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Interreg South Baltic
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Oxygen enriched combustion: Experimental part

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Lithuanian Energy Institute

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Actual problem

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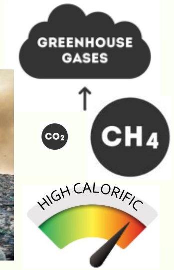

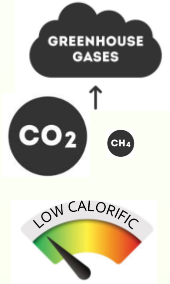

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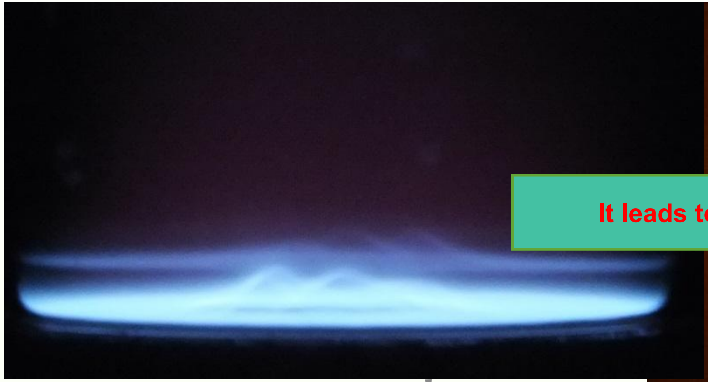
Reason of oxygen-enrichment need for clean combustion



It leads to

Advantages:

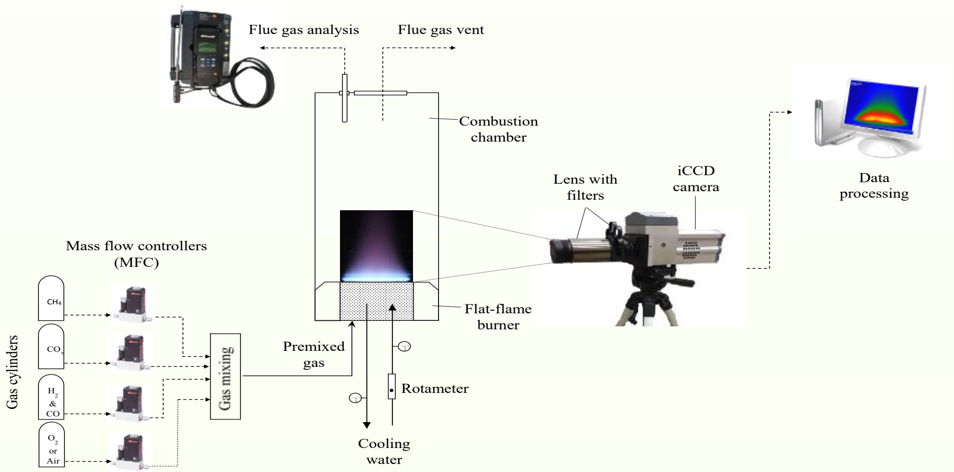
- Reduced CO2 emissions
- Increased share of renewable energy
- Lower NOx compared to natural gas combustion

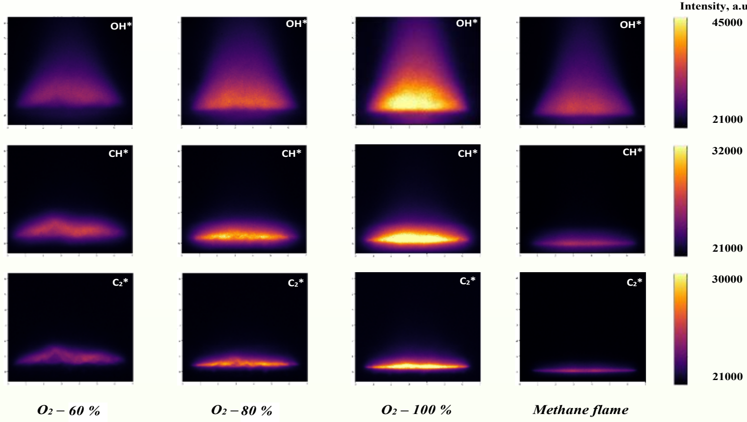
Disadvantages:

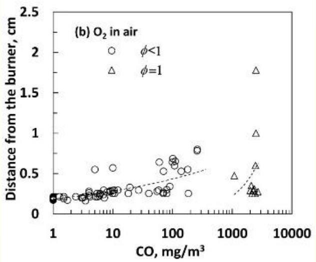
- The flame instability or extinction
- Thermo-acoustic waves causing vibrations or sudden pressure variations in the combustion system
- Reduced the combustion efficiency and equipment longevity.

