Life Cycle and R4-I Activities

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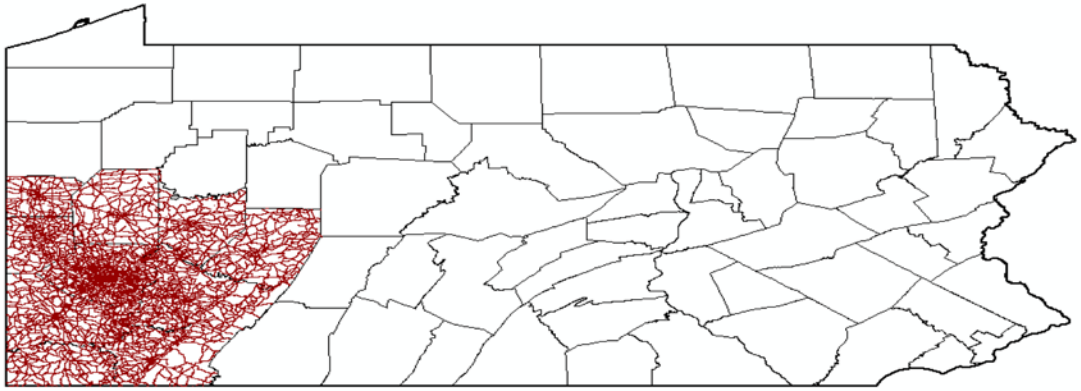
GHG Emission Reduction?

