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Catalytic Pyrolysis of Biomass – an Effective Method for the Fuels Obtaining

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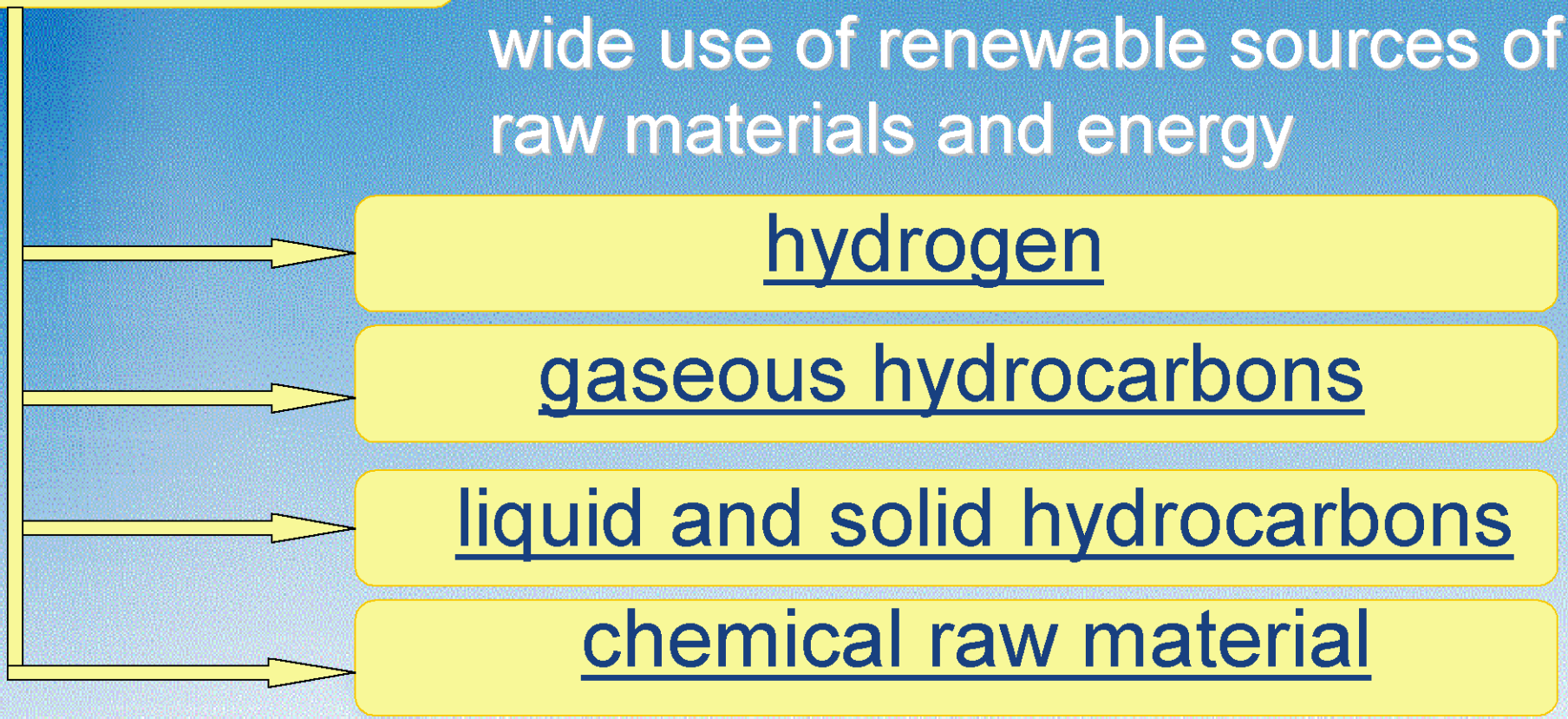
Location of Tver Technical University

Location of Abo Akademi

Biomass

One of the most important problems of modern world is the wide use of renewable sources of raw materials and energy



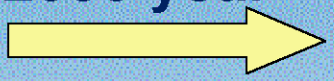
Biomass is a natural renewable, which can be used for the obtaining of hydrogen, gaseous, liquid and solid hydrocarbons and chemical raw material.

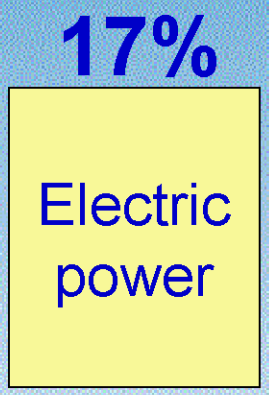
The experts forecasts

According to the experts forecasts the humanity will be able

Biomass

2050 year

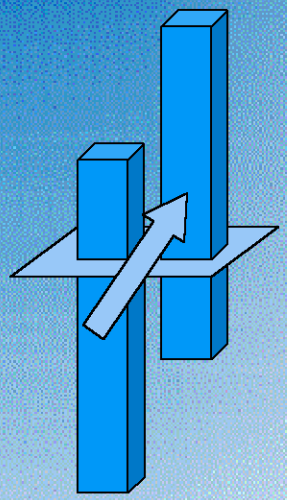




The estimation of the world biomass energy potential allows us to propose that biomass should be considered one of the main renewable energy sources of the nearest future. According to the experts forecasts the humanity will be able to obtain up to 38% of the fuel consumed and up to 17% of electric power from biomass by 2050. Besides the successful biomass treatment connects with solution of the number of social and environmental problems.

Demirbas A. Biomass resources for energy and chemical industry. Energu Edu Sci Technol 2000; 5, 21 – 45.
Heermann, C., F. J. Schwager, et al. Pyrolysis & Gasification of Waste: A worldwide technology and business review, Juniper Consultancy Services LTD. 2001.

Energy obtaining from renewable organic raw material



The use of catalytic technologies in the fuels production

- allows intensifying low-grade natural raw material fining and ennoblement
- results in the depreciation and the increase of fuel ecological value.

These technologies

Processing of organic raw material

- Peat
- Organic waste

Most processes for energy obtaining including

- Gasification stage
- Pyrolysis

Biomass Processing can be

Complex

- Gasification
- Pyrolysis

Commercially valuable

Simple

- Combustion
- Soil improvement

Gasification is the process of material thermal treatment in fixed bed, fluidized bed reactors with oxygen, steam or there combination blowing. Gasification with air blowing allows formation of gases mixture characterized by heat of combustion from 3 to 6 MJ/m^3 depends on type of raw material and process conditions.

Pyrolysis is high temperature organic materials decomposition without air access. The target product of pyrolysis – gas, enriched with small chain hydrocarbons. Pyrolysis processing allows formation of gas mixture characterized by heat of combustion from 20 to 30 MJ/m^3.

