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# TURKEY 'S NATURAL GAS DEMAND PROJECTIONS

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## ABSTRACT

Today natural gas is the type of energy that we use/need in our daily life, i.e. heating, electricity generation, cooling… Turkey's energy demand is increasing approx. 8% per year that is one of the highest rates in the world. And among other energy sources used in Turkey, i.e. coal, hydro, wind, solar, geothermal…, natural gas is the fastest growing energy source used in Turkey. In Turkey the usage of natural gas was 0.5 bcm in 1987, in 1990 it was 6 bcm, and in 2018 it reached approx. 49.3 bcm. Although Turkey imports fossil fuels/energy sources, in all scenario Turkey's natural gas usage is projected to further increase remarkably in the future. Natural gas that is used in Turkey is imported from Russia, Iran, Azerbaijan, Algeria, Nigeria and Qatar by signing long term "Take or Pay" contracts and these contracts constitute a heavy economic load on Turkey's economy. In addition MoE's (Turkey's Ministry of Energy) one of the energy strategy/aim is to become a natural gas trading hub in the region. To reach these aims, energy contracts should be planned in detail and correctly. In the study interviews with energy experts/managers are performed and fuzzy mathematical model (by using fuzzy AHP and fuzzy TOPSIS) is developed to calculate Turkey's natural gas demand under high and low scenarios. By the help of model, the usage of natural gas amount in Turkey between 2020 and 2030 is calculated. In the study, between 2020 and 2030 under high demand scenario natural gas usage in Turkey will be increased by 35% and reached to appox. 79 bcm, and under low demand scenario Turkey's total natural gas demand will be decreased by approx. 7% and reached to approx. 40 bcm. By considering these scenarios Turkey is developing energy projects/contracts to become lead energy transit country and new energy contracts/projects could help underpin an effective and valuable regional storage hub that serves both Turkish and EU.

**Keywords:** Natural Gas Demand, Energy Hub, Fuzzy Logic, Fuzzy AHP, Fuzzy TOPSIS, Turkey



## 1. INTRODUCTION

Today energy and related powered devices are an integral part of society. Humanity's earliest days saw the discovery of fire through wood combustion, and the use of charcoal for smelting metals dates back as early as approx. 7000 years ago, i.e 5000 years BC. Various natural oils were used for a range of purposes, such as whale oil for lamps. The Industrial Revolution led to the massive use of coal as fuel, and the extraction of petroleum and various other oils became extremely important with the advent of internal combustion engines.

Today fossil fuels, i.e. coal, oil, and natural gas, are still widely used in the World's energy sector. Today, approximately 24 percent of the energy consumption of the US comes from natural gas. More than one-half of the homes in US and approx. two-third of the homes in Turkey use natural gas as their main heating fuel. Natural gas is a colorless, shapeless, and odorless gas. Because it has no odor, gas companies add a chemical to it that smells similar to rotten eggs. By doing so, the leakage of gas can be detected easily. Natural gas is an essential energy resource not only in homes but also in industrial sector; natural gas is an essential raw material for many common products, i.e. paints, fertilizers, plastics, antifreeze, and medicine.

Energy management problems are solved by multiple objective optimization methods, i.e. i.e. MOP methods. Multiple objective optimization in engineering is often very challenging to solve, necessitating sophisticated techniques to tackle. Multiple objective optimization considers optimization problems involving more than one objective function to be optimized simultaneously. Multiple objective optimization is typically suitable in such problems where decisions regarding optimal solutions are taken by consideration of the trade-offs between the conflicting objectives. Past studies in literature using multiple objective programming model (Wang, 2009, 2018, Deshmukh, S.S., 2009, Lee et al., 2010, Ho et al., 2018, Enea, 2018, Chen et al., 2015, Cayir et al., 2018, Pokharel, Chandrashekara, 1998, Incekara, 2017, Iniyana, 2006, Borges, Antunes, 2003, Chang, 1996, Gu, 2006, Saaty, 2012, Mangla, 2015, Satrovic, 2018, Chen, et al., 2001, Incekara, 2017, Incekara, 2018; 2019, Incekara, 2020) were performed for energy investment/expansion plans of regions/countries.

## 2. TURKEY'S ENERGY SECTOR

Turkey's energy sector has been developed in a manner aimed at contributing to economic growth and national prosperity with an approach centered on the principle of supply security. Most of the Turkey's electricity is generated by using mainly fossil fuels, i.e. mainly natural gas and indigenous coals (approx. %55). By the end of 2019 the distribution of Turkey's installed power by resources are; 31.4% hydraulic, 29.0% natural gas, 22.4% coal, 8.0% wind, 1.5% geothermal, 6.0% solar and 1.7% other sources.



### 2.1. Turkey's Natural Gas Sector

Fossil fuels play an important role in Turkey's energy mix, with natural gas being the most significant. In 2014, around 48% of natural gas was used for electricity production, 25% was used by the industry and 19% was used in households. Natural gas shares in the energy mix of Turkey have declined in recent years. In Turkey's electricity generation natural gas source had a share of 37.2 % in 2017 and in 2018 it had a share of 30.6%.

