
Thermochemical conversion routes of lignocellulosic biomass

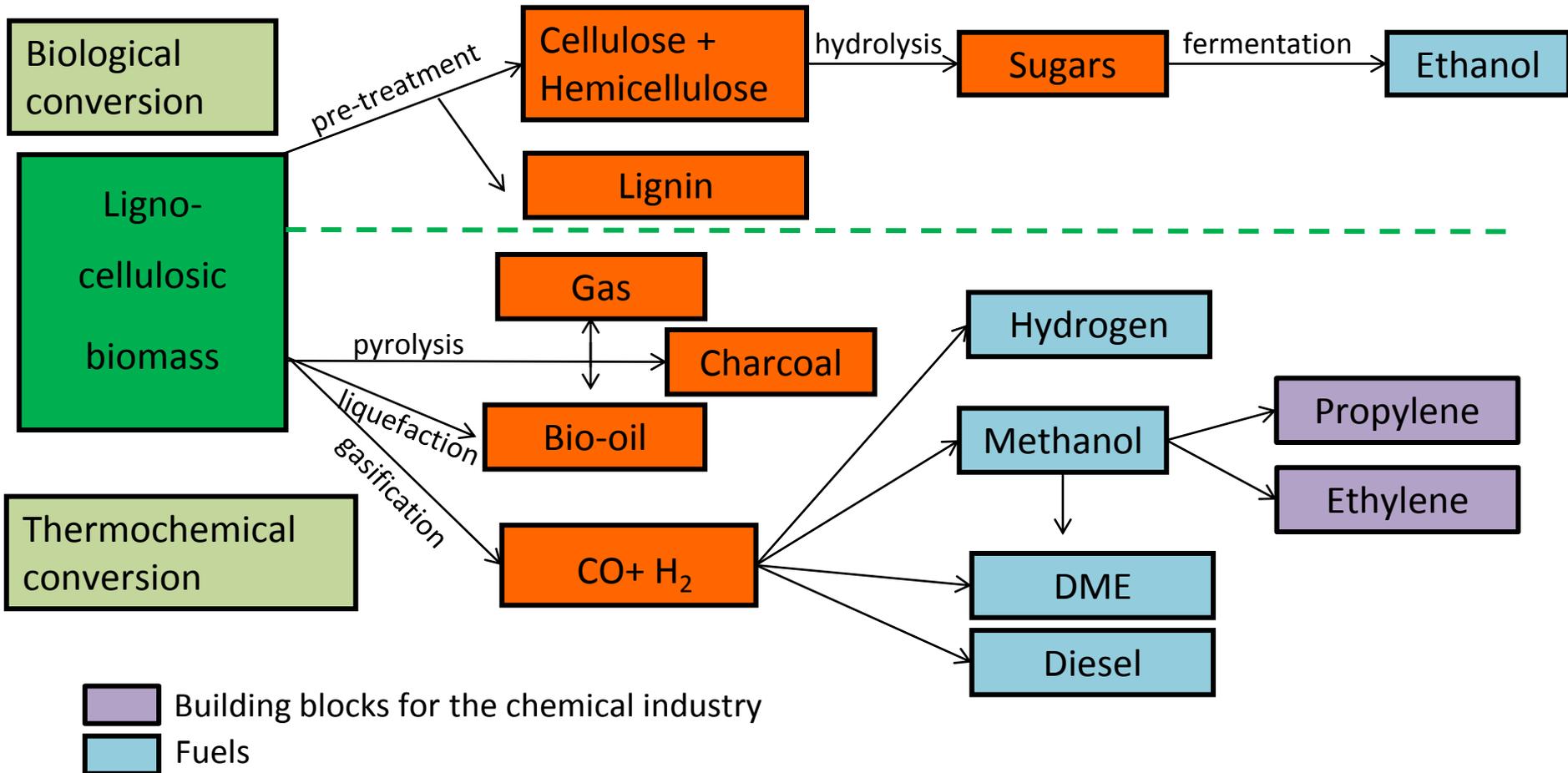
S. GERBINET and A. LEONARD
saicha.gerbinet@ulg.ac.be

