Key factors for the economic modelling of lignocellulosic bio refinery concepts

Workshop 1: Driving forces and basic conditions of developing a wood-based bio-refinery in Switzerland

Dr. Guido Hora,
Fraunhofer WKI
Bienroder Weg 54 e
38108 Braunschweig

Bundesministerium für Bildung und Forschung

Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz

ptJ Projektträger Jülich Forschungszentrum Jülich

FNR Fachagentur Nachwachsende Rohstoffe e.V.

Paul Klee Zentrum, Bern, Suisse
December 10th 2015

Fraunhofer WKI

Overview

- Introduction and Motivation
- The European Way to establish Lignocellulosic Biorefineries –

  Driving Forces and State-of-the-art
- Conception and Planning – Focus on: Feedstocks and Output
- CAPEX and OPEX Cost Factors
- Model Calculations
- Selected Case Studies
- „Soft“ Factors with Impact on Economics
- Summary and Outlook

Motivation for economics

- The economics of biomass-derived 2nd generation fuels and bio-based chemicals from Lignocellulosic resources are a major challenge
- The main task before investing in lignocellulosic bio refining plants is the identification and calculation of predominant cost factors, mainly expressed in CAPEX and OPEX.
- Major cost driving factors, such as price of feedstock, scale of plant, investment costs, output products and others and their impact on the economy of scale must be modelled and analyzed.
- Additional “soft” factors play vital roles in the success of any economic model.

Establishment and growth of the European bioeconomy through biorefineries

Political Concepts in Germany

Bioökonomie als Chance
für das 21. Jahrhundert

Guido Hora

Paul Klee Zentrum, Bern, Suisse
December 10th 2015

Fraunhofer WKI

Conception and planning – Focus on: Feedstocks and output

Source: K. Melin and H. Hurmes, Cellulose Chem. Technol.. 45 (7-8), 443-454, 2011

Table 2
Hydrolysis platform conversion routes: raw material cost, raw material cost after subtraction of by-product income and minimum production cost (in €/MWh for substance and €/t for chemicals)

Biochemical platform and subsequent upgrading	Raw material/Species								
	Domestic softwood in Finland		Domestic hardwood in Finland			Foreign trees		Non-wood Biomass	
	Pine	Spruce	Black Alder	Aspen	Silver Birch	Eucalyptus	Larch	Bagasse	Wheat Straw
All C5 and C6 sugars production rest for energy									
Raw material cost, €/MWh	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0
Raw material cost, €/ton raw material	85.8	85.8	85.8	85.8	85.8	85.8	85.8	85.8	85.8
By-product income, €/ton raw material	36.4	35.3	34.3	34.0	33.3	35.3	32.4	24.6	25.2
Min. operating costs, €/MWh (LHV of product)	18.2	21.4	19.2	18.7	17.2	15.8	18.3	20.1	19.8
Hemicellulose sugars production									
Cellulose to fiber utilization process									
Lignin and rest for energy									
Heat revenue, €/ton raw material	36.7	35.0	29.9	26.6	28.9	35.2	31.7	17.1	35.2
Cellulose by-product income, €/ton raw material	205	219	240	266.5	205	208.5	230	205	150
Min. production costs, €/MWh (LHV of fuel)	-14.7	-17.7	-17.1	-20.0	-9.9	-14.9	-15.6	-9.4	-61.2
C6 sugars for ethanol rest for energy, €/ton raw material	39.2	39.8	45.4	43.2	45.2	39.1	33.4	36.8	36.9
By-products revenue, €/ton raw material	46.6	46.0	40.4	42.6	40.6	46.7	52.4	49.0	49.0
Production cost, €/MWh product	19.0	19.7	21.6	21.3	22.4	19.6	20.3	27.3	26.7
Ethanol (C6 sugars) + other sugars									
Biogas + energy									
Biogas, €/ton raw material	7.9	7.9	27.1	25.5	41.5	27.0	10.6	42.5	42.5
Heat, €/ton raw material	36.4	37.0	35.6	34.0	30.2	29.4	29.5	21.5	21.5
By-products revenue, €/ton raw material	41.5	40.9	23.1	26.3	14.1	29.4	45.7	21.8	21.8
Production cost, €/MWh product	16.9	17.5	12.3	13.1	7.8	12.4	17.7	12.2	11.9
Ethanol + biogas + high-value lignin to high-value use									
High-value lignin, €/ton raw material	135	135	110	81.5	94.5	155	150	75	150
Sugars for biogas, €/ton raw material	7.9	7.9	27.1	25.5	41.5	27.0	10.6	42.5	42.5
Heat, €/ton raw material	16.3	18.0	17.7	16.4	13.3	10.4	13.5	13.3	12.6
Operating by-products, €/ton raw material	-73.4	-75.1	-69.0	-37.5	-63.4	-106.6	-88.3	-44.9	-119.3

Conception and planning – Focus on: Feedstocks and output

Table 1. Examples of bioproducts supply-chain characteristics.

Bioproduct example	Category	Replacement / substitution	Green advantage	Key supply chain competitive factor
Electricity	Bioenergy (true commodity)	Replacement	Possible, depending on government policy	Efficiency. Mill integration and use of heat, access to biomass.
Bioethanol	Transportation biofuel (true commodity)	Substitution for gasoline	Possible, depending on government policy	Efficiency. Large scale, access to biomass.
Acetic acid	Biochemical (true commodity)	Replacement	No, obtained already from biomass	Efficiency. Larger scale, access to biomass.
Succinic acid	Fine biochemical	Replacement	No, obtained already from biomass	Efficiency. Will probably be used as a building block.
Cellulose nanocrystals	Specialty biochemical	Substitution	Functionality will be the main differentiator	Responsiveness. Customer satisfaction & market development critical.
Bio-polyethylene	Biomaterial (pseudo commodity)	Replacement	Possible, for certain customers	Efficiency mainly. However, possibility of targeting more specialized markets.
Polylactic acid	Biomaterial (pseudo commodity / specialty)	Substitution	Possible	Efficiency mainly. Responsiveness if specialized markets are targeted. Functionality and market development critical.
Bio-based carbon fiber	Biomaterial (specialty)	Replacement (mainly)	Possible, but functionality is the main differentiator	Responsiveness. Customer satisfaction & market development critical.

