WASTE TO ENERGY – HIGHER EFFICIENCY WITH EXTERNAL SUPERHEATING

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SUMMARY: The electrical efficiency of waste-to-energy (W-t-E) plants currently operating does not yet meet the new standards proposed by the European Union in the revision of the Directive 2006/12/EU (Waste framework Directive). The net electrical efficiency of W-t-E plants is only 20% up to 24%. The net electrical efficiency is not sufficient to achieve a power to heat ratio of 0.6 or in future 0.65 according to the proposed revision of the EU Waste Directive. In this presentation solutions for increasing the efficiency are shown. A new process technology for state-of-the-art waste-to-energy and biomass incineration plants will be presented.

1. INTRODUCTION

The electrical efficiency of waste-to-energy (W-t-E) plants currently operating does not yet meet the new standards proposed by the European Union in the revision of the Directive 2006/12/EU (Waste framework Directive). The net electrical efficiency of RDF-Incineration plants is about 20% to 24%. The net electrical efficiency is not sufficient to achieve a power to heat ratio of 0.6 or in future 0.65 according to the proposed revision of the EU Waste Directive.

We hereby present a new process technology for state-of-the-art W-t-E and biomass incineration plants. The following measures are already implemented in different plants on industrial scale:

1. Reducing of waste gas losses by adjusting the lambda value to less than 1.25. The process is controlled by a substoichiometric atmosphere on the grate. The fuel gas from the substoichiometric grate is burned in a multi-stage process.
2. Increasing energy efficiency with higher steam parameters by external superheating.
3. Reduction of heat loss by using waste heat after flue gas cleaning, for instance preheating of fresh air, condensate-preheating or district heating with condensation of flue gas.

All three alternatives for measures to increase efficiency are, separately, already in use on industrial scale in a few plants. External superheating to achieve higher steam parameters is also currently done with natural gas and live steam. For this purpose the use of the “peak load fuel” natural gas or oil is not efficient for “base load plants” like W-t-E plants or biomass plants in the long run.

Relatively low cost external superheating is possible with the newly developed BiFuelCycle-concept with lignite or anthracite. Its advanced efficiency will be demonstrated by combustion-calculation and calculation of the water-steam-cycle. The calculated net electric efficiency of > 35% for the BiFuelCycle-plant is about 25% to 50% higher than the efficiency of modern waste-to-energy plants and is able to meet the requirements of the proposed revision of the EU Directive without further measurements.

2. REDUCTION OF LAMBDA VALUE

Coal firing power plants have a boiler efficiency of about 93 % opposed to W-t-E plants with about 83 % boiler efficiency. This is because W-t-E plants are operated with higher lambda values and relatively high flue gas temperature after the boiler. To avoid overheating of the grate bars there is typically no combustion air preheater using flue gas. Minimizing of lambda value is limited by the incineration process. For incineration of an inhomogenous fuel such as waste, a high lambda value is necessary and higher exhaust gas heat losses are unavoidable. Figure 1 shows the correlation between lambda value and adiabatic temperature in the boiler.

