



Slovenská spoločnosť pre techniku prostredia, člen ZSVTS, REHVA
Stavebná fakulta STU Bratislava, Katedra TZB
Slovenská komora stavebných inžinierov

zborník prednášok

z 31. medzinárodnej vedecko-odbornej konferencie

VYKUROVANIE 2023

na tému

**Energetické koncepcie a bezpečnosť
zásobovania teplom**



20. - 24. marec 2023

Horný Smokovec

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PRÍHOVOR

31. medzinárodná vedecko-odborná konferencia VYKUROVANIE 2023

Vážení kolegovia,
Účastníci a sympatizanti konferencie Vykurovanie 2023.

Sme veľmi radi a tešíme sa, že už po pandemickej situácii sa môžeme konečne s Vami stretnúť, tento-krát už na 31. ročníku, tejto najvýznamnejšej konferencie v oblasti zásobovanie budov teplom, ktorá bude zameraná na nosnú tému, a to:

"Energetické koncepcie a bezpečnosť zásobovania teplom".

Nosnou časťou konferencie sú monotematické semináre na aktuálne témy, súčasne sme pripravili aj viaceré prezentácie, tak generálnych ako i hlavných partnerov konferencie, uskutoční sa výstavka popredných firiem v predmetnej oblasti, v neposlednom rade môžeme diskutovať za účasti mediálnych partnerov počas kávových prestávok. S prednáškami vystúpi okolo 100 odborníkov, pričom ich príspevky budú publikované v takmer 500 stránkovom zborníku, zároveň 35 popredných firiem bude prezentovať svoje výrobky, zariadenia a technológie.

Konferencia už tradične ponúka 13 samostatných seminárov v rámci 5 obsahovo ucelených monotematických dní, súčasne 4 aktuálne diskusné fóra, zároveň sa udelia ocenenia za celoživotný prínos v oblasti vykurovania, ako aj cena pre mladého odborníka.

Odborný program pozostáva z 5 samostatných celkov prislúchajúcich jednotlivým dňom:

- Energetika budov
- Progresívna výroba tepla
- Obnoviteľné zdroje energie
- Automatizácia vo vykurovaní
- Energetické služby

Konferencia je určená odborníkom z oblasti vykurovania a energetiky budov, projektantom, prevádzkovateľom, investorom, zástupcom bytových družstiev a podnikov, spoločenstvám vlastníkov bytov, predstaviteľov štátnej správy, školstva, vedy a výskumu.

Tešíme sa na príjemné chvíle počas 31. ročníka konferencie VYKUROVANIE 2023.

Prof. Ing. Dušan Petráš, PhD.
odborný garant konferencie

VIII. SEKCIA

ENERGETICKÉ ZHODNOTENIE ODPADU

vedie: doc. Ing. Ľudovít Kolláth, PhD.

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EVALUATION OF THE ESTABLISHMENT OF HUHA 2 WASTE INCINERATION PLANT IN THE DISTRICT HEATING SUPPLY OF BUDAPEST

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Abstract

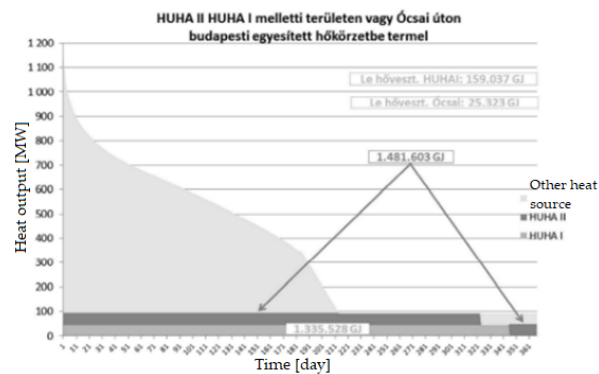
Globally, 1.3 trillion tonnes of municipal solid waste is generated each year, equivalent to 180 kg per person per year. This is expected to rise to 2.2 trillion tonnes by 2025. In developed countries such as the European Union and the USA, this figure is significantly higher. According to the EU regulatory framework, the most efficient waste management methods are prevention, recycling and energy recovery. The worst option is landfilling of municipal solid waste due to space requirements, aesthetic and environmental impacts, and the release of unused methane from decomposition into the atmosphere. The GWP of methane is twenty-five times that of CO₂, making it a significantly bigger problem for global warming. In addition to environmental impacts, reducing energy dependency has recently become a major concern for European countries due to the Russian-Ukrainian war, which has led to severe gas price increases and security of supply problems.

In the framework of this study, I have carried out an economic analysis of the establishment of a second incineration plant in Budapest, taking into account the evolution of international gas prices.

