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Optimal green energy planning for sustainable development: A review

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A R T I C L E I N F O

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A B S T R A C T

Globalization leads the modern world towards green sources of energy. Green energy is clean sources of energy that have a lower environmental impact compared to conventional energy technology. Green energy plays a significant role in the strategic energy planning process for any country. Regarding energy resources, India plays an important part on the world scene. However, the energy systems of the different regions and territories varied on various parameters. Therefore, a detailed green energy planning for sustainable development has been studied extensively to find the most suitable common strategy for energy management to answer the following questions: (i) which approaches were predominantly applied in a particular region? (ii) Which evaluating criteria were paid more intentness to energy planning for sustainable development in that region? (iii) Is there any inadequacy of the approaches?. Various decision-making strategies, integrated approaches, combined methods have proposed to characterize the energy management problem by different researchers. In modern power management, the performance of different green energy is evaluated against multiple criteria rather than considering a single factor-consumption. This paper reviews the various work on distinct approaches, integrated approaches, multi-criteria decision-making methods, etc., for green energy planning and scheduling problem. This research not only provides confirmation that the energy management strategies are better than the traditional methods, but also aids the researchers and decision makers in applying the procedures.

1. Introduction

The global energy use has grown since the industrial revolution in close relation with the increase of welfare. Fossil fuels were the primary resources used to provide power, and, despite the efforts to increase the use of green energy sources in the energy mix, fossil fuels seems to continue being one of the principal sources of energy shortly. A rising awareness of environmental issues, due to the increase in the negative impact of fossil fuels on the environment, the precarious nature of dependency on fossil fuel imports, and the advent of green energy sources alternatives; has forced many countries, especially the developing ones to use green energy sources. Environment-friendly and capable of replacing conventional sources in a variety of applications at competitive prices. The exploitation of green energy sources has gained enormous interest during recent years. The current world economic crises have slowed down the energy markets, but some local recoveries show that this lower energy use trend may not to stay. Besides the energy demand growth due to long-term economic growth, the energy market is also facing a new challenge.

The modern energy management is to maintain long-term partnerships with energy, and use fewer, but reliable strategies. Therefore, choosing the right energy management involves much more than scanning a series of the price list, and choices will depend on a broad range of factors which include both quantitative and qualitative. Voluminous hybrid energy management of physical system, mathematical programming, zig-bee technology, analytical hierarchy process, Monte Carlo method, fuzzy approaches, supervisory control and data acquisition system, plan-do-check-act, analytical network process, analytical neural network, genetic algorithm, game theory approach, impedance spectroscopy method, distributed self-organizing network management, p-freen mechanism, data envelopment analysis, energy management system, hypothetical model, Economic optimal management model, Continuous power flow method, PEA's program on design, implementation, and evaluation, Simple numerical algorithm, Simple probabilistic method, A multi-objective chaotic particle swarm optimization (MOCPSO) method, green energy management by Homer software, modified bacterial foraging optimization algorithm, reinforcement learning algorithm, energy and utility management maturity model, power profiling algorithm, participatory rural appraisal method, consumer demand model, global model based anticipative building energy management system, modified simulated annealing triple-optimizer, hybrid thermal-compressed air energy storage, Pinch

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Analysis based method, statistical and machine learning technique, index decomposition analysis-artificial neural network data envelopment analysis, integrated energy supply and CO_2 mitigation network, micro-controller and supervisory control and data acquisition, Gaussian adaptive resonance theory map, fuzzy analytical hierarchy process, Hybrid Genetic Algorithm and Monte-Carlo simulation approach, Fuzzy Possibilistic-joint probabilistic mixed-integer programming (FPJPMIP) model, Index Decomposition Analysis (IDA), Artificial Neural Network (ANN) and Data Envelopment Analysis (DEA), Panel vector auto regression (PVAR) and impulse response function analyses, Modified elimination and choice translating reality (ELECTRE) under a hesitant fuzzy environment etc. approaches such as their hybrids and many other methods have been proposed for energy planning and energy source selection problem. At least two-hundred and six research articles are criticizing the literature on imperishable energy planning and scheduling problem. Since these items review the literature up to recent sixty years 1957–2017), this paper extends them by surveying the multiple energy management evaluation and selection approaches through a literature review and classification of the various research articles. Related works appeared in numerous research articles were gathered and analyzed so that the following three questions can be answered: (i) which approaches were predominantly applied in a particular region? (ii) Which evaluating criteria were paid more intentness to energy planning for sustainable development in that region? (iii) Is there any inadequacy of the approaches? This review article limelights on the ontogeny and application of different optimization techniques for optimal green energy planning under the exploitation of the existing energy scheme based on the subsequent rational and observations:

- Literally, the repercussion of optimization in the functioning article can be thoughtful, because it leads to increase the energy production in an optimal manner.
- Without optimization and owed responsibility in planning and scheduling the source associated elements are always put to work on the availability even if there is excrescent energy supply.
- A certain appraisal gimmick has to be disseminated in the optimization techniques to single out and overcome the material that demands typical care, somewhat linger for the transgression to eventuate in future energy planning for sustainable development.

The main objectives of this study are delineated below:

- To find out the most popular approach adopted in the sustainable energy evaluation and selection.
- To discover the most common criteria considered by the decision makers in assessing and selecting the best green energy sources available in the globe.

This paper has coordinated in the act of grasping: Section 2 and three critically describe the particular methods and integrated approaches respectively. Sections 4 and 5 describe the combination methods and other approaches respectively, Section 6 analyses the most popular procedures, confers the most current evaluating criteria, and treasure out the snag of the advents. Part 7 exhort for future work. Section 8 concludes the paper.

2. Individual approaches

Twenty-three out of two-hundred and six research articles (11.16%) applied hybrid energy management of physical systems (HEMPS). Their applications and evaluating criteria used in the methods is summarized in Appendix 1. The data retrieval strategy is also depicted in Fig. 1.

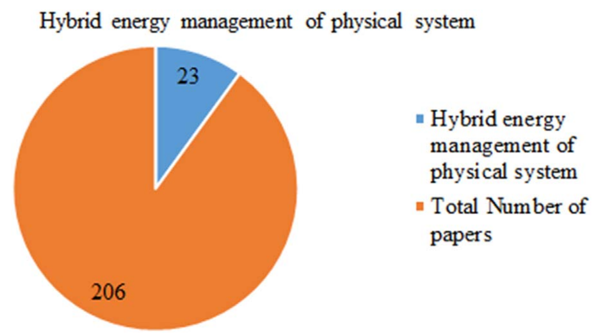

Fig. 1. Data recovery plan for HEMPS.

2.1. Hybrid energy management of physical system

Maréchal et al. [1] used effect modeling and optimization (EMO) tool to improve or evaluate the energy efficiency designed for synthesis reactor and the reforming reactor in methanol synthesis strategy at a global level. The application tool allows identifying the process improvement, including the combined production of heat and mechanical power in a gas turbine and the steam network system.

Voivontas et al. [2] developed GIS decision support system for the evaluation of renewable energy sources potential and the financial analysis of renewable energy investments for Wind Park. The developed model helps to predict precise estimation of the expected energy output and installation cost which had been viable for financial analysis of alternatives.

Stefano [3] investigated potential energy efficiency of lighting systems at Melbourne University. Research shows that overall cost effectiveness of the lighting technology which reduces energy consumption as well as lower CO_2 emissions.

According to Koopmans and Velde [4], bottom-up models can be typically used for lower energy demand and higher energy efficiency compared to a top-down approach which could be useful for policy analysis.

Balachandra and Shekar [5] showed that high initial purchase costs, uncertainties in returns and the tendency of consumers to use high discount rates in investing in energy efficient devices were a tough task. A mixed integer programming model played a crucial role to develop a portfolio of both inefficient and active lighting devices for better future regarding energy and peak demand.

Energy consumption and forecast for chemical plants have been investigated by the top-down and bottom-up approach. According to Bieler et al. [6] top-down approach was used to examine the overall energy consumption for chemical plant building. The bottom-up approach could be beneficial to find the apparatus level for the use of production process without any production going on of that particular plant building.

Vogt [7] showed that bottom-up modeling required extensive inventory to measure energy consumption over any period whereas, the top-down approach used a high level of information about performance associated data corresponding to energy consumption.

Brown et al. [8] applied an MILP technique to decrease the minimum energy requirement (MER) by replacing the steam injections to mixing tanks by heat exchangers to identify the best energy conversion options to optimize the production of combined heat and power (CHP) with no change to the MER.

Muller et al. [9] proposed a combination of top-down and bottom-up approaches for tracking energy saving opportunities in the food-processing industry. The energy consumption with other parameters was correlated with top-down modeling, and bottom-up approaches characterized the thermodynamic requirements of the process operation. The top-down models could be used as reliable tools for targeting and monitoring measures of forecasting and budgeting energy consumption and bottom-up approaches was able to identify the gap to overcome energy losses.

Tuladhar et al. [10] applied top – down bottom – up integrated modeling framework for climate change analysis of the U.S. electricity sector. Because of the model's flexibility, the authors were able to analyze the significant uncertainties surrounded for climate change policies in a cost effective manner.

Tiba et al. [11] developed geographic information system as a decision-making tool and applied to both for planning and management of the solar energy system. The system mainly developed for energy management as well as programs for states and municipalities. The tool was able to handle both the planning and management of the solar system of states and cities, in earlier, which was only handling the planning of the energy system.

Apak et al. [12] examined the different financial risk management instrument of a region that is required to encounter the needs of the green energy. The primary objective was that the green energy industry could significantly reduce the investors’ risk perceptions by improving the challenges of cost-effective risk management and insurance programs. All the challenges facing by green energy sectors were addressed explicitly for future development.

Radulovic et al. [13] used the public lighting energy management to establish the connection of the energy market liberalization and sustainable development in urban areas. Research indicated the significant lower emissions of carbon dioxide (CO_2) which undertake initiatives in energy management to ensure their future sustainable development.

Karimov et al. [14] applied efficient management of water resources between upstream and downstream countries with the supplement of the wind and solar energy for the proper and efficient generation of electric power. The measures of different active parameters allowed facilitating the fair and efficient management of water resources.