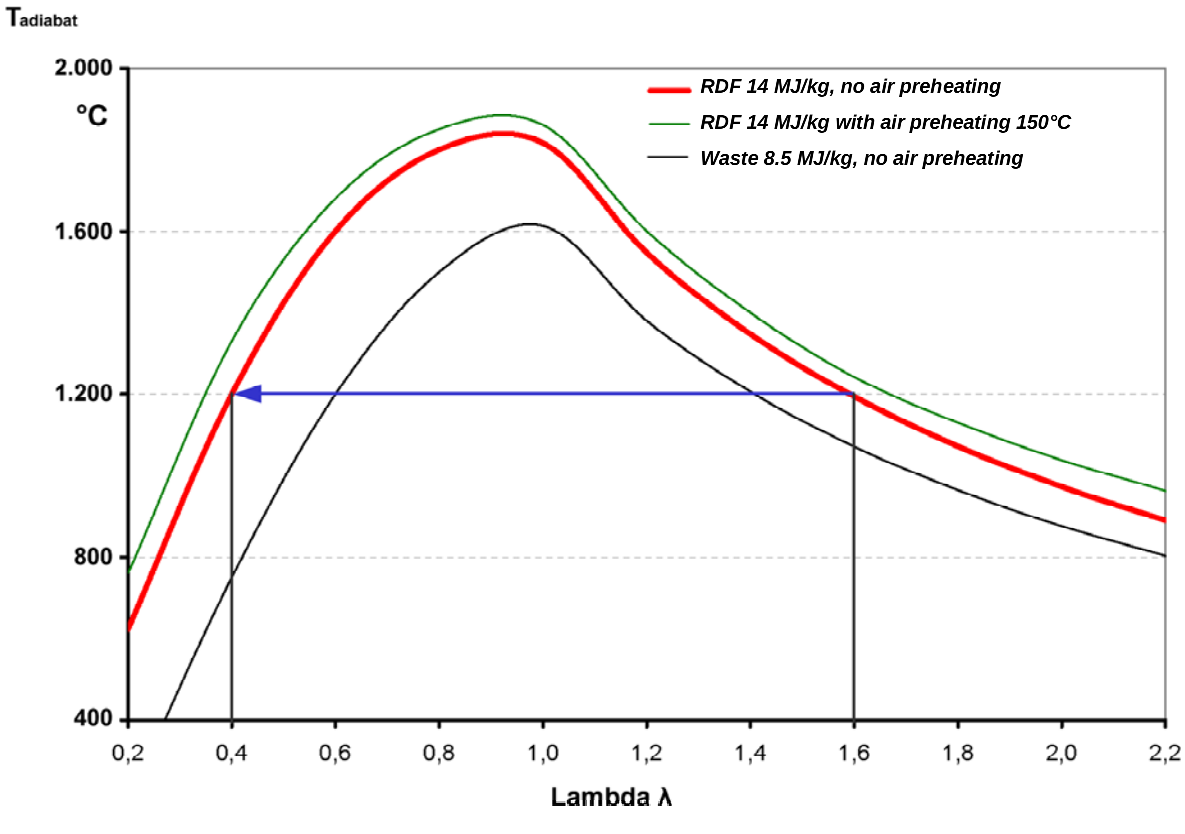

Figure 1: Adiabatic temperature against lamda value

A lower lambda value of 1.1 to 1.2 can be achieved with substoichiometric combustion on a grate (partly gasification) by applying the following optimizations:

- Adapted firing power control
- Homogenization of the flue gas stream by air, recirculating flue gas or steam injection and/or by installation of features with additional air injection as shown in figure 2.

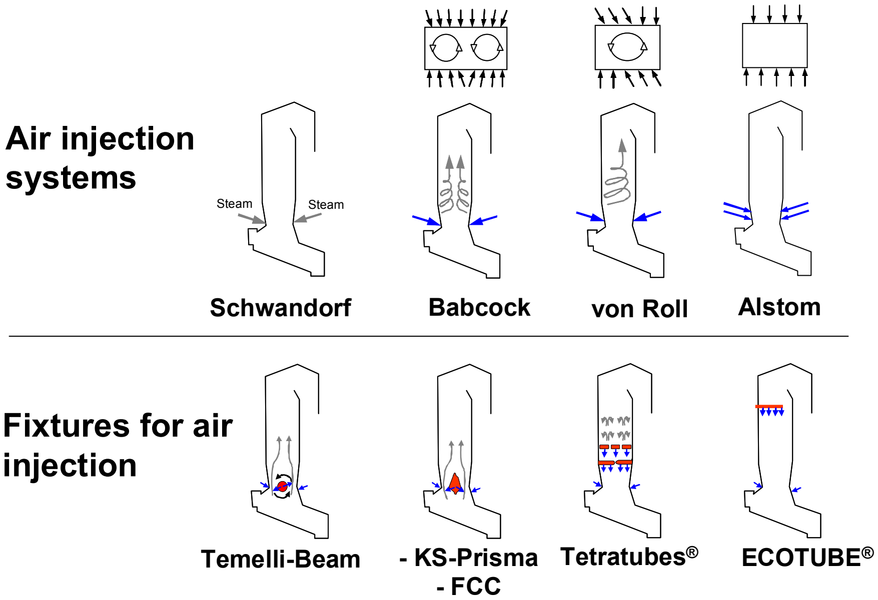

Figure 2: Flue gas homogenization and combustion air distribution, different concepts

