Association européenne pour la Biomasse

European Biomass Association

SECRETARIAT :
JOSSART Jean-Marc
Croix du Sud 2, Bte 11
1348 Louvain-la-Neuve
BELGIUM
Tél. and fax : + 32 10 47 34 55
Mobile : +32 478 77 36 09
e-mail : jossart@aebiom.org
http://www.aebiom.org

Report to project Key Issues for Renewable Heat in Europe - K4RES-H

Innovation for BioHeat

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1. Introduction

This report has to purpose to show innovative production of heat or cold which are produced with biomass (deliverable #24 of the project). First, the innovative air conditioning system will be exposed. The energy which is utilised by a “classical” air conditioning system is used by the compressing unit, thus the innovation has to purpose to replace power compressing unit by “heat compressing unit”. Those units are adsorption and absorption unit.

The second part is constituted by innovative Combined Heat and Power (CHP) systems. In one hand, a CHP using pebble heat technology is presented, which permits to increase the heat and power yield and in the second hand a tri-generation system (CHPC with last C for cold) is described, producing heat, power and cold. Those 2 systems allow recovering heat in the exhaust gases which is normally lost with classical CHP cycles.

In the third part, one innovative application of individual production of heat is exposed: the condensing pellets boiler, which allows recovering heat contains in the smoke in the form of steam. This application allows increasing the yield of the boiler.

All these systems are at a level of demonstration for the moment with no large scale commercialisation.

