INSTITUTE OF NUCLEAR SCIENCES VINČA
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Research in the field of renewable energy sources and energy efficiency

Biomass research (the fundamental and the applied research, as well as the development of mathematical models of the combustion and heat transfer processes are aimed at development of the commercial devices in accordance with the industry)

Research directions

- Cigar combustion of the baled biomass (fuels: byproducts of the agricultural production and energy crops, collected in the form of bales)
- Fluidized bed (FB) combustion (fuels: waste food oils, glycerin, paper industry sludge, residues from crude oil reservoirs, corn infected by aflatoxins, fruit stones, corn cob, wood chips, wood bark, pellets, etc.)
- Combustion of fire wood in the household furnaces and boilers
- Combustion of the pulverized coal supported by the swirl burners
- Co-combustion in energy plants
- Ignition and fire support in the large-scale boilers burning low-grade pulverized coal and biomass dusts
- Development of the thermal energy storage with phase change of medium
- Numerical simulation of the processes of combustion and heat transfer, for the purpose of the technology and developed devices
- Application of additives and catalysts for the purpose of optimization of the combustion process and environment protection
- Investigation of the possibility of returning the biomass ash into the soil
- Biomass gasification
- Thermophysical characterization of the baled biomass (determining porosity, permeability, thermal conductivity)
- Defining the impact of the cold flue gas recirculation on the global combustion kinetics of the baled biomass, as well as on the temperature decrease in the combustion process

Experimental apparatuses:

- Small fixed bed furnace designed for determining of the combustion kinetics (works on the TGA principle, with a possibility to change the height and density of the fuel, air flow and the oxygen concentration in the air mixture)
- Cigar-type furnace burning baled biomass of dimensions 0.4x0 .x0.8 m. It was designed for determining of combustion characteristics of different biomasses, and obtaining project parameters for commercial facilities.
- Industrial-demonstrational boiler with power 1.5-2MW, for industrial tests for obtaining project parameters for commercial facilities.
- A number of small laboratory apparatuses with fluidized bed designed for obtaining data on combustion phenomena in fluidized bed (ash sintering, combustion kinetics, drying, etc.)
- Experimental apparatus with fluidized bed with power up to 150 kW, with possibility for in-bed and on-bed fuel feeding

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- Experimental apparatus (boiler) with fluidized bed with power up to 500 kW, suitable for a long-term testing in stationary regimes, designed for obtaining project parameters for commercial facilities.
- Furnace with power up to 500 kW designed for investigation of the pulverized fuel combustion
- Apparatus for the thermophysical characterization of baled biomass
- Software packages for numerical simulation of processes related to combustion and heat transfer:
    - Cigar combustion of baled biomass
    - The burn-out of the gas combustion products above the bed where the baled biomass is combusted
    - Simulation of solid fuel combustion in the fluidized bed
    - Simulation of fluidized bed hydrodynamic
    - Simulation of jet penetration into the fluidized bed
    - Simulation of heat transfer in the small household furnaces
    - Simulation of solid fuel fragmentation in the fluidized bed

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Experimental apparatuses


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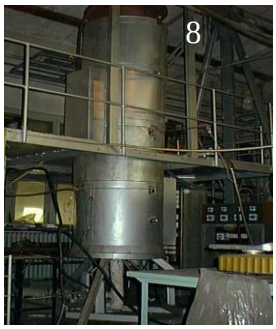
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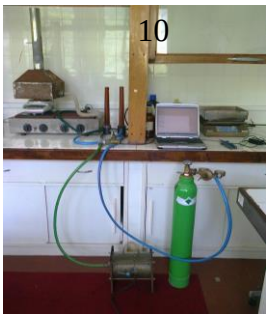
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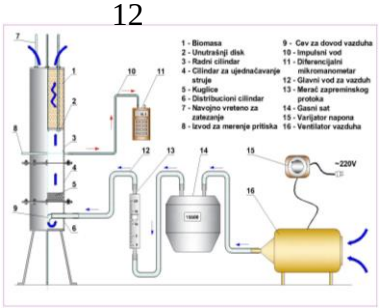

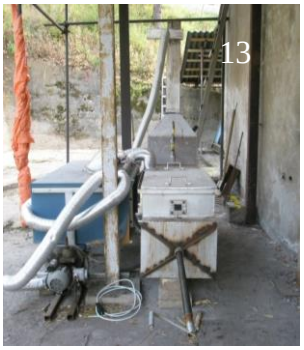
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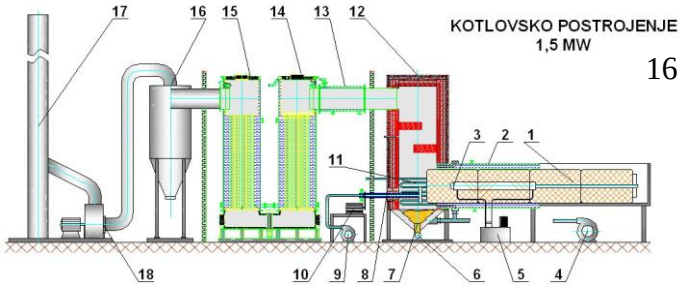

