Life Cycle Assessment results on the technologies of Bio4Africa

Georgios Lanaras-Mamounis

DREVEN Greece

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BIOENERGY FOR LOCAL PRODUCTION

CONFÉRENCE INTERNATIONALE

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www.Bio4Africa.eu

This project has recieved funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101000762

Our Role in the BIO4AFRICA project

- The **sustainability assessment** of the BIO4AFRICA project technologies and value chains through LCA, LCC and S-LCA studies-Task 5.4

- The **comparison of the project's technologies with standard (conventional) practices** through LCA, LCC and S-LCA studies-Task 5.4

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What do we mean by the term “sustainability assessment”?

Environmental Impacts (LCA)

- **Contribution to environmental problems, such as:**
  - Climate Change
  - Acidification
  - Eutrophication
  - Human health problems related to pollution
  - Etc.

Economic Impacts (LCC)

- **Cost related insights, such as:**
  - Capital Expenditures (CAPEX)
  - Operational Expenditures (OPEX)
  - End-of-Life cost (EoL)

Social Impacts (SLCA)

- **The societal profile of the studied technologies, in terms of:**
  - Impacts on important stakeholder groups (e.g. local community, workers, etc.)
  - Positive (e.g. creation of jobs) and negative (e.g. child labor) outcomes

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Our Methodology

BIO4AFRICA

- For performing the LCA, LCC and S-LCA studies, DREVEN follows global guidelines on LCA (ISO 14040/44: 2006, UNEP Guidelines)

Goal and Scope Definition

- The system and its critical parameters (boundaries, functional unit(s)) are defined

Inventory Analysis

- Information regarding the environmental flows of the system are collected
- The system is modelled in appropriate LCA software and databases (OpenLCA, EcoInvent, SHDB)

Impact Assessment

- The environmental impacts are quantified and measured

Interpretation

- Analyses on the results are performed

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Key Methodological Aspects

- For the **LCAs**, the LUC related to the cultivation of the feedstocks of the technologies is modelled

- For the **LCCs**, some key assumptions are: Project's lifetime, Discount rate , Depreciation rate, Repair and maintenance rate, Administrative costs rate, End-of-Life ratio

- For the **S-LCAs**, an initial filtering of key societal aspects to focus on is necessary. For this reason, consortium workshops were organized

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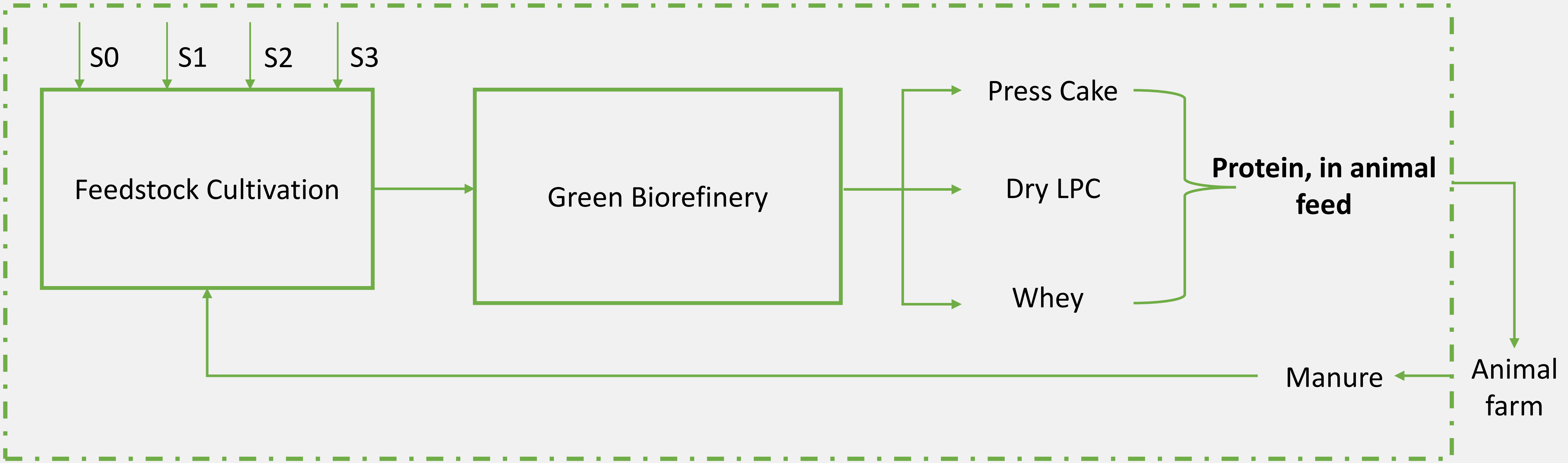
System 1: Green Biorefinery, Uganda (GRASSA, KRC)



Scenario	Description
Fertilization S0	Chemical fertilizers & manure
Fertilization S1	Chemical fertilizers
Fertilization S2	Chemical fertilizers + Intercropping
Fertilization S2	Chemical fertilizers + Intercropping + Manure

- Functional unit: 1 tonne of protein in press cake, dry LPC, whey
- Partial mechanization of cultivation, biorefinery unit in fields

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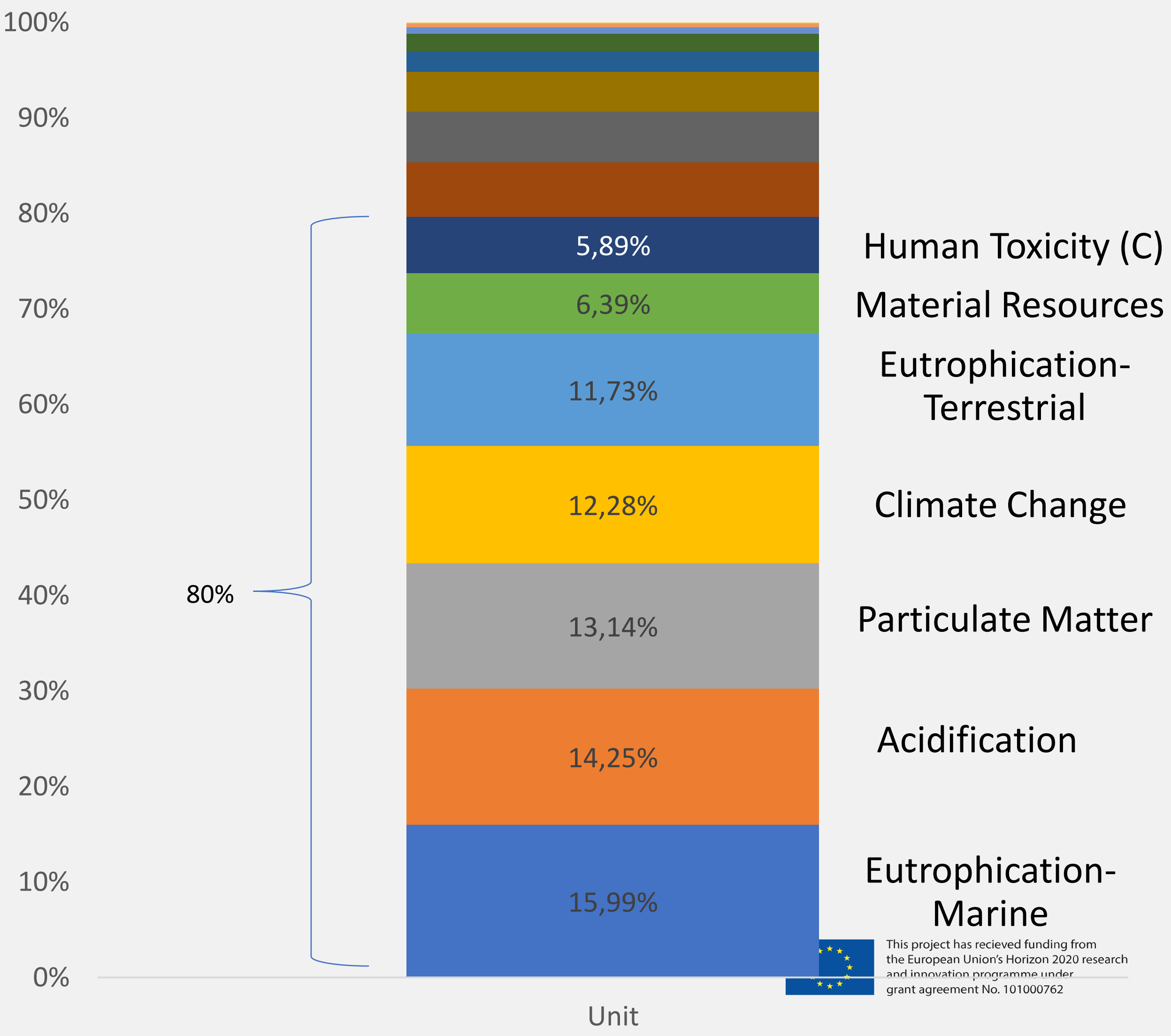
System 1 LCA Results