University of Liège

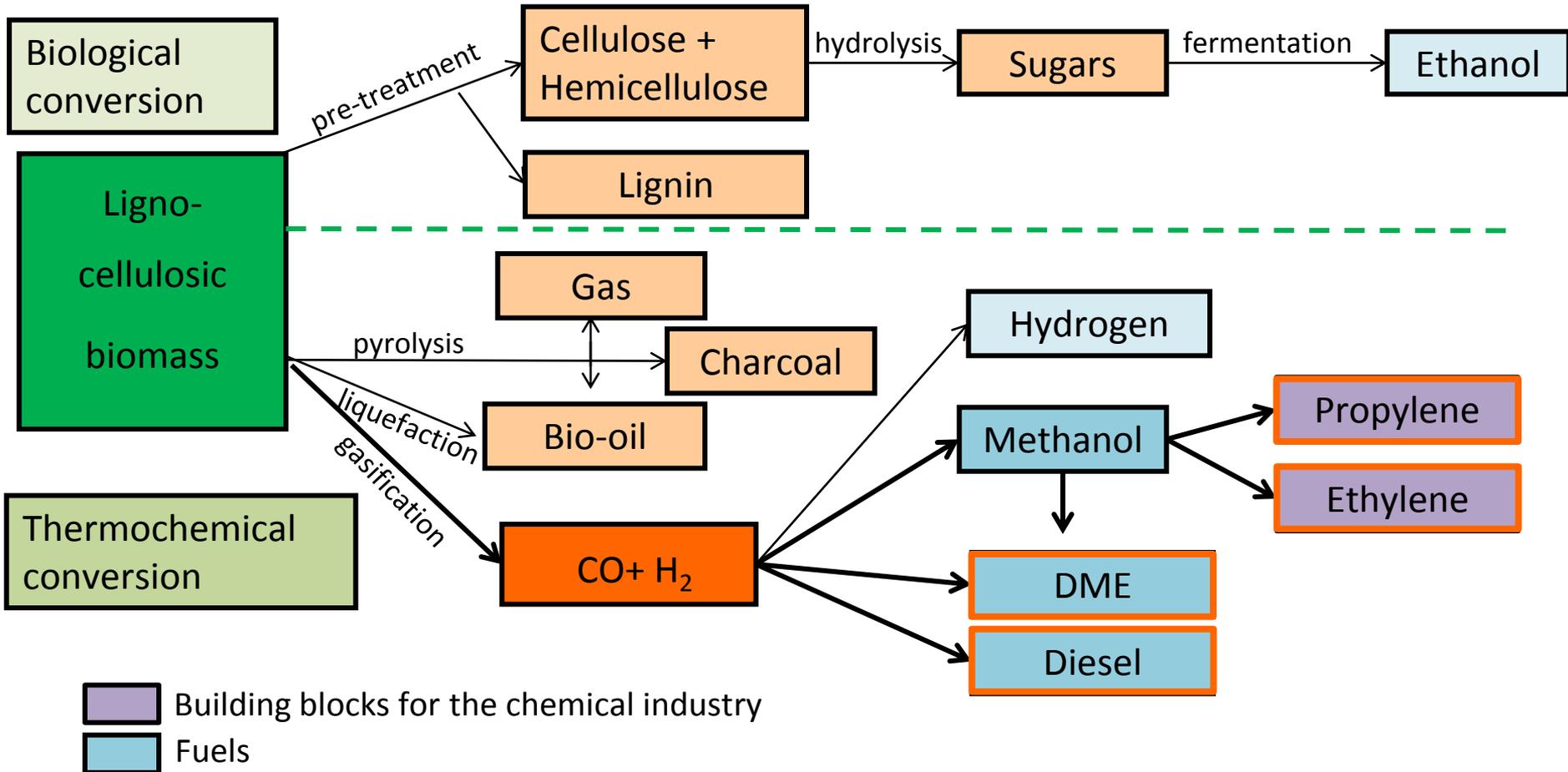
LABORATORY of CHEMICAL ENGINEERING

Processes and Sustainable development

Introduction



Introduction

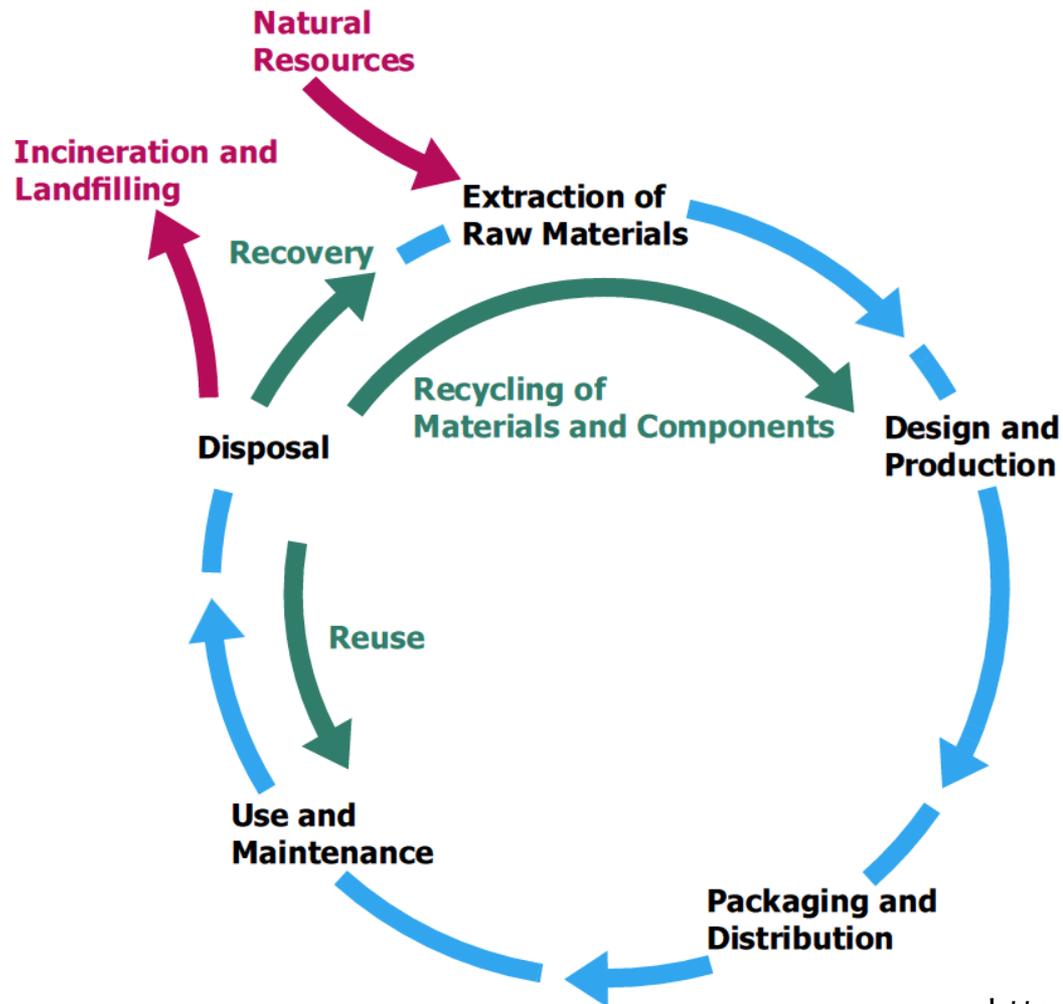


Goals

Determine the environmental impact of the different routes of **lignocellulosic biomass** valorisation by **thermochemical conversion (gasification)**

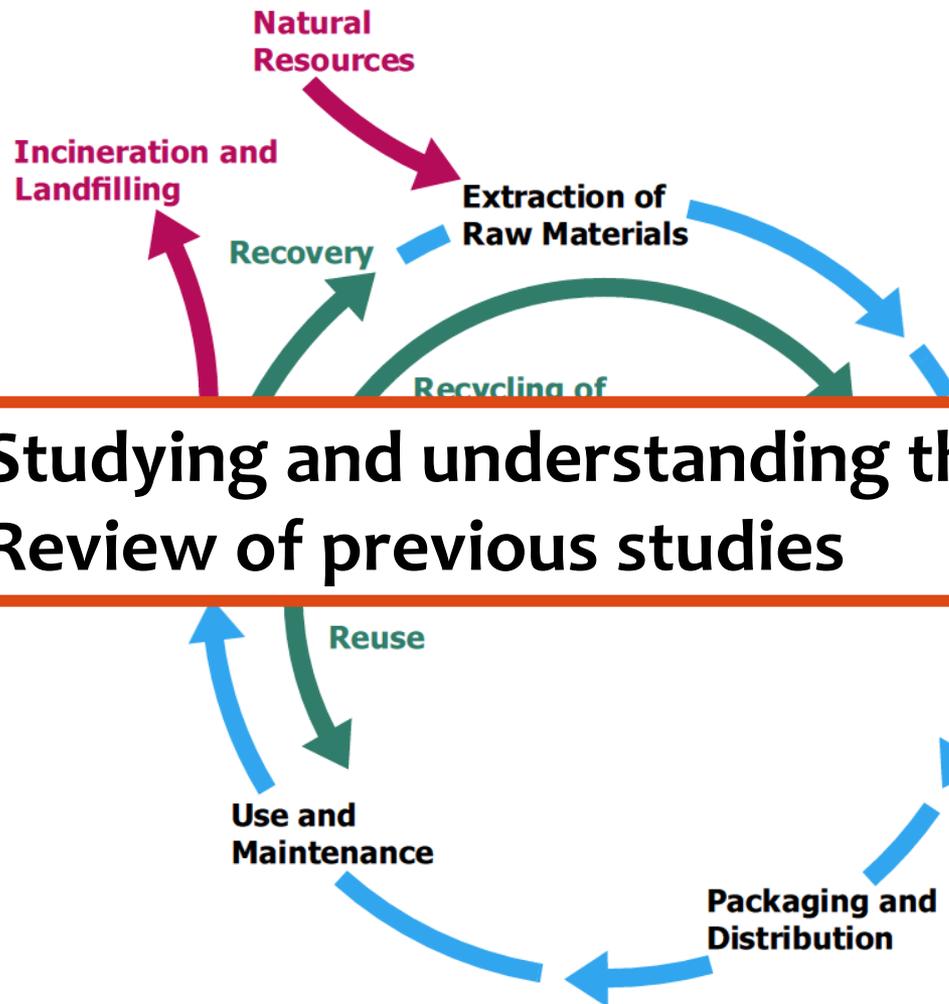
→ Tools : **Life Cycle Assessment (LCA)** methodology

The LCA methodology



<http://www.unep.fr/scp/lifecycle/>

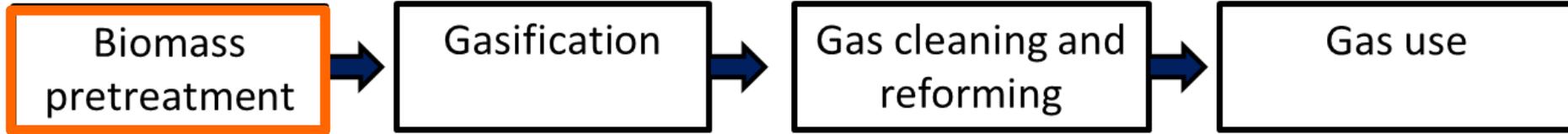
The LCA methodology



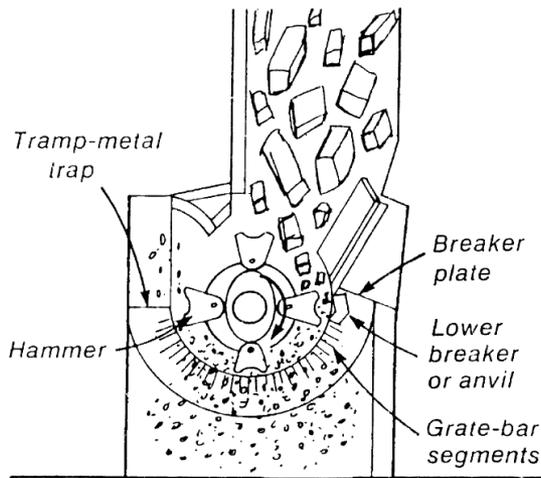
- Studying and understanding the processes
- Review of previous studies

