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Balanced scorecard-based analysis about European energy investment policies: A hybrid hesitant fuzzy decision-making approach with Quality Function Deployment

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ABSTRACT

This study aims at analyzing the performance results of the European policies in energy investment within an integrated multidimensional quality measurement approach. For this purpose, the quality function deployment is adopted to the multidimensional performance measurement based on the balanced scorecard method. The dimensions and criteria of customer and technical requirements, process design, and performance measurement are defined to measure each process of QFD (Quality Function Deployment) for the energy investment policies with the supported literature. Within this context, the customer and technical requirements for energy investment policies are evaluated by considering the fuzzy decision matrix in the first process of the QFD and then, the technical requirements are used to rank the new service/product process of the energy investments in the second process of QFD. The balanced scorecard perspectives and the key factors are defined to rank the European energy investment policies respectively. Accordingly, the possible priorities of the European energy investment policies are discussed to conduct the most remarkable and efficient energy operations and the relevant results to contribute the improvement of energy sector are highlighted.

1. Introduction

Energy is an essential issue for surviving the life of the people. Additionally, it has also a significant effect to increase the investment in the countries because it is an important kind of raw material. As a result of this situation, the profit margin in energy sector went up very much especially due to the high level of consumption and business operations in the last years. Hence, the competition in the energy sector has increased very much almost all around the world.

Due to the hard competition, it is obvious that energy companies should take necessary actions to survive in this environment. Firstly, focusing on end users may be an example investment alternative. Second, some companies may prefer to increase the capacity and storage of the energy. Moreover, producing sustainable energy operations may be another investment policy for energy companies. Furthermore, some companies may focus on renewable energy sources. In addition to these policies, energy companies may also prefer to give importance to the affordability of energy prices.

Accordingly, Europe has an important impact on energy investments. Because Europe has a strategic importance with respect to the location in the world. Therefore, it attracts the attention of many different energy companies. Furthermore, it plays a significant role in the world with respect to the energy generation and consumption. Within this context, European Commission energy report in 2017 states that Europe has 5.6% of world energy production. Moreover, it has also 11.9% of world energy consumption. Another important point in this report is that Europe has 10.2% of world CO_2 emissions[1]. Moreover, according to this report, Europe is the continent that has very significant amount of renewable energy consumption in the world.

Owing to these issues, different energy policies are taken into the consideration in Europe. Firstly, it is thought that in the future, renewable energy will play a key role (Lam & Dai, 2015; Wood, Wang, Abdul-Rahman, & Abdul-Nasir, 2016). Therefore, it can be seen that especially the countries with high GDP prefer to make investment in this area. On the other side, the countries in the Euro-

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[1] https://www.energy.eu/publications/EU-energy-in-figures.pdf.

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pean zone are logistically suitable to make investments for increasing the storage and capacity. On the other hand, it is expected to increase the need of energy with the potential growth in individual consumption. Therefore, some companies in that region mainly focus on the end users. Cost efficiency becomes a prominent issue of energy investment after the global economic crisis. It is also understood that some companies opt for collaboration with other institutions to improve sustainable power in energy operations.

The study considers the performance results of the European energy investment policies. Within this framework, an integrated multidimensional quality measurement approach is used. Moreover, the quality function deployment is adopted to the multidimensional performance measurement. For this purpose, the dimensions and criteria are identified for customer and technical requirements, new product/service development policies and balanced scorecard perspectives. In addition to these aspects, 5 different energy investment policies for European energy companies are determined (Apajalahti, Lovio, & Heiskanen, 2015; Buchanan, Russo, & Anderson, 2014; Yu, Yu, & Lou, 2016).

However, for energy investment policies, it is believed that group decisions play a significant role especially in the strategy selection and policy development. The main reason is that different users' preferences of a group for a given item can be provided as the group hesitation about the preference of such an item for expressing uncertain information in the multi-criteria decision-making problems (Xu & Zhang, 2013). Also, in Castro, Barranco, Rodríguez, & Martínez (2017), it was proposed a hesitant group recommender model (HGRM), based on CF and HFS, while it keeps all information avoiding the aggregation process by considering the group hesitation.

Accordingly, in our proposal is considered the use of group hesitation for the evaluation of customer's requirements dimensions by using hesitant fuzzy DEMATEL methodology. Moreover, the criteria of customer requirements are weighted by using hesitant fuzzy AHP approach. After defining the weights of dimensions and criteria, an integrated analysis of QFD is performed. In this process, there are 4 different steps and the effect of each step on the next step will be taken into the consideration and the investment policies are ranked with the hesitant fuzzy TOPSIS.

The novelty of the study is to analyze the European energy investment policies with the process of quality function deployment and balanced scorecard progressively and to suggest a novel hybrid hesitant fuzzy decision-making model for ranking the investment policies. For this purpose, it is provided the multiple values from decision makers that are interpreted as the hesitation of the group of individuals for each stage of the QFD and the different preferences of decision makers are considered for evaluating the balanced scorecard-based analysis of the European energy investment policies under the uncertain information. Thus, it is possible to discuss the comprehensive results of the QFD by ranking the investment policies with the integrated decision-making process. Because of that condition, it is thought that this situation has a significant contribution to the literature.

This study consists of 5 sections. After the introduction part, the Section 2 defines the QFD and its proposed dimensions in energy industry under the hesitant fuzzy environment. The following section represents the methodology and model construction. Fourth section gives the details of the analysis results and the final section discusses the results and presents the recommendations for the further studies.

2. QFD in energy industry under the hesitant fuzzy environment

QFD-based performance measurement of the investment policies with the hesitant fuzzy sets is a novel issue for the Energy industry. Progressive model of QFD represents four-stage analysis to construct the multidimensional evaluation of the European energy investment policies. In the first stage, the house of quality is defined by examining the customer and technical requirements. After that, the second stage is applied by comparing the technical and new product/service development process. In the third stage, the process and balanced scorecard-based factors are evaluated to find out the final weights of the evaluation criteria for the energy investment policies respectively. Evaluation model is analyzed by using a hybrid hesitant fuzzy decision-making model. Hesitant fuzzy sets are widely used for modelling the possible values for the membership degree (Rodríguez et al., 2016; Torra, 2010) and motivated for the difficulty that appears when the membership degree of an element must be established, and the difficulty is not because of an error margin or due to some possibility distribution (Rodríguez, Martínez, Torra, Xu, & Herrera, 2014). For this purpose, preferences of each decision maker are considered in the group decision process as the group hesitation (Castro et al., 2017). Accordingly, hesitant fuzzy DEMATEL for weighting the dimension and hesitant fuzzy AHP for the criteria of customer requirements are applied in the first stage. In the following stages, hesitant fuzzy TOPSIS is considered for solving the progressive impacts of each stage. Proposed dimensions and the details of integrated model are defined as follows.

The QFD is introduced to measure the performance of product qualities multi-dimensionally by using the voice of customers and engineering requirements at the same time (Akao & Mizuno, 1994). In other words, it focuses on the whole process from the production of the products to the purchasing them by the customers. In this process, the QFD methodology gives importance to the customer satisfaction. This approach has basically 4 different phases (Chan & Ko, 2010; Hauser & Clausing, 1988). The details of these phases are depicted on Fig. 1.

Fig. 1 shows that the first stage of QFD is defined as the House of Quality firstly applied for designing the industrial process in 1970s (Hauser & Clausing, 1988). In this stage, the relationship between customer needs and design requirement is explained. The method is progressively extended to the quality improvement of the other service and production problems such as suppliers (Asadabadi, 2017; Van et al., 2018) and customers (Wood et al., 2016; Yadav & Goel, 2008). Within this framework, the relationship between design requirement and critical part characteristics is aimed to identify in the second phase.

In addition to them, in the third phase, a matrix is created to understand the relationship between critical part requirements and critical process parameters. Moreover, in the last phase, the relationship between critical process parameters and production requirement is determined (Popoff & Millet, 2017). As it can be understood, the important point in this issue is that the results of the previous stages are taken into the consideration. Therefore, it can be said that QFD methodology gives importance to various interactive relationship of many different factors at the same time (Bolar, Tesfamariam, & Sadiq, 2017)

Moreover, it can also be seen that QFD approach is also preferred to make analysis in many different industries. For instance, Park, Geum, and Park (2015) and Pakizehkar, Sadrabadi, Mehrjardi, and Eshaghieh (2016) tried to evaluate the quality of the services in banking sector. Similar to these studies, Buttigieg, Dey, and Cassar (2016) and Khare and Sharma (2013) considered this methodology in order to make an analysis in health sector. Moreover, Naspetti, Alberti, and Solfanelli (2015) and Alba-Elías, Las-Heras-Casas, González-Marcos, Alfonso-Cendón, and Castejón-Limas (2014) focused on food industry and Wang (2007) made a study for airline industry with the help of this approach. These studies give information that QFD methodology is not considered within the energy industry in a sufficient manner. Therefore, in this

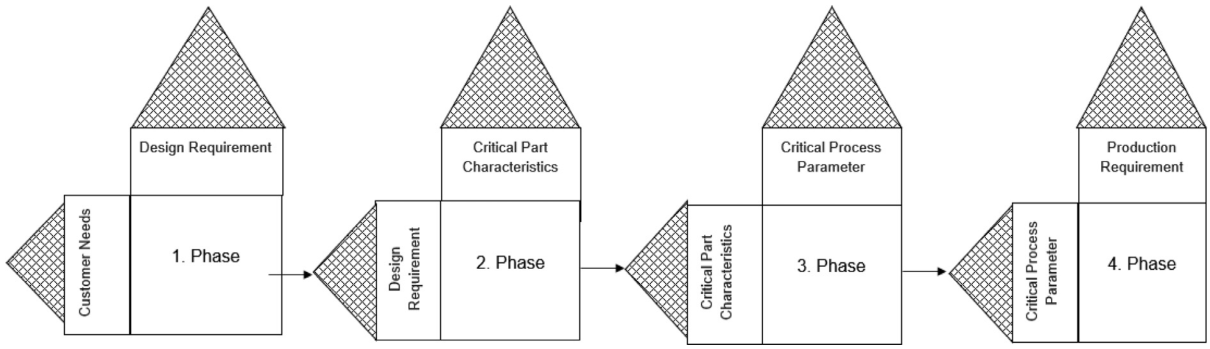

Fig. 1. 4 Different phases of QFD approach.

Table 1
Customer requirements of QFD.

