Miten ymmärtää puubiomassan kaasutusta paremmin? - Hiilen kaasutusmallin kehittäminen

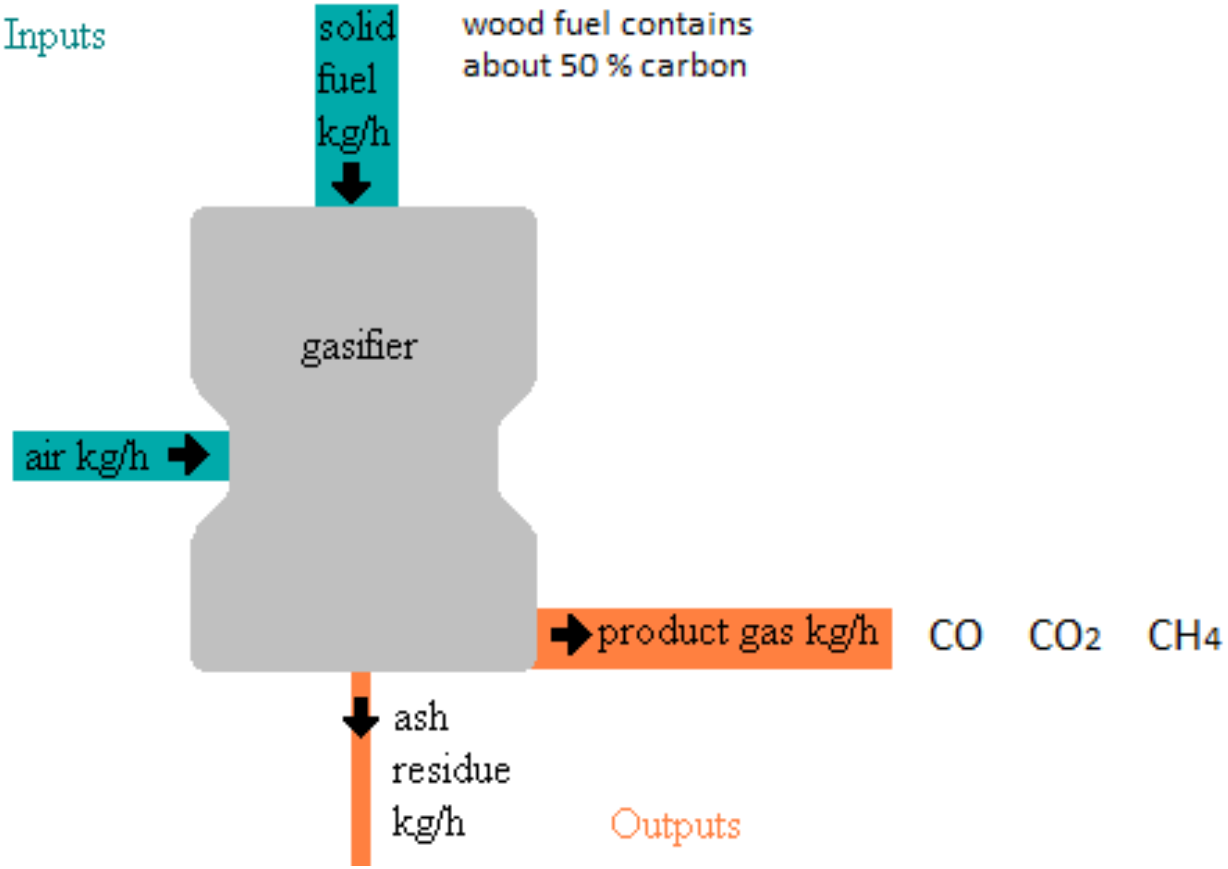
How to Improve Understanding of Gasification of Woody Biomass? - Development of the Carbon Gasification Model

