BIOMASS CONVERSION COURSE

Doctoral School
EPFL

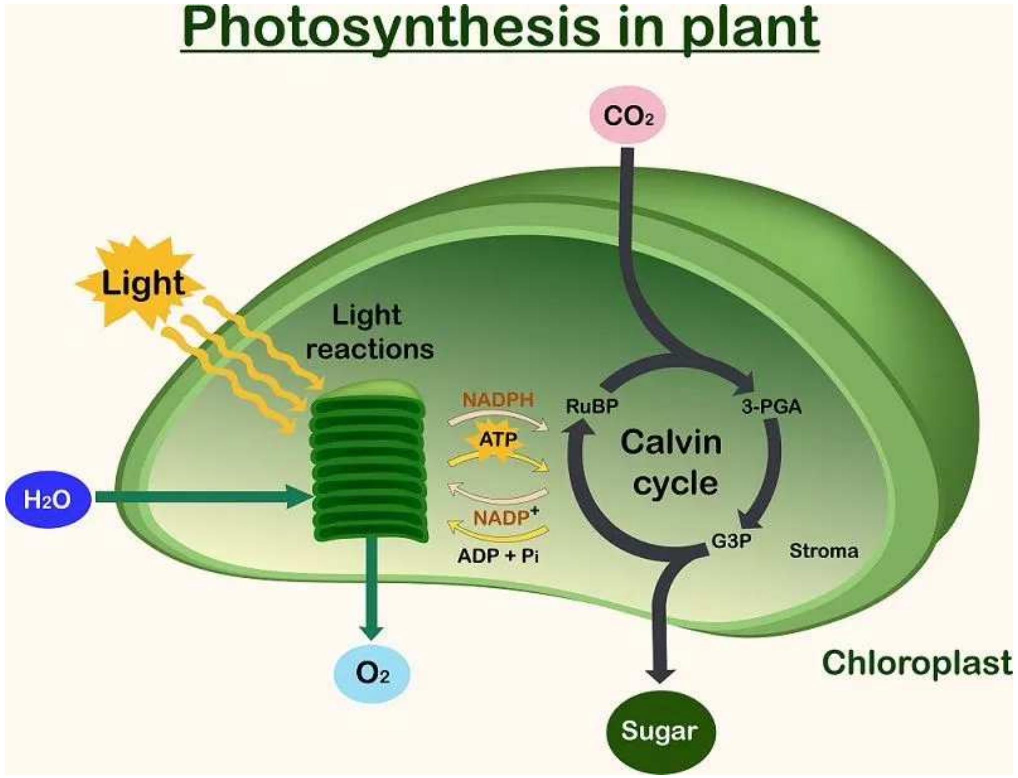
Introduction – Part 2

Photosynthesis

Characterization

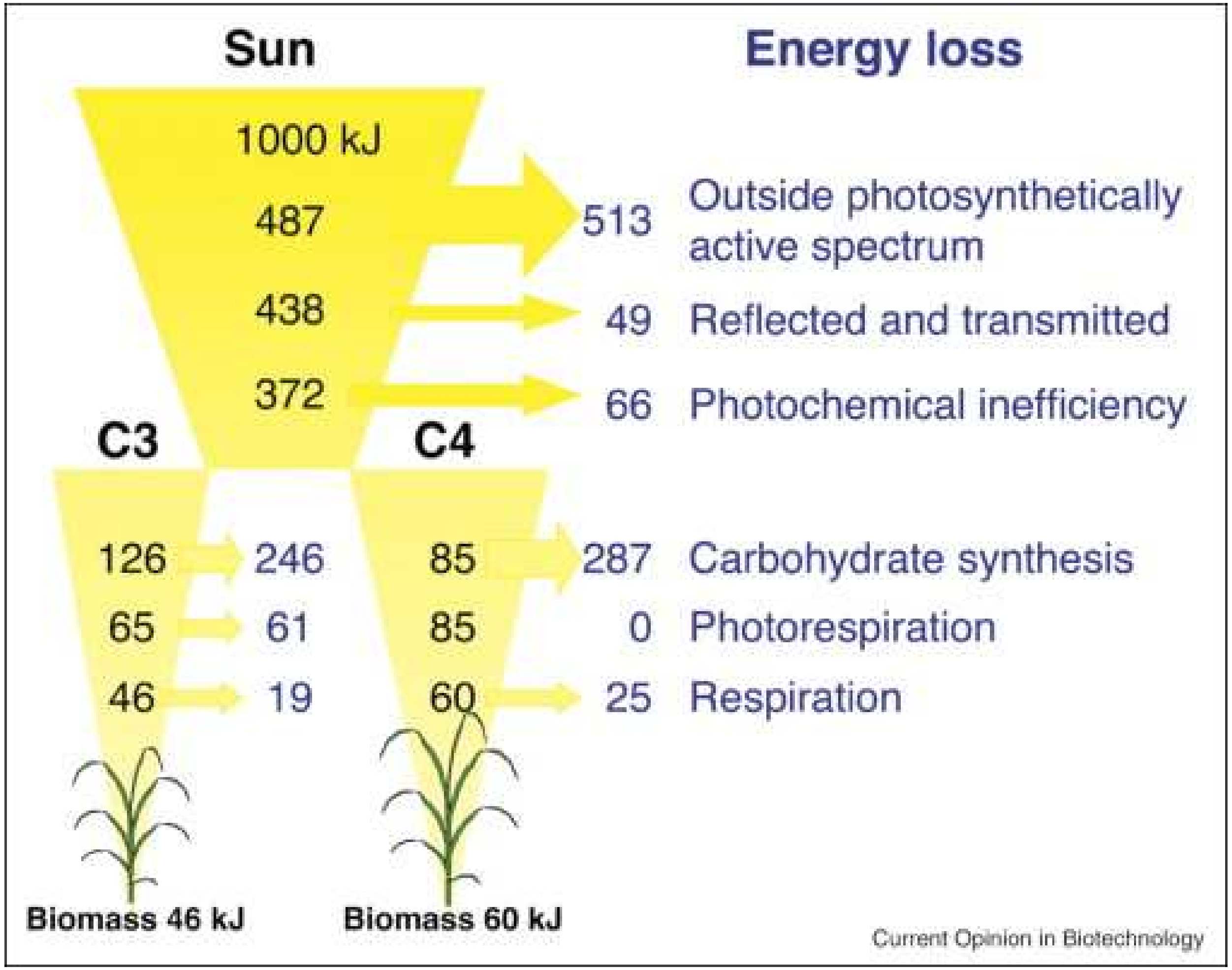
Main Conversion Routes

Overall, photosynthesis is a process that takes water, carbon dioxide, and sunlight, and converts it into oxygen and glucose. There are a large number of biochemical steps involved, but these steps are generally divided into two major processes: the light reactions and the Calvin Cycle.



Source: https://biologydictionary.net/

Theoretical Efficiency



4,6 – 6,0%

https://doi.org/10.1016/j.copbio.2008.02.004

EXAMPLES OF HIGH BIOMASS PRODUCTIVITY

(Slesser & Lewis, 1979; Leight el al. 1987; Klass, 2004) (Higher heating value: 15.6-20.0 Mj kg^{-1})

Biomass community	Location	Yield (t dry w. ha^{-1} year^{-1})	Photosynthetic efficiency (%)
Hybrid poplar *(Populus spp.) (C3)*	Minnesota	8 -11	0.3- 0.4
Water hyacinth *(Eichornia crassipes)*	Missisipi	11 – 33 (>150)	0.3- 0.9
Switchgrass *(Panicum virgatum) (C4)*	Texas	8-20	0.2- 0.6
Sweet sorghum *(Sorghum bicolor) (C4)*	Texas-California	22 - 47	0.6-1.0