Experiments in a small scale setup:
Oxygen enriched combustion of waste biogas

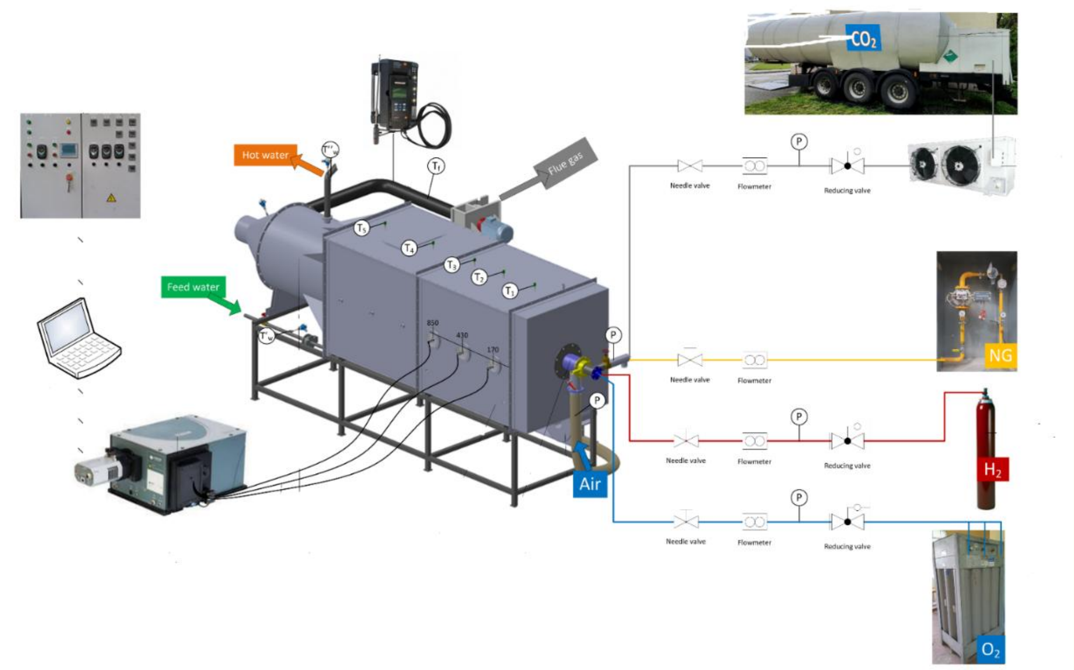
Combustion parameters	
CH_4 in CO_2	30, 25, **20**, 15 vol%
O_2 in N_2	21, 40, 60, 80, 100 vol%
Fuel to air ratio	**1.0**, 0.91, 0.83, 0.77, 0.71, 0.67, 0.63

