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Energy sustainability analyses using feasible indicators for urban areas

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Abstract:

Energy sustainability is a priority for each city and contribute to development and improve the quality of life for human also it emphasis on environment sectors. Without doubt applying appropriate indicator is an effective factor achieve energy sustainability in urban areas and is as effective tool for policymakers and energy experts. The urban areas has important for us and energy supply and energy consumption in that is an essential issue. The main purpose of present this study is explores investigating and selecting feasible indicators to achieve energy sustainability in urban areas. Analysis of city energy sustainability development index (CESDI) in this research is presented that effect on urban quality and contribute to enhance quality of life for its inhabitants. As a result, the study shows that using proper indicators in a specified framework with good planning and appropriate policies lead to energy sustainability in residential areas.

Keyword: Energy Planning, Energy sustainability, CESDI method, Indicators, Urban area

Nomenclature

AE	Access energy	FA	Forest area
AER	Access to electricity urban and rural	GDP	Gross domestic product
AFW	Annual freshwater withdrawals	GNI	Gross national income
CCP	Changing consumption patterns	LA	Land area
CE	CO ₂ Emission	NRE	Non Renewable resource
EA	Energy accessibility and equity	POP	Population
EAFF	Energy affordability	RE	Renewable resource
EC	Electricity consumption	St	Strategies
EI	Energy intensity	TFC	Total final consumption
EIN	Energy investment	TFCC	Total final consumption in Commercial
		TFCH	Total final consumption in Household
ENV	Environment	TFCT	Total final consumption in Transport
EPR	Energy production from renewable energy	TPES	Total primary energy source
ESe	Energy security	UP	Urban planning
ET	Energy technology		

1. Introduction

Cities are known as an important and strategic worldwide area, because in these areas doing main human social and economic activities [1]. Now, more half of the world's population lives in urban area and this population increases in future that this factor can make different problems for its inhabitants definitely [2]. In addition, cities have a role to play in the energy consumption, thus improving energy consumption situation in them, can extremely lead to save energy of each country. Indeed, with increase population of cities, increases required energy of their inhabitants, hence, having a proper plan can be effective to prevent of this issue [3]. Energy supply security, Economic growth, , environmental conservation, and social acceptability are among targets that now investigates by the policy makers and energy experts in the line of energy sustainability achievement.

Development of sustainable energy indexes by the utilization of new indicators: A comparative study

A. Armin Razmjoo a, Andreas Sumper a,b, Afshin Davarpanah

Also with expanding the cities, CO₂ emission increases and it threatens our future and our environment day to day [4]. With these description, move toward to energy sustainability is a proper way to overcome on existing problems. In fact, energy sustainability is as one of the most significant challenges facing urban today society and future world. In fact, energy supplying needs

of the present without compromising the ability of future generations to meet their own needs is the main mean of energy sustainability [5]. Also, now energy sustainability is one of the most important issues for each country that is extremely involved with policy. It means that, the reliable energy supply and affordable is importance and is a main policy in each country. Since urban density extremely lead to more energy consumption, thus how access to energy and use of energy by cities inhabitants, is important for the future [6]. Hence, can say that, achieving to sustainability and specially energy sustainability is one of the most issues of our time. Of course, political and energy experts are good aware of this concept and trying with different proper planning, reduce the cost and energy intensity for inhabitants of cities [7]. Nowadays, all governments are trying to enhance quality life for inhabitants of cities specially in access and consumption of energy [8]. Thus, with regard to this reality that city areas has important as a strategic dimension for governments, needs to special planning in the line of energy sustainability [10]. It means, to achieving energy sustainability in cities, a set of influential sustainability indicators is indispensable. These indicators could allow and help us to identify the present problems and remove them [11]. In addition, to evaluate the energy sustainability in different sectors, it is necessary to determine the driving factors influencing all parts. For example, can find that in which sector has the most energy consumption and how can control it. Actually, finding the main cause of problems lead to how can revise and remove an issue [12]. Many researches around the world have investigated the energy sustainability of urban areas in different subjects. These research works include: Investigating three important challenges for the compact city with emphases on sustainability.

Three Challenges for the Compact City as a Sustainable Urban Form: Household Consumption of Energy and Transport in Eight Residential Areas in the Greater Oslo Region Erling Holden and Ingrid T. Norland

Energy planning with regard to environmental, social and economic dimensions and in the line of sustainability.

Reference: Sustainable energy planning by using multi-criteria analysis application in the island of Crete Author links open overlay panel Theocharis Tsoutsos

Measuring urban energy sustainability for Malaga and Barcelona cities in the Spain

Reference: Measuring urban energy sustainability and its application to two Spanish cities: Malaga and Barcelona MJ Marquez-Ballesteros, L Mora-López, P Lloret-Gallego, A Sumper, ...

Sustainable cities and society 45, 335-347

Developing new indexes and indicators to achieve sustainable energy

Reference: [Development of sustainable energy indexes by the utilization of new indicators: A comparative study](#)

AA Razmjoo, A Sumper, A Davarpanah
Energy Reports 5, 375-383

Evaluating energy saving in the residential buildings systems,

Reference: Energy saving evaluation of passive systems for residential buildings in hot and dry regions Hossein Goudarzia, Ali Mostafaeipour

In addition, Kammen D et al investigated city-integrated using renewable energy and in order to achieve sustainability. They in this research showed that renewable energy has positive effect on environment and energy supply in urban areas.

Reference: City-integrated renewable energy for urban sustainability Daniel M. Kammen^{1,2,3*} and Deborah A. Sunter^{1,3}

Cumo F et al investigated sustainable management for urban areas with a holistic approach. They in this study, presented some influential instruments that can be effective for EU contributions with help to reduce the energy consumption and energy balance.

Reference: Urban policies and sustainable energy management Fabrizio Cumo, Davide Astiaso Garcia, Laura Calcagnini, Fabrizio Cumo, Flavio Rosa*, Adriana Scarlet Sferra

Carreón JR et al presented a research agenda for urban metabolism to sustainable development and using urban energy systems. They investigated various options to create sustainable energy systems such as energy consumption reduction, energy supply, technology development and etc.

Reference: Urban energy systems within the transition to sustainable development. A research agenda for urban metabolism

Author links open overlay panel Jesús Rosales Carreón, Ernst Worrell

Effects urbanization on energy demand and urban structures investigated by Madlener R et al . These researchers considered different processes and mechanisms and relevance of these mechanisms between developed and developing countries in order to answering to energy demand of inhabitants in urban areas using proper urban planning and urbanization management.

