

## ANALYSIS OF NATURAL GAS DOMESTIC CONSUMPTION IN BULGARIA ACCORDING TO THE FLOORAGE AND THE OUTSIDE TEMPERATURE

**Martin Boyadjiev<sup>1</sup>, Veselin Christov<sup>2</sup>**

<sup>1</sup>Department of Oil and Gas Drilling and Production, University of Mining and Geology "St. Ivan Rilski", 1700 Sofia; martinb@mgu.bg

<sup>2</sup>Department of Computer Science, University of Mining and Geology "St. Ivan Rilski", 1700 Sofia; V.Christov@gmail.com

**ABSTRACT.** Raw data given from one of the biggest natural gas distribution company for monthly domestic consumption in many Bulgarian towns with different sizes are used in this analysis. The influence that the floorage and outside temperature affect on monthly domestic consumption is examined. A neural network is find and trained with minimal error, what does prognosis for monthly consumption of one family according to the floorage size, the month from heating season and the outside temperature. Key words: natural gas, consumption, forecast, whether, temperature, artificial neural network.

### АНАЛИЗ НА ВЪТРЕШНАТА КОНСУМАЦИЯ НА ГАЗ В БЪЛГАРИЯ ПО ОТНОШЕНИЕ НА ПЛОЩ И ВЪНШНА ТЕМПЕРАТУРА

**Мартин Бояджиев, Веселин Христов**

Минно-геоложки университет "Св. Иван Рилски", 1700, София; martinb@mgu.bg, V.Christov@gmail.com

**РЕЗЮМЕ.** Разглеждат се месечните данни за консумацията на газ при една от най-големите разпределителни компании на газ за много български градове.

### Introduction

Due to the large distances that delivers natural gas to consumers and the lack of local storage in the surrounding area of large consumers, the accuracy in short-term forecasting consumption of gas is of great importance for economic and reliable operation of gas distribution network. There are daily and weekly forecasting needs of a particular interest in the case of increased consumption when the capacity for accumulation of a network is reduced. In this case, is highly expressed a no stationary mode of operation of gas distribution networks. For their efficient management and reliable operation are required precise models on which to reliably predict short-term consumption of natural gas. Current investigation is based on the experience of the gas supplying in Bulgaria.

The goal is finding relationships describing the domestic consumption of natural gas to households based on the heating surface and monthly average temperatures.

indication we split consumers in 10 groups according to their residential area (Table 1).

This division stems from the most common floorages in the records and allows you to spot anomalies and relationships in the consumption of natural gas for heating in households.

Table 1. Types of house sizes, m<sup>2</sup>

Type	Housing Size
1	to 56
2	from 57 to 66
3	from 67 to 76
4	from 77 to 86
5	from 87 to 96
6	from 97 to 116
7	from 117 to 146
8	from 147 to 196
9	from 197 to 296
10	from 297 to 399

### Task analysis

Sought to find relationships input data were processed by filtering to exclude users with no data on monthly consumption of natural gas, or it is zero. Consumers themselves were divided according to residential area of heating surface. Observing the grouping of the number of houses based on this

**Average monthly consumption for the winter months in the period 2006-2009.**

Two surveys of consumers were carried out throughout the country and those of gas supplied city.

### Average monthly consumption for the whole country:

Following relationships were analyzed:

1. The average consumption of one consumer from each of 10-type sizes of the residential area for the months of the three seasons (Fig. 1);

