WP5-WP1

Discussion on the conversion technologies for biomass in CEESA

January 19, 2010, Davide Tonini, Brian Vad Mathiesen and Thomas Astrup

General comments

1. Table 1: It reports the use of biomass potential in CEESA. Similar to Table 21 in "IDAs klimaplan 2050". (including all conversion losses with the technologies proposed used here)
2. Table 2: Overview of the conversion technologies and main byproducts from conversion of some biomass to biofuel
3. Table 3: Overview of the main parameters and efficiencies related to biomass thermal gasification and anaerobic digestion

A mathematical modeling was implemented in order to calculate all the potential biofuels, syngas, biogas and power generated by utilizing the biomass in different technologies, such as transesterification, bioethanol production, gasification, anaerobic digestion and combustion. Technology data used were taken from:

- For biofuels production, the values (parameters and process efficiencies) are taken according to Ecoinvent (2007).
- For biogas generation from manure, the values are taken according to Wenzel et al. (2007).
- For biogas generation from other biomasses, the values are taken from Ecoinvent (2007).
- For gasification of wood chips, the values are taken from Ahrenfeldt et al. (2006).
- For gasification of straw, the values are taken from Bentzen et al. (2002).
- With respect to gasification of wood and (eventually) RDF, the values are taken from Arena et al. (2009), Arena et al. (2010), Henriksen (2009).
- Willow, fire wood and the other wood products are assumed to have the same efficiencies as for wood chips and straw.

Note that the listed uses of biomass in CEESA and biomass conversion technologies does not take into account the potential for process integration. Please give comments and suggestions for improvements.

Comments on Table 3

The Cold Gas efficiency represents the amount of energy which is transferred from the fuel to the syngas (final product of the gasification together with char and tar). It provides an idea of the energy loss in the conversion process. It does NOT include the energy required for the conversion process. It is defined as:

$$CGE = \frac{Qsyngas \cdot LHVsyngas}{Qfuel \cdot LHVfuel}$$

Where:

Qsyngas	Generated amount of syngas per unit of fuel (Nm^3/tonne wet material)
Qfuel	Fuel fed to the system (tonne wet material)
LHVsyngas	Lower Heating Value of the syngas (GJ/Nm^3)
LHVfuel	Lower Heating Value of the fuel (GJ/tonne wet material)

Comments on (residual) waste-to-energy potential technologies

1. Incineration: Best available technologies for residual waste-to-energy conversion

2. Renaissance concept: enzymatic pretreatment of the residual waste. The output consists of a liquid fraction (anaerobically digested or gasified leading to the production of a gas) and a solid fraction (combusted or gasified). Recycling is also done for metals, glass and (eventually) plastic after the pretreatment. Status: research. A pilot plant is operating in CPH.

3. Thermal gasification: applicable with good efficiency on sorted RDF, packaging waste, plastic waste and paper waste (CGE = 0.62 for RDF, 0.6 for mixed plastic, 0.88 for polyolephines (PE, PP), 0.4 for pulp-waste paper from paper processing facilities, 0.68 for packaging waste). Status: research. The first full-scale plants are being commissioned in Japan, US and some in EU. Advantages: more flexible than incineration. The syngas can be used in reciprocating engines, SOFC, power plants or used for chemicals production. Disadvantages: the gasification requires low ash-content material, homogenous feed, clean-up of the syngas (low tar content), and eventual post-treatment of the char.

4. MBT (mechanical biological treatment) of the residual waste. Common in Italy, France and Germany. The output consists of a high-quality RDF fraction (LHV=15-20 GJ/tonne ww, sent to combustion or gasification) and a stabilized waste (mainly stabilized organic) which is usually used as final/daily cover material for landfills or directly disposed with very low gas generated). Status: well-known technology.

Table 1 Use of biomass potential in CEESA (BAU scenario)

	Potential technology	Energy carrier	Carrier energy required in IDA 2050 (PJ)[1]	Biomass required in IDA 2050 (PJ)[1]	**BAU-Biomass potential in CEESA (PJ)**	Carrier energy potential in CEESA (PJ)[1]
Biofuel to transport						
methane	anaerobic digest.	methane	5.7	18.4	**18.4**	5.7
bio jet-fuel	-	jetfuel	33.4	?	**0**	0
biodiesel	transesterification	biodiesel	29.1	61.8	**3.4**	1.6
Individual heating	small boilers	gas	3.1	3.8	**3.8**	3.1
Industry (1)[2]	gas turbines	gas	60[3]	73.2	**73.2**	46.5
Industry (2)	steam turbine-cogen.	biomass				13.5
District heating plants	large boilers	gas	6.5	7.9	**7.9**	6.5
Decentralized CHP	gasif.-SOFC-dec.	gas	28.7	85.8	**85.8**	28.7
Centralized CHP	gasif.-SOFC-cen.	gas	41.7			41.7
Waste incineration	incineration	waste	44.4	44.4	**47**	47
Total			251			194.3

