Development of the hybrid MCDM model for cloud computing adoption strategic management

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Abstract

With the widespread use of distributed alternative energy sources, electric cars, energy storage systems, and technologies like Cloud Computing (CC), Big Data, and the IoT, energy management in CC contexts has developed. Concerns about the Energy Cloud's performance goals are presented in this fashion as a major development point (EC). The aims of this essay include identifying key FPVs and how they relate to issues in EC, as well as formulating an approach to overseeing the growth and maturity of EC settings. Through literature research, FPVs were identified as well as their influence on each other.

It was determined that those FPVs were an important, secondary, motivational factor, and independent voters by using the AHP approach. An all-encompassing management model for EC is presented in the article, and it can be used as a compass for making strategic choices on technical, organizational, commercial, and regulatory matters. This model may be tailored to the specifics of the business landscape and its breadth.

Keywords: AHP; Cloud Computing; IoT; Big Data; MCDM

1. Introduction

"Power consumption" is the term used to describe the techniques used to increase energy efficiency, which is critical to decreasing energy expenses[1][2]–[5] and boosting the profitability of businesses [6]. Furthermore, while minimizing energy usage has become a persistent concern [7], economic growth and energy consumption expand in a dependent way [8]. Energy from renewable sources has made energy systems more cost-effective [9], and electric cars and energy storage systems may help keep energy networks stable[9]. Since energy systems are always evolving and diversifying, new computational technologies are needed to keep up with this ever-changing marketplace.

Technology such as Cloud Computing (CC) and the Internet of Things (IoT) begin to play an essential part in this energy management. CC is a technique to remotely store, monitor, and control data [10], and considering its flexible and extensible qualities, CC may be also employed in smart grid domains[11]. IoT devices capture data and send it to the cloud, where it is processed in centralized cloud-based data science analyses by cloud experts [12]. These IoT gateways act as intermediary smart devices and the cloud platforms, storing, analyzing, and transforming user information into actionable management information.[13]

Connectivity between customers and distribution networks may be achieved using a neutral bargaining agent, which oversees purchases, sales, and transfer of energy in the Power Cloud[14]. For the EC layout, layers and management support blocks may be used to depict the flurry of data and information linked to energy, while the management support blocks enable administrative activities to be completed [15]. The shift to an Energy Cloud Administration (ECM) environment is

Doi : https://doi.org/10.54216/FPA.030203
Received: January 02, 2021 Accepted: May 12, 2021

costly and complex[16]. Thus, there is a need to conduct research from a business viewpoint connected to EC, such as performance assessment, decision-making, and the proper use of access to finance[17]

A company's or institution's activity has to be evaluated to assess whether or not its goals have been met[18]. For example, several sorts of company assessments may be conducted using the inherent aspects of these firms as a foundation. FPVs can also be used in this assessment because they are fundamental elements of multidimensional models that are structured to help defy the assessment actions of judgment designs [19] that aid in planning in the most diverse areas and scenarios, such as EC (Environmental Contingencies). In this method, the major aspects of the EC environment development and dispersion may be mapped and arranged in management models.

This study was prompted by the shift in energy management systems from centralized to distributed modes of operation. A company's performance goals must be translated into FPVs and the definition of these objectives may be used to aid in the planning and design of strategies for implementing, developing, and maturing regionalized EC environments. When developing these planning and development plans, these FPVs must be linked to the difficulties that EC faces. According to this, a lack of understanding of how electricity may be utilized most effectively is exacerbated by increases in electricity efficiency and the large integration of renewable energy supplies. EC can assist in the most efficient and environmentally friendly use of energy possible.

As a result, the goal of this paper is to identify FPVs, link them to EC issues, and construct a management model for EC environment development and maturity.

To define and debate, in the framework of cloud-based electricity consumption, what were the FPVs that need to be effectively handled by firms and academics working in this field.

To plan and coordinate the creation, deployment, and maturity of the EC environment, a management approach for EC based on the FPVs' interactions is proposed. To help spread the development and incorporation of new computing technologies into the management of energy, this article proposed a management system for EC contexts that would increase the efficiency with which this energy is used.

The following is how the rest of the study is laid out: The essay is divided into five sections: a literature review in Section 2, a methodology section in Section 3, findings and discussion in Section 4, and a conclusion in Section 5.