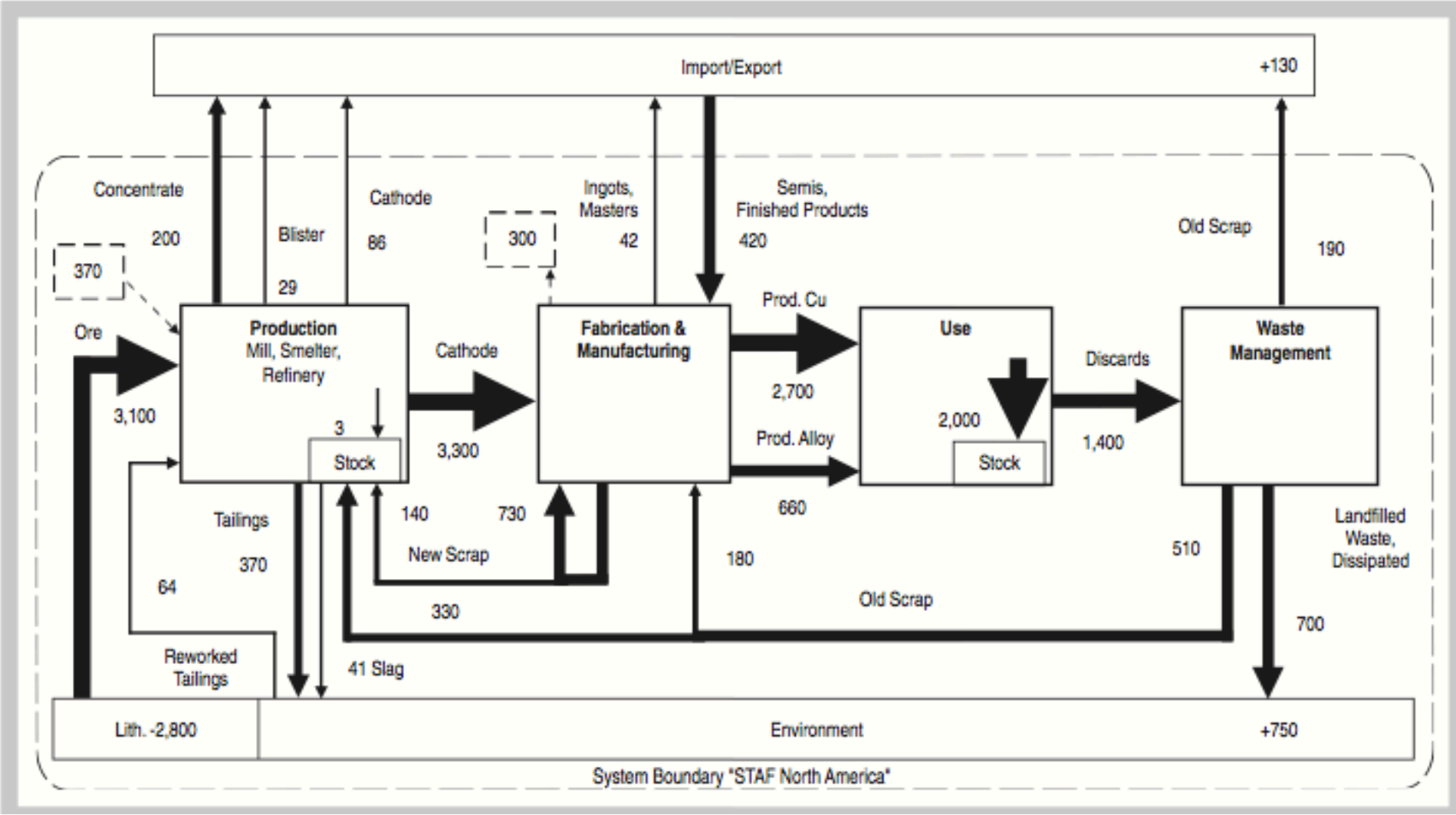
-200%

Recycled Materials Resource Center

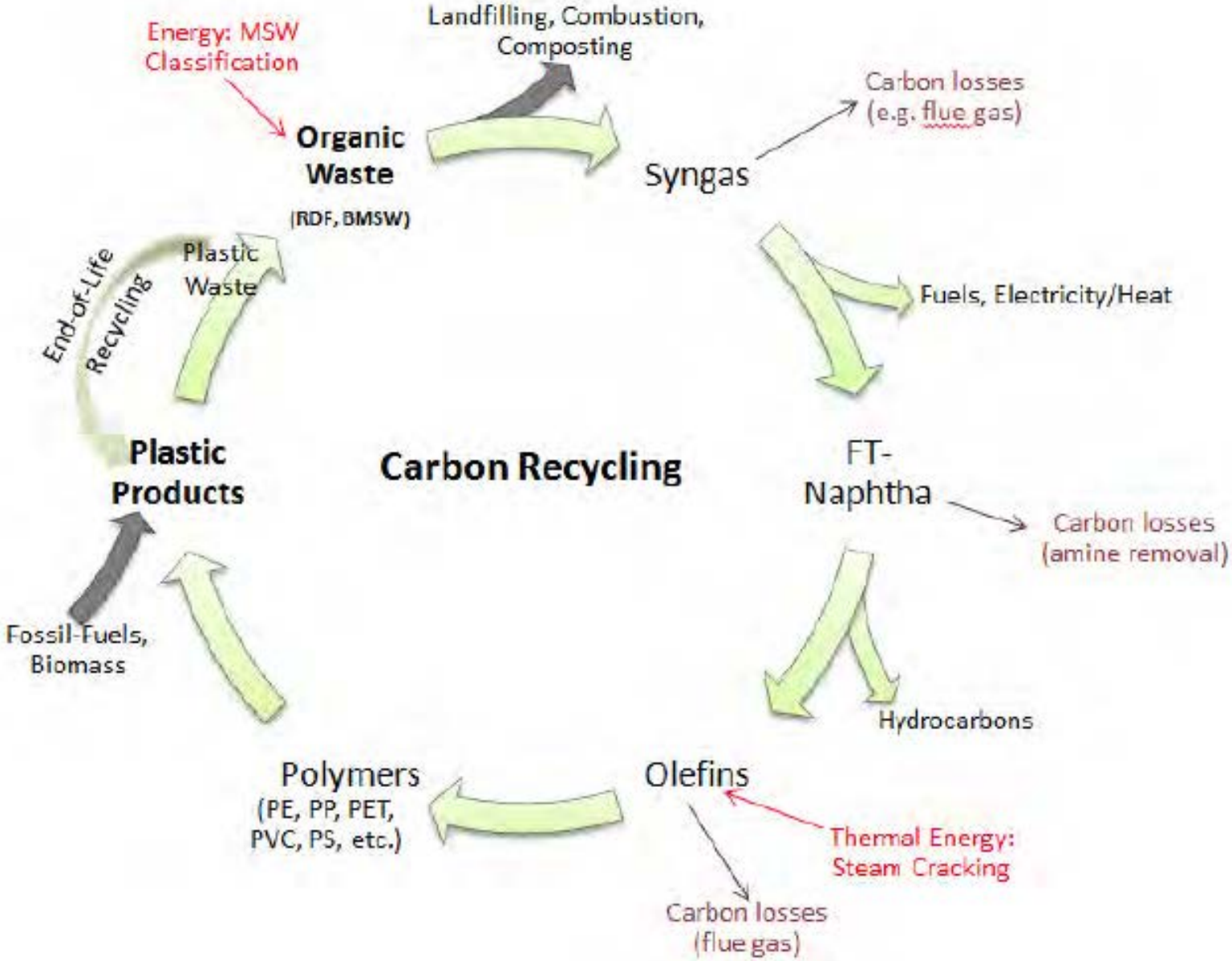


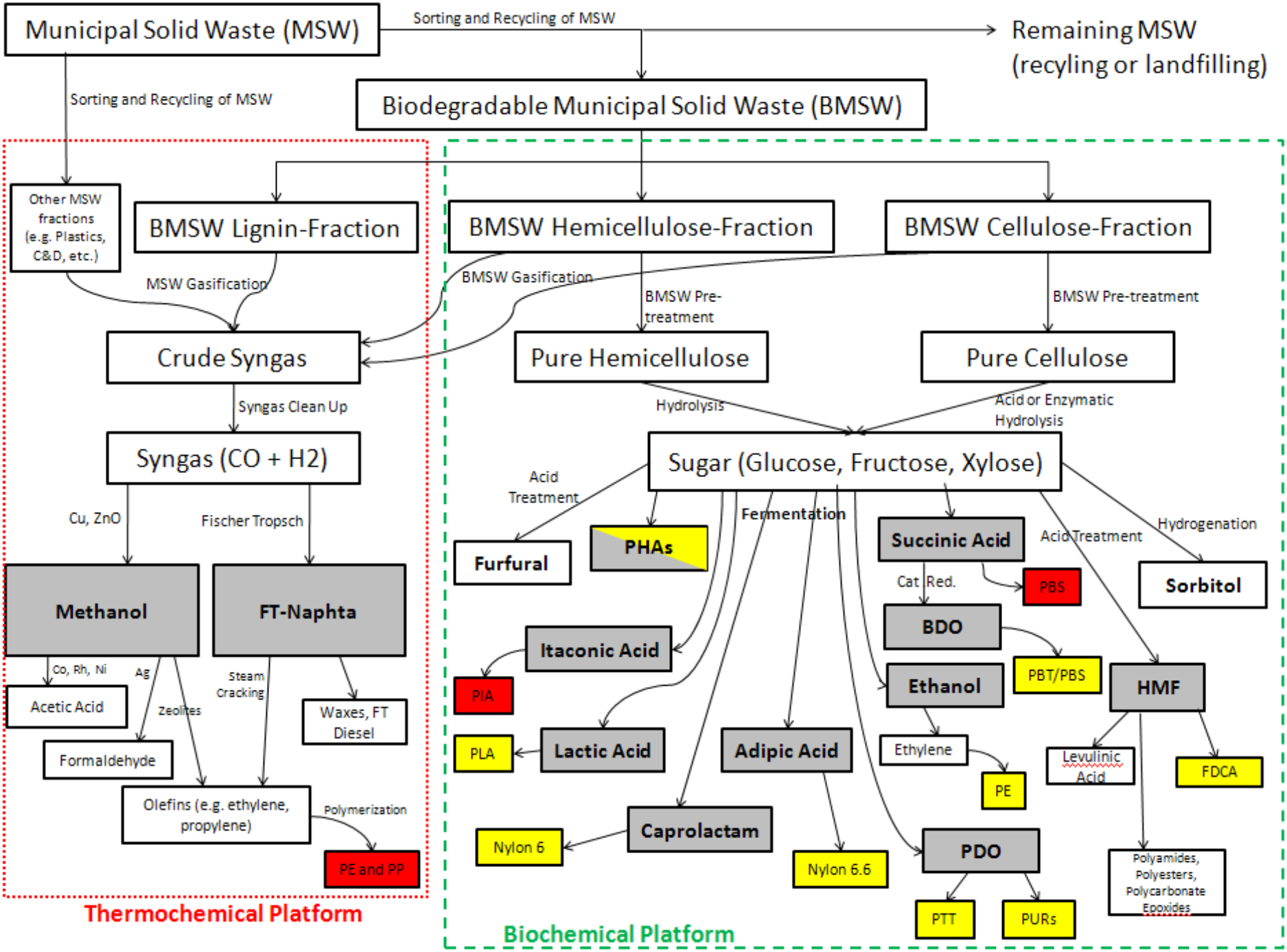
Materials Flow Analysis

North American Copper MFA



Lifset, R. J., et al. "Where has all the copper gone: The stocks and flows project, part 1." *JOM* 54.10 (2002): 21-26.


Energy: MSW Classification
Landfilling, Combustion, Composting
Organic Waste
(RDF, BMSW)
Syngas
Carbon losses (e.g. flue gas)
Fuels, Electricity/Heat
FT-Naphtha
Carbon losses (amine removal)
Hydrocarbons
Olefins
Thermal Energy: Steam Cracking
Carbon losses (flue gas)
Polymers
(PE, PP, PET, PVC, PS, etc.)
Plastic Products
Fossil-Fuels, Biomass
Plastic Waste
End-of-Life Recycling
Carbon Recycling


Municipal Solid Waste (MSW)
Sorting and Recycling of MSW
Remaining MSW (recyling or landfilling)
Sorting and Recycling of MSW
Biodegradable Municipal Solid Waste (BMSW)
Other MSW fractions (e.g. Plastics, C&D, etc.)
