THERMODYNAMIC AND ECONOMIC ANALYSIS OF DIFFERENT FUELS USAGE ON EXAMPLE OF RESIDENTIAL BUILDING

ТЕРМОДИНАМИЧКА И ЕКОНОМСКА АНАЛИЗА КОРИШЋЕЊА РАЗЛИЧИТИХ ЕНЕРГЕНАТА НА ПРИМЕРУ СТАМБЕНЕ ЗГРАДЕ

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1. Introduction

- For a full understanding and valorization of energy processes and phenomena, only a quantitative approach is not sufficient.
- Beside the amount of energy, its quality also has to be considered.
- A large part of the energy needs in buildings can be satisfied with low-quality energy (e.g. heating, DHW preparation).
- Almost all energy used in buildings comes from high-quality energy sources.
- This thermodynamic mismatch in quality of energy on the supply side and on the side of use can clearly be shown by an exergy (qualitative) analysis.
- There is a high potential for a more rational use of energy in building sector.

2. Building and system description

- Building is located in Belgrade, with a total heated area of 162 m^2, well insulated, and U-values of thermal envelope are below the maximal values prescribed by Serbian rulebook on the energy efficiency.
- Analyzed energy sources for different needs:

Case	Heating	DHW	El. appliances, lighting	Auxiliary
1	coal	electricity	electricity	electricity
2	natural gas	natural gas	electricity	electricity
3	electricity	electricity	electricity	electricity
4	district heating	electricity	electricity	electricity
5	heat-pump	heat-pump	electricity	electricity

3. Methodology

- The energy analysis was performed using actual methodology prescribed in Serbian Regulations regarding energy efficiency in buildings .
- Energy and exergy flows are calculated in reverse order, from final, over delivered to primary (taking into a consideration the corresponding losses).
- Carbon-dioxide emission was obtained using the specific emission data for different fuels and based on primary energy needs.
- The energy cost analyzes was done only for used energy.
- Actual costs for different fuels and tariff systems were used.

3. Methodology

Exergy analysis

- Exergy - maximal useful work. Exergy is a measure of energy quality. It is a usable part of energy, that can be transformed into other forms of energy.
- Different forms of energy do not have the same quality.
- Electrical energy is the highest quality energy, its quality factor is $\gamma_{el}=1$.
- Heat is the energy of lower quality. Its quality depends on temperature.

  (eg: $t_o=0^oC \Rightarrow$ **a)** $t=1000^oC \Rightarrow \gamma_q \approx 0.79$; **b)** $t=20^oC \Rightarrow \gamma_q \approx 0.07$)

- The chemical exergy of a fosil fuel is approximately equal to higher heating value, the quality factor of the fossil fuels is around 1.
- Unlike of the energy, in energy processes the exergy can be lost, destroyed.
- High overall exergy efficiencies means the exploitation of the large part of the available exergy content and the use of energy in a rational way.

4. Results and discussion

- Indoor air is considered to be heated up to 20°C and DHW up to 55°C.
- Analysis was carried out on the monthly basis.

