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Model of the Balance of Fuel Wood Consumption and Emissions Production During Building Heating Depending on the Climatic Conditions of Slovakia

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Abstract : The paper presents a model of the influence of the climatic conditions of Slovakia on the consumption of firewood and the production of emissions in creating thermal comfort in a heated building. The temperature of atmospheric air in the range from -11°C to -18°C in winter and the number of days of the heating period in the range of 202-253 in individual localities of Slovakia is reflected in the size of heat losses of the heated building, fuel consumption and emissions production. The presented model allows to balance the consumption of firewood and emission production for individual localities in Slovakia based on the climatic conditions of the locality, the size of the heated object, the thermal efficiency of the boiler and the type of firewood.

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1 Introduction

The surface of the territory of the Slovak Republic is characterized by great diversity and representation of several geographical types. From the lowlands in the south of Slovakia, the country passes through a range of hills and highlands to the mountains - the High Tatras located in the north of Slovakia. However, most of the country is slightly undulating with an average altitude of 392 m. The territory of Slovakia from the aspect of climate is divided into three climatic areas: warm, moderately warm and cold.

The warm climate area extends to an altitude of 400 m occupies lowlands and low-lying basins with an average air temperature of 8 - 10°C. The length of the annual sunshine is more than 1500 hours.

The mildly warm climate area is located at an altitude of 400 to 800 m and occupies higher basins, highlands and lower mountains with an altitude of 700 - 800 m. The average annual air temperature in this area does not exceed 8°C.

The cold climatic region of Slovakia consists of the highest positions of the mountains with an altitude of over 800 m. The average air temperature in these localities is below 8°C.

The mentioned climatic conditions and the alternation of seasons were and are the reason for heating the buildings in which one stays in order to create thermal comfort.

The aim of this work is to present a model for calculating the annual consumption of firewood and emissions in creating thermal comfort in the interior of the building, or building located on the territory of Slovakia depending on the location, the size of the heat loss of the interior, or the heated object, the thermal efficiency of the heat source for individual assortments of firewood.

2 Experimental

The heat loss of a heated object Q is quantified according to STN EN 12 831. The calculation of the heat loss of a heated object for the heating seasonal period is described by the equation:

$$Q_r = \frac{3600 \cdot 24}{10^9} \cdot Q \cdot \varepsilon \cdot \frac{t_i - t_{es}}{t_i - t_e} \cdot d \qquad [\mathrm{GJ \cdot year^{-1}}] \qquad (1)$$

The length of the heating season (d), according to the legislation valid on the territory of Slovakia [1, 2], is defined by the time: 1 September to 31 May of the following year. The real length of the heating season of a given locality lasts from 202 to 253 days, depending on climatic conditions. It starts when the average ambient air temperature drops below 13°C for two consecutive days and the weather forecast does not indicate that it should not warm up and ends when the average atmospheric air temperature rises above 13°C for two consecutive days.

The fuel consumption to compensate for the heat loss of a heated building during the heating season is balanced by the equation:

$$B_r = \frac{Q_r}{Q_n \cdot \eta} \cdot 10^5 \quad [\text{tons·year}^{-1}] \qquad (2)$$

Firewood from forest stands as well as plantations of fast-growing woody plants [3 - 10] is from the energetic-chemical point of view formed by combustible elements: carbon C^d = 50.0 ± 1.5 %, hydrogen H^d = 6.1 ± 0.5 %, oxygen O^d = 43.3 ± 3.0 %, nitrogen N^d = 0.1 ± 0.05 % and inorganic content - ash A^d = 0.5 - 1.5 %. The negative property of firewood is its affinity for water and water steam. The moisture content of the firewood reduces both the calorific value of the fuel and the thermal efficiency of the boiler. Influence of moisture content on calorific value of firewood for the needs of practice the authors: [3, 5, 11, 12] describe by mathematical relation:

$$Q_n^r = 18\,840 - 21\,353 \cdot \frac{w}{100} \quad [\text{kJ·kg}^{-1}] \qquad (3)$$

The rate of decrease in thermal efficiency (boiler) on the moisture content of firewood and the temperature of flue gases emitted from the heat source is quantified by Dzurenda and Banski in [13,14,15]. For energy-environmental combustion of firewood in accordance with the works [16 - 24] and the temperature range of flue gases emitted from a small heat source to the atmosphere t_{fg} = 150 - 400°C and not exceeding the emission values: carbon monoxide EL_{CO} = 3000 mg.m^{-3} a ash with carbon black $EL_{C\text{-}TZL}$ = 150 mg.m^{-3} thermal efficiency, small heat source describes the relationship:

$$\eta = [(-0.003.w^2 + 0{,}069.w + 86.746) - (0.001.w + 0.071).(t_{fg} - 150)] \quad [\%] \qquad (4)$$

For small heat sources, hot water boilers for UK systems with heat input 5 - 50 kW and heat input 50 - 300 kW in Šoltés - Randa: "*Elaboration of design of emission factors for combustion plants for the Ministry of the Environment of the Slovak Republic*" they state emission factors for solid renewable fuels (lump wood, energy chips and wood pellets). The values of emission factors are given in Table 1.

The production of emissions for the heating season is balanced by the equation:

$$M_{emission-i} = B_r \cdot EF_{emission-i} \quad [\text{kg.year}^{-1}] \qquad (5)$$

To streamline the work for determining the annual fuel consumption of the boiler and the production of emissions, a program was developed in the EXCEL software - in the form of a calculation table. After entering the data: heat loss from the building, locality of Slovakia, type of fuel, moisture content in the fuel, heat output of the boiler and flue gas temperature, the program provides information such as: annual heat loss of the building in the given locality of Slovakia, annual consumption of firewood in tons and annual emission production (PM, CO, NOx) in kilograms.