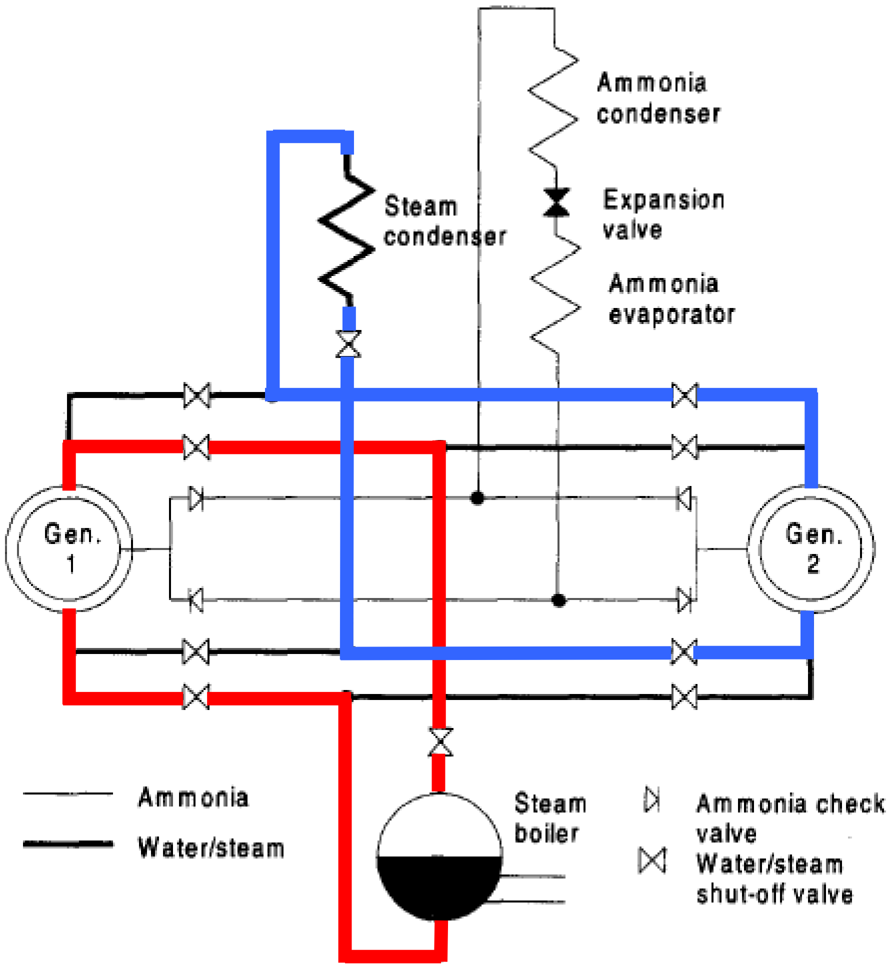
2. Air conditioning

2.1. Rapid cycling solar/biomass powered adsorption refrigeration system

Principle

The principle is to use an adsorption system which adsorb a gas at ambient temperature and release it when the system is warmed. 2 adsorption-desorption units are in opposition of phase to replace the compressor of a “classical” production of cold unit. The fluid which can be used is ammonia. The schematic diagram (figure 1) shows the functioning of the system. The blue is cold water and the red is warm water or steam. The production of cold is done by the ammonia evaporator. [Critoph R.E., 1999]

Figure 1: Schematic of an adsorption air conditioning unit

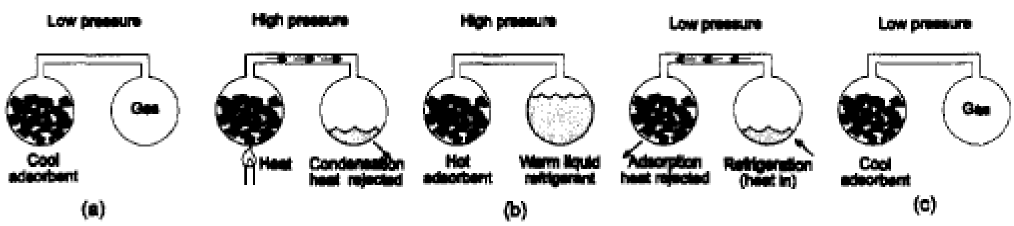


Source: Critoph R.E., 1999

The adsorption cycle

In this innovation, the production of cold is done by an adsorption cycle. Adsorption refrigeration cycles rely on the adsorption of a refrigerant gas into an adsorbent at low pressure and subsequent desorption by heating. In its simplest form an adsorption refrigerator consists of two linked vessels, one of which contains adsorbent and both of which contain refrigerant as shown in Figure 2 [Critoph R.E., 1999].

Figure 2: the adsorption cycle



In the first step, the whole system is at low pressure and contains refrigerant gas. The adsorbent contains a large quantity of gas. In the second step, the adsorbent is heated and rejects the gas which condenses in the second vessel. While it condenses, it rejects heat. During the third step, the whole system is at high pressure. In the fourth step the gas evaporates and is readsorbed by the adsorbent. During this step, the gas takes heat for evaporation. In the final step, the system is at the same state than in the first step. This system produces cold during a half part of the cycle, to produce cold continuously, two such cycles must be worked out of phase. The adsorbent is made in carbon and the refrigerant gas is ammonia. For increase the performance of the system, two beds could be used.

Experimental system

The system shown in figure 1 is composed by 2 generators with adsorbent in it. The laboratory system has a large number of valves but a production version would have a single spool valve with two possible states. If we suppose that the generator 1 drives out refrigerant gas (ammonia) and the generator 2 adsorbs gas, we can see the way used by the water/steam to warm the generator 1 (red) and to cold the generator 2 (blue). The water is warmed by the steam boiler and cold by a condenser. The generator 1 drives out ammonia which goes to the ammonia condenser (heat reject) and then to an evaporator where cold is produced. Finally, the gas arrives in the second generator where it is adsorbed. When the generator 1 has finished to drives out the gas, the system is inversed and then, it is the generator 2 which drives out gas and generator 1 which adsorbs. So the system works out of phase.