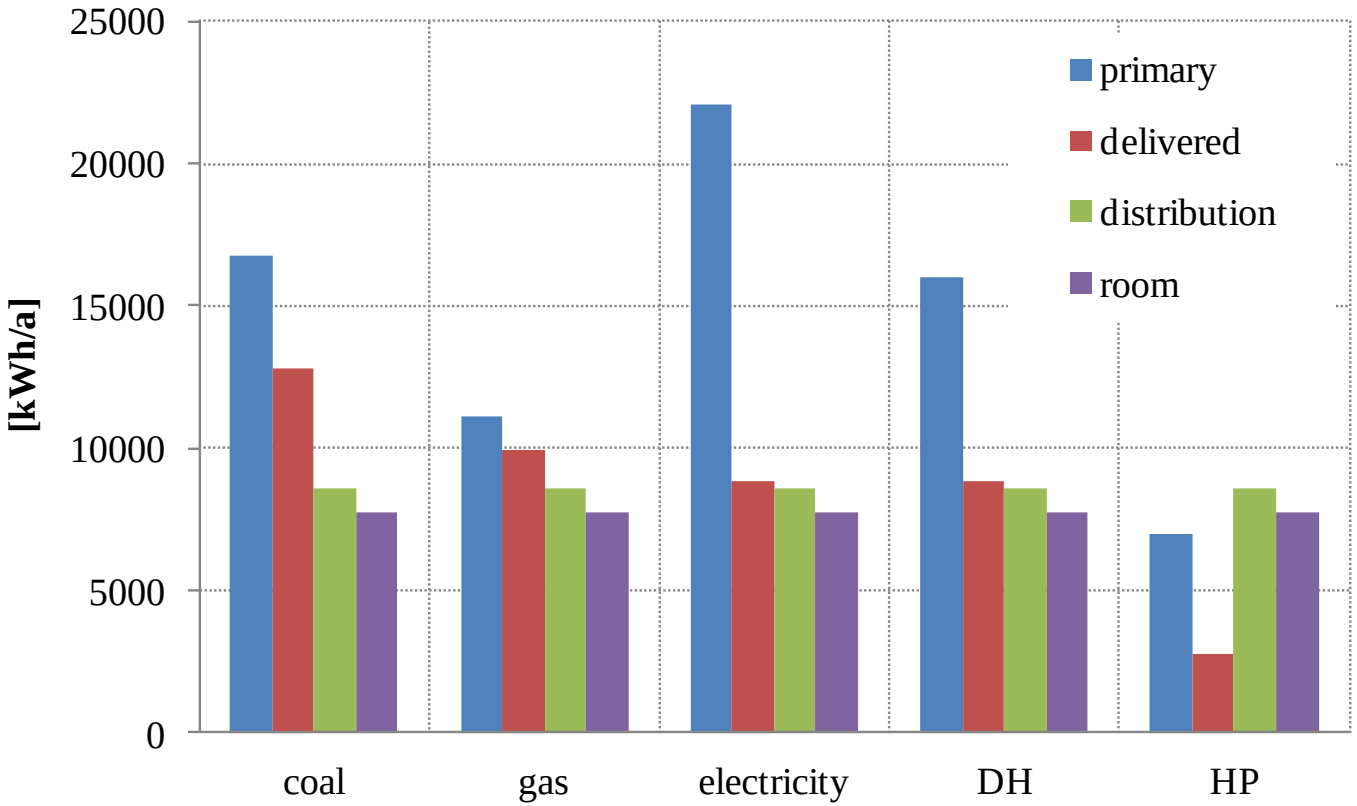