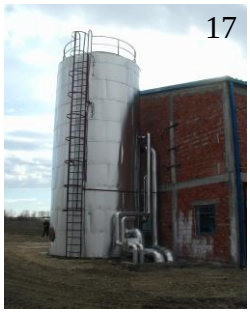

1. Experimental FB furnace, power up to 100kW, 2. Experimental FB boiler, power up to 500 kW, 3. Experimental FB apparatus (D=100 mm) for determining characteristics of combustion behavior in FB combustion of a fuel), 4. FB gasifier (D=200 mm), 5. Swirl burner for pulverized fuel with adjustable blades, 6. Pulverized fuel feeder, 7. Furnace for testing the swirl burners, 8. Tube furnace for testing of a pulverized fuel, 9. Household wood oven with high heat accumulation, convective transfer of the heat from the oven walls, catalyzer for decrease of CO emission and water/gas heat exchanger in the third draft, 10. Experimental apparatus for determination of combustion kinetics of a biomass (straw), 11. Heat storage with phase change of the medium, 12. Experimental installation for determination of permeability coefficient of a straw, 13. and 14. Experimental apparatus for determination of the combustion characteristics of baled biomass, 15. Experimental-demonstrational boiler burning small bales (0.4x0.5x0.8 m), power up to 60kW, 16. Experimental-demonstrational boiler, power 1.5-2 MW, with cigar-type combustion of various baled biomass, 17. A view to the boiler-house and heat storage, 18. A view to the boiler house and the cyclone (pos.16 in Figure 16), 19. A view to the heat exchanger with the vertical gas stream (pos.14 and pos. 15 in Figure 16), 20. A view to the adiabatic furnace and the feeding tunnel (pos. 2, 4 and 12 in Figure 16)

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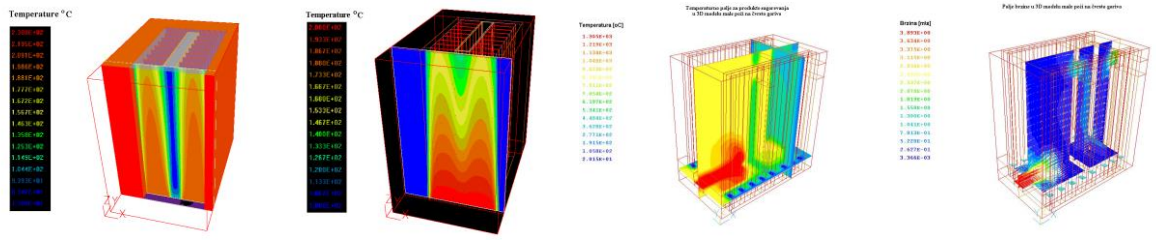
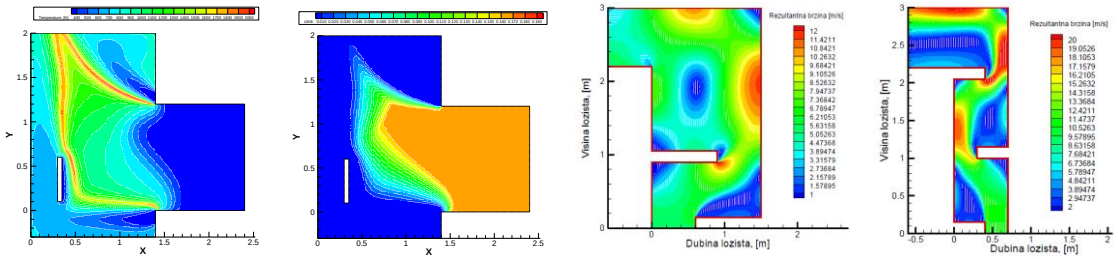
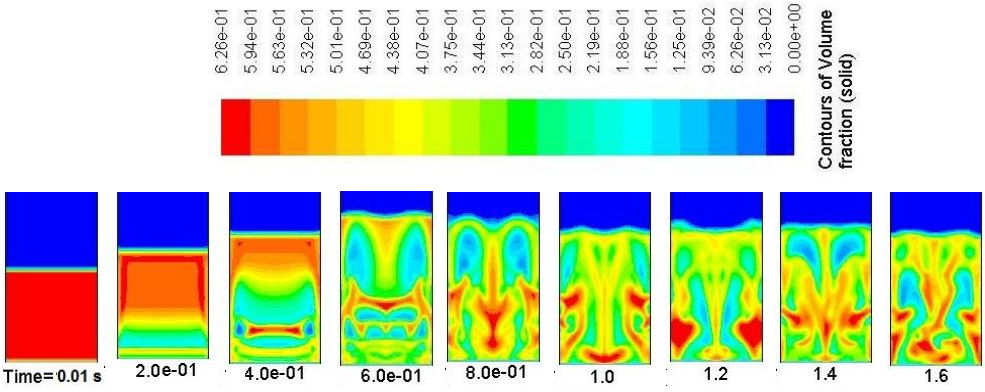
The mathematical modeling: a visual representation of the selected model results



