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Investigating energy sustainability indicators for developing countries

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ABSTRACT

Achieving solutions to energy sustainability requires regular planning and long-term appropriate actions. In this regard, using appropriate indicators are one of the most important and effective solutions. The aim of this study is investigating a set of energy sustainability indicators for developing countries based on SDGs and sustainable energy development index (SEDI) method. In addition to investigating the SEDI method, we will explore a group of indicators that has a greater effect on energy sustainability and describe it comprehensively.
Selecting the SEDI method in this work has two main causes; firstly, this method has multidimensional attention to energy sustainability and secondly can be a good method to find strong and weak indicators for a country. Also, the relations between selected energy indicators and sustainable development are described in this study. Firstly, we gathered the required data for four years from 2012 until 2015 years from IEA and World Bank and then analysed it. In conclusion, according to existing data the SEDI ranking of each country will be obtained.Results show that in comparison with past years, all studied countries intend to achieve a remarkable growth in energy sustainability.

Keyword:

Energy sustainability;
Indicator;
SEDI;
Developing country

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1. Introduction

One of the most important current issues in the world is energy supply that has remarkable effect on communities [1, 2]. In addition, energy supply is one of the most important factors for development [3, 4]. Today, more than half of the world's people are living in cities, which will be much more populated by 2050, reaching about two thirds of the world's population [5]. On the other hand, increasing the world's population will lead to more fossil fuels and global warming [6-8].

In this regard, UN intends by 2030 to implement many practical goals to prevent more problems relating to human rights, especially in the energy field. One of the most important factors of SDGs is energy sustainability [9]. Energy sustainability provides a better situation to energy consumers from various aspects such as access, affordable, technology and etc. Also, energy sustainability has significant effect on the environment [10-12]. Energy sustainability is a range spread of different subjects like policy, environment end efficiency [13].

2. Theoretical background

Indicators are conceptual tools for sustainability assessments that can be influential in many sectors. Energy policymakers and energy experts using indicators are able to take better decision for activity areas [14]. With regard to these descriptions, some of the done studies can be presented for better understanding [15].

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Neves et al, investigated with a review of existing practices investigated energy sustainability indicators in order to local energy planning. They in this review showed that how indicators can be effective for energy planning and assessment different current problems. In addition, they showed, with use of the indicators can monitor the targets and do proper the actions [16].

With regard to energy accessibility importance especially electrical energy, razmjoo et al presented, technical study in order to investigate energy sustainability using renewable energies. They used homer software and with regard to wind-solar energy potential, analysed energy sustainability hybrid system for two cities in the south-east of Iran. In this study, total electrical energy production by PV array for Zabol and Zahak were 1700 (kWh/yr) and 1669 (kWh/yr),and the amount of wind turbine capacity was calculated at 9036 (kWh/yr) and 7263 (kWh/yr) for Zabol and Zahak respectively [17].

Bhattacharyya et al presented a critical review and analysis of energy access programmers for sustainable development. In this article they emphasized an overall revision related to access energy methods and more use of renewable energy as one of the proper ways to access energy. Also, an important energy indicator is investigated in this study [18]. Mardani et al, by using multiple

Nomenclature

AER	Access to electricity urban and rural
AFW	Annual freshwater withdrawals
CCh	Climate change
CCP	Changing consumption patterns
Cr	Coal reserve
EAE	Energy accessibility and equity,
EAFF	Energy affordability
EC	Electricity consumption
ECS	Economic Sustainability
EEI	Enhance economy infrastructure
EI	Energy intensity
EIM	Energy intensity management
ENS	Environment Sustainability
EP	Energy productivity
ES	Energy sustainability
ESe	Energy security
Et	Energy technology
GNI	Gross national income
GDP	Gross domestic product
Gr	Gas reserve
IRS	Increase share of renewable energy in different sectors
IS	Institutional Sustainability
ITI	Improvement transport infrastructures
INV	Investment
Or	Oil reserve
Pb	Production Biomass
Pc	Production coal
Pe	Production energy
Pg	Production gas
PISEG	Promote inclusive and sustainable economic growth
Po	Production oil
REC	Renewable energy consumption
RS	Resilient and sustainable.
SS	Social Sustainability
TCEC	Total final consumption in commercial
TCO_2	Total CO_2
TCNR	Total consumption natural resource
TFC	Total final consumption
TFCT	Total final consumption in transport
TFA	Total Forest area
TLA	Total land area
TS	Technical Sustainability
TNR	Total natural resources
TPES	Total primary energy supply
ULCT	Use of low carbon technologies
UP	Urban planning
USG	Use of smart grids and electric grid
WS	Water & Sanitation and access to health water
V_{act}	Actual number of indicators
X	Actual number
X_{max}	Maximumnumber of indicators
X_{min}	Minimum number of indicators

criteria decision-making method investigated energy sustainability, especially by renewable energy. They reviewed many related articles in this regardinto two main application areas such as sustainable energy and renewable energy and based on them presented their results [19].

Assess energy technologies for rural electrification using a sustainability index has been done by Mainali et al. They presented energy technology sustainability index (ETSI) to this evaluation. Also, they proved thatmature technologies have better sustainability performance than among the other options [20].

Moreira et al investigated the effective indicators associated with energy sustainability. They used academic and institutional sources, analysed influential indicators in the line of the energy sustainability. In fact, they showed that indicators have an effect on all aspects of energy sustainability dimensions, thus, should be considered by policymakers and energy experts accurately. Also, in this study they emphasized that for achieving energy sustainability, in addition to a mutual review, needs to have appropriate infrastructures in this regard. [21].