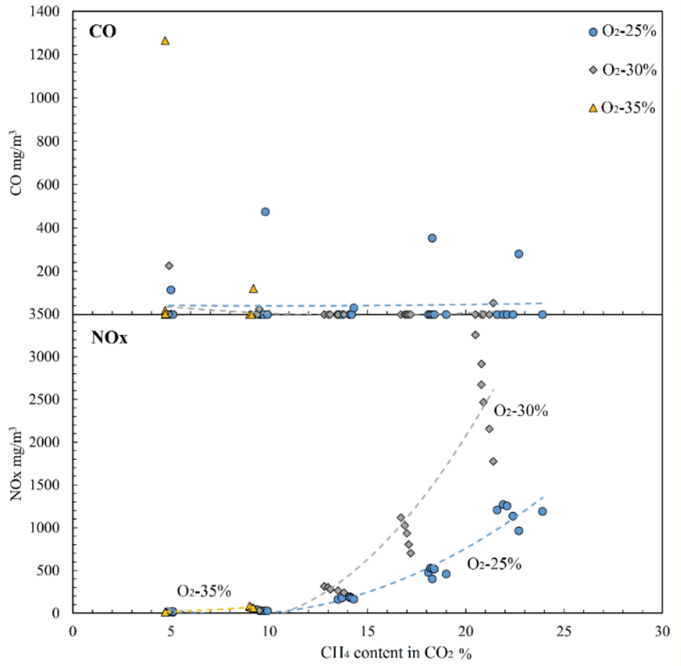




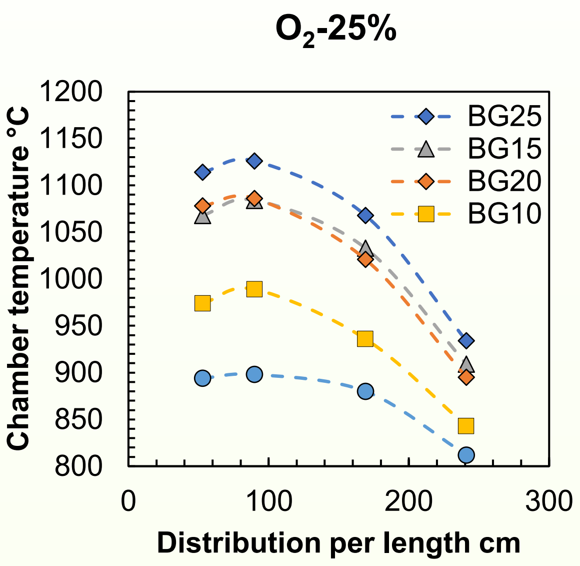


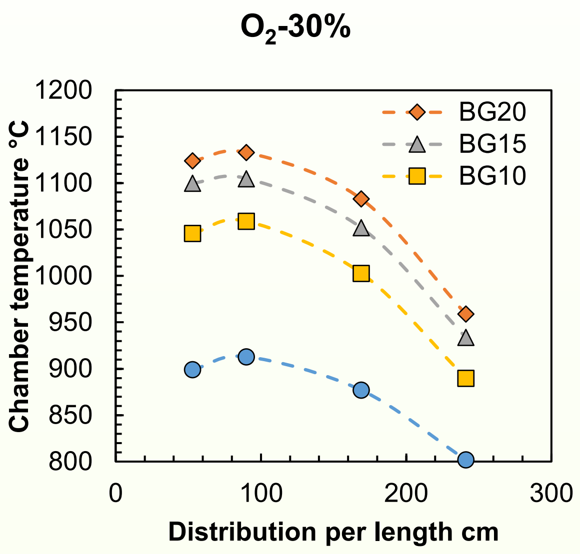
Experiments in 200kWth combustion system: Emissions

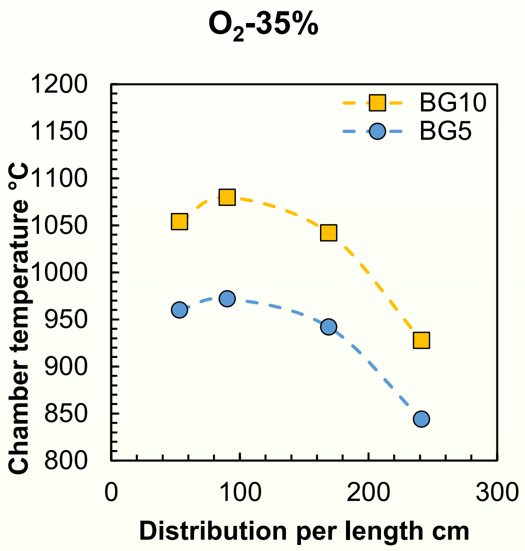




Experiments in 200kWth combustion system: Temperatures







Oxygen enriched combustion in SI engine for clean energy production

Basic technical data

Electrical output	30 kW
Heat output nominal/max.1)	59,0/59,0 kW
Voltage	400 V
Frequency	50 Hz
electrical efficiency	30,9 %
heat efficiency nominal/max.1)	60,8/60,8 %
total efficiency nominal/max. 1)	91,7/91,7 %
fuel input	97,1 kW
secondary circuit temperature inlet/outlet	65/85 °C
low heat value	23,3 MJ/m3
min. methane content	50 %