- Characterization of all environmental impacts (EF3.1), per F.U.

Acidification	5.53673e+1	mol H+-Eq
Climate change	1.90883e+3	kg CO2-Eq
Climate change: biogenic	4.08059e+0	kg CO2-Eq
Climate change: fossil	1.51658e+3	kg CO2-Eq
Climate change: land use and land use change	3.88178e+2	kg CO2-Eq
Ecotoxicity: freshwater	2.27460e+4	CTUe
Energy resources: non-renewable	1.80412e+4	MJ, net calorific value
Eutrophication: freshwater	1.41107e+0	kg P-Eq
Eutrophication: marine	4.57614e+1	kg N-Eq
Eutrophication: terrestrial	2.42206e+2	mol N-Eq
Human toxicity: carcinogenic	2.06887e-5	CTUh
Human toxicity: non-carcinogenic	2.18168e-5	CTUh
Ionising radiation: human health	4.51968e+1	kBq U235-Eq
Land use	1.51077e+4	dimensionless
Material resources: metals/minerals	2.33284e-2	kg Sb-Eq
Ozone depletion	1.72897e-5	kg CFC-11-Eq
Particulate matter formation	3.78348e-4	disease incidence
Photochemical oxidant formation: human health	1.55342e+1	kg NMVOC-Eq
Water use	1.27070e+3	m3 world Eq deprived

- Total weighted single score IC contribution per F.U.



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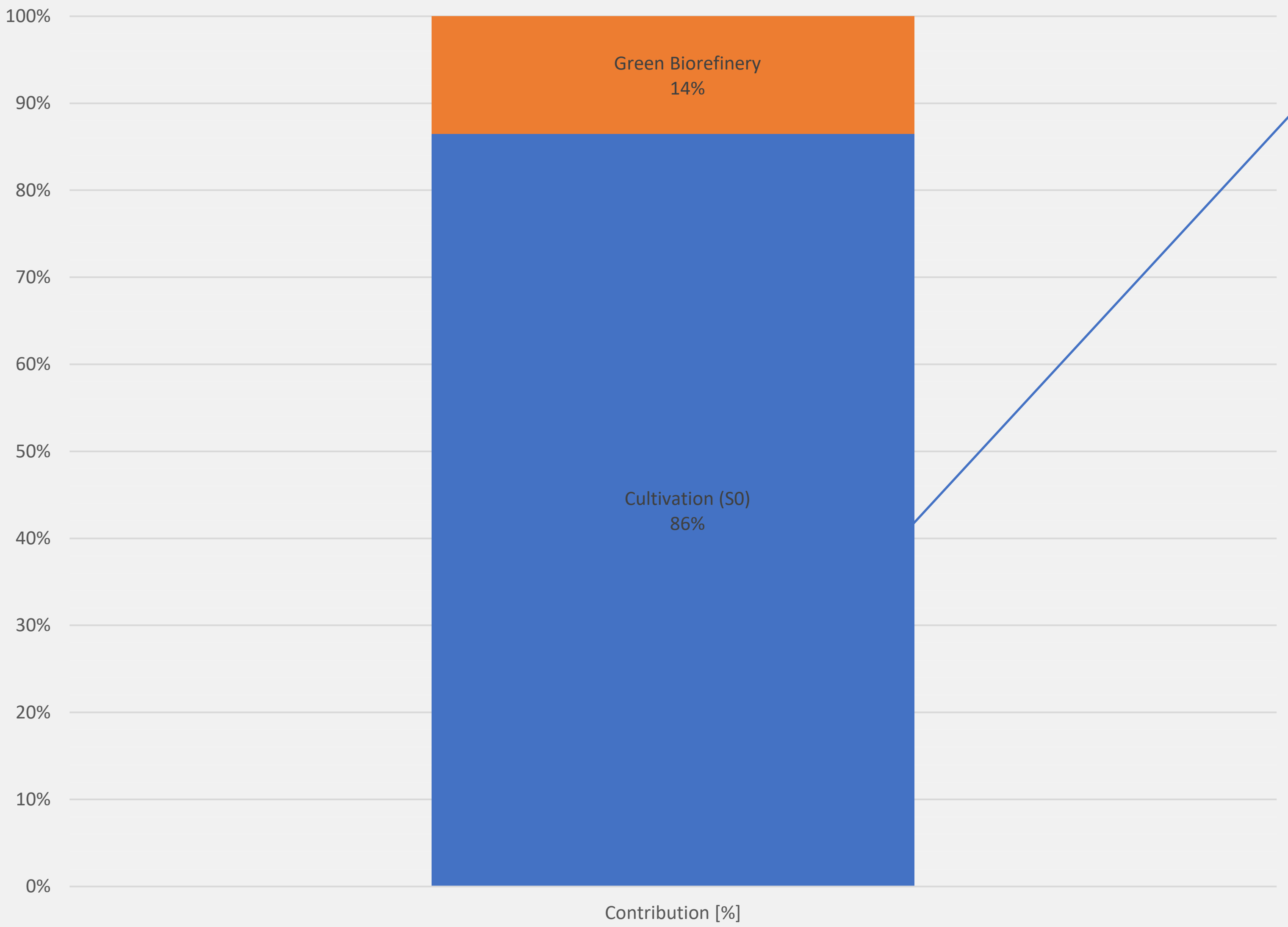
System 1 LCA Results

- Total average contribution of main processes in all important IC (%)



- Further analysis on the cultivation process showed that the average contribution of fertilizers is 70% of the total (81% of Cultivation).