Customer dimensions	Customer criteria	References
Physical conditions (D1)	Closeness to the customers (C1)	Achtenhagen, Brunninge, and Melin (2017), Buttigieg et. al. (2016), Büyüközkan and Berkol (2011), Low and Ng (2018), Purnomo and Sufa (2015), Wood et al. (2016)
	Information technology infrastructure (C2)	Ferreira, Nery, and Pinheiro (2016), JosephNg (2018), Mohamad, Zainuddin, Alam, and Kendall (2017), Wood et al. (2016)
Reliability (D2)	Ease of use of products/services (C3)	Assemi, Jafarzadeh, Mesbah, and Hickman (2018), Osiro, Lima-Junior, and Carpinetti (2018), Roy et. al. (2018), Wang and Chen (2018)
	Physical security (C4)	Alassafi, Hussain, Ghashgari, Walters, and Wills (2017), Bonfanti (2016), Khare and Sharma (2013), Osiro et al. (2018), Watkins (2016)
Responsiveness (D3)	Customer support (C5)	Buttigieg et al. (2016), Jeong and Oh (1998), Lockwood (2017), Wuyts, Rindfleisch, and Citrin (2015), Xu, Munson, and Zeng (2017)
	Products/services suitable for market demand (C6)	Celotto, Loia, and Senatore (2015), Kumar and Tandon (2017), Ren, Qiu, Wang, and Lin (2016)
Costs and earnings (D4)	Competitive costs (C7)	Klein et al. (2018), Kumar and Kumar (2017), Osiro et al. (2018)
	Efficiency (C8)	Lun, Shang, Lai, and Cheng (2016), Helo, Gunasekaran, and Rymaszewska (2017), Osiro et al. (2018), Wood et al. (2016), Yadav and Goel (2008)

study, the proposed method is applied to energy industry for the aim of making contribution to the literature. The details of this situation are explained in the following subtitle.

2.1. Proposed dimensions of QFD in energy industry

While analyzing similar studies in the literature, it can also be seen that there are only a few studies in which QFD approach is used to make analysis in energy industry. For example, Servert, Labanda, Fuentealba, Cortes, and Pérez (2014) considered this methodology to select the best solar energy project in Northern Chile. In addition to this study, Schillo, Isabelle, and Shakiba (2017) focused on the biofuels policies with the help of this approach. While analyzing similar studies in the literature, it can be understood that the studies focus on energy sector with QFD approach are very limited. Therefore, it can be said that a new study, which analyzes the investment alternatives in energy sector, makes a significant contribution to the literature. By analyzing similar studies, 4 customer dimensions and 8 customer criteria are proposed in this study. Table 1 shows the dimensions and criteria regarding customer expectations. In this table, supported literature is also stated for these proposed dimensions and criteria.

Table 1 shows that 4 different dimensions and 8 criteria are identified with respect to customer expectations from energy companies. As for the dimension of physical condition (D1), it is understood that closeness to the customers and IT infrastructure play a significant role. It is also determined that customers expect to use the products easily and have physical security regarding the dimension of reliability (D2). Moreover, for the dimension of responsiveness (D3), customer support plays a key role and products should be convenient to market demand. Finally, it is also determined that costs should be competitive and there should be efficiency for the dimension of costs and earnings (D4). In addition to the customer dimensions and criteria, the dimensions and criteria for technical requirement should also be defined to make analysis with QFD. Within this framework, 3 different dimensions and 7 different criteria are proposed. Table 2 gives information about these technical requirements and supported literature for these proposed dimensions and criteria.

Table 2 explains that there are 3 different dimensions regarding the technical requirement of energy companies. Within this framework, technological capacity and accessibility are defined as the criteria of operational facilities (D1). In addition to them, with respect to the dimension of financial condition (D2), it is identified that companies should have necessary capital amount and make an effective cost management. Moreover, as for the dimension of external factors (D3), it is understood that services should be customized according to the market needs. Furthermore, companies should also monitor the market trends so as to be more successful. The final important point within the scope of this dimension is that there should be an effective communication with the suppliers. On the other side, 4 different dimensions and 10 different criteria are proposed with respect to the new product development process. Table 3 emphasizes the dimensions and criteria for

Table 2
Technical requirements of QFD.

Technical dimensions	Technical criteria	References
Operational facilities (D1)	Technological capacity (C1)	Tsai and Hsieh (2009), Kaplan (2012), Lam and Dai (2015), Wood et al. (2016)
	Accessibility (C2)	Deb and Ahmed (2018), Noor and Foo (2014), Pakizehkar et al. (2016)
Financial conditions (D2)	Capital adequacy (C3)	Mili, Sahut, Trimeche, and Teulon (2017), Hassan, Unsal, and Tamer (2016), Büyüközkan and Berkol (2011)
	Cost management (C4)	Focacci (2017), Mun and Jang (2018), Osiro et al. (2018), Büyüközkan and Berkol (2011), Yadav and Goel (2008)
External factors (D3)	Customized services based on market needs (C5)	Lynn (2016), Steiner, Eggert, Ulaga, and Backhaus (2016), Jeong and Oh (1998), Buttigieg et al. (2016)
	Monitoring market trends (C6)	Layman (2014), Foroudi, Gupta, Nazarian, and Duda (2017), Buttigieg et al. (2016)
	Ease of contact with suppliers (C7)	Mittal et al. (2017), Lo (2015), Büyüközkan and Berkol (2011), Asadabadi (2017)

Table 3
New product development process of QFD.

New product development dimensions	New product development criteria	References
Design (D1)	Collecting the new ideas of new product/service development (C1)	Dong and Wu (2015), Hong and Kim (2016), Büyüközkan and Berkol (2011)
	Selecting the ideas of new product/service development (C2)	Lin, Kreifeldt, Hung, and Chen (2015), Coulter (2016), Pakizehkar et al. (2016)
Analysis (D2)	Monitoring the progress of the ideas (C3)	Staron et al. (2015), Ryals et. al. (2015), Pakizehkar et al. (2016)
	Evaluating the outcomes (C4)	Novak, Koliba, Zia, and Tucker (2015), López-Forniés, Sierra-Pérez, Boschmonart-Rives, and Gabarrell (2017), Yadav and Goel (2008)
Development (D3)	Improving the ideas with cross functional teams (C5)	Calantone, Vickery, and Dröge (1995), Gatignon, Gotteland, and Haon (2016), Pakizehkar et al. (2016)
	Redesigning the system priorities (C6)	Gopalakrishnan, Libby, Samuels, and Swenson (2015), Andrei et. al. (2015), Khare and Sharma (2013)
	Adopting the personnel for the final design (C7)	Witt and Rao (2015), Chen, Wang, Huang, and Shen (2016), Osiro et al. (2018)
Initiating (D4)	Pretesting the new products/services (C8)	West and Miciak (2015), Lagerkvist, Normann, and Åström (2017), Buttigieg et al. (2016)
	Testing the market environment (C9)	Garina, Garin, Kuznetsov, Popkova, and Potashnik (2017), Zaina and Alvaro (2015), Buttigieg et al. (2016)
	Commercializing the new products/services (C10)	Cuervo-Cazurra, Nieto, and Rodríguez (2017), Gosens et al. (2018)

mew product development process and states supported literature for the proposed dimensions and criteria.

Table 3 demonstrates that collecting and selecting the new ideas of new product/service development are identified as the criteria of the design dimension (D1). Additionally, it is also determined that there should be a monitoring process for these ideas and the outcomes should be evaluated within the concept of analysis dimension (D2). Moreover, cross functional teams should also be created to improve the ideas and system priorities should be redesigned within the scope of development dimension (D3). It is also important for this dimension that personnel should be adopted for the final design. Furthermore, with respect to the initiating design, there should be a pretesting, testing, and commercializing the new products/services. Additionally, Table 4 focuses on balanced scorecard (BSC) perspectives for energy industry. Because BSC approach has 4 different sections, 4 different dimensions for this purpose are identified in this stage. Additionally, 12 different criteria are also proposed by considering these 4 dimensions.

Table 4 demonstrates that with respect to the financial performance dimension (D1), expected returns on investment, potential growth in operating income and decrease in operational cost with mass production come to the forefront. In addition to them, regarding consumer compliance dimension (D2), it is identified that existed customers should be satisfied with the new products and these products should be designed according to the customer needs. Another important criterion for this dimension is the feedback of business environment. For the dimension of organizational compliance (D3), it is defined that working teams should perform effectively, organizational goals should be clarified, and personnel should participate the idea generating process in a very active manner. As for the final dimension of competitional compliance, benchmarking with market, generating R&D activities and training are defined as the criteria. After analyzing all dimensions and criteria, 5 different alternative investment policies for energy companies are proposed. The details of these alternatives and supported literature are shown on Table 5.

Table 5 states that 5 different alternative policies for European energy investment are determined by analyzing similar studies in the literature. First of all, focusing on the end users may be an alternative for these companies. The main reason behind this situation is that the importance of individual consumption in this area goes up. Hence, the need for energy increases as well. In addition to this strategy, it is also possible for these companies to increase the capacity and storage of the energy. Within this framework, since Europe has a strategic importance regarding location, it attracts to the attention of many different investors. Moreover, some energy companies may also focus on sustainable energy operations. For this purpose, companies may prefer to

Table 4
BSC perspectives of QFD.

BSC perspectives	Dimensions	Criteria	References
Finance	Financial performance (D1)	Increase in expected returns on investment (C1)	Marchioni and Magni (2018), Do et. al. (2018), Khare and Sharma (2013)
		Potential growth in operating income (C2)	Carlson and Pressnail (2018), Chen, Lin, and Tsai (2018), Yadav and Goel (2008)
		Decrease in operational cost with mass production (C3)	Jalonen, Ristimäki, Toiviainen, Pulkkis, and Lohtander (2016), Elgammal, Papazoglou, Krämer, and Constantinescu (2017), Yadav and Goel (2008), Wood et al. (2016)
Customer	Consumer compliance (D2)	Growing satisfaction of existing customers (C4)	Ennew, Binks, and Chiplin (2015), Han and Hyun (2015), Buttigieg et al. (2016)
		Designing products/services that meet customer demands (C5)	Tukker (2015), Cui and Wu (2016), Jeong and Oh (1998), Wood et al. (2016)
		Considering the feedback of business environment (C6)	Restuccia, Brentani, Legoux, and Ouellet (2016), Stark (2015), Buttigieg et al. (2016)
Internal process	Organizational compliance (D3)	Consistency of working team (C7)	Salavati, Abdi, and TeymoorPayandeh (2015), Beaume, Maniak, and Midler (2009), Büyüközkan and Berkol (2011), Pakizehkar et al. (2016)
		Clarifying organizational goals (C8)	Wang (2018), Mayfield and Mayfield (2016), Khare and Sharma (2013)
		Considering the ideas of the personnel with their active participation (C9)	Cheng, Song, and Li (2017), Chang (2018), Osiro et al. (2018), Mohammadi, Sadi, Nateghi, Abdullah, and Skitmore (2014)
Learning and growth	Competitional compliance (D4)	Benchmarking competitive market environment using market-based database (C10)	Petit and Vanzeveren (2015), Chuang et. al. (2015), Buttigieg et al. (2016)
		Generating new R&D activities (C11)	Homburg, Alavi, Rajab, and Wieseke (2017), Grimpe, Sofka, Bhargava, and Chatterjee (2017), Wood et al. (2016)
		Improving training activities to contribute quality development (C12)	Fraenkel, Haftor, and Pashkevich (2016), Genç and Di Benedetto (2015), Osiro et al. (2018), Mohammadi et al. (2014)

Table 5
Alternative policies for European energy investment.

