CONTENTS

FIGURES

A detailed analysis is presented concerning 122 biomass CHP plants using solid biomass. The analysis is presented in terms of fuel, technologies, plant size, construction time as well as investment costs.

1.1 Biomass CHP plants using solid biomass- Comparison of selected European countries

In Figure 1 the number of existing CHP pants in selected European countries is shown. In Germany exist 47 and in Austria 25 CHP plants with solid biomass. In all countries the CHP plants without co firing with fossil fuel dominate.

In Figure 2 the share of existing solid biomass CHP plants is given, where again Germany and Austria are the most dominating countries with a considerable number of CHP plants.

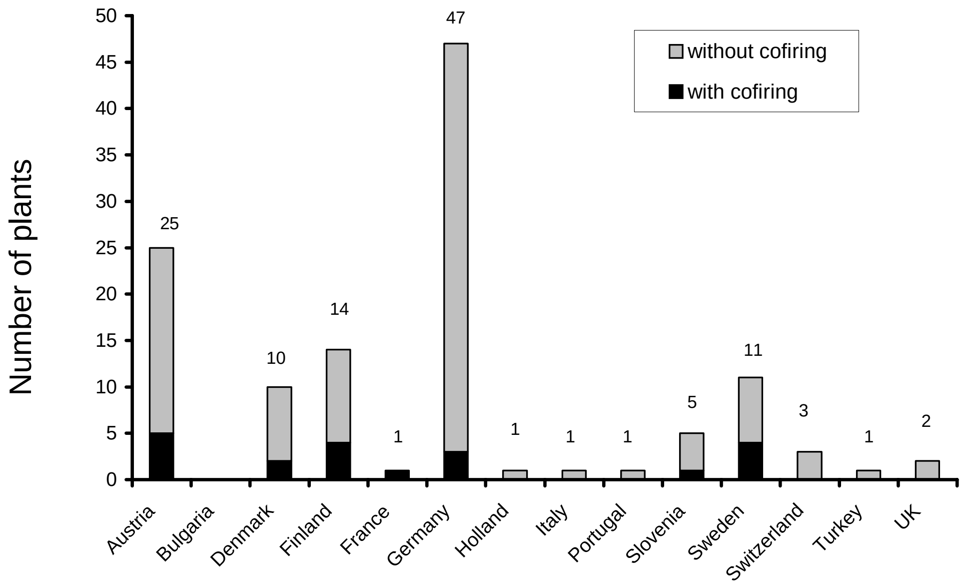
In Figure 3 the construction year of the existing CHP plants with solid biomass are shown.

In Figure 4 the technologies for the solid biomass CHP plants are shown where the steam cycle systems with steam turbine and steam engine are the most dominating technology. The reason is, that the steam cycle is more or less the only currently commercially available technologies for solid biomass CHP.

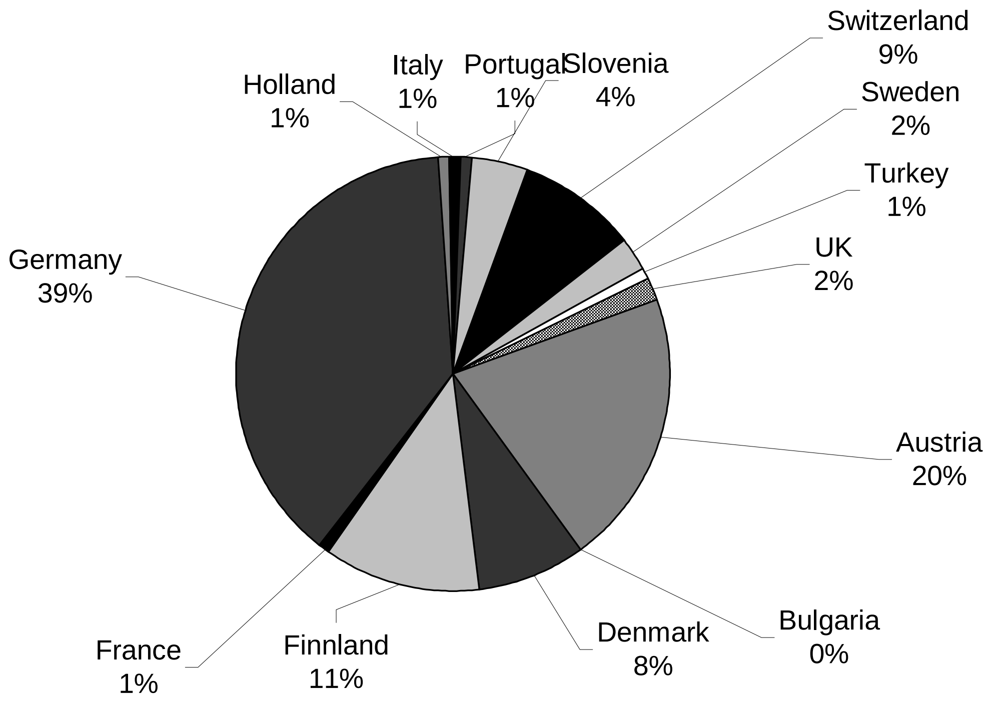
In Figure 5 the character of the existing CHP plants with solid biomass are shown, where it is evident, that most of them are commercial plants, but also a considerable number of them has a demonstration and pilot character. The demonstration and pilot CH plants are mainly investigating new CHP technologies like organic Rankine cycle, hot air turbine or Stirling engine.

In Figure 6 the installed electric power of the biomass CHP plants with solid biomass are shown. Most of the installed electric power is lower than 5 MW_{el}, even a significant number of CHP plants have an electric power of less than 1 MW_{el}.

In Figure 7 the share of the different solid biomass fuels is shown. The most dominating solid biomass fuel is wood chips from forestry and saw mill residues, whereas bark, paper sludge and waste wood is also relevant.



<u>Figure 1:</u> Number of soild biomass CHP plants



<u>Figure 2:</u> Distribution of plants (total number 122)