2. The average consumption of one consumer for each month in a season (Fig. 2);

3. Average consumption of a consumer for season (Fig. 3).

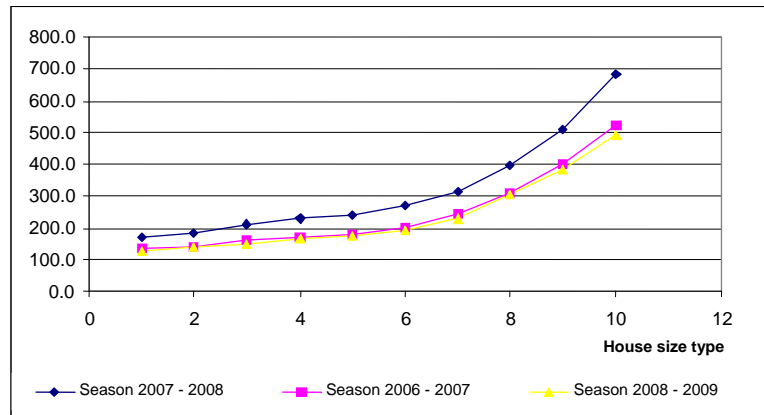


Fig. 1. Seasonal domestic consumption throughout the country in housing sizes

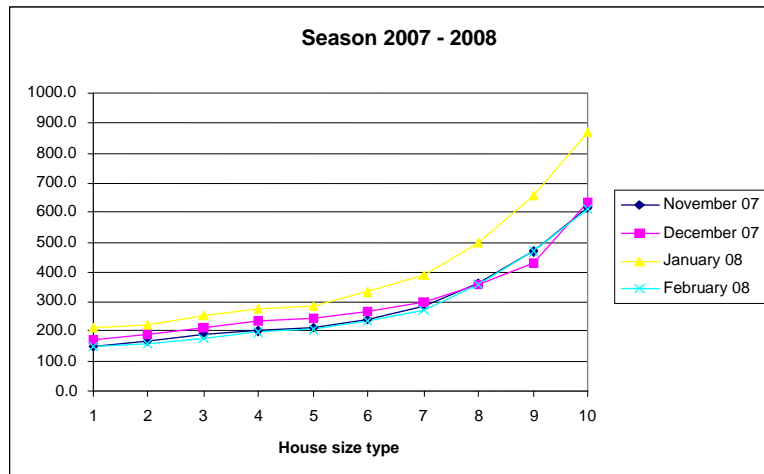


Fig. 2. Consumption compared to average sizes of households for the whole country

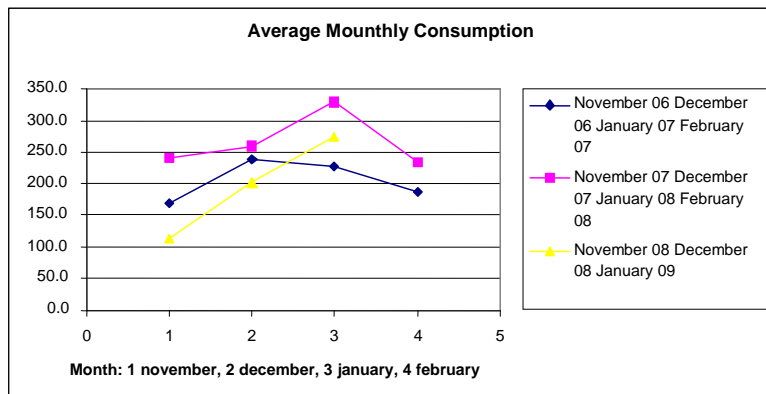


Fig. 3. The monthly average consumption for three seasons of a household with average floorage

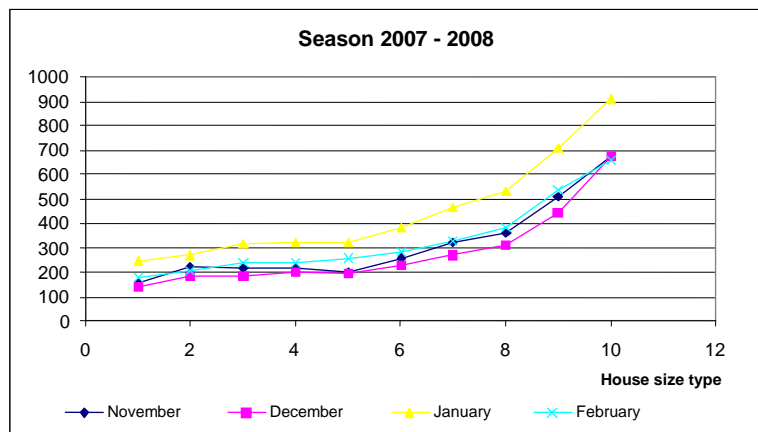


Fig. 4 Average domestic monthly consumption in Sofia

**Average monthly consumption in a city:** On the basis of data on consumption are calculated monthly average consumption and the number of consumers for the 10-type users (Fig. 4).

If we compare graphs of Figures 1 and 4 we will see that household consumption of Sofia is greater than that of the whole country.

**Key observations:**

- The highest consumption was in January (consumption reported by the companies);
- The relative monthly consumption per square meter is highest for houses with sizes from 40 to 76 m<sup>2</sup>, reaching more than 3.15 m<sup>3</sup>;
- In the warm winter months consumption in the small apartment (about 60 m<sup>2</sup>) is almost flush with those of 100 m<sup>2</sup>;
- In the cold winter months consumption in the apartment with size about 70 m<sup>2</sup> is equal and higher than in the three-bedroom homes;

Assuming that most households are heated with uniform two contour boilers, and then apartments with size 92 m<sup>2</sup> consume natural gas with a high efficiency. Smaller apartments may have lower consumption, but the relative cost of gas is higher.

