An Energy Systems Engineering Approach to Household Energy Supply

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Abstract: The total household energy consumption has undergone a net progression in the last decades. Stabilizing concentrations of greenhouse gases in the atmosphere requires transforming the global energy system from one that is 85% fossil-fuel-based and CO_2 emitting to one that is largely non emitting. When considering future household energy supply, evaluating alternatives from a system context is essential. A study has been undertaken to investigate the optimal energy supply mix including local renewable energy sources as well as dispersed generation. The major steps of systems engineering process are outlined starting from the energy use patterns and accomplishing by the analysis of several options with the criteria of primary energy consumption and carbon dioxide emission reduction potential.
The secure, clean and economically sound energy supply system of the future should integrate a spectrum of large scale and local resources thus combining the benefits of centralized and distributed systems.

Introduction

During the last decades, a number of events have highlighted the vulnerability of the current centralized energy supply infrastructure.
It is evident that shifting from the centralized energy supply system to small-scale decentralized systems, where energy production and consumption are usually tightly complied, might improve reliability and security of supply through using more energy sources. A system approach to the local renewable energy resources is a promising concept addressing distributed generation as an alternative solution for technical, economical and environmental constraints of conventional power systems [1].
The systems engineering process outlined in this report contained the following steps:

- What are the present patterns of supply and demand for energy
- Can the requirements for different forms of energy met in more efficient ways
- Identify alternatives that will solve the problem
- Develop evaluation criteria
- Select preferred alternatives
- Identify technology development goals

1 Household Energy Consumption

The statistical data of household energy consumption vary greatly around the world according to the climate, living standards and lifestyles Hungarian households consume about a quarter of the energy used by final consumers and the natural gas is the dominant source of energy for the households. Natural gas is the principal fuel for space and water heating with grid supplied electricity for lighting needs, household appliances etc. A small part of the residential heat needs is met by cogeneration or district heating. Majority of the residential energy demand covered by burning gas and oil directly. Advances in building design could make huge savings in energy use for space heating.
A more efficient way of using the energy of fuels is to burn them in combined heat and power generating units to provide both heat and electricity. Using CHP systems to supply the needs of households entails either installing a separate unit in each dwelling or constructing networks to distribute the heat. The cogeneration concept leads to improved energy utilization by burning less fuel and reducing harmful emissions.

2 The Role of Renewable Energy in Household Consumption

The most extensively available alternative sources for households are carbon-based: energy crops, agricultural and forestry wastes and municipal wastes.
Although their use produces carbon dioxide emission, this is largely compensated by the carbon dioxide removed for the atmosphere by growing vegetation in a planned rotation or in the case of municipal waste by preventing more damaging emissions of methane. Recently, the political climate prefers them as primarily fuels to generate electricity. However, local biomass and municipal wastes should be regarded as having a premium role in supplying heat. Biomass energy can be produced and converted efficiently into more convenient forms such as pellets, gases, liquids and electricity over a range of scales. Besides biomass, heat pumps, solar thermal panels (STP), photovoltaic have the potential to be widely implemented for household purposes.

3 Comparison of Household Supply Alternatives

Demand for primary energy is affected not only by demand from final users, but also by the overall efficiency of the energy system in matching the locations, forms and time patterns in which energy is required with the locations, forms and time patterns in which it is available. ***Fig. 1***. shows the heat and use efficiency of different sources and technologies. Along the x axis different heat producing technologies are listed and grouped according their input energy sources: primary sources and electricity. Efficiency of all steps of handling the energy sources from occurrence to end use were considered,

from extraction to final conversion through transportation, processing, intermediary conversion and distribution.

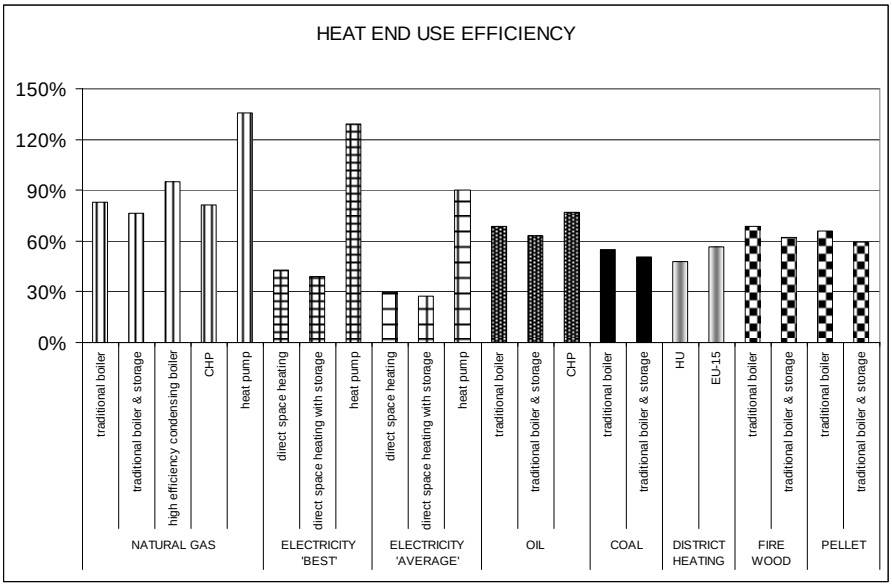

Figure 1
Heat end use efficiency

The inherent effacing values of the last step-conversion to heat are widely known: traditional boilers are around 90%, high efficiency condensing boilers are between 95% and 105%, electricity from grid is 33% as average option, the distribution loss is further 8%. Efficiency of heat pumps and local CHP units may vary in a wide range. In case of natural gas fuelled heat pump 150%, in case of electricity driven heat pump 300% were chosen CHP unit has 90% efficiency. In cases of option with storage an additional 10% heat loss was calculated [2]. The criteria selected for the comparison of various household supply alternatives are primary energy consumption and carbon dioxide emission reduction potential. The reference case is an average grid-based system: an average family house connected to the municipal electricity and natural gas distribution grid. The power demand satisfied from the grid, the heat demand space heating and hot water- is satisfied from natural gas using a high efficiency condensing boiler. Beside the reference case, 13 scenarios were configured and evaluated. Site performance index (SPI) and CO_2 emission values are presented in ***Fig. 2. and 3.*** The site performance index is the ratio of the energy content of primary energy commodities used to satisfy the demand. Electricity, natural gas, biomass are commodities, but the sun radiation is