Pyrolysis is one of the best method for biomass conversion

The products of Pyrolysis

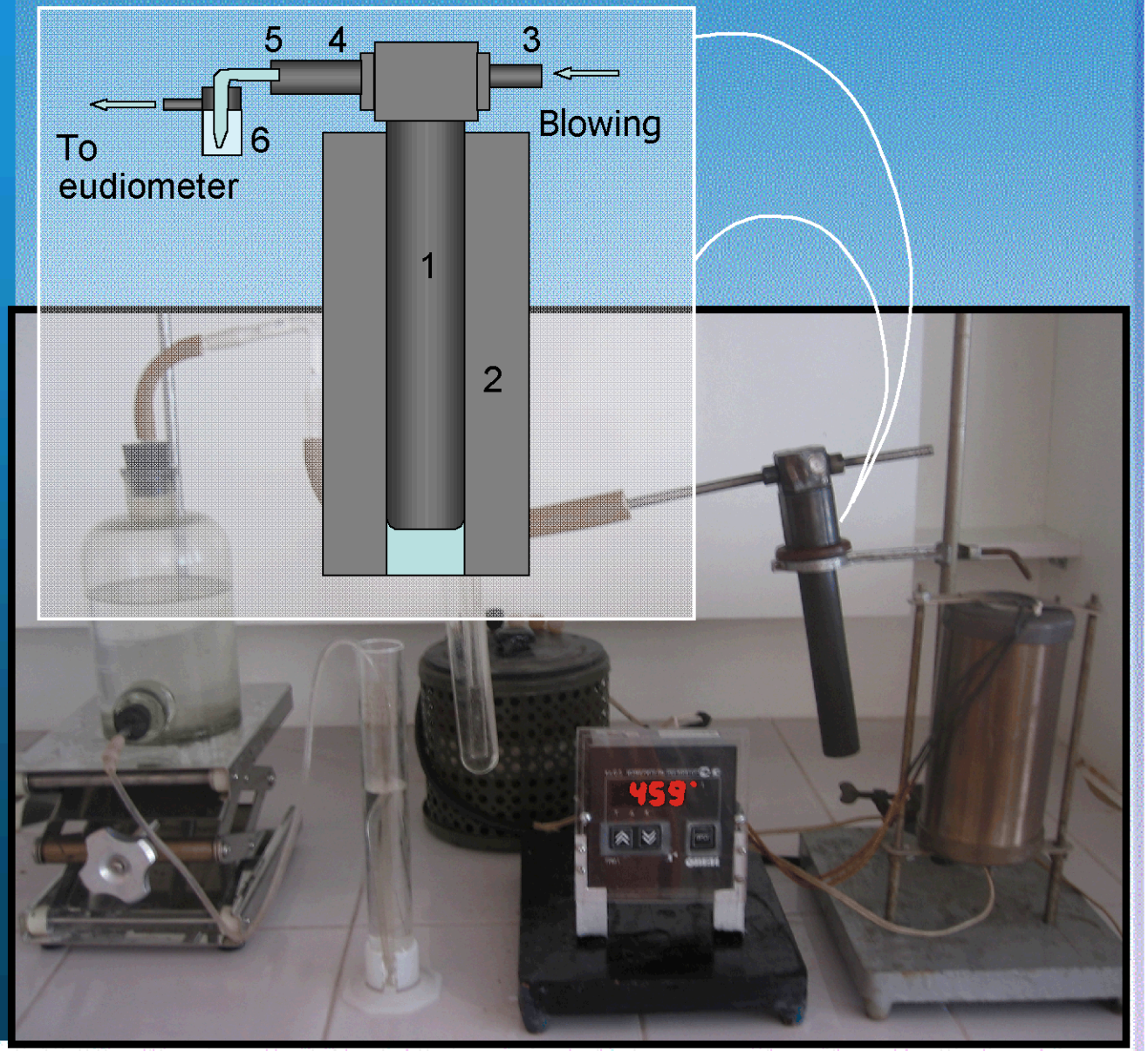
- gas
- Oil (liquid)
- solids

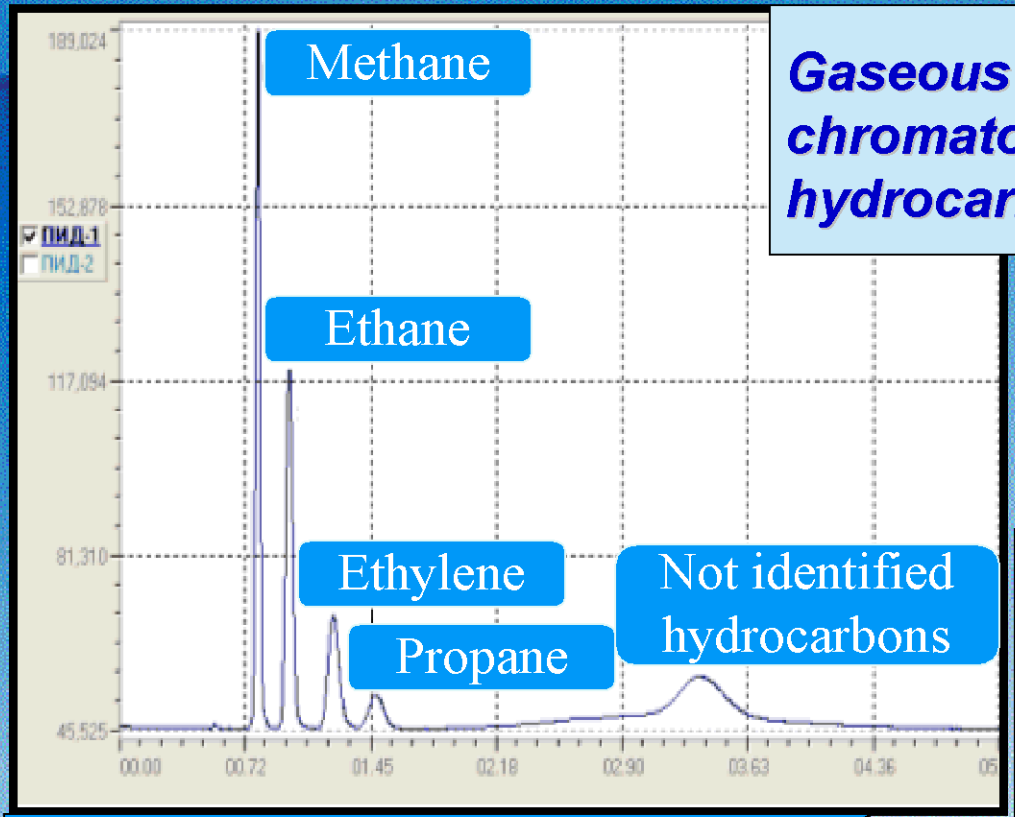
The target of this work is the obtaining of gaseous fuel with characteristics very close to methane. The main characteristic of gaseous fuel is specific volume heat of combustion.

Methane specific volume heat of combustion is 34 MJ/m^3.

Laboratorial setup for pyrolysis of solid biomass

The experimental tube reactor consists of a steel reactor 1 (it's volume is 20 ml) and a heater 2. The temperature of a heater is set by a laboratory system of temperature control and can be varied from 350 to 700°C. The reactor has fitting 3 for inert gas inlet and fitting 4 for gas outlet, which is connected to auto sampler 5 supplied with hydraulic lock 6 to prevent the mixing of the gas obtained during pyrolysis. The gas goes into the eudiometer serving for the gas amount measuring.



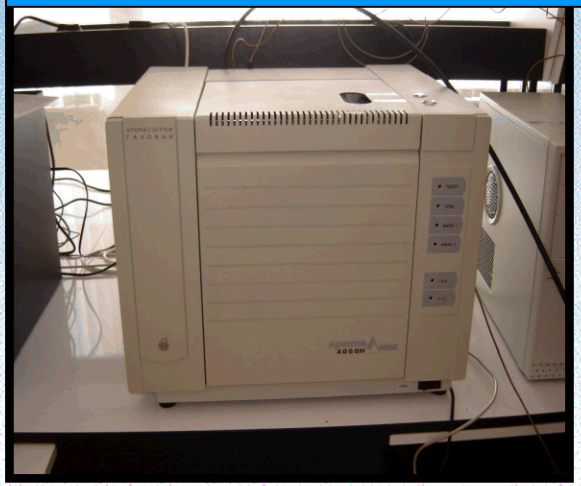


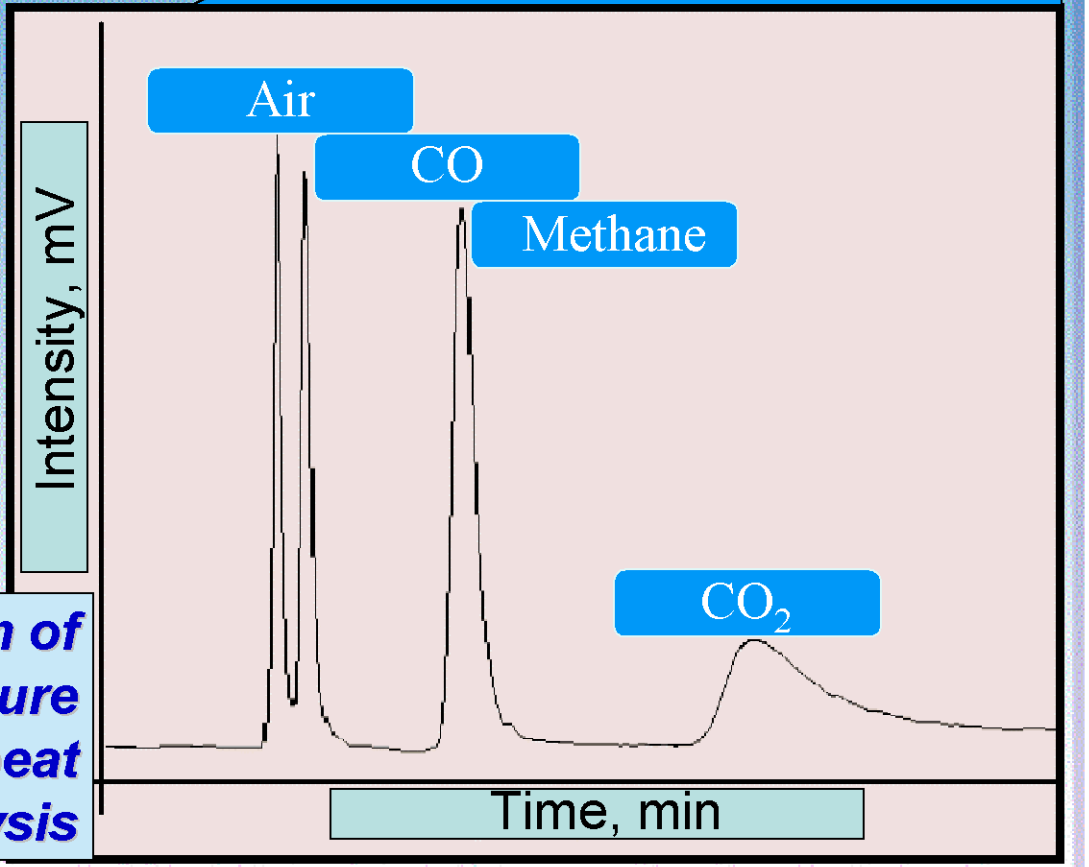
Gaseous mixture chromatogram, hydrocarbons analysis