Researcher Sanna Oikari, Kokkola University Consortium Chydenius

Professor Jukka Konttinen, University of Jyväskylä, Dept. of Chemistry

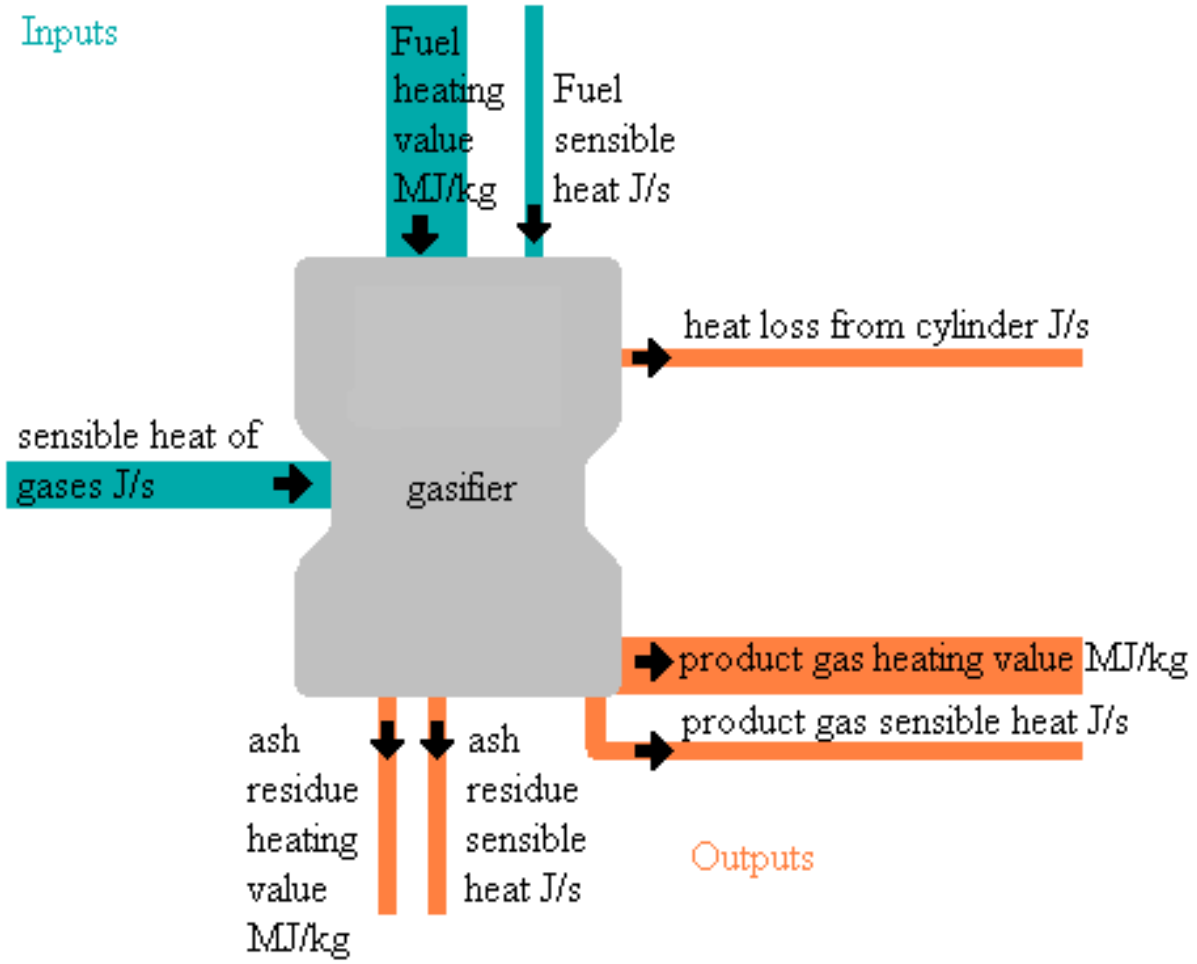
Carbon balance

Hiilitase



Energy balance

Energiatase



Research plan

HIGHBIO2 2011-2013
Biomass to Energy and Chemicals

WP1 Share of the project:

Optimization of the gasification process

Mathematical models for:

- Material balance
- Energy balance
- Efficiency and carbon conversion

-> create a common measurement and calculation method

comparison to measurements

Modeling benefits

- Easy to test many variables
- Understand phenomenon more deeply
  → optimization of gasification process
- Cost efficient
- Safe
- A working model can also be applied in design and simulation of a commercial process
  - Also operator training can become possible

Model needs to be validated with experimental results

Downdraft Gasifier Modeling

•One-dimensional

Model

•Focus on reduction zone of the gasifier

•Based on equations: material and energy conservation, reaction rate, pressure gradient of a fluid flowing through a bed etc.

