EVALUATION OF FEEDING ISTANBUL EUROPEAN SIDE NATURAL GAS DISTRIBUTION NETWORK FROM TPAO SILIVRI UNDERGROUND STORAGE FACILITIES DURING PEAK DEMANDS

Fatih ÜNLÜUYSAL
Mechanical Engineering-Bsc
Petroleum and Natural Gas Engineering-Msc

Distribution Network Project Chief,
IGDAS - Istanbul Gas Distribution Industry and Trade Inc., Istanbul, Turkey
funluuysal@igdas.com.tr

ABSTRACT

In Turkey, 35 percent of the total residential gas consumption is in Istanbul. IGDAS provides gas to about 2.7 million residences located at the European side of Istanbul. The reliability in service of such a network requires a well established supply and demand balance. Peak demands, particularly during winter season, naturally creates problems on maintaining the necessary supply chain. Therefore, from the supply point of view, additional gas reserve is required.

TPAO Northern Marmara and Deðirmenkoy gas fields are actively used as underground gas storage facilities to supply natural gas to BOTAS high pressure pipeline network during the peak periods.

This paper presents a study on feeding Istanbul European side natural gas distribution network from TPAO underground gas storage facilities. The results are discussed and some recommendations are given.

Key words: 1.Underground Storage, 2. IGDAS, 3. TPAO, 4. BOTAS

1. INTRODUCTION

The positive role of energy within today's world on economical development and social life quality is extremely obvious. According to the data of International Energy Agency (IEA), in case of continuance of energy production and consumption habits of today, it is being estimated that in 2030 the world energy requirement will increase by 50% compared to 2007 and that 92% of this requirements will be covered by fossil fuels [1].

Today, when technological developments gained considerable acceleration, energy consumption increases rapidly along with industrialization and increase of population, and in the selection of energy source the energy types with least environmental effect besides high efficiency comes to the forefront. Under these conditions, natural gas characterized as environmentally friendly gains importance and demand as a highly efficient energy source.

Today due to rapid economical growth, industrialization, population increase, urbanization, environmental effects, natural gas replaces petroleum, electricity and coal in domestic, commercial and industrial areas by some of its superior qualifications in addition to energy policies. Natural gas consumption also increases each year in our country, and it becomes obligatory to well analyse and protect the supply demand balance in natural gas market where demand is covered through import.

In Istanbul natural gas distribution activities are being performed by IGDAS *(Istanbul Gas Distribution Industry and Trade Incorporated Company)* A significant part such as 65% of natural gas being consumed in whole Istanbul in domestic, commercial and industrial areas is being covered by the natural gas distribution network of European side of Istanbul. European side distribution network, providing natural gas to nearly 2.5 million subscribers and being rather close to TPAO *(Turkish Petroleum Corporation)* North Marmara and Degirmenkoy natural gas underground storage facilities compared to other inner city gas distribution networks, is crucial in strategic respect in order to be fed by these underground storage facilities and to provide security of supply.

In this study TPAO North Marmara and Degirmenkoy natural gas underground storage facilities are evaluated, and in the light of the IGDAS natural gas distribution network structure and statistical information of subscriber consumption values, feeding distribution network from underground storage facilities during peak demands in case of cut on the BOTAS *(Turkish- Petroleum Pipeline Corporation)* national transmission line are addressed.

2. TPAO SILIVRI STORAGE FACILITIES

2.1 Settlement and General Description of TPAO Silivri Storage Facilities

Silivri Underground Natural Gas Storage Facilities are composed of North Marmara Natural Gas Field which is actually discovered in 1988, having a reservoir depth of 1 200 meters and being the first natural gas field of Turkey that is in the sea and of Degirmenkoy Natural Gas Field which is discovered in 1994 and having a reservoir depth of 1 100 meters. They are selected as the most convenient fields to be improved as natural gas storage facilities in Thrace Peninsula as the reservoir and production specifications of these fields being convenient for use as storage reservoir and as they are proximate to BOTAS main natural gas transmission line and to Istanbul.

Official opening of the plant is realized on July 20, 2009 and it supplies gas to BOTAS 36" main natural gas transmission line in winter when required and performs injection activity from BOTAS line in summer.

Storage Project Surface Facilities are being composed of North Marmara Collection Manifold constructed at the location where long expansion horizontal wells are drilled for North Marmara Field, Degirmenkoy Collection Manifold constructed at the location where directional wells are drilled at Degirmenkoy Field and including parser unit, Common Facility constructed within an area of 167 000 m² that is 3 500 m. from the North Marmara horizontal well location, 13 500 m. from Degirmenkoy collection point and 4 500 m. from BOTAS main main natural gas transmission line, and 20”-24” pipeline between this facility and North Marmara Collection Manifold and 16” pipe line between this facility and Degirmenkoy Manifold.

Connection of TPAO Storage facilities and BOTAS transmission line is given in Figure 2.1.

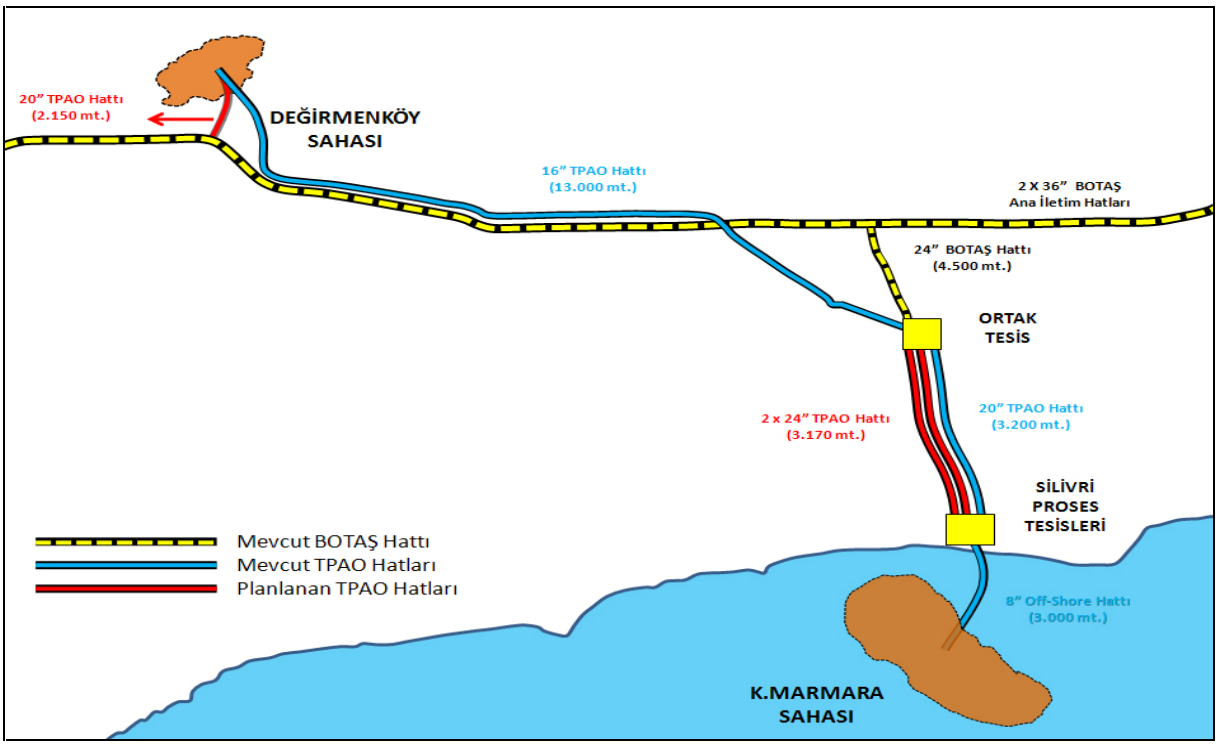

Figure 2.1 : TPAO Silivri storage facilities and BOTAS connection lines [3].

2.2 Current and Planned Capacity Information of Storage Facilities

Studies are continuing to increase the daily production capacity of the facility to 50 Million Sm³ from 15 Million Sm³ by the planned PHASE 1-2 and 3 investments.

By the inclusion of PHASE 1-2 and 3 projects and storage activities in other fields to capacity, it is being planned to reach a storage volume of annually 3 Billion Sm³ in total [5]. Information regarding the current and planned capacity increases at the facility are given in Chart 2.1.

