Economics of decentralized hydrothermal carbonization of biogas digestate: A casy study from Germany

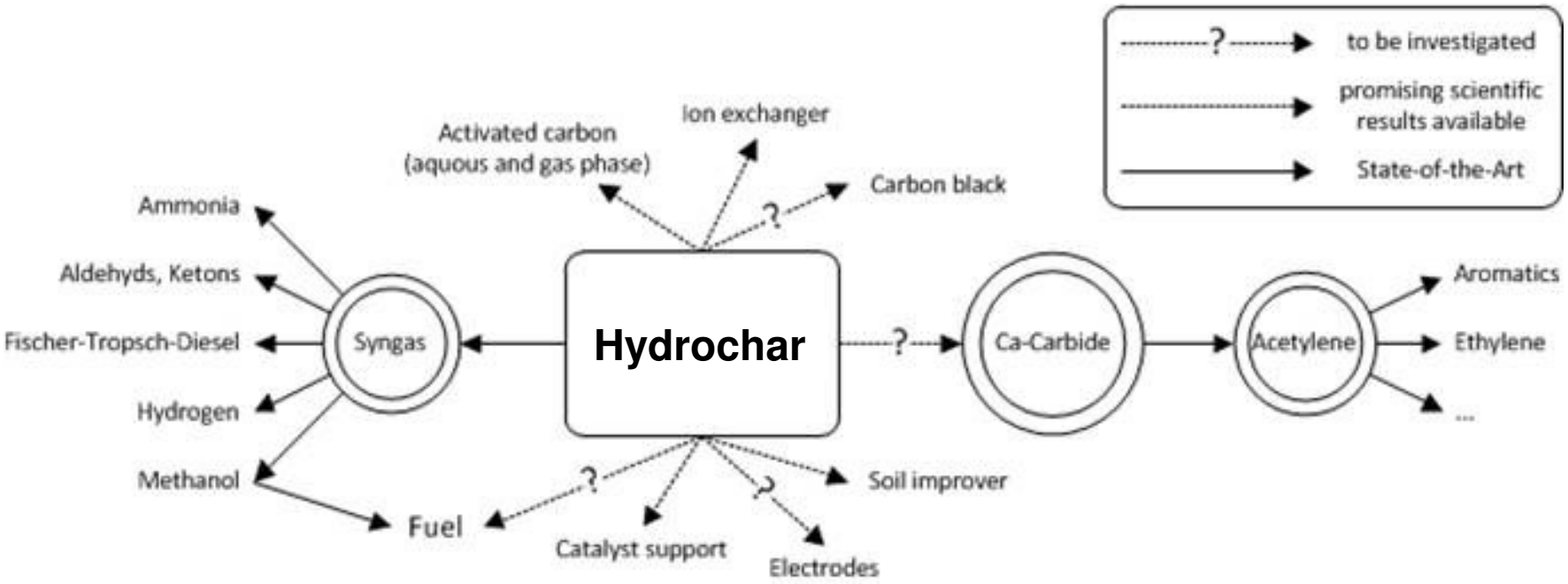
250th ACS National Meeting, Boston, Massachusetts
Division of Environmental Chemistry
Session - Hydrothermal Carbonization: Possibilities and Limits for Feedstocks, Processes and Applications
August, 16, 2015, 4:25 PM - 4:50 PM

Kay U. Suwelack, Dominik Wüst,
Andrea Kruse

Fraunhofer INT

Introduction

Hydrothermal carbonization – How to put the value in?