2. Related Work

Managing energy systems has become more crucial than ever as the use of renewables and electric car charging stations has grown in popularity[20]. [21]It is thus critical to pick a suitable storage technology and optimize size to provide a high level of dependability and a low cost of capital [22]. When it comes to monitoring and characterizing user consumption habits in real-time, energy management may play a key role [23].
It is vital to regulate energy usage in micro-grids, buildings, smart grids, and smart cities[24]. [25]So new systems and technologies are needed to monitor and regulate data on energy [24], generating synergy between the various types of energy in the system, indicating new prospects for development in the power generation with beneficial implications for users [26]. Thus, it is possible to create cost-effective or somehow power sources to engage in the electricity market while also having excellent negotiation strength [27]. Distributed energy resources are becoming more common in current systems, and as a result, correct energy management models are becoming increasingly vital [28]. It's also important to build cloud-based power management models.

Microgrids, smart meters, warehouses, IoT, web, big data, and other technologies may be used to integrate distributed generation systems into the electric grid through the EC, which is a platform established with technical and economic requirements for this purpose. It is the foundation of cloud-based power management [29] that the EC serves as a scalable significant energy management system. As a result, to support ECM, the creation of cloud-based Internet of Things (IoT) applications is now a must.
The fundamental flow of records and knowledge about energy occurs in the layers connecting the Electrical and Implementation layers, while management and complementing activities take place in the network facilitates blocks. Finally, the Regulation layer tries to introduce the regulatory features

Doi : https://doi.org/10.54216/FPA.030203
Received: January 02, 2021 Accepted: May 12, 2021

so that the whole EC ecosystem may have the appropriate dynamics and adhere to certain rules. EC legislation [30].
As ECM is still in its infancy in most countries, a lot of studies are required in this field. An ECM-related study of FPVs and how they interact becomes significant if this assumption is correct.

3. The MCDM AHP Method

It is shown in Figure 1 how the methodological approaches used to construct the FPVs administration model for evaluating EC environments growth and maturity were put together. Step-by-step instructions and outputs for every step are presented on each side of this figure 1.
As part of the first stage, a literature review is undertaken of the FPVs and theoretical subsidies needed to support talks regarding the deployment of EC settings, as well as the challenges that must be solved. Two experts from each of these FPVs were asked for their thoughts on the current problems for implementing EC environments in a survey conducted in phase two. The weights of the FPVs were calculated using the AHP approach in step 3. When discussing every FPV and its classification by AHP in step 4, it becomes feasible to suggest an FPV management model for EC that may reflect the findings of this study.

For this purpose, a survey of specialists in the fields of energy and computer science and management was established and used.
First, the AHP approach was used to calculate the weight of the various criteria and sub-factors. A questionnaire was used to compare the resilience components and sub-factors in a paired fashion. Experts used a 12-segment format to answer each question.

The MCDM problem's performance is influenced by several factors. Each criterion's weight value may be used to express its relative relevance, with the total weight of all the MCDM problem's criteria being regulated by a value of 1.

In the MCDM problem, Saaty [31] presented the AHP approach for determining the appropriate weights for each criterion. Pairwise comparison of two criteria is used in the AHP approach. Because of this, the number of pair-wise comparisons increases. This comparison is made using the Saaty scale developed by Saaty in [32]. The Saaty scale uses nine preference points to allow the expert to indicate however many times somewhat one criterion is favored over the other. The MCDM problem's pairwise comparison is carried out by a questionnaire based on the competence of three evaluators (experts).

Set up the comparison matrix for each pair.
Members of the experts were then tasked with comparing and contrasting the primary criteria and their sub-factors. There are several advantages to this form of comparison, such as the fact that almost all of the factors are taken into account. After building the pairwise matrix, the opinions of experts are combined into one matrix. The following is an illustration of the established matrices:

$$X = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{n1} & \cdots & x_{nn} \end{bmatrix}$$

Checking the consistency of a matrix in pairs
It is vital to evaluate the consistency of the pairwise comparison before deciding the weight of indicators.

$$CR = \frac{CI}{RI}$$

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

If the CR is less than 0.1. Then the opinions of exerts are valid and go to the next step.

Then normalize the aggregated pairwise matrix. Then compute the weights of the criteria.