	Injection (Million Sm³/day)	Withdrawal (Million Sm³/day)	Storage Capacity (Billion m³)
BOTAS Agreement	14	17	2.10
Phase-1 Project	16	17	2.661
Phase-2 Project	16	25	3.0
Phase-3 Project	25	50	3.0
GENERAL TOTAL	**25**	**50**	**3.0**

Chart 2.1: Current and planned capacities of TPAO Silivri storage facilities

3. IGDAS DISTRIBUTION NETWORK AND ITS SECTIONS

Natural gas distribution networks are being classified in three parts as low pressure, mid pressure and high pressure in general as per pressure class.

Low pressure: Transmitted to PE network with the available pressure as to provide the effective pressure required at the device inputs being used. Interior installation lines having a design pressure in between 21 mbar-300 mbar are within this class.

Mid pressure: Operation system supplying gas in between 0.6 mbar - 4 bar to PE network and to clients through pressure regulators.

High pressure: Network system supplying gas of over 4 bars (at pressure interval of 4 bar-20) to large consumers through regulators. Gas at this pressure is carried through steel lines.

IGDAS Natural Gas Distribution Network can be evaluated in six parts as being RM-A Stations, Main Carrier Steel Lines, PE Distribution Lines, PE Service Lines, District (Regulating) Stations and Client (Regulating) Stations.

3.1 RM-A Stations

RMS-A station is where the pressure filtration, measurement, heating, regulation, odorization processes are realized in order to deliver the natural gas from the high pressure transmission network to city network. RM-A stations are also called as "City Gate Stations". At stations the gas of 35-75 barg pressure is reduced to 25-19 barg level.

3.2 Main Carrier (Steel) Lines

Pressure of gas reaching the City Gate Stations (A-type pressure measurement and reduction stations) through transmission lines is reduced as per pressure class and reaches min carrier (steel) lines.

IGDAS steel line network is designed according to maximum 25 barg and minimum 6 barg operation pressure. At IGDAS steel network, steel pipes of API 5L GrB standard in between 4”-30” are being used. Steel lines are designed with a diameter of 30”-28” at entrance points to network from RMS-A stations being the junction points and with less diameters towards the end points of network.

BOTAS national transmission line within the borders of Istanbul and having an operation pressure of 70 barg, and IGDAS steel distribution network having an operation pressure of 20 barg are shown in Figure 3.1.

3.3 Polyethylene (PE) Distribution Lines

It is the system that carries the gas from district (regulator) stations to residences and industrial and commercial consumers. Gas transmitted from main carrier lines (at high or mid pressure) reaches the distribution lines by reduction of pressure as per pressure class of distribution lines (mid or low) through regional regulators. In the current technology PE pipes are being used at mid and low pressure distribution lines.

3.4 PE Service Lines

Building connection lines providing the relation in between polyethylene (PE) service lines, PE distribution lines and consumption system internal installation through service regulators and having the same pressure class. Service lines compose a large part of the operation cost of natural gas distribution system, conclude at the station of industrial large consumers or at a box installed on the facade or on the ground (pavement etc) as per the condition.

3.5 District (Regulating) Stations

Gas, being carried at 6-25 barg pressure through steel transmission lines, is reduced to 1-4 barg pressure value at regional regulators and delivered to PE network. Moreover gas being transmitted to regional regulators through steel network is filtered at these units. As being the first grade flowing the RM-A stations, these stations and client (regulating) stations being fed by steel line (steel skid) are also called B type stations o RMS-B stations. At IGDAS network 450 units of regional regulators are being used to feed the European side and approximately 250 is being used to feed the Anatolian side.

3.6 Client (Regulating) Stations

Stations where the gas, carried by steel transmission or PE distribution lines, is transmitted to clients of high consumption industrial – commercial activity or to site type lodgings having high consumption. Natural gas is transmitted to clients at gas usage pressure level of 6-20 barg through client stations (steel skid) being fed from steel network and to clients at gas usage pressure level of 1-4 barg through client stations (PE skid) being fed from PE network. For clients lower than 1 barg, for example for clients at gas usage pressure level of 300 mbar, additional stations are used that provides 2nd grade pressure reduction in addition to the first station.

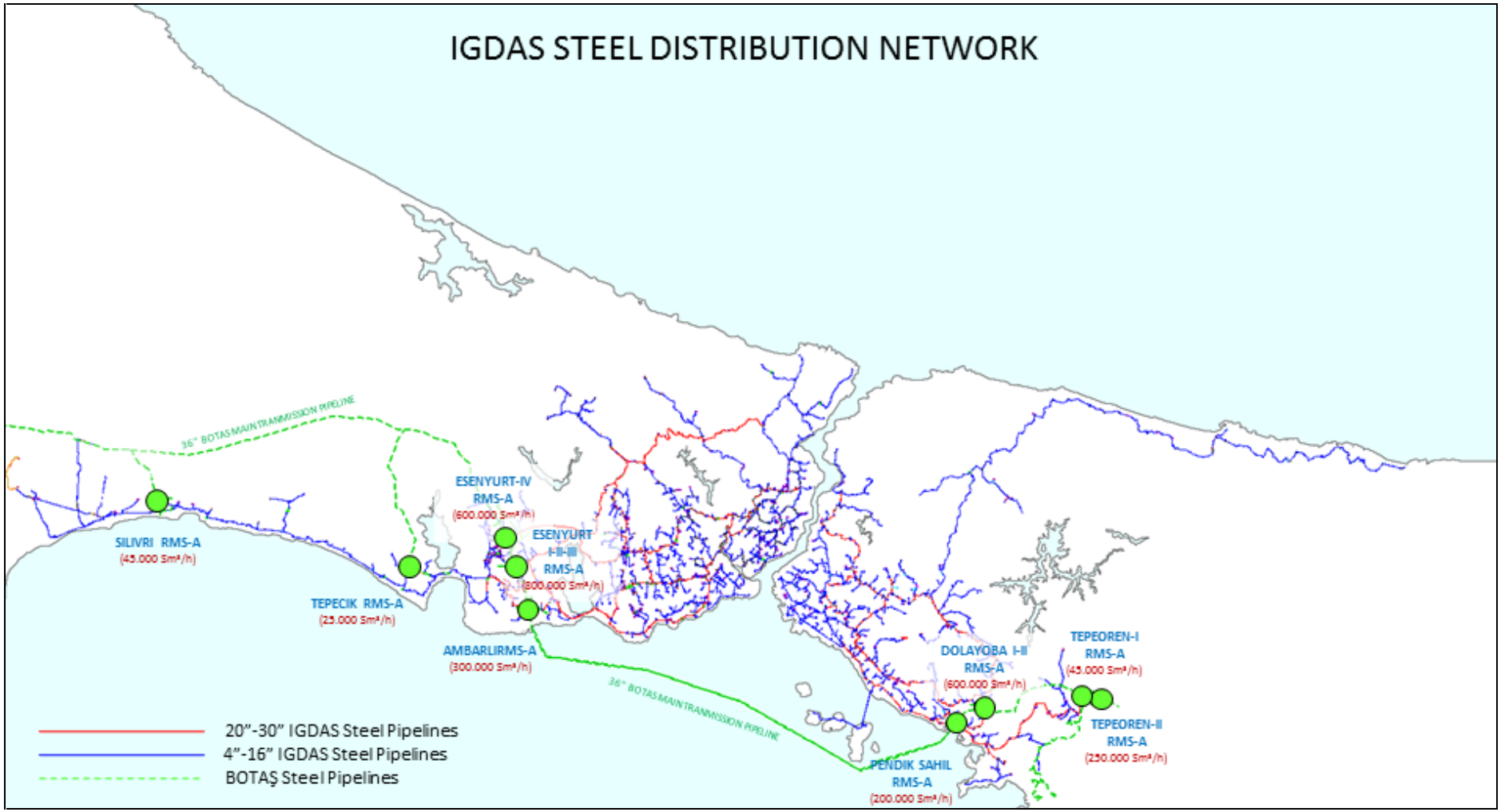

Figure 3.1 : BOTAS transmission line and IGDAS steel natural gas distribution network

4. IGDAS NETWORK SUBSCRIBER – CONSUMPTION INFORMATION

IGDAS network have reached a subscriber number of 4 803 366 by end of 2011 excluding industrial clients. Distribution of 4 803 366 subscribers is given in Chart 4.1 and Figure 4.1, and the number of industrial institutions being *free consumers*, having an annual natural gas consumption of 800 thousand Sm³ and over and number of industrial institutions being *non-free consumers*, having an annual natural gas consumption of less than 800 thousand Sm³ by the end of 2011 is given in Chart 4.2 and Figure 4.2.