Source: LP Dansereau *et al.* DOI: 10.1002/bbb.1490; *Biofuels, Bioprod. Bioref.* 8:716–727 (2014)

CAPEX Cost Factors

- General assumptions
  - ✓ Capex Scaling factors
  - ✓ Equipment scaling factors
  - ✓ Discounts
  - ✓ Contingency
  - ✓ ….

- Total Direct Costs
  - ✓ Electrical
  - ✓ Instrumentation
  - ✓ Installation costs
  - ✓ Pipe Rack costs
  - ✓ Equipment & vessels
  - ✓ Main processing unit
  - ✓ Civil/Site Preparation
  - ✓ Buildings
  - ✓ ….

- Total Other Costs
  - ✓ Engineering
  - ✓ Construction management
  - ✓ ISBL module shipment
  - ✓ Spare parts
  - ✓ Dryer (for Biomass processing)
  - ✓ Contingency
  - ✓ ….

- Total Costs

  + Commissioning
  + Training

Total Capex

OPEX Cost factors

- **General assumptions**
  - ✓ Theoretical hours per day/year
  - ✓ Operating hours per day/year
  - ✓ Nominal and turned-up capacity
  - ✓ Labor scaling factor
  - ✓ ….

- **Variable Expenses**
  - ✓ General Utilities
  - ✓ Chemicals
  - ✓ Additives
  - ✓ By-products
  - ✓ Disposals/Waste
  - ✓ Plant availability
  - ✓ ….

- **Fixed Expenses**
  - ✓ Labor
  - ✓ Social Benefits
  - ✓ Maintenance & repair
  - ✓ Others, such as
    - ✓ Logistics
    - ✓ General Administration
    - ✓ Municipal taxes
    - ✓ Travel
    - ✓ ……..

- **Total Fixed Expenses**

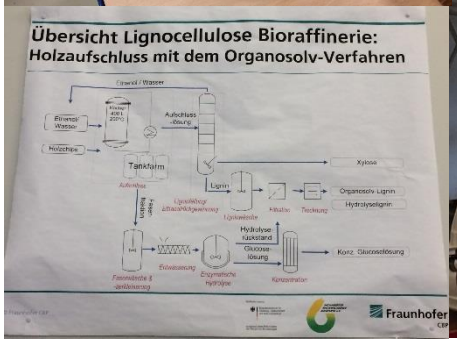
  + Plant availability ratio

Total OPEX

Case Study I

OS-Pretreatment Method I

Fraunhofer CBP
Lignocellulose biorefinery – Pilot Plant



Guido Hora

Paul Klee Zentrum, Bern, Suisse
December 10th 2015

Fraunhofer WKI

Model Calculation for a Organsolv-Pretreatment Process

Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz

FNR Fachagentur Nachwachsende Rohstoffe e.V.

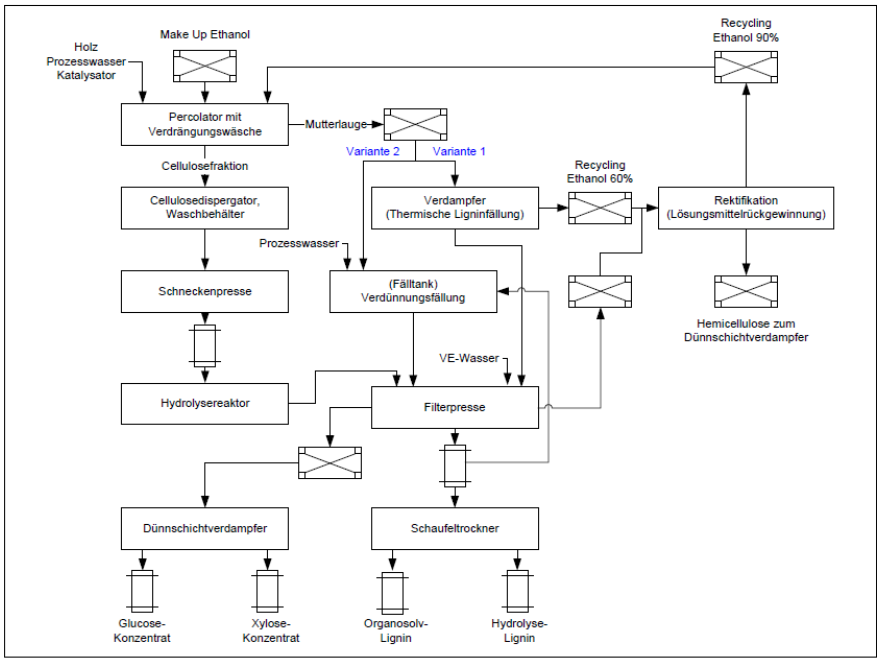


Abb. 69: Vereinfachtes Prozessschema des integrierten Gesamtprozesses gemäß dem aktuellen Planungsstand. (Quelle: CBP)

Tab. 105: Zusammenfassung der Annahmen für die Prozessfahrweise zur Simulation, Flotte je 1:4 (Quelle: KIT-IIP)

	Parameter	Wert	
Holzaufschluss		**Aufschluss ohne Schwefelsäure**	**Aufschluss mit Schwefelsäure**
	Druck	18 bar	18 bar
	Temperatur	180 °C	170 °C
	Aufenthaltsdauer	4 Stunden	2 Stunden
	Verhältnis Ethanol:Wasser	1:1	1:1
	Schwefelsäurekonzentration (bezogen auf Holz)	–	0,94 %
Faserfraktion	Wassergehalt nach Abtrennung	50 %	
	Wasserzugabe Reinigung	5-fache Menge der Festphase, 1. Wäsche EtOH/H_2O-Gemisch, 2. Wäsche H_2O	
Ligninfällung	Ethanolgehalt in Flüssigphase nach Fällung	20 %	
	Ligninausbeute	90 %	
Ligninwäsche	Wasserzugabe Wäsche	4-fache Menge an Lignin	
	Wassergehalt Lignin nach Fällung	50 %	
Lignintrocknung	Wassergehalt des Lignins nach Trocknung	10 %	
Hydrolyse	Feststoffkonzentration	20 %	
	Temperatur	50 °C	
	Aufenthaltsdauer	48 Stunden	
	Glucoseausbeute	86 %	