The BiFuel Cycle concept is based on the described optimization and is designed according to the following general rules:

- Reduction of lambda value to less than 1.25 to lower the amount of flue gas
- Less corrosion and slagging despite higher steam pressure by Homogenisation of flue gas temperature in the first flue
- Focus on better total efficiency
- Flexible fuel parameters up to a heating value of 32,000 kJ/kg
- Reduction of fly ash
- Better slag properties (burnout, fusion)
- Reduction of flue gas emission
- Less utilities because of less NOx

The concept is designed using well known technologies and components as shown in figure 3:

- Grate fired steam boiler with substoichimatric combustion (for example Igelsta Power plant, Södertälje, Sweden with about 100 MW)
- KS-Prisma for the first air injection
- Tetratubes for further air injection
- Tetratubes or ECOTUBE for the final air injection and addition of chemicals for NOx-reduction at a temperature of 850 °C to 950 °C
- Optimized firing control with separate control for grate and afterburner
- Optional steam injection through fixtures or boiler walls for flue gas homogenisation

As shown in figure 3, the temperature profile avoids peaks higher than 950°C, even at high heating values, and such provides optimum conditions for NOx-reduction and disintegration of dioxine precursors such as for example PCB.

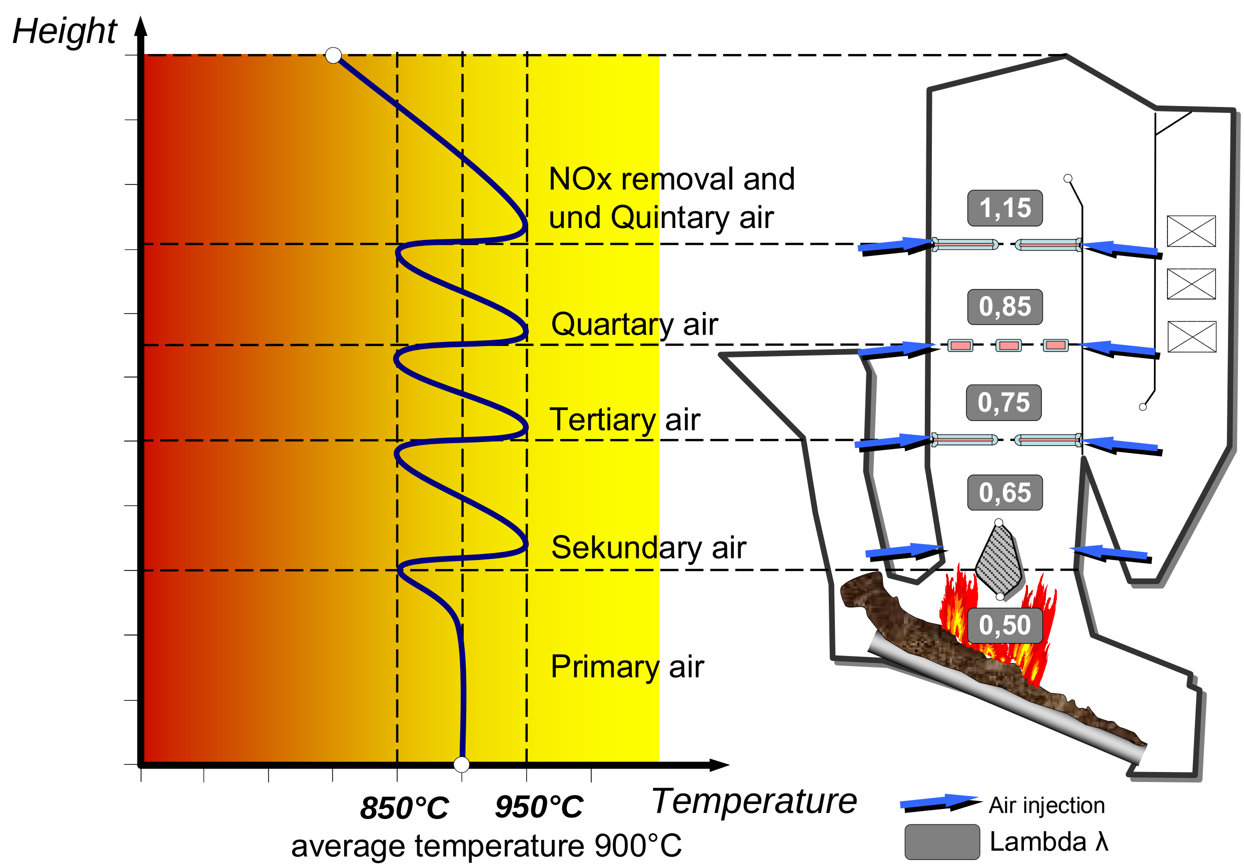

Figure 3: Temperatur profile with optimized firing concept

3. HIGHER STEAM PARAMETERS

Aside from optimized combustion, higher overall efficiency of a W-t-E plant can also be achieved by better use of waste heat. The BiFuel Cycle concept comprises both by using external superheating.

There is no sense in using precious fossil fuels like oil or natural gas for superheating steam from W-t-E plants. These fuels can be burned much more efficiently in separate power plants.

Solid fuels with a lower fuel inherent efficiency such as lignite are much more suited for the pupose. Another possibility would be the intergration of the W-t-E plant into an existing power plant. However, coal fired power plants generally are not as flexible to allow for additional live steam superheating.

4. DEVELOPMENT OF A SUITABLE SUPERHEATER

As a suitable technology for the proposed superheater we developed a circulated fluidized bed reactor with refractory lining (bricks). 75% of the process heat is coupled out via the fluidized bed cooler (see figure 4).

