ASSESSING THE TECHNICAL AND ECONOMIC POTENTIAL OF HIGH EFFICIENT CHP AND EFFICIENT DISTRICT HEATING AND COOLING: THE METHODOLOGY USED FOR THE "COMPREHENSIVE ASSESSMENT" IN AUSTRIA

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Overview

The reduction of greenhouse gas emissions from the energy system is one of the central challenges of the 21st century. This is tried to be achieved by an increased use of renewable energy sources and increasing the efficiency of the energy system. Heating and cooling accounts for almost one third of the final energy use and plays a central role in achieving energy efficiency targets. The current structure of the heating and cooling system has grown historically and energy-related investment decisions are based primarily on economic considerations.

As part of the EU Energy Efficiency Directive (2012/27/EU) [2] all Member States have to develop a comprehensive assessment of the potential for the use of high-efficient combined heat and power (CHP) and efficient district heating and cooling[1] by the end of 2015..

In a first step relevant heating and cooling demand regions exceeding certain consumption or production thresholds listed in the directive have to be identified and the potential of renewable energy and efficient technologies should be determined for each region. For these regions an economic cost-benefit analysis has to be performed in the second step.

This leads to the central questions of the work described in this paper:

1) How can significant heating and cooling demand regions be identified and characterized?
2) How do different characteristics of these regions influence the cost-benefit analysis of high-efficient CHP and efficient district heating and cooling opportunities?

Method

First, a definition of the relevant system boundaries of heating and cooling demand and supply regions is done. These boundaries include the temperature level up to 300 °C that can be provided by CHP and the values specified in the directive of at least 20 GWh of annual heating and cooling consumption for industrial zones and a plot ratio[2] of at least 0.3 for the heating demand of municipalities and conurbations.

Second, the actual demand for heating and cooling is identified and two scenarios for the year 2025 are developed using the techno-economic bottom-up model INVERT/EE-Lab [1]. This model calculates the building related heating and cooling demand on a highly disaggregated level of a 250x250 m resolution. As the suggested plot ratio of 0.3 is achieved only in very few areas in Austria, a modified approach is used within the model INVERT/EE-Lab: To determine the main district heating regions, all neighboring 250x250 m raster elements with a heat density greater than 10 GWh/km² are connected. Then all of the regions are identified that fulfill a plot ratio of 0.25 reduced by a factor that is dependent on the energy within this connected region. The minimum annual energy demand should exceed 10 GWh to be classified as a main district heating region.

Third, the current state of supply in terms of existing plants and district heating networks is investigated, to include relevant infrastructure into the cost benefit analysis.

In a fourth step the technical potentials for CHP and district heating and cooling including electricity plants, waste incineration plants and industrial waste heat are evaluated. Just high efficient technologies according to the energy efficiency directive are taken into account. To determine the regional potentials technical approaches like the suitable roof area for solar thermal collectors, the availability of natural gas within a certain distance or existing waste capacities for incineration plants are used. The combination of the demand with the existing

[1] A CHP-plant is referred to as high-efficient when the primary energy savings of combined production excess 10 % compared to separated production and a district heating system is referred to as efficient when it uses at least 50 % renewable energy, 50 % excess heat, 75 % CHP-heat or 50% of a combination of these sources
[2] 'plot ratio' means the ratio of the building floor area to the land area in a given territory

potentials for renewable energy and efficient technologies as well as the existing supply systems then leads to a characterization of different types of heating and cooling demand and supply regions.
Based on this classification in a last step a cost benefit analysis is conducted for these different typical regions for the two demand scenarios for 2025. To calculate the economic capacities and the full load hours of the CHP plants hourly electricity prices, hourly heat demand and the opportunity costs of covering the load by a central gas boiler are considered. The load-dependent heat generation cost for each technology includes investment costs, O&M costs, fuel and emission certificates costs. For the technologies connected to a district heating network additional costs for transmission and distribution pipes depending on the distance from the supply technology to the network and the heat density within the network are considered. Therefore every region is divided into sub-regions with different heat densities. The network costs are calculated for a model network with fixed parameters for size, layout and temperature level. Furthermore the costs for a peak load gas boiler that covers 20 % of the peak energy demand are included. According to these costs a technological merit order is established for every region. Starting from the sub-regions with the highest density and with existing net infrastructure the cheapest technology in the merit order is used to cover the demand until the potentials or a maximal connection density is reached. In addition to the two heat demand scenarios sensitivities of the results against a high CO2 price, a low gas price and a high electricity price are evaluated.

Results

The described procedure results in three different types of demand areas: 1) regions with high heat densities and high heat demand where district heating can play a central role, 2) regions with lower heat densities where mainly local technologies are the most economic alternative, and 3) industrial heat demand points with a potential for the use of CHP.
With the criteria previously described 38 main regions suitable for district heating were identified. Together they represent more than 40 % of the energy demand for space conditioning and hot water in Austria. The yearly heating demand in 2025 varies between the regions from about 10 GWh to approximately 17 TWh. About one-third of this energy lies in areas with energy densities above 60 GWh/km² whereas the Vienna region accounts for 90 % of this third. The 2nd third of the energy lies in areas with densities between 35 and 60 GWh/km² and the last third in areas with energy densities below 35 GWh/km². First calculations on the distribution costs for the different energy densities gave total costs of about 21 €/MW_{th} for district heating networks in areas of more than 60 GW/km². These costs include investment costs of about 16 €/MW_{th} and O&M costs of about 5 €/MW_{th}. In areas with less than 10 GW/km² the total costs reach 41 €/MW_{th} consisting of 31.5 €/MW_{th} for the network infrastructure and 9.5 €/MW_{th} for the O&M.
The remaining regions, which do not fulfill the mentioned criteria, are classified into typical regions according to similar characteristics. Such regions can be both smaller towns and villages with accumulated service and residential areas where there may be potential for the use of CHP of medium power.
Industrial heat demand points are grouped by their size and process type or product. Only the heating and cooling demand which is suitable for the use of CHP is considered. Together the industrial heat demand points which are suitable for CHP do account for approx. 30 TWh per year and represent 65 % of the heating and cooling demand of the whole industry.

Discussion and conclusions

The calculations of the heating and cooling demand for the building sector on a raster elements-basis led to an underestimation of the plot ratio of these raster elements compared to values in the literature. Therefore a correction of the plot ratio was done assigning the heated space of these raster elements to neighboring elements with higher plot ratios. A simplification in the regional adaption of the cost benefit analysis has been done in using one model size for the district heating network and for each technology. Another limitation in the accuracy lies in the fact that no dynamic interdependency between the electricity market were taken into consideration.
The cost benefit analysis based on classification of the different demand and supply regions allow for a first estimation of the potentials of these regions and to determine whether they are suitable for district heating or the usage of CHP. But this does not replace detailed feasibility studies for the individual regions with identified potentials.

References

[1] Müller A. (ongoing, 2014): “The development of the built environment and its energy demand for space conditioning and domestic hot water supply. A model based scenario analysis.” Vienna University of Technology
[2] EU Energy Efficiency Directive (2012/27/EU)