Alternative policies	References
Focusing on end users (A1)	Buchanan et al. (2014), Balta-Ozkan and Le Gallo (2018), Apajalahti et al. (2015)
Increasing the capacity and storage of the energy (A2)	Magagna and Uihlein (2015), Goodenough (2014), Yu et al. (2016), Lam and Dai (2015)
Producing sustainable energy operations (A3)	Shariatzadeh, Mandal, and Srivastava (2015), Peck and Parker (2016), Pace (2016), Wood et al. (2016)
Renewable energy sources (A4)	Inchauspe, Ripple, and Trück (2015), da Silva, de Marchi Neto, and Seifert (2016), Habibullah et al. (2015), Lam and Dai (2015), Wood et al. (2016)
Improving the affordability of energy prices (A5)	Pinto, Szklo, and Rathmann (2018), Choi, Lee, Khanal, Park, and Bae (2015), MacDougall (2017), Lam and Dai (2015), Wood et al. (2016)

make collaboration with other institutions to improve sustainable power in energy operations. Furthermore, making investment on renewable energy sources may be another alternative. It is thought that in the future, the importance of this aspect goes up very much due to increase in the sensitivity for environmental issues. Finally, some energy companies may also prefer to improve the affordability of energy prices. Especially after global mortgage crisis and European debt crisis, cost efficient investment opportunities come into prominence.

2.2. Hesitant fuzzy sets

Hesitant fuzzy sets (HFSs), were introduced by Torra and Narukawa (2009) as an extension of fuzzy sets in which, given a reference set, the membership function does not provide only one value but a set of them, which provides a way of modelling hesitation (Rodriguez, Martinez, & Herrera, 2012). The method is preferred to solve the difficulties in determining the membership of an element to a set caused by a doubt between the different values (Xia & Xu, 2011). The uncertainty on the possible values is somehow limited, for instance two experts discuss the membership x into A, and one desires to assign 0.5 and the other 0.6 and it is presented by a hesitant fuzzy element {0.5,0.6} to get the reasonable results from the decision making groups and define the results more objectively (Torra & Narukawa, 2009).

X is a preference set, and hesitant fuzzy set on X in terms of a function h that when applied to X returns a subset of [0, 1]. The output of fuzzy rule-based systems in terms of hesitant fuzzy sets is represented as

$$M = \{\mu_1, \ldots, \mu_N\} \tag{1}$$

Where M is a set of N membership functions.

$$h_M(x) = \cup_{\mu \in M}\{\mu(x)\} \tag{2}$$

$$h^-(x) = \min h(x) \; and \; h^+(x) = \max h(x) \tag{3}$$

Where h is an hesitant fuzzy set, h^- is the pair of functions, $1 - h^+$ defines the intuitionistic fuzzy set. The membership function h of the hesitant fuzzy set is defined as

$$h^c(x) = \cup_{\gamma \epsilon h(x)}\{1 - \gamma\} \tag{4}$$

The union and intersection of two hesitant fuzzy sets h_1 and h_2 are represented

$$(h_1 \cup h_2)(x) = \left\{h \in (h_1(x) \cup h_2(x)) | h \geq \max\left(h_1^-, h_2^-\right)\right\}, \text{ or} \tag{5}$$

$$(h_1 \cup h_2)(x) = (h_1(x) \cup h_2(x))_\alpha^+ \textit{for } \alpha = \max\left(h_1^-, h_2^-\right) \tag{6}$$

$$(h_1 \cap h_2)(x) = \left\{h \in (h_1(x) \cup h_2(x)) | h \leq \max\left(h_1^+, h_2^+\right)\right\}, \text{ or} \tag{7}$$

$$(h_1 \cap h_2)(x) = (h_1(x) \cup h_2(x))_\alpha^- \textit{for } \alpha = \min\left(h_1^+, h_2^+\right) \tag{8}$$

2.3. Hesitant fuzzy DEMATEL

The DEMATEL (decision making trial and evaluation laboratory) is introduced by the Geneva Research Centre of the Battelle Memorial Institute (Baykasoğlu, KaplanoğLu, DurmuşOğLu, & ŞAhin, 2013). The DEMATEL technique is frequently used for analyzing the relationship of the factors in the complex problem. It is aimed to visualize the sophisticated relationship among the criteria by converting the causal relationship into a visible structure (Hsu & Liou, 2013; Hsu et al. 2013; Hu, Lu, & Tzeng, 2014; Liu, You, Zhen, & Fan, 2014; Wang & Chen 2012). The method also gives the comprehensive results by providing the hierarchical structure as well as the interdependence among the criteria. Thus, the technique is widely applied for computing the central criteria to find the effectiveness of the factors and avoiding the over fitting for evaluation (Jeng & Tzeng, 2012; Patil & Kant, 2014).

The DEMATEL is also applied for making better decisions under the fuzzy environment (Abdullah & Zulkifli, 2015; Büyüközkan & Çifçi, 2012; Khorasaninejad, Fetanat, & Hajabdollahi, 2016; Kuo, 2011). The method is also extended by considering the hesitant fuzzy sets in terms of a function defining a set of membership values. The hesitant fuzzy DEMATEL provides the flexibility from the lack of knowledge under the uncertainty imprecision and subjective information in case of the relationship of systems are generally presented with a subset of [0,1] (Torra, 2010). The extended method can be summarized as follows (Baykasoğlu et al., 2013; Chiu, Tzeng, & Li, 2013; Hsu, Wang, & Tzeng, 2012; Hu et al., 2014; Kuo, 2011; Uygun, Kaçamak, & Kahraman, 2015; Yang, Shieh, Leu, & Tzeng, 2008)

Step 1: Rate the relation between the dimensions with a subset of [0,1]. The decision makers appoint their priorities to evaluate the degree of the influence using the values between 0 and 1.

Step 2: Compute the collective hesitant fuzzy initial direct-relation fuzzy matrix. The direct relation matrix is constructed using the evaluations of the decision makers for each dimension and criterion. The decision makers' scores can be obtained to present the pairwise comparisons of the dimensions and criteria with the hesitant fuzzy sets. The collective initial direct-relation fuzzy matrix $\tilde{Z}$ is constructed from the collective scores provided by the experts. $\tilde{Z}_{ij}$ presents the degree of the influence using the hesitant values.

$$\tilde{Z} = \begin{bmatrix} 0 & \tilde{Z}_{12} & \cdots & \cdots & \tilde{Z}_{1n} \\ \tilde{Z}_{21} & 0 & \cdots & \cdots & \tilde{Z}_{2n} \\ \vdots & \vdots & \ddots & \ddots & \vdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \tilde{Z}_{n1} & \tilde{Z}_{n2} & \cdots & \cdots & 0 \end{bmatrix} \tag{9}$$

The average fuzzy scores of l experts' opinions are used to obtain the initial direct-relation matrix with the Eq. (10).

$$\tilde{Z}^k = \frac{\tilde{Z}^1 + \tilde{Z}^2 + \tilde{Z}^3 + \cdots \tilde{Z}^l}{l}, \quad k = (1, 2, \ldots, l) \tag{10}$$

Step 3: Normalize the direct effect matrix. The values are attained by normalizing the initial influence matrix with the following equations.

$$\tilde{x} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \ddots & \ddots & \vdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{n1} & \tilde{x}_{n2} & \cdots & \cdots & \tilde{x}_{nn} \end{bmatrix} \tag{11}$$

where

$$\tilde{x}_{ij} = \frac{\tilde{z}_{ij}}{r} \text{ and } r = max_{1 \leq i \leq n}\left(\sum_{j=1}^{n} \tilde{z}_{ij}\right) \tag{12}$$

Step 4: Build the total influence matrix T. I is an identity matrix and $\lim_{h \to \infty} N^h = [0]_{n \times n}$.

$$\begin{aligned} T &= N + N^2 + N^2 + \ldots + N^h \\ &= N\left(I + N + N^2 + \ldots + N^{h-1}\right)(I - N)(I - N)^{-1} \end{aligned} \tag{13}$$

$$T = N\left(I - N^h\right)(I - N)^{-1} = N(I - N)^{-1}, \text{ when } \lim_{h \to \infty} N^h = [0]_{n \times n} \tag{14}$$

Step 5: Compute the influential network relation map. For this purpose, the sum of each row and column for T can be provided by the following equations, where vector r represents the sum of all vector rows $r = (r_1, \ldots, r_i, \ldots, r_n)$, and vector y indicates the sum of all vector columns $y = (y_1, \ldots, y_i, \ldots, y_n)$. i equals j, $i, j \in \{1, 2, \ldots, n\}$, $(r_i + y_i)$ defines the total degree of the influence among criteria, and the higher its value, the closer the criterion is to object's central point. $(r_i - y_i)$ is the degree of causality among criteria. When $(r_i - y_i)$ is positive, it means that criterion i influences other criteria. Otherwise, the criterion is influenced by other criteria.

$$T = \left[t_{ij}\right]_{n \times n}, \quad i, j = 1, 2, \ldots, n \tag{15}$$

$$r = \left[\sum_{j=1}^{n} t_{ij}\right]_{n \times 1} = (r_i)_{n \times 1} = (r_1, \ldots, r_i, \ldots, r_n) \tag{16}$$

$$y = \left[\sum_{i=1}^{n} t_{ij}\right]'_{1 \times n} = \left(y_j\right)'_{1 \times n} = (y_1, \ldots, y_i, \ldots, y_n) \tag{17}$$

2.4. Hesitant fuzzy AHP

Saaty (1977) developed analytic hierarchy process (AHP) which for making decisions in complex situations. The subjective views of decision makers can be taken into the consideration by considering hierarchical evaluation of the alternatives and criteria. However, this hierarchical evaluation was criticized by many different researchers. Owing to this issue, some extensions of the method are available for sophisticated decision-making conditions, and the earlier extension of the method is developed as the analytic network process (ANP) method to generalize the hierarchical approach to decision making by Saaty (1996). After that, several novelties in the method are provided to solve the complex real-world decision making problems such as fuzzy approach. One of well-known extension is Chang's extent analysis to solve the hierarchy process under the fuzzy environment (Chang, 1996) and there are several examples of the extent method such as Chang, Kuo, Wu, & Tzeng, 2015; Dağdeviren, 2008; Lee, 2013; Shafiee, 2015; Yüksel

& Dağdeviren, 2010. In this process, data obtained from decision makers is converted to linguistic variables.