<http://www.unep.fr/scp/lifecycle/>

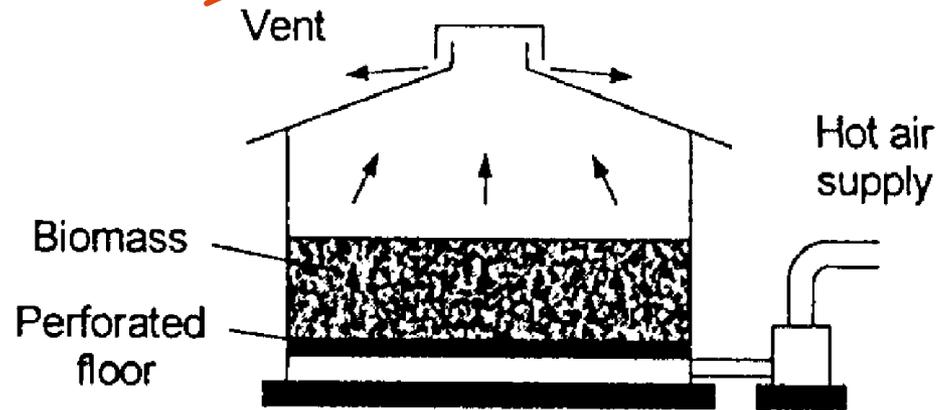
The Processes



→ Size reduction and drying



Hammermill [1]

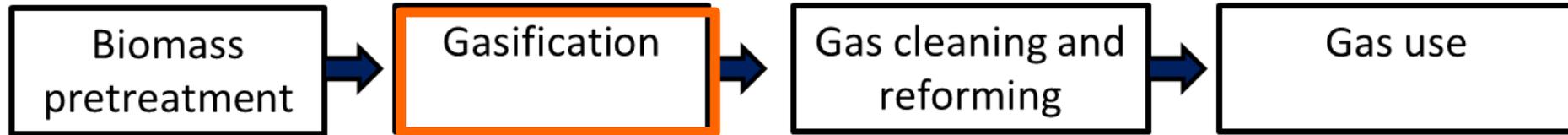


Perforated Floor bin dryer [1]

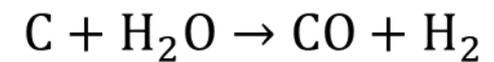
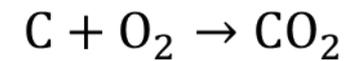
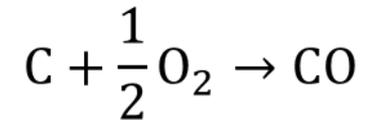
→ particle size between 20 and 80 mm

→ water content < 20%

The Processes

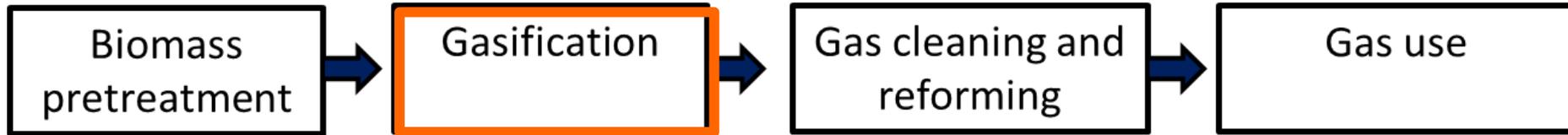


Biomass + Oxidizing agent → Syngaz



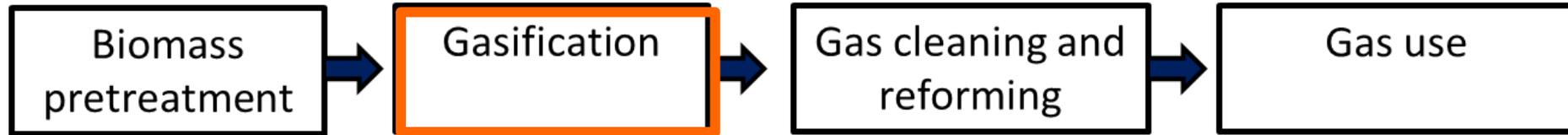
Component	% (volume)
CO	28-36
H ₂	22-32
CO ₂	21-30
CH ₄	8-11

The Processes



Biomass + **Oxidizing agent** → Syngaz

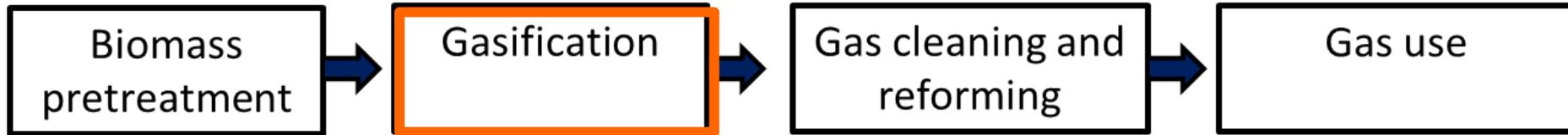
The Processes



Biomass + **Oxidizing agent** → Syngaz

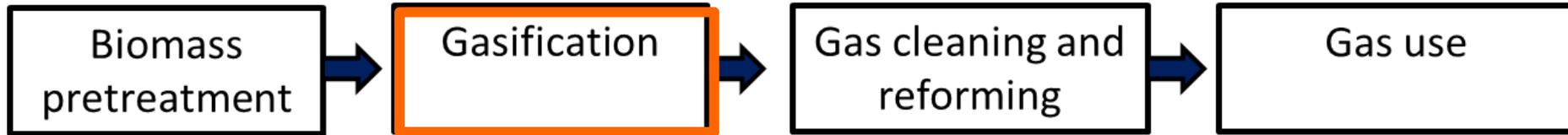
- Air
- Oxygen (gas with higher LHV)
- Steam (gas with more H₂)

The Processes



Biomass + Oxidizing agent → Syngaz

The Processes



Biomass + Oxidizing agent → Syngaz

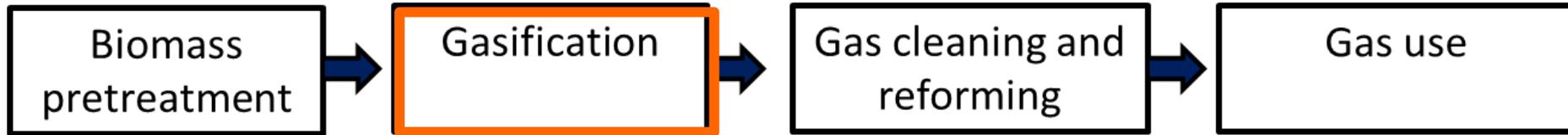
1. T: 600 – 1000 °C

→ Heat supply:

- Allothermal or autothermal

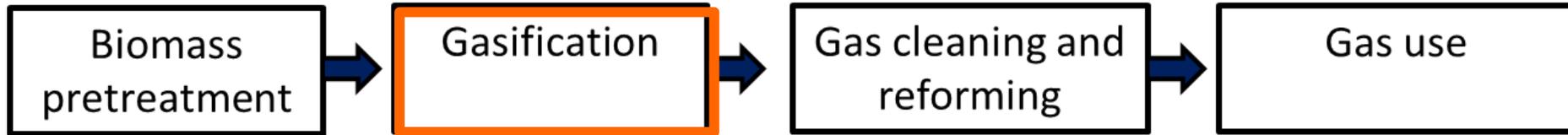
2. Oxidizing agent flow rate

The Processes



Biomass + Oxidizing agent → Syngaz

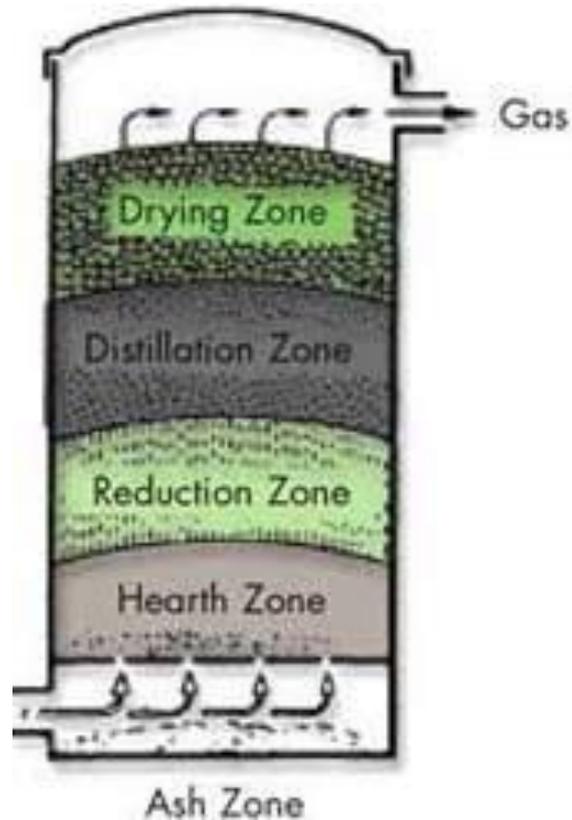
The Processes



Biomass + Oxidizing agent → Syngaz

Reactor type

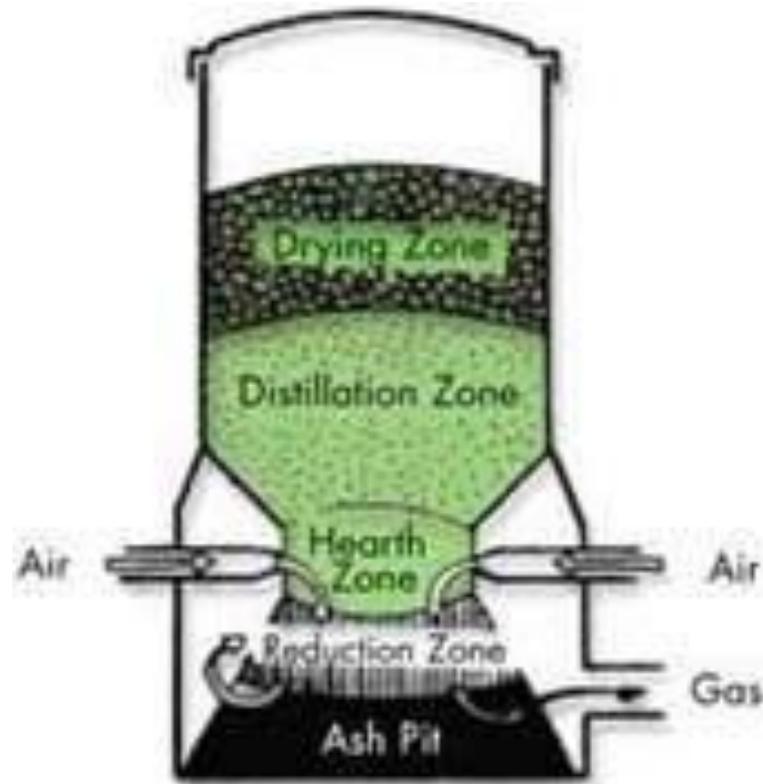
The Processes



Reactor type : Fixed-bed updraft

<http://www.greenstone.org/greenstone3/nzdl%3Bjsessionid=07001AC50F490ADE7B6F119FBC17633F?a=d&c=cdl&d=HAS110boeb9f4e955c5d5918ob.10.1.np&sib=1&p.s=ClassifierBrowse&p.sa=&p.a=b>

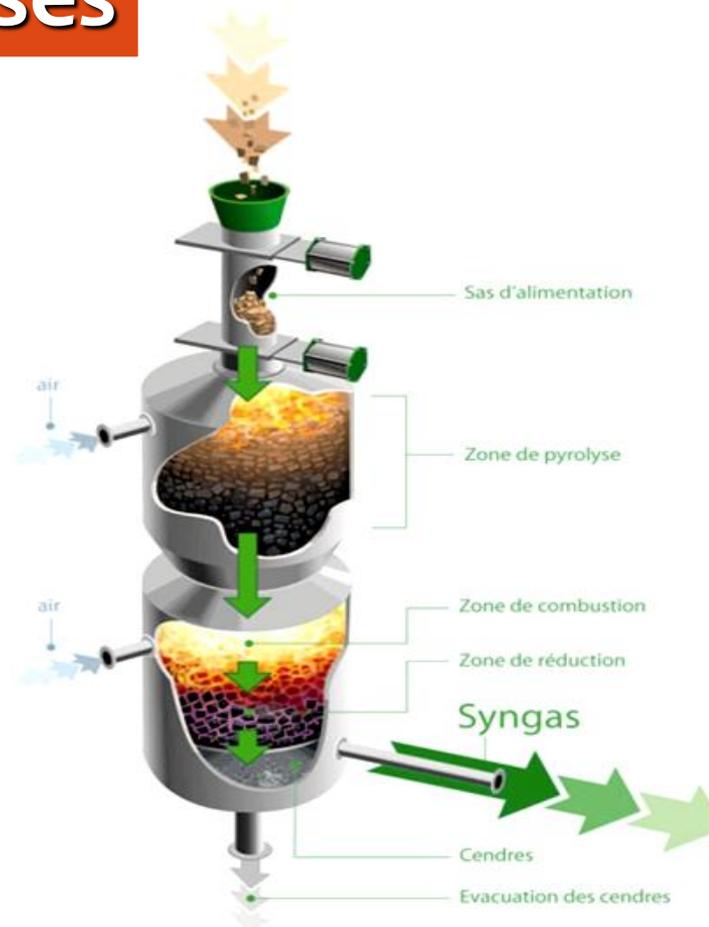
The Processes



Reactor type: Fixed-bed downdraft

<http://www.greenstone.org/greenstone3/nzdl%3Bjsessionid=07001AC50F490ADE7B6F119FBC17633F?a=d&c=cdl&d=HAS110boeb9f4e955c5d59180b.10.1.np&sib=1&p.s=ClassifierBrowse&p.sa=&p.a=b>

