



BIOSYNTHETIC®
TECHNOLOGIES

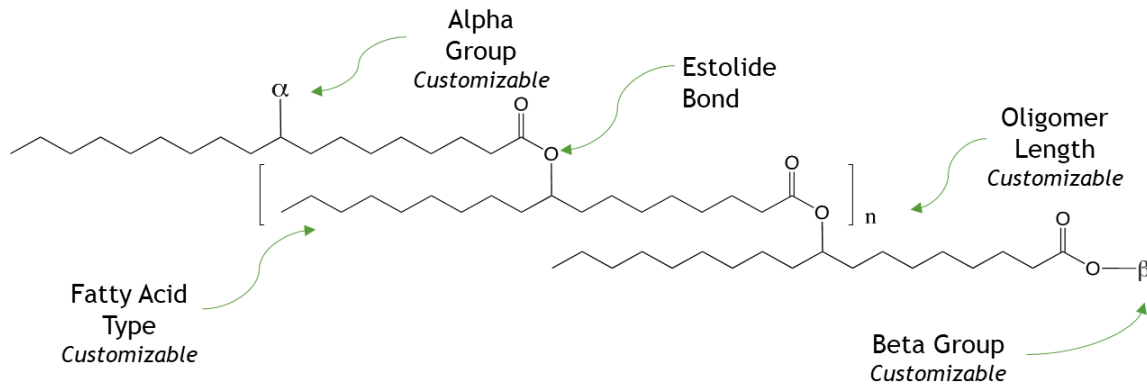
LCA Considerations for Lubricant Base Oils
Dr. Matthew Kriech

General “Pitfalls” of LCA Work

- An LCA done well and used properly can be a valuable tool for making strides toward sustainability
 - ISO 14040 (LCA principles & framework)
 - ISO 14044 (detailed LCA methodologies)
 - ISO 14067 (carbon footprint of products)
- However, there are pitfalls in LCAs that need to be addressed
 - Boundary Conditions Matter
 - Analysis Paralysis
 - What about Performance?

Boundary Conditions Matter - LCA For Estolides

General Estolide Structure



- Highly Customizable
- Fatty Acid (Oleic, 12HSA, Lauric, Acetic ...)
- Source (Soy, Palm, Coconut, Castor)
- Process (Continuous, Batch)
- Viscosity (ISO680, ISO150, ISO22)

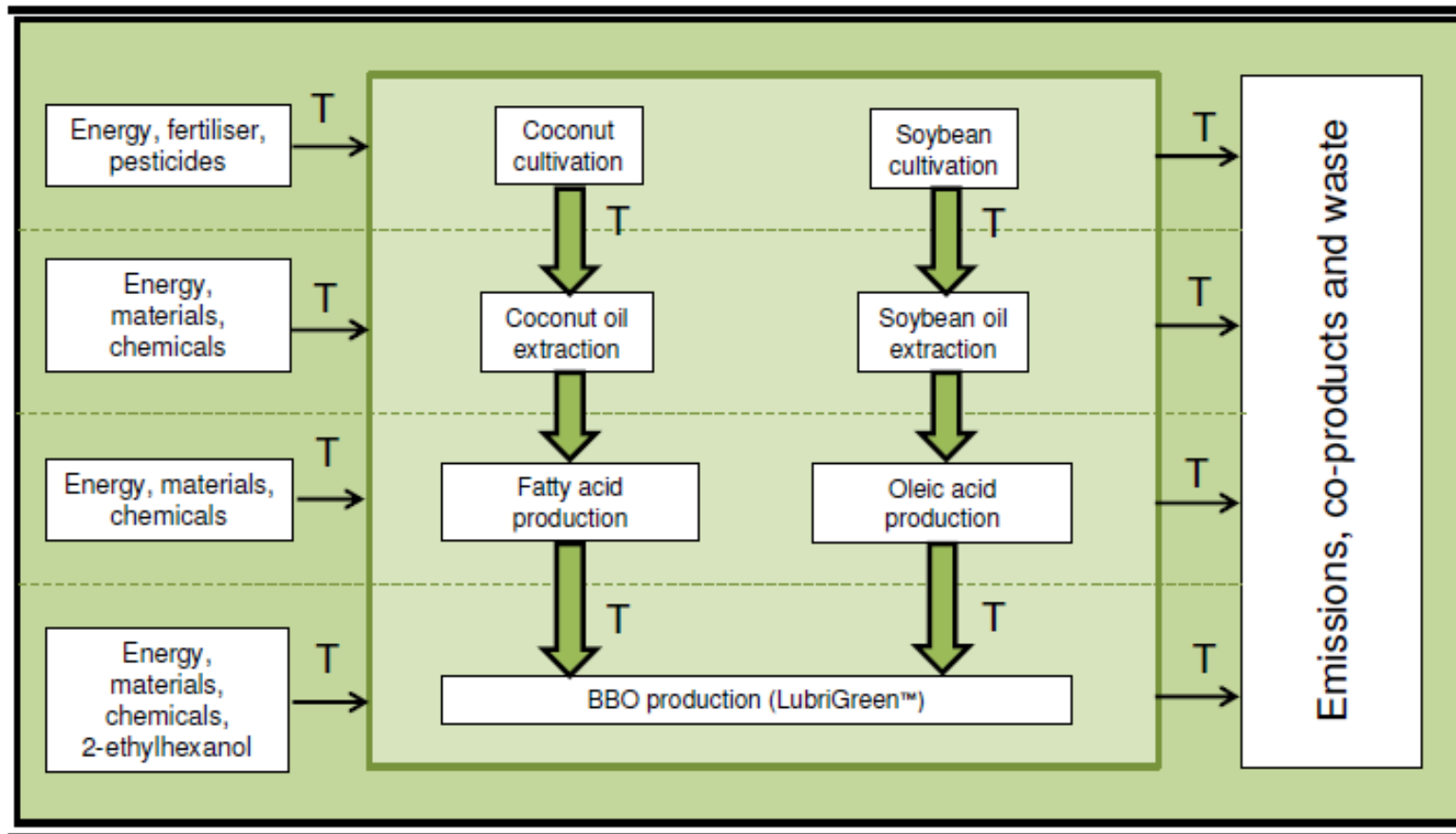
Process #1 (Studied by ERM Consulting)
Continuous utilizing Soybean and
Coconut
Gradle to Gate