SUBSCRIBER PORTFOLIO (Excluding Industry)	UNIT (I.S.N.)	DISTRIBUTION (%)
RESIDENCE	3 940 113	% 82
COMMERCIAL	623 628	% 13
OFFICIAL INSTITUTION	135 994	% 2.8
FREE CONSUMER	103 631	% 2.2
GENERAL TOTAL	**4 803 366**	**% 100.00**

Chart 4.1: IGDAS subscriber portfolio [9].

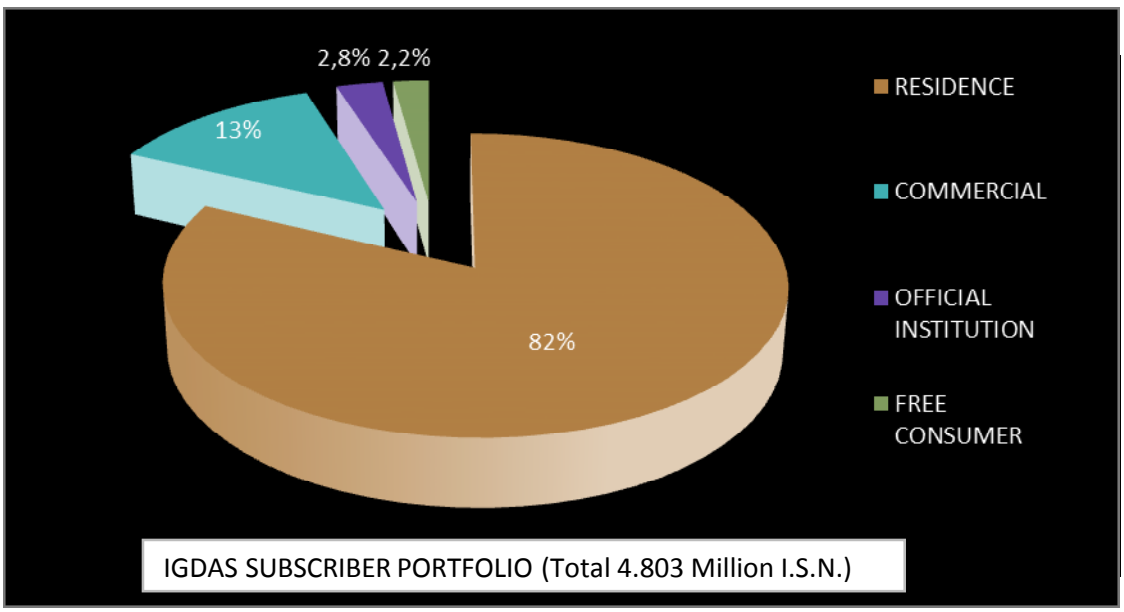

Figure 4.1 : IGDAS subscriber portfolio.

Independent Section Number (I.S.N.) given in Chart 4.1 is being defined as number of residences, stores constituting the basis of subscription and calculated as deeming 1 unit for the first 200 m² heating area at residences and offices using natural gas for heating and as 1 unit for each additional heating area of 100 m².

End of 2011	UNIT	CONSUMPTION (Sm³/year)
INDUSTRIAL (FREE CONSUMER)	459	454 563 161
INDUSTRIAL (NON-FREE CONSUMER)	727	75 735 733
GENERAL TOTAL	**1 186**	**530 298 894**

Chart 4.2: IGDAS free and non-free industrial subscriber numbers [9].

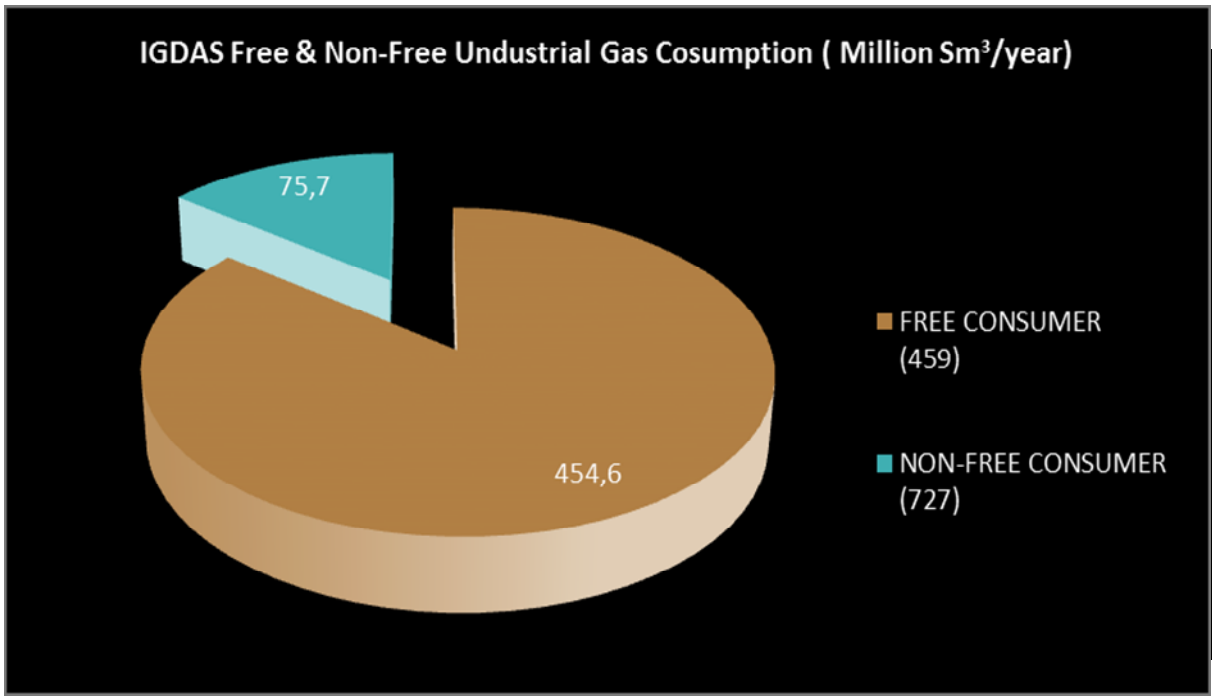

Figure 4.2 : IGDAS free and non-free industrial subscriber numbers [9].

Industrial gas consumption of free consumers of IGDAS network in between 2004-2011 is shown in Figure 4.3 and average domestic unit natural gas consumption in between 2004-2011 is shown in Figure 4.4. And in Chart 4.3 natural gas drawing and subscriber information of the network is given.

When Chart 4.3 is evaluated, despite the number of natural gas users increased by average 8.8 % annually in between 2006-2009, the natural gas consumption in the whole network is being observed to decrease by average 2.4% annually. It is being estimated that the decrease on consumption despite the increase of number of subscribers arises from increase on energy prices, thus in the natural gas consumption of following years no increase is being expected in parallel with the increase of subscriber number.

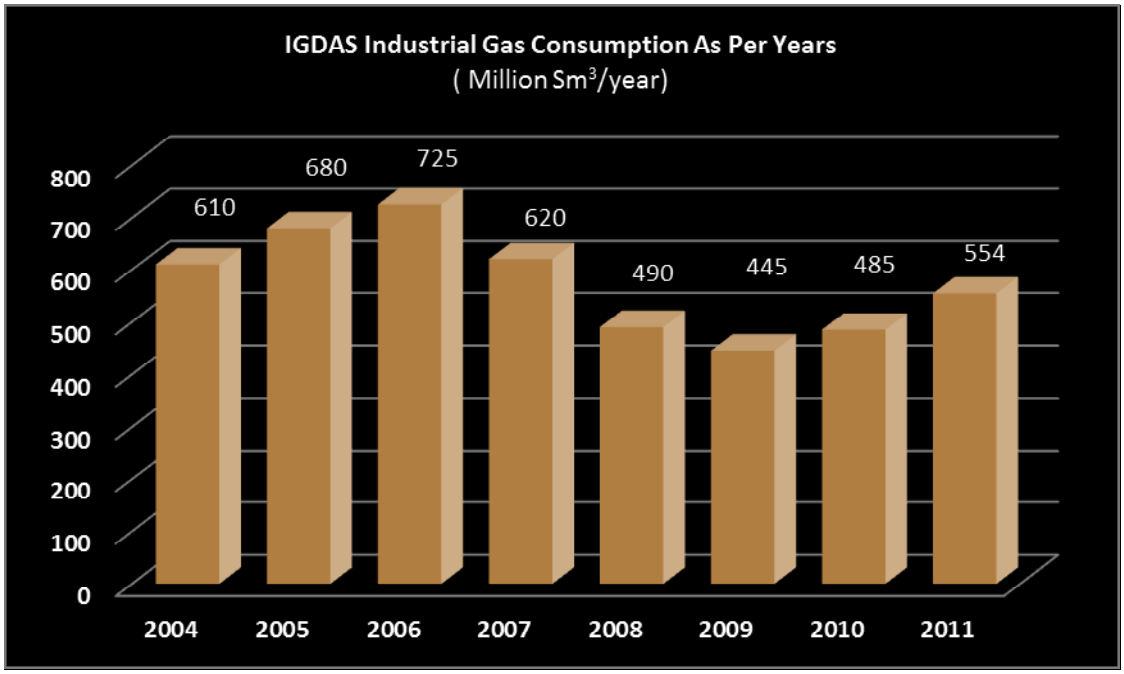

Figure 4.3 : IGDAS industrial gas consumption as per years [9].