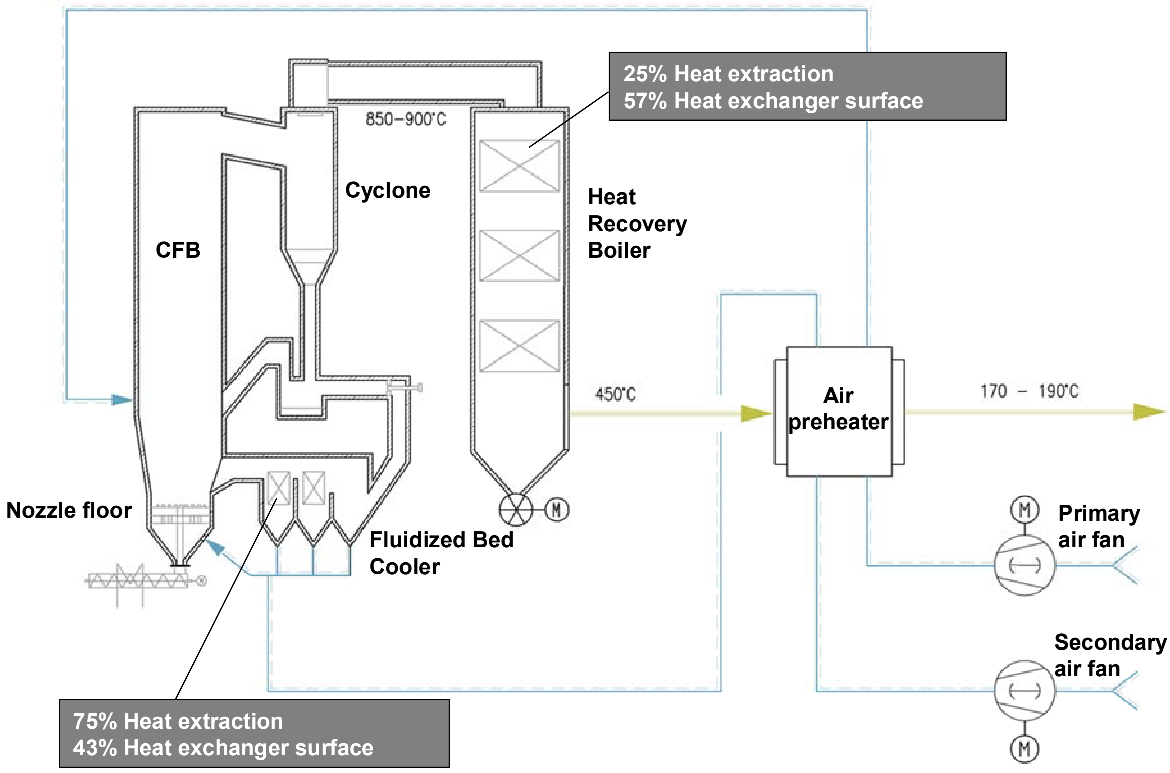

Figure 4: Ratio of heat exchanger surfaces and heat extraction

4. WATER-STEAM-CYCLE BIFUELCYCLE

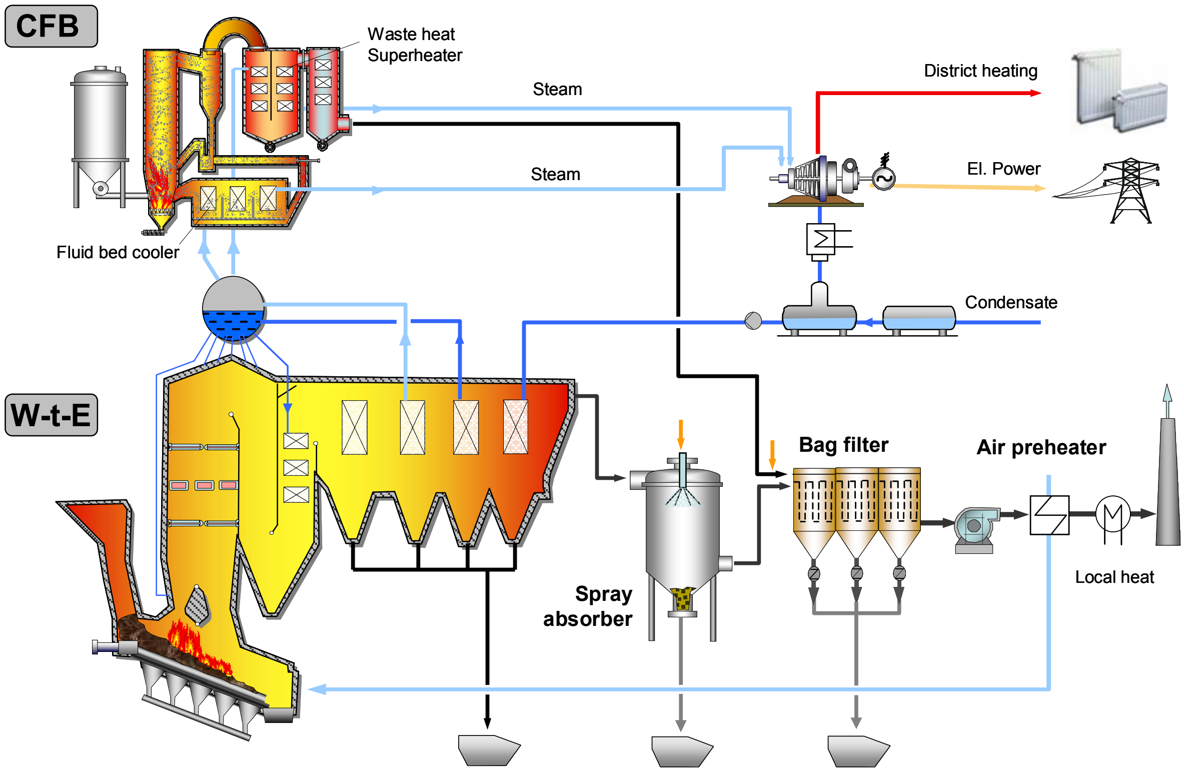

Figure 5: Process Flow Diagram BiFuelCycle

Figure 5 shows the process flow diagram of the BiFuelCycle concept. Because of the external superheating, the steam parameters pressure and temperature are defined as follows:

- Maximum steam pressure of the W-t-E plant, limited by
  - Corrosion potential of the waste fuel
  - Process optimisation of the combustion
  - Corrosoin protection measures
- Available steam turbines, depending on the plant size.

Steam pressure up to 180 bar with evaporation temperature of 357 °C is possible. However, steam drum pressure should not be higher than 165 °C to enable a natural circulation process. The T,s –diagram is shown in figure 6.