However, some issues could arise in the process of expert opinions into the fuzzy sets and hesitant fuzzy AHP approach could be considered to convert the expert choices into the hesitant values. For this purpose, Chang's extent analysis is modified to the hesitant fuzzy sets and the modified approach is summarized below

Step 1: Construct the collective hesitant fuzzy pair-wise comparison matrix. Hesitant values provided from the decision makers for the criteria of each dimension are constructed as the collective hesitant fuzzy matrix.

$$\tilde{A} = \begin{bmatrix} 0 & \tilde{a}_{12} & \cdots & \cdots & \tilde{a}_{1n} \\ \tilde{a}_{21} & 0 & \cdots & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \ddots & \vdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & \cdots & 0 \end{bmatrix} \tag{18}$$

Step 2: Compute the minimum, average, and maximum values of the hesitant scores. Hesitant scores of k experts are considered to define the minimized, averaged, and maximized values of the scores by Eqs. (19)–(21).

$$l_j = min_{1,\ldots,k}\left(\tilde{a}_{ij}\right) \tag{19}$$

$$m_j = \frac{\tilde{a}_{ij}^1 + \tilde{a}_{ij}^2 + \tilde{a}_{ij}^3 + \ldots \tilde{a}_{ij}^k}{k} \tag{20}$$

$$u_j = max_{1,\ldots,k}\left(\tilde{a}_{ij}\right) \tag{21}$$

Step 3: The value of fuzzy synthetic extent with respect to the ith object is defined as:

$$S_j = \sum_{j=1}^{m} M_{gi}^j \times \left(\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^j\right)^{-1} \tag{22}$$

To attain $\sum_{j=1}^{m} M_{gi}^j$, build the fuzzy addition operation of m extent analysis relative to values for a particular matrix as:

$$\sum_{j=1}^{m} M_{gi}^j = \left(\sum_{j=1}^{m} l_j,\ \sum_{j=1}^{m} m_j,\ \sum_{j=1}^{m} u_j\right) \tag{23}$$

And to obtain $\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^j\right]^{-1}$, perform the fuzzy addition operation $M_{gi}^j (j = 1, 2, \ldots, m)$ of values such that:

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^j = \left(\sum_{j=1}^{m} l_i,\ \sum_{j=1}^{m} m_i,\ \sum_{j=1}^{m} u_i\right) \tag{24}$$

Then compute the inverse of the vector in Eq. (24) such that:

$$\left(\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^j\right)^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i},\ \frac{1}{\sum_{i=1}^{n} m_i},\ \frac{1}{\sum_{i=1}^{n} l_i}\right) \tag{25}$$

Step 4: The degree of the possibility of $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ is defined as:

$$V(M_2 \geq M_1) = sup[\min(\mu_{M_1}(x), \mu_{M_2}(y))] \tag{26}$$

and can be equivalently expressed as follows:

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \mu_{M_2}(d) = \begin{cases} 1, & if\ m_2 \geq m_1 \\ 0, & if\ l_1 \geq u_2 \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, & otherwise \end{cases} \tag{27}$$

where d is the ordinate of the highest intersection point D between μ_{M_1} and μ_{M_2} to compare M_1 and M_2, the values of $V(M_1 \geq M_2)$ and $V(M_2 \geq M_1)$ are needed.

Step 5: The degree possibility for a convex fuzzy number to be greater than k convex fuzzy numbers $M_i (i = 1, 2, \ldots, k)$ can be defined by

$$V(M \geq M_1, M_2, \ldots, M_k) = V[(M \geq M_1) and (M \geq M_2) and \ldots and (M \geq M_k)] = \min V(M \geq M_i),\quad i = 1, 2, \ldots, k \tag{28}$$

Assume that

$$d'(A_i) = \min V(S_i \geq S_k) \tag{29}$$

for $k = 1, 2, \ldots, n;\ k \neq i$. Then the weight vector is given by

$$W' = \left(d'(A_1), d'(A_2), \ldots, d'(A_n)\right)^T, \tag{30}$$

where $A_i (i = 1, 2, \ldots, n)$ are n elements.

Step 6: Via normalization, the normalized weight vectors are

$$W' = (d(A_1), d(A_2), \ldots, d(A_n))^T, \tag{31}$$

where W is a nonfuzzy number.

2.5. Hesitant fuzzy TOPSIS

TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) is firstly introduced as a type of multi criteria decision making approach in 1980s (Hwang & Yoon, 1981). The method aims to rank the alternatives by constructing the finite set in the maximized distance from the negative ideal solutions and the minimized distance from the positive ideal solutions. The method recently is applied by using fuzzy set theory as the examples of Ervural et al. (2018), Walczak and Rutkowska (2017), and Gupta and Barua (2017).

The TOPSIS method is also revised for hesitant fuzzy sets progressively and Hesitant fuzzy TOPSIS is constructed to evaluate the alternatives under the hesitant decision-making approach more accurately. The steps of Hesitant fuzzy TOPSIS method can be illustrated as (Zhang & Wei, 2013):

Step 1: Construct the collective hesitant fuzzy decision matrix. The evaluation scores of alternatives for criteria from the decision makers are considered to construct the collective hesitant fuzzy decision matrix.

Step 2: Calculate the ideal and negative solution due to the benefit and cost criteria

$$A^+ = \left\{h_1^+, \ldots, h_n^+\right\} \tag{32}$$

$$\text{Where}\quad h_j^+ = \cup_{i=1}^{m} h_{ij} = \cup_{\gamma 1j \epsilon h_{ij}, \ldots, \gamma_{mj} \epsilon h_{mj}} max\left\{\gamma_{1j}, \ldots, \gamma_{mj}\right\}\ j = 1, 2, \ldots, n \tag{33}$$

$$A^- = \left\{h_1^-, \ldots, h_n^-\right\} \tag{34}$$

$$\text{Where}\quad h_j^- = \cup_{i=1}^{m} h_{ij} = \cup_{\gamma 1j \epsilon h_{ij}, \ldots, \gamma_{mj} \epsilon h_{mj}} min\left\{\gamma_{1j}, \ldots, \gamma_{mj}\right\}\ j = 1, 2, \ldots, n \tag{35}$$

Step 3: Weight the separation of each alternative from the ideal solution by the Eqs. (36) and (37).

$$B_i^+ = w_i \times \left\|h_{ij} - h_j^+\right\| \tag{36}$$

$$B_i^- = w_i \times \left\|h_{ij} - h_j^-\right\| \tag{37}$$

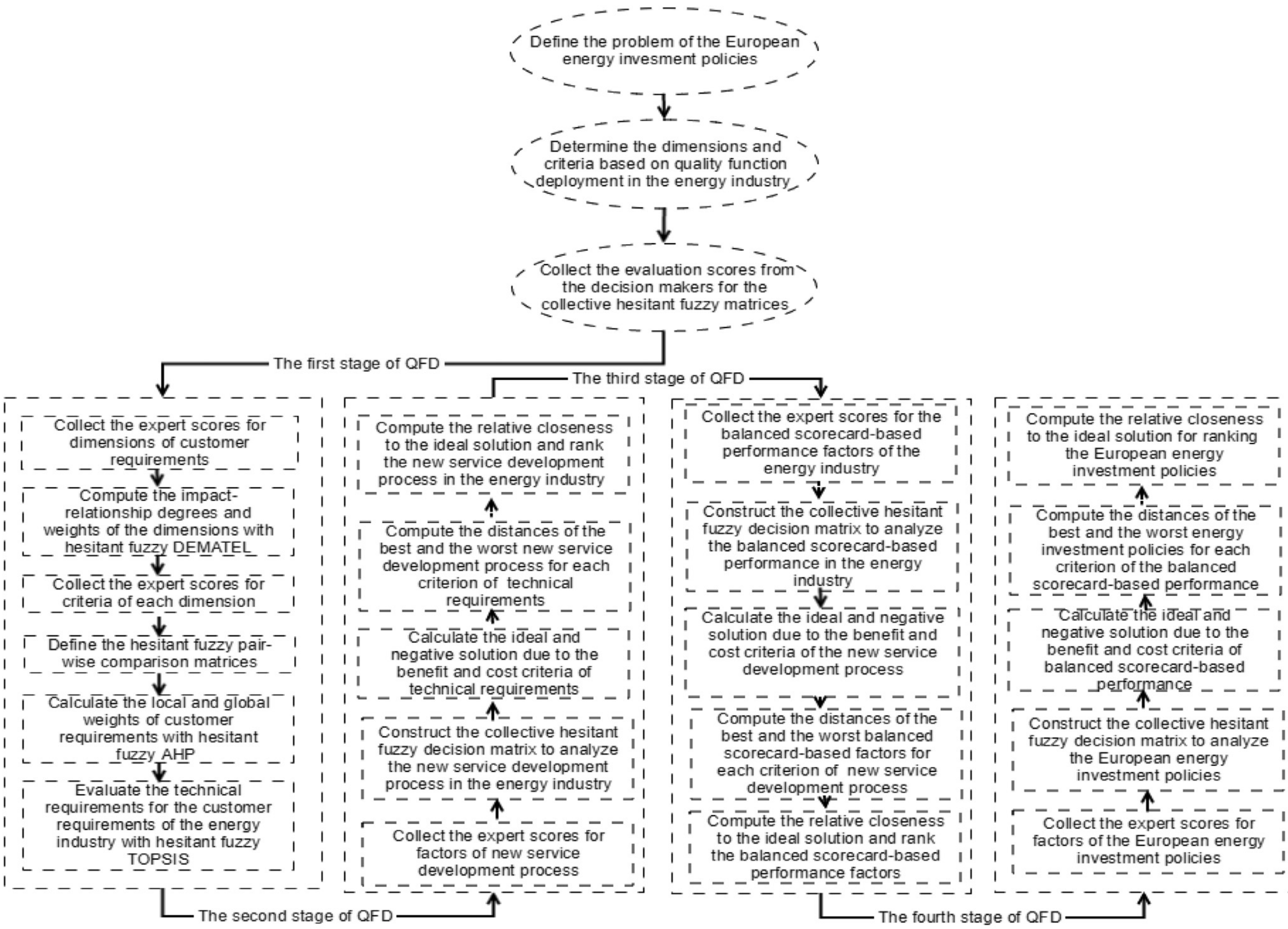

Fig. 2. Proposed model for balanced scorecard-based analysis of the European energy investment policies using the QFD approach.

Where w_i defines the weights of the criteria.

Step 4: Calculate the distances of the best and the worst alternatives for each criterion by the Eqs. (38) and (39).

$$D_i^+ = \sum\nolimits_{j=1}^{n} B_i^+ \tag{38}$$

$$D_i^- = \sum\nolimits_{j=1}^{n} B_i^- \tag{39}$$

Step 5: Compute the relative closeness to the ideal solution for ranking alternatives as follows

$$RC_i = \frac{D_i^-}{D_i^+ + D_i^-} \text{ for i} = 1, 2, \ldots, \text{m and } 0 \le RC_i \le 1 \tag{40}$$

3. Model construction

A hybrid hesitant fuzzy decision-making approach integrated with quality function deployment approach is proposed to understand the performance results of European investment energy policies. Within this framework, several dimensions are identified by considering customer expectations, technical requirements, new product development process and balanced scorecard-based perspectives for energy industry. Accordingly, the flowchart of the proposed model is defined in Fig. 2.