- For this reason, alternative fertilization scenarios were built (GRASSA) and examined through LCA

- Also, a conventional standard product (soybean meal), representative of the Ugandan market, was modelled through LCA (per 1 ton of protein)

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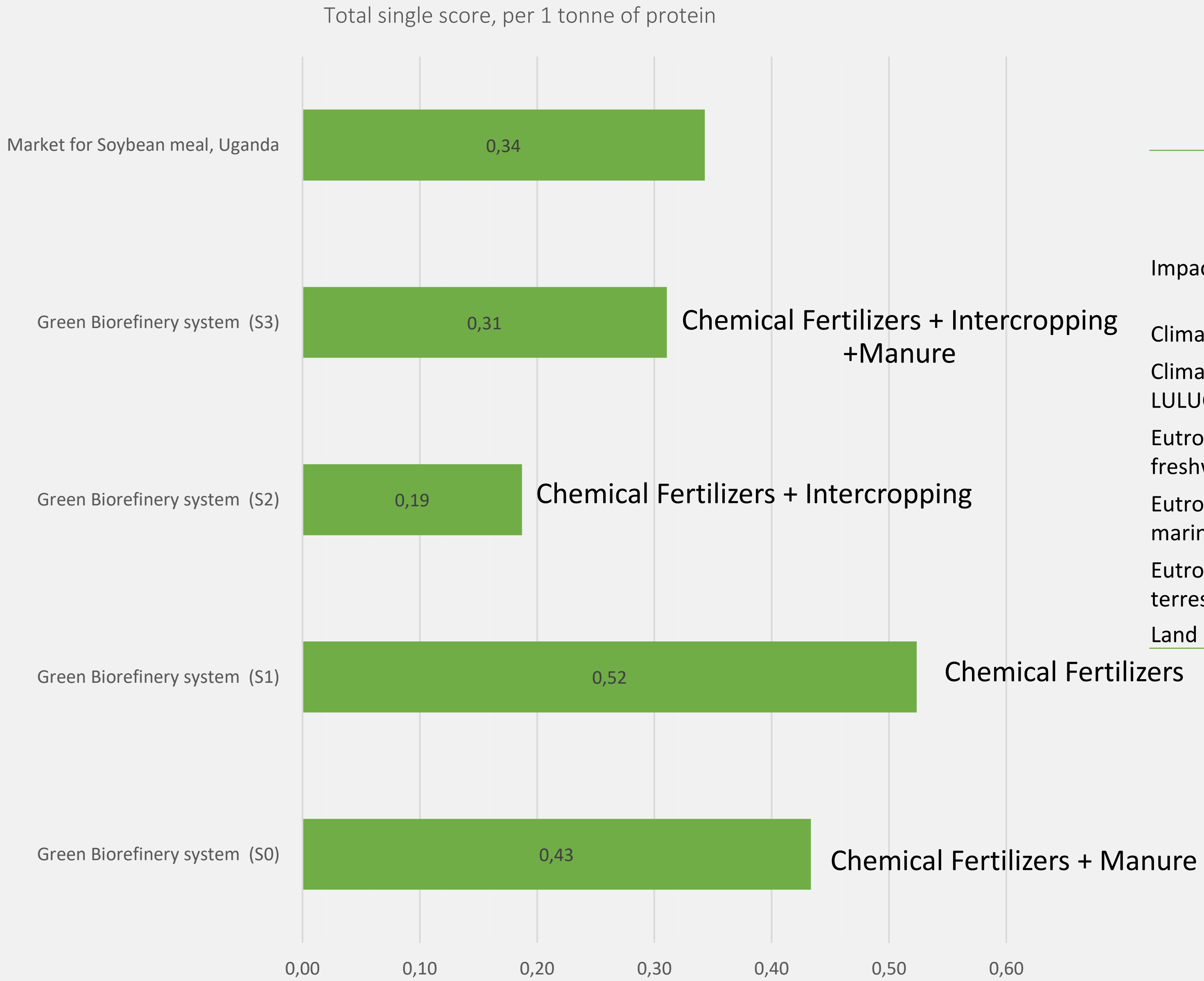
System 1 LCA Results



Key IC, per 1 tonne of protein

Impact categories	Unit	Green Biorefinery System (S0)	Green Biorefinery System (S1)	Green Biorefinery System (S2)	Green Biorefinery System (S3)	Market for Soybean meal, Uganda
Climate change	kg CO2-Eq	1.91E+03	2.70E+03	1.66E+03	1.52E+03	5.94E+03
Climate change: LULUC	kg CO2-Eq	3.88E+02	3.89E+02	3.88E+02	3.88E+02	4.39E+03
Eutrophication: freshwater	kg P-Eq	1.41E+00	1.62E+00	8.29E-01	1.31E+00	6.58E-01
Eutrophication: marine	kg N-Eq	4.58E+01	4.65E+01	2.25E+00	2.92E+01	2.01E+01
Eutrophication: terrestrial	mol N-Eq	2.42E+02	2.61E+02	2.90E+01	1.55E+02	3.16E+01
Land use	-	1.51E+04	1.85E+04	1.43E+04	1.36E+04	2.09E+05

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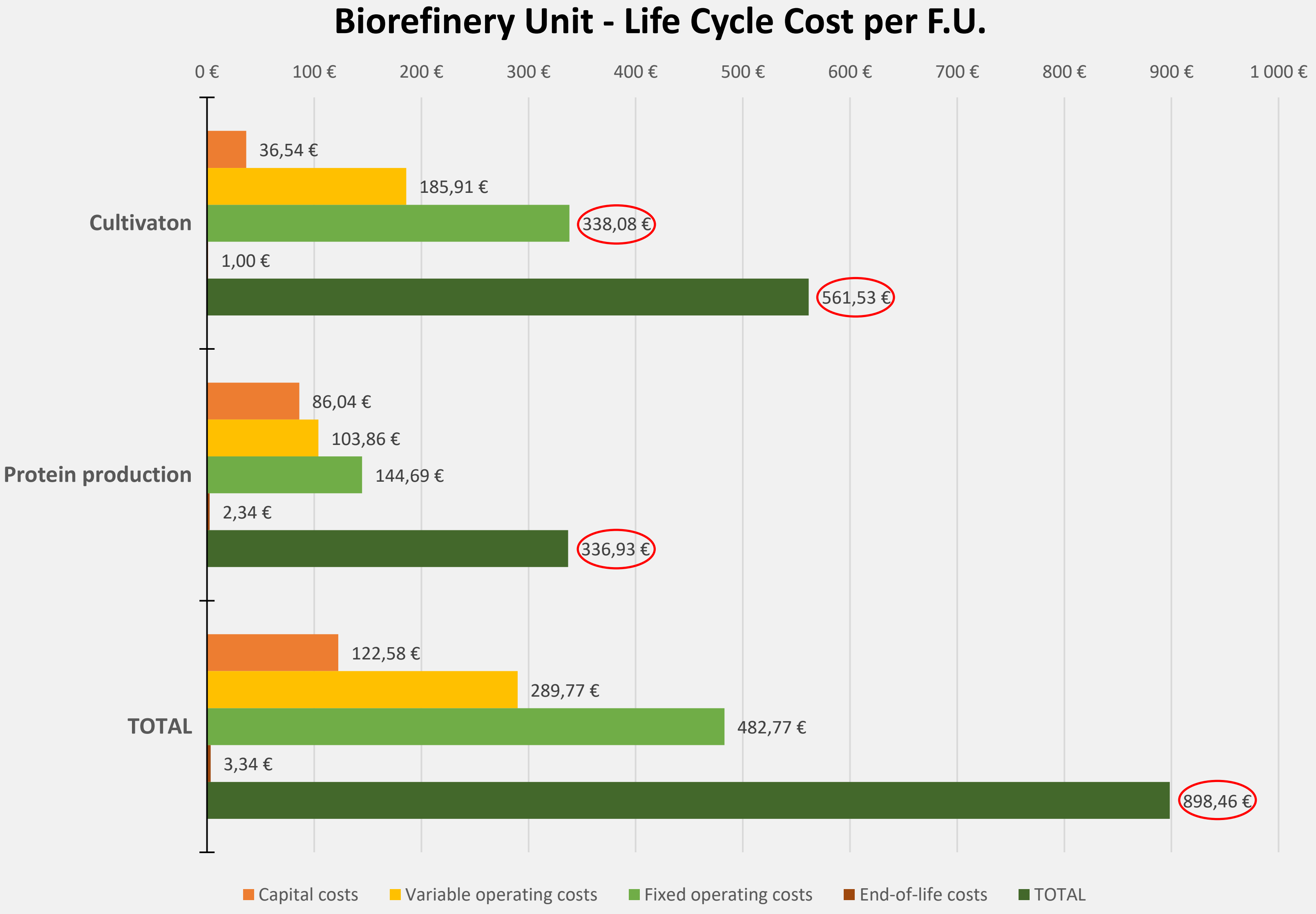
System 1 LCC Results



