Life Cycle Analysis of Polyols from Soy Oil or Castor Oil

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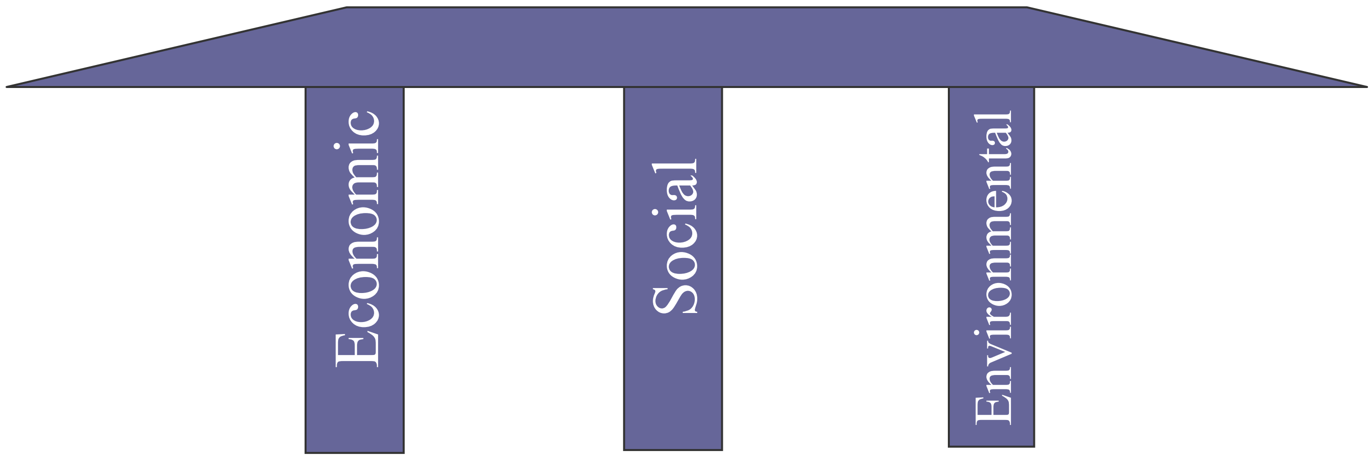
Summary

- Vegetable oils are a polymer feedstock that offers significant environmental benefit
- Magnitude of impact depends critically on assumptions about farming

The three pillars of sustainability



- Core belief: Need to be successful in all three areas to survive in the long run
- Use of sustainability metrics is one way to improve products, processes, and behaviors
- LCA is one way to quantify the environmental dimension

LCA methodology for this study

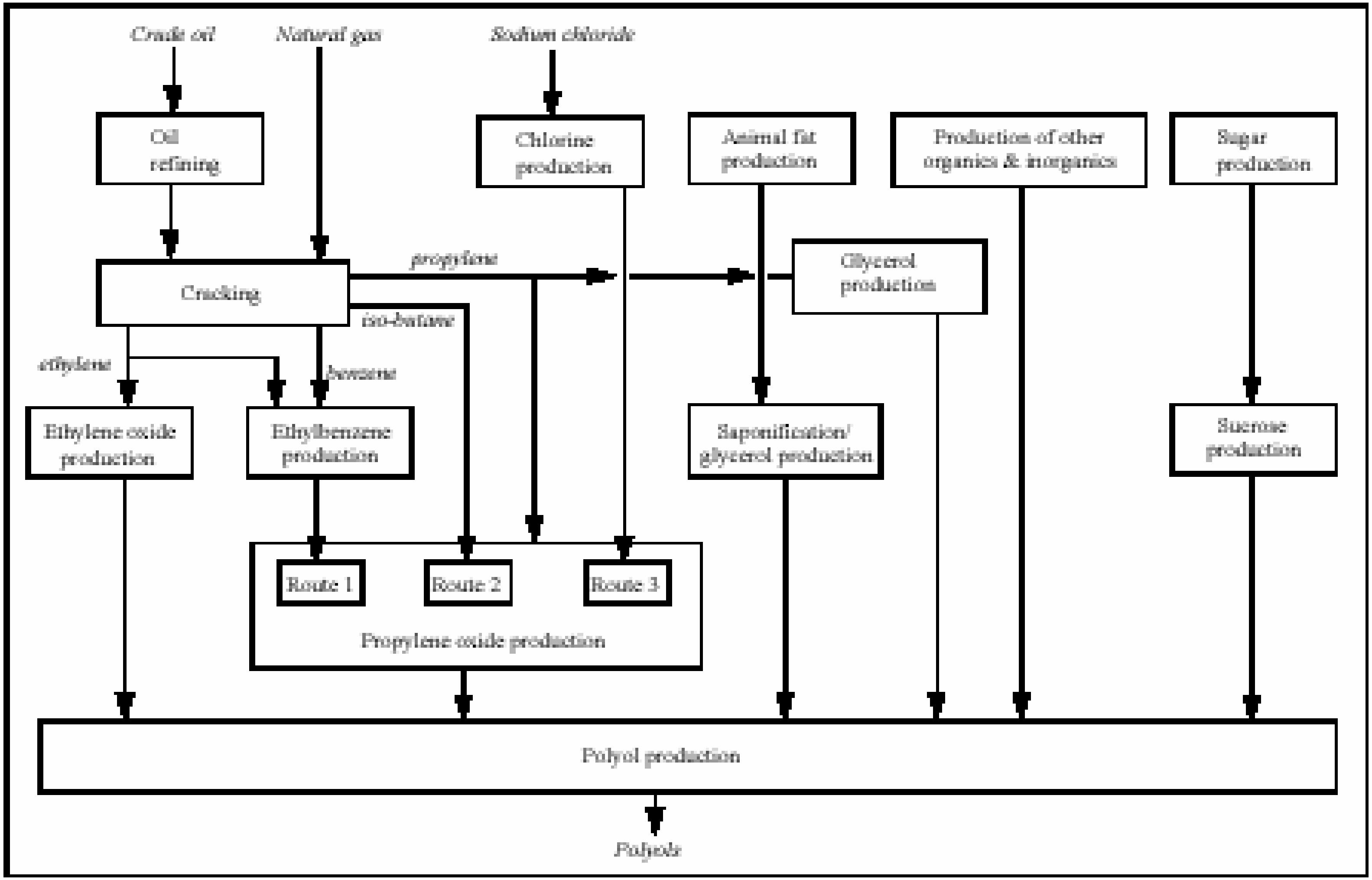
- "Cradle to gate" boundaries
  - Use & fate of product is same in all cases, so cancel out in a comparison
- Use "mid-point" impacts
  - "CO_2-equivalents" rather than life-years, for example
- Use "Boustead Model"
  - Most widely used LCA framework in Dow
    - Builds on substantial internal data from 90's
- Key metrics:
  - Gross energy intensity, mass intensity, fossil resource use, water use, greenhouse gases, acid gases

