationship diagram for Sensitivity Analysis 3

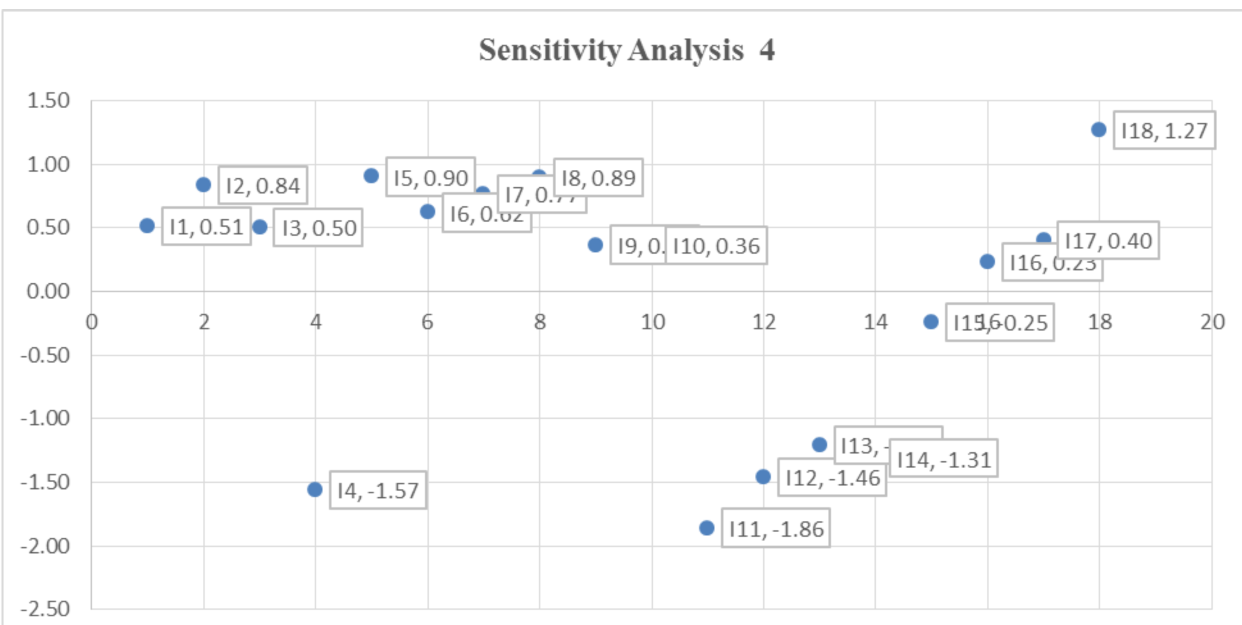

Figure A.4: Causal relationship diagram for Sensitivity Analysis 4

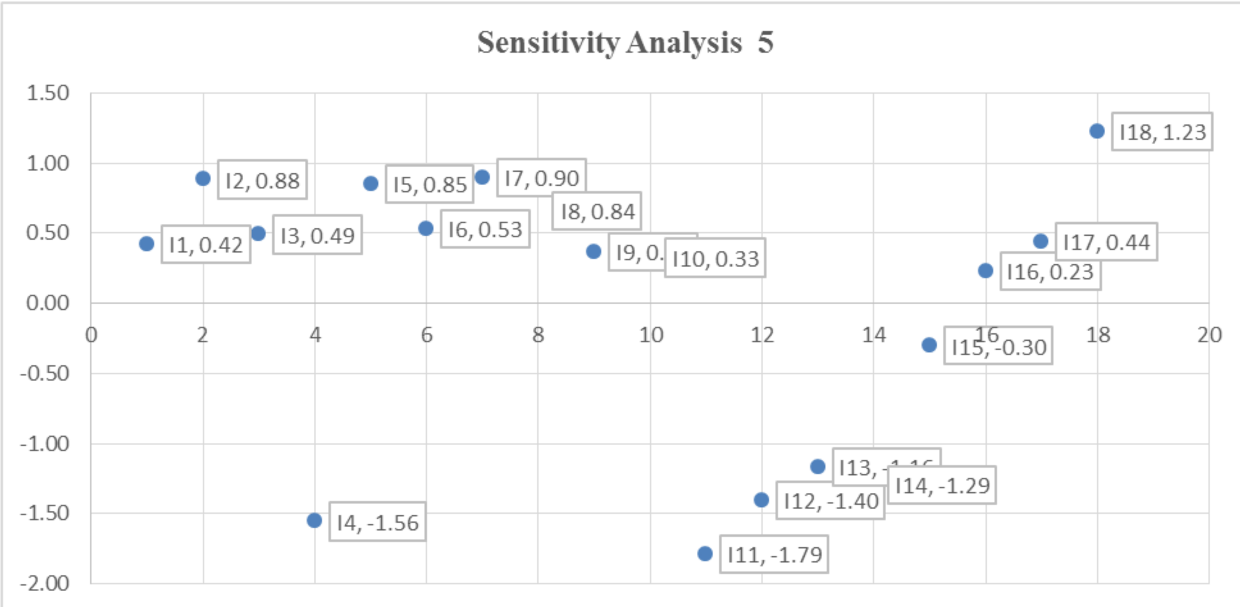

Figure A.5: Causal relationship diagram for Sensitivity Analysis 5