Lignocellulosic conversion to ethanol:
the environmental life cycle impacts

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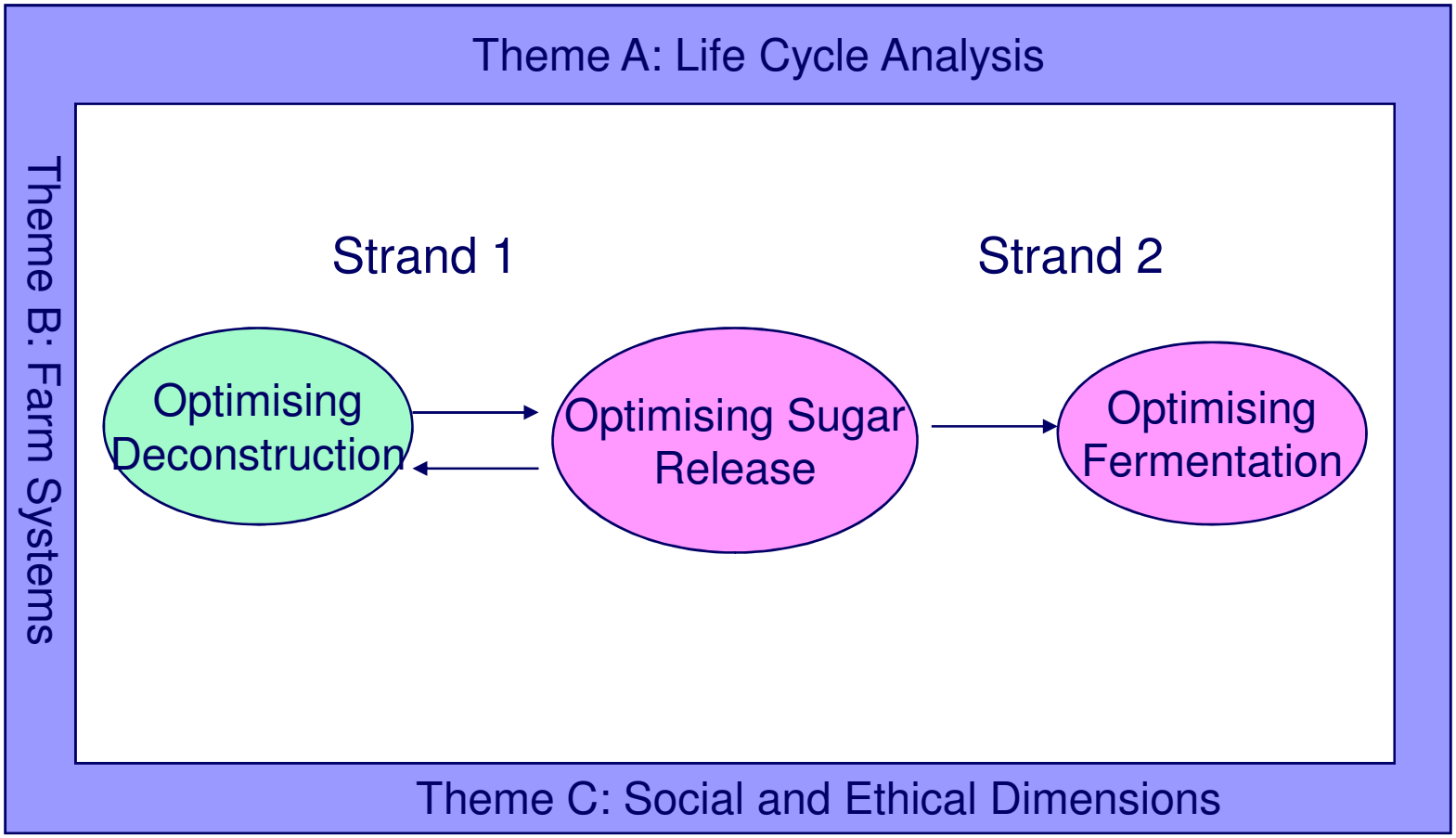