Temperature field in the zone of heat exchanger and flow and temperature field in the small household furnace (Fig.7)



Temperature and concentration fields in the adiabatic furnace (pos. 12 in Fig. 9) with the cigar-type burning of the baled biomass



Development of the solid volume fraction distribution for Regime 1 fluidization conditions.

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Participation in international projects

(2004 - 2007) ADEG PROJECT (INCO-CT-2004-509187) "Advanced Decentralization Energy Generation Systems in Western Balkans" project, financed by the European Commission through INCO program of 6th FRAMEWORK PROGRAM. Participants: Serbia, Greece, Portugal, Germany, Croatia, Bosnia and Herzegovina.
The subject of the research project is the possibility of decentralized electricity generation in the Western Balkans, using renewable energy sources. Maps of renewable energy sources by municipalities were formed, possible technical solutions were considered, as well as investment and operating costs. Also, the applicable level of the biomass utilization in the future was considered.

(2006 – 2008) BIOM-ADRIA-1 Project:"The use of biomasses as a primary source of energy in the Adriatic Basin countries". Ref. No. 1202.010-07. Participants: Serbia, Italy (Adriatic New Neighborhood Program INTERREG – CARDS – PHARE)
The main goal of the project was selection of of the referent technical-technological solution for utilization of biomass as an energy source, i.e. optimal technical solution that enables optimal biomass utilization for power and heat production, which would at the same time enables industrial and communal application.

(2009 – 2012) CEI financed Applied Research Project BIOM-ADRIA – 2 "Development And Improvement of Technologies, Methodologies ynd Tools for The Enhanced Use of Agricultural Biomass Residues", Ref.no. 213.026-09. Participants: Serbia, Italy
The subject of the research project is the development of technologies, methodologies and tools in order to promote the use of waste from agricultural production as an energy source. Work on the project included experimental testing and modeling of combustion of baled straw, possibilities to use the land, where the ash and tailings are disposed, for the cultivation of energy crops and the possibility of recycling the ash of biomass for the purpose of breeding soil.

05/2004 – 04/2007	Project, financed by the European Commission through INCO program of 6th FRAMEWORK PROGRAM.	ADEG PROJECT (INCO-CT-2004-509187) "Advanced Decentralization Energy Generation Systems in Western Balkans"
04/2007 – 07/2008	CEI financed Applied Research Project BIOM-ADRIA – 1	"The use of biomasses as a primary source of energy in the Adriatic Basin countries". Ref. No. 1202.010-07.
07/2009 – 06/2012	CEI financed Applied Research Project BIOM-ADRIA – 2	"Development and improvement of technologies, methodologies and tools for the enhanced use of agricultural biomass residues", Ref.no. 213.026-09.

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The main research results:

Furnaces and boilers with fluidized bed combustion developed to the industrial application (more than 40 industrial facilities with power of 1,4-5 MW)

Vertical dryers for grains, developed to the industrial application. They are using waste biomass as a fuel for the hot air generation. Dozens of plants with a capacity of 4-40 t/h were produced, many of them exported.

Vertical corn dryer, with 2x5MW FB furnace

Boilers with cigar-burning of baled biomass -residues of agricultural production and some energy plants (two facilities were built, one for the combustion of small bales and one for large bales)

Industrial application did not stop the development. Now the research is aimed at improving the developed facilities.