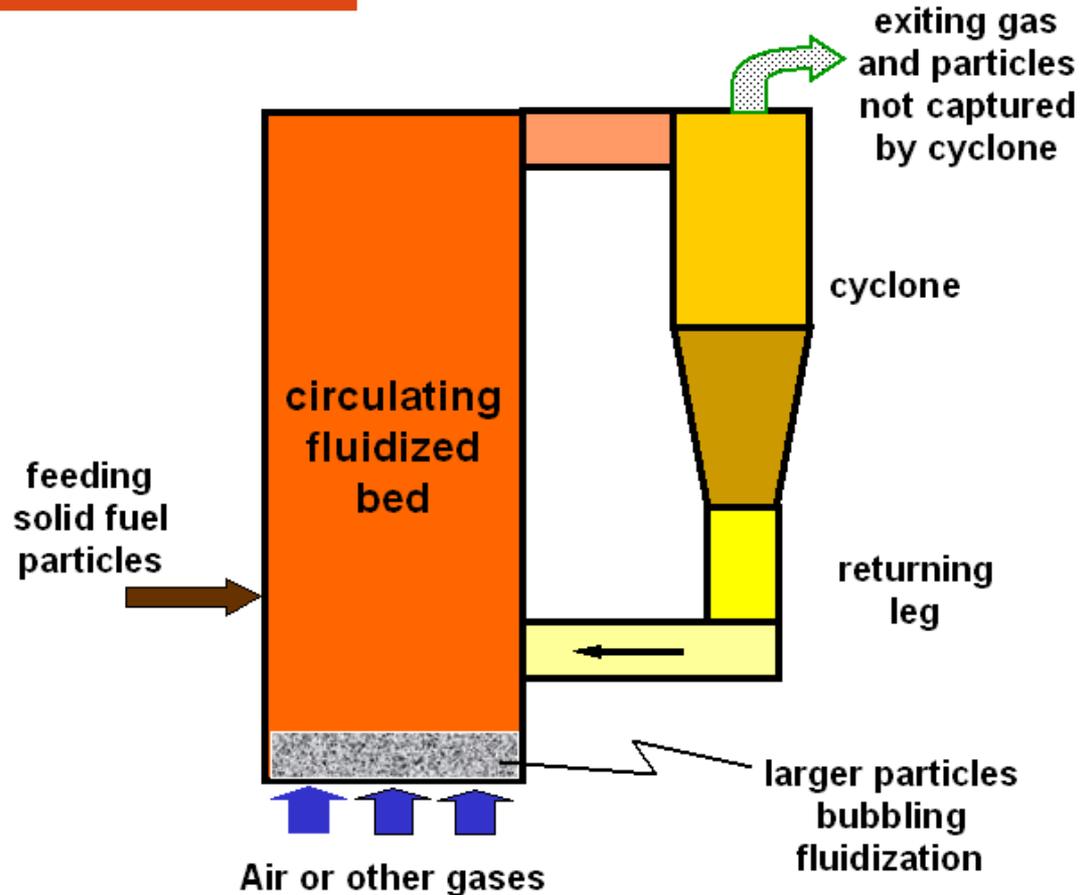
The Processes



Reactor type: Fixed-bed multistage (Xylowatt)

<http://www.xylowatt.com/La-gazefication-XYLOWATT/g-xylowatt-technologie-notarr-production-de-gaz-propre.html>

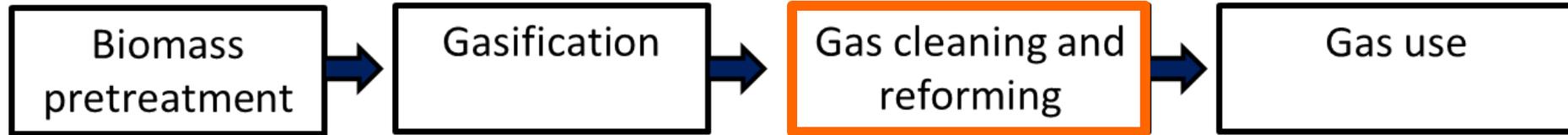
The Processes



Reactor type: Fluidized-bed circulating

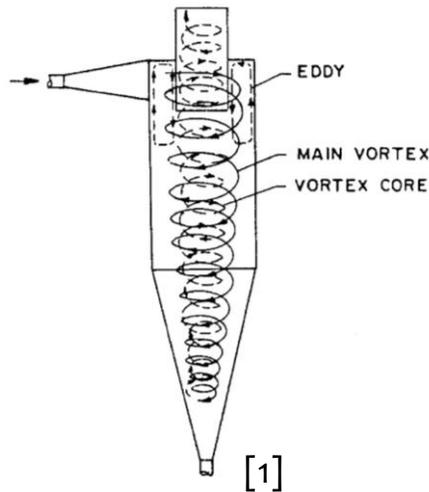
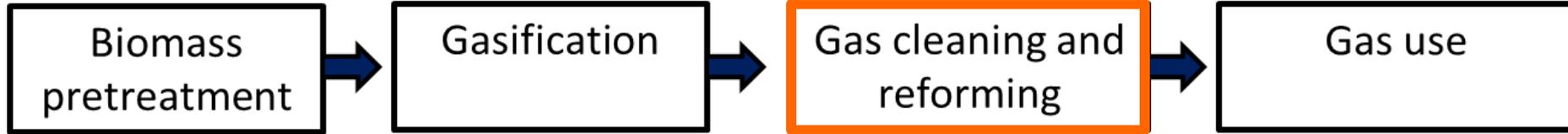
<http://www.csfmb.com/services>

The Processes



- Nitrogen and sulfur compounds
- Particulate removal
- Alkali removal
- Tar elimination
- Reformage

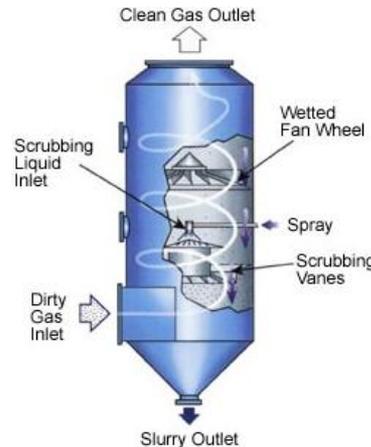
The Processes



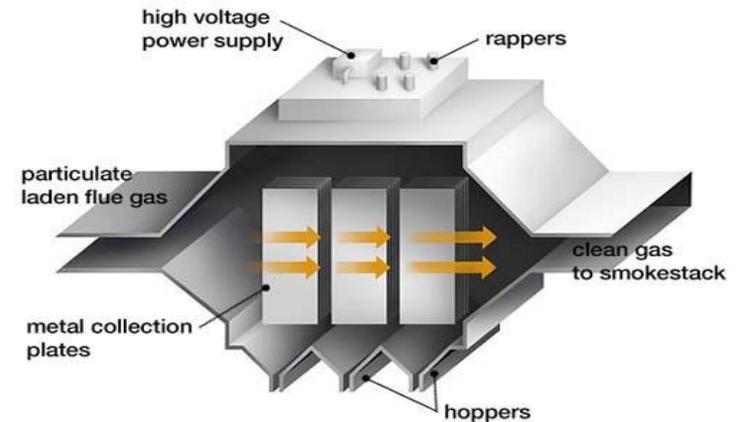
- **Particule** : biomass (ash and char)+ bed → plugging

→ Cyclone (larger particules)

