Climate Technology in a Wood Chips Boiler House

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***Abstract* – One of the innovative solutions of climate technologies is a pilot project relating to the condenser of fuel combustion products which is installed at a chips-fuelled boiler house in the Ludza city. A commercial experiment with the use of a gas condenser has been run at a boiler-house. An empirical model has been obtained, that describes the relation between the specific greenhouse gas (GHG) emissions reduction and the temperature difference of irrigation liquid & condensate mixture.**

***Keywords* – gas condensing unit, wood chips boiler house, greenhouse gas emissions, climate technology**

I. INTRODUCTION

Power industry issues are of crucial importance for the development of European countries, forcing the European Union to respond to the following challenges − e.g. those of climate change, ever increasing dependence on import, deficiency in energy resources, accessibility to safe energy at an acceptable price, etc.

EU is pursuing an ambitious energy policy, which encompasses all types of energy resources − ranging from fossil fuels (oil, gas and coal) to nuclear power and renewable energy resources (sun, wind, biomass, geothermal, hydro and wave energy), thus providing prerequisites for a new industrial revolution that would create the energy-saving economy, ensuring at the same time much more reliable, competitive and sustainable energy consumption.

The main directions in creation of the energy and climate policy in Europe are as follows.

- Energy efficiency (as refers to products, buildings and services);
- Common/General energy policy (the European energy policy, market-oriented instruments/tools, energy technologies, financial instruments);
- Security and extension/expansion of supply;
- Domestic energy market;
- Nuclear power;
- Renewable energy (electrical energy/electric power, heating &cooling, biofuel).

The European Union (EU) has been one of the leaders in the climate change control for a long time − also on the global scale, playing a dominant role in the creation of such a unifying document as the United Nation's Framework Convention on Climate Change (UNFCCC) in 1992 and the relevant Kyoto Protocol (ratified in 1997).

As early as in the 1990s, EU took significant steps towards reduction of its green-house gas (GHG) emissions. In 2000 the European Commission launched the Europe Climate Change Programme (ECCP), based on which a wide spectrum of new policy instruments and measures were accepted and introduced. These included also the EU Emissions Trading system (EU ETS), which has become one of the EU aspirations to reduce the cornerstone emissions in an economically profitable way, and the legislation concerning limitation of fluorine-containing GHG emissions.

The monitoring data and forecasts for 15 countries (being the EU member-states at the time of the Kyoto Protocol ratification in the year 2002) show that they are to achieve the goals envisaged by the Kyoto Protocol as to the reduction of GHG emissions during the period of 2008-2012 by 8%, as compared with those in 1990. However, it should be born in mind that the Kyoto Protocol is only the first step in this direction, while its goal has to be achieved by 2012.

Currently, the purpose of international negotiations of the UNFCCC scope is to reach the global agreement on the actions for climate change prevention after 2012.

In January 2007, the European Commission put forth proposals and possibilities/opportunities for the ambitious global agreement, as a part of the integrated climate change control and energy policy: to set limits on the global warming, to reduce it by 2% by 2020. The EU leaders approved this vision in March of 2007. They agreed on the 30% EU GHG emissions reduction by 2020, as compared with the 1990 level, in view of the readiness of other developed states to introduce comparable reductions in the context of a global agreement. It was also envisaged to make Europe a highly energy-efficient low-carbon (dioxide) economic zone via reducing the emissions at least by 29%, irrespective of the decisions to be made by other countries.

To fulfil these obligations, the EU leaders set three main goals to be achieved by 2020:

- 20% decrease in the energy consumption (as compared with the forecasted trend);
- 20% increase in the share of the renewable energy resources (RER);
- 10% increase in the specific weight of biofuel in the petrol and diesel fuel consumption.

In January 2008, the Commission published most of the climate and energy packages and the related legislative projects in order to introduce the mentioned goals and meet the obligations. In December 2008, the European Parliament and Council came to agreement on the package that would help to transform Europe into a low-carbon (dioxide) economic zone and strengthen its energy independence.

EU is ready to reduce its total emissions in 2020 by at least 20%, as compared with the 1990 level, and is ready to bring the reduction up to 30%, provided that also other countries are ready to do this within the framework of the new global agreement. Europe has set itself the task/goal to raise the share of renewable energy resources in the fuel mix to 20% by 2020.

The climate and the RER package determines the expected contribution of each member-state to achievement of the goals and offers a number of measures intended to help in this undertaking.