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Lab-scale site preparation

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CHP plant installation

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Oxygen enriched combustion:
Mathematical models

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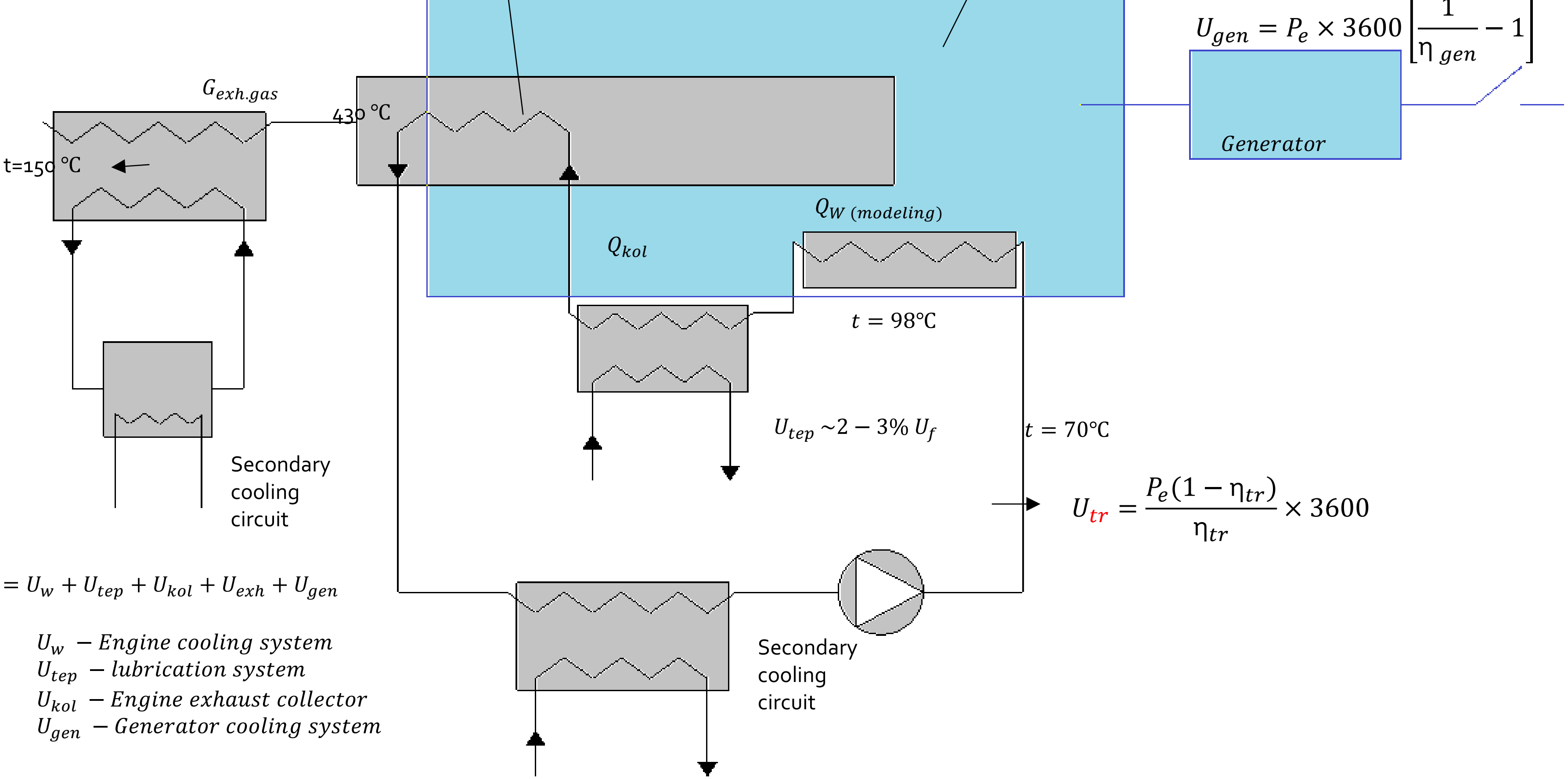
- The engine model is freely chosen (Otto cycle)
- Objective – determination of U_H, the result using AVL BOOST calculations and controlled by the regulation of the heat dissipation system