Polyol LCA

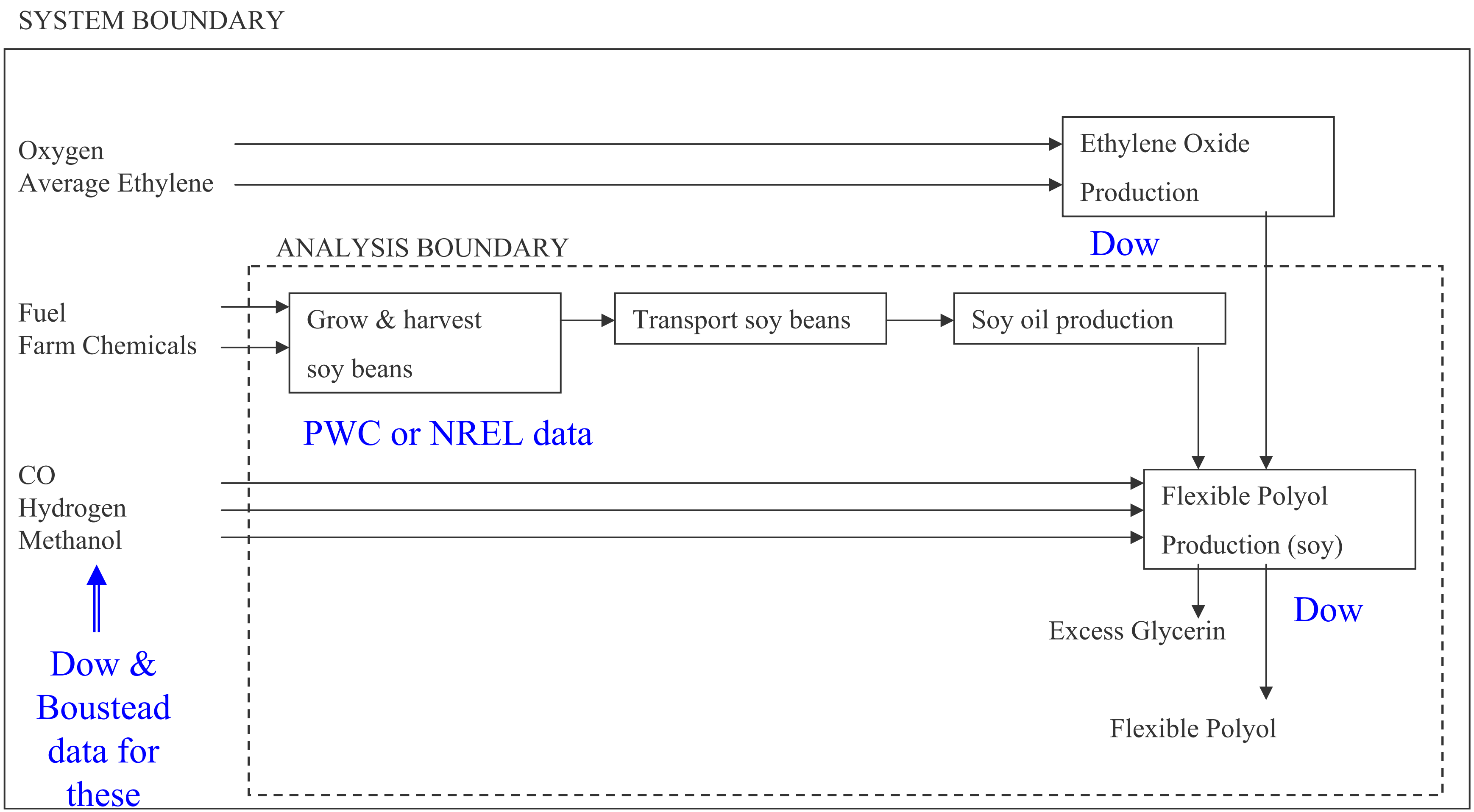
- Goal: Cradle to Gate comparison of flexible foam polyol made through conventional petrochemical routes or from soy oil.
  - Polymer is made by polymerizing <u>either</u> propylene oxide (PO) <u>or</u> a seed oil derivative with an initiator
  - Initiator is made from glycerin and ethylene oxide (EO)
  - EO is a petrochemical in all scenarios, so product is not 100% bio-based, but has <u>identical mechanical properties</u>
- Production options
  - Current technology – European industry average
  - Soy-based
  - Castor-based