The central strategic element is the strengthening and extension/expansion of the EU Emissions Trading system − the main instrument for emissions reduction in an economically beneficial way.

The emissions from the sectors encompassed by the trading system are to be reduced by 21% by 2020, as compared with the 2005 level. In ETS, a unified framework will be created in the EU limits, in which the allocation of a free emission quota will be gradually (by 2020) replaced by the quota auction.

In the last twenty years, the increasingly more attention is devoted to the climate change issue. Technologies that allow the green-house gas (GHG) emissions to be reduced are called the “climate technologies”. To introduce the appropriate technological solutions, investments are needed; therefore, a special programme for financing the climate change issues which supports implementation of the climate technologies has been established in Latvia.

One of the innovative solutions of these technologies is a pilot project relating to the condenser of fuel combustion products (installed at a chips-fuelled boiler house in the Ludza city) and meant for deep cooling of flue gases. The innovative elements of the technological equipment installed within the framework of the pilot project have been patented [1]. Currently, experimental tests of the applied technologies are under way, and their results are presented below (in the Results section).

The deep cooling of flue gases implies that these gases are to be cooled below the dew point. Technologically, this means that proper conditions should be provided for this process, i.e. allowing the condensation of vapours contained in flue gases.

In this case, we receive additional heat (i.e. not accounted for when defining the least combustion heat − the parameter employed for determination of a boiler-house’s efficiency). Therefore, the technologies for deep cooling of flue gases make it possible to achieve the efficiency above 100% [2.3].

The gains at the use of flue gas condensers are not only of the state and municipality importance; these are important also for the society as a whole and for its members. What is more, these gains could be considered in the global context as related to the impact upon the climate change.

To receive the thermal energy in a flue gas condenser, less fuel is required. If the fuel is renewable, e. g. power-generating wood, its effective use allows saving of fossil fuel in another energy source, and, therefore, reduction of GHG emissions from a boiler-house.

II. Modelling of the Green-House Gas Emissions Reduction

The primary task when modelling the GHG emissions reduction is evaluation of the possibilities hidden in the technological solutions. Besides, an appropriate model would help to forecast the co-financing volume needed for climate technologies to achieve their most effective introduction.

The algorithm of *the/our* GHG emissions reduction model is illustrated in Fig.1, where the relationship between the calculation, database and experimental data modules can be seen.

The specific GHG emissions reduction, tCO_2 /MWh, depends on the heat produced in the boiler:

$$\Delta\ CO_2 = CO_2/Q_b, \tag{1}$$

where

$\Delta\ CO_2$ is specific GHG emissions reduction, tCO_2 /MWh.

Q_b is the heat produced in the boiler, MWh.

The possibility to achieve a reduction in GHG emissions can be substantiated economically via the investment payback time, calculation of the internal income, and determination of the emissions reduction efficiency.

In this paper, different economic factors are proposed: the specific GHG emissions reduction gain (per unit of heat produced in a boiler-house), owing to a smaller amount of GHG emissions entering the environment, as well as the emission trade options accepted in Europe and worldwide.

The specific GHG emissions reduction gain is determined by the following equation:

$$T_{GHG} = \Delta\ CO_2 * M_{EM},\ Euro/MWh, \tag{2}$$

where

T_{GHG} is specific obtaining of GHG emission reduction related to the heat energy produced in the boiler house, EUR/MWh;

M_{EM} is the market price of GHG emissions, EUR/tCO_2.

The specific load of a boiler is determined as its actual load − the installed capacity ratio:

$$q = Q_{act}/Q_{inst},\ MW/MW, \tag{3}$$

where

q is specific load, MW/MW;

Q_{act} is the actual load of the boiler, MW;

Q_{inst} is the installed capacity of the boiler, MW.

