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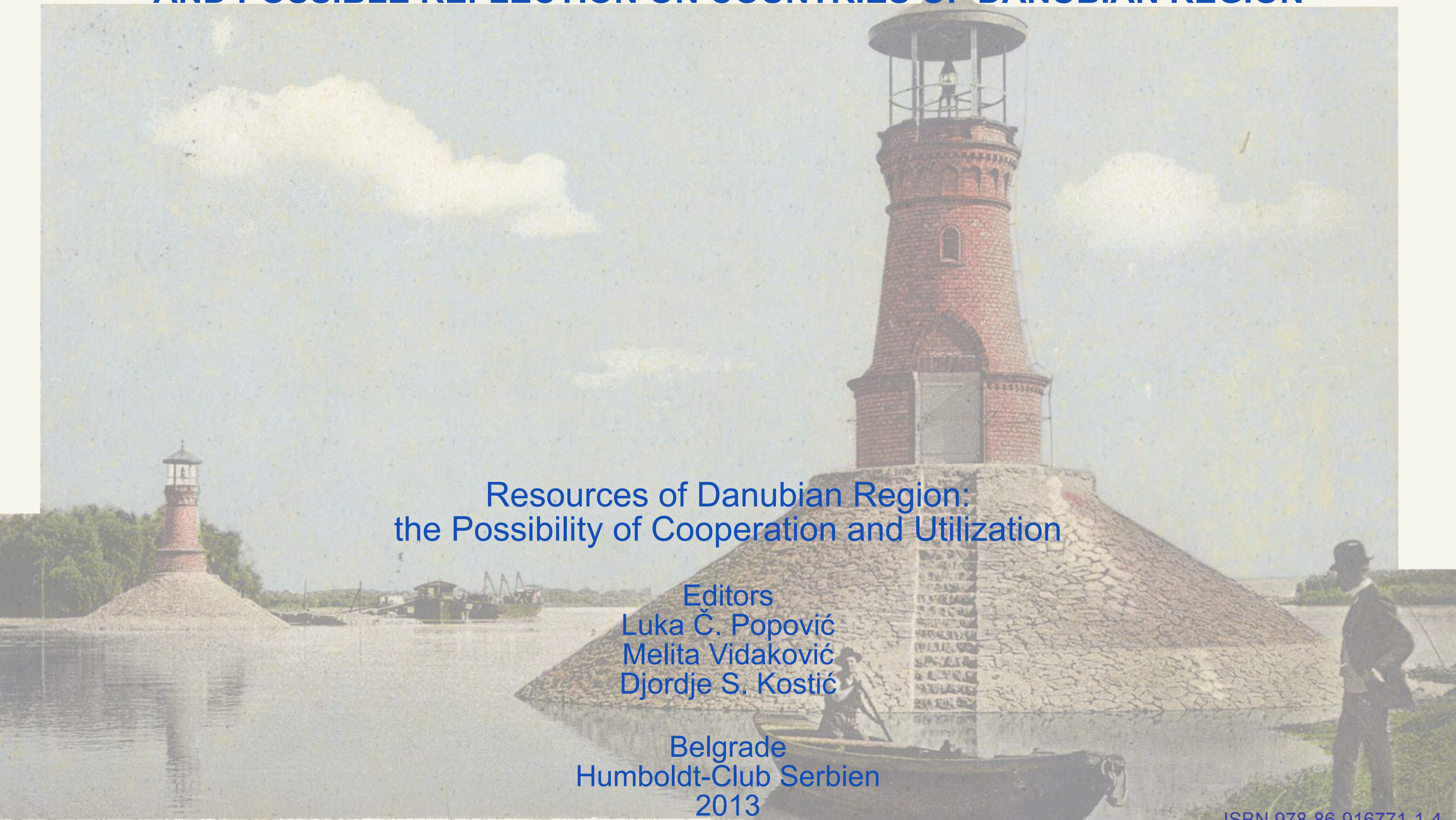
# UTILIZATION OF BALED BIOMASS FOR ENERGY PURPOSES IN SERBIA, AND POSSIBLE REFLECTION ON COUNTRIES OF DANUBIAN REGION



Resources of Danubian Region:
the Possibility of Cooperation and Utilization

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Поздрав из Костолца
Nachahmung verboten
Kunstanstalt Karl Schwidernoch, Wien III. Pillersdorfg. 4.