Seck et al. [15] developed the detailed bottom-up energy model for the non-energy intensive industry to evaluate the energy efficiency and CO_2 emission reduction at a high-level. The modeling was done by energy end-use owing to the unsuitability of the end-product/process approach used in the energy intensive industry modeling. The model established a useful decision-making tool for evaluating potential energy savings at the highest level of disaggregation, as well as offer better subsectoral screening.

Ren et al. [16] have applied a bottom-up energy system optimization model for “urban-rural cooperation” to develop a local low-carbon society. In this model, both cost minimization and emission minimization was considered from both economic and environmental viewpoints. The solar heater, heat pump as well as natural gas fired power plant and combined heat and power systems was more attractive compared with other green energy options to reduce the CO_2 emissions at a reasonable cost. Also, the proposed system is the choice solution from both economic and environmental viewpoints.

Tooke et al. [17] presented an approach that utilizes airborne light detection and ranging data to estimate the energy demand for residential building and urban area. The data set was used for the calculation of baseline estimation of energy demand for adjacent regions within cities.

Sowa et al. [18] presented a bottom-up modeling approach for plant-to-heat system. The proposed model evaluated the operational strategies on economic and technical aspects for the generation of green energies within a virtual power plant. The proposed method ensured an intense schedule for each unit considering the technical constraints.

Vaillancourt et al. [19] applied multi-regional energy model that has been developed using the most advanced TIMES optimization framework and analyzed possible future for the integrated energy system under different baselines corresponding to different oil prices and socio-economic growth in a long term horizon. The proposed model is the only optimal design covering the broad diversity of rural energy systems on a long term horizon in detail.

Horowitz and Bertoldi [20] used top-down and bottom-up approach to developing a harmonized calculation model. The top-down approach was used to collect energy consumption data whereas; bottom-up approach stands for energy statistics indicators. The developed model helps to analyze aggregate energy efficiency and sustainable development indexes.

Dai et al. [21] investigated that the future energy consumption and CO_2 emission pathways could be measured by top-down and bottom-up models for harmonizing the economic development. This model predicted the CO_2 emission rate by using a soft-link methodology to narrow the gap between the researchers as well as policymakers.

Park et al. [22] have applied bottom–up energy system analysis model for the deployment of the cost of electricity generation from renewable sources. This report shows that the renewable energy was able to play a greater role in reducing greenhouse gas (GHG) emission if the R & D reduces investment and maintenance cost.

Ghedamsi et al. [23] applied bottom-up approach for forecasting and modeling of energy consumption of the residential building. The degree-days method as well as geographic information system (GIS) technique was used to create the cartography of climatic zone. In each region, the energy consumption for heating, cooling and domestic appliances was calculated by this approach.

2.2. Mathematical programming

Among two-hundred and six journal articles, thirty-six papers (17.47%) formulated the energy management problems by various types of mathematical programming (MP) methods. Their applications and evaluating criteria used in the approaches is summarized in Appendix 2. The data retrieval strategy is also depicted in Fig. 2.

Smith [25] developed a contract net protocol for solving communication and control in a distributed problem solver. The developed model used to achieve various goals likely distributing power and data to avoid bottlenecks.

Groumpos et al. [26] presented a new mathematical model using dynamic programming techniques to optimize energy flow between the various subsystems of photovoltaic power systems. The suggested model also benefited in an optimal way to an efficient online load management and shedding control.

Groumpos and Papegeorgiou [27] devised a tracking algorithm to implement optimum load control scheme for the stand-alone photovoltaic power system. The invented model minimized the total lifecycle cost of the system while, at the same time, the battery was protected and the load priorities were observed.

Bose and Anandalingam [28] designed a goal programming model to capture multiple objectives involved in sustainable energy management considering various economic sectors. The proposed model was used to measure the energy efficiency and effect of pollutant emission reduction in an urban area of Delhi, India.

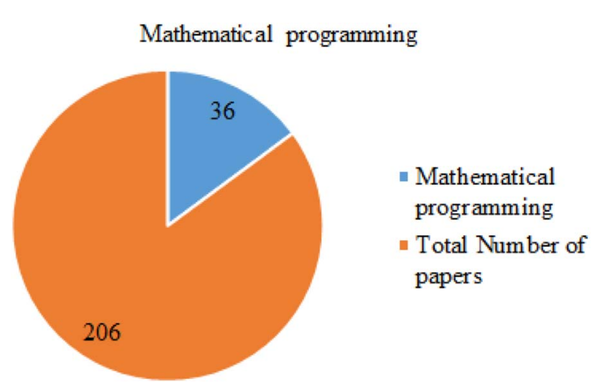

Fig. 2. Data recovery strategy for MP.

Chedid and Rahman [29] shows that CAD/CAA tool could help the designers for optimal design of hybrid green energy system. Research indicated that linear programming techniques played a tremendous role to minimize the average production cost of energy while considering both environmental and operation phases.

Malik and Satsang [30] used a computer-based mixed integer linear programming data extrapolation technique for energy systems planning. They have shown how the model was suitably scaled for obtaining the optimal mix of energy resources and technologies for the Wardha District (Maharashtra State, India) using a computer-based MILP technique [38].

An overview of industrial energy supply structure based on biomass was presented by Nagel [31] using mixed integer linear programming. The mixed integer linear programming model based on the dynamical evaluation of economic efficiency could help to find the most economical and ecological supply structure. The developed model showed that the energy prices have the greatest influence on the economy [38].

As described by Bagajewicz and Barbaro [32] the public capacity planning problem was also used to illustrate the concepts of two-stage stochastic programming for planning under uncertainty.

Jaccard et al. [33] applied CIMS based MARKAL a traditional optimization model of the energy-economy system. Research indicated that CIMS had been initially put forwarded in Canada for policy simulation but did not have any capability to financial cost minimization. Whereas, MARKAL model could be helps the decision makers to minimize the uncertainties related to trading off energy cost and greenhouse gas emission reduction.

Antunes et al. [34] proposed multiple objective mixed integers linear programming model [24] for power generation expansion planning of supply-side. The advanced model considered demand side management for optimal energy planning including flat revenues.

Energy planning under uncertainty had been investigated by Barbaro and Bagajewicz [35] to optimize various risk parameters to industrial consumers. A two-stage stochastic programming based on the mixed-integer linear model, also been implemented by G´omez-Villalva and Ramos [36] for minimizing the tradeoff cost and total energy supply cost to deregulated energy markets.

Cabero et al. [37] proposed a multivariate scenario-tree construction methodology to manage the market risk faced by a hydrothermal generation company in the medium-term. The developed model was able to identify the uncertainty in fuel prices, power demand, water inflows, and electricity prices.

Chakraborty et al. [39] implemented a distributed intelligent energy management system to optimize operating costs for integrated renewable energy sources in a distributed generating system for high-frequency AC microgrid. A fuzzy ARTMAP neural network was also used to forecast hourly energy generation, and the implemented system had achieved the improvement of battery life also.

Dounis and Caraiscos [40] applied a multi-agent control system for the design of agent-based intelligent control systems in buildings. The advanced control system successfully managed the user's thermal comfort, air quality as well as energy conservation.

Pourmousavi et al. [41] used particle swarm optimization which had been inspired by natural direct search method to find real-time optimal energy management solutions for a stand-alone hybrid wind micro-turbine system. The particle swarm optimization based energy management algorithm could be helpful for maximizing the turbine capacity and minimizing the cost and environmental emissions.

Lagorse et al. [42] proposed a distributed management solution based on the paradigm of multi-agent systems for the complete validation of centralized energy management system. This proposed model had been capable of energy management of hybrid system connected to the grid.

Li et al. [43] developed a greenhouse gas mitigation oriented inexact dynamic energy system management model for a regional energy management system. The method was a hybrid methodology of interval mathematical programming, fuzzy linear programming and multi-stage stochastic programming. The advanced model adequately addressed the complexities of various system doubts as well as with multi-stage stochastic decision problems within energy systems.

Jun et al. [44] developed a macro multi-agent solution based on Java agent development to energy management in the distributed hybrid renewable energy generation system. The proposed system improved the performance of commercial and power quality of the distributed hybrid renewable energy generation system.

Battistelli et al. [45] proposed an optimization tool for the assessment of energy management of vehicle to the grid system. The optimization model, able to assess the effect of the vehicle to grid as a contribution to the management of energy resources of the small electric energy system.

Kermani et al. [46] used hybrid vehicle model for energetic studies and the energy management problem with an offline optimization algorithm based on the minimum principle to predict control scheme. The proposed model provided a comparison between fuel consumption and battery state of charge monitor and allowed guarantying bounds on the state of charge error while providing adequate fuel consumption.

Marzband et al. [47] proposed a modified conventional energy management system based on the LEM algorithm to find out the hourly power set-points of distributed energy resources as well as to maximize the utilization of existing distributed energy resources. The proposed model is capable of locating a global solution of the related market clearing price problem and able to manage the total cost reduction of power generation.

Baziar and Kavousi-Fard [48] proposed a self-adaptive optimization algorithm based on θ-particle swarm optimization to consider the uncertainties in the optimal energy management of the microgrids, including different green power sources likely photovoltaics, wind turbine, microturbine, a fuel cell as well as storage devices. The proposed method is feasible and satisfactorily perform the analysis on grid connected in the microgrid.

Yang and Wang [49] developed a multi-agent control system coupled with an intellectual optimizer for intelligent building control. Particle swarm optimization is utilized to find the optimal solution for achieving the maximum comfort level in the presence of energy shortages.

Zhang et al. [50] formulated a mixed integer linear programming approach for the optimal scheduling of energy consumption in smart homes. Distributed energy resources operation and electricity consumption household tasks were scheduled based on real-time electricity pricing and forecasted green energy output. This model considered the customer's viewpoint, with a given real-time electricity price profile over time.

Marzband et al. [51] constructed an energy management system algorithm, based on mixed-integer nonlinear programming for the microgrid to achieve maximum efficiency, improve economic dispatch as well as acquiring the best performance and reducing the global cost of generated power.

The proposed algorithm proved the efficiency of a gravitational search method for managing and exchanging power in smart grids and enabled utility companies to have an energy management tool with the optimizing ability to use non-dispatchable and energy storage.