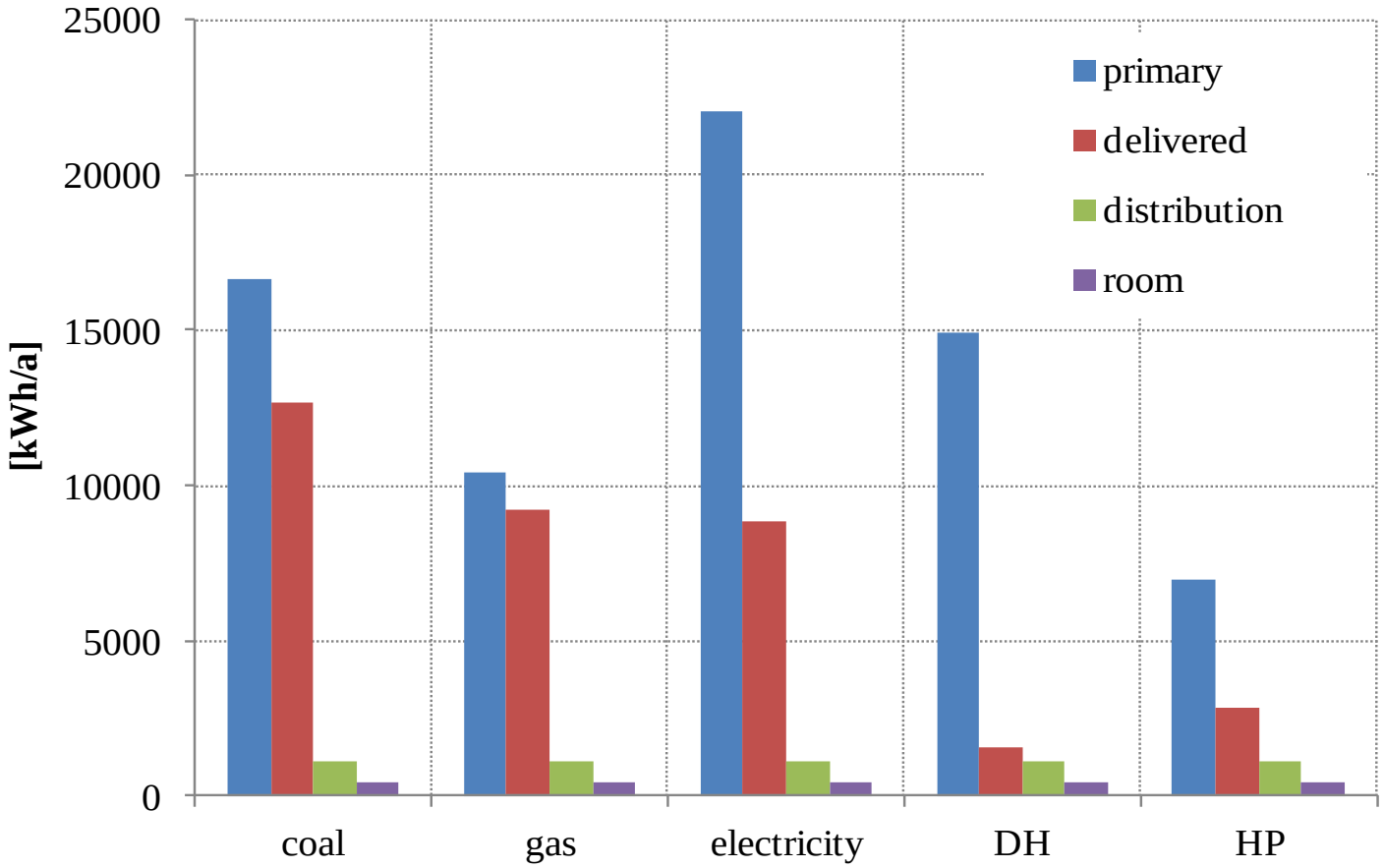