Turkey's own domestic gas production mostly meets less 2% of its consumption, and only 0.66% in 2017. In 2013, about 98% of gas imports originated from five countries, although the share of these five countries in imports dropped to 91.3% in 2017. In 2018 Turkey imports most of its natural gas from Russia (51.9% of the total), Iran (16.7%), Azerbaijan (11.8%), Algeria (8.4%) and Nigeria (2.4%) (EMRA, 2018). Turkey's natural gas purchase agreements are presented in Table 1 and its locations in Figure 1.

Table 1. Turkey’s Natural Gas Purchase Agreements (BOTAS, 2018)

| **Contracts** | **Amount (billion m3/yıl)** | **Date of Contract** | **Duration (year)** |
|---|---|---|---|
| Russian Fed. (West) | 6 | 14 February 1986 | 25 |
| Algeria (LNG) | 4 | 14 April 1988 | 20 |
| Nigeria (LNG) | 1.2 | 9 November 1995 | 22 |
| İran | 10 | 8 August 1996 | 25 |
| Russian Fed. (Blue Stream) | 16 | 15 December 1997 | 25 |
| Rus. Fed. (West) | 8 | 18 February 1998 | 23 |
| Turkmenistan | 16 | 21 May 1999 | 30 |
| Azerbaijan (Phase 1) | 6.6 | 12 March 2001 | 15 |
| Azerbaijan (Phase 2) | 6 | 25 November 2011 | 15 |
| Azerbaijan (TANAP) | 16 (6 bcm for Turkey) | 20 May 2014 | 49 |
| Russia (Turk Stream) | 31.5 (half of it for Turkey) | 10 November 2016 | 49 |
| Greece (Sell) | 0.75 | 10 April 2007 | 15 |



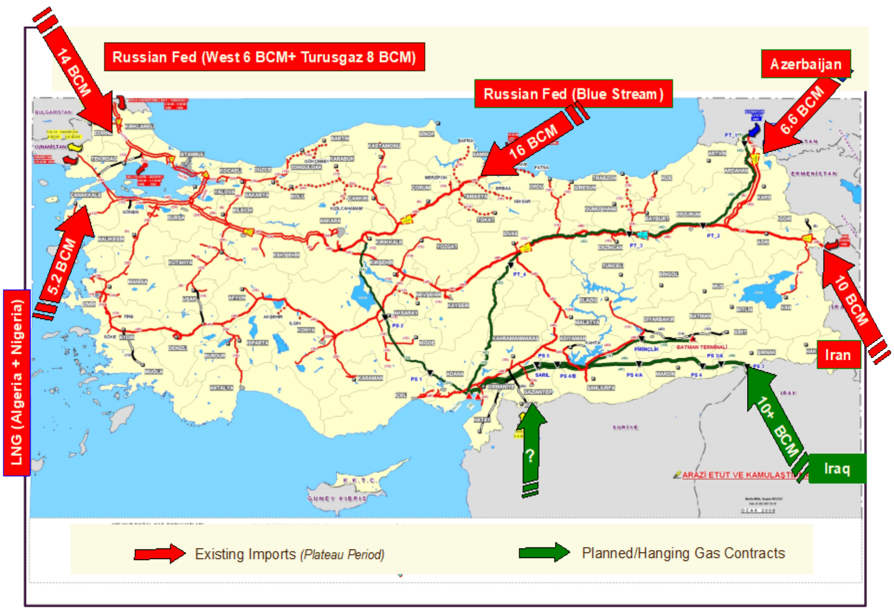


Figure 1. Turkey’s Natural Gas Contracts Amounts and Locations (BOTAS, 2012)

Turkey is heavily reliant on gas imports, from both pipeline and LNG (Liquefied natural gas). In 2017, combined imports amounted to 53.7 bcm, representing an approximate increase of 15% – the highest level of consumption in the history of Turkey (EMRA, 2018). A key reason for this increase was the fact that natural gas power plants have had to work at a higher than expected rate, in order to make up for the shortfall in hydroelectric power, with generation from hydro-electric power plants being much lower than the average in 2017. Whereas in 2019 the usage of natural gas in Turkey is lower that the value in 2017.

MoE works to a goal of storing an amount that corresponds to about 20% of its consumption (EMRA, 2018). Turkey has achieved a great leap in terms of natural gas distribution in recent years. Before 2001, natural gas was only distributed in 6 provinces; but at the end of 2017, gas distribution services were available in all of Turkey's provinces.

Turkey is a neighbouring to fossil fuel reached countries, i.e. 75.5 trillion m3 of the natural gas reserves (38.4%) are located in Middle Eastern countries, 66.7 trillion m3 (33.9%) in Europe&Euroasia countries and 32.5 trillion m3 (16.5%) in African/Asia Pacific countries. In terms of countries supplying natural gas to Turkey, dependence on Russia (mainly) still continues despite the latter's gradually increasing amount but decreasing share in Turkey's total natural gas imports.