Petrochemical Polyol Production

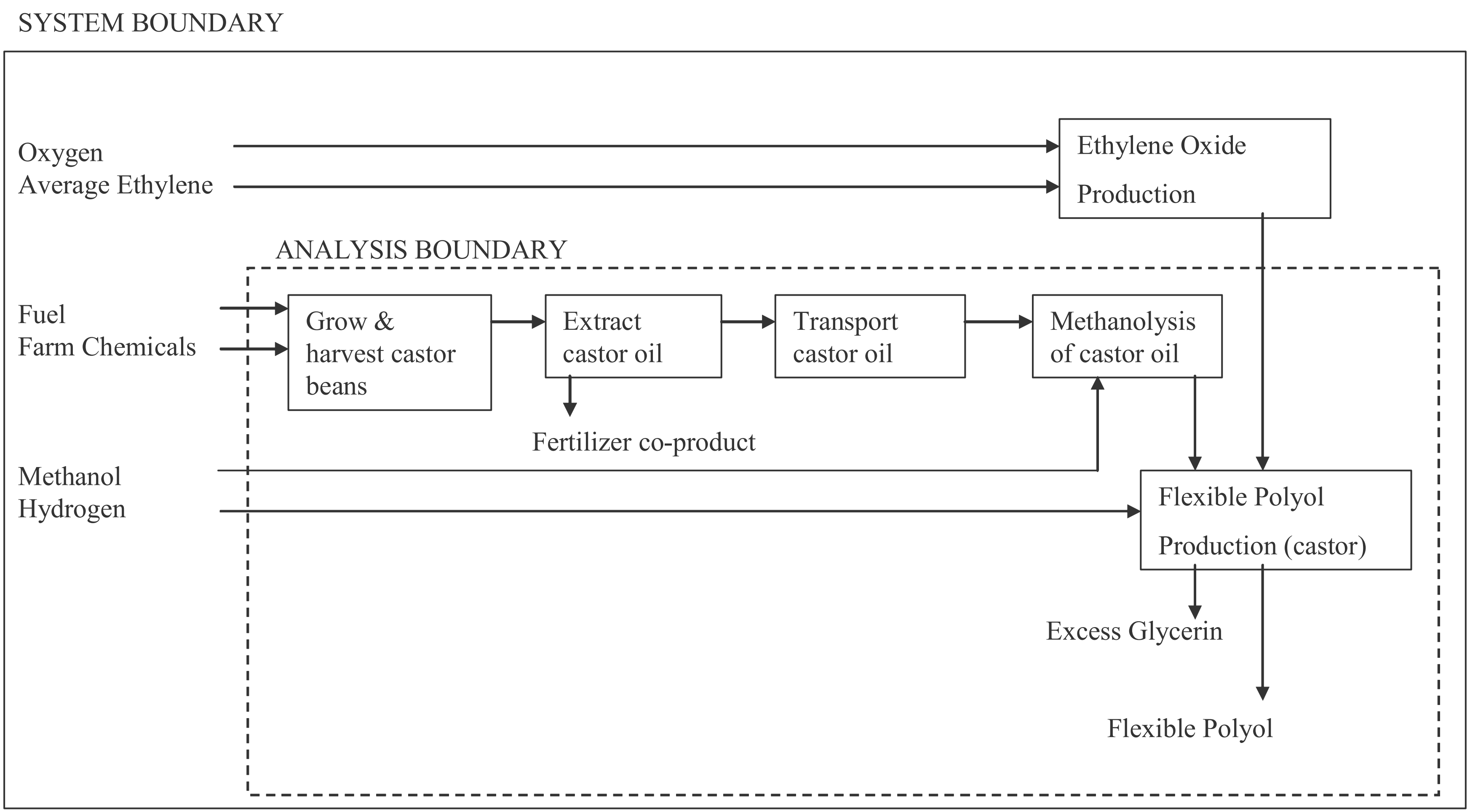
APME 1995 survey of 12 plants in Europe (from Plastics*Europe)*