Diagram gives the clear information regarding the energy efficiency of energy transformation in observed process.

Fig. 1. Energy flow through process for different energy sources for heating

4. Results and discussion

- The temperature regimes were determined in every part of the system.



The whole chain of energy transfer has to be analyzed, starting from primary value.

Fig. 2. Exergy flow through process for different energy sources for heating

4. Results and discussion

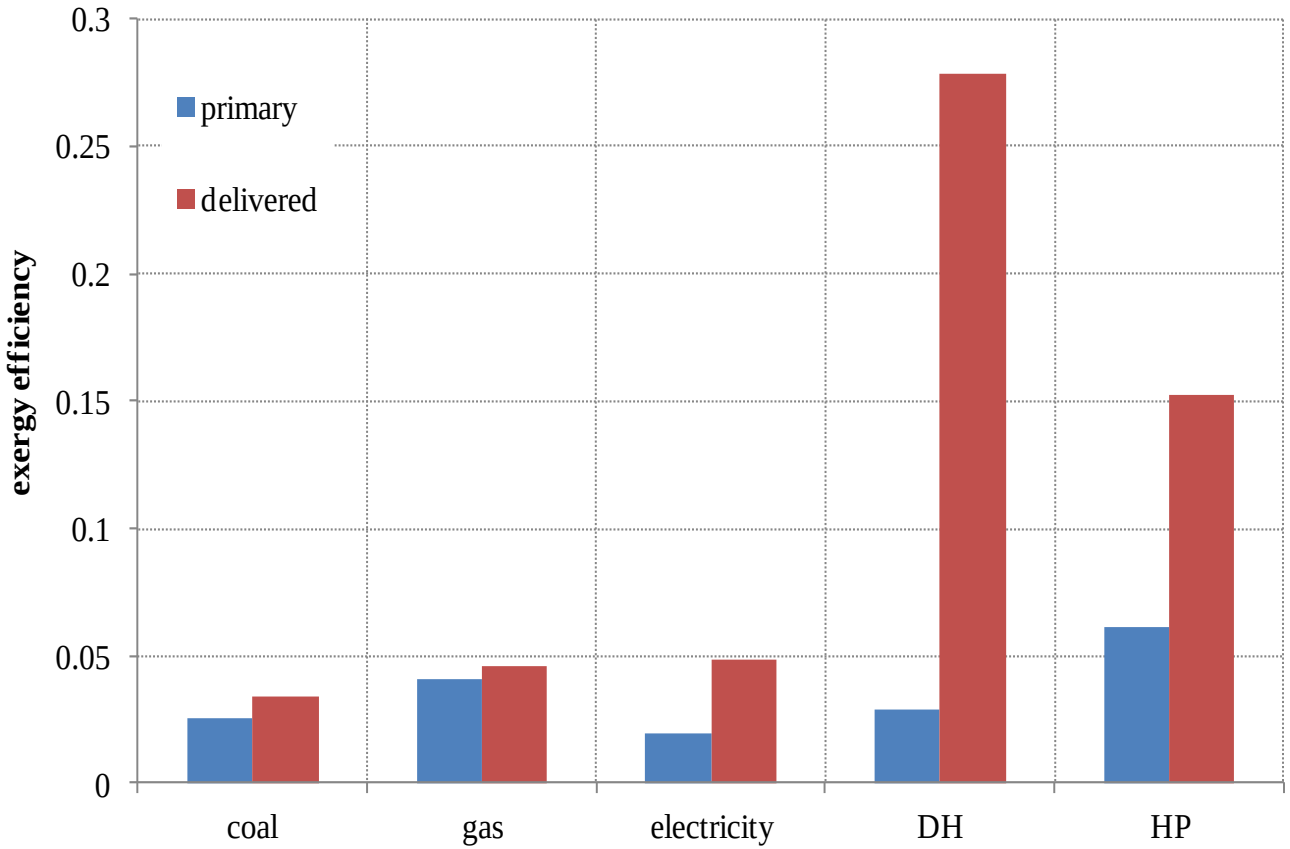


Fig. 3. Seasonal values of exergy efficiency for different energy sources for heating