**Abstract.** The paper consider the possibility of using baled biomass for energy production in Serbia without disturbing balance in the human or animal food production. Similar possibilities for baled biomass utilization certainly exists in all countries of the Danube region, especially those that border with Serbia, because of the similarity in climate, the terrain and the type of agricultural production. The possibilities of utilization of bales originated from agricultural biomass residues are discussed in this article. However, the conclusions are valid for all biomass types collected in form of bales: some energy plants, remnants of grapevine and fruit trees and park trees pruning.
**Key words:** agricultural biomass, bales, combustion

## Introduction

During late seventies of the last century, due to the serious energy crisis, people's perception of the energy consumption changed, and an awareness arouse that there will be no more cheap energy and, in relatively close future, reserves of fossil fuels, in particular liquid and gas fossil fuels, will be depleted. At that time started an intensive development of renewable energy technologies. Researchers from the Institute of Nuclear Sciences "Boris Kidrič" (now "Vinča Institute") in the "Laboratory for Thermal Engineering and Energy" developed technology for the utilization of low grade fuels, industrial waste, and biomass, for energy purposes. The fluidized bed technology for fuel combustion was developed up to the industrial implementation, and a Serbian company designed and built more than 40 fluidized bed industrial plants. Average power of those plants was 1.5 -5 MW, and in some of those units biomass was used as the fuel. During the process, all aspects of the biomass combustion have been studied, especially for the agricultural biomass. The biomass combustion has proven to be very different from the fossil fuels and wood biomass combustion.

End of the last century was a difficult period for Serbia, as well as for Vinča Institute. In that time, our researchers turned to development of combustion technologies utilizing remains of agricultural biomass, the largest single potential of renewable energy in Serbia. Not even the reputable producers of thermal energy equipment have offered adequate solutions for combustion of this type of biomass. On the other hand, technologies for utilizing wood biomass are fully developed up to industrial scale. That was the main reason for decision of the Vinca researchers to start development of the technology of utilizing agricultural biomass. Mechanical Faculty of Belgrade University was included in the research. The residues of the agricultural biomass are usually collected on the fields in the form of bales, and it is preferable to use it in unchanged form (without cutting, grinding, pelletizing). In this article, an overview of the development process is given. As the situation is similar for the most of the countries of the Danubian region, a similar scenario could be applied there. Here, we could come up with an idea on cooperation between scientific institutions and industry of this region.

## Technology development

Considering the biomass potential in Serbia, given in Figures 1 and 2, and the presented basis, main principles of the biomass utilization could be laid out / 1/:

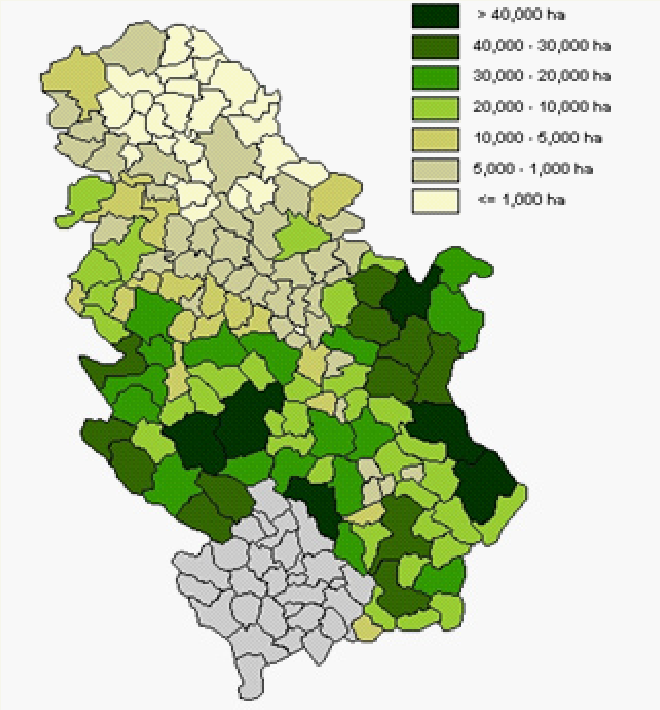



**Figure 1.** Share of forest biomass in Serbia

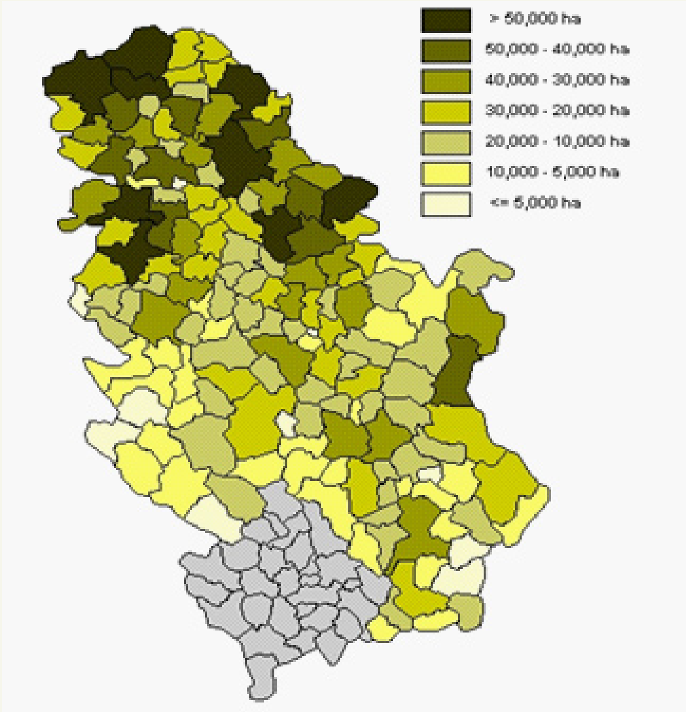



**Figure2.** Share of agricultural biomass in Serbia

- Technology has to be suitable for the most common agricultural biomass (remains of agricultural production collected on fields in form of bales),
- Technology should correspond to potentials of the local industry,
- Technology should satisfy environmental norms,
- Energy efficiency has to be ≈ 85%, for thermal plants, and ≈80% for CHP plants, like in EU.

- Devices have to be simple, thus cheap, both in terms of low investment, self consumption and operation/maintenance costs,
- Logistic systems (for collection, transport, storage, ash management) should be developed at the same time.

In deciding on which direction to take, a report of EU Institute of Energy, Peten, Holland /14/ had a significant impact. It gave an overview of recommended technologies of biomass combustion (Table 1.) and their rating for each type of biomass. In Table 1 is stated that the most favorable technology of straw combustion is the so called cigarette combustion.

| | Firewood | Wood chips | Wood powder | Pellets | Briquettes | Straw |
|---|---|---|---|---|---|---|
| 1. Open fireplace | 0 | – | – | – | 0 | – |
| 2. Manual stove | + | – | – | – | + | – |
| 3. Automatic burner | – – | + | – | + + | – – | + |
| 4. Batch combustion | 0 | – – | – – | – – | – | + |
| 5. Fixed inclined grate | – – | + | – | + | – | – |
| 6. Travelling grate | – – | + + | – | + + | – | + |
| 7. Vibrating grate | – – | + | – | + | – | + |
| 8. Underfeed stoker | – – | + | – | + | – – | – |
| 9. Dust burner | – – | – – | + | – – | – – | – |
| 10. Cigar burner | – – | – – | – – | – – | – – | + + |

Note: Combustion systems (1-3) are suitable for small-scale applications, while combustion systems (4-10) are appropriate for large-scale facilities.
Legend: (– –) Not possible; (–) Not appropriate; (0) The penalties are compensated to a given extent by the advantages; (+) Appropriate; (++) Very appropriate

**Table 1** – Overview of technologies of biomass combustion

Development of the 'cigarette' combustion technology of straw bales has arisen within several research projects financed by Serbian Ministry of Science. In these projects associates of Faculty of Mechanical Engineering of Belgrade University, Faculty of agricultural, and Faculty Technical Sciences of Novi Sad University, and Soil Institute, Belgrade, have participated.

Development comprised several phases, reported in literature /1-13, 15/:

- Analysis of the operation data of the similar facilities;
- Laboratory investigation of the potential fuels;
- Investigation of combustion characteristics of potential fuels;
- Simulation of combustion in cigarette combustion furnaces, in order to optimize of the furnace dimensions;
- Construction and testing of the experimental facilities, first small then industrial-scale, for the purpose of obtaining project parameters and correction of the mathematical models;
- Development of the methodology for heat accumulator calculations;
- Development of the automatic control software;
- Construction of the hot-water boiler, designed for industry, demonstration, and experiments, power of 1.5 -2 MW;
- Detail testing of the boiler.

**Chronology of the devlopment**

Some of the results of the developed mathematical models are presented in Figures 3-10.

