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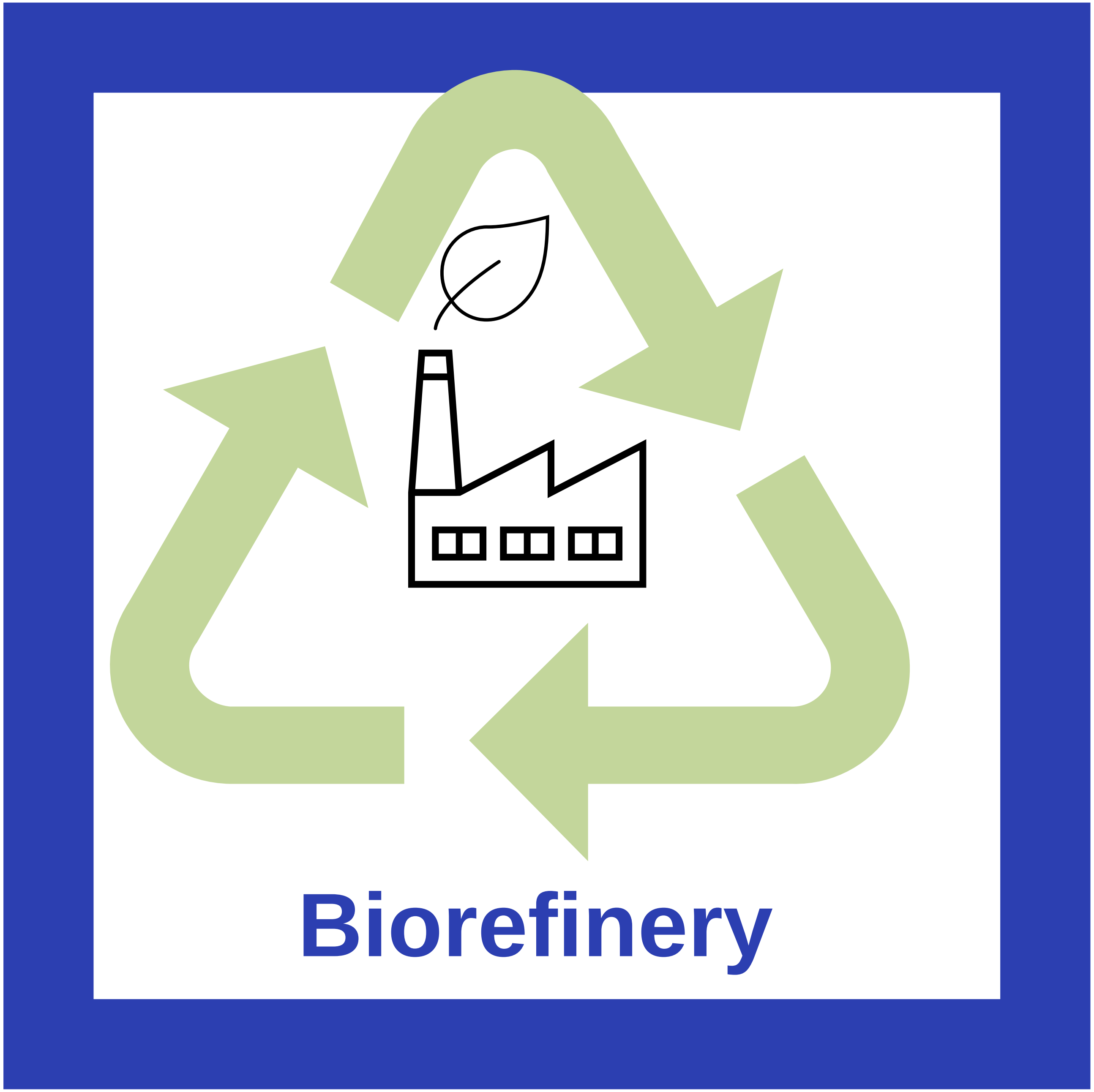
Eng Energy & Environment


Biorefinery

Information

Professor: Carla Silva (camsilva@ciencias.ulisboa.pt)

Wednesdays

16h-19h30

Room: 8.2.13

Information

Professor: Carla Silva (camsilva@ciencias.ulisboa.pt)

5 challenges!

Oral evaluation: discussing the challenges

07-06-2022

27-06-2022

20-07-2022

Definition & examples

IEA Bioenergy

Technology Collaboration Programme

IEA Bioenergy Task 42
"Biorefineries"

"Biorefining is the sustainable processing of biomass into a spectrum of marketable products and energy".