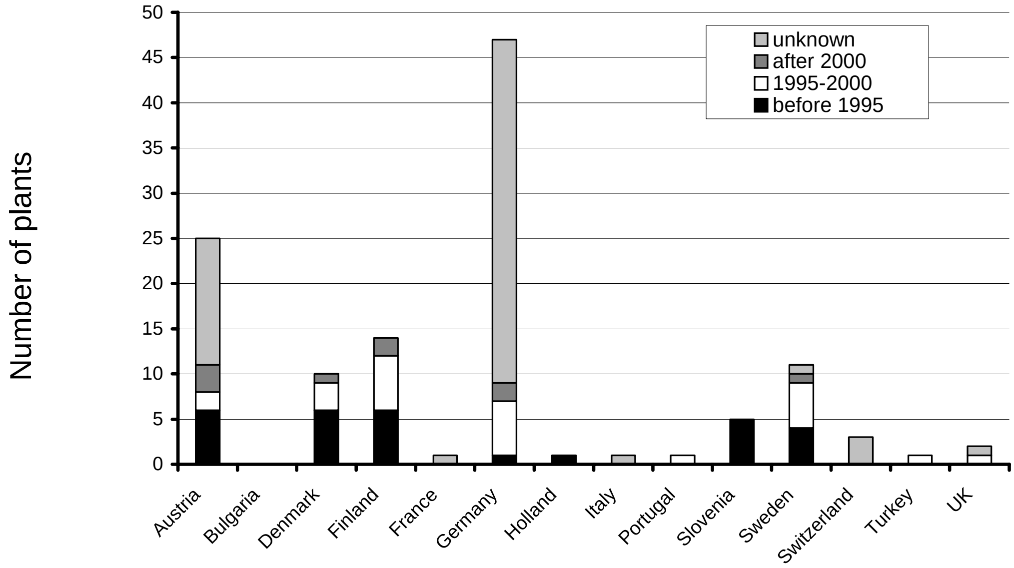


Figure 3: Construction years of the CHP plants with solid biomass

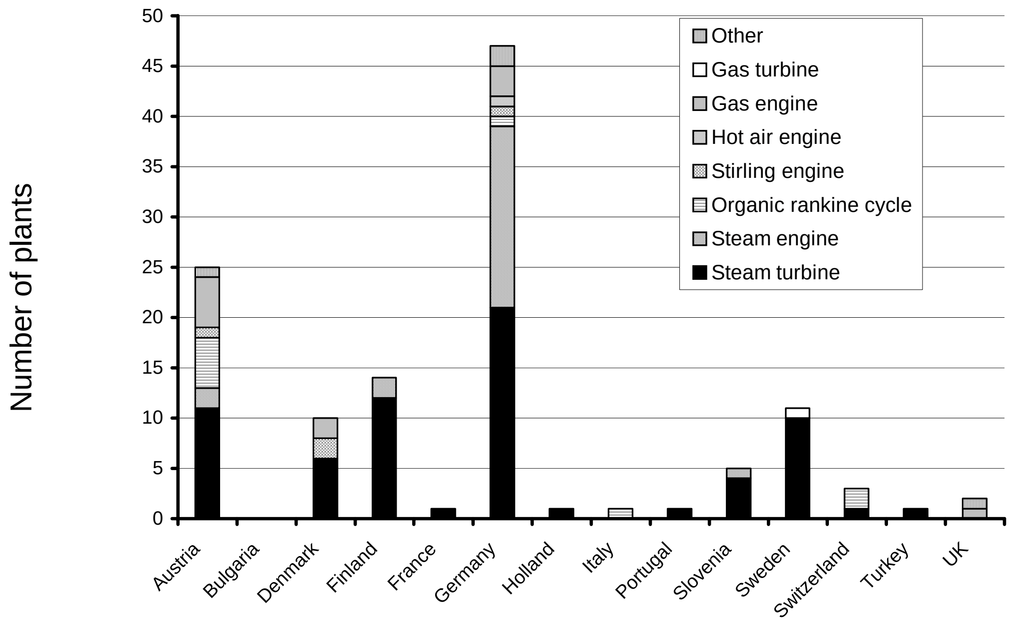


Figure 4: Technologies of CHP plants with solid biomass

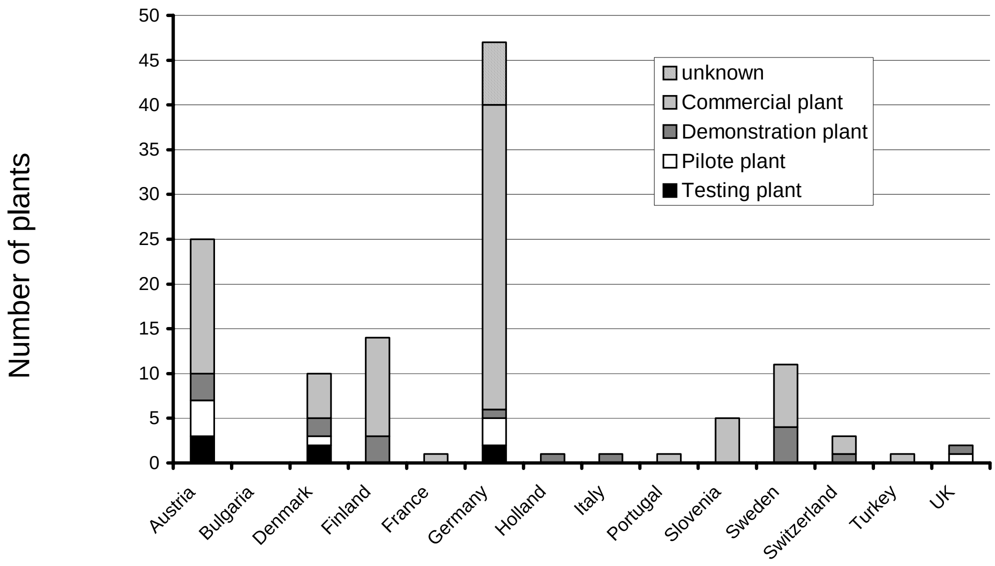


Figure 5: Character of CHP plants with solid biomass

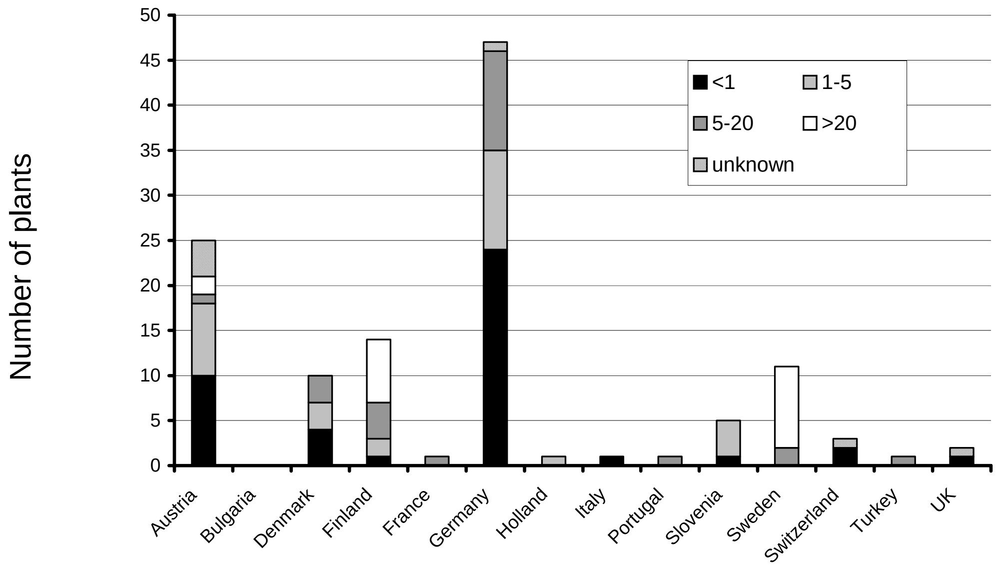


Figure 6: Electric power of CHP plants with solid biomass

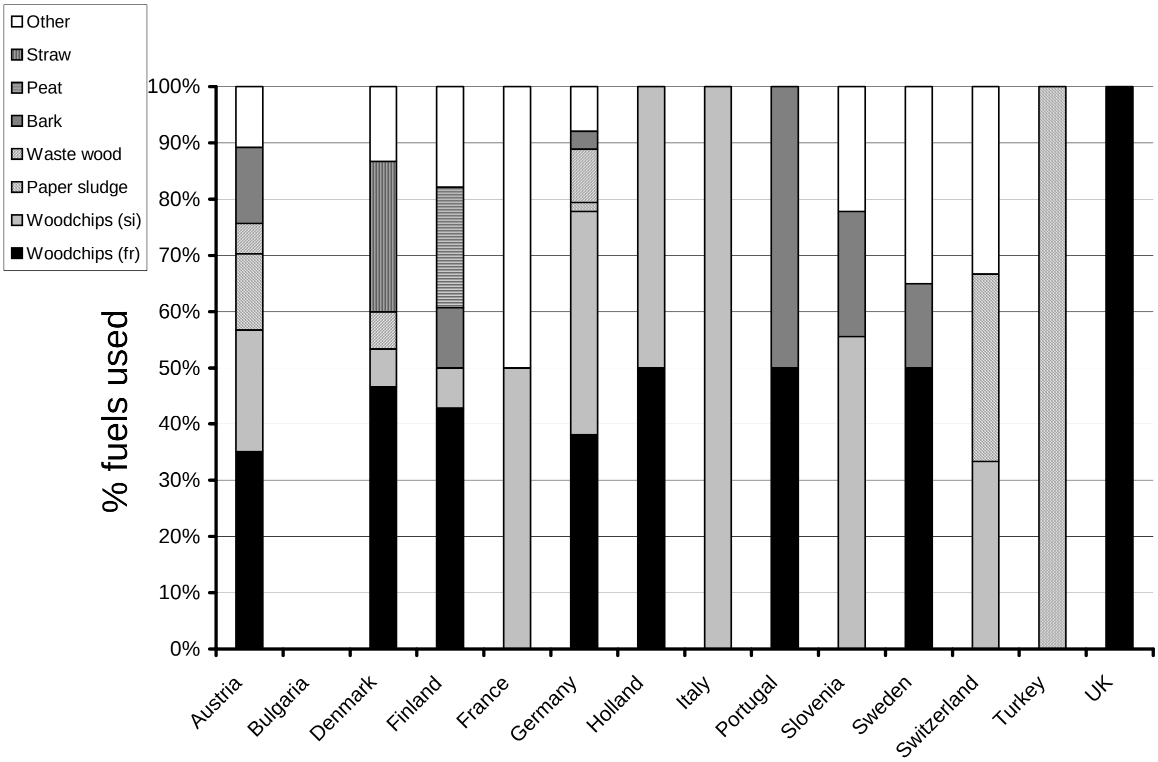


Figure 7: Share of solid biomass fuels used in the CHP plants

1.2 Construction year of existing solid biomass CHP plants

In Figure 8 the share of the construction year for the 122 CHP plants with solid biomass are shown. For nearly 50% of the existing solid biomass plants it was not possible to get information on the construction year, about ¼ of the existing biomass plants were built before 1995 and between 1995 and 2000. 7% of the analysed CHP plants were erected after 2000.

