**M A R M A R A U N I V E R S I T Y**

F ACULTY OF ENGINEERING

# ENERGY ANALYSIS AND MAKE %100 SUSTAINABLE RENEWABLE ENERGY IN ISTANBUL STUDENT PROJECT I

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**By**

**MEHMET BULAT - YAKUP KALALİ**

**SUBMITTED TO THE DEPARTMENT OF MECHANICAL ENGINEERING IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE**

**OF**

**BACHELOR**

**OF SCIENCE**

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**MARMARA**

**UNIVERSITY**



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## ABSTRACT

Renewable energy is generated from natural processes that are continuously replenished. This includes sunlight, geothermal heat, wind, tides, water, and various forms of biomass. This energy cannot be exhausted and is constantly renewed. Renewable energy is a term used for an energy source that is an alternative to using fossil fuels. Generally, it indicates energies that are non-traditional and have low environmental impact. The term alternative is used to contrast with fossil fuels according to some sources. By most definitions alternative energy doesn't harm the environment, a distinction which separates it from renewable energy which may or may not have significant environmental impact.

When we look up today’s energy consumption and production levels, it is obvious that the energy planning of the cities should be done by up-to-date and scientific methods with the help of sustainable road maps. To achieve this, one must analyze the needs of the cities, have sufficent information about the sectors and utilize the potential on an optimum level. The TIMES method is a proven method in order to build energy models of the countries and cities via technology rich energy, economy, ecology and engineering approach.

In this thesis, Istanbul province selected as example region to build an energy model and road map.

# SYMBOLS

**TWh:** Terawatthour

**$CO_2$:** CarbonDioxide

**ktoe:** 1000 tonsofoilequivalent

**Mt:** Millionton

**GW.h/a:** Gigawatthourannum

**MW/a:** Megawattannum

**bcm:** billioncubicmeters

**t:** ton

**kj/kg:** kilojouleperkilogram

**MW:** Megawatt

**$m^3$**: Cubicmeter

**$kWh/m^2.day$:** Kilowatthourpersquaremeterperday

**GW:** Gigawatt

**$kWh/m^2.year$:**Kilowatthourpersquaremeterperyear

**ha:** Hectare

**$^oC$** : CentigradeCelsius

**MVA:** MegavoltAmpere

**PJ:** Petajoule

**MWh:** Megawatthour

**$:** USdollar

**USD/kWh:** UnitedStatesdollarsperkilowatthour

**MWe:** MegawattElectrical

**$/kg.H_2$:** Dollarperkilogram hydrogen

**Kg/day:** Kilogram perday

**$H^+$** : Hydrogenions

**$W/m^2$: Wattpersquaremeter**

**$Km^2$**: Squareofkilometer

**kt:** Kilotons

# ABBREVIATIONS

**BAU:** Business as Usual

**BOTAŞ:** Petroleum Pipeline Company

**CEA:** City Energy Analyst

**EMRA:** Energy Market Regulatory Authority

**ETSAP:** Energy Technology System Analysis Program

**EU:** European Union

**GHG:**Greenhouse Gasses

**HOMER:**Hybrid Optimization of Multiple Energy Resource

**HVAC:**Heating Ventilating and AirConditioning

**IEA:**International Energy Agency

**IMF:**International Monetary Fund

**KTEP:**Kilo Tone Equivalent of Petroleum

**LEAP:**Long Range Energy Alternatives Planning System

**OPEC:**Organization of Petroleum Exporting Countries

**MAED:**Model for Analysis of Energy Demand

**MARKAL:**Market Allocation

**MENR:**Ministry of Energyand Natural Resources

**MTEP:**Million tons of equivalent of petroleum

**NREL:**National Renewable Energy Laboratory

**PEM:**Proton Exchange Membrane

**PV:**Photovoltaic

**REP:**Reformer-Electrolyzer-Purifier

**RES:**Reference Energy System

**RETScreen:**RETScreen Clean Energy Management Software

**TFC:**Total Final Consumption

**TIMES:** Time Integrated Markal-Efom System

**TPES**:Total Primary Energy Supply

**TURKSTAT:**Turkish Statistical Institute

**USA:**United States of America

**MTA:**Mineral Researchand Exploration

## FIGURES



## LIST OF TABLES

# CHAPTER 1 – INTRODUCTION

## 1.1 The Problem and The Brief Solution

Energy is the most important aspect of the life. From a single human cell to biggest countries, energy is the driving force of those systems. Thermodynamic laws and modern science tell us the energy is limited and it can't be created nor destroyed. Within this limits, human being must learn to live with finite energy sources in their environments. We call this environment as "Earth". If we go further, these environments become continents, countries, states, provinces and even towns, neighborhoods and our homes.

Today, total population of world become 7.6 billion person and total energy consumption reached to nearly 110,000 TWh. Only 6.3% of this consumption is being produced by renewable sources such as solar, wind, bio and geothermal energy. This means nearly 93.7% of total energy consumption is to meet by conventional energy sources. Which shows us, world is consuming their finite energy sources. Worse than to use finite sources, conventional fuels are releasing highly toxic greenhouse gasses to our environment.

This brief overlook proves that, humankind must lean clean sources to provide their energy needs. Rather than conventional sources, renewables such as solar, wind, biomass and geothermal are rejuvenating by earths periodic movement around the sun. This movement creates relatively infinite and clean energy.

## 1.2 Conducted Studies and Aim

There are 4 fundamental steps to create clean and sustainable environments. First step is the increase of renewable share in energy production methods. Second step is the efficient use of energy. Third step is the renovating old fashion power lines with the smart grid. Fourth and final step is to plan this complex supply-demand web by the most scientific and contemporary methods. Answer-TIMES is the modern and scientific method that to build and evaluate the countries and cities by mathematical approach. Answer-TIMES is based on technology rich structure and fortified by energy-economy-ecology data.

By the light of this 4-fundamental information, this study aims to create a reference energy system of Istanbul province with Answer-TIMES between 2016-2031 to analyze alternative energy technology strategies with scenarios. Particularly, objective of this thesis is to find answers to the following questions.

- What is the cost of 100% renewable energy transition in Istanbul province?
- What is the potential of bioenergy sources and effect to the Istanbul energy system?

• Cost of greenhouse gas mitigation scenarios by implementation of various alternative scenario and technologies.

• Implementation of Turkish Government official renewable energy targets to Istanbul province.

• Cost and effects of the storage technologies.

Developed countries are already using the energy modelling methods since 1990's in their regional roadmaps. For example, in 2001 a study carried out by Chen Wenying and Wu Zongxin in Tsinghua University about China's future sustainable energy development strategies. The study aimed to find increasing the share of renewable energy and mitigation of greenhouse gasses across the China. Energy model created between 1995-2050 with the future business as usual projections. Then, alternative scenarios written about CO2 mitigation via application of advanced thermal power generation, increasing the share of renewables and nuclear power. Also, the energy model looked for syngas production via coal to promote clean energy in urban use [1].

Another country level energy modelling study made for Romania. In this study Roman Kanala, Emmanuel Fragniere, Francesco Moresino created Romanian energy model about social behaviors in residential heating. Residential heating described into system by three technologies; envelope, heating system and consumer behavior. Aim of this study to find about public behavior changes in residential heating for designing better policies. Also related study shows that TIMES can model the social behaviors.[2]

An important study conducted about France. Edi Assoumou and Nadia Maizi created the France energy model to find differences between official and worldwide guidelines about carbon value assumptions. Results shows that official carbon value reports are 4 times lower than other methodologies for 2050 and 14 times lower than 2020 data. Experts pointing out that it is only possible to reach that levels by optimistic combination of assumptions [3].

Country level energy planning studies are very important for governmental level, but another dimension is cities and urban studies. Comodi, Cioccolanti and Gargiulo carried out a study about Italian seaside town named Pesaro. Researchers aimed to find effectiveness of local-scale energy policies in three sectors: household, transport and public sector. They evaluated the city Pesaro in three different approach: business as usual, exemplary public sector and exemplary municipality. They also add the effects of increasing summer tourism and seasonal consumption. Researchers evaluated micro-cogeneration alternatives for local targets. In this research the results showed that best way to achieve the local targets are replacement of old

technologies with the more efficient ones, improvement of building energy performances and promoting renewable options such as PV, solar thermal and micro-cogeneration.[4]

An interesting research conducted for California, United States. Christopher Yang and Joan Ogden from University of California made an energy model for evaluation of renewable and low carbon hydrogen production alternatives for long term (2050) fuel infrastructure. The research evaluated the impact of policies on renewables and low carbon hydrogen pathways. In the conclusion, they found that low-cost and low-carbon hydrogen is only achievable in the medium-long term period. And, the study points out that carbon capture and sequestration is important to achieve the goals of the state.[5]

In the energy modelling studies, researchers usually dealing with the small portion of the problems of the domains to tackle the problems one by one. But in some researches, experts can aim to achieve 100% renewables. It was not possible to reach 100% renewable communities twenty years ago because of the investment cost of the renewables. But now, drastically dropping technology costs are allowing to achieve 100% renewable communities. Because of this, researchers from France and Schneider-Electric aimed to convert Reunion Island-France to 100% renewable powered community by the end of the 2030. The results show that researchers achieved the 100% renewable energy by lowering the demands 10% and putting renewable energy in to use. In the research, coal, distillate fuel oil and heavy oil burners shut down by the end of the 2030 and instead of conventional sources, hydro, ocean thermal conversion, solar, wave energy converters, wind, geothermal, sugarcane bagasse and municipal waste facilities put in use to meet the islands demands. Among the other researches, especially this study is crucial to see how to achieve 100% renewable communities by symphony of every possible renewable options.[6]

For previous semester of this project we've gained lot of informations about Answer times energy module. This project we learnd how can we put data values we obtained how to show RES system of the Istanbul City. This project, researches and predictions experience create energy system.

In chapter 2, general background will be given about Turkish energy outlook and forecasts. In this chapter, socio economic and potentials of Istanbul will be discussed. In chapter 3, Answer-TIMES methodology, formulations, parameters and datasets will be discussed. Addition to chapter three, to create the Istanbul Answer-TIMES model, reference energy system, parameters and data sets will be introduced. In the final chapter, the results and discussions finalize the study.

## CHAPTER 2 - BACKROUND

### 2.1 Istanbul Electricity, Natural Gas, LPG, Coal and Petroleum

#### 2.1.1 Electricity

Istanbul's power plant installed power is 2,764 MW. The power plants in Istanbul, which have a total of 52 power plants, generate approximately 6.474 GW of electricity annually. The electricity distribution service of Istanbul is provided by BEDAŞ on the European side and AYEDAŞ on the Anatolian side.[7]

| İstanbul Enerji Santralleri Profili | |
|---|---|
| Aktif Santral Sayısı : | 52 |
| Kurulu Güç : | 2.764 MW |
| Kurulu Güce Oranı : | % 2,98 |
| Yıllık Elektrik Üretimi : | ~ 6.474 GWh |
| Türkiye Tüketimine Oranı : | % 2,13 |
| Lisans Durumu : | 37 lisanslı, 15 lisanssız |

Figure-1: Istanbul Power Plants Profile

| İstanbul Elektrik Santrali Tipleri | | |
|---|---|---|
| Güneş | 2,94 MW | 0,1 % |
| Rüzgar | 260,95 MW | 9,4 % |
| Jeotermal | 0,00 MW | 0,0 % |
| Biyogaz | 52,96 MW | 1,9 % |
| HES | 0,00 MW | 0,0 % |
| Doğalgaz | 2.447,17 MW | 88,5 % |
| Kömür | 0,00 MW | 0,0 % |
| Diğer | 0,00 MW | 0,0 % |

Figure-2: Istanbul Power Plants Types

Turkey while producing 304 TWh of electricity in 2018, according to data serves 303 TWh consumption. When we look at these data, we can say that it can produce and consume its own energy. We see that it imports and exports energy to Greece, Bulgaria and Georgia countries and our neighboring regions. 88.66% of the total electricity imports of 2,211,506.39 MWh in 2019 were from Bulgaria, 11.17% from Georgia, and 0.17% from Greece. Of the total 2,788,667.28 MWh electricity exports in 2019, 95.66% was made to Greece and the remaining 4.34% to Bulgaria and Georgia.