The proposed model defines an integrated approach to evaluate the European energy investment policies multidimensionally. The method starts with the DEMATEL to analyze the multidimensional effects of balanced scorecard-based QFD approach. It is thought that not only the weight, but also the causal relationship among the dimensions has a significance. On the other side, hesitant fuzzy AHP is considered to weight the criteria. The main reason is that criteria are independent from each other. Accordingly, the DEMATEL provides the influencing and/or influenced degrees of each dimension among them. By considering the analysis results of the DEMATEL, the method continues by using the AHP to compute the weights of the criteria hierarchically. Thus, it is possible to obtain the comprehensive results for the factors of QFD. After that, the TOPSIS is used for ranking each step of QFD with the factor weights. For this purpose, Quality Function Deployment (QFD) approach is adapted to a hybrid hesitant fuzzy decision-making model in the fourth stages, to solve some issues such as the loss of information in the aggregation process and not considering the preferences of all decision makers. First, decision making problem on the European energy investment policies has been defined to construct the dimensions, sub-dimensions and alternatives. After that, the dimensions and criteria of Energy Industry based on the QFD have been determined to represent the decision-making model of the energy industry as shown in Tables 1–5.

Proposed dimensions and criteria of QFD in Energy Industry are defined based on the literature review. In the first round, a set of criteria, dimensions, and alternative policies of European energy investment are constructed to discuss with the decision makers and then, they are revised by considering some comments of the decision makers regarding the combining or excluding some factors in the QFD. In the second round, the dimensions, criteria, and alternatives are accomplished based on the final corrections. After that, four decision makers that are the academicians and the industry experts in the field of energy and quality management have been appointed to provide the linguistic evaluations for the dimensions, criteria and alternative policies. The academicians consist of the professors from outstanding universities in Europe who have significant researches in the subject of energy economics. Additionally, experts consist of the general managers who work in a top management level in energy companies which have an important place in this industry. However, the normalize values are related to center of gravity of the linguistic values "equal importance (0,0,0)", "weak (0,1,2)", "moderate (1,2,3)" and so on. For weighting dimensions and criteria, linguistic and fuzzy scales are defined as “equal importance-(0)”, “weak-(0.1)”, “moderate-(0.2)”, “moderate plus-(0.3)”, “strong importance-(0.4)”, “strong plus-(0.5)”, “demonstrated-(0.6)”, “highly-(0.7)”, “extreme importance-(0.8 between 1)”. For ranking alternatives, linguistic and fuzzy scales are “absolutely low-(0)”, “very low-(0.1)”, “low-(0.2)”, “slightly low-(0.3)”, “middle-(0.4)”, “slightly high-(0.5)”, “high-(0.6)”, “very high-(0.7)”, “absolutely high-(0.8 between 1)”.

Conceptually, the first stage of the proposed model could be corrected by the several studies using the DEMATEL method in the process of the customer requirements with the QFD. Wang and Shih (2013) identify the impacts of functional attributes on customer requirements by the DEMATEL. Wang and Hsueh (2013) incorporate the customer preference and perception using the DEMATEL into the process of product development. Yazdani, Chatterjee, Zavadskas, and Zolfani (2017) propose the integrated QFD-MCDM framework including the inter-relationships between the customer requirements with the DEMATEL. Wang and Chen (2012) use the fuzzy DEMATEL for the priorities of technical attributes in a market-oriented manner of QFD. The AHP method in the first stage similarly is used by Kamvysi, Gotzamani, Andronikidis, and Georgiou (2014), Lin, Wang, Chen, and Chang (2008), Onar, Büyüközkan, Öztayşi, and Kahraman (2016), Scott, Ho, Dey, and Talluri (2015), and, Kahraman, Ertay, and Büyüközkan (2006) to compute the weights of criteria for each dimension in the QFD process. The TOPSIS in the remaining stages for weighting and ranking factors of QFD is also used in the several studies such as for choosing ideal gas fuel (Akbaş & Bilgen, 2017), knowledge management system selection (Lie et al. 2014), market segments evaluation (Dat, Phuong, Kao, Chou, & Van Nghia, 2015), sustainability development of SMEs (Hsu, Chang, & Luo, 2017), evaluating bridge design (Malekly, Mousavi, & Hashemi, 2010).

Accordingly, in the first stage of QFD, the house of Quality is applied by defining the customer and technical requirements for the energy industry. Initially, evaluation results of customer requirement dimensions have been collected to construct the collective hesitant fuzzy direct-relation matrix using the Eq. (9). Hesitant fuzzy DEMATEL method has been applied to compute the impact-relationship degrees of the dimensions and weights of customer requirements by the formulas (10)–(17). And then, the criteria of the customer requirements have been analyzed by considering Hesitant fuzzy AHP approach with the Eqs. (18)–(31). Thus, weights of dimensions and criteria for customer requirements have been computed in the first stage of QFD entitled the house of Quality. Accordingly, the evaluation matrix of customer and technical requirements have been computed with hesitant fuzzy TOPSIS technique using the formulas (32)–(40). Customer requirements have been defined as a set of criteria and technical requirements have determined as alternatives for ranking the technical results. Consecutively, the relative closeness results of hesitant fuzzy TOPSIS have been weighted to consider in the next stage of QFD respectively. First stage results of QFD demonstrate that which technical requirement has the best importance in the customer requirements for the energy investment policies.

In the second stage of QFD, technical requirements and new service development process of the energy industry have been considered to analyze the priorities in the energy industry. Weight results of technical requirements, provided in the first stage, have been used for ranking new service development process in the second stage with the hesitant fuzzy TOPSIS. Similarly, ranking results of new service development process have been converted to the weights in order to rank the balanced scorecard-based performance results in the third stage of QFD.

In the third stage of QFD, new service development process and the balanced scorecard-based performance factors have been evaluated to rank the performance results. Accordingly, ranking results of hesitant fuzzy TOPSIS have been computed to have the relative importance and thus, weighted performance results have been considered in the final stage of QFD.

In the fourth stage of QFD, the European energy investment policies have been ranked according to the balanced scorecard-based performance results of the energy industry using hesitant fuzzy TOPSIS. Thus, the integrated evaluation process could be applied by considering the stages of QFD consecutively.

4. A case of the European energy industry

4.1. Weighting the dimensions of customer requirements with hesitant fuzzy DEMATEL

In the first stage, the dimensions of customer requirements are weighted by using hesitant fuzzy DEMATEL. For this purpose, 4 decision makers, who are experts in this subject, evaluated this process. As a result of this evaluation, hesitant fuzzy direct influence matrix and the crisp direct-influence matrix have been computed respectively by the Eqs. (9) and (10). The normalized direct influence matrix has been provided with the formulas (11) and (12) and the total relation matrix has been constructed with the Eqs. (13) and (14). The impact relationship degrees and weights of the dimensions are created with the formulas (15)–(17). These details are given on Tables 6–10.

Table 10 gives information about the impact-relationship degrees and weights of the dimensions. Within this framework, $D\tilde{}_i^{def}$ and $R\tilde{}_i^{def}$ values are calculated by considering the Eqs. (16) and (17). In these equations, r refers to the $D\tilde{}$ whereas y gives information about $R\tilde{}$. These values help to calculate the weights. Table 10 shows that reliability (D2) is the dimension which has the highest importance. On the other side, it is also identified that the dimension of physical conditions (D1) has the lowest weight. Another important point of this table is that the dimension of costs and earnings (D4) is the most influencing factor whereas the dimension of responsiveness (D3) is the most influenced factor by looking at the values of $\tilde{D}_i^{def} - \tilde{R}_i^{def}$. Therefore, it can be said that the companies give more importance to the safety conditions of the products to attract the attention of the customers.

4.2. Weighting the criteria of customer requirements with hesitant fuzzy AHP

In the second step of the analysis, the criteria of customer requirements are weighted with the hesitant fuzzy AHP. The details of pair-wise comparison matrix for the criteria of the physical condition dimension (D1) are given on Table 11.

In this process, Chang’s extended method is modified for hesitant fuzzy approach by formulas (18)–(31). For this purpose, the values of decision makers are divided into 3 different values as minimum, average and maximum points. After that, the fuzzy pairwise comparison matrix for this dimension is calculated and the details of this matrix are demonstrated on Table 12.

This calculation process is also implemented for other dimensions of customer requirements. The details of these aspects are shown on Tables 13–18.

Table 6
The collective hesitant fuzzy direct-influence matrix for dimensions of customer requirements.

Dimensions	D1	D2	D3	D4
Physical conditions (D1)	{0}	{0.5, 0.6, 0.7}	{0.6, 0.7}	{0.4, 0.5}
Reliability (D2)	{0.5, 0.6, 0.7}	{0}	{0.5, 0.6, 0.7}	{0.5, 0.7}
Responsiveness (D3)	{0.4, 0.5}	{0.5, 0.6, 0.7}	{0}	{0.6, 0.7}
Costs and earnings (D4)	{0.6, 0.7}	{0.5, 0.6, 0.7, 0.8}	{0.5, 0.6}	{0}

Table 7
The crisp direct-influence matrix.

Dimensions	D1	D2	D3	D4
D1	0.000	0.600	0.550	0.450
D2	0.600	0.000	0.625	0.550
D3	0.475	0.575	0.000	0.525
D4	0.625	0.650	0.550	0.000

Table 8
The normalized direct-influence matrix.

Dimensions	D1	D2	D3	D4
D1	0.000	0.329	0.301	0.247
D2	0.329	0.000	0.342	0.301
D3	0.260	0.315	0.000	0.288
D4	0.342	0.356	0.301	0.000

Table 9
The total-relation fuzzy matrix.

Dimensions	D1	D2	D3	D4
D1	2.878	3.284	3.153	2.853
D2	3.362	3.287	3.417	3.104
D3	3.060	3.250	2.896	2.855
D4	3.448	3.631	3.471	2.943

Table 10
The impact-relationship degrees and weights of the dimensions.

Dimensions	$\tilde{D}_i^{def}$	$\tilde{R}_i^{def}$	$\tilde{D}_i^{def}+\tilde{R}_i^{def}$	$\tilde{D}_i^{def}-\tilde{R}_i^{def}$	Weights
D1	12.168	12.747	24.916	−0.579	0.245
D2	13.170	13.453	26.623	−0.283	0.262
D3	12.061	12.937	24.998	−0.876	0.246
D4	13.493	11.755	25.248	1.738	0.248

Table 11
The collective hesitant fuzzy pair-wise comparison matrix for the criteria of physical conditions (D1).

Criteria	C1	C2
Closeness to the customers (C1)	{0}	{0.4, 0.5, 0.6, 0.8}
Information technology infrastructure (C2)	{0.2, 0.4, 0.5, 0.6}	{0}

Table 12
The fuzzy pair-wise comparison matrix for D1.

Criteria	C1			C2		
Closeness to the customers (C1)	0	0	0	0.40	0.58	0.80
Information technology infrastructure (C2)	0.20	0.42	0.60	0	0	0

Table 13
The collective hesitant fuzzy pair-wise comparison matrix for the criteria of reliability (D2).