1. IMPORTANCE OF THE INSTALLATION

In the course of the study, I examined the establishment of the second waste-to-energy plant in Budapest, HUHA 2. Based on a previously prepared siting study by Főtv, I chose the site of HUHA 2 in South Pest, near Ócsai road. [1] The power plant to be installed was compared with the Kelenföld, Kispest and Csepel power plants, which currently supply the area of installation, from the point of view of economy and return on investment. These plants are all gas-fired plants and therefore the basis of comparison was also a gas-fired plant. Currently, in Hungary, most of the municipal solid waste (MSW) generated is landfilled, which raises environmental issues and goes against EU regulations, so the use of energy from MSW is a profitable activity. The plant has an annual waste capacity of 230 000 tonnes of MSW, which can be further increased by the installation of a pre-sorting plant. To achieve this separation, I have installed a pre-sorter in the plant, which converts the MSW into RDF (Refused Derived Fuel) or SRF

(Solid Recovered Fuel), greatly increasing its calorific value and thus its quality as a fuel. The calorific value of MSW ranges from 7.5 to 10.5 MJ/kg, while the calorific value of SRF/RDF ranges from 19 to 21 MJ/kg. [3] In the documentation prepared for Főtv, the operating parameters for connection to different heat districts are discussed, of which the connection to the whole Budapest district heating network is examined below. In this state, the plant operates as a base-load power plant for most of the year with a thermal output of 55 MW and a corresponding electrical output of 14.6 MW, which I will use in the following.



1. Figure: Time – Heat power output diagram of HUHA 2 [1]

2. ECONOMIC ANALYSIS

2.1. Investment Costs

As a first step, I determined the investment costs. Since the value assessment of the study since 2017 has not been carried out, and the cost of the elements to be included in the plant is determined by a personal bid, I determined the inflation rate at the time of the study since 2017, which was 25.5%. [4] I then multiplied the adjusted 2017 investment cost prices by the value of inflation to get the potential investment costs today.

2.2. Annuities

Once the investment costs have been determined, I have calculated an annuity for the investment, which allows me to determine the costs projected for each year of operation. For the annuity calculation, I set the inflation rate at 7%. The reason for this was that, although the current inflation rate will exceed 9% in May 2022, it is unrealistic to use this rate for the whole 20-year lifetime. I have taken the nominal interest rate to be 5%. I split the investment into an equity part and a debt part, which I then adjusted for inflation over the 20-year period. The annual return thus obtained, adjusted for inflation, was determined for each year of operation. I carried out the same steps for the own contribution to the investment (excluding, of course, the interest on the loan) and then summed the values obtained for each year to obtain the total annuity for each year. There is a HUF 2.5 billion co-payment for the investment, which would be provided by the investor. In addition, HUF 50 billion would be provided by the City of Budapest as an investment amount, with the remaining balance to be covered by borrowing or co-financing.

2.3. Fixed and Variable Costs

For the fixed costs, I followed a similar logic as for the investment costs, adjusting most of the costs for inflation, such as maintenance, labour, etc. For the variable costs, it was a step more complicated, as energy prices could not be determined on this basis.

For transport costs, I calculated the costs based on the change in fuel prices, for electricity revenues I used HUPX data for the current European market prices, which at the time of writing the study was €265, which at a currency exchange rate of 380 HUF/€ is 100,700 Ft/MWh. Based on CEEGEX data, I calculated the international gas price, which is 96 €/MWh, equivalent to 37 240 HUF/MWh.

2.4. Determining the cost of CO₂ quotes

CO₂ quota prices are calculated on the basis of the total energy produced.

$$C_{CO_2} = \frac{(E_{heat,sold} + E_{electricity,sold}) * \frac{\dot{m}_{MSW}}{10^6}}{\eta_{msw,cogeneration}} * p_{CO_2}$$

Where:

- C_{CO_2} = CO₂ quota price [Ft]
- $E_{heat,sold}$ = thermal energy sold per year [kWh/year]
- $E_{electricity,sold}$ = annual electricity sold [kWh/year]
- $\dot{m}_{MSW}$ = specific CO₂ emissions from TSZH combustion [g/kWh]
- $\eta_{msw,cogeneration}$ = Cogeneration efficiency of HUHA 2 [-]
- p_{CO_2} = price of the CO₂ quotas [Ft/t]

To determine the cost of the quota, we first need to know what the specific emissions of the MSW combustion are.

$$\dot{m}_{MSW} = \frac{(1 - \alpha) * f_{MSW,weight}}{F}$$

Where:

- α = climate neutrality ratio [-]
- $f_{MSW,weight}$ = specific CO₂ emissions of MSW by mass [tonnes(CO₂)/kg(MSW)]
- F = calorific value of MSW [MJ/kg]

The value of the climate neutrality ratio is $\alpha = 0.5$ according to the Hungarian regulations. The alpha indicates that the part of the energy produced by the power plant is considered to be renewable energy and thus exempt from CO₂ quota prices and emissions.