5.34 kg CO2 eq

Process #2 (Studied by ERM Consulting)
Batch utilizing Castor
Gradle to Gate

~1.35 kg CO2 eq

Boundary Conditions and Analysis Paralysis



T - transport

General Block Flow for Estolide LCA

- Conducted by Environmental Resources Management
- Cradle to Gate
- Continuous Flow Process
- Soy Bean for Oleic
- Coconut for Lauric Acid
- Followed ISO Standards

Analysis Paralysis: That's a Lot of Numbers

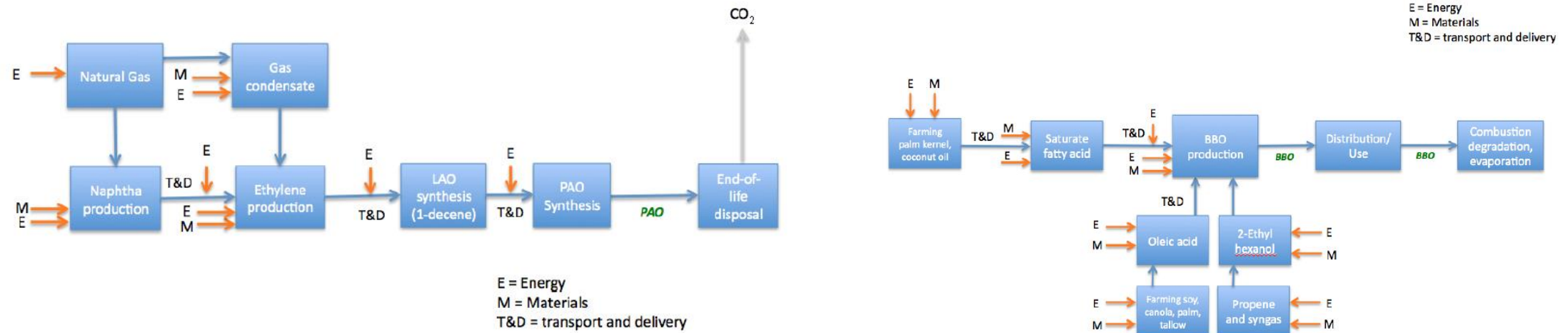
LCA Results for LubriGreen® base oil – cradle-to-gate

