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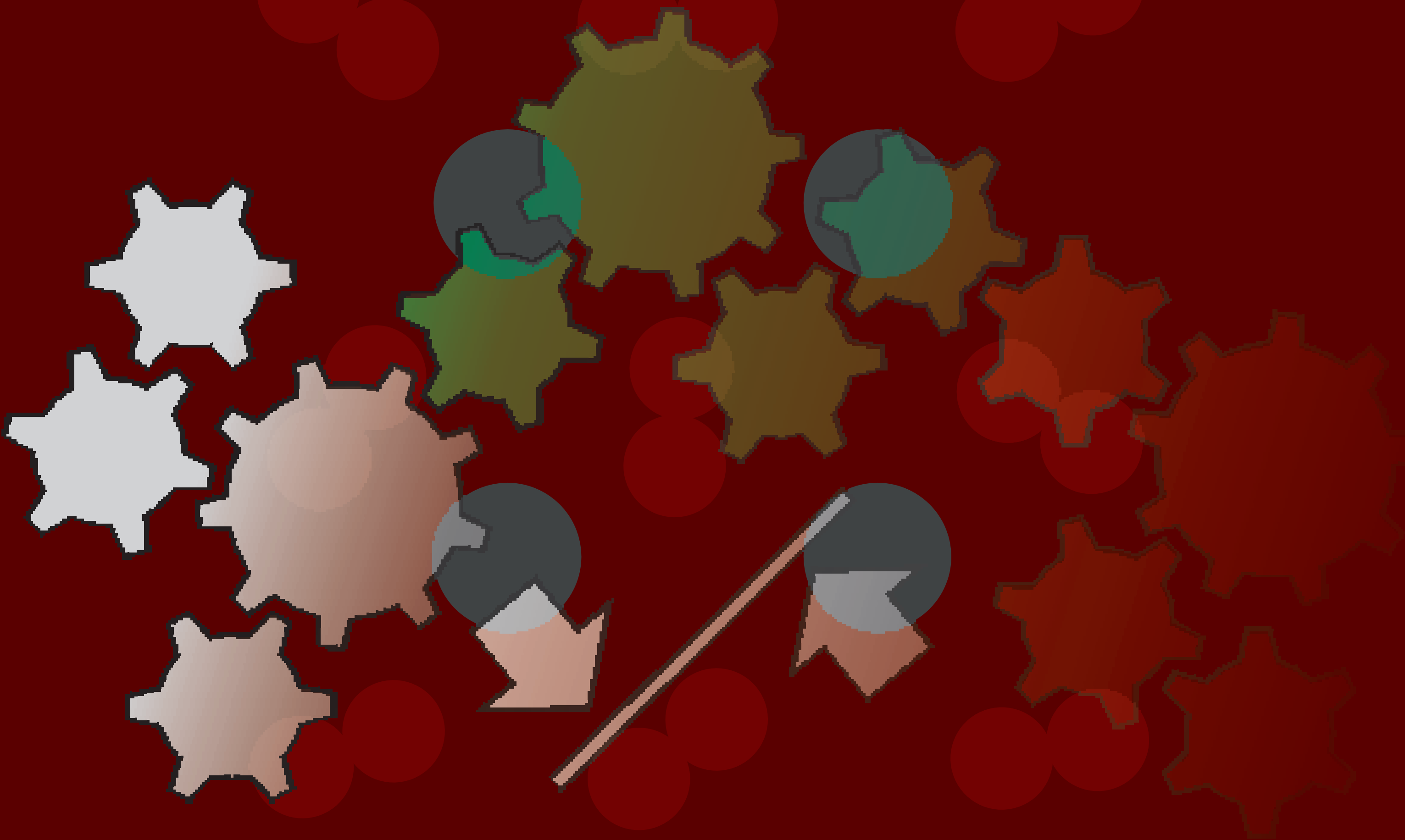

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NEGATIVE IMPACTS OF PHOTOVOLTAIC ELECTRIC STATION OPERATION FOR DISTRIBUTION OF ELECTRICAL ENERGY IN SOBRANCE

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Keywords: photovoltaics, photovoltaic power plant, electricity distribution
Abstract: Photovoltaic power plants recorded in the world of very rapid increase in installations connected to the distribution network. Although they are referred to as the cleanest sources of electricity, their unpredictability causes major problems for distribution network operators. If the current commissioning rate continues, PV power would lead to the modification of several aspects of power system and could influence the stability of the system. The report is dealt to a problematic of negative impact photovoltaic electric stations installed in location Sobrance for distributing electric energy. The main task and idea of the report is advert to the positive and negative impact of installation photovoltaic electric stations on base of measurement of real operation.

1 Introduction - Electricity transmission and distribution systems in the Slovak Republic

The current form of the Slovak power system has been built since the 1950s on a transmission voltage of 220 kV, later on 400 kV. This transmission system is a compact total, whose core mission is to transfer power from large power generators and interstate transmissions (Figure 1). The distribution network has a very complex structure that provides long-distance transmission and distribution of electricity to consumers. For long-range transmission, the voltage at the plant is transformed into a very high voltage of 110 kV, 220 kV or 400 kV. individual power plants are by overhead line connected to electrical network. The lines interconnect individual sources and transformer stations so that the energy transfer can be operatively controlled depending on the instantaneous electricity consumption in different areas, even in the event of a fault in some part of the network [1].

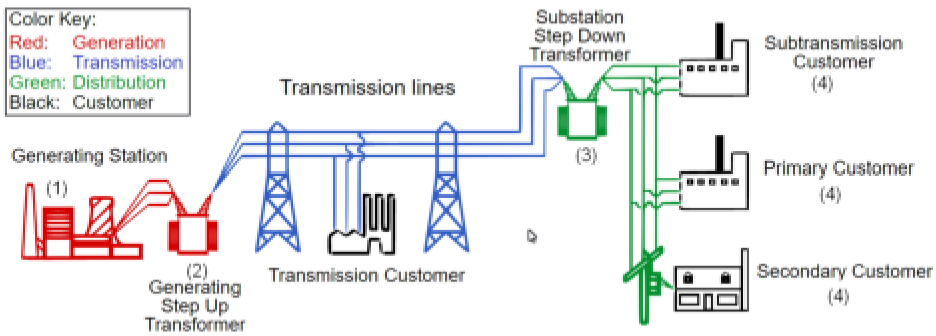

Figure 1 Scheme of power transmission from power plant to user [1]

The electric energy leaves electric power plant (1), the voltage increases in the transformer station (2). Electric energy is transfer by electric wiring. Voltage is transformed down at the place of use (3) and the electrical connections transported electrical energy to consumers (4).

Transmission system is subsystem of Slovak electricity system which connects all major entities operating in the Slovak electricity system and ensures a decisive share of foreign cooperation. The transmission system consists of interconnected, particularly high-voltage, very high-voltage power lines, electricity installations necessary for

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the transmission of electricity in the demarcated area, interconnected power lines and electricity installations needed to connect the transmission system with the transmission system outside the demarcated area. The transmission system also includes measuring, protection, control, signalling, information and telecommunications equipment necessary for the operation of the transmission system.

The distribution system consists of interconnected very high voltage electric lines up to 110 kV, including high voltage or low voltage, and electricity equipment needed to distribute electricity to a limited area; the distribution system shall also include electrical wiring and power equipment which provides for the transport of electricity from a part of the territory of the European Union or from a part of the territory of third States to a defined territory, unless such wiring or electrical equipment interconnects the national transmission system with the transmission system of a Member State of the European Union; with a third country transmission system [2].

2 Distribution network

At the transformer station, very high voltage is transformed into a high voltage of 110 kV, some of electrical energy is distributed to big companies of heavy industry and to the transducer ensuring the supply of electrified railway lines. The remaining part is distributed to consumers (light industry, cities, municipalities) where it is transformed to 22 kV. The last transformation to a low voltage of 230 V and 400 V occurs in the businesses, municipalities and neighbourhoods themselves [3-4].

2.1 Services in the electricity supply system

In addition to providing power and power to its transmission and distribution, utilities must also provide customers with additional services. In addition to providing power and amount (kW, kWh), the quality of the supply too. This means keeping the voltage, frequency, reliability, voltage purity (higher harmonic and sinusoidal deformation), overvoltage prevention and so on. These services are provided by both the manufacturer (power plants and power companies) and distribution companies. Independent manufacturers, industry producers, municipal companies as well as customers can also be involved in reinsurance. The issue is discussed and modified in the Decree of the Regulatory Office for Network Industries No. 275/2012 Coll., Laying down quality standards for electricity transmission, electricity distribution and supply [5].

When providing relevant services, it is necessary to observe on the needs of the customer as a customer of electrical work and performance. With regard to end appliances, lighting, computer technology, the primary requirement is a stable frequency and compliance with standard voltage. The fundamental requirement for maintaining the frequency is to maintain a balance between production and consumption throughout the power system, which implies a stable operation of power plants and power grid. This implies the need to provide both control power and continuous reserve power. At the same time, the agreed voltage level must be maintained. This requires a suitable network structure as well as means for regulating reactive power [6-8].

Based on customer requirements in the electrical supply system, we can define the following important services:

- Active power control;
- Continuous reserve power;
- Voltage compliance (reactive power control);
- Voltage hardness (voltage fluctuations);
- Disaster Recovery Equipment;
- Emergency provisions and emergency measures;
- Traffic control.

Against frequency deviations outside the very narrow band, the primary reserve control of the power plant part is activated in a decentralized manner with an activation time of a few seconds and a maximum duration of 15 min. The primary control power is generated by all members, i.e., within the specified range and field of the key. regardless of the cause of the change in frequency. The time-limited disposable primary control power is then replaced by secondary control with a activation time of several minutes and a total duration in hours. It acts selectively only in the regulatory region where the power deviation occurred. Regulatory mechanisms and reserve maintenance mean that the system's performance balance is always balanced.

To maintain voltage quality, the operator must dimension and operate the network to have sufficient reactive power sources and appropriate control equipment. In addition, all network customers, i. manufacturers and customers adhere to regulatory requirements for technical boundary conditions, i. cos phi, current harmonic components, unbalance, load variations, etc. The necessary capacitance and inductive power is typically produced in the compensating devices or taken from the power plants. In exceptional cases, reactive power may be produced by the customer.

It follows from the above that renewables cannot practically ensure the maintenance of frequency and power balance and thus important services in the electricity supply system. Put simply, this "work" for photovoltaic power plants must be done by conventional power plants in the system. It depends on the ratio of installed power of photovoltaic power plants (non-renewable RES) and conventional power plants [9,10].

3 Description of the monitored PV plant

Electricity is produced by photovoltaic cells based on monocrystalline. Produced DC current is changing to alternating current in inventor with required parameters electrical network ~ 230 / 400V 50 Hz. The power output is through the 0.4 kHz / 22 kV transformer station of 1000 kVA and the high voltage line connection. The measuring and control technology is concentrated in the dispatching facility. Own night power is 7 W, at operation 599 W. Estimated lifetime of the building is 25 years.

The building features a set of 5,400 pieces of "Eoplly" 125S-185 PV modules with monocrystalline silicon cells with a unit power of 185 Wp, which are stationary on a metal structure anchored in a 35 ° ground. The total installed power is 999,000 Wp. Each string is connected to Solutronic inverters, 158 Solplus 55 and 1 Solplus 50 each. The maximum output and nominal AC power is 5.7 kW each. Cabling is halogen-free copper type FLEX-SOL, cables are laid in bundles - surface mounting. Transformation is provided by the Betonbau UK 3048 type block transformer for the TOHn 399/22 1000 kVA transformer. MV switchgear is Schneider Electric type SM6 with SF6 insulation. It contains the DM1-A input field, the GBC-B 630 A measurement field, the QM 200 A input field. The measurement is made on the MV side. There is a 4-quadrant LZQJ meter with a member for automatic data collection and data concentrator. The operation is automatic, unattended, autonomous.

Specific risk, resp. the fact to be taken into account in the operation of the node not only in Sobrance is the construction of renewable resources, namely PV power plants, for the construction of which are favourable conditions in the given region.

The support of renewable sources in Slovakia is mainly due to the fact that the distribution company is obliged to preferentially connect the renewable source to the distribution system; surcharge and assumption of responsibility for deviation. According to the applicable technical regulations, the connection of the power supply to the system must not cause a voltage increase of more than 2% at the connection point compared to the pre-connection condition. The stated "connectivity" is directly related to the size of the short-circuit power at the point of connection, which presents the hardness of the grid at that location. The short-circuit power in the Sobrance ES on the 22 kV busbars is about 150 MVA.

Figure 2 illustrates the operation of the 22 kV VN network in which renewable sources are installed, namely PV plants. The coverage of the daily consumption diagram (blue curve) is the sum of the supply from the power supply station (in this particular case EN Sobrance) and the supply of electricity produced in the PV power plants (red curve). The nature of the PV plant shown in the daily diagram is reminiscent of a sinusoid, of course, with a peak at noon, when the maximum of daylight is reached. A key aspect of network operation is the deviation. The figure shows the deviation that was caused by the failure of part of the PV plant's production due to alternating cloud.