Advantages

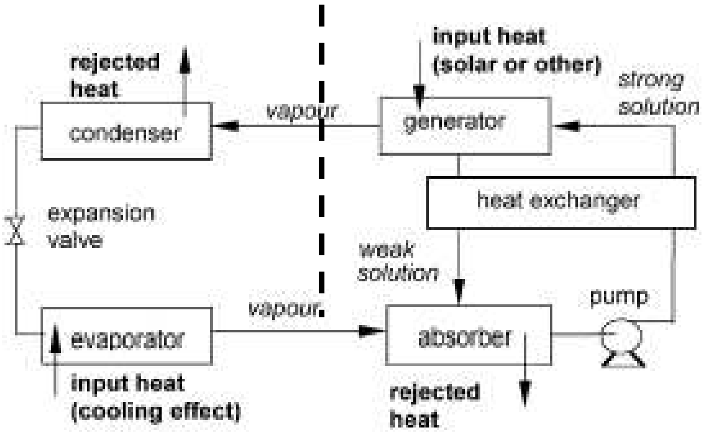
This innovation could save CO_2 emission, because heat could come from a renewable source (biomass or sun for example). It could also decrease the use of power which is generally uses in the cold unit. Thus, the functioning could be cheaper than for a classical cold unit. Another advantage is : it could be used where there is no power supply.

2.2. Air conditioning by an absorption cycle

Principle

Absorption is the process of attracting and holding moisture by substances called desiccants. Desiccants are sorbent, i.e. materials that have an ability to attract and hold other gases or liquids, which have a particular affinity for water. The principle is, at a high pressure, the desiccants absorb the steam and reject heat and at a low pressure, the desiccants reject the water and absorb heat. Figure 2 shows the principle of the air conditioning system, the part at the right of the dotted line replace the compressor of a "classical" cold unit [Soteris A.K., 2004]

Figure 2: Basic principle of the air conditioning system



Source: Soteris A.K., 2004

As shown in the figure 2, the vapour from the evaporator come to the absorber where it is absorbed in the desiccant (the heat is rejected). The solution becomes strong in water. A pump pumps the strong solution to the generator where heat (for example, from biomass) is used to separate, by evaporation, the vapour and the desiccant. The weak solution comes back to the absorber and the vapour goes to the condenser where heat is rejected. Then, the pressure decrease with an expansion valve and the vapour is condensed in an evaporator (heat input). The most usual combinations of fluids include lithium bromide-water (LiBr–H2O) where water vapour is the refrigerant and ammonia–water (NH3–H2O) systems where ammonia is the refrigerant. To increase the performance, double effect absorption chiller could be used where there are two stages of generation to separate the refrigerant from the absorbent [Soteris A.K., 2004].

Advantages

The advantages are nearly the same than for the adsorption air conditioning:

- It saves CO_2 emissions
- It decreases the use of power, although it uses power to pump the desiccant from the absorber to the generator, but this use is less than from a compressor. A consequence is a cheaper functioning

However, in opposition to the adsorption air conditioning, it could not be used where there is no power supply, because power is necessary for the pump.

Barriers to growth

There is a high investment cost: 135 000 € tax excluded for an absorption unit of 200 kW of cold. So, this system is adapted i.e. for place where there is a limited power supply.

A demonstration plant in Italy

Such a system has been developed in Italy (Dr Franco Pesce- Agricultural Dept.- Basilicata Region-Potenza(PZ)- Italy) and a demonstration project was realised, managed by ITABIA and supported by

- Industries: Yazaki Energy Systems Ltd and Biotermica S.r.L-Milan (Italy)
- Regional and local governments: Agricultural Dept. of Basilicata Region and Comunità Montana Collina Materana-Stigliano (MT)

For Italy, an additional advantage is the decrease in the risk of electric blackout during summer.

The production of "cold" is done by bioheat, through an absorption Li-Br cycle fed by hot water produced in a biomass boiler. The Li-Br cycle (rather than the ammonia cycle) has been selected due to the possibility of using lower process temperatures (90 C°), adequate to the commercial biomass water boilers on the market. The ammonia cycle requires temperatures up to 300 C°, with high pressure steam, or diathermic oil boilers.
The proposed system will be constituted by two main components:

- Hi-tech biomass water boiler (by Froeling)
- Absorption chiller (by Yazaki)

Plant operation

The plant is supposed to operate for 2.000 hours/year during the winter season.
During the summer and the intermediate seasons other 2.000 hours/year are foreseen (air cooling and sanitary water production).

The total quantity of wood (chipped wood at a moisture content equal to 35%) is estimated around 60 t/year.