Mohammadi et al. [52] proposed an efficient stochastic framework to investigate the effect of uncertainty on the optimal energy management of microgrids by the use of a probability distribution function. He proposed a stochastic framework, the risks of load forecast error, wind turbine generation, photovoltaic generation and the market price were considered for analysis. Adaptive modified firefly algorithm makes use of a robust modification process to enhance the diversity of the algorithm to move towards the promising global optimal solution quickly.

Chen and Phillips [53] evolutionary based dynamic energy management framework to reduce the overall energy consumption without degrading network performance. The primary function of the developed algorithm was to place the unused resources of energy in a sleep state. The algorithm was evaluated using a multi-layer fluid flow event-driven simulator to assess its potential. The analysis results showed that the ability of dynamic energy management scheme to save energy depends on many factors, such as quiet and busy thresholds and traffic load.

Faxas-Guzmán et al. [54] developed a load control algorithm to gain an optimal energy management over system loads and the battery storage. To determine the reliability of the regime for a better energy management that guarantee the energy supply for critical loads. The algorithm has a better performance and provides a better compromise between the state of charge of the battery bank and the capacity availability.

Amokrane et al. [55] proposed an approach, called optimal green routing and link scheduling by formulating the problem as an integer linear program to reduce energy cost as well as carbon footprints of computer networks and to find out the optimal throughput without impacting on the energy consumption. The approaches achieved significant gains regarding energy consumption, flow acceptance ratio and delivered performance, compared to the shortest path routing, and the minimum link residual capacity based routing.

Ahmed et al. [56] proposed a new methodology to include a financial risk management framework of two-stage stochastic programming for energy planning to minimize cost subject to environmental constraints. The proposed method provided a great economic potential as it had a significant effect on reducing the total cost of electricity production.

Wu and Zhou [57] suggested a multi-agent-based energy-coordination, control system by considering the self-constraint and monitoring objective of each agent by maximum economic benefit. The proposed model improves the overall efficiency of the large scale utilization of green energy.

Misra et al. [58] developed a network model, indicating the hierarchy of power stations, substations and end users. Proposed algorithm name as LAMCR was undertaken regarding multiple constraints such as cost, delay, and energy consumption in and throughput. The proposed method optimized performance of smart grids of fault tolerance and energy management while exhibiting higher packet delivery ratio, lesser delay, and lower energy consumption, which improves the throughput of the system.

Sechilariu et al. [59] designed a multi-layer supervision, control structure, to diminish the energy cost carried out by mixed integer linear programming in real-time power limit and storage capacity. In the model, forecasting of power production and load power demand, storage capability, grid power limitations, grid time-of-use tariffs, optimizes energy cost and handles instantaneous power balancing in the microgrid was considered. The optimization model gives a better energy performance while minimizing load shedding and all constraints of power system elements.

2.3. Zig-Bee technology

Eight research papers out of two-hundred and six research articles (3.88%) applied zig-bee technology in the energy planning process. Its application and evaluation criteria used in the approach is summarized in Appendix 3. The data retrieval strategy is also depicted in Fig. 3.

As mentioned by Han and Lim [60], Yi et al. [62], Batista et al. [64], Yi et al. [65] and Mu and Hun [66] smart energy market required two types of ZigBee networks for device control and energy management. Nowadays organization uses IEEE 802.15.4 and ZigBee for the efficient supply of energy towards home networks. Their investigated result not only save money but also make good sense to encourage the government and various organizations for green building preparation. ZigBee technology was widely studied and deployed recently because of its low cost and simplicity.

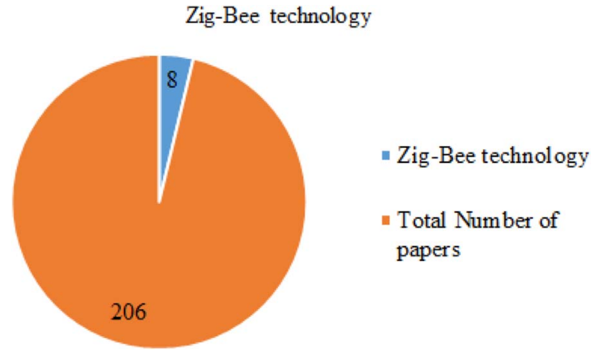

Fig. 3. Data recovery strategy for zig-bee technology.

Huang et al. [61] proposed a zig-bee monitoring system to protect the building from the electric short circuit. The proposed system was able to enhance the functions of traditional distribution system by using powerful overload limit concept. Also, a self-protection operates with temperature control was built in the outlet for fire prevention.

Batista et al. [63] used an open source tool with zig-bee technologies for monitoring photovoltaic and wind energy systems, and also for building and home energy management. Their investigation results expressed the proficiency of zig-bee [67] devices applied in circulating green generation and smart metering systems for an extended period without any maintenance.

2.4. Analytical hierarchy process

Out of two-hundred and six research articles six papers (2.91%) utilized analytical hierarchy process in the energy planning process. Its application and evaluation criteria used in the approach is summarized in Appendix 4. The Information recovery plans are depicted in Fig. 4.

Lefort et al. [69] developed a hierarchical control structure based on model predictive control [68,70] for managing energy in residential houses to minimize the building energy cost considering various constraints. The structure was self-possessed of two anticipative layers: a scheduling with a long time horizon and a piloting dealing with a short time horizon to minimize the energy cost while managing the occupant comfort and compared to a centralized control approach. This method able to optimize the energy cost by taking advantage of the cheaper price electricity and local production while maintaining the occupant comfort and also able to deal with large-scale systems considering grid and system power constraints.

Sindhu et al. [71] applied strength-weakness-opportunity-challenges (SWOC) analysis of solar energy deployment in India context based on analytical hierarchy process to improve the quality of life for sustainable future. The presented study could assist policy planners, and concerned authorities to understand the strengths, weaknesses, opportunities and challenges of solar energy to plan, manage and develop it efficiently to attain sustainability.

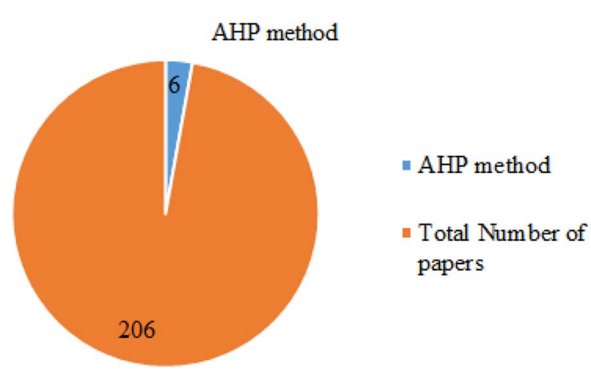

Fig. 4. Information recovery plans for AHP method.

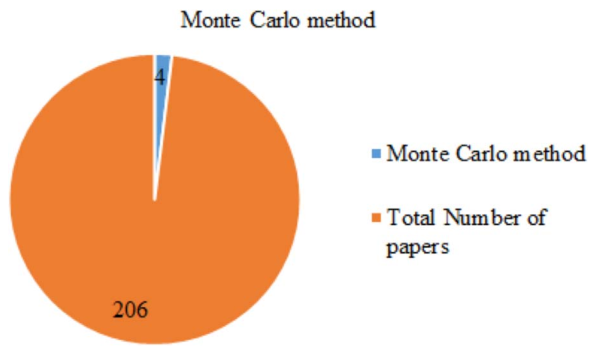

Fig. 5. Data recovery approach for MC method.

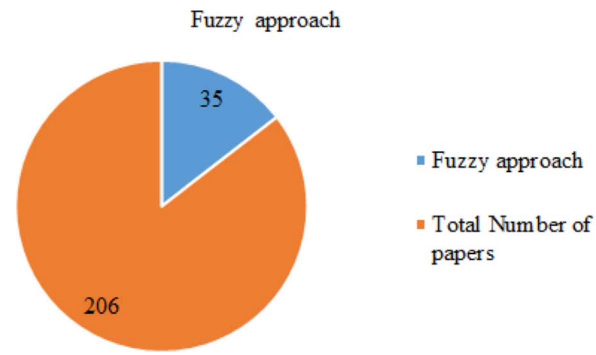

Fig. 6. Data recovery approach for fuzzy methods.

An overview of the logistics capabilities of offshore wind ports Akbari et al. [72] used an analytical hierarchy process for significant installation and maintenance namely physical characteristics, connectivity, and layout of the harbor. The methodology suitable applied by the decision makers of a various number of offshore wind farms located off the North Sea coast of the United Kingdom.

Shad et al. [73] proposed a set of general factors based on analytical hierarchy process, weighted harmonic mean and Shannon's entropy method for green buildings in the Iranian context. The developed Iranian Green Building Assessment Tool (IGBT) based on weighted factors was able to improve environmental, social and economic aspects in the construction process. Proposed research also a thoughtful reference to the policy makers for sustainable future.

2.5. Monte Carlo method

Four papers out of two-hundred and six research articles (1.94%) used Monte Carlo (MC) method in the energy planning process. Its application and evaluation criteria used in the approach is summarized in Appendix 5. The data retrieval strategy is also depicted in Fig. 5.

Hasan et al. [74] developed a new optimization process, namely Monte Carlo method, i.e., randomly generating sequences of the heating system states, testing these sequences, and then choosing the best one for the heating according to the least consumption or the least price. Research allows shifting of energy consumption to the reasonable pricing period.

Da Silva Pereira et al. [75] presented a methodology that uses Monte Carlo method to estimate the risk in renewable energy source connected to the grid in the region of Brazilian Amazon for sustainability. The work also described investment risk in power generation projects. Whereas, the developed methodology was failed to minimize the production cost but maximize energy demand.

An innovative method was put forward by Bendato et al. [76] for investment profitability in renewable power plants. The advanced innovative approach was able to generate the best economic return over the entire life cycle of the solar power plant system.

Pask et al. [77] developed a hybrid methodology based on Monte Carlo simulation to evaluate the sustainability associated with risk. The sustainability indicator hybrid approach had been used in the manufacturing industry to identify the most sustainable way to increase energy conversion. The advanced hybrid model was more useful because it incorporates uncertainty into the final desirability of energy management for sustainable development.

2.6. Fuzzy approaches

Among two-hundred and six journal articles thirty-five papers (16.99%) applied fuzzy logic to evaluate the energy planning and best management strategy. Their applications and evaluating criteria used in the approaches is summarized in Appendix 6. The data retrieval procedure is also depicted in Fig. 6.