Doi : https://doi.org/10.54216/FPA.030203
Received: January 02, 2021 Accepted: May 12, 2021

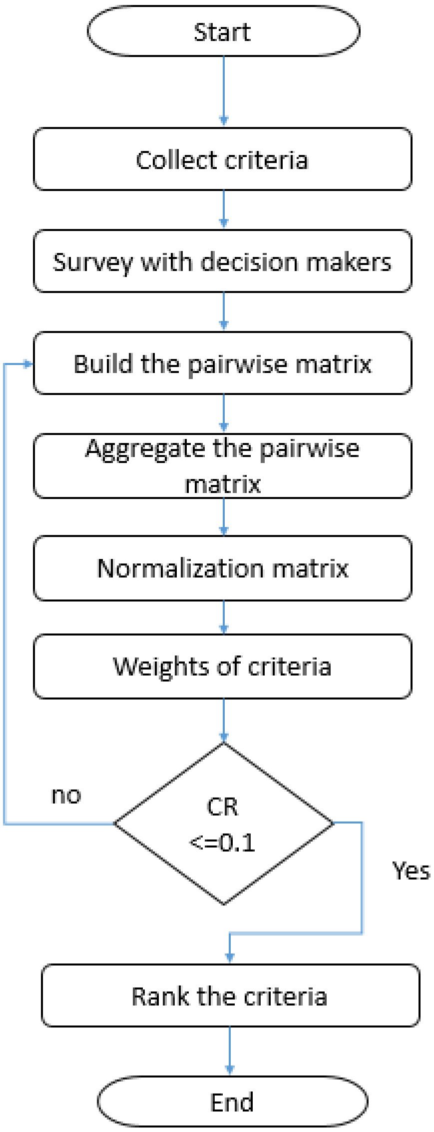

Figure 1: The flowchart of the AHP method

4. The AHP Results

Sustainability is defined as operating in a manner that ensures the present generation's well-being without jeopardizing the future generation's well-being ECC1.

Mobility There are several advantages to having systems and equipment that are mobile, such as the ability to move them physically or utilize their capabilities while they are in motion ECC2. Interoperability When two systems can interact with each other, they're called interoperability ECC3.

Scalability Expanding a system's capacity means using all of the system's resources to meet the increased demand ECC4.

It's all about getting the most bang for your buck when it comes to delivering goods and services ECC5.

Doi : https://doi.org/10.54216/FPA.030203
Received: January 02, 2021 Accepted: May 12, 2021

Flexibility The capacity of a system, product, or business to adapt to conditions is known as flexibility ECC6.

Personal information supplied in confidence must be kept private and protected from unauthorized disclosure by adhering to a code of confidentiality ECC7.

The energy's potency Shows how energy may be utilized efficiently, safely, and reliably without causing harm to the environment or endangering the well-being of its consumers at a reasonable cost ECC8.

Efficacy of the system consists of properly carrying out duties and optimizing resources including time, space, money, people, and raw materials ECC9.

Resilience An energy or data system's resilience is needed when it loses connectivity with the main system, continuing to function when this inability is caused by severe and unforeseen occurrences ECC10.

How well an item can do its job in the time frame and circumstances it was designed for is known as a product's "reliability," which may be defined as its ability to complete its duties as specified in a specific project ECC11.

Availability Ability to be there when required is the ability of an individual, system, product, or service ECC12.

Interoperability, scalability, and affordability are the most critical FPVs in the first quadrant, and they are seen as critical to the development of EC because of their prevalence and close association with the variables that lead to systemic benefits.

The first criteria are evaluated in table 1. Then their opinions are combined in Table 2. Then normalize their values in table 3. The weights of the criteria are computed as shown in figure 2. From figure 2 the ECC1 is the highest weight followed by ECC2 then ECC3 then ECC4. The least weight is ECC12.

AHP research demonstrates that the prices of power and cloud systems are significantly relevant but modestly influential for making decisions. Energy management is difficult because of the exorbitant prices of energy systems, supply difficulties, and regulatory duties related to emissions and global warming. In this approach, experts argued for the provision of financing that would allow the lowest sectors of society to adhere to distributed energy generating systems.

Expanding the idea of CC to include the energy resources consumed and making efficient use of computing resources may also help to reduce the implementation costs of EC (. A decrease in prices and acceptance of facilitated credit lines is critical, as well as marketing strategies that combine household and business users in much the same free electricity market, and taxes solely on the quantity of energy bought or sold by the users. For the experts, this is a critical issue.

To create scalable and interoperable solutions, the EC architecture in layers must be organized. Devices on a network may connect via a common platform to operate together in the Fog layer, where the interconnection of devices enables real-time energy monitoring. This is an important idea for IoT. According to the experts, a standardized communication protocol is required to enable various hardware manufacturers to participate in this market and communicate with each other across different platforms and consumers.