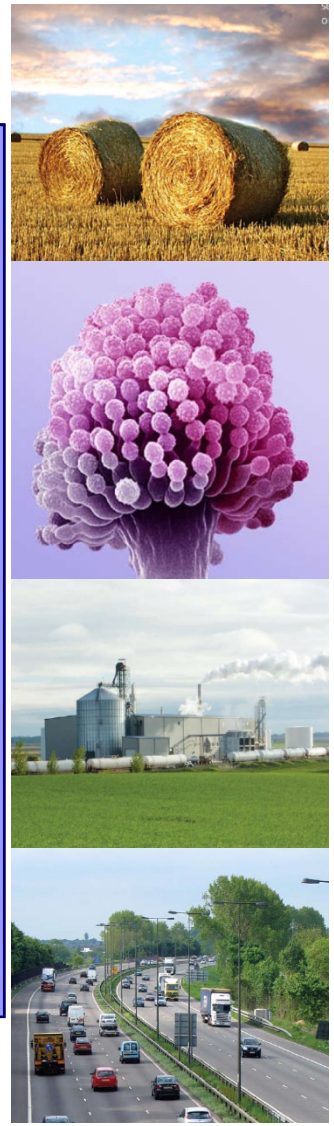
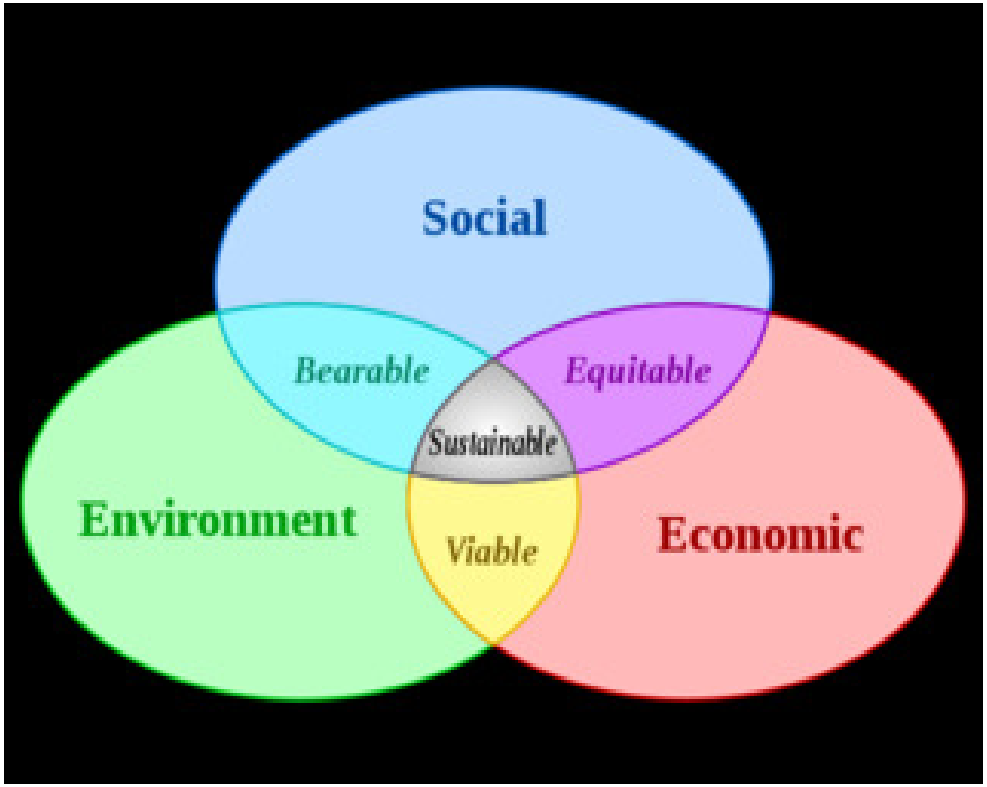
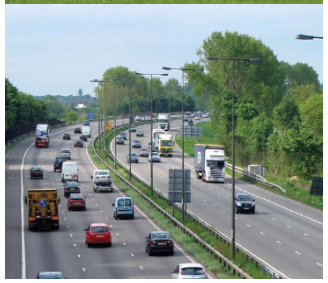
Programme LACE: Lignocellulosic Conversion To Ethanol