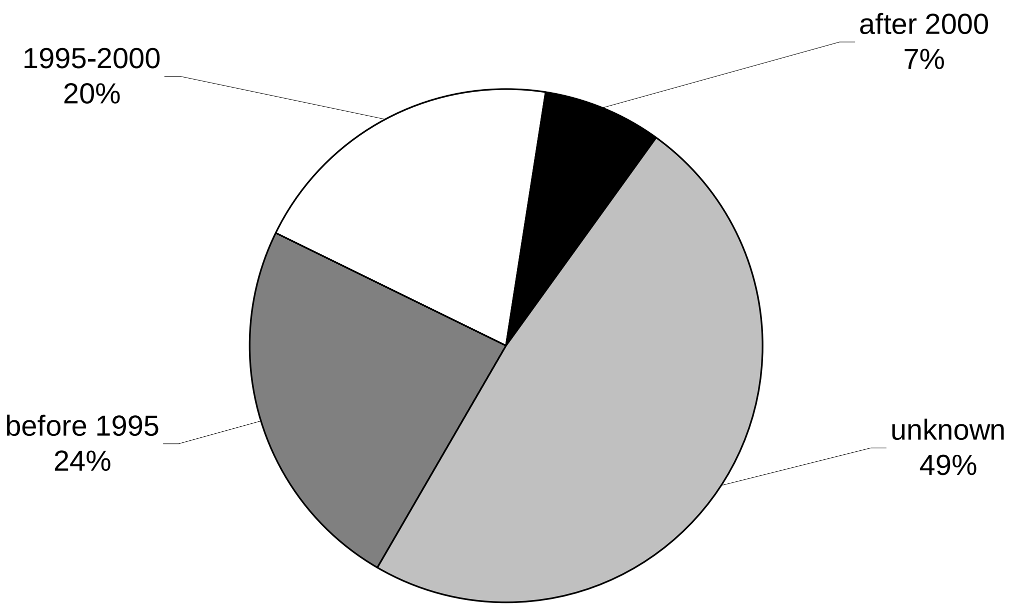


Figure 8: Construction years of the 122 CHP plants with solid biomass

1.3 Technologies of existing solid biomass CHP plants

In Figure 9 the technologies for the 122 CHP plants with solid biomass are shown, the steam turbine with 57% is the most important technologies followed by the steam engine with 19%. The other technologies are less than 22%, because these technologies are still under development.

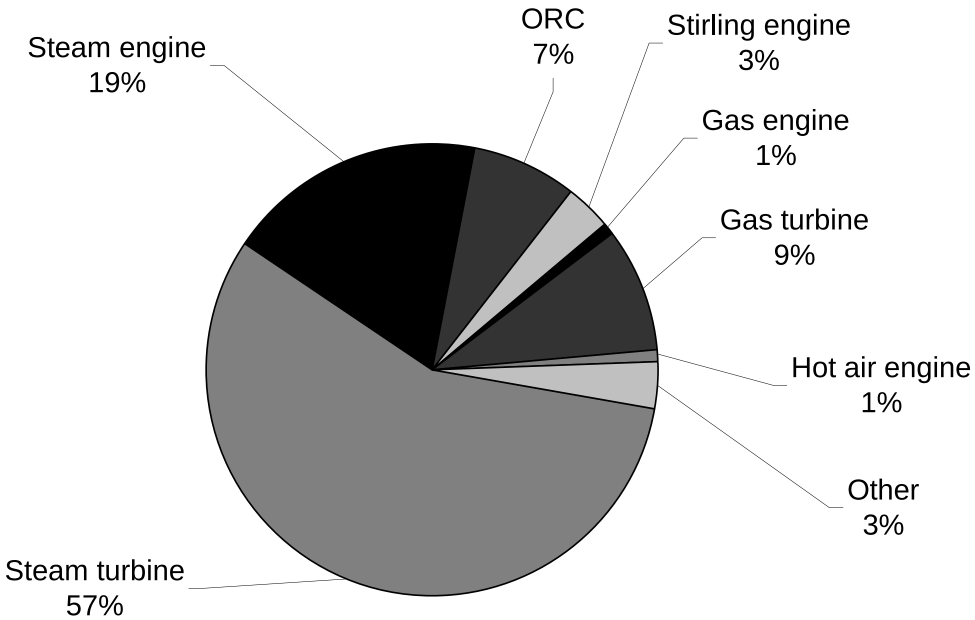


Figure 9: Type of power generation in the 122 CHP plants with solid biomass

Type of solid biomass fuels of existing CHP plants

In Figure 10 the type of the solid biomass fuel is shown. The wood chips dominate, whereas 38% are wood chips from forestry and 24% are wood chips from saw mill residues. Bark with 8%, waste wood with 5% and paper sludge with 4% are also important biomass fuels used in CHP applications.

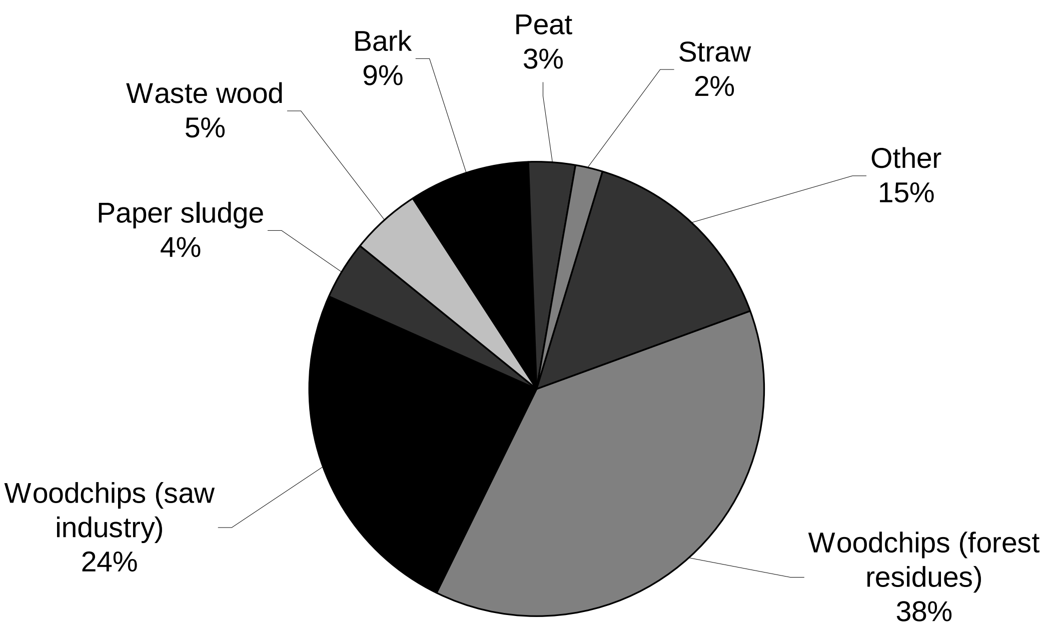


Figure 10: Fuels of the 122 analysed solid biomass CHP plants

1.4 Character of existing solid biomass CHP plants

In Figure 11 the character of the 122 CHP plants with biomass are shown. 67% of the existing plants are commercial plants and 14% are demonstration plants. The rest is 7 pilot plants and 6% testing plants, which mainly are used to collect experience with new CHP technologies for solid biomass applications.

In Figure 12 it is shown, that 84% of the 122 solid biomass CHP plants have no co firing of fossil fuels, whereas 16% are co firing installation with fossil fuels, mainly coal.