BMSW Lignin-Fraction
BMSW Hemicellulose-Fraction
BMSW Cellulose-Fraction
MSW Gasification
BMSW Gasification
BMSW Pre-treatment
BMSW Pre-treatment
Crude Syngas
Pure Hemicellulose
Pure Cellulose
Syngas Clean Up
Hydrolysis
Acid or Enzymatic Hydrolysis
Syngas (CO + H2)
Sugar (Glucose, Fructose, Xylose)
Acid Treatment
Fermentation
Cu, ZnO
Fischer Tropsch
Furfural
PHAs
Succinic Acid
Acid Treatment
Hydrogenation
Sorbitol
Cat. Red.
PBS
Methanol
FT-Naphta
BDO
Itaconic Acid
PBT/PBS
Co, Rh, Ni
Ag
Steam Cracking
Ethanol
HMF
PIA
Acetic Acid
Zeolites
Waxes, FT Diesel
PLA
Lactic Acid
Adipic Acid
Ethylene
Levulinic Acid
FDCA
Formaldehyde
PE
Olefins (e.g. ethylene, propylene)
Polymerization
Caprolactam
Nylon 6
PDO
Nylon 6.6
Polyamides, Polyesters, Polycarbonate Epoxides
PE and PP
PTT
PURs
Thermochemical Platform
Biochemical Platform

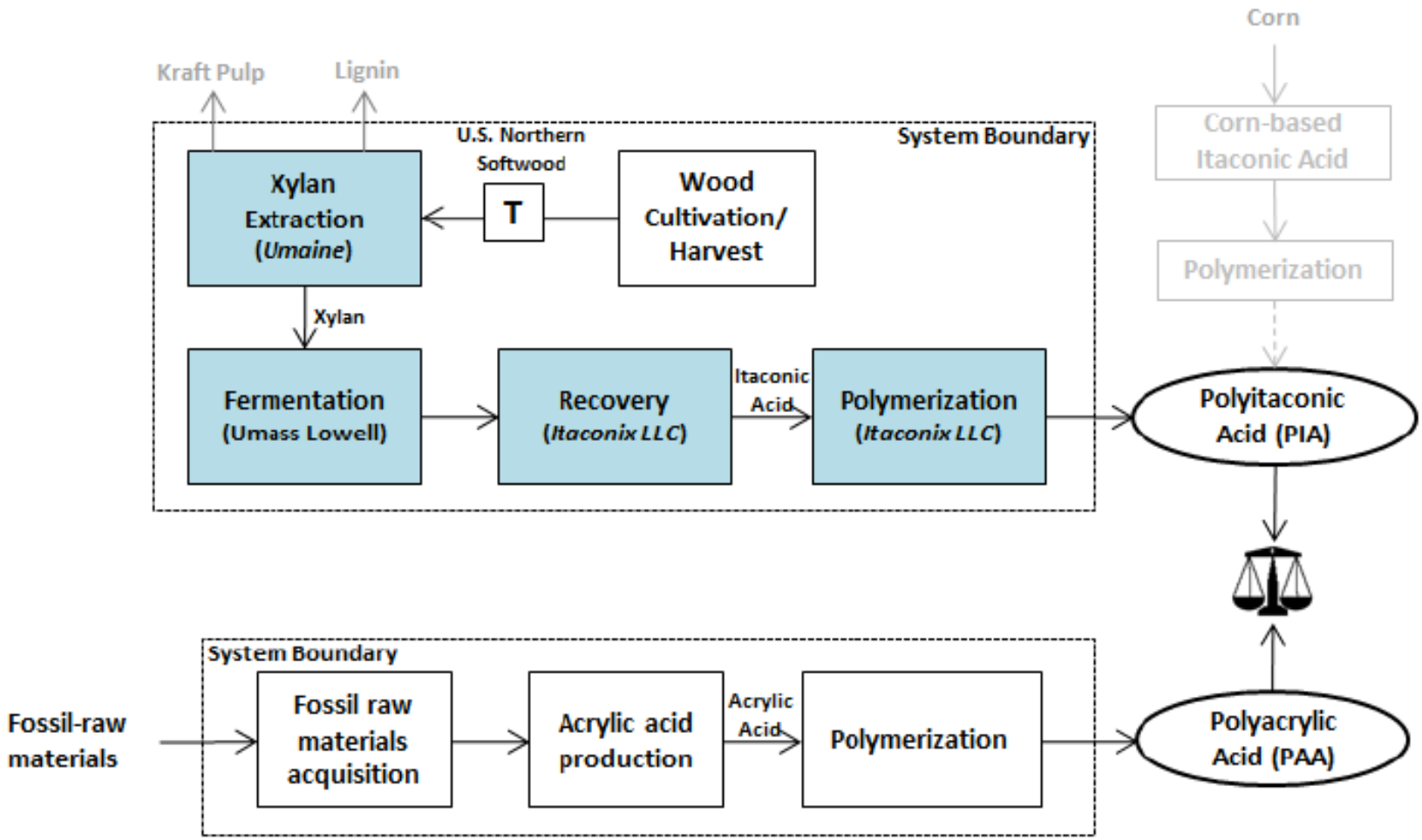


Figure 2 Initial flowchart of the systems studied.