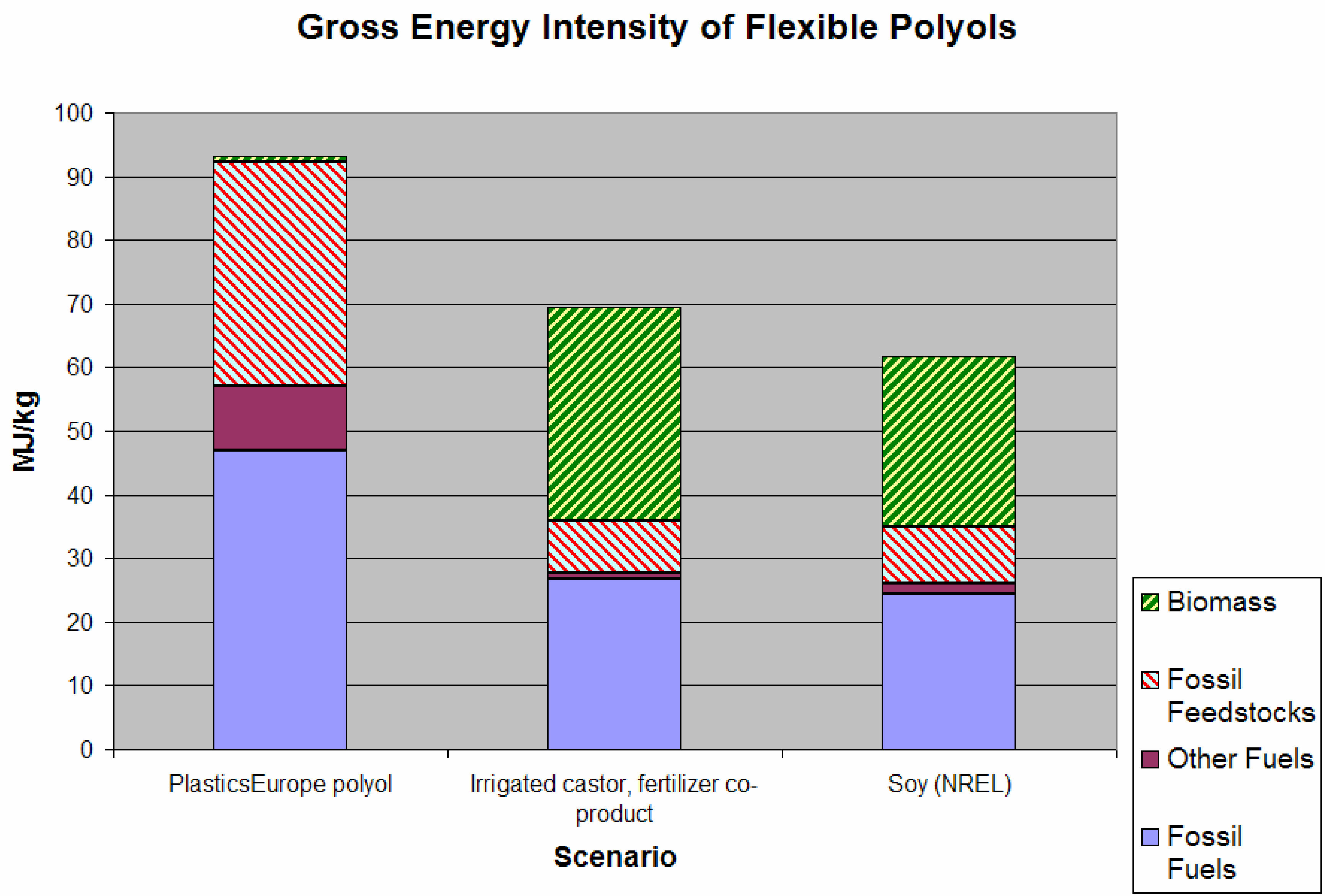


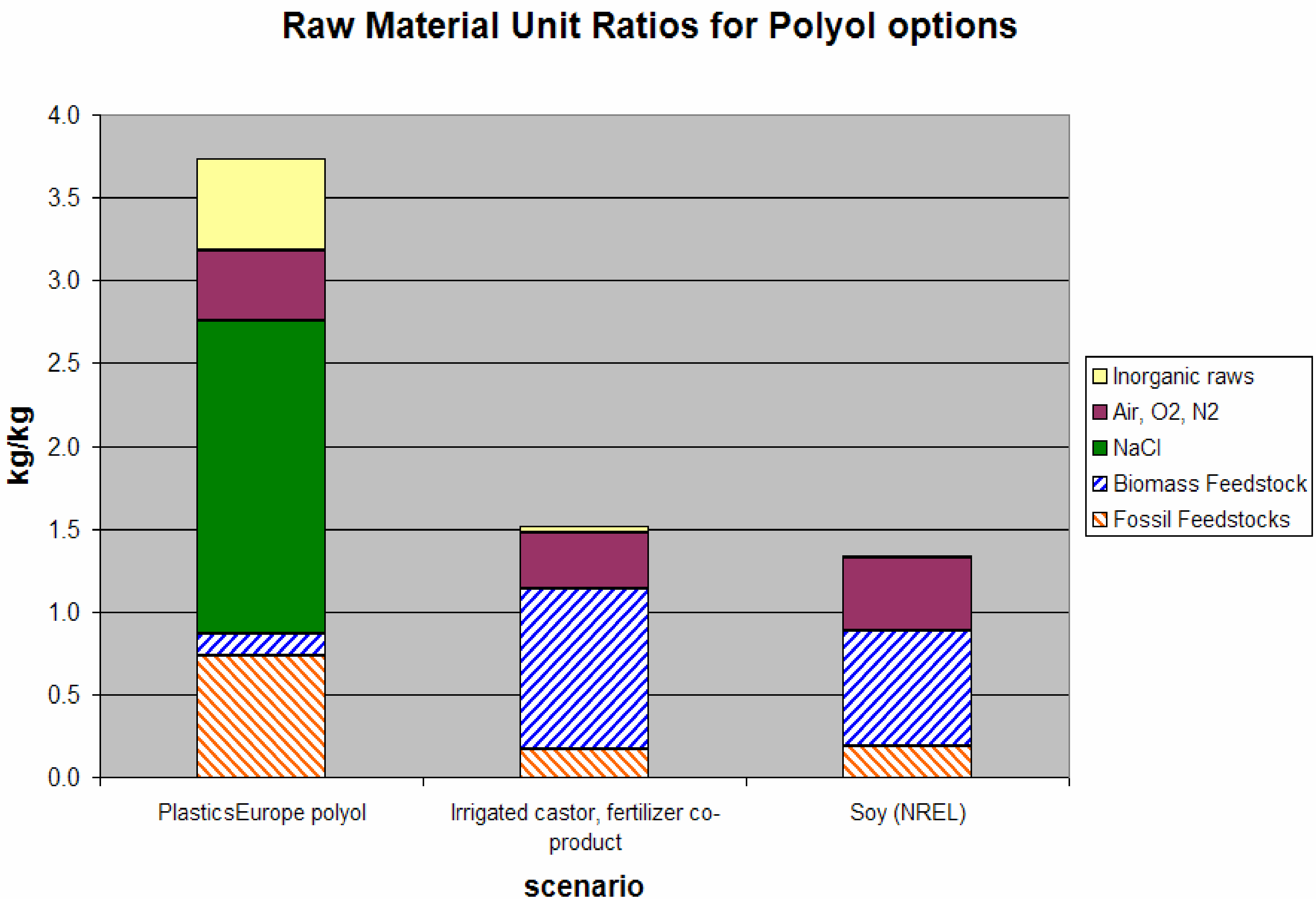
Soy polyol LCA boundaries



Castor polyol LCA boundaries

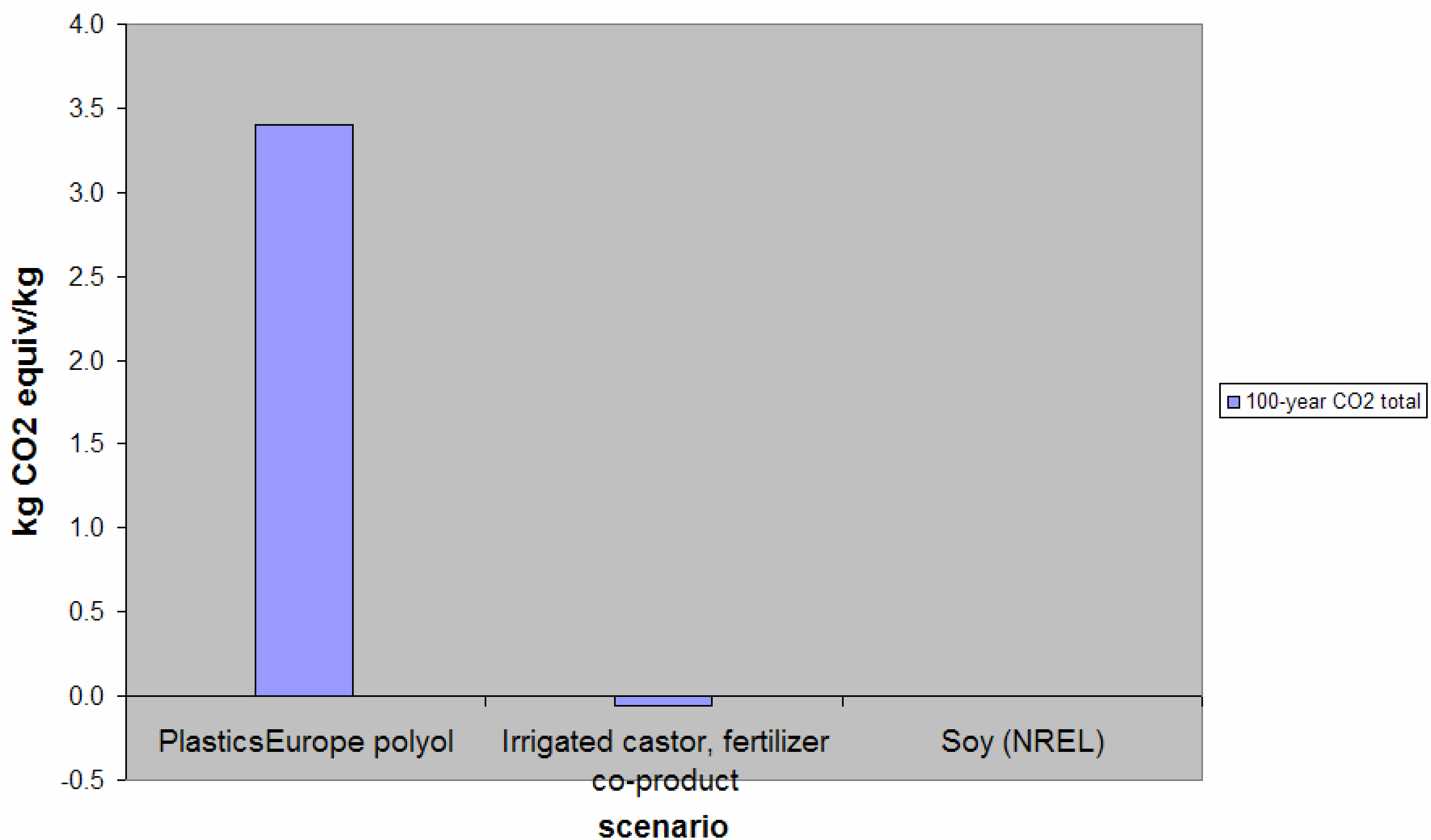



Gross Energy Intensity of Flexible Polyols
100
90
80
70
60
50
40
30
20
10
0
MJ/kg
PlasticsEurope polyol
Irrigated castor, fertilizer co-product
Soy (NREL)
Scenario
Biomass
Fossil Feedstocks
Other Fuels
Fossil Fuels



Raw Material Unit Ratios for Polyol options
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
kg/kg