Model References

- GILTRAP D.L. et al. A steady state model of gas-char reactions in a downdraft biomass gasifier. Solar Energy, January 2003, Vol. 74, Issue 1, pp. 85-91.
- WANG Y and KINOSHITA C.M. Kinetic model of biomass gasification. Solar Energy, 1993, Vol. 51, pp 19-25.
- BABU B.V. and SHETH P.N. Modeling and Simulation of Reduction Zone of Downdraft Biomass Gasifier: Effect of Char Reactivity Factor. Energy Conversion and Management, September 2006, Vol. 47, Issues 15-16, pp. 2602-2611
- BABU B.V. and SHETH P.N. Modeling and Simulation of Reduction Zone of Downdraft Biomass Gasifier: Effect of Air to Fuel Ratio. Journal on Engineering and Technology, 2007, Vol. 2, Issue 3, pp. 35-40
- GAO N. and LI A. Modeling and simulation of combined pyrolysis and reduction zone for a downdraft biomass gasifier. Energy Conversion and Management, December 2008, Vol. 49, Issue 12, pp. 3483-3490.

Model References

- KOUFOPANOS C.A., LUCCHESI A. and MASCHIO G. Kinetic modelling of the pyrolysis of biomass and biomass components. The Canadian Journal of Chemical Engineering, February 1989, Vol. 67, Issue 1, pp. 75–84.
- ROY P.C., DATTA A. and CHAKRABORTY N. Modelling of a downdraft biomass gasifier with finite rate kinetics in the reduction zone. International Journal of Energy Research, July 2009, Vol. 33, Issue 9, pp. 833-851.
- ZAINAL Z. A. et al. Prediction of performance of a downdraft gasifier using equilibrium modeling for different biomass materials. Energy Conversion and Management, August 2001, Vol. 42, Issue 12, pp. 1499-1515
- RATNADHARIYA J.K. and CHANNIWALA S.A. Three zone equilibrium and kinetic free modeling of biomass gasifier – a novel approach. Renewable Energy, April 2009, Vol. 34, Issue 4, pp. 1050-1058.
- THUNMAN H. et al. Composition of Volatile Gases and Thermochemical Properties of Wood for Modeling of Fixed or Fluidized Beds. Energy Fuels, 2001, Vol. 15, Issue 6, pp. 1488-1497.