Reference: Promoting and implementing urban sustainability in China: An integration of sustainable initiatives at different urban scales

Bao-Jie He^{a,*}, Dong-Xue Zhao^b, Jin Zhu^a, Amos Darko^c, Zhong-Hua Gou^d

This paper has three novelties: firstly, it comprehensively reviews energy sustainability studies for urban areas; secondly, it considers existing weakness in the question framework and answers them obviously; and thirdly, it present new indicators as effective tools for policymakers and energy experts.

2. Importance of energy sustainability for cities with emphases on clean energy and technology

Energy supply is one of the most important issues for all governments. Because it can help each government to have a regular program for each regions and sections accurately. In this regard, different resources with their inherent potential has most effect for energy production. Table 1 shows Total Primary Energy Supply (TPES) by source from 1990 to 2016 years based on IEA report and in unit ktoe. As can see in this table the main resource for supplying energy are fossil fuels that it lead to more production of CO₂ emission, but fortunately use of renewable energy from 1990 to 2016 year has been increased year to year.

Table 1. Total Primary Energy Supply (TPES) by source from 1990 to 2016 years based on IEA report and based on Ktoe.

Year	Coal	Natural gas	Nuclear	Hydro	Geothermal, solar, etc.	Biofuels and waste	Primary and secondary oil
1990	2220183	1663518	525520	184324	36603	909368	3233897
1995	2207026	1807686	608098	213142	42464	972036	3374906
2000	2316125	2072073	675467	225131	60159	1022197	3662923
2005	2993746	2359231	721706	252346	70265	1096114	4000746

2010	3652298	2735488	718829	296247	110420	1221756	4139699
2015	3850534	2943686	670298	335745	204339	1317216	4347259
2016	3730886	3034954	679649	349223	225627	1349289	4390197

Source: IEA World Energy Balances 2018 - <https://webstore.iea.org/world-energy-balances-2018>

On the other hand, energy consumption is a serious challenge for policy makers and energy expert. Actually, high consumption of energy in the cities due to high demand of its inhabitants should be considered accurately [13]. Supplying energy for residential areas and economic areas, has been caused that policymakers has had special view on this issue [090].

Energy Sustainability: A Pragmatic Approach and Illustrations

Marc A. Rosen

Fig. 1 shows the percentage of total energy consumption by sector in 2015 and 2016 years. As can see in this fig, industrial, transport and residential sections has more present of energy consumption respectively. Also, it should be mentioned that these three sections, has most global CO₂ emissions.

Reference: Energy and CO₂ management for chemical and related industries: issues, opportunities and challenges

Ramsagar Vooradi, Sarath Babu Anne, Anjan K. Tula, Mario R. Eden, Rafiqul Gani

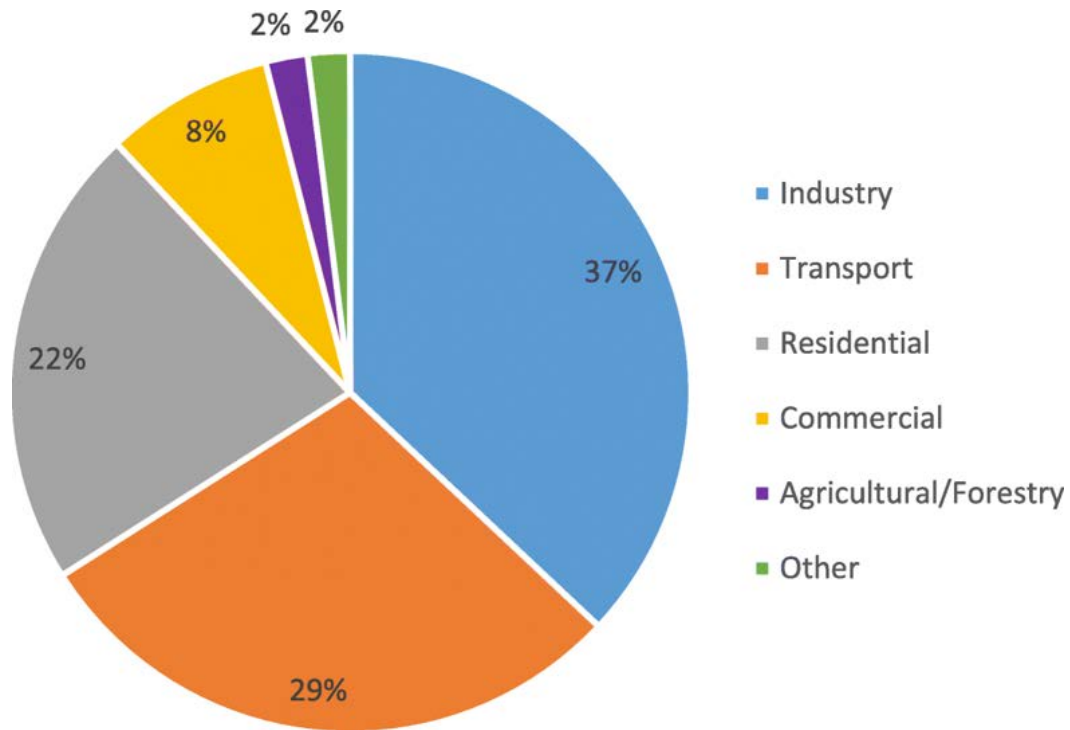


Fig.1. Percentage of total energy consumption by sector in 2015 and 2016

With these descriptions, it should be noticed that energy sustainability could be applied in the whole of energy system of urban areas using new technologies such as EVs in order to energy storage and to provide energy services to inhabitants in different seasons. In addition, using new technologies such as EVs could have positives effects on environment and good way to achieve energy sustainability. [900].

Reference: Using electric vehicles for energy services: Industry perspectives Author links open overlay panel C. Weillera A. Neely

Electric cars and wind energy: Two problems, one solution? A study to combine wind energy and electric cars in 2020 in The Netherlands Sandra Bellekom a , René Benders a,* , Steef Pelgröm b , Henk Mol

No only energy supply on the time is important for cities population, also can say that forecasting energy needs of future for them and city active industrials is an essential issue [14]. Energy sustainability as much as can make energy balance for different cities, also can prevent most problems related to energy such as lack of proper accessible energy of inhabitants [15]. Also, regarding to energy resources limitation and environmental impacts, energy sustainability is

becoming a global necessity. Thus, moving toward energy sustainability has numerous benefits for all countries of the world.

Electric cars and wind energy: Two problems, one solution? A study to combine wind energy and electric cars in 2020 in The Netherlands Sandra Bellekom a , René Benders a,* , Steef Pelgröm b , Henk Mol

2.1. Identifying influential indicators to achieve energy sustainability in cities

The majority of the energy sustainability challenges, is belongs to the urban environment, because these zones has more need to energy. Also important role of energy sustainability is clear for each person. Recently many attention has been given to developing assessment energy sustainability frameworks and use of proper tools for urban areas. It shows that architects, urban planners, and decision makers has specific targets related to energy sustainability. To reach energy sustainability, use of specific indicator is required for measuring and monitoring the energy use in urban area. Since energy indicators has an effective key role for urban areas, hence, having an innovative approaches and policies targeted to select and implement them, can be more remarkable to achieving energy sustainability successfully.

