

Control potential of different operating methods in small-scale wood pellet combustion (COPECOM)

ERA-NET Bioenergy,
Small-Scale Combustion - Workshop
23.5.2007

Combustion control

- **Advanced process control is a tool to manage**
 - t Emission levels now and in the future
 - è gaseous emissions and fine particles
 - t Large load, fuel and power fluctuations
 - t Fouling, drifting, wearing

- **Goals**
 - t Continuous monitoring and minimization of losses and emissions
 - è advanced sensors and signal processing
 - è monitoring and optimization of combustion
 - è adaptable control methods
 - t Reduction of maintenance and service costs
 - è methods for monitoring and managing process deviations
 - è condition monitoring



Automated control of small-scale combustion

- **Methods**

- t Mathematical modelling and simulation
 - advanced methods and strategies for controlling air and fuel feed (MPC, optimal control, fuzzy/neural,...)
- t Embedded systems, advanced sensors, signal processing

- **Challenges**

- t Price of small production units
- t Micro-scale CHP
- t Solutions must be reliable
 - behaviour of combustion process depends on time, disturbances and combustion conditions
 - number of combustion units → dissimilarity of combustion environments → adaptation needed

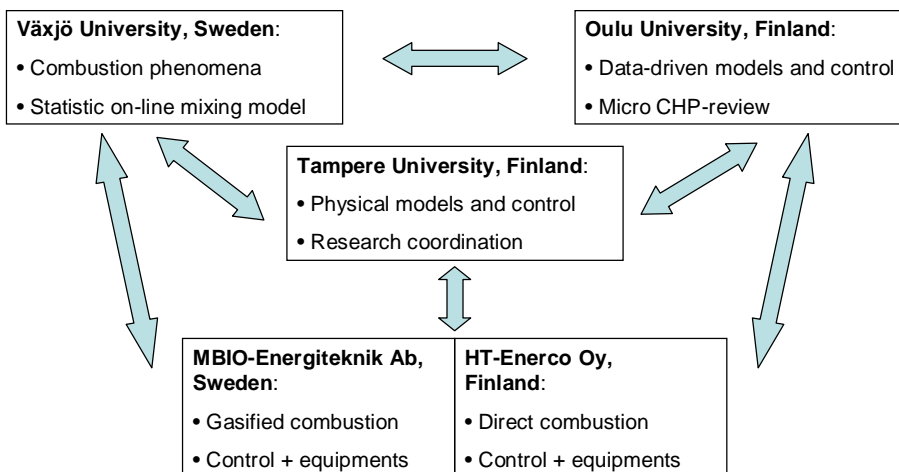
Automated control of small-scale combustion

- **Benefits and influences**

- Improved management of non-steady states
 - è stabilisation of combustion process
 - è faster recovery after disturbances
- Optimization of combustion temperatures and air staging
 - è maximisation of annual efficiency
 - è minimisation of emissions
- Modernisation of combustion systems
 - è cost effectiveness
 - è energy savings

Research consortium

Research consortium



Växjö University, Sweden

- Established in 1999
- Department of Bioenergy Technology
 - Professors Björn Zethraeus and Mehri Sanati
 - Major research activities concern all parts of the bioenergy sector
 - fuel properties and handling
 - biological processes
 - gasification
 - fuel conversion and combustion modelling for heat production
 - high-temperature applications
 - One major research project CHRISGAS
 - an integrated project in the 6'th framework
 - pressurised gasification for the future production of automotive fuels
 - Växjö University is the project coordinator

Small scale Bioenergy research at Tampere University of Technology , Finland

Researcher, MSc Timo Korpela
Tampere University of Technology
Institute of Automation and Control

Institute of Automation and Control

The Institute of Automation and Control is founded in 1969 and it is the main educational research centre in Automation and Control technology in Finland. Research and educational activities of ACI are concentrated on:

- Automation and Information Technology
- Intelligent Systems
- System Theory
- Process Simulations
- Process and Energy Automation
- Pulp and Paper
- Automation and Microsystems

à For us, Bioenergy has been an application under the red headlines for 3 decades. Small scale Bioenergy has been a part of research since 2004.