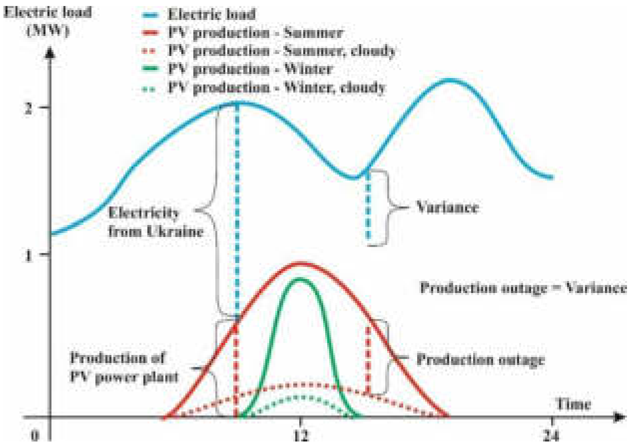

Figure 2 Daily load diagram - illustration of networking with PV plant in different modes

Figures 3, 4 and 5 show the course of electricity supply from a PV power plant with an installed capacity of 999 KW in location Ostrov to the grid.

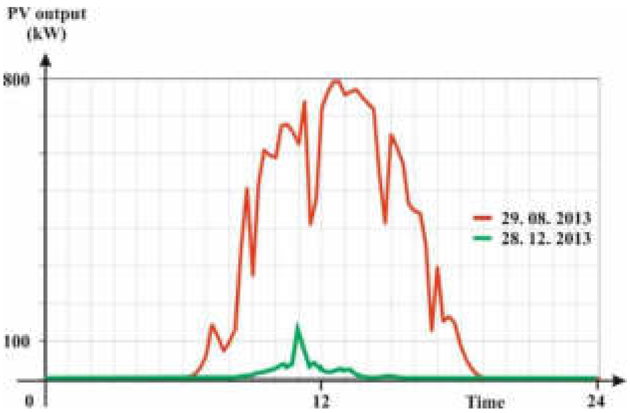

Figure 3 Photovoltaic power station Ostrov - daily consumption patterns on selected days

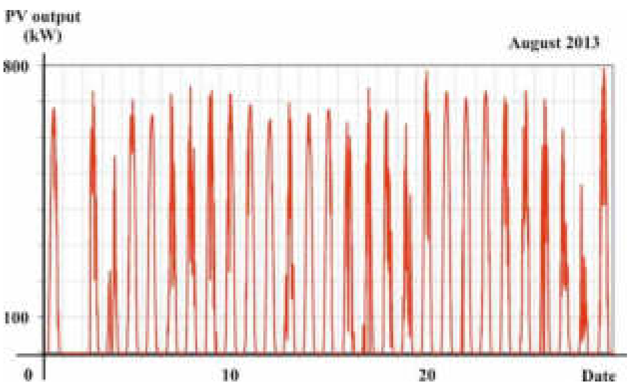

Figure 4 PVPS Ostrov - monthly consumption August 2010

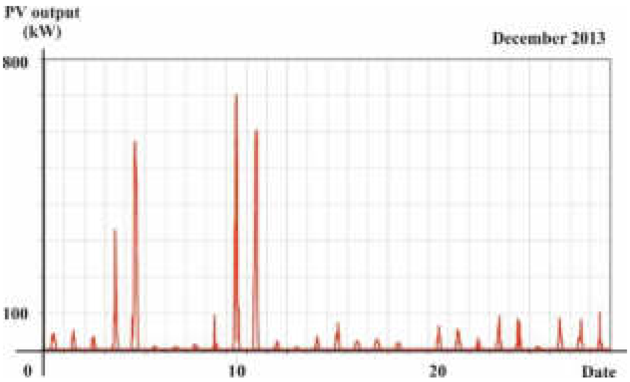

Figure 5 PVPS Ostrov - monthly consumption December 2010

The following figure 6 represents the sampling diagram, measured at the electricity supply to ES Sobrance from ES Uzhgorod for the month of April 2013.

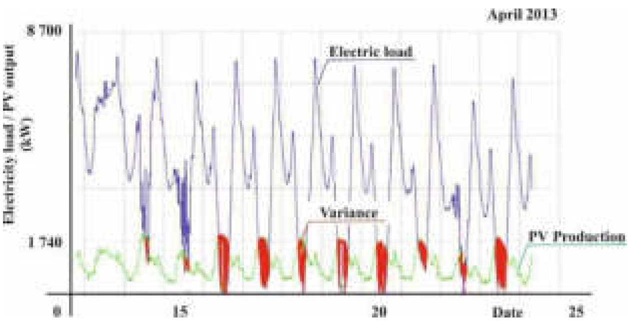

Figure 6 load curve in diagram 17. 4. 2013 - 23. 4. 2013 measured on electricity supply to EN Sobrance from EN Uzhgorod

It is clear from the diagram that with a gradual decrease in demand and increasing production from the PVP, the minimum load diagram is deepened and reaches a negative value on 15 April 2013. In practice, this means that part of the demarcated area of Sobrance creates a situation where electricity generation from PV plants exceeds the real consumption of customers and there is a reverse flow of electricity. This situation is considered technical and commercially incorrect.

This situation is the result of an overall decrease in electricity demand for both industrial and household customers and electricity generation from photovoltaic power plants. It is evident from the presented data and balances that such a situation arises because in the given area the installed capacity of renewable sources is approximately 10 MW comparable with the achievable maximum consumption. Rationalization measures only contribute to the reduction of demand. As mentioned, such an operating condition is not technically feasible and raises problems in the business area [11,12]. At the same time, the legislators assumed that electricity supplies from renewable sources would represent only a fraction of the total consumption in the Slovak distribution [13].

4 Conclusion

Part of the demarcated area "Sobrance" represents an almost laboratory example of the size of the area, the structure of the collection and the renewable sources built, to monitor the impact of the operation of renewable resources on the operation of the electricity distribution network in terms of both positive and negative impacts. The following can be noted:

- Considering the favourable conditions in the given area, a relatively large concentration of PV power plants arises, as well as the construction of combined facilities for electricity and heat production.
- The region has an agricultural character; there are few industrial customers with the required output of more than 100 kW.
- A significant share of consumption is made by households

Looking ahead, no significant increase in demand is expected. With regard to the economic crisis in particular, the construction of a logistics-agrarian complex in the Ostrov - Revištia site has been abandoned. It cannot be expected to increase the standard of equipment for household electrical appliances. Compared to the past, the share of direct electric heating of households as well as storage heating has significantly decreased (with respect to the proximity of a large employer Vojany Power Station, the inhabitants used advantageous rates for electric heating).

Electricity generation from PV plants is heavily dependent on the season, day mode and is subject to weather changes. Production is difficult to predict [14,15].

The disadvantage of PV power plants is that they supply only active energy resp. only active power. The reactive power required to operate a certain range of appliances must be subsidized from another source. For this reason, the public electricity network cannot only be operated with PV plants in the off-grid mode. PV power plants by their location represent decentralized sources of electricity. As a result, a high voltage power supply can "transport" electricity to a relatively remote customer at the cost of higher losses. The ideal situation in this respect is consumption at the production site. In view of the evolving potential of renewable - decentralized resources, the need to develop new solutions to ensure reliable operation within the prescribed limits and requirements at all tensions and using currently available resources can be expected. The optimal solution for such situations will be clearly the so-called SMART Networks and Solutions [16,17].

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REDUCING THE ENVIRONMENTAL POLLUTION ON TRANSPORT IN CITIES

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Keywords: CNG, air pollution, energy consumption, air pollutants, transport, filling stations

Abstract: P According to recent estimates, transport accounts the quarter of the world's energy demand, thus contributes significantly to the release of greenhouse gases. Most of it comes from fossil fuels, and therefore it is important that governments support the users to choose one of the environmentally friendly modes of transport. One of the main causes of air pollution is primarily the amount of gases emitted by gasoline and diesel engines. The air pollution of road traffic is determined by the number of vehicles, their modernity, technical condition and the type of used fuel. The legal and technical measures created to reduce the environmental pollution include tightening the regulation of vehicle entry, propagating new generation of vehicles that meet environmental requirements and mandating an environmental review. The goal of the research is to sum up the causes of air pollution in large cities, focusing on the traffic loads. In the research the writer will evaluate and quantify the environmental impact of the use of CNG in transport based on statistical analyses and description of the related technologies.

1 Introduction - World energy use

Primary energy sources are those energy sources that can be found in nature. The tremendous amount of informational, technological and industrial development that has taken place over the past decades, as well as massive population growth, is constantly increasing the energy demand of the Earth. As a source of energy, coal is still significant nowadays, despite the fact that around the world people are trying to limit the incineration of coal. Furthermore, significant fossil fuels are crude oil and natural gas. As the number of revealed hydrocarbon stocks will increase over the years as well as the technologies that enable the use of natural gas will be significant, there will be an increasing role for the use of natural gas. Combustion of natural gas has a lower environmental impact than the combustion of oil, for example in combined cycle gas turbine power plants case too. It can be noticed that the use of renewable energy has increased in the last 15 years, although it still hasn't got as significant role as the fossil energy sources. For example, subsidies in Europe have an important role in wind and solar power, and biomass-based power generation is also having a continuous development.

From the available data, a table has been made to show how much energy has been spent in different parts of the world in recent years.

Figure 1 shows the percentage composition of world energy consumption for 2006. According to the data, Asia accounts for the largest share of total energy demand, that is 35%, and Asia accounts for nearly half of its total energy demand from coal burning. Another major proportion still has North America, Europe and Eurasia. The least amount of energy was consumed by Africa.

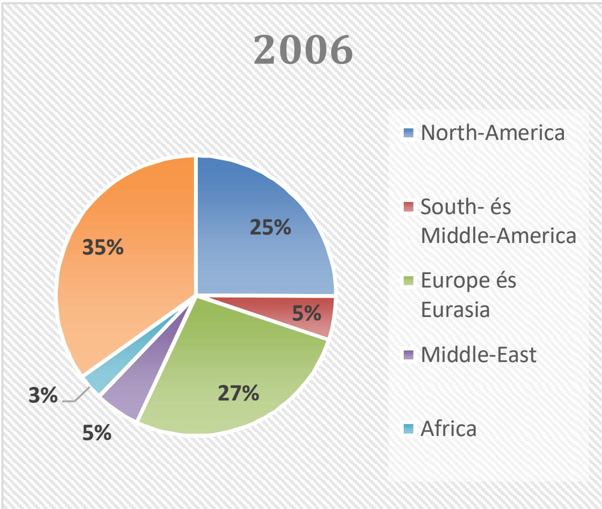

Figure 1 Percentage Distribution of Energy Consumption in 2006, Source: www.bp.com, Own modification

In Figure 2, the data has been summarized for 2016. Total energy consumption increased by around 15% in 10 years, but in Europe and Africa there is also a declining trend in the share of energy use. There was a 5% decline in Europe and 2% in Africa, although according to statistics Africa basically consumes very little energy compared to the rest of the world. The largest consumer in 2016 can also be named Asia by 42%. With a 7% increase over 10 years, practically Asia makes up for almost half of Earth's total energy consumption.

Figure 3 shows the energy consumption by fuels from 2000 to 2040. It can be seen that in the last 20 years, energy use from transport has increased steadily. The plan is to reduce the intensity of consumption in the coming decades, and to gain space for other fuel types alongside oil.