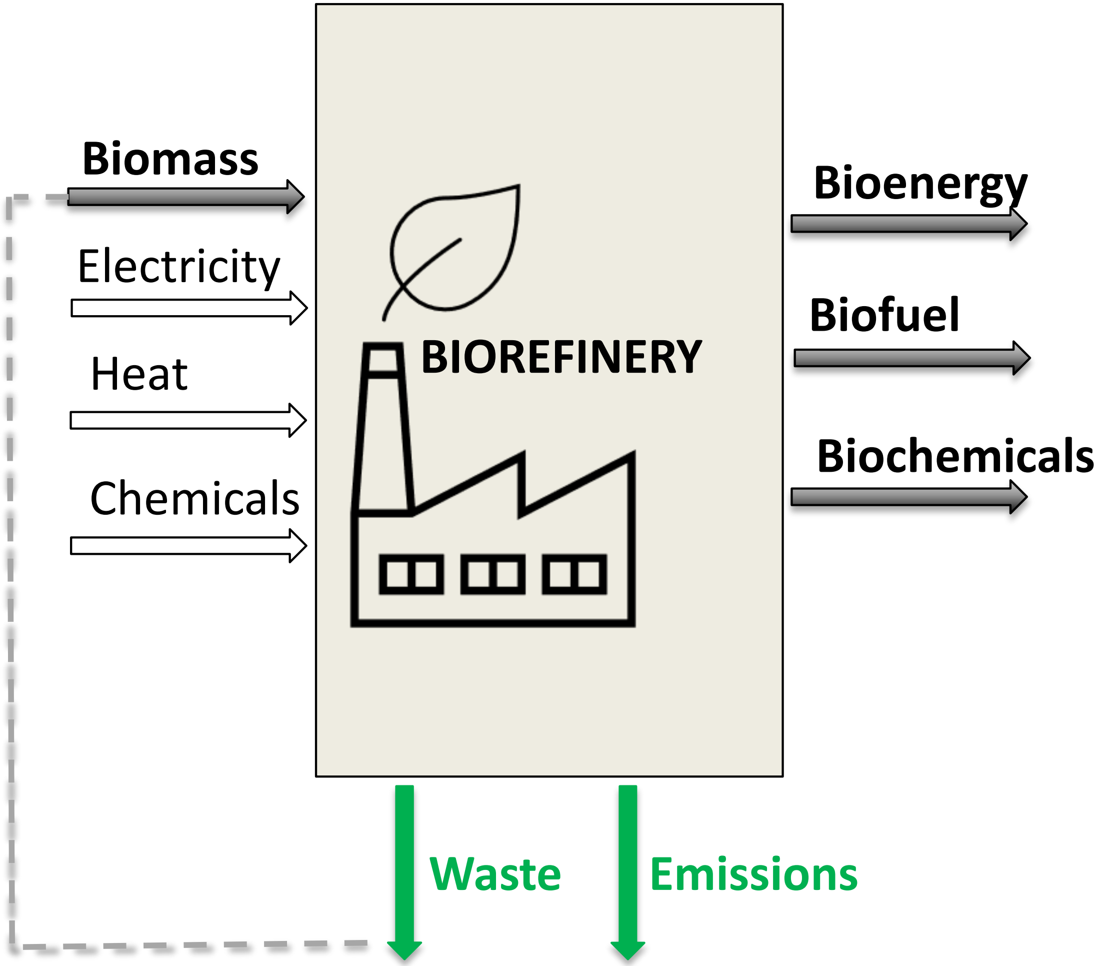
2007

Definition & examples

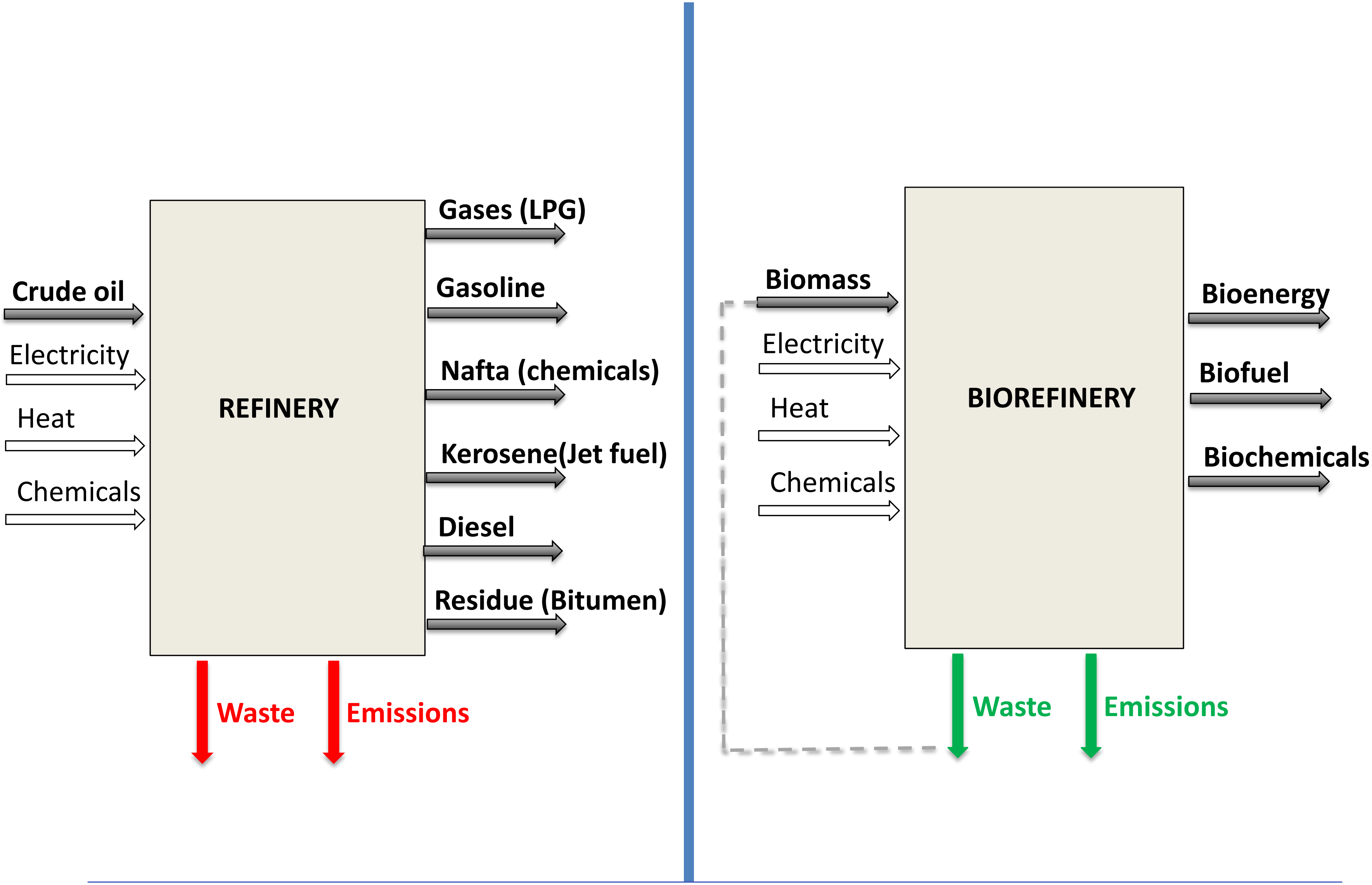
The biorefinery concept: Using biomass instead of oil for producing energy and chemicals, Energy Conversion and Management, Volume 51, Issue 7, 2010, Pages 1412-1421, ISSN 0196-8904, https://doi.org/10.1016/j.enconman.2010.01.015

Processes

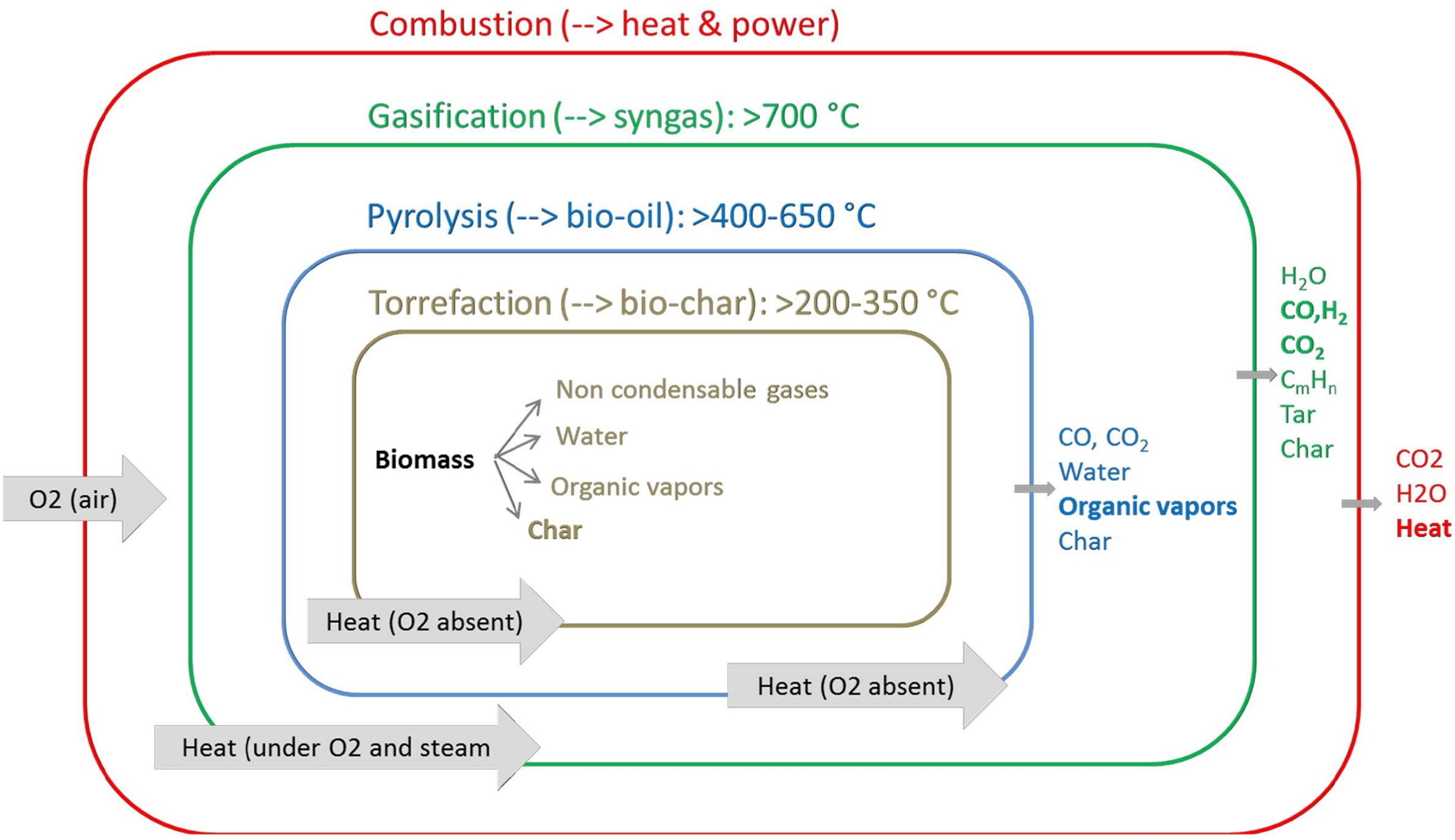
Collect and pre-treat: Decompose biomass in: Build products:



Definition & examples

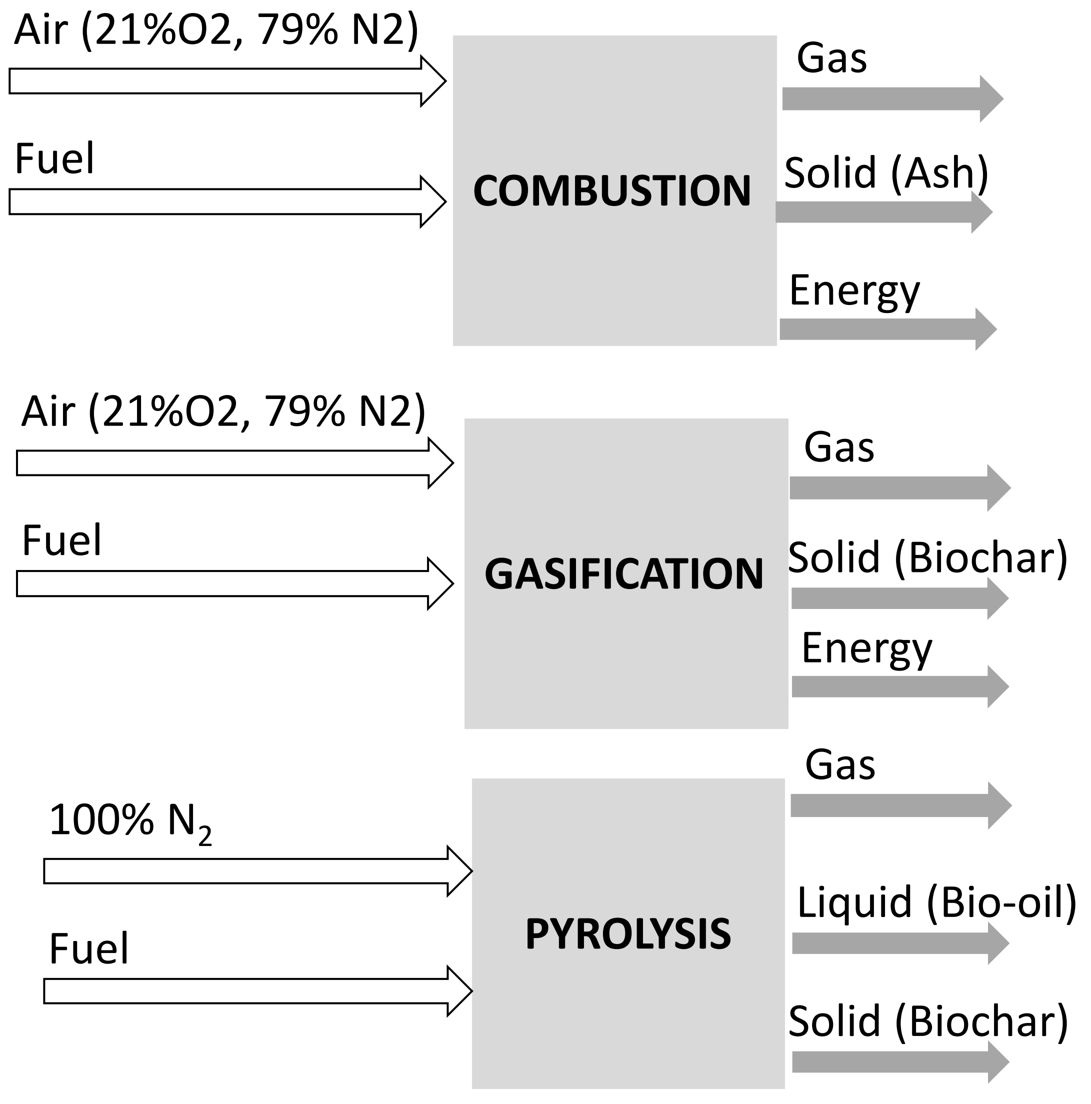


Thermochemical processes



•DOI: [10.1016/j.ejbt.2017.01.004](https://doi.org/10.1016/j.ejbt.2017.01.004)

Thermochemical processes

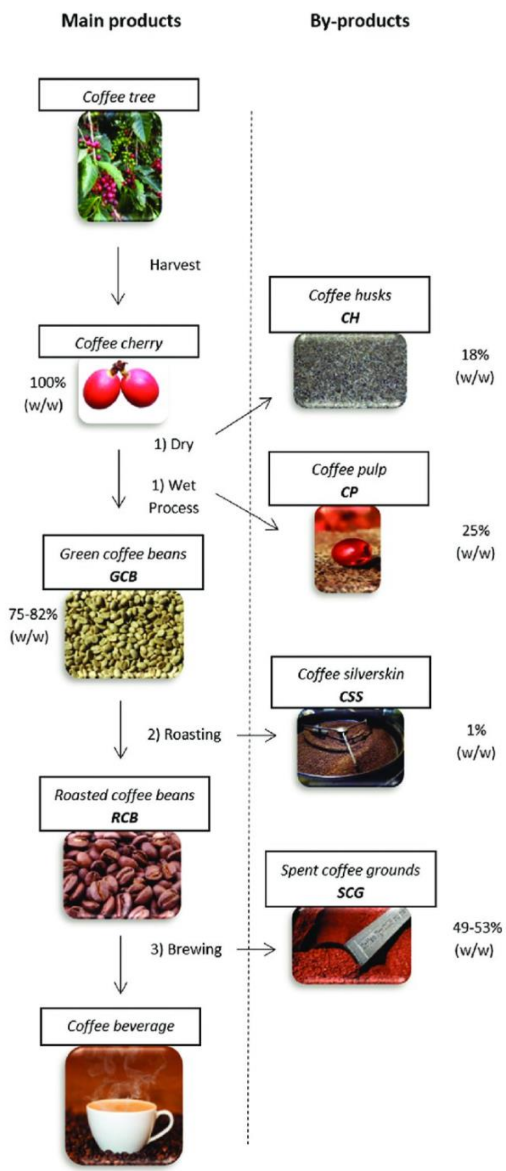


Thermochemical processes

https://doi.org/10.1016/j.wasman.2011.09.025

	Combustion	Gasification	Pyrolysis
Aim of the process	To maximize waste conversion to high temperature flue gases, mainly CO_2 and H_2O	To maximize waste conversion to high heating value fuel gases, mainly, CO, H_2, and CH_4	To maximize thermal decomposition of solid waste to gases and condensed phases
Operating conditions			
Reaction environment	Oxidizing environment, excess stoichiometric oxygen	Reducing, low oxygen	Zero oxygen
Reactant gas	Air	Usually air, could be oxygen enriched, or steam	None
Temperature	850–1,200 °C	500–1,500 °C, depending on specific process	500–800 °C
Pressure	Atmospheric	Atmospheric	Slight positive
Process output			
Produced gases	CO_2, H_2O	CO, H_2, CO_2, H_2O, CH_4	CO, H_2, CH_4, and other hydrocarbons
Pollutants/unwanted byproducts	SO_2, NOX, HCl, PCDD/F, particulates	H_2S, HCl, NH_3, HCN, tar, particulates	H_2S, HCl, NH_3, HCN, tar, particulates

Thermochemical processes



TORREFACTION

Heating no oxygen

CENTRO de CIÊNCIA do CAFÉ

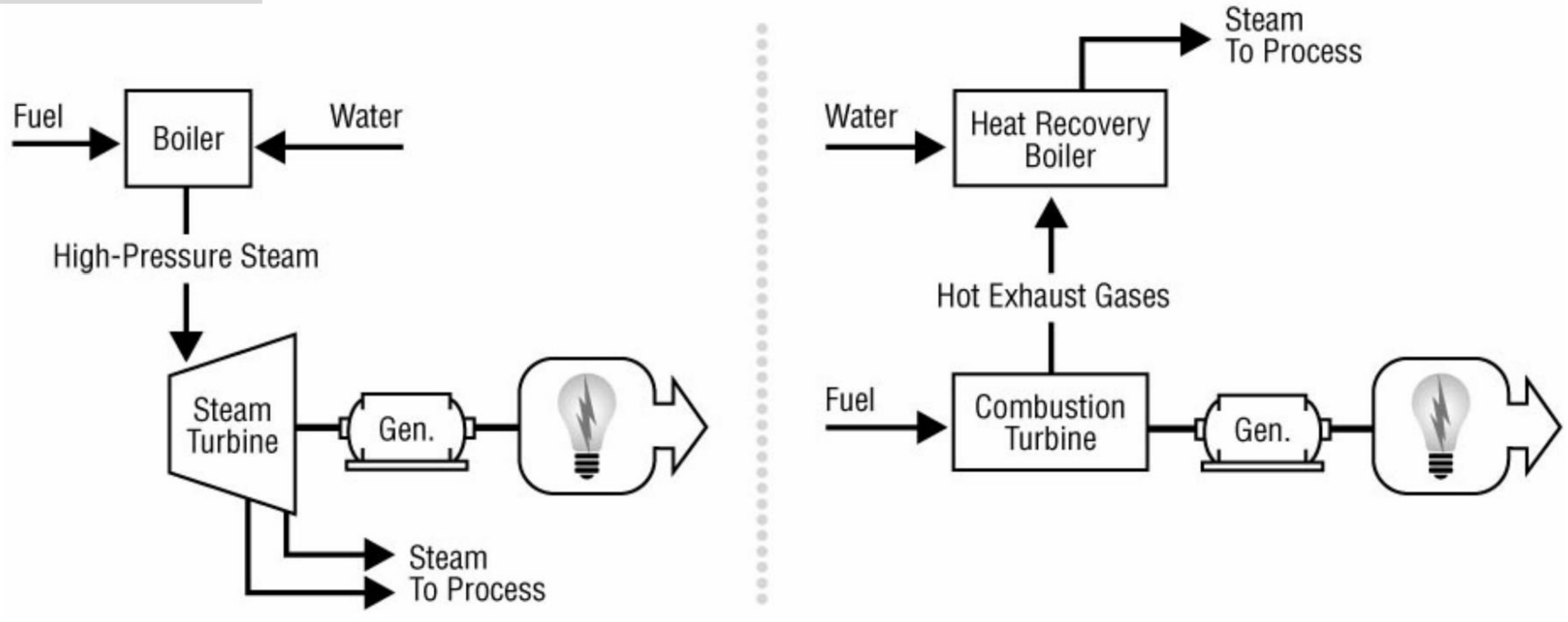
Herdade das Argamassas, 7370-171 Campo Maior

Thermochemical processes

COMBUSTION

STEAM (T=Temperature, P = Pressure)