According to current data, Istanbul produces 7,198,655 MWh of electricity, while consuming 39,518,502 MWh of electricity. Turkey's electricity transmission system, known as the 66 kV high voltage level, is an integrated system consisting of 154 kV and 400 kV networks. Therefore, it is not possible to determine the boundaries of the transmission system on a regional or provincial basis. However, transformer capacities within the provincial borders can give an idea about the electricity potential for these provinces. Nevertheless, due to the integrated electrical system, a transformer in the province can be connected to another transformer center

outside the city boundaries, and a production facility within the province may be connected to a transformer within the same province or within the borders of another province.

The city of Istanbul benefits from the Thrace Region on the European Side, and from Kocaeli, Bursa and Zonguldak provinces on the Anatolian Side and from the electricity transmission system with energy transmission lines.[8]

#### 2.1.1.1 Pricing

Electricity Market Law stipulates a market structure based on bilateral agreements. Electricity price in the said market is determined by mutual agreement of buyers and buyers. Therefore, the prices determined by bilateral agreements are within the knowledge of the relevant parties and are not shared with the public. On the other hand a significant portion of consumer electricity market in Turkey is to provide energy from subject to price regulation. For this reason, it is important to change the prices and price components subject to regulation over the years.[9]

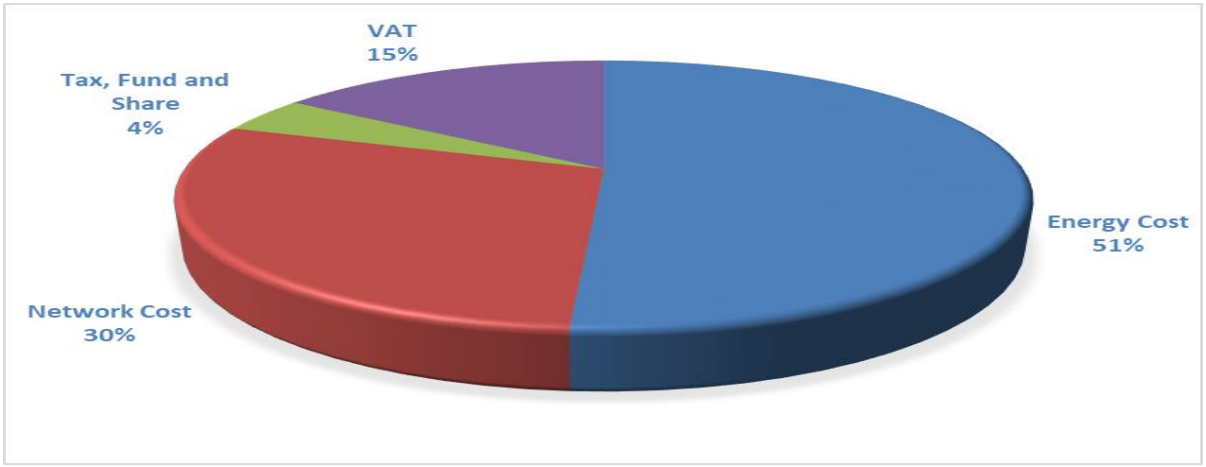


Figure-3: Share of Items on Residence Electricity Invoice in 2019 (%)

As can be seen from Figure-3 , the most important item out of the retail energy amount is the network amount with 30% share from the components in the invoices of consumers in the residential group.

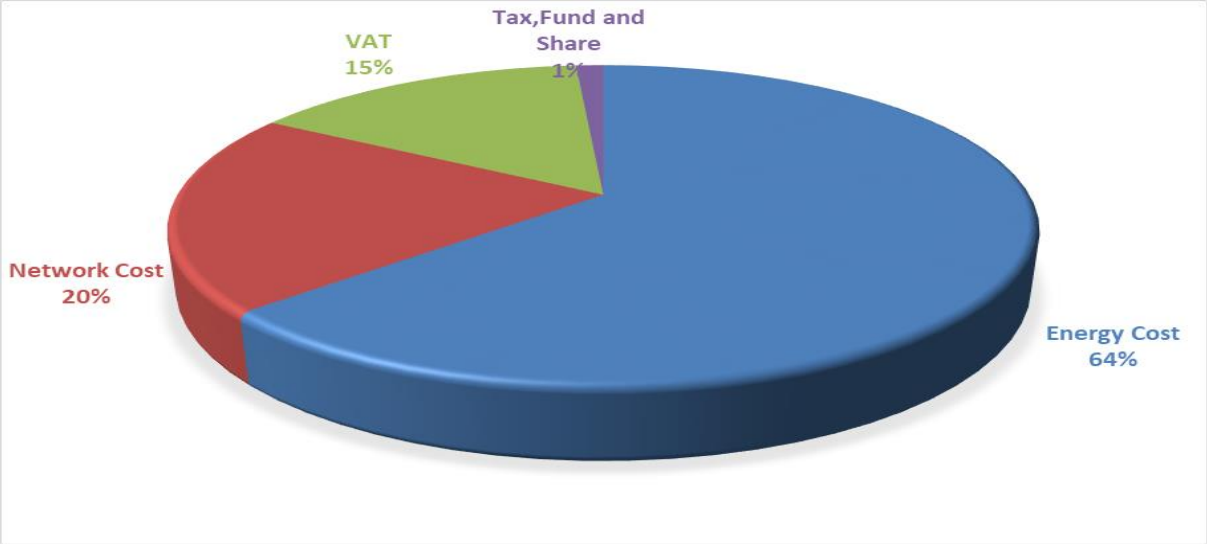


Figure-4: Share of Items on Industry Electricity Invoice in 2019 (%)

### 2.1.2 Natural Gas

Turkey's natural gas needs are imported almost all from abroad. Considering the fields where natural gas production is carried out, it is seen that the most production is made in the fields within the province of Istanbul with a share of 44.47%. Then Tekirdağ with 38.68% and Kırklareli with 11.64% follow.

| **Provinces/Months** | **January** | **February** | **March** | **April** | **May** | **June** | **July** | **August** | **September** | **October** | **November** | **December** | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| İSTANBUL | 16,78 | 18,19 | 20,40 | 20,61 | 19,76 | 17,09 | 18,70 | 16,20 | 17,38 | 16,72 | 14,69 | 14,20 | **210,71** |

Table-1: Monthly Natural Gas Production by Istanbul Province in 2019 (Million $Sm^3$)

The import quantities and shares realized between 2009 and 2019 are given in the Table-1 on the basis of the source country[10]

| **Countries** | **Russia** | | **Iran** | | **Azerbaijan** | | **Algeria** | | **Nigeria** | | **Other**** | | **Total** | **Change (%)** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Yıllar** | **Amount** | **Share (%)** | **Amount** | **Share (%)** | **Amount** | **Share (%)** | **Amount** | **Share (%)** | **Amount** | **Share (%)** | **Amount** | **Share (%)** | **Amount** | |
| **2009** | 19.473 | 54,31 | 5.252 | 14,65 | 4.960 | 13,83 | 4.487 | 12,51 | 903 | 2,52 | 781 | 2,18 | **35.856** | **-4** |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **2010** | 17.576 | 46,21 | 7.765 | 20,41 | 4.521 | 11,89 | 3.906 | 10,27 | 1.189 | 3,13 | 3.079 | 8,09 | **38.036** | **6,08** |
| **2011** | 25.406 | 57,91 | 8.190 | 18,67 | 3.806 | 8,67 | 4.156 | 9,47 | 1.248 | 2,84 | 1.069 | 2,44 | **43.874** | **15,35** |
| **2012** | 26.491 | 57,69 | 8.215 | 17,89 | 3.354 | 7,3 | 4.076 | 8,88 | 1.322 | 2,88 | 2.464 | 5,37 | **45.922** | **4,67** |
| **2013** | 26.212 | 57,9 | 8.730 | 19,28 | 4.245 | 9,38 | 3.917 | 8,65 | 1.274 | 2,81 | 892 | 1,97 | **45.269** | **-1,42** |
| **2014** | 26.975 | 54,76 | 8.932 | 18,13 | 6.074 | 12,33 | 4.179 | 8,48 | 1.414 | 2,87 | 1.689 | 3,43 | **49.262** | **8,82** |
| **2015** | 26.783 | 55,31 | 7.826 | 16,16 | 6.169 | 12,74 | 3.916 | 8,09 | 1.240 | 2,56 | 2.493 | 5,15 | **48.427** | **-1,7** |
| **2016** | 24.540 | 52,94 | 7.705 | 16,62 | 6.480 | 13,98 | 4.284 | 9,24 | 1.220 | 2,63 | 2.124 | 4,58 | **46.352** | **-4,28** |
| **2017** | 28.690 | 51,93 | 9.251 | 16,74 | 6.544 | 11,85 | 4.617 | 8,36 | 1.344 | 2,43 | 4.804 | 8,7 | **55.250** | **19,2** |
| **2018** | 23.642 | 47,02 | 7.863 | 15,64 | 7.527 | 14,97 | 4.521 | 8,99 | 1.668 | 3,32 | 5.061 | 10,21 | **50.282** | **-8,99** |
| **2019** | 15.196 | 33,61 | 7.736 | 17,11 | 9.585 | 21,20 | 5.678 | 12,56 | 1.756 | 3,88 | 5.260 | 11,63 | **45.211** | **-10,08** |

Table-2: Amount of Imported Natural Gas by Source Country between 2009-2019 (Million Sm3)

** Others represent the countries of imported spot LNG

As seen at Table-2 ; Turkey is dependent on imports mainly for the gas coming from Russia.

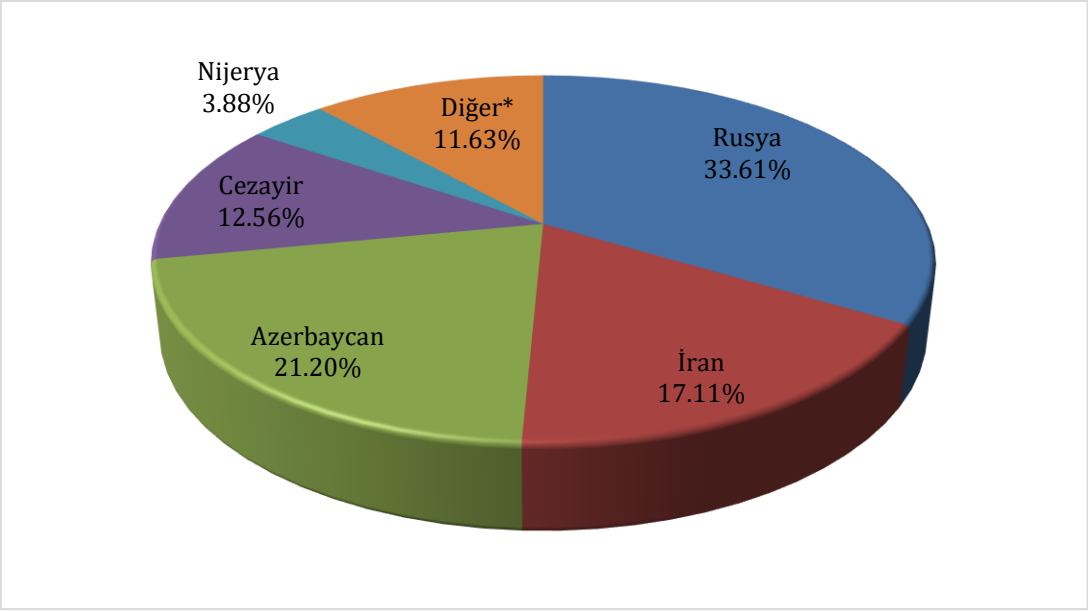


Figure-5: Amount of Imported Natural Gas by Source Country between 2009-2019 (Million Sm3)

* Other represents the countries of imported sport LNG.