Analytical complex

Gasochrom 2000

Kristallucs 4000M





Chromatogram of gaseous mixture from peat pyrolysis

Characteristics of cotton grass sphagnous peat

Decomposition rate	30%
Ash level	5%

Peat characteristics, %

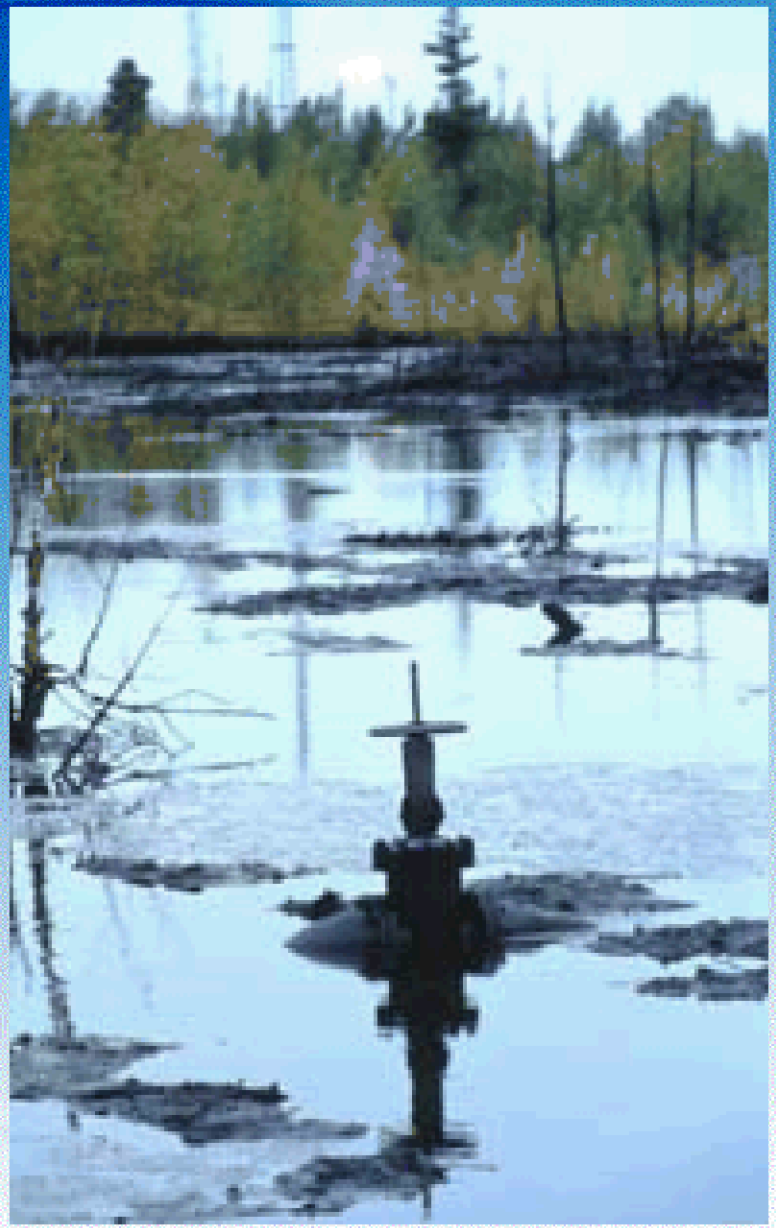
Water soluble	4.0
Easy hydrolyzing compounds	30.4
Lignin	6.8
Bitumen	8.5
Cellulose	6.7
Humic acids	26.0
Fulvic acids	17.1