The interconnection, maneuverability, and confidentiality of smart homes and cities are all supported by energy management systems that are properly constructed. The experts emphasized the need of integrating diverse users via predetermined degrees of access to records/knowledge, all through technologies that are stable and safe connections with financial and market agent systems.

For energy management apps and their computational demands, researchers expect that CC can meet or exceed the scaling of CC when hosting applications. This scalability CC while hosting applications spares the user from having to worry about confining and updating the system's

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capacity According to the experts, it's critical to have data centers that use less energy and are continually expanding their capacity to operate software securely and lightly. IoT resources must be structured to make it easy to add more devices afterward, making use of the EC's scope, to solve these difficulties. The usage of blockchain has also been suggested by experts as a solution to overcome these difficulties and implement the EC. Scalability issues are a mystery for now since blockchain is a modern tech.

Table 1: The pairwise matrix of the first expert

	ECC1	ECC2	ECC3	ECC4	ECC5	ECC6	ECC7	ECC8	ECC9	ECC10	ECC11	ECC12
ECC1	1	9	5	9	6	9	6	1	1	1	6	6
ECC2	0.111111	1	5	5	8	7	5	3	9	9	6	6
ECC3	0.2	0.2	1	9	9	8	9	9	6	9	9	5
ECC4	0.111111	0.2	0.111111	1	9	8	8	9	8	9	9	6
ECC5	0.166667	0.125	0.111111	0.111111	1	5	8	8	9	7	5	1
ECC6	0.111111	0.142857	0.125	0.125	0.2	1	5	8	8	9	9	6
ECC7	0.166667	0.2	0.111111	0.125	0.125	0.2	1	8	8	5	9	3
ECC8	1	0.333333	0.111111	0.111111	0.125	0.125	0.125	1	8	6	9	4
ECC9	1	0.111111	0.166667	0.125	0.111111	0.125	0.125	0.125	1	7	9	3
ECC10	1	0.111111	0.111111	0.111111	0.142857	0.111111	0.2	0.166667	0.142857	1	8	2
ECC11	0.166667	0.166667	0.111111	0.111111	0.2	0.111111	0.111111	0.111111	0.111111	0.125	1	6
ECC12	0.166667	0.166667	0.2	0.166667	1	0.166667	0.333333	0.25	0.333333	0.5	0.166667	1

Table 2: The combined pairwise matrix

	ECC1	ECC2	ECC3	ECC4	ECC5	ECC6	ECC7	ECC8	ECC9	ECC10	ECC11	ECC12
ECC1	1	7.333333	5.666667	8.333333	7	7.666667	6	1	1	1	6	7
ECC2	0.140212	1	4.333333	5.333333	7	7.333333	6.333333	4.666667	7.666667	7.666667	6	6
ECC3	0.180952	0.244444	1	3.666667	6.333333	7	6.333333	7.333333	7	6.333333	6.333333	6
ECC4	0.121693	0.188889	0.703704	1	6.333333	7.333333	6.666667	8	6.666667	9	7.666667	6.333333
ECC5	0.148148	0.15	0.17037	0.17037	1	5	6.666667	6	7	5.666667	6.333333	2.666667
ECC6	0.132275	0.136905	0.15	0.136905	0.2	1	5	7.333333	7.333333	9	6.333333	5.666667
ECC7	0.166667	0.17037	0.17037	0.155952	0.152778	0.2	1	8.666667	7.333333	6.333333	7.333333	3
ECC8	1	0.263889	0.14537	0.126323	0.175	0.138889	0.115741	1	7	6	7.333333	3.333333
ECC9	1	0.132275	0.148148	0.152778	0.151323	0.138889	0.14537	0.144841	1	6.333333	7	2.333333
ECC10	1	0.132275	0.17037	0.111111	0.180952	0.111111	0.161905	0.166667	0.15873	1	7	4
ECC	0.166	0.166	0.170	0.132	0.170	0.245	0.145	0.145	0.148	0.15	1	7

Doi : https://doi.org/10.54216/FPA.030203

Received: January 02, 2021 Accepted: May 12, 2021

11	667	667	37	275	37	37	37	37	148			
ECC12	0.148148	0.166667	0.175	0.15873	0.722222	0.177778	0.333333	0.333333	0.555556	0.375	0.148148	1