Definitely we can say that small homes are “oversized” in relation to the power used for heating.

Overall consumption of energy derived from natural gas for heating in households is 30 percent higher than the same heat produced by electrical appliances. This is explained by the poor regulation of the equipments, by their inappropriate choice and by incorrect dimensioning and design of gas / heating system, which ultimately leads to low efficiency of operation of gas appliances and high consumption of natural gas.

**Average maximum and minimum monthly consumption in city:** For the research period the average maximum and minimum monthly consumption is obtained and is shown in the table below:

Table 2. Maximum and minimum monthly consumption for a city

Size, m <sup>2</sup>	November		December		January		February	
	max	min	max	min	max	min	max	min
to 56	152	94	138	119	163	247	111	178
from 57 to 66	220	91	217	147	223	267	159	204
from 67 to 76	220	107	203	160	219	313	152	238
from 77 to 86	219	110	217	179	227	321	155	240
from 87 to 96	198	119	201	188	218	319	151	256
from 97 to 116	258	125	257	195	259	383	180	281
from 117 to 146	317	153	329	251	319	465	250	324
from 147 to 196	361	192	371	292	371	531	271	381
from 197 to 296	507	272	516	399	506	711	394	539
from 297 to 399	672	313	672	466	629	908	444	657

**Observations**

- From the survey period it is the highest consumption in January 2008, which is explained by the lowest monthly average temperature throughout the studied period (-2.4 °C).
- Even then the house of 90 m<sup>2</sup> has consumed gas as those of 70 m<sup>2</sup> and less gas than those with 80 m<sup>2</sup>.
- The least monthly consumption was in November 2008 when they were the highest average temperatures (+6.8 °C).

## Forecasting by neural network

A neural network trained by existing data can be using to predict the gas consumption a household. This study used the system Statistica 7 of StatSoft Inc. This system has various built-in neural networks, which may be produced different statistical investigations. Difficulty in this analysis is the selection among many possibilities of the type and characteristics of a neural network that can give the best results for specific research. Fortunately, in Statistica 7 there is a module called the Intelligent Problem Solver (IPS), in which several neural networks with different characteristics can be set and train on the same data. In such way the best of them can be found, which gives the least error.

Based on the data we have for a city: house size of domestic consumer, monthly consumption of gas for 10 months (winter seasons for 3 years) and average temperature for these months, we decided to use a neural network with three inputs and one output as follows:

Inputs: FT – type of house sizes  
M – months  
T – average temperature  
Output: Q – average consumption

As with previous studies the housing sizes were divided into 10 type 1, 2, ..., 10 (Table 1). Months for which we have data, and average temperatures are:

1. November - 2006, 2007 and 2008.

2. December – 2006, 2007 and 2008.

3. January – 2007 and 2008.

4. February – 2007 and 2008.

Average consumption Q was calculated for the 10 type sizes, for the 10 months. In such way it was received the training sample of 100 records.

To find a neural network that will give the best estimate IPS module of Statistica 7 is used. In the IPS the following types of networks were set:

- Generic Regression Neural Network (GRNN),
- neural networks with Radial Based Function (RBF) ,
- Multilayer Perseptron – 3 layer (MLP3) – 1 input, 1 hidden and 1 output layer,
- Multilayer perceptron – 4 layers (MLP4) – 1 input, 2 hidden and 1 output layer.

The first three networks have three layers with one hidden layer, and the fourth has four layers with two hidden layers. They were set:

- Maximum number of nodes in the hidden layer - 10
- Training time – 15 minutes
- Criteria for selecting the best network – minimum error training
- Number of networks selected for the best – 2.

After training two best networks were received:

Table 3. Two best neural networks received by IPS

	Profile	Train Perf.	Train Error	Training/Members	Inputs	Hidden	Output
1	RBF 3:3-10-1:1	0.306293	0.001916	KM,KN,PI	3	10	1
2	RBF 3:3-10-1:1	0.281327	0.001760	KM,KN,PI	3	10	1

KM – K-Means (Center Assignment)

KN – K-Nearest Neighbor (Deviation Assignment)

PI – Pseudo-Invert (Linear Least Squares Optimization)

The table shows that the second neural network with radial basis functions (3 nodes in the first input layer, 10 nodes in the hidden layer and one node in output layer) is the best: training error 0.00176; correlation between the actual training data and estimate the network - 0.9596. Figure 5 shows the type of neural network.