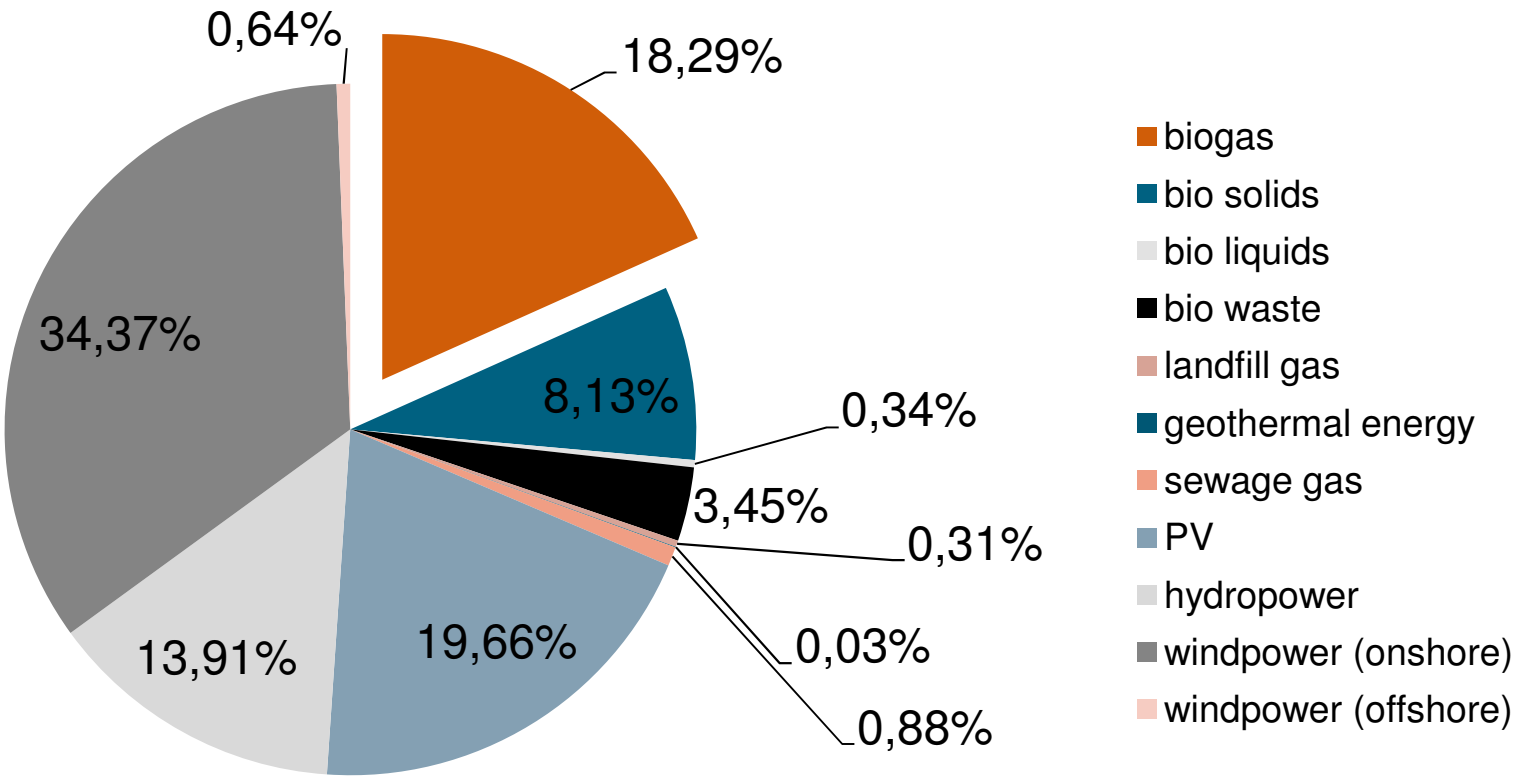
Fraunhofer INT

Agenda

1. Introduction
2. Why is HTC of biogas digestate promising?
3. Process Design Assessment (PDA)
4. Levelized costs of energy output
5. Conclusions

Why is HTC of biogas digestate promising? 1/3

Gross electricity production from renewable sources in Germany in 2013.

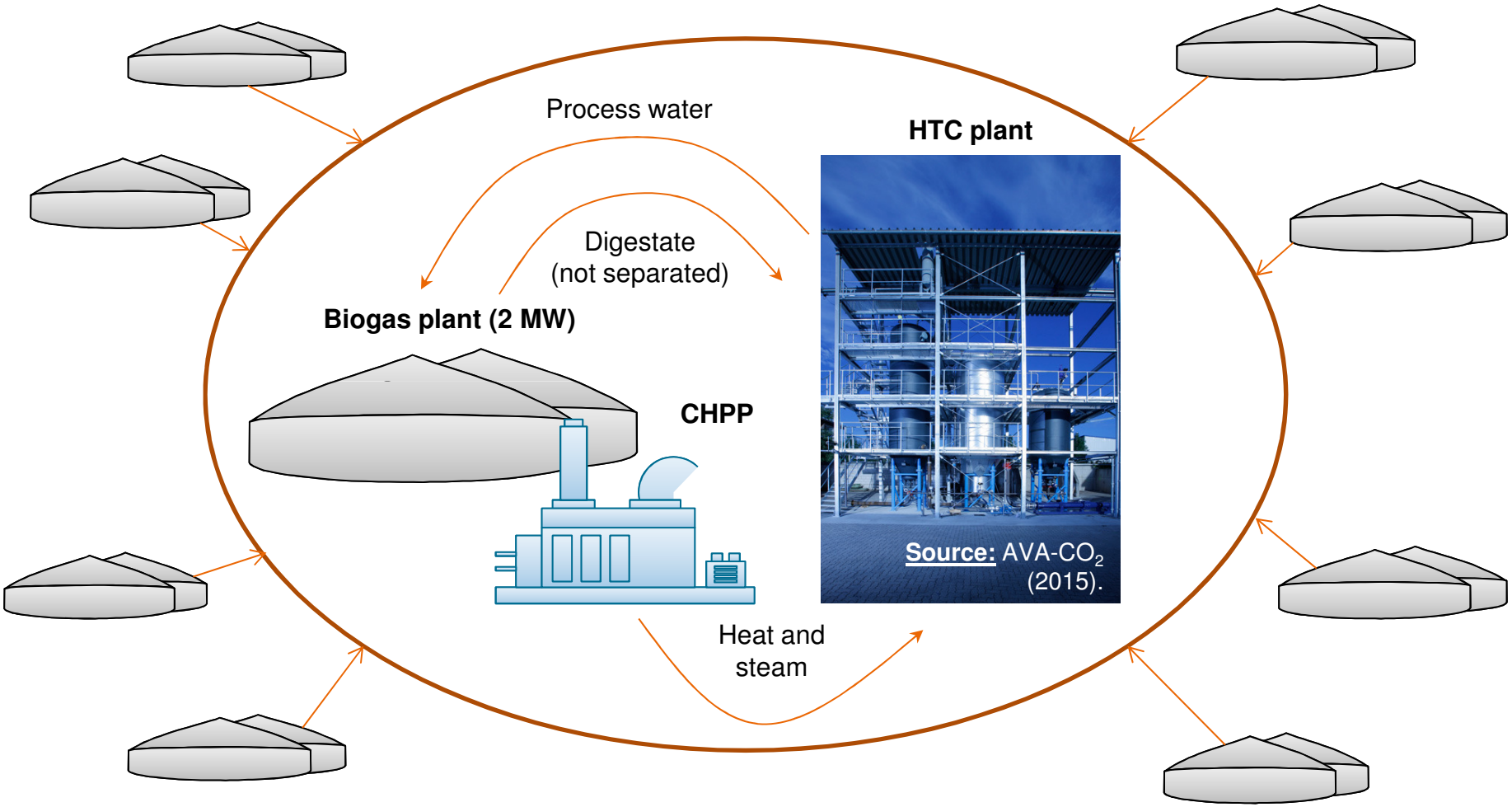


In 2013 the renewable electricity in Germany reached 549 PJ (25,4 % of gross production). Nearly 100 PJ were produced by biogas plants.