$$U_{gen} = P_e \times 3600 \left[\frac{1}{\eta_{gen}} - 1\right]$$

$$U_{tr} = \frac{P_e(1-\eta_{tr})}{\eta_{tr}} \times 3600$$

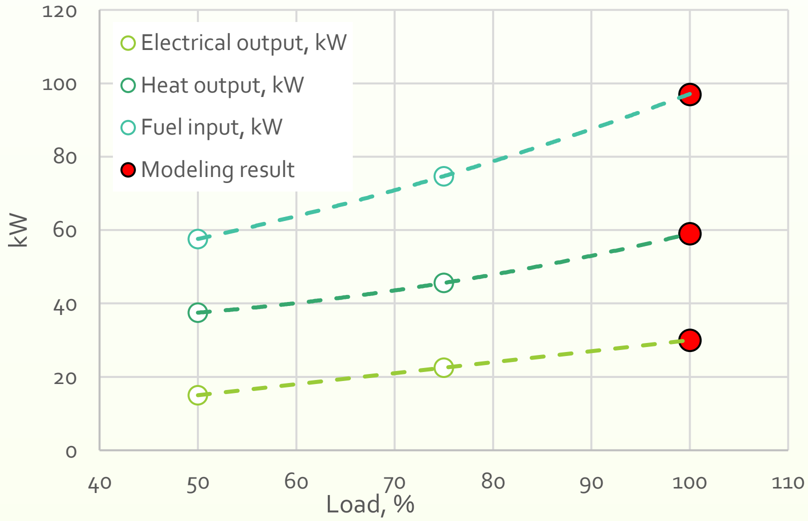
$$U_H = U_w + U_{tep} + U_{kol} + U_{exh} + U_{gen}$$

U_w – *Engine cooling system*
U_{tep} – *lubrication system*
U_{kol} – *Engine exhaust collector*
U_{gen} – *Generator cooling system*

Modeling results (I)

Research and optimization of mathematical modeling of operational parameters and energy balance components of cogeneration plants operating on landfill gas (CH_4 35% + CO_2 65%)

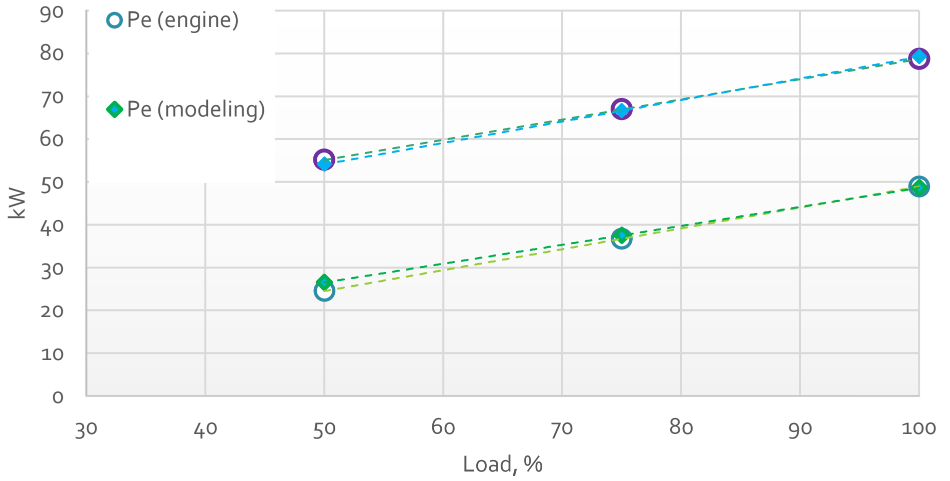
	100	100	100	75	50
Electrical output, kW	30	30	30	22.5	15
Heat output, kW	59	59.1	59	45.6	37.5
Gas consumption, m3/h	15	15	15	11.6	8.9
Fuel input, kW	97.1	97	97.1	74.7	57.6
Electrical efficiency, %	30.9	30.9	30.9	30.1	26
heat efficiency, %	60.8	60.9	60.8	61	65.1
total efficiency, %	91.7	92	91.7	91.1	91.1