Table 1 Emission factors for solid renewable fuels burned in small heat sources with a heat input of 5 - 300 kW [25]

Fuel	Boiler	Heat input kW	Emission factor [kg.t$^{-1}_{fuel}$]		
			PM	CO	NO_x
Firewood	Combustion	5 - 50	2.31	36.19	1.22
		50 - 300	2.05	30.90	1.27
	Gasification	5 - 50	0.96	17.93	0.61
		50 - 300	0.90	14.09	0.58

3 Results and discussion

The given mathematical model (program) is applied to determine the annual consumption of firewood of a small energy source - hot water boiler ATMOS DC 18 S for creating thermal comfort in a family house Kompakt 40 (Figure 1) located in the most favorable and unfavorable climatic conditions in Slovakia, Bratislava and Liptovský Mikuláš (Table 2).

Figure 1 Hot water boiler ATMOS and family house Kompakt 40

Table 2 Annual fuel wood consumption and emissions for localities: Bratislava and Liptovský Mikuláš

Input parameters		Symbol	Location	
			Bratislava	Liptovský Mikuláš
Heat loss of the building according to STN EN 12 831		Q [W]	8 000	9 500
Calculated indoor air temperature		t_i [ºC]	+ 20	+ 20
Calculated temperature of atmospheric air in the exterior		t_e [ºC]	- 12	- 18
Average outdoor air temperature during the heating season		t_{es} [ºC]	+ 4	+ 2.4
Number of days of the heating season		d [-]	202	253
Correction factor for the absence of heat losses		ε [-]	0.9	0.9
Moisture of burnt wood of wood Beech		w [%]	20	20
Temperature of emitted flue gases		t_{fg} [ºC]	200	200
Annual thermal heated building		Q_r [GJ.year^{-1}]	62.83	86.56
Annual consumption of firewood		B_r [t.year^{-1}]	5.24	7.21
Emissions	particulate matter	PM [kg.year^{-1}]	5.03	6.92
	carbon monoxide	CO [kg.year^{-1}]	93.87	129.32
	nitrogen oxides	NO_x[kg.year^{-1}]	3.19	4.40

A comparison of the annual heat loss of a *Kompakt 40* family house, the consumption of firewood for creating thermal comfort in a given family house and the production of emissions shows that the worse climatic conditions of Liptovský Mikuláš are reflected in an increase in the consumption of air-dried beech firewood by 2.15 t.year^{-1} is 37.8 % more and increase the production of emissions *PM* by 43.6%, *CO* = 37.7 % and *NOx* = 37.7 %.

4 Conclusions

The paper presents a model for calculating the annual consumption of firewood and emissions production for the creation of thermal comfort in the interior or heated object located in Slovakia depending on the locality of Slovakia, the size of heat loss of the heated object, type of fuel, moisture content in the fuel, heat output of the boiler and fuel gas temperature.

The application of the model allows the user for any location in Slovakia to objectively plan in preparation for the heating season the amount of firewood of the wood to create thermal comfort in the heated object and at the same time informs him about the degree of atmospheric emissions.

Used symbols

d - number of days of the heating season in the given locality, -;
t_i - indoor air temperature, °C;
t_e - outdoor air temperature, °C;
t_{es} - average outdoor air temperature during the heating season, °C;
t_{fg} - temperature of flue gases emitted from the heat source, °C;
w - firewood moisture %;
B_r - fuel consumption to compensate for heat losses of the heated object during the heating season, t·year^{-1};
$EF_{emission\text{-}i}$ - emission factor, kg.t$^{-1}{}_{fuel}$;
Q - heat loss of the heated object, W;
Q_r - heat loss of the heated object during the heating period, GJ·year^{-1};
Q_n - calorific value of firewood, kJ·kg^{-1};
η - thermal efficiency of a small heat source, %;
ε - correction factor for non-participation of heat losses, -;

5 The reference list

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The Determination of Water Content in Natural Gas: Aspen Hysys Simulation and P,T Analysis

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Abstract : Natural gas is currently one of the most important fossil fuels in the group of non-renewable energy sources, which is used very widely due to its properties. In order to be able to use it safely, it must be adjusted in accordance with the technical-delivery conditions before use. One of the basic quality parameters of natural gas is the water content, which is set at a maximum value of 110 mg per m^3 of natural gas. For this reason, it is necessary to correctly determine the water content before the gas treatment, in order to choose the right dehydration technology. In this article, three methods were used to determine the water content of natural gas.

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1 Introduction

Natural gas is a non-toxic, non-respirable, highly flammable gas that is an important fossil fuel. It has no toxic or annoying effects and together with the air in the range of 5 - 15% it forms an explosive mixture. It is lighter than air, colorless, and tasteless, so when it is treated, an odorous substance is added - an odorant, so that it can be identified in the air when detecting possible leaks. Unlike other fossil fuels, natural gas has clean combustion and lower emissions of harmful products in the air.

Chemically, it is a natural mixture of gaseous substances, which consists essentially of aliphatic acyclic hydrocarbons (alkanes) with a predominant methane content. Other components with a certain percentage are ethane, propane, butane, pentane, and, very rarely, the hydrocarbons hexane and heptane are present in natural gas. At the same time, non-hydrocarbon impurities such as carbon dioxide, nitrogen, helium, argon, hydrogen sulfide, and last, but not least, water are also present in natural gas [1,2]. It is the water contained in the ground that causes considerable problems in its transport by gas pipelines. At the same time, the presence of water in the natural gas reduces the calorific value of the gas, which is the main functional property of the use of said natural gas. By not complying with the basic requirements for gas treatment to the required quality, water can condense in the transport process, which can lead to the following problems in piping systems [3,4,5]:

- hydrate formation;
- water plugs formation (water freezing);
- corrosion of the piping system.

The moisture content or the water content of natural gas significantly affects the technological process of gas extraction, transport, and storage, so this parameter is very important. The humidity of gas is most often given in three ways, while in the gas industry the water content in the natural gas is most often expressed in absolute humidity (Φ) [6,7]:

$$\Phi = \frac{m_{H_2O}}{V} (kg/m^3) \qquad (1)$$

where:

m_{H_2O} – mass of the water vapor (kg);

V – water vapor mixture (m^3).