Ref: BMWi - AGEE-Stat – 2/2014.

Why is HTC of biogas digestate promising? 3/3

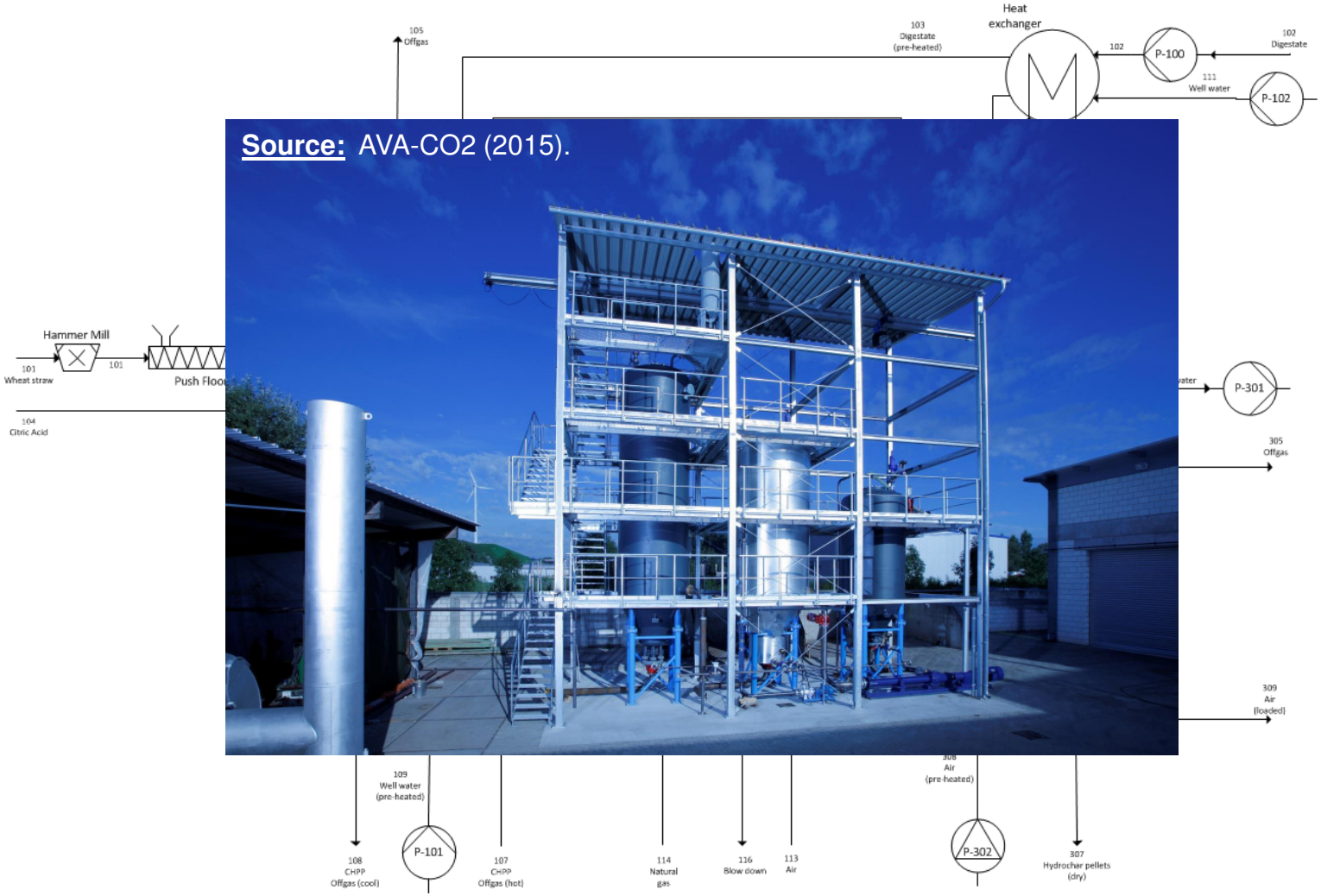
The concept – A Biogas-HTC-Biorefinery.



Fraunhofer INT

Process Design Assessment (PDA) 1/3

Flow chart model of the up-scaled batch process.

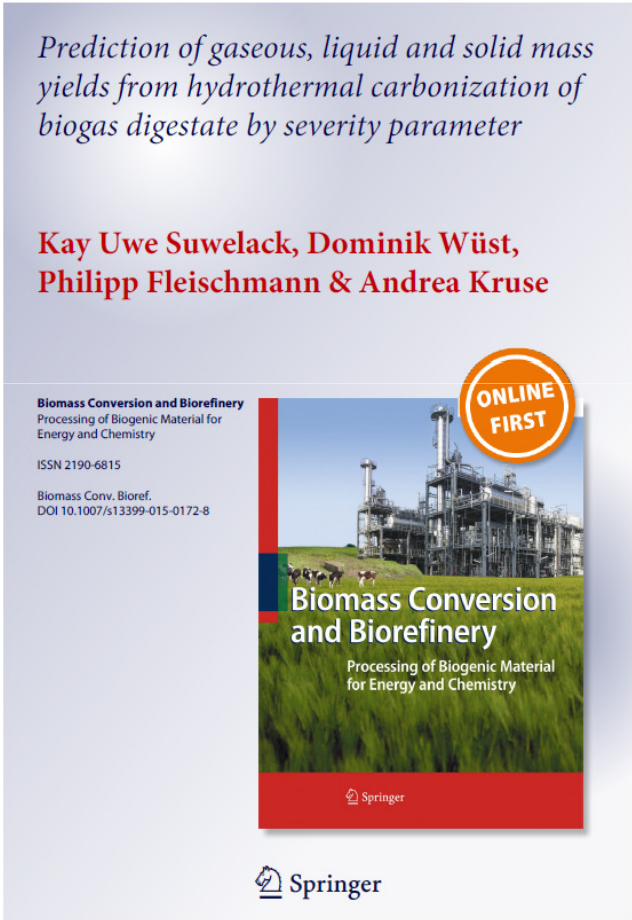


Source: AVA-CO2 (2015).