Reference: Residential energy behaviour: does generation matter? Annika Carlsson-Kanyama,1 Anna-Lisa Lindén2 and Björn Eriksson1

Having the features such as applicable, influential, measurable and compatible with urban area, are the most important factors to select and implement an indicators related to energy sustainability in a society to achieving the considered objectives. Confidently can say that, if indicators select in an appropriate framework, are able to enhance the quality life of urban inhabitants. Thus, proper indicators if based on an accounted policy were implemented, a sustainable energy, affordable and safe will bring for all households and society.

Reference: Energy sustainability analysis based on SDGs for developing countries

A. Armin Razmjoo, Andreas Sumper & Afshin Davarpanah

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**AA Razmjoo, A Sumper, A Davarpanah
Energy Reports 5: 375-383**

Actually, providing the reliability of sustainable energy supply, is an important goal to gain energy sustainability for inhabitants in urban areas. Presenting applicable patterns for inhabitants in energy field such as low energy consumption patterns, more training people in energy consumption field, improvement the policies and regulations energy, use of new systems with high efficiency, use of envelope in building, more use of public transport and specially EVs to reduce CO₂ are the best energy sustainable indicators to help people and can be influential to enhance quality of life for them. Also attention to indicators compatible with both policy and energy balance program, definitely has most impact on energy sustainability of cities.

Reference: Energy Sustainability: A Pragmatic Approach and Illustrations
Marc A. Rosen

Towards Efficient Energy Management and Power Trading in a Residential Area via Integrating a Grid-Connected Microgrid
Sheraz Aslam 1, Nadeem Javaid 1,* ID , Farman Ali Khan 2, Atif Alamri 3, Ahmad Almogren 3 and Wadood Abdul 3

2.2. Proper policies to consume of energy of inhabitants

Many energy policies are not enough or not well-defined, Thus, need that again be investigated and revised. Understand people needs should be primary priority for politicians and they can easily forecast the necessary needs for urban inhabitants in future. Attending to people needs should be an important for politicians and always they making correct decision with regard to all aspects of society and people life.

Reference: Energy sustainability analysis based on SDGs for developing countries
A. Armin Razmjoo, Andreas Sumper & Afshin Davarpanah

Reference:Energy decisions reframed as justice and ethical concerns Authors: Benjamin K. Sovacool^{1,2, *}, Raphael J. Heffron³ , Darren McCauley⁴ , Andreas Goldthau^{5,6}

There are many differences between selecting and implementing indicators in an ideal world and real world. It means that many of selected indicators in ideal world, are not possible to

implementing in real world. Indeed, even if investigated with highest precision in ideal world, is not an enough reason to implement them, because it is possible that in real world, some unexpected incidents intervene and make different problems. By the way, multidimensional analyses from different aspects can be effective to reach acceptable results before implementation indicators. Policy acting as a principal framework to find and making decision indicators in a plan. Actually proper and timely policy more quickly can lead to desirable results in sustainability. Selecting appropriate, logical and executive criteria can contribute to find measured indicators in direction achievement to energy sustainability for urban areas.

Reference: Energy indicators for sustainable development

Author links open overlay panel [vanVerdLucilleLanglois](#)

Reference: Energy governance, energy security and environmental sustainability: A case study from Hong Kong

Author links open overlay panel [CameronHolleya](#)

3. Methodology for the objective selection

Since, implementing appropriate energy indicators can be effected on the quality of life for cities inhabitants, hence, urban energy sustainable indicators are crucial and important tool for measuring urban energy status and helping the society progress to achieve energy sustainability. The emphases of this study is on energy sustainability for residential areas using effective indicators and in the line of SDGs and Habitat III and CESDI method. This research divided in two stages. In first stage, four effective indexes in sustainable development investigated especially for urban areas and explained comprehensively. In second stage, an impressive group including eight indicators investigated that has most effect on urban areas from the energy sustainability point of view and for them was selected sub-indicators. For selecting final sub-indicators, a lot of sub-indicators in framework a set, were selected and then from among of them the best and most effect sub-indicators were used in this study. These chosen sub-indicators with high percent of effect on energy sustainability, are main and could minimalize existing issues in urban areas.

4. Comprehensive description of four important indexes

4.1. Policy

Because of high facilities and better progress in cities, people prefer live in urban areas, so they can have better quality of life and access to many things that want [16]. Also since so many of us live in cities, thus the urban area is important for all of us and in this regard can be more seen importance of indicators [17]. On the other hand, remarkable key role of policy and policymaker will be increased simultaneously. Actually in policy section, attention to a good relationship between urban planners and policy makers are important, because friendly relation can be a good policy to eliminate many problems. [18]. Urban interests must always be prioritized and appropriate decisions are taken using expert persons views and in specific framework to achieving favourable results [19]. Use of city inappropriate and incompatible programs not only makes many problems and negative impacts in urban area also lead to conflicting effects for policymakers and urban planners [20]. Thus, all actions should be prioritized and implemented with regard to common goals and be compatible in direction of urban developing and achieving to satisfied public results for cities inhabitants [21]. The policymaker that focus on energy sustainability in cities, have a special view on the sets of indicators that present by city planners and that it shows the importance of indicators [22]. Since each indicator is used to the effectiveness of the policy change and progress, hence, is important that from the first to be considered an obvious and targeted approach in this field. Indeed, indicators are a key role in energy sustainability but they cannot easily and automatically impact policymaking and need to some specific laws to implementation. Firstly, it should be proved that sets of presented indicators are practical and useful, secondly these are coherently with society, and thirdly a governments be able to implement them easily [23]. As above mentioned, to use of indicators in society, it is important the considering of cycle of policy-making. It means that the indicators are effective in both theoretical and operational views thus, the role of policy-making is remarkable to implement indicators in cities [24]. Actually, to achieve energy sustainability goals in specific terms, having a strong and accounted policy program in side of an excellent managing and monitoring on the progress, not only can lead to desirable results, also it will caused the attract more public support that can be effective to continue other plans in the future. As a result, can say to implement energy sustainability indicators in cities, is need to proper strategies and practical instruments in this field, accurate evaluation and finally executive them [11].