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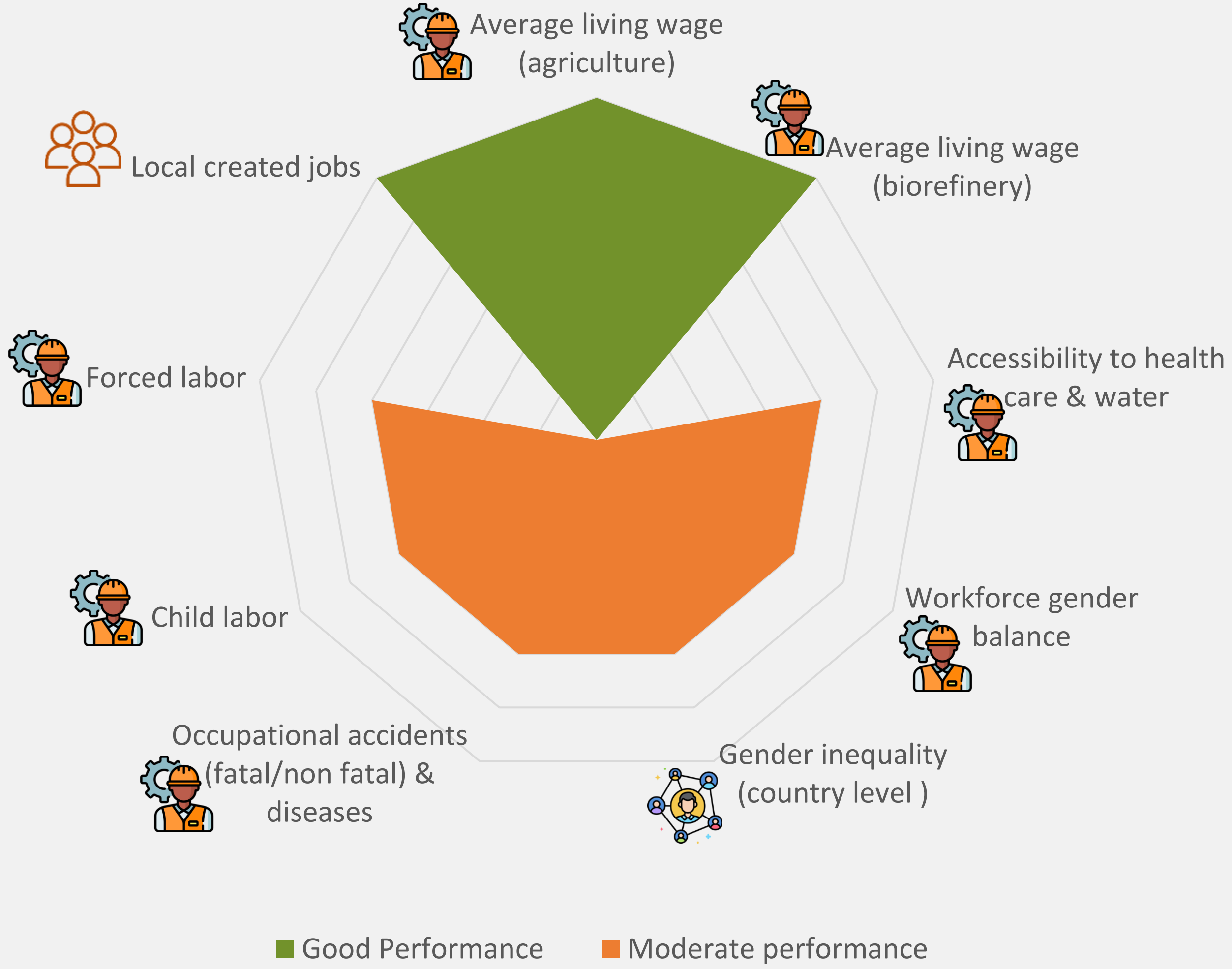
System 1 S-LCA Results

Workers

Local community

Society



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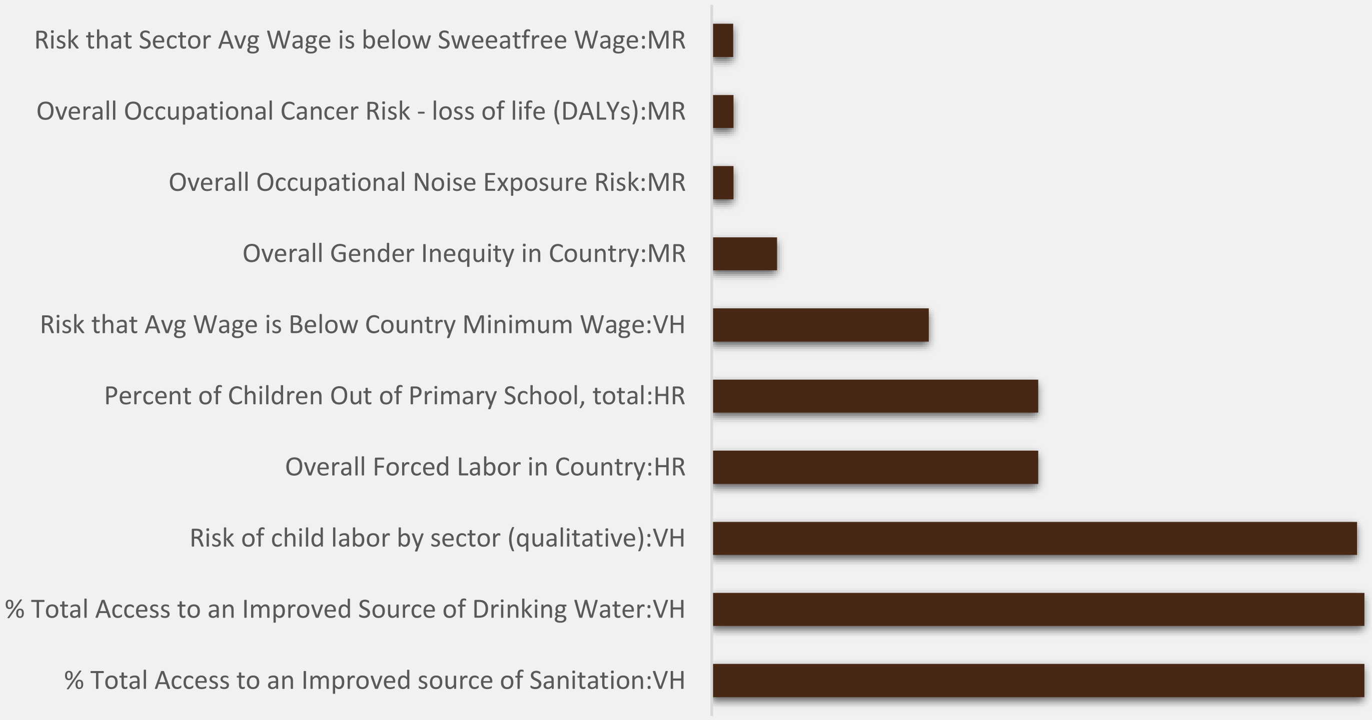
System 1 S-LCA Results

Pilot data

- Higher compensation than country & sector
- 20 new vacancies
- Women’s participation in the workforce
- No child & forced labor
- No occupational accidents
- Access to water