Fraunhofer INT

Process Design Assessment (PDA) 2/3

Mass balancing for HTC of biogas digestate (mass yield prediction by severity parameter)



Input: C | T | t

Severity and yield models:

$$R_{OH} = \exp\left(\frac{C - C_{ref}}{\lambda C_{ref}}\right) \times \exp\left(\frac{T - T_{ref}}{\omega}\right) \times t$$

$$Y = a + b \times \ln(R_{OH})$$

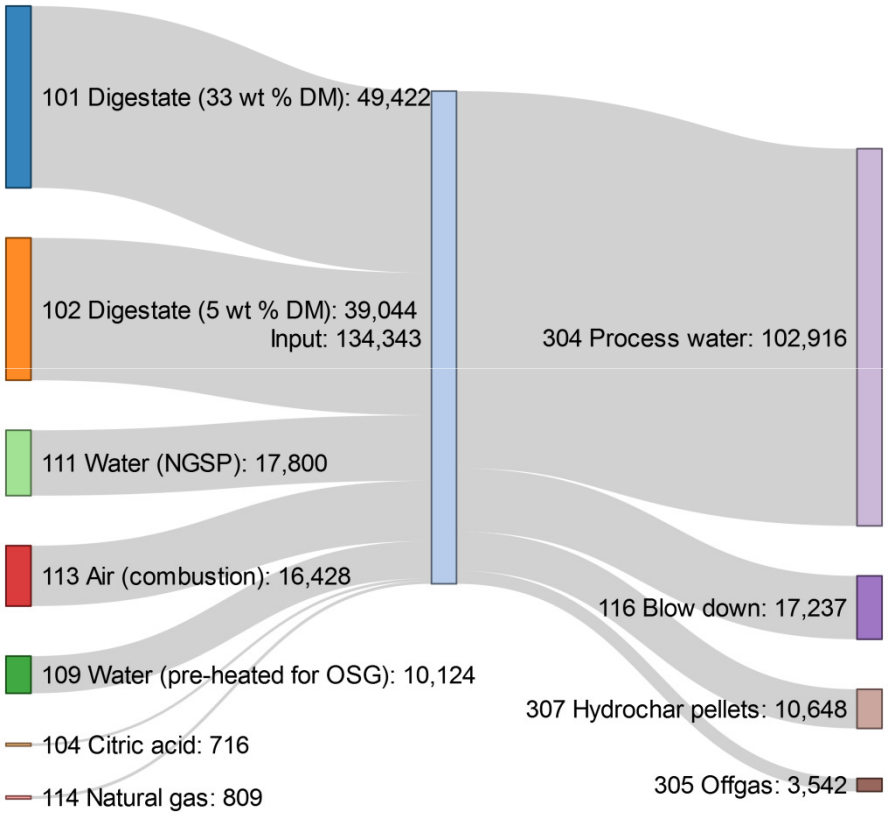
Output: Y_s | Y_l | Y_g | O/C | H/C | HHV

Fraunhofer INT

Process Design Assessment (PDA) 3/3

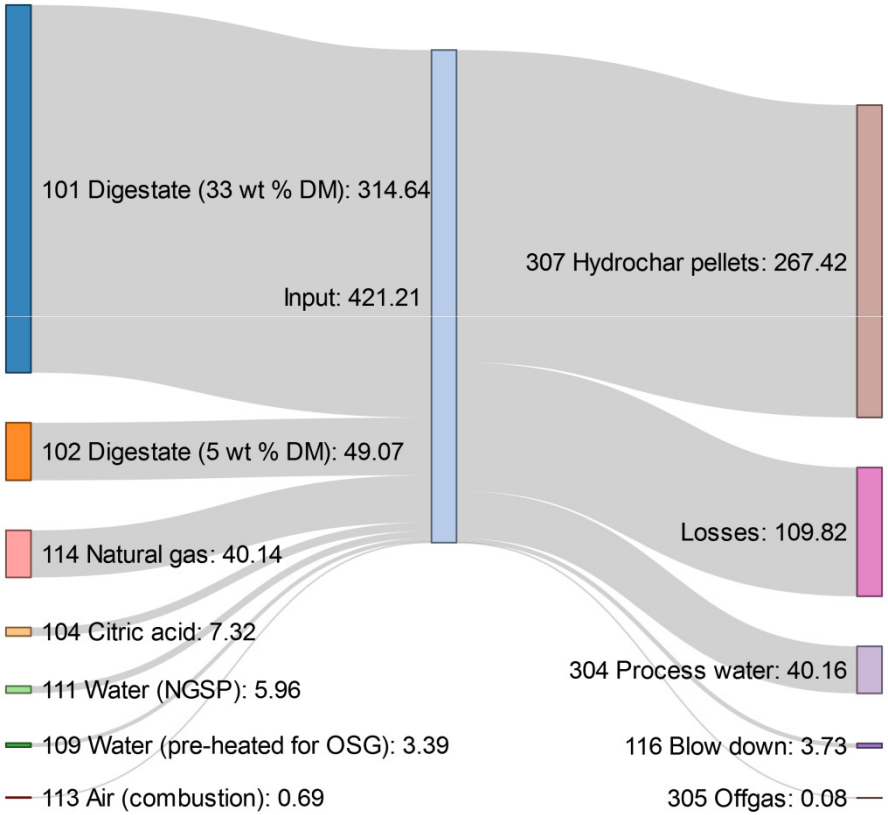
Mass and energy balancing by thermodynamic modelling

mass balance (Mg/a)



energy balance (TJ/a)