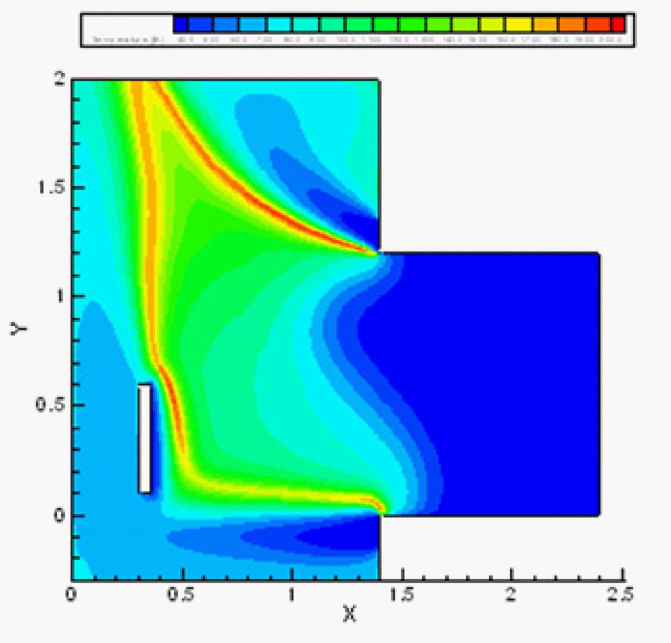



**Figure 3.** Temperature profile within and around bale

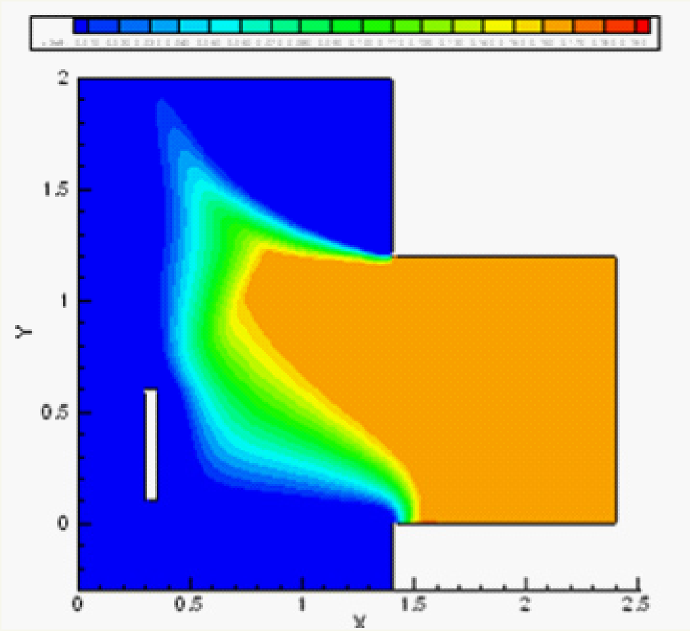



**Figure 4.** Concentration of carbohydrates (C3H8) profile within and around bale

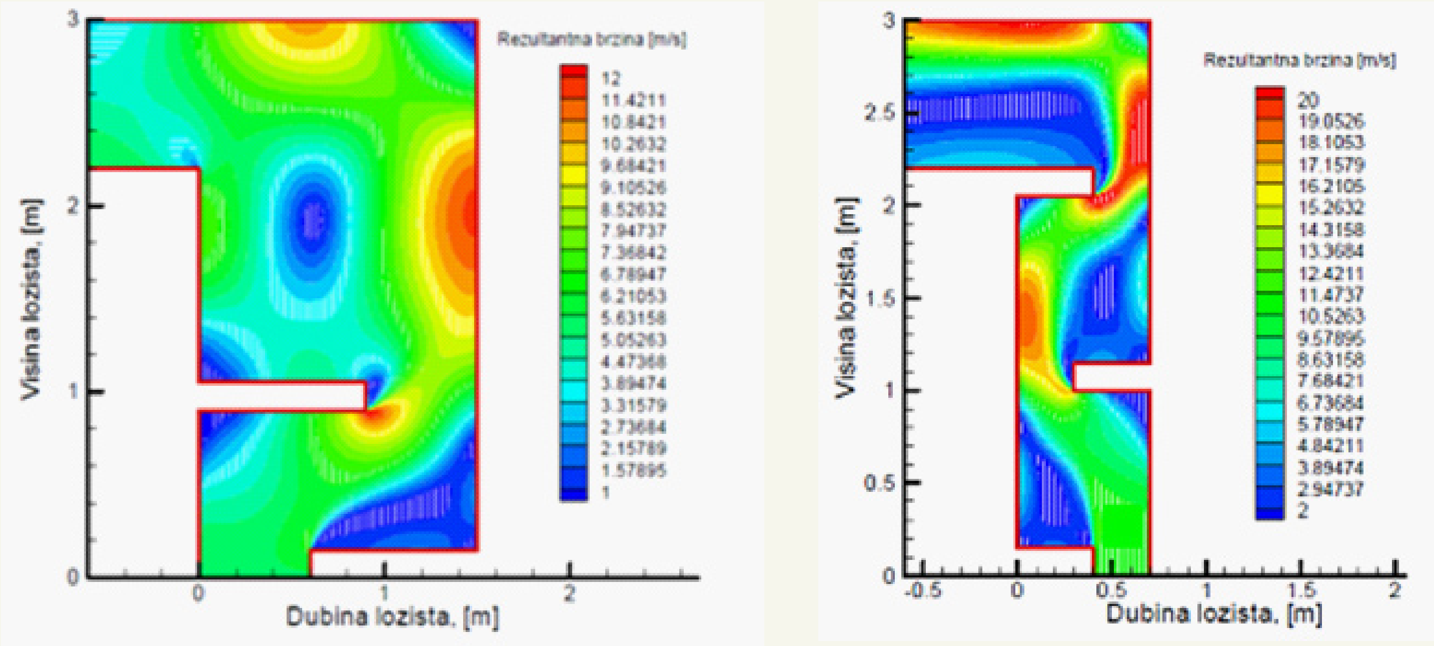