Table 3: The normalization matrix

	ECC1	ECC2	ECC3	ECC4	ECC5	ECC6	ECC7	ECC8	ECC9	ECC10	ECC11	ECC12
ECC1	0.192132	0.727101	0.435773	0.427838	0.237939	0.210939	0.154235	0.022326	0.018917	0.01699	0.087615	0.128834
ECC2	0.026939	0.09915	0.333238	0.273816	0.237939	0.201768	0.162803	0.104189	0.145031	0.130256	0.087615	0.110429
ECC3	0.034767	0.024237	0.076901	0.188249	0.215278	0.192597	0.162803	0.163726	0.132419	0.107603	0.092482	0.110429
ECC4	0.023381	0.018728	0.054116	0.051341	0.215278	0.201768	0.171372	0.17861	0.126114	0.15291	0.111952	0.116564
ECC5	0.028464	0.014873	0.013102	0.008747	0.033991	0.137569	0.171372	0.133958	0.132419	0.096276	0.092482	0.04908
ECC6	0.025414	0.013574	0.011535	0.007029	0.006798	0.027514	0.128529	0.163726	0.138725	0.15291	0.092482	0.104294
ECC7	0.032022	0.016892	0.013102	0.008007	0.005193	0.005503	0.025706	0.193495	0.138725	0.107603	0.107085	0.055215
ECC8	0.192132	0.026165	0.011179	0.006485	0.005948	0.003821	0.002975	0.022326	0.132419	0.10194	0.107085	0.06135
ECC9	0.192132	0.013115	0.011393	0.007844	0.005144	0.003821	0.003737	0.003234	0.018917	0.107603	0.102217	0.042945
ECC10	0.192132	0.013115	0.013102	0.005705	0.006151	0.003057	0.004162	0.003721	0.003003	0.01699	0.102217	0.07362
ECC11	0.032022	0.016525	0.013102	0.006791	0.005791	0.006751	0.003737	0.003246	0.002803	0.002548	0.014602	0.128834
ECC12	0.028464	0.016525	0.013458	0.008149	0.024549	0.004891	0.008569	0.007442	0.010509	0.006371	0.002163	0.018405

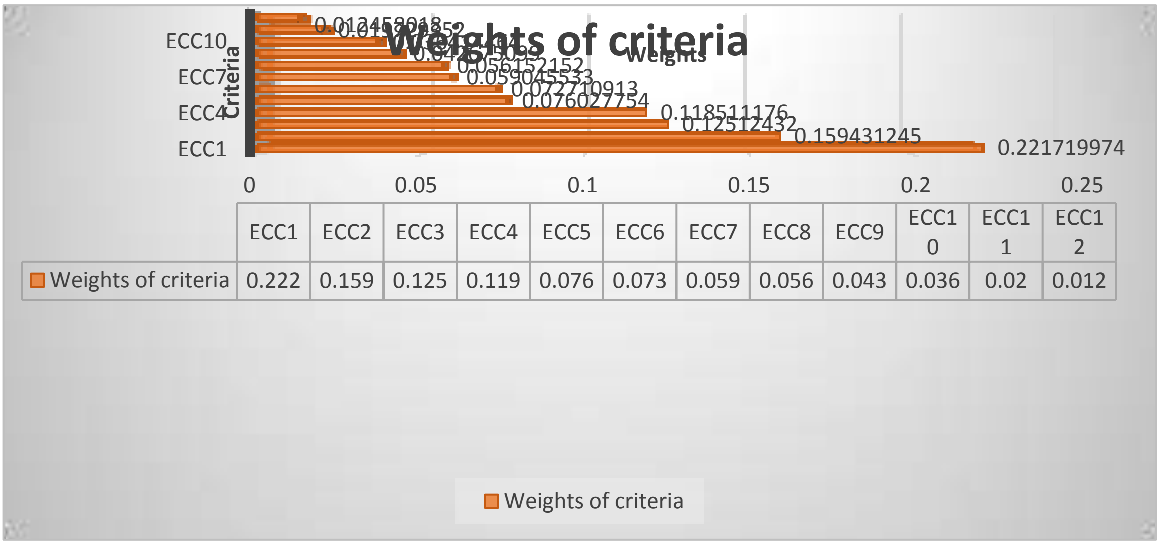

Figure 2: The weights of the criteria

Doi : https://doi.org/10.54216/FPA.030203

Received: January 02, 2021 Accepted: May 12, 2021

5. Conclusion

To reach the goal of this essay, the authors conducted research with experts and used literature to explore and contextualize the issues that EC faces as it matures and grows. A strategy diagram and model for the maturity and growth of the EC were able to be drawn up in this framework, which allowed for the consideration of these FPVs for the ECM.