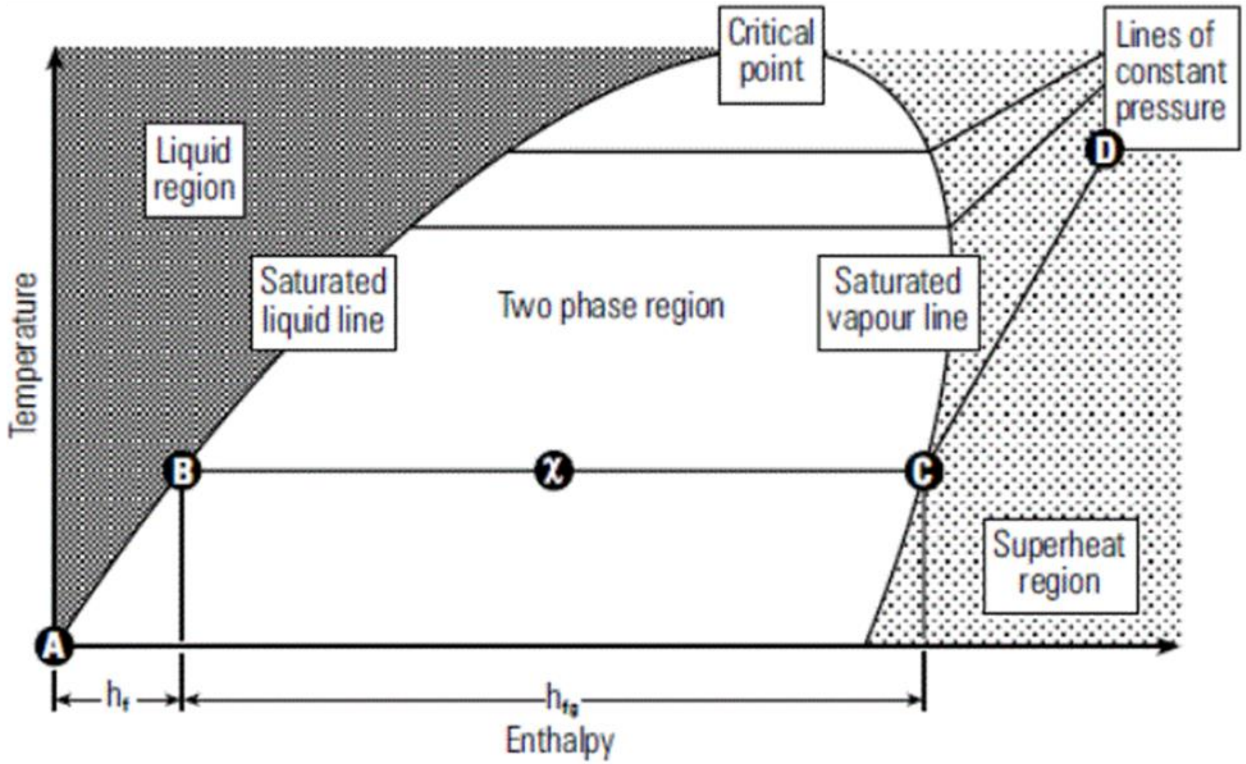
Figure 1. Typical CHP Configurations



Thermochemical processes

STEAM (T=Temperature, P = Pressure)

Water



Water

H_2O

TABLE A-3 Properties of Saturated Water (Liquid–Vapor): Pressure Table

		Specific Volume m^3/kg		Internal Energy kJ/kg		Enthalpy kJ/kg			Entropy kJ/kg · K		
Press. bar	Temp. °C	Sat. Liquid $v_f \times 10^3$	Sat. Vapor v_g	Sat. Liquid u_f	Sat. Vapor u_g	Sat. Liquid h_f	Evap. h_{fg}	Sat. Vapor h_g	Sat. Liquid s_f	Sat. Vapor s_g	Press. bar
0.04	28.96	1.0040	34.800	121.45	2415.2	121.46	2432.9	2554.4	0.4226	8.4746	0.04
0.06	36.16	1.0064	23.739	151.53	2425.0	151.53	2415.9	2567.4	0.5210	8.3304	0.06
0.08	41.51	1.0084	18.103	173.87	2432.2	173.88	2403.1	2577.0	0.5926	8.2287	0.08
0.10	45.81	1.0102	14.674	191.82	2437.9	191.83	2392.8	2584.7	0.6493	8.1502	0.10
0.20	60.06	1.0172	7.649	251.38	2456.7	251.40	2358.3	2609.7	0.8320	7.9085	0.20
0.30	69.10	1.0223	5.229	289.20	2468.4	289.23	2336.1	2625.3	0.9439	7.7686	0.30
0.40	75.87	1.0265	3.993	317.53	2477.0	317.58	2319.2	2636.8	1.0259	7.6700	0.40
0.50	81.33	1.0300	3.240	340.44	2483.9	340.49	2305.4	2645.9	1.0910	7.5939	0.50
0.60	85.94	1.0331	2.732	359.79	2489.6	359.86	2293.6	2653.5	1.1453	7.5320	0.60
0.70	89.95	1.0360	2.365	376.63	2494.5	376.70	2283.3	2660.0	1.1919	7.4797	0.70
0.80	93.50	1.0380	2.087	391.58	2498.8	391.66	2274.1	2665.8	1.2329	7.4346	0.80
0.90	96.71	1.0410	1.869	405.06	2502.6	405.15	2265.7	2670.9	1.2695	7.3949	0.90
1.00	99.63	1.0432	1.694	417.36	2506.1	417.46	2258.0	2675.5	1.3026	7.3594	1.00
1.50	111.4	1.0528	1.159	466.94	2519.7	467.11	2226.5	2693.6	1.4336	7.2233	1.50
2.00	120.2	1.0605	0.8857	504.49	2529.5	504.70	2201.9	2706.7	1.5301	7.1271	2.00

Thermochemical processes

TABLE A-3 Properties of Saturated Water (Liquid–Vapor): Pressure Table

		Specific Volume m^3/kg		Internal Energy kJ/kg		Enthalpy kJ/kg			Entropy kJ/kg · K		
Press. bar	Temp. °C	Sat. Liquid $v_f \times 10^3$	Sat. Vapor v_g	Sat. Liquid u_f	Sat. Vapor u_g	Sat. Liquid h_f	Evap. h_{fg}	Sat. Vapor h_g	Sat. Liquid s_f	Sat. Vapor s_g	Press. bar
3.50	138.9	1.0786	0.5243	583.95	2546.9	584.33	2148.1	2732.4	1.7275	6.9405	3.50
4.00	143.6	1.0836	0.4625	604.31	2553.6	604.74	2133.8	2738.6	1.7766	6.8959	4.00
4.50	147.9	1.0882	0.4140	622.25	2557.6	623.25	2120.7	2743.9	1.8207	6.8565	4.50
5.00	151.9	1.0926	0.3749	639.68	2561.2	640.23	2108.5	2748.7	1.8607	6.8212	5.00
6.00	158.9	1.1006	0.3157	669.90	2567.4	670.56	2086.3	2756.8	1.9312	6.7600	6.00
7.00	165.0	1.1080	0.2729	696.44	2572.5	697.22	2066.3	2763.5	1.9922	6.7080	7.00
8.00	170.4	1.1148	0.2404	720.22	2576.8	721.11	2048.0	2769.1	2.0462	6.6628	8.00
9.00	175.4	1.1212	0.2150	741.83	2580.5	742.83	2031.1	2773.9	2.0946	6.6226	9.00
10.0	179.9	1.1273	0.1944	761.68	2583.6	762.81	2015.3	2778.1	2.1387	6.5863	10.0
15.0	198.3	1.1539	0.1318	843.16	2594.5	844.84	1947.3	2792.2	2.3150	6.4448	15.0
20.0	212.4	1.1767	0.09963	906.44	2600.3	908.79	1890.7	2799.5	2.4474	6.3409	20.0
25.0	224.0	1.1973	0.07998	959.11	2603.1	962.11	1841.0	2803.1	2.5547	6.2575	25.0
30.0	233.9	1.2165	0.06668	1004.8	2604.1	1008.4	1795.7	2804.2	2.6457	6.1869	30.0
35.0	242.6	1.2347	0.05707	1045.4	2603.7	1049.8	1753.7	2803.4	2.7253	6.1253	35.0
40.0	250.4	1.2522	0.04978	1082.3	2602.3	1087.3	1714.1	2801.4	2.7964	6.0701	40.0
45.0	257.5	1.2692	0.04406	1116.2	2600.1	1121.9	1676.4	2798.3	2.8610	6.0199	45.0
50.0	264.0	1.2859	0.03944	1147.8	2597.1	1154.2	1640.1	2794.3	2.9202	5.9734	50.0
60.0	275.6	1.3187	0.03244	1205.4	2589.7	1213.4	1571.0	2784.3	3.0267	5.8892	60.0
70.0	285.9	1.3513	0.02737	1257.6	2580.5	1267.0	1505.1	2772.1	3.1211	5.8133	70.0
80.0	295.1	1.3842	0.02352	1305.6	2569.8	1316.6	1441.3	2758.0	3.2068	5.7432	80.0
90.0	303.4	1.4178	0.02048	1350.5	2557.8	1363.3	1378.9	2742.1	3.2858	5.6772	90.0
100.	311.1	1.4524	0.01803	1393.0	2544.4	1407.6	1317.1	2724.7	3.3596	5.6141	100.
110.	318.2	1.4886	0.01599	1433.7	2529.8	1450.1	1255.5	2705.6	3.4295	5.5527	110.