Correct Energy policymaking in Denmark, investigated by Sovacool et al. They showed that how Denmark by appropriate policy in the energy field, obtained a good situation in energy sustainability [22].Energy services situation for rural development, investigated by Kaygusuz et al. They investigated practical programs to access energy in this regard. They also in this study, to improve access energy for inhabitants, emphasized more attention to women [23].

There are four important reasons to write this research. First of all, this study presents a comprehensive discussion related to energy sustainability. Second of all, effective sets of indicators are presented that has the remarkable effect on energy sustainability. These selected indicators are in the framework of a group which is related to SDGs (17 UN goal), Urban Habitat and SEDI method. Also, these seven indicators, are as a valuable benchmark to policy-making and can be used to determine practical priorities and to monitor the progress of 10 developing countries.Third of all, this work presents a conceptual discussion in regard to energy sustainability, and gives an answer to many questions related to it.

Actually, our focus in this research is based on identifying and presenting suitable indicators to measure energy sustainability in line SDGs (17 UN goal), UN-Habitat III (14 goals) and SEDI for developing countries. Fourth of all, we try to find a common gap between 10 studied countries. This work, in addition, is analysing energy sustainability using essential indicators and based on the sustainable energy development index method (SEDI). In this regard, correct policies and measures developed to achieve improvements in energy sustainability. Also discussed appropriate indicators for energy sustainability and choosing strategies based on them.

2. Comprehensive description related to group of selected indicators

Achieving to energy sustainability needs to different factors such as use of appropriate indicators, and have energy planning. In this regard, indicators and sub-indicators could be influential as tools for measuring it [24-26]. Indicators are a strong tool to help the policymakers and energy expert to measure energy sustainability which is useful to policymakers, energy analysts and statisticians. Also, indicators give us a deeper understanding of the existing problems [27]. Indeed, energy sustainability indicators, are selected by policymakers or energy experts [28].

They can demonstrate to us, what needs to be done to improve the weak points in regard to the current energy system of a country. Thus, if we can identify and use them correctly, the political targets will be easily achieved [29]. In this research, we present effective indicators related to energy sustainability that are appropriate to implement in developing countries. These presented indicators are to identify the weak points in the line of achieving to energy sustainability. Use of the seven selected indicators can help us to identify the main gaps in energy sustainability policy.

The group of selected indicators in this study are strongly dependent on the energy field. According to the layout of table 2, seven selected indicators are the minimum number of an influential group relevant to energy sustainability. Also, they are extremely related to SDGs (17 UN goal), UN-Habitat III (14 goals) and SEDI indicators [73, 74]. Each indicator alone has sub-indicators that more complete it. All indicators have a close relationship together because they together make an effective set to improve infrastructure a country, especially in energy.

2.1. Environmental impacts

The use of fossil fuels in the industry has led to significant industrial development [30]. Today, a significant part of human energy needs is satisfied by fossil fuels [31]. But apart from these benefits, fossil fuels are the main source of carbon dioxide emissions, which is one of the greenhouse gases which results in environmental pollution and global warming [32]. Todays, global warming and air pollution have become a major challenge in many countries around the world [33].

In fact, global warming and air pollution have widespread effects that cause environmental, climatic and health problems, and if they continue, severe consequences will be created around the world [34]. Among fossil fuels, coal is considered the most polluting fuel source and natural gas as the cleanest fuel source [35]. Thus, with these descriptions pollution prevention should be recognized as a key component of sustainable development and long-term planning.

2.2. Renewable energy

Renewable energies or alternative energy, are those kind of the energies that are used to generate energy without net carbon emission [36]. Renewable resources are affordable, available and clean also these energies are sustainable because they have the least environmental impact [37]. Sustainable energy should be widely encouraged because it does not harm the environment and is widely used to reduce energy costs. [38]. Today, the use of renewable energy has reduced a part of global power generation costs that was produced by fuel fossils [39-41].

According to the analysis by Lazard's 2017, that was about the Levelized cost of energy among four kinds of conventional energy resources for electrical production in recent years, the cost of energy for both solar- wind technology, then other resources has dropped by almost 6% compared to the year before last year.Actually wind energy with $45 and Solar with $50 in comparison with nuclear energy $148, Coal $102 and Gas $60 are most affordable and cleaner [75].

2.3. Transport

Urbanization is a social and physical process that requires a public and regular transportation sector[42]. Transportation is primarily a special means of social activity that should be accessible to all people and affordable [43].

Since transport is an important sector for energy and use of fossil fuels thus use of new vehicles and reducing dependence on fossil fuels in the transport sector is a priority that can be done by proper policy actions. At present variety of transportation system and vehicle used in the world that the most important them including Airplane, Train, Bus, Motorcycle, Bicycle and electrical vehicles. Also hybrid system such as electrical cars are expanded andbecome using day to day that has significant impact to reduce CO_2 emission and annual world sales of electric vehicles (EVs) increased during recent years [44, 45].

The transportation system, if accompanied by proper planning, will increase job opportunities, market access, contribute to climate change (reducing air pollution), improve road safety. Significant measures have been taken and ongoing in various cities for developing countries, particularly in the field of transport, such as the development of transport infrastructure, the creation of modern transportation systems like highways, public transportation, airport improvement in order to increase travel opportunities and more choices. These measures also have positive effects on the safety of roads and environmental issues [46, 47].