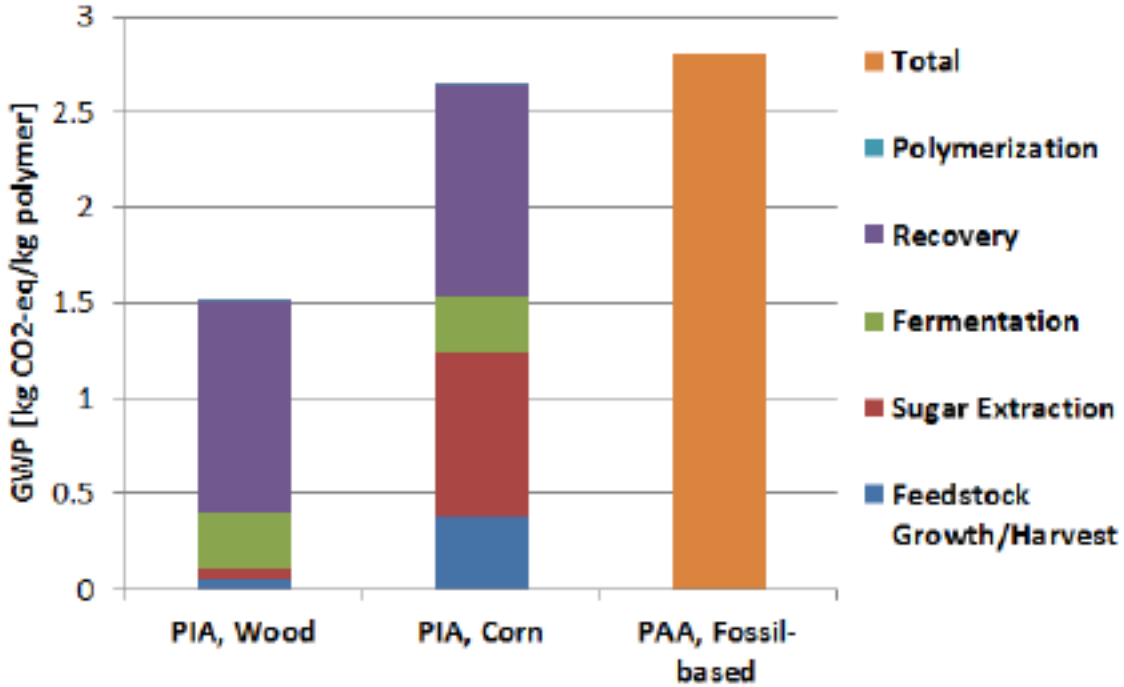


Figure 7 Global warming potential (GWP) of the PIA polymers (1 kg at the factory gate) from wood and corn feedstock compared to the production of an equivalent amount of PAA from fossil-feedstock.

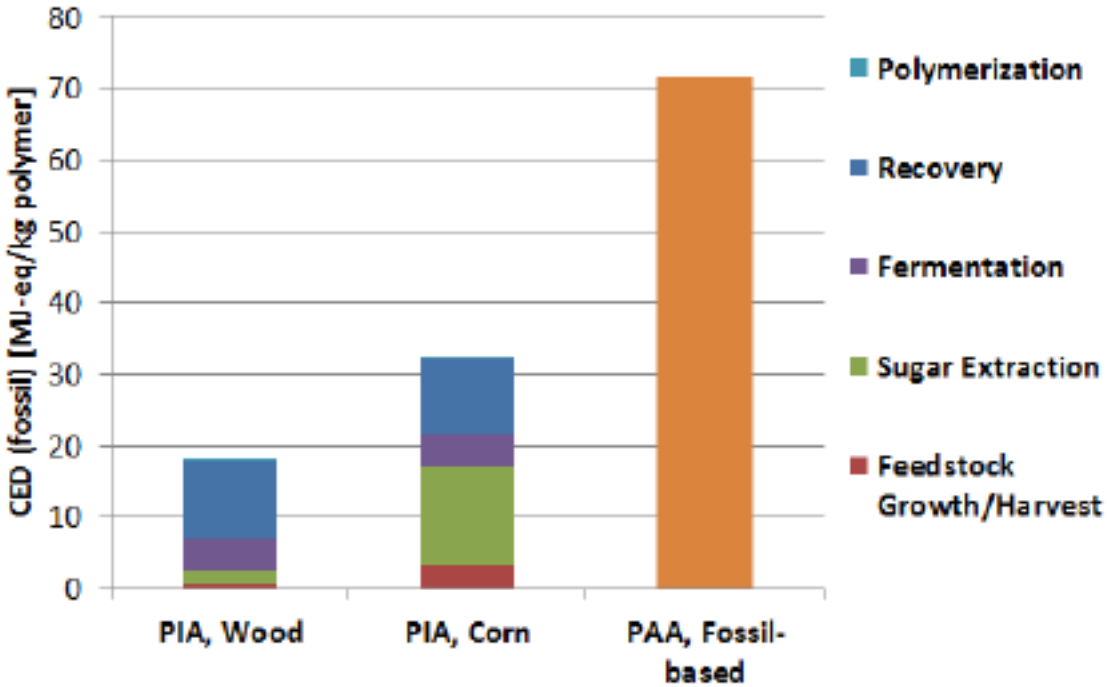


Figure 9 Cumulative energy demand (CED – fossil/nuclear) for the three polymer production routes.