Sustainable biofuel





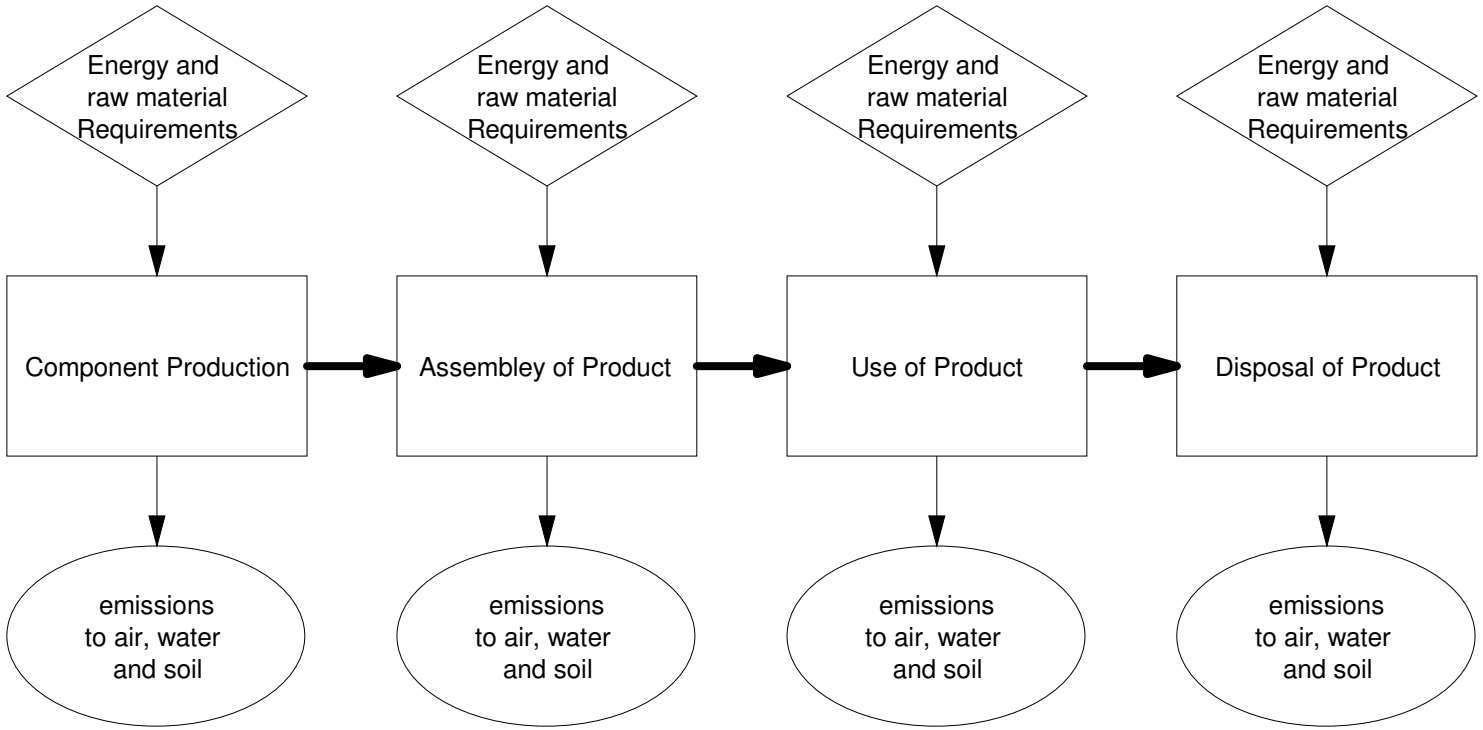
Sustainable biofuel

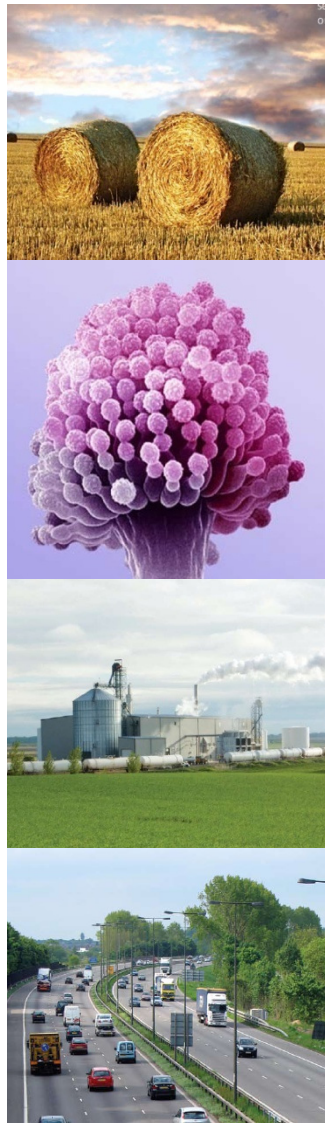
- Energy analysis;
- Environmental life-cycle assessment (LCA), assessed in terms of various pollutant emissions;
- Integrated appraisal of biofuel chain




Life cycle assessment

LCA is an environmental management tool to determine the environmental impact of a product or system over its whole life – from production, through use and to recycling, reuse or disposal (from “the cradle to the grave”).





Life cycle assessment

METHODOLOGY

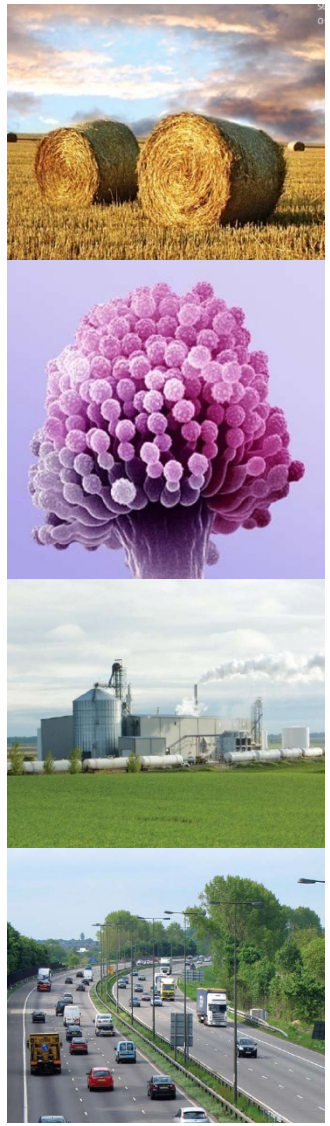