2.4. Use of Energy & Energy efficiency

Energy use is essential for all humans especially in buildings, industries and other sections [48-50]. According to recent estimates and should be more considered forecasts regarding the storage of oil, gas, and coal, energy consumption and in this regard should be more used of proper methods [51, 52] Today, people are well aware of the different and hard ways to energy production and the environmental issues associated with it, and they themselves are also eager to save energy [53, 54].

Also today, energy saving in the industrial and building sectors of, which are the most consumer sectors, is of great importance. There are several ways to save and manage energy consumption such as energy audits, training expansion save energy field and using the low consumption types of equipment and controller of energy.

In fact, the role of the use of equipment and facilities for energy save has highly significant. All consumers and users, with the use of energy-saving technologies such as high-performance machines (HEMs), variable speed drives (VSDs) and intelligent control systems for buildings (lighting and HVAC systems), can have more control on the amount of energy consumption in industrial and building sectors. On the other hand, it saves a significant amount of electrical energy and energy costs, which will be economically significant [55, 56].

2.5. Resource access of energy in developing countries

Today, developing countries are faced with a variety of energy challenges, which are increasing day by day. In fact, developing countries have more need to access energy for expand different industrials and remove basic problems such as health and education than developed countries because in developing countries still an important part of the population does not have access to basic energy services [57].

Energy availability and energy affordability are important and very necessary. Despite all the global advances, millions of households in developing countries have insufficient access to energy or cheap energy. This situation causes poverty, health damage, local service delivery constraints, increasing vulnerability to climate change, limiting the expansion of opportunities, reducing environmental sustainability at the local, national and global levels, and has a negative impact on education and health. On the other hand, it can be said that today access to energy should be a political goal. Because most of the countries that have enjoyed better access to electricity have made significant progress since, indeed, their government has addressed this issue as a national political goal [58].

2.6. Resiliency

Now, the stability and security of energy supplies in parts of the world and especially in cities is threatened through unpredictable hazards such as natural disasters, Internet problems, and various fluctuations. Therefore, in this regard, it is necessary to prevent such problems by appropriately planning and creating the necessary infrastructure [59].

The frequency of recent incidents including natural disasters such as earthquakes, tsunamis, and hurricanes, and also difficulties caused by the economic downturn has highlighted the vulnerability of human settlements and makes the appropriate consideration of resiliency in the planning for future of urban areas of vital significance. The concept of flexibility is an approach to managing socio-ecological systems that address the development of preventive measures and disaster risk management. Flexibility Given the identification of future risks, a conceptual framework for assessing urban energy flexibility identifies planning and design criteria that can have to be a positive effect on some aspects of human life [59].

2.7. Policy

Population growth in various cities and increasing use of energy especially in developing countries, has caused many problems including in the field of the environment. The long-term nature of sustainable development leads countries to design a sustainable global planning system [60].

In fact, appropriate policies must be adopted to prevent future problems, and long-term and appropriate measures. For instance measures such as implementation of sustainable development policies that have a significant impact on the conservation and proper utilization of energy resources and will take place in order to eliminate barriers and limitations of economic, organizational and general development prospects [61].

The adoption of correct and growth-oriented policies within the framework of modernization theory, will bring sustainable development in all sectors and at different global, regional and local levels [62]. Policies such as sufficient energy supply, proper urban transport planning, environmental measures, educational and cultural programs are including applied policies for sustainable development [63].

3. Importance of Indicators

There are several important goals to measure energy sustainability which can be interpreted in a few questions and answers. What aspects of energy sustainability to measure are important? Which ones is for conserving or developing? And how they can improve energy sustainability? [64]. To answer these questions, we should know that energy sustainability will not be obtained easily and it needs a long-time plan and a correct and practical policy. Hence, to measure energy sustainability, identification of the weaknesses is very important, because it can help us to improve energy sustainability and achievement it [65, 66].

Indeed, all aspects of energy sustainability are important and should be considered. But always all of them are not in priority. So one should be paid attention to most important aspects and these are as a necessity for help to policymakers [67] . Therefore, to find the most important aspects of energy sustainability, we should define different indicators and criterion based on need [68].

These indicators and criterions, allow us to locate ourselves present condition relative to conditions that have prevailed in the past, then we can with regular planning move in the line of our self-targets [69]. Indicators can be divided into different groups such as descriptive indicators, performance indicators, and efficiency indicators. Overall, energy sustainability indicators should be simple, easy, useful, feasible, appropriate, benchmark, understandable and reasonable [69].

The main target of the indicators is collecting of the required information by multiple data and simplification them. Actually, indicators are able to simplify the complex information. They are as influential tools in hand of policymakers and can be used to measure the main issues and to find appropriate ways[70]. Also, indicators are used to supply correct and useful information to help policymakers in order to identify the main issues of a country. Indicators increase the public awareness in order to strengthen the public support of policy measures and monitoring on assigned targets [71].

Fig 1 shows a relation between Energy sustainability and group of indicators for developing countries

Table 1 shows the relation between Items and related indicators to SDGs (17 UN goal), UN-Habitat III (14 goals) and SEDI. As can see in this table a group of indicators related to UN17 goals and Urban Habitat themes presented that can have a good effect on sustainability.