Control development of small scale solid biomass fired systems

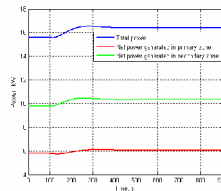
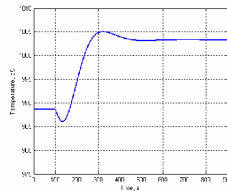
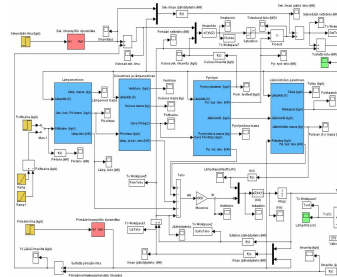
- Modelling of wood pellet combustion for control purposes
 - Modelling based on physics of combustion
- Control development of wood chip and wood pellet fired systems
 - Cost effective systems
 - Passive open loop control and active feedback control
 - Soft sensor approach
 - Hierarchical solutions

Mathematical modelling and simulation of combustion

- Dynamical modelling for control purposes

$$\rho c \frac{\partial T}{\partial t} = \frac{1}{r^2} \frac{\partial}{\partial r} \left(\lambda r^2 \frac{\partial T}{\partial r} - \mathcal{Q}_r \right) + \sum \Delta h_f \dot{m}_f$$

- Case – Wood pellet combustion simulator
 - 5 % step change to fuel feed
 - Temperature response
 - Power responses at different combustion zones



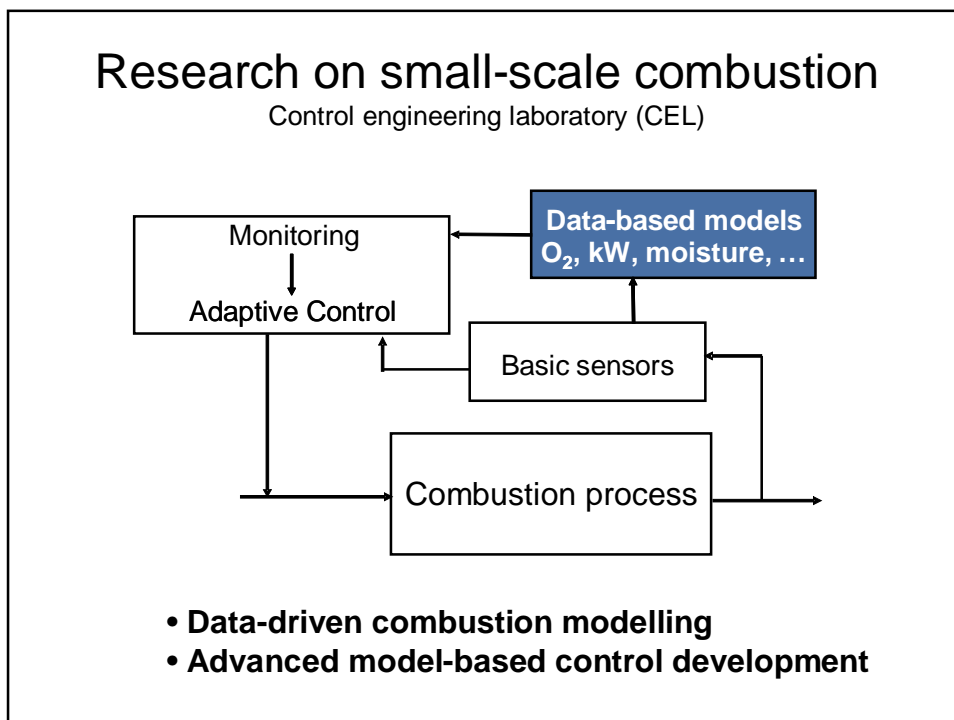
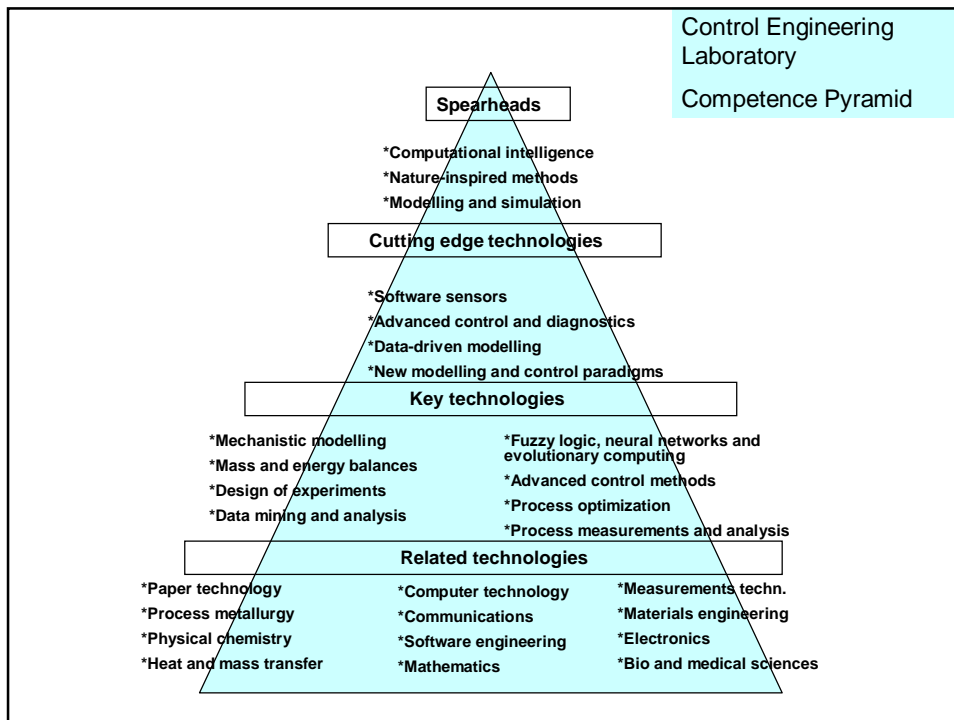
University of Oulu, Finland Control engineering laboratory (CEL)