In order to evaluate the incoming benefits (economical, social and environmental) a process monitoring on energy balances and biofuel cost will be carried out.

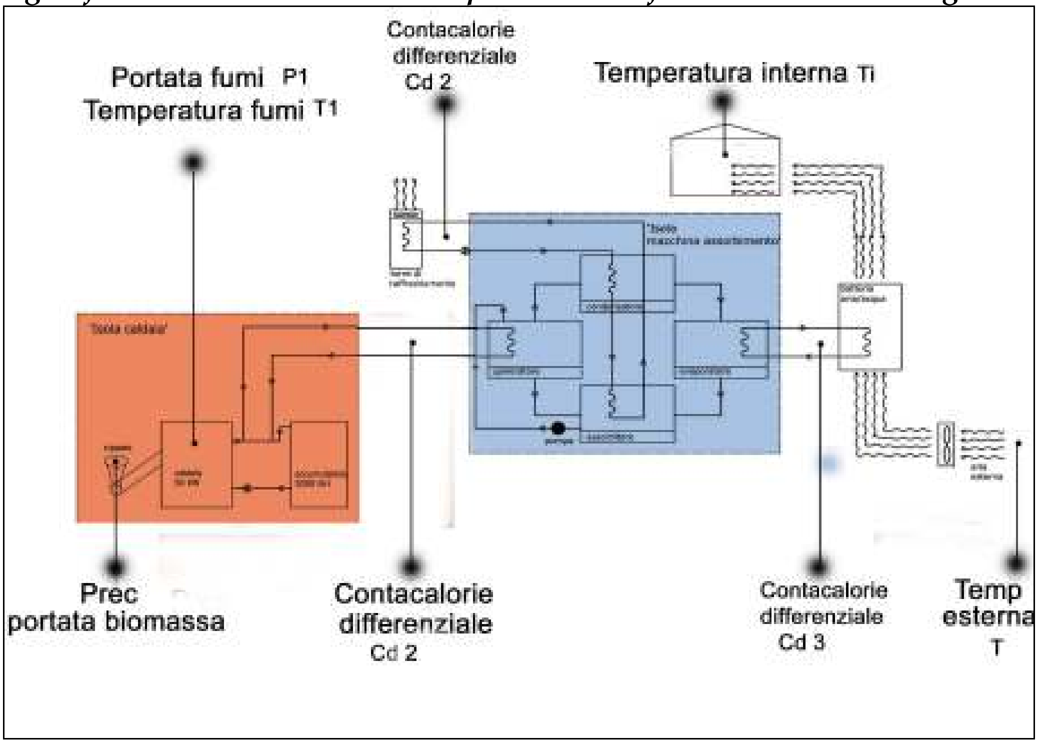
Experimental system

The main experimental aspect regards the monitoring of the energy and economic balances, to be compared with the balances of conventional electric air-conditioning systems.

In the erection phase, the plant will be provided with all the necessary instrumentation to allow the monitoring phase.

The instrumentation scheme is shown in the below figure:

Design of Biomass boiler and absorption chiller for household heating/cooling



Prec : Biomass feed measurer
Cd1 : Boiler net heat production
Cd2 : Cooling tower net heat loss
Cd3 : Useful heat/cold
T : Outside temperature
T1 : Flue-gas temperature
P1 : Flue-gas flow

Capital cost

Capital cost is estimated around € 65.000. The extra capital cost, if compared to a conventional electric split conditioner , is around € 30.000.