PlasticsEurope polyol
Irrigated castor, fertilizer co-product
Soy (NREL)
scenario
Inorganic raws
Air, O2, N2
NaCl
Biomass Feedstock
Fossil Feedstocks

Greenhouse Gas Emissions for Polyols



Sensitivity analysis

- Pick key inputs by contribution to gross energy
- Vary by ±20%
- Soy:

Input variable	Gross enegy	Fossil use	GHG reduction	Inorganic raws	water use
Electricity use in oil plant	1.1%	1.5%	1.4%	0.0%	0.0%
EO production	4.5%	8.8%	3.8%	10.3%	1.1%
Yield (Grow and harvest soy beans)	0.7%	1.3%	0.9%	1.3%	15.4%
Natural gas use in oil plant	0.6%	1.1%	0.8%	0.0%	0.0%
Cabon monoxide production	1.9%	3.2%	1.3%	7.4%	0.0%

- Castor:

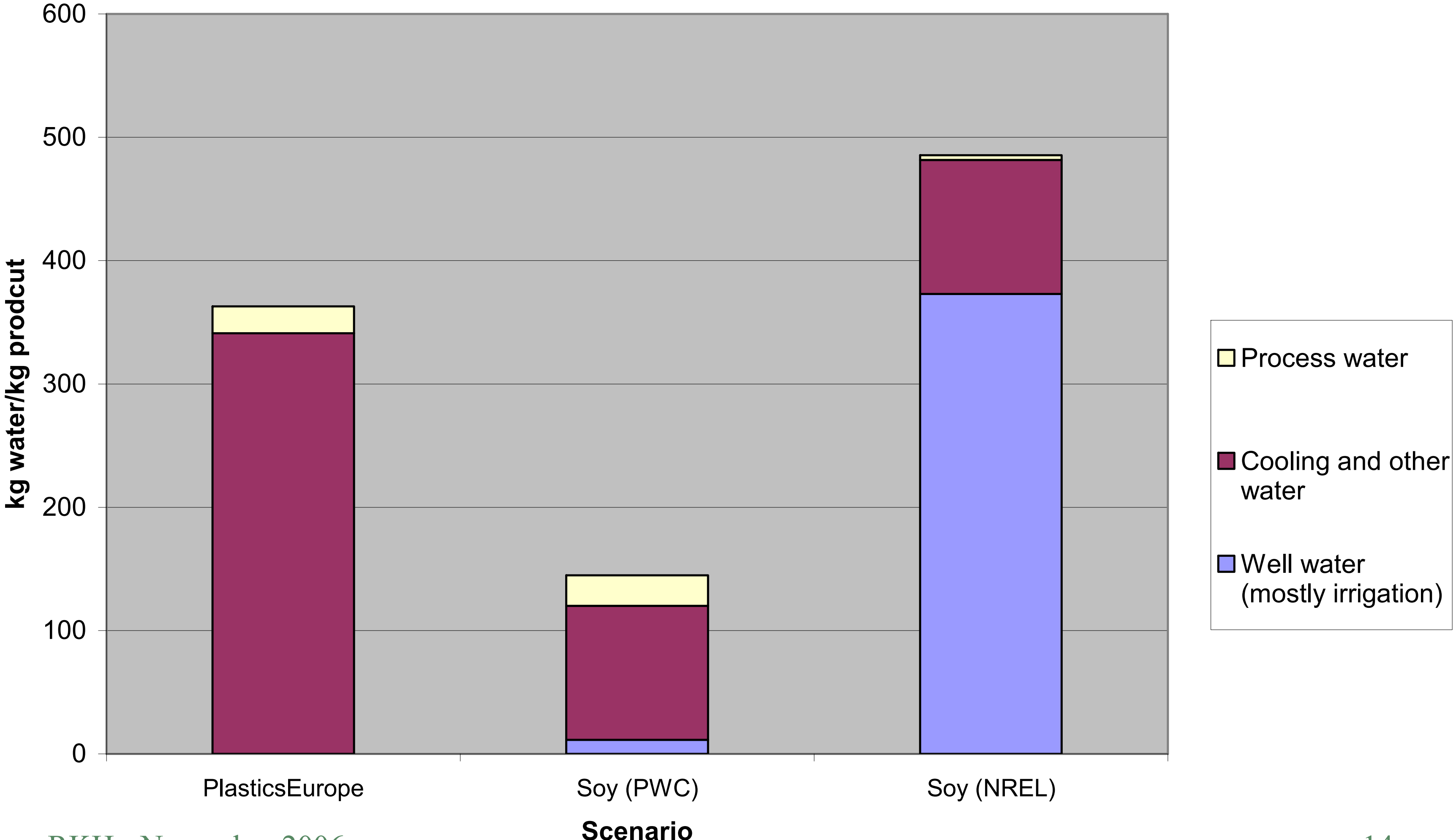
Input variable	Gross enegy	Fossil use	GHG reduction	Inorganic raws	water use
Crop yield	3.8%	6.7%	9.9%	9.0%	17.1%
Inirigation energy (natural gas)	2.7%	4.8%	5.3%	0.0%	0.0%
EO mass in polymer	3.3%	6.1%	4.2%	10.9%	0.3%
Fertilizer use	1.0%	1.4%	1.5%	9.0%	0.0%
Electricity use in seed oil production	0.8%	1.3%	1.7%	0.0%	0.0%
Steam use in polymer plant	1.7%	2.8%	3.3%	0.0%	0.0%