4.2. Economy

Economic is an essential factor to reach energy sustainability. Because affordable energy supply for cities inhabitants, can be lead to access energy them easily [25]. Since now the quality of our life is extremely dependent to access energy [26], hence energy supply for all people especially urban areas that has more consumption of energy than others should be affordable, reliable and abundant [27]. The energy sustainability in economic sector, should be elaborated and implemented within an appropriate framework for urban areas. Indeed, the main goal of energy sustainability from the economic point of view, should be based on a useful and applicable assigned program to correct energy consume, having low cost and high efficiency for all of people [28]. It means that only more use of resources should not be considered a goal by planners for consumers, and an equilibrium plan combination simultaneous of high efficiency and economy should be investigated in this sense. Actually, only attention to energy efficiency, increases energy use by consumers and it makes most cost by them [29]. Also can be mentioned that the inefficiency of energy sustainability programs in economic sector, moreover increases energy consumption, so increases cost for inhabitants of urban areas [30]. Thus, from the economic point of view, energy sustainability indicators must be correct selected and applied in a way that is both appropriate and acceptable to the people of the community and also suitable for governments.

4.3. Environment

Daily consumption of energy, has impact on environment that we live in it, thus kind of energy consumed and environment are main issue for all of us [14]. On the other hand, use of fossil fuels causes global warming and air pollution and threats our plant [31]. At present, in the most countries of the world, a plan related to less carbon-intensive and even carbon-free energy is investigated as a part of main programs of governments to achieve energy sustainability for future [32]. Variety type of program has been presented by policy makers such as more use of natural gas as cleanest major fossil fuel [33] and renewable energy to more help in energy supply [34]. Low carbon policy should be considered as most important policy in for environment sector. Determination appropriate environment indicators and implement it, is a positive step to achieve energy sustainability. Undoubtedly use of practical indicators that are compatible with environment, is

most effective for urban areas in this sense [35]. These programs first of all, needs to a comprehensive plan to demonstrate to policymakers in order to convince them. Then selection proper indicators and finally implementation them respectively. Fortunately, today's in the environment sector is carried out much progress to use of proper indicators for urban area, but still it needs to be more measurement and enhancement by governments [36]. Also in this regard, other appropriate solutions can be very effective such as increase new technologies based on economic policies, limitation regulations for production growth in rich countries and financial support of big producers to reduce greenhouse emissions and more use of renewable energy.

4.4. Social

Can confidently say that the most produced energy by industrials, is consumed in urban society, actually, urban areas are most consumer [15]. Planning to develop energy sustainability especially for social sector is one of the most important tasks of energy planners of each area. Energy planners and policymakers need to consider and have appropriate and sustainable targets for urban development in terms of energy [37]. If energy planners and energy experts are not be able to measure the ultimate goal of society, it will be impossible to manage it. energy sustainability management therefore needs to define sustainability goals that need to be continuously investigated and evaluated and end were capable to implementation [26]. Since the performance of each society in energy sector and especially in social energy sustainability program is different and it depends to variety of factors in community, therefore, the most important indicators related to energy sustainability from the social aspect, should be assessment, determined and implemented [38]. In this regard determination and assessing social indicators by experts of society has important and it is considered as a priority to gain energy sustainability [39]. Because, indicators play an important role to energy sustainability for urban areas, hence, achieving to energy sustainability of society, without a strong insight, use of a set of credible sustainability indicators, practical and a clever decision is made to implement it is impossible. Indeed, real energy sustainability indicators, are capable to define goal, also measure the method and degree of implementation of it [40]. Surely only a theoretical definition of energy sustainability social is not enough to reach energy sustainability in urban areas and it should be measured in practice [41]. Thus to gain energy sustainability in urban areas, needs to an accounted strong strategies with cooperation of governmental policymakers and cities programmers based on both theoretical and

applicable program [42]. Fig 2 shows the four main indexes in this study in the line of energy sustainability. As it clears in this fig, for achieving energy sustainability, policy, environment, social issues and economy are main indexes.

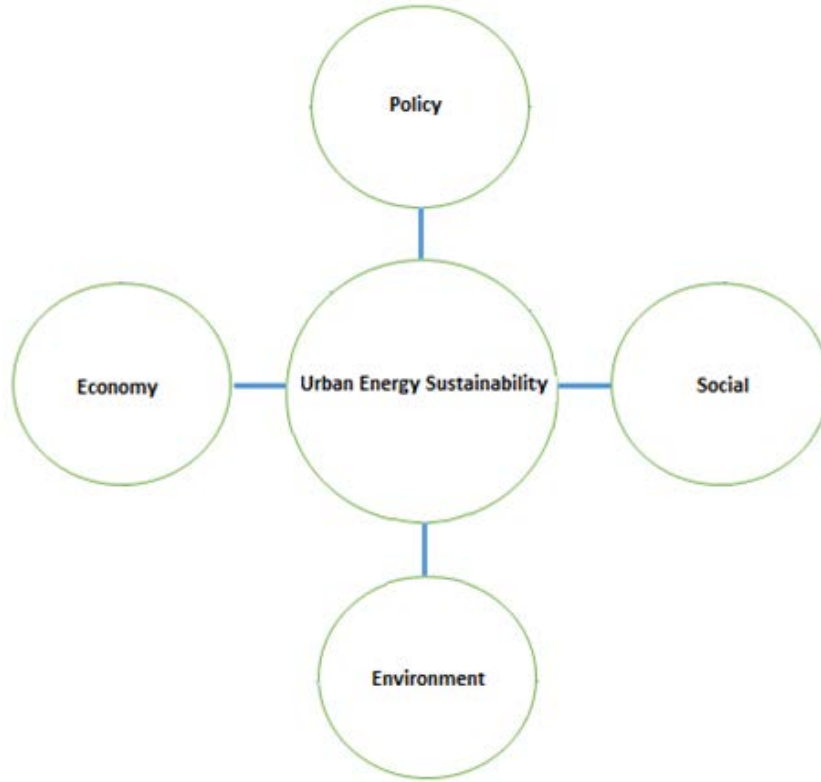


Fig 2. Four main indexes in this study in the line of energy sustainability

Table 2. Shows four main indexes with influential indicators based on fig 2. This table is made based on four main indexes and related indicators in the line of energy sustainability. Actually, the most important indicators were selected in order to identify the best framework in energy sustainability. On the other hand, we are be able using this suggested table for choosing the appropriate strategies in order to improve quality life of urban inhabitants and near to energy.

Table 2. Four main indexes with related indicators based on fig 2.

Index	Indicator
Policy	ESe, EI, EIN, ET, UP, St, TPES, TFC
Economy	EAFF, EIN, GDP, GNI, EC, EA, TFC
Environment	CE, AFW, FA, LA, NRE, RE
Social	CCP, EA, EAFF, EC, ESe, ET, TPES, TFC, TFCC, TFCH, TFCT, POP

Moreover, Fig 3 shows a total schematic of urban energy sustainability and four main divided indexes with relevant indicators it. In this fig, main indexes as urban energy sustainability pillars are in above and relevant indicators to them are in down of this fig. Also this fig demonstrates that how energy resource can divide fairly between main sectors to gain energy sustainability.