Table 2 shows the most important sub- indicators which has positive impact on the group of selected indicators in this study. This table is most important because this table will be assigned the relationship between groups of indicators with SEDI. This table has three main parts. First part is the group of indicators that

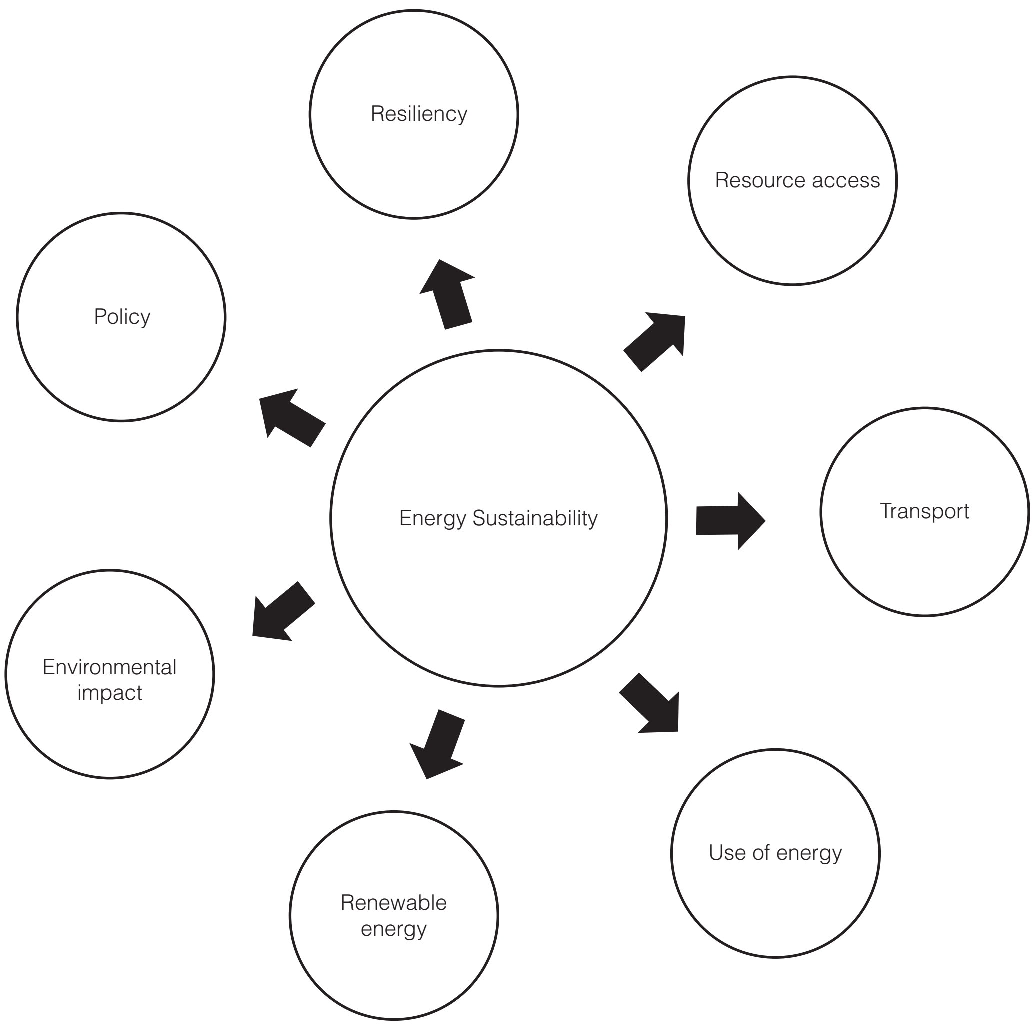

Figure 1: Relation between Energy sustainability and group of indicators for developing countries

Table 1. Relationship between Items and related indicators to UN17 goals and SEDI

Group of indicators	SDGs indicators	UN-Habitat III indicators	SEDI indicators
Environmental impacts	CCh, AFW, WS, Et, CO_2, ENS	CCh, WS, AFW, Et, CO_2	ENV, INS, TEC
Renewable energy	EAFF, ES, INV, Et, IRS, REC	INV, ES, EAFF	ENV, SOC , TEC, ECO, INS
Transport	AER, EA, EAFF, Et, EC, ITI, UP, TFC,TFCT, RS, USG	UP, ITI, EAFF, ES, RS, TFCT, USG	SOC, TEC, ECO, ENV
Use of Energy	AER, CCP, EA, EAFF, EC, EI, EIM, EPI, ESe, Et, Pb, Pg, Po, Pc, TPES, REC, RS, TCEC, TFC, TFCT, USG	EA, EAFF, ESe, AER, Et, USG EC, USG	ENV, TEC, SOC , INS
Resource of energy	AFW, Cr, Gr, Or, LA, FA, TNR, TCNR	LA, Cr, Gr, Or, AFW	ENV, TEC, SOC
Resiliency	AER, AFW, LA, EIM , INV, ITI, PISEG, UP, WS, EEI	UP, WS, AER, EIM, INV	SOC, TEC, ECO
Policy	GNI, GDP, PISEG, CCP, ES, EA, UP, ULCT, TNR, EIM, ESe, INV, REC, ESe	UP, GNI, GDP, REC, ESe	SO, ECO, TEC

Table 2. Group of indicators with sub-indicators

Group of indicators	Sub-Indicator	Related SEDI indicators
Environmental impact	ULCT, IRS, CCP, ET, INV	ENV1-2, TEC1-3, SOC1
Renewable energy	EIM,IRS, EAFF, ET, INV, TS	ENV1-2, TEC1-3, SOC1, INS1
Transport	AER, EA, IRS, ET, INV,UP, USG	TEC1-3 ,ECO2-3, ENV1-2, SOC1
Use of energy	AER, REC, ET, IRS, TNR, INV, ES, EIM, EA	TEC1-3, INS1, ECO1-3, ENV1-2, SOC1
Resource of energy	TNR, TLA	SOC1-2, TEC1-3
Resiliency	UP, WS, AER, ET, IS, INV	SOC1, TEC3, ECO2-3, INS 1
Policy	INV, ESe, EAFF, EIM, ES, TLA,TPES	SCO1-2, ECO1-3, TEC1-3

have described them in above and have the remarkable effect on sustainability.