(enthalpy and chemical energy flows)



Process parameter: pH 7 | **T = 245°C** | t = 120 min

Fraunhofer INT

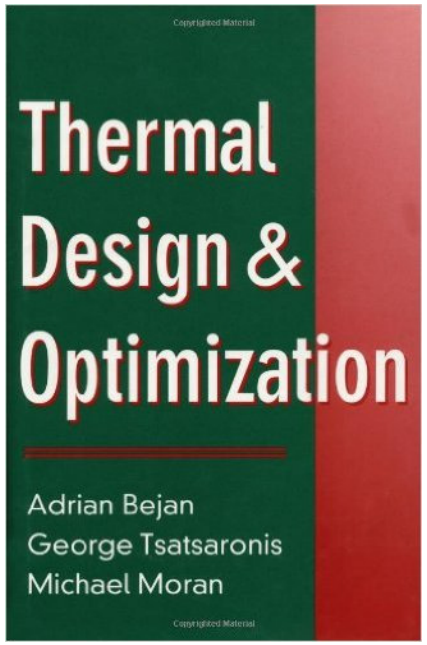
Levelized costs of energy output 1/5

CAPEX estimation approach

Plant capacity [MW_{HHV}]	TCI [M€]	Specific investment [€ kW^{-1}]
21.62	13.33	789

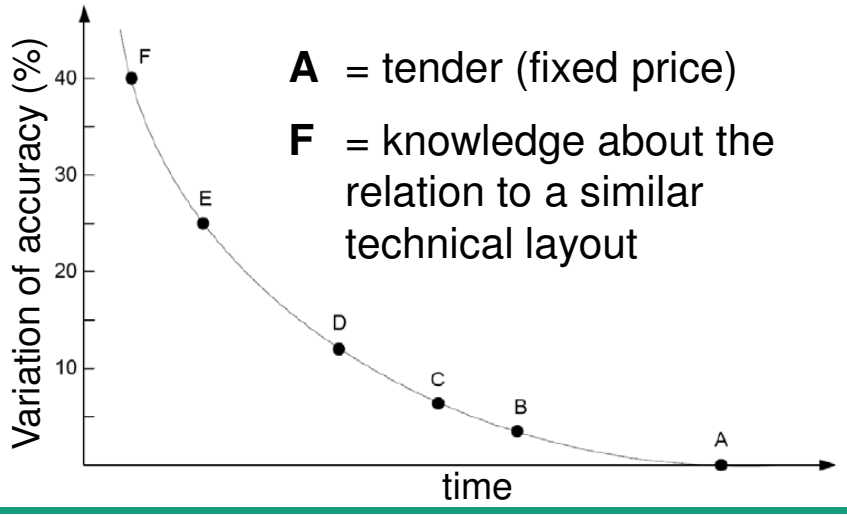
Ref: calculated after Reza et al. (2014).

CAPEX	(M€)
I. Fixed-capital investment (FCI)	**6.45**
A. Direct costs (DC)	4.52
1. Onsite costs (ONSC)	*4.13*
2. Offsite costs (OFSC)	*0.39*
B. Indirect costs (IC)	1.94
1. Engineering and supervision	0.32
2. Construction costs	0.65
3. Contingencies	0.97
II. Other outlays	**1.18**
Total capital investment (TCI)	**7.63**



$$I_2 = I_1 \left(\frac{Cap._2}{Cap._1} \right)^{0.67}$$

Ref: Wirth et al. (2011).



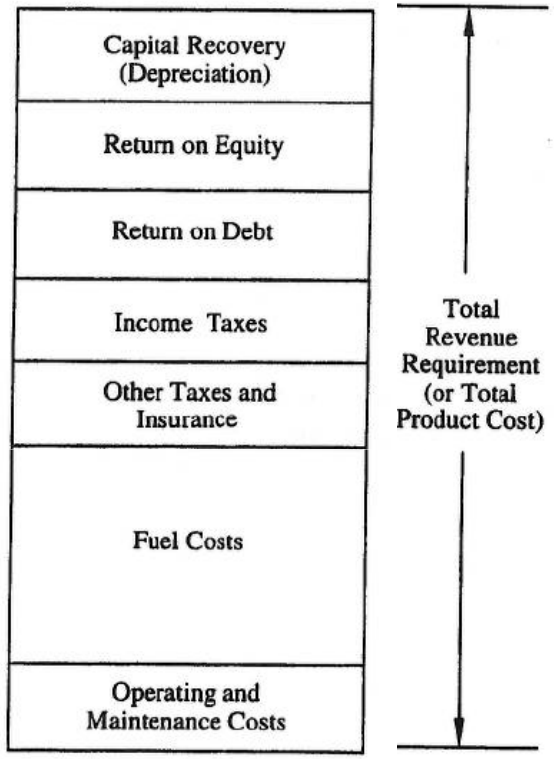
A = tender (fixed price)

F = knowledge about the relation to a similar technical layout

Fraunhofer INT

Levelized costs of energy output 2/5

General assumptions, OPEX & FINEX (base case)



Ref: Bejan et al. (1996).