Thermochemical processes

Tab

TABLE A-4 *(Continued)*

T °C	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg·K	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg·K
	p = 160 bar = 16.0 MPa (T_{sat} = 347.44°C)				p = 180 bar = 18.0 MPa (T_{sat} = 357.06°C)			
Sat.	0.00931	2431.7	2580.6	5.2455	0.00749	2374.3	2509.1	5.1044
360	0.01105	2539.0	2715.8	5.4614	0.00809	2418.9	2564.5	5.1922
400	0.01426	2719.4	2947.6	5.8175	0.01190	2672.8	2887.0	5.6887
440	0.01652	2839.4	3103.7	6.0429	0.01414	2808.2	3062.8	5.9428
480	0.01842	2939.7	3234.4	6.2215	0.01596	2915.9	3203.2	6.1345
520	0.02013	3031.1	3353.3	6.3752	0.01757	3011.8	3378.0	6.2960
560	0.02172	3117.8	3465.4	6.5132	0.01904	3101.7	3444.4	6.4392
600	0.02323	3201.8	3573.5	6.6399	0.02042	3188.0	3555.6	6.5696
640	0.02467	3284.2	3678.9	6.7580	0.02174	3272.3	3663.6	6.6905
700	0.02674	3406.0	3833.9	6.9224	0.02362	3396.3	3821.5	6.8580
740	0.02808	3486.7	3935.9	7.0251	0.02483	3478.0	3925.0	6.9623
	p = 200 bar = 20.0 MPa (T_{sat} = 365.81°C)				p = 240 bar = 24.0 MPa			
Sat.	0.00583	2293.0	2409.7	4.9269				
400	0.00994	2619.3	2818.1	5.5540	0.00673	2477.8	2639.4	5.2393
440	0.01222	2774.9	3019.4	5.8450	0.00929	2700.6	2923.4	5.6506
480	0.01399	2891.2	3170.8	6.0518	0.01100	2838.3	3102.3	5.8950
520	0.01551	2992.0	3302.2	6.2218	0.01241	2950.5	3248.5	6.0842
560	0.01689	3085.2	3423.0	6.3705	0.01366	3051.1	3379.0	6.2448
600	0.01818	3174.0	3537.6	6.5048	0.01481	3145.2	3500.7	6.3875
640	0.01940	3260.2	3648.1	6.6286	0.01588	3235.5	3616.7	6.5174
700	0.02113	3386.4	3809.0	6.7993	0.01739	3366.4	3783.8	6.6947
740	0.02224	3469.3	3914.1	6.9052	0.01835	3451.7	3892.1	6.8038
800	0.02385	3592.7	4069.7	7.0544	0.01974	3578.0	4051.6	6.9567

Thermochemical processes

STEAM (T=Temperature, P = Pressure) Energy Content

Specific Enthalpy = kJ/kg

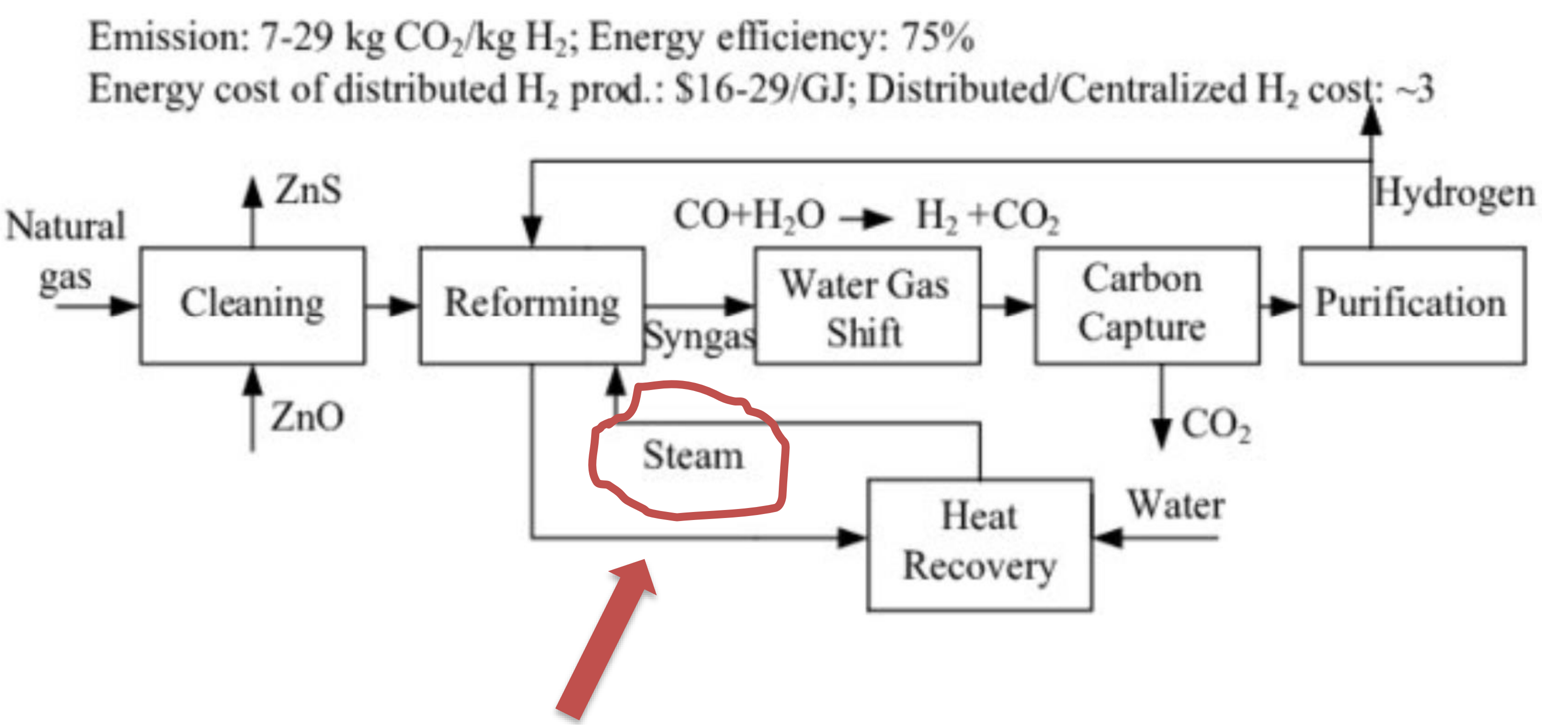
From tables, for example, SUPERHEATED VAPOUR

@99.63 °C, 1 atm, 2675.5 kJ/kg (**2.68 MJ/kg**)

@750 °C, 200 atm, 3940 kJ/kg (**3.94 MJ/kg**)

Hydrogen Production by Natural Gas

Matzen, Michael J.; Alhajji, Mahdi H.; and Demirel, Yasar, "Technoeconomics and Sustainability of Renewable Methanol and Ammonia Productions Using Wind Power-based Hydrogen" (2015). Yasar Demirel Publications.
http://digitalcommons.unl.edu/cbmedemirel/9



Thermochemical processes

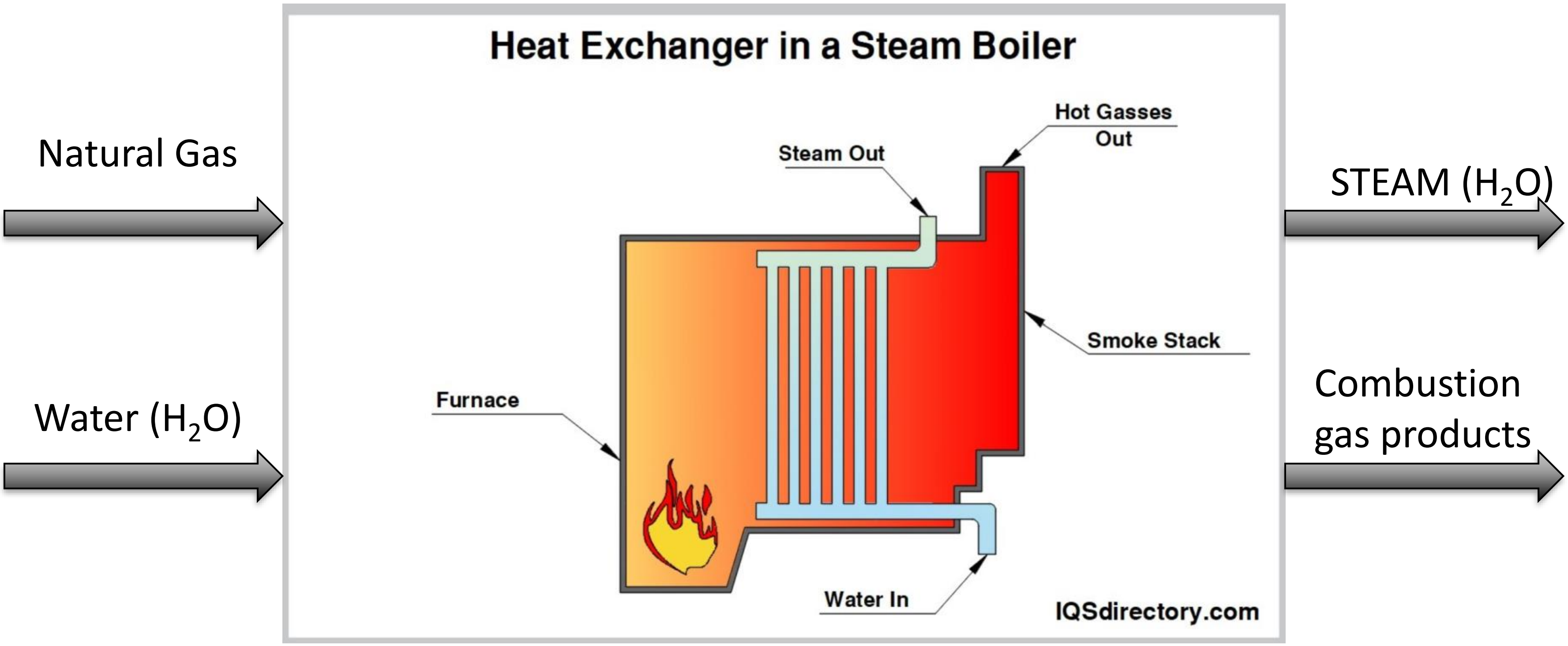
Hydrogen Production by Natural Gas

A steam methane reformer (SMR) uses steam heat (H_2O), pressure, and a catalyst to convert methane (CH_4) into hydrogen ($3H_2$) and carbon monoxide (CO). For this reaction to occur, the temperature must be within 700–1,000°C, while the pressure can vary from 3 to 25 bar

$$CH_4 + H_2O \leftrightarrow CO + 3H_2$$

STEAM 750 °C

Steam production by Natural Gas combustion



Processes – Esterification & Transesterification

Table 9. Summary of fuel properties used for the Well-To-Wheels integration (Gases)