Source: J. Michels et al.: *Lignocellulose-Bioraffinerie - Aufschluss lignocellulosehaltiger Rohstoffe und vollständige stoffliche Nutzung der Komponenten*, https://www.ti.bund.de/media/ti-themenfelder/Nachwachsende_Rohstoffe/Bioraffinerie/Pilotprojekt_Lignocellulose_Bioraffinerie_Schlussbericht.pdf, DECHEMA e.V., 2014

Model calculations

Main parameters and selected data sets for economic modelling based on (Michels 2014)

Parameter	Data
Process	Organsolv-pre-treatment with and without sulforic acid
Main output after drying	Organosolv-Lignin
Processing capacity in t/a PC	400.0000
Operating hours in h OH	8.000
PC/OH in t/h	50
Production capacity per h	7.5
Production capacity per a	60.000,00
By-products	Glucose Hydrolysis Lignin Xylose
Feedstock infeed assumptions	100% Beech wood chips 75% Beech / 25 % A I recycling wood 50% Beech / 50 % A I recycling wood 100% A I Recycling wood
Feedstock price assumptions in € per dry t	Beech wood chips: 70 (best) :100 (basic) :150 (worst case) A I Recycling Wood: 10 (best) : 35 (basic) : 55 (worst case)
Investment costs in Mio. €	60.00 (without sulfonic acid) 55.00 (with sulfonic acid)

Model calculations

	Unit	massflow input/output
primary materials		
woodwaste AI (Euwid Recycling 32.2014) beech wood (Leuna)	[t/h]	50,00
auxiliary materials		
ethanol	[t]	6.080,00
sulfuric acid	[t/h]	-
enzymes	[t/h]	64 € per t glucose
energy sources		
electricity (6 kV)	[kWh/y]	60.800.000,00
Steam (16 - 20 bar)	[t/y]	387.377,13
Steam (1,7 - 4 bar)	[t/y]	80.215,63
process water	[t/y]	1.600.000,00
cooling	[m³/y]	22.175.701,14
operating costs		
labor costs (4 shifts à 5 employees à 39,5 €/h)		1.580.000,00 €
overhead ((80 percent of (labor costs + fringe costs))+ (40 percent of maintenance))		
creditnotes for energy		
maintenance and repair		
revenues for byproducts		
glucose	[t/y]	151.680,00
hydrolysis lignin	[t/h]	42.240,00
xylose	[t/h]	17.208,00
investment related costs		
depreciation of "amount invested"	[€/y]	6.100.000,00 €
taxes, insurances	[€/y]	1.220.000,00 €
fringe costs	[€/y]	474.000,00 €
capital costs	[€/y]	2.440.000,00 €