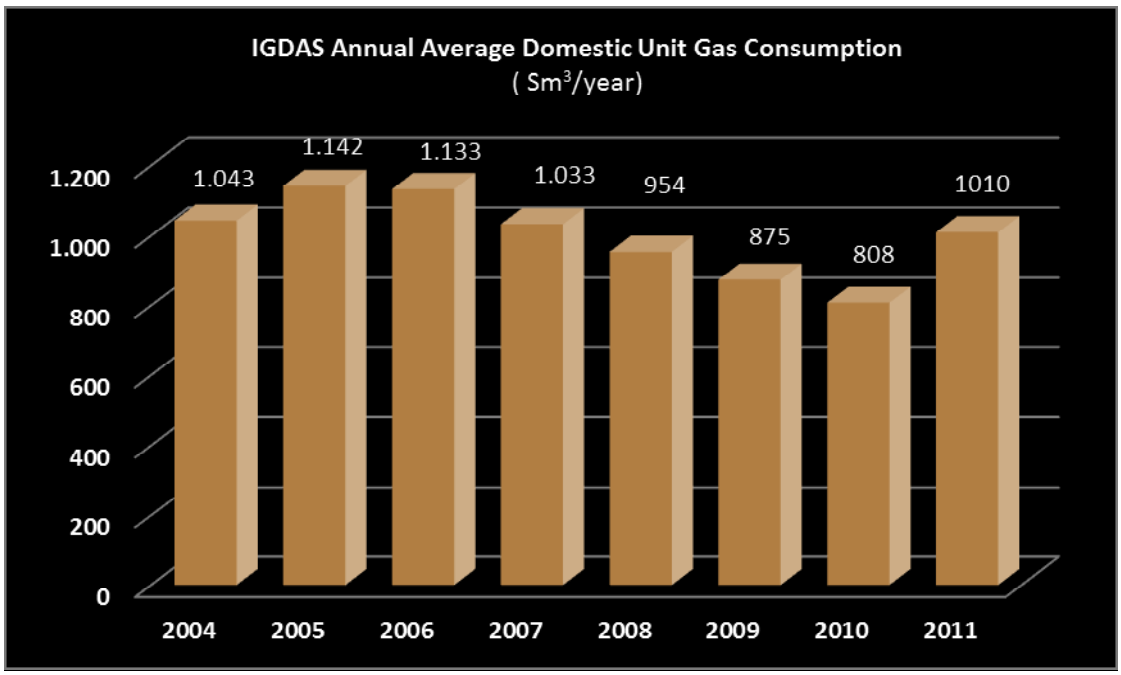

Figure 4.4 : IGDAS annual average domestic unit gas consumption [9].

NETWORK DATA	2004	2005	2006	2007	2008	2009	2010	2011
TOTAL CONSUMPTION (Million Sm³)	3 000	3 720	4 127	4 050	3 950	3 831	3 988	5 372
EUROPEAN SIDE CONSUMPTION (Million Sm³)	1 944	2 410	2 646	2 590	2 496	2 335	2 282	3 117
EUROPEAN SIDE / TOTAL CONSUMPTION RATE (%)	64.08	64.78	64.11	63.85	63.95	63.00	57.20	58.02
DOMESTIC CONSUMPTION (Million Sm³)	2 390	3 040	3 400	3 430	3 460	3 386	3 357	4 536
INDUSTRIAL CONSUMPTION OF FREE CONSUMERS (Million Sm³)	610	680	725	620	490	445	485	554
TOTAL GAS USERS BY THE END OF THE YEAR (Million I.S.N.)	2.29	2.67	3.00	3.32	3.62	3.87	4.15	4.49
INCREASE OF GAS USERS COMPARED TO PREVIOUS YEAR (%)	11.93	16.59	12.35	10.66	9.03	6.90	7,20	8,20
INCREASE OF CONSUMPTION COMPARED TO PREVIOUS YEAR (%)	10.83	24.11	10.94	-1.86	-2.46	- 3.01	4.11	34.67
ANNUAL AVERAGE DOMESTIC UNIT CONSUMPTION (Sm³)	1.043	1.142	1.133	1.033	956	875	808	1010

Chart 4.3 : IGDAS network natural gas consumption and subscriber information in between 2004-2009 [9].

In Chart 4.4 and Figure 4.5, subscriber, consumption and daily average temperature information of days when peak demand realized in between 2004-2011 is shown [9].

DATE	TOTAL CONSUMP. (Million Sm³/day)	EUROPEAN SIDE CONSUMP. (Million Sm³/day)	TOTAL CONSUMP. EXCEPT FREE CONSUMP. (Million Sm³/day)	INDUSTRIAL CONSUMP. (Million Sm³/day)	GAS USER (I.S.N.)	UNIT CONSUMP. (Million Sm³/day)	DAILY AVERAGE TEMPERATURE (C°)
13.02.2004	**22.91**	11.68	20.90	2.01	1.97	10.61	**-4.5**
07.02.2005	**28.12**	17.56	25.92	2.20	2.32	11.17	**-0.2**
26.01.2006	**32.39**	20.26	31.05	1.34	2.68	11.58	**-1.2**
05.02.2007	**26.66**	16.57	24.65	2.01	3.02	8.16	**3.0**
18.02.2008	**35.35**	21.63	33.00	2.35	3.36	9.82	**-1.6**
26.02.2009	**28.25**	17.16	25.43	2.82	3.66	6.94	**3.8**
25.01.2010	**37.27**	22.71	35.78	1.49	3.89	9.19	**-2.4**
09.03.2011	**36.78**	22.33	35.91	0.87	4.20	9.02	**1.6**

Chart 4.4 : IGDAS maximum natural gas drawing dates in between 2004-200 [9].