**Figure 5** Profiles of the flue gases velocities in two versions of the adiabatic furnace

**Figure 6** Experimental facility

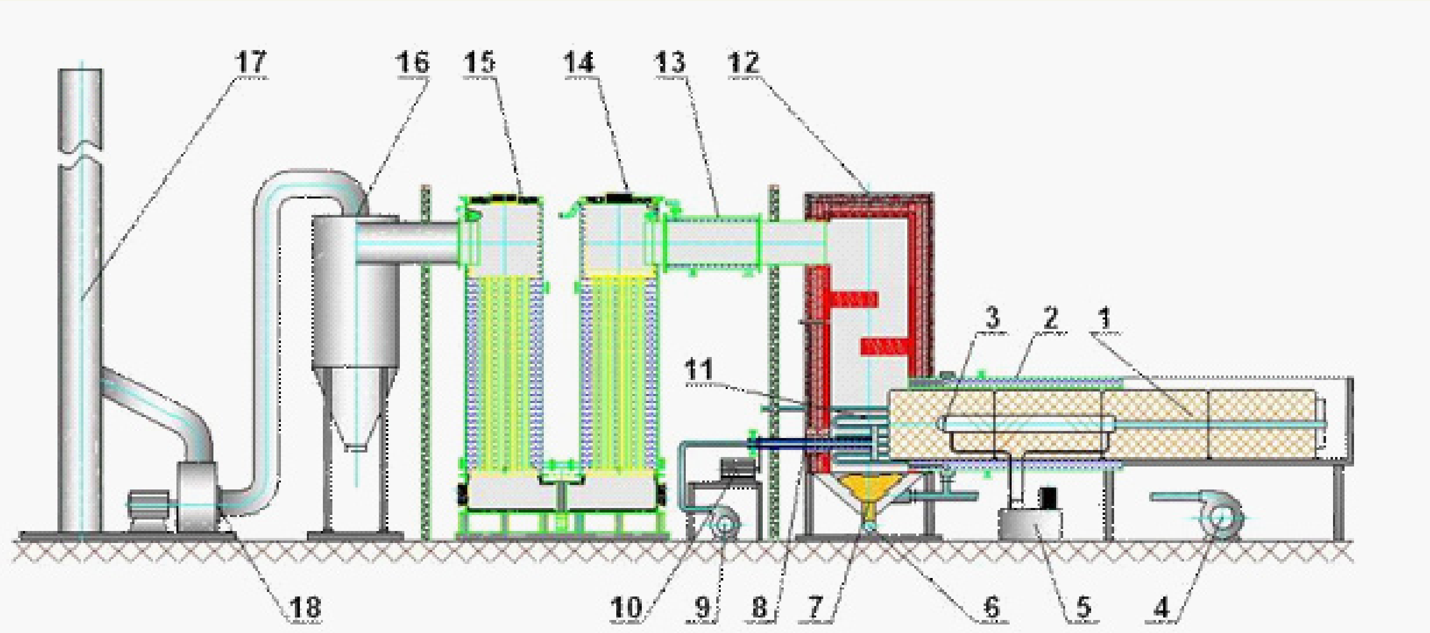
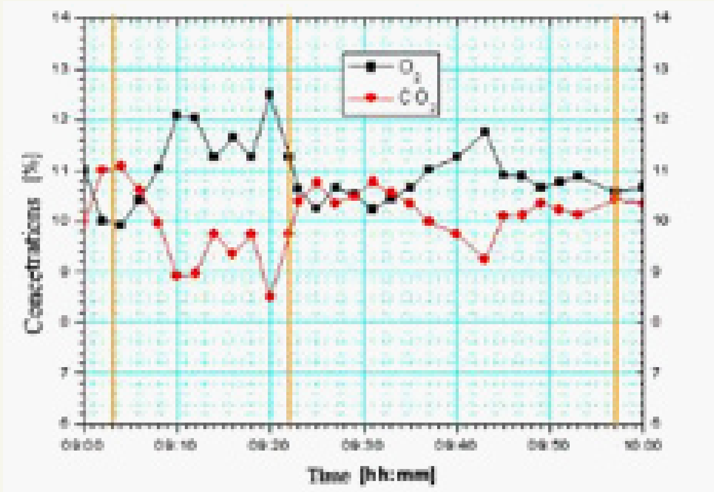