One of the expressions of the moisture content in natural gas is the dew point value. The dew point represents the temperature at a given pressure, or the pressure at a given temperature, at which the gas is maximally saturated with water vapor (the absolute humidity of the gas reaches 100%). It applies specifically to the value of the temperature at which water vapor begins to condense from the gas mixture. The dew point temperature is different for different absolute humidity of the gas: the higher the water vapor content of the gas, the higher the dew point temperature. To express the dew point of water in the gas, we can also use the so-called equilibrium constant (k) which is defined as the ratio of the molar fraction in the vapor phase (y_i) to the molar fraction of the same component in the liquid phase (x_i)[12].

$$K_i = \frac{y_i}{x_i} \qquad (2)$$

Dew point expression: the sum of the molar fraction of the component in the liquid phase is equal to the proportion of the molar fraction in the vapor phase and the equilibrium constant [5,12].

$$\sum \frac{y_i}{K_i} = \sum x_i = 1 \qquad (3)$$

2 Methods and methodology

The water content of natural gas mainly depends on the temperature, pressure, and composition of the natural gas. This issue has been addressed by scientists in publications [8,9,10,11]. Currently, there are several methods of expressing the water content itself, the most basic of which are:

a) manual calculation according to publication Netusil, Ditl [11]:

$$W_{water} = 593{,}335.\exp(0{,}005486.T_G).P_G^{\ -0{,}81462} \qquad (4)$$

where:

W_{water} – water content (kg/1.10^{6}m^3 gas);

T_G – natural gas temperature (°C);

P_G – natural gas pressure (MPa).

b) Empirical plots according to publication Campbell [12]:

The water content of the natural gas, which does not contain a significant amount of acidic impurities (e.g. H_2S) determined by means of a nomogram, is shown in Figure 1. This method represents a satisfactory determination of the value allowed for the technological calculation. The water content shown on the y-axis represents its maximum content in the natural gas which the gas can maintain at said pressure and temperature, i.e., the gas is completely saturated with water vapor. Temperature representing the x-axis thus represents the dew point temperature of the water in the gas at said pressure. The resulting value of the water content in the gas is given by the intersection of the vertically guided line from the x-axis and the line representing the pressure values.

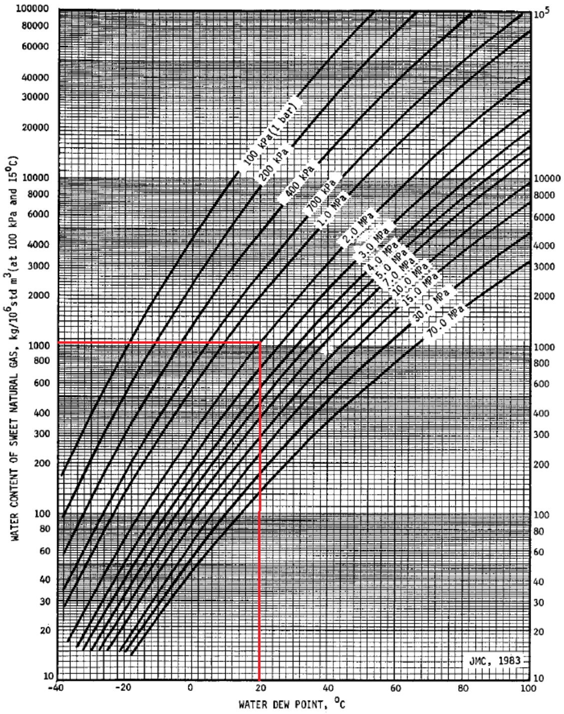

Figure 1 Water content of Natural gas

c) Aspen Hysys simulation (software)

Aspen Hysys simulation software from Aspentech company is used as one of the main software used to determine the water content of natural gas in the oil and gas industry. Methodology, how to saturate gas stream with water by two ways will be presented in the following steps figures.

1step: determination of natural gas component list.

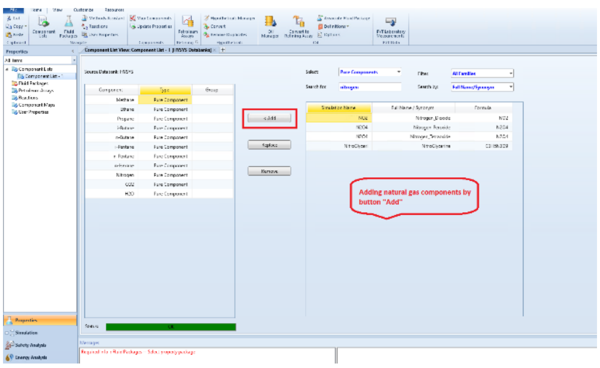

Figure 2 Hysys component list

2step: selection of right fluid package (for this case, Peng-Robinson property package was be chosen).

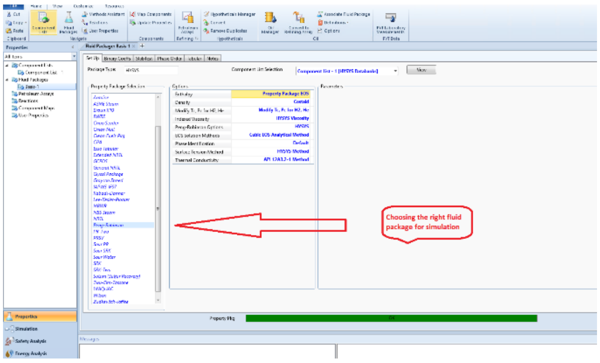

Figure 3 Hysys fluid package list

3step: determination of input data (composition, temperature, pressure and flow rate for gas and water stream).

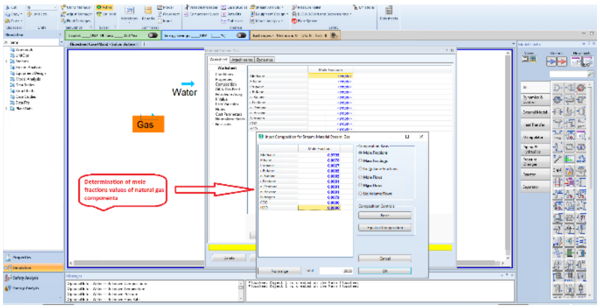

Figure 4 Input composition data

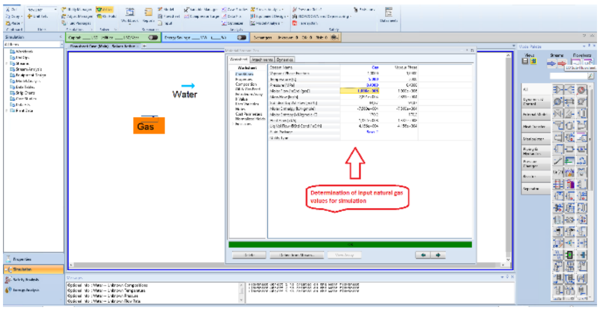

Figure 5 Input pressure, temperature and flow rate data

4step: first way how to saturate gas stream with water is by using stream saturator (manipulator). It is a fast and accurate way to just enter only relative humidity %. The resulting water content is in mg/m^3 gas, which is equivalent to a kg/1.10^{6}m^3 gas.