Coniferous forest	England	34	1.8
Maize *(Zea mays) (C4)*	Israel	34	0.8
Tree plantation	Congo	36	1.0
Algae (sewage ponds)	California	49 - 74	1.3-1.9
Tropical forest	West Indies	59	1.6
Sugar cane *(Saccharum officinarum)*	Hawaii-Java	64-87	1.8-2.6
Napier grass *(Pennisetum purpureum)*	Hawaii, Puerto Rico	85-106	2.2-2.8

Biomass Characterization

Biomass Characterization

Proximate analysis

Moisture(M) + Volatile Matter(VM) + Ash(A) + Fixed Carbon (FC) = 100

Ultimate analysis

Elemental composition: C, H, O, N, S

Biochemical analysis

Cellulose, Hemicellulose, Lignin, Lipid, Carbohydrate, Protein

Charaterization Analysis

Ultimate analyses for typical biomass materials (wt%)

Material	C	H	O	N	S	Ash
Cypress	55.0	6.5	38.1	–	–	0.4
Ash	49.7	6.9	43.0	–	–	0.3
Beech	51.6	6.3	41.4	–	–	–
Wood (average)	51.6	6.3	41.5	0	0.1	1
Miscanthus	48.1	5.4	42.2	0.5	<0.1	2.8
Wheat straw	48.5	5.5	3.9	0.3	0.1	4
Barley straw	45.7	6.1	38.3	0.4	0.1	6
Rice straw	41.4	5	39.9	0.7	0.1	
Bituminous coal	73.1	5.5	8.7	1.4	1.7	9
Lignite	56.4	4.2	18.4	1.6[a]	–	5

[a] Combined N and S.