Social hotspots_Agricultural sector



MR: Medium Risk HR: High Risk VR: Very High Risk

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System 1 – Key Takeaways

- Alternative fertilizing methods (manure, intercropping), show significant potential for reduction of environmental impact **(LCA)**
- The most environmentally competitive scenarios are S2 (intercropping-0.19) and S3 (intercropping+manure-0.31), in relation to the conventional product (soybean meal protein-0.34) **(LCA)**
- Chemical fertilizer and manure use leads to leaching of nutrients and increase of certain related IC (e.g., Eutrophication) **(LCA)**
- Soybean meal protein has significantly higher climate change impacts, mainly due to LUC. However, soybean has nitrogen binding capacity and less leaching of nutrients at the cultivation stage **(LCA)**
- The cultivation stage is the costliest. This is primarily attributed to the fixed operating costs, driven by the rents for land and the labor costs. The next most significant expense category is variable operating costs, which include expenditures on seeds and fertilizers **(LCC)**
- The pilot of Uganda performed better that the average in identified "risk" areas for the country and sector **(SLCA)**

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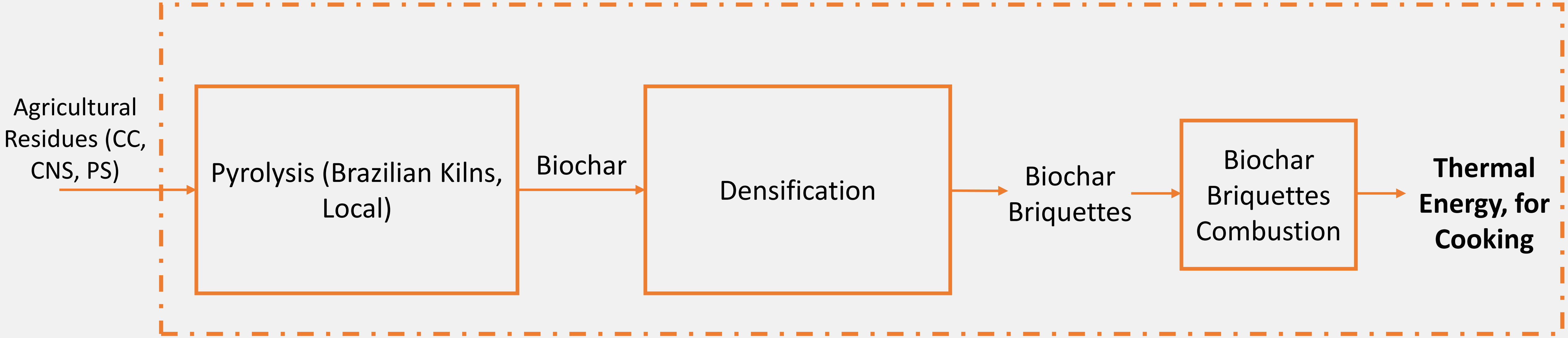
System 2: Combined Pyrolysis/Densification line, Senegal (UASZ)



- Functional unit: 1 KWh of net thermal output Energy (20% efficiency)

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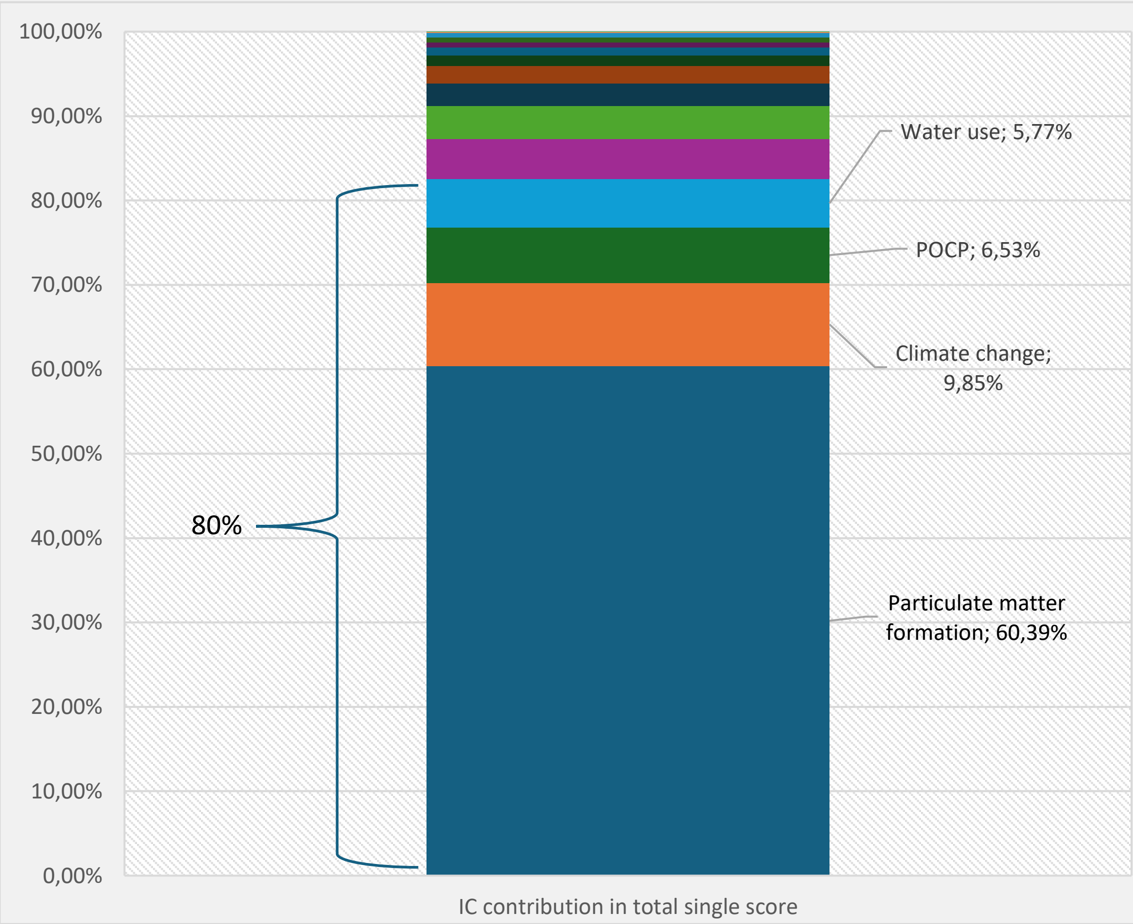
System 2 LCA Results

- Characterization of all environmental impacts (EF3.1), per F.U.