estimated values

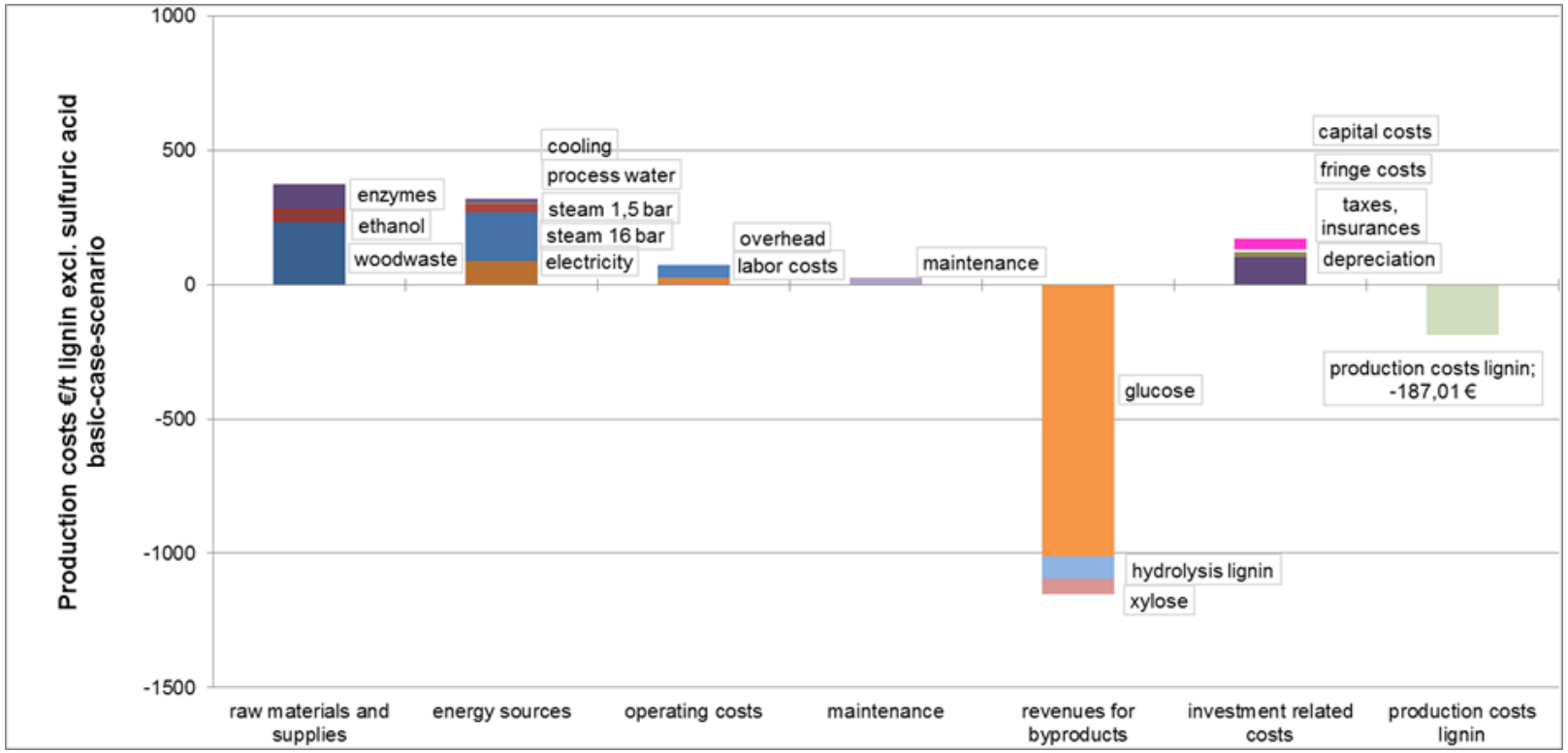
linear depreciation

Model calculations

	basic-scenario *excluding* sulfuric acid			basic-scenario *including* sulfuric acid		
		100 percent beechwood	100 percent woodwaste		100 percent beechwood	100 percent woodwaste
	price per unit	product-related costs [€/t product]	product-related costs [€/t product]	price per unit	product-related costs [€/t product]	product-related costs [€/t product]
primary materials						
woodwaste AI (Euwid Recycling 32.2014)	35,00 €	- €	233,33 €	35,00 €	- €	233,33 €
beech wood (Leuna)	100,00 €	666,67 €	- €	100,00 €	666,67 €	- €
auxiliary materials						
ethanol	500,00 €	50,67 €	50,67 €	500,00 €	50,67 €	50,67 €
sulfuric acid	100,00 €	- €	- €	100,00 €	6,67 €	6,67 €
enzymes	36,00 €	91,01 €	91,01 €	36,00 €	91,01 €	91,01 €
energy sources						
electricity (6 kV)	0,088 €	88,67 €	88,67 €	0,088 €	88,67 €	88,67 €
Steam (16 - 20 bar)	28,00 €	180,78 €	180,78 €	28,00 €	159,92 €	159,92 €
Steam (1,7 - 4 bar)	23,50 €	31,42 €	31,42 €	23,50 €	31,42 €	31,42 €
process water	0,14 €	3,60 €	3,60 €	0,14 €	3,60 €	3,60 €
cooling	0,042 €	15,34 €	15,34 €	0,042 €	15,15 €	15,15 €
operating costs						
labor costs (4 shifts à 5 employees à 39,5 €/h)	1.580.000,00 €	26,33 €	26,33 €	1.580.000,00 €	26,33 €	26,33 €
overhead ((80 percent of (labor costs + fringe costs))+ (40 percent of maintena	2.850.000,00 €	47,50 €	47,50 €	2.686.720,00 €	44,78 €	44,78 €
creditnotes for energy						
maintenance and repair						
	1.525.000,00 €	25,42 €	25,42 €	1.368.000,00 €	22,80 €	22,80 €
revenues for byproducts						
glucose	400,00 €	- *1.011,20 €*	- *1.011,20 €*	400,00 €	- *1.011,20 €*	- *1.011,20 €*
hydrolysis lignin	118,00 €	- *83,07 €*	- *83,07 €*	118,00 €	- *78,82 €*	- *78,82 €*
xylose	200,00 €	- *57,36 €*	- *57,36 €*	200,00 €	- *108,80 €*	- *108,80 €*
investment related costs						
depreciation of "amount invested"		101,67 €	101,67 €		91,20 €	91,20 €
taxes, insurances		20,33 €	20,33 €		18,24 €	18,24 €
fringe costs		7,90 €	7,90 €		7,90 €	7,90 €
capital costs		40,67 €	40,67 €		36,48 €	36,48 €
	total costs	**246,32 €**	**- 187,01 €**	**total costs**	**162,67 €**	**- 270,67 €**