Proximate analysis of some biomass feedstocks (wt%)

Biomass	Moisture[a] (%)	VM (%)	FC (%)	Ash (%)	LHV (MJ/kg)
Wood	20	82	17	1	18.6
Wheat straw	16	59	21	4	17.3
Barley straw	30	46	18	6	16.1
Lignite	34	29	31	6	26.8
Bituminous coal	11	35	45	9	34

[a] Intrinsic.

Source: McKendry. Bioresources technology 83 , 2012

Energy – Heating Value

Higher Heating Value (Boie's correlation)

HHV[kJ/kg] = 351.7 C wt% + 1162.49 H wt% + 104.67 S wt% - 110.95 O wt% + 62.80 N wt%

Lower Heating Value

LHV = HHV - Δh_{VL} x ($m_{H2O,out}/m_{fuel,in}$) [kJ/kgfuel]

Δh_{VL} = 2450 kJ/kg

Biomass Conversion Routes

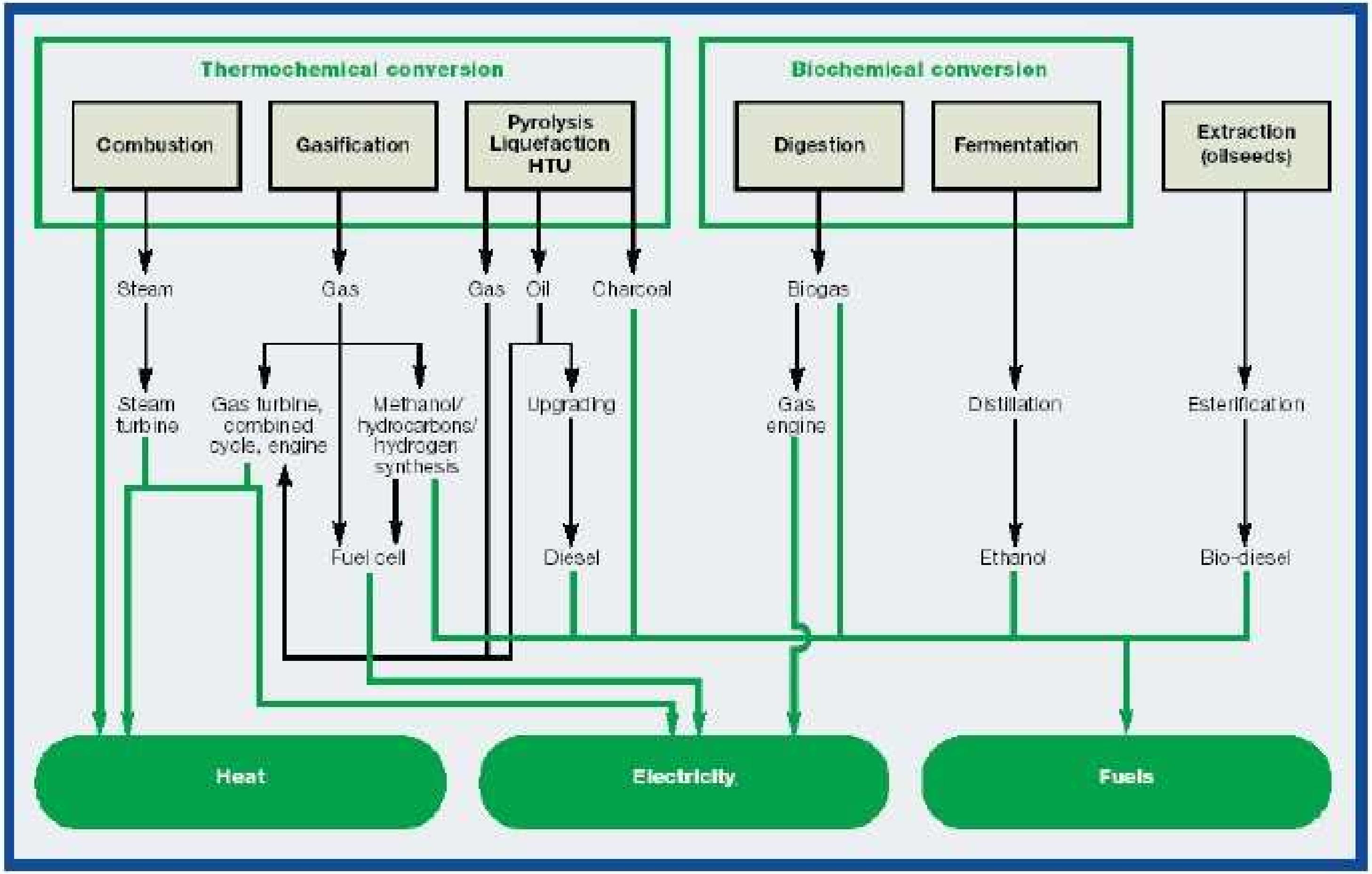


Figure 1: Main conversion options for biomass to secondary energy carriers [WEA, 2000]. Some categories represent a wide range of technological concepts as well as capacity ranges at which they are deployed, and these are dealt with further in the text.