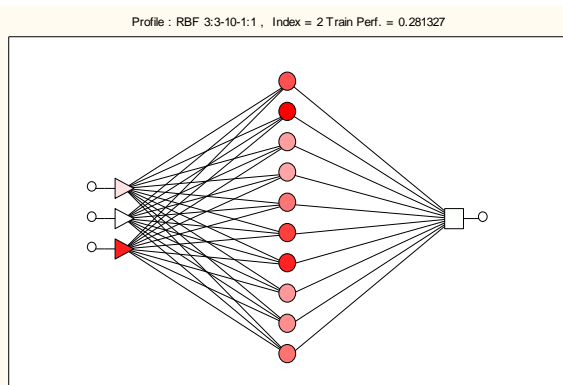


Fig. 5. Scheme of using neural network

Using in such way found the best neural network a forecast was carried out according to the type of housing sizes from 1 to 9, months from 1 to 4 and temperatures -4, -2, 0, 2, 4 and 6°C.

The results are summarized in Figures 6, 7 and 8. Figure 6 again shows that the consumption increase for houses in sizes from 57 to 96 m<sup>2</sup> is minimal.

In Figure 7 it is evident that the highest consumption has in January, which is the coldest month in Bulgaria. From Figure 8 it is shown the dependence of consumption by temperature. It confirms the conclusions made in (Christov, Boyadjiev, 2008).

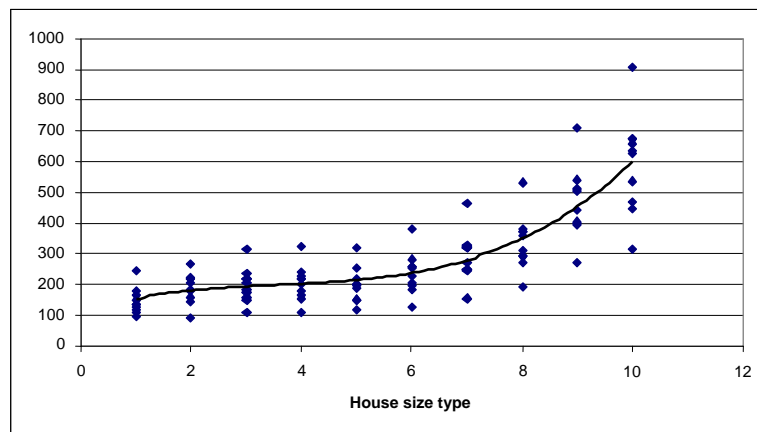


Fig. 6. Dependence of consumption by house size

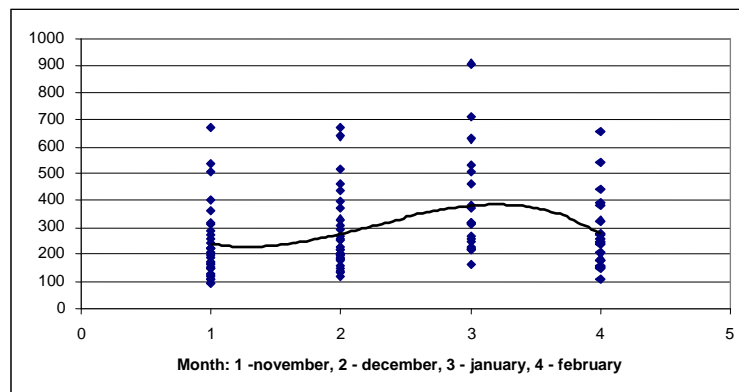


Fig. 7. Dependence of consumption by the month

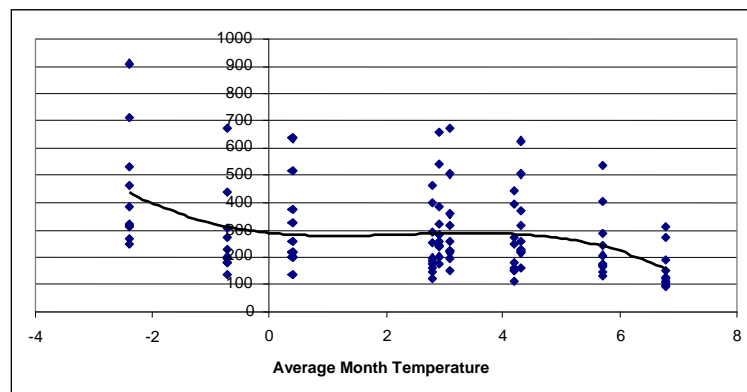


Fig. 8. Dependence consumption / temperature

## Conclusions

Distributed average monthly consumption of natural gas per household is about 300 m<sup>3</sup>.

Relative consumption of natural gas per unit area decreases with increasing the house size (Fig. 9), as it is the highest for hose size of 60 m<sup>2</sup>.