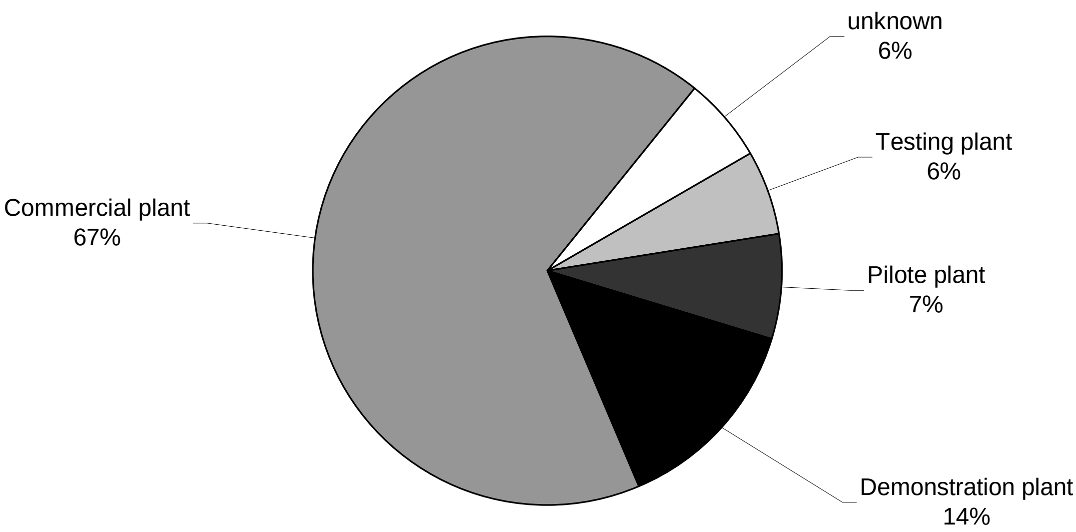


Figure 11: Character of the 122 CHP plants with solid biomass

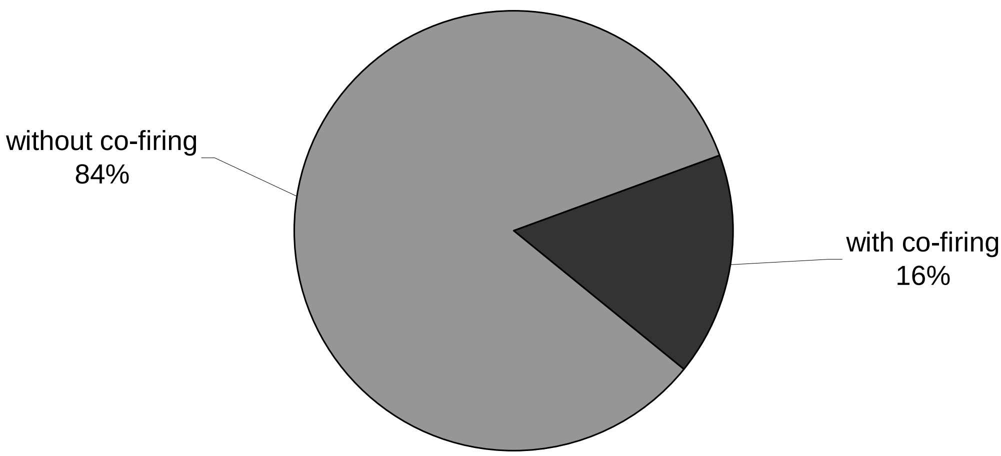


Figure 12: Share of the 122 solid biomass CHP plants with and without co-firing

1.5 Electric and thermal power of existing solid biomass CHP plants

In Figure 13 the electric power of the 122 analysed solid biomass CHP plants are shown. 35% have an electric power of less than 1 MW_{el} and 24% have an electric power between 1 and 5 MW_{el}. Only 15% have an electric power of more than 20MW_{el}, this reflects that biomass is more used in small CHP applications where on important reason is, that the use of the heat is easier than in bigger applications.

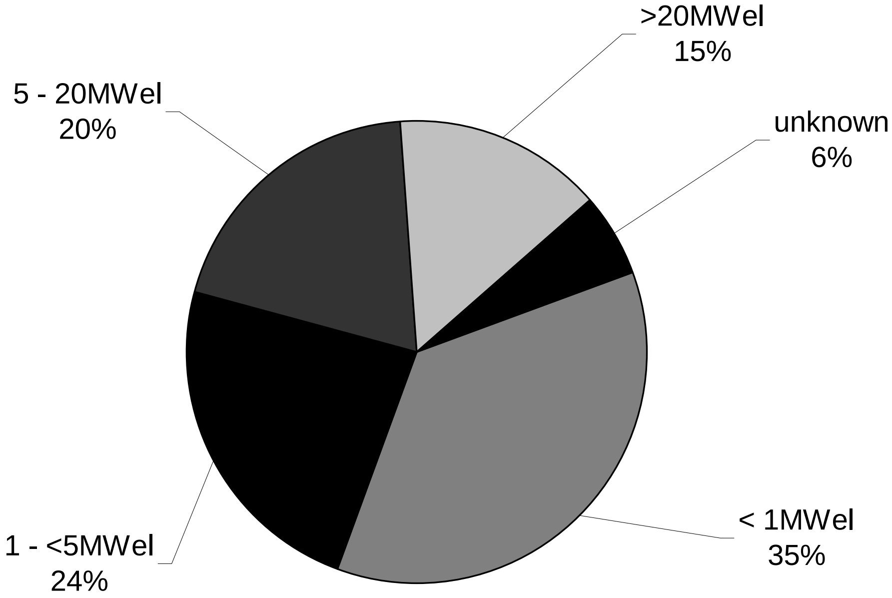


Figure 13: Electric power of the 122 analysed solid biomass CHP plants

In Figure 14 the electric and thermal power of the 122 solid biomass CHP plants are shown, where in Figure 15 a selection of plants with less than 50 MW_{el} and in Figure 16 with less than 5 MW_{el} is given. The range between electric and thermal power is quite big, whereas the big CHP (> 20 MW_{el}) applications have a comparatively low thermal power than the smaller CHP (< 5 MW_{el}). But for all CHP biomass plants it can be summarized, that the installed thermal power is very much depending on the regional or local conditions to satisfy an existing heat demand.

In Figure 17 the ratio of electric and thermal power is shown in relation to the fuel power, for more details in Figure 18 this correlation is shown for applications with less than 20 MW_{fuel}. The ratio of electric and thermal power varies very much for all CHP applications. The ratio of electric and thermal power seems to be very much depending on the side specific conditions that are mainly dominated by the possibilities of the use of the heat.

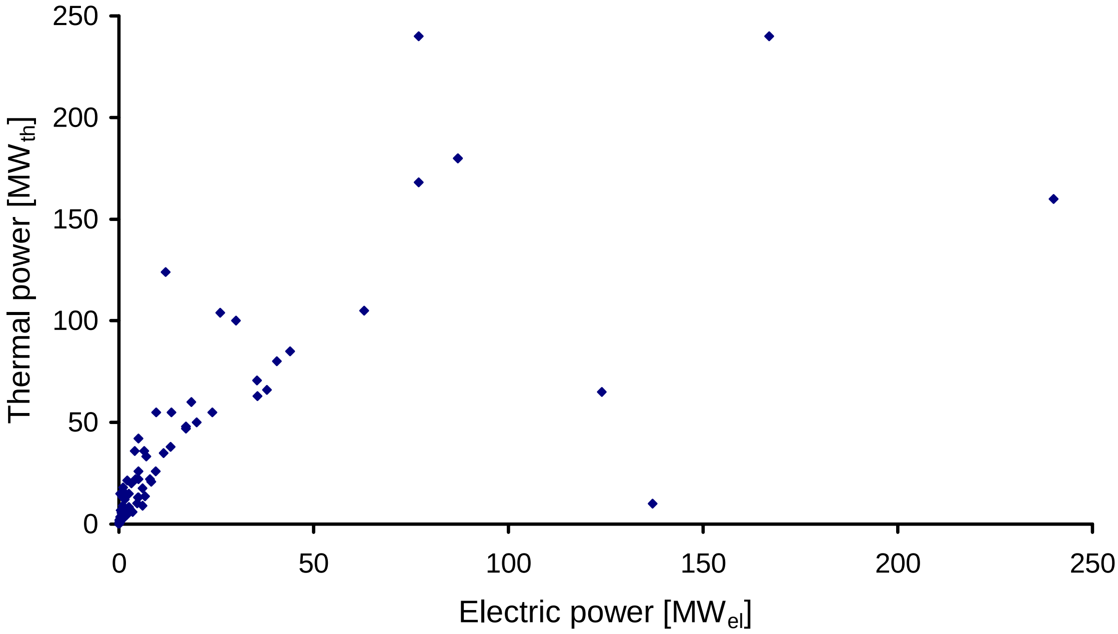


Figure 14: Electric and thermal power of the 122 analysed solid biomass CHP plants