Criteria	C3	C4
Ease of use of products/services (C3)	{0}	{0.5, 0.6, 0.7}
Physical security (C4)	{0.3, 0.4, 0.5}	{0}

Table 14
The fuzzy pair-wise comparison matrix for D2.

Criteria	C3			C4		
Ease of use of products/services (C3)	0	0	0	0.50	0.63	0.70
Physical security (C4)	0.30	0.38	0.50	0	0	0

Table 15
The collective hesitant fuzzy pair-wise comparison matrix for the criteria of responsiveness (D3).

Criteria	C5	C6
Customer support (C5)	{0}	{0.5, 0.6}
Products/services suitable for market demand (C6)	{0.4, 0.5}	{0}

Table 16
The fuzzy pair-wise comparison matrix for D3.

Criteria	C5			C6		
Customer support (C5)	0	0	0	0.50	0.55	0.60
Products/services suitable for market demand (C6)	0.40	0.45	0.50	0	0	0

Table 17
The collective hesitant fuzzy pair-wise comparison matrix for the criteria of costs and earnings (D4).

Criteria	C7	C8
Competitive costs (C7)	{0}	{0.5, 0.6, 0.7}
Efficiency (C8)	{0.3, 0.4, 0.5}	{0}

Table 18
The fuzzy pair-wise comparison matrix for D4.

Criteria	C7			C8		
Competitive costs (C7)	0	0	0	0.50	0.63	0.70
Efficiency (C8)	0.30	0.38	0.50	0	0	0

Table 19
Local and global weights of customer requirements with hesitant fuzzy AHP.

Dimensions	Local weights	Criteria	Local weights	Global weights
Physical conditions (D1)	0.245	C1	0.55	0.134
		C2	0.45	0.111
Reliability (D2)	0.262	C3	0.69	0.180
		C4	0.31	0.082
Responsiveness (D3)	0.246	C5	0.67	0.163
		C6	0.33	0.082
Costs and earnings (D4)	0.248	C7	0.69	0.171
		C8	0.31	0.078

In addition to these issues, local and global weights of customer requirements are calculated by using hesitant fuzzy AHP method. The details of these results are stated on Table 19.

Table 19 emphasizes that ease of use of products/services (C3) has the highest importance. In addition to this aspect, it is also defined that efficiency (C8) has the lowest weight in comparison with other criteria. This situation gives information that the companies should mainly focus on easiness of the usage of the products in order to make the customers more satisfied.

			Technical Requirement								
			Operational Facilities	Financial Conditions					External Factors		
			C1 C2...C(n-1) Cn								
	Physical Conditions	C1	C1,C1	C1,C2	...	...	...	...	...	...	C1,Cn
			...	...	...	...	...	...	...	...	...
Customer Requirements	Reliability	C2	.	.	.	.	.	.	.	.	.
		.	.	.	.	.	.	.	.	.	.
	Responsiveness	.	.	.	.	.	.	.	.	.	.
	Costs and Earnings	C(n-1)	C(n-1),C1	...	...	...	...	...	...	...	C(n-1),Cn
		Cn	Cn,C1	....	...	...	...	...	...	...	Cn,Cn

Fig. 3. House of quality.

Table 20
The collective hesitant fuzzy decision matrix for technical requirements.

Alternatives/criteria	Closeness to the customers (C1)	Information technology infrastructure (C2)	Ease of use of products/services (C3)	Physical security (C4)
Technological capacity (A1)	{0.5, 0.6}	{0.6, 0.7, 0.8}	{0.5, 0.6, 0.7}	{0.3, 0.4}
Accessibility (A2)	{0.6, 0.7}	{0.6, 0.7, 0.8}	{0.6, 0.7}	{0.4, 0.5}
Capital adequacy (A3)	{0.2, 0.3, 0.4}	{0.2, 0.3, 0.4}	{0.4, 0.5}	{0.3, 0.4, 0.5}
Cost management (A4)	{0.3, 0.4}	{0.3, 0.4}	{0.4, 0.5}	{0.3, 0.4}
Customized services based on market needs (A5)	{0.4, 0.5, 0.6}	{0.5, 0.6}	{0.6, 0.7, 0.8}	{0.4, 0.5, 0.6}
Monitoring market trends (A6)	{0.5, 0.6}	{0.5, 0.6}	{0.5, 0.6}	{0.4, 0.5}
Ease of contact with suppliers (A7)	{0.6, 0.7}	{0.5, 0.6}	{0.5, 0.6, 0.7}	{0.3, 0.4}
Alternatives/Criteria	Customer support (C5)	Products/services suitable for market demand (C6)	Competitive costs (C7)	Efficiency (C8)
Technological capacity (A1)	{0.6, 0.7, 0.8}	{0.5, 0.6}	{0.4, 0.5, 0.6}	{0.6, 0.7, 0.8}
Accessibility (A2)	{0.5, 0.6, 0.7, 0.8}	{0.5, 0.6, 0.7}	{0.4, 0.5}	{0.5, 0.6}
Capital adequacy (A3)	{0.4, 0.5, 0.6}	{0.3, 0.4, 0.5}	{0.4, 0.5}	{0.4, 0.5}
Cost management (A4)	{0.4, 0.5, 0.6}	{0.4, 0.5}	{0.6, 0.8}	{0.6, 0.7}
Customized services based on market needs (A5)	{0.6, 0.8}	{0.6, 0.7, 0.8}	{0.5, 0.6}	{0.5, 0.6}
Monitoring market trends (A6)	{0.5, 0.6, 0.7}	{0.6, 0.8}	{0.5, 0.6}	{0.5, 0.6}
Ease of contact with suppliers (A7)	{0.6, 0.7}	{0.4, 0.5, 0.6}	{0.4, 0.5}	{0.5, 0.6, 0.7}

4.3. Weighting the technical requirements with hesitant fuzzy TOPSIS

In the third phase, customer requirements are compared with technical requirements. Thus, this phase constitutes the first step of QFD. The details of this phase are illustrated on Fig. 3.

According to the decision makers' evaluation, the collective hesitant fuzzy decision matrix for technical requirements is created. The details of this matrix are shown on Table 20.

Table 20 shows the evaluation of decision makers for technical requirement based on customer requirements. Additionally, the weights of technical requirements are computed by the Eqs. (32)–(40) and the results are shown in Table 21.

In Table 21, that RCi values are calculated with the help of hesitant fuzzy TOPSIS method according to the evaluation results emphasized in Table 20. In addition to this aspect, weights of technical requirements are identified by considering RCi values. By considering the proportions of the relative closeness to the ideal solution, the weights of the technical requirement are calculated. It is determined that customized services based on market needs (A5) is the most important item while capital adequacy (A3) has the lowest significance. Hence, it is obvious that the companies should customize their services according to the expectations of the customers.

Table 21
Values of RCi and weights of technical requirements.

Technical requirements	D+	D-	RCi	Weights
Technological capacity (A1)	0.185	0.251	0.576	0.175
Accessibility (A2)	0.181	0.255	0.585	0.178
Capital adequacy (A3)	0.367	0.069	0.157	0.048
Cost management (A4)	0.268	0.168	0.385	0.117
Customized services based on market needs (A5)	0.164	0.272	0.624	0.190
Monitoring market trends (A6)	0.207	0.228	0.525	0.160
Ease of contact with suppliers (A7)	0.246	0.190	0.436	0.133

4.4. Weighting the new service/product development process with hesitant fuzzy TOPSIS

In the fourth phase, technical requirements are compared with new service/product development process. Thus, this phase constitutes the second step of QFD. The details of this phase are illustrated on Fig. 4.

In the second step of QFD, the weights, which are calculated in the first step of QFD, are used in order to consider the integrated influence of technical requirements in the first step. According to

			New Service/Product Development Competencies									
			Design	Analysis		Development				Initiating		
			C1	C2...C(n-1)								Cn
Technical Requirements	Operational Facilities	C1	C1,C1	C1,C2	...	...	...	...	...	...	...	C1,Cn
			...	...	...	...	...	...	...	...	...	...
	Financial Conditions	C2	.	.	.	.	.	.	.	.	.	.
	External Factors	.	.	.	.	.	.	.	.	.	.	.
		.	.	.	.	.	.	.	.	.	.	.
		C(n-1)	C(n-1),C1	...	...	...	...	...	...	...	...	C(n-1),Cn
		Cn	Cn,C1	....	...	...	...	...	...	...	...	Cn,Cn

Fig. 4. New service/product development competencies based on technical requirements.

Table 22
The collective hesitant fuzzy decision matrix for new service/product development process.

Alternatives/criteria	Technological capacity (C1)	Accessibility (C2)	Capital adequacy (C3)	Cost management (C4)
Collecting the new ideas of new product/service development (A1)	{0.6, 0.7, 0.8}	{0.6, 0.7}	{0.3, 0.4, 0.5}	{0.5, 0.6}
Selecting the ideas of new product/service development (A2)	{0.5, 0.6}	{0.6, 0.7}	{0.3, 0.4}	{0.5, 0.6}
Monitoring the progress of the ideas (A3)	{0.6, 0.7, 0.8}	{0.6, 0.7}	{0.3, 0.4}	{0.5, 0.6}
Evaluating the outcomes (A4)	{0.6, 0.7, 0.8}	{0.5, 0.6}	{0.4, 0.5}	{0.5, 0.6}
Improving the ideas with cross functional teams (A5)	{0.5, 0.6}	{0.6, 0.7, 0.8}	{0.4, 0.5}	{0.5, 0.6, 0.7}
Redesigning the system priorities (A6)	{0.5, 0.6}	{0.5, 0.6}	{0.4, 0.5}	{0.5, 0.6, 0.7}
Adopting the personnel for the final design (A7)	{0.6, 0.8}	{0.6, 0.7}	{0.5}	{0.5, 0.6}
Pretesting the new products/services (A8)	{0.5, 0.6, 0.8}	{0.5, 0.6}	{0.5, 0.6}	{0.6, 0.7}
Testing the market environment (A9)	{0.5, 0.6, 0.7}	{0.5, 0.6}	{0.5, 0.6}	{0.6, 0.7}
Commercializing the new products/services (A10)	{0.5, 0.6, 0.7}	{0.6, 0.7, 0.8}	{0.5, 0.6}	{0.6, 0.7}
Alternatives/Criteria	Customized services based on market needs (C5)	Monitoring market trends (C6)	Ease of contact with suppliers (C7)	
Collecting the new ideas of new product/service development (A1)	{0.6, 0.7, 0.8}	{0.6, 0.7, 0.8}	{0.4, 0.5, 0.6}	
Selecting the ideas of new product/service development (A2)	{0.6, 0.7, 0.8}	{0.6, 0.7, 0.8}	{0.5, 0.6}	
Monitoring the progress of the ideas (A3)	{0.7, 0.8}	{0.6, 0.7, 0.8}	{0.5, 0.6}	
Evaluating the outcomes (A4)	{0.6, 0.7, 0.8}	{0.6, 0.7, 0.8}	{0.5, 0.6}	
Improving the ideas with cross functional teams (A5)	{0.6, 0.7}	{0.5, 0.6}	{0.4, 0.5}	
Redesigning the system priorities (A6)	{0.6}	{0.5, 0.6}	{0.4, 0.5}	
Adopting the personnel for the final design (A7)	{0.6, 0.7}	{0.5, 0.6}	{0.4, 0.5}	
Pretesting the new products/services (A8)	{0.5, 0.6}	{0.5, 0.6}	{0.4, 0.5, 0.6}	
Testing the market environment (A9)	{0.5, 0.6}	{0.6, 0.7, 0.8}	{0.5, 0.6, 0.7}	
Commercializing the new products/services (A10)	{0.6, 0.7}	{0.5, 0.6, 0.7}	{0.5, 0.6}	

the decision makers' evaluation, the collective hesitant fuzzy decision matrix for new service/product development process is created. The details of this matrix are shown on Table 22.