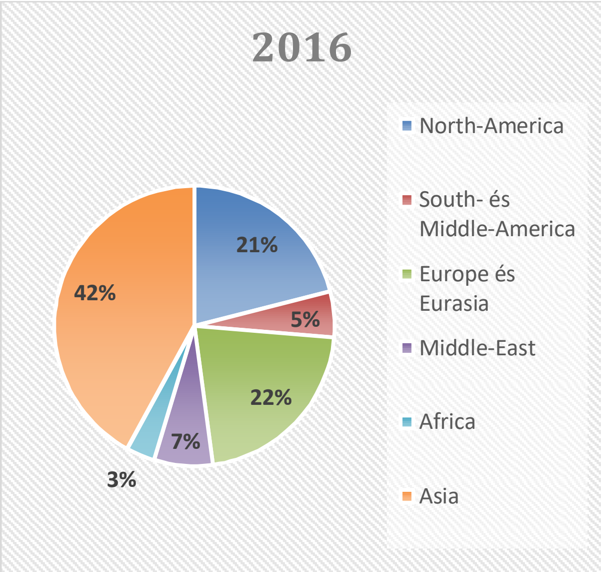

Figure 2 Percentage Distribution of Energy Consumption in 2016, Source: www.bp.com, Own modification

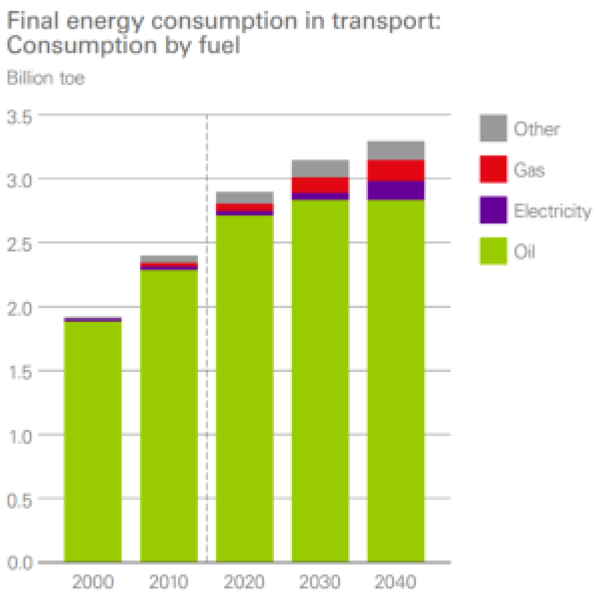

Figure 3 Final energy consumption in transport: Consumption by fuel, Source: https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/energy-outlook/transport-energy-consumption-by-fuel-eo19-p44-l.pdf

So taking into account the data, the world's energy needs have continued to grow, and will likely increase. Although the role of renewable energy sources is even bigger year by year, it still does not have the same role as fossil fuels. This essentially means that much of the world's energy needs will continue to be generated from fossil fuels, which will increase the environmental burden [1].

2 Presentation of air pollutants

Materials are considered to be air pollutants, which are completely independent of origin and state of the environment in such a way as to harm, negatively affect, and cause material damage to people's lives.

Pollutants from our atmosphere can come from natural and artificial sources, the latter being called anthropogenic pollutants. Anthropogenic pollutants consist of three main areas: transport, energy production and industry. The most important source is burning fossil fuels in these sectors. Examples of natural air pollutants include volcanoes (with sulphur oxides and powders), forest fires (carbon monoxide, carbon dioxide, nitrogen oxides and powders), wind storms (dust), live plants (hydrocarbons, pollen) (methane, hydrogen sulphide), soils (viruses, dust) and the sea (salt).

Air pollutants may come from pointy and diffuse sources. The sources where the concentration and the volume flow can be clearly determined are the exact ones. Diffusion (or surface) is the source where indirect measurements and calculations can be used to determine the amount of substance entering the environment.

The process of air pollution can be characterized by the following parameters:

- emissions,
- transmission,
- immission.

The amount of pollutants released into the atmosphere is called emission, the unit of measure is kg/h. Transmission is the spread of these materials, while the ambient air quality of a given space can be characterized by the term "immission".

Pollutants in the environment may be gases, dusts, fog or smoke. One of the groups of powders:

- the sediment dust (1000-10 mm),
- the floating dust (10-0.1 mm).

Some significant air pollutants:

- Carbon monoxide: It comes mainly from the transport industry into the air (or mining, combustion), it can reduce concentration and even cause death.
- Sulphur oxides: Due to the burning of fossil fuels and the industry (production of sulphuric acid, mining, ore preparation, cellulose production), they can cause respiratory diseases.
- Nitrogen oxides: Nitrogen oxides are produced in the production of nitrogen fertilizers, nitric acid production, transport, and energy production. They primarily damage the mucous membrane of the eye. Nitrogen dioxide forms in the atmosphere with oxygen and water to form nitric acid, causing acid sedimentation.
- Powders: Powders of varying particle size (from industry, especially mining, cement industry, combustion of fuels, etc.) can cause respiratory and cancerous diseases.
- Flue gas: Flue gas from services and households, or mainly from combustion processes, contains carbon monoxide, carbon dioxide, water vapour, carbon black, sulphur dioxide, nitrogen oxides, methane, hydrocarbons, etc. [2].

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2.1 Analysing world CO2 emissions

Figure 4 and figure 5 shows CO2 emission data for the continents of the world. According to the data, it can be stated that CO2 emissions are increasing globally despite the fact that there is a steady decline in some areas. The main reason for this is the high carbon dioxide emissions from Asian areas. There has been no increase in CO2 emissions so much as there, between 2006 and 2016, it was 26%.

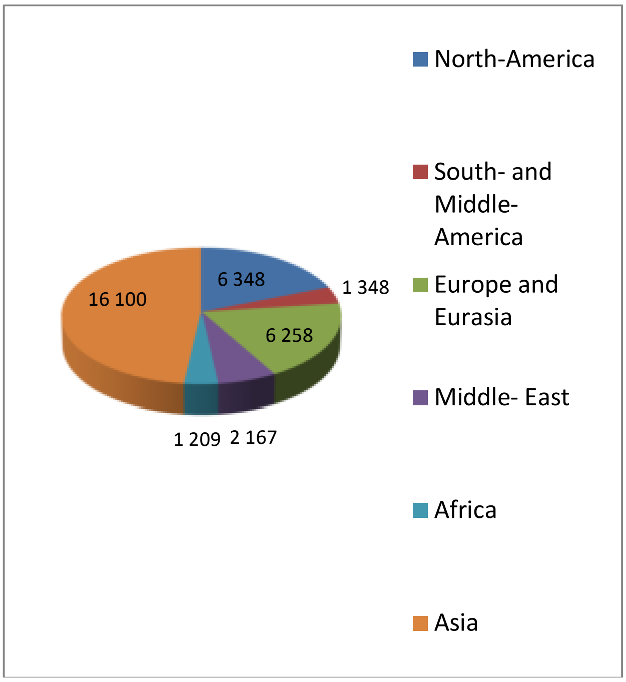

Figure 4 World CO2 emissions, Source: www.bp.com, Own modification

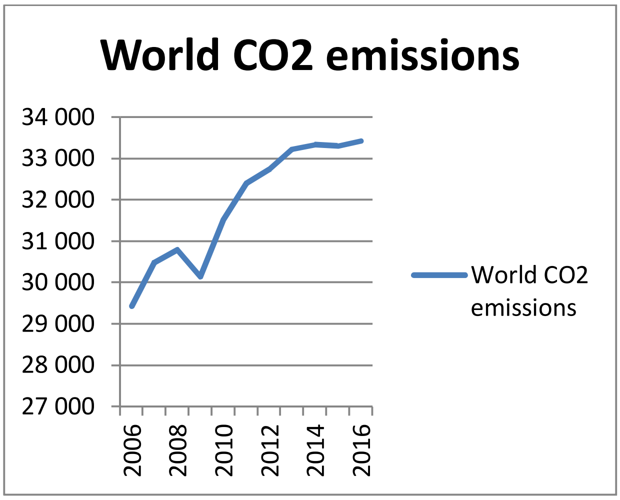

Figure 5 World CO2 emissions, Source: www.bp.com, Own modification

2.1.1 Presentation of the adverse effects of transport on the airspace

The main cause of greenhouse gas emissions is the burning of fossil fuels. Harmful emissions can be derived from a variety of sources:

- Industry;
- Energy industry;
- Transport;
- Households.

According to recent data, most pollutants released from transport directly after the energy industry, so a detailed analysis of the exact amount of environmental burden on today's motor vehicles has done and presented why it is extremely important that professionals search for alternative technologies, the most efficient way to ensure the cleanest possible traffic, especially in urban terms.

The recent smog alarms have also pointed out that the environmental classification of motor vehicles is poorly performed by specialists assigned to this task. In this case, our country has taken over the EU guidelines that have been causing various problems in Germany, France, the United Kingdom, even in developed western countries.

Smog is made up of tiny, invisible or visible particles (smoke) that, when inhaled into our body, can cause cancer, lung disease or death. This is because these particles contain heavy metals and other toxic substances.

There are two types of smog:

- London-type smog: This type is typical in the winter months due to low temperature. Since air movement is small, concentrations of pollutants are mostly caused by carbon burning, including carbon particles in the atmosphere.
- Los-Angeles smog: It is typical in the summer months, it is caused by car traffic, the sunshine produce ozone from the materials released, which is also harmful for humans.

In 1952, in London, for a 5-day smog, many people died. The number of deaths was estimated at 4 to 12 000.

Comparison of old and new types of diesel vehicles

Old diesel-powered vehicles were characterized by huge smoke streaks that were generated by the operation of diesel engines. This type of carbon black is made up of larger particles so that it cannot penetrate to the bloodstream through the lungs as the mucous membrane of the lung absorbs these particles. Carbons enter the atmosphere, which can cause chronic bronchitis, lung damage, allergies and asthma.

The new types of diesel cars apparently do not emit smoke. Particulate Filters (DPFs) (Fig. 6) have been released that thoroughly filter out the generated smoke, reducing nitrogen oxide emissions. So they seem like an environmentally-friendly vehicle, but it must also be taken into account that carbon dioxide emissions and carbon black particles less than 2.5 microns are significantly increased. These ultra-small particles are now invisible, so it does not seem to emit smoke from modern diesel vehicles. However, these particles pass through the lung mucus without problems: they immediately get into the blood and poison the human body more intensely than their old type counterparts.

Figure 6 Particulate Filters, Source: http://dpf-szuro-tisztitas.hu/

In addition, particles smaller than 2.5 microns are much more active, attracting much more heavy metals and other toxic substances from the atmosphere, which are already heavily carcinogenic and toxic.

Number of fatalities

According to the official annual report of the European Union, the number of fatalities due to smoke having a particle size smaller than 2.5 microns in 2016 is summarized in Table 1.

Table 1 Number of fatalities

Germany	73 400
France	45 120
Italy	66 630
Romania	25 330
England	37 930
Hungary	12 890
Slovakia	5 620
Austria	6 960

Source: http://kifogasokvilaga.hu/miert-karosabb-modern-dizel-auto-mint-regi-csotrogany/

It is clear from the data that the largest number is in Germany and in the larger European countries, which in my opinion may be due to the intensity of the spread of more modern diesel cars in the developed countries compared to the less developed countries. If we look at the numbers in Hungary, it can seem that we are in a better position compared to other countries, but in this case I did not take into account the size of the countries in the question.

Population data:
- Germany: 82 million;
- France: 61 million;
- Italy: 59 million;
- Romania: 21 million;
- England: 61 million;
- Hungary: 10 million;
- Slovakia: 5 million;
- Austria: 8 million.

In the case that these data are also taken into account and proportioned to the number of population, we get the following numbers:

The number of deaths per 10 000 people:
- Germany: 9.1;
- France: 7.0;
- Italy: 11.1;
- Romania: 12.6;
- England: 5.9;
- **Hungary: 13.0;**
- Slovakia: 10.3;
- Austria: 8.2.

It turns out that the worst situation of the countries surveyed is in Hungary, while in England there is the least number of deaths due to air pollution [3].

Based on the data presented, it is clear that it is vital for professionals to develop alternative technologies that minimize the pollution of the atmosphere. One of these solutions can be provided by CNG technology.

3 The CNG technology

3.1 Features of CNG

CNG is an English abbreviation, meaning Compressed Natural Gas. This new and promising fuel type is rapidly expanding in transport and vehicle industry. A CNG vehicles (Fig. 7) fuel tank is capable of storing about 16 to 20 kg of fuel, making it capable of an average of 3-400 km. (This applies to passenger cars.) The most important element of CNG is methane. Contrary to fossil fuels, CNG is less likely to burden our environment, as methane burns far less harmful to the atmosphere than other fuels. In fact, since it is a gaseous fuel due to rapid combustion in the chamber, higher efficiency combustion occurs. Benefits of CNG powered vehicles:
- Carbon dioxide emissions are approx. 10% lower than diesel engines and 25% lower than petrol engines.
- Emission of solid particles is virtually impossible.
- Nitrogen oxide emission does not exceed the limit of EURO 6 norm [4-6].

Fuels used by motor vehicles with internal combustion engines must meet certain conditions, namely:
- High energy density;
- Easy handling;
- Provide the right quantity;
- The combustion product should have the least harmful effects on humans and the environment [6,7].

The last point of environmental protection is becoming more and more emphasized today, but this condition is not consistent with gasoline and diesel. The most important element of fuels is energy density, which is also related to volume and weight. The price of gasoline and diesel oil by volume, CNG price is determined by weight. The energy density per mass is important because of storage.