Elemental analysis, %

C	H	N	O
53.61	5.96	0.79	40.79

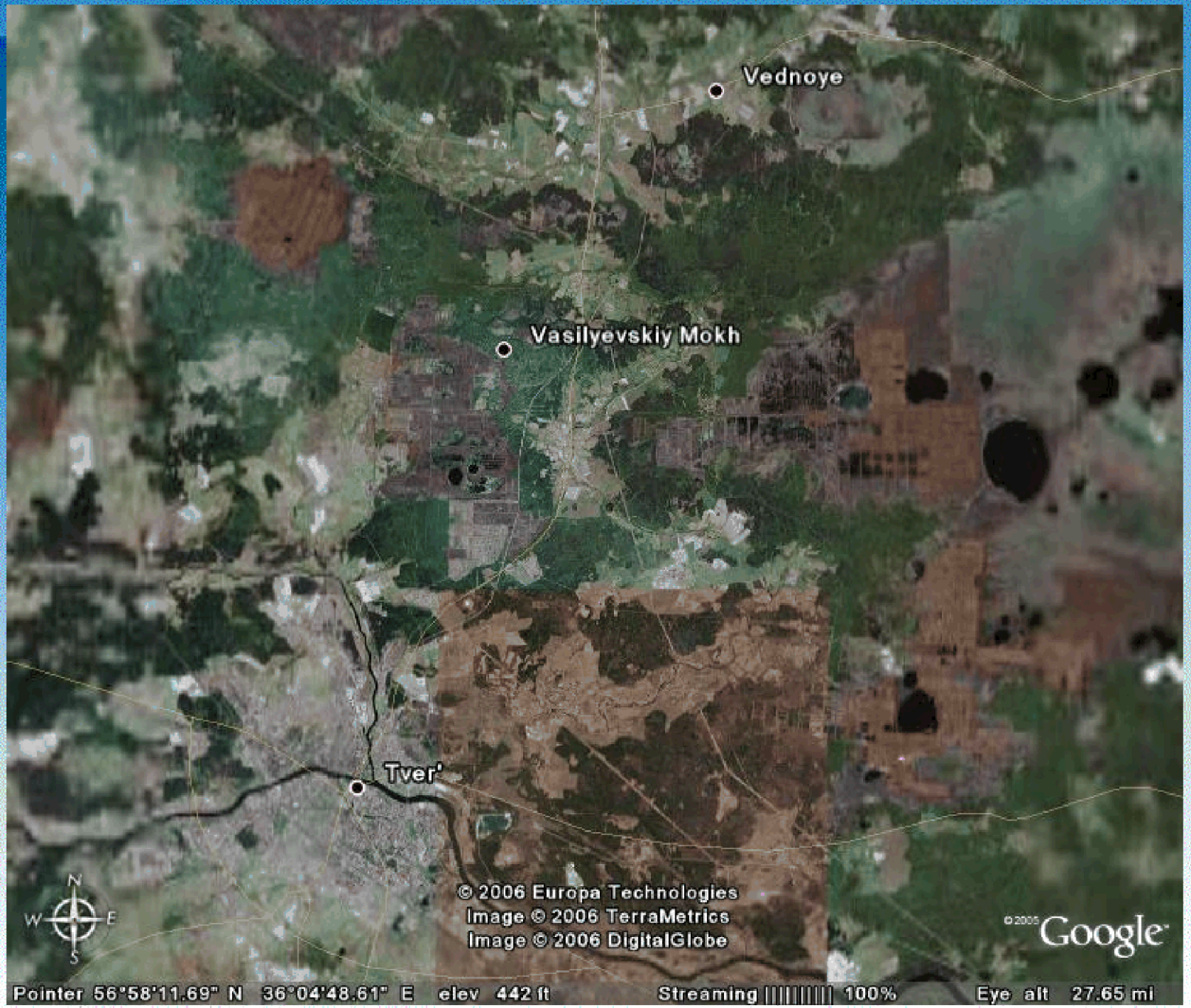
Approximate formula

$C_{44}H_{60}O_{25}$



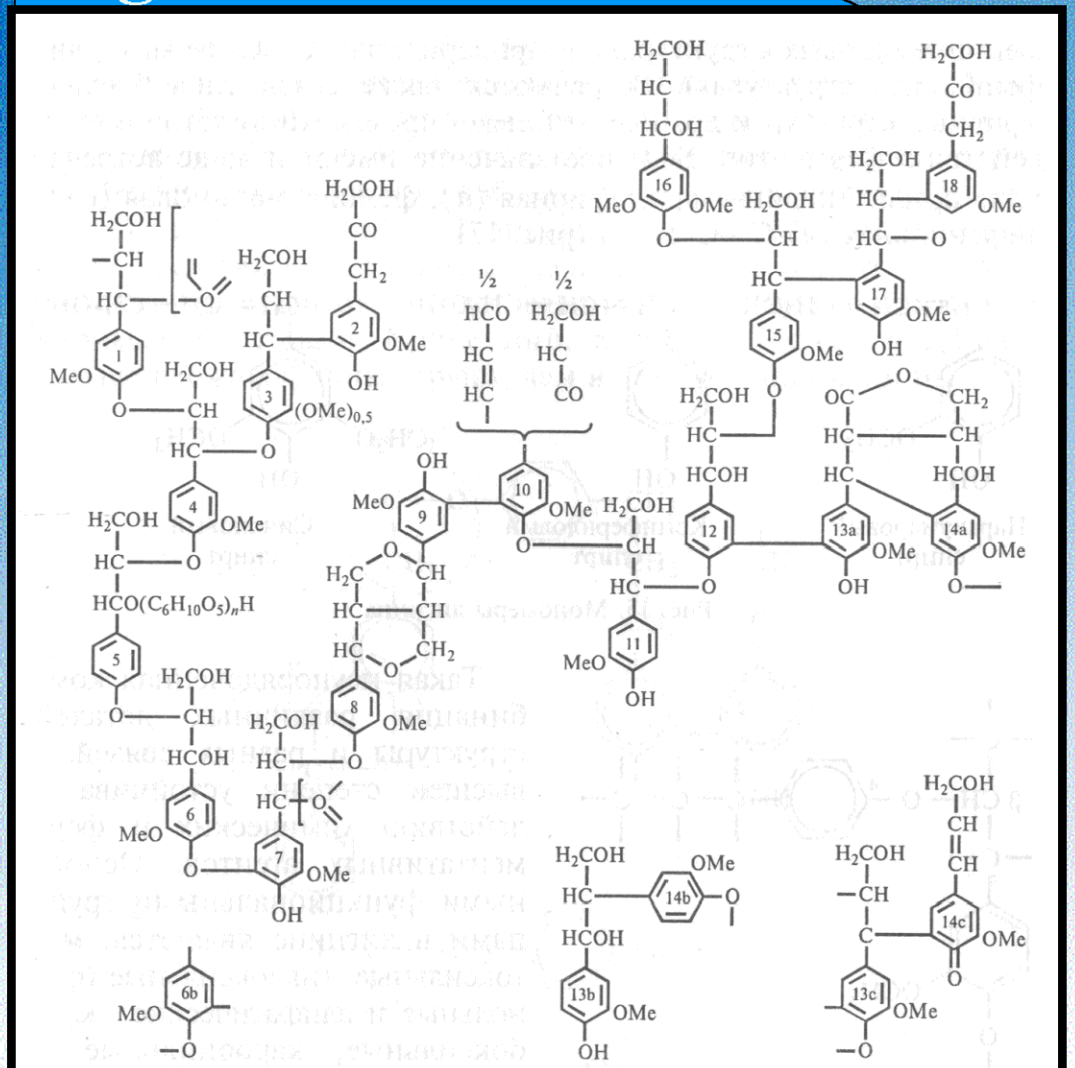
PEAT PYROLYSIS

Peat is a biofuel. Peatbogs occupy 4 mln. sq. km., 14% of which belong to Russia. This unique natural resource is a partially renewable energy source. Annual growth of the peat deposits is about 60 mln. tons.

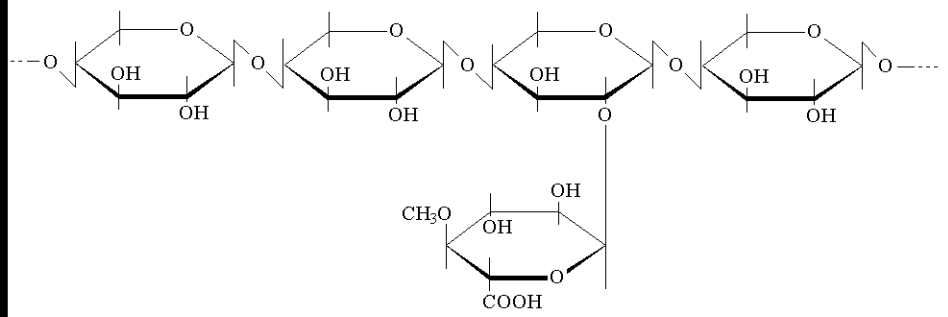

Vednoye
Vasilyevskiy Mokh
Tver'
© 2006 Europa Technologies
Image © 2006 TerraMetrics
Image © 2006 DigitalGlobe
©2005 Google
Pointer 56°58'11.69" N 36°04'48.61" E elev 442 ft
Streaming 100%
Eye alt 27.65 mi

The main pyrolysis compounds of peat

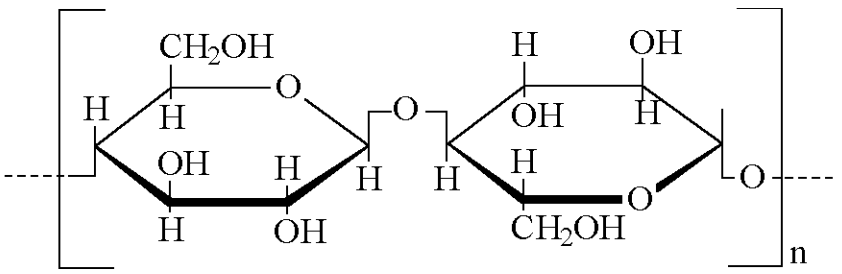
Lignin



Hemicellulose



Cellulose

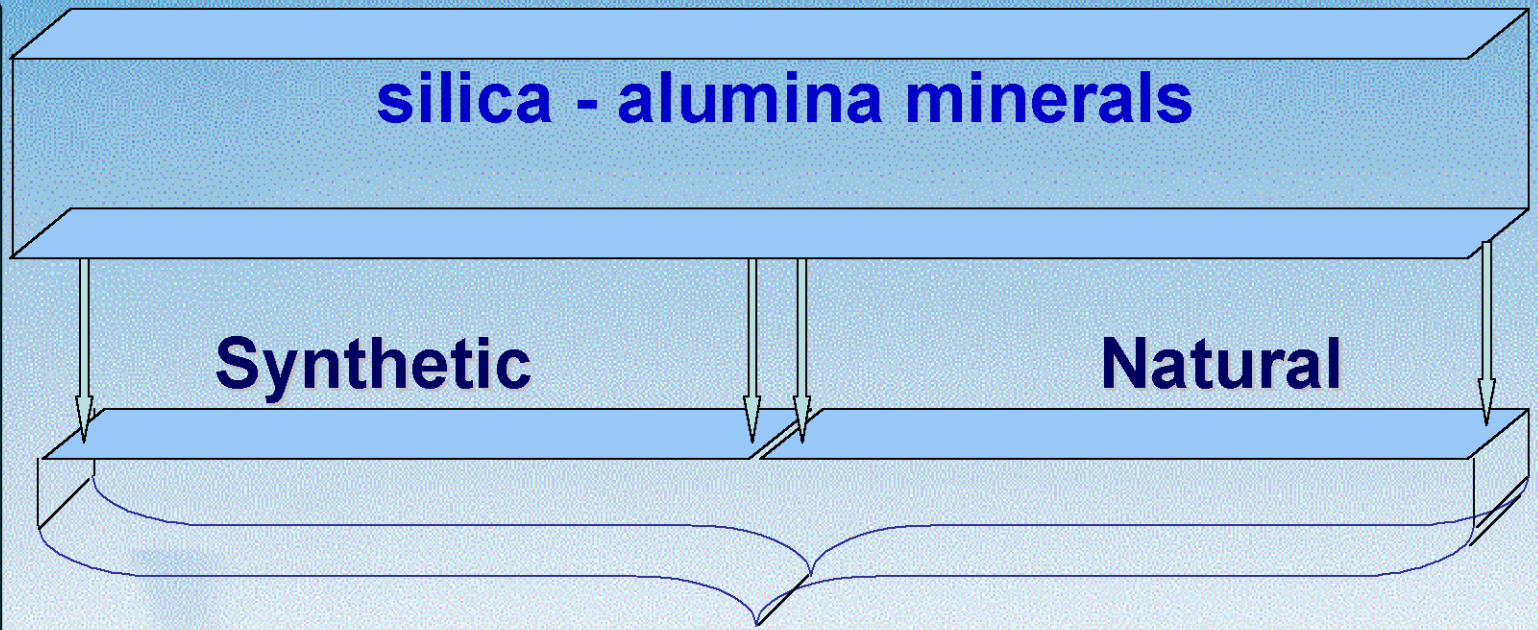


Processes taking place during peat thermal decomposition

- Cracking is decomposition of -C-C- bonds of organic compounds
- Depolymerization of organic materials
- Thermal dissociation of acid and base complexes
- Dehydration and saponification
- Water addition