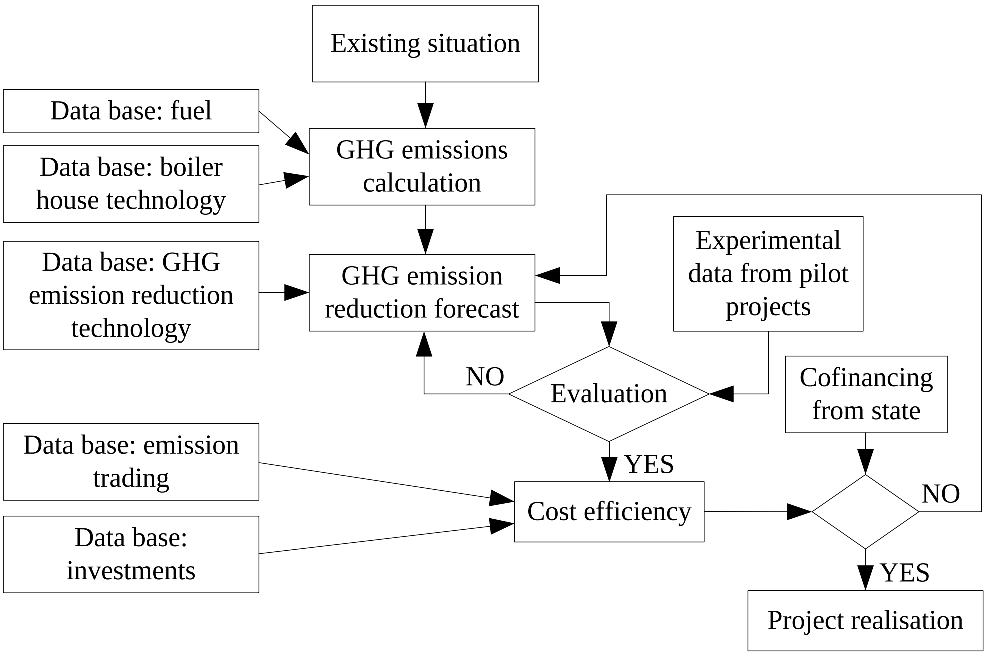

Fig.1. The algorithm of the GHG emissions reduction model.

III. Description of the Experimental Setup

Commercial experiment with the use of a gas condenser has been run at a boiler-house of the Ludza city's district heating system. In the boiler-house, a chips-fuelled boiler with the nominal capacity of 7 MW is installed. Near the boiler-house, a two-stage condenser is placed in the horizontal section of which irrigation nuzzles are made at the gas flow centre, while another row of nuzzles is arranged in the vertical section to make the irrigating liquid which comes into direct contact with flue gases.

Heat-and-mass exchange processes take place in the gas condenser between the drizzling liquid and flue gases. The thermal energy amount received in the gas condenser depends on how effectively these processes are organised. Their influence on the end result differs: a smaller role is played by convection, radiation, and heat conduction, while the most significant contribution is made by the evaporation and condensation processes [4, 5].

The block-diagram of the experimental setup illustrating the possibility of tracing the changes in GHG emissions is shown in Fig. 2.

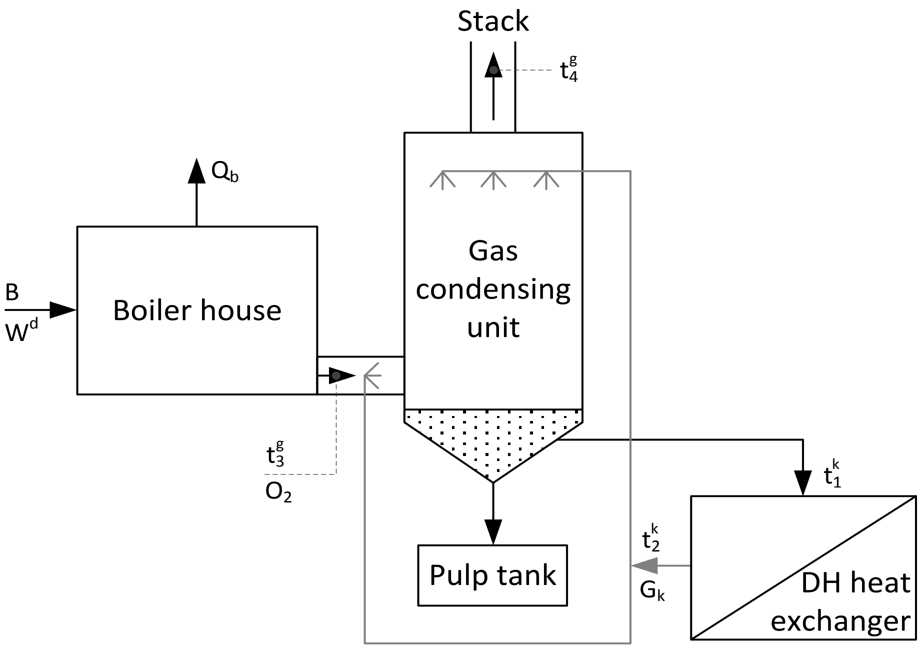

Fig. 2. Block-diagram of the experimental setup with a gas condenser.