As mentioned by Zimmermann [79] fuzzy set had been used as a new tool for the formulation and solution of any decision problem. After various discussion theory of fuzzy sets put forward by Zadeh [78] could be applied to energy management problem by using fuzzy linear programming considering two prominent constraints: either tolerance constraints or equality constraints described by Dubois and Parade [80] without increasing the computational effort.

Garcia et at. [81], Benard et al. [83] and Ciabattoni [107,108] demonstrated a predictive control model based on fuzzy logic inference system to minimize household electricity consumption patterns. The tool had been used to evaluate the self-consumption percentage of a residential photovoltaic plant. Reflected model was able to assess the real economic cost-benefit analysis in the new net metering Italian scenario.

Huang et al. [82] introduced a grey fuzzy integer programming (GFIP) method and its application to regional solid waste management planning under uncertainty. The continuous variable solutions related to grey decisions for waste flow allocation problem plays a significant role by this put forwarded method. Although, grey linear programming model was utilized by Huang et al. [84] to solve waste flow distribution planning within a municipal solid waste management system under uncertainty.

The modeling of cogeneration systems of auxiliary devices and the effectiveness of the modeling was evaluated by Rommelfanger [85] and Lee et al. [86] for operation scheduling scheme of electricity generation. Fuzzy linear programming was used to minimize the level of exploitation cost for thermal energy over power scheduling system.

Kolokotsa et al. [87] presented an optimized fuzzy controller system to control the environmental parameters via smart card unit. Genetic algorithm techniques were used to shift properly fuzzy controller to minimize the energy consumption. The developed model was tested in the building of the Laboratory of Electronics of the Technical University of Crete.

Dufo-López and Bernal-Agustín [89] invented the Hybrid Optimization by Genetic Algorithms (HOGA) program for hybrid photovoltaic systems. The program was developed by C++ and have the capability to show best results when compared to other optimization techniques. The developed program showed the economic advantages under worst-case conditions based on energy availability.

Nelson et al. [91] developed a program to size the economic evaluation of a hybrid wind/photovoltaic/fuel cell (FC) generation system for a typical home in the Pacific Northwest. The developed program also was able to minimize the fuel-cell cost for hybrid energy production.

Wang and Singh [92,94] utilized a stochastic model for combined heat and power (CHP) based on an improved particle swarm optimization method. The model was developed to deal economic dispatch by simultaneously considering multiple conflicting objectives on energy production.

Paris et al. [96] proposed a strategy based fuzzy controller, to provide the best results offered by fuzzy logic targeting to reduce energy consumption and promoting the use of green energy while ensuring thermal comfort when heating “multi-energy” buildings [83,93,95].

Zangeneh et al. [97] proposed a static fuzzy multi-objective model to optimize some conflicting and competing for objective functions including energy demand, energy price and operating and investment costs. The constructed model would not only reduce the investment risks of distributed generation technologies but also would enable the optimal penetration of marginal revenues.

Erdinc et al. [98] proposed a hybrid system with a fuzzy logic based energy management strategy to characterize the fluctuations of green sources, in particular for the wind and solar energy. In the hybrid system, wind turbine for use the wind energy, photovoltaic panels for solar energy [111], a fuel cell for providing backup power and a battery unit for storing the possible excess electricity and supplying the transient load was considered for the study. The proposed system has the capability to evaluate the feasibility of stand-alone hybrid green energy units for future energy systems.

Zhang et al. [99] proposed a supervision strategy based on fuzzy logic and graphical methodology for ecological indicators to reduce the CO_2 emissions [88,90] and electricity bill of a commercial building, using photovoltaic and storage systems. From the results, it was found that fuzzy logic supervision strategy may be an adaptive tool to solve these kinds of problem and graphical methodology able to reduce the energy bill cost and CO_2 emission.

Gitizadeh et al. [100] presented a modified normal boundary intersection method using general algebraic modeling system based on fuzzy logic to maximize the project lifetime economic return, minimization of CO_2 emission, and minimization of the fuel price risk due to the use of non-renewable energy sources onshore and offshore wind and solar power plants.

García et al. [101] developed novel hourly energy management system using a fuzzy logic control to satisfy the energy demanded by the load and maintain the state-of-charge of the battery and the hydrogen tank [106] for a stand-alone hybrid green energy system. While optimizing the utilization cost and lifetime (25 years) of the energy management system, the proposed control method meets the objectives established for the management system on the hybrid green energy system and achieved a total cost saving of 13% over other simpler energy management system based on control states.

Moradi et al. [102] proposed a hybrid optimization method involving the particle swarm optimization and the linear programming algorithms which employ the fuzzy set theory to build up an energy management system with high-cost efficiency and reduction of air pollution. The proposed optimization scheme provided a roughly pyramidal solution space which can be readily explored to identify optimum ranges for the objective function corresponding to positive net present value regions in the presence of uncertainty.

Dong et al. [103] developed a fuzzy radial interval linear programming model for robust planning for energy management considering environmental and constraint-conservative. The design offers detail energy management plans for decision makers and could guarantee optimal economic and ecological benefits under desirable system reliability.

Ho et al. [104] formulated a decision model for energy conservation and green energy for campuses, by employing multi-objective linear programming and fuzzy two-stage algorithm to reduce CO_2 emissions [77,110]. Through the analysis, the non-inferior solution of a set of low-carbon campus energy conservation design was obtained.

Li et al. [105] constructed a fuzzy dual-interval multi-stage stochastic programming approach for the planning of integrated energy-environment system. The method was derived by incorporating the concepts of fuzzy programming, interval parameter programming, and dual-interval programming within a multi-stage stochastic optimization framework. From the analysis, it was found that the reasonable solutions could be generated for both binary and continuous variables, interactions among multiple energy-environment related activities could be reflected in a mixed uncertain environment. Based on the obtained solutions, optimized decision alternatives could be created. The approach helps policy makers to identify strategies related to green energy production and allocation.

Dong et al. [106] developed a superiority–inferiority-based mini max-regret analysis model for supporting the decision makers, to identify an optimal approach for planning electricity generation and capacity expansion in energy management systems under uncertainty. In the proposed model, the techniques of fuzzy mathematical programming with the superiority and inferiority measures and minimax regret analysis were incorporated within a general framework. From the analysis results, it was found that the model can help decision makers to identify an optimal strategy of planning electricity generation and capacity expansion based on a minimax regret level under uncertainty.

A model combining fuzzy sets, analytic hierarchy process, opinion aggregation method, and information axiom method was proposed by Cebi et al. [109] and Indragandhi et al. [112] to obtain the most appropriate location for a biomass power plant at Aegean Region Turkey. The developed model was able to decrease fossil fuel combustion and consequently net greenhouse gas emissions since no new carbons aren't released to the atmosphere. Research indicate that the constructed model was more user-friendly for sustainable energy planning operation.

2.7. Supervisory control and data acquisition system

Five papers (2.42%) utilized supervisory control and data acquisition (SCADA) system in the energy planning process. Their applications and evaluating criteria used in the approaches is summarized in Appendix 7. The data retrieval strategy is also depicted in Fig. 7.

Chen [113] explored a systematic methodology based on the real-time predictive dynamic supervisory operation for building thermal systems. The advanced method minimized the energy consumption and operating cost with different activity schedules under various weather conditions.

Ma et al. [114] developed a supervisory control strategy based on a hybrid optimization technique, namely performance map and exhaustive search (PMES) for online control of building central cooling water systems to enhance their energy efficiency. The performance map control strategy was more energy efficient and computational cost effective than other methods for practical online application.

Figueiredo and Sá Da Costa [115] constructed a supervisory control and data acquisition system to evaluate energy management platform for intelligent buildings. The developed system optimizes the energy waste and gives customer satisfaction. Also, a new platform connecting the supervisory control and data acquisition supervisory system (operational level) and the MATLAB software (interactive level), named supervisory control and data acquisition MATLAB platform was the significant contribution of the work to handle complex control algorithms.

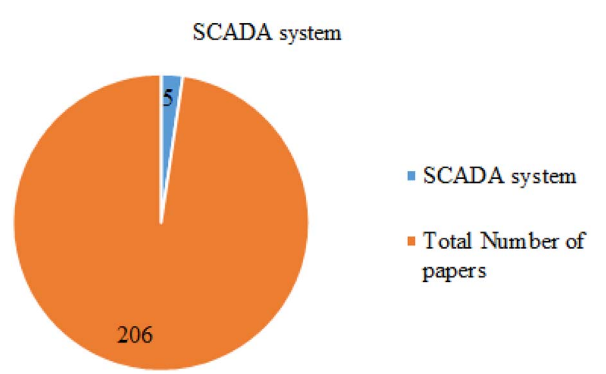

Fig. 7. Data recovery strategy for SCADA system.

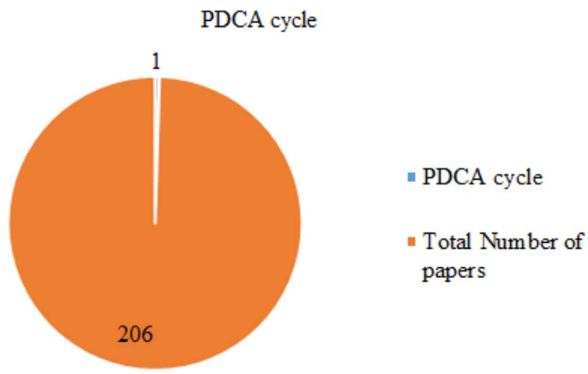

Fig. 8. Data recovery strategy for PDCA cycle.

Du Plessis et al. [117] developed an energy management system for the large cooling system of deep mines connecting supervisory control and data acquisition [116] for real-time monitoring and alarming increase the energy savings. Without adversely affecting mine cooling requirements an average electric power conservation was realized for all the sites.

2.8. Plan-do-check-act cycle

One paper (0.48%) used plan-do-check-act (PDCA) cycle for the energy management system evaluation. Its application and evaluating criteria employed in the approach is summarized in Appendix 8. The data retrieval strategy is also depicted in Fig. 8.

O'Donnell et al. [118] presented a new holistic and reproducible checking mechanism called scenario modeling method that compares actual performance and completes the plan-do-check-act cycle of energy management and environmental interdependencies of the building manager. The model provided the maximum organizational benefit and demonstrated cost saving views. The proposed model can be upgraded in future, including software environment to create and edit data from a specifically defined model view definition.