Impact category	Unit	Total	Coconut cultivation	Saturated fatty acid production from coconuts	Soybean cultivation	Oleic acid production from soybeans	2-ethylhexanol production	Base oil production	Transport
Climate change	kg CO2 eq	5.345	3.235	0.459	0.279	0.198	0.436	0.501	0.237
Ozone depletion	kg CFC-11 eq	1.17E-07	1.74E-09	8.08E-09	7.58E-09	7.18E-09	1.94E-08	2.90E-08	4.39E-08
Human toxicity, cancer effects	CTUh	1.09E-07	5.79E-08	5.84E-09	2.46E-08	4.83E-09	6.96E-09	8.37E-09	3.05E-10
Human toxicity, non-cancer effects	CTUh	3.98E-06	2.69E-06	2.90E-08	1.16E-06	2.65E-08	2.79E-08	2.66E-08	1.59E-08
Particulate matter	kg PM2.5 eq	2.80E-03	1.33E-03	4.23E-04	3.08E-04	1.86E-04	2.68E-04	1.19E-04	1.66E-04
Photochemical ozone formation	kg NMVOC eq	1.11E-02	2.18E-03	9.88E-04	7.67E-04	7.74E-04	2.62E-03	7.34E-04	3.08E-03
Acidification	molc H+ eq	0.0804	0.0567	0.0014	0.0126	0.0014	0.0026	0.0022	0.0035
Freshwater eutrophication	kg P eq	1.29E-03	5.91E-04	3.15E-04	2.28E-04	5.28E-05	4.43E-05	5.33E-05	2.12E-06
Marine eutrophication	kg N eq	0.0349	0.0267	0.0006	0.0056	0.0002	0.0005	0.0002	0.0011
Freshwater ecotoxicity	CTUe	16.61	10.32	0.67	3.25	0.58	0.83	0.66	0.29
Water resource depletion	m3 water eq	2.51E-02	4.41E-05	4.14E-04	2.22E-02	9.11E-04	1.40E-03	1.57E-04	3.49E-05
Metal depletion	kg Fe eq	2.10E-03	1.34E-04	8.21E-04	2.17E-04	1.73E-04	5.62E-04	1.48E-04	4.35E-05
Fossil depletion	kg oil eq	0.816	0.095	0.051	0.044	0.050	0.322	0.172	0.082

- Now what?
- Can I compare these number with other numbers?
- Are small and medium-sized lubricant manufacturers staffed to do something with these numbers??
- Coconuts are bad???

Analysis Paralysis: Comparing Numbers

■ LCA#2b - Cradle to Gate LCA with PAO Compared to Estolides - ISO 14040 by Eco-Shift Consulting



	GHG intensity	% GHG reduction
1A + 2A (Coconut oil and Palm oil)	1.305 kg CO ₂ e/kg BBO	67.9%
1A + 2B (Coconut oil and Canola oil)	1.051 kg CO ₂ e/kg BBO	74.2%
1A + 2C (Coconut oil and Tallow oil)	1.304 kg CO ₂ e/kg BBO	67.9%
1A + 2D (Coconut oil and Soy oil)	1.078 kg CO ₂ e/kg BBO	73.5%
1B + 2A (Palm kernel and Palm oil)	1.104 kg CO ₂ e/kg BBO	72.9%
1B + 2B (Palm kernel and Canola oil)	0.849 kg CO ₂ e/kg BBO	79.1%
1B + 2C (Palm kernel and Tallow oil)	1.102 kg CO ₂ e/kg BBO	72.9%
1B + 2D (Palm kernel and Soy oil)	0.877 kg CO ₂ e/kg BBO	78.5%



PAO 4.067 kg CO₂ eq
 Estolide 1.305 kg CO₂ eq
 Estolide (LCA 1) 5.345 kg CO₂ eq

4x Difference Between LCAs

Analysis Paralysis: What is the Conclusion?

Comparative LCA between bio-based and petroleum-based lubricants

Identification of data gaps to consider when providing decision support

Patrik William-Olsson



Very detailed 93 page study on the subject conducted in 2020

Final Conclusion: “There are unanswered questions that would need more investigation before switching to a bio-based lubricant. The results of this report cannot be used to either motivate a switch or to keep using petroleum-based lubricants.”

What About Performance?



BASF and Fuchs Hydraulic Performance Study

- Both mineral based Hydraulic Fluids
- HVLP Multi Grade Hydraulic Oil
 - Higher initial Climate Impact (kg CO2 eq)
- HLP Monograde Hydraulic Oil
 - Lower initial Climate Impact (kg CO2 eq)

- “Holistically considering the products’ full life cycle around the usage in a crawler excavator, the findings of the EEA study clearly indicated the lower environmental impact and lower overall cost especially in use of the studied premium HVLP fluid (high performance multigrade hydraulic oil) versus standard HLP fluid (monograde hydraulic oil)”

“This advantage is mainly based on an improved diesel fuel economy throughout the use phase - primarily due to improved volumetric fluid efficiency lower friction and lower fluid mass circulation ratio - which clearly overcompensates a slightly higher environmental footprint of these products in the cradle-to-gate phase.”

PERFORMANCE MATTERS and CAN BE BIGGEST IMPACT on CO2 EMISSIONS



THANK YOU

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