Istanbul's share in the amount of national natural gas consumption realized as 45.285.498.42 $Sm^3$ in 2019 is given in the Table-3.

| Province | Pipeline | LNG | CNG | Auto LNG | Auto CNG | Total |
|---|---|---|---|---|---|---|
| İSTANBUL | 7.544,118 | 92,345 | 1,693 | 7,888 | | **7.646,043** |

Table-3 Distribution of National Natural Gas Consumption by Istanbul in 2019 ($Sm^3$)

Detailed Distribution of Natural Gas Sales by Companies and Sectors for Istanbul in 2019 (Sm3)

| İSTANBUL | License Type | Conversion / Cycle Sector | Energy Sector | Transportation Sector | Industry Sector | Service Sector | Household | Other | Total |
|---|---|---|---|---|---|---|---|---|---|
| AKPET GAZ ANONİM ŞİRKETİ | CNG License | | | | 12.588,53 | | | -81.955,22 | -69.366,69 |
| | Wholesale License | | | | 4.478.347,92 | 203.222,71 | | -1.972,06 | 4.679.598,57 |
| AYGAZ DOĞAL GAZ TOPTAN SATIŞ ANONİM ŞİRKETİ | Wholesale License | | | | 1.498.581,91 | | | 219.243,06 | 1.717.824,97 |
| BAHÇEŞEHİR GAZ DAĞITIM ANONİM ŞİRKETİ | Distubition License | | | | | 4.193.511,16 | 23.158.343,63 | | 27.351.854,78 |
| BOTAŞ (BORU HATLARI İLE PETROL TAŞIMA ANONİM ŞİRKETİ) | Import License | 1.177.127.661,23 | | | 57.009.033,09 | | | | 1.234.136.694,32 |
| GENİA TURKEY ENERJİ YATIRIMLARI ANONİM ŞİRKETİ | CNG License | | | | | 262.767,11 | | | 262.767,11 |
| GİTAŞ GAZ İŞLETMELERİ TAŞIMACILIK ANONİM ŞİRKETİ | CNG License | | | 547.979,31 | 3.469.350,34 | | | | 4.017.329,65 |
| HABAŞ SINAİ VE TIBBİ GAZLAR İSTİHSAL ENDÜSTRİSİ ANONİM ŞİRKETİ | CNG License | | | | 641.912,50 | 55.775,00 | 6.750,00 | 14.540,50 | 718.978,00 |
| | Wholesale License | | | | 40.285.813,00 | 10.873.881,00 | | 8.039.774,50 | 59.199.468,50 |
| İGDAŞ İSTANBUL GAZ DAĞITIM SANAYİ VE TİCARET ANONİM ŞİRKETİ | Distubition License | 173.617.422,60 | | | 455.388.267,43 | 1.360.769.155,00 | 4.285.382.403,00 | | 6.275.157.248,03 |
| İPRAGAZ ANONİM ŞİRKETİ | Wholesale License | | | | 4.752.017,00 | 83.158,00 | | 819.119,42 | 5.654.294,42 |
| NATURELGAZ SANAYİ VE TİCARET ANONİM ŞİRKETİ | CNG License | | | 7.335.164,81 | 767.445,04 | | | 4.428,40 | 8.107.038,25 |

| İSTANBUL | License Type | Conversion / Cycle Sector | Energy Sector | Transportation Sector | Industry Sector | Service Sector | Household | Other | Total |
|---|---|---|---|---|---|---|---|---|---|
| OMV ENERJİ TİCARET ANONİM ŞİRKETİ | Wholesale License | | | | 24.669.588,65 | 256.963,00 | | | 24.926.551,65 |
| OR-CAN DOĞAL GAZ TOPTAN SATIŞ DAĞITIM ANONİM ŞİRKETİ | Wholesale License | | | | 20.323,00 | | | | 20.323,00 |
| SERALGAZ SINAİ VE TIBBİ GAZLAR İNŞAAT MALZEMELERİ TİCARET VE SANAYİ LİMİTED ŞİRKETİ | CNG License | | | | 4.012,50 | | | | 4.012,50 |
| TEZ OKSİJEN SANAYİ VE TİCARET ANONİM ŞİRKETİ | CNG License | | | | 5.977,34 | 3.000,00 | | | 8.977,34 |
| TÜRKİYE PETROLLERİ ANONİM ORTAKLIĞI | Wholesale License | | | | 149.825,00 | | | | 149.825,00 |
| | TOTAL | 1.350.745.083,83 | | 7.883.144,12 | 593.153.083,25 | 1.376.701.432,98 | 4.308.547.496,63 | 9.013.178,60 | 7.646.043.419,40 |

Table-4: Detailed Distribution of Natural Gas Sales by Companies and Sectors for Istanbul in 2019 (Sm3)

### 2.1.2.1 Tariff and Pricing

Table-5 shows the average unit prices of natural gas that distribution and supply companies sell to the household and industrial customer in 2019 and breakdown of these unit prices. Average Unit Prices of Natural Gas Sold by Distribution and Supplier Companies to Household and Industrial Consumers in 2019 (TL / $Sm^3$)[11]

| | | Natural Gas Cost | System Usage Cost | VAT | SCT | Total |
|---|---|---|---|---|---|---|
| 2019 I. Half-Year | Household | 0,890014 | 0,228583* | 0,023 | 0,205487 | 1,347084 |
| | Industry | 1,351527 | 0,141521** | 0,023 | 0,272889 | 1,788937 |
| 2019 II. Half-Year | Household | 1,159498 | 0,267610* | 0,023 | 0,261019 | 1,711127 |
| | Industry | 1,516921 | 0,163925** | 0,023 | 0,306692 | 2,010538 |

Table-5: Average Unit Prices of Natural Gas Sold by Distribution and Supplier Companies to Household and Industrial Consumers in 2019 (TL / Sm3)

- The average of system usage prices counted as if between 0 – 100.000 $Sm^3$ consumption level

- The average of system usage prices counted as if between 100.001 – 1.000.000consumption level

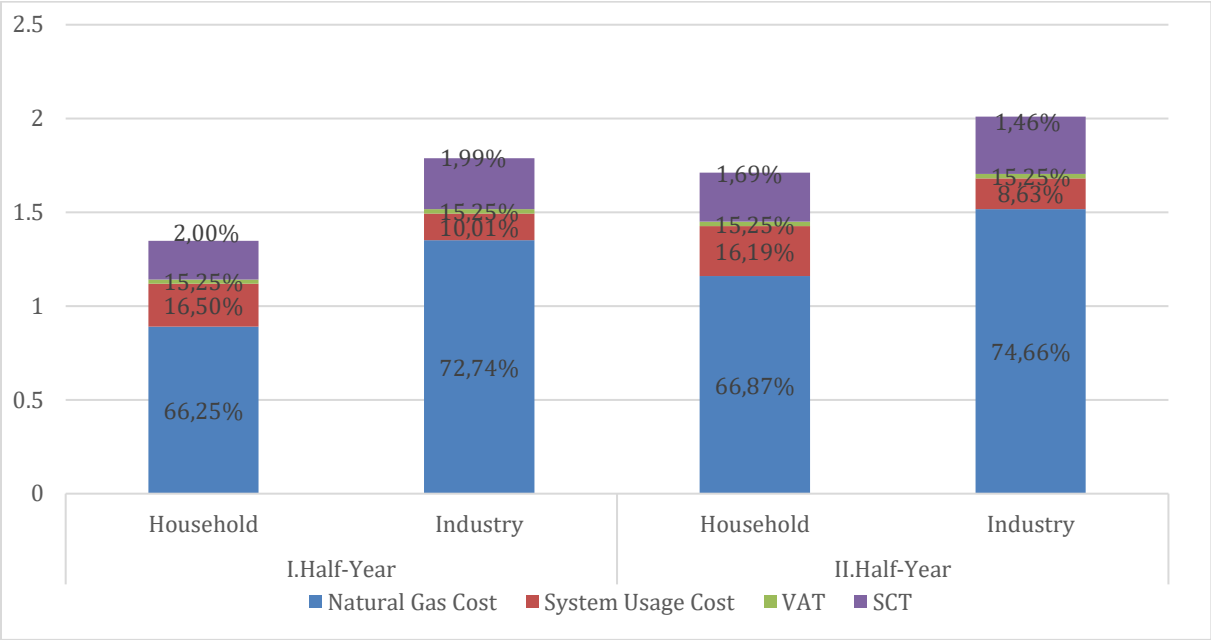


Figure-6: Pricing Graph

### 2.1.3 Coal

| Kömür ve Linyit Yakıtlı Termik Santraller Profili | |
|---|---|
| **Kayıtlı Santral Sayısı :** | 42 |
| **KTS Kurulu Güç :** | 20.300 MWe<br>Kayıtlı: 19.719 MWe |
| **Kurulu Güce Oranı :** | % 21,45 |
| **Yıllık Elektrik Üretimi :** | ~ 105.711 GWh |
| **Üretimin Tüketime Oranı :** | % 35,24 |

Table-6: Total Powe Plant Powers

There are many coal mines throughout Turkey, but Istanbul is not one of the major production cities. There are few mineral reserves.[12]

| Saha Adı | Rezerv (1000 ton) | | | | | | | | Analiz Sonuçları | | | | Eş değeri (1000 ton) | | Kullanım Yeri | İşletme Şekli |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Görünür | Muhtemel | Mümkün | Toplam | Kaynak | Potansiyel | Genel Toplam | İşletilebilir | Su % | Kül % | S % | AID KCal/kg | Petrol | Taş Kömürü | | |
| Şile Kirazlıyatak | 1.123 | - | - | 1.123 | - | - | 1.123 | 794 | 25,55 | 22,65 | - | 2915 | 327 | 468 | Teshin | Açık |
| Şile Üvezli | - | 4.868 | - | 4.868 | - | - | 4.868 | - | 25,55 | 22,65 | - | 2915 | 1.419 | 2.027 | Teshin | Açık |
| Şile Avcıkoru | - | 6.282 | - | 6.282 | - | - | 6.282 | - | 25,55 | 22,65 | - | 2915 | 1.831 | 2.616 | Teshin | Açık |
| Silivri Sinekli | 114.000 | 76.000 | - | 190.000 | - | - | 190.000 | - | 27,50 | 36,57 | - | 1908 | 35.046 | 50.066 | Teshin Sanayi | Kapalı |
| TOPLAM | 115.123 | 87.150 | - | 202.273 | - | - | 195.952 | 794 | | | | | 38.623 | 55.177 | | |

Table-7: Istanbul Mineral Reserves Analysis Table

### 2.1.4 LPG (Liquified Petroleum Gas)

**Production ;**

LPG production of refinery license holders increased by 17,98% with respect to previous year's production and reached to 1.081.577 tons in 2019.

**Import ;**

3.103.979 tons of LPG was imported by refinery, distribution and processing (petrochemical) license holders in 2019, representing 6,11% decrease with respect to LPG import in 2018.

In 2019, LPG was imported from 20 different countries/regions. In the order of highest import amount; Algeria, the USA, Kazakhstan, Norway and Russia represented the top 5 import countries.

**Export ;**

100.225 tons of LPG was exported by refinery and distribution license holders in 2019, representing 8,92% decrease with respect to LPG export in 2018.

In 2019, LPG was exported to 11 different countries/regions. In the order of highest export amount Switzerland, the Turkish Republic of Northern Cyprus, Lebanon, Greece and Egypt represented the top 5 export countries.

**Domestic LPG Sales ;**

728.643 tons of bottled LPG, 112.994 tons of bulk LPG and 3.354.429 tons of autogas LPG, and 4.177.612 tons of LPG in total were sold in 2019.

If LPG sales in 2019 are compared to LPG sales in the previous year; bottled LPG sale decreased by 2,88%, bulk LPG sale decreased by 16,33% and autogas sale increased by 2,17%. Accordingly, total LPG sales increased by 0,75%.

In 2019, bottled LPG had 17,44% market share, bulk LPG had 2,26% market share and autogas had 80,30% market share.