General inflation rate (r_i)	2.0%
Financial inflation rate ($r_{i,fin}$)	0.0%

OPEX (= OTXI + FC + OMC)

I. Raw materials and operating supplies		
A. Raw materials	Amount	Price (€ unit^{-1})
Digestate (separated)	49,422 t/a	5.00
Digestate	39,044 t/a	-
B. Operating supplies	Amount	Price (€ unit^{-1})
Citric acid	716 t/a	800.00
Water	27,925 t/a	1.00
Natural Gas	40,103 GJ/a	11.11
Electricity	1,399 GJ/a	33.33
Others	1 unit	40,000
II. Staff	Amount	Price (€ unit^{-1})
Engineer	1,760 h/a	45.00
Technician	8,760 h/a	30.00
III. Operation and maintenance	Factor ONSC	Factor
Maintenance high wear components	70%	10%
Maintenance low wear components	30%	2%
IV. Administration	Factor TCI	
Insurance	0.5%	
Accounting and annual balance sheet	1 unit	10,000 €
Contingencies	0.5%	

FINEX (TCR + ROI + ITX)

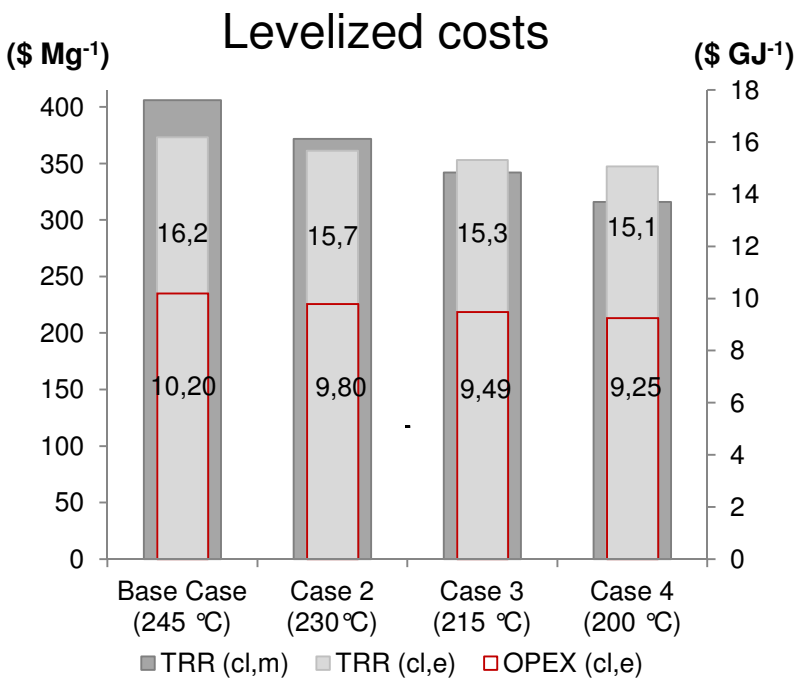
Depreciation (TCR)	*EPL*	15 years
Return on investment (ROI)	i_{eff}	10%
Taxes (ITX)	*Tax rate*	25%

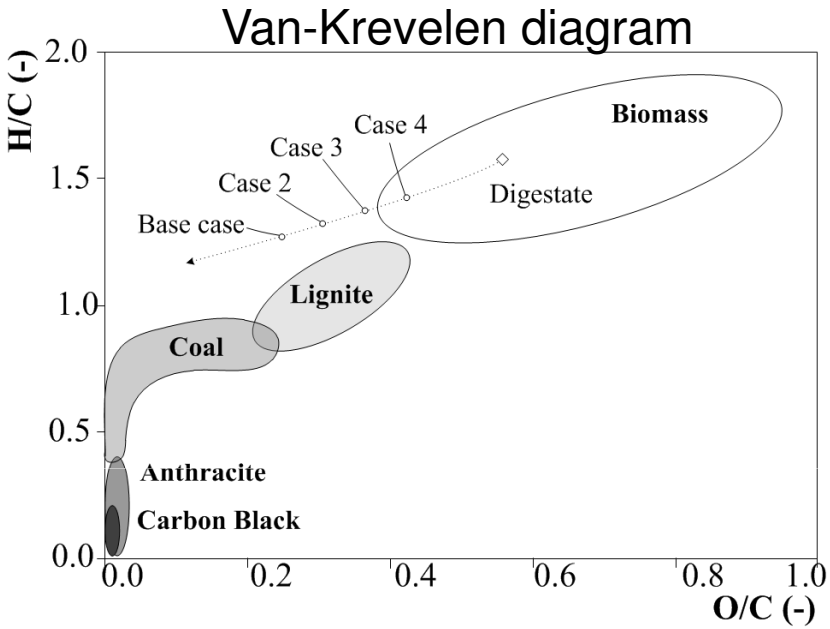
$$TRR = TCR + ROI + ITX + OTXI + FC + OMC$$