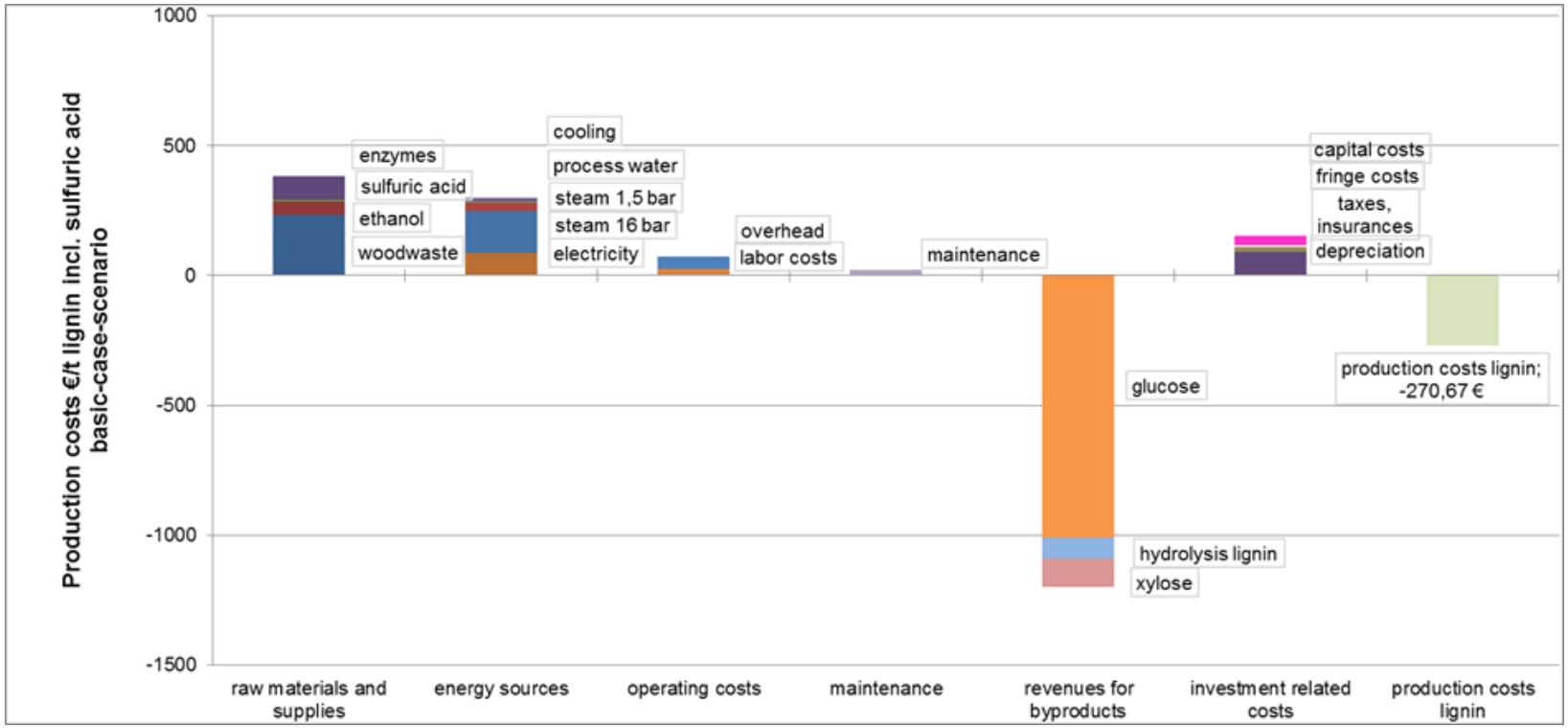
Model calculations

*Influencing of cost parameters on the production cost for lignin for an organosolv-pre-treatment process **without** sulphur acid by utilisation of 100% A I recycling waste wood as feedstock.*



Model calculations

*Influencing of cost parameters on the production cost for lignin for an organosolv-pre-treatment process **with** sulphur acid by utilisation of 100% A I recycling waste wood as feedstock.*