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Researches on the biomass-to-energy projects

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2. Ana Marinković, MSc, chemist, engaged in the chemical analysis and environmental research; e-mail: mica@vinca.rs
   e-mail: aradojevic@vinca.rs
3. Dragoljub Dakić, PhD, external collaborator, head of the team that built the 2MW boiler, with the cigar-type combustion of baled biomass head of the team that built large laboratory installations zgradnjom velikih lab. Instalacija
   e-mail: dakicdr@vinca.rs
4. Goran Živković, PhD, director of Laboratory for Thermal Engineering and Energy, engaged in research of the heat storage
   e-mail: goran.zivkovic@vinca.rs
5. Stevan Nemoda, PhD, head of the project for FB systems development
   e-mail: snemoda@vinca.rs
6. Aleksandar Erić, PhD, engaged in the modeling and experiments of cigar-type combustion of biomass
   e-mail: erica@vinca.rs
7. Dejan Đurović, PhD, deputy director of Laboratory for Thermal Engineering and Energy dealing with PR, engaged in the modeling and experiments of cigar-type combustion of biomass (burn-off of the gases in the freeboard)
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8. Branislav Repić, PhD, head of the project for development of the cigar-type combustion of the baled biomass
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Measuring equipment used for the research of combustion and heat and mass transfer phenomena

Nr.	Device	Producer/type	Purpose
Measure equipment for fuel and ash characterization			
1	Flame photometer	SHERWOOD 360	Amount of Na2O and K2O in ash
2	Calorimeter	IKA C200	High heating value of solid and liquid fuels
3	UV/visible Spectrophotometer	BIOCHROM-LIBRA S22	Amount of titanium, phosphorus and chlorine
4	HPLC- High-performance liquid chromatography	THERMOSCIENTIFIC ULTIMATE 3000	Separates the components in a mixture, to identify each component, and to quantify each component
5	Carbon, Hydrogen, Nitrogen Determinator LECO, with sulfur module	LECO - CHN 628	Amount of carbon, hydrogen, nitrogen, and sulfur in a fuel
6	TGA701 Thermogravimetric Analyzer	LECO – TGA 701	Amount of ash, volatiles, moisture, and char
7	Analyzer	THERMOSCIENTIFIC ISQ™ LT	Amount of organic and non-organic compounds in liquid solutions
8	Device for the ash melting temperature	SCHMELTZ	Ash melting temperature, in oxidizing and reducing atmosphere.
9	Multifunctional PH meter	CONSOR C933	Amount of fluorine in liquid solutions
10	Set of gases necessary for equipment operation		
11	Auxiliary equipment, balances, grinders, sieves, annealing and drying ovens, sand bath, etc.		
Gas analyzers (flue gas analyzers)			

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1	Continuous Emissions Analyzer	SERVOMEX 4900-C1	Concentration of CO and CO_2 in flue gas
2	Continuous Oxygen analyzer with a paramagnetic sensor	M&C PMA-10	Concentration of O_2 in flue gas
3	Continuous gas analyzer with a zirconium probe and IR sensors	FUJI ZKJ-3	Concentration of O_2, CO_2, NO and SO_2 in flue gas
4	Continuous gas analyzer with an electrochemical and paramagnetic sensors	IMR 3000-P	Concentration of CO_2, CO, O_2, SO_2, NO, and NO_2 in flue gas
5	Analogue gas analyzer with a paramagnetic cell	SERVOMEX 572	Concentration of O_2 in flue gas
6	Continual chemiluminescent NOx/NO analyzer	ECOPHISICS S-70	Concentration of NO_x in flue gas
7	Gas conditioner with a heated hose and additional equipment	JCT Analysentechnik H343FA	Gas cleaning and preparation before introducing to gas analyzer
8	Gas conditioner with a heated hose and additional equipment	JCT Analysentechnik 22.P112301	Gas cleaning and preparation before introducing to gas analyzer
9	Gas conditioner with a heated hose and additional equipment	IMR 600	Gas cleaning and preparation before introducing to gas analyzer
10	Gas conditioner	M&C PSS-5	Gas cleaning before introducing to gas analyzer
11	Set of gases necessary for the control and calibration of the gas analyzers		
Equipment for the determining of concentration of solids in flue gas			
1	Gas sampler	Design of Vinca Institute	Isokinetic gas sampling

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2	Source Sampling Console	APEX XC-572-V	Isokinetic gas sampling
3	Automatic Isokinetic Sampler	Paul Gothe AISS	Isokinetic gas sampling
4	Automatic Isokinetic Sampler	Paul Gothe ITES	Isokinetic gas sampling
5	Auxiliary equipment: vacuum pumps, barometers, digital manometers, thermometers balances, analytical balances, etc.		
Equipment for thermo-physical and warranty measurements in boilers and furnaces, heat exchangers (water heating, pre-evaporators, steam heaters, etc.) turbines, filters, fan and other grinders and other devices			
1	A number of probes (water or air cooled), length up to 5m, with auxiliary equipment listed under item 5 of previous specification		
2	A number of multichannel acquisition systems with flexible software for data acquisition and processing		

LECO - CHN 628 and LECO – TGA 701

HPLC THERMOSCIENTIFIC

ULTIMATE 3000