The second part shows the sub-indicators related to the group that can be as a help for them. And the third part, is shows the related these sub-indicators with SEDI indicators. As can see in this table, INV (Investment) and REC (Renewable energy consumption) sub-indicators have most repetition time than other sub-indicators in this table, because two mentioned sub-indicators can create most positive changes in the line of energy sustainability.

4. Methodology for the objective selection

In this study energy sustainability for 12 developing countries is considered based on SDGs (17 UN goal), UN-Habitat III (14 goals) and SEDI method. Firstly, seven influential indicators associated with energy sustainability and in the line of SDGs is selected and described. Then with having four year data from IEA and World Bank, the sustainable energy development index (SEDI) is investigated. For both the group of indicators and SEDI method, related sub-indicators is obtained and analysed.

For do these stages, firstly, we described in detail about SDGs (17 UN goal) and UN-Habitat III (14 goals) and then we determined which goals are most related to SEDI. After that, we described the group of indicators and found the proper sub-indicators for them and determined which of them is related to SEDI indicators directly and indirectly. Finally, we collected related data with indicators and analysed them. After these stages, obtained the SEDI rank for each developing countries. It is believed that the discussions and results drawn in the present study will be effective to energy experts and energy policy makers.

5. Results and discussion

As previously mentioned and emphasized, appropriate determination of indicators and sub-indicators can be influential for achieving energy sustainability by policymakers and energy experts. Also, since the SEDI consists five main indicators and several sub-indicators, thus for obtain proper results in this regard should be investigated from different aspects and dimensions. Actually, if we can investigate all main indicators of SEDI accurately and for each of them determine the proper sub-indicators, achieving desirable targets will be carried out easily.

For calculate SEDI, is necessary to obtain the technical sustainability, economic sustainability, Social sustainability, Environmental sustainability, and institutional environmental sustainability. When all indicators were obtained, should be normalized and obtained the average of them [72]. The main purpose of these indicators is a conceptual investigation in regards to Sustainability for each country. Each country needs to have an appropriate infrastructure in various sustainability sectors. Sustainability depends on a variety of factors, which by their general integration, will make the development of a country.

The close relationship between social development, economic development, environmental conservation and enhancement of life quality are essential in sustainability. The main concept of sustainability is to achieve the lasting satisfaction of human needs and improvement the quality of life.

Thus, it needs to select the proper method and investigating the most important sectors from the all different aspects. Based on this review, we conclude that it is necessary to create a new method to improve the SEDI in order to assess the sustainability performance. In this study, proper analyses with requirements on the concept of sustainability are made in order to set-up the general framework and the specific cases of country sustainability are discussed.

5.1. Technical sustainability

Technical sustainability that can calculate with different data such as share of depletable (non-renewable) energies, depletion coefficient of local energy resource and overall system conversion efficiency is for improving the ability of the energy supply system to providing the now and future needs of society effective, reliable, and from clean sources. In this part resources such as crude oil, coal, natural gas, hydro-power, nuclear or renewable energies are used as inputs include the primary energy resources. This part is including TEC1-3 that for normalization it can be used of Eq. 1.

5.2. Economic sustainability

Economic always an important part for our living and has a vital role in the future and progress. GDP for all countries has important for growth and welfare inhabitants; actually, it is the main factor in development. The normalization of this dimension is better that have been the higher value, thus for normalization can be obtained by Eq. 1. Also, to obtain this dimension calculate per capita consumption of commercial energy, final energy intensity and share of productive use of energy data are needed.

5.3. Social sustainability

To assess the distributional effect of energy for a society, can obtain the accessibility to energy supply by calculating this dimension. Per capita consumption of clean energies in the residential sector and Income inequality (GNI coefficient) is necessary to obtain this dimension. In this indicator, normalization can be calculated by Eq. 1.

5.4. Environmental sustainability

This dimension has is related to environmental problems and the CO2 issue. Actually, global warming and Climate change have been caused as a world problem and all a special obligation to reducing greenhouse gases. Environmental sustainability can be calculated by obtaining a share of dirty fuels in residential energy consumption and carbon intensity. Also for normalization this dimension the smaller value is better, thus Eq. 2 will be used.

5.5. Institutional sustainability

Institutional sustainability is one of the most important sectors in sustainability. It can show the level of local participation in the management and control of the energy system. The sector depends on several factors such as public participation, local skill base, local regulation and protection of investors and consumers is needed. Calculate overall self-efficiency is important for this dimension. Also, since has higher value is better for this part, thus for normalization can use of Eq. 1.