Turkey has "East-West" and "South-North" energy projects. The "East-West" natural gas pipeline projects which are envisaged to bring gas from Caspian and the Middle East regions to Europe through Turkey are referred to as "Southern Gas Corridor" (SGC). Turkey's international natural gas projects are listed below:

i. Baku-Tbilisi-Erzurum Natural Gas Pipeline (BTE)

ii. Turkey-Greece Interconnector (ITG)

iii. Western Route (Russia-Turkey Natural Gas Pipeline)

iv. Blue Stream Natural Gas Pipeline

v. Iran-Turkey Natural Gas Pipeline

vi. Trans-Anatolian Natural Gas Pipeline (TANAP)

vii. TurkStream Natural Gas Project



Turkey's existing natural gas storage facilities projects are listed below:

i. BOTAŞ Silivri offshore gas storage project: 2.84 BCM under ground; maximum injection 16 MCM/day and maximum withdrawal 25 MCM/day; additional 1.8 BCM by 2023

ii. BOTAŞ Tuz Gölü under ground gas storage project: 1.2 BCM under ground; maximum withdrawal 20 MCM/day: additional 4.2 BCM by 2023

iii. Çalık Tuz Gölü under ground gas storage project; 1 BCM (will be constructed)

iv. Toren Tarsus under ground gas storage project: 3 BCM (will be constructed)

v. BOTAŞ Marmara Ereğlisi LNG Terminal: 255K M3 LNG; maximum regasification 8.2 BCM/year and maximum withdrawal 37 MCM/day

vi. Ege Gaz Aliağa LNG Terminal: 280K M3 LNG; maximum regasification 6.0 BCM/year and maximum withdrawal 16.4 MCM/day

vii. BOTAŞ Dörtyol FSRU Terminal: 167 MCM LNG; maximum withdrawal 20 MCM/day

viii. BOTAŞ Saros FSRU Terminal: 167 MCM LNG; maximum withdrawal 20 MCM/day (will be constructed)

### 2.2. Turkey's Main Energy Goals in 2023: Vision 2023

Turkey's energy goals & objectives in 2023 are defined in the Turkey's Ministry of Energy and Natural Resource (MENR:MoE)'s "Security of Energy Market and Supply Strategy" document (SEMSS) (MENR, 2009). There is no demand forecast for natural gas in the Vision 2023 energy agenda of MoE. Whereas in this study power plants that use natural gas has the following constraints which are EMRA's objectives:

- In 2023 considering MENR's international energy agreements that have "take or pay" conditions (BOTAS 2012), MENR's plan is to produce electricity from natural gas; as per high demand scenario 179075 GWh, as per low demand scenario 110915 GWh.

$$\sum_{g=9}^{10} \sum_{z=1}^{8} C_{gz} = 179075 \tag{1a}$$

$$\sum_{g=9}^{10} \sum_{z=1}^{8} C_{gz} = 110915 \tag{1b}$$

## 3. FUZZY MULTI CRITERIA DECISION MAKING METHODS (FMCDM)

In the study; an integrated Fuzzy AHP- Fuzzy TOPSIS approaches are used to assess/evaluate Turkey's natural gas sector.

In literature Fuzzy Multi Criteria Decision Making Methods (FMCDM) are used in different fields by many researchers and Fuzzy AHP & Fuzzy TOPSIS are also used in many sectors, i.e. to select best renewable energy resource of Turkey, to select best project (Enea and Piazza, 2004), performance evaluation of national R&D companies (Deshmukh, 2009), to evaluate intelligent timetable (Isaai et al., 2011), to evaluate the criteria for human resource for science and technology (Chen et al., 2015), for analyzing customer preferences (Kumar, 2015), to evaluate risk analysis in green supply chain (Mangla et al., 2015), and to select machine tools (Nguyen et al., 2015).



### 3.1. Fuzzy AHP Method

Since the standard AHP method does not include the possibility of situations with ambiguity in the estimation, it is possible to upgrade this method with fuzzy approach. This approach is called the Fuzzy AHP method. Instead of one defined value, in the Fuzzy AHP method full range of values that include unsafe attitudes of decision maker should be generated. For that process it is possible to use triangular fuzzy numbers, trapezoidal or Gaussian fuzzy numbers. The Fuzzy AHP method suggests their application directly in criteria pairs comparison matrix. Triangular fuzzy numbers are used in most cases/problems by many researchers in literature because of this reason in the study triangular fuzzy numbers method is used in Fuzzy AHP method. A triangular fuzzy number that is defined in R set can be described as Ñ= (l, n, u) where l is the minimum, n is the most possible and u is the maximum value of a fuzzy case. Its triangular membership function is characterized below (Deng, 1999) which is presented in Figure 2 and in equation (2).

$$\mu\tilde{N}(x) = \begin{cases} (x-l)/(n-l), & l \leq x \leq n \\ (x-u)/(n-u), & n \leq x \leq u \\ 0, & x < l \text{ or } x > u \end{cases} \tag{2}$$

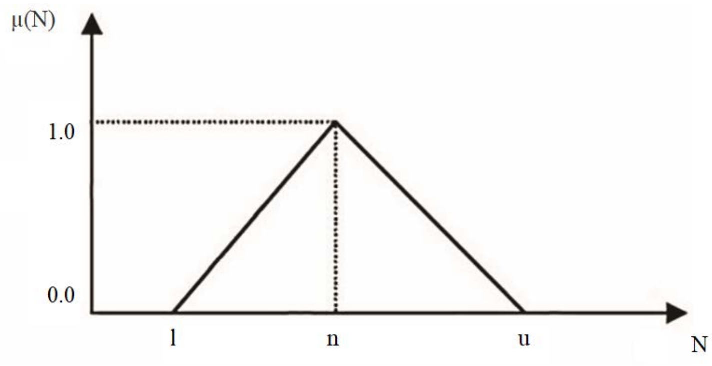


Figure 2. Triangular fuzzy number

Triangular fuzzy number Ñ (shown in Figure 2) can be described as an interval of real numbers where each of them has a degree of belonging to the interval between 0 and 1. Triangular fuzzy number is defined with three real numbers, expressed as l, n and u. In the study the performance of each scenario to each criterion is introduced as a fuzzy number. And in the study the ratings of qualitative criteria are considered as linguistic variables. These linguistic variables can be expressed in positive triangular fuzzy numbers as described in Table 2.