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[1] According to IDAs Klimaplan (Table 21, page 90, Baggrundsrapport). When referring to gas as carrier, the amount of biomass is recalculated based on typical efficiencies of the process considered (i.e. rapeseed to RME)

[2] It is assumed that the energy required by industries is met both by gas and direct biomass combustion (mainly byproducts from biofuels production)

[3] Compared to IDAs Klimaplan the energy demand for the industry sector is decreased from 80 to 60 PJ

Table 2 Potential and selected conversion technologies and main byproducts in CEESA (BAU scenario)

Biomass potential				Potential conversion technologies				Byproducts generated				
Biomass	PJ	tonne	LHV (GJ/t)	To biofuels	Gasif.	AD	Comb.	Selected	Byproduct 1	amount (PJ)	Byproduct 2	amount (t)
rapeseed	3.4	123,690	27.5	X			X	to RME	rape meal	1.2	K_2SO_4	802
willow	0.5	33,784	14.8	X	X		X	gasification	char			
grass	6.8	453,333	15.0	X	X	X	X	Anaer. Digest.	fibers	4.5	proteins	68,000
straw	65	4,482,759	14.5	X	X		X	gasification	char		tar	
beet top	0.2	98,039	2.0	X		X	X	Anaer. Digest.	digestate			
animal manure	27	5,400,000	5.0	X	X	X	X	Anaer. Digest.	liq. fraction (t)	1,791,375	digestate	0
fiber fraction	2	147,438	13.6	X		X	X	Anaer. Digest.	digestate			
mill residues	0.9	45,455	19.8	X	X		X	Anaer. Digest.	digestate			
beet pulp	1.7	328,947	5.2	X		X	X	Anaer. Digest.	digestate			
molasses	1.2	447,761	2.7	X		X		Anaer. Digest.	digestate			
potato pulp	0.3	105,634	2.8	X		X	X	Anaer. Digest.	digestate			
brewer's grain	0.6	141,176	4.3	X		X	X	Anaer. Digest.	digestate			
whey	2.8	3,111,111	0.9	X		X		Anaer. Digest.	digestate			
wood chips	7.7	407,407	18.9	X	X		X	gasification	char		tar	
fire wood	26	1,276,011	20.4	X	X		X	gasification	char		tar	
unexploited forest increment	17	834,315	20.4	X	X		X	gasification	char		tar	
wood pellets	2.6	127,601	20.4	X	X		X	gasification	char		tar	
wood residues	6.3	318,182	19.8	X	X		X	gasification	char		tar	
waste	47	4,700,000	10.0	X	X	X	X	combustion	bottom ash		fly ash	
TOTAL	219									6.7		

Table 3 Efficiencies of the thermal gasification and anaerobic digestion technologies for each type of biomass (BAU scenario)

Biomass	(PJ)	Heat (PJ)	El (PJ)	CGE[4]	Gas yield (Nm^3/t)	LHV$_{gas}$ (GJ/Nm^3)	Gross[5] energy in gas (PJ)
rapeseed							Not relevant here
willow	0.5	0.07	0.01	0.93	2118	0.0065	0.5
grass	6.8	0.23	0.05		210	0.01974	1.9
straw	65.0	7.79	0.66	0.85	1896	0.0065	55.3
beet top	0.2	0.06	0.01		67	0.02404	0.2
manure	8.6	1.03	0.25		67	0.0223	2.6
fiber fraction	2.0	0.43	0.04	0.85	3203	0.0036	1.7
mill residue	0.9	0.12	0.01	0.93	2833	0.0065	0.8
beet pulp	1.7	0.20	0.05		67	0.02404	0.5
molasses	1.2	0.27	0.06		67	0.02404	0.7
potato pulp	0.3	0.06	0.02		67	0.02404	0.2
brewer's grain	0.6	0.08	0.02		320	0.02404	1.1
whey	2.8	1.85	0.45		44	0.01794	2.4
wood chips	7.7	1.01	0.09	0.93	2704	0.0065	7.2
fire wood	26.0	3.41	0.29	0.93	2915	0.0065	24.2
Forest unexploited increm.	17.0	2.23	0.19	0.93	2915	0.0065	15.8
wood pellets	2.6	0.34	0.03	0.93	2915	0.0065	2.4
wood residues	6.3	0.83	0.07	0.93	2833	0.0065	5.9
waste[6]							Not relevant here
TOTAL	**150.2**	**19.8**	**2.2**				**121.4**

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[4] CGE=Cold Gas Efficiency. It is the most important parameter to assess the energy efficiency of a gasification process. See below

[5] The energy content of the gas does not take into account the energy required for the plant heat/energy consumptions

[6] Only the residual waste (after source separation) which is today used for energy purposes is here considered

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