Catalysts for peat pyrolysis

As the catalysts of the process of peat pyrolysis we used:



Alumosilicates materials and experiment conditions

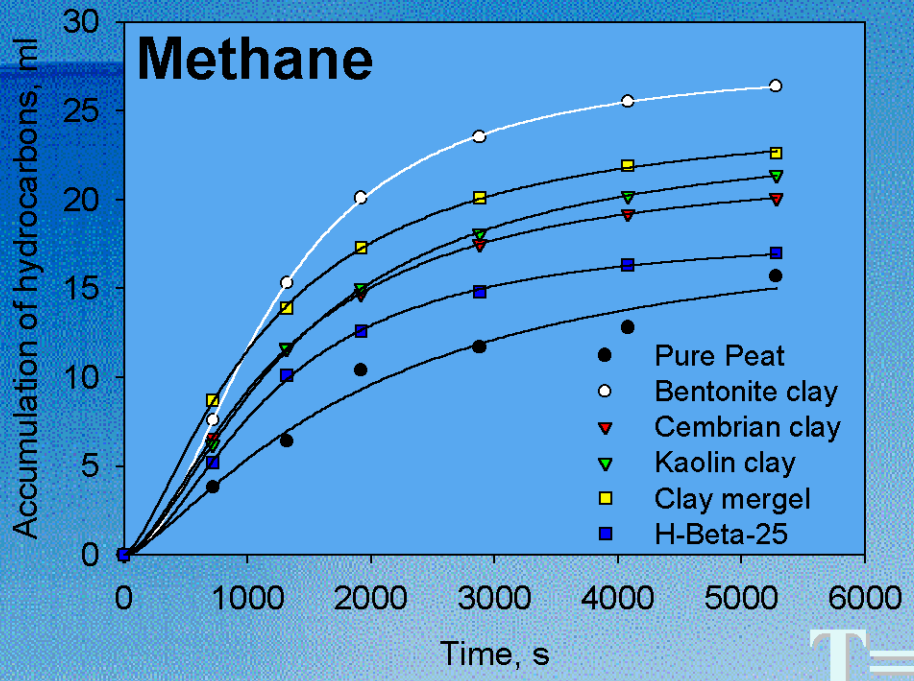
Clays: Bentonite, cambrian, kaolin, mergel

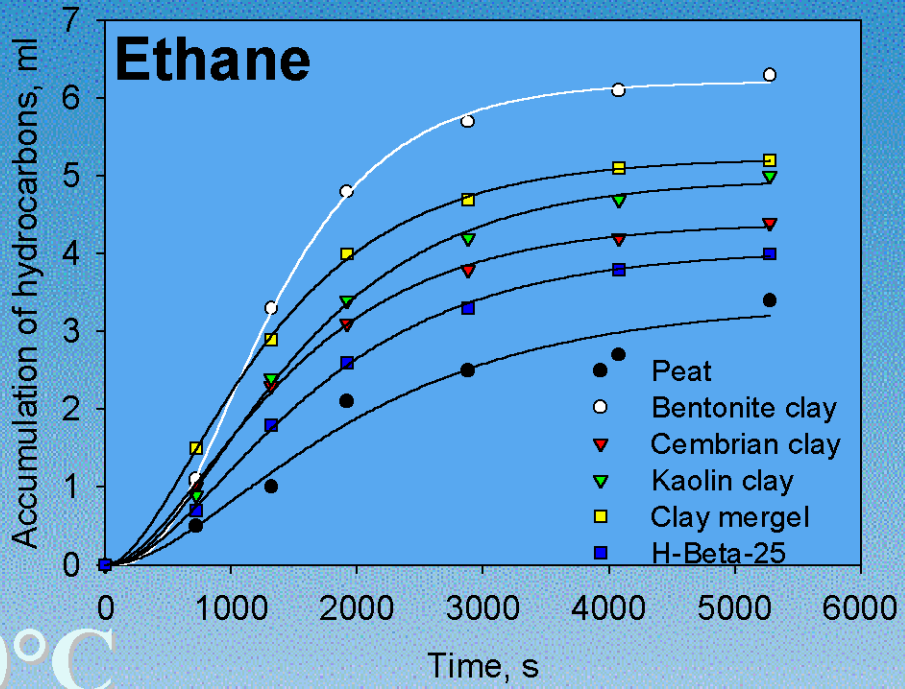
Zeolites: H-Beta-25, H-Mord-20, Fe-H-Y-12-IE, Fe-H-Beta–25-IE, Fe-H-ZSM-5-IE, Fe-H-Mord-20-IE, Fe-H-Beta-150-IE.

Substrate	Sphagnum peat
Substrate mean diameter	0.125-1 mm
Substrate mass	2 g
Alumosilicates concentrations, wt %	2…40%
Temperature	410…650°C

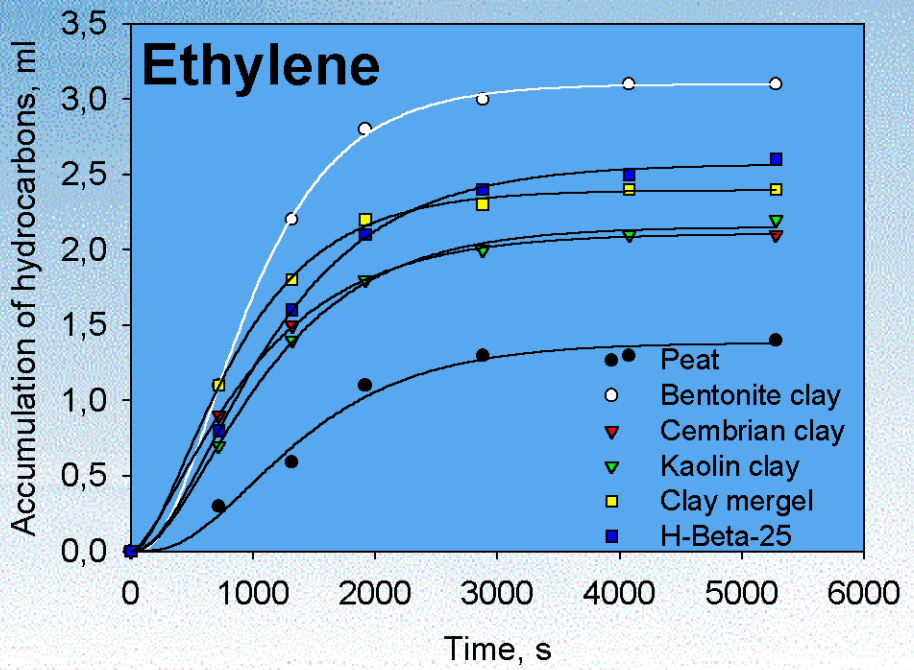
For investigation of optimal conditions for peat pyrolysis the following parameters were varied

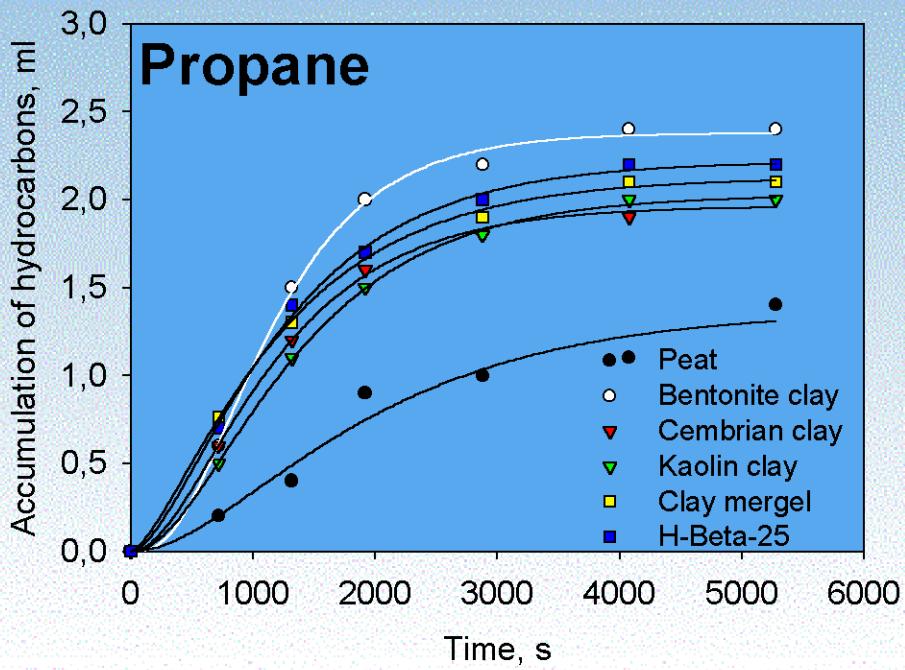
- Alumosilicates type;
- Concentration of alumosilicates;
- Temperature;
- Humidity.