Dependence on temperature and consumption is best described by “hyperbolic tangent” (Fig. 8), which was detected at the study for consumption forecasting for the city of Stara Zagora with clear zones of saturation of air temperatures above +10 and below -5°C (Christov, Boyadjiev, 2008).

Houses of group number 5 (90 m<sup>2</sup>) uses gas for heating with now working gas installations most effectively (Fig. 10).

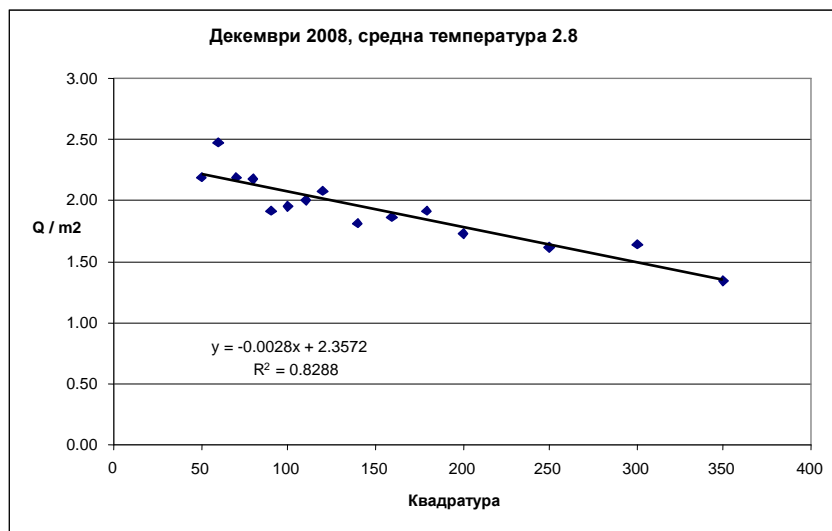


Fig. 9. Average consumption per square meters for Sofia

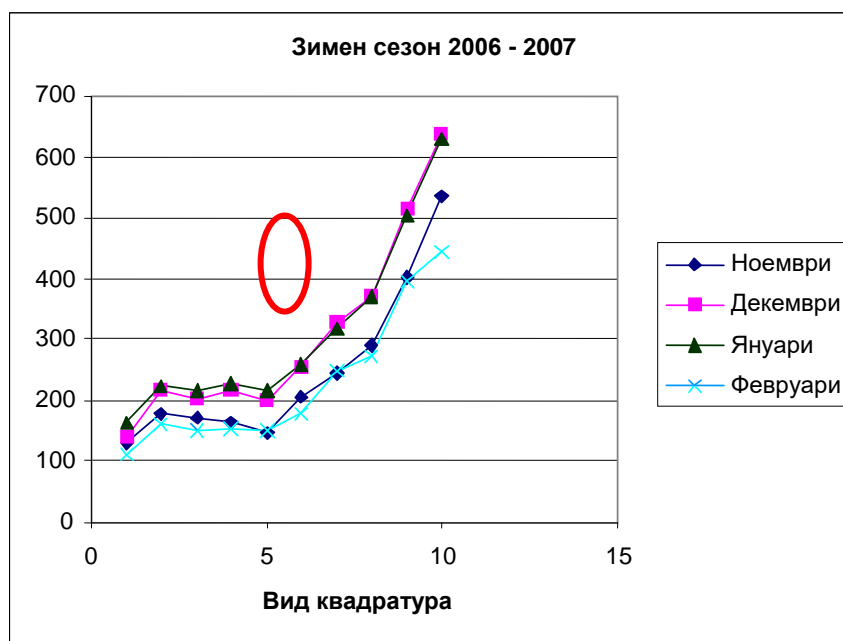


Fig. 10. House of group 5 use less than or equal volumes of gas to those of 2, 3, 4 and 6 groups

## References

- Christov V., M. Boyadjiev. 2008. A mathematical model for short-time forecast of natural gas consumption. – In: *Proceedings of "Oil and Gas Prospectivity of the Balkan – Black Sea Region"*, Varna, 1-4 Oct. 2008, 232-240 (in Bulgarian).
- Defireli J., S. Gil. 2004. *Modelo de Prediccin del Consumo de Gas Natural*. ENARGAS.

- Ivezic D. Short. 2008. Term Natural Gas Consumption Forecast. – *FME Transactions*, 34.
- Physical Properties of Natural Gas*. GASUNIE. 1998.
- Агаев, Н. Б. 2007. Краткосрочное прогнозирование объема газопотребления с использованием искусственным нейронных сетей. – *Нефтегазовое дело*, 4.

Препоръчана за публикуване от  
Катедра "Сондиране и добив на нефт и газ", ГПФ