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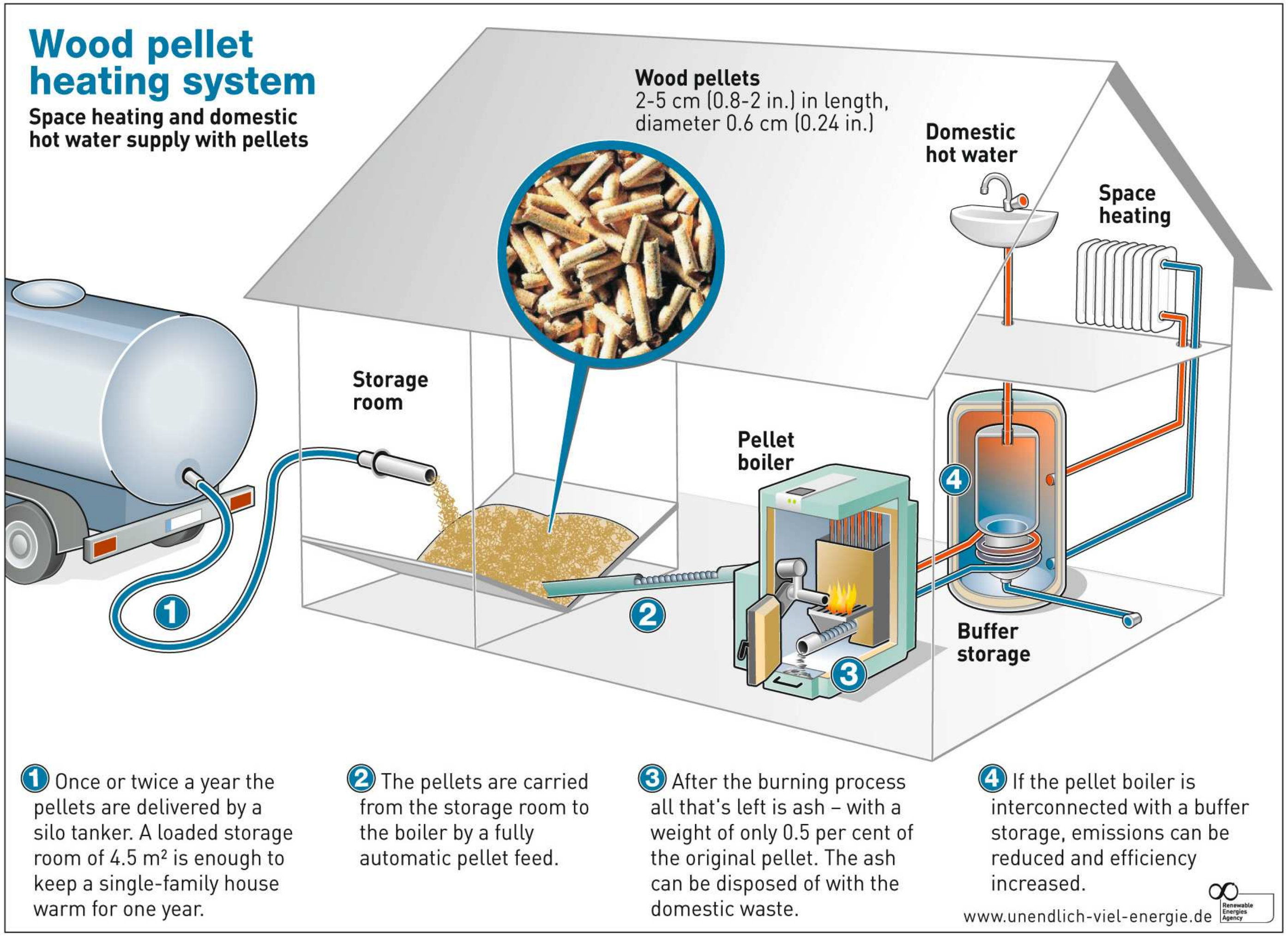