Cost-Benefits features

<u>Operating costs of a conventional split conditioner</u>

- kWh_{el} x working hours x working factor
- Electric energy fare: 0,14 €/ kWh_{el}
- Yearly energy cost: € 7.000

Operating costs of proposed innovation

- kWh_{th} x working hours x working factor
- Biomass cost: 0,02 €/kWh_{th}
- Yearly energy cost: € 1.000

Extra capital cost PAY- BACK

- 6 years

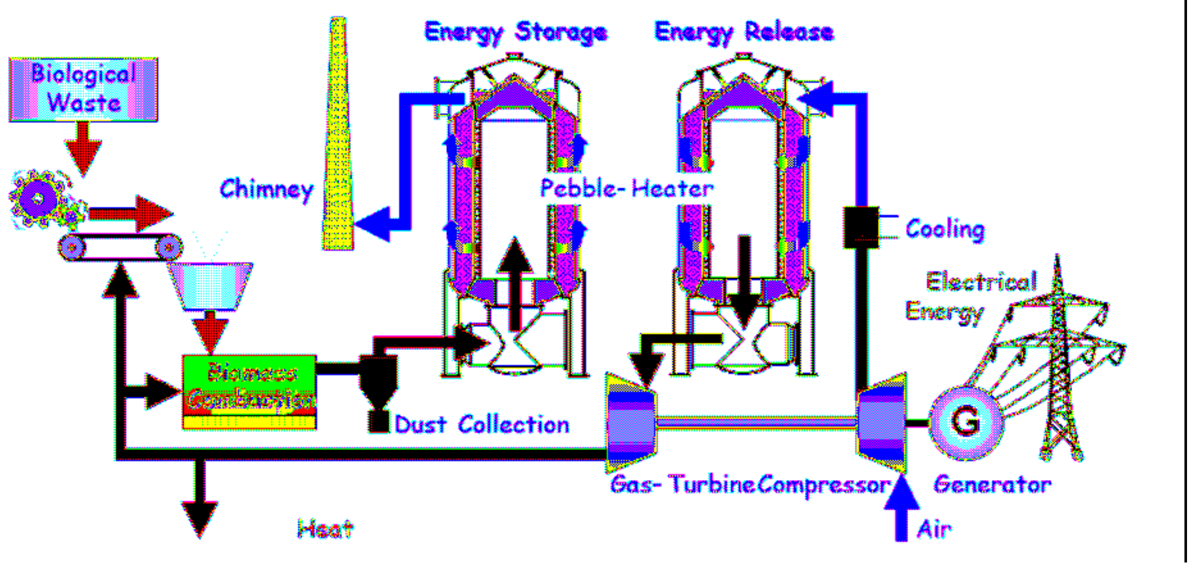
3. Combined heat and power (CHP)

3.1. CHP with pebble-heat-technology

Principle

The principle is to recover heat to increase the sum of the heat and power yield. The pebble-heater allows it because it stores heat and releases it afterwards. Thus, it is a discontinuous system and it needs in minimum 2 pebble-heaters functioning in opposition of phase. The figure 3 shows the process. [Stevanovic D., 2001]

Figure 3: process of a CHP with pebble heat technology



Source: Stevanovic D., 2001

In one hand, the biomass fuel goes to a combustor (fluidized bed, fixed bed, etc.). Then, the hot combustion gases go to the first pebble heater where the gases are cooled (energy storage). In the other hand, the ambient air is compressed (4,5 bar), cooled (90°C) and injected in the second pebble heater where the heat is released. Then, the hot compressed air (4,5 bar - 830°C) goes to the gas-turbine compressor where it is expanded to 1,03 bar. The turbine allows to compress the cold air and to produce power. The most part of the expanded air is used as preheated combustion air for the biomass combustor. The rest may, for example, be used to dry the biomass fuel. [Stevanovic D., 2001]

Barriers to growth and advantages

There are two economic barriers with the CHP in comparison with the classical power plant:

- The high specific investment costs
- The high expenditure for the logistics of biomass collection and transportation

To overcome those barriers it is necessary to develop a low cost CHP plant for small capacities (less than 5 MW_{power}) to decentralize the units. The CHP must to have low maintenance costs and high heat and power efficiencies. Those goals cannot be achieved with classical technology based on steam or combined steam and gas cycles. They are not suitable for small and decentralized units and they cannot be fitted well to the possibilities and restriction of biomass.