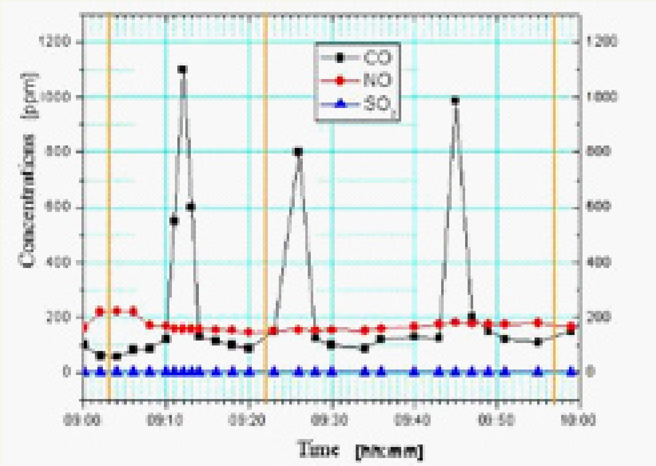

**Figure 7** Scheme of the hot-water industrial boiler, power 1.5 -2 MW

**Figure 8** Views to the heat accumulator, furnace, hydraulic fuel feeder and the bale storage

Concentration of $O_2$ and $CO_2$

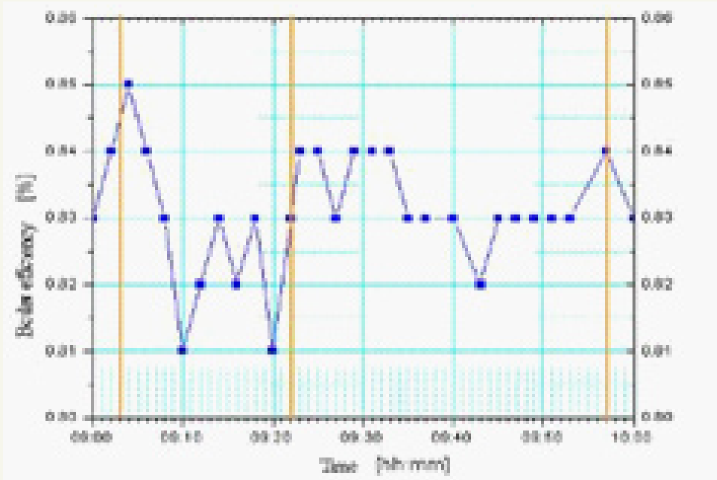





Concentration of CO, NO and $SO_2$








Boiler efficiency



**Figure 9** Some of the experimental results

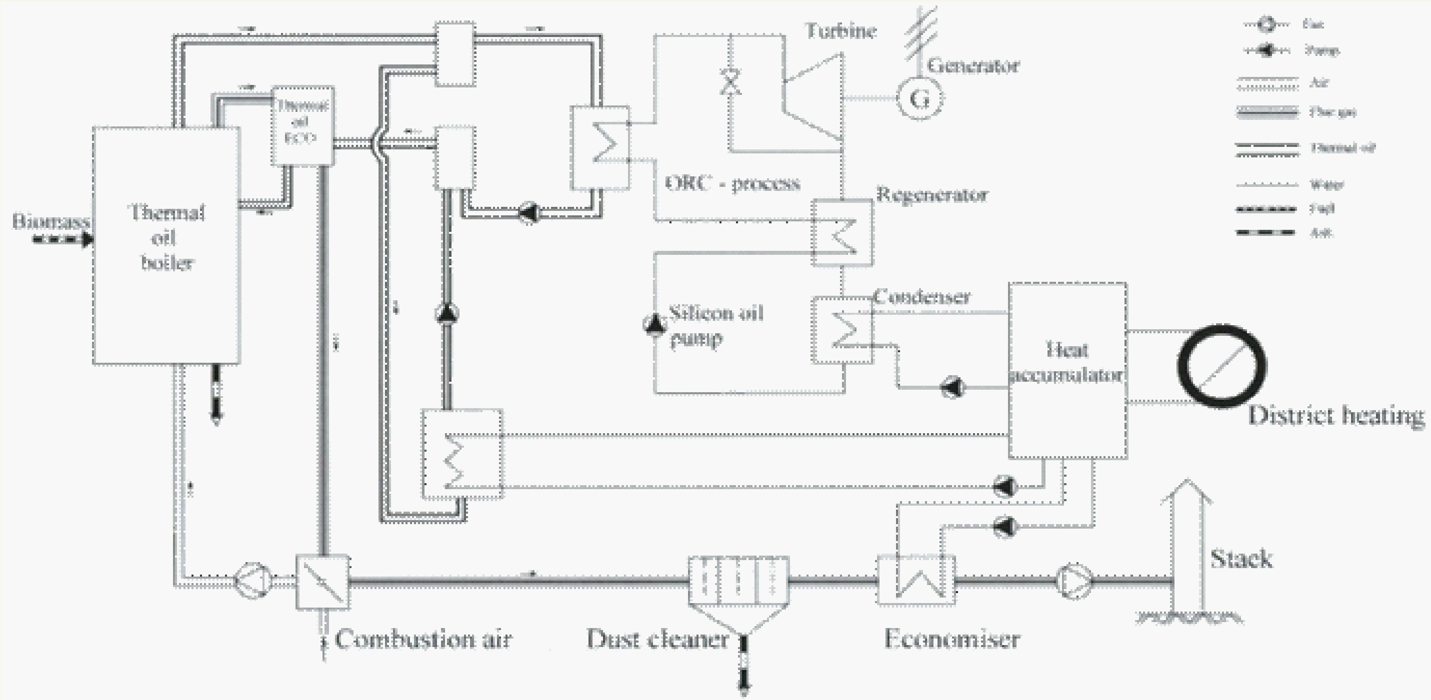



**Figure 10** Scheme of the ≈4 $MW_t$ CHP facility in Padinska Skela /16/

The technological scheme in Figure 10 has been taken from the literature /16/, which was prepared for the Swiss State Secretariat for Economic Affairs – SECO. Republic of Serbia was granted 6.816.000€ on the basis of that document.

## Analysis of possible solutions

The main reserves of agricultural biomass are placed in basins of the biggest rivers (Figures 1 and 2), that is: in Danubian part of Serbia (in northern part of the country – in AP of Vojvodina), in the region of river Sava, lower part of Drina and Velika Morava. Only in AP Vojvodina, there are over 450 villages, 30 suburbs and 6 towns. If the rest of the Danubian part of Serbia counts in, the number of the urban units where the agricultural remains are the most dominant type of biomass adds up to 550 villages, 40 suburbs and 10 towns, one of them being capitol – Belgrade.

The level of urbanization of these urban units is different; some of them are partially gasified, especially those in AP Vojvodina, whereas some of them have district heating (larger towns). The share of biomass utilization in district heating is negligible in comparison with the share of the fossil fuels. There is a possibility to substitute existing fossil fuel district heating facilities with those fired with biomass, as well as build biomass fired district heating systems on the periphery of these urban units. The users of the heating could pay it with the biomass, directly. The remains of the agricultural production would be used for heating, instead of burning or plowing on fields; the heating would be cheaper; and most of the users would not pay the heating with cash, but biomass.