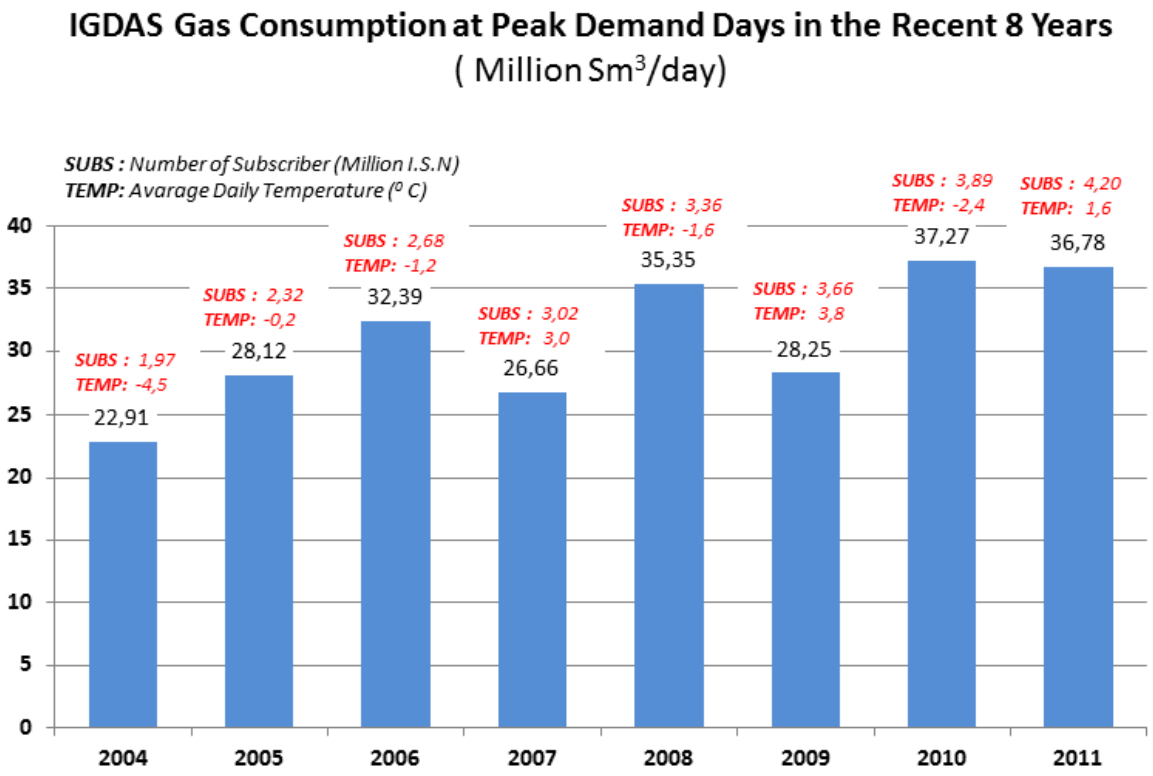

Figure 4.5 : IGDAS gas consumption at peak demand days in the recent 8 years [9].

5. FEEDING OF IGDAS FROM TPAO STORAGE FACILITIES

5.1 Necessity of Storage

Natural gas transmission and distribution companies face a seasonally varying gas demand due to increase of demand required for heating residences in winter and due to the gas requirements of large industrial institutions. Construction of distribution / transmission pipe line at a capacity that will be able to respond to such a possible peak demand condition brings an unnecessary and high cost with it, and this condition is being partially resolved in practice by making cuts on gas supply to industrial section in winter. And in many countries this change in demand is being covered by storing gas at underground in summer and by delivering to current pipe line in winter [7,8].

Within the scope of storage activity being planned for Istanbul gas distribution network, IGDAS will benefit from the Degirmenkoy and North Marmara natural gas storage facilities in two forms. These can be summarized as providing additional capacity increase in case the capacity provided by the current BOTAS line is partially limited and as feeding the network partially from storage facilities in case of gas flow interruption on main transmission line.

5.1.1 Providing capacity increase for European side in addition to BOTAS line

Low pressure problem is being faced in winter on current steel lines and especially at end points due to the yearly expansion of natural gas distribution network within the borders of Istanbul where IGDAS provides natural gas distribution service, increase of number of subscribers and gas users, and thus increase of gas consumption compared to past. As the RM-A stations are geographically at the entrance (Esenyurt) and exit (Pendik) points of the city on each side, low pressure is being faced at end points which is not due to capacity.

During peak demands in winter, gas flow rate on the lines increases due to low pressure and abrasion at micro level may occur on the interior surface of pipeline in case of flow due to friction by high flow rate. This condition causes the increase of contamination at end points of steel network, and thus causes operational problems such as shortening of filter renewal period at regional regulators or client stations being fed by steel network.

Natural gas consumption increases in all the cities having natural gas distribution due to low temperature and meteorological data in Turkey, and thus low pressure occurs on the BOTAS national transmission line. For that reason in gas drawing periods of highest flow rate, it is being anticipated to feed the European side distribution network by an individual transmission line to be installed fro TPAO Silivri storage facilities to RM-A stations' output lines in addition to the capacity being provided from BOTAS line.

In case providing gas supply to IGDAS network from TPAO storage facilities, it will ensure less gas supply from the BOTAS transmission line which is equal to that amount and moreover pressure reduction operation will not be required at RMS-A stations for the gas being pressurized at storage facilities and delivered to BOTAS transmission line.

5.1.2. Feeding of European side network in case of interruption on BOTAS line

Gas supply on BOTAS national transmission line that reaches Turkey from Russia over Balkan countries can be interrupted from time to time due to international disputes. However, by the crisis faced with Ukraine in January 2008, gas supply being at a daily level of 42 Million Sm³ from this line is stopped for a temporary period.

In that period, when natural gas consumption in Turkey was high due to weather conditions, gas flow from the BOTAS west transmission line feeding also Istanbul could be covered partially by the current capacity increase at Marmara Eregli LNG terminal and by natural gas supply from TPAO Silivri storage facilities at a daily capacity of *16.7 Million Sm³* [4].

On the distribution network of IGDAS, there is no network connection in between Europe and Anatolia sides of Istanbul. In case of international disputes on BOTAS transmission line at the route of Esenyurt-Avcılar-Marmara Denizi-Pendik-Dolayoba-Tuzla or in case of a possible damage on the Marmara Sea passage section of line having high possibility of earthquakes, European side of Istanbul will be required to be fed from TPAO Silivri storage facilities and Anatolian side will be able to be partially fed by the connection of BOTAS transmission line with other provinces [11].

5.2 Determination of Natural Gas Mount to be Covered from Storage Facilities

Information regarding the monthly and annual natural gas consumption of IGDAS European side is shown in Figure 5.1 and Figure 5.2. When Chart 4.4, Figure 5.1, Figure 5.2 and Figure 5.3 are evaluated, it is being observed that maximum natural gas drawings for European side is realized at a level of monthly maximum *500 Million Sm³* and daily maximum *22.71 Million Sm³* in between November – March.

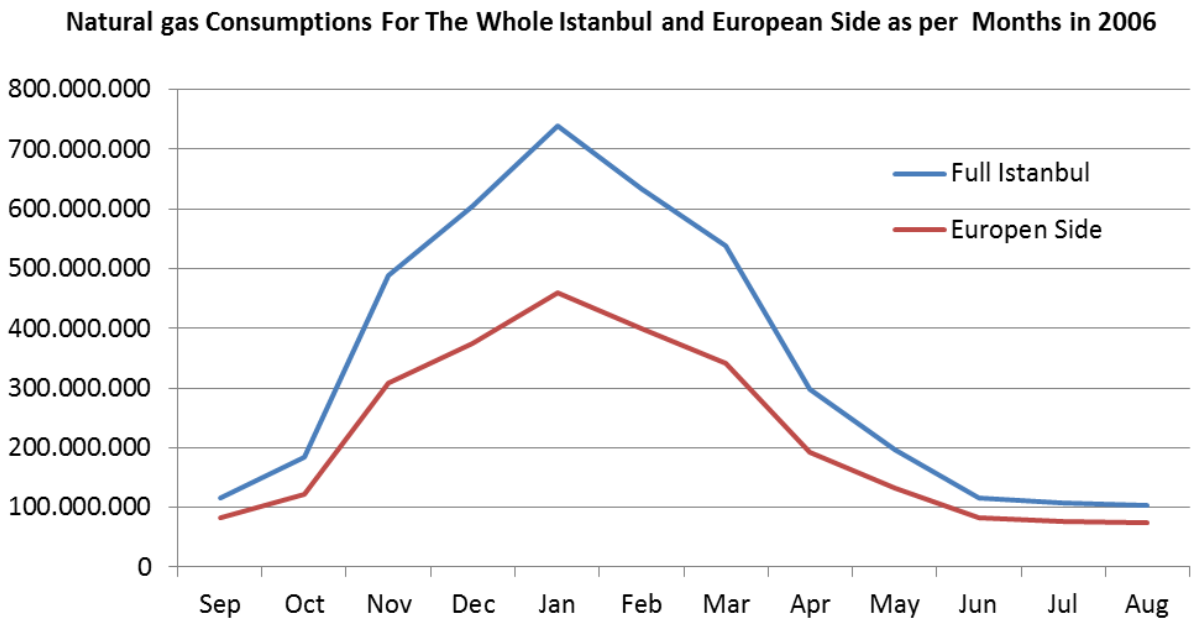

Figure 5.1: Natural gas consumptions for the whole Istanbul and European side as per months in 2006 [9].