2.9. Analytical neural process

Nine papers (4.36%) uses Analytical Neural Process (ANP) for the energy management problem. Their applications and evaluating criteria utilized in the approaches is summarized in Appendix 9. The data retrieval strategy is also depicted in Fig. 9.

The analytic network process [119–123,125] was used for decision making to incorporate feedback and independent relationship between decision alternatives and attributes. The methodology was capable of taking into consideration both tangible and intangible criteria without sacrificing their relationships, and it can deal with all kinds of dependencies systematically.

Cheng et al. [124] showed that analytic network process was

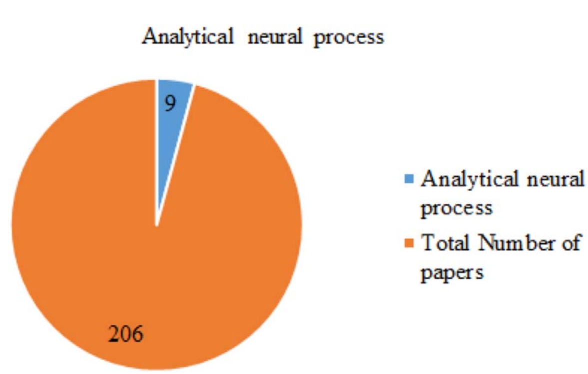

Fig. 9. Data recovery strategy for ANP process.

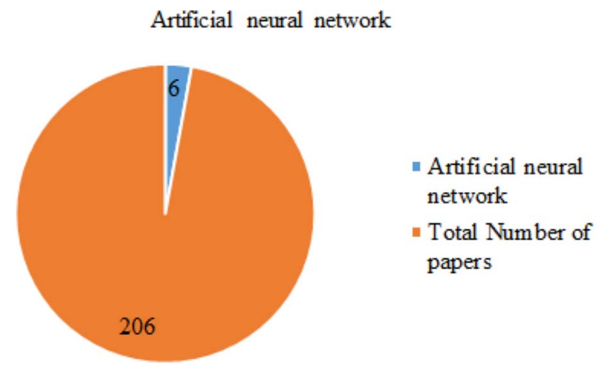

Fig. 10. Data recovery strategy for ANN method.

appropriate for region/location selection for future energy production which would be economically viable.

Önüt et al. [126] analyzed the energy consumption regarding efficient use of energy sources of manufacturing industry for a particular country using multiple criteria decision-making method which includes human judgments, physical and indefinable criteria, priorities and trade-offs between goals and benchmark regarding energy management.

Shiue and Lin [127] proposed an analytic network process model with the combination of benefits, opportunities, costs, risks and balance scorecard to evaluate recycling strategies for obtaining optimal results in the solar energy industry. The proposed model was helped by prioritizing and weighing the complex relations among competitive advantages involved in assessing the optimal recycling strategies.

2.10. Artificial neural network

Six papers (2.91%) used the artificial neural network in the energy management problem. Their applications and evaluating criteria employed in the approaches is summarized in Appendix 10. The data retrieval strategy is also depicted in Fig. 10.

Kalogirou [128] used the artificial neural network in the field of solar energy for modeling and design of a solar steam generating plant, for the estimation of a parabolic-trough collector's intercept factor and local concentration ratio and the modeling and performance prediction of solar water-heating systems. They have also been estimated the heating loads of buildings for the prediction of the energy consumption of a passive solar building.

Morel et al. [129] developed an Neurobat algorithm based on artificial neural network control model to deal with the real conditions of any building [130]. The developed algorithm was tested for water heating systems of buildings in Switzerland. It had been shown that the controller operation is satisfactory from the beginning and optimal regarding the cost function.

A hybrid structure based on solar energy was proposed by Santos et al. [131] to simulate the thermodynamic behavior of pools. The proposed work enable to track losses due to human activity which use computational neural models to incorporate the climatic information of the regions being analyzed for energy efficiency.

Yuce et al. [132] proposed an artificial neural network approach based on reasonable prediction and control system to predict energy consumption and thermal comfort level of an indoor swimming pool. A calibrated simulation model was used to generate significant amounts of data sets to train the corresponding artificial neural network prediction engine. According to the results, the Levan berg-Marquardt training algorithm based artificial neural network model was found as best performed artificial neural network. The proposed method can be used as a cost function engine to develop an intelligent energy management system.

Calderaro et al. [133] developed an innovative decentralized voltage

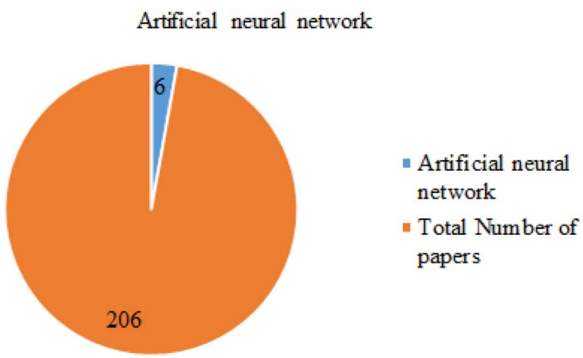

Fig. 11. Data recovery strategy for GA method.

Fig. 12. Data recovery strategy for game theory approach.

control approach based on the neural network to produce maximum power from green energy sources. One of the most relevant aspects of the proposed control strategy is that it is more flexible than the previously proposed approaches by other researchers.

2.11. Genetic algorithms

Five papers (2.42%) applied Genetic Algorithms (GA) for energy management. Their applications and evaluating criteria used in the approaches is summarized in Appendix 11. The data retrieval strategy is also depicted in Fig. 11.

Ahmadi and Dincer [134] demonstrated an evolutionary genetic algorithm for combined heat and power plant for cogeneration system that produces electricity. The results show that for an exact unit cost of fuel, the values of design parameters increase, as the required, with net power output increases.

Kaviri et al. [135] presented a multi-objective optimization system using the genetic algorithm approach for extensive thermodynamic modeling of a dual pressure combined cycle power plant considering set of component costs, the fuel cost injected into the combustion chamber, duct burner cost and the cost of energy. From the result, it was found that gas turbine temperature, compressor pressure ratio and pinch point temperatures are significant design parameters and any changes in these design parameters leads to a drastic change in objective functions.

Feroldi and Zumoffen [136] proposed an optimal sizing methodology based on genetic algorithm integrated into the energy management strategy for a hybrid energy system regarding the loss of power supply probability, costs, and bio-ethanol consumption. The methodology provided a flexibility to accommodate the design to different scenarios, according to the availability of green resources and bio-ethanol.

Shaikh et al. [137] developed multi-agent control system in combination with stochastic optimization using a genetic algorithm for energy management of buildings. The model was used for simulations of efficient management of energy and consumer comfort. The advanced control system provided a significant improvement in energy consumption and interior environmental comfort.

Tong [138] utilized a genetic algorithm-based the Index of Distribution (IOD) model that could generate the plan of buildings corresponding to a particular IOD. The design provided considerable flexibility in buildings locations. The results of the model could be used as a valuable reference in the planning of buildings in green spaces.

2.12. Game theory approach

Out of two-hundred and six research articles only five papers (2.42%) used game theory approach in the energy management evaluation process. Its application and evaluation criteria used in the procedure is summarized in Appendix 12. The data retrieval strategy is also depicted in Fig. 12.

Lasaulce and Tembine [139] and Aplak and Sogut [140] evaluated the scope of energy management regarding the decision-making process of the industry and the environment in game theory approach by using multi-criteria decision-making methods. This strategy balanced the industrial use of green energy in a sustainable way that reflexes the environment.

Tang et al. [141] adopted game theory approach in analyzing and identifying the best strategy for the biomass industry. In another word, by analyzing this scenario using game theory approach, an optimal non-cooperative strategy could be determined. The advanced game theory approach could be applied to the decision support framework for the biomass industry management team.

Attia et al. [142] proposed a new Bayesian game model to optimally integrated green electricity sources into a power network to charge electric vehicles (EVs') batteries. The model promoted the electricity network capacity and had an eco-friendly effect on the environment by minimizing the usage of polluting energy sources. The developed model helped to efficiently integrate the EVs into the smart grid (SG) and used green electricity sources with more flexibility and less loss.

Liang et al. [143] aimed to reveal the occupancy scenarios, namely, owner-occupied (baseline scenario), single occupied, and multi-occupied buildings in green retrofit projects under uncertainty by game theory analysis. The identified reasons were also beneficial to the policy makers, particularly in their effort to promote green renovation by considering the requirements of owners and occupiers under the different occupancy types.

2.13. Impedance spectroscopy method

One paper (0.48%) used an impedance spectroscopy method in the energy management system. Its application and evaluation criteria used in the approach is summarized in Appendix 13. The data retrieval strategy is also depicted in Fig. 13.

Depernet et al. [144] developed a low-cost online impedance spectroscopy method to address the problem of the limited lifetime of storage batteries and the difficulties of their maintenance in isolated areas without electricity.

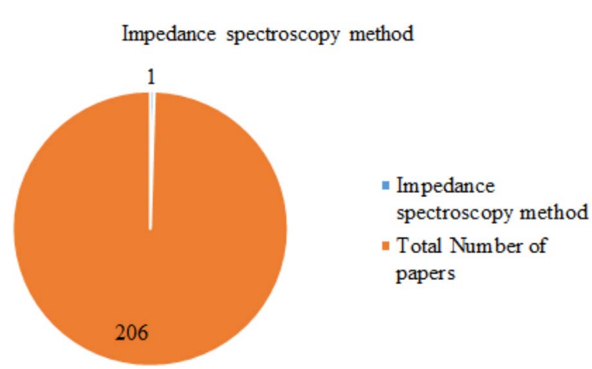

Fig. 13. Information recovery strategy for impedance spectroscopy method.

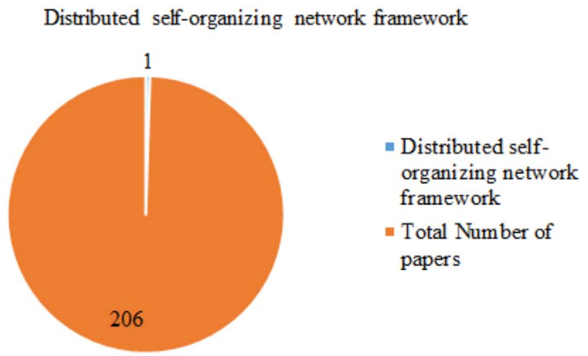

Fig. 14. Data recovery plan for Distributed Self-Organizing Network management.