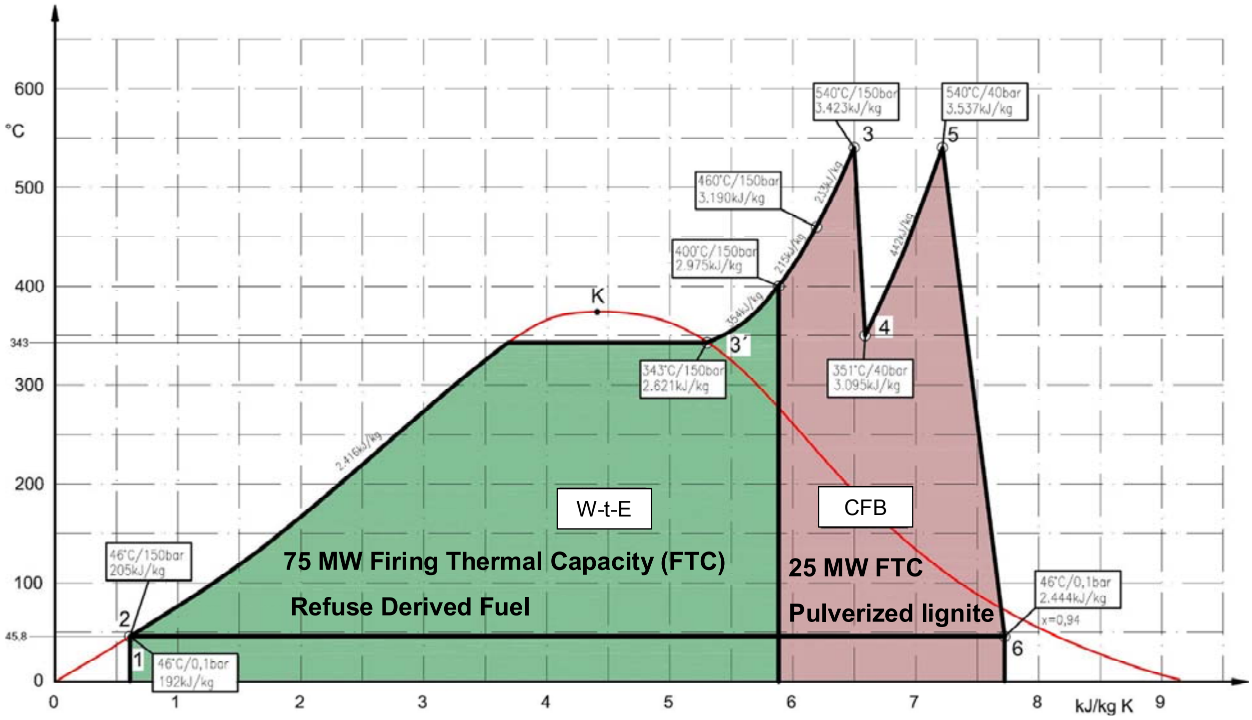

Figure 6: T,s-diagram BiFuel Cycle

For intermediate superheating by CFB, anthracite or lignite can be used. Main process (waste boiler) and side process (CFB) with different fuel are connected via the steam drum. The BiFuelCycle process requires at least one intermediate superheating step. Figure 7 shows the fuel proportion of waste (RDF) and lignite for the CFB-superheater.