37.990 tons of standardized LPG was sold by distribution license holders in 2019.[13]

LPG Sales by Distributors in Istanbul Province in 2019

| License owner's | January-March | | April-June | | July-September | | October-December | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Amount (tons) | Share (%) | Amount (tons) | Share (%) | Amount (tons) | Share (%) | Amount (tons) | Share (%) | Amount (tons) | Share (%) |
| AYGAZ A.Ş. | 24.326 | 30,15 | 24.653 | 29,20 | 26.530 | 30,59 | 26.281 | 30,19 | **101.789** | **30,04** |
| SHELL & TURCAS PETROL A.Ş. | 12.761 | 15,81 | 14.697 | 17,41 | 15.456 | 17,82 | 15.361 | 17,65 | **58.274** | **17,20** |
| PETROL OFİSİ A.Ş. | 9.137 | 11,32 | 9.971 | 11,81 | 9.941 | 11,46 | 9.634 | 11,07 | **38.683** | **11,41** |
| BP PETROLLERİ A.Ş. | 6.954 | 8,62 | 7.811 | 9,25 | 7.912 | 9,12 | 7.179 | 8,25 | **29.856** | **8,81** |
| İPRAGAZ A.Ş. | 6.499 | 8,05 | 5.883 | 6,97 | 5.876 | 6,78 | 6.765 | 7,77 | **25.024** | **7,38** |
| GÜZEL ENERJİ AKARYAKIT A.Ş. | 4.824 | 5,98 | 4.575 | 5,42 | 4.752 | 5,48 | 4.598 | 5,28 | **18.750** | **5,53** |
| MİLANGAZ LPG DAĞITIM TİC. VE SAN. A.Ş. | 4.522 | 5,60 | 4.821 | 5,71 | 4.257 | 4,91 | 4.605 | 5,29 | **18.204** | **5,37** |
| AYTEMİZ AKARYAKIT DAĞITIM A.Ş. | 3.537 | 4,38 | 3.795 | 4,50 | 3.533 | 4,07 | 3.868 | 4,44 | **14.734** | **4,35** |
| NORM GAZ PETROL ÜRÜNLERİ SANAYİ TİC. A.Ş. | 2.197 | 2,72 | 2.372 | 2,81 | 2.723 | 3,14 | 2.809 | 3,23 | **10.100** | **2,98** |
| HABAŞ PETROL ÜRÜNLERİ SAN.VE TİC. A.Ş. | 1.366 | 1,69 | 1.333 | 1,58 | 1.349 | 1,56 | 1.553 | 1,78 | **5.601** | **1,65** |
| ENERJİ GAZ A.Ş. | 1.453 | 1,80 | 1.428 | 1,69 | 1.368 | 1,58 | 1.348 | 1,55 | **5.597** | **1,65** |
| TP PETROL DAĞITIM A.Ş. | 437 | 0,54 | 725 | 0,86 | 708 | 0,82 | 685 | 0,79 | **2.556** | **0,75** |
| ERGAZ SAN.VE TİC. A.Ş. | 476 | 0,59 | 432 | 0,51 | 548 | 0,63 | 613 | 0,70 | **2.069** | **0,61** |
| AKPET GAZ A.Ş. | 494 | 0,61 | 464 | 0,55 | 466 | 0,54 | 330 | 0,38 | **1.753** | **0,52** |
| YILDIRIM PETROL TİCARET VE NAKLİYAT A.Ş. | 442 | 0,55 | 451 | 0,53 | 369 | 0,43 | 250 | 0,29 | **1.513** | **0,45** |
| KADOOĞLU PETROLCÜLÜK TAŞIMACILIK TİCARET SANAYİ İTHALAT VE İHRACAT A.Ş. | 360 | 0,45 | 267 | 0,32 | 296 | 0,34 | 341 | 0,39 | **1.264** | **0,37** |

| License owner's | January-March | | April-June | | July-September | | October-December | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Amount (tons) | Share (%) | Amount (tons) | Share (%) | Amount (tons) | Share (%) | Amount (tons) | Share (%) | Amount (tons) | Share (%) |
| YURTPET AKARYAKIT LPG DAĞITIM PAZARLAMA SAN.VE TİC. LTD. ŞTİ. | 349 | 0,43 | 298 | 0,35 | 285 | 0,33 | 236 | 0,27 | **1.167** | **0,34** |
| STAR SIVILAŞTIRILMIŞ GAZLAR DAĞITIM VE PAZARLAMA A.Ş. | 356 | 0,44 | 242 | 0,29 | 89 | 0,10 | 109 | 0,13 | **797** | **0,24** |
| ARGAZ LPG DOLUM TEVZİİ İNŞ. SAN.VE TİC. A.Ş. | 99 | 0,12 | 100 | 0,12 | 89 | 0,10 | 86 | 0,10 | **373** | **0,11** |
| ERAGAZ PETROL ÜRÜNLERİ SAN.VE TİC. A.Ş. | 22 | 0,03 | 33 | 0,04 | 93 | 0,11 | 223 | 0,26 | **371** | **0,11** |
| GÜVENAL GAZ SAN.VE TİC. A.Ş. | 44 | 0,05 | 29 | 0,03 | 35 | 0,04 | 51 | 0,06 | **159** | **0,05** |
| TERMOPET AKARYAKIT A.Ş. | 14 | 0,02 | 24 | 0,03 | 25 | 0,03 | 27 | 0,03 | **90** | **0,03** |
| ECOGAZ LPG DAĞITIM A.Ş. | 0 | 0,00 | 0 | 0,00 | 0 | 0,00 | 47 | 0,05 | **47** | **0,01** |
| GÜNEŞ GAZ ULUSLAR. NAK. TİC. VE SAN. A.Ş. | 6 | 0,01 | 8 | 0,01 | 9 | 0,01 | 17 | 0,02 | **40** | **0,01** |
| AKÇAGAZ PETROL ÜRÜNLERİ SAN.VE TİC. A.Ş. | 9 | 0,01 | 6 | 0,01 | 7 | 0,01 | 7 | 0,01 | **29** | **0,01** |
| SOCAR TURKEY PETROL ENERJİ DAĞITIM SAN.VE TİC. A.Ş. | 0 | 0,00 | 0 | 0,00 | 15 | 0,02 | 13 | 0,02 | **28** | **0,01** |
| TRABZONGAZ LPG SAN. NAKLİYAT VE TİC. A.Ş. | 4 | 0,00 | 2 | 0,00 | 4 | 0,00 | 4 | 0,00 | **13** | **0,00** |
| GESAN YATIRIM VE TİCARET A.Ş. | 2 | 0,00 | 1 | 0,00 | 0 | 0,00 | 4 | 0,00 | **6** | **0,00** |
| **TOTAL** | **80.688** | **100** | **84.420** | **100** | **86.733** | **100** | **87.044** | **100** | **338.885** | **100** |

Table-8: LPG Sales by Distributors in Istanbul Province in 2019

### 2.1.4.1 Price

Our country monitors Sonatrach market prices in terms of LPG product prices and LPG prices are published once a month as Propane and Butane. While calculating the reference price, 70% of the Butane price and 30% of the Propane price published in the relevant market are taken. In this context, the course of prices for mix LPG (FOB) and Brent crude oil (FOB) throughout 2019 are presented in Figure-8.[14]

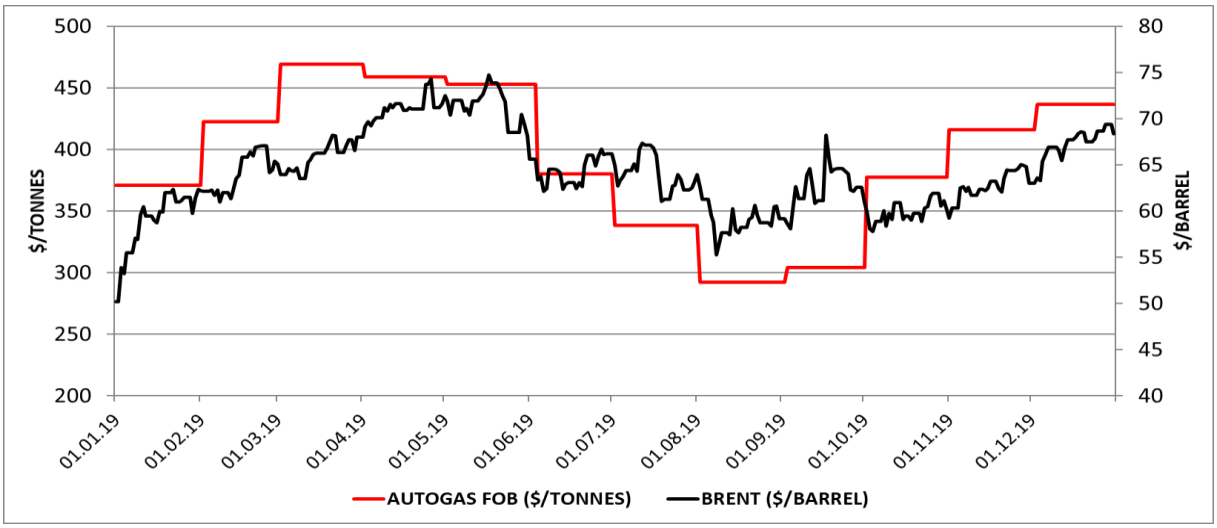


Figure-8 : LPG ($/Tons) and Brent (Dtd-$/Varil) Price Course in 2019

The data converted to TL/lt is presented in Figure-9.

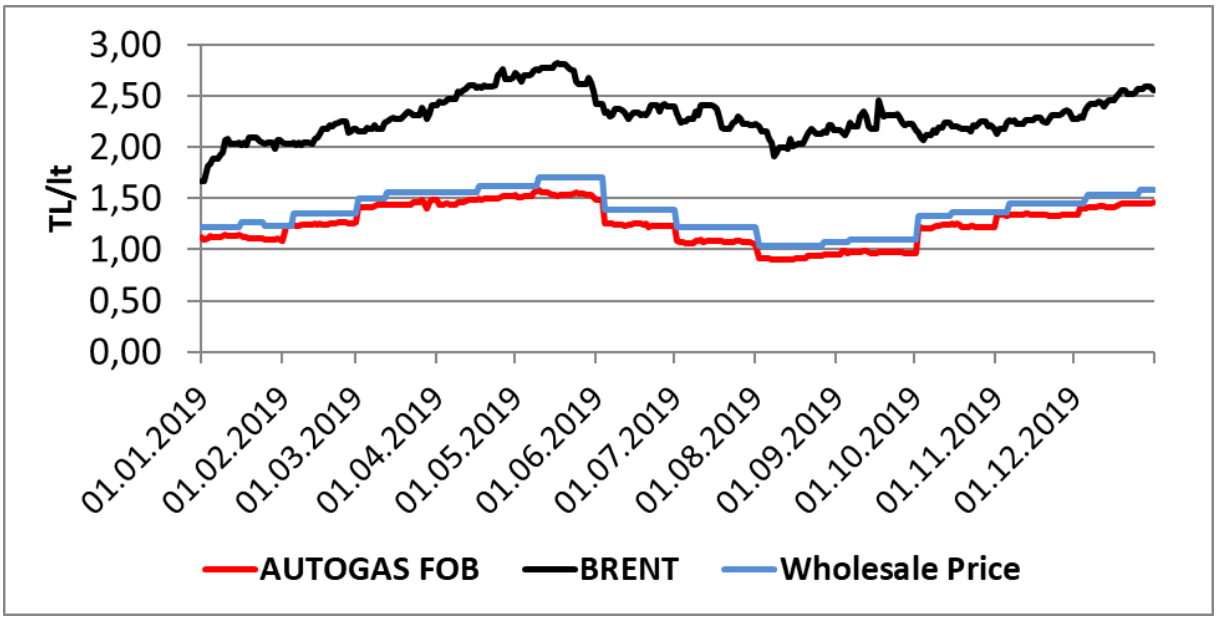


Figure-9 : LPG ve Brent (Dtd) Course in 2019 (TL/lt)

### 2.1.4.1.1 LPG (Autogas) Price Formation in 2019 (Istanbul European Side)

In this section, for indicative purposes, the share of items in the final price of LPG (Autogas) including the taxes on Istanbul European Side of the top eight companies with the highest volume are examined in Table 9 and Figure 10.

| Period | Product | Product Price | Wholesaler Margin | Revenue Share | Total Distributor and User Margin | Total Tax | Total Price |
|---|---|---|---|---|---|---|---|
| **2019** | LPG Autogas | 1,252 | 0,118 | 0,00494 | 0,820 | 1,535 | 3,730 |