FPVs and the interactions and influences over them for ECM are visually shown in this article, which has theoretical consequences. According to the management model, each change made to important points will affect other places in the chain of command. The FPVs of mobility and sustainability drive the growth of power systems to cloud-based solutions, whereas isolated points have a limited influence on the dynamics of EC. As a result, the AHP technique was able to describe these FPVs, giving fundamental subsidies for the construction of an ECM model relevant to firms in the EU.

References

[1] A. Lawrence, T. Nehler, E. Andersson, M. Karlsson, and P. Thollander, “Drivers, barriers and success factors for energy management in the Swedish pulp and paper industry,” *Journal of cleaner production*, vol. 223, pp. 67–82, 2019.

[2] S. F. Hazudin, M. A. R. A. Kader, N. H. Tarmuji, M. Ishak, and R. Ali, “Discovering small business start up motives, success factors and barriers: A gender analysis,” *Procedia Economics and Finance*, vol. 31, pp. 436–443, 2015.

[3] S. Aparcana, “Approaches to formalization of the informal waste sector into municipal solid waste management systems in low-and middle-income countries: Review of barriers and success factors,” *Waste management*, vol. 61, pp. 593–607, 2017.

[4] V. Beillan *et al.*, “Socio-economic barriers and success factors in the development of low energy consumption housing. A comparative study in three European countries,” *Act*, 2009.

[5] R. Hill, P. I. Pert, J. Davies, F. J. Walsh, and F. Falco-Mammone, *Indigenous land management in Australia: extent, scope, diversity, barriers and success factors*. Citeseer, 2013.

[6] H. D. Mohammadian, “IoE–A solution for energy management challenges,” in *2019 IEEE Global Engineering Education Conference (EDUCON)*, 2019, pp. 1455–1461.

[7] S. M. Hakimi and A. Hasankhani, “Intelligent energy management in off-grid smart buildings with energy interaction,” *Journal of Cleaner Production*, vol. 244, p. 118906, 2020.

[8] L. Miller and R. Carriveau, “Energy demand curve variables–An overview of individual and systemic effects,” *Sustainable Energy Technologies and Assessments*, vol. 35, pp. 172–179, 2019.

[9] J. C. O. Aravena, A. Aghahosseini, D. Bogdanov, U. Caldera, E. Muñoz-Cerón, and C. Breyer, “The role of solar PV, wind energy, and storage technologies in the transition toward a fully sustainable energy system in Chile by 2050 across power, heat, transport and desalination sectors,” *International Journal of Sustainable Energy Planning and Management*, vol. 25, pp. 77–94, 2020.

[10] N. Kulkarni, S. Lalitha, and S. A. Deokar, “Real time control and monitoring of grid power systems using cloud computing.,” *International Journal of Electrical & Computer Engineering (2088-8708)*, vol. 9, no. 2, 2019.

[11] G. Dileep, “A survey on smart grid technologies and applications,” *Renewable energy*, vol. 146, pp. 2589–2625, 2020.

[12] Y.-Y. Chen, Y.-H. Lin, C.-C. Kung, M.-H. Chung, and I.-H. Yen, “Design and implementation of cloud analytics-assisted smart power meters considering advanced artificial intelligence as edge analytics in demand-side management for smart homes,” *Sensors*, vol. 19, no. 9, p. 2047, 2019.

[13] A. Yassine, S. Singh, M. S. Hossain, and G. Muhammad, “IoT big data analytics for smart homes with fog and cloud computing,” *Future Generation Computer Systems*, vol. 91, pp. 563–573, 2019.

[14] A. Giordano, C. Mastroianni, D. Menniti, A. Pinnarelli, and N. Sorrentino, “An energy community implementation: The unical energy cloud,” *Electronics*, vol. 8, no. 12, p. 1517, 2019.

[15] J. L. Schaefer, J. C. M. Siluk, P. S. de Carvalho, J. Renes Pinheiro, and P. S. Schneider, “Management Challenges and opportunities for energy cloud development and diffusion,” *Energies*, vol. 13, no. 16, p. 4048, 2020.