- No single input has dominant impact – results robust to uncertainty in individual inputs

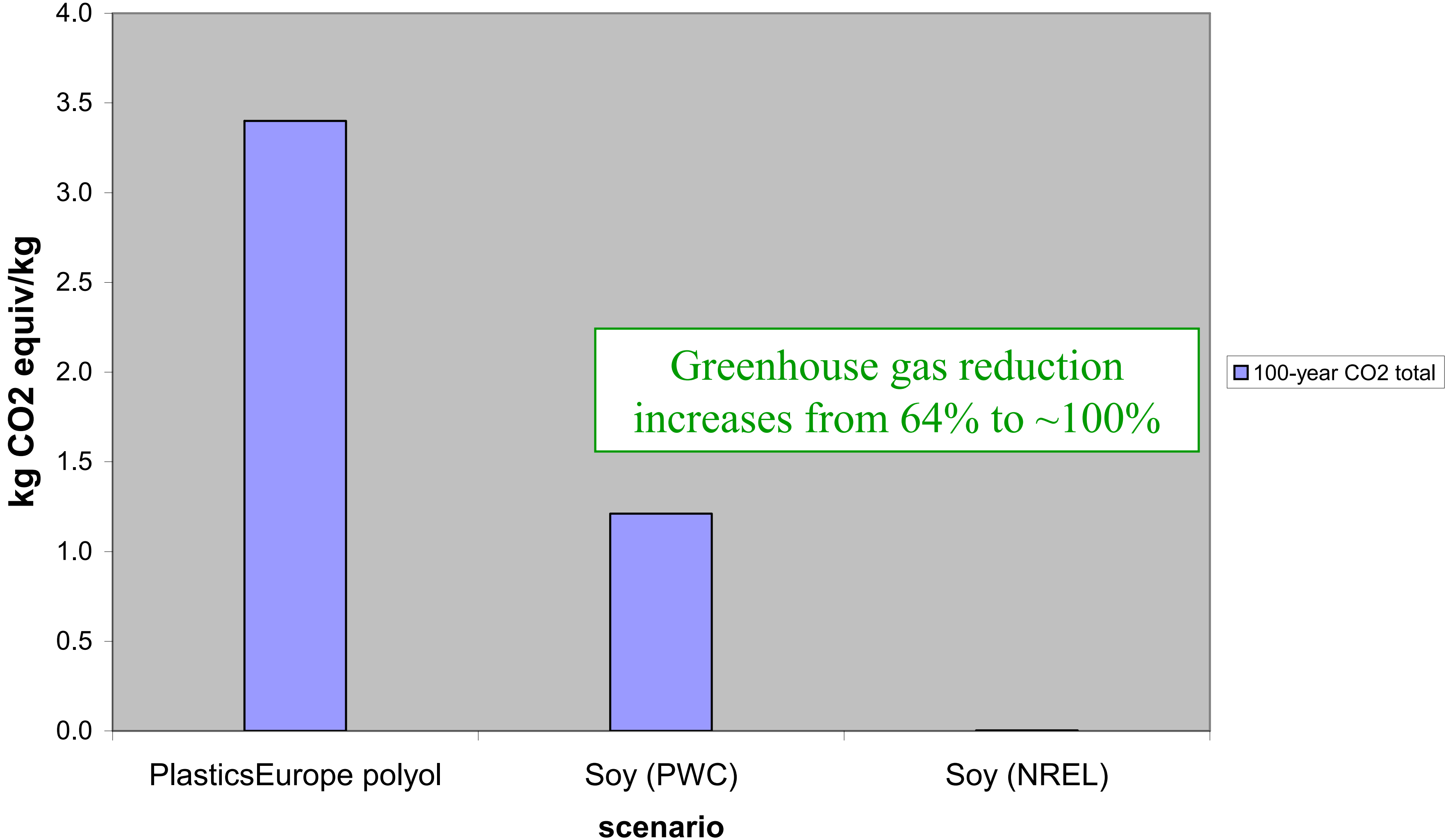
Soy farming models

- Two prior studies: NREL (for biodiesel) & PWC (for a 100% soy based carpet backing)
- Used different data sources for farm inputs, notably irrigation
- Chose different models for N_2O emissions from fields
  - N_2O is 310X CO_2 as greenhouse gas
  - Field measurements are varied
  - NREL: model as fallow land – no net new N_2O
  - PWC: Use UN IPCC model based on input chemicals, plant nitrogen content, and assumptions on residues