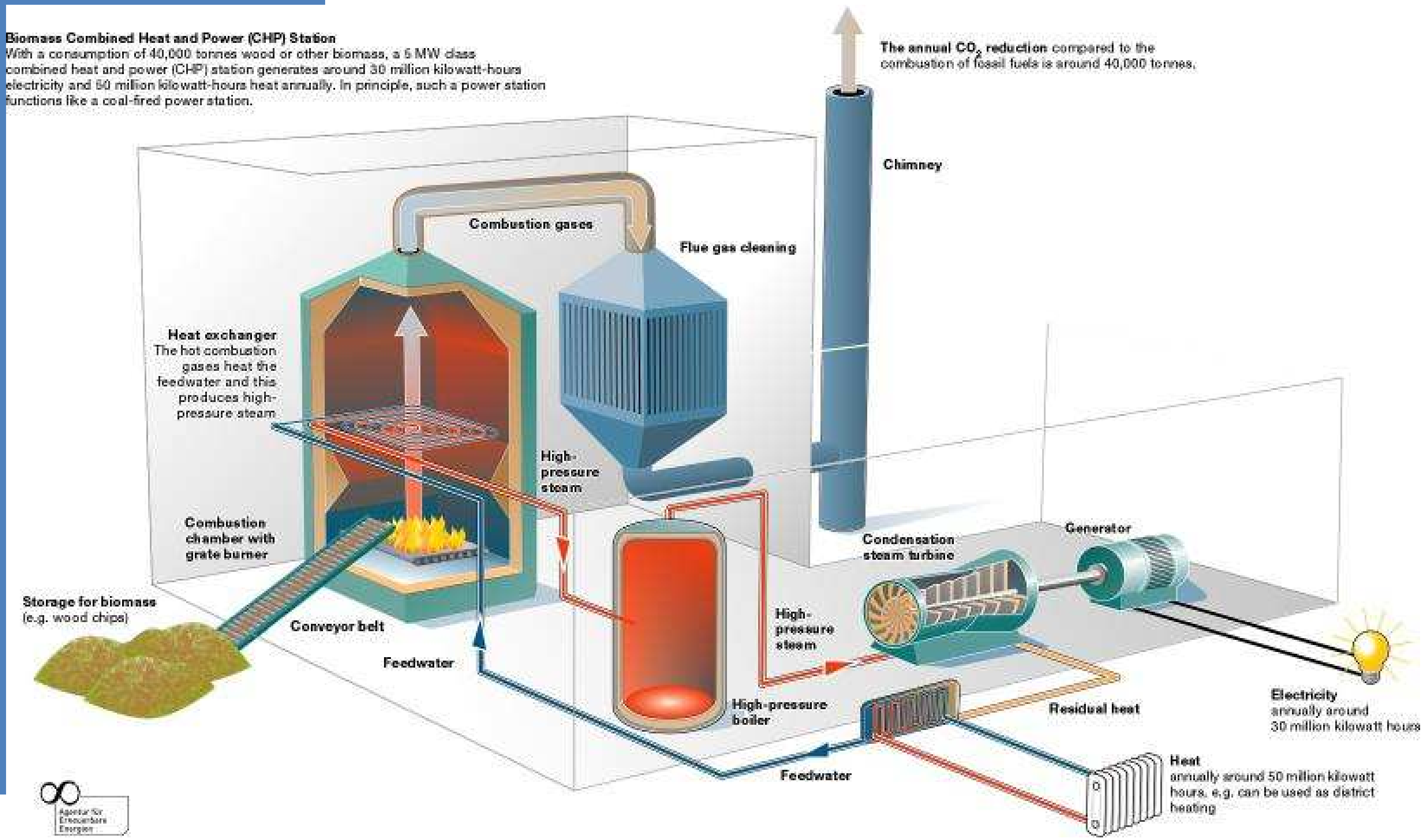
Biomass Combustion