4. Results and discussion

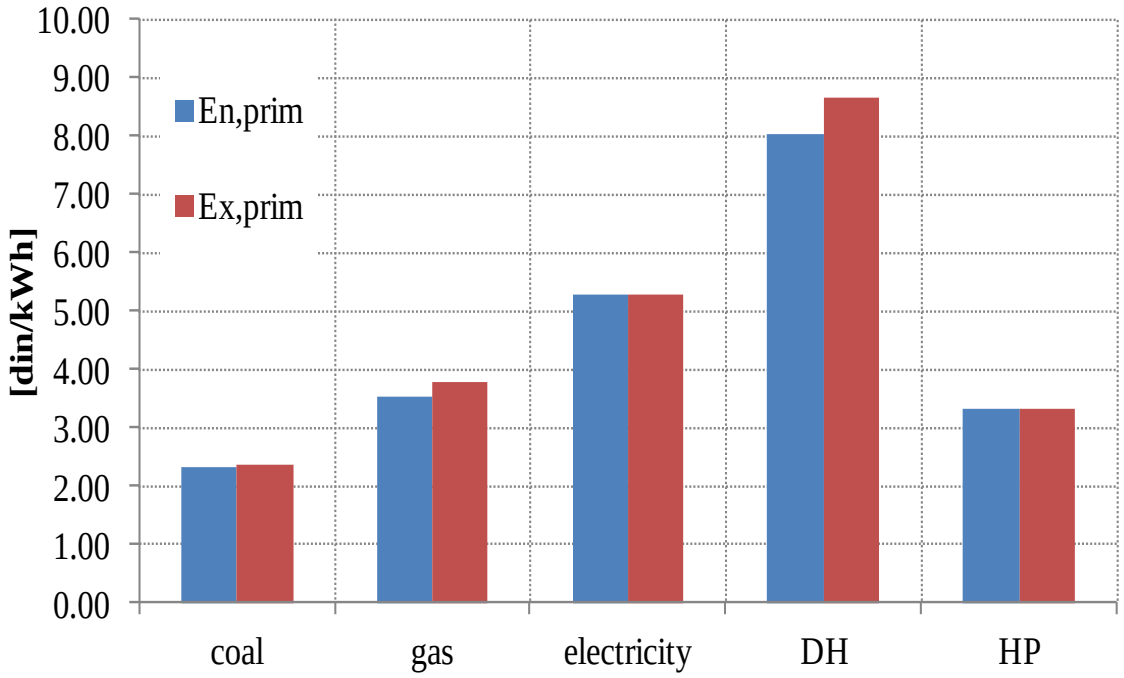


Fig.4. Prices of primary energy and exergy for heating

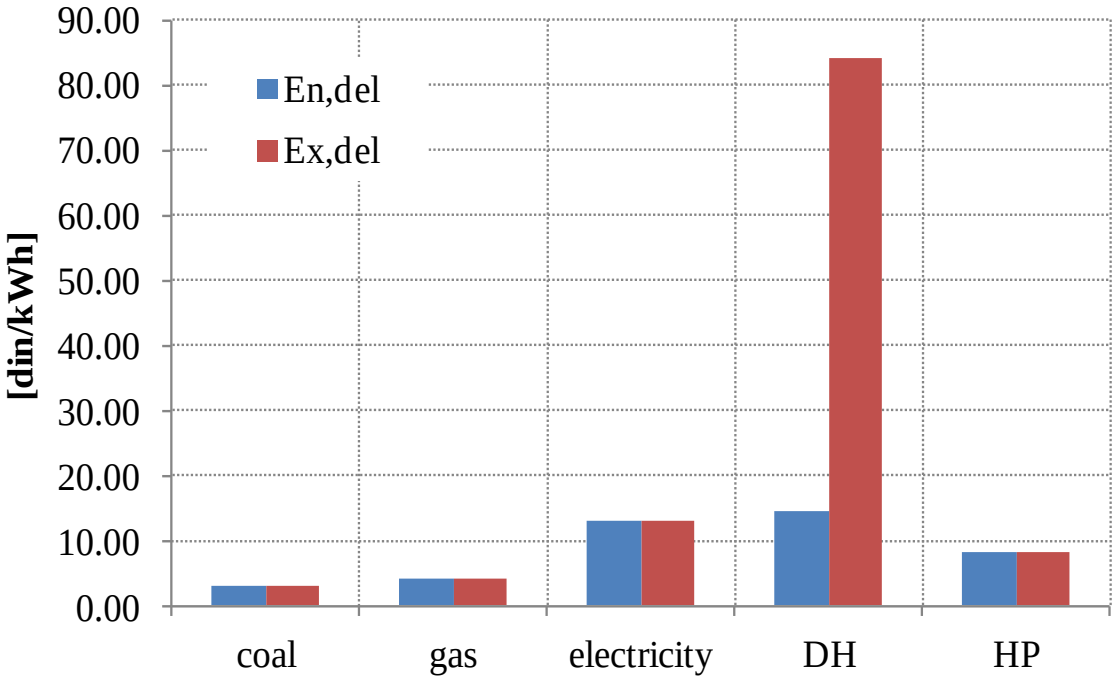


Fig. 5. Prices of delivered energy and exergy for heating

According to the thermodynamic approach, the price of the fuel should be proportional to its quality. The energy supplier and customer should be motivated by price politics to use energy in a thermodynamically rational way (to save the quantity and the quality).