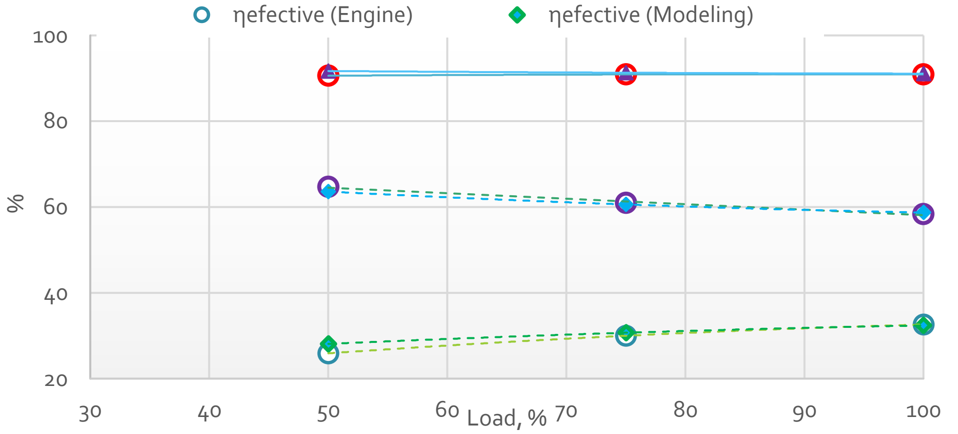


Modeling results (II)

- Modeling carried out with engine operating up to **33% CH4**.
- η_{gen} assumed to be 0.9 (based on engine specification).
- Qh is a sum of heat in cooling water and heat from exhaust gas, tg assumed to be 433 ℃

	100	75	50	
Pe (engine)	48.9	36.7	24.5	kW
Pe (modeling)	48.6	37.5	26.5	kW
Qh (heat energy)	78.7	66.9	55.1	kW
Qh (heat energy modeling)	79.2	66.6	54.1	kW
Pme (engine)	0.85	0.64	0.42	Mpa
Pme (modeling)	0.85	0.65	0.46	MPa
Pf (engine/modeling)	135	109.9	85.1	kW
ηefective (Engine)	32.6	30	25.9	%
ηefective (Modeling)	32.4	30.7	28.1	%
ηthermal (engine)	58.3	60.9	64.7	%
ηthermal (modeling)	58.7	60.6	63.6	%
η (engine)	90.9	90.9	90.6	%
η modeling	91.1	91.3	91.7	%





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Preliminary assessment

Based on engine Micro 30 included in TB 40, can potentially operate with 48%CH_4 52%CO gas fuel.

- **First stage: Adaptation of a single-zone mathematical model for operation on landfill gas**
- **Second stage: Analytical research: determination of thermodynamic indicators of cylinder filling components in a naturally aspirated engine for modeling (within the operational load range)**
- **Modeling of energy performance indicators of the Micro 30 cogeneration plant (Combined Heat and Power) based on the initial plan by LEI**
- **Modeling of energy performance indicators of the Micro 30 cogeneration plant**
- **Development of the structural energy balance diagram for Micro 30 cogeneration plants, calculation and verification of indicators based on specification data**
- **Application of a single-zone mathematical model for project tasks was carried out to evaluate air and fuel mixtures of broad chemical composition** (air: $O_2 + N_2 + CO_2 + H_2O$ + Ar; fuel: C + H + O_2 + S + H_2O) **(2020.12 – 2024.06)"**

Analytical studies (fragments): Determination of $CH_4 + CO_2$ components in a broader operational load range of the power plant."

- **{Gas composition from air} → f(R_{mis}, S_{mis}, G_{mis}) → G_air (at $\lambda \approx 1.0$) → (Partial pressure): P_1 ($O_2 + N_2$) + P_2 ($CO_2 + CH_4$) → V_air + V($CH_4 + CO_2$) → (Mixture supply pressure) at f(λ) = 1.0**

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THANK YOU FOR ATTENTION

Do you have any question?

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