Specific mass CO₂ emissions based on the CEWEP report $f_{MSW,weight} = 0.9$ tonnes (CO₂)/kg(MSW). [5] If the calorific value of MSW is assumed to be 8 MJ/kg, the specific CO₂ emission value is $\dot{m}_{MSW} = 202.5$ g/kWh.

We can then give the quota costs we calculated earlier. The quota price is currently 19 760 HUF/tonne (CO₂), which is much higher than 5 years ago (5,000 HUF in 2017) and is currently increasing exponentially. The cost of quotas for the MSW has become HUF 2 806.86 million per year. The coupled efficiency of HUHA 2 is 80.9% based on the projected electrical and heat output performances, with 63.9% for heat extraction and 16.9% for electrical extraction.[6][7] The CO₂ quota cost of natural gas-fired power plants can be obtained using the same logic, and I have assumed a cogeneration efficiency of 0.8 for gas turbine power plants.

I calculated the specific CO₂ emissions of natural gas using a stoichiometric equation and specific heat. Based on these calculations, the specific emissions of gas are 198 g/kWh. The CO₂ emissions of HUHA 2 would be higher than those of gas turbine power plants, with a difference of more than 20 000 tonnes per year. In reality, the CO₂ emissions from the incineration of HCH would be reduced if the amount of landfill gas released during landfilling were included, but this is not addressed in this study.

2.5. Net Present Value and Payback Period

In the net present value calculation, I considered two cases: in the first case, the investment would be self-financed, and in the second case, the investment would be financed with HUF 50 billion in subsidies and loans in addition to the HUF 2.5 billion co-financing. The calculation method is as follows:

$$NPV = \sum_n \frac{I_{net}}{(1+r)^n} - C_{investment}$$

Where:

- NPV = net present value [Ft]
- I_{net} = yearly net income [Ft]
- r = inflation [-]
- $C_{investment}$ = cost of investment [Ft]

We can calculate the payback period by measuring where the NPV is zero ($NPV=0$). In the case of loans, the net present value of the annual repayments has to be subtracted from the profits, calculated as follows:

$$NPV_{loan} = \sum_n \frac{\frac{C_{loan}}{m} * (1 + THM)^n}{(1+r)^n}$$

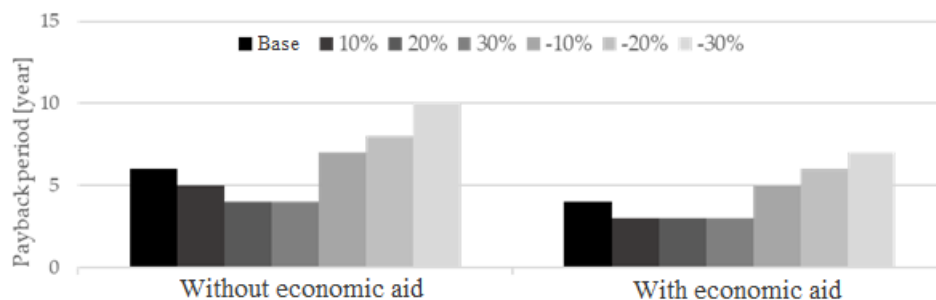
Where:

- NPV_{loan} = the present value of the loan repayments [Ft]
- C_{loan} = sum of the loan [Ft]
- THM = bank interest on the loan [-]
- m = duration of the loan in years [-]

From the credit adjusted subsidised NPV, the present value of the loan repayments over the life of the loan should also be deducted.

$$NPV = \sum_n \frac{I_{net}}{(1+r)^n} - C_{investment} - NPV_{loan}$$

I have assumed a loan term of 15 years and an APR of 0.053 based on the values at the time of writing the study. Since the investment cost I used is only an estimate and does not include the recent increase in raw material and labour costs, I also calculated the changes in the investment cost I calculated to a $\pm 30\%$ level and then used these to make the return calculations. The results are shown below on 2. Figure:



2. Figure: Evolution of payback periods with changes in investment cost

Several cases have the same payback period as shown in the graph. This can be explained by the sampling interval of the calculation, which measured the data in annual intervals, of course, measured in months, as gas prices rise each project would pay back sooner.