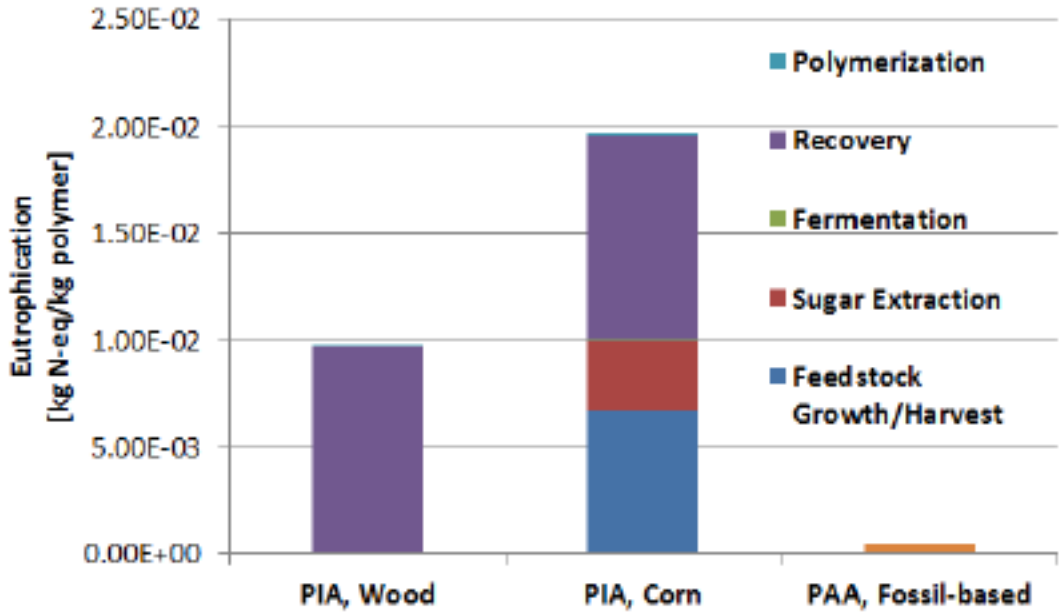


Figure 13 Eutrophication impacts associated with the production of 1 kg polymer at the factory gate.