The following parameters were measured in the experiment: the chips consumption, B, and its moisture content, W^d; the heat produced by the boiler, Q_b; the flue gas temperatures at the inlet and outlet of the flue gas condenser, t_3^g and t_4^g, respectively; the oxygen concentration in flue gases before the condenser, O_2; the flow of drizzling liquid & condensate mixture and its temperatures at the inlet and outlet of the flue gas condenser, t_1^k and t_2^k, respectively.

The experimental setup is made in such a way that it is usable either with a filling (in order to increase the condensation surface) or without it. In the experiment, operational parameters of the gas condenser could be varied, e.g. by varying the feed of drizzling liquid and condensate mixture, as a whole, or arranging various feeds to the first and second row of slots or nuzzles.

IV. Results of the commercial experiment

In the experiment, the green-house gas emissions reduction has been proved to depend on the design and operational parameter of the gas condenser, with the total number of variables being over 20.

In the mathematical treatment of the experimental data, the results of the regression analysis relating to GHG emissions were employed (see Fig. 3).

The regression analysis of the experimental data has resulted in an empirical relationship which correlates with these data well enough (the correlation coefficient is R^2 = 0.6).

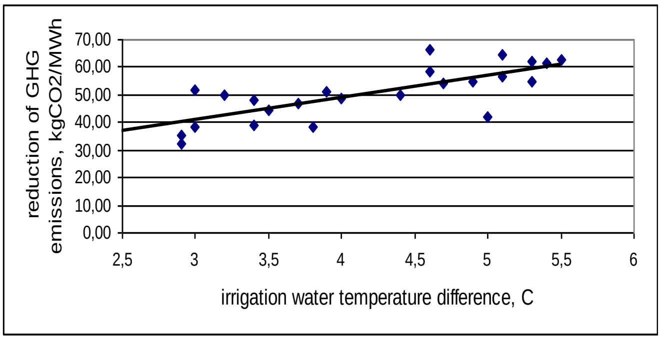

Fig.3. The specific reduction of GHG emissions vs. the irrigation water and the condensate mixture temperature difference.

The empirical model obtained describes the relation/correlation between the specific GHG emissions reduction and the irrigation liquid & condensate mixture temperature difference. Mathematically, it is expressed in the form:

$$\Delta\ CO_2 = 8.14\ (t_1^k - t_2^k) + 16.35,\ tCO_2\ /MWh, \qquad (4)$$

where

t_1^k is the temperature of the irrigation liquid and the condensate mixture at the outlet of the gas condensing unit, ^oC;

t_2^k is the temperature of the irrigation liquid and condensate mixture at the inlet of nuzzles, ^oC.

The GHG emissions reduction depends also on the temperature of the irrigation liquid and the condensate mixture before and after nuzzles. The experimental data show that at even a minor temperature difference (2-3^{o}C) and at a constant liquid flow it is possible to achieve the specific reduction in GHG emissions up to 25-30%.

V. GHG emissions reduction gain

The specific gain in the GHG emissions reduction (per heat energy unit) achieved at the boiler-house depends on the price of the corresponding quota on the emissions market.

In the years of 2010 and 2011, the prices of the GHG emission quotas fluctuated in the range from 12 to 15 EUR/ tCO_2. According to the forecast of EU specialists, in the next emission trade span (2013 – 2020) this price would be in the range of 30 − 50 EUR/tCO_2. Based on this forecast, a scheme of GHG emission quota distribution has been worked out for the third emission trade span. The dependence of the specific gain in GHG emissions reduction on the boiler capacity is exemplified in Fig.4, where the emission price on the market is assumed to be 30 EUR/tCO_2.

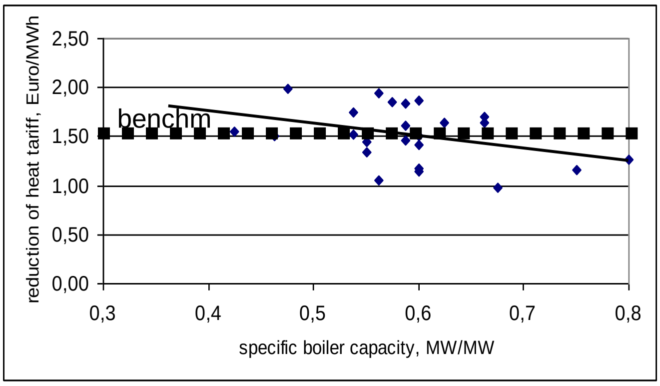

Fig.4. Specific gain in GHG emissions reduction *vs.* specific boiler capacity (with an exemplary benchmarking).