+ wet scrubbers, barrier filters or electrostatic precipitators

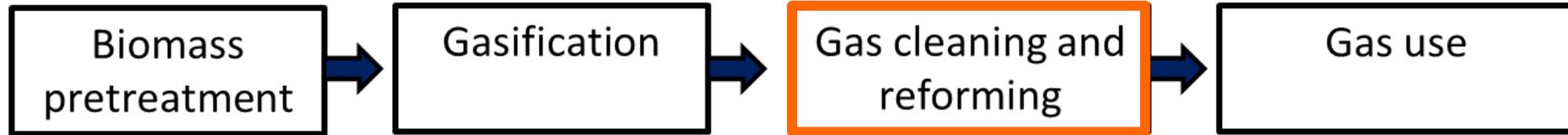


<http://www.ustudy.in/node/3145>



<http://holbert.faculty.asu.edu/wise/electrostaticprecip.html>

The Processes



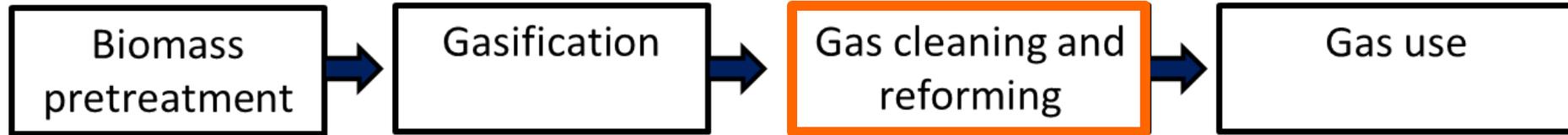
- **Alkali removal :**

Cooling and passing barriers filters



http://www.filtrationgroup.com/index.php/main.page/Pre-Filter_Barrier_Filters

The Processes



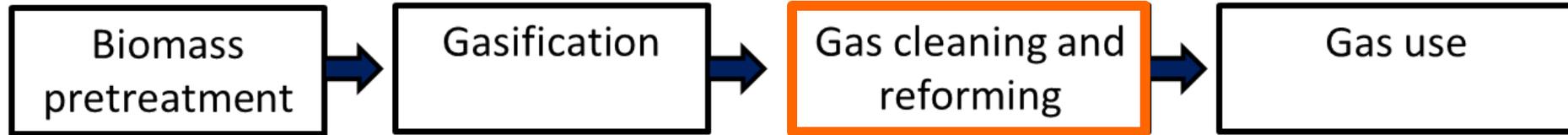
- Tar elimination

→ Primary technologies: in gasifier

→ Secondary technologies

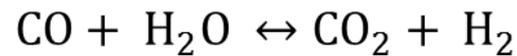
- wet : water and venturi scrubbing → condense tar compounds
- hot: cracking tar → high temperature

The Processes

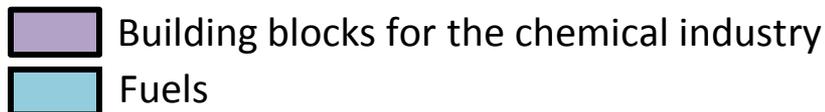
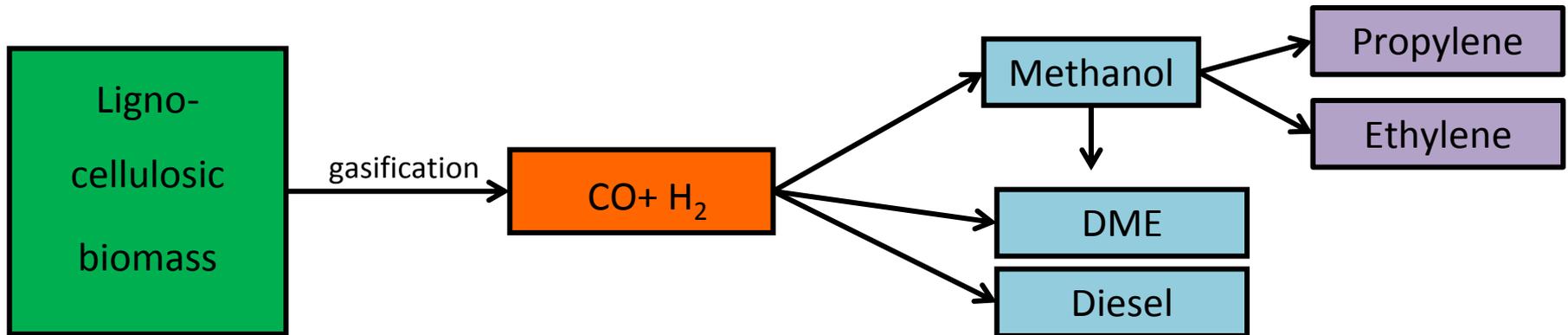
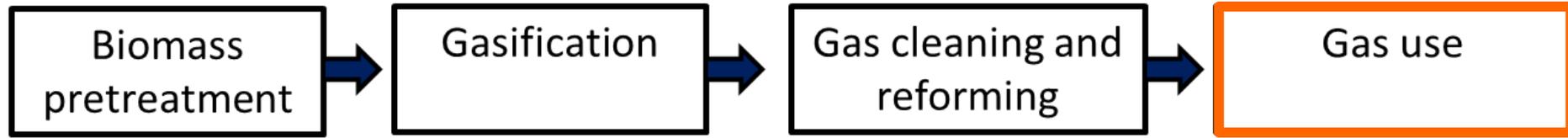


- Reformage

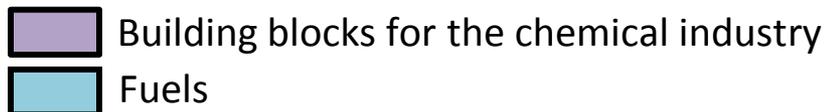
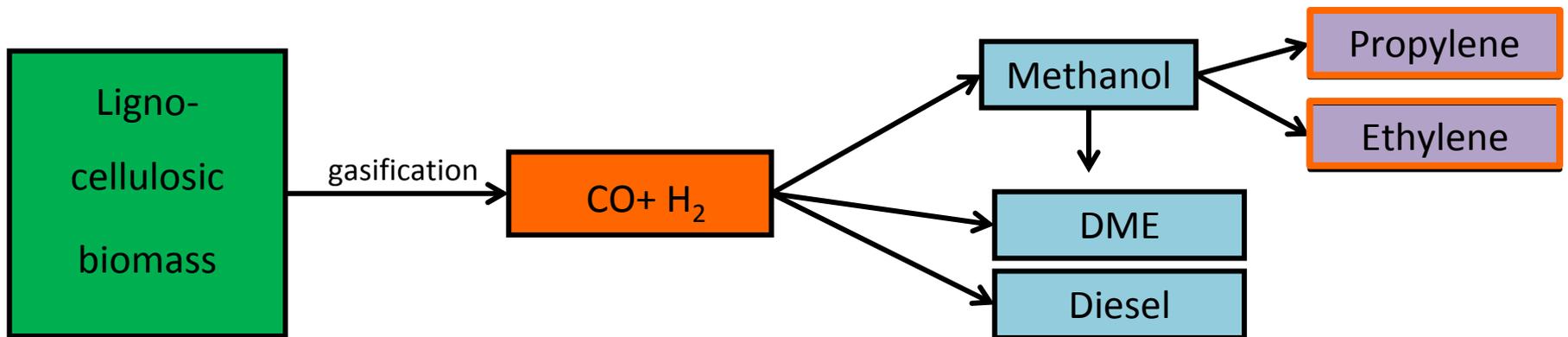
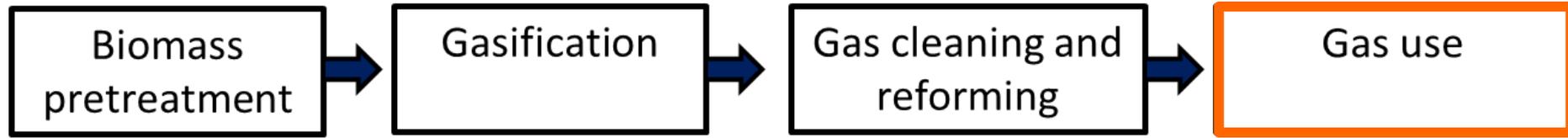
Water-shift reaction : adjuce the H₂/CO rapport