With regard to that these indicators have various dimensions and expressed with different measurement units, hence is used the normalization technique [72]. In this study after collect data and elementary calculation, each indicator should be normalized between 0 and 1 using the two following methods:

In this study, UNDP method was used for normalization, actually when a definition indicator should have high-value eq.1 is better than used and when that the indicator should have low value is better than the use of eq.2 for evaluation. In two formula V is the indicator value, V_{ACT} is the actual indicator such as a country, V_{Max} is the maximum value of indicator and the V_{min} is the minimum value of the indicator. Table 3 shows used method for SEDI calculation. Actually, in this table five essential indicators related to SEDI with solvation methods have been presented.

$$V=\frac{V_{ACT}-V_{Min}}{V_{Max}-V_{Min}} \quad (1)$$

$$V=\frac{V_{Max}-V_{ACT}}{V_{Max}-V_{Min}} \quad (2)$$

6. Indices calculation

This work investigates the strengths and weaknesses of a country with attention to their existing resources, economic, environment situation; hence the ranking is based on these mentioned factors. It is obvious that each country after considering these factors will obtain a specific ranking, although this study emphasizes that results are not absolute, using collected data of each country between 2012-2015 years and via IEA information will lead to these results.

Therefore, if a country intends that to gain a better rank in future, it needs to strengthen the sectors that are weak in them, and that should minimize their problems. That means each country should determine its energy policy according to the results obtained, and act in this regard to follow the correct practices, which they can learn from developed countries.

For calculating SEDI we need to obtain technical, economic, social, environmental and institutional indicators as following [72]:

Table 3. Selected indicators for analysing SEDI of for studied developing countries

Dimension	Indicators (Units)	Used method
TEC 1	Share of depletable (non- renewable) energies in TPES	$\frac{TCNR}{TPES}$
TEC 2	Depletion coefficient of local energy resource	$\left(\frac{Po}{Ro}\right)+\left(\frac{Pg}{Rg}\right)+\left(\frac{Pc}{Rc}\right)+\left(\frac{\frac{Pb}{Pe}}{\frac{Tfl}{Tla}}\right)$
TEC 3	Overall system Conversion Efficiency	$\frac{TFC}{TPES}$
ECO1	Per capita consumption of commercial energies	$\frac{TCEC}{Population}$
ECO 2	Final energy intensity	$\frac{TFC}{GDP\ PPP}$
ECO 3	Share of productive use of energy	$\frac{TFC-REC}{TFC}$
SOC 1	Per capita consumption of clean energies in the residential sector	$\frac{TCE}{Population}$
SOC 2	Income inequality	GNI Cofficient
ENV 1	Share of "dirty fuels" in residential energy consumption	$\frac{TNR}{REC}$
ENV 2	Carbon intensity	$\frac{TCO_2}{TPES}$
INS 1	Overall Self Sufficiency	$\frac{EP}{TPES}$

Technical sustainability can be obtained as following formula

$$TS = (1\text{-}TEC1 \times TEC2) \times TEC3 \quad (3)$$

For calculate economic benefit per capita there is a formula as following

$$Eb = ECO1 \times ECO2 \quad (4)$$

Social sustainability can be calculated as following formula

$$Ss = SOC1 \times (1\text{-}SOC2) \quad (5)$$

Also can be calculated environmental sustainability by below formula

$$ENs = ENV1 - ENV2 \quad (6)$$

Economic sustainability can be obtained as following formula

$$ECs = (ECO1 \times ECO3)/ECO2 \quad (7)$$

Table 4 shows obtained results by 2015-year data for SEDI calculation. As it is clear, Albania country has first rank and India has end rank between these countries in this table.

Table 5 shows obtained results by 2014-year data for SEDI calculation. As can see in this table studied country in different indicators has a better score than together.

Table 4. Obtained results by 2015-year data for SEDI calculation

Rank	Country	TEC	ECO	SOC	ENV	INS	SEDI
1	Albania	1	0.479	0.132	0.921	0.682	0.642
2	Croatia	0.309	1	0.144	0.918	0.366	0.547
3	Jordan	0.366	0.332	1	1	0	0.539
4	Iran	0.646	0.498	0	0.443	1	0.517
5	Bulgaria	0.195	0.987	0.077	0.849	0.461	0.513
6	Peru	0.589	0.343	0.024	0.842	0.75	0.509
7	Tunisia	0.067	0.403	0.23	0.942	0.412	0.41
8	China	0.346	0.251	0.829	0	0.603	0.405
9	Georgia	0.17	0.404	0.073	0.914	0.189	0.35
10	India	0	0	0.022	0.556	0.462	0.208

Table 5. Obtained results by 2014-year data for SEDI calculation

Rank	Country	TEC	ECO	SOC	ENV	INS	SEDI
1	Albania	1	0.42	0.119	0.995	0.635	0.633
2	Croatia	0.499	1	0.138	0.977	0.393	0.601
3	Peru	0.61	0.387	0.002	0.9	0.858	0.551
4	Iran	0.736	0.464	0	0.496	1	0.539
5	Jordan	0.311	0.367	1	0.989	0	0.533
6	Bulgaria	0.221	0.935	0.074	0.92	0.463	0.522
7	Tunisia	0.116	0.451	0.238	1	0.464	0.453
8	China	0.379	0.235	0.843	0	0.624	0.416
9	Georgia	0.089	0.448	0.076	0.963	0.215	0.358
10	India	0	0	0.007	0.598	0.48	0.217