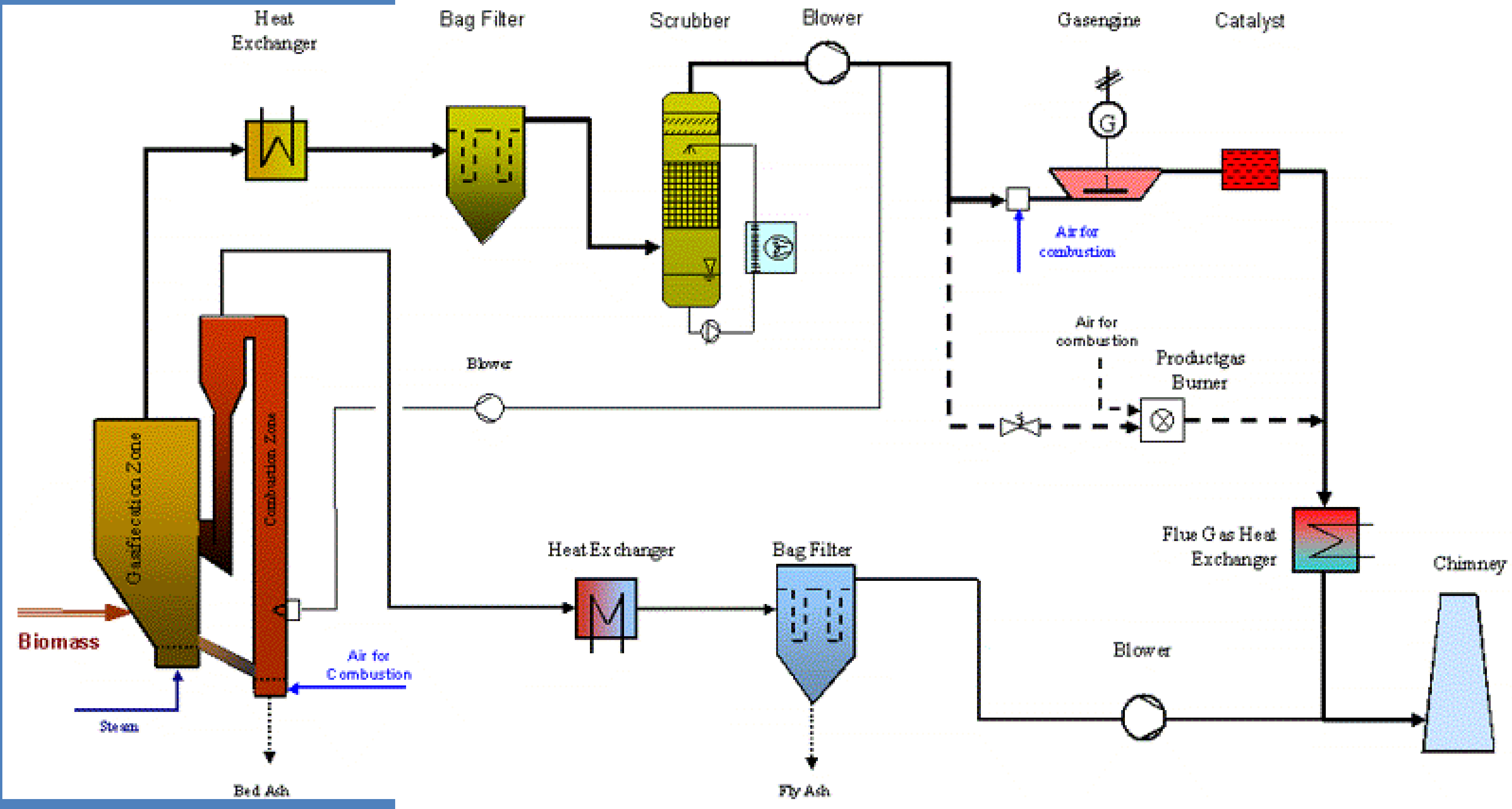
http://www.unendlich-viel-energie.de/

Biomass CHP – Steam Cycle



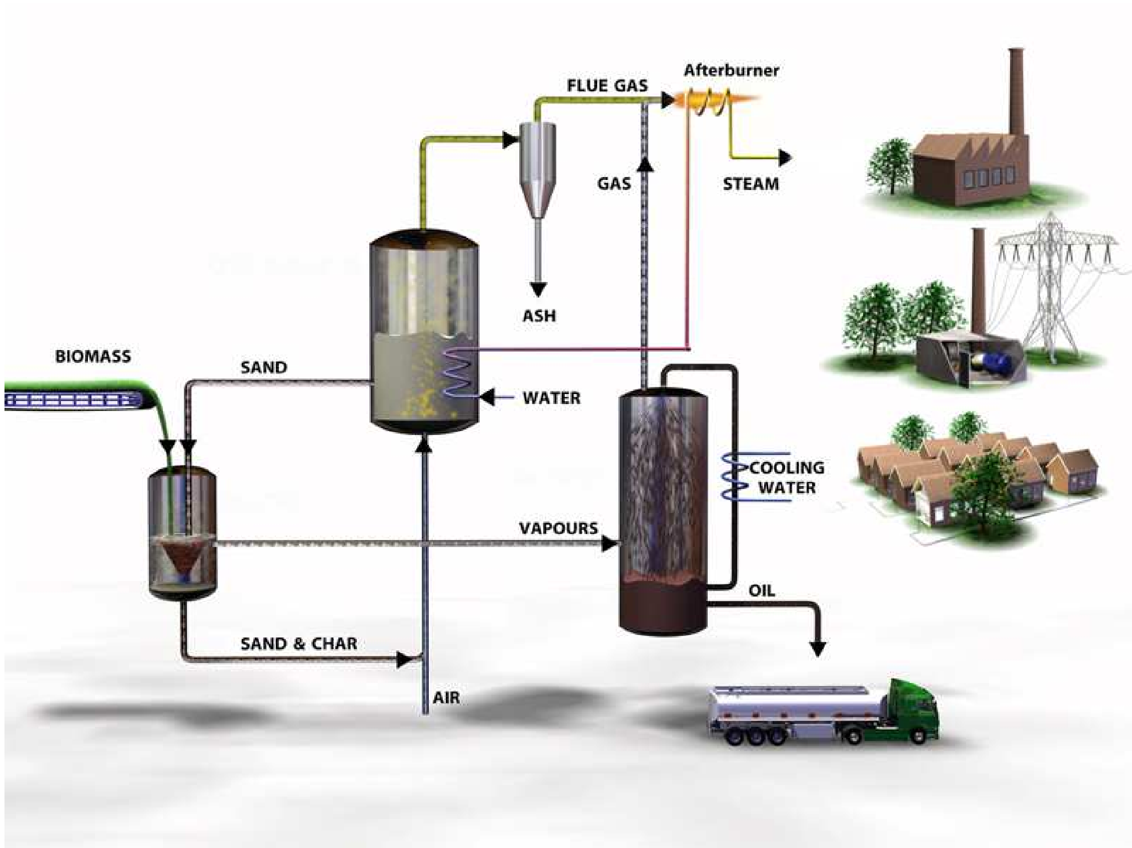
http://www.unendlich-viel-energie.de/