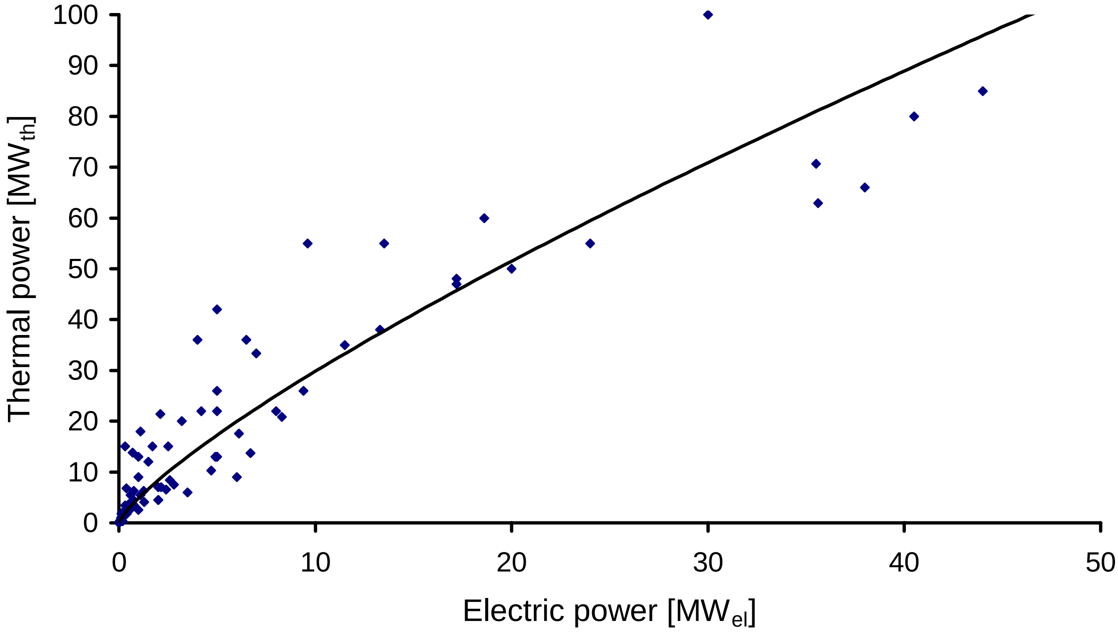


Figure 15: Electric and thermal of the solid biomass CHP plants with less than 50 MW_{el}

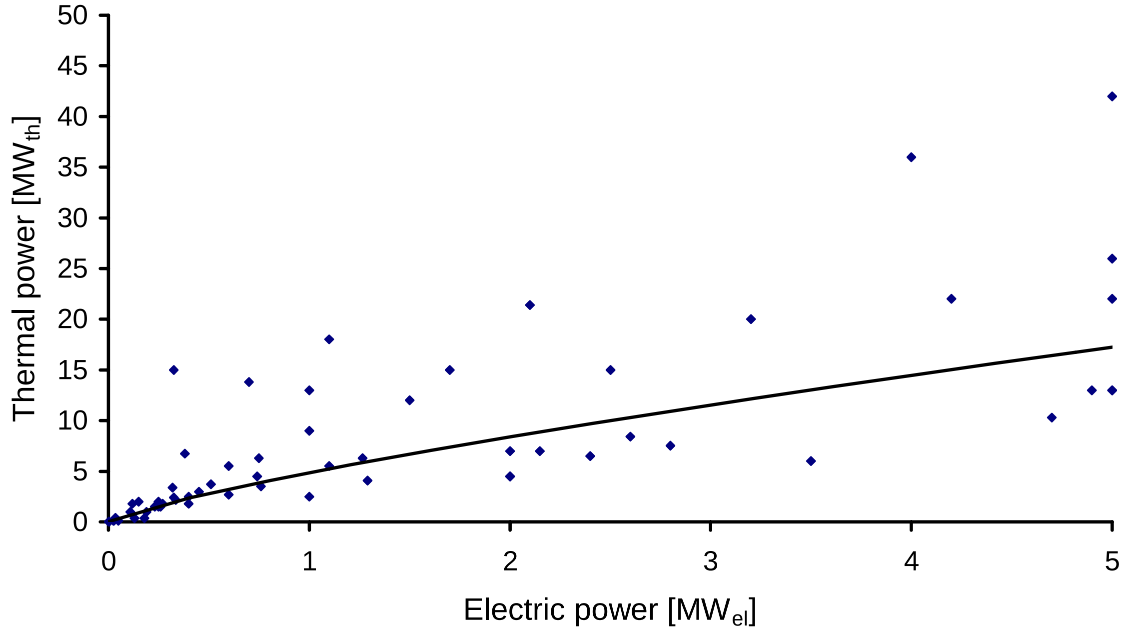


Figure 16: Electric and thermal of the solid biomass CHP plants with less than 5 MW_{el}

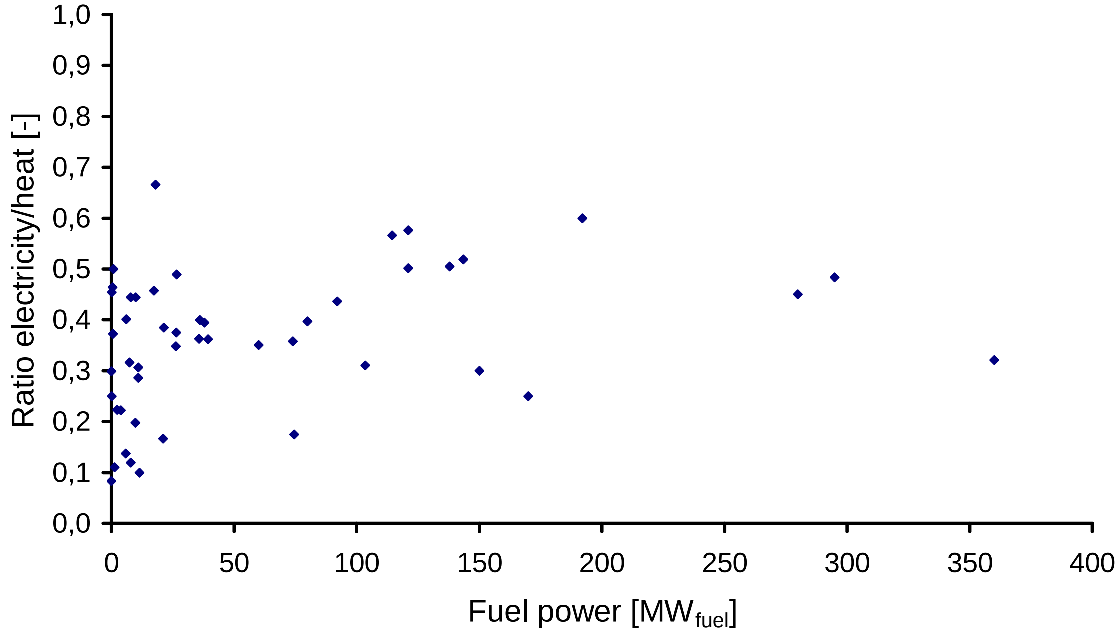


Figure 17: Ratio electricity/heat and fuel power for the 122 solid biomass CHP plants

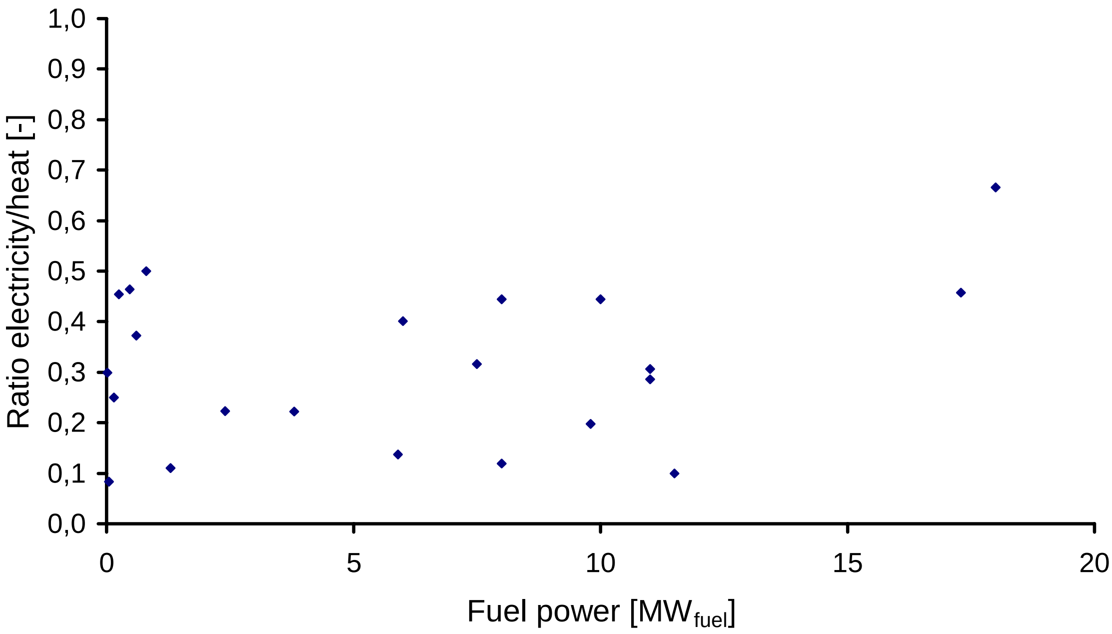


Figure 18: Ratio electricity/heat and fuel power for the 122 solid biomass CHP plants with less than 20 MW_{fuel})

1.6 Efficiencies of existing solid biomass CHP plants

In Figure 19 the electric efficiency of the 122 solid biomass CHP plants is shown compared to electric power. In general it can be concluded that the electric efficiency is increasing with the electric power, and small CHP applications have a relatively low electric efficiency. In big Co firing CHP plant very high efficiencies are possible depending on the fossil fuel used as main energy carrier.