Model results

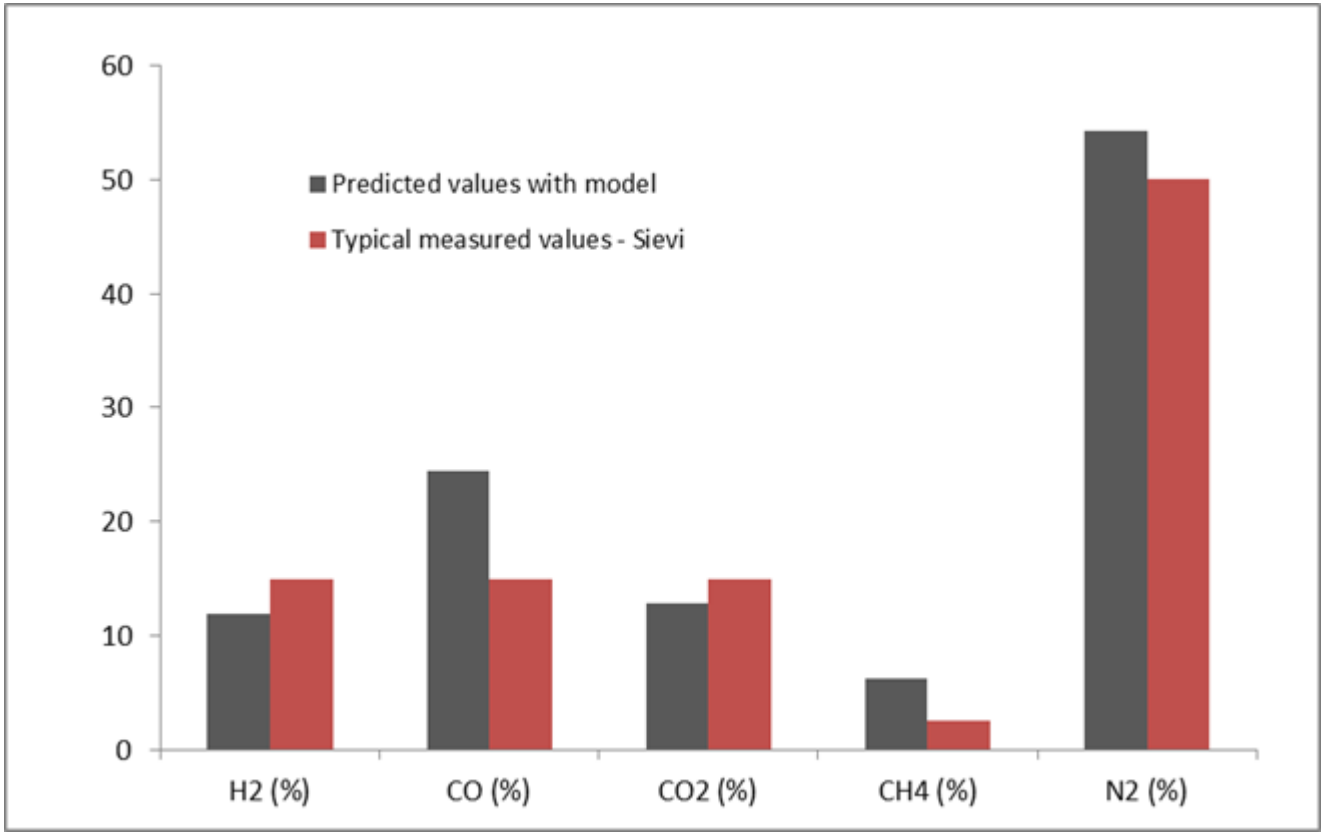
Product gas composition - Model results compared with measurements made in Sievi pilot-gasifier