Table 6. Obtained results by 2013-year data for SEDI calculation

Rank	Country	TEC	ECO	SOC	ENV	INS	SEDI
1	Albania	1	0.464	0.114	0.978	0.64	0.639
2	Croatia	0.433	0.977	0.115	0.943	0.374	0.569
3	Peru	0.725	0.371	0.002	0.88	0.864	0.568
4	Jordan	0.425	0.388	1	1	0	0.562
5	Iran	0.795	0.477	0	0.492	1	0.552
6	Bulgaria	0.253	1	0.074	0.882	0.452	0.532
7	Tunisia	0.098	0.466	0.204	0.964	0.507	0.447
8	China	0.393	0.223	0.762	0	0.618	0.399
9	Georgia	0.183	0.357	0.084	0.912	0.252	0.357
10	India	0	0	0.016	0.603	0.487	0.221

Table 7. Obtained results by 2012-year data for SEDI calculation

Rank	Country	TEC	ECO	SOC	ENV	INS	SEDI
1	Albania	1	0.427	0.116	0.951	0.599	0.618
2	Jordan	0.414	0.386	1	1	0	0.56
3	Iran	0.702	0.512	0	0.541	1	0.551
4	Croatia	0.32	1	0.106	0.947	0.34	0.542
5	Peru	0.628	0.31	0.002	0.882	0.818	0.528
6	Bulgaria	0.188	0.988	0.068	0.889	0.454	0.517
7	Tunisia	0.052	0.451	0.194	0.96	0.526	0.436
8	Georgia	0.317	0.179	0.074	0.981	0.195	0.349
9	China	0.331	0.201	0.566	0	0.611	0.341
10	India	0	0	0.017	0.656	0.486	0.231

Table 6 shows obtained results by 2013-year data for SEDI calculation. Albania and Croatia have obtained first and second rank in this table in sustainability energy development index (SEDI).

Table 7 shows obtained results by 2012-year data for SEDI calculation. As above mentioned in SEDI analyses all studied country can have different scores and ranking. For instance, Jordan country in this table that has investigated by 2012 data, has been acquired second ranking between other countries.

Table 8 shows a comparison results of SEDI calculation for selected countries belongs 2012-2015 years. This table shows a total average ranking for a studied country that has investigated by four years' data. Totally, Albania, Croatia, and Jordan have obtained the high score in SEDI.

In addition, fig 2 shows the total average illustrative diagram of sustainable energy development based on indicators. This fig has been created by a mathematical model also obtained results are relative for each dimension.

Table 9 shows a chart of considered countries based on SEDI averagely. This table shows the amount of growth for these countries during four years in SEDI. As can see Croatia in all considered years, has a stable Rank and is first.

SEDI ranking with a number for developing countries is obvious in fig 3. In this table moreover, score rank for

Table 8. Comparison obtained results of indicators calculation for obtaining SEDI belongs 2012-2015 years

Rank	Country	TEC	ECO	SOC	ENV	INS	SEDI
1	Albania	1	0.447	0.12	0.961	0.639	0.634
2	Croatia	0.413	0.994	0.125	0.946	0.368	0.568
3	Jordan	0.379	0.368	1	0.997	0	0.548
4	Iran	0.719	0.487	0	0.493	1	0.539
5	Peru	0.638	0.352	0.007	0.876	0.822	0.538
6	Bulgaria	0.214	0.977	0.073	0.885	0.457	0.521
7	Tunisia	0.083	0.442	0.216	0.966	0.477	0.438
8	China	0.362	0.227	0.75	0	0.614	0.39
9	Georgia	0.189	0.347	0.076	0.942	0.212	0.353
10	India	0	0	0.015	0.603	0.478	0.219

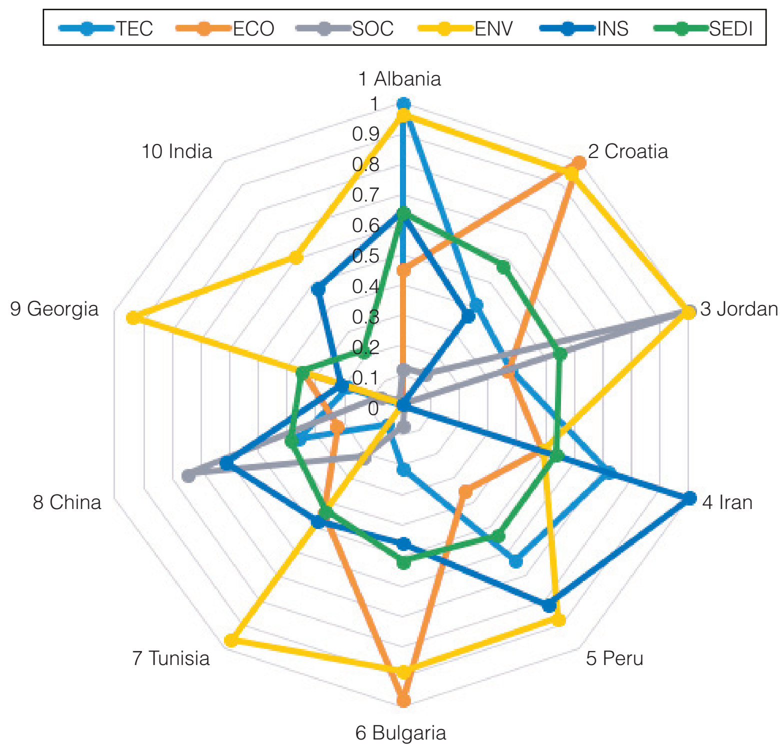

Figure 2: Total average illustrative diagram of sustainable energy development

Table 9.SEDI ranking of considered countries

Country / Year	Albania	Croatia	Jordan	Iran	Peru	Bulgaria	Tunisia	China	Georgia	India
2012	0.618	0.542	0.56	0.551	0.528	0.517	0.436	0.341	0.349	0.23
2013	0.639	0.569	0.562	0.552	0.568	0.532	0.447	0.399	0.357	0.22
2014	0.633	0. 601	0.533	0.539	0.551	0.513	0.453	0.416	0.358	0.22
2015	0.642	0.547	0.539	0.517	0.509	0.513	0.41	0.405	0.35	0.21
2012-15	0.633	0.552	0.548	0.54	0.539	0.521	0.436	0.39	0.353	0.22