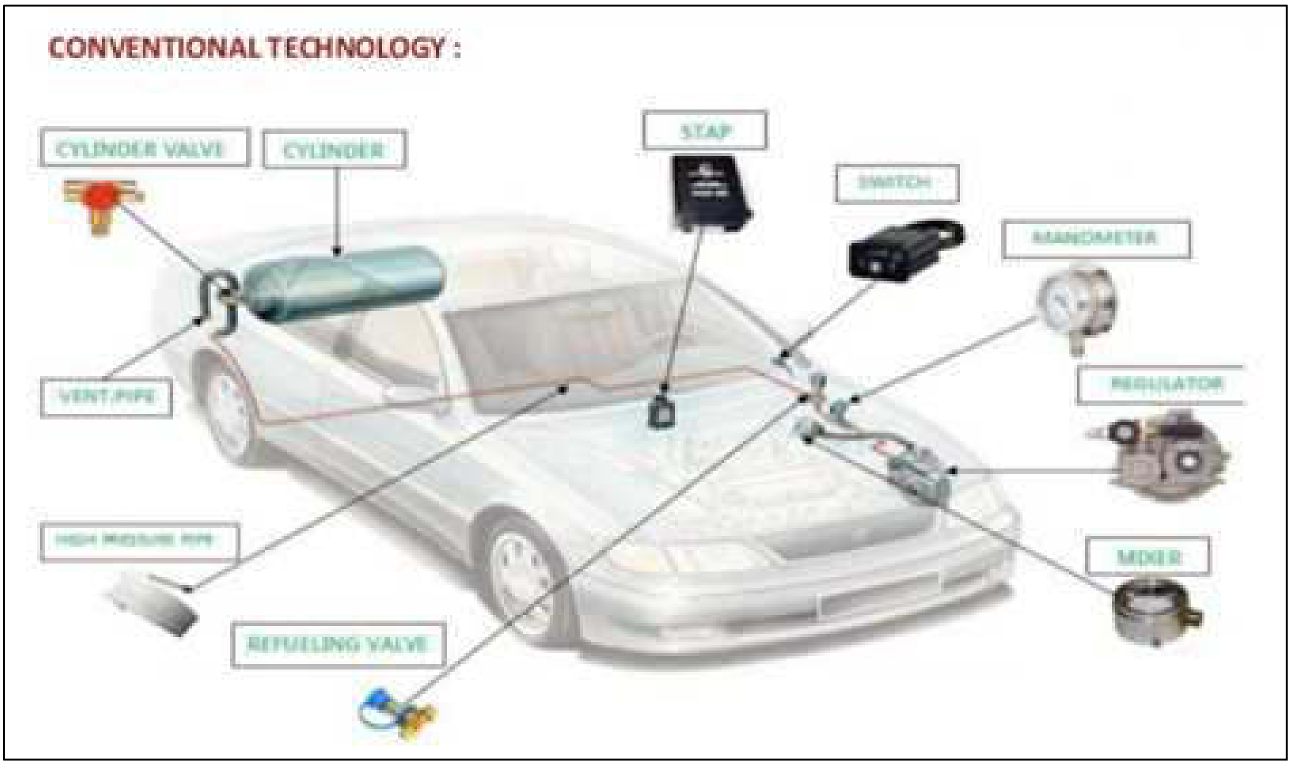

Figure 7 CNG fuelled car fuel system, Source: https://www.slideshare.net/rubel2012/vehicle-cng-conversion-technology

1 kg of CNG contains about as much energy as 1.5 litres of gasoline or diesel oil. In these vehicles there are cylindrical containers with high pressure cylindrical steel or composite material located. Depending on what kind of material the containers are made of, their weight can be 30 to 80 kg and their capacity is 90 to 150 litres. Their maximum permissible pressure will always depend on their size and country of the production [4-6].

3.2 The role and structure of filling stations

One of the most important elements of the implementation of natural gas transport is the design, construction and operation and maintenance of the filling stations. The construction of the filling station and the refuelling process itself are more complicated than for other fuels.

Figure 8 shows the structure of a CNG filling station. Compressed natural gas is produced by compressor technology in the filling station area. One typical feature of the compressor stations is the charge capacity Nm3/h, which is the typical amount of charge capacity within the vehicle for 1 hour. (Natural gas at 15 ^{o}C and ambient pressure). Based on this, we distinguish two types of filling stations:

- Slow Chargers: These stations have a capacity of less than 100 Nm^3/h, which is about 2-3 hours for cars.
- Fast chargers: Stations with a capacity of 100 Nm3/h or higher, with a charge time of 3-8 minutes, depending on the volume of the tank to be charged [4].

Charging starts from the minimum pressure buffer, and in principle it continues until the pressure in the container is equalized by pressing the buffer tank. In the case the flow rate of the natural gas flowing into the tank does not exceed the specified limit; the system will switch to the higher pressure tank. If the pressure in the buffer tank reaches a pre-set threshold, the compressor starts, and begins filling the vehicle fuel cylinders and the buffer storage at a nominal pressure [6].

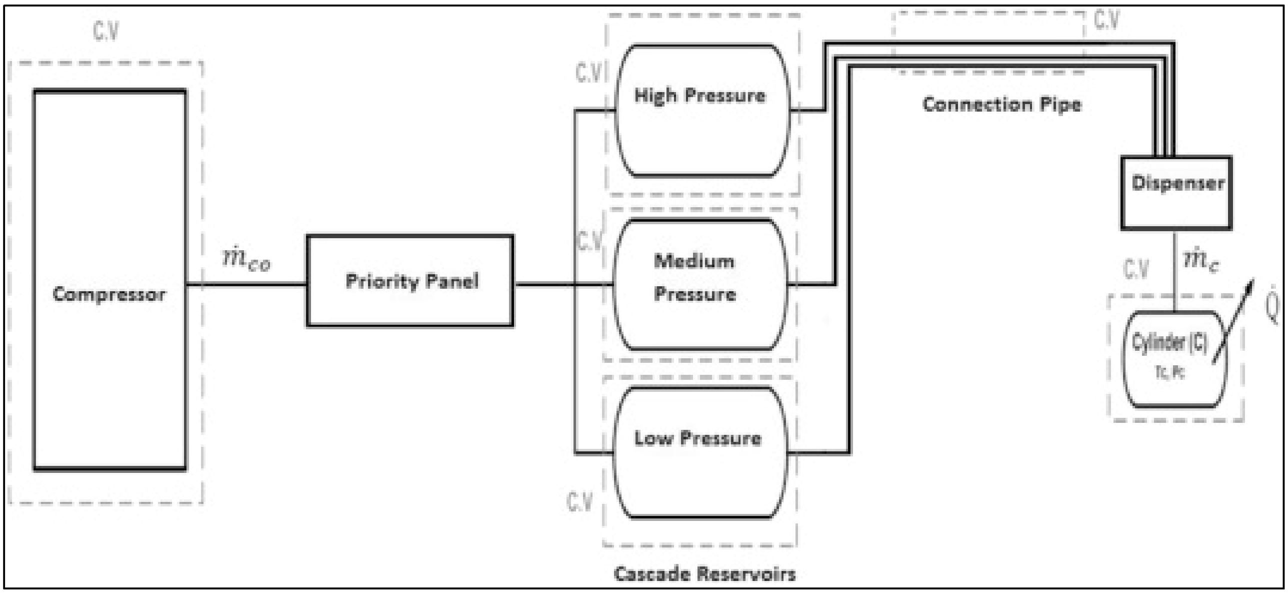

Figure 8 CNG refuelling station, Source: https://www.sciencedirect.com/science/article/pii/S1875510016300270

4 International outsourcing

The propagation of CNG vehicles is mainly influenced by the nature of pipeline gas supply in the area. The spread of CNG-powered vehicles in the world is different, due to different energy options and different political views. In 2014, the world's total CNG vehicle fleet was 22.3 million, which covered 2% of all vehicles. Countries with the largest natural gas station are listed in Table 2.

Table 2 Countries with the largest CNG vehicle fleet

Country	Fleet
Iran	4.0 million
China	4.0 million
Pakistan	3.7 million
Argentina	2.5 million
Brazil	1.8 million
India	1.8 million
Italy	900 thousand
Columbia	500 thousand
Uzbekistan	450 thousand
Thailand	462 thousand
Ukraine	388 thousand
Armenia	244 thousand

Source: www.cngport.hu

CNG has grown into one of the most important fuels in the other Asian countries mentioned in table 2. In many places in India, public transport is also use CNG based buses. According to the decision of the Government of Pakistan, in the most populous province, every bus in 2007 had to change to CNG plant. In China, 3700 CNG stations have been installed in 2014, but the propulsion of vehicles is not fully in line with the number of filling stations. Due to the regulation of the 12th Five Year Plan and the possibility of subsidies, the spread of CNG buses and trucks has been increasing in recent years [4,8].

In Africa and in the Middle East the best performing country is Egypt, with 63 000 gas-powered vehicles and 95 filling stations [9].

In Canada, gas mining is significant, and natural gas is sold at a favourable price in the form of CNG. In addition, it has many fuelling stations that serve the more than 12 000 CNG vehicle fleet. In the United States, the situation is similar, there is plenty of natural gas available. There are 873 filling stations and 114 000 vehicles in the country [10,11].

Gas-fuelled transport in the South American countries is very popular. The stock is mainly made up of the taxi fleet of major cities that are concentrated in Brazil and Argentina.

Just as Figure 9 shows, when we look at CNG technology at European level, there are big differences. In the first place, Italy has 1 173 filling stations, 1 million cars and 3 000 buses.

Germany stands at second place with 921 stations and their numbers are growing at a high rate. The fuel used is largely biomethane from renewable energy sources.

The gas-fuelled traffic in Hungary has a decade-long history, currently about 2 000 CNG vehicles are on the roads. The year 2010 was a low point for the gas transport, but since then, continuous development has begun. A total of 60 waste trucks and 240 buses run on the roads. In Hungary there are currently 9 filling stations operating publicly [4].

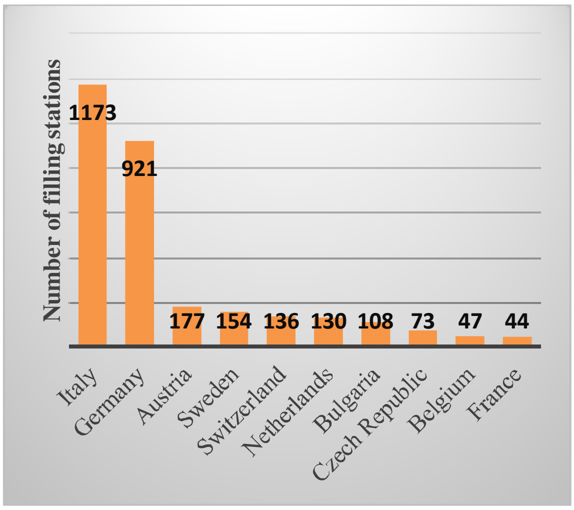

Figure 9 European countries with filling stations, Source: www.cngport.hu

4.1 The role of CNG in Hungary

Since 2010, CNG consumption in Hungary has been rising steadily, according to the latest data, the consumption was 8 million cubic meters in 2015, and in 2016 it was 12 million. This is still a significant amount despite we know that 50 million cubic meters of natural gas per month in Italy are used for transport, so there is still room for improvement. In the framework of the Clean Mobility Strategy, the European Union has set out the directives that set the legal basis for supporting renewable energy production, the use of clean and energy efficient vehicles, the deployment of alternative fuels and the development of the necessary infrastructure. The EU expects that the charging infrastructure for alternative-driven vehicles will be set up on TEN-T routes (M1-M5 motorway, M7-M3 motorway and Danube route). The European Network Development Fund receives 3 aid projects for Hungary. Within the framework of the PAN-LNG project, five LNG-L-CNG filling stations and a mini liquefying plants, which are completely independent of the gas pipeline network, are going to build. During the implementation of the PAN-LNG 4 DANUBE project, an LNG filling and transfer station will be set up at the Csepel Free Port, where the vehicles of three transport sectors - ships, lorries and trains - will be served with liquefied natural gas. The CLEAN FUEL BOX project includes the construction of 39 L-CNG filling points, which do not require a gas pipeline to operate.

CNG and LNG drives have a number of advantages, both for heavy vehicles and buses. The Hungarian Post has completed a 2-month test with the Iveco CNG tractor, with a spectacular result: the vehicle achieved fuel savings of 3.5 million forints per 100 000 kilometres. Such a tractor runs on an average of 120-160 thousand kilometres, so it is about to return its price over its useful life of five years. In Hungary, CNG-powered buses are typically used in local public transport, such as in Kaposvár, Miskolc. These vehicles have the same maintenance demand as conventional diesel engines, ranging from 400 to 500 kilometres, ideal for serving local passenger needs. On the other hand, CNG buses for inter-use are available on the market, such as Scania Interlink or Iveco [12]. A total of 60 waste trucks and 240 buses run on the roads, 80 of them in Miskolc, 71 in Budapest, 40 in Kaposvár, 39 in Szeged and 10 in Zalaegerszeg. In Hungary there are currently 9 filling stations operating publicly [4].