Case 1 is gasificators typical gas composition

Case 2 and 3 are earlier measurements

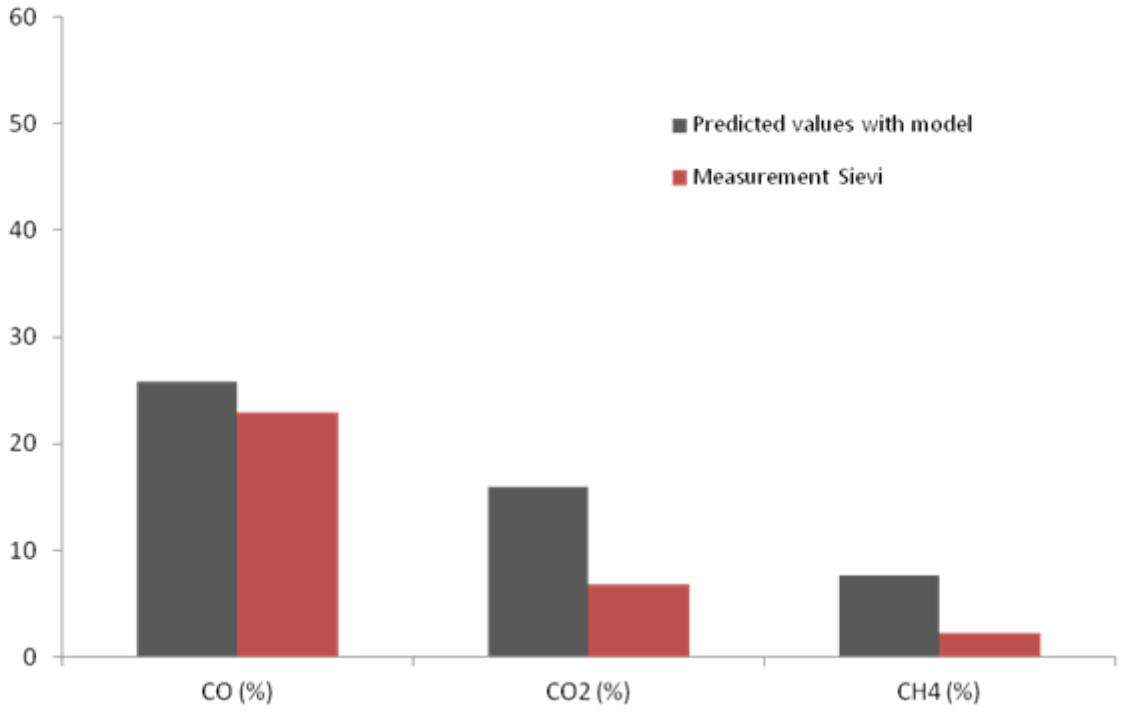
Comparison

Model results compared with typical product gas composition



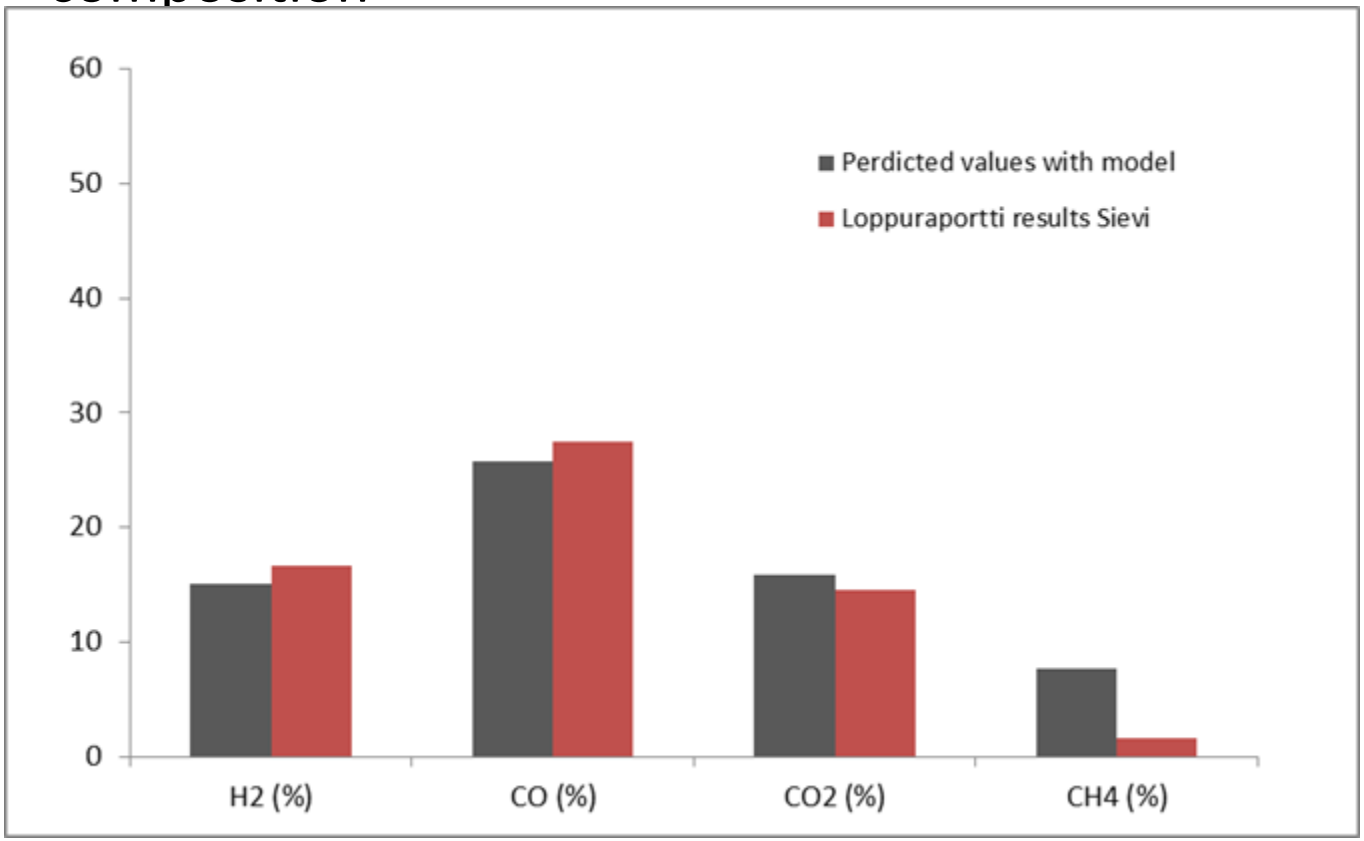
Comparison

Model results compared with case 2 gas composition

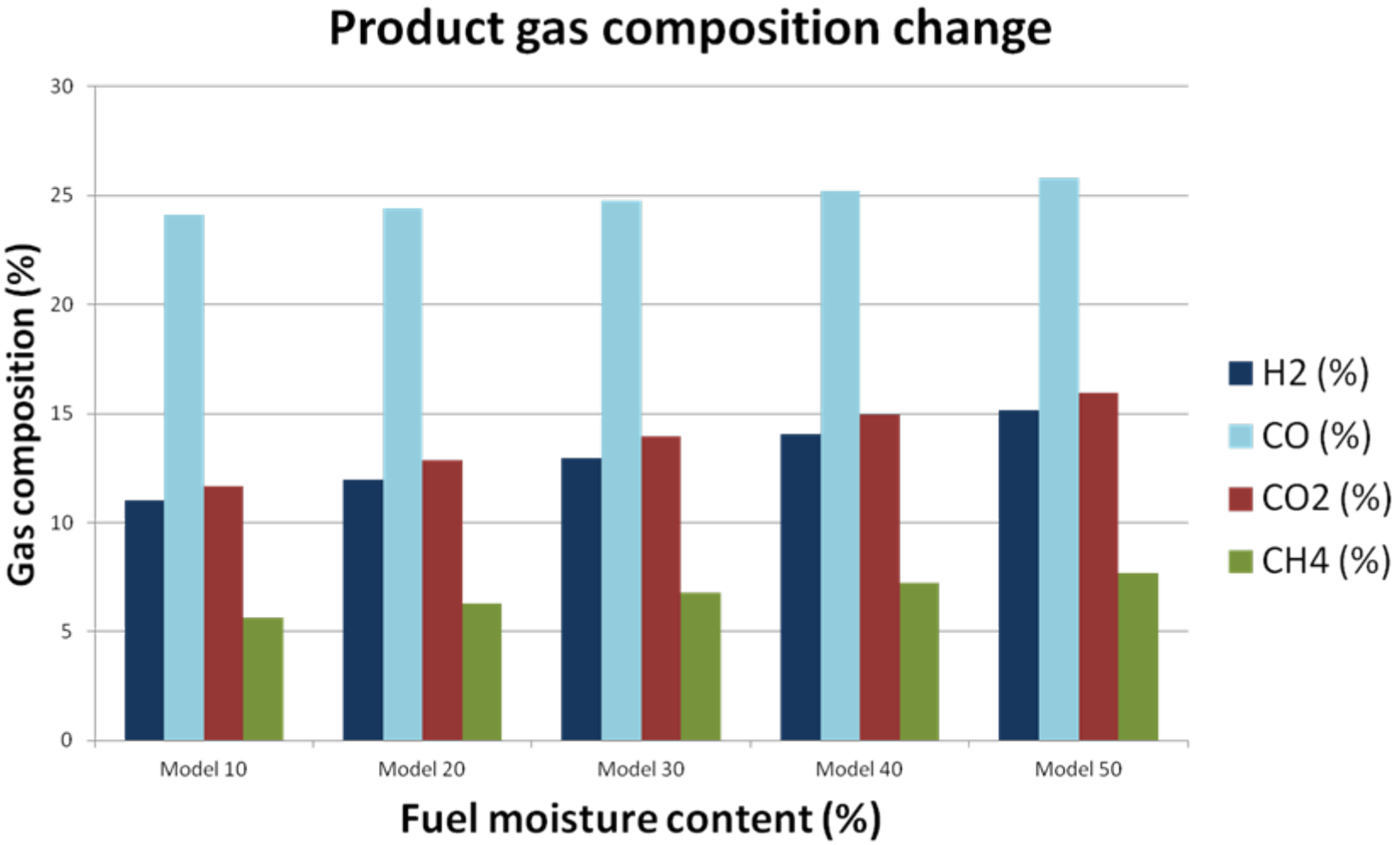


Comparison

Model results compared with case 3 product gas composition



Fuel moisture



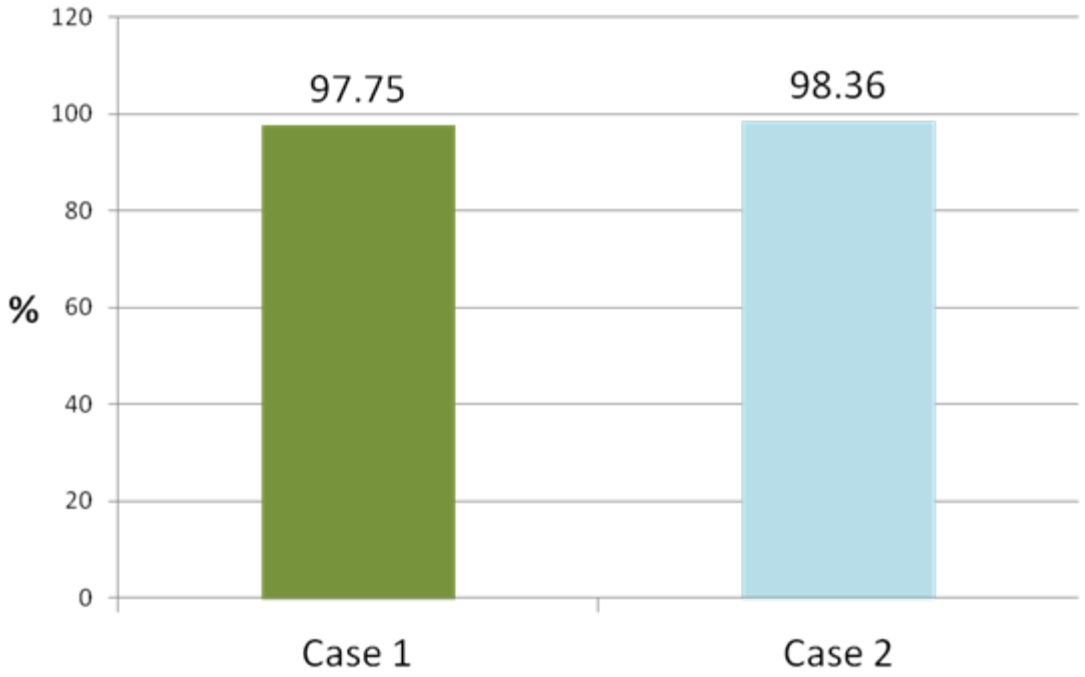
Carbon balance

Carbon balance of Centrias pilot-plant at Sievi

–Approximations: 30 % of air needed in combustion

–Output/Input relation calculation

–near 100 %