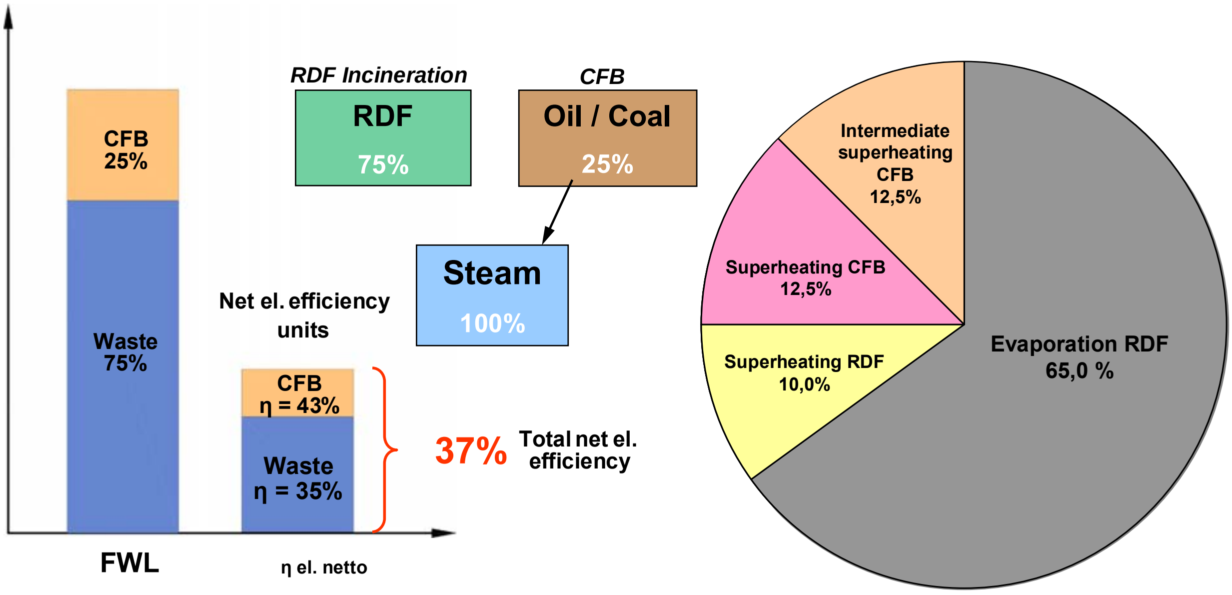

Figure 7: Fuel ratio, evaporation and energy

The net electrical efficiency for the BiFuelCycle concept relates to the overall fuel input. To compare the net el. efficiency of waste incineration with BiFuel Cycle to waste incenration withconventional W-t-E, the fuel inherent efficiency for lignite combustion has to be taken into account as well. In figure 7 net el. efficiency for lignite is assumed with 43 %.

Figure 8 shows the circuit diagram of a standard W-t-E plant with calculated net el. efficiency of 23 -24 %.