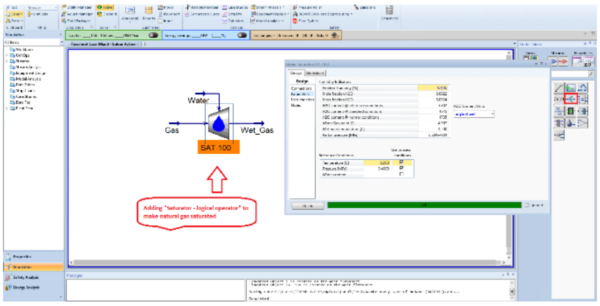

Figure 6 The first way of simulation

The second way is by using mixers, where gas and water are mixing together. Then they are going through the two-phase separator, where the free water is captured and the gas stream leaving the top of the separator contains only water in the vapor phase (Figure 7).

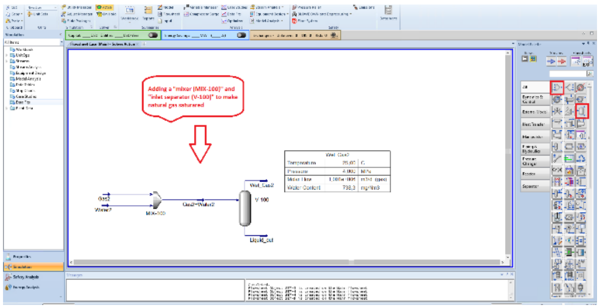

Figure 7 The second way of simulation

The figure below shows the Hysys work environment with both methods of simulation. The simulation process is performed using the unit palette on the right side of the figure, where all the units such as separators, valves, pumps, manipulators, and many others are found.

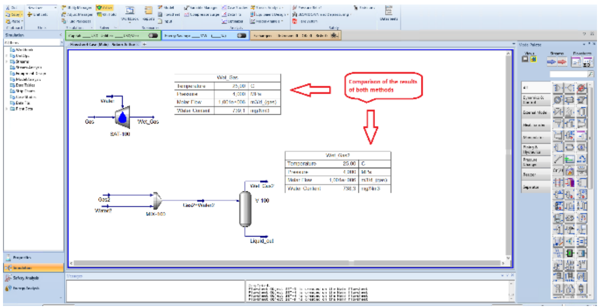

Figure 8 The both methods of simulation

3 Results and discussion

In this article, the following literature input data were used to achieve the results. The natural gas in reservoir is occurred at different temperatures and pressures and whose daily flow rate is $1.10^6 m^3$. The gas compositions and flow rate value are necessary for Hysys simulations.

Table 1 Feed gas compositions and process conditions

NG Temperature (°C)	5;10;15;20;22; 25;28;30;35;40;
NG Pressure (MPa)	0,4;0,7;1;2;3;4;5;7;10;15
NG flow rate (m^3/24hod)	1000000
Components	**Compositions**
Methane (CH_4)	0,9795
Ethane (C_2H_6)	0,0078
Propane (C_3H_8)	0,0027
i-Butane (C_4H_{10})	0,0005
n-Butane (C_4H_{10})	0,0005
i-Pentane (C_5H_{12})	0,0001
n-Pentane (C_5H_{12})	0,0001
n-Hexane (C_6H_{14})	0,0001
Nitrogen (N_2)	0,0079
Carbon Dioxide (CO_2)	0,0008
Total	1,0

where:

NG – natural gas.

Table 2 Results for different pressure and temperature

			Water content (mg.m^{-3})			
MN	T	P	E	M	H1	H2
1	5	0,4	1800	1646,6	1735	1734
2	10	0,7	1500	1373,2	1419	1418
3	15	1	1400	1351	1400	1400
4	20	2	1100	1010,6	1004	1003
5	22	3	850	810,6	789,9	789,1
6	25	4	800	755,9	739,1	738,3
7	28	5	800	743,1	733,2	732,4
8	30	7	700	630,4	635,7	634,9
9	35	10	700	620,3	654,6	653,8
10	40	15	650	586,5	670,6	669,8

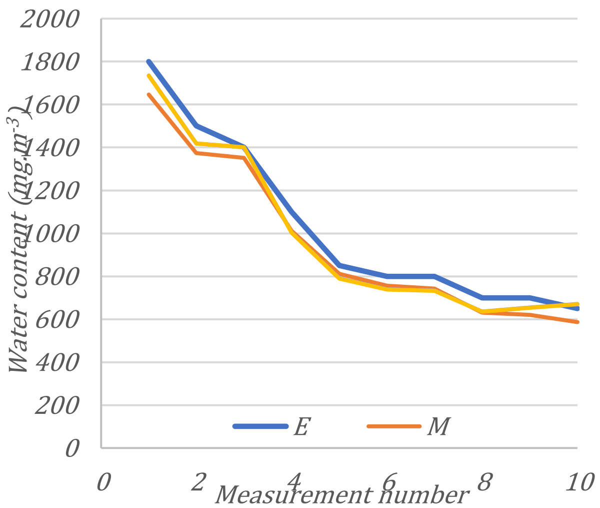

Figure 9 Plot of values from Table 2

where:

MN – measurement number (Table 2);

T – temperature (°C)(Table 2);

P – pressure (MPa) (Table2);

E – empirical plots;

M – manual calculation;

H1 – hysys simulation (1method);

H2 – hysys simulation (2method).