Table-9: Domestic Autogas Price Formation (TL/lt)

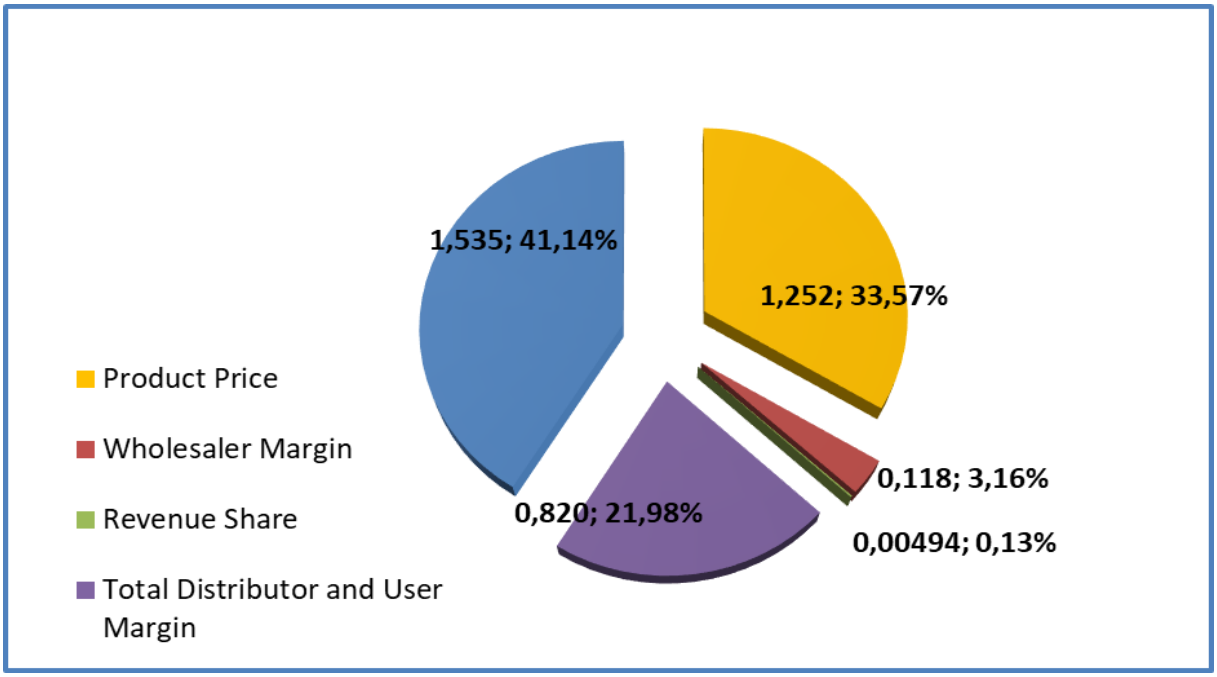


Figure-10: Domestic Autogas Price Formation in 2019 (TL/lt)

When Table 9 and Figure 10 are analyzed, it is seen that tax and income share constitutes 41.28%, product cost constitutes 33.57% and gross profit margin of companies operating in the market constitutes 25.15% of the final autogas price of 3.73 TL/lt.[14]

### 2.1.5 Petroleum

**Production in 2019 compared to 2018:**

- Total refinery petroleum products production increased by 38,84% to 34.712.676,927 tonnes,
- Diesel types production increased by 46,84% to 13.642.113,671 tonnes,
- Gasoline production increased by 12,89% to 5.287.867,933 tonnes,
- Aviation fuels production increased by 24,62% to 5.964.837,849 tonnes,
- Marine fuels production increased by 32,81% to 2.345,459,557 tonnes,
- Other production decreased by 61,44% to 7.117.493,604 tonnes.

**Imports in 2019 compared to 2018:**

- Total imports of petroleum products increased by 17,99% to 44.822.756,254 tonnes,
- Crude oil imports increased by 53,70% to 31.073.819,090 tonnes,
- Import of diesel types decreased by 8,67% to 10.901.420,042 tonnes,
- Import of fuel oil increased by 0,55% to 556.581,360 tonnes,
- Import of aviation fuels decreased by 26,46% to 354.256,256 tonnes,
- Import of other product decreased by 35,90% to 1.906.156,475 tonnes.

**Exports in 2019 compared to 2018:**

- Total exports of petroleum products increased by 60,92 % to 14.281.813,497 tonnes,
- Exports of gasoline types increased by 21,83% to 2.972.490,236 tonnes,
- Exports of diesel types increased by %1.353,69 to 2.121.842,787 tonnes,
- Export of aviation fuels increased by 30,50 % to 5.056.892,940 tonnes.

**Domestic sales[1] in 2019 compared to 2018:**

- Total petroleum product sales decreased by 3,85% to 26.737.749,895 tonnes,
- Gasoline sales increased by 2,98% to 2.399.341,118 tonnes,
- Diesel type sales decreased by 4,42 % to 22.535.057,252 tonnes,

**Bunker sales[2] in 2019 compared to 2018:**

[1]Includes sales of free circulation fuel to dealers, freelancers and unlicensed end-users.
[2]Includes deliveries to end-users within the scope of domestic sales and transit regime.

- Total bunker sales decreased by 12,41% to 3.358.520,800 tonnes,
- Aviation fuels sales decreased by 4,16% to 1.227.356,589 tonnes,
- Sales of marine fuels decreased by 29,29% to 1.562.605,263 tonnes,
- Diesel type sales increased by 10,20% to 458.073,862 tonnes.

**Transit Regime Deliveries in 2019:**

- 710.802,531 of fuel and 32.222,814 tonnes of bunker delivery in diesel types,
- 1.522.306,703 tonnes of bunker delivery were made in marine fuels,
- 54.899,235 tonnes of bunker delivery were made in Aviation fuels.

- **Price Movements:** During the year 2019, the prices of gasoline and diesel have changed in our country depending on the prices in the international market and the average dealer selling price without tax realized as 3,33 TL/liter for Unleaded Gasoline 95 Octane and 3,59 TL/liter for diesel.[15]

### 2.1.5.1 GASOLINE and DIESEL PRICE FORMATION in 2019 (İstanbul European Side)

In this section, to be indicative, the breakdown of final price (including tax) of gasoline and diesel for Istanbul European Side are examined.

Gasoline Types Price Formation (İstanbul European Side – One Liter);
There are four officially defined Gasoline Types in 2018, which are "*Unleaded Gasoline 95 Octane", "Unleaded Gasoline 95 Octane (E10)", "Unleaded Gasoline 98 Octane" and "Unleaded Gasoline 98 Octane (E10)*". But, only unleaded gasoline 95 octane from these products is widely sold at fuel stations. This product is presented in two different forms, standard and differentiated. The breakdown of price for these products is shown in Table-10 and in Figure-10.[16]

| Year | Product | Price | Wholesaler Margin | Income Share | Total Distributor and Dealer Margin | Total Tax | Final Sales Price |
|---|---|---|---|---|---|---|---|
| 2019 | **Unleaded Gasoline 95 Octane*** | 2,602 | 0,071 | 0,00393 | 0,657 | 3,355 | 6,689 |
| | **Unleaded Gasoline 95 Octane(Other)*** | 2,602 | 0,071 | 0,00393 | 0,688 | 3,360 | 6,725 |

Table-10: Gasoline Types Price Formation in 2019 (TL/LT)

When Table-10 is examined; 50,22% of final price (6,689 TL/LT) is tax and the remainder is product cost (38,90%) and gross profit margin of companies operating in the market (10,88%).

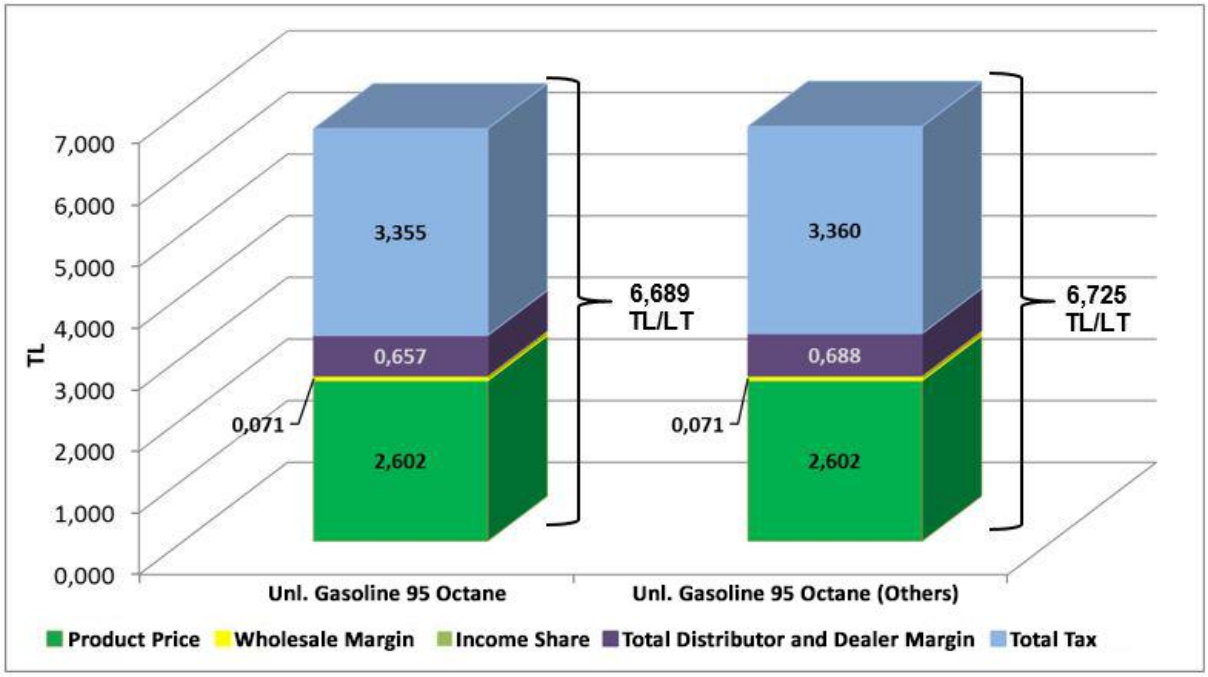


Figure-11: Gasoline Types Domestic Price Formation in 2019 (TL/LT)

Diesel Types Price Formation (İstanbul European Side – One Liter);

There is currently one officially registered type of engine. The Diesel Types sold with different commercial names at fuel stations are known as “Eurodiesel” in public, which has Sulphur content of 10 ppm. In practice, fuel stations have two types of diesel, normal and differentiated, which have the same standards. The breakdown of price for these products is shown in Table-11 and in Figure-11.

| Year | Product | Price | Wholesaler Margin | Income Share | Total Distributor and Dealer Margin | Total Tax | Final Sales Price |
|---|---|---|---|---|---|---|---|
| **2019** | **Diesel **** | 2,874 | 0,022 | 0,00393 | 0,691 | 2,702 | 6,293 |
| | **Diesel (Diğer)**** | 2,874 | 0,022 | 0,00393 | 0,731 | 2,708 | 6,339 |

Table-11. Diesel Types Price Formation in 2019 (TL/LT)