The CHP with pebble heat technology meets the needs:

- It is especially suitable for small capacities (100 kWe – 3 MWe) → decentralized units
- It has small investment costs
- It has high efficiency of power production (between 30% and 37%) because the pebble-heater allows very high heat recuperation efficiency. So the use of biomass is maximize

The other advantages are:

- saving CO_2 emission because it uses biomass
- decreasing the energetic dependence
- production of sustainable heat and power
- could be decentralized in part of some country where there is no energy supply

There is also the disadvantage, which is the same for all the CHP, to must use all the heat.

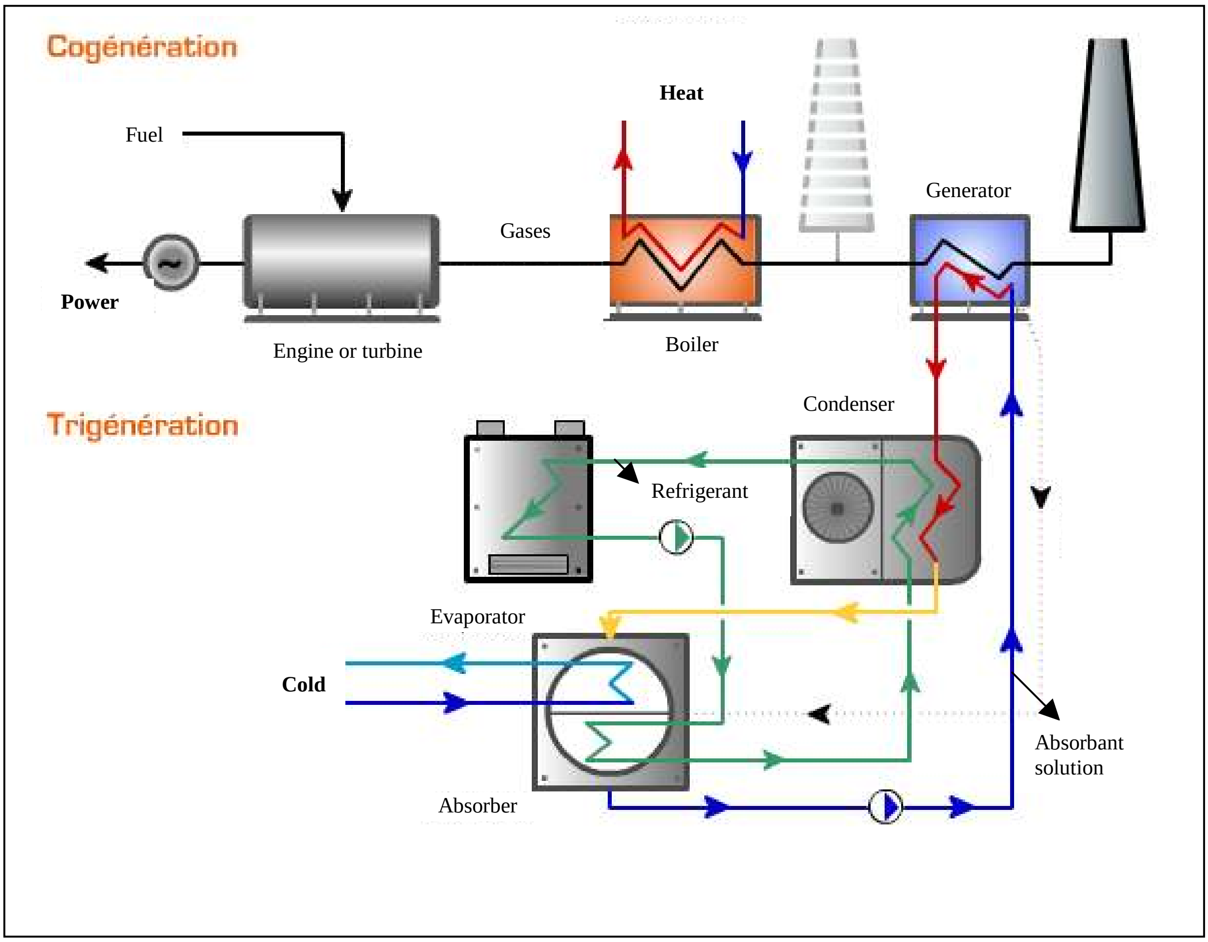
3.2. Combined Heat, Power and Cold (CHPC)