available free. With this definition SPI can be higher than 100% if sun radiation is in the input mix or electricity exported to the grid, which reduces the amount of electricity to be produced by central power plants. In the case of CO_2, the emission was calculated from the carbon content of the used primary energy source. In the case of biomass sources, they were considered as zero emission ones. The electricity export of bio CHP reduces the centralised power plant CO_2 emissions and results in negative emission of the test site.

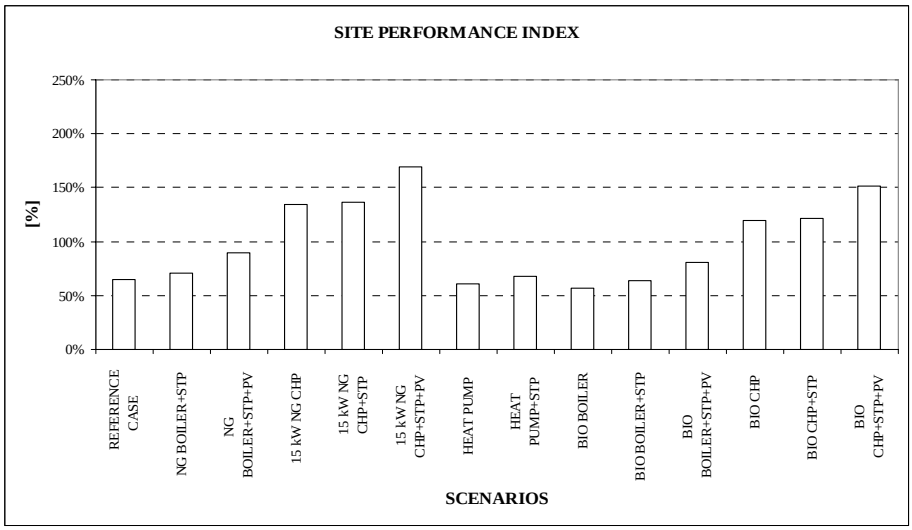

Figure 2
Site performance index

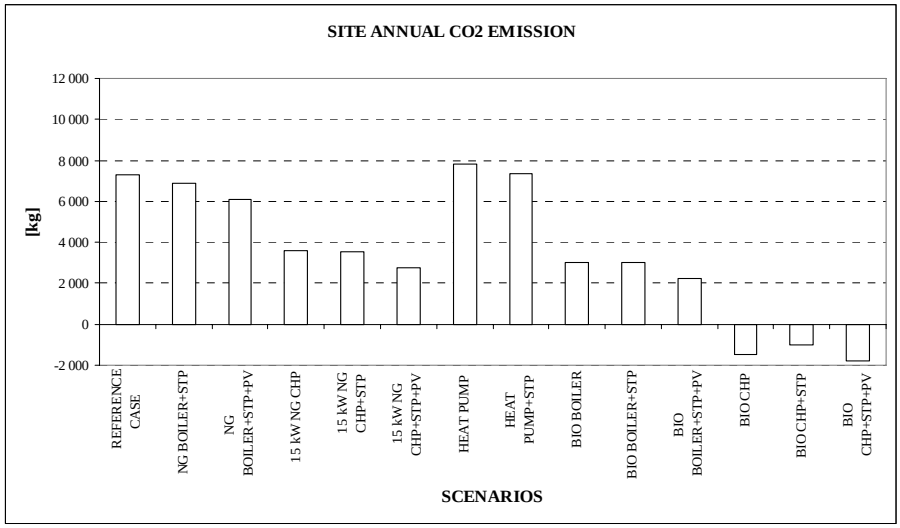

Figure 3
Test site annual CO_2 emission values

4 R and D Needs for a More Efficient Household Energy Supply

The need for further research and development is apparent in order to mobilise the full potential of alternative technologies.
The major R and D goals have to focus on the following items:

- reduced environmental impact
- lower initial cost
- lower operation and maintenance costs
- longer lifetime and extending the time between overhauls
- higher efficiencies
- higher reliability and availability.

5 Conclusions

Decentralised energy systems can significantly contribute to increase the overall efficiency of existing energy systems, decrease the dependency of import resources and to reduce CO_2 emissions. Considering the limited transportability of heat, decentralised supply systems open new application field for innovative cogeneration options. All CHP systems, if well sized, result in a reduction of primary energy use, though different

technologies have different impacts. CHP systems with on-site renewable resource seem to have the best performance.

References

[1] P. Kádár: A háztartás, mint intelligens fogyasztó, Elektro Installateur, 2008. No. 1., pp. 16-18.
[2] Krómer, I., Bessenyei Z.: Comparison of Benefits of Distributed Generation Technologies Using Multi-Criteria Analysis, 8th International Conference on Heat Engines and Environmental Protection 20-23 May 2007, Balatonfüred, Hungary