Seven capital companies decided in 2009 to sign a letter of intent aimed at promoting the infrastructure of the CNG vehicle use infrastructure. Under the contract, each signatory undertook to continuously update its own fleet of vehicles with natural gas vehicles, and the gas supply company in Budapest undertook to set up filling stations themselves. [6]

The mission of the City Transport of Miskolc is to "Pass passengers in a predictable, safe and environmentally responsible way. Reducing the emission of exhaust gas from vehicles in the case of environmentally friendly transport." This can be accomplished by maintaining the vehicles and constantly updating them. The City Transport of Miskolc is paying more attention to environmental protection, which shows that recently, 75 new CNG buses were sold to Miskolc. A compressed gas powered bus is much more environmentally friendly than a diesel one, and can be operated at 25-40% cheaper. Although the purchase price is 8-15 million forints higher, the investment will return relatively quickly. Based on the calculations, fuel savings are approximately 30-40 HUF per miles compared to diesel vehicles, so after 250-300 thousand kilometres the bus fleet will pay off and after that operation is much cheaper than the diesel engine.

The buses in Miskolc with CNG technology comply with the strictest Euro 6 environmental protection standards, and the emission levels almost equal to zero. The environmental impact of CNG and diesel vehicles in Hungary was first measured in Miskolc in March 2016 under real operating conditions. During the measurements, Neoplan (diesel, Euro IV engine) and the new MAN (compressed-air Euro VI motor) buses were performed on three Miskolc lines. The comparative measurements were made for 90 passengers. On the basis of the final results it can be stated, that from the CNG buses 98.0-98.5% less nitrogen oxides (NOx) are released into the atmosphere than from the diesel engines. Noise pollution is also significantly reduced due to new buses because the noise level of the CNG engine is much lower than that of similar power diesel vehicles.

Figure 10 shows the CNG filling station in Miskolc, which is the only station in Northern Hungary. In addition to the company's buses, it is open to individuals and companies throughout the day, it has an automated payment system, allowing you to pay for a card and also provide an invoice [13].

Figure 10 CNG fuelling station in Miskolc, Source: http://mvkzrt.hu/mvk-cng-toltoallomas

5 Conclusion

The purpose of the research was to sum up the causes of air pollution in large cities and to demonstrate how air pollution is continuously reduced due to the development of CNG traffic. In the research based on statistical analyses and description of the related technologies, the environmental impact of the use of gas-based motor fuels has been evaluated. Based on data series of the recent years, it was shown how the intensity of the emission of pollutants changed as a result of the introduction of environmentally-friendly CNG buses in several major European cities. Based on the data, although many countries show a decline in the emission of pollutants, if we look at the problem at global level, there is still a sustained increase in this area. So it can be said that the emission of pollutants is too high in order to reduce it globally with the current CNG vehicle fleet.

In my opinion, it would be important to carry out tests where the operation of diesel buses would be stopped in a given city, and instead of that they should put CNG vehicles in service during that period, and measure the quality of that air every day. By evaluating the data from these studies, it could be concluded with certainty what could be the perspective of designing and operating a CNG-based vehicle fleet and how much this can reduce the air pollution in cities.

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HYDROGEN COMPRESSOR UTILIZING OF METAL HYDRIDE

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Keywords: metal hydride, hydrogen, absorption, hydrogen compressor

Abstract: After low pressure hydrogen production by electrolysis of water, compression is required to increase the storage pressure in the final containers. The use of metal hydride materials seems to be a very effective way to increase the pressure of stored hydrogen. Heating these alloys significant increase the hydrogen pressure. The article describes the design of the compressor for using the generated heat at absorption process of the hydrogen into metal alloy during compression process. The equilibrium pressure, by which the absorption process occurs, is highly dependent at temperature of alloy. Difference in equilibrium pressures of MH materials at acceptable temperature change led to the effort to create a hydrogen compressor. The article describes the basic characteristic of hydrogen compressor and its actual state of development.

1 Introduction

Hydrogen is a chemical element with indication H and atom number 1. Hydrogen is non-toxic, without colour, taste and odor at standard temperature and pressure. Nevertheless, its properties are unique and important. Hydrogen is most numerous chemical substances in the space especially in the stars and gas packets of the planets. It is found on the Earth in the form of hydrocarbons and water [1].

Hydrogen is non occurring in the molecular unbound form. The most often the hydrogen produces by partial oxidation of natural gas, steam reforming and electrolysis of water.

In the case that hydrogen is not consumed right after production, is the necessary its storage. The majority of the storage methods require the using of the compressor which will increase the pressure to the desired level. The increase of the pressure is necessary due to the low density of hydrogen.

Hydrogen can be stored in high pressure vessels, in cryogenic containers and using adsorption and absorption materials.

Perspective hydrogen storage materials are metal hydride (MH) alloys that absorb hydrogen in the intimate space of its crystalline grid. These materials are characterized by a considerable pressure gradient, depending on the changing temperature. This knowledge can be used to compress hydrogen using MH trays [2].

2 Storage of hydrogen in the solid phase

In general, fuel tanks that are exposed to high loads must store high density energy, resist external mechanical effects, high pressure and temperature differences.

Hydrogen may be stored on the surface of the solids by adsorption, but also within the solids by absorption. In adsorption (Figure 1a), hydrogen is bonded to the surface of the material, either by hydrogen molecules or by hydrogen atoms. When hydrogen is absorbed (Figure 1b, c), the hydrogen molecule is dissociated and the atoms are then diffused into the metal lattice. This method allows storage of hydrogen at ambient temperature and pressure. Finally, hydrogen may be bound by a strong chemical reaction in molecular structures such as chemical compounds containing hydrogen atoms (Figure 1d) [3].

Metal hydrides offer several advantages over pressure storage or cryogenic storage:

- SAFETY: The safety limits for hydrogen storage in metal hydride are negligible compared to liquid or compressed hydrogen.
- SHUTDOWN: In the standby mode of the metal hydride reservoir, hydrogen is not released into the environment due to evaporation, as is the case with cryogenic storage.
- LOW PRESSURE: The metallic reservoir operates at a pressure range of between 8 and 30 bars (which corresponds to the electrolyser output pressure in the production of hydrogen by electrolysis and thus often does not require the use of compressors).

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- PERFORMANCE: Selected metal hydrides have fast kinetics and achieve fast charging and discharging rates, as well as the high volumetric density of stored hydrogen.
- SIMPLIFIED USE: Metal hydride storage systems can be easily transported and installed. Additionally, the end of the metal hydride life cycle does not pose a danger to the environment [4].

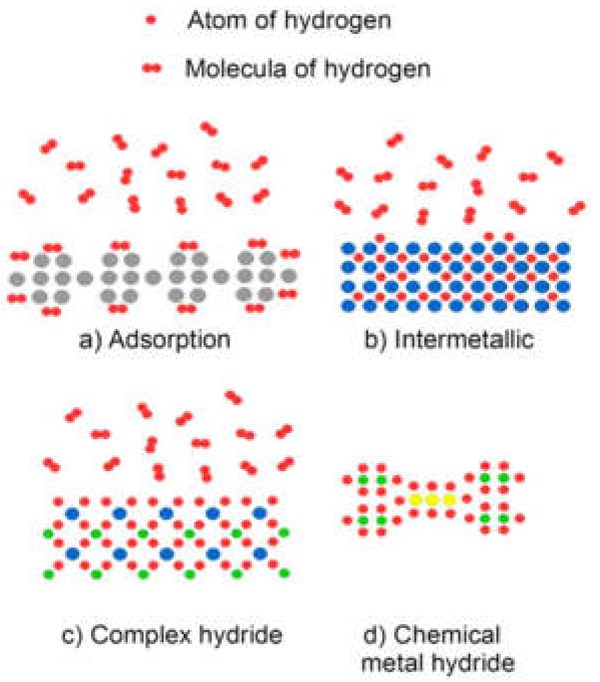

Figure 1 Possibilities of storage of hydrogen in the solid phase [3]

3 Storage of hydrogen in the metal hydrides

The metal hydride is formation by the metal and hydrogen atoms. Metal and hydrogen form two different types of the hydride. Alpha phase is if the metal absorbs only one part of hydrogen and the beta phase if the metal is completely saturated with hydrogen. Metals differ in their ability to catalytically dissociate hydrogen, which ability is dependent on surface structure, morphology and metal purity.

The optimal properties of the materials for hydrogen storage are: the high sorption capacity of hydrogen to the unit weight and volume, the low energetic difficulty (low generation of thermal during absorption), the low dissociative temperature, the medium dissociative pressure, the low temperature during production of the metal hydride, the minimum needed energy for desorption of hydrogen, the reversibilitation, the fast kinetic of the absorption-desorption cycle, high stability and oxy resistance (high service life), low recycling costs and high safety.

4 Basic characteristic of the hydrogen compressor

The compressor for compressing hydrogen, which is driven by the interaction of the hydride formation in the metal or in the intermetallic compound with hydrogen to the metal hydride, is considered to be a promising application for the hydrogen energy system. The advantage of a hydrogen compressor lies in its simplicity in design, compactness, safety, reliability, and absence of moving parts and the possibility of consuming waste heat instead of electricity.

Hydrogenation of the metal, respectively, alloys can be described by the following equation:

$$M(s)+\frac{x}{2}H_2(g) \xleftrightarrow{\text{absorption/desorption}} MH_x(s)+Q \qquad (1)$$

where:
M – metal or alloy,
s – solid faze,
g – gas faze,
Q - generated thermos during absorption (J).

Process of produce of metal hydride by absorption of hydrogen into to alloy is accompanied by heat release Q. In desorption process, during decomposition, the alloy consumes approximately to the same quantity of heat.

Absorption and desorption process is strongly dependent to own characteristic of the reaction (1) including their thermodynamic and kinetic characteristics which include very important process of the heat and mass transfer. Also, important aspects include the composition, structure and morphology of the fixed phase involved in the process. These properties are related to basic aspects of the studied metal hydride material, mainly.

Using of the metal hydride for thermal compression of the hydrogen is founded on the equilibrium pressure and temperature described by van Hoff's equation (2) [5,6]:

$$\ln p_{eq} = \frac{\Delta H}{RT} - \frac{\Delta S}{R} \qquad (2)$$

where:
ΔH - Enthalpy change (J·mol-1),
ΔS - Entropy change associated with absorption or desorption in a metal hydride (J·K-1).

As shown in figure (Fig. 2), single-stage compressor operation consists of 4 processes:

- DA – Absorption of hydrogen in low temperature (TL) and low pressure (PL),
- AB – Adequate heating and compression at change from temperature TL to temperature TH,
- BC – Desorption of the compressed hydrogen at temperature TH and at increased pressure PHA,
- CD – Adequately cooling from TH to TL.

The compressor is starting to perform desorption of the hydrogen if the equilibrium pressure of the hydride exceeds a set pressure value discharge In this case the pressure of the storage is constant with set value of the discharge pressure. The principle of operating the single-stage hydrogen compressor is shown in figure 2.

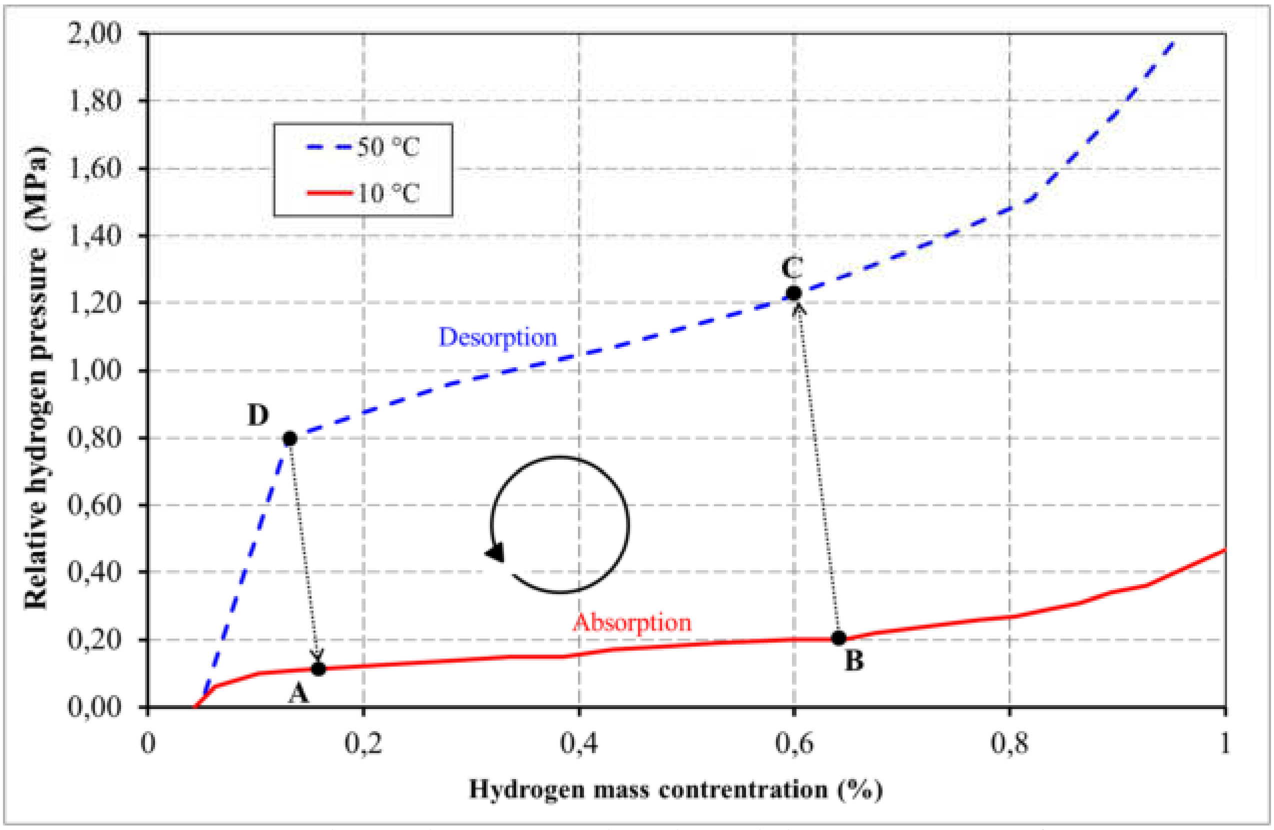

Figure 2 The principle of operation of the single-stage hydrogen compressor MHx [6]