Based on the achieved results (Table 2, Figure 9), we can state that we will achieve satisfactory results using all three methods. As the most accurate results we will consider the value obtained by software Aspen Hysys, due to its usability in oil and gas industry and the declaration of its accuracy in various publications. We can say with certainty that, for theoretical interests, methods 1 and 2 will provide a satisfactory and, above all, rapid determination of the water content of natural gas.

Because the above values represent results for different pressure and temperature values, an analysis of the dependence of the water content in NG on the change in temperature and pressure was performed. The effect of the pressure changes at a constant temperature, and the temperature changes at constant pressure on the water content in NG are represented by the following tables and figures:

Table 3 Water content for T (30°C) and different pressure

			Water content (mg.m^{-3})			
MN	T	P	E	M	H1	H2
1	30	0,4	7500	6489,8	8530	8529
2	30	0,7	4500	4113,8	4933	4932
3	30	1	3300	3076,5	3495	3494
4	30	2	1800	1749,2	1819	1818
5	30	3	1400	1257,2	1262	1262
6	30	4	1000	994,5	985,7	984,9
7	30	5	800	829,2	821	820,2
8	30	7	600	630,4	635,7	634,9
9	30	10	500	471,5	501,5	500,7
10	30	15	400	338,8	403,9	403,1

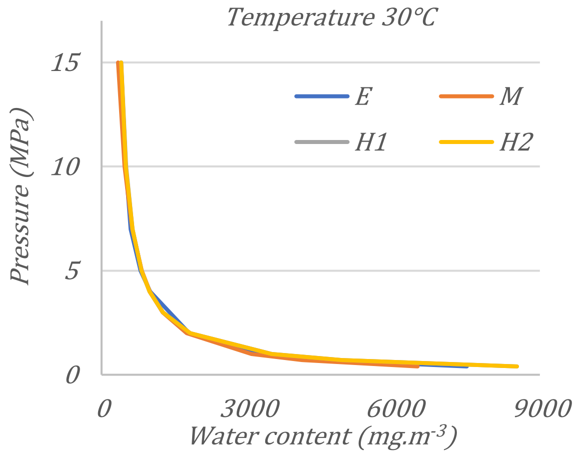

Figure 10 Plot of values from Table 3

From the Figure 10 above we can say that the pressure drop at a constant temperature characterizes the increase in the water content of the natural gas. In practice, this means that the lower the natural gas pressure in the underground reservoir, the higher the water content of the natural gas.

Table 4 Water content for pressure 2 (MPa) and different temperature

			Water content (mg.m^{-3})			
MN	T	P	E	M	H1	H2
1	5	2	400	443,8	376,1	375,3
2	10	2	520	583,9	528,5	527,7
3	15	2	750	768,2	733	732,2
4	20	2	1000	1010,6	1004	1003
5	22	2	1100	1127,8	1135	1134
6	25	2	1200	1329,6	1359	1358
7	28	2	1400	1567,4	1621	1620
8	30	2	1800	1749,2	1819	1818
9	35	2	2200	2301,3	2408	2408
10	40	2	3000	3027,5	3157	3156

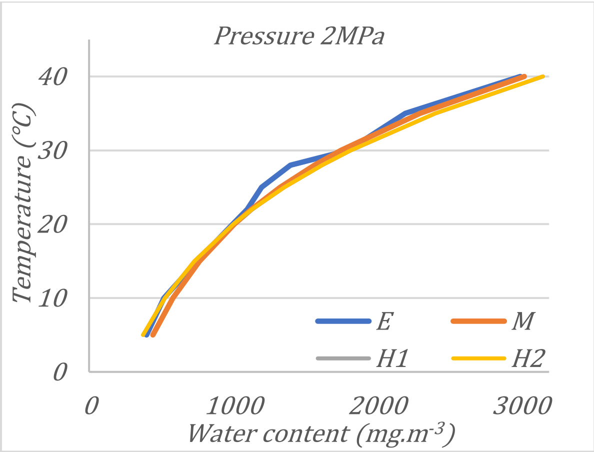

Figure 11 Plot of values from Table 4

Based on the achieved results (Table 4) and the graphical dependence of temperature and water content of constant pressure (Figure 11) we concluded, that with the increasing temperature, the water content in NG increases. Combining the pieces of knowledge gained from this analysis, we concluded that the maximum saturation of natural gas by water vapor is achieved in the lowest pressure values and the highest temperature values.

4 Conclusion

Based on the above results, analysis and comparisons, the following conclusions can be drawn. All three methods of saturating natural gas with water are suitable and represent a way to obtain the desired results. The first method, using a chart (E – empirical plots by Campbell), is the fastest way. Its limitation lies in the inaccuracy of the measurement because the resulting values are readable from the graph but represent a significant degree of inaccuracy due to its scale on the x, y-axis. Method 2 (M - manual calculation) is a more suitable way of calculation, without the use of software, as we get an exact value as a result (even in decimal numbers). We consider the use of software Aspen Hysys to solve this problem to be the best because, in addition to temperature and pressure, it also considers the composition of natural gas, which ultimately affects the final value. With the correct use of the software, we can quickly and accurately obtain results at different input values. By analysis of temperature changes at constant pressure, and pressure changes at a constant temperature, we can confirm that the highest concentration of water vapor in natural gas is at the lowest pressure and the highest temperature. This fact is very important in the design of the dehydration processes, where the process plant engineer must take into account the maximum possible saturation of natural gas with water vapor.

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Issues in the Field of Municipal Waste Management

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Abstract : EU waste management policies aim to reduce the environmental and health impacts of waste and improve the efficiency of the use of EU resources. The long-term goal of these policies is to reduce the amount of waste generated and when waste production is necessary to support their resources and to achieve a higher level of recycling and safe disposal of waste. At present, the waste management of Slovakia has many problems and does not fulfill the goals of the European Union in this direction. Comparison of waste management in Slovakia and in other EU countries allows us to find out what is the main difference and in what ways the desired result is achieved in accordance with the regulations of the European Union.

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1 Introduction

The current situation in the field of municipal waste collection is today one of the most current problems in all countries of the world. It is characterized by high specific volumes of solid waste generation and their accumulation in the environment.