In Figure 20 the electric efficiency is shown for biomass CHP applications with an electric power of less than 10 MW_{el}. Compared to bigger application the electric efficiency of steam turbine is lower but it is still higher than applications with steam engines. Gas turbines and gas engine, that are driven with wood gas from gasification, seem to have a reasonable high efficiency in small scale biomass CHP applications.

In Figure 21 the electric efficiency is shown for biomass CHP applications with an electric power of less than 1 MW_{el}. The electric efficiency of small CHP applications is very much depending on the technology and configuration used, therefore relatively high electric efficiencies above 20% and relatively low efficiencies below 10% are possible. Some small scale CHP applications are mainly designed to satisfy an existing heat demand where the production of electricity is only a “positive” side effect.

In Figure 22 the electric, thermal and total efficiency of the 122 solid biomass CHP plant are shown in dependence of the electric power, and in Figure 23 for CHP plants with less than 50MW_{el}. As mentioned above the electric efficiency is increasing with an increasing total electric power, whereas the thermal efficiency is decreasing with increasing electric power, because the amount of heat produced could not be used totally. Therefore the total efficiency, the sum of electric and thermal efficiency is decreasing over the size of the CHP plant, because big parts of the produced heat must be given to the environment, because there is no economic reasonable use of the total heat produced in the region around the CHP location; long transportation of heat is not very economic. In general small CHP applications are more common to satisfy a predefined heat demand and are therefore often driven by the heat demand. The big CHP plants are more oriented to produce electricity and the use of some heat is a so called “positive” side effect. The operation of big CHP plants is more electricity oriented.

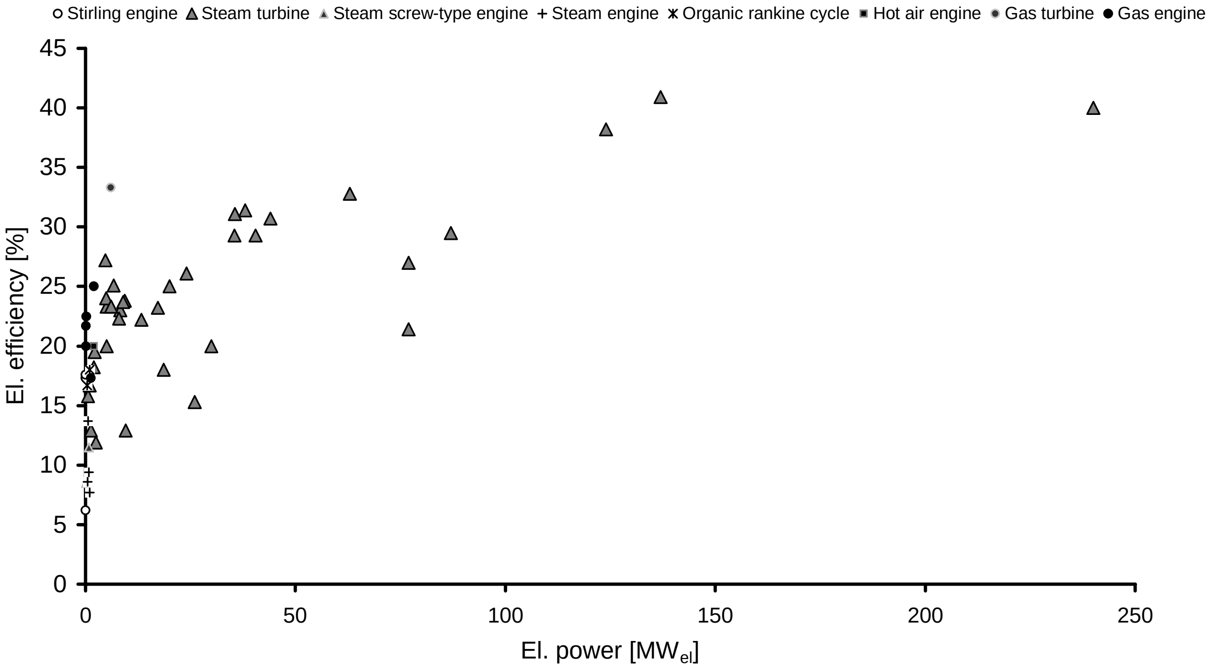


Figure 19: Electric power and electric efficiency of 122 solid biomass CHP plants

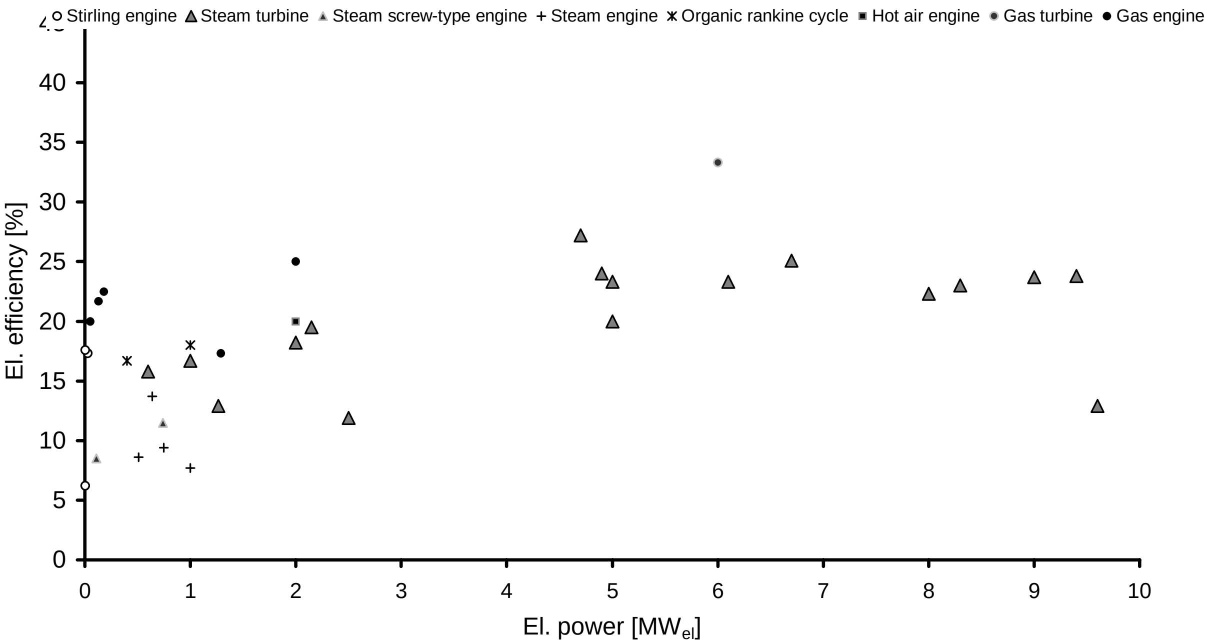


Figure 20: Electric power and electric efficiency of solid biomass CHP plants with an electric power of less than 10 MW_{el}