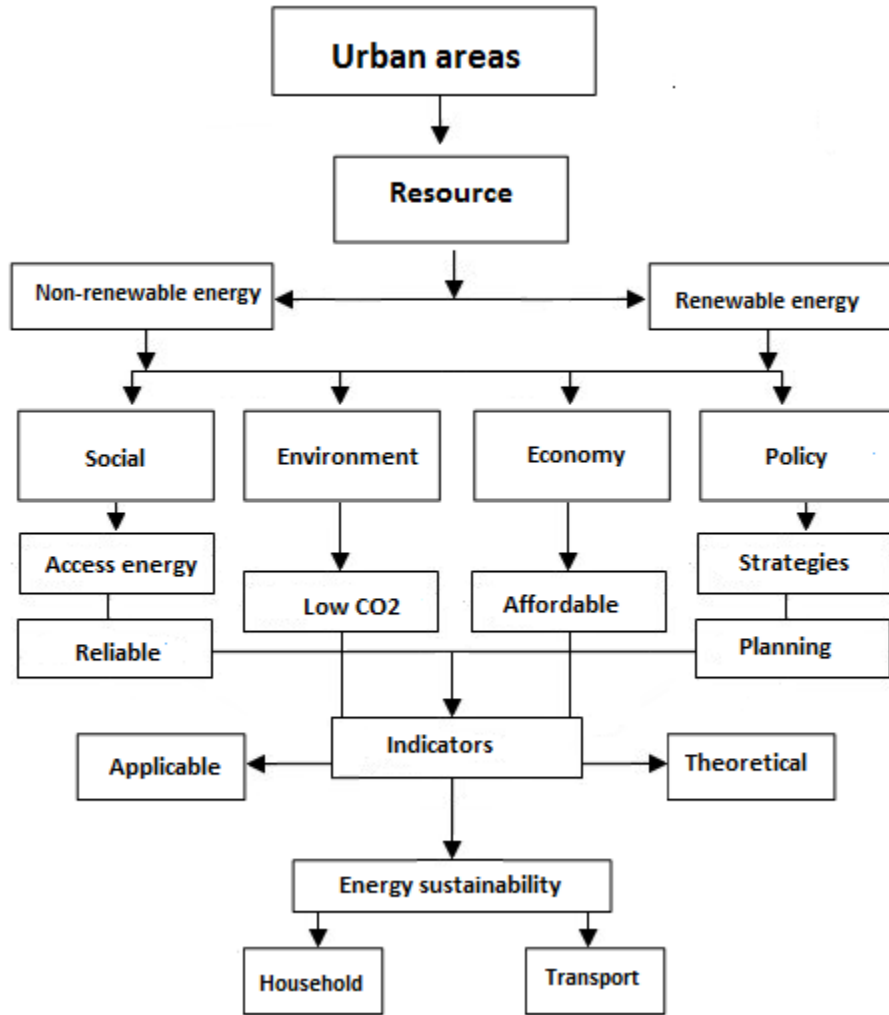


Fig 3. A total schematic of urban energy sustainability and divided indexes with relevant indicator

4.5. Group of effective indicators of energy in urban area

The selection of appropriate indicators is definitely an effective step to achieve sustainability in energy field. There are different types of indicators to improve energy sustainability, but which of this indicators are better and more practical in this sense. Hence, proper analyze for selecting indicators is important thing to achieving goals of energy sustainability. Indeed, it is necessary that know which indicators can focus better impact on energy sustainability. On the other hand, this investigation should be consisting both quantitative and qualitative indicators that could better analyzed and selected to achieve energy sustainability. The selected indicators have sub-indicators that correspond to main elements and lead to energy sustainability. In this regard, eight indicators in framework a group relevant to four main indexes of sustainable development, investigated. These indicators has most effect on energy sustainability.

- **Energy resource**
- **Environment**
- **Economy**
- **Transport**
- **Use of Energy**
- **Resiliency**
- **Policy**
- **Household**

Table 3 shows the group of indicators with sub-indicators that has most effect on energy sustainability in cities. Also in this fig the third pillar shows that relation between sub-indicators pillar with 4 indexes CESDI respectively.

Table 3. Group of selected indicators with sub-indicators

Group of indicators	Sub-Indicator	Related to 4 indexes CESDI respectively
Energy resource	NRE, RE, LA, FA	ENV, ECO, SOC, POL
Environment	AFW,CE , FA, LA, NRE	ENV, SOC, POL, ECO
Transport	AE, EC, NRE, RE, TFCT, TPES, TFC	SOC, ECO, ENV, POL
Use of energy	AE, EAFF,EC, TPES, TFC, EI, EPR, , EA,	POL, ECO, ENV1,SOC
Resiliency	AE, AFW, EC, TPES,TFC, UP	ENV, SOC, POL, ECO
Policy	ESe, EI, EIN, EPR, EPNR, ET, UP, St, TPES	POL, SCO1, ECO, ENV
Economy	EAFF, EIN, GDP,GNI, EC, EA, TFC	ECO, SOC, POL, ENV
Household	AE, AFW, EA, EQ, EI, EC, TPES, TFC, UP	SOC, ENV, ECO, POL

5. Result and discussion

Importance a city when will be specified that most or all of the its inhabitants are satisfied of quality of life. Indeed, live in a city for a person is important from the variety aspects such as welfare, education, economic, access energy, and etc. Approximately in each city there is many urban problems that this subject impacts on the degree of quality of life for inhabitants Access energy subject that lead to energy sustainability always considered as a remarkable issue for all of cities inhabitants. In this regard, our results suggest that with regard to increasing day to day population of cities and energy supply sensitive for in habitants, thus needs a regular planning. The following sections report our results about this issue. Fig 4. Demonstrates a schematic of energy supply from primary resources made by authors. This fig in different sections and based on existing resource and with regard to eight selected indexes was designed. As it is clear, resources is divided in two main parts as total primary energy supply (TPES) and then these resources used in two significant section such as transport and household used and in the end of this fig is economic section. This fig demonstrates that for achieving energy sustainability based on resources, should be considered effective policy and appropriate planning. In fact, if we can modify the amount consumption of energy with an excellent management in different section correctly, surely will have not problem in the future for energy supply for inhabitants of cities.