Professor Kauko Leiviskä

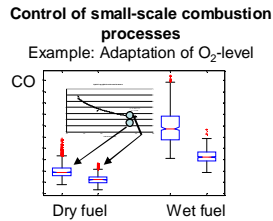
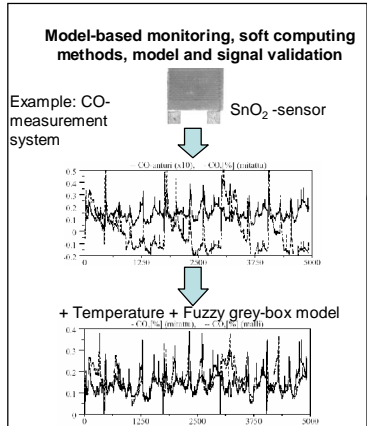
Researcher Mika Ruusunen

UNIVERSITY of OULU
OULUN YLIOPISTO

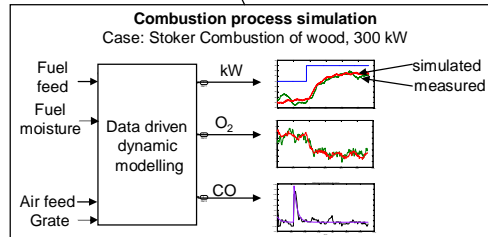
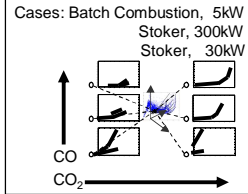




Combustion Research, CEL

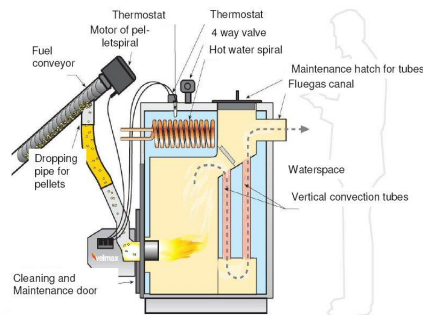


Data analysis for optimal combustion conditions



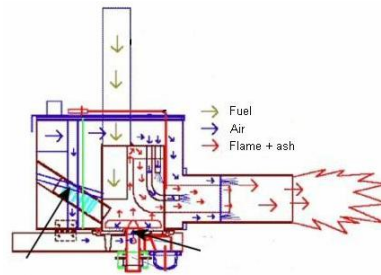
HT Enerco Oy, Finland

- Finnish family company
- Founded in 2000
- Sister company of HT Lasertekniikka, which is the biggest laser cutting company in Finland
- Produces
 - pellet boilers (15 – 20 kW)
 - pellet burners (20 kW)
 - Velmax
 - bioenergy boilers (30 - 500 kW)



MBIO Energieteknik Ab, Sweden

- Swedish bioenergy company
- 7 years research experience relating to pellets combustion
- Objectives of development
 - to develop each phase of combustion and heat transfer processes to ideal level
 - modular solution
 - to build as easy constructions as possible with standard components
- MBIO has developed a new type of pellets burner called Biona
 - burner is based on gasification
 - pellets are refined prior to fuel feed
 - feedback control by temperature measurement