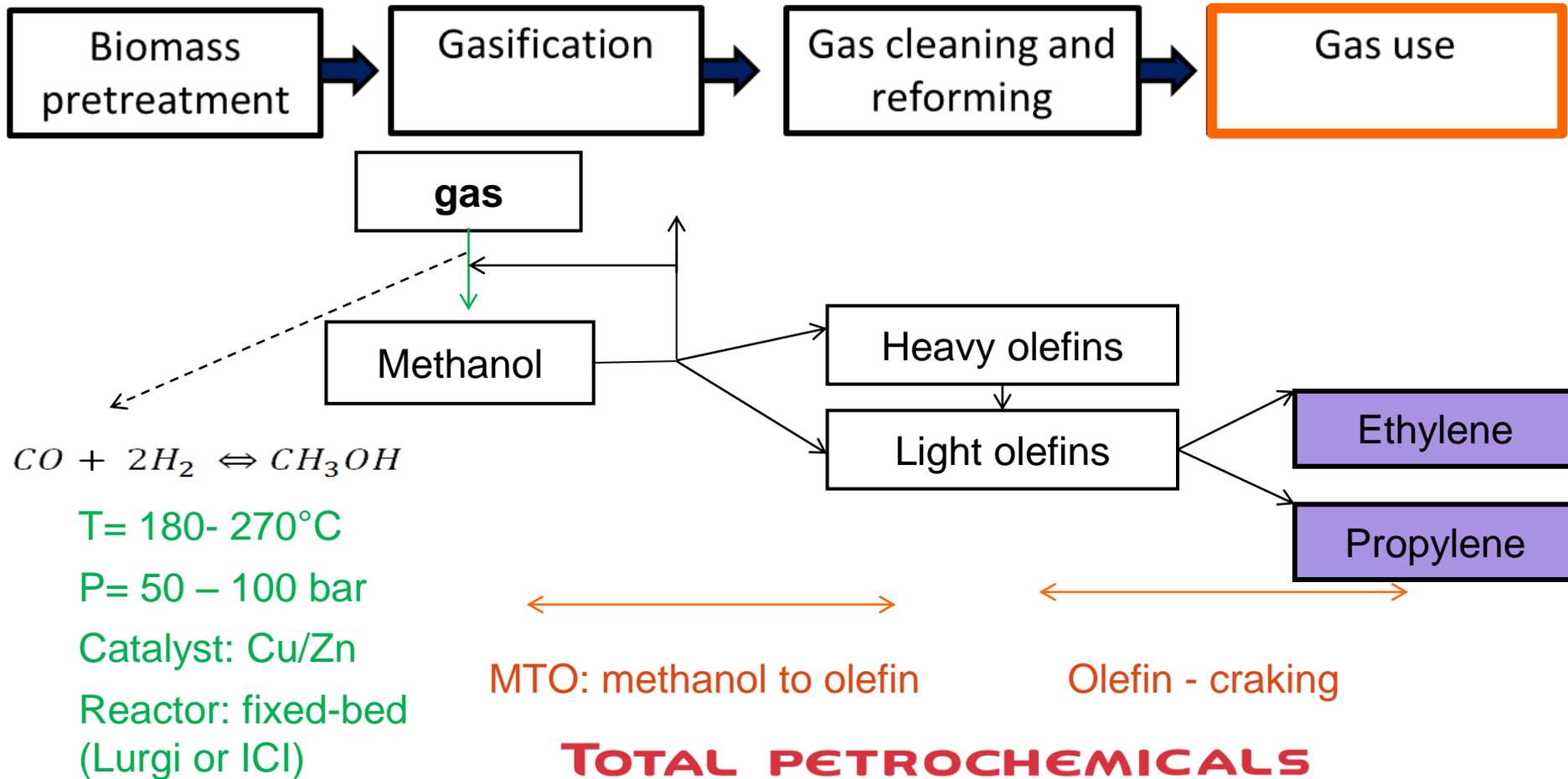
The Processes



The Processes

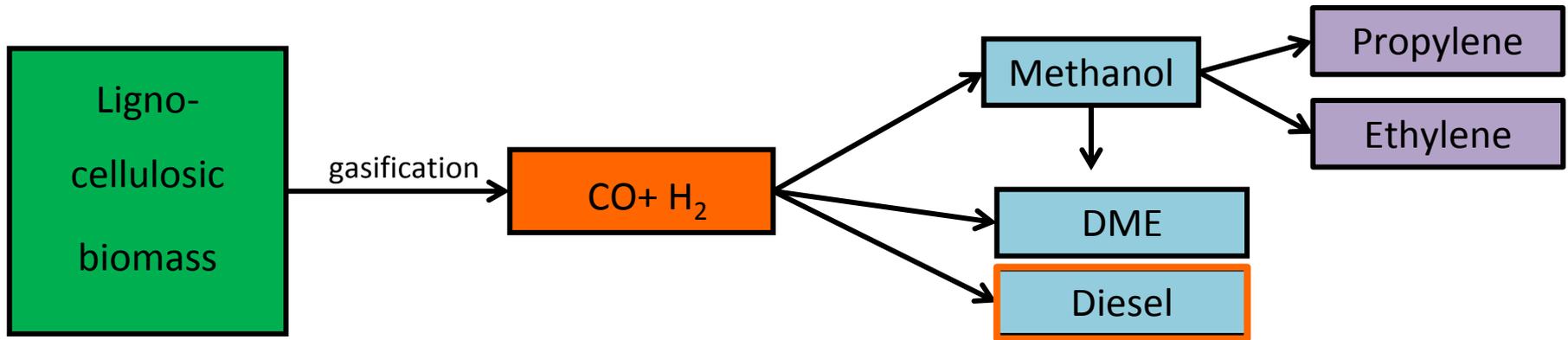
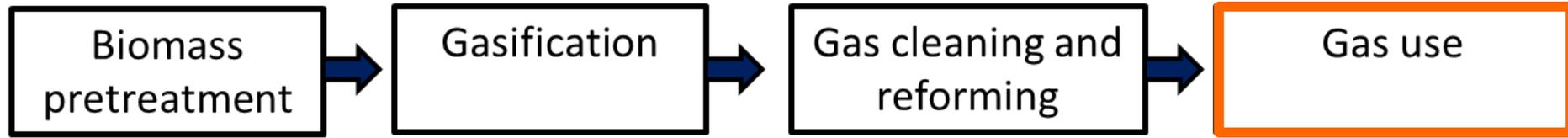


The Processes



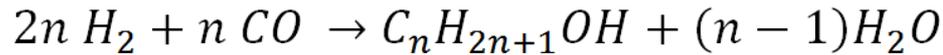
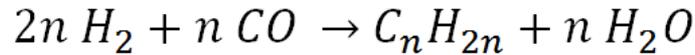
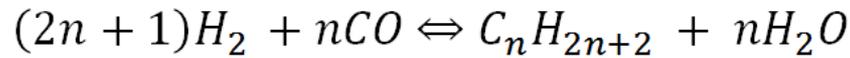
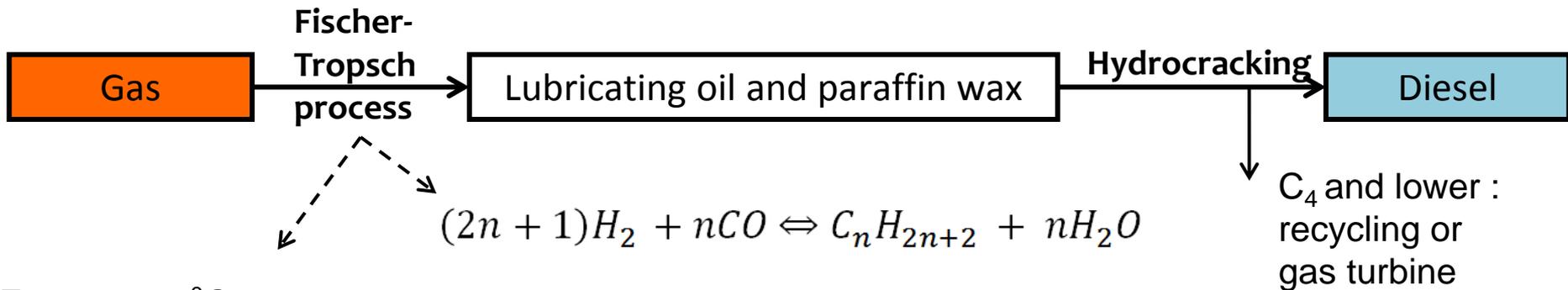
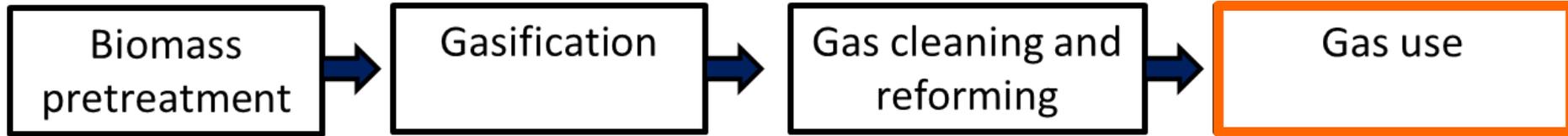
http://www.totalpetrochemicals.com/SiteCollectionDocuments/Press_releases_news/2010/cp_mto-20100630-en.pdf