4. Results and discussion

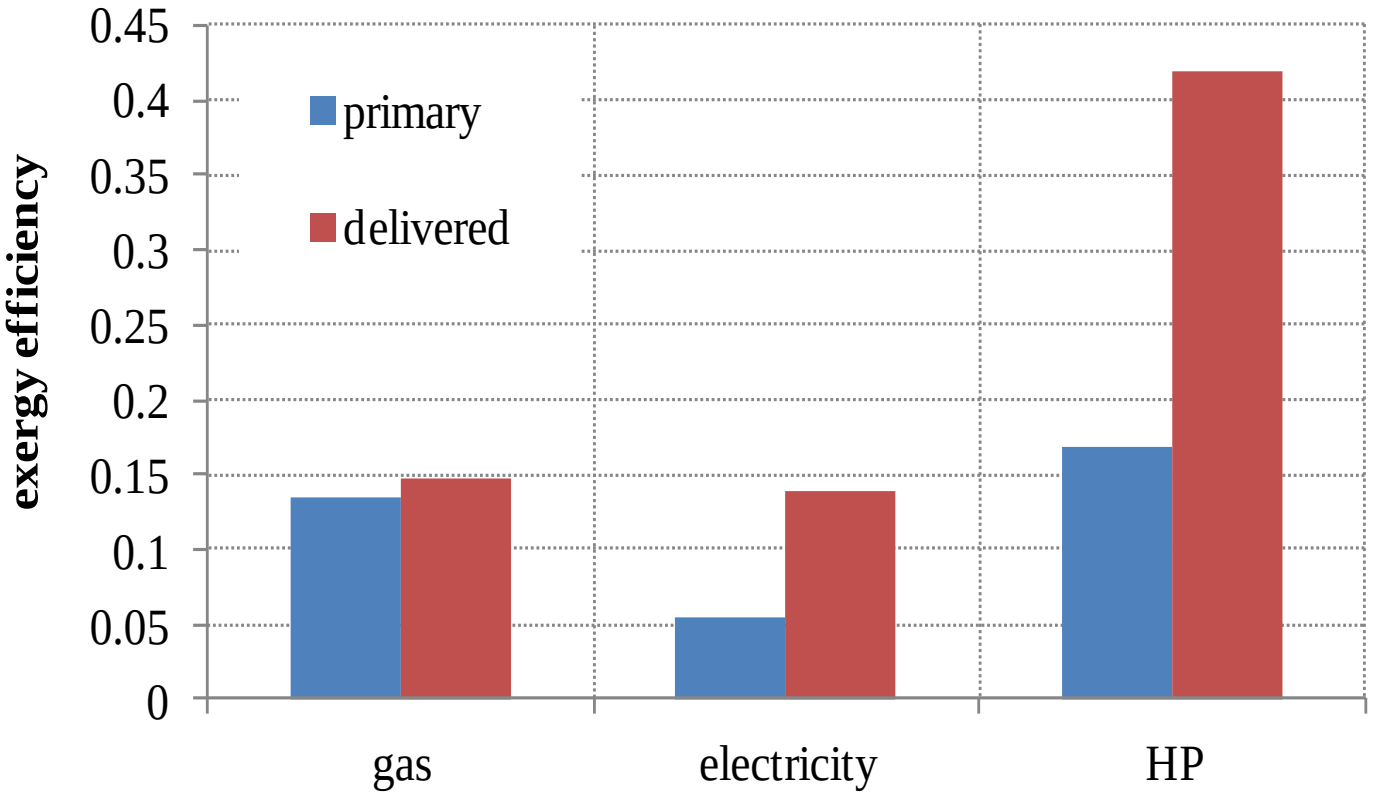


Fig. 6. Exergy efficiency for different energy sources for DHW

4. Results and discussion

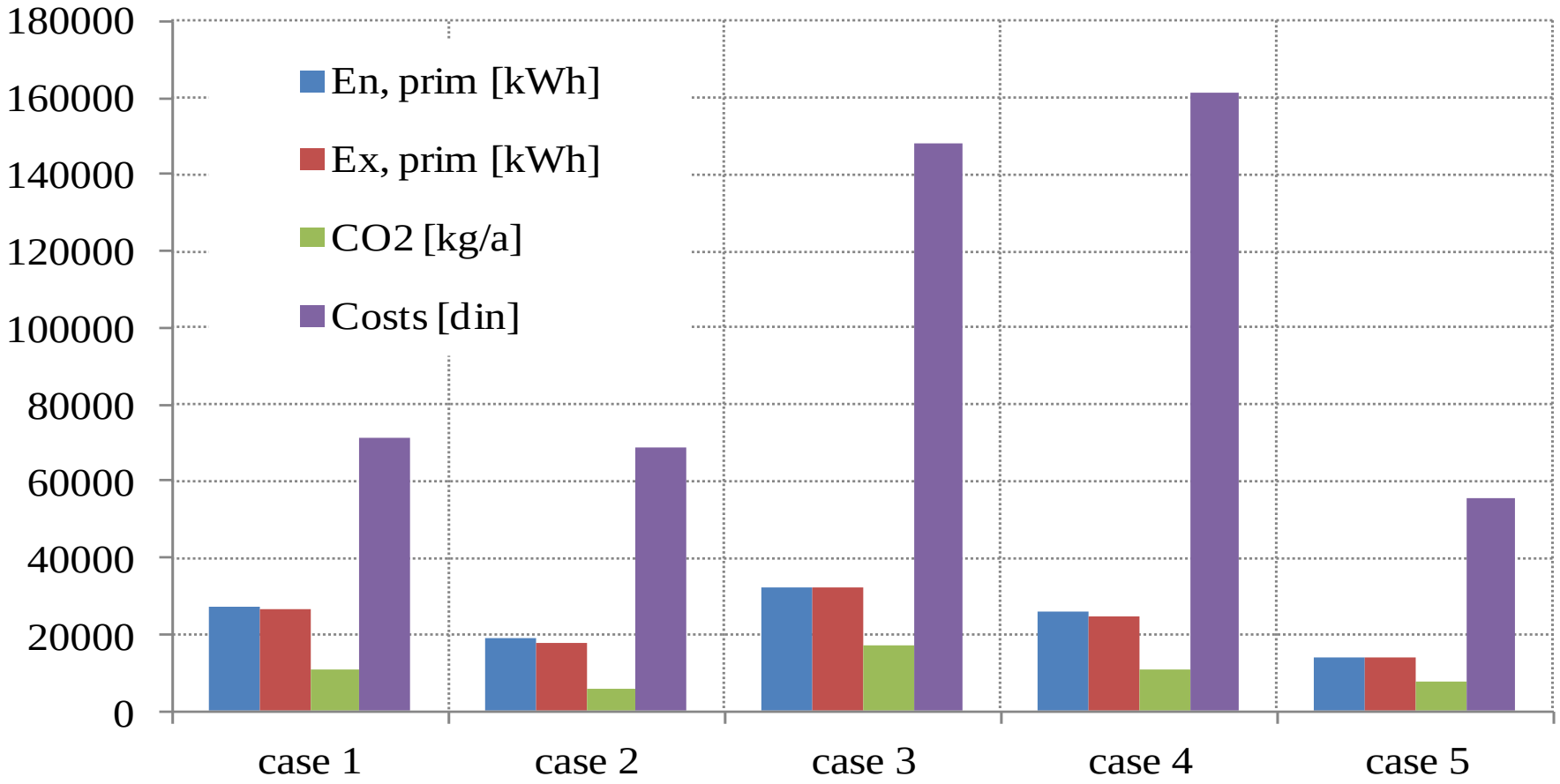


Fig. 7. Total primary energy, total primary exergy, CO_2 emission and costs for different cases

5. Conclusions

- The aim of this paper was not to emphasize the best fuel, neither the combination of fuels for usage in buildings, but to show thermodynamic method of fuel and cost valorization.
- Thermodynamically, there is no adequate justification for high quality fuels usage for heating and DHW preparation, because of their low exergy efficiency. Waste heat, energy from heat pumps and other renewable energy sources better fulfill this purpose.
- Whole chain of energy transfer has to be analyzed, starting from primary energy, because that is the only manner to get the appropriate conclusion.
- From exergy analysis, it is possible to draw out the important conclusion such is that in an exergy efficient energy system, combustion processes should not be used for direct generation of low temperature heat.

Thank you for the attention!

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