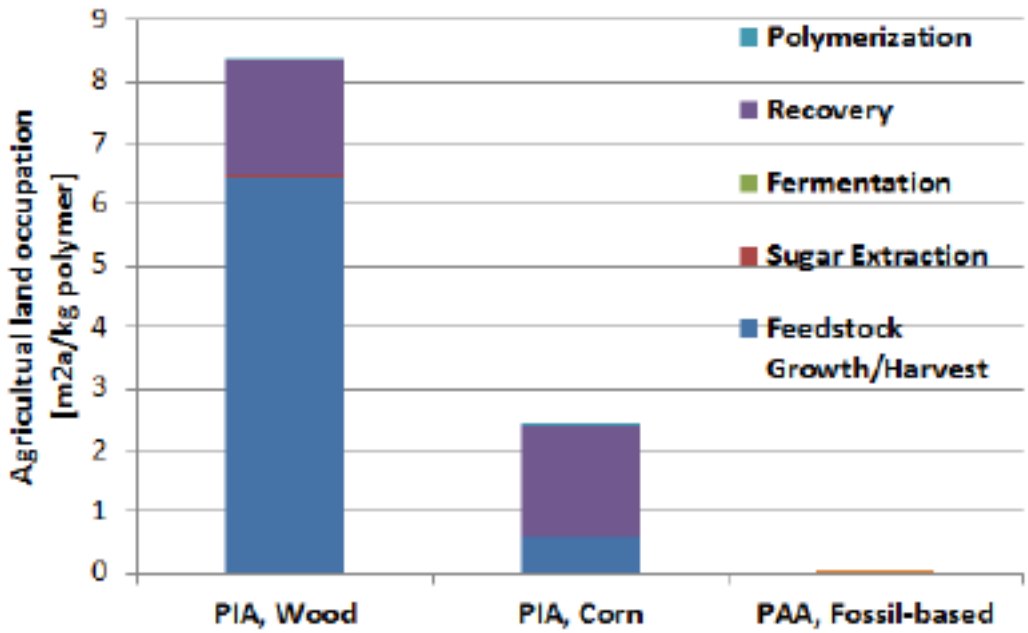
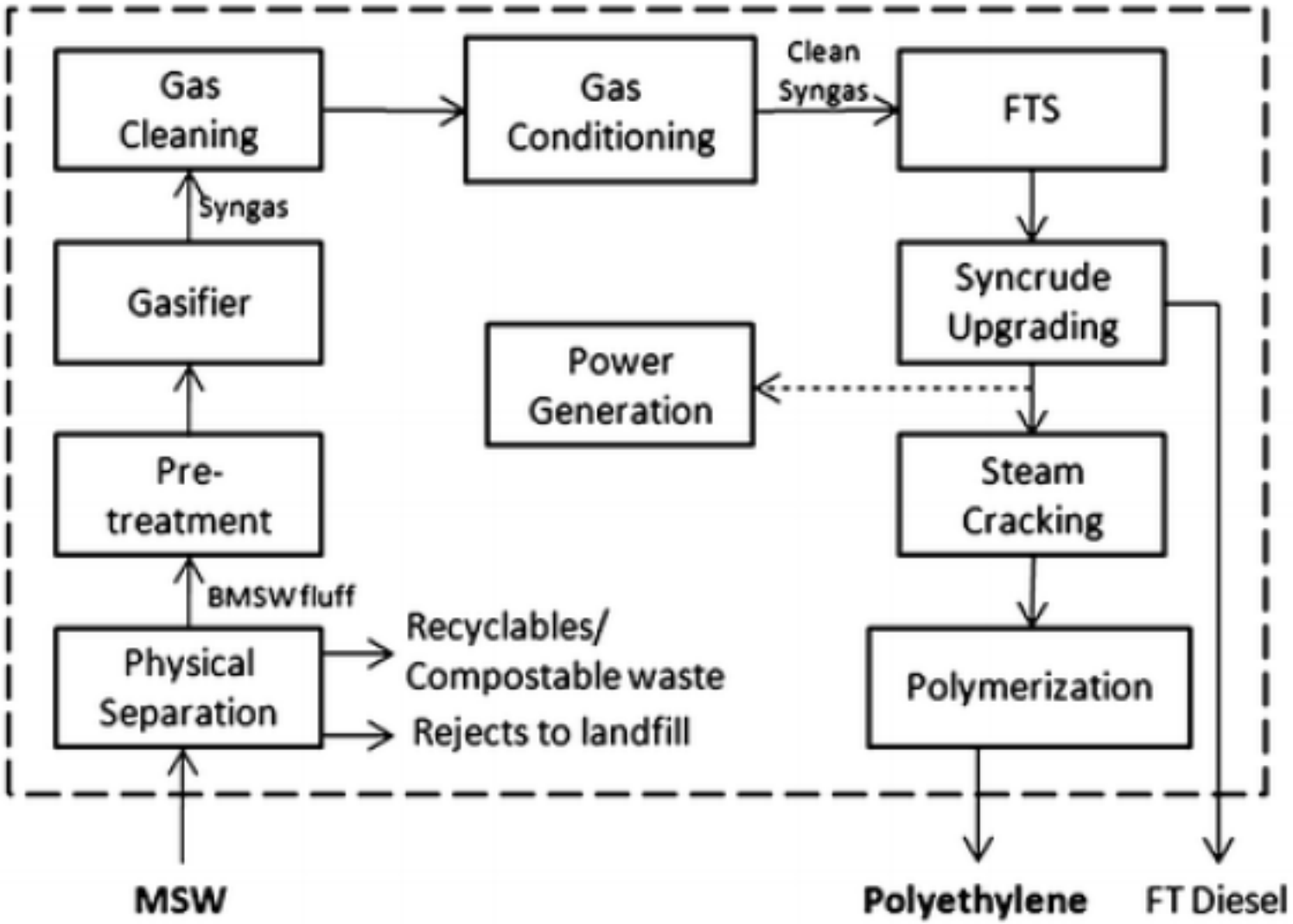
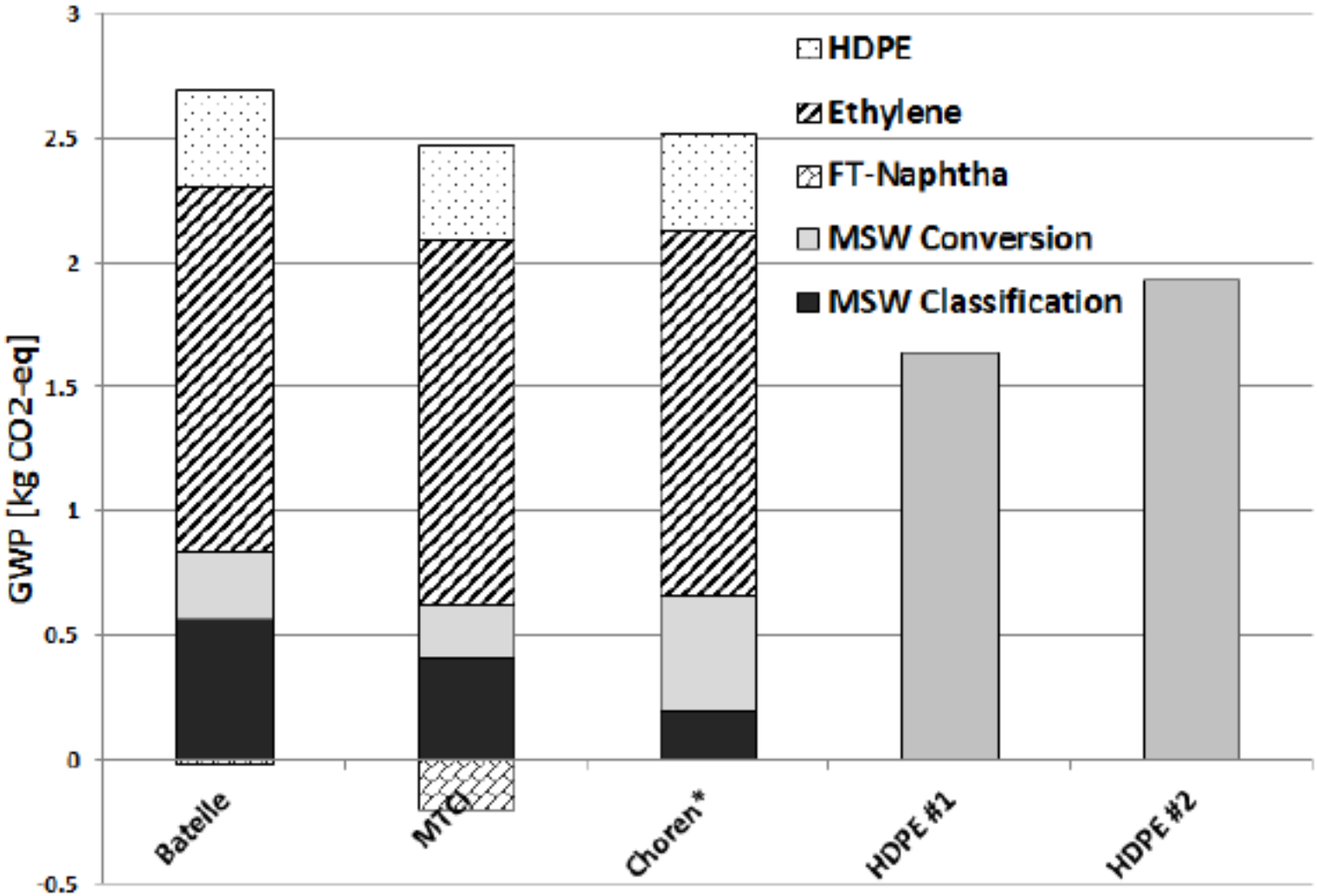
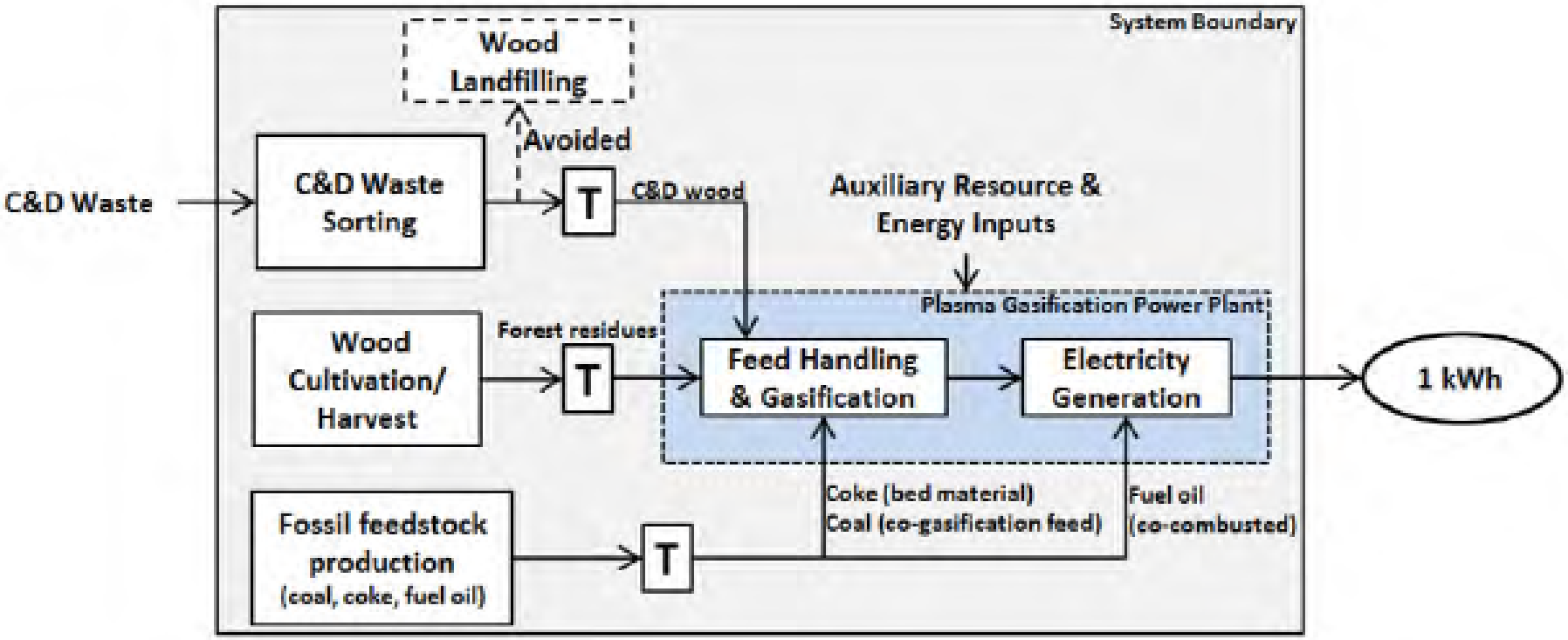