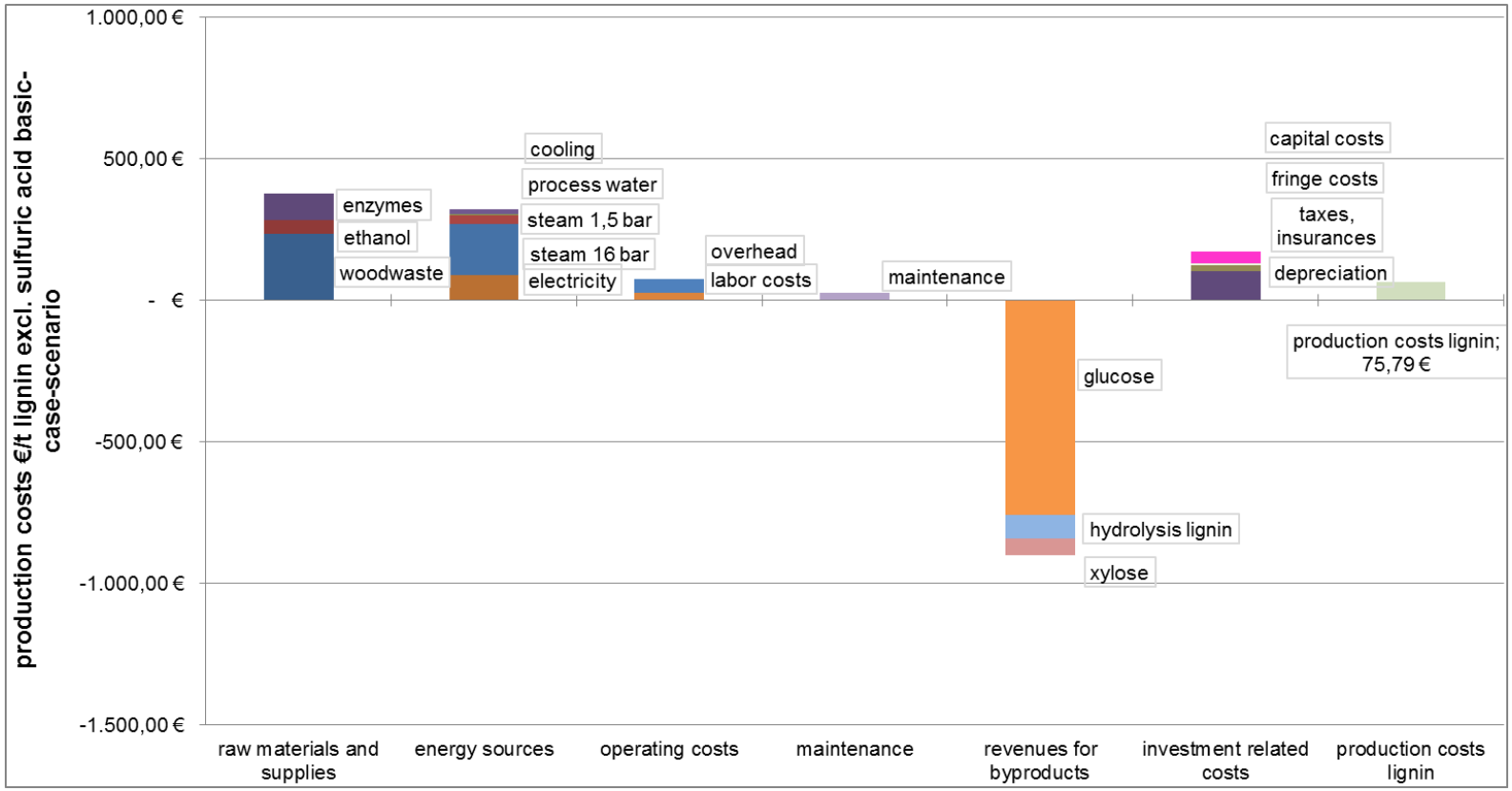


Model calculations

	basic-scenario *excluding* sulfuric acid			basic-scenario *including* sulfuric acid		
		100 percent beechwood	100 percent woodwaste		100 percent beechwood	100 percent woodwaste
	price per unit	product-related costs [€/t product]	product-related costs [€/t product]	price per unit	product-related costs [€/t product]	product-related costs [€/t product]
primary materials						
woodwaste AI (Euwid Recycling 32.2014)	35,00 €	- €	233,33 €	35,00 €	- €	233,33 €
beech wood (Leuna)	100,00 €	666,67 €	- €	100,00 €	666,67 €	- €
auxiliary materials						
ethanol	500,00 €	50,67 €	50,67 €	500,00 €	50,67 €	50,67 €
sulfuric acid	100,00 €	- €	- €	100,00 €	6,67 €	6,67 €
enzymes	36,00 €	91,01 €	91,01 €	36,00 €	91,01 €	91,01 €
energy sources						
electricity (6 kV)	0,088 €	88,67 €	88,67 €	0,088 €	88,67 €	88,67 €
Steam (16 - 20 bar)	28,00 €	180,78 €	180,78 €	28,00 €	159,92 €	159,92 €
Steam (1,7 - 4 bar)	23,50 €	31,42 €	31,42 €	23,50 €	31,42 €	31,42 €
process water	0,14 €	3,60 €	3,60 €	0,14 €	3,60 €	3,60 €
cooling	0,042 €	15,34 €	15,34 €	0,042 €	15,15 €	15,15 €
operating costs						
labor costs (4 shifts à 5 employees à 39,5 €/h)	1.580.000,00 €	26,33 €	26,33 €	1.580.000,00 €	26,33 €	26,33 €
overhead ((80 percent of (labor costs + fringe costs))+ (40 percent of maintena	2.850.000,00 €	47,50 €	47,50 €	2.686.720,00 €	44,78 €	44,78 €
creditnotes for energy						
maintenance and repair						
	1.525.000,00 €	25,42 €	25,42 €	1.368.000,00 €	22,80 €	22,80 €
revenues for byproducts						
glucose	300,00 €	- *748,40 €*	- *748,40 €*	300,00 €	- *748,40 €*	- *748,40 €*
hydrolysis lignin	118,00 €	- *83,07 €*	- *83,07 €*	118,00 €	- *78,82 €*	- *78,82 €*
xylose	200,00 €	- *57,36 €*	- *57,36 €*	200,00 €	- *108,80 €*	- *108,80 €*
investment related costs						
depreciation of "amount invested"		101,67 €	101,67 €		91,20 €	91,20 €
taxes, insurances		20,33 €	20,33 €		18,24 €	18,24 €
fringe costs		7,90 €	7,90 €		7,90 €	7,90 €
capital costs		40,67 €	40,67 €		36,48 €	36,48 €
	total costs	**509,12 €**	**75,79 €**	**total costs**	**425,47 €**	**- 7,87 €**

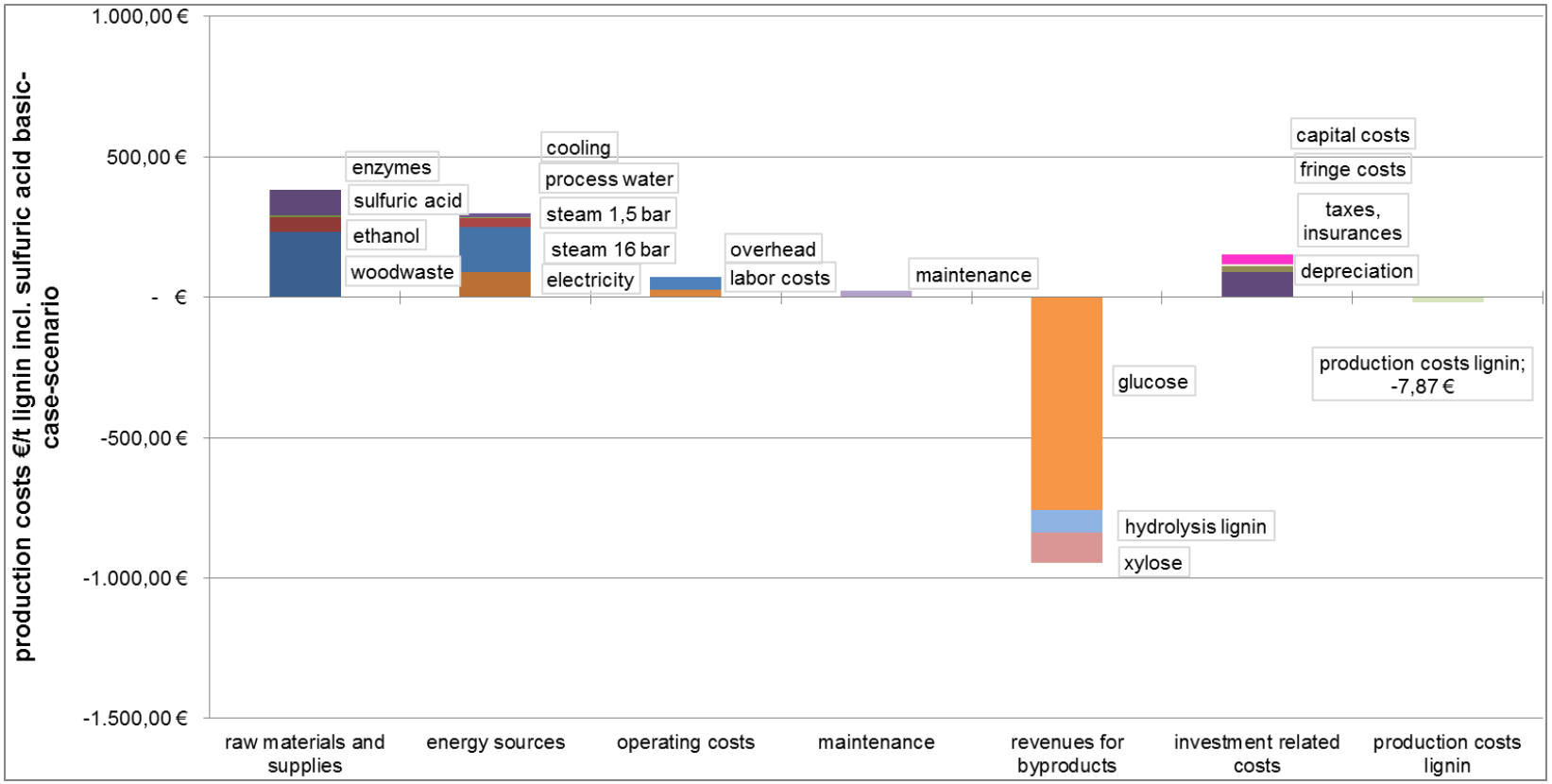
Model calculations

*Influencing of cost parameters on the production cost for lignin for an organosolv-pre-treatment process **without** sulphur acid by utilisation of 100% A I recycling waste wood as feedstock. (glucose price: Nov. 2015)*



Model calculations

*Influencing of cost parameters on the production cost for lignin for an organosolv-pre-treatment process **with** sulphur acid by utilisation of 100% A I recycling waste wood as feedstock. (glucose price: Nov. 2015)*