Principle

The principle is to have a CHP plus a recovering of the energy still present in the gases after the recovering of the heat. It will be used to produce cold with an absorption or adsorption system. Those systems, which have already been explained above, can produce cold with heat. [Daoud I., 2006]

The figure 4 shows the system

Figure 4 : Combined Heat, Power and Cold



Source : RWE solutions, www.rwesolutions.fr (2005)

Barriers to growth and advantages

The CHPC allows producing power during a longer time than with the CHP. Indeed, in the case of an office building in mid latitude in Europe for example, heat is only necessary between October and May, the CHP function only during 4500 hours/year (with heat storage). The rest of the time, the building needs cold. Thus, with a CHPC, power can be produced during 7000 hours. So it is more energy efficient. [Daoud I., 2006]

For the economical aspects, the CHPC is less profitable than the CHP because the yearly gain increase doesn't compensate the increase of the investment (+ 135 000 € tax excluded for an absorption unit of 200 KW of cold). But the return on investment (ROI) for CHPC (250 kW_{power} – 358 kW_{heat} – 200 kW_{cold}) is less than 5 years. If the CHPC is renewable (for example in using vegetable oil) it is possible to reduce the ROI to 3 to 4 years , under Belgium green certificates conditions (201 643 €/year). [Daoud I., 2006]. It should be noted that this Belgian scheme takes heat and cold into account to calculate the amount of green certificates allocated to a CHP or CHPC unit.

For the environment, the "renewable" CHPC is better, because it produces 71 tons of CO_2 versus 229 tons with the references (reference power plant: 177 CO_2 tons – reference boiler: 11 CO_2 tons – production of cold: 41 CO_2 tons). [Daoud I., 2006]

However, the CHPC has to be cheaper in the investment cost to attract managers of office buildings.

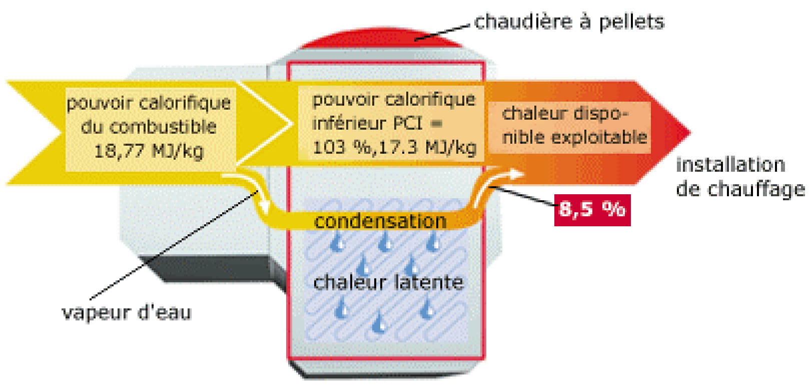
4. Production of heat

4.1. Pellets condensing boiler

Principle

The principle is the same as in gas condensing boiler. The energy still present in the combustion gases in the form of steam is recovered. The vapour in those gases is condensed and allowing to recover energy → 10-15% of the lower calorific value (PCI) (figure 5). The temperature of the smoke is between 130°C – 145 °C for a pellets boiler without a condensing system and ~70°C for a boiler with a condensing system. [www.pelletsheizung.at/_de/pelletsheizung/technik_pell_plus.htm, 2005]

Figure 5: principle of the condensing boiler



Source: www.pelletsheizung.at/_de/pelletsheizung/technik_pell_plus.htm

For an optimal use of the boiler, the return temperature of the system must be lower than 30°C.

Barriers to growth and advantages

In the environmental point of view, the condensing boiler allows to reduce the particles and soot in the combustion gases.
In the economical point of view, it permits to increase the yield and thus to decrease the functioning costs, but the investment cost are higher than for a "classical" pellets boiler. Of course the condensing pellets boiler has the same advantages than a "classical" pellets boiler:

- It saves CO_2 emissions
- It uses renewable energy

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