3. DETERMINING THE UNIT COSTS

One of the main indicators of the operation and economics of power plants is the unit cost, which is the amount of money invested to produce 1 kWh of energy. These indicators can be determined for both heat and electricity supply. The annuity values calculated earlier are used again here, because these subtotals will give us the annual cost of building the plant with the loans. After separating the fixed and variable costs, we can now calculate an aggregate unit cost, which does not yet take into account heat and electricity.

$$f = \frac{(A + C_{fix} + C_{variable})}{E_{heat,sold} + E_{electricity,sold}}$$

Where:

- f = specific cost [HUF/kWh]

The variable heat costs were determined by taking into account the impacts and power outputs as follows:

$$p_{heat} = p_{variable} * \left(1 - \frac{P_{electricity}}{P_{heat}}\right) * \left(1 - \frac{\eta_{electricity}}{\eta_{heat}}\right)$$

Where:

- p_{heat} = variable heat cost [Ft]
- $P_{electricity}$ = electrical power output [MW]
- P_{heat} = delivered thermal power [MW]
- $\eta_{electricity}$ = electrical partial efficiency [-]
- η_{heat} = heat input coefficient [-]

For the calculation of the variable electricity cost, only the difference between the variable cost and the previously calculated variable heat cost is needed.

$$p_{electricity} = p_{variable} - p_{heat}$$

To calculate the specific heat costs, I took into account the annuity costs, the fixed costs and the variable costs calculated above. For the accuracy of the calculation, I have allocated the investment costs in proportion to the energy produced, so that the actual cost of production is more apparent.

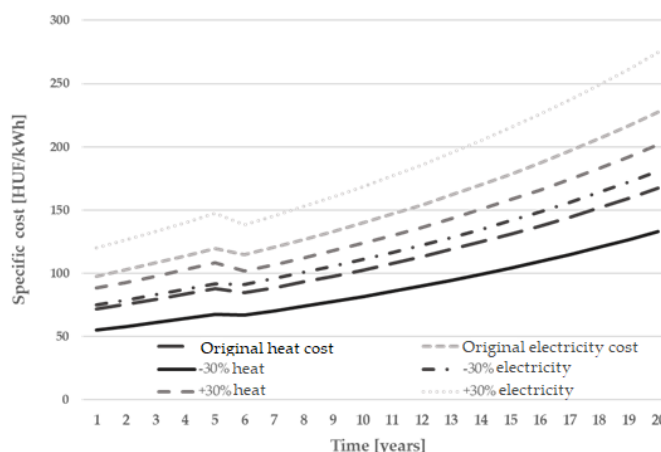
$$f_{heat} = \frac{(A + C_{fix}) * \left(1 - \frac{P_{electricity}}{P_{heat} + P_{electricity}}\right) + p_{heat}}{E_{heat,sold}}$$

Ahol:

- f_{heat} = specific heat cost [Ft/kWh]

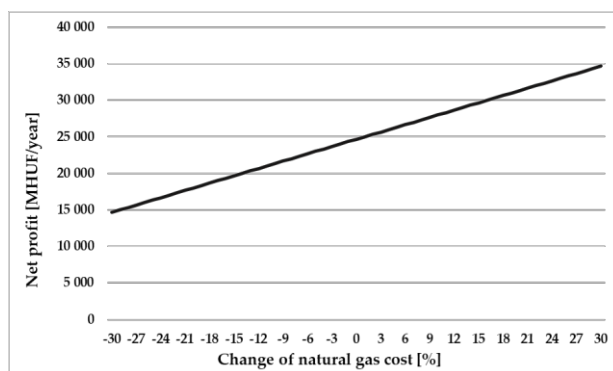
Specific electricity costs are determined using the same methodology. Due to the instability of the gas market, I have calculated gas prices here too to within $\pm 30\%$ of the current case.

Figure 3 illustrates for us the dependence of the specific heat and electricity costs on the gas price as a function of the life year. To avoid overcrowding the diagram, I have only shown the extreme values for the $\pm 30\%$ gas price change with the current 'baseline' costs. The diagram shows a break in the functions at year 5, because, taking into account the averaged installation time and the investment costs of the three gas plants over an assumed 20-year period, this depreciation period would end 5 years after the construction of HUHA 2, after which the investment costs would no longer increase the unit costs.



3. Figure: Evolution of specific heat and electricity costs with changes in gas prices

The net profit of HUHA 2 from the state's point of view is positively correlated with the gas price, and the diagram below illustrates how much profit the plant could make depending on the gas price.



4. Figure: Net profit realised by HUHA 2 as a function of gas prices

4. SUMMARY

In the light of the results presented, it can be concluded that although MSW combustion has its negative aspects, mainly in terms of the complexity of meeting the requirements, the use of poor quality fuel and the corrosion problems it causes, it has a huge economic advantage over gas-fired power plants and many environmental benefits, which are also reflected in the EU regulations. In conclusion, HUHA 2 would be an economically very fast-returning power generation unit, dynamically adapting to international prices, which could generate a net revenue of HUF 25 billion per year for the public administration at the gas prices prevailing at the time of the study.

Acknowledgements

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