Within the solution of the design hydrogen compressor was drawn up the scheme of the involvement (Fig. 3), which contains three metal hydride tanks and pipeline network for hydrogen with valves (V1 until V6). They will serve to regulate the filling and emptying of metal hydride tanks (MH_1 until MH_3). Each of the MH tanks will be equipped with temperature sensors t_1, t_2 and t_3. The diagram includes pressure sensors for each hopper and hydrogen output (p_1 until p_4). In scheme are shown three-way zone valves (TZ_1 until TZ_4), which will be regulate the circulation of the cooling or, respectively, heating water. VT_1 and VT_2 are heat exchangers that are part of the heat pump HP. The heat pump allows the collection of heat from the storage tank where the heat is absorbed and supplied to the pressure-increasing tank. The chiller (Ch) is also part of the assembly, which will, if necessary, help to cool the metal hydride tanks.

The hydrogen storage is ongoing in closed thermodynamic cycle at low temperatures. In the figure 3 is showed filling operation of the MH_1 tank where it occurs the hydrogen molecules are dissociated and subsequent the diffusion of atoms into the intermetallic structure of the alloy. During this reaction the heat is generated. The blue darts represent cooling water circuit. This circuit withdraws the generated heat and with the help of the heat pump the transports the thermal energy into the tank MH_2.

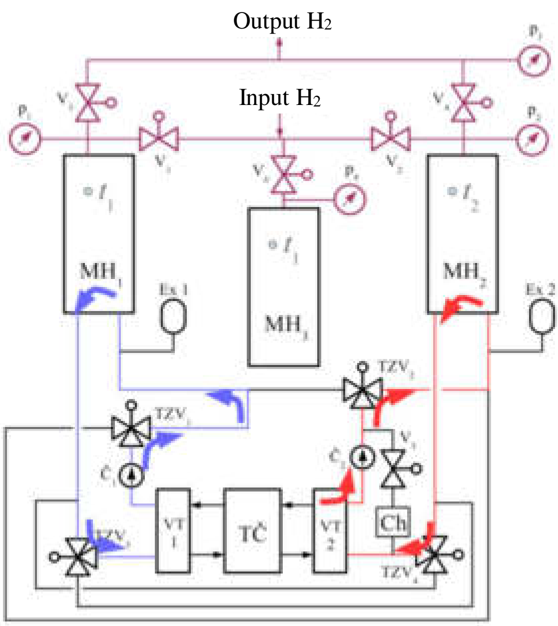

Figure 3 Scheme of the operation of the hydrogen compressor when filling the MH1 tank

We consider, the alloy in tank MH_2 is already saturated. By feeding the heat generated by tank MH_1 the pressure in the MH_2 tank increases. Subsequently, hydrogen can be desorbed from the alloy to the next stage of the compressor. Thus, the capacity of the MH_2 container is again reduced to its original state and the cycle can be switched to the opposite mode to ensure continuous operation of the hydrogen compressor.

Compressor uses absorption of the hydrogen into the two MH tanks arranged tandem. For transport of heat between tanks is used heat pump. The valve V_1 is open during hydrogen absorption into MH_1, while valve V_3 is closed. Heat is generated during this reaction. This heat removes the cooling circuit (highlighted by blue colour) connected to the heat pump evaporator (VT_1). In the tank MH_2 there is an increase in pressure the due to heat transfer by heating circuit (highlighted by red colour) from heat pump capacitor (VT_2). When the required pressure in the MH_2 tank is reached, the valve V_4 opens while the valve V_2 remains closed. Therefore, hydrogen is released to a higher degree of compression. After the MH_2 tank is emptied, valve V_4 and V_1 are closed.

5 Concurrency state of the hydrogen compressor

At the Department of Energy Technology, within the framework of the APVV project and in cooperation with the company TATRANAT – water heaters, s.r.o. was designed heat pump (Fig. 4) water-water.

Figure 4 Heat pump water-water

The heat output of this heat pump is 1.5 kW with a cooling output of 1.2 kW. The R134a refrigerant with a weight of 900g is used in the heat pump. Measurements are currently taking place to optimize the amount of refrigerant to ensure continuous cooling and heating. For measurements, the heat pump was connected according to the following diagram (Fig. 5).

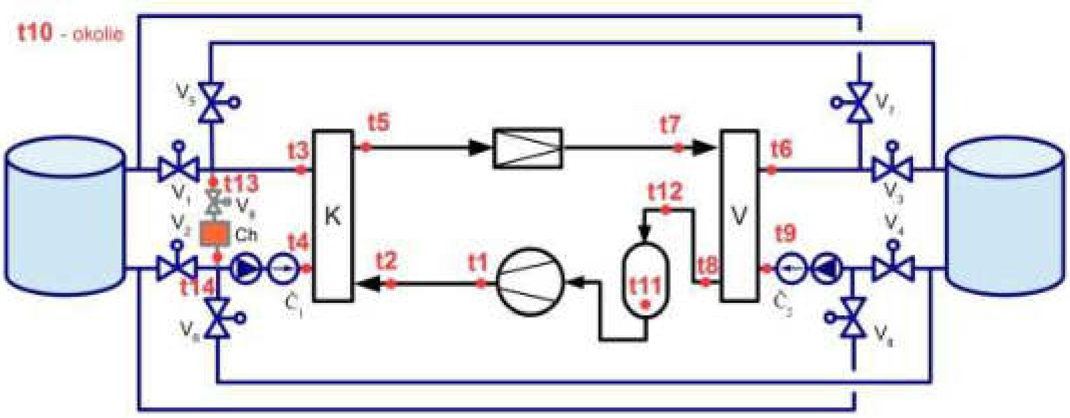

Figure 5 Connection of heat pump

Instead of the MH tanks were used in the measurement the water tanks, the amount of which corresponded to the heat capacity of two MH alloys with La, Ni and Ce alloys. The measurements were carried out in a temperature range of 10 to 50 °C. When the heat pump is operating, the heat output is still greater than the cooling, so the cooler is also included in the experimental set, which is cooled down to 50 °C if the chilled tank has not yet reached the temperature of 10 °C.

During the measurement, the compressor is switched off after several cycles. This emergency shutdown caused an increase in pressure over 2.3 MPa on the safety pressure switch. This pressure increase caused a sharp change in temperature in the condenser and evaporator. Subsequently, the amount of refrigerant from the original 900 g was adjusted to 700 g.

6 Conclusion

The development of a hydrogen compressor has a great potential for innovative social and economic needs in the development and application of hydrogen technologies in the automotive industry and transport, especially in the context of the Slovak and European innovation strategy.

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RISK EVALUATION IN ENERGETIC INDUSTRY

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Keywords: energetic industry, energetic security, energetic sector risk, energetic services

Abstract: The keywords should be Energetic industry is presently meeting the pressure to provide stable availability of supplies with aim to secure economic growth, as well as pressure of living environment protection. There is therefore necessary to search position of energetic industry from the view of its risk to provide long-term prosperity and contribution for national economy in individual countries. Presented contribution searches external and internal aspects of threatening of the energetic industry stability from the view of sector risk and prediction of demand and offer development from area of energetic services. The prediction shows high dependence in EU on import of energetic commodities from unstable regions, which threatens energetic security of countries. There is therefore necessary to provide long-term prosperity by creation of positive financial indexes that would provide decreasing of bankruptcy risk.

1 Introduction

Development of human population is more and more connected also with natural, technical and technological catastrophes and their impacts to the society by the way of vast damages and losses [1]. Due to the mentioned there is necessary to increase importance of risks evaluation not only at the single working place and in the company, but also in the individual sectors and countries [2].

Presently the world economy is characterized by a globalization process, which means a national economy is part of a global economy, which influenced, but also determines a certain trend of the national economy development. In this connection industrial sectors present a part of the global economy, which determines certain complexity in the development of any industrial sector [3,4].

Industrial sectors (not excluding energetic industry) face presently pressure of living environment protection [5], both as an initiative from the side of governments, and from the side of global competition, not excluding pressure from the side of consumers [6].

Moreover, presently in energetic industry the task is how to provide energetic security of countries and regions [7]. This is perceived from various aspects, for example as stable availability of energetic supplies by the way to provide economic growth in producing, as well as in consumers countries with the lowest possible costs and prices differences [8].

Number of legislative decrees must be regarded, supporting and demanding in documented a way for evaluation of risks in various industrial activities and at the various level of business activities management [9,10]. Risk evaluation, as everyday part of management and decision processes, enables to create new solution and to improve „running“ processes by the way to achieve long term determined goals of the company and satisfaction of employees, consumers and society.

The goal of presented contribution will be therefore to search the position of energetic industry from the view of its risk to provide long-term prosperity and contribution for the national economy of individual countries. To provide such long-term prosperity demands concentration to creation of positive financial indexes that would provide decreasing of bankruptcy risk in the given sector [11].

2 Methodology

Organization of Petroleum Exporting countries (OPEC) and its partners – including Russia, leading world producer – extended agreement to limit production to nine months till December 2018. Declared goal was to decrease stocks to their five years average, production by 1.8 million barrels per day, or to the level around 2% of world production. This time the agreement includes Libya and Nigeria, which should limit production to the highest level in 2017. The results of this agreement were that in January 2018 Brent and „West Texas Intermediate“ (WTI, north American index that had been used as well as reference index for determination of petroleum prices) at level 67 USD and 61 USD. Establishment of American pipelines of new generation with improved capacity could help to remove difference between prices Brent and WTI at level 4 USD in second half of 2018.

After achievement of record values in 2018, petroleum stocks remained too high (140 million barrels over five years averages), but they decreased and they should achieve five years average in second half of 2018 (Figure 1). Except of mentioned demand was increasing every half a year, overcoming gap between offers at the markets in 2017. Capital expenses could be smoothly increasing between leading companies in the sector (Chevron, ExxonMobil, Shell, Total, BP), acting in whole value chain (research, production, distribution), since they used an increased margin in 2017 [12].

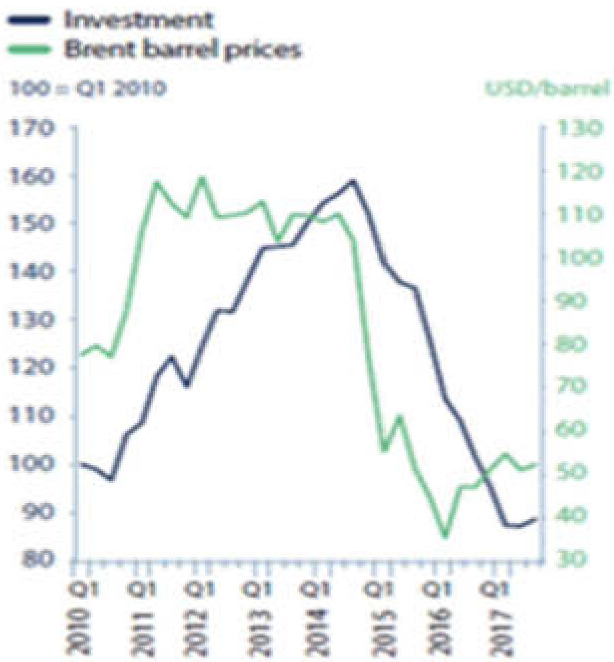

Figure 1 Trends of investments development in the sector
Source: www.macrotrends.net

Energetic industry demands from the view of long-term prosperity providing in the society to evaluate external and internal aspects of its stability threatening, to find out alternative possibilities for new sources using, as well as to manage reliably, safely and effectively everyday activities of its operation with a goal to observe quality [9]. Single evaluation of the sector risk results from the analysis of positive and negative sides in energetic industry (Table 1).

Table 1 Positives and negatives of energetic industry

Positives	Negatives
Resistance against prices fluctuation in leading companies	High debt level, especially between slate oil companies
Expected high demand in the future, connected to the high worldwide growth of consumption	High volatility of oil prices
Effort of gas companies to simplify the production	Surplus of oil production
Implementation of an agreement about production freezing	Redundant capacity of services in several oil and gas companies

Source: COFACE handbook, 2017, p. 228

Evaluation of the risk in the sector can be done by various approaches. One of them is to follow up following:

- Corruption failures (in the country of energetic company residence) during four consequent quarters,
- Payment period, announced by purchasers (aggregated according to sectors and countries),
- Expected financial results for the next four quarters (aggregated according to sectors and countries),
- Experiences with payment ability according to the sector and country of residence [13].

Evaluation of the bankruptcy risk in the sector (through credit risk) by the company COFACE is based on changes in financial data, published by more than 6000 listed companies from emerging Asia, North America, Latin America, Western Europe, Middle Europe and Middle East with Turkey. An indicator of credit risk presently summarizes change of turnover, profitability, indebtedness, cash flow and claims, registered by analytics of company COFACE. It distinguishes four categories of the risk:

- Low,
- Medium,
- High,
- Very high risk.

3 Results and discussion

The results of the risk evaluation in the energetic industry according to the individual countries during (with determination of development), is illustrated by Table 2.

Table 2 Development of energetic industry risk in individual countries

Year	2018	2017	Development
Latin America	High	Very high	Improving
North America	Low	Very high	Improving
Middle and Eastern Europe	Medium	High	Improving
Western Europe	Medium	High	Improving
Asia	High	High	Stable
Middle East and Turkey	High	High	Stable

Source: www.coface.com

Figure 2 illustrates development in the analysed period in graphical illustration. Mentioned risk results from the development of demand and offer of energetic services.

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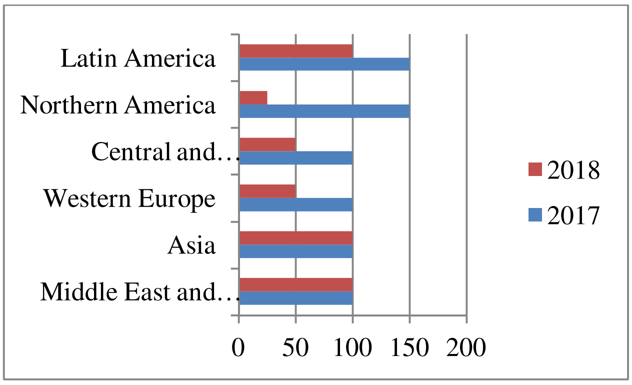

Figure 2 Development of risk in energetic industry in 2017-2018

3.1 Prediction of demand development in energetic services

According international energetic agency (International energy agency - IEA) the worldwide demand on oil should achieve in 2018 approximately 98.9 million barrels daily, which presents smooth growth by 1.3% in comparing with 2017, but it is significantly under worldwide economic growth by 3.7%. This trend shows more and more effective using of fossil fuels in main consumers countries.

Demand in Europe will be probably stagnating from 2018, almost by 15 million barrels per day. Development of consumption could be in case of strong winters increasing, which presents most a probable scenario. Refineries used rapid decrease of oil prices from June 2014 to improve their margin (calculated by NWE Brent range). But oil prices still present the most important part of total costs of refineries till 50% volume. Despite mentioned, costs on energy present 28% of total expenses, mainly in American refineries. The main consequence will be vulnerability of European demand, which will be less influenced by prices volatility. Meanwhile last years had recorded decrease of European capacity of refineries, the newest investments (for example in company Total at Anvers) record higher trust of the sector, mostly when speaking about earth gas [14,15].

Demand on oil products in USA should remain fixed and from 2018 there is expected growth by 1%. Margin of refineries should be still stabilized (after achievement of pick 29 USD per barrel – price determined after hurricanes, which caused offer decrease. Tax reforms in USA, orientated to decreasing of income tax for legal entities should help refineries. Except of mentioned measure of production capacities using in 2017 increased by 4 points against 2016. This trend is explained by combined effect of margin increasing, as well as oil prices Brent growth in comparing with WTI.

Present balancing of China economy should lead in following years to slowdown of its growth. Growth of GDP is expected in China economy by 6.5% in comparing with 6.7% in 2017. Due to the mentioned consumption of energy in China should be growing according IEA not so quickly – by 2.7%. There is probable that China will import less oil and improve effectiveness of oil using. India will be from 2018 probably again one of the main consumers countries with rapid demand growth (in 2018 by 6.7%).

3.2 Prediction of offer demand in the energetic industry

In spite of agreement, in which there is expected freezing of production level in OPEC countries and in Russia, from 2018 offer should increase again by 1% and it should achieve 100 million barrels per day due to the positive prices for American shale oil producers. Prediction of development for capital expenses (by 4.3% in 2018) in the energetic sector is still not sufficient, and companies of oil and gas services will have permanent problems.

According US Energy Information Administration (EIA) oil production in USA should achieve from 2018 record level 10 million barrels per day. Main producers of shale oils managed to decrease significantly its profit and to increase by this way productivity and decrease the costs. Production in USA was strengthened by increased production of wells, although it remains under levels in last years. Next positive aspect is decrease of bankruptcies in the mining sector. But companies have still limited cash flow with debt payment that is in 2018 higher than in previous year (115.8 milliard, which is by 172% higher). It could cause next bankruptcies in energetic business. Investments prospects in energetic companies will be limited due to the financial demands.

In Western Europe after 2016 there was recorded turnover in financial results of leading companies. Segment E & P make profit from higher prices Brent. Smoothly improved financial situation of the companies helped from 2018 to increase forecasts of European companies, providing oil and gas services that are depended on investments. According JPMorgan Chase & Co. in 2017 average profit of the sector increased in Europe by 9% against 6% in North America.

Production in China should remain in decrease, which started in 2016 and 2017, decreasing by 2.6% in 2018. It is caused by governmental industrial policy, preferring production of earth gas. Government is therefore trying to privatize companies in this sector gradually. In Latin America perspectives of the sector should be strengthened from 2017 due to the Brasilia returned to the growth, production in area Lula and investments in area Libra.

Due to the position of energetic industry in national economy structure we made comparing of its position with other sectors. Table 3 illustrated the comparison of industrial sectors from the view of risk evaluation.

From the comparing of industrial sectors risk there is obvious that position of Energetic industry, together with construction, is the worst almost in all analysed areas, in spite in European space there is recorded high risk, but in American space the risk is still significantly high. The energetic industry did not recorded in any area medium risk. Therefore, there is sufficient space for its decreasing [16].

Table 3 Risk comparing in the individual industrial sectors

Sector	North America	Latin America	Middle Europe	Western Europe	Asia	Middle East
Agriculture	Medium risk	High risk	Medium risk	High risk	Medium risk	High risk
Automotive industry	Medium risk	High risk	Low risk	Low risk	Medium risk	High risk
Chemical industry	Low risk	High risk	Medium risk	Medium risk	High risk	High risk
Construction	Medium risk	Very high risk	High risk	Medium risk	Very high risk	High risk
Energetic industry	Very high risk	Very high risk	High risk	High risk	High risk	High risk
ICT	Medium risk	Medium risk	Medium risk	Low risk	High risk	High risk
Pharmaceutics industry	Low risk	Medium risk	Medium risk	Medium risk	Low risk	Low risk
Retail	High risk	High risk	Medium risk	Medium risk	Medium risk	High risk
Clothing industry	High risk	High risk	Medium risk	High risk	High risk	High risk
Transport	Medium risk	High risk	Medium risk	Medium risk	Medium risk	Medium risk

Low risk
Medium risk
High risk
Very high risk

Source: own processing according COFACE, 2017, p.223

4 Conclusions

Providing of sustainable economic growth is conditioned by providing of reliable energy supply with optimal costs and proper protection of living environment. Presently European Union disposes with most open and most integrated unique market with electric energy and gas. Majority of industrial developed countries recorded during last decades of energetic market significant tasks and together with collapse of central planned economies the trend of its liberalization became global – influencing policy of transitive economies, developing countries and international agencies. High EU dependence on import of energetic commodities from unstable regions threatens energetic security of countries. Therefore, the task to the future will be to deal with this problem with great attention not only from the side of research institutions, but mostly by the narrow cooperation with practice in effort to find out solutions for optimal solving of energetic security.

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ACCUMULATION OF HIGH-POTENTIAL CHEMICAL ENERGY OF METHANE TO HYDRATES

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Keywords: hydrate, hydrate formation, energy source, accumulation, methane
Abstract: For countries with limited access to conventional hydrocarbon gases, methane hydrates appear as a possible source of energy or as a strategic concern for the creation of alternative natural gas reserves. Currently, natural gas hydrates are beginning to be included in the considerations of gas supply for the next decades. From a perspective point of view, the accumulation of natural gas in the form of hydrate structures and subsequent release, if necessary, proves to be very advantageous. Storing gas in such a form creates an energy-efficient interest in developing and innovating technology in this area.

1 Introduction

In general, a hydrate is defined as a substance containing water and hydrocarbons (or other gases) [1]. It is commonly found in the world in solid form, which accounts for about 85% of water and 15% of gas [2]. From a chemical point of view, hydrates belong to a group of compounds known as clathrates (from the Latin word *"clatratus"*, grated) [3]. The amount of hydrocarbon molecules captured depends on the shape of the crystal lattice because methane is not chemically bound but only "trapped" in the crystal lattice. To put it simply, the natural gas hydrate is a clathrate formed by water molecules, where a molecule of one of the natural gas hydrocarbons is trapped in the cavity. The hydrocarbon gas molecule is surrounded by water molecules [4].

Due to the formation and retention of hydrate structures, the gas concentration is critically dependent on a sufficient amount of water molecules surrounding them. Since they are ice-like compounds, hydrates at room temperature and pressure are unstable. The stability of hydrocarbon gas hydrates is mainly related to the structure of these substances and the interaction of several factors that interact with each other under certain physical conditions [1]. The formation of hydrates predominantly determines the presence of water and hydrocarbon gases in a concentration allowing the formation of clathrate structures (Figure 1), at the temperature and pressure at which the hydrates normally occur. It is clear from the foregoing that the occurrence of hydrates is limited to two types of geological area, namely permafrost in the polar continental shelves (Figure 2) and in sediments under the seabed [5].

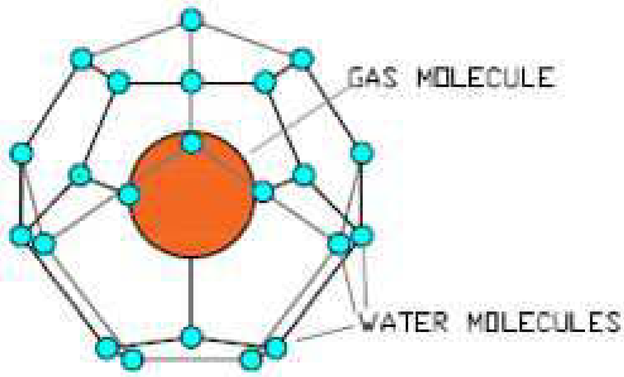

Figure 1 Typical hydrate structure with water molecules

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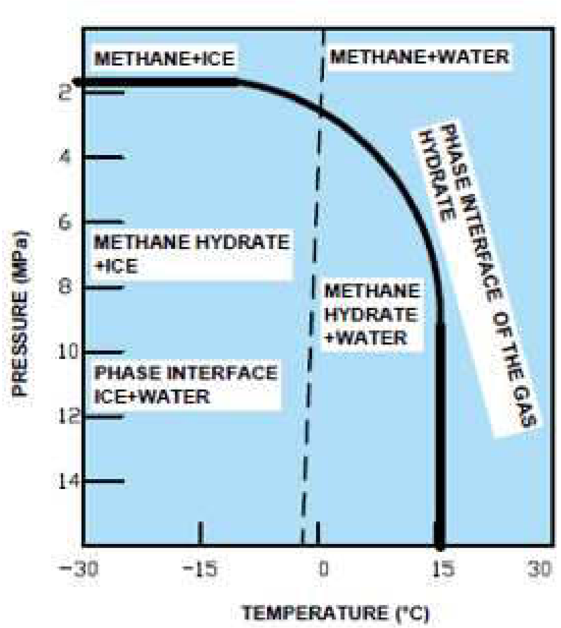

Figure 2 Phase diagram of methane hydrate formation

2 Natural gas hydrates

Natural gas is a mixture of gaseous hydrocarbons whose main component is methane. The formation of natural gas can be partly attributed to the thermal decompositions of organic matter and therefore very often occurs in deposits along with oil or coal. It can occur in various form and one of them is CNG (Compressed Natural Gas) is compressed natural gas to a pressure of about 20 MPa. The second form is LNG (Liquefied Natural Gas), is a liquefied natural gas at -162 °C. It consists predominantly of methane and higher hydrocarbons with little inert gas. However, hydrates have been considered as a potential source of energy for decades, especially for countries with limited access to conventional hydrocarbons or for the strategic interest in creating alternative natural gas reserves. From a perspective, the accumulation of standard natural gas in the form of synthetically generated hydrates appears to be very advantageous. The storage of natural gas in hydrates appears to be particularly beneficial in terms of safety. Because natural gas hydrates can be stored at higher temperatures and lower pressures compared to other storage technologies, for example liquefaction or compression [6].

Saving energy in a convenient form for safe storage and its subsequent release is a challenge in processes where energy is needed to accumulate. At present, a high emphasis is placed on the overall efficiency of these processes, in terms of energy use, energy efficiency and energy storage (Figure 3, Table 1). Hydrates have the potential to provide peak coverage in cogeneration of electricity and heat by natural gas released from hydrates [2].

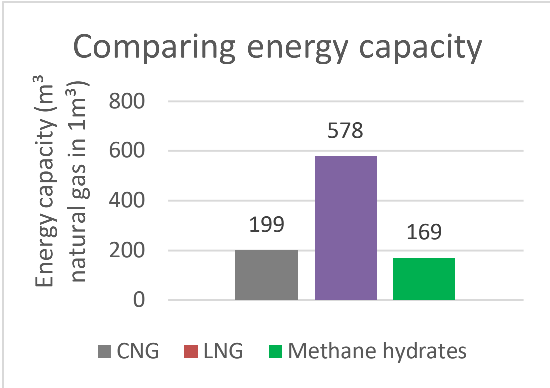

Figure 3 Comparing energy capacity

Table 1 Parameters of individual accumulation methods

	Energy capacity (m^3)	Specific energy ($MJkg^{-1}$)	Energy density (MJm^{-3})	Energy input ($kJkg^{-1}$)
CNG	**199**	**49**	**6914**	**2430**
LNG	**578**	**49**	**20093**	**908**
Methane hydrates	**169**	**7**	**5880**	**416**

3 Quantification of hydrate generation

For the calculation of hydrate formation, we can proceed with two basic methods, manual or computerized calculation method [7].

3.1 Manual calculation method

These methods are based on the equilibrium of the three phases, namely liquid water - hydrate - water vapour. When designing processes involving hydrates, it is a problem to predict the pressure and temperature conditions at which the hydrates will be formed. The advantage of manual calculation methods is e.g. a quick estimate of the hydrate formation conditions but the disadvantage is their inaccuracy. However, these methods are still popular. Manual calculation methods include e.g. gas gravity method and K-factor method.

The gas gravity method is simple, including only one graph (Figure 4) from which temperature and pressure can be read, with gas density being the third parameter. The disadvantage of this method is some inaccuracy with respect to experimental results [7].

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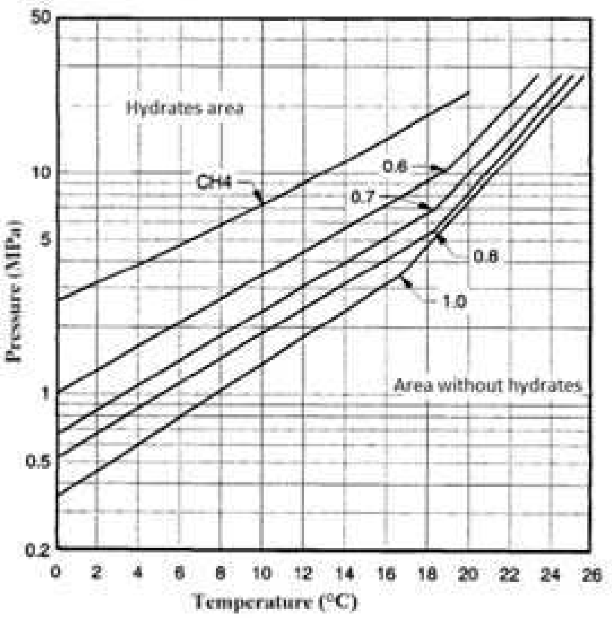

Figure 4 Occurrence of natural gas hydrates, gas gravity method

Another method is the K-factor method. The K-factor (distribution coefficient) is determined as the distribution of components between hydrate and gas:

$$K_i = \frac{y_i}{s_i} \quad (1)$$

Where y_i and S_i are molar fractions of component i in steam and in hydrate respectively. Water is not included in the calculation. Graph versions are available in SI units, for each of the components commonly found in natural gas such as methane, ethane, propane, isobutane, n-butane, hydrogen sulphide and carbon dioxide. This method is not suitable for high pressures ~ 10 MPa. For pure methane, it does not provide results at pressures above 20 MPa. It is rational to use a K- factor of up to 7 MPa and a temperature of 0 - 20 ° C. This method is less accurate for mixtures. The accuracy of this method is in the range of 10-15% [8].

Another method for predicting hydrates is named after Baellia and Witchert. The basis for this method is the gravity of the gas, but the graph (Figure 5) is much more complicated than the gas gravity method of Katz-a. The main difference is the presence of hydrogen sulphide (up to 50 mol%) and propane (up to 10%). The effect of propane comes in the form of temperature correction, which is a function of hydrogen sulphide pressure and concentration. Said method is intended for use with sour gas and is thus significantly different from the above-mentioned methods [7].

The graph was designed to predict at what temperature a hydrate is formed that contains oxygen gas of known composition at a given pressure. For application of the diagram, the content of hydrogen sulphide in the sour gas may range from 1 to 50%. While the hydrogen sulphide to carbon dioxide ratio is between 10: 1 and 1: 3. Under these conditions, according to the graph, hydrate formation can be assumed ± 1.11 ° C for 75% of cases. Baillie and Witchert claim that for a given pressure their table estimates the hydrate temperature to 1.7 °C for 90% of their tests [7].

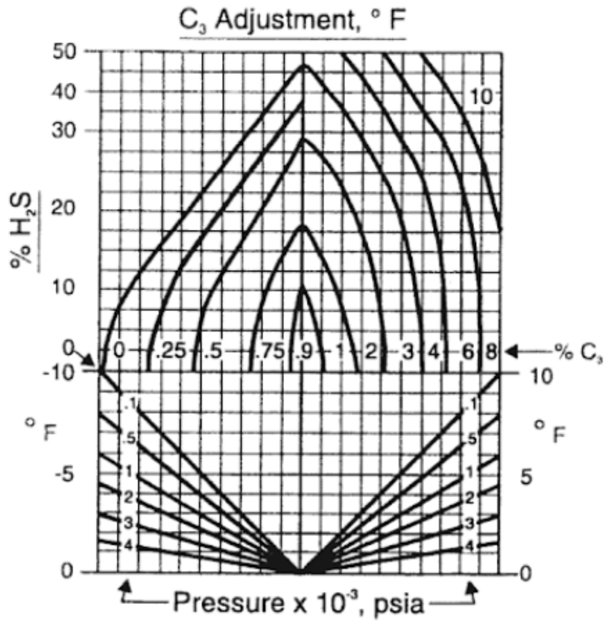

Figure 5 Baillie-Witchert chart for estimating hydrate formation conditions in SI units

3.2 *Computer calculation method*

They use complex algorithms based on phase equilibrium of chemical potentials. Phase Equilibrium, van der Waals and Platteeuw, Parrish and Prausnitz, Ng and Robinson, and there are several commercial hydrate software such as EQUI-PHASE Hydrate or CSMHYD [7].

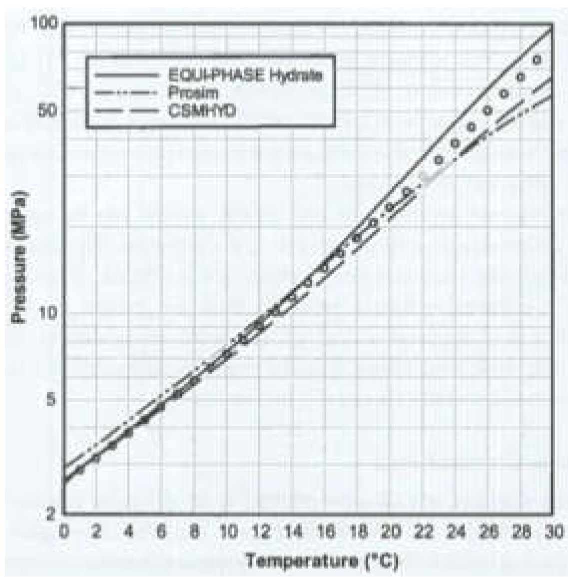

Figure 6 Hydrate Locus Loci of Methane

Figure 6 shows the hydrate locus for pure methane. Throughout the range of pressure shows on this plot, all three software packages are of acceptable error. Only at extreme pressures do the errors exceed 2 °C.

First, consider pressures below 10 MPa, which is a reasonable pressure limit for the transportation and processing of natural gas. However, it is not sufficient for the production of gas [9].

4 Design for experimental device

The design of the experimental device was based on these temperature and pressure requirements (Figure 7). Temperature 0 ° C to 20 ° C and pressure 25 MPa.

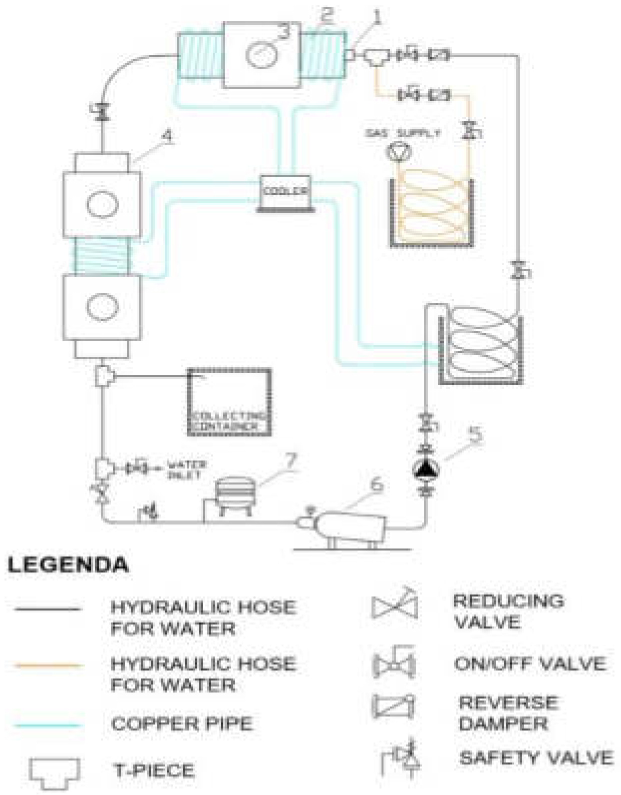

Figure 7 Schematic of experimental device

Table 2 Schematic positions on the experimental device

	Part of device	Model/type
1	Nozzle	Spray angle 51° and 155°
2	Vessel VN1	φ175/146,9 mm,
3	Sapphire visor	Normal φ 50 mm
4	Vessel VN2	Φ175/146,9 mm
5	Plunger pump	P = 4,7 kW, Q = 5,1 l.min-1,
6	Accumulator	Volume 20l, working pressure 207 bar
7	Expansion tank	Reflex-refix DT 80, working pressure 16 bar,

The experimental device forms a closed circuit of the elements listed in Table 2, which are interconnected by hydraulic hoses. Before commissioning the system, it is necessary to fill the system with water through the water supply. The circulation of water in a closed circuit will provide a plunger pump that will suck and compress the water to the desired pressure of 25 MPa. The water after cooling will be cooled by the cooling device and then under the required pressure of 25 MPa it will flow through the hydraulic hose, through the non-return valve towards the nozzle. The device consists of two high-pressure circuits. In the first circuit, as mentioned, the working medium is water. The second circuit is a natural gas compressor, which compresses the gas to a desired pressure of 25 MPa.

The compressed gas is then cooled to the desired temperature and will pass through the hose through the non-return valve towards the nozzle where it is mixed with the pressurized water. The resulting mixture flows into the nozzle where it is atomized into small particles. Subsequently, various forms of hydrate will be formed. The water and natural gas mixture will initially flow from the vessel through the pipe to the high pressure vessel after filling. After filling the high pressure vessels with the gas and water mixture to the visible area, the shut-off valve is closed. From that moment on, the seeds of the hydrate will be formed and the time after the formation of the hydrate will be measured. Through the sapphire visors placed on the outer casing of the container, it will be observed how the natural gas hydrates occur.

5 Conclusion

The article presents a schematic of experimental equipment that is primarily intended for the continuous generation of natural gas hydrates. The design and principle of the device function are based on the knowledge of typical mechanisms of methane hydrate formation. Methane hydrates are formed in places where methane and water are found at temperatures and pressures that are favourable to hydrate formation. These conditions are most commonly found in marine sediments and arctic permafrost. Further research could proceed, for example, by rapidly and continuously producing methane hydrates in an economically efficient manner. Methane hydrates have the potential and therefore this issue would deserve increased attention and the necessary development of technology in this area.

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