Model calculations

			basic-scenario *excluding* sulfuric acid					
	investment		61.000.000 €		81.000.000 €		101.000.000 €	
				100 percent woodwaste		100 percent woodwaste		100 percent woodwaste
	Unit	massflow input	price	product-related costs	price	product-related costs	price	product-related costs
primary materials				[€/t product]		[€/t product]		[€/t product]
woodwaste AI (Euwid Recycling 32.2014)	[t/h]	50	35 €	248 €	35 €	248 €	35 €	248 €
beech wood (Leuna)			100 €	- €	100 €	- €	100 €	- €
auxiliary materials								
ethanol	[t]	6.080	500 €	54 €	500 €	54 €	500 €	54 €
sulfuric acid	[t/h]	-	100 €	- €	100 €	- €	100 €	- €
enzymes	[t/h]	64 € per t glucose	36 €	101 €	36 €	101 €	36 €	101 €
energy sources								
electricity (6 kV)	[kWh/y]	60.800.000	0,088 €	94 €	0,088 €	94 €	0,088 €	94 €
Steam (16 - 20 bar)	[t/y]	387.377	28,00 €	192 €	28,00 €	192 €	28,00 €	192 €
Steam (1,7 - 4 bar)	[t/y]	80.216	23,50 €	27 €	23,50 €	27 €	23,50 €	27 €
process water	[t/y]	1.600.000	0,14 €	4 €	0,14 €	4 €	0,14 €	4 €
cooling	[m³/y]	22.175.701	0,042 €	16 €	0,042 €	16 €	0,042 €	16 €
operating costs								
labor costs (4 shifts à 5 employees à 39,5 €/h)		1.580.000	1.580.000 €	28 €	1.580.000 €	28 €	1.580.000 €	28 €
overhead ((80 percent of (labor costs + fringe costs))+ (40 percent of maintenance))			2.850.000 €	50 €	3.370.000 €	60 €	3.890.000 €	69 €
creditnotes for energy								
maintenance and repair								
			1.525.000 €	27 €	2.025.000 €	36 €	2.525.000 €	45 €
revenues for byproducts								
glucose			300 €	- *806 €*	300 €	- *806 €*	300 €	- *806 €*
hydrolysis lignin			118 €	- *88 €*	118 €	- *88 €*	118 €	- *88 €*
xylose			200 €	- *61 €*	200 €	- *61 €*	200 €	- *61 €*
investment related costs								
depreciation of "amount invested"	[€/y]		6.100.000 €	108 €	8.100.000 €	143 €	10.100.000 €	179 €
taxes, insurances	[€/y]		1.220.000 €	22 €	1.620.000 €	29 €	2.020.000 €	36 €
fringe costs	[€/y]		474.000 €	8 €	474.000 €	8 €	474.000 €	8 €
capital costs	[€/y]		2.440.000 €	43 €	3.240.000 €	57 €	4.040.000 €	72 €
			total costs	**67 €**	**total costs**	**142 €**	**total costs**	**216 €**
			Change in percentage					
			Production cost	0%		111%		223%
			Investment	0%		33%		66%

Case Study I

OS-Pretreatment Method I - PAYBACK PERIOD

Pricing:
Feb. 2014 /
Nov. 2015

		Beechwood	Wastewood	Beechwood	Wastewood
	Quantity t/y	Price EUR/t		m EUR/a	
Income / Revenues					
Glucose	152.000	300	300	46	46
Xylose	17.000	200	200	3	3
Hydrolysis Lignin	42.000	118	118	5	5
Organosolv Lignin	60.000	622	622	37	37
Total				**91**	**91**
Costs / Expenditures					
Raw materials	400.000	100	35	40	14
Utilities				28	28
Labour incl. overheads				4	4
Maintenance				2	2
Other				10	10
Total				**84**	**58**
Capital investment (in mio. EUR)				**61**	**61**
Payback period (a)				**4,5**	**1,5**
Production costs OS-Lignin		500	66		

Basic data source: "Lignocellulose-Bioraffinerie" Aufschluss lignocellulosehaltiger Rohstoffe und vollständige stoffliche Nutzung der Komponenten (Phase 2) Gemeinsamer Abschlussbericht zu den wissenschaftlich-technischen Ergebnissen aller Teilvorhaben; Michels et al.; [https://www.ti.bund.de/media/ti-themenfelder/Nachwachsende_Rohstoffe/Bioraffinerie/Pilotprojekt_Lignocellulose_Bioraffinerie_Schlussbericht.pdf]

Case Study I

OS-Pretreatment Method I - PAYBACK PERIOD

Pricing:
Feb. 2014 /
Nov. 2015

		Beechwood	Wastewood	Beechwood	Wastewood
	Quantity t/y	Price EUR/t		m EUR/a	
Income / Revenues					
Glucose	152.000	300	300	46	46
Xylose	17.000	200	200	3	3
Hydrolysis Lignin	42.000	118	118	5	5
Organosolv Lignin	60.000	622	622	37	37
Total				**91**	**91**
Costs / Expenditures					
Raw materials	400.000	100	35	40	14
Utilities				28	28
Labour incl. overheads				4	4
Maintenance				2	2
Other				10	10
Total				**84**	**58**
Capital investment (in mio. EUR)				**101**	**101**
Payback period (a)				**7,5**	**2,6**
Production costs OS-Lignin		500	66		

Basic data source: "Lignocellulose-Bioraffinerie" Aufschluss lignocellulosehaltiger Rohstoffe und vollständige stoffliche Nutzung der Komponenten (Phase 2) Gemeinsamer Abschlussbericht zu den wissenschaftlich-technischen Ergebnissen aller Teilvorhaben; Michels et al.; [https://www.ti.bund.de/media/ti-themenfelder/Nachwachsende_Rohstoffe/Bioraffinerie/Pilotprojekt_Lignocellulose_Bioraffinerie_Schlussbericht.pdf]