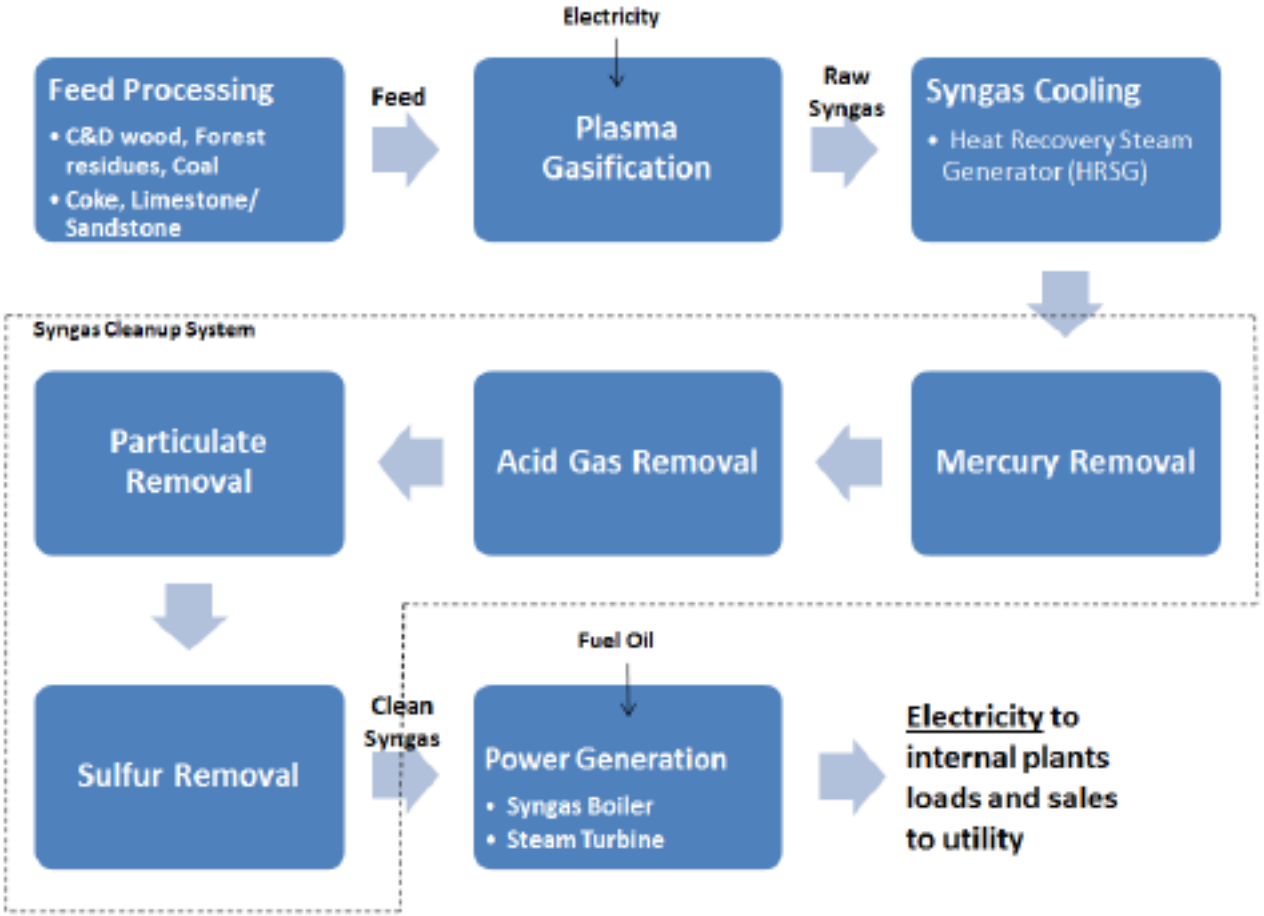
Figure 17 Agricultural land occupation associated with the production of 1 kg of polymer at the factory gate.