Fuel	Density	RON / CN	LHV	Elemental composition of Carbon	CO_2 emission factor (Fuel combustion)	
	kg/ m³i.N.*	---	MJ/kg	%m	g/MJ	kg/kg
DME (liquefied via pressurisation at 288.15 K)	670	55	28.4	52.2	67.3	1.91
LPG (liquefied via pressurisation at 288.15 K)	550	**	46.0	82.4	65.7	3.02
CNG (EU mix piped NG)	0.780	**	46.6	70.8	56.1	2.60
CNG (2016 Mix)	0.782	**	46.6	71.3	56.2	2.62
CNG (2030 Mix average)	0.782	**	46.8	71.7	56.2	2.63
H-CNG (2016)	0.775	**	48.0	73.5	56.2	2.69
H-CNG (2030)	0.775	**	48.0	73.5	56.2	2.70
CNG (Russian NG quality)	0.727	**	49.2	73.9	55.1	2.71
CNG (upgraded biogas)	0.752	**	46.1	71.3	56.7	2.61
LNG (EU mix. 2016/2030)	0.798	**	49.1	75.6	56.4	2.77
LNG (Upgraded biogas 2016/2030)	0.716	**	50.0	74.9	54.9	2.74
Shale gas	0.727	**	49.2	73.9	55.1	2.71
Hydrogen (CGH2 & cCGH2)	0.090***	#	120.0	0.0	0.0	0.00
Liquid Hydrogen			120.0	0.0	0.0	0.00

Notes:
*) All values are related to standard conditions according to DIN 1343 (0.1013 MPa; 273.15 K) & ISO 2533 (288.15 K);
**) can vary significantly;
***) 0.084 kg/m³ @ 288.15 K (as indicated in the TTW report). The pressure of the CGH2 at the refueling station amounts to 88 MPa. CGH2 is stored in the vehicle at a pressure of maximum 70 MPa at 15°C.
The pressure of the CNG in the stationary CNG storage at the refueling station amounts to 25 MPa. CNG is stored at a pressure of maximum 20 MPa in the vehicle at 15°C.

Additional components:

- AdBlue CO_2 emission factor: 0.24 kg/kg

Prussi, M., Yugo, M., Padella, M., Edwards, R., Lonza, L and De Prada, L., JEC Well-to-Tank report v5: Annexes, Hamje, H., editor, EUR 30269 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-21707-7, doi:10.2760/06704, JRC119036.

Thermochemical processes

Steam production by Natural Gas combustion

Natural Gas
(EU mix piped NG)

LHV = 46 MJ/kg

56.1 gCO_2/MJ

How much natural gas to produce 100 kg hot water?

$$mNG*LHV = \frac{mcp\Delta T}{\eta}$$

$$mNG = \frac{mcp\Delta T}{LHV*0.85}$$

$$mNG = \frac{100kg*4.18\frac{kJ}{kgK}*50K}{46000\frac{kJ}{kg}*0.85} = 0.69kg$$

CO_2 = 56.1*0.69*46*10^-3 = 1.79 kg

Heat exchanger efficiency = 85%

Thermochemical processes

Steam production by Natural Gas combustion

How much emissions to produce **100 kg** water?

$$mNG*LHV= \frac{mcp\Delta T}{\eta}$$

$$mNG= \frac{mcp\Delta T}{LHV*0.85}$$

$$mNG= \frac{100kg*4.18\frac{kJ}{kgK}*50K}{46000\frac{kJ}{kg}*0.85} = 0.69kg$$

CO_2 = 56.1*0.69*46*10^-3 = 1.79 kg

Steam production by Natural Gas combustion

How much emissions to produce **100 kg** steam ? @750 °C, 200 atm, 3940 kJ/kg (**3.94 MJ/kg**)

$$mNG*LHV = \frac{\frac{MJ}{kg}*kg}{\eta}$$

$$mNG = \frac{3.94*100}{56.1*0.85}$$

$$CO_2 = \frac{3.94*100}{0.85} *46*10\text{^}{-3} = 21.3 \text{ kg}$$

Emission Factor (EF)

$EF_{\text{vapor produced natural gas}}$ = 21.3/100 = 0.213 kg CO2/kg = 0.05 kg CO2/MJ

Thermochemical processes

Biodiesel vs Diesel?????

Assignement#2 & #3

Thermochemical processes

Fossil Fuel Comparator for Biodiesel

Table 1. Summary. Refinery allocation results based on extended literature review[4]

	Consequential "Marginal" (gCO_{2eq}/MJ)			**Attributional "Average" ($g\ CO_{2eq}/MJ$)**			
	JEC [1] (Concawe)		JRC paper (2017)	Aramco paper [4]		JRC paper[2]	Sphera (2020)
	JEC v4 [1]	**JEC v5 [3]**	JRC [2]	Standard mass allocation	Customized allocation [4]*	EN (2)	Mass & Energy
Gasoline	7	**5.5**	5.8	10.2	7.6	5.7 - 5.8	9.6
Diesel	8.6	**7.2**	7.2	5.4	6.8	5.8 -	3.4

LCA-Life Cycle Assessment

ICS › 13 › 13.020 › 13.020.10

ISO 14040:2006

Environmental management — Life cycle assessment — Principles and framework

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FORMAT

✔ PDF

PAPER

CHF 11

ABSTRACT

PREVIEW

ISO 14040:2006 describes the principles and framework for life cycle assessment (LCA) including: definition of the goal and scope of the LCA, the life cycle inventory analysis (LCI) phase, the life cycle impact assessment (LCIA) phase, the life cycle interpretation phase, reporting and critical review of the LCA, limitations of the LCA, the relationship between the LCA phases, and conditions for use of value choices and optional elements.

ISO 14040:2006 covers life cycle assessment (LCA) studies and life cycle inventory (LCI) studies. It does not describe the LCA technique in detail, nor does it specify methodologies for the individual phases of the LCA.

The intended application of LCA or LCI results is considered during definition of the goal and scope, but the application itself is outside the scope of this International Standard.

GENERAL INFORMATION

Status : Published | **Publication date :** 2006-07

Edition : 2 | **Number of pages :** 20

Technical Committee : ISO/TC 207/SC 5 Life cycle assessment

ICS : 13.020.10 Environmental management | 13.020.60 Product life-cycles

SUSTAINABLE DEVELOPMENT GOALS

This standard contributes to the following Sustainable Development Goal:

13

LCA-Life Cycle Assessment

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ISO

ICS › 13 › 13.020 › 13.020.10

ISO 14044:2006

Environmental management — Life cycle assessment — Requirements and guidelines

ABSTRACT

PREVIEW

ISO 14044:2006 specifies requirements and provides guidelines for life cycle assessment (LCA) including: definition of the goal and scope of the LCA, the life cycle inventory analysis (LCI) phase, the life cycle impact assessment (LCIA) phase, the life cycle interpretation phase, reporting and critical review of the LCA, limitations of the LCA, relationship between the LCA phases, and conditions for use of value choices and optional elements.

ISO 14044:2006 covers life cycle assessment (LCA) studies and life cycle inventory (LCI) studies.

GENERAL INFORMATION

Status : Published

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Number of pages : 46

Technical Committee : ISO/TC 207/SC 5 Life cycle assessment

ICS : 13.020.10 Environmental management | 13.020.60 Product life-cycles

SUSTAINABLE DEVELOPMENT GOALS

This standard contributes to the following Sustainable Development Goals:

12 13

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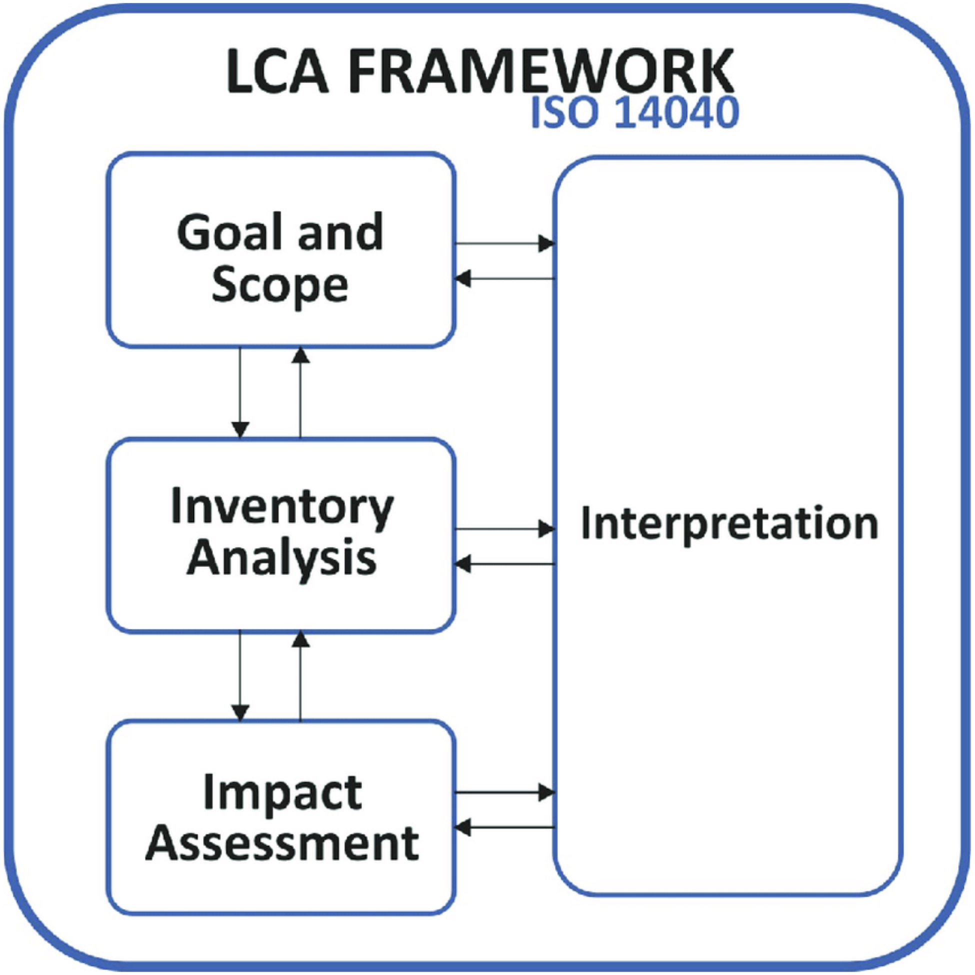
CHF 158

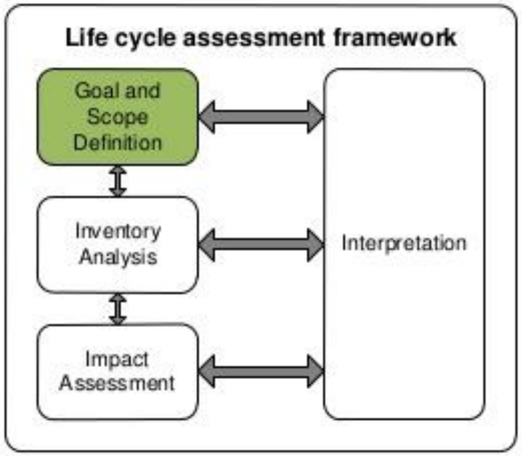
LCA-Life Cycle Assessment



LCA-Life Cycle Assessment

How to do LCA according to ISO 14040/44

- Goal & Scope Definition:
  - Determination of purpose, scope and system boundaries
- Life Cycle Inventory:
  - Data collection, modeling & analysis
- Impact Assessment:
  - Analysis of inputs and outputs using category indicators
- Interpretation:
  - Draw conclusions
  - Checks for: completeness, contribution, sensitivity analysis, consistency w/ goal and scope, analysis, etc.



Industrial Ecology Consultants 33

LCA-Life Cycle Assessment

Some significant calculation considerations are outlined in the following.

- **Allocation procedures** are needed when dealing with systems involving multiple products (e.g. multiple products from petroleum refining). The materials and energy flows as well as associated environmental releases shall be allocated to the different products according to clearly stated procedures, which shall be documented and justified.

ALCA = ATRIBUCIONAL LIFE CYCLE ASSESSEMENT

4.3.4.2 Allocation procedure

The study shall identify the processes shared with other product systems and deal with them according to the stepwise procedure [3)] presented below.

a) **Step 1**: Wherever possible, allocation should be avoided by

1) dividing the unit process to be allocated into two or more sub-processes and collecting the input and output data related to these sub-processes, or

2) expanding the product system to include the additional functions related to the co-products, taking into account the requirements of 4.2.3.3.

b) **Step 2**: Where allocation cannot be avoided, the inputs and outputs of the system should be partitioned between its different products or functions in a way that reflects the underlying physical relationships between them; i.e. they should reflect the way in which the inputs and outputs are changed by quantitative changes in the products or functions delivered by the system.

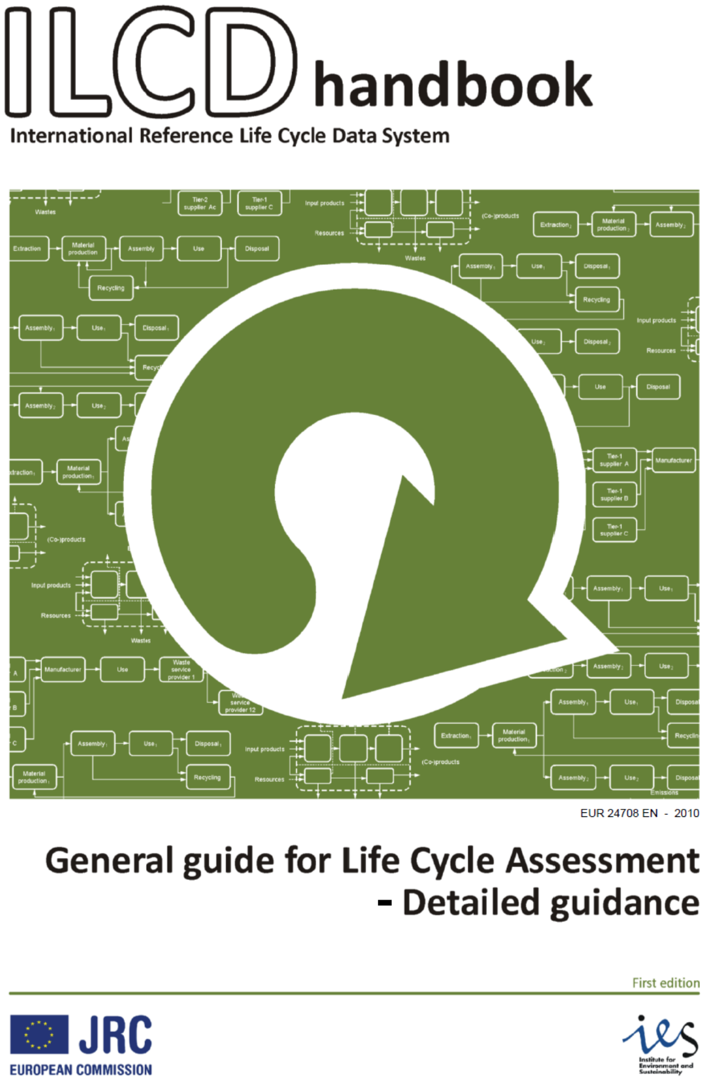
c) **Step 3**: Where physical relationship alone cannot be established or used as the basis for allocation, the inputs should be allocated between the products and functions in a way that reflects other relationships between them. For example, input and output data might be allocated between co-products in proportion to the economic value of the products.

Some outputs may be partly co-products and partly waste. In such cases, it is necessary to identify the ratio between co-products and waste since the inputs and outputs shall be allocated to the co-products part only.

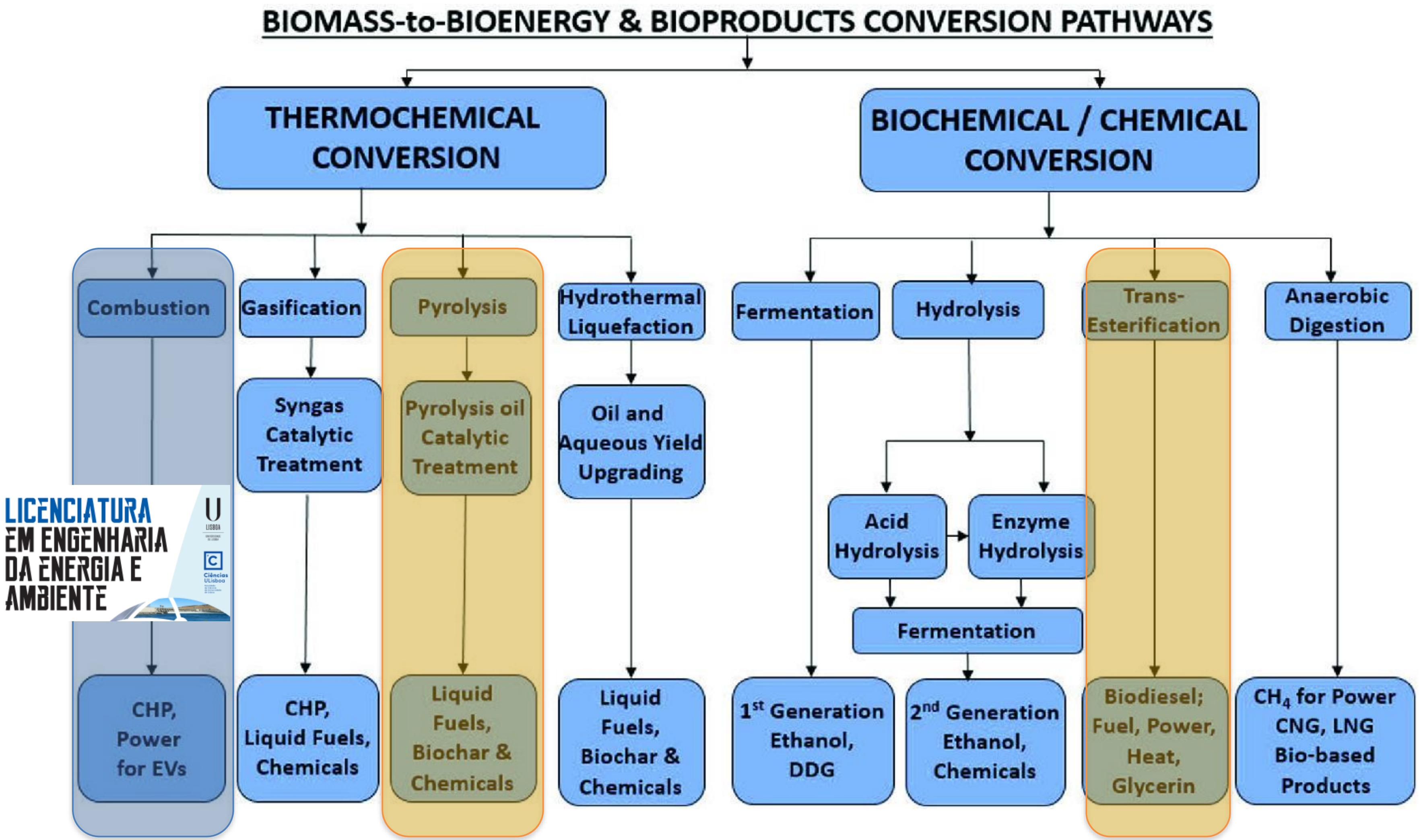
Allocation procedures shall be uniformly applied to similar inputs and outputs of the system under consideration. For example, if allocation is made to usable products (e.g. intermediate or discarded products) leaving the system, then the allocation procedure shall be similar to the allocation procedure used for such products entering the system.