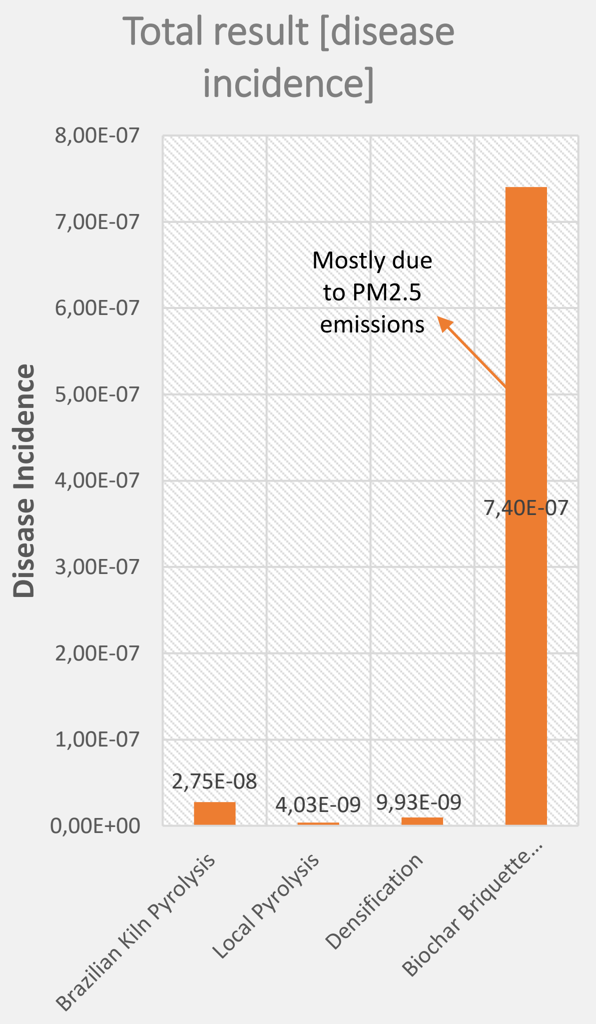
Acidification	8.47120e-3	mol H+-Eq
Climate change	7.02172e-1	kg CO2-Eq
Climate change: biogenic	3.68537e-1	kg CO2-Eq
Climate change: fossil	3.22862e-1	kg CO2-Eq
Climate change: land use and land use change	1.07728e-2	kg CO2-Eq
Ecotoxicity: freshwater	3.39082e+0	CTUe
Energy resources: non-renewable	3.28678e+0	MJ, net calorific value
Eutrophication: freshwater	6.69120e-5	kg P-Eq
Eutrophication: marine	3.42980e-3	kg N-Eq
Eutrophication: terrestrial	3.72052e-2	mol N-Eq
Human toxicity: carcinogenic	1.34737e-10	CTUh
Human toxicity: non-carcinogenic	8.08396e-9	CTUh
Ionising radiation: human health	5.25535e-3	kBq U235-Eq
Land use	1.91601e+1	dimensionless
Material resources: metals/minerals	2.07999e-6	kg Sb-Eq
Ozone depletion	4.58492e-9	kg CFC-11-Eq
Particulate matter formation	7.82329e-7	disease incidence
Photochemical oxidant formation: human health	1.10937e-2	kg NMVOC-Eq
Water use	1.54511e+0	m3 world Eq deprived

- The analysis of IC contribution per total single score showed that the most important IC are <u>Particulate Matter (60%), Climate Change (10%), Photochemical Oxidant Formation (POCP, 7%), and Water Use (6%)</u> (≈80% of the total impact)

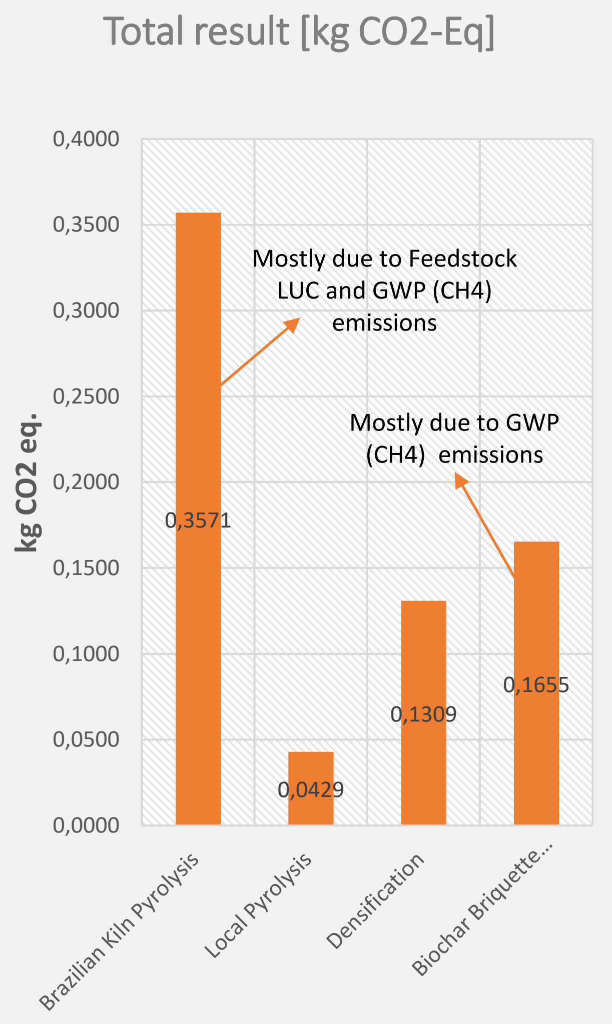


System 2 LCA Results

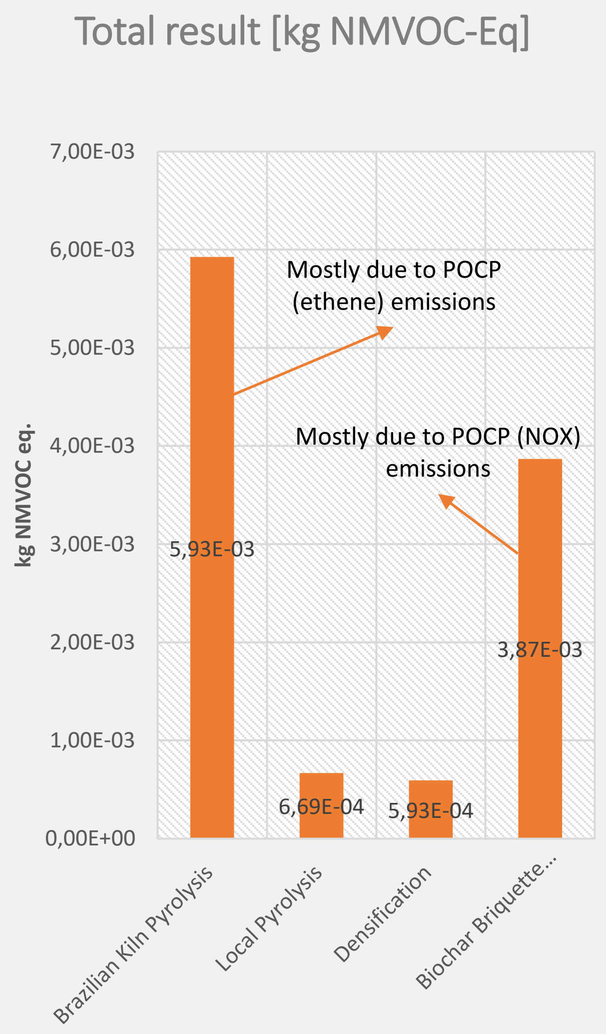
Impact per process, per F.U.- **PM formation (60%)**



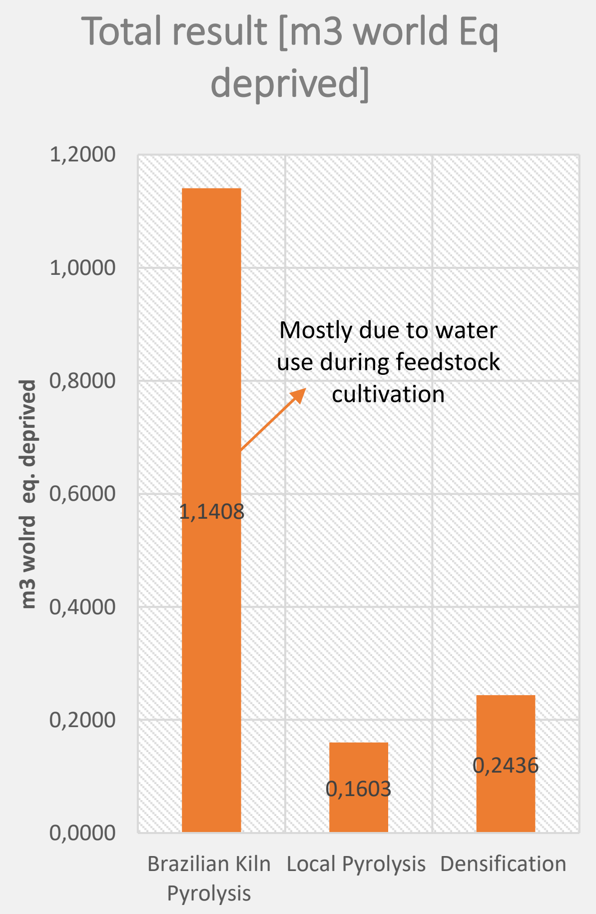
Impact per process, per F.U.- **Climate Change (10%)**