Table 2. Linguistic Variables for the Alternatives

| Linguistic Terms-Abbreviation | Linguistic Variables | Triangular Fuzzy Numbers |
|---|---|---|
| SDA | Strongly Disagree | (0, 0, 0.15) |
| DA | Disagree | (0.15, 0.15, 0.15) |
| LDA | Little Disagree | (0.30, 0.15, 0.20) |
| NC | No Comment | (0.50, 0.20, 0.15) |
| LA | Little Agree | (0.65, 0.15, 0.15) |
| A | Agree | (0.80, 0.15, 0.20) |
| SA | Strongly Agree | (1, 0.20, 0) |



After forming a matrix of fuzzy criteria comparison it should be defined vector of criteria weights W. For that purpose, the following equations/steps were used in the study.

Let X ={x1 , x2 ,..., xm } be an object set, and G={g1 ,g2 ,...,gn} be a goal set. N extent analysis values for each object can be obtained as $N_{gi}^{1}, N_{gi}^{2}, \ldots, N_{gi}^{n}$ i= 1,2,…n

**Step 1:** The values of fuzzy extensions for the i-th object are given in Expression (3);

$$Si = \sum_{j=1}^{n} N_{gi}^{j} \otimes \left[\sum_{i=1}^{m} \sum_{j=1}^{n} N_{gi}^{j}\right]^{-1} \qquad (3)$$

In order to obtain the expression $\left[\sum_{i=1}^{m} \sum_{j=1}^{n} N_{gi}^{j}\right]$ it is necessary to perform additional fuzzy operations with n values of the extent analysis, which is represented in Equation (4) and (5);

$$\sum_{j=1}^{n} N_{gi}^{j} = \left(\sum_{j=1}^{n} lj, \sum_{j=1}^{n} nj, \sum_{j=1}^{n} uj\right) \quad (4)$$

$$\left[\sum_{i=1}^{m}\sum_{j=1}^{n} N_{gi}^{j}\right] = \left(\sum_{i=1}^{m} li, \sum_{i=1}^{m} ni, \sum_{i=1}^{m} ui\right) \quad (5)$$

And it is required to calculate the inverse vector above by using Expression (6);

$$\left[\sum_{i=1}^{m}\sum_{j=1}^{n} N_{gi}^{j}\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{m} ui}, \frac{1}{\sum_{i=1}^{m} ni}, \frac{1}{\sum_{i=1}^{m} li}\right) \quad (6)$$

**Step 2:** While $N_1$ and $N_2$ are triangular fuzzy numbers, the degree of possibility for $N_2 \geq N_1$ is defined as:

$$V(N_2 \geq N_1) = \sup_{y \geq x} \left(\min(\mu N_1(x), \mu N_2(y))\right) \quad (7)$$

It can be represented in the following manner by Expression (8):

$$V(N_2 \geq N_1) = hgt(N_2 \cap N_1) \mu N_2(d) \quad (8)$$

$$= \begin{cases} 1, & \text{if } n_2 \geq n_1 \\ 0, & \text{if } l_1 \geq l_2 \\ \frac{(l_1 - u_2)}{(n_2 - u_2)(m_1 - l_1)}, & \text{otherwise} \end{cases} \quad (9)$$

Where d is the ordinate of the highest intersection point D between $\mu N_1$ and $\mu N_2$.

To compare $\mu N_1$ and $\mu N_2$, values of both, $V(N_2 \geq N_1)$ and $V(N_1 \geq N_2)$ are needed.

**Step 3:** The degree of possibility for a convex fuzzy number to be greater than k convex numbers Ni (i=1,2,...,k) can be defined by expression (10);

$$V(N \geq N_1, N_2, ..., N_k) = V[(N \geq N_1), (N \geq N_2), \dots, (N \geq N_k)] \quad (10)$$

$$= \min V(N \geq N_i = 1,2,3,\dots,k$$

Assume that Expression (11) is;

$$d'(A_i) = \min V(S_i \geq S_k) \quad (11)$$

for k=1,2,...,n; k ≠ i. So the weight vector is obtained by Expression (12);

$$W' = (d'(A_1), d'(A_2), ..., d'(A_m))^T \quad (12)$$

where, $A_i$ (i =1,2,...,n) consists of n elements.

**Step 4:** Through normalization, the weight vectors are reduced to Expression (13);

$$W = (d(A_1), d(A_2), ..., d(A_n))^T \quad (13)$$

where W represents an absolute number.

### 3.2. Fuzzy TOPSIS Method

The fuzzy TOPSIS calculation most important step is given in Equation (14) (Song et.al., 2013; Viswanadham, 2013), i.e. Creating the Decision Matrix; aggregated ratings are calculated by using Equation (14):

$$\tilde{V}ij = \frac{1}{2}\left[\tilde{v}_{ij}^{1} \oplus \tilde{v}_{ij}^{2} \oplus \dots \tilde{v}_{ij}^{s}\right] \quad (14)$$

where $\tilde{v}_{ij}^{s}$ is the performance rating value obtained from s-th decision maker.