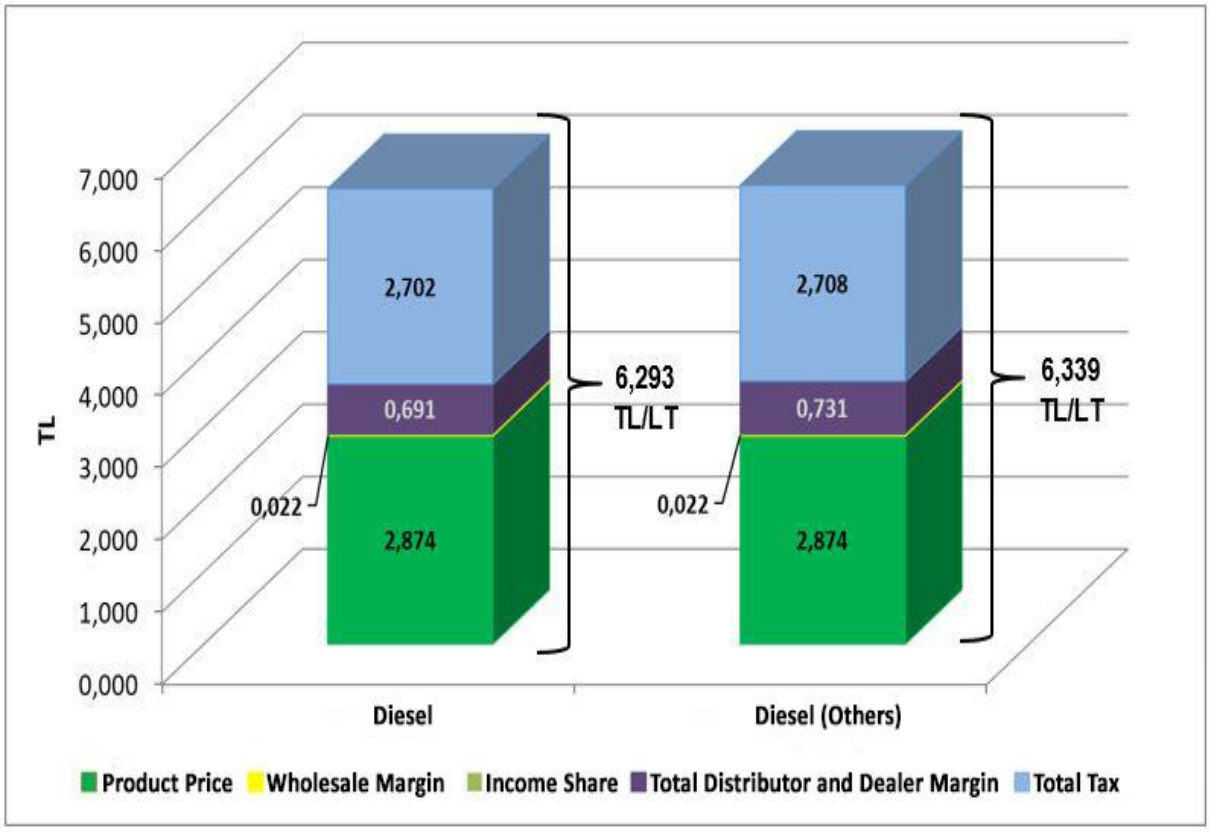


Figure-12. Diesel Types Domestic Price Formation in 2019 (TL/LT)

When Table 10 is examined; 42,98% of final price (6,293 TL/LT) is tax and the remainder is product cost (45,67%) and gross profit margin of companies operating in the market (11,34%).

## CHAPTER 3 -METHODOLOGY

In this paper, Answer-Times modelling has been used in the analysis. Times is an optimization method used for energy, environment and economy models for cities. It is the energy modeling of a country, city or any area. The program can work in different regions and at different time intervals, also provides the opportunity to create multiple various scenarios and compare them. Model basically calculates energy and cost results in selected scenarios depending on technological and environmental factors. It is usually applied to the analysis of the entire energy sector, but may also be applied to study single sectors such as the electricity and district heat sector.

The scope of the model extends beyond purely energy-oriented issues, to the representation of environmental emissions, and perhaps materials, related to the energy system. In addition, the model is suited to the analysis of energy-environmental policies, which may be represented with accuracy thanks to the explicitness of the representation of technologies and fuels in all sectors.

### 3.1 Reference Energy System

To make the project and enter the data into the program, it is necessary to design a reference energy system. Reference energy system is formed by connecting the process/devices/demands in 6 categories. Energy is produced from imported (natural gas, coal or petroleum products) or existing sources (wind, solar, hydro) using appropriate process technologies. Most important and critical energy is electrical energy. These energies are directed to demand technologies. Finally, these demand technologies are divided into demand categories.

İstanbul imports coal, diesel fuel, gasoline, LPG from the outside area. İstanbul generates electrical energy with Istanbul has 23 Natural Gas Power Plant,13 Photovoltaic power station,11 Wind Power Plan and 4 Bio-gas Power plants.It exports most of the electricity it produces to other cities. Residential and commercial demand group contains; space conditioning, cooking, illumination, cleaning and entertainment demands. Major industry sectors are sugar, flour, nut, cement, marble, cable, weapon and iron steel, these sectors make up most of the industry demand group. Other demand sectors are; agricultural demand, passenger and freight transportation demand and city service demand. Also, high emissions occur due to fossil fuels used.

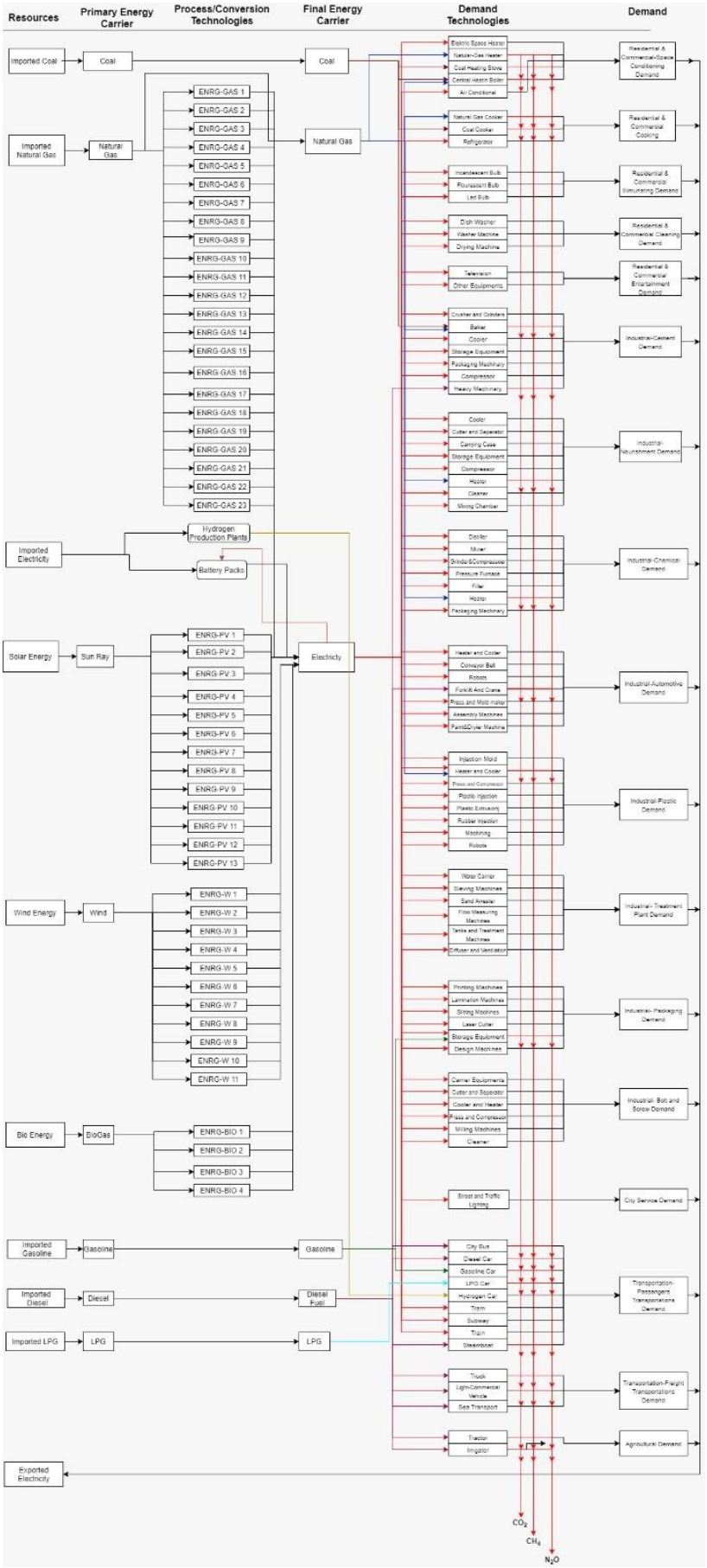


Figure 13- Reference Energy system of İstanbul

### 3.2 Answer Times Model Approach

A database was setup starting in 2018 and going at 1 year intervals until 2050. New regions which are region 1 and impexp region have been created from the region management section of the main page of the program.

Under the global tab annual inflation rate (G_DRATE) must be entered

#### 3.2.1 Commodities

First of all, it is necessary to define the raw materials and energy resources used in the city. Commodities are be inputs or outputs of process technologies. There are energy carriers, demand for energy services and environmental indicator as subsets for define the commodity. It is necessary to choose the appropriate option according to the type of energy carrier e.g. fossil, electricity, renewable. For the demand groups, also choose option below to demand for energy services subset. Agricultural, industrial, commercial and residential options were used in this project. Also if there is an emission related study, it is necessary to add the emissions to this section. Under de environmental indicator tab greenhouse gas option must be select for emissions.

For the energy carriers which are exported or imported, define another commodity that has the same name but only the region is different. Imports and exports needs to be defined for not cause a problem in the model.

| Commodities | | |
|---|---|---|
| 1 | $CO_2$ | Greenhouse Gas |
| 2 | Coal | Fossil |
| 3 | Diesel | Fossil |
| 4 | Electricity | Electricity |
| 5 | Gasoline | Fossil |
| 6 | LPG | Fossil |
| 7 | Manure | Limited-Renewable |
| 8 | Natural Gas | Fossil |
| 9 | Solar | Unlimited Renewable |
| 10 | Waste Heat | High-Temperature Heat |
| 11 | Water | Unlimited Renewable |
| 12 | Wind | Unlimited Renewable |

Table-12: Commodities in the Model.

### 3.2.2 Processes

In this tab process technologies (power plants) and demand technologies are defined. In order to define process technology, inputs and outputs of technology must be defined before. So firstly demand technologies must be defined in this tab. For the demand technologies, demand device option must be select. In the input and output commodities tab, the inputs and outputs of the technology are selected. Inputs of demand devices is fuels or electricity, outputs of demand devices is their commodity group e.g. residential, industrial etc.

The bound on activity which is annual energy consumption (ACT_BND) and activity efficiency (ACT_EFF) values of all demand technologies should be entered. If the demand device runs on fossil fuel and causes emissions, emission factor (FLO_EMIS) must be entered.

After defining all the demand technologies, start to define process technologies. For the process technologies, electric generation option must be select. Inputs of power plants are their working fuel or renewable sources. Outputs of power plants are electricity.

The bound on activity which is annual energy consumption (ACT_BND) value of all process technologies should be entered. Also power plant's variable costs (ACT_COST) and fixed operating and maintenance costs (NCAP_FOM) are should be defined. If the power plants working with fossil fuel and causes emissions, emission factor (FLO_EMIS) must be entered.

#### 3.2.2.1 Power Plants

There is no information on how many MWh of energy each power plant generates in 2018. Production values in the energy atlas belong to 2016. According to the information in EPDK reports, İstanbul's energy production decreased after 2016 despite the increase in installed capacity. I assumed the production in 2018 by proportioning the production of the plants in 2016 according to the values in 2018.

If no increase or decrease for energy production is planned by the power plants in the coming years, I assume that the amount of energy produced by the power plants are constant in all years for base scenario.

For the variable and fixed costs, the program uses the dollar rate in 2000. For this reason, current costs are written according to the dollar rate in 2000 using the inflation rate in money

### 3.2.2.1.1 Natural Gas Power Plants

More than half of İstanbul's energy production takes place in natural gas power plants. There are only 3 natural gas power plants but 2 of them are the most energy production power plants in the city. . For the natural gas power plant select electric generation option under the set membership tab. In the input and output commodities tab select natural gas for input commodity and select electricity for output commodity.