Impact per process, per F.U.- **POCP (7%)**



Impact per process, per F.U.- **Water Use (6%)**



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System 2 LCA Results

- Additional LCA modellings were performed:
- 1 KWh of net thermal energy output from biochar briquettes (30%, 40% efficiency)
- 1 KWh of the net thermal energy output of the standard market mix of thermal energy for cooking in Senegal (charcoal, firewood, LPG)
- 1 KWh for all of the above sources separately, without losses

Fuel	Contribution per 1 KWh (%)	Considered efficiency (%)
Bıochar briquette	100%	20% (standard), 30%, 40%
Senegalese market mix	↓	↓
Firewood	52%	20%
Charcoal	19%	24%
LPG	29%	54%

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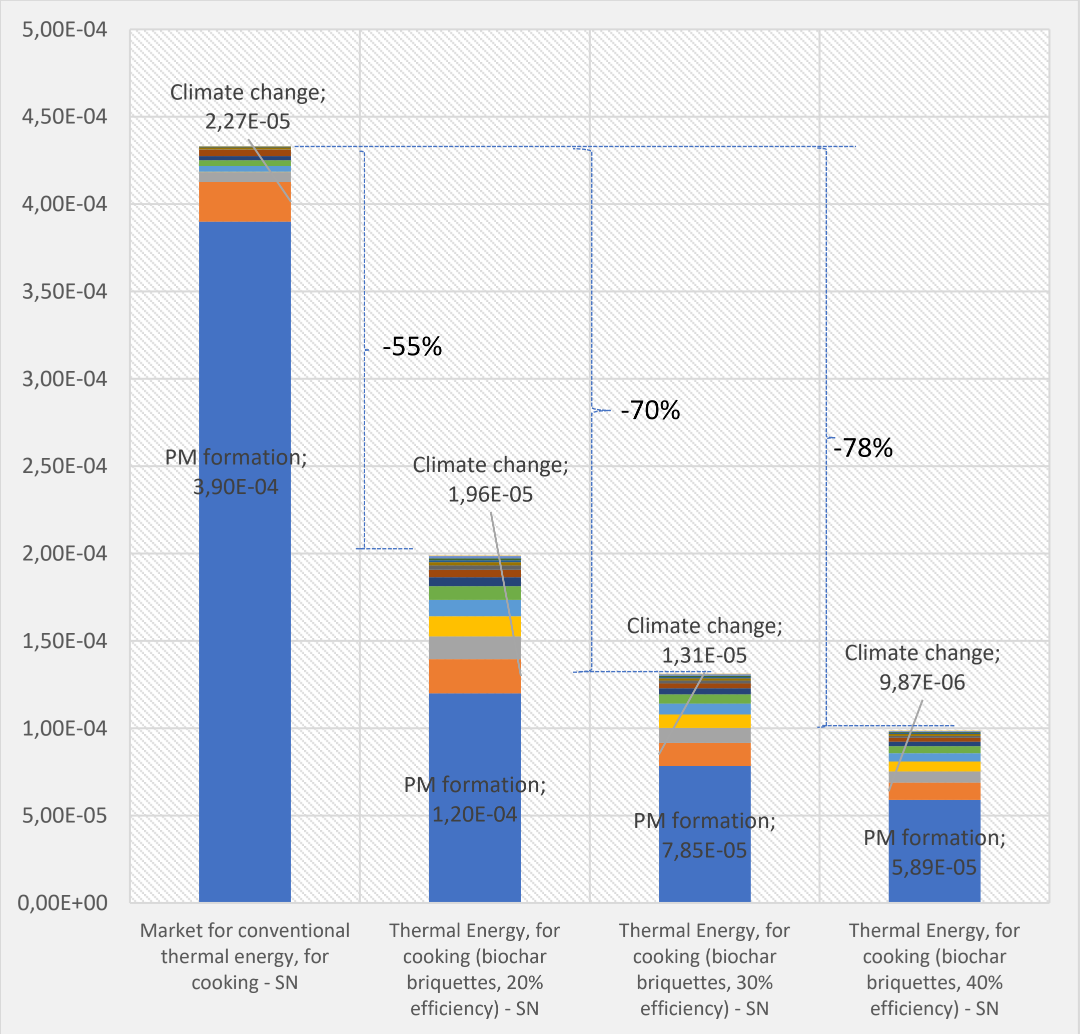
System 2 LCA Results

- Comparing 1 KWh of thermal energy from biochar briquette (considering different efficiencies) and the Senegalese market mix (total single score)



- A focus on climate change ICs, per 1 KWh of thermal output (from biochar briquette in different efficiencies and the Senegalese market mix) for cooking

Impact categories	Unit	Market for conventional thermal energy, for cooking - SN	Thermal Energy, for cooking (biochar briquettes, 20% efficiency) - SN	Thermal Energy, for cooking (biochar briquettes, 30% efficiency) - SN	Thermal Energy, for cooking (biochar briquettes, 40% efficiency) - SN
Climate change	kg CO2-Eq	0.81373	0.70217	0.46967	0.35399
Climate change: biogenic	kg CO2-Eq	0.20024	0.36854	0.24549	0.18427
Climate change: fossil	kg CO2-Eq	0.22325	0.32286	0.217	0.16433
Climate change: land use and land use change	**kg CO2-Eq**	**0.39024**	**0.01077**	**0.00718**	**0.00539**