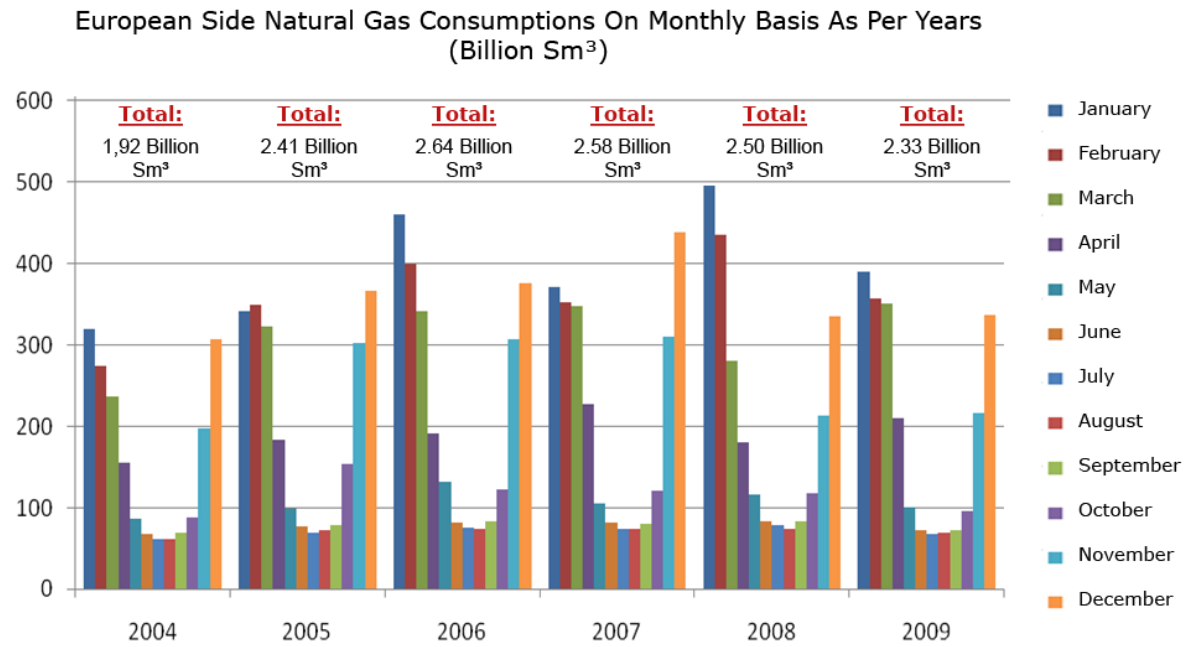

Figure 5.2 : European side natural gas consumptions on monthly basis as per years [9].

According to the network records, maximum hourly consumption value for European side is realized at the level of *1.090 Million Sm³*.

At times when temperature is under -1 ˚C, pressure value at BOTAS transmission line decreases to 38 barg levels depending on the general consumption in Turkey. In this case capacity problem occurs on BOTAS transmission line even if the RMS-A capacities are sufficient. It is necessary to determine the natural gas amount to be provided from storage facilities during peak periods by making simulation according to scenarios to be composed as per criteria of providing gas supply in addition to RMS-A flow rates due to capacity problem at BOTAS line and deactivation of RM-A stations as the result of interruption on BOTAS line on European side network.

5.3 Storage Facilities – IGDAS Network Connection Pipeline Investment

5.3.1 Legal status

Legal entities who will make storage as per Natural Gas Market Law No 4646 of 18.04.2001 shall receive license from EMRA *(Republic Of Turkey Energy Market Regulatory Authority)* in order to involve in storage activities of natural gas as underground and above ground gas or LNG: It is forbidden to involve in storage activity without the license in subject. Real entities making license request shall conform the conditions within the legislation to be issued.

Real entities applying to receive storage license shall;

a. Have technical and economical sufficiency to make storage,

b. Commit that they will manage all their storage capacities to be available under their possession in a manner as to assist the coordinated and secure operation of the system,

c. Commit that the storage capacities -to be available in their possession- to be put into service in an objective and equal manner in case the system is suitable [10].

IGDAS has natural gas distribution license within Istanbul as per the license received from EMRA. Only TPAO and BOTAS have natural gas storage license in Turkey.

Thus IGDAS shall realize the required investment –to be benefited at storage facilities- over a third company.

5.3.2 Evaluation of TPAO facilities – IGDAS network connection points

BOTAS high pressure natural gas transmission line reaches Anatolian side by Mar mara Sea passage following the Silivri, Büyükçekmece, Esenyurt, Ambarli route in Istanbul.

IGDAS RM-A stations providing gas supply to European side, main steel line and connections being fed from these stations are shown on Figure 5.3

Again as observed in Figure 5.3, the output line of the new Esenyurt-IV station in subject is designed with 30" diameter and its connection to 30" main steel line of largest capacity, that is directly fed from the current Esenyurt I-II-III RM-A station and that provides gas supply to European side, is made. Moreover 30" take-off is constructed on the output line of new RM-A station which has just constructed in 2010 intended to be fed from the TPAO Silivri storage facilities.

24", 28" and 30" main steel lines, being fed by the RM-A stations on the IGDAS network, do not have connection with each other at internal points of the network due to the composition of alternative feeding. For that reason the connection from TPAO Silivri storage facilities to IGDAS network is first assessed to be made to current 30" manifold point at the output of Esenyurt-IV RM -A station which is closer to storage facilities compared to other RM-A stations. (Figure 5.3)

5.3.3 Connection line route

For the BOTAS main transmission line routes within Turkey having an operation pressure of 70 bar, the lands with the character of forest land –where population is low, outside the city centers where there is no traffic etc - are selected in order to keep the environmental effect at minimum level in case of any damage on the line. As the TPAO storage facilities – IGDAS European side network connection line route will be designed of higher pressure than the IGDAS steel network lines having an operation pressure of 20 bar, it shall be of the same quality with the BOTAS main transmission line routes.

The distance of Common Facility, ensuring the connection of TPAO North Marmara and Degirmenkoy storage facilities to BOTAS line, to the Esenyurt-IV RM-A station constructed in 2010 is about 62 km.

As IGDAS does not have expropriation authority, the expropriation band of 70 meters belonging to BOTAS that extends along the BOTAS transmission line and that passes from the north of Silivri and Büyükçekmece counties is considered as the most convenient route for the connection line.