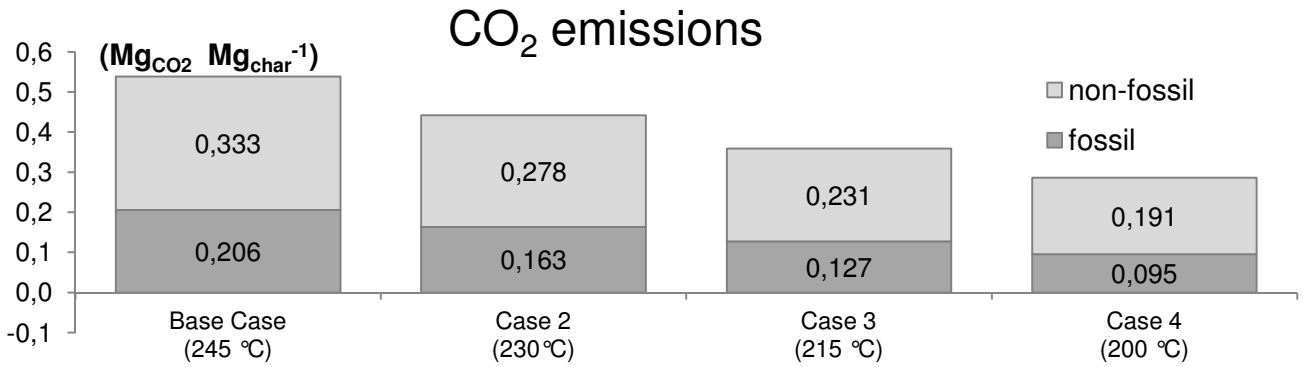
Fraunhofer INT

Levelized costs of energy output 3/5

Modelling the process with different temperature levels

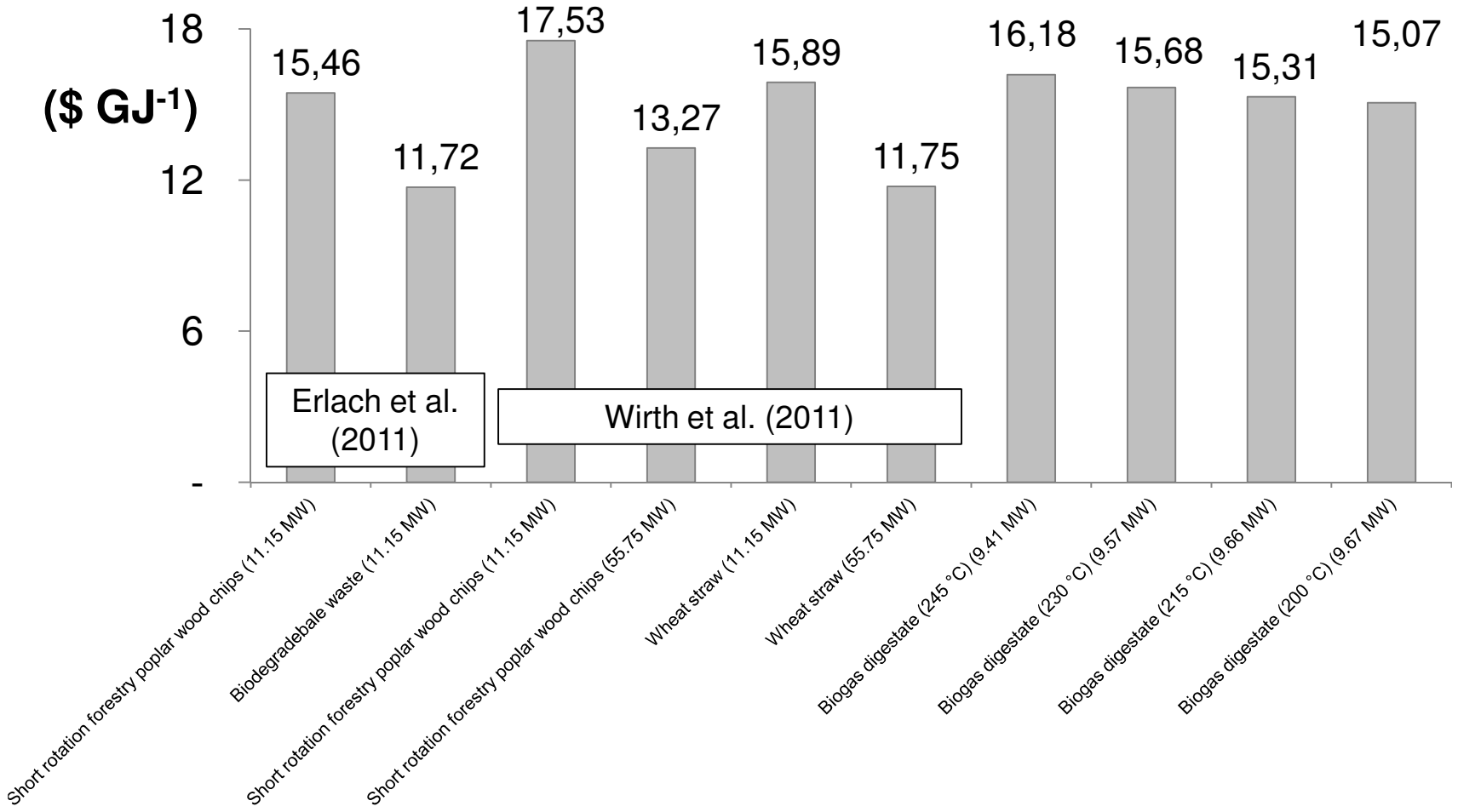






Levelized costs of energy output 4/5

Comparision with the literature

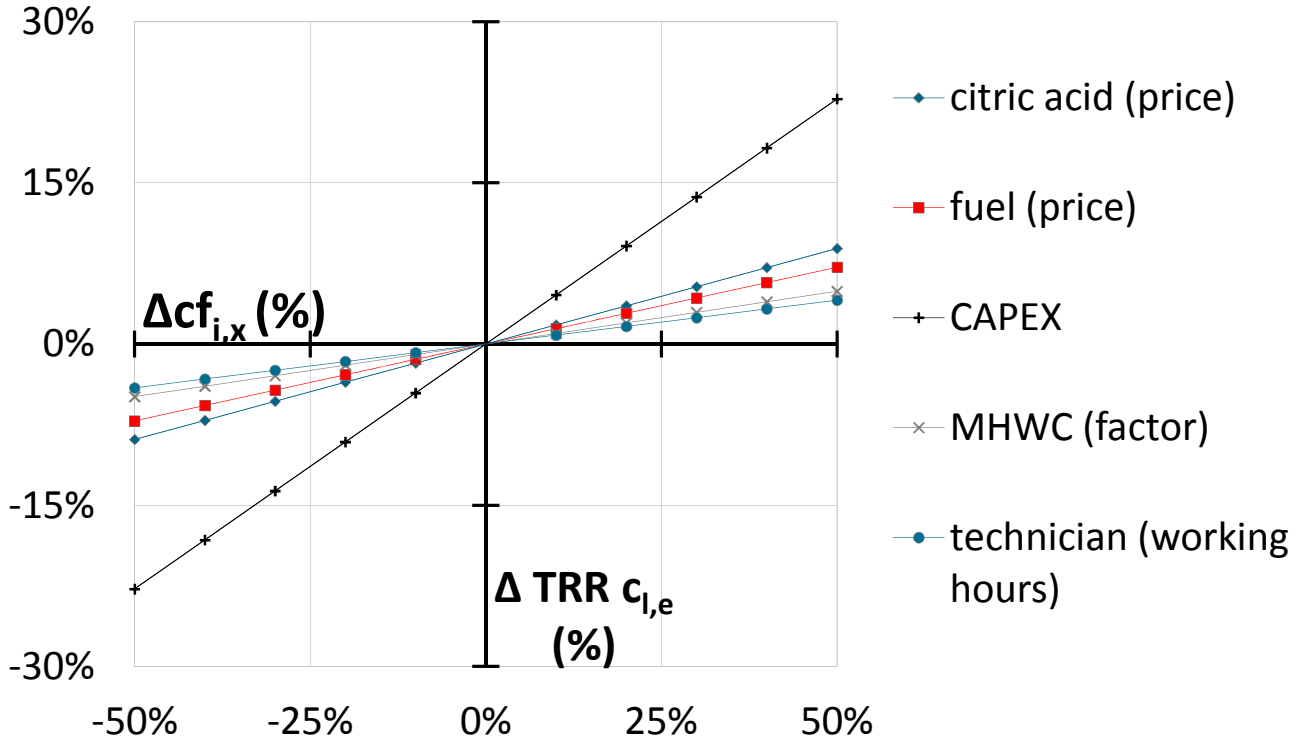


Fraunhofer INT

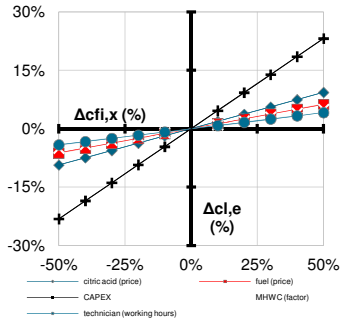
Levelized costs of energy output 5/5

Sensitivity analysis – Base Case

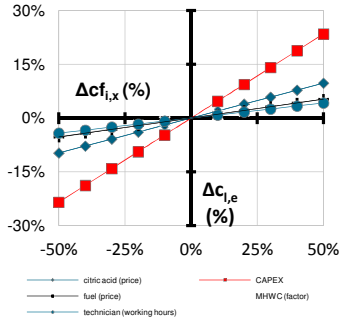
Most relevant cost factors (excl. ROI+ITC)	
1 Catalyst (price)	17.8%
2 Natural Gas (price)	14.3%
3 Depreciation (TCR)	11.7%
4 Maintenance high wear components (factor)	9.8%
5 Technician (working hours)	8.2%



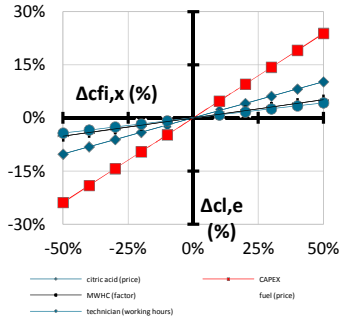
Case 2



Case 3



Case 4



Fraunhofer INT

Conclusions

(1) Combination of biogas and HTC plants is very promising.

(2) The prediction models for mass yields and hydrochar properties published are powerful tools for process optimization.

(3) Depreciation (CAPEX | TCI) is the most sensitive cost factor in our model and can change results (TRR $c_{l,e}$) by +/- 25 %.

Contact

Kay Uwe Suwelack
MSc | MEng
Scientist | Deputy Division Head
Technology Assessment and Strategic Planning
Division Corporate Technology Foresight (CTF)

Fraunhofer Institute for Technological Trend Analysis (INT)

Tel.: +49-2251-18-340
Fax: +49-2251-18-38-340
kay.uwe.suwelack@int.fraunhofer.de