The specific GHG emissions reduction gain has been determined by processing mathematically the experimental data for an empty (without filling for enlargement of the condensation surface) gas vapour washer. This gain decreases with the boiler capacity increasing. Such a tendency is obtained as a result of the regression analysis, and is explainable by the elevated gas velocity in the condenser, which, in turn, has a detrimental effect on the condensation process.

The method for modelling the specific gain in GHG emissions reduction comprises the benchmark determination which is applicable to gas condensers of the type, being suited for the emission prices established on the emission market. The method has been approved for the market price of 30 EUR/tCO_2.

VI. Conclusions

1. As a result of the regression analysis applied to the experimental data, an empirical relationship has been obtained which satisfactorily correlates with these data. An equation has been derived that describes the relation between the specific GHG emissions reduction and the temperature difference of the irrigation liquid and the condensate mixture.
2. The GHG emissions reduction depends on the difference in the temperatures after and before slots. The experimental data evidence that even at a minor temperature difference (2 – 3^{o}C) and at constant liquid flow it is possible to achieve the specific reduction in GHG emissions up to 25-30%.
3. The specific GHG emissions reduction gain has been determined by processing mathematically the experimental data for an empty (without filling for enlargement of the condensation surface) gas scrubber. As a result of the regression analysis, a tendency has been obtained which testifies that the specific gain is decreasing with the boiler capacity increasing. This could be explained by the increased gas velocity in the condenser which, in turn, affects adversely the condensation process.
4. The method worked out for modelling the specific gain in the GHG emissions reduction comprises the benchmark determination which is applicable to gas condensers of the type, being suited for the emission prices established on the emission market. The method has been approved for the market price of 30 EUR/tCO_2.

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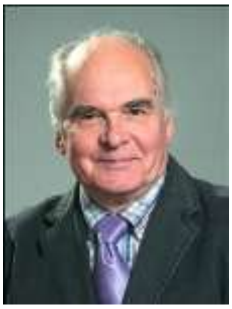

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Edgars Vīgants, Dagnija Blumberga, Ivars Veidenbergs. Klimata tehnoloģijas šķeldas katlu mājā.
Raksts veltīts vienam no klimata tehnoloģiju inovatīviem risinājumiem ir kurināmā degšanas produktu kondensatora pilotprojekts dūmgāzu dziļai dzesēšanai šķeldas katlu mājā Ludzas pilsētā. Dūmgāzu dziļa dzesēšana nozīmē, ka dūmgāzes dzesē zemāk par rasas punkta temperatūru. Šāds nosacījums tehnoloģiski tiek realizēts tādējādi, ka tiek nodrošināti tādi procesu īstenošanas apstākļi, ka tiek panākta dūmgāzēs esošo tvaiku kondensācija. Šajā gadījumā tiek iegūts siltums, kurš netiek ņemts vērā, nosakot zemāko sadegšanas siltumu, kuru izmanto katlu māju lietderības koeficienta noteikšanā. Ieviests no ekonomisks parametrs: īpatnējais SEG emisiju samazinājuma ieguvums uz saražoto siltumenerģijas vienību katlu mājā, pateicoties mazākam SEG emisiju apjomam, kas nonāk apkārtējā vidē, un emisiju tirdzniecības dažādiem variantiem Eiropā un pasaulē. Pilotprojekta vietā realizēts uzstādīto tehnoloģisko iekārtu rūpnieciskais eksperiments, kura laikā savākto datu apstrādes un regresijas analīzes rezultātā iegūts empīrisks modelis, kas rāda siltumnīcefekta gāzu emisiju samazinājuma ieguvumu atkarību no izsmidzināšanas ūdens temperatūras starpības, pie kam novērots, ka lielāka šķidruma temperatūru starpbība dod lielāku siltumnīcefekta gāzu emisiju samazinājumu. SEG emisiju samazinājumam noteikšanai izstrādāts modelis, kura algoritmā iestrādāta saikne starp aprēķinu, datu bāžu un eksperimentālo datu moduļiem.