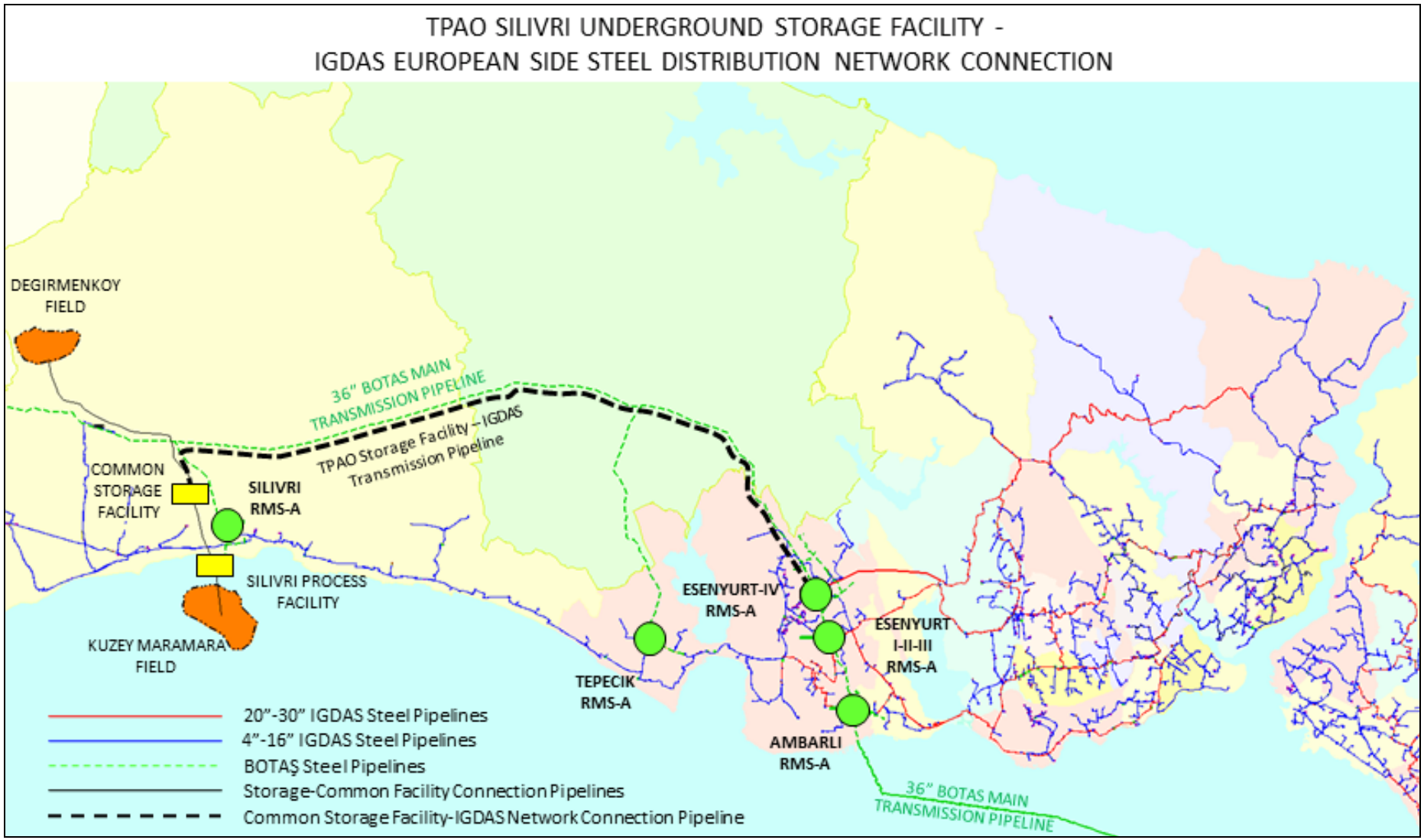

Figure 5.3 : TPAO storage facilities – IGDAS network connection.

6. STORAGE FACILITIES – IGDAS NETWORK SIMULATION STUDIES

6.1 Distribution Network Analysis Methods

Suitable network design is the most important condition of providing continuous gas supply being among the common values and objectives of gas distribution networks. The obligation of network projects, made in order to meet this condition, to be economical also affects the commercial success of companies significantly.

In practice these two criteria negatively affects each other, in other words non-problematic network is not being economical for the company in respect of gas supply to their clients and the network being convenient for economical criteria can cause problems in gas supply. Thus during generation of network projects, the balance of these basic and contrasting criteria before engineering shall be composed.

In natural gas distribution in Turkey, it is obligatory to conform the laws and legislations determined by Energy Market Regulatory Authority (EMRA) of Turkey. According to international criteria, the speed of gas shall not exceed 25 m/s and 30-35 m/s speed shall be permitted during crisis. For example it is necessary to ensure minimum 6 barg at IGDAS steel lines and minimum 1.5 barg value at polyethylene lines. But when 6 barg is a limit value, it is suggested to be able to ensure minimum 10 barg value in practice.

6.2. Consumption Scenarios and Simulation Results

6.2.1 Consumption scenarios and simulation parameters

The result of sample simulation made on the gas analysis program for the feeding of IGDAS European side natural gas distribution network from TPAO North Marmara and Degirmenkoy storage facilities is given in Figure 6.1. Information regarding the assumed acceptances for simulations and the consumption scenarios are as follows:

1) The peak demand flow value that is realized until now for European side is *1 090 000 Sm^3/h.* According to the projection of IGDAS regarding the number of current and possible subscribers for 2013 is *1 280 000 Sm^3/h.*

2) The share of industrial consumption within the peak demand anticipation for 2013 is *161 000 Sm^3/h*, and share of domestic and commercial consumption is *1 119 000 m^3/h.*

3) The highest pipe diameter used at IGDAS steel network is 30". The pipe line to be installed in between TPAO Storage Facilities - IGDAS network is deemed to be installed with a maximum diameter of 30" due to the already available equipment for operational activities such as repairs and maintenance and also the storage line being able to be used as network transfer line when required.

4) It is assumed that the output pressures of RM-A stations, which will be included In gas supply provision scenarios intended for additional capacity increase from TPAO storage facilities as the result of partial capacity insufficiency on BOTAS line, are set at the *23-25 barg* interval.

5) Different scenarios are evaluated as per the pressure of natural gas from TPAO storage facilities to connection line being 25 bar, 30 bar, 40 bar and over 50 bar.

6) In calculations for all the scenarios, it is assumed that the 30" connection line of TPAO storage facilities – IGDAS European Side network connection is realized by the 30" take-off point connection planned at the output of RMS-A station of Esenyurt -IV with a capacity of 600 000 Sm^3/h.

7) A route parallel to the BOTAS 36" line is selected as the TPAO storage facilities – IGDAS network connection line route and calculation is made according to that route.

8) As the result of each simulation, the input pressure value for all the district (regulating) stations connected to steel network and gas flow rate for all the pipelines in between each nod connected to steel network is calculated and results are written on the calculation sheet. In simulation studies calculation is made on 5.810 units of nods for the steel network of European side.

9) As the result of calculation, it is concluded that the system design is convenient for scenarios where minimum pressure is higher than 6 barg value and maximum gas flow rate is under 35 m/s.

10) In simulation studies the loads on steel network are calculated considering the natural gas consumption values of all regional regulators and client stations at highest flow rate for the condition where industrial consumption exists and considering the drawing values of only regional regulators at highest flow rate for the condition where there is cut in the industrial gas supply.

11) The flow rates of district (regulating) stations and client 8regulating) stations being fed from steel network at highest flow rate is obtained by increasing the values, received from the IGDAS SCADA system, for 18.02.2008 when the highest drawing occurred for 2008 as per the 2013 projection.

6.2.2 Consumption scenarios

Simulation studies intended for feeding of IGDAS European side natural gas distribution network from TPAO North Marmara – Degirmenkoy underground natural gas storage facilities includes two different conditions.

First among these is the provision of gas supply for the distribution network intended for additional capacity increase from TPAO storage facilities as the result of partial capacity insufficiency at BOTAS line. Partial capacity insufficiency on BOTAS line that occurred in 2008 winter is being assessed as the most possible condition to occur in the following years. This condition is evaluated in 5 different scenarios anticipating the activation of stations at different drawing flow rates or their deactivation by setting the output pressures of RM-A stations, that feed the European side distribution network, to different values.

And the condition of having an flow interruption on BOTAS line is evaluated in a different scenario where the drawing of RM-A stations that still supplies gas to network is deemed as zero, where industrial consumption at distribution network is cut and where the network is fed completely from TPAO storage facilities.

The summary of simulation studies intended for feeding of IGDAS European side natural gas distribution network from TPAO North Marmara – Degirmenkoy underground natural gas storage facilities is given in Chart 6.1.

According to Chart 6.1; it is possible for capacity increase to benefit from the TPAO North Marmara – Degirmenkoy underground natural gas storage facilities for the IGDAS European side natural gas distribution network during peak periods in winter months without having a complete flow interruption on the BOTAS main transmission line. In this case it is necessary to provide a natural gas supply with minimum 25 barg pressure and 225 000 Sm³/h flow rate from TPAO storage facilities and to design the connection line with 30" diameter. (Scenario 5).

In case of having 30% capacity problem on BOTAS line, the 420 000 Sm^3/h part of 1 280 000 Sm^3/h flow rate required by the network without making a cut on the industrial consumption will be able to be covered from the TPAO storage facilities. And the remaining 860 000 Sm^3/h network load will be able to be covered from the RM-A stations that feed

European side by the provision of 649 000 Sm^3/h flow rate of the Esenyurt I-II-III RM-A station with a capacity of 800 000 Sm^3/h- at 80% capacity and at 23 barg output pressure and 211 000 Sm^3/h flow rate of the Ambarli RM-A station –with a capacity of 300 000 Sm^3/h at 70 % capacity and at 23 barg output pressure. (Scenario 4)

420 000 Sm^3/st flow rate anticipated in this scenario is possible to be covered from the storage facilities by the current capacity of TPAO storage facilities and it will be able to be applied in practice within the capacity problem possible to occur on the BOTAS line in the following years.

In case of TPAO Storage facilities – IGDAS network connection line being constructed with 30" diameter and provision of gas supply from storage facilities with at least 53 barg output pressure and 1 119 000 Sm^3/h flow rate, feeding of network is possible by making cuts on the industrial consumption. Providing gas supply from storage facilities at this amount seems to be possible by the current capacity of facilities. But the operation of the system will be able to be provided in case of increase of the capacities of facilities (Scenario 6).