The Processes



-  Building blocks for the chemical industry
-  Fuels

The Processes

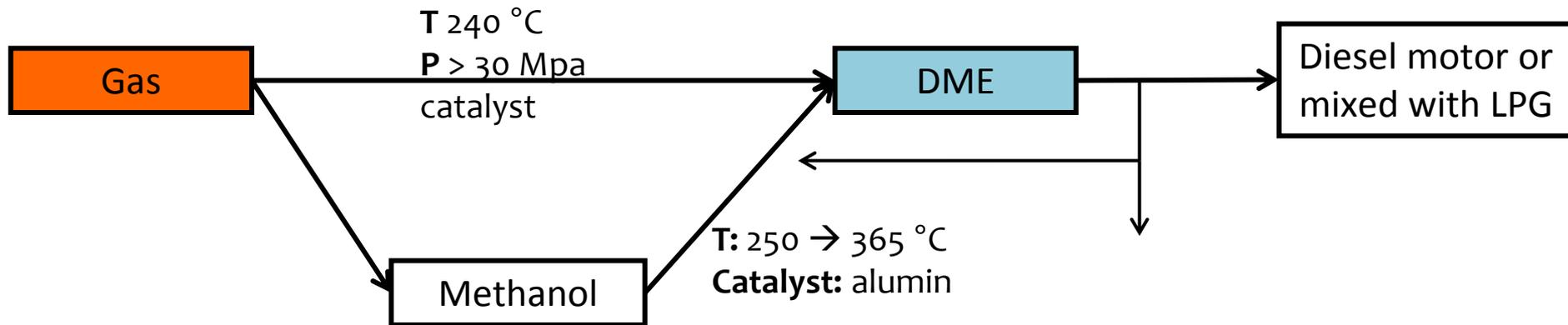
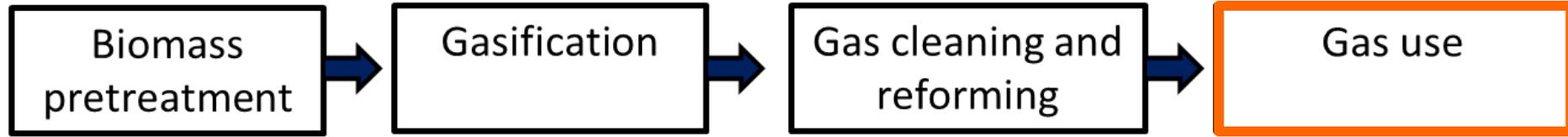


T: 200 – 250 °C

Catalyst: Co or Fe

Reactor: fluidized or multi-tubular fixed bed

The Processes



Previous studies

→ Many studies on the technological aspects of lignocellulosic biomass gasification, but **few on the environmental aspects** (LCA)

→ **Results:**

Lignocellulosic biomass $><$ fossil fuels

- **Better:** Global Warming Potential

Emissions

- **Worst:** Energy Consumption

Cost

→ But this studies are generally **not completed**

Previous studies

→ This studies present generally **some lacks**:

No study about propylene and ethylene

No study relative to the Belgian situation

But also:

- Fuel type
- Impact of Land Use Change (direct or indirect)
- No Well-to-wheel
- Impact categories
- Economic aspects
- Comparison with fossil fuel or biofuel
- Sensitivity analysis
- Incertitude analysis

Conclusions and perspectives

- Promising processes for substituting fossil fuels.
BUT their environmental impact remains uncertain
→ **LCA methodology**
- LCA adapted to include land use change effect.
Practical example: miscanthus culture in Belgium
- Economic viability assessed
- **LCA** → decision helping tool

Thank you for your attention

University of Liège

LABORATORY of CHEMICAL ENGINEERING

Processes and Sustainable development

saicha.gerbinet@ulg.ac.be

Bibliography

1. Cummer, K.R. and R.C. Brown, *Ancillary equipment for biomass gasification*. Biomass and bioenergy, 2002. **23**.
2. Liu, G., et al., Making Fischer-Tropsch Fuels and Electricity from Coal and Biomass: Performance and Cost Analysis. *Energy & Fuels*, 2011. **25**.
3. van Vliet, O.P.R., A.P.C. Faaij, and W.C. Turkenburg, Fischer-Tropsch diesel production in a well-to-wheel perspective: A carbon, energy flow and cost analysis. *Energy Conversion and Management*, 2009. **50(4)**: p. 855-876.
4. Gill, S.S., et al., Combustion characteristics and emissions of Fischer-Tropsch diesel fuels in IC engines. *Progress in Energy and Combustion Science*, 2011. **37(4)**: p. 503-523.
5. Kalnes, T.N., et al., A Technoeconomic and Environmental Life Cycle Comparison of Green Diesel to Biodiesel and Syndiesel. *Environmental Progress & Sustainable Energy*, 2009. **28(1)**: p. 111-120.
6. Sunde, K., A. Brekke, and B. Solberg, Environmental Impacts and Costs of Hydrotreated Vegetable Oils, Transesterified Lipids and Woody BTL-A Review. *Energies*, 2011. **4(6)**: p. 845-877.
7. Grillo Reno, M.L., et al., A LCA (life cycle assessment) of the methanol production from sugarcane bagasse. *Energy*, 2011. **36(6)**: p. 3716-3726.
8. Kumabe, K., et al., Environmental and economic analysis of methanol production process via biomass gasification. *Fuel*, 2008. **87(7)**: p. 1422-1427.
9. Komiyama, H., et al., Assessment of energy systems by using biomass plantation. *Fuel*, 2001. **80(5)**: p. 707-715.

Bibliography

10. Wu, M., Y. Wu, and M. Wang, Energy and emission benefits of alternative transportation liquid fuels derived from switchgrass: A fuel life cycle assessment. *Biotechnology Progress*, 2006. **22**(4): p. 1012-1024.
11. 10. Fleming, J.S., S. Habibi, and H.L. MacLean, Investigating the sustainability of lignocellulose-derived fuels for light-duty vehicles. *Transportation Research Part D: Transport and Environment*, 2006. **11**(2): p. 146-159.
12. Reinhardt, G.A. and E.v. Falkenstein, Environmental assessment of biofuels for transport and the aspects of land use Competition. *Biomass & Bioenergy*, 2011. **35**.
13. ISO, ISO 14040 : Management environnemental - Analyse du cycle de vie - Principes et cadre, ISO, Editor. 2006.
14. ISO, ISO 14044 : Management environnemental - Analyse du cycle de vie - Exigences et lignes directrices, ISO, Editor. 2006.
15. Kumar, A., D.D. Jones, and M.A. Hanna, Thermochemical Biomass Gasification: A Review of the Current Status of Thechnology. *Energies*, 2009. **2**
16. Warnecke, R., Gasification of biomass: comparison of fixed bed and fluidized bed gasifier. *Biomass & Bioenergy*, 2000. **18**.