Table 22 shows the evaluation of decision makers for new product/service development process based on technical requirement. Additionally, the weights of new product/service development process are demonstrated on Table 23.

In Table 23, that RCi values are calculated with the help of hesitant fuzzy TOPSIS method according to the evaluation results emphasized in Table 22. Moreover, weights of new product/service development process are identified by considering RCi values with the help of the Eqs. (38)–(40). The proportions of relative closeness to the ideal solution are used to calculate the weights. It is concluded that monitoring the progress of the ideas (A3) has the

Table 23
Values of RCi and weights of new service/product development process.

New service/Product development process	D+	D-	RCi	Weights
Collecting the new ideas of new product/service development (A1)	0.140	0.148	0.515	0.121
Selecting the ideas of new product/service development (A2)	0.155	0.133	0.462	0.109
Monitoring the progress of the ideas (A3)	0.125	0.163	0.566	0.133
Evaluating the outcomes (A4)	0.138	0.151	0.523	0.123
Improving the ideas with cross functional teams (A5)	0.197	0.092	0.318	0.075
Redesigning the system priorities (A6)	0.206	0.083	0.287	0.067
Adopting the personnel for the final design (A7)	0.181	0.107	0.371	0.087
Pretesting the new products/services (A8)	0.201	0.088	0.304	0.071
Testing the market environment (A9)	0.168	0.120	0.416	0.098
Commercializing the new products/services (A10)	0.146	0.142	0.494	0.116

			BSC Perspectives										
			Financial Performance	Consumer Compliance	Organizational Compliance				Competitional Compliance				
			C1	C2	......							C(n-1)	Cn
New Product Development Process	Design	C1	C1,C1	C1,C2	...	...	...	...	...	...	...	...	C1,Cn
			...	...	...	...	...	...	...	...	...	...	...
	Analysis	C2	.	.	.	.	.	.	.	.	.	.	.
		.	.	.	.	.	.	.	.	.	.	.	.
	Development	.	.	.	.	.	.	.	.	.	.	.	.
		.	.	.	.	.	.	.	.	.	.	.	.
	Initiating	C(n-1)	C(n-1),C1	...	...	...	...	...	...	...	...	...	C(n-1),Cn
		Cn	Cn,C1	....	...	...	...	...	...	...	...	...	Cn,Cn

Fig. 5. Balanced scorecard-based performance criteria considering new service/product development competencies.

			European Alternative Energy Investment Policies										
			Focusing on end users	Increasing the capacity and storage of the energy	Producing sustainable energy operations			Renewable energy sources		Improving the affordability of energy prices			
			C1	C2	......							C(n-1)	Cn
BSC Perspectives	Financial Performance	C1	C1,C1	C1,C2	...	...	...	...	...	...	...	...	C1,Cn
			...	...	...	...	...	...	...	...	...	...	...
	Consumer Compliance	C2	.	.	.	.	.	.	.	.	.	.	.
		.	.	.	.	.	.	.	.	.	.	.	.
	Organizational Compliance	.	.	.	.	.	.	.	.	.	.	.	.
		.	.	.	.	.	.	.	.	.	.	.	.
	Competitional Compliance	C(n-1)	C(n-1),C1	...	...	...	...	...	...	...	...	...	C(n-1),Cn
		Cn	Cn,C1	....	...	...	...	...	...	...	...	...	Cn,Cn

Fig. 6. European energy investment policies based on balanced scorecard-based performance criteria.

highest weight. On the other side, it is defined that pretesting the new products/services (A8) is the least important aspect.

4.5. Weighting the balanced scorecard-based criteria with hesitant fuzzy TOPSIS

In the fifth phase, new service/product development process is compared with balanced scorecard-based performance criteria. Thus, this phase constitutes the third step of QFD. The details of this phase are given on Fig. 5.

In the third step of QFD, the weights calculated in the second step of QFD are taken into the consideration. The main reason behind this situation is to use integrated influence of new product/service development process identified in the second step. As a result of the evaluation of decision makers, the collective hesitant fuzzy decision matrix for balanced scorecard-based performance criteria is created. The details of this matrix are given on Table 24.

Table 24 shows the evaluation of decision makers for balanced scorecard-based criteria based on technical requirement. Additionally, the weights of these criteria are demonstrated on Table 25.

Table 25 explains the process of calculating the weights of the balanced scorecard-based criteria. Within this scope, Eqs. (38)–(40) are considered in order to calculate the weights of each criteria. It is determined that considering the feedback of business environment (A6) has the highest weight in comparison with others. On the other hand, increase in expected returns on investment (A1) and potential growth in operating income (A2) are the aspects that have the lowest importance. It shows that companies can be more successful if they mainly focus on the feedback from business environment.

4.6. Ranking the European energy investment policies with hesitant fuzzy TOPSIS

In the last phase, balanced scorecard-based performance criteria are compared with European energy investment policies. Hence, this phase refers to the fourth and the last step of QFD. The details of this phase are shown on Fig. 6.

In the last step of QFD, the weights calculated in the third step of QFD are used. Therefore, it is possible to consider the integrated influence of BSC perspectives determined in the third step.

Table 24
The collective hesitant fuzzy decision matrix for balanced scorecard-based performance criteria.

Alternatives/Criteria	Collecting the new ideas of new product/service development (C1)	Selecting the ideas of new product/service development (C2)	Monitoring the progress of the ideas (C3)	Evaluating the outcomes (C4)
Increase in expected returns on investment (A1)	{0.4, 0.5}	{0.4, 0.5}	{0.4, 0.5, 0.6}	{0.5, 0.6, 0.7}
Potential growth in operating income (A2)	{0.4, 0.5}	{0.5}	{0.4, 0.5}	{0.5, 0.6}
Decrease in operational cost with mass production (A3)	{0.4, 0.5}	{0.5, 0.6}	{0.4, 0.5}	{0.5, 0.6, 0.8}
Growing satisfaction of existed customers (A4)	{0.5, 0.6, 0.8}	{0.6, 0.7}	{0.5, 0.6, 0.8}	{0.6, 0.8}
Designing products/services that meet customer demands (A5)	{0.6, 0.7, 0.8}	{0.6, 0.7, 0.8}	{0.6, 0.7}	{0.6, 0.7}
Considering the feedback of business environment (A6)	{0.6, 0.7, 0.8}	{0.7, 0.8}	{0.5, 0.6, 0.7, 0.8}	{0.5, 0.6, 0.8}
Consistency of working team (A7)	{0.5, 0.6}	{0.5, 0.6}	{0.5, 0.6}	{0.7, 0.8}
Clarifying organizational goals (A8)	{0.5, 0.6}	{0.4, 0.5, 0.6}	{0.5, 0.6}	{0.6}
Considering the ideas of the personnel with their active participation (A9)	{0.6, 0.7}	{0.5, 0.6}	{0.5, 0.6, 0.7}	{0.6, 0.7}
Benchmarking competitive market environment using market- based database (A10)	{0.6, 0.7, 0.8}	{0.6}	{0.5, 0.6, 0.7}	{0.6, 0.7}
Generating new R&D activities (A11)	{0.6, 0.7}	{0.5, 0.6}	{0.6, 0.7, 0.8}	{0.6, 0.7}
Improving training activities to contribute quality development (A12)	{0.6, 0.7, 0.8}	{0.6, 0.7}	{0.6, 0.7, 0.8}	{0.6, 0.7}
Alternatives/Criteria	Improving the ideas with cross functional teams (C5)	Redesigning the system priorities (C6)	Adopting the personnel for the final design (C7)	Pretesting the new products/services (C8)
Increase in expected returns on investment (A1)	{0.4, 0.5}	{0.5}	{0.4, 0.5}	{0.5, 0.6}
Potential growth in operating income (A2)	{0.4, 0.5}	{0.4, 0.5, 0.6}	{0.5}	{0.5, 0.6}
Decrease in operational cost with mass production (A3)	{0.4, 0.5}	{0.5, 0.6}	{0.5}	{0.5, 0.6}
Growing satisfaction of existed customers (A4)	{0.6, 0.7}	{0.5, 0.6}	{0.5, 0.6, 0.8}	{0.6}
Designing products/services that meet customer demands (A5)	{0.6, 0.7}	{0.6, 0.7}	{0.6, 0.7, 0.8}	{0.6, 0.7}
Considering the feedback of business environment (A6)	{0.7, 0.8}	{0.6, 0.7}	{0.6, 0.7, 0.8}	{0.6, 0.7}
Consistency of working team (A7)	{0.6, 0.7, 0.8}	{0.5, 0.6, 0.7}	{0.6, 0.7, 0.8}	{0.5, 0.6}
Clarifying organizational goals (A8)	{0.6, 0.7, 0.8}	{0.6, 0.7}	{0.6, 0.7, 0.8}	{0.5, 0.6, 0.7}
Considering the ideas of the personnel with their active participation (A9)	{0.7, 0.8}	{0.6, 0.7}	{0.6, 0.7, 0.8}	{0.6, 0.7}
Benchmarking competitive market environment using market- based database (A10)	{0.6, 0.7}	{0.6}	{0.5, 0.6}	{0.6, 0.7}

(*continued on next page*)

Table 24 (*continued*)

Alternatives/Criteria	Collecting the new ideas of new product/service development (C1)	Selecting the ideas of new product/service development (C2)	Monitoring the progress of the ideas (C3)	Evaluating the outcomes (C4)
Generating new R&D activities (A11)	{0.6, 0.7}	{0.6, 0.7}	{0.6}	{0.6}
Improving training activities to contribute quality development (A12)	{0.6, 0.7}	{0.6, 0.7, 0.8}	{0.6, 0.7, 0.8}	{0.6, 0.7}
Alternatives/Criteria	Testing the market environment (C9)	Commercializing the new products/services (C10)		
Increase in expected returns on investment (A1)	{0.5, 0.6}	{0.5, 0.6, 0.8}		
Potential growth in operating income (A2)	{0.5, 0.6}	{0.5, 0.6}		
Decrease in operational cost with mass production (A3)	{0.5, 0.6}	{0.5, 0.6}		
Growing satisfaction of existed customers (A4)	{0.5, 0.6}	{0.5, 0.6}		
Designing products/services that meet customer demands (A5)	{0.6, 0.7, 0.8}	{0.5, 0.6}		
Considering the feedback of business environment (A6)	{0.6, 0.7, 0.8}	{0.6, 0.7}		
Consistency of working team (A7)	{0.5, 0.6}	{0.5, 0.6}		
Clarifying organizational goals (A8)	{0.5, 0.6}	{0.5, 0.6}		
Considering the ideas of the personnel with their active participation (A9)	{0.6, 0.7}	{0.5, 0.6}		
Benchmarking competitive market environment using market- based database (A10)	{0.6, 0.7}	{0.6}		
Generating new R&D activities (A11)	{0.6, 0.7}	{0.5, 0.6}		
Improving training activities to contribute quality development (A12)	{0.6, 0.7}	{0.5, 0.6}		

Table 25
Values of RCi and weights of balanced scorecard-based criteria.