Biomass Integrated Gasification Power Plant



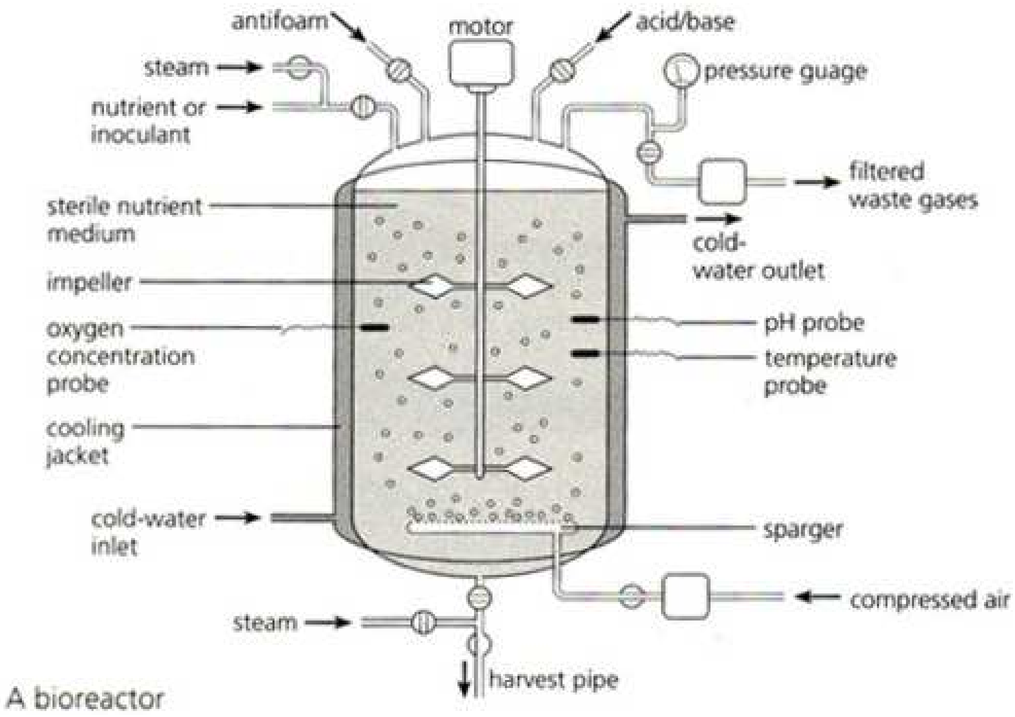
Source: http://www.sintef.no

Fast Pyrolysis



Source: http://www.btgworld.com

Fermentation to alcohol