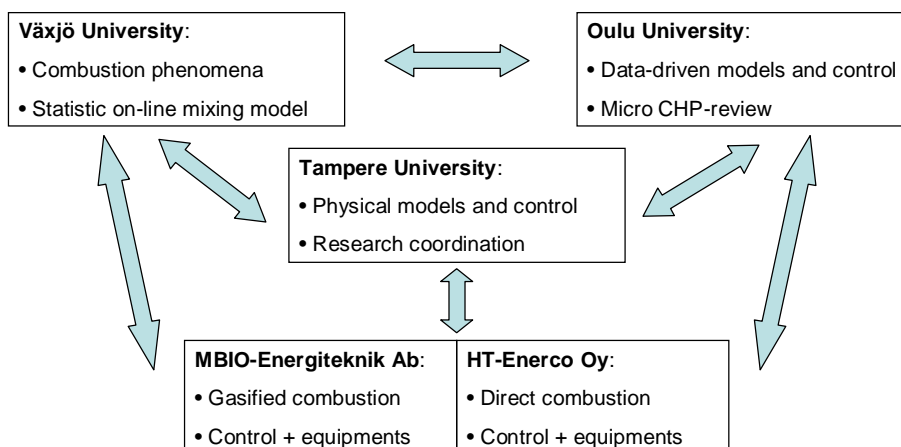
The project

COPECOM

Research focus and targets

- Control potential of pellet burners – research on gasified and direct combustion, *experimental*
- Physical + data-based modelling and control development, *experimental/theoretical*
- An analysis of integrated small-scale power production and storage, *theoretical*

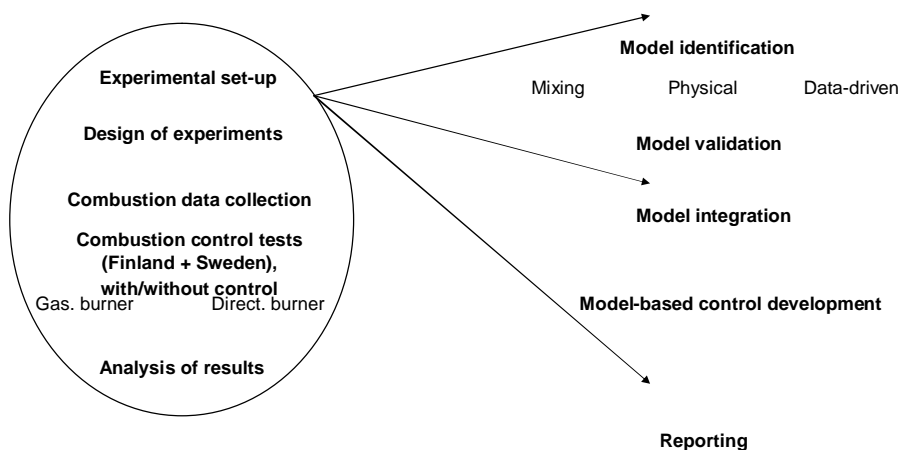
Research contributions



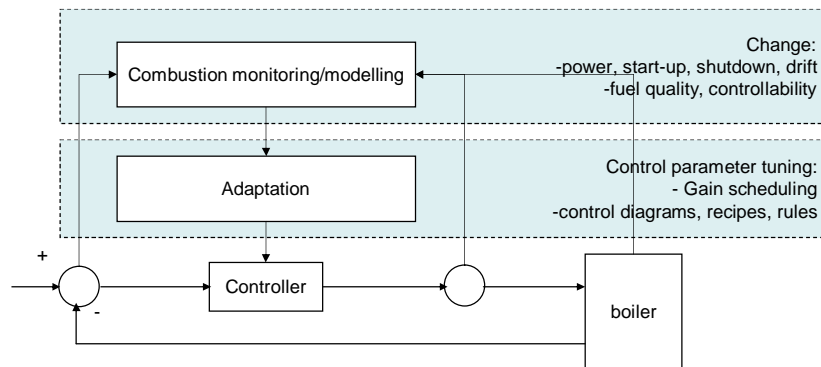
Milestones

- 06/2007 MS1: * Small-scale power production: theoretical review
* Adaptation of physical combustion model to different burners
- 10/2007 MS2: * Process identification and data analysis
* Verification and validation of physical models to measurements
* Statistical model completed in first version
- 02/2008 MS3: * Control strategy framework and its evaluation
- 04/2008 MS4: * Reporting, publications