- In an LCA study, the energy and materials used, and pollutants or wastes released into the environment as a consequence of a product or activity are quantified over the whole life-cycle, 'from cradle-to-grave'.

STANDARDS

- ISO 14040 series – Environmental Life Cycle Assessment
- PAS 2050 – Life Cycle GHG Emissions of Goods & Services

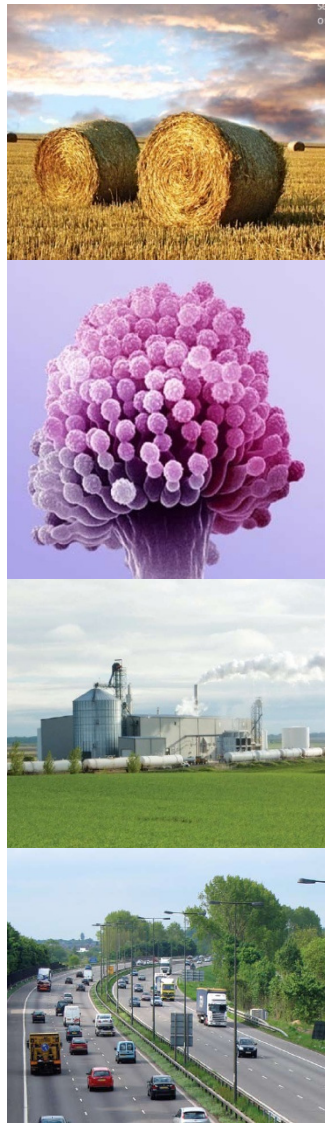
DATABASES

- Ecoinvent
- Bath - Inventory of (*Embodied*) Carbon and Energy [ICE]



LCA Stages

- Goal Scoping
- Inventory
- Impact Assessment
  - Classification
  - Characterisation
  - (Normalisation)
  - (Valuation)
- Improvement Assessment – Interpretation