References

[1] Wirth B, Eberhardt G, Rothe P, Erlach B, Rolinski S, Lotze-Campen H. Hydrothermal carbonization: influence of plant capacity, feedstock choice and location on product cost. In: Proceedings of the 19th European Biomass Conference and Exhibition; 2011, p. 6–10.

[2] Bejan A, Tsatsaronis G, Moran MJ. Thermal design and optimization. New York: Wiley; 1996.

[3] Suwelack KU, Wüst D, Fleischmann P, Kruse A. Prediction of gaseous, liquid and solid mass yields from hydrothermal carbonization of biogas digestate. Biomass Conv. Bioref. 2015(N.N.).

[4] Reza MT, Andert J, Wirth B, Busch D, Pielert J, Lynam JG et al. Hydrothermal Carbonization of Biomass for Energy and Crop Production. Applied Bioenergy 2014;1(1).

[5] Stemann J, Erlach B, Ziegler F. Hydrothermal Carbonisation of Empty Palm Oil Fruit Bunches: Laboratory Trials, Plant Simulation, Carbon Avoidance, and Economic Feasibility. Waste Biomass Valor 2013;4(3):441–54.

[6] Erlach B, Wirth B, Tsatsaronis G. Co-Production of Electricity, Heat and Biocoal Pellets from Biomass: A Techno-Economic Comparison with Wood Pelletizing. In: World Renewable Energy Congress – Sweden, 8–13 May, 2011, Linköping, Sweden: Linköping University Electronic Press; 2011, p. 508–515.

[7] Wirth B, Mumme J, Erlach B. Anaerobic treatment of waste water derived from hydrothermal carbonization. In: 20th European Biomass Conference and Exhibition, p. 18–22.