System Information		SCENARIOS					
		1	2	3	4	5	6
TPAO Storage Facilities – Network Connection Line Pressure (barg)		**40**	**40**	**40**	***30***	**25**	**53**
TPAO Storage Facilities – Network Connection Line Flow Rate (Sm^3/h)		703 259	719 403	721 418	***419 753***	224 258	1 119 000
Esenyurt I-II-III RMS-A	***Flow rate (Sm^3/h)***	376 705	370 246	355 739	***649 124***	769 146	RMS-A STATIONS NOT ACTIVE DURING BOTAS LINE CUT
	Output Pressure (barg)	24	23	23	***23***	23.50	
Silivri RMS-A	***Flow rate (Sm^3/h)***	38 954	26 269	–	–	–	
	Output Pressure (barg)	25	23	–	–	–	
Ambarli RMS-A	***Flow rate (Sm^3/h)***	–	–	202 768	***211 047***	286 521	
	Output Pressure (barg)	–	–	23	***23***	23.75	
Industrial Gas Cut		Yes	Yes	No	***No***	No	Yes
Network Min. Regional Regulator Input Pressure (barg)		18.10	16.78	14.76	***14.38***	14.55	8.05
Network Max. Gas Flow Speed (m/h)		19.9	19.8	23.2	***23.2***	22.1	32.6
Network Feeding Status		***Can be fed***	***Can be fed***	***Can be fed***	***Can be fed***	***Can be fed***	***Can be fed at limit conditions.***

Chart 6.1 : IGDAS-TPAO underground gas storage facilities connection simulation results.

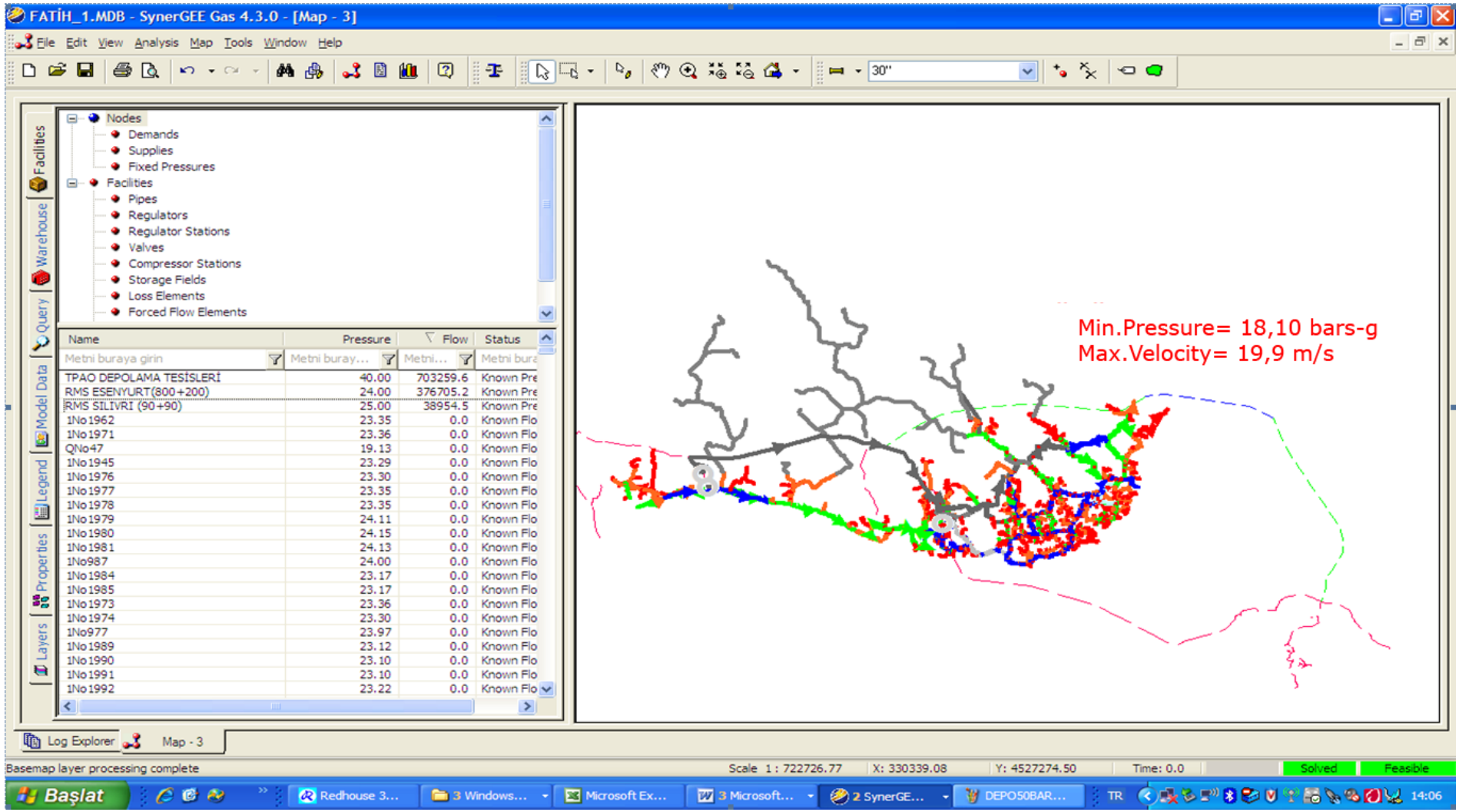

Figure 6.1 : TPAO Silivri Storage Facilities IGDAS Network Connection Simulation Sample

In all the simulation studies, simulation program provides the pressure value at network input points of connection line of TPAO storage facilities – IGDAS European side distribution network as 23-25 barg as output. As this pressure interval 25 barg is lower than the IGDAS distribution network maximum operation pressure and is lower than the network pressure at that point, installation of additional pressure reduction system is not necessary.

Thus remote control of the system can be ensured in case of installation of flow control valves to be installed on the connection line and of measurement system to be installed at output of TPAO storage facilities or at network entrance points and of SCADA connection for the whole system.

7. RESULTS AND SUGGESTIONS

Istanbul European side is geographically close to the TPAO Thrace underground natural gas storage facilities than other natural gas distribution regions having high consumption.

During peak periods of European side natural gas distribution network in winter, feeding from the TPAO Thrace underground natural gas storage facilities as an alternative to BOTAS transmission line is a significant option being faced in order to provide safety of supply. With this aim in case of realization of connection line investment to be installed in between storage facilities – IGDAS network, system is able to provide gas supply to network during partial capacity problems on BOTAS line.

In case of having partial capacity problem on BOTAS main transmission line, the pressure of storage line – IGDAS network connection line and RMS-A output pressures are synchronously controlled and loads as per the drawing value of network can be distributed to TPAO storage facilities and RM-A stations and thus to BOTAS main transmission line at the rate of instant capacity of storage facilities and BOTAS line.

When the connection line investment in subject is realized by IGDAS, the connection line will be able to be used as Büyükçekmece-Silivri region IGDAS network transmission line in case of non-usage of storage facilities in the future or in case of providing gas supply only to BOTAS main transmission line from the facilities.

Moreover in case of capacity increase of LNG facilities of BOTAS at Marmara Ereglisi location, direct gas supply from LNG facilities to IGDAS distribution network will be able to be provided through a separate connection from connection line to LNG facilities during a possible crisis of cut on BOTAS line.

Operations have started for the transfer of natural gas purchase contracts owned by BOTAS -which is responsible for natural gas import in Turkey- to private sector. In the following years natural gas import is being planned to be realized by private companies over the current system. In this condition, by using the connection line to be constructed by IGDAS from TPAO storage facilities to IGDAS European side natural gas distribution network, natural gas will be imported by private companies without any carriage fee and transmission of natural gas -brought to Thrace region through current or new transmission lines- to distribution network will be able to be provided.

The injection of gas -corresponding the natural gas amount to be provided to IGDAS network from TPAO storage facilities in winter- to storage facilities in summer when the drawing is low to be performed from the BOTAS line or IGDAS network over the connection line to be installed and conditions of netting in between BOTAS – IGDAS and the ownership and operation responsibility of the connection line to be constructed shall be negotiated additionally.

In order to have the system operate with optimal efficiency TPAO storage facilities shall be considered as a source which can be benefited from in case of a partial capacity problem on BOTAS transmission line and a planning for the natural gas cut for other institutions (official institutions, large scale business organizations etc.) -except residences- besides the industrial natural gas consumption shall be made.

The results obtained in this study, that is realized intended for feeding of IGDAS European side natural gas distribution network from TPAO Thrace underground natural gas storage facilities in winter months during peak demand periods, are also a suggestion for the strategic planning studies carried out by IGDAS management for the safety of supply of distribution network.

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