Methane
Accumulation of hydrocarbons, ml
Time, s
Pure Peat
Bentonite clay
Cembrian clay
Kaolin clay
Clay mergel
H-Beta-25


Ethane
Accumulation of hydrocarbons, ml
Time, s
Peat
Bentonite clay
Cembrian clay
Kaolin clay
Clay mergel
H-Beta-25

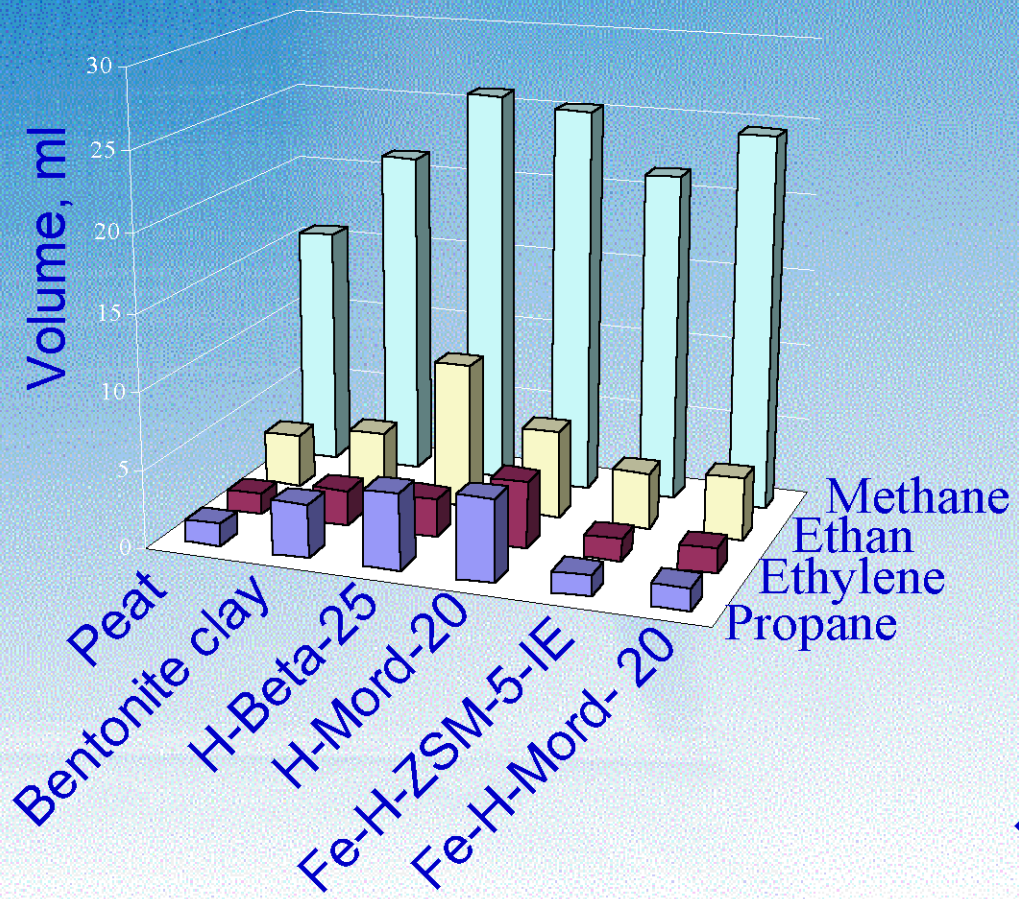
T=460°C

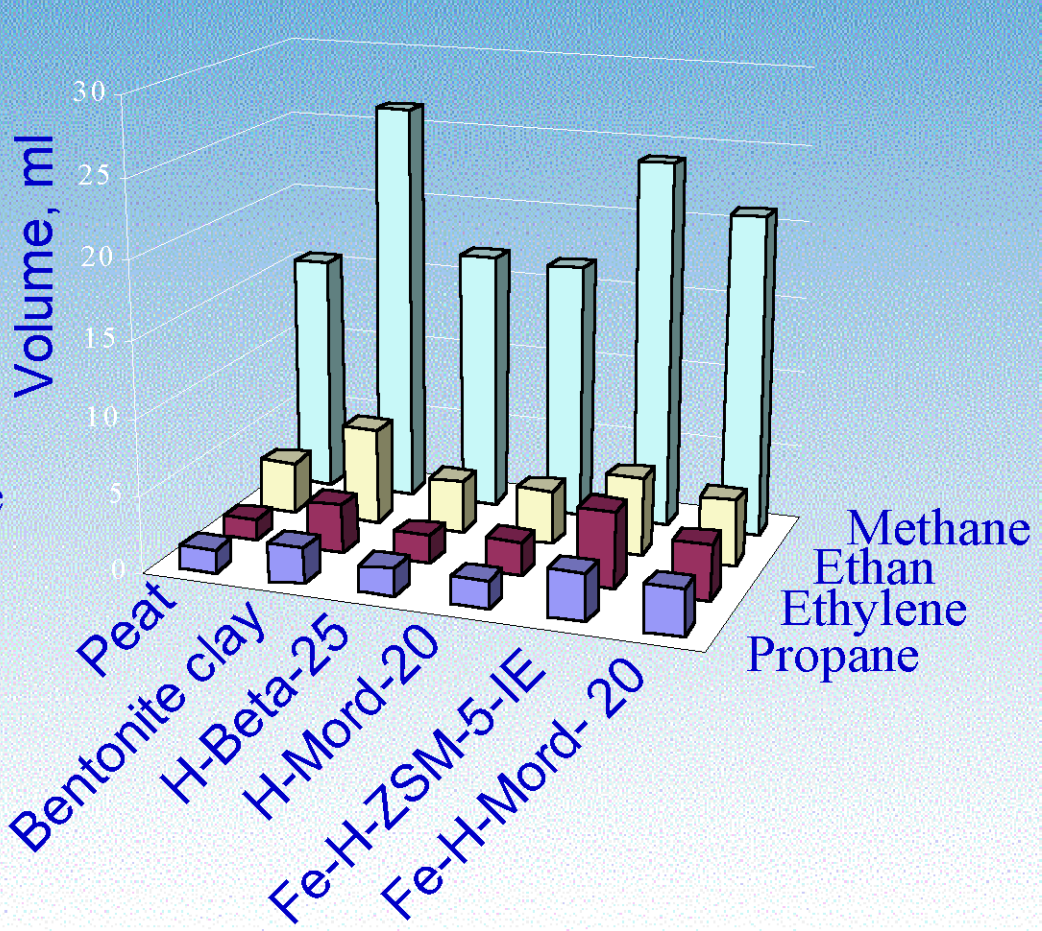

Ethylene
Accumulation of hydrocarbons, ml
Time, s
Peat
Bentonite clay
Cembrian clay
Kaolin clay
Clay mergel
H-Beta-25


Propane
Accumulation of hydrocarbons, ml
Time, s
Peat
Bentonite clay
Cembrian clay
Kaolin clay
Clay mergel
H-Beta-25