2.14. Distributed self-organizing network framework

Only one paper (0.48%) used distributed self-organizing network framework for the energy management evaluation process. Its application and evaluation criteria used in the approach is summarized in Appendix 14. The data retrieval strategy is also depicted in Fig. 14.

Cao et al. [145] proposed Distributed self-organizing network framework, a multilevel control mechanism; that can be applied for any Wireless Sensor Networks with various nodes independently. Distributed self-organizing network structure not only used as an instrument for the new management application but also improve network performance such as packet delivery rate and energy consumption.

2.15. Prediction FREE energy neutral power management mechanism

One paper (0.48%) used P - FREEN mechanism for energy management. Its application and evaluation criteria used in the approach is summarized in Appendix 15. The data retrieval strategy is also depicted in Fig. 15.

Peng and Low [146] proposed a prediction free energy neutral (P-FREEN) power management device to implement the budget, assigning principles (BAPs) based solely on currently observed energy harvesting rate and battery extra energy level. P-FREEN can recover the battery energy level under extreme operation conditions.

2.16. Self-organized things framework

There is only one paper (0.48%) applied self- organized things framework in the energy management system evaluation. Its application and evaluation criteria used in the approach is summarized in Appendix 16. The data retrieval strategy is also depicted in Fig. 16.

Akgül and Canberk [147] proposed an energy efficient self-organized things framework (SOT) to minimize the overall energy consumption and stabilize the battery lifetime. This framework integrates self-configuration, self-optimization, and self-healing to reduce human intervention for energy efficient topology by putting additional devices into sleep mode and increases the lives of the things. The effects of different traffic load were also guaranteed durability by this framework.

Fig. 16. Information recovery plan for SOT framework.

2.17. Data envelopment analysis

Six papers (2.91%) utilized data envelopment analysis in the energy management system evaluation. Its application and evaluation criteria used in the approach is summarized in Appendix 17. The data retrieval strategy is also depicted in Fig. 17.

Farrell [148] and Lee and Lee [149] proposed an adjustment to the traditional approach by using data envelopment analysis for obtaining more accurate information, such as the energy management effectiveness of the office buildings in Taiwan. The proposed method benchmarked buildings energy performance usually took into consideration of a wide range of different factors, including floor area, some occupants, climate condition, the energy efficiency of the equipment used, and setting of indoor temperature and so on.

Lei et al. [150] used data envelopment analysis to find the bottleneck of foreign direct Investment (FDI) attractiveness and to identify the potential energy market of Chinese provinces. The model and its implementation mechanism considered cost efficiency and profit efficiency changes energy productivity index. This study also offered policy advice and guidelines to developing nations for setting policies and programs to attract FDI in the energy field.

Yu and Chan [151] used data envelopment analysis (DEA) to analyze control and an operational problem to improve chiller system performance. The energy effectiveness based on DEA estimated the possible performance without capital investment on the existing system and applicable for another thermal system.

Meng et al. [152] used data envelopment analysis to measure China's regional energy efficiency and carbon emission efficiency. An empirical study was conducted using data envelopment analysis model by Wu et al. [153] to evaluate the environmental efficiency of

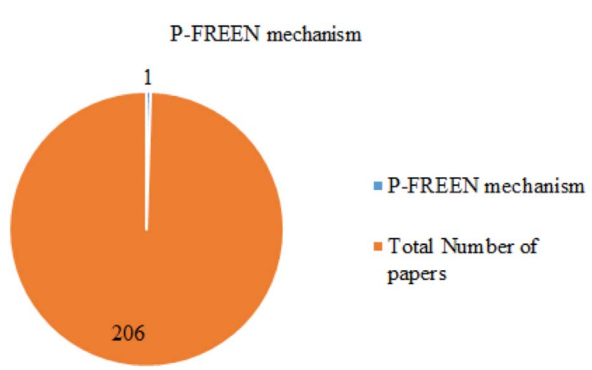

Fig. 15. Data recovery plan for the P-FREEN mechanism.

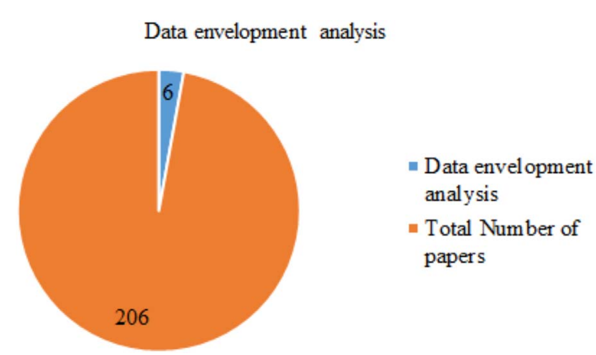

Fig. 17. Data recovery procedure for DEA method.

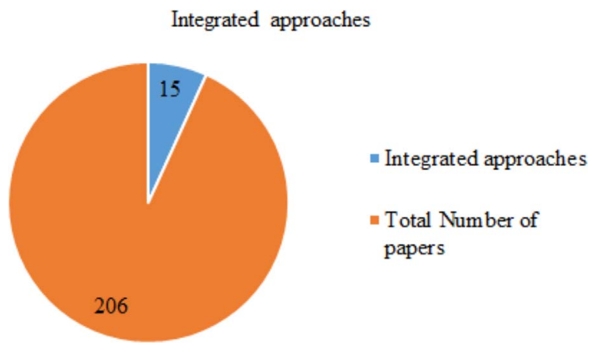

Fig. 18. Data recovery strategy for integrated approaches.

municipalities' provinces in China. The economic impacts and facilitate sustainable development also analyzed by this approach.

3. Integrated approaches

Among two-hundred and six journal articles fifteen research papers (7.28%) proposed integrated approaches and their hybrids to deal with the energy evaluation and selection problem. Their applications and evaluating criteria used in the procedures is summarized in Appendix 18. The data retrieval strategy is also depicted in Fig. 18.

Liu et al. [154] developed an integrated fuzzy possibilistic-joint probabilistic mixed-integer programming (FPJPMIP) model to the expansion planning of power generation under uncertainty. The developed model was able to reduce the risk of energy system failure cost to maintain the stability and other practical problems that were associated with the complex and uncertain information.

Chang [155] applied integrated neural networks (NNs) with turn-on transient energy analysis of the cogeneration systems. Thus the effectiveness of power system and an internal load of cogeneration system has been identified by using non-intrusive energy management (NIEM) system based on genetic algorithm. For economic dispatch that can significantly reduce computation time, fuel cost, power cost, and air pollution.

Adhikari et al. [156] proposed an integrated optimization technique for building and district energy design to reduce the global impact of dynamic energy management system. The developed models incorporate building energy technology and a smart grid for obtaining energy efficiency, reliability, and security of energy infrastructures also it can be applicable for future.

Olanrewaju et al. [157] utilized an integrated index decomposition analysis (IDA) – artificial neural network (ANN) and data envelopment analysis (DEA) for the industrial energy management system. The technique provides strength on analyzing the consumption of energy for policy makers and stakeholders of industry based on quantitative assessment dependent on mathematical programming. This model can be utilized by the policy makers to improve industrial energy efficiency computation and optimization of energy consumption.

Han and Lee [158] developed an integrated energy supply and CO_2 mitigation network (IESCMN) for the identification of energy requirement and available energy sources for industry. In this model, IESCMN strategy minimizes energy cost, because sources (boiler, turbine) and sinks (energy requirement) can be connected to each other to transfer good energy compared to the individual operation of each technology.

Wu et al. [159] proposed an integrated approach based on supervisory control and data acquisition techniques, which can reduce the peak demand as well as save the energy for the air conditioner. The proposed integrated method is reliable for commercial use and also reduce the CO_2 emission in a cost effective manner compared to Zigbee technology.

Mokhtar et al. [160] developed Gaussian adaptive resonance theory map (GARTMAP) for building intelligent heat management system (IHMS) for better (automated) energy control and thermal comfort of a building environment. The proposed method provides better energy control and thermal comfort in comparison to the existing rule-based multi-agent system approach.

Abdullah and Najib [161] proposed a new method of intuitionistic fuzzy analytic hierarchy process (IF-AHP) to deal with the real case experiment of solving the sustainable energy planning decision problem. The proposed IF-AHP was successfully tested in nuclear energy source selection.

Cosmi et al. [162] used an integrated planning and development self-assessment analysis (SAA) methodology to characterize the energy systems regarding policy background, energy users, and infrastructures as well as market behavior and community attitude to sustainable development.

Garshasbi et al. [163] modeled a novel hybrid Genetic Algorithm and Monte-Carlo simulation approach for the prediction of instantaneous and cumulative net renewable energy generation balances and the hourly amount of energy taken from and supplied to the central energy grid. The renovated model was capable of modifying and readjusting the energy consumption patterns of buildings via appropriate predefined policies and well-designed monitoring systems.

Woldeyohannes et al. [164] developed an integrated renewable energy system (IRES) model to address the challenging issues related to renewable energy (RE) resources optimization in the areas where providing power from the main grid. The developed optimization model could be used as a decision-making support tool to evaluate and select various alternative renewable energy resources and to determine the optimal locations for developing these resources.

Çelikbilek and Tüysüz [165] presented a grey-based multi-criteria decision model for the evaluation of renewable energy sources which integrates Decision Making Trial and Evaluation Laboratory, Analytic Network Process and multi-criteria optimization and compromise solution (Serbian name: VlseKriterijumska Optimizacija I Kompromisno Resenje) methods. Finally, the effectiveness and the applicability of the developed model was performed by using the proposed grey multi-criteria optimization and compromise solution method for the evaluation and ranking of the renewable energy sources in the energy sector.

Olanrewaju and Mbohwa [166] put forward an integrated model utilizing the functions of Index Decomposition Analysis (IDA), Artificial Neural Network (ANN) and Data Envelopment Analysis (DEA) for measuring the Canadian industry's carbon dioxide (CO_2) emission rate. The developed model was able to determine the causative factors responsible for emission, forecast emission or to optimize.