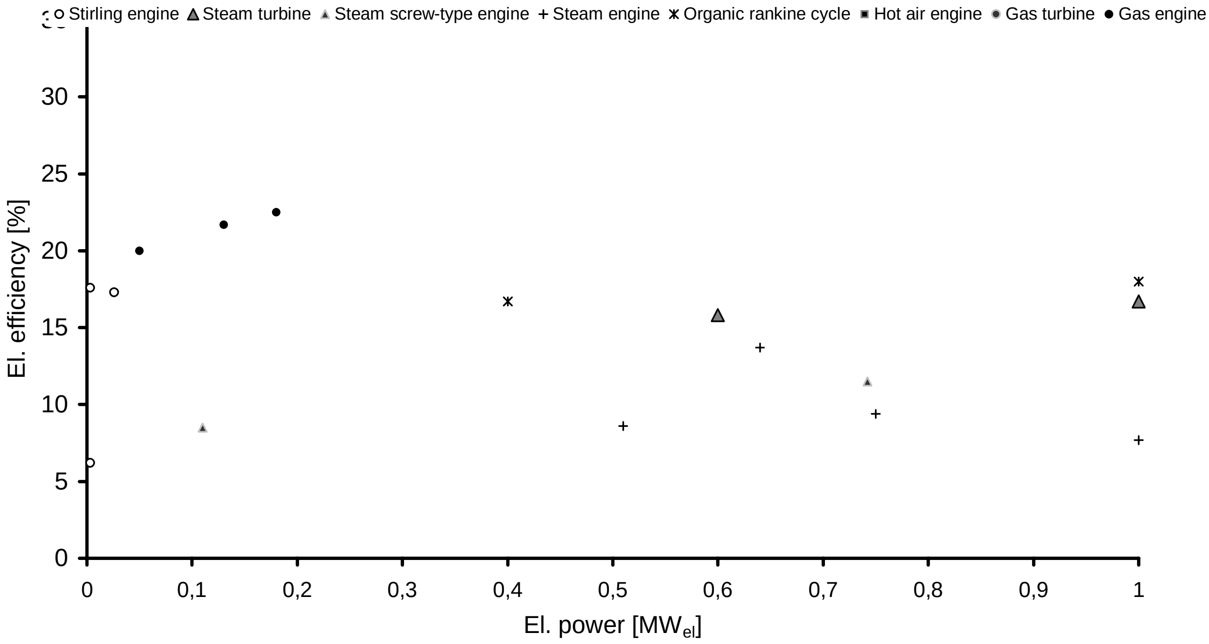


Figure 21: Electric power and electric efficiency of 122 solid biomass CHP plants with an electric power of less than 10 MW_{el}

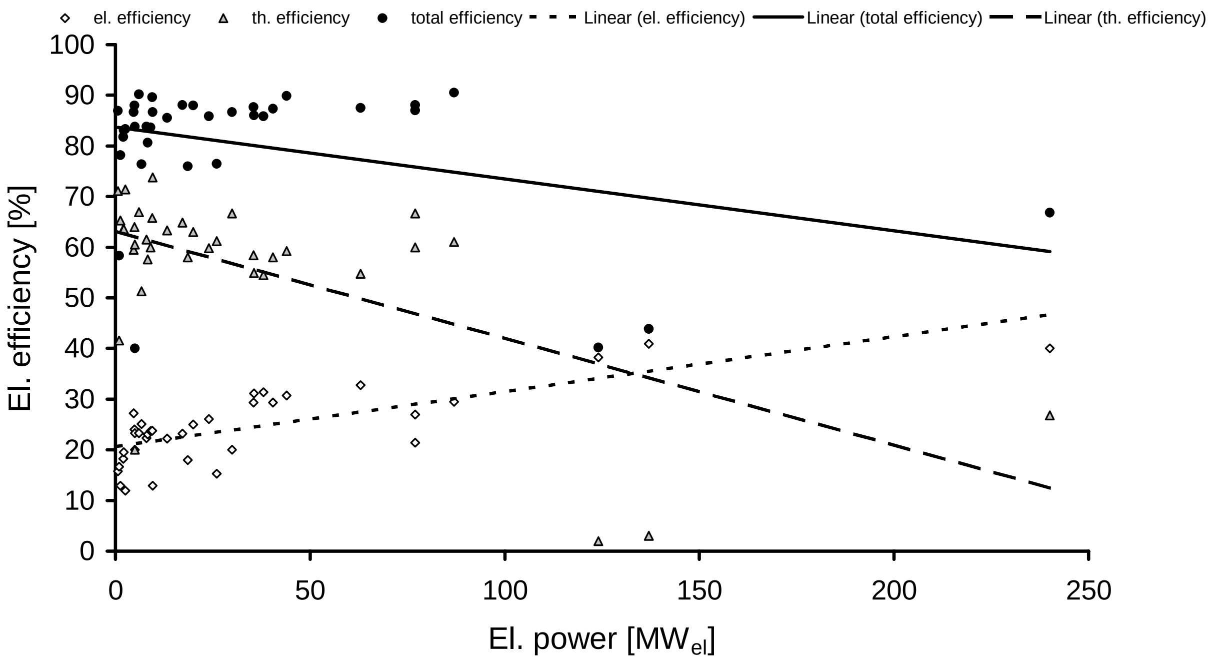


Figure 22: Electric power and electric efficiency of solid biomass CHP plants with steam turbines

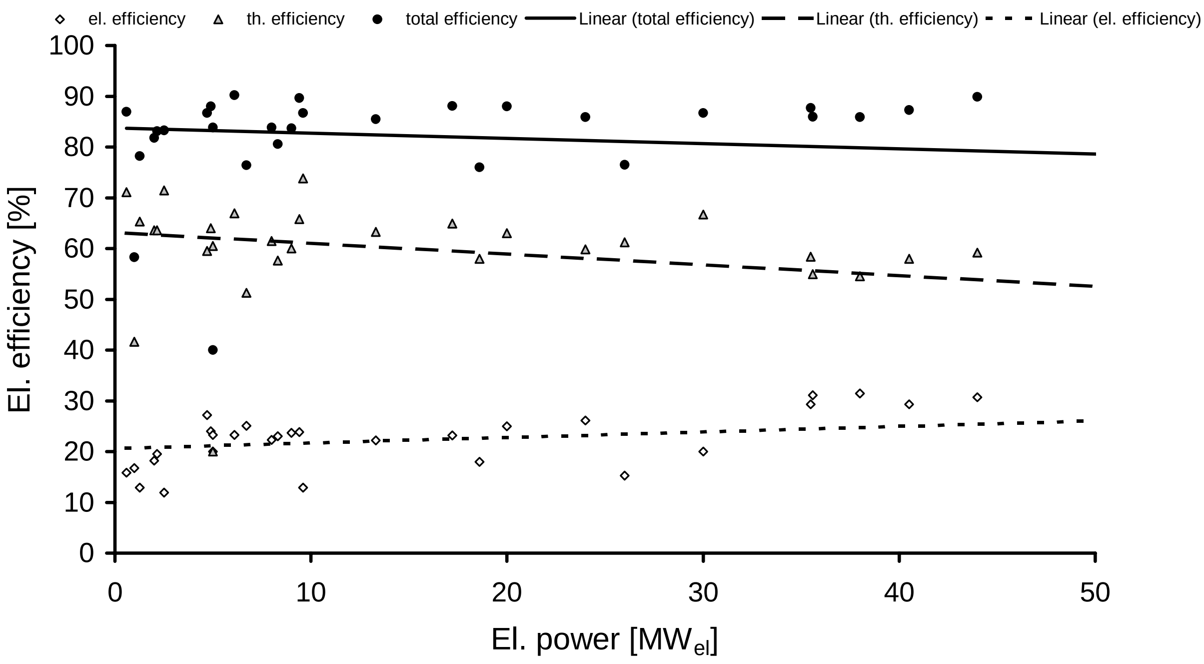


Figure 23: Electric power and electric efficiency of solid biomass CHP plants with steam turbines electric power less than 50 MW_{el}

1.7 Investment costs of existing solid biomass CHP plants

In Figure 24, Figure 25, Figure 26 and Figure 27 the specific investment costs are shown in relation to the installed electric power of the 122 solid biomass CHP plants, which are sorted by the character of the plant, the technologies and the electric power installed. The specific investment cost decrease with an increasing installed electric power. Of course commercial CHP plants have in general lower specific costs than demonstration and pilot plants. For CHP applications above 2 MW_{el} the steam cycle with a steam turbine seems to have the lowest specific investment cost. For applications below 2 MW_{el} future results of ongoing demonstration and pilot projects will bring information, what might be low-cost technologies for small scale solid biomass CHP applications.