The basic steps of proposed fuzzy TOPSIS method can be described as follows:

**Step 1:** In the first step, a panel of decision makers (DMs) who are knowledgeable about supplier selection process is established. In a group that has K decision-makers (i.e. D1, D2, ..., Dk) are responsible for ranking (yjk) of each criterion (i.e. C1, C2, …, Cn) in increasing order. Then, the aggregated fuzzy importance weight for each criterion can be described as fuzzy triangular numbers $\tilde{v}j$ = ($a_j$, $b_j$, $c_j$) for k = 1, 2, …, K and j = 1, 2, …, n. The aggregated fuzzy importance weight can be determined as follows:

$$d_j = \frac{min}{k}\{y_{jk}\},\ b_j = \frac{1}{K}\sum_{k=1}^{K} yjk,\ c_j = \frac{max}{k}\{y_{jk}\} \quad (15)$$

Then, the aggregated fuzzy importance weight for each criterion is normalized as follows:

$\tilde{v}j$ = ($a_{j1}$, $b_{j2}$, $c_{j3}$)

$$\text{where } v_{j1} = \frac{\frac{1}{dj}}{\sum_{j=1}^{n}\frac{1}{dj}},\ v_{j2} = \frac{\frac{1}{bj}}{\sum_{j=1}^{n}\frac{1}{bj}},\ v_{j3} = \frac{\frac{1}{cj}}{\sum_{j=1}^{n}\frac{1}{cj}} \quad (16)$$

Then the normalized aggregated fuzzy importance weight matrix is constructed as $\tilde{V}$ = ($\tilde{v}_1$, $\tilde{v}_2$, …, $\tilde{v}_n$)

**Step 2:** A decision matrix is formed.

$$X = \begin{bmatrix} x11 & x12 & \cdots & x1n \\ x21 & x22 & \vdots & x2n \\ \cdots & \cdots & \vdots & \cdots \\ xm1 & xm2 & \ldots & xmn \end{bmatrix} \quad (17)$$



**Step 3:** After forming the decision matrix, normalization is applied. The calculation is done using equations 18 and 19.

$$r_{ij} = \frac{\frac{1}{xij}}{\sqrt{\sum_{i=1}^{m}\frac{1}{xij^2}}} \quad \text{for minimization objective, where } i = 1, 2, \ldots, m \text{ and } j = 1, 2, \ldots, n \quad (18)$$

$$r_{ij} = \frac{xij}{\sqrt{\sum_{i=1}^{m} xij^2}} \quad \text{for maximization objective, where } i = 1, 2, \ldots, m \text{ and } j = 1, 2, \ldots, n \quad (19)$$

Then, normalized decision matrix is obtained as:

$$R = \begin{bmatrix} r11 & r12 & \cdots & r1n \\ r21 & r22 & \vdots & r2n \\ \cdots & \cdots & \vdots & \cdots \\ rm1 & rm2 & \ldots & rmn \end{bmatrix} \quad (20)$$

**Step 4:** Considering the different weights of each criterion, the weighted normalized decision matrix is computed by multiplying the importance weight of evaluation criteria and the values in the normalized decision matrix. The weighted normalized decision matrix $\tilde{V}$ for each criterion is defined as:

$$\tilde{V} = [\tilde{V}_{ij}]_{mxn} \quad \text{for } i = 1, 2, \ldots, m \text{ and } j = 1, 2, \ldots, n \quad (21)$$

Where $\tilde{V}_{ij} = r_{ij} \times \tilde{o}_j$

Here $\tilde{V}_{ij}$ denotes normalized positive triangular fuzzy numbers.

**Step 5:** Then fuzzy positive ($\tilde{A}^*$) and fuzzy negative ($\tilde{A}^-$) ideal solutions are determined as follows:

$\tilde{A}^* = (\tilde{v}_1^*, \tilde{v}_2^*, \ldots, \tilde{v}_n^*)$ where

$\tilde{V}_j^* = \left\{\max_i(vij1),\ \max_i(vij2), \max_i(vij3)\right\}$ and

$\tilde{A}^- = (\tilde{v}_1^-, \tilde{v}_2^-, \ldots, \tilde{v}_n^-)$ where

$\tilde{V}_j^- = \left\{\min_i(vij1),\ \min_i(vij2), \min_i(vij3)\right\}$

for i = 1, 2, …, m and j = 1, 2, …, n (22)

**Step 6:** Then the fuzzy distance of each alternative from fuzzy positive and fuzzy negative ideal solutions are calculated as:

$$\tilde{a}_i^* = \sqrt{\sum_{j=1}^{n}(\tilde{v}_j^* - \tilde{v}_{ij}^*)} \quad \text{and} \quad \tilde{a}_i^- = \sqrt{\sum_{j=1}^{n}(\tilde{v}_j^- - \tilde{v}_{ij}^-)} \quad i = 1, 2, \ldots, m \tag{23}$$

**Step 7:** Then the fuzzy closeness coefficient $\tilde{N}$ is determined as:

$$\tilde{N}_i = \frac{\tilde{a}_i^-}{\tilde{a}_i^* + \tilde{a}_i^-} \quad i = 1, 2, \ldots, m \tag{24}$$

The fuzzy closeness represents the distances to the fuzzy positive ideal solution and the fuzzy negative ideal solution simultaneously.