Balanced scorecard-based criteria	D+	D-	RCi	Weights
Increase in expected returns on investment (A1)	0.284	0.068	0.192	0.036
Potential growth in operating income (A2)	0.284	0.068	0.194	0.036
Decrease in operational cost with mass production (A3)	0.273	0.079	0.225	0.042
Growing satisfaction of existed customers (A4)	0.184	0.169	0.479	0.089
Designing products/services that meet customer demands (A5)	0.147	0.205	0.583	0.108
Considering the feedback of business environment (A6)	0.109	0.243	0.690	0.128
Consistency of working team (A7)	0.196	0.156	0.442	0.082
Clarifying organizational goals (A8)	0.198	0.155	0.439	0.081
Considering the ideas of the personnel with their active participation (A9)	0.167	0.185	0.525	0.097
Benchmarking competitive market environment using market- based database (A10)	0.168	0.184	0.523	0.097
Generating new R&D activities (A11)	0.169	0.183	0.519	0.096
Improving training activities to contribute quality development (A12)	0.146	0.206	0.584	0.108

Additionally, by considering the evaluation of decision makers, the collective hesitant fuzzy decision matrix for European energy investment policies is created. The details of this matrix are demonstrated on Table 26.

Table 26 explains the evaluation of decision makers for European energy investment policies based on balanced scorecard-based criteria. In addition to this issue, the ranking of these alternatives is given on Table 27.

Table 27 shows that the most important factor is "increasing the capacity and storage of the energy (A2)" in European energy investment policies as a result of integrated QFD approach. This shows that because Europe has a strategic importance regarding

Table 26
The collective hesitant fuzzy decision matrix for the European energy investment policies.

Alternatives/Criteria	Increase in expected returns on investment (C1)	Potential growth in operating income (C2)	Decrease in operational cost with mass production (C3)	Growing satisfaction of existed customers (C4)
Focusing on end users (A1)	{0.6, 0.7}	{0.6, 0.7}	{0.6, 0.7}	{0.6, 0.7, 0.8}
Increasing the capacity and storage of the energy (A2)	{0.6, 0.7}	{0.6, 0.7}	{0.6, 0.7}	{0.5, 0.6}
Producing sustainable energy operations (A3)	{0.5, 0.6}	{0.5, 0.6}	{0.6, 0.7}	{0.6, 0.7}
Renewable energy sources (A4)	{0.5, 0.6, 0.7}	{0.5, 0.6}	{0.5, 0.7}	{0.5, 0.6}
Improving the affordability of energy prices (A5)	{0.5, 0.6}	{0.5, 0.6}	{0.6, 0.7}	{0.6, 0.7, 0.8}
Alternatives/Criteria	Designing products/services that meet customer demands (C5)	Considering the feedback of business environment (C6)	Consistency of working team (C7)	Clarifying organizational goals (C8)
Focusing on end users (A1)	{0.6, 0.7}	{0.5, 0.6}	{0.5, 0.6}	{0.5, 0.6}
Increasing the capacity and storage of the energy (A2)	{0.6}	{0.6, 0.7}	{0.6, 0.7}	{0.5, 0.6}
Producing sustainable energy operations (A3)	{0.5, 0.6}	{0.6, 0.7}	{0.6}	{0.6}
Renewable energy sources (A4)	{0.6, 0.7}	{0.5, 0.6, 0.7}	{0.5, 0.6}	{0.5, 0.6}
Improving the affordability of energy prices (A5)	{0.6, 0.7}	{0.6, 0.7, 0.8}	{0.5, 0.6}	{0.5, 0.6}
Alternatives/Criteria	Considering the ideas of the personnel with their active participation (C9)	Benchmarking competitive market environment using market- based database (C10)	Generating new R&D activities (C11)	Improving training activities to contribute quality development (C12)
Focusing on end users (A1)	{0.5, 0.6}	{0.6, 0.7}	{0.6, 0.7}	{0.5, 0.6}
Increasing the capacity and storage of the energy (A2)	{0.6}	{0.6, 0.7, 0.8}	{0.6, 0.7}	{0.6, 0.7}
Producing sustainable energy operations (A3)	{0.6, 0.7}	{0.6, 0.8}	{0.6}	{0.6}
Renewable energy sources (A4)	{0.5, 0.6}	{0.5, 0.6, 0.7}	{0.6, 0.7}	{0.5, 0.6, 0.7}
Improving the affordability of energy prices (A5)	{0.6, 0.7}	{0.6, 0.7}	{0.6, 0.7}	{0.5, 0.6}

Table 27
Values of RCi and ranking of the European energy investment policies.

European energy investment policies	D+	D-	RCi	Ranking
Focusing on end users (A1)	0.108	0.106	0.495	2
Increasing the capacity and storage of the energy (A2)	0.099	0.115	0.537	1
Producing sustainable energy operations (A3)	0.114	0.099	0.465	4
Renewable energy sources (A4)	0.130	0.083	0.389	5
Improving the affordability of energy prices (A5)	0.110	0.104	0.485	3

location, it attracts to the attention of many different investors. It can be seen that this conclusion is very similar to some studies in the literature (Magagna & Uihlein, 2015; Yu et al., 2016). In addition to this policy, it is also identified that "focusing on end users (A1)" is on the second rank. In other words, investors think that the need for energy has an increasing trend because of increase in individual consumption. Balta-Ozkan and Le Gallo (2018) and Apajalahti et al. (2015) also underlined the importance of this point in their studies. Moreover, the policy of "improving the affordability of energy prices (A5)" has the third place in the ranking.

On the other side, it is also understood that "producing sustainable energy operations (A3)" and "renewable energy sources (A4)" are the least important policies. These results underline the opposite aspects of some studies in the literature (Peck & Parker, 2016; Wood et al., 2016). The main reason behind this condition is to solve the sustainability problem regarding energy in Europe region. Thus, investors do not give too much importance to this aspect. While considering the results, it can be said that European energy companies should focus on the investment alternatives of "producing sustainable energy operations" or "renewable energy sources". In this process, these companies should redesign these alternatives by considering the important points emphasized in this study so that they can be more attractive for customers. Therefore, it can be possible to improve the energy industry by diversifying the investment alternatives. Moreover, this situation has a positive influence in the economic growth and life standards of the people.

Additionally, this study conceptually points out some new issues. For example, this study considers an integrated methodology with QFD approach which is accepted to present very sensitive results (Asadabadi, 2017; Büyüközkan & Berkol, 2011). Another important point is that this study uses hesitant fuzzy AHP, DEMATEL and TOPSIS, but there are limited studies in the literature with this context. Moreover, this study underlines some strategic policies for energy industry. For instance, it is defined that increasing the capacity and storage of the energy and focusing on end users are appropriate policies according to the results of this study. It can be seen these policies are also highlighted in some different studies (Apajalahti et al., 2015; Yu et al., 2016). Similarly, it can also be understood that these policies are underlined at the governmental level. As an example, the hydrogen production is one of the most recent discussion on the innovative solutions of capacity increase and the storage in the European energy industry.

5. Conclusion

This study focuses on the evaluation of the performance results of the European energy investment policies. For this purpose, an integrated multidimensional quality measurement approach is taken into the consideration. In addition to this aspect, the quality function deployment is adopted to the multidimensional performance measurement. Within this framework, customer and technical requirements, new product/service development policies and balanced scorecard perspectives are defined. Furthermore, 5 different energy investment policies for European energy companies are identified while analyzing similar studies in the literature. Different preferences of decision makers are considered as the hesitation of the group of individuals in each stage of the QFD and they are evaluated to rank the European energy investment policies.

In the analysis process, firstly, dimensions of customer requirements are weighted by using hesitant fuzzy DEMATEL. It is concluded that reliability (D2) is the dimension that has the highest significance. In addition to this aspect, it is also understood that physical conditions (D1) has the lowest weight in comparison with the others. On the other side, it is also determined that the dimension of costs and earnings (D4) is the most influencing factor while the dimension of responsiveness (D3) is the most influenced factor. After analyzing the significance of the dimension with hesitant fuzzy DEMATEL, the criteria of customer requirements are weighted with the help of hesitant fuzzy AHP. It is stated that that ease of use of products/services (C3) and competitive costs (C7) are the most important criteria. On the other hand, physical security (C4) and efficiency (C8) have the lowest importance.

After that, an integrated analysis is performed by considering QFD approach. Within this framework, in the first step, decision makers evaluated technical requirement based on customer requirements. Next, new product/service development process is evaluated by considering the integrated influence of technical requirements calculated in the first step. In the third step of QFD, BSC perspectives are analyzed by using the integrated influence of new product/service development process identified in the second step. In the final step, European energy investment policies can be ranked by considering the integrated influence of BSC perspectives determined in the third step. As it can be seen, in integrated analysis of QFD, each step has an effect on the next step.

As a result of hesitant fuzzy TOPSIS analysis, it is determined that the most important factor is "increasing the capacity and storage of the energy (A2)" in European energy investment policies. In other words, it can be understood that this policy attracts to the attention of many different investors because Europe has a strategic importance regarding location. Furthermore, it is also determined that "focusing on end users (A1)" is another important energy investment alternative. It can be understood that, due to the increase in individual consumption in Europe, investors would redesign the policies by increasing the need for energy in the near future.

However, it is also identified that "producing sustainable energy operations (A3)" and "renewable energy sources (A4)" are the least significant investment policies. By considering these results, it is recommended that European energy companies should focus on the investment alternatives of "producing sustainable energy operations" or "renewable energy sources". In this process, it can also be very beneficial that these policies should be redesigned by looking the aspects emphasized in this study. Hence, it may be much easier to attract the attention of the customers and this situation has an influencing effect on the improvement of energy sector. In this study, energy investment alternatives are evaluated for Europe. Nevertheless, it is believed that a new study, which makes comparison between different continents for this subject, will also make contribution to the literature.

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