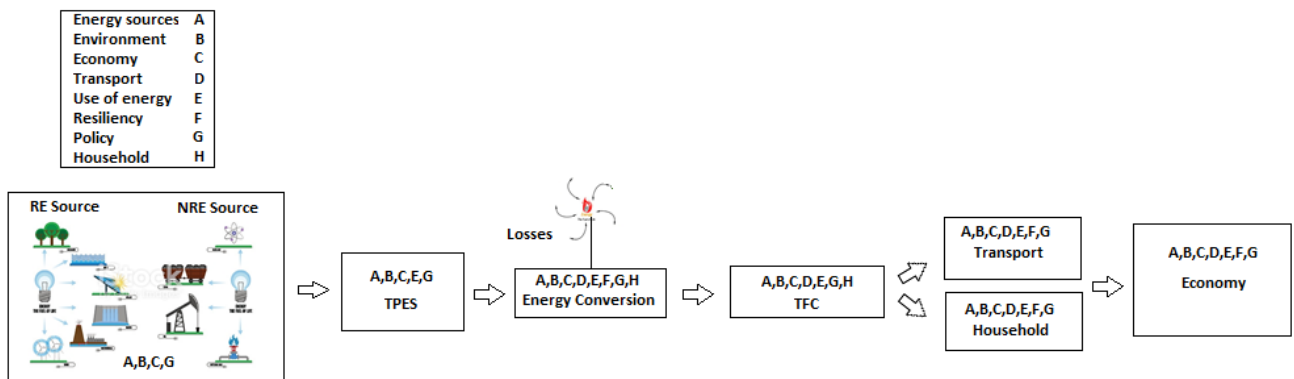


Fig 4. A schematic of energy supply from primary resources with relevant indicators
Source: Authors

In addition, Table 4 demonstrate the most important sub-indicators related to eight selected indicators that is based on design of the fig 2.

Table 4. Influential indicators and sub-indicators based on design of the fig 1.

Sub-indicators	Resource	TPES	EC	TFC	Transport	Household	Economy
Total non-renewable and renewable energy	√	√	x	x	√	√	√

Total production energy by non-renewable energy	x	√	x	x	√	√	√
Total production energy by renewable energy	x	√	x	x	√	√	√
Non-renewable end renewable resource	√	√	√	√	√	√	√
Total consumption energy by non-renewable energy	x	x	x	√	√	√	√
Total consumption energy by renewable energy	x	x	x	√	√	√	√
Amount of CO ₂ emission	x	√	√	√	√	√	√
Amount of investments in energy	x	√	x	√	√	√	√
Reduction fuel fossils by technology	x	x	√	√	√	√	√
Amount of energy intensity	x	√	x	√	√	√	√
Electrical consumption by renewable end non- renewable energy	x	x	x	√	√	√	√
Percent of economic growth by energy sector	x	√	√	x	√	√	√

5.1. Energy sustainability

SDGs targets by 2030 extremely emphasizes on energy sustainability and specially energy access, also, the utilization of renewable energy with an effective policy and as a reliable way to supply a part of the required energy for the countries that have not sufficient resource for a good future. In this regard as above mentioned, using feasible indicators for implementation as useful tools is most factor for achieving energy sustainability. These indicators with sub-indicators make a chain of energy sustainability for residential areas. Fig 5 shows energy sustainability with considering most important indicators and sub-indicators in the line of on SDGs and UN-Habitat III. Indeed, the main objective of this Fig is energy access in the best possible state for residential inhabitants as secure, reliable, abundant, accessible and affordable. It is shown in Figure 5.