In addition, there would be some indirect benefits of such a scenario. Extending of active working period of a district heating plant would be one of them. It means that if a district heating plant works only for heating in Serbia, it is used only ≈180 day/year with ≈45% average capacity, 18 hour/day. Extending of life time of a plant leads to shorter pay-back period, which is a well-known fact for investors. With a good planning, working period of biomass energy plant can be extended on all year, with 65-80% of installed capacity. For example, that means organizing a small industrial zone next to the biomass district heating plant, which is using heat for food production (drying: fruits, vegetables, mushrooms, herbs), greenhouses, small milk and meat industry facilities, etc. Building combined heat and power (CHP) units could, also, benefit the sustainable development. On the other hand, it would mean new work opportunities for many local residents. Agricultural production in the vicinity of such a heating/industrial plant could be changed to more profitable, such as: farming, growing: fruits, vegetables, medicinal and spice herbs, early: fruits, vegetables and flowers from greenhouses etc. In this way, the products could be sold earlier and reach higher prices. Also, the village cooperatives could be revived, which is one of the prerequisites for preventing the countryside depopulation. Similar situation is all over the Danubian region, especially for countries of former Yugoslavia and Warsaw pact.

In Tables 2 and 3 the comparative economic parameters of plants of the same power, fired with baled biomass, light fuel oil, heavy fuel oil, and gas are shown. Adopted power of the facilities in all the cases were 4 MW. In the analysis, except the boiler, the investment included: necessary infrastructure (roads, water supply, drainage, fire protection), the building of the boiler house, storage with equipment. The prices in the calculation were taken for the average conditions in Serbia: average gross earnings workers 800€ a month and 1kw/h electricity costs 0.05€.