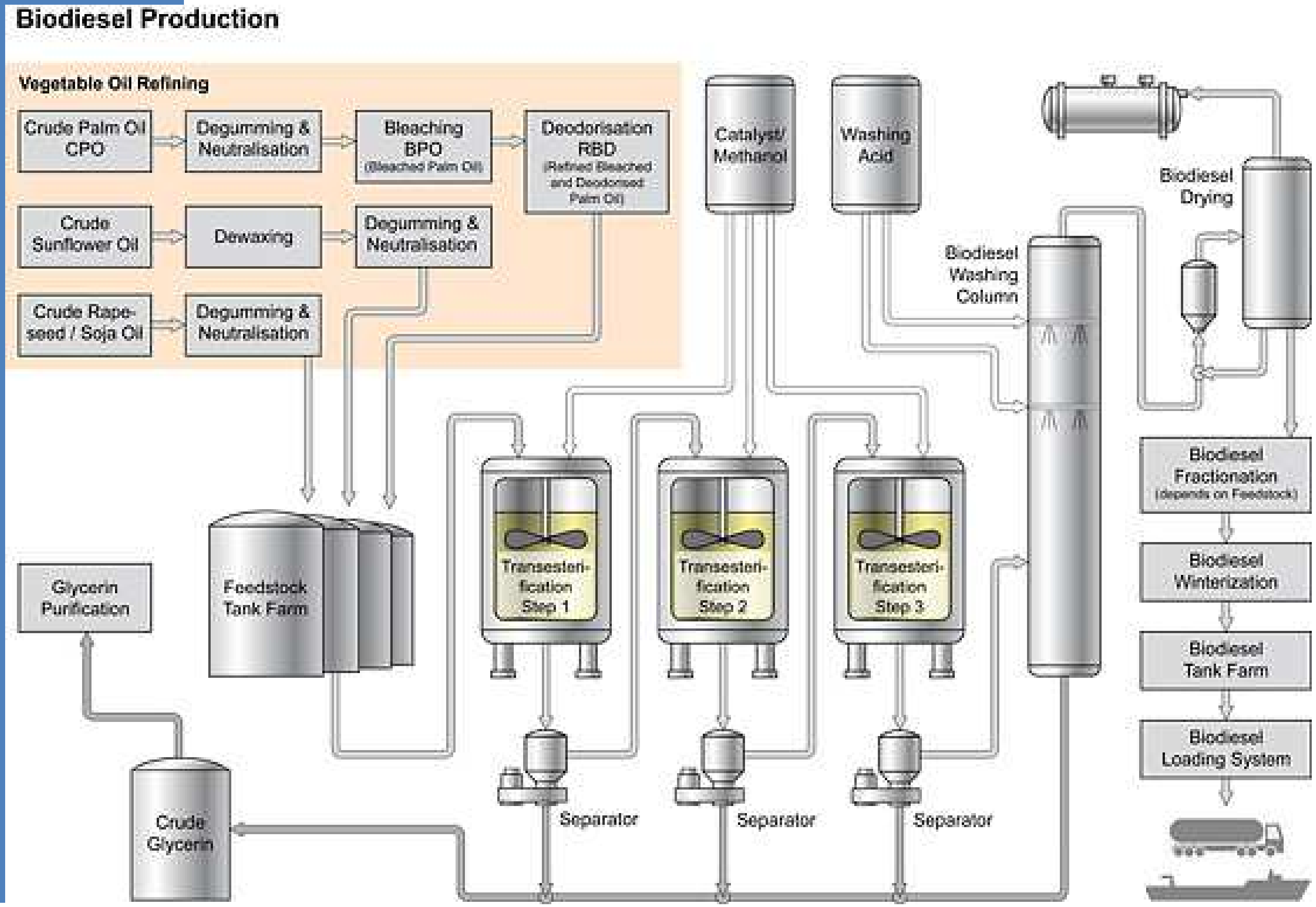


Source: http://www.fermenter.co.in

Biomethanation

Source: http://www.rfontanaconsultoria.com.br/

Transesterification of Vegetable Oils



Source: http://www.endress.com