[16] R. Bukhsh, N. Javaid, S. Javaid, M. Ilahi, and I. Fatima, “Efficient resource allocation for consumers' power requests in cloud-fog-based system,” *International Journal of Web and Grid Services*, vol. 15, no. 2, pp. 159–190, 2019.

[17] J. L. Schaefer, J. C. M. Siluk, I. C. Baierle, and E. O. B. Nara, “A scientometric approach to analyze scientific development on renewable energy sources,” *Journal of Data and Information Science*, vol. 6,

Doi : https://doi.org/10.54216/FPA.030203

Received: January 02, 2021 Accepted: May 12, 2021

no. 1, pp. 87–119, 2021.

[18] E. Domínguez, B. Pérez, A. L. Rubio, and M. A. Zapata, "A taxonomy for key performance indicators management," *Computer Standards & Interfaces*, vol. 64, pp. 24–40, 2019.

[19] L. Ensslin, A. Dutra, and S. R. Ensslin, "MCDA: a constructivist approach to the management of human resources at a governmental agency," *International transactions in operational Research*, vol. 7, no. 1, pp. 79–100, 2000.

[20] M. A. Mohamed, H. M. Abdullah, M. A. El-Meligy, M. Sharaf, A. T. Soliman, and A. Hajjiah, "A novel fuzzy cloud stochastic framework for energy management of renewable microgrids based on maximum deployment of electric vehicles," *International Journal of Electrical Power & Energy Systems*, vol. 129, p. 106845, 2021.

[21] L. Ruan, Y. Yan, S. Guo, F. Wen, and X. Qiu, "Priority-based residential energy management with collaborative edge and cloud computing," *IEEE Transactions on Industrial Informatics*, vol. 16, no. 3, pp. 1848–1857, 2019.

[22] M. S. Javed *et al.*, "Economic analysis and optimization of a renewable energy based power supply system with different energy storages for a remote island," *Renewable Energy*, vol. 164, pp. 1376–1394, 2021.

[23] S. K. Howell, H. Wicaksono, B. Yuce, K. McGlinn, and Y. Rezgui, "User centered neuro-fuzzy energy management through semantic-based optimization," *IEEE transactions on cybernetics*, vol. 49, no. 9, pp. 3278–3292, 2018.

[24] Y. Liu, C. Yang, L. Jiang, S. Xie, and Y. Zhang, "Intelligent edge computing for IoT-based energy management in smart cities," *IEEE network*, vol. 33, no. 2, pp. 111–117, 2019.

[25] M. A. Al Faruque and K. Vatanparvar, "Energy management-as-a-service over fog computing platform," *IEEE internet of things journal*, vol. 3, no. 2, pp. 161–169, 2015.

[26] M. Geidl, G. Koeppel, P. Favre-Perrod, B. Klockl, G. Andersson, and K. Frohlich, "Energy hubs for the future. IEEE Power Energy Mag 2007; 5: 24–30." 2007.

[27] Y. Wang *et al.*, "Energy trading and management strategies in a regional integrated energy system with multiple energy carriers and renewable-energy generation," *Journal of Energy Engineering*, vol. 147, no. 1, p. 4020076, 2021.

[28] M. Alhussein, S. I. Haider, and K. Aurangzeb, "Microgrid-level energy management approach based on short-term forecasting of wind speed and solar irradiance," *Energies*, vol. 12, no. 8, p. 1487, 2019.

[29] R. Govindarajan, S. Meikandasivam, and D. Vijayakumar, "Cloud computing based smart energy monitoring system," *International Journal of Scientific and Technology Research*, vol. 8, no. 10, pp. 886–890, 2019.

[30] P. S. de Carvalho, J. C. M. Siluk, J. L. Schaefer, J. R. Pinheiro, and P. S. Schneider, "Proposal for a new layer for energy cloud management: the regulatory layer," *International Journal of Energy Research*, vol. 45, no. 7, pp. 9780–9799, 2021.

[31] T. L. Saaty, "A scaling method for priorities in hierarchical structures," *Journal of mathematical psychology*, vol. 15, no. 3, pp. 234–281, 1977.

[32] T. L. Saaty, "Decision making with the analytic hierarchy process," *International journal of services sciences*, vol. 1, no. 1, pp. 83–98, 2008.

Doi : https://doi.org/10.54216/FPA.030203

Received: January 02, 2021 Accepted: May 12, 2021