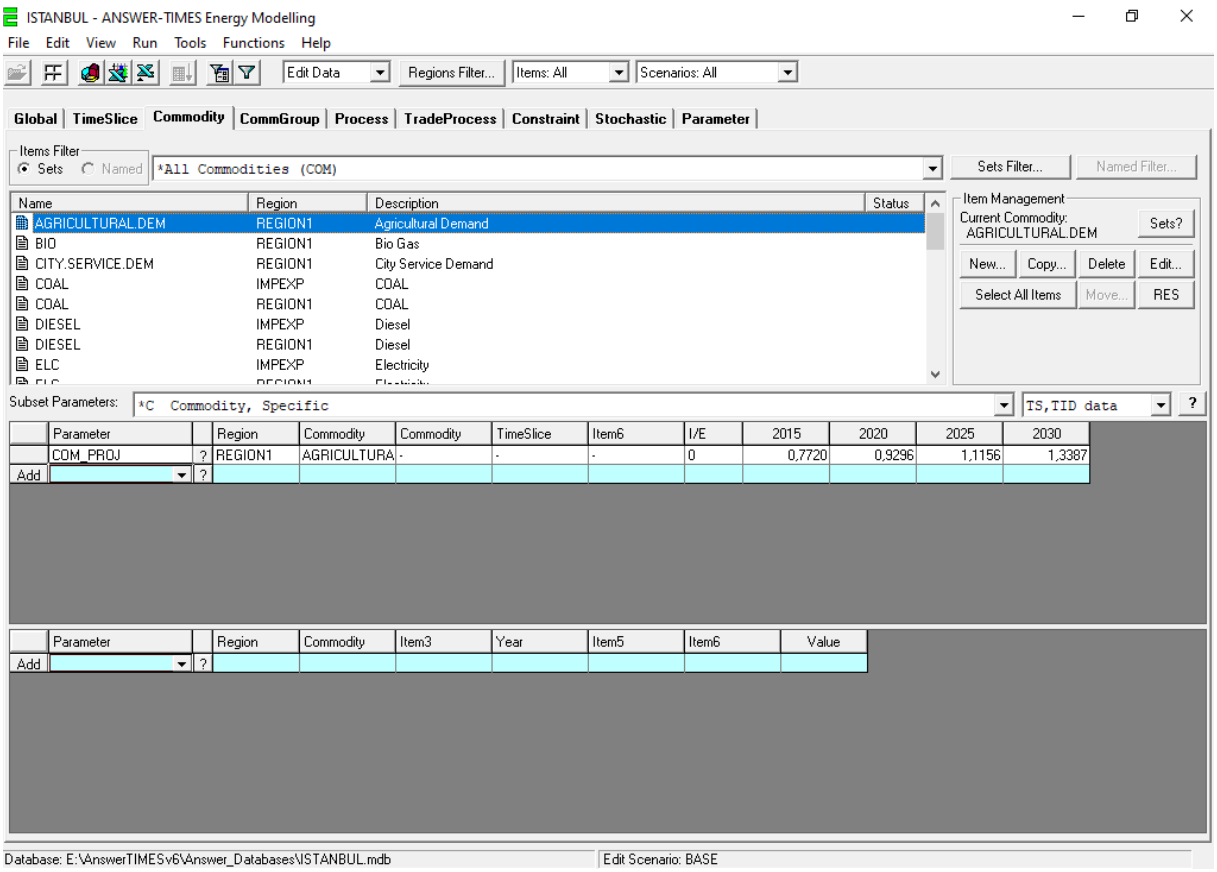


Figure-14 The Commodity tab in Answer Times

### 3.2.2.1.1 Wind Power Plants

Wind power plants are the most energy producing plants after natural gas and hydroelectric power plants. There are 11 wind power plants in İstanbul.

Wind Energy power plants don’t have variable cost value (ACT_COST).

Wind Energy power plants fixed and operating maintenance cost value (NCAP_FOM) is 17.7162 million $/GW

#### 3.2.2.1.2 Bio-Gas Power Plants

There are 4 biogas power plants in İstanbul. Their capacities and the amount of energy produced are small.

Biogas power plants variable cost value (ACT_COST) is 0.9028 million $/PJ .

Biogas power plants fixed and operating maintenance cost value (NCAP_FOM) is 85.0676 million $/GW

### 3.2.2.2 Residential and Commercial Demand Group

According to the 2018 National Energy Balance Table the number of coal, natural gas and electricity used in the residential and commercial zones is certain. But, electricity usage of each city is clearly determined in the EPDK 2018 Electricity Sector Report. So I proportioned the consumption percentages of the electrical appliances and EPDK report.

For the natural gas and coal usage, assuming that the use in residential and commercial areas is proportional to the population, the values of the energies used in İstanbul were calculated.

Natural gas and coal are used for heating and cooking in residential areas. More than half of the houses in Turkey used natural gas for heating and cooking demand. So I did a calculation based on this information it is known that natural gas used for cooking and heating.

#### 3.2.2.2.1 Residential and Commercial Cooking

Another basic demand sector of city. Coal, natural gas and electric powered demand devices are used in this sector. For example; Coal Cooker.

Although most of the houses use natural gas stoves, the coal mine is frequently used in some commercial zones, such as bakery, restaurants or patisseries. For the coal cooker select demand device option under the set membership tab. In the input and output commodities tab select coal for input commodity and select residential and commercial cooking demand group for output commodity.

Coal cooker efficiency value (ACT_EFF) is 0.5

#### 3.2.2.2.2 Residential and Commercial Cleaning

This is one of the sectors where only electrical appliances are available and a lot of electricity is consumed. For example; Washing Machine

For the washing machine select demand device option under the set membership tab. In the input and output commodities tab select electricity for input commodity and select residential and commercial cleaning demand group for output commodity.

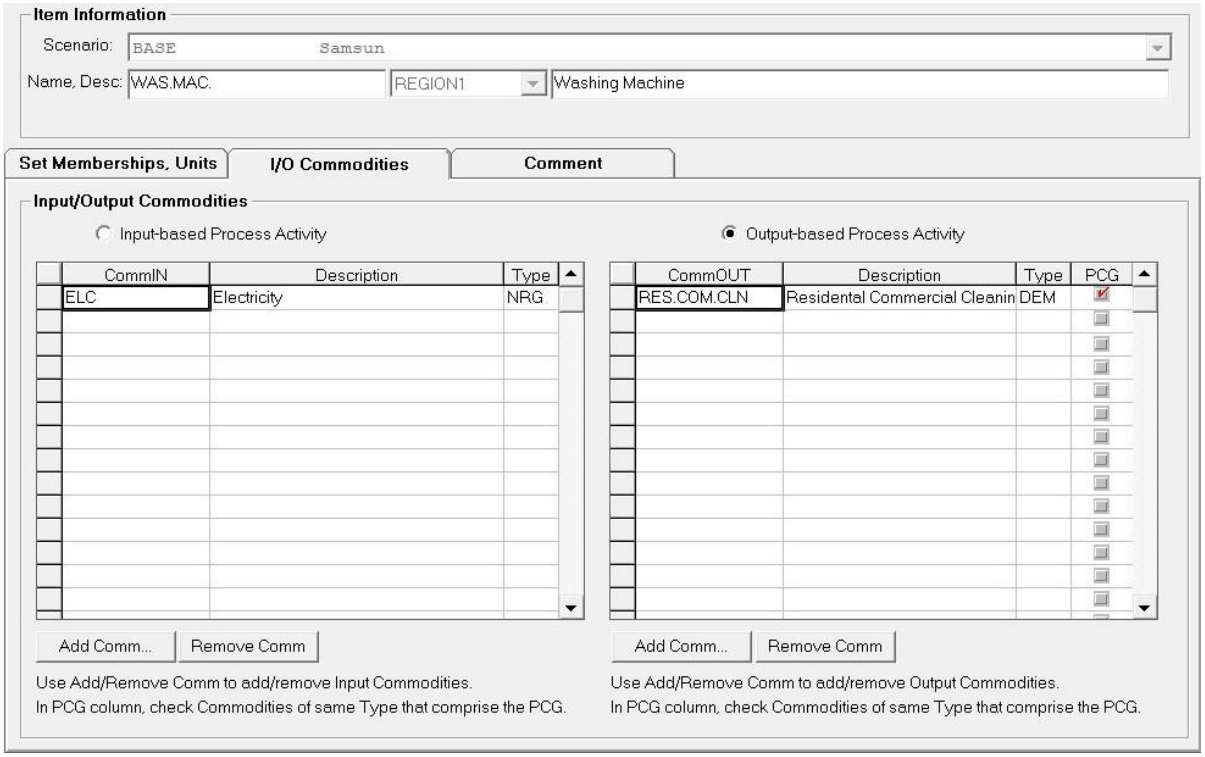


Figure-15: Input and output commodities of washing machine in Answer Times

### 3.2.2.2.3 Residential and Commercial Illuminating

Common all over the world most bulbs used for lighting are fluorescent bulb. They are more efficient than incandescent bulbs. Although LED lighting is much more efficient than others, it has just started to be used .

### 3.2.2.2.4 Residential and Commercial Entertaining

Televisions take the biggest share in this group. Also computers, gaming consoles or other devices are included in this sector.

### 3.2.2.3 Industrial Demand Group

The Industry demand in Istanbul is very huge. Istanbul has 15 milioons of population and most crowded city in Turkey. Besides of that the industry is developed. According to data from the energy balance table I use the gross output ratio shaft to calculate the amount of spending in the

industrial sector in İstanbul. I also benefited from the resources determined by large companies in İstanbul to create and distribute this amount to different sub-sectors.

#### 3.2.2.3.1 Industrial Cement Demand

Cement is a product frequently produced in Turkey. There are three large cement factories in İstanbul. Although it is not very much in energy consumption, it has an important share for city's energy consumption.

### 3.2.2.4 City Service Demand

According to the EPDK 2015 Electricity Sector Report, the amount of electricity used for lightning in İstanbul was calculated under the lightning tab. The lightning means street and traffic lights, lighting in residential and commercial areas is not included.

### 3.2.2.5 Transportation

According to the 2018 National Energy Balance Table the amount of fuel used for land vehicles, ships and planes is available in the table. To find fuel use in the city, I multiplied the value in the table by the ratio of the number of vehicles in the city to the number of vehicles in the country.

Bus, minibus, small truck, truck, tractor and special purpose vehicles are use diesel fuel.

Since the amount of energy release and emissions generated by aviation fuels, marine fuels and diesel fuels are very close, I assume that input commodity of cargo plane and cargo ships are diesel

#### 3.2.2.5.1 Gasoline

The first vehicles produced in the world are gasoline vehicles. Today, usage rates are decreasing due to their low efficiency and gasoline being more expensive than diesel fuel. But, because they produce more power, gasoline engines are used in all small motor vehicles such as motorcycles.

For the gasoline car select demand device option under the set membership tab. In the input and output commodities tab select gasoline for input commodity and select passenger transportation demand group for output commodity.

#### 3.2.2.5.2 Diesel

All big and commercial vehicles in the world have diesel engine. Diesel engines are more efficient than others (gasoline, LPG). That's why diesel vehicles are the most preferred vehicles in the world. However diesel fuel has higher emissions than other fuels. In this case, it can be said that the vehicles most harmful to the environment are vehicles with diesel engines.

#### 3.2.2.5.3 LPG

LPG (liquefied petroleum gas) vehicles have been used in Turkey for the last 35 years. More efficient and cheaper than gasoline vehicles. Also LPG has a lower emission factor value compare to gasoline and diesel fuel. LPG is used only on some road vehicles.

For the LPG car select demand device option under the set membership tab. In the input and output commodities tab select LPG for input commodity and select passenger transportation demand group for output commodity.

LPG cars are the only demand device that uses LPG in the model. So 2.102 PJ LPG are used.

For the bound on activity value (ACT_BND): 2.102*0.35 = 0.7357 PJ

### 3.2.2.6 Agricultural Demand

According to the 2018 National Energy Balance Table the number of diesel used for Agriculture is certain. Assuming that all diesel used in agriculture is used by the tractor. According to the 2018 Land Motor Vehicles table taking the ratio of the number of tractors in Turkey with the number of tractors in İstanbul, so I calculated the energy used for tractors in İstanbul.

## 3.2.3 Trade Process

Imported and exported energy sources in the city are defined in this tab. The energy carriers which are defined previously in the commodity section will be defined as taken from the market region in trade process tab. Whether the energy carrier is imported or exported is defined by checking the appropriate box in the trade matrix.

For the trade processes price of import/export (IRE_PRICE) values must be entered.
IRE_PRICE unit is million$/PJ. Also the program uses the dollar rate in 2000 as the currency.