Antonakakis et al. [167] examined the dynamic interrelationship in the output energy-environment nexus by applying panel vector autoregression (PVAR) and impulse response function analyses on energy consumption. The advanced analysis could be tested between high economic growth rates and unsustainable environment and low or zero economic growth and environmental sustainability dilemma.

Mousavi et al. [168] presented a new decision model based on modified elimination and choice translating reality (ELECTRE) under a hesitant fuzzy environment for solving the multi-attribute group decision-making (MAGDM) problems and energy policy with unknown information.

4. Combined approaches

Among two-hundred and six journal articles nine papers (4.36%) applied combined methods to evaluate the energy scheduling and select the best management strategy. Their applications and evaluating criteria used in the methods is summarized in Appendix 19. The data retrieval procedure is also depicted in Fig. 19.

Alsumait et al. [170] presented a new approach based on a hybrid algorithm consisting of Genetic Algorithm (GA), Pattern Search (PS)

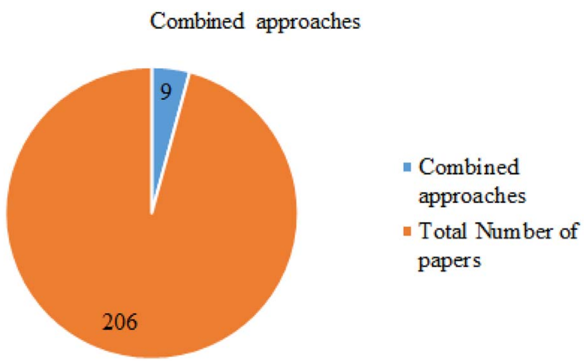

Fig. 19. Data recovery approach for combined approaches.

and Sequential Quadratic Programming (SQP) techniques to solve the public power system Economic dispatch (ED) problem. A fuzzy adaptive particle swarm optimization (FAPSO) algorithm with Nelder–Mead (NM) simplex search called FAPSO-NM was also proposed by Niknam [171] for solving the ED problem considering the valve point effect. The proposed algorithms were able to improve the economic functions for sustainable future.

Roche et al. [173] proposed a multi-agent system combined with an economic and environmental dispatch algorithm obtained through an optimization algorithm based on differential equations for the flexible and efficient operation of gas power plants. The algorithm is capable of reducing the cost function as well as NO_X emission levels.

Huang and Lee [169] and Ibrahim et al. [175] developed a dynamic, economic optimal management model for interstate hybrid water heating system, where the green coverage factor (GCF) plays a significant role in total delivered energy. The proposed optimal energy management model yields reliable results and could be generalized to other locations for substantial annual savings.

Güngör et al. [172], Lu et al. [174], Jayasekara et al. [176] and Ai et al. [177] combined an interior-point algorithm and pattern search algorithm for distributed networks to enhance the performance of the grid by civilizing the voltage stability and tumbling distribution losses for consumers. The results of the proposed model highlight the capability of distribution losses, reduce peak demand and improve green energy utilization.

5. Other approaches

Various researchers suggested many other simplified and hypothetical methods (twenty-nine papers or 14.07%). Their applications and evaluating criteria used in the procedures is summarized in Appendix 20. The data retrieval strategy is also depicted in Fig. 20.

Kruangpradit and Tayati [178] described PEA's program on design, implementation, and evaluation of hybrid renewable energy systems for electrification of remote villages in Thailand. The presented model was introduced to monitor the system operation and control performance by using a radio phone modem for the small power plant.

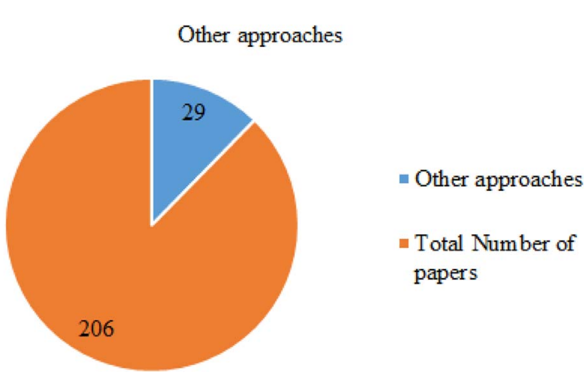

Fig. 20. Data recovery procedure for other approaches.

Vastag et al. [179] proposed a framework to evaluate corporate environmental strategies. The proposed framework analyzed environmental risks on two dimensions. One was, the endogenous environmental hazards, arises from the internal operations of the company and the other one, the exogenous environmental hazards, and were determined by the corporation's external world: its location, it's ecological setting and the demographic characteristics of the physical environment in which it operates.

Kellogg et al. [180] developed a simple numerical algorithm for generation unit sizing to determine the optimum production capacity and storage needed for a stand-alone, wind, PV, and hybrid wind-PV system in a remote area in Montana with a typical residential load. Also, an economic analysis had been performed to justify the use of renewable energy versus nearest existing power.

A basic conceptual model of environmental management within operations was developed by Klassen and Whybark [181]. The advanced design helped operations managers on environmental issues ranges from proactive to reactive, and this was intrinsically related to the investment pattern in environmental technologies.

Amundsen [182] integrated energy management into energy management system (EMS) to reduce Norwegian emissions of greenhouse gasses. The integrated methodology reduced CO_2 emissions and energy generation cost for the betterment of the cleaner environment.

Barton and Infield [183] developed a simple probabilistic method to predict the ability of energy storage to accommodate the intermittency of wind-powered generation. The method could be applied to stand-alone systems or too weak electricity grids where the level of wind-powered generation would be limited by network constraints.

Liang and Liao [184] presented a fuzzy optimization approach for solving the production scheduling problem with consideration of the wind and solar energy systems. The main feature of the proposed fuzzy-optimization approach was that the forecast hourly load, available water, wind speed and solar radiation errors could be taken into account using fuzzy sets to obtain the optimal generation schedule under an uncertain environment.

A multi-objective chaotic particle swarm optimization (MOCPSO) method was put forward by Cai et al. [185] to solve the environmental/economic dispatch (EED) problems considering both economic and ecological issues. The advanced method could result in significant environmental and economic effects by minimizing the fuel costs and lower emissions of the power systems.

Gordić et al. [186] considered energy management system, organization and energy politics in metal working industry for auditing to identify the cost of energy use, possibly wastage, and alternatives. This verification provides a guideline for entrepreneurs of implementing energy management strategies to reduce energy dependency regarding energy cost and increase the profitability of any factory.

Cumo et al. [187] developed an approach to evaluate and improve the energy flows from nature to city and vice-versa. This method reveals the urban cell energy balance through innovative technology with the use of green resources for sustainable urban energy management.

Ashourian et al. [188] proposed a combined approach as a backup to the green energy system for electricity generation in a viable and reliable way. The proposed method utilizes the load profile and geological conditions of a particular region that reduces CO_2 emission and cost function.

Nikolova et al. [189] employed an approach for solving generation scheduling problem for different conventional power-plant units by using classical and green energy sources (GES). In this method, power balance equation in the form of inequality and output limits of thermal and hydro units were considered. The approach minimizes the total production costs, for real-time operating system constraints.

Motevasel et al. [190] proposed an interactive fuzzy-modified bacterial foraging optimization (MBFO) algorithm for thermal and electrical storage to minimize the operating cost and emission. This proposed approach smartly cover the total electrical and thermal load demand on economic and environmental criteria.

Kuznetsova et al. [191] constructed a two step-ahead reinforcement learning algorithm for optimal energy management actions. The developed framework gives the capability to the original customer, to learn about the stochastic environment for optimal energy administration of a micro-grid.

Ngai et al. [192] developed an energy and utility maturity framework for precise measurement and control (EUMMM), for analyzing the maturity level of energy and utility management in the organization. This study provides a robust guideline for manufacturing organizations in the field of sustainable energy optimization.

Rollins et al. [193] developed a novel power profiling approach to identify critical energy consumption using a smartphone application coupled with an off-the-shelf home energy measurement infrastructure. The advanced model gives casual links between activity and home energy management using a small number of monitoring devices.

Rosyidi et al. [194] used the participatory rural appraisal method (PRA) approach for the energy needs assessment in the countryside. The proposed energy approach accompanied with the economic benefits of green energy solution; likely biogas energy package for cooking and local entrepreneurs for improvement of living conditions of rural people.

Gruber et al. [195] presented an appropriate consumer energy demand model based on a probabilistic approach for the generation of detailed energy profiles. The proposed model is helpful to minimize the cost function.

Missaoui et al. [196] were the first group of researchers considering, global model based on anticipating building energy management system (GMBA-BEMS). The proposed model can optimize user comfort and energy cost for physical constraints like energy price and power limitations for smart homes.

Velik and Nicolay [197] proposed a modified simulated annealing triple optimizer for optimal energy management of microgrids. The proposed approach is a robust method for determining optimal energy management and financial gain maximization in microgrids which is helpful for the different economic application.

TANG et al. [198] evaluated that systematic energy efficient technology has been applied in the field of the steel industry, has to build as soon as possible if they want to take full usage of energy in all aspects. Utilization of system energy savings is guidelines of energy conservation and emission reduction of any steel industry.

Arigliano et al. [199] proposed an open source framework, to change its position from a real energy consumer to an energy combined producer, stores, and user. The proposed model was more flexible with the uncertainty behavior of green power generation for sustainable development.

Yang et al. [200] proposed a novel hybrid system by advanced adiabatic compressed air energy storage (AA-CAES). As a promising emission-free technology to the advanced civilization wind power integration, diminishes abandoned wind power and perk up the monetary return per capital cost of the system by escalating power output.

Fantozzi et al. [201] proposed an ice water, energy management, and control approach, focusing on the water circulation network, which enables a significant reduction in water loss and energy utilization in a cost-effective manner.

Santhosh et al. [202] studied an integrated engineering system for its management to develop a systematic method for achieving sustainability in the field of energy-water nexus. The system plays a significant role in relieving process constraints and reducing energy cost.

Wang et al. [203] proposed a novel power demand and supply management scheme defining a distribution uncertainty of green energies. The proposed system reduced the energy cost and was useful for policy making for the future MGCC.