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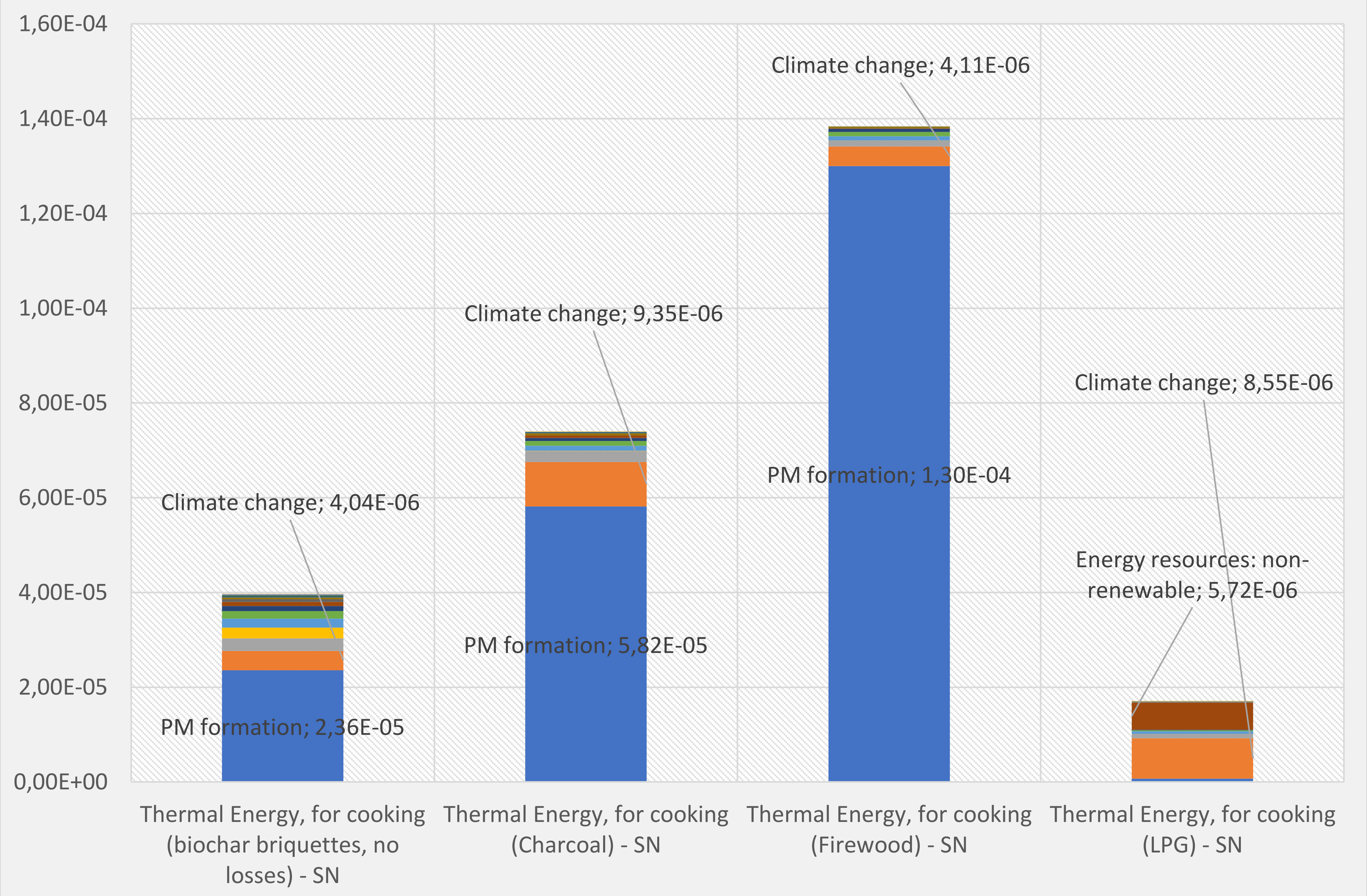
System 2 LCA Results

- Total single score, per 1 KWh of thermal output for cooking per different source (no losses considered)



- For all sources, PM and climate change are the most significant ICs (exception: LPG, low PM, high RUff)
- Best performing is LPC, followed by biochar briquette (≈x2 the total impact of LPG). Then, charcoal follows (≈x4 the total impact of LPG), and firewood (≈x8 the total impact of LPG)

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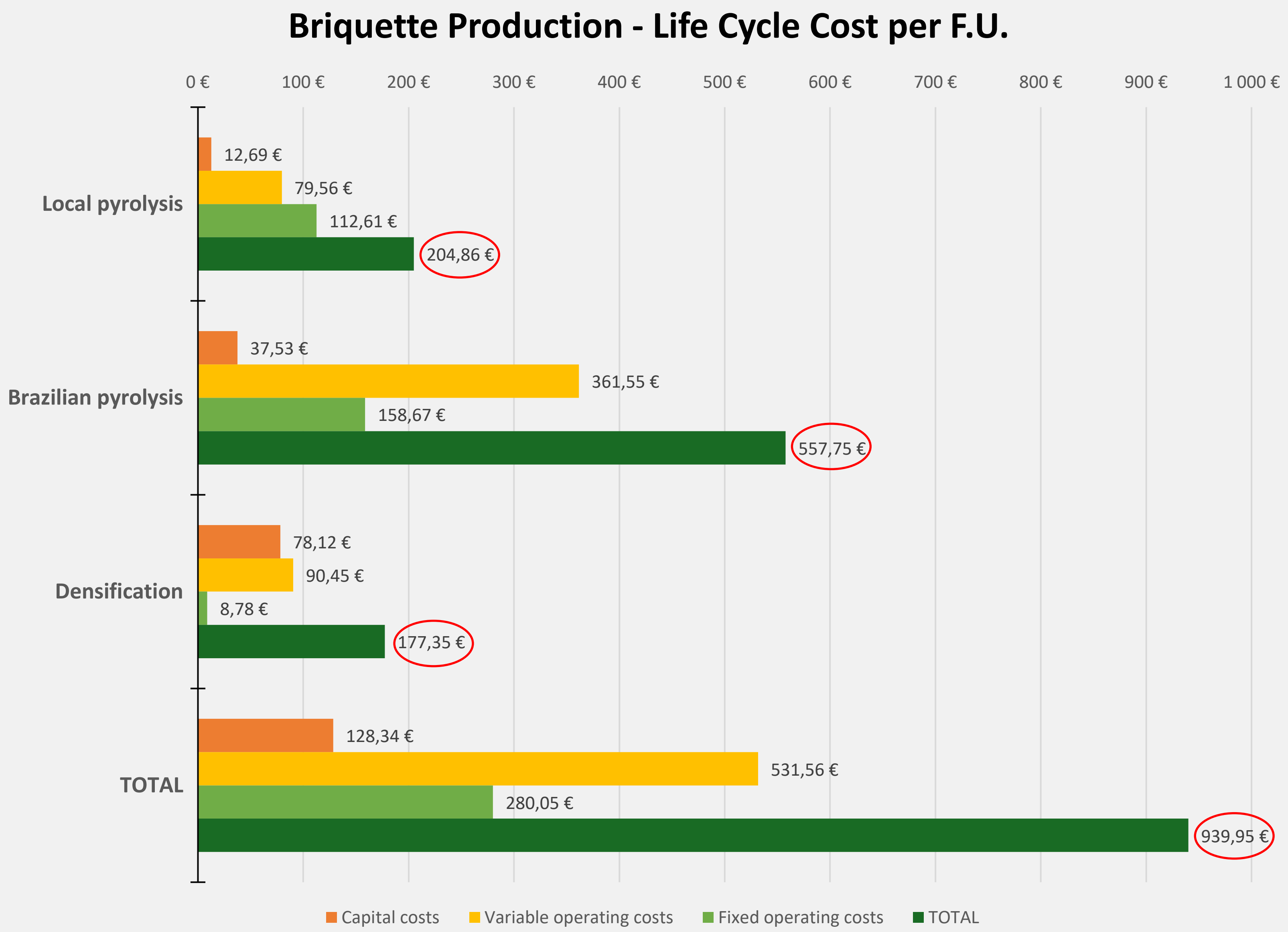
System 2 LCC Results



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System 2 – Key Takeaways

- Most impacts for the biochar briquette occur in the biochar briquette (emissions) combustion and pyrolysis processes (feedstock and emissions) **(LCA)**
- Thermal energy from biochar briquettes performs much better than the average thermal energy of the Senegalese market mix due to lower PM emissions, and lower CC-LULUC. Charcoal and firewood production in the Senegalese market mix for thermal energy leads to deforestation (and related CC impacts). This is not the case for briquette thermal energy, as it valorizes agricultural residues **(LCA)**
- Increased efficiency of combustion and cooking appliances that contain/filter PM particles may lead to even better environmental performance for the biochar briquette **(LCA)**
- Taking all considered sources of thermal energy into account (without losses), the biochar briquette performs much better than firewood and charcoal, and falls a bit behind LPG, mainly due to the production of PM particles during combustion **(LCA)**
- The brazilian pyrolysis stage is the costliest, followed by the local pyrolysis (21,8%) and densification (19%). Most costs are attributed to variable operating expenses, primarily driven by the cost of raw materials. **(LCC)**

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Status and way forward

- 3 technologies (Green Biorefinery, Pyrolysis, densification) and 2 countries (Uganda, Senegal) already covered

- LCA, LCC, S-LCA studies for Ghana and Cote D'Ivoire already underway, and to be finalized soon

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