Case Study II

OS-Pretreatment Method II - PAYBACK PERIOD

		Hardwood	Wastewood	Hardwood	Wastewood
	Quantity t/y	Price EUR/t		m EUR/a	
Income / Revenues					
Xylitol		3.500	3.500	45	45
Itaconic acid		1.500	1.500	46	46
Lignin		1.000	1.000	44	44
Fertiliser [N,P]		952/1.080	952/1.080	0,2	0,1
Total				**135**	**135**
Costs / Expenditures					
Raw materials	150.000	70	55	11	8
Utilities				47	47
Labour				5,2	5,2
Other direct costs				8,6	8,5
Overhead costs				42	41
Total				**113**	**110**
Capital investment (in mio. EUR)				**152**	**152**
Payback period (a)				**4,7**	**4,3**

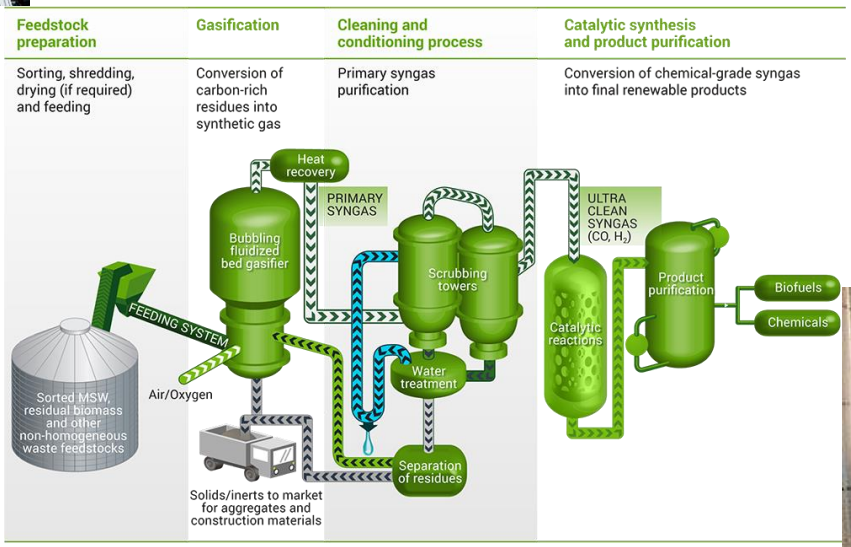
Pricing: 2013

Case Study III

Gasification with catalytic capturing C and H process
Industrial scale

Turning trash into clean fuels and chemicals. With its proprietary technology, **Enerkem** converts non-recyclable municipal solid waste into methanol, ethanol and other widely used chemical intermediates.

Enerkem



Enerkem

www.enerkem.com

Case Study III

Gasification with catalytic capturing C and H process - PAYBACK PERIOD Industrial scale

		20% Wastew.	50% Wastew.	20% Wastew.	50% Wastew.
	Quantity l/y	Price EUR/t		m EUR/a	
Income / Revenues					
Ethanol	38.000.000	0,39	0,39	15	15
Total				**15**	**15**
Costs / Expenditures					
Wastewood [20% / 50%]	20.000/50.000	- 35	- 35	- 1	- 2
MSW [80% / 50%]	80.000/50.000	- 70	- 70	- 6	- 4
Utilities / Ash				4	4
Labour incl. overhead				5	5
Maintenance				2	2
Other				7	7
Total				**11**	**12**
Capital investment (in mio. EUR)				**75**	**75**
Payback period (a)				**9,8**	**11,3**
Production costs Ethanol		0,29	0,31		

Pricing: 2013

Case Study IV a

STEAM EXPLOSION Pretreatment - PAYBACK PERIOD

		Poplar	Wastewood	Poplar	Wastewood
	Quantity t/y	Price EUR/t		m EUR/a	
Income / Expenditures					
Current				28	28
Fertilizer				1	1
Ethanol	100.000	824	824	82	82
Total				**112**	**112**
Costs / Expenditures					
Raw material	400.000	60	55	24	22
Utilities				23	23
Indirect costs				51	51
Total				**98**	**96**
Capital investment (in mio. EUR)				**496**	**496**
Payback period (a)				**10,6**	**10,1**
Production costs Ethanol		684	664		

Pricing: 2013

Case Study IV b

STEAM EXPLOSION Pretreatment - PAYBACK PERIOD

	Quantity t/y	Price EUR/t		m EUR/a	
Income / Expenditures					
Current				28	28
Fertilizer				1	1
Ethanol	100.000	385	385	39	39
Total				**68**	**68**
Costs / Expenditures					
Raw material	400.000	60	55	24	22
Utilities				23	23
Indirect costs				51	51
Total				**98**	**96**
Capital investment (in mio. EUR)				**496**	**496**
Payback period (a)				**160,0**	**97,3**
Production costs Ethanol		684,00	664,00		

Pricing: 2015

Other important “soft” factors with major impact on economics

- **Feedstock supply agreement**
  - Size of the investment project
  - Type and quality requirements of LC feedstock
  - Duration and delivery dates of supply
  - Volume of daily/weekly/month/yearly delivery
  - Bargaining strength of partners
  - Nation, federal and/or regional legislations
- **Output product(s) sales contracts**
  - Market volume, long-term price scenario, volatility etc.
  - Industrial partner as buyer and/or stakeholder on a JV basis?
  - Production quantity and product quality guarantee

Summary and outlook

- Multitude of Biorefinery concepts for LC feedstock are available with varying industrial scale readiness level
- Technical plant specifications including feedstock type and main products(s) impact on CAPEX and OPEX
    - + plus proper feedstock supply agreements
    - + plus proper product sales contracts to form a sound basis for economic modeling
- Economics are moderately feedstock and highly output product price sensitive & improve significantly with lower feedstock prices and stable product revenues
- Long term supply contracts and a higher number of output products ***can*** secure economics and attract investors

Key factors for the economic modelling of lignocellulosic bio refinery concepts

Workshop 1: Driving forces and basic conditions of developing a wood-based bio-refinery in Switzerland

Contact: Guido Hora,

guido.hora@wki.fraunhofer.de
Fraunhofer WKI
Bienroder Weg 54 e
38108 Braunschweig
Tel.: ++495312155373
www.rewobioref.eu

Bundesministerium für Bildung und Forschung

Projektträger Jülich Forschungszentrum Jülich

Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz

FNR Fachagentur Nachwachsende Rohstoffe e.V.

Paul Klee Zentrum, Bern, Suisse

December 10th 2015

Fraunhofer WKI