Calculation of IRE_PRICE value;

For petroleum products (gasoline, diesel and LPG) I found how much energy consumption of 1 liter of these fuels. I converted the value in KWh to PJ. I took the average sales price of 1 liter of fuels in 2018 and multiplied by the PJ value. I converted this price in Turkish lira to million dollars.

For natural gas, I found how much energy consumption of 1 cubic meters of natural gas. I converted the value in KWh to PJ. I found how much money is 1 cubic meter of natural gas in 2018 and multiplied by the PJ. I converted this price in Turkish lira to million dollars.

For coal, I found out how much energy a kilo of coal will extract by burning . I converted the value in KWh to PJ. I found the selling price of a kilo of coal in 2018 and multiplied by the PJ. I converted this price in Turkish lira to million dollars.

For electricity, I found the selling price of 1kWh of electricity in 2018 and multiplied by the PJ . I converted this price in Turkish lira to million dollars.

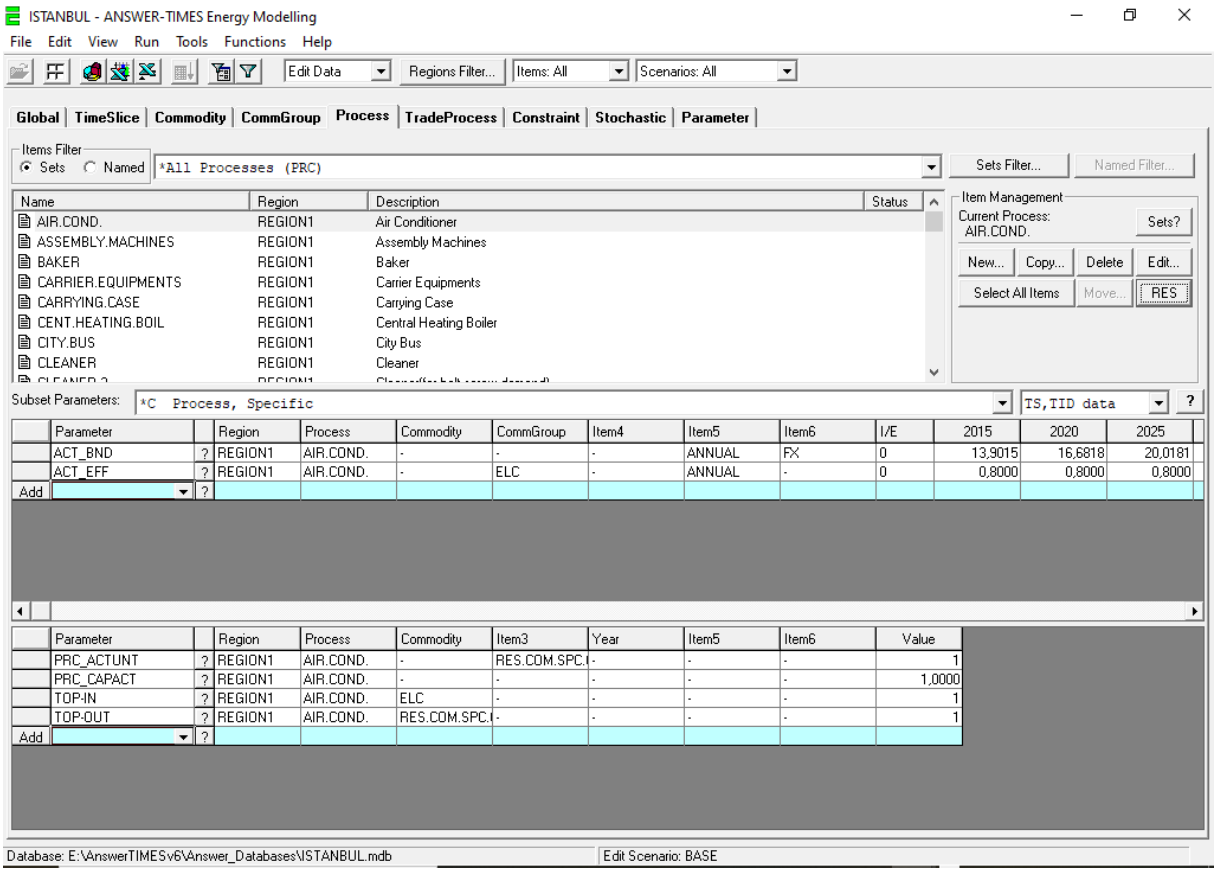


Figure-16 Process Tab in Answer Times

## CHAPTER 4 -RESULTS AND CONCLUSION

Istanbul's energy model has been created by using Answer Times software. Supply and demand balances were established for this city. This model was built for between 2015 and 2030. The effects of the technologies to be added or removed to the system can be examined. Economically efects of those energy systems can be decided after those datas by using alternavite energy scenarios. Thus, we can evaluate our city's long and medium time plan energy road and environmental factors.The municipalities,States or Goverments can prepare future energy plans by using this software.

| | Efficiency (Decimal Fraction) (ACT_EFF) | Fix bound with activity (Petajoule) (ACT_BND) | | | | Demand (Petajoule) (COM_PROJ) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2015-2030 | 2015 | 2020 | 2025 | 2030 | 2015 | 2020 | 2025 | 2030 | |
| Refrigerator | 0,95 | 30,4703 | 36,5640 | 43,8520 | 52,6220 | 28,9467 | 34,7358 | 41,6594 | 49,9909 | Electricity |
| Air Conditioner | 0,8 | 13,9015 | 16,6818 | 20,0181 | 24,0217 | 11,1212 | 13,3454 | 16,0144 | 19,2173 | |
| Washing Machine | 0,75 | 7,8697 | 9,4436 | 11,3323 | 13,5987 | 5,9022 | 7,0827 | 8,4992 | 10,1990 | |
| Dish Washer | 0,75 | 3,2515 | 3,9018 | 4,6821 | 5,6185 | 2,4386 | 2,9263 | 3,5115 | 4,2138 | |
| Dryer | 0,8 | 2,9688 | 3,5625 | 4,2750 | 5,1300 | 2,3750 | 2,8500 | 3,4200 | 4,1040 | |
| elc. Space Heater | 0,95 | 8,6199 | 10,3438 | 12,4125 | 14,8950 | 8,1889 | 9,8266 | 11,7918 | 14,1502 | |
| Television | 0,75 | 6,2137 | 7,4564 | 8,9476 | 10,7371 | 4,6602 | 5,5923 | 6,7107 | 8,0528 | |
| Incandescent | 0,1 | 6,4852 | 7,7822 | 9,3386 | 11,2063 | 0,6485 | 0,7782 | 0,9339 | 1,1206 | |
| Florasan | 0,3 | 2,0979 | 2,5174 | 3,0208 | 3,6249 | 0,6293 | 0,7552 | 0,9062 | 1,0874 | |
| Led | 0,9 | 1,5739 | 1,8886 | 2,2663 | 2,7195 | 1,4165 | 1,6997 | 2,0396 | 2,4476 | |
| Other | 0,6 | 10,1033 | 12,1239 | 14,5486 | 17,4583 | 6,0619 | 7,2743 | 8,7291 | 10,4749 | |
| Coal Heating Stove | 0,5 | 2,0733 | 2,4879 | 2,9854 | 3,5824 | 1,0366 | 1,2439 | 1,4927 | 1,7912 | COA |
| Central Heating Boil. | 0,5 | 2,0733 | 2,4879 | 2,9854 | 3,5824 | 1,0366 | 1,2439 | 1,4927 | 1,7912 | |
| Coal Cooker | 0,5 | 2,0733 | 2,4879 | 2,9854 | 3,5824 | 1,0366 | 1,2439 | 1,4927 | 1,7912 | |
| Natural Gas Heater | 0,85 | 4,5579 | 5,4694 | 6,5632 | 7,8758 | 3,8742 | 4,6489 | 5,5787 | 6,6944 | NG |
| Central Heating Boil. | 0,85 | 2,7347 | 3,2816 | 3,9379 | 4,7254 | 2,3244 | 2,7893 | 3,3472 | 4,0166 | |
| Natural Gas Cooker | 0,7 | 1,8231 | 2,1877 | 2,6252 | 3,1502 | 1,2762 | 1,5313 | 1,8383 | 2,2051 | |

Figure-17 Residental Demand Table

From the Figure 17, Residental and Commercial datas has been shown. Those demands has been founded by research and using refering EPDK reports. Our model takes these data as reference. These demand technologies consumed up to 114.91 petajoules of electricity in 2015,in Istanbul. The amount of future demand electricity of city has been reffered by the growth of the economy of Turkey and GSYIH asumptions for Turkey Central Bank. The model has all those data and all the energy road plans has been decided by using those results.

The research on electricity, natural gas, LPG, coal and oil resources has been conducted for the province of Istanbul. We determined whether these sources came from the city or from outside of the city. The price analysis of energy resources has been calculated by using import and export data of our country.

## CHAPTER 5–REFERENCES

[1]Wenying,C.Zongxin,W.,(2001).StudyonChina'sFutureSustainableEnergyDevelopmentStrategy Using MARKALModel.JournalofTsinghuaUniversity,41(12),103-106

[2]Kanala,R.Fragniera,E.Moresino,F.,(2013).ExtensionoftheSocial MARKALConcept toResidentialHeating inTIMESRomaniaCountryModel.EnergyforSustainabilityMultidisciplinaryConference,8-10 September,Coimbra,Portugal

[3]Assoumou,E.Maizi,N.,(2011).CarbonValueDynamicsforFrance: AKeyDrivertoSupportMitigationPledgesatCountryScale.EnergyPolicy,39(7),4325-4336

[4]Comodi,G.Cioccolanti,L.Gargiulo,M.,(2012).MunicipalScaleScenario:AnalysisofanItalianSeasi deTownWithMARKAL-TIMES.EnergyPolicy,41,303-

[5]Yang,C.Ogden,J.,(2013).Renewableand Low CarbonHydrogenforCalifornia-Modeling theLong TermEvolutionofFuelInfrastructureUsing aQuasi-SpatialTIMESModel.InternationalJournalofHydrogenEnergy,38(11),4250-4265

[6]Drouineau,M.Maizi,N.Assoumou,E.Mazauric,V.,(2010).TIMESModelfortheReunionIsland: Addressing ReliabilityofElectricitySupply.InternationalEnergyWorkshop,June,Stockholm,Sweden

[7]Istanbul Power Plants
https://www.enerjiatlasi.com/sehir/istanbul/

[8] Electricity Market for 2020 Sector Report for November
https://www.epdk.gov.tr/Detay/Icerik/3-0-23/elektrikaylik-sektor-raporlar

[9] 2019 Electricity Market Development Report
https://www.epdk.gov.tr/Detay/Icerik/3-0-24/elektrikyillik-sektor-raporu

[10] Turkey's Natural Gas Supply and Consumption Policies Evaluation Report
https://www.mmo.org.tr/sites/default/files/gonderi_dosya_ekleri/180cffd6a8e829d_ek.pdf

[11] Natural Gas Market Sector Report November 2020
https://www.epdk.gov.tr/Detay/Icerik/3-0-95-1007/dogal-gazaylik-sektor-raporu

[12] MTA-Istanbul Province Mining and Energy Resources
https://www.mta.gov.tr/v3.0/sayfalar/bilgi-merkezi/maden_potansiyel_2010/Istanbul_Madenler.pdf

[13] Liquefied Petroleum Gases (LPG) Market for November 2020 Sector Report
https://www.epdk.gov.tr/Detay/Icerik/3-0-105-1002/lpgaylik-sektor-raporlari

[14] Liquefied Petroleum Gases (LPG) Market 2019 Sector Report
https://www.epdk.gov.tr/Detay/Icerik/3-0-108-1002/lpgyillik-sektor-raporlari

[15] Petroleum Market Sector Report November 2020
https://www.epdk.gov.tr/Detay/Icerik/3-0-104-1008/petrolaylik-sektor-raporu

[16] 2019 Petroleum Market Sector Report
https://www.epdk.gov.tr/Detay/Icerik/3-0-107/yillik-sektor-raporu