Detailed research steps



Advanced control system for small-scale combustion, a framework



Experimental set-up

- **Motivation**

- Control test campaigns (gasified+direct)
- Combustion process (gasified+direct) comparison
- Data for model identification and validation

Comparing results

- Efficiency
 - Direct/indirect calculation
 - Estimated annual eff.
- Reduced CO, O₂, NO_x vol.-%/ppm (mg/MJ)
- Reliability
- Cost-effectiveness
- Synchronization with Växjö
 - Test procedures/sequences
 - Repeatability of experiments, comparable quality indices

Project deliverables

- An integrated model-based control strategy for small-scale biomass units and evaluation within two cases
- A comparison of control potential: gasification and conventional combustion processes
- Theoretical analysis of distributed power production and –storage possibilities with biomass, small-scale heat or product gas as a primary energy source
- Publications
- Knowledge exchange between universities and companies

Recent publications

Korpela, T., Björkqvist, T. & Lautala, P. 2006. Modelling of Wood Pellet Combustion for Control Purposes, Pellets 2006, 2nd World Pellet Conference, Jönköping, Sweden, 30 May-1 June 2006, Proceedings, p. 97–104.

Korpela, T. 2006. Control of Wood Chip Fired Systems. Tampere University of Technology, Institute of Automation and Control, Report 2006:1. In Finnish.

Ruusunen Mika & Leiviskä Kauko, Fuzzy modelling of carbon dioxide in a burning process, Control Engineering Practice, Vol 12/5 (2004) pp. 607-614.

Ruusunen Mika, Monitoring of Small-Scale Biomass Combustion Processes, Department of Process and Environmental Engineering, Control Engineering Laboratory, Report Series A 29. March 2006. 28 p. ISBN 951-42-8027-X. ISBN 951-42-8028-8 (pdf). <http://ntsatsat.oulu.fi/index.php?257>

Ruusunen Mika, Effect Of Automatic Control Technologies on Emission Reduction in Small-scale Combustion, In: (Ed. Hytönen Kati & Jokiniemi Jorma) Reduction of fine particle emissions from residential wood combustion - final report, Workshop in Kuopio on May 22-23, 2006. Report 3/2007, ISSN 0786-4728.

Combustion Control of Small Scale Wood Fired Appliances - International Workshop 17 June 2005 VTT Processes, Jyväskylä, Finland.

<http://akseli.tekes.fi/opencms/opencms/OhjelmaPortaali/ohjelmat/Pienpuu/en/CombustionControl.html>

Contact information

Växjö University

Prof. Björn Zethraeus
School of Technology and Design
Department of Bioenergy Technology
Växjö University
351 95 Växjö, Sweden

Phone: +46 470 708 738
Fax: +46 470 708 756
Mail: Bjorn.Zethraeus@vxu.se
Web: www.vxu.se

University of Oulu

Prof. Kauko Leiviskä &
Researcher Mika Ruusunen (contact person)
University of Oulu
Control engineering laboratory
P.O. Box 4300
90014 University of Oulu, Finland

Phone: +358 8 553 2465
GSM: +358 40 836 1468
Fax: +358 8 553 2304
E-mail: mika.ruusunen@oulu.fi, kauko.leiviska@oulu.fi
Web: ntsatsat.oulu.fi

Tampere University of Technology

Prof. Pentti Lautala, Senior Scientist Tomas Björkqvist &
Researcher Timo Korpela (contact person)
Tampere University of Technology
Institute of Automation and Control
P.O. BOX 692
33101 Tampere, Finland

Phone: +358 3 3115 2563
GSM: +358 50 329 0703
Fax: +358 3 3115 2340
E-mail: timo.korpela@tut.fi, pentti.lautala@tut.fi,
tomas.bjorkqvist@tut.fi
Web: www.tut.fi

MBIO-Energiteknik AB

Jörgen Bech
MBIO-Energiteknik AB
Industriv 18
360 32 Gemla, Sweden

Phone: +46 470 671 00
Fax: +46 470 671 50
E-mail: jorgen@mbio.se, info@mbio.se
Web: www.mbio.se

HT Enerco Oy

Ilkka Uusi-Maahi, CEO
HT Enerco Oy
Hallitie 7
42800 Haapamäki, Finland

Phone: +358 10 774 5030
GSM: +358 40 511 0606
Fax: +358 10 774 5095
E-mail: ilkka.uusi-maahi@htlaser.fi, enerco@htlaser.fi
Web: www.htenerco.fi