Impact of farm model on water use



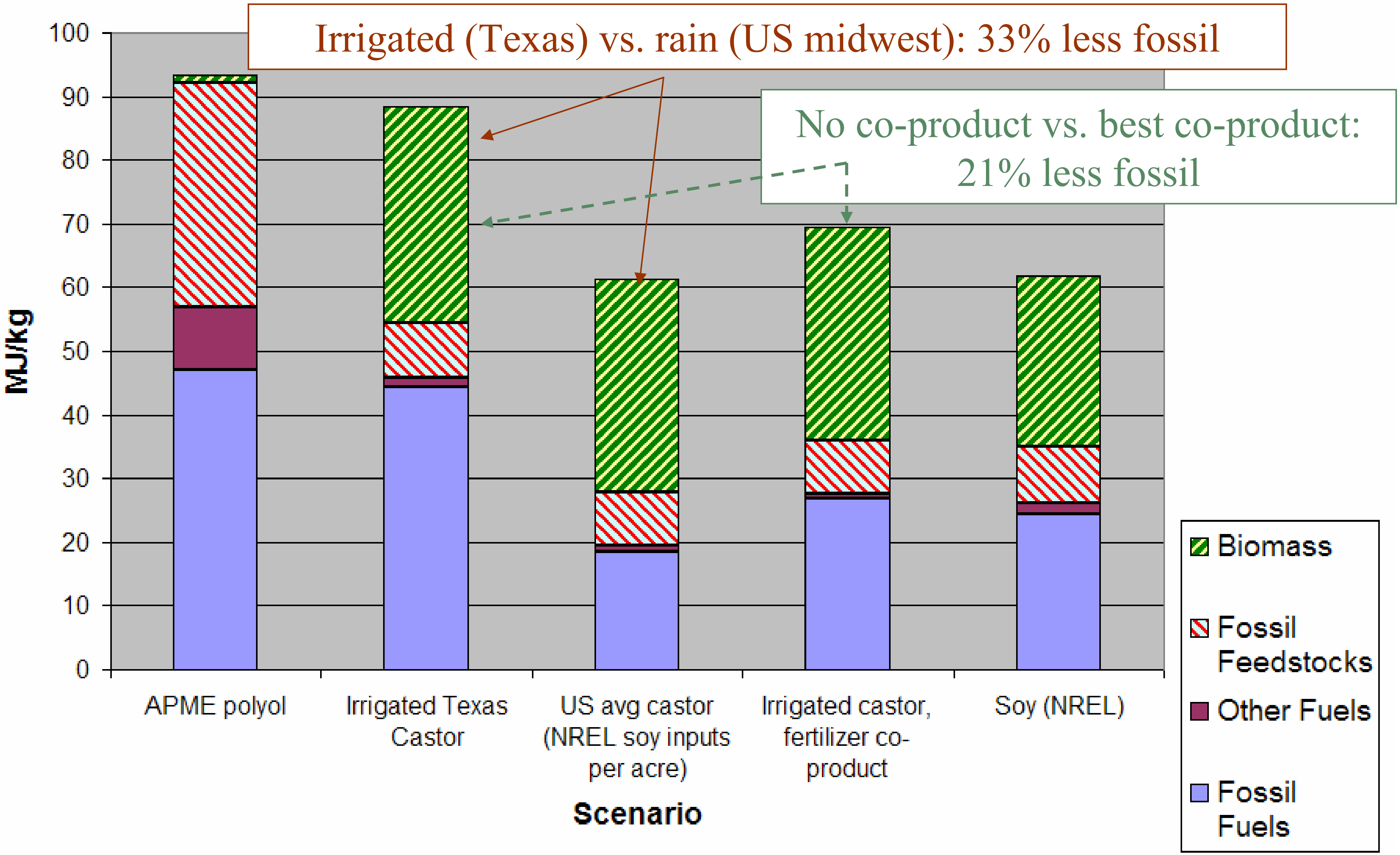
Impact of farm model on greenhouse gas emissions



Forecasts for castor farming

- No LCA results exist for commercial US castor
  - Two estimates on farm inputs:
    - Castor Oil, Inc., inputs for irrigated Texas fields
    - Assumed "like soy" (per acre) for elsewhere in US
- In LCA, if one set of inputs (or emissions) makes multiple products, one must allocate these in some way to the co-product
  - Two estimates on co-products
    - No useful co-products; castor oil carries all burdens
    - Cold-press meal is useful as fertilizer; same burdens per mass

Gross Energy Intensity of Flexible Polyols



Conclusions

- Not ALL bio-based materials look good – LCA can identify which are better
- LCA provides insights by showing impacts of raw material and processing choices
  - Input assumptions are critical
    - Farm model & co-product assumptions have >20% impacts
- Polyols made from soy or castor oil offers significant environmental benefits
  - Use only ~42% of fossil resources
  - Decouples polyols from chlorine chemistry
  - Can be greenhouse-gas neutral