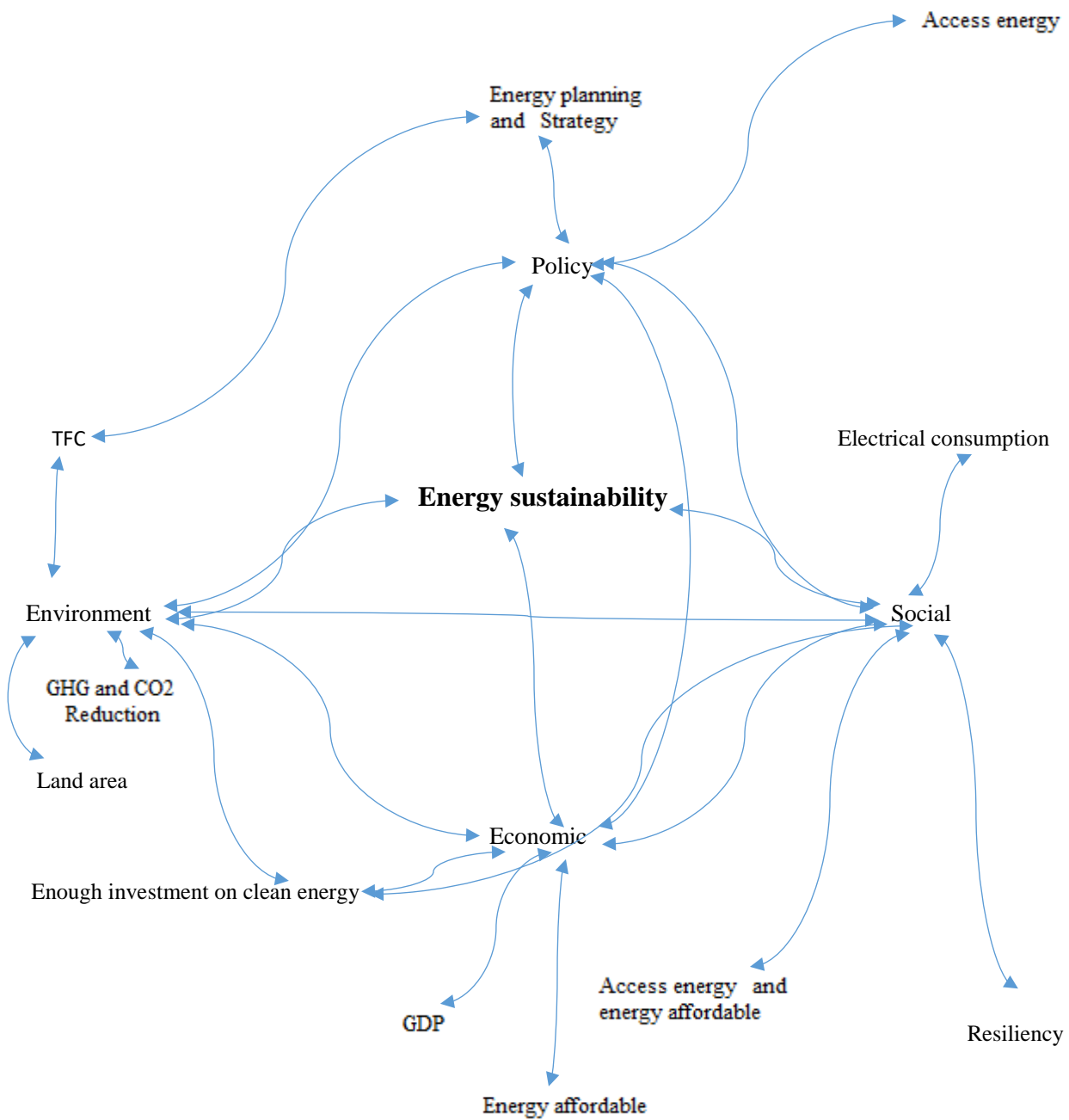


Fig 5. Energy sustainability dynamic schematic

5.2. Smart city and energy sustainability

Without doubt, with regard to expanding cities and different demands by its inhabitants, moving toward a smart city that use of incorporates information and new technologies in order to improve the quality and performance of urban services will be increased in the future. Important issues such as energy supply regarding to limitation of fossil fuels, climate change, public transportation and cities costs, are enough causes for make smart cities. Also, should be emphasized that smart city needs to smart economy, smart governance, smart mobility, smart environment, smart living and smart people. Thus, having an appropriate approach by policymakers and cities programmers to select of correct indicators in this regard can catalyze to solution of related issues and achievement to energy sustainability. Fig 6 shows hierarchical structure of application areas related to smart cities. As can see energy sustainability can be influential in some parts of this fig.

Smart cities with big data: Reference models, challenges, and considerations
Chiehyeon Lima,^{a,*} Kwang-Jae Kim^b, Paul P. Maglio^c

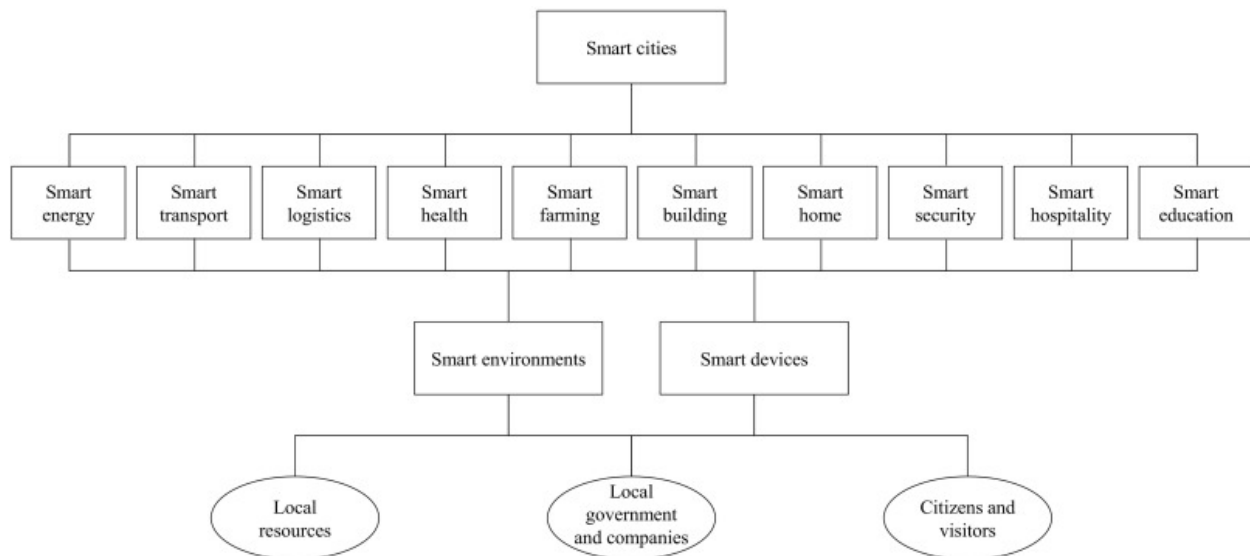


Fig. 6. Hierarchical structure of application areas related to smart cities

Since smart city has a near relation with energy sustainability, thus was presented table 5 that shows carried out studies in this regard.

Table 5. Studies on the energy sustainability and smart cities.

Main author	Summery description of the work
Stephan Maier, 2016	Investigation on utilization of proper planning for the city development using optimal energy technology networks and policy.
Farnaz Mosannenzadeh, 2017	Consideration smart energy city both theoretical and practical and presented smart energy solutions for development them.
George Lazaroiu, 2012	Presentation a new method and calculated smart indicators weight for smart city by fuzzy logic method
Martín García Vaquero, 2019	Investigation national plan for smart cities for Spain based on Policy, Sustainability and using clean energy.
Angeliki Kylili, 2015	Presentation practical standards (potential of ZEBs in SET-Plan smart cities) in the field of energy and for building
Kramers, Anna, 2014	Investigation information technology knowledge to reduce energy use in cities with an analytical framework.
Morris Brenna, 2012	Suggestion a sustainable energy microsystem for the integration of different subsystems for buildings in cities.
Daniel M. Kammen, 2016	Consideration city-integrated using renewable energy for urban sustainability
Mark Deakin, 2018	Investigation sustainability of city that can be as energy efficient low carbon zones
R Niemi, 2012	Investigation carrier networks in urban areas for distributed renewable energy generation in order to improve energy sustainability.
Tan Yigitcanlar, 2018	Investigation smart city practices for 15 UK cities to in achieving sustainable urban outcomes.
María V. Moreno, 2014	Consideration user centric smart buildings to achieve energy sustainable for smart city

6. Conclusion

Energy supply for urban areas is an important issue. With regard to this subject that contemporary cities are more dependent on use of fossil fuels to energy supply, thus, has high potential to produce CO₂ and move toward global warming. Since, cities usually are known with having compressed population as a high consumer of energy, hence, Today's, energy supply for them has been becoming a strategic issue for city planners. Then achieving energy sustainability can be useful as a proper way in this regard. This paper investigates the indicators and sub-indicators which effects on energy sustainability in urban areas. The paper commences with a review of energy sustainability concept, important indicators and policy. Then, four influential indexes in the line of sustainable development described comprehensively. In the next stage, illustrates eight sub-indicators that has most effect on energy sustainability and for each of them select proper sub-indicators. And finally, results are over with description of energy sustainability and connect with smart city. Indeed, the main objective of this study is define and determine a set of indicators that can be effected to measure energy sustainability of urban area and their influence on the quality of urban life. All of these selected indexes, indicators and sub-indicators are related to energy sustainability of urban areas directly. The results shows that for achieving energy sustainability in urban areas have appropriate strategy, planning and effective indicators should be considered and applied for different sections.