**Table 2**. Comparison of the heating plants for various fuels

| Comparison Parameter | Fuel | | | |
|---|---|---|---|---|
| | Biomass | Light fuel oil | Heavy fuel oil | Gas |
| Fuel price | 45 €,/t | 1100 €,/t | 550 €,/t | 0,4 €/m$^3$ |
| Investment | 1.200.000 | 280.000 | 350.000 | 250.000 |
| Overall efficiency | 0,84 | 0,90 | 0,88 | 0,92 |
| Average load | 70% | 70% | 70% | 70% |
| Working days per year | 360 | 360 | 360 | 360 |
| Fuel consumption | 8.100 t/year | 2.300 t/ year | 2.400 t/ year | 2.450.000 |
| Total fuel costs | 364.500 €/ year | 2.530.000 €/ year | 1.320.000 €/ year | 980.000 €/ year |
| Energy produced | 24.200.000 kWh/ year | 24.200.000 kWh/ year | 24.200.000 kWh/ year | 24.200.000 kWh year |
| Number of workers in a shift | 2 | 1 | 1 | 0,5 |
| Working power costs | 81.000 | 40.500 | 40.500 | 20.000 |
| Energy consumption costs | 15.000 | 10.000 | 15.000 | 6.000 |

| | | | | |
|---|---|---|---|---|
| Maintenance costs | 25.000 | 10.000 | 15.000 | 6.000 |
| Price of 1 kWh | 2 €c/kWh | 10,66 €c/kWh | 5,74 €c/kWh | 4,18 €c/kWh |
| prices ratio 1kWh/1kWh$_{BM}$ * | 1 | 5,33 | 2,87 | 2,09 |
| Difference in costs in comparison with biomass facility per year | | 2.205.000 | 1.005.000 | 627.000 |
| ** Simple pay-back period in comparison with the biomass facility | | 0,42 year | 0,85 year | 1,5 year |
| 25 year return (during the lifetime of the facility) in comparison with the referent fuel € | | 55.125.000 | 24.125.000 | 14.475.000 |

* $_{BM}$ – biomass

** pay-back period is going to be somewhat longer in case the investment is realized through a bank loan.

**Table 3** Comparison of the heating plants for various fuels

| Comparison Parameter | Fuel | | | |
|---|---|---|---|---|
| | Biomass | Light fuel oil | Heavy fuel oil | Gas |
| Investment | 3.000.000 | 2.000.000 | 2.150.000 | 1.900.000 |
| Overall efficiency | 0,78 | 0,85 | 0,82 | 0,87 |
| Heat produced | 20.000.000 kWh/year | 20.000.000 kWh/ year | 20.000.000 kWh/ year | 20.000.000 kWh/year |
| Electricity produced | 4.350.000 kWh/ year | 4.350.000 kWh/ year | 4.350.000 kWh/ year | 4.350.000 kWh/ year |
| Price of kWh el. | 13,6 €C/kWh | 5 €C/kWh | 5 €C/kWh | 8,89 €C/kWh |
| Energy consumption costs | 25.000 | 20.000 | 25.000 | 15.000 |
| Maintenance costs | 40.000 | 25.000 | 30.000 | 20.000 |
| Price of 1kWh produced | ≈2,2 €c/kWh | ≈11 €c/kWh | ≈6 €c/kWh | ≈4,4 €c/kWh |
| Profit from electricity (€) | 590.000 | 220.000 | 220.000 | 387.000 |
| Difference in costs in comparison with biomass facility per year | | 2.475.000 | 1.275.000 | 728.000 |
| * Simple pay-back period in comparison with the biomass facility | | 0,40 god | 0,66 god | 1,51 god |
| 25 year return (during the lifetime of the facility) in comparison with the referent fuel € ** | | 57.000.000 | 27.000.000 | 15.000.000 |

*Pay-back period is going to be somewhat longer in case the investment is realized through a bank loan.

**The calculation is was carried out for guaranteed feed-in electricity tariffs of 12 years

## Conclusion

Presented results made it clear that the biomass heating plants have very low operation costs in comparison to fossil fuel heating plants. CHP plants are somewhat more profitable, taking into the account the income from electricity. On the other hand, the difference is not that big, especially in conditions when the feed-in electricity tariffs are guaranteed for next 12 years. Produced electricity must be considered in a much wider social view, and therefore, the lawmakers have to extend the duration of the feed-in electricity tariffs to the facility lifetime and to introduce sliding scale for the biomass electricity price the same way as for small gas CHP facilities. The financial parameters show here are valid for Serbia, it may vary in Danubian region. The biggest difference is expected in the parameters in relation to gross wages, fuel prices and electricity prices. For the other factors taken into account the conditions in Danubian region is similar. We believe that the presented development shows a good example of utilizing of agricultural biomass, at the same time not disturbing the food production. The authors would be very proud if our work would inspire collaboration between scientific and governmental institutions and companies of the region, for the purpose of building joint demonstrational facility of this kind. In that respect, we are ready to cooperate with all interested parties.

## Acknowledge

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