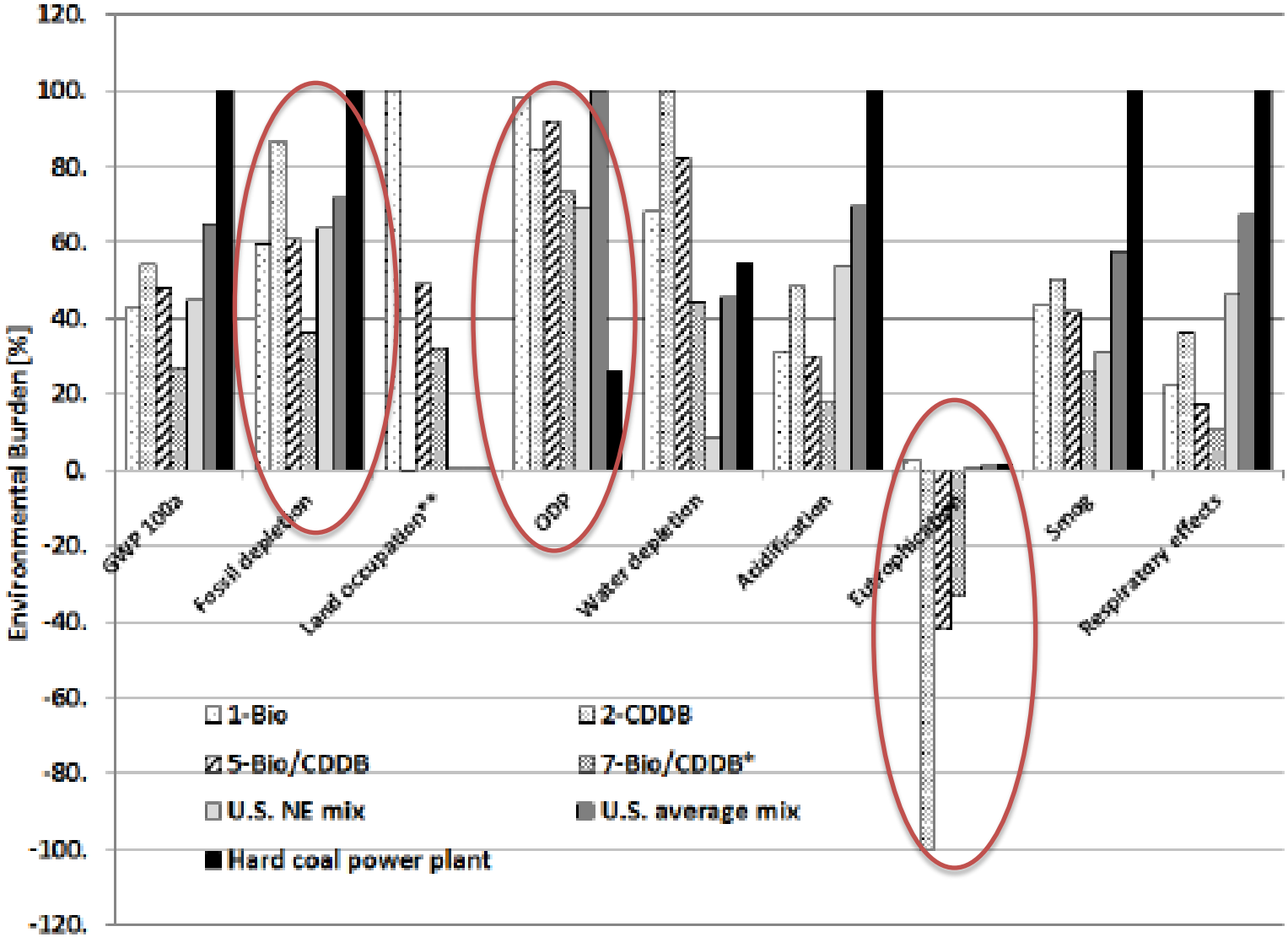

Gas Cleaning
Gas Conditioning
Clean Syngas
FTS
Syngas
Gasifier
Syncrude Upgrading
Power Generation
Pre-treatment
Steam Cracking
BMSW fluff
Physical Separation
Recyclables/ Compostable waste
Rejects to landfill
Polymerization
MSW
Polyethylene
FT Diesel


HDPE
Ethylene
FT-Naphtha
MSW Conversion
MSW Classification
GWP [kg CO2-eq]
3
2.5
2
1.5
1
0.5
0
-0.5
Batelle
MTG
Choren*
HDPE #1
HDPE #2

Electricity production from waste wood sources




Electricity
Feed Processing
• C&D wood, Forest residues, Coal
• Coke, Limestone/ Sandstone
Feed
Plasma Gasification
Raw Syngas
Syngas Cooling
• Heat Recovery Steam Generator (HRSG)
Syngas Cleanup System
Particulate Removal
Acid Gas Removal
Mercury Removal
Sulfur Removal
Clean Syngas
Fuel Oil
Power Generation
• Syngas Boiler
• Steam Turbine
Electricity to internal plants loads and sales to utility


120.
100.
80.
60.
40.
20.
0.
-20.
-40.
-60.
-80.
-100.
-120.
Environmental Burden [%]
GWP 100a
Fossil depletion
Land occupation**
ODP
Water depletion
Acidification
Eutrophication
Smog
Respiratory effects
1-Bio
2-CDDB
5-Bio/CDDB
7-Bio/CDDB*
U.S. NE mix
U.S. average mix
Hard coal power plant

Conclusions

- Systems analysis an important research tool
- Often are tradeoffs, or burdens in other parts of the life cycle
- R4-I should lead to quantifiable, tangible benefits – resource consumption, environmental burdens, etc.

Thank you!

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