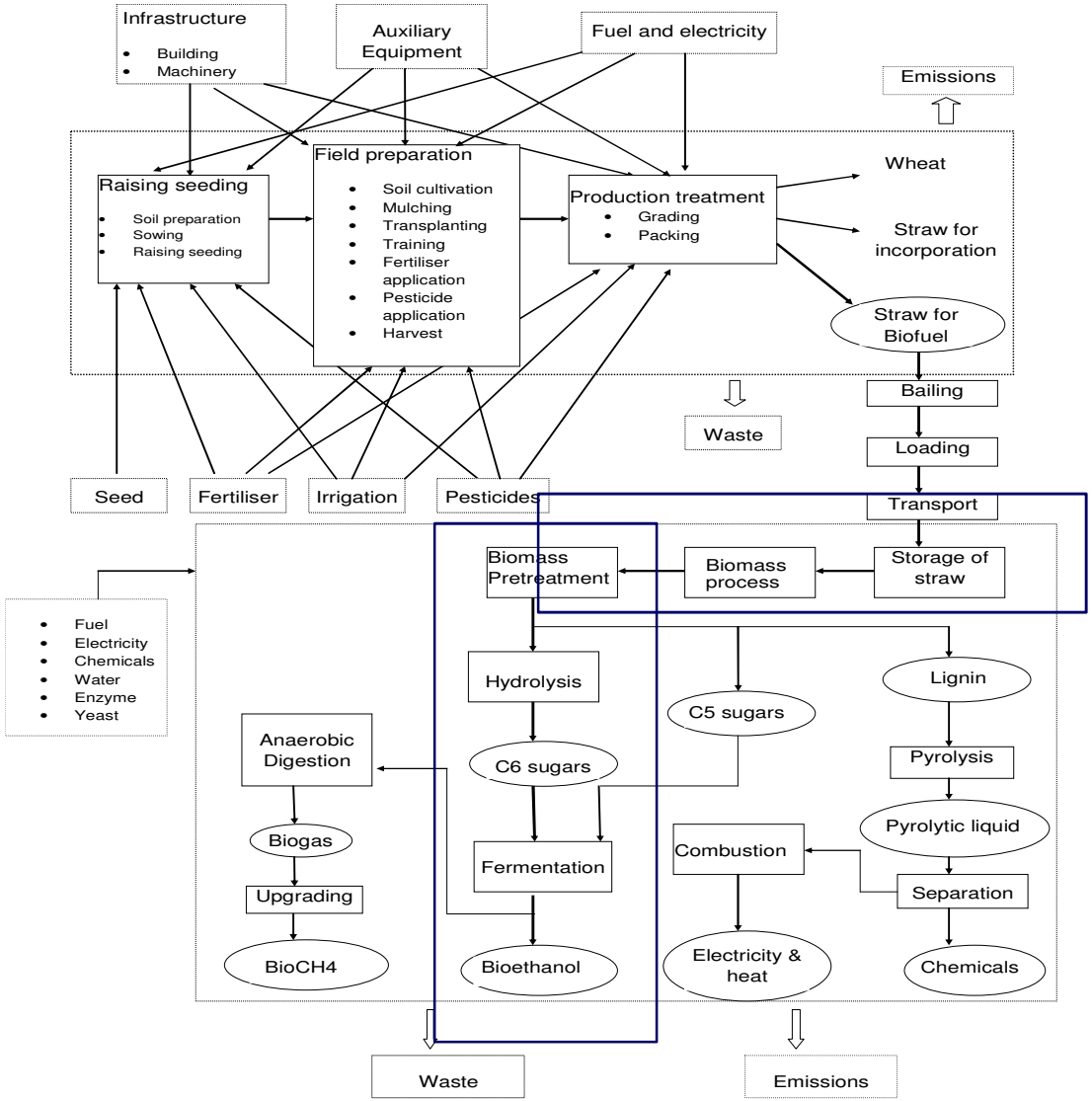


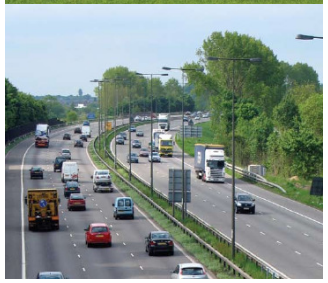
The Biofuel Life-Cycle

- Crop harvesting > Processing > End Use