**Step 8:** The fuzzy closeness coefficient defuzzified as follows:

$$N_i = \sqrt[3]{N_{i1} \cdot N_{i2} \cdot N_{i3}} \tag{25}$$

Fuzzy AHP and Fuzzy TOPSIS procedures and required calculations have been coded/solved by using MATLAB program.

### 3.3. Selection of Natural Gas Energy Resources in all sectors of Turkey: Projects Dimensions and Evaluation Model

Turkey's natural gas energy resources in all sectors, i.e. measuring scale, consists of 7 dimensions-main criteria and 31 evaluation factors-sub-criteria. In the process of prioritization of criteria, subcriteria and alternatives, the DMs used in the selection process was consulted. A questionnaire was developed following the methodology proposed for the below methods, which was answered by 18 experts/DMs.

In the study 7 main criteria, i.e. Technical Criteria (C1), Economic Criteria (C2), Natural Gas Hub Criteria (C3), Socio-Political Aspect (C4), Environmental Criteria (C5), Gas Transmission System Availability Criteria (C6), Risk Criteria (C7) and 31 related subcriteria are evaluated/assessed by each expert/DM. For the case of prioritization of the criteria, after the aggregation process performed with the answers of the 18 experts, the comparison matrix was obtained. The pairwise comparison matrices for subcriteria and alternatives are calculated.

Subsequently, the normalized pairwise comparison matrix of criteria was obtained. The priority vector and the CR for the criteria were obtained. To obtain the other priorities, the same procedure presented for the criteria was applied. In order to facilitate the calculations; which enters the individual judgments of the experts and generates the local and global preferences of all levels of the hierarchical tree (criteria and subcriteria).

Hereunder, Turkey's natural gas energy resources used in all sector's main criteria and related sub-criteria are described:

### 3.3.1. Technical Criteria

The technical aspect is an important part of choosing natural gas resources. The criteria define the technical relevance of the natural gas related issues/equipments to be implemented according to the scope established in the following subcriteria; i.e. Technology Maturity, Efficiency, Capacity Factor, Spare parts availability, Infrastructure.

### 3.3.2. Economic Criteria

The economic criteria allow for incorporation of the benefits and costs incurred in implementing the project, according to the scope established in the below subcriteria. The economic aspect is significant for the selection and ranking of usage of natural gas in Turkey. The various sub-criteria have been identified from economic perspectives which are; Investment costs, Operation and Maintenance (O&M) Cost, Resource Potential, Price, Reliability & Feasibility, Payback period.



### 3.3.3. Natural Gas Hub Criteria

The establishment of a natural gas hub in Turkey can unlock significant benefits, that would support the country's economic, environmental, and energy security goals. While a hub would not bring foreign exchange earnings to Turkey from exports of its indigenous production and transit gas exports, it would enable such earnings for associated financial and physical services, providing foreign exchange revenues for Turkish investors and traders. A hub would also help facilitate energy investments in domestic gas production in Turkey, especially in shale gas production, where the period from investment to payoff tends to be much briefer than for conventional production. The related sub-criteria are; Gas Resource Diversity, Economic Benefits, Price Stability, Energy Security.

### 3.3.4. Socio-Political Aspect

The socio-political aspect is crucial for the natural gas projects in Turkey. Similarly, this aspect has important sub-criteria and each of these has been described here: Public Acceptance, Energy Security, Institutional Arrangement, Regulatory Mechanism.

### 3.3.5. Environmental Criteria

The environmental criteria incorporate the impact of the implementation of the energy project/system in the environment, according to the scope established in the following subcriteria; GHG Emissions, Pollution, Requirement of Land, Visual Impact, Hazardous Waste, Impact on Environment.

### 3.3.6. Gas Transmission System Availability Criteria

The gas transmission system availability is an important part of choosing an optimal project. Since it will reduce the cost of energy projects significantly. The related sub-criteria are; Gas Transmission Line System Availability, Efficiency, Capacity Factor,

### 3.3.7. Risk Criteria

With the risk criteria, the objective is to incorporate the risks to which the system is exposed to the occurrence of unforeseen situations but that can significantly affect its functioning. The related sub-criteria are; Natural phenomena, Investment risk, Storage and Interconnections risks, Technological obsolescence.

### 3.4. Determining the evaluation criteria weights with Fuzzy AHP Approach

Firstly, each DM practiced pair-wise comparisons of Turkey's natural gas demand's dimensions and evaluation factors by using fuzzy AHP. Using the survey data acquired from these experts, integrated pair-wise comparison matrices are formed by combining all expert opinions. Thus, the pair-wise comparison values are converted to triangular fuzzy numbers and fuzzy pair-wise comparison matrices are created, presented in Table 3.

$$l_{ij} = \min_k\{a_{ijk}\} \qquad n_{ij} = \frac{1}{K}\sum_{j=1}^{K} b_{ijk} \qquad u_{ij} = \max_k\{c_{ijk}\} \tag{26}$$