Reference:

1. Adam, K., et al., *Methodologies for city-scale assessment of renewable energy generation potential to inform strategic energy infrastructure investment*. Cities, 2016. **54**: p. 45-56.
2. Mavromatidi, A., E. Briche, and C. Claeys, *Mapping and analyzing socio-environmental vulnerability to coastal hazards induced by climate change: An application to coastal Mediterranean cities in France*. Cities, 2018. **72**: p. 189-200.
3. Santamouris, M., et al., *On the impact of urban climate on the energy consumption of buildings*. Solar energy, 2001. **70**(3): p. 201-216.
4. Yu, W., R. Pagani, and L. Huang, *CO2 emission inventories for Chinese cities in highly urbanized areas compared with European cities*. Energy Policy, 2012. **47**: p. 298-308.
5. Clayton, T. and N. Radcliffe, *Sustainability: a systems approach*. 2015: Routledge.
6. Sorrell, S., *Reducing energy demand: A review of issues, challenges and approaches*. Renewable and Sustainable Energy Reviews, 2015. **47**: p. 74-82.
7. Parajuli, R., et al., *Biorefining in the prevailing energy and materials crisis: a review of sustainable pathways for biorefinery value chains and sustainability assessment methodologies*. Renewable and Sustainable Energy Reviews, 2015. **43**: p. 244-263.
10. Tan, B., et al., *Optimal selection of energy efficiency measures for energy sustainability of existing buildings*. Computers & Operations Research, 2016. **66**: p. 258-271.
11. Neves, A.R. and V. Leal, *Energy sustainability indicators for local energy planning: Review of current practices and derivation of a new framework*. Renewable and Sustainable Energy Reviews, 2010. **14**(9): p. 2723-2735.
12. Shen, L.-Y., et al., *The application of urban sustainability indicators—A comparison between various practices*. Habitat International, 2011. **35**(1): p. 17-29.
13. Armaroli, N. and V. Balzani, *The future of energy supply: challenges and opportunities*. Angewandte Chemie International Edition, 2007. **46**(1-2): p. 52-66.
14. Asif, M. and T. Muneer, *Energy supply, its demand and security issues for developed and emerging economies*. Renewable and Sustainable Energy Reviews, 2007. **11**(7): p. 1388-1413.
15. Holden, E. and I.T. Norland, *Three challenges for the compact city as a sustainable urban form: household consumption of energy and transport in eight residential areas in the greater Oslo region*. Urban studies, 2005. **42**(12): p. 2145-2166.
16. Rogerson, R.J., *Quality of life and city competitiveness*. Urban studies, 1999. **36**(5-6): p. 969-985.
17. Mori, K. and A. Christodoulou, *Review of sustainability indices and indicators: Towards a new City Sustainability Index (CSI)*. Environmental Impact Assessment Review, 2012. **32**(1): p. 94-106.
18. McCool, S.F. and G.H. Stankey, *Indicators of sustainability: challenges and opportunities at the interface of science and policy*. Environmental management, 2004. **33**(3): p. 294-305.
19. Krebs, T.B., *Urban interests and campaign contributions: Evidence from Los Angeles*. Journal of Urban Affairs, 2005. **27**(2): p. 165-176.
20. Brudney, J.L. and R.E. England, *Urban policy making and subjective service evaluations: are they compatible?* Public Administration Review, 1982: p. 127-135.
21. Agyeman, J. and T. Evans, *Toward just sustainability in urban communities: building equity rights with sustainable solutions*. The ANNALS of the American Academy of Political and Social Science, 2003. **590**(1): p. 35-53.
22. Briassoulis, H., *Sustainable development and its indicators: through a (planner's) glass darkly*. Journal of Environmental Planning and Management, 2001. **44**(3): p. 409-427.
23. Hezri, A.A. and M.N. Hasan, *Management framework for sustainable development indicators in the State of Selangor, Malaysia*. Ecological indicators, 2004. **4**(4): p. 287-304.
24. Kemp, R., S. Parto, and R.B. Gibson, *Governance for sustainable development: moving from theory to practice*. International Journal of Sustainable Development, 2005. **8**(1-2): p. 12-30.

25. Sorrell, S., *Energy, economic growth and environmental sustainability: Five propositions*. Sustainability, 2010. **2**(6): p. 1784-1809.
26. Madlener, R. and Y. Sunak, *Impacts of urbanization on urban structures and energy demand: What can we learn for urban energy planning and urbanization management?* Sustainable Cities and Society, 2011. **1**(1): p. 45-53.
27. Connolly, D., et al., *Heat Roadmap Europe: Combining district heating with heat savings to decarbonise the EU energy system*. Energy Policy, 2014. **65**: p. 475-489.
28. Camagni, R., R. Capello, and P. Nijkamp, *Towards sustainable city policy: an economy-environment technology nexus*. Ecological economics, 1998. **24**(1): p. 103-118.
29. Hu, J.-L. and C.-H. Kao, *Efficient energy-saving targets for APEC economies*. Energy policy, 2007. **35**(1): p. 373-382.
30. Dincer, I. and M.A. Rosen, *Exergy: energy, environment and sustainable development*. 2012: Newnes.
31. Zhang, X.-P. and X.-M. Cheng, *Energy consumption, carbon emissions, and economic growth in China*. Ecological Economics, 2009. **68**(10): p. 2706-2712.
32. Rosen, M.A., *Energy sustainability: A pragmatic approach and illustrations*. Sustainability, 2009. **1**(1): p. 55-80.
33. Demirbas, A., *The importance of natural gas as a world fuel*. Energy Sources, Part B, 2006. **1**(4): p. 413-420.
34. Razmjoo, A., et al., *Techno-economic evaluation of standalone hybrid solar-wind systems for small residential districts in the central desert of Iran*. Environmental Progress & Sustainable Energy, 2017. **36**(4): p. 1194-1207.
35. Brown, M.A. and B.K. Sovacool, *Developing an energy sustainability index to evaluate energy policy*. Interdisciplinary Science Reviews, 2007. **32**(4): p. 335-349.
36. Vera, I. and L. Langlois, *Energy indicators for sustainable development*. Energy, 2007. **32**(6): p. 875-882.
37. Naess, P., *Urban planning and sustainable development*. European Planning Studies, 2001. **9**(4): p. 503-524.
38. Burgess, R. and M. Jenks, *Compact cities: sustainable urban forms for developing countries*. 2002: Routledge.
39. Alwaer, H. and D. Clements-Croome, *Key performance indicators (KPIs) and priority setting in using the multi-attribute approach for assessing sustainable intelligent buildings*. Building and environment, 2010. **45**(4): p. 799-807.
40. Moussiopoulos, N., et al., *Environmental, social and economic information management for the evaluation of sustainability in urban areas: A system of indicators for Thessaloniki, Greece*. Cities, 2010. **27**(5): p. 377-384.
41. Keirstead, J. and M. Leach, *Bridging the gaps between theory and practice: a service niche approach to urban sustainability indicators*. Sustainable Development, 2008. **16**(5): p. 329-340.
42. Keirstead, J., M. Jennings, and A. Sivakumar, *A review of urban energy system models: Approaches, challenges and opportunities*. Renewable and Sustainable Energy Reviews, 2012. **16**(6): p. 3847-3866.