The rate of waste production is growing worldwide. In 2016, the world's cities produced 2.01 billion tons of solid waste, a footprint of 0.74 kilograms per person per day. With rapid population growth and urbanization, annual waste production is expected to increase by 70% from 2016 levels to 3.40 billion tons in 2050 [1].

Slovakia is no exception and has many problems with waste management. Every year, the amount of waste produced is constantly growing, at the same time not enough attention is paid to this issue.

Waste management is not perfect in many respects, in principle the traditional waste collection system used is obsolete and has many disadvantages.

2 Analysis of the current state

In 2018, the total waste production in the EU amounted to 2609.16 mil. tons of waste, and in Slovakia the total production of waste was 12.4 mil. tons of waste. The development of waste production in Slovakia is shown in Graph 1.

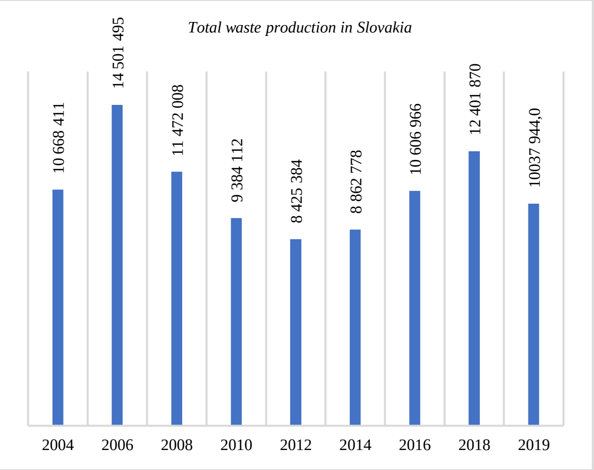

Figure 1 Total waste production in Slovakia in 2004-2019 (Eurostat)

The graph shows that the volume of waste produced increased from 2004 to 2006, then gradually decreased by almost 42% from 2006 to 2012, from 2012 to 2018 again increased to 32% smoothly, and from 2018 by 2019 it decreased by 19%.

The annual production of waste in the European Union is approximately 2.6 billion tons of waste. Of the total volume of waste produced in the European Union, municipal waste accounts for almost 10%, and in Slovakia for the last 5 years it accounts for almost 19% of the total volume of waste produced.

Dissatisfaction with the high share of landfilling of all municipal waste and including mixed municipal waste - 51% and 85%, which sets 1,198,249 tons and 985,297 tons respectively in 2019, is also a problem.

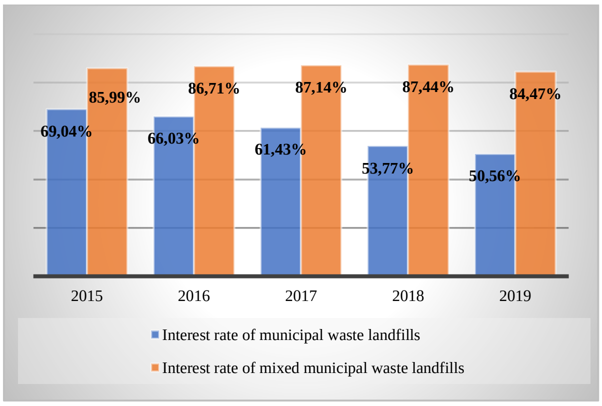

Figure 2 Interest rate of municipal waste storage in 2015-2019 (Eurostat)

According to the OECD and SO SR data, the development of municipal waste production per capita according to the OECD and SO SR data in 2019 is 434 kg and is growing very fast, from 2013 to 2019 it increased by 43% and on average the EU increased by only 2,7%, as shown in the graph [2].

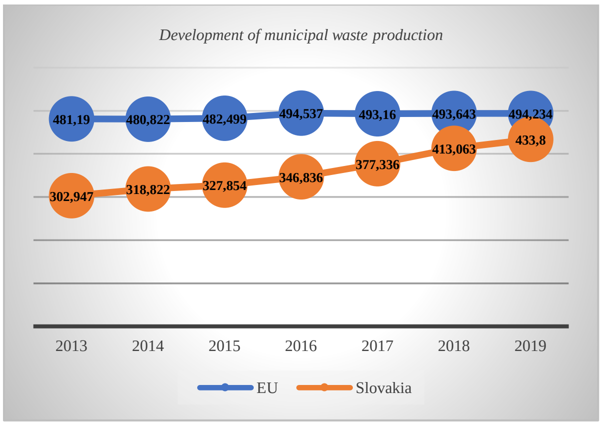

Figure 3 Development of municipal waste production per kilogram/inhabitant 2015-2019 (Eurostat)

The European Union increased its production of municipal waste by 13 kg per capita in the period we adopted, while in Slovakia this amount increased by 130 kg per capita between 2013 and 2019, which is 10 times more than the European Union average.

According to the data of the Supreme Audit Office of the Slovak Republic, Slovakia is landfilled twice compared to the middle level of the EU and the state does not have an effective management system for individual landfill operators. Over the last ten years, the volume of landfilled waste has been growing at an average rate of 3.5% per year per capita.

The Supreme Audit Office states that landfills are not sufficiently controlled and endangers environmental pollution and will also have a significant impact on the state budget. There is a risk of sanctions from the European Union due to the inability to comply with Slovakia's obligations, which endangers the quality of the environment and is a threat to EU fines.

There are more than 100 landfills in operation in Slovakia, while another 800 are no longer used, they are to be closed and the operator is obliged to recultivate them.

In the period 2017–2019, the European Commission identified several shortcomings by which the Slovak Republic violated its obligations in the area of waste management. [3]

Waste management is one of the most important topics in Slovakia, due to the sustainability of environmental quality, economic growth and consumption.

Today, Slovakia is one of the countries of the European Union that has a lower recycling rate and the highest landfill rate. The transformation of the economy, rapid economic development and the raising of living standards bring problems for the environment and its stability.

The new requirements for the transformation of the economy will mean that Slovakia will have to undertake significant structural reforms in waste management in the coming years.

Every landfill can become an environmental problem. It affects the environment with noise, smell, environmental pollution, frequent problems with landfills are fires and closed landfills are problems with environmental problems in the future.