Table 3. Fuzzy mutual criteria comparison

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 |
|---|---|---|---|---|---|---|---|
| C1 | (1, 1, 1) | (3, 5, 7) | (5, 7, 9) | (5, 7, 9) | (7, 9, 11) | (7, 9, 11) | (7, 9, 11) |
| C2 | (1/7, 1/5, 1/3) | (1, 1, 1) | (1, 3, 5) | (5, 7, 9) | (7, 9, 11) | (5, 7, 9) | (5, 7, 9) |
| C3 | (1/9, 1/7, 1/5) | (1/5, 1/3, 1) | (1, 1, 1) | (3, 5, 7) | (7, 9, 11) | (7, 9, 11) | (3, 5, 7) |
| C4 | (1/9, 1/7, 1/5) | (1/9, 1/7, 1/5) | (1/7, 1/5, 1/3) | (1, 1, 1) | (1, 7, 9) | (3, 5, 7) | (1, 3, 5) |
| C5 | (1/11, 1/9, 1/7) | (1/11, 1/9, 1/7) | (1/11, 1/9, 1/7) | (1/9, 1/7, 1) | (1, 1, 1) | (1, 3, 5) | (1, 3, 5) |
| C6 | (1/11, 1/9, 1/7) | (1/9, 1/7, 1/5) | (1/11, 1/9, 1/7) | (1/7, 1/5, 1/3) | (1/5, 1/3, 1) | (1, 1, 1) | (1, 7, 9) |
| C7 | (1/11, 1/9, 1/7) | (1/9, 1/7, 1/5) | (1/7, 1/5, 1/3) | (1/5, 1/3, 1) | (1/5, 1/3, 1) | (1/9, 1/7, 1) | (1, 1, 1) |

After acquiring the fuzzy comparison matrices, importance weights of natural gas demand's dimensions; evaluation criteria is calculated by the FAHP method. According to the calculated criteria weights for natural gas demand's weights; the most important evaluation dimension/main-criteria is "Natural Gas Hub Criteria" with 0.247 importance weight, the second important evaluation dimension is "Economical Criteria" with 0.152 importance weight and the third important evaluation dimension is "Environmental Criteria" with 0.119 importance weight.

### 3.5. Ranking the alternatives by Fuzzy TOPSIS methods

For the evaluation of Turkey's natural gas sector's demands, Fuzzy TOPSIS approach is conducted with the collected data of DM's surveys/interviews. Primarily, the linguistic variables of the alternatives are created. By the help of criteria weights, Fuzzy TOPSIS method's steps are performed/completed and Turkey's natural gas sectors that affect demand are ranked from the best to the worse. Primarily, the linguistic variables of the alternatives are created thusly in Table 4.

Table 4. Linguistic Variables of the Alternatives in Fuzzy TOPSIS method

| Criteria / Sectors | C1 | C2 | C3 | C4 | C5 | C6 | C7 |
|---|---|---|---|---|---|---|---|
| Household | SA | SA | SA | SA | SA | SA | SDA |
| Industry | SA | A | SA | A | SA | A | SDA |
| Energy | SA | SA | SA | SA | SA | SA | SDA |
| Transportation | A | LA | SA | A | A | A | SDA |
| Public service | SA | SA | SA | SA | A | SA | DA |
| Fishing, agriculture, forestry | A | A | A | SA | LA | A | DA |

Then Fuzzy TOPSIS method is used for the ranking of 6 main natural gas sectors according to the relative distance values of alternatives (CCi). Since natural gas sector has 10 values between 2020 to 2030, the values of indicators are set into triangular fuzzy numbers.

Utilizing the method of triangular fuzzy numbers, the fuzzy numbers of financial ratios are obtained. After applying the steps in Fuzzy TOPSIS method, i.e. defined steps in Section 3.2., natural gas sector's performance scores are ranked. The ranking of the alternatives is as follows: Energy (first ranked), Industry (second ranked), Household (third ranked), Transportation (fifth ranked), Public service, Fishing, agriculture, forestry. The reason of it is in energy sector; gas-fired power plants has operational flexibility and allows natural gas to respond to both seasonal and short-term demand fluctuations and to enhance electricity supply security in power systems.

## 4. CONCLUSION AND DISCUSSIONS

Natural gas is the fastest growing fossil fuel, accounting today for 23% of global primary energy demand and nearly a quarter of electricity generation. Being the cleanest burning fossil fuel, natural gas provides a number of environmental benefits compared to other fossil fuels, particularly in terms of air quality and greenhouse gas emissions. The natural gas market is becoming increasingly globalized, driven by the availability of shale gas and the rising supplies of flexible liquefied natural gas. As natural gas trade increases, so does the interconnectivity of gas markets, creating new facets and dimensions of natural gas security, as a demand or supply shock in one region will have repercussions in others.

In Turkey natural gas is still the primary source for electricity production. However, Turkey does not have indigenous resources and imports more than 98.0% of the natural gas it consumes. Turkey's natural gas main transmission grid is fed by six international pipelines, i.e. West Line, Blue Stream, Eastern Anatolian, Baku-Tbilisi-Erzurum Pipelines, Turk Stream, TANAP. Furthermore, the grid incorporates four LNG terminals including two FSRUs as well as two Underground Natural Gas Storage Facilities.

Turkey has long been developing plans to avail itself of the opportunities offered by its geographical location offers and has taken on the mission of acting as a bridge for natural gas transmissions to EU, i.e. being energy hub in the region. In recent years, Turkey has started and completed the construction of new international transit energy projects, i.e. TANAP, Turk Stream. Turkey is geographically located between energy producing countries of its region with more than 75% of the world's proven oil and gas reserves and the well-developed European energy consumer markets. This privileged natural position provides Turkey with both opportunities and responsibilities in terms of energy security.