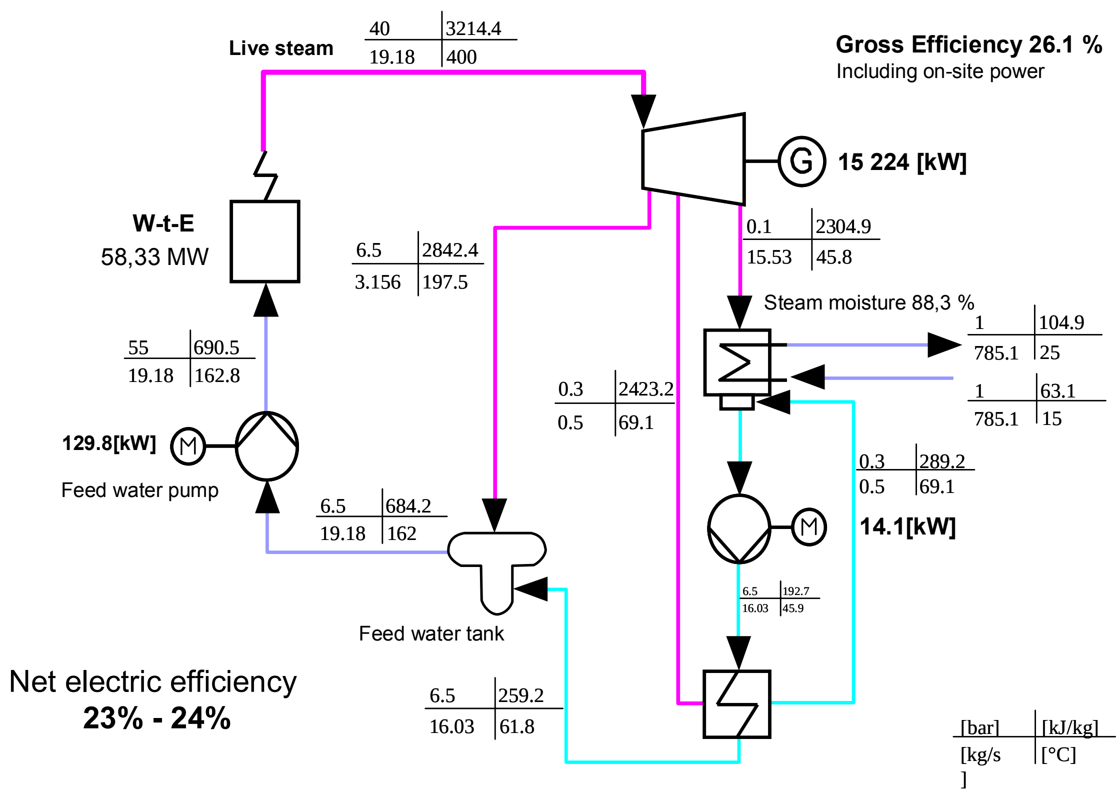

Figure 8: KPRO circuit-diagram standard W-t-E plant

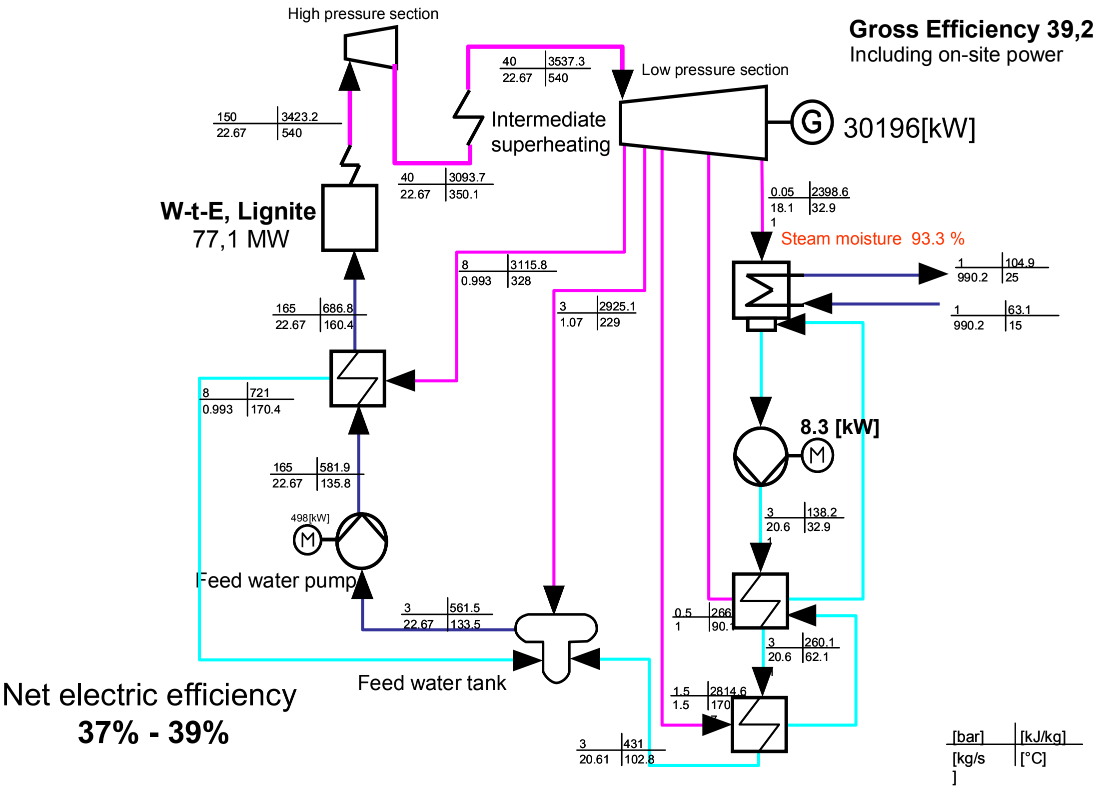

Figure 9: KPRO circuit-diagram standard BifuelCycle plant

The circuit diagram of the BiFuelCycle plant, with CFB intermediate superheating and lignite, is depicted in figure 9. The net el. efficiency is 37-39%, depending on the plant site.

The CFB fuel has a large effect on the efficiency of waste incineration. Natural gas for example has a fuel inherent net el. efficiency of 63% in a mordern combined cycle plant. With using natrual gas for superheating the net el. efficiency of waste incineration would be as low as 28% to 30% compared to 37% to 39% with lignite.

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