3 Comparison of the generation and storage of municipal waste in Slovakia and in other countries

We will perform an analysis and comparison of the generation and landfilling of municipal waste in the

Visegrad Four countries as well as in more developed countries such as Germany, Denmark and Sweden.

The basis for the analysis is Eurostat data for the production and landfill of municipal waste in kilograms per capita, because it is the most objective criterion for estimating the production and landfill of waste, because the population and countries are very different, even several tens of times [4].

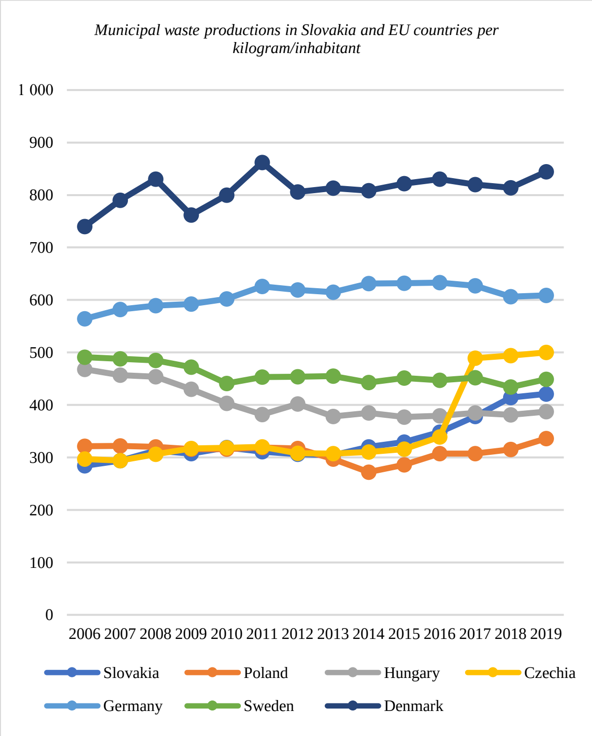

Figure 4 Municipal waste productions in Slovakia and EU countries per kilogram/inhabitant in 2006-2019 (Eurostat)

In this graph we see that, calculated per capita, Slovakia produces more municipal waste than Poland, Hungary, is at the same level as Sweden and is gradually growing to the level of the Czech Republic. By the way, the level of municipal waste production in the Czech Republic has already exceeded the average EU level, namely 494 kg / capita.

The following things to consider are that Sweden produces 7% more waste than Slovakia, Germany 45% more, and Denmark more than twice, as can be seen in Figure 4.

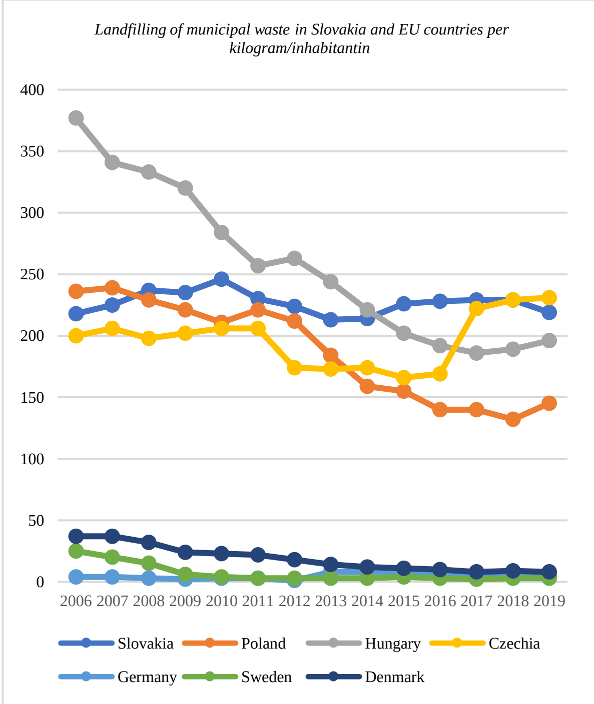

Figure 5 Landfilling of municipal waste in Slovakia and EU countries per kilogram/inhabitantin 2006-2019 (Eurostat)

Next, an analysis of municipal waste landfills was performed. Here we can already see the tendency that Slovakia year after year reduces the number of municipal waste, although it still has the highest percentage compared to the Visegrad Four until 2019, this year the Czech Republic "surpassed" Slovakia in this indicator.

There is a visible difference between Sweden, Denmark and Germany compared to Slovakia and other V4 countries. There is 3 kg of landfilled municipal waste per capita in Sweden, while in Slovakia it is 219 kilograms.

Figure 6 shows the percentage ratio of municipal waste landfills in Slovakia and in EU countries per kilogram / inhabitant. In 2019, this provided for:

- Slovakia 52.02%
- Hungary 50.65%
- Czech Republic 46.20%
- Poland 43.15%
- Germany 0.82%
- Sweden 0.67%
- Denmark 0.95%

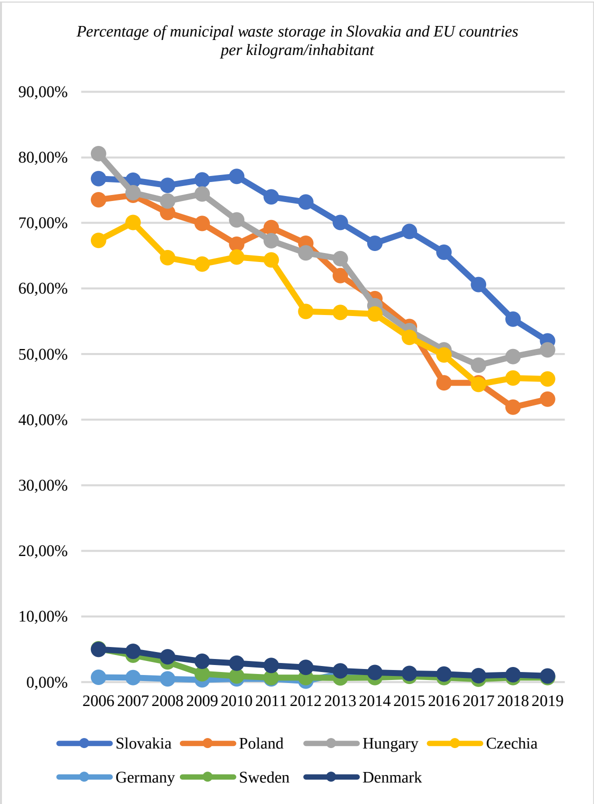

Figure 6 Percentage of municipal waste storage in Slovakia and EU countries per kilogram/inhabitant in 2006-2019 (Eurostat)

Compared to the Visegrad Four countries in Slovakia, the percentage of municipal waste landfills is higher by 1.4% from Hungary, 5.8% from the Czech Republic and 8.9% from Poland. Compared to Sweden, Denmark and Germany, Slovakia has a significantly higher rate of municipal waste landfill, given that in these countries it is less than 1%.