Further development

Model improvement

•Less difference between experimental values and model results

measurements from same experiment

more measurements, less evaluated values

Conclusions

Material and energy balance are one way to analyze and optimize gasification.

Model predicted quite well product gas composition, but development continues in future.

Modeling is useful tool, because it’s cost efficient and it increases understanding.

References

1. PIENINIEMI, K. ja MUILU, Y.; Kaasutus ja tuotekaasun analysointi, kirjassa: Lassi, Ulla ja Wikman, Bodil (toim.), Biomassan kaasutus sähköksi, lämmöksi ja biopolttoaineiksi, HighBio projektijulkaisu, Jyväskylän yliopisto, Kokkolan yliopistokeskus Chydenius, Kokkola 2011
2. MUILU, Y.; EK-puukaasu Loppuraportti, Centria tutkimus ja kehitys, Ylivieska, 15.09.2007
3. LAMPINEN, A.; Uusiutuvan liikenne-energian tiekartta. Pohjois-Karjalan ammattikorkeakoulun julkaisuja B:17, Joensuu 2009, 437 s.
4. Maol taulukot, Otava, Helsinki 1996
5. ALAKANGAS, E. 2000. Suomessa käytettävien polttoaineiden ominaisuuksia, Otamedia Oy, Espoo, Valtion teknillinen tutkimuskeskus, VTT tiedotteita 2045.
6. SOUZA-SANTOS, M.L. 2010. Solid Fuels Combustion and Gasification, Modeling, Simulation and Equipment Operations, CRC Press Taylor &Francis Group, London