Kilkis [204] benchmarked a city sustainability index is namely the sustainable development of energy, water, and environment systems (SDEWES). The SDEWES index is useful to trigger learning, action, and collaboration among cities to transition to a more sustainable future in the field of energy.

A Pinch Analysis based method for allocating different energy sources demands of a region was proposed by Bandyopadhyay and Desai [205]. The proposed method was able to determine the cost optimum mix of various energy sources. The advanced practice helped in reducing the burden of subsidy significantly by appropriately utilizing locally available renewable energy sources in Lakshadweep Islands, India.

Theo et al. [206] presented an overview of numerical and mathematical modeling based optimization techniques for distributed generation (DG) system. The primary purpose of this work was to compare different aspects of DG optimization techniques, explore their applications, and identify potential directions for renewable energy forecasting models based on their prediction horizons under uncertainty for better and more user-friendly DG energy planning.

6. Observation and recommendation

In this paper, 206 journal articles, which appeared in the period from 1957 to 2017, solving the sustainable energy planning problem using distinct approaches, mathematical modeling, the multi-criteria decision-making strategies and other optimization techniques were collected. The approaches; including individual, integrated, combined and other, their appositeness and gauge paradigm used in the accession are retrograde in Appendices 1–20. Some observations based on these journal articles are made in the following subsections [207].

6.1. Most popular approach

The first objective of this paper is to find out the most popular approach adopted in the sustainable energy evaluation and selection by various researchers. As found in the previous sections, the specific procedures (184 papers or 89.32%) were slightly more attractive than the integrated approaches (15 articles or 7.28%).

According to Appendix 21, the most famous individual approach is mathematical programming using different algorithms, followed by fuzzy approaches, hybrid energy management of physical systems, ANP, ZigBee technology, AHP, DEA, ANN, genetic algorithm, SCADA, game theory approach, and other techniques. These strategies are most popular because of their robustness. In the past, it was used to measure only the energy efficiency of any system based on numerical data only. But the green energy selection problem are both quantitative and qualitative criteria, tangible and intangible results, subjective and objective factors and so on. Also, multi-criteria decision-making approaches and their hybrids can also be used for sustainable energy planning by green energy sources.

As shown in Appendix 22, there are various integrated approaches for sustainable green energy evaluation and selection. It was perceived that the unified genetic algorithm with the neural network approach is more reliable to predict sustainable future. The above method is widely applicable due to its modesty, ease of adoption, and tremendous resilience. Genetic algorithm (GA) has been integrated alongside other approaches, as well as neural network (NN), data envelope analysis, fuzzy set theory, geometric progression, grey relational analysis, multi-criteria decision making and multi-objective programming. Moderately, the integrated GA-NN approaches are the most fashionable. The primary reason is that the individual techniques have unique advantages. Based on the above analysis, it is believed that the process must be beneficial for decision makers if ENTROPY-analytical hierarchy process (AHP), AHP-quadratic programming (QP) and AHP-artificial bee colony (ABC) optimization techniques are integrated together.

Again this review paper reveals that various methods had been used to optimal green energy planning for sustainable development, to undestand the fundamental reason for the above mendioned question. As depicted in Appendix 25 it was noticed that hybrid energy management of the physical system is more prevalent corresponding to different regions followed by mathematical modeling, fuzzy approaches, and AHP method, etc. For example, some author(s) considered region as the best choice for the optimal green energy planning ([28,30]; urban area of Delhi, Wardha District- Maharashtra State, India, [2]; for wind park island of Crete, Greece, [33]; economic effects in Canada, [8]; for newsprint mill located at Canada, [93]; China's regional energy requirement, [10]; U.S electricity sector, [11]; for PV systems for state and municipalities of Brazil, [3]; for lighting system at Melbourne University, [13]; for public lighting in the croation city of Rijeka, Karomov et al., [14] ; hydropower project for Uzbekistan and Tazakistan, European Union, [16]; low carbon society in China, [19]; energy forecasting model for Canada, [20,21]; China's regional CO_2 emission, [22]; electricity generation sector in South Korea, [71]; India's solar energy deployment, [72]; for wind farm located in UK, [73]; building in Iran, and so on). Thereafter, Keeping in mind "energy for sustainability" explore the terms energy savings, environment, economy, energy supply, risk factors, location and transportation, CO_2 emission, energy production capacity, energy efficiency, cost effectiveness, energy comfort, energy storage, energy demand, energy consumption, market price, energy planning, energy policy and security etc. were the most dominating factors to energy planning for that regions.

6.2. Most popular evaluating criteria

The second aim of this paper is to discover the most common criteria considered by the decision makers in assessing and selecting the best green energy sources available in the world. More than a hundred measures were proposed, and they were summarized in Appendix 24. The most popular criterion are variety of energy cost, energy efficiency, energy consumption, renewable sources, energy storage, energy economy, environment, CO_2 emission, energy policy, capacity, energy demand, energy supply, risk factors, location and transportation, energy comfort, payback period, fuellcell, energy market and pricing, energy planning, energy scheduling, improvement, energy uncertainty, energy constraints, quality, resilience, robust optimization, benefit, distribution, sustainability, recovery, recycling, retailers and customers and energy security. On the other side, the most popular decisive factors are lack of 'planning', succeed by location; 'eco-friendly environment', 'infra- structures', 'economic and social information', 'demographics', 'non-electrification', 'political risk', 'market risk', 'delivery risk', 'location of plant', 'power transmission line', 'energy intensity', 'lifespan', 'personal agent', 'local agent', 'mediator', 'information provider', 'decision maker', 'control executor', 'central agent', 'occupant', 'actuators', 'poor stability', 'delay', 'throughput', 'fuel selection', 'capacity constraints', 'solar generator', 'operating hours', 'load forecast error', 'market price', 'equality constraints', 'energy storage device', 'power balance', 'environmental performance', 'resilience', 'economic capability', 'supply management', 'energy cost savings', 'cost of material', 'irrigation system', 'equipment and labour', 'demand control', 'clean energy', 'process control', 'process constraints', 'reliability', 'geographical condition', 'energy potential capability', 'service', 'management', 'technology', 'research and development', 'finance', 'flexibility', 'safety', and 'environment'.

There are seven papers (3.39%) Appendix 23 considering combined approaches in green energy planning and selection process. Various attributes have been found in the articles, such as "Genetic Algorithm (GA), Pattern Search (PS) and Sequential Quadratic Programming (SQP)", "fuzzy adaptive particle swarm optimization (FAPSO) algorithm with Nelder–Mead (NM) simplex search", "multi-agent system architecture combine with an economic and environmental dispatch algorithm", "dynamic modeling," "an interior-point algorithm and pattern search algorithm," "Advanced metering infrastructure (AMI), communication technologies, quality-of-service (QoS)", and so on.

Based on the above findings, it was revealed that cost, energy savings, and other factors are not the most widely adopted criterion. The traditional single or multi-criteria approach based on lowest price is no longer supported and robust enough for green energy source selection. It would be helpful for the decision makers, managing the green energy sources by using different hybrid optimization tools and MCDM techniques in such a way that would be a success story of the local region with a global impact.

6.3. Other observations

This paper reviews 206 journal articles that have been published in different reputed journals from 1957 to 2017 for recent sixty years shown in Appendix 20. It is observed that various relevant studies were carried out by different researchers in energy planning for sustainable development using modified "Economic optimal management model", "Continuous power flow method", "PEA's program on design, implementation, and evaluation", "Simple numerical algorithm", "Simple probabilistic method", "A multi-objective chaotic particle swarm optimization (MOCPSO) method", "Pinch Analysis based method", "bacterial foraging optimization algorithm", "reinforcement learning algorithm", "energy and utility management maturity model", "participatory rural appraisal method", "consumer demand model", "modified simulated annealing triple-optimize", etc. and "multi-criteria decision making approaches (MCDM)". It is estimated that the number will keep increasing in the coming years because of the importance of sustainable green energy planning for social acceptance is an effective energy strategy [207] for green energy source selection.

7. Future work

Although the approaches mentioned above can deal with multiple and conflicting criteria, they have not taken into consideration the impact of business aspiration and compulsion of any building, industry, power plant, wireless sensor network, microgrid by appraising index. In the real world, the weighting of sustainable energy planning index depends on a lot of executive transcendence and strategies. In many cases, the weighting is assigned arbitrarily without considering the "right to be heard" of ordinary people. To facilitate the "right to be heard" like an ordinary people of society is considered, an integrated analytical approach, combining AHP-ABC, AHP-GA, AHP-QP, gravitational search algorithm, Kuhn-Tucker conditions and many other optimization techniques, should be used to reduce the energy consumption strategically. The usefulness of evaluating strategy is arranged on the degree of achieving the proper planning for sustainable energy use. This may result in some level of inconsistency, and therefore degrade the policy of decisions made. Nevertheless, the author proposes ENTROPY-AHP method, ENTROPY-ANP method, ENTROPY-TOPSIS method, ENTROPY-COPRAS method, AHP–ABC analysis has not been applied to the sustainable energy evaluation and the energy source selection problem yet. There is less amount of work on the green energy source selection for sustainable development.

8. Conclusion

In this paper, a detailed review is done based on the bottoms up energy scheduling, mathematical modeling, fuzzy theory, multi-criteria decision-making approaches, combination and simplified other optimization techniques for sustainable energy planning and scheduling strategy from the year 1957–2017 to get the detailed idea about recent trends in the field of works on energy planning and scheduling strategy. From the survey, it was found that numerous individual, integrated, combined and other approaches were proposed to solve the energy scheduling and planning problem. Most of the articles show that various techniques had been implemented for optimal green energy plan for sustainability in different regions in the globe. The most famous single approach is mathematical modeling with various algorithms, whereas the entire prominent integrated approach is GA with QP-NN. It is also found that cost of green energy source selection is not the most widely adopted criterion. Instead, the most traditional standard used for evaluating the sustainable energy scheduling followed by low CO_2, NO_X emission, and so on. This research proves that the traditional single measure approach based on lowest cost is not supportive and robust enough in contemporary energy management. The fixed cost-based approach cannot guarantee that the green energy source selection is global optimal because of social acceptability and customer oriented criteria were not considered. Moreover, some endorsements were made positioned on the inadequacies of some agreements. This research can positively aid the researchers and energy managers in solving the energy planning and scheduling dilemma adequately.

Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.rser.2016.12.105.

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