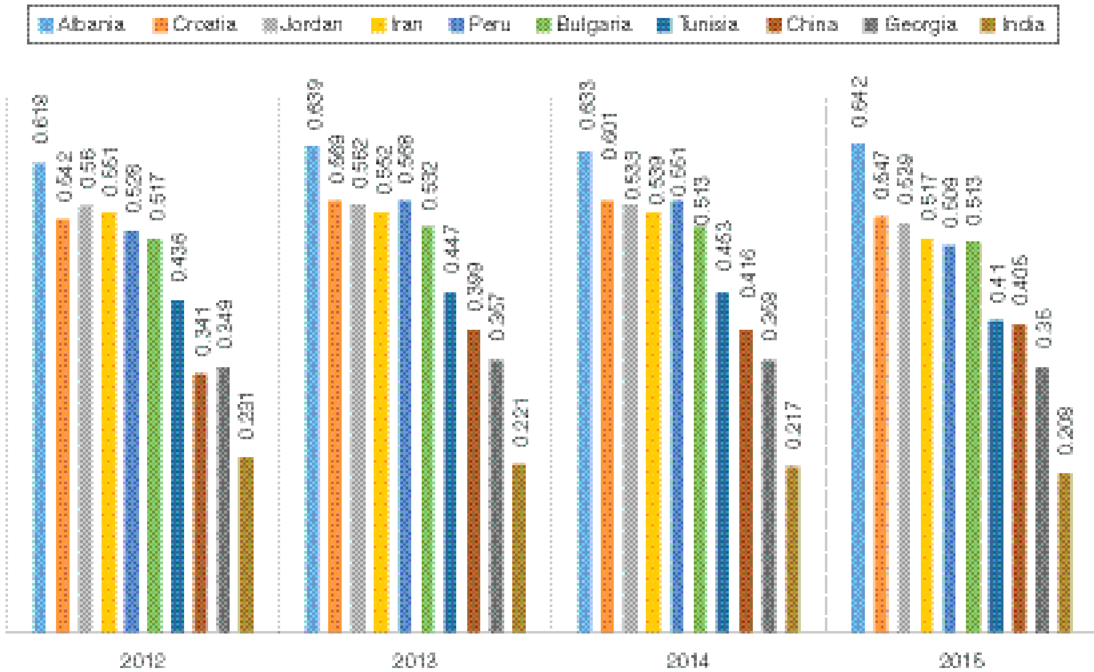

Figure 3: SEDI ranking with number

each country in four years' investigation, the obtained number of them is obvious in the side of each country.

7. Conclusion

Since evaluating sustainability performance is a multi-dimensional issue, then it is necessary that from different dimension views analysed and considered. At present, most countries in the world have regular programming and policy to reach sustainable development. Indeed, sustainable development is vital for the future of each country, especially developing countries. The purpose of this research is investigating a set of appropriate energy sustainability indicators for the 10 developing countries according to SDGs and SEDI method.

This analysis has been carried out with various and real data from well-known organizations. Firstly, we collected four years of required data that belonged 2012 to 2015 years from IEA and World Bank data organizations from and then analysed them separately. A comparison between considered countries showed that all parts of sustainability have to need to extend and enforce essential indicators to achieve sustain-ability equally. In addition, the results show that in comparison with past years, all studied countries, have seen remarkable growth in sustainability during these years.

Based on this study, there are two common issues between them that are the most important problems. One of them is that these countries are still dependent on fossil fuels as the main energy source. The other, is that in these countries there is not a practical policy for monitoring the operational system. In fact, in order to implement effective indicators in regards to energy sustainability, there needs to a strong policy.

Among studied countries, Albania and Croatia had the highest ranking in SEDI from 2012-2015 years and India had ranked at the bottom. It should be mentioned that these analyses are not absolute for these countries and these results only were obtained based on their resources. Thus, should be noticed that this study is relative and only can be showed the performance of these countries in energy sustainability based on existing data.

For instance, as we can see in table 8, Peru in Technical and Institutional sustainability indicators has a high relative score and in Social indicator has low score among these countries. Indeed, with regards to obtained results we can say that this study first identifies weak and strong indicators of each country's sustainability especially in the energy sector and then compares them. Also, it should be implemented the useful measures by policymakers, to improve each indicator related to social, economic and environment sectors.

Each research has many advantages and disadvantages. Although this study, determined the strengths and weaknesses of each country, it is extremely dependent on the resource and policy system of each country. Indeed, without a regular planning by policymakers and energy experts and with regards to existing capacities any country, an achievement to energy sustainability is challenging.

Thus, we presented a group of indicators with a comprehensive description, which is important to achieve energy sustainability and have a decisive role in achieving it. If these presented indicators get implemented by policymakers, it can be influential to improve energy sustainability. It could be mentioned that changes in the determined indicator structure, can lead to changes in the different sector of energy such as supply, intensity, and consumption. In fact, we based on principles and scientific perspectives, selected these indicators to measure energy sustainability.

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