4 Components of advanced waste management

After a brief analysis of the information on waste collection and recycling systems and on the overall waste management in Sweden, Denmark and Germany, we can highlight the main and most important aspects that can be monitored in this area. They dump the smallest amount of waste in the world and their recycling rate is constantly growing.

How is this implemented and how do they achieve these results? We will highlight the main points by which this is done.

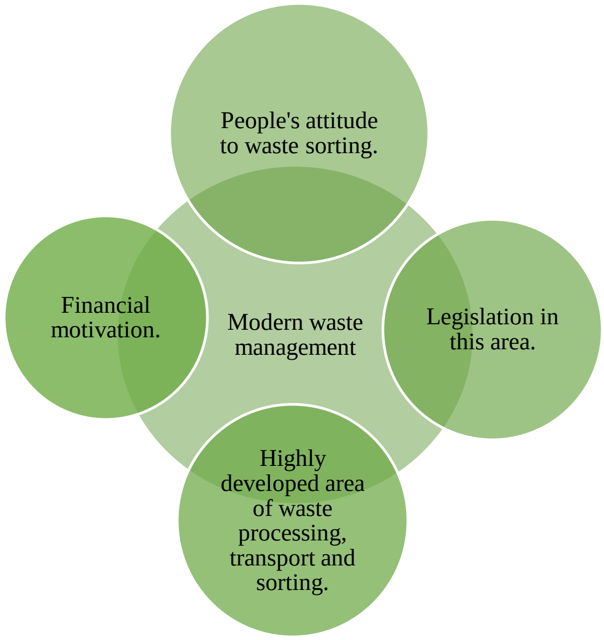

Figure 7 Main parts of a modern waste management system

As mentioned above, all these countries have been on the road to modern waste management for a long time, and during this time they have all made a clear rule that waste must be sorted anytime, anywhere, this is the first and important point - people's attitude to sorting. waste. At present, in these countries, one simply does not understand "how is it possible not to sort garbage?" People need to understand that waste management directly affects the well-being of the country, the environment and, above all, themselves.

Legislation - Another important point is the laws that regulate this area. This significantly affects the whole system as a whole, from the production stage of any products that will become, in whole or in part, waste in the future. Also at the level where they were created, it is mainly a matter of waste sorting. For example, legislation to promote the use of recycled material in Germany - the tax on the production of paper products depends on the amount of recycled material used.

Financial incentives are directly linked to the law and the attitudes of people and businesses towards waste management, and this is an equally important point. It can be "positive" and "negative", for example the amount of payment for waste collection can be regulated according to how well you sort the waste - it is a "positive" motivation, negative - for example fines and sanctions, for example for mishandling waste in production , not using recycled materials in everyday life, people - for accumulating waste in the wrong place.

In Sweden, for example, if you want to dispose of a larger amount of waste of a certain type, you have to order a relatively expensive service or you can do it yourself free of charge by taking the waste to a sorting plant.

Highly developed area of waste treatment, transport and sorting - we are talking about waste collection systems, system systematization, sorting centers, sorting facilities, waste incinerators (for example, in Sweden more than 50% of waste is recovered), hazardous waste landfills, waste recycling facilities [5,6,8].

However, all these technological solutions can only work if all other rules of conduct for waste are met, because they are all as strongly connected as possible and, for example, without proper sorting of waste by humans, no sorting center can solve this problem [9].

5 Conclusion

The problem of waste is currently one of the biggest problems in the world, and it is this problem that is becoming the subject of growing debate and is the result of a great deal of research and innovation in this area.

The amount of waste in Slovakia is constantly growing and is increasing significantly every year, in 2019 it sets almost 434 kg / inhabitant. Compared to today's European Union average, it is still lower, the EU average is 494 kg / capita, but according to the trend, this number will soon exceed the average. An even more serious problem is access to waste, its landfill, low level of treatment and recycling.

Although the level of recycling is increasing every year, the percentage of landfilling is slightly decreasing - from 2015 to 2019 the percentage of landfilling of municipal waste decreased by 19% and the percentage of landfilling of mixed municipal waste decreased by 1.5%, but these are not the results that the Slovak Republic should achieve in view of the significant increase in the amount and volume of waste, as well as the fulfillment of the European Union's objectives and plans in this area [7,8].

The waste management system in Slovakia is imperfect and has many problems. One of them is the high level of landfilling of municipal waste, and most importantly, mixed municipal waste, according to data for 2019; it is 51% of all municipal waste, or 85% of mixed municipal waste. The problem of landfilling is also reflected in the large number of landfills and their problematic nature. Landfills cover large areas and damage the environment and people.

It should be noted that from the above analysis we see that Slovakia does not produce as much waste as other countries, for example compared to Germany. The difference is that in other countries the waste management system differs significantly at all stages, which is crucial in this case.

The solution to this problem should take place in many stages of waste management and should be comprehensive.

To improve the global situation, it is necessary to combine all factors in the field of waste management, namely legislative measures, propaganda and support for good culture of waste management, introduction of innovations in the form of automatic waste collection system and probably the main conscious and responsible approach to waste management. Of course, according to the hierarchy of waste behavior, in Slovakia and in the EU, attention should be paid to the first two rules - waste prevention and preparation for re-use, which already means in the production of the product, in such a way that it can be in the future recycle and reuse.

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