In the study, fuzzy mathematical model (by using fuzzy AHP and fuzzy TOPSIS) is developed to calculate Turkey's natural gas demand under high and low scenarios. Turkey's natural gas energy resources in all sectors, i.e. measuring scale, consists of 7 dimensions-main criteria and 31 evaluation factors-sub-criteria. In the process of prioritization of criteria, subcriteria and alternatives, the DMs used in the selection process was consulted. A questionnaire was developed following the methodology proposed for the below methods, which was answered by 18 experts/DMs.



And in the study 7 main criteria, i.e. Technical Criteria (C1), Economic Criteria (C2), Natural Gas Hub Criteria (C3), Socio-Political Aspect (C4), Environmental Criteria (C5), Gas Transmission System Availability Criteria (C6), Risk Criteria (C7) and 31 related subcriteria are evaluated/assessed by each expert/DM. For the case of prioritization of the criteria, after the aggregation process performed with the answers of the 18 experts, the comparison matrix was obtained. The pairwise comparison matrices for subcriteria and alternatives are calculated. Subsequently, the normalized pairwise comparison matrix of criteria was obtained. The priority vector and the CR for the criteria were obtained. To obtain the other priorities, the same procedure presented for the criteria was applied. In order to facilitate the calculations; which enters the individual judgments of the experts and generates the local and global preferences of all levels of the hierarchical tree (criteria and subcriteria).

In the study, firstly, each DM practiced pair-wise comparisons of Turkey's natural gas demand's dimensions and evaluation factors by using fuzzy AHP. Using the survey data acquired from these experts, integrated pair-wise comparison matrices are formed by combining all expert opinions. Thus, the pair-wise comparison values are converted to triangular fuzzy numbers and fuzzy pair-wise comparison matrices are created. After acquiring the fuzzy comparison matrices, importance weights of natural gas demand's dimensions; evaluation criteria is calculated by the FAHP method. According to the calculated criteria weights for natural gas demand's weights; the most important evaluation dimension/main-criteria is "Natural Gas Hub Criteria" with 0.247 importance weight, the second important evaluation dimension is "Economical Criteria" with 0.152 importance weight and the third important evaluation dimension is "Environmental Criteria" with 0.119 importance weight.

In the study Fuzzy TOPSIS method is used for the ranking of 6 main natural gas sectors according to the relative distance values of alternatives. After applying the steps in Fuzzy TOPSIS method, i.e. defined steps in Section 5.2., natural gas sector's performance scores are ranked. The ranking of the alternatives is as follows: Energy (first ranked), Industry (second ranked), Household (third ranked), Transportation (fourth ranked), Public service, Fishing, agriculture, forestry. The reason of the selection of energy is; in energy sector gas-fired power plants has operational flexibility and allows natural gas to respond to both seasonal and short-term demand fluctuations and to enhance electricity supply security in power systems.

MoE has made direct investments to provide natural gas services to more consumers throughout Turkey, as well as the significant expansion of natural gas distribution infrastructures. FMCDM's results show that Turkey natural gas sector's supply contracts should have been secured from more diversified sources of foreign supply and being energy hub in the region. These investments and take-or-pay contracts were needed to meet Turkey's growing energy needs, especially to supply modern energy services. Turkey could take to advance the establishment of a natural gas hub is the elimination of destination clauses in gas contracts. An added benefit of this would be the increased progress towards cost-reflective pricing, a benefit for both Turkey and EU's energy consumers.

Competitive energy markets are a desirable goal for the future of energy. Measured, purposeful, and thoughtful actions that are objectively analyzed and transparently developed are the right path. Turkey should continue to build on its current laws and policies that lay the groundwork for the privatization of its energy markets. It should divest natural gas contracts to private parties while continuing to ensure investment in critical infrastructures such as natural gas storage and regasification terminals. Turkey's energy hub will bring the stability, flexibility, and liquidity to the energy sector and the region.



In the study, between 2020 and 2030 under high demand scenario natural gas usage in Turkey will increase by 35% and reach appox. 79 bcm, and under low demand scenario Turkey's total natural gas demand will decrease by approx. 7% and reach approx. 40 bcm. And Oxford Institute for Energy Studies (OIES) forecast that natural gas demand in Turkey would grow modestly but steadily and might reach 67–70 bcm/year by 2030.

Turkey's natural gas infrastructure is growing and importing natural gas from more diversified sources of supply, actions that enhance the role of natural gas in Turkey and the region. Many regulatory and market changes are already in line with Turkey's goals to privatize its electricity and natural gas markets, although much work remains to be done. Progress towards a Turkish natural gas hub would depend on continued implementation of these reforms and realization of new energy projects. By considering these scenarios Turkey is developing energy projects/contracts for transporting natural gas to be produced/extracted/contracted in the neighbouring regions, i.e. middle East region, Caucasus region, Caspian region, East Mediterranean-offshore region… to EU through Turkey that will decrease the natural gas price in Turkey and EU. By constructing new international natural gas pipelines, as well as other recent investments in natural gas distribution and LNG infrastructure could enhance Turkey's position as an energy bridge from hydrocarbon-rich states to Europe.

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