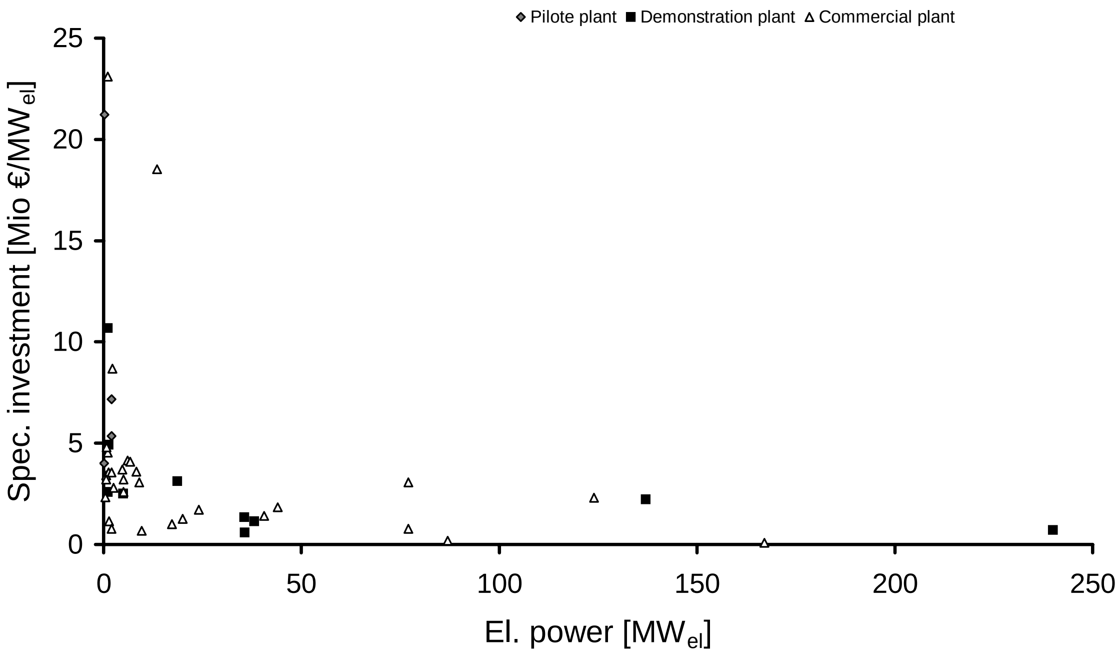


Figure 24: Specific investment costs and electric power of the 122 solid biomass CHP plants sorted by character of plant

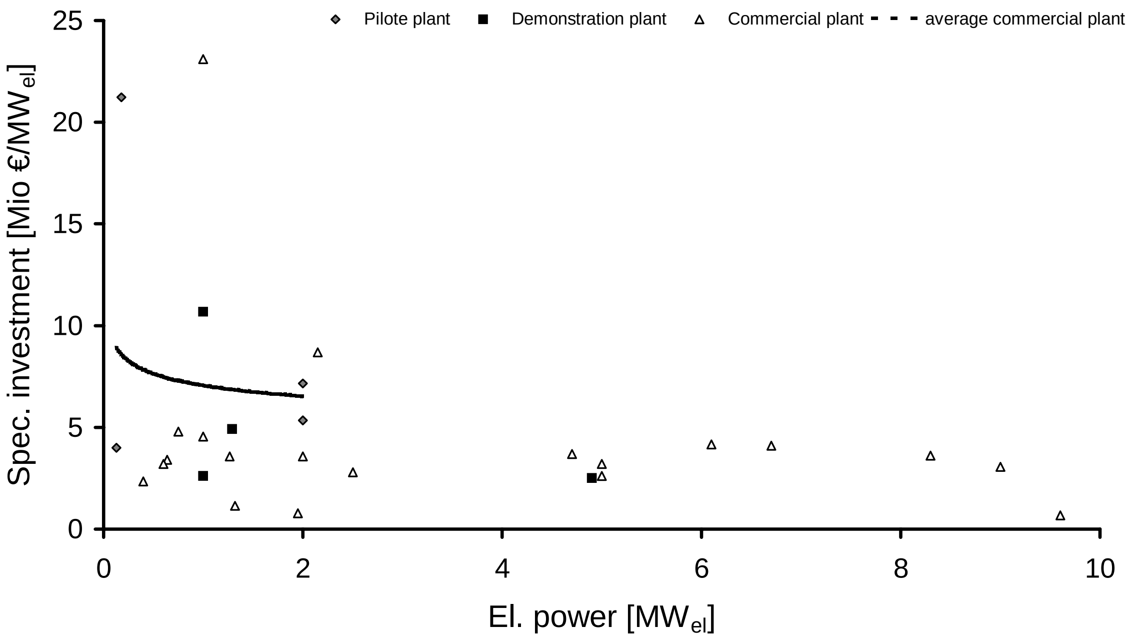


Figure 25: Specific investment costs and electric power of the 122 solid biomass CHP plants sorted by character of plant and with an electric power of less than 10 MW_{el}

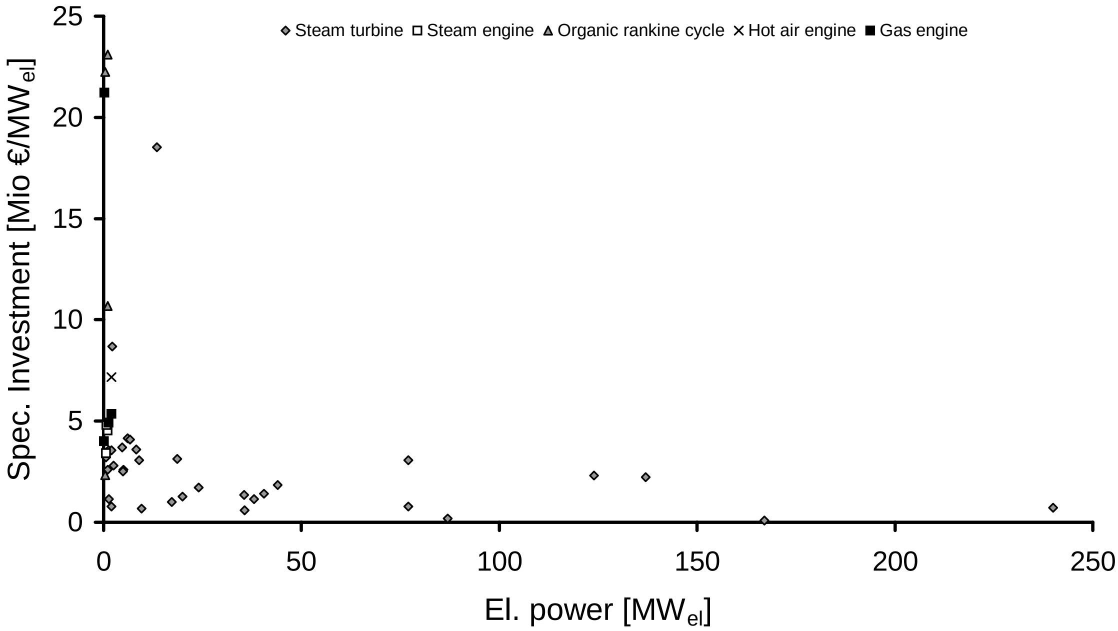


Figure 26: Specific investment costs and electric power of the 122 solid biomass CHP plants sorted by sorted by the different technologies

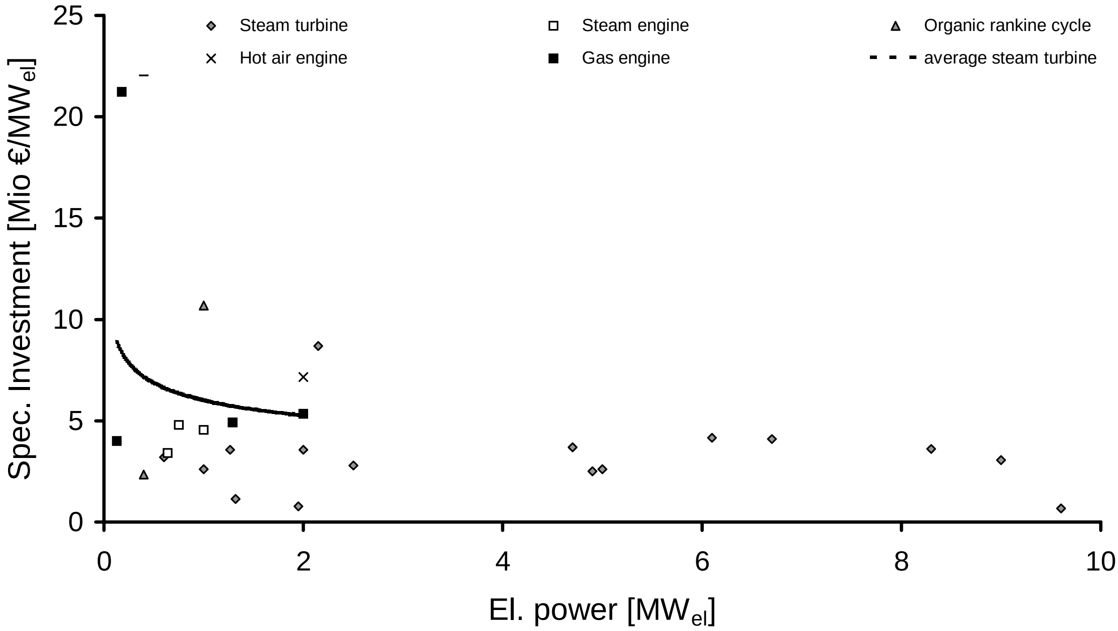


Figure 27: Specific investment costs and electric power of the 122 solid biomass CHP plants sorted by sorted by the different technologies and with an electric power of less than 10 MW_{el}