Hydrocarbons volume in gaseous phase for different alumosilicates types

T=460°C





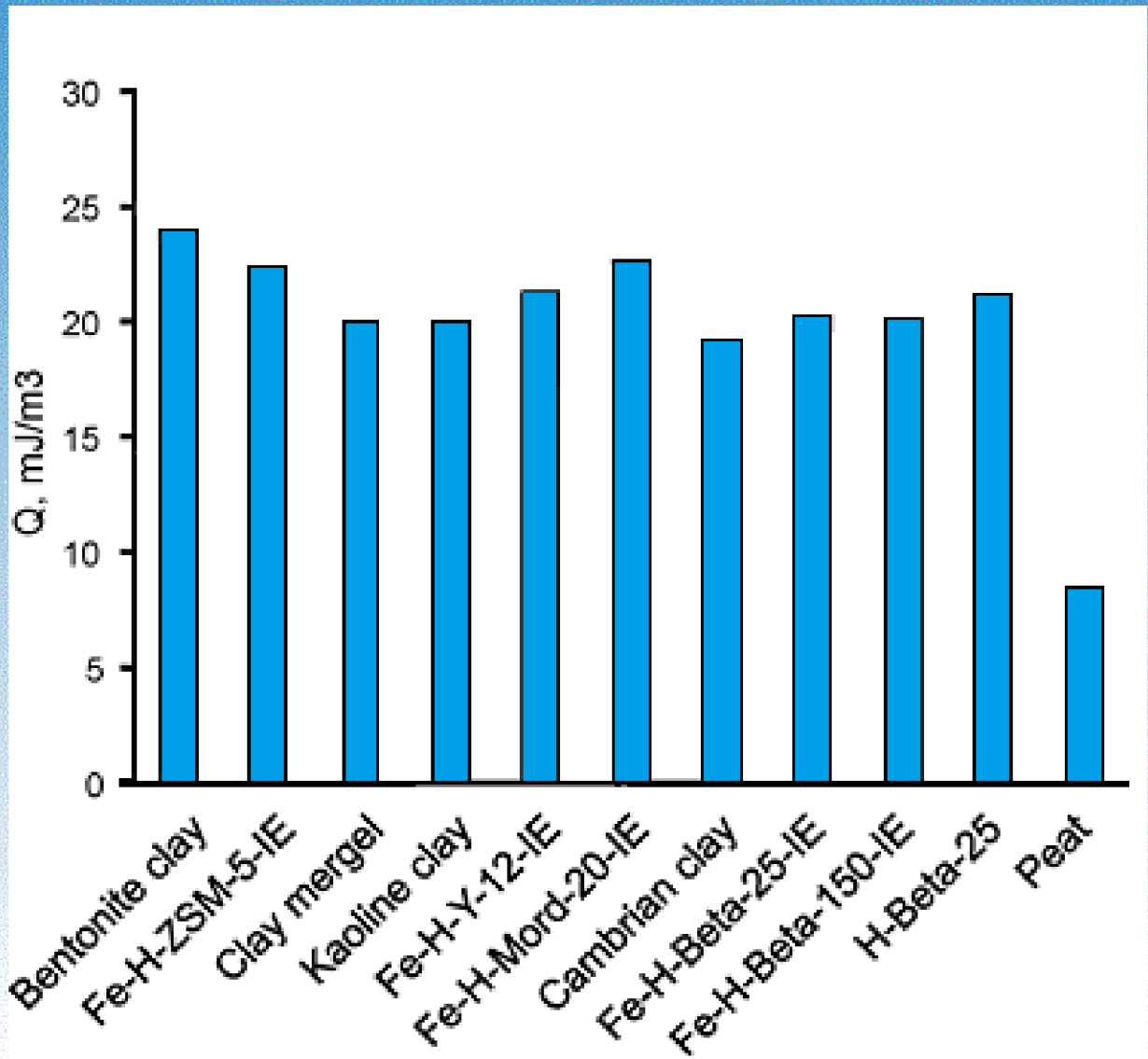
The heat of combustion of the gaseous mixture obtained during the peat pyrolysis