The inventory is based on material balances between input and output. Allocation procedures should therefore approximate as much as possible such fundamental input/output relationships and characteristics.

LCA-Life Cycle Assessment



Processes – Conversion Technologies

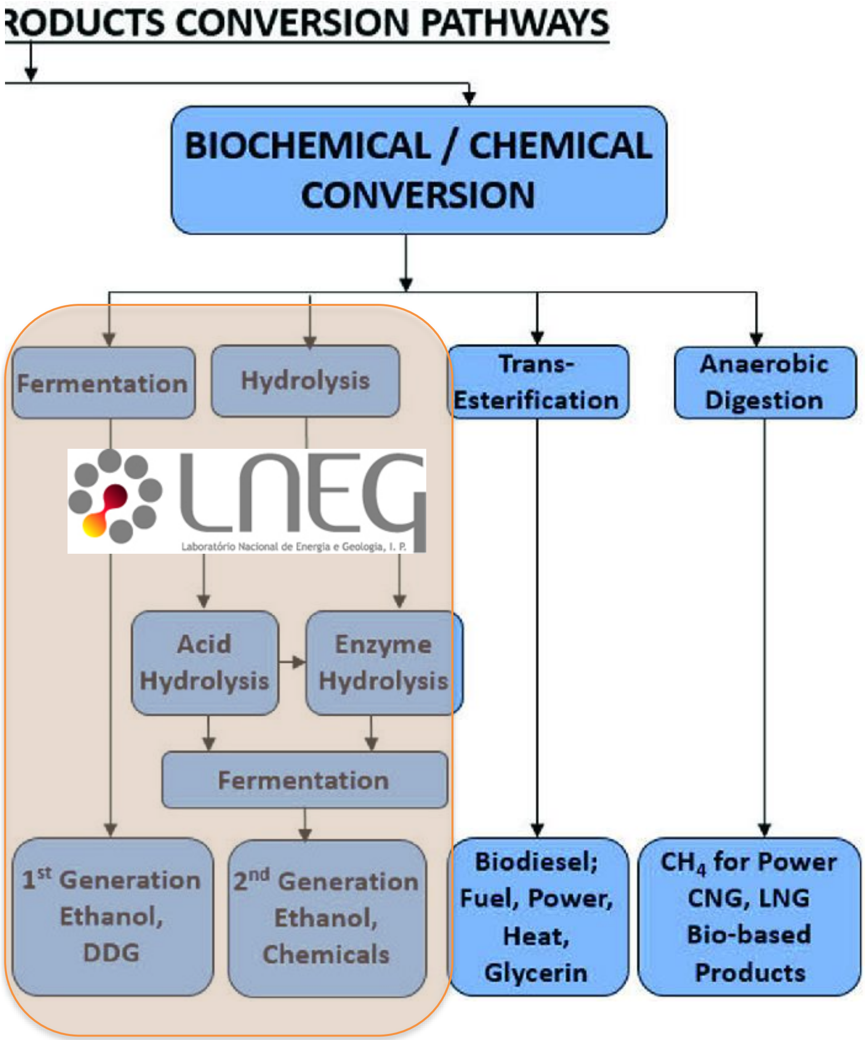


Processes – Biochemical conversion

Day 6 April: Biorrefinarias com processos de fermentação.

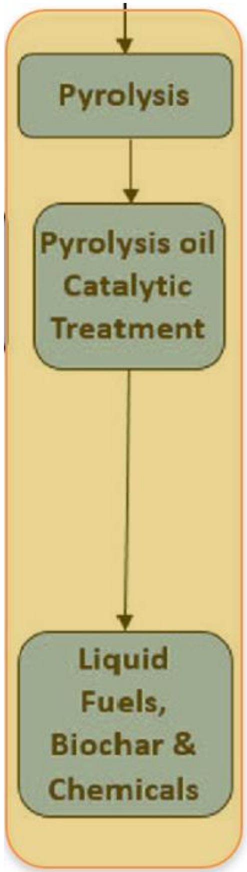
Easter holydays 13 - 19 April

Day 20 April: Visita de estudo projeto GREENFUEL edificio F LNEG.



Processes – Biochemical conversion

Pyrolysis products: **Biochar** and **Bio-oil**



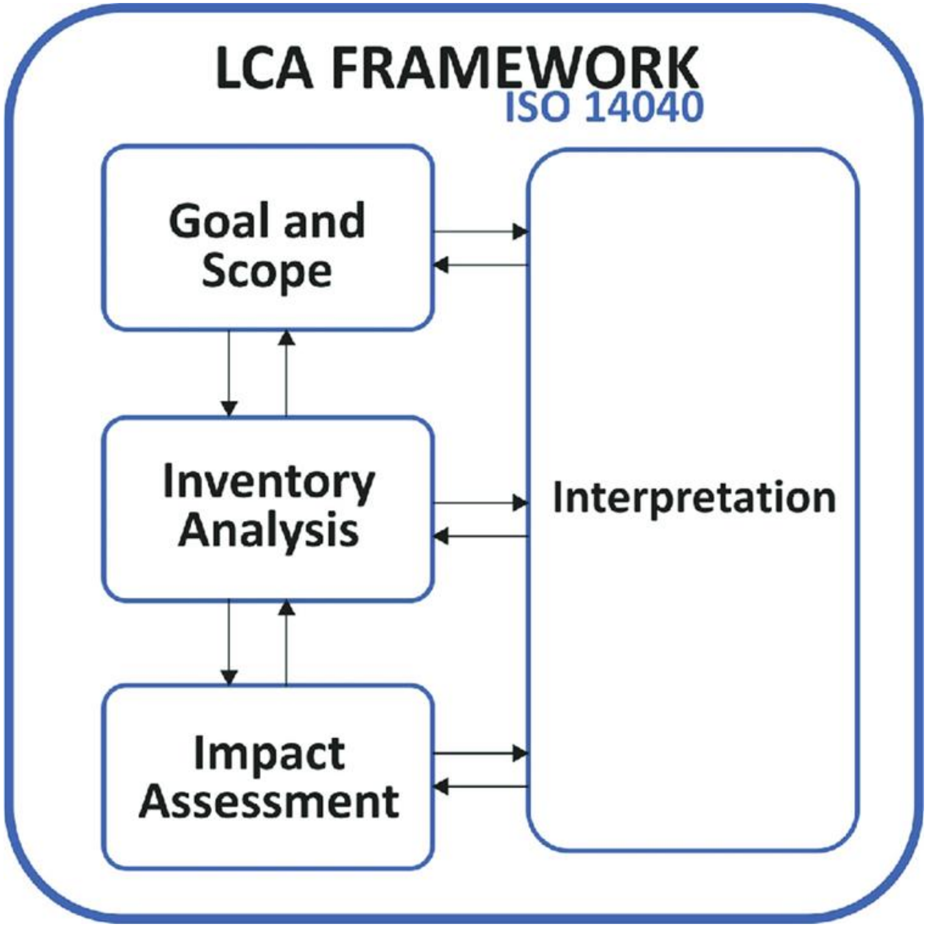
Day 4 May

Day 11 May

NOVA SCHOOL OF SCIENCE & TECHNOLOGY

Challenge #4

Relate the ISO 14040 LCA steps with your work in challenge #2 and #3 (deadline oral examination)



Challenge #4

Relate the ISO 14040 LCA steps with your work in challenge #2 and #3 (deadline oral examination)

Send pdf e-mail

25-05-2022 quar 16-19h | 8.2.13

07-06-2022 ter 16:30:00 19:30:00 03:00:00 1.3.14 | 1.3.15

27-06-2022 seg 16:30:00 19:30:00 03:00:00 1.3.14 | 1.3.15

Thanks

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