T = 460°C

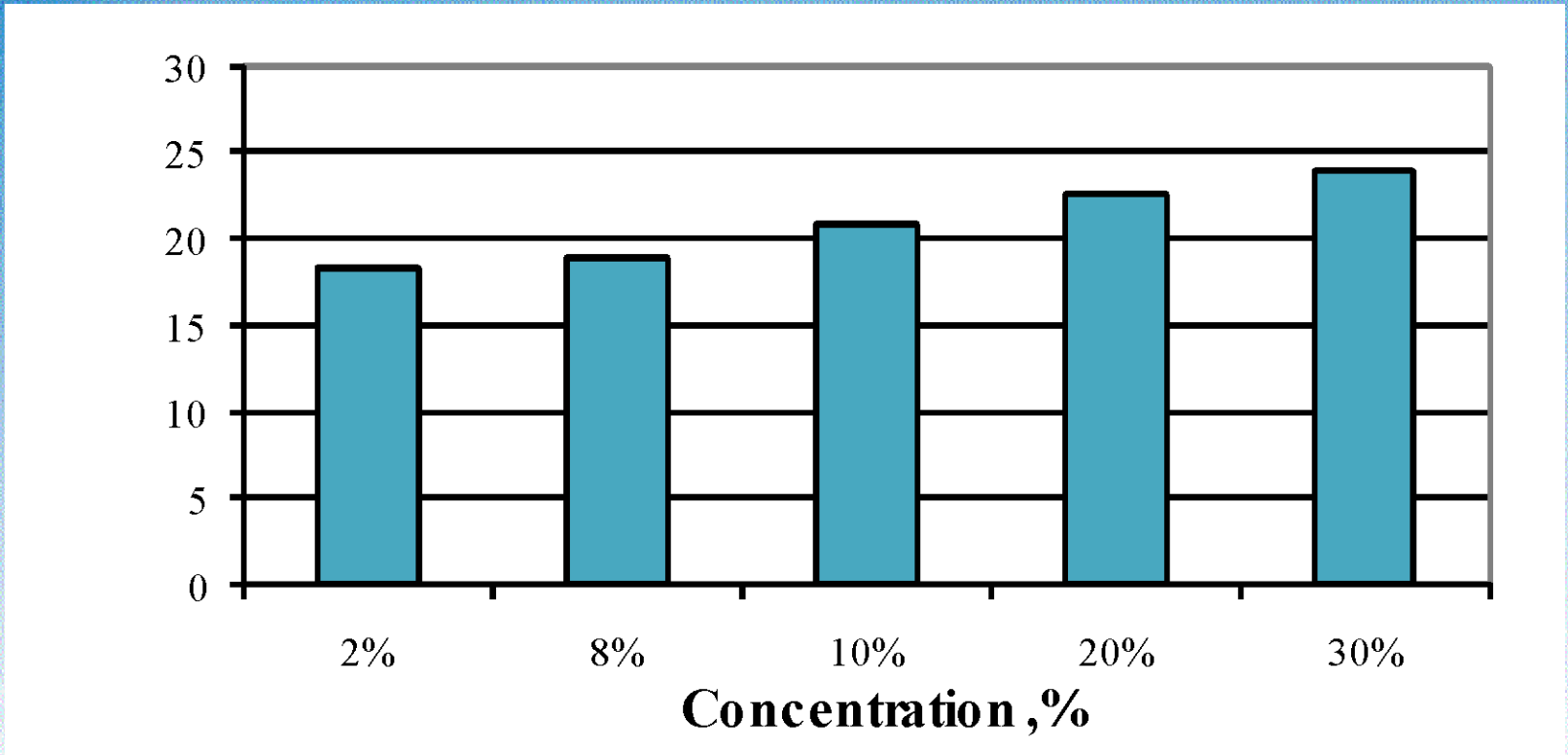
Alumosilicates concentration, wt %

clays 30%

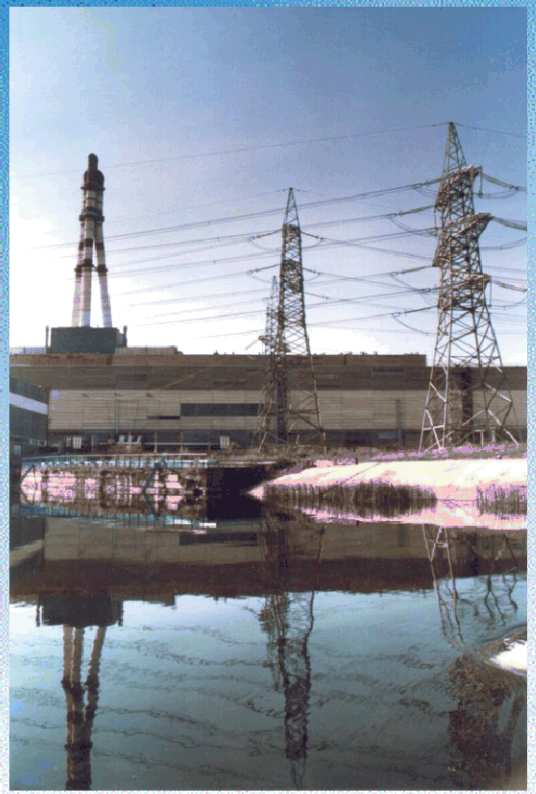
zeolites 2%

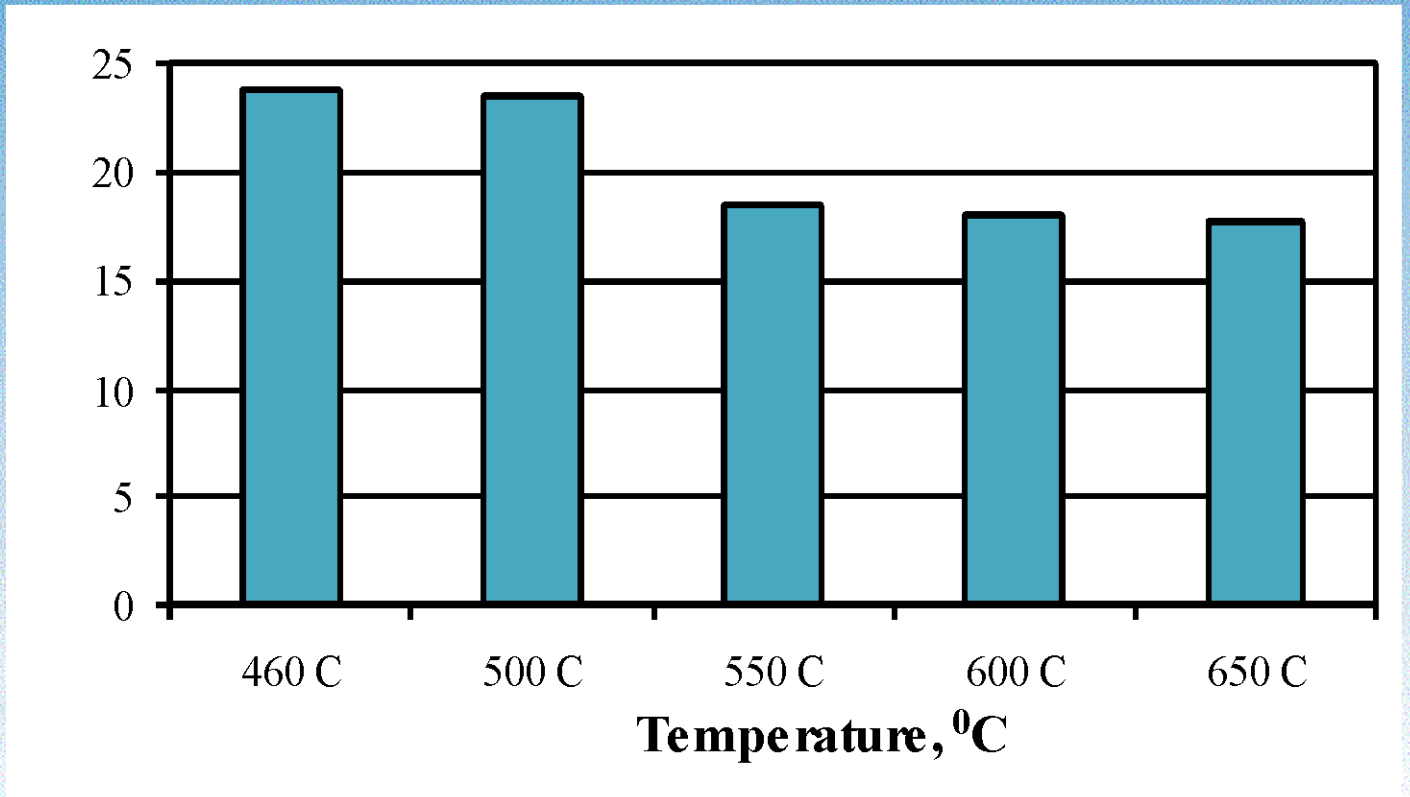


The influence of the bentonite clay concentration on the heat of combustion of the gaseous mixture



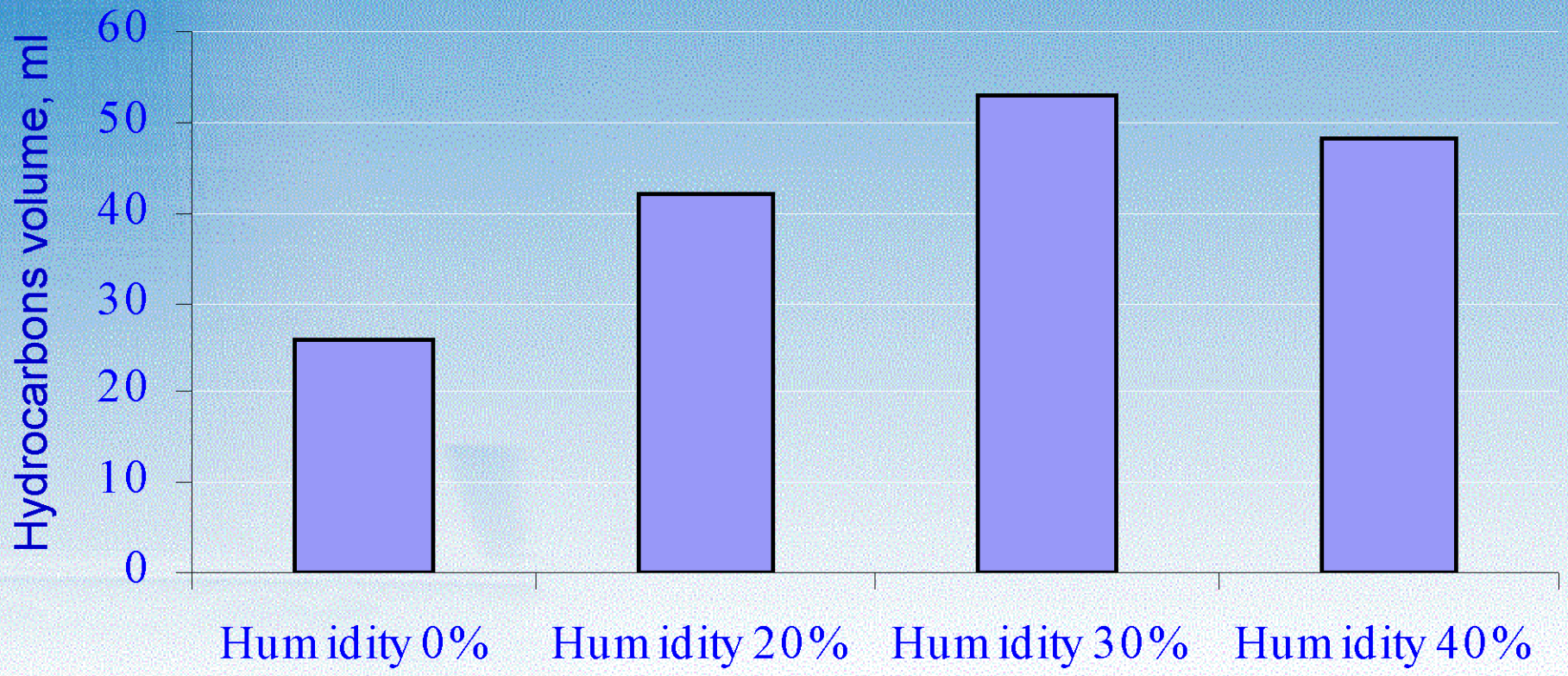
The influence of the temperature on the heat of combustion of the gaseous mixture in the presence of 30 wt.% of bentonite clay





Influence of substrate humidity

Gaseous mixture volume depending on the peat humidity for bentonite clay



The influence of mixture composition on the heat of combustion of pyrolysis gases

Component of the substrate	Heat of combustion at 2% of catalyst loading, MJ/m³	Heat of combustion at 30% of catalyst loading, MJ/m³
Bentonite clay	16.27	23.88
Cembrian clay	14.65	19.15
Caoline clay	10.66	19.93
Clay mergel	10.70	19.94
H-Beta-25	20.74	18.29
H-Mord	20.76	18.10
Peat without any additives	8.52	

Values of activation energies for the process of peat pyrolysis

Gas	E_a, kJ/mol		k_0	
	Not catalytic process	Catalytic process	Not catalytic process	Catalytic process
Methane	85	38	$1 \cdot 10^2$	$7 \cdot 10^6$
Ethane	68	37	$6 \cdot 10^4$	$2 \cdot 10^9$
Ethylene	51	38	$9 \cdot 10^1$	$5 \cdot 10^4$
Propane	41	22	$3 \cdot 10^3$	$9 \cdot 10^8$

Conclusions

- The use of catalyst allows decreasing the temperature of peat pyrolysis from 700^{0}C to 460…480^{0}C, decreasing the activation energy almost twice and increasing the rate of pyrolysis.
- The best results were revealed for bentonite clay at 460°C at concentration of 30%(wt.).
- The use of bentonite and blue clay as the catalysts of the peat pyrolysislt was revealed to result in increase of hydrocarbons yield by 2,1 and 2,5 times accordingly.
- The experimental data allows coming to the conclusion of the availability of bentonite clay use as the catalytic system in the processes of peat pyrolysis for the industrial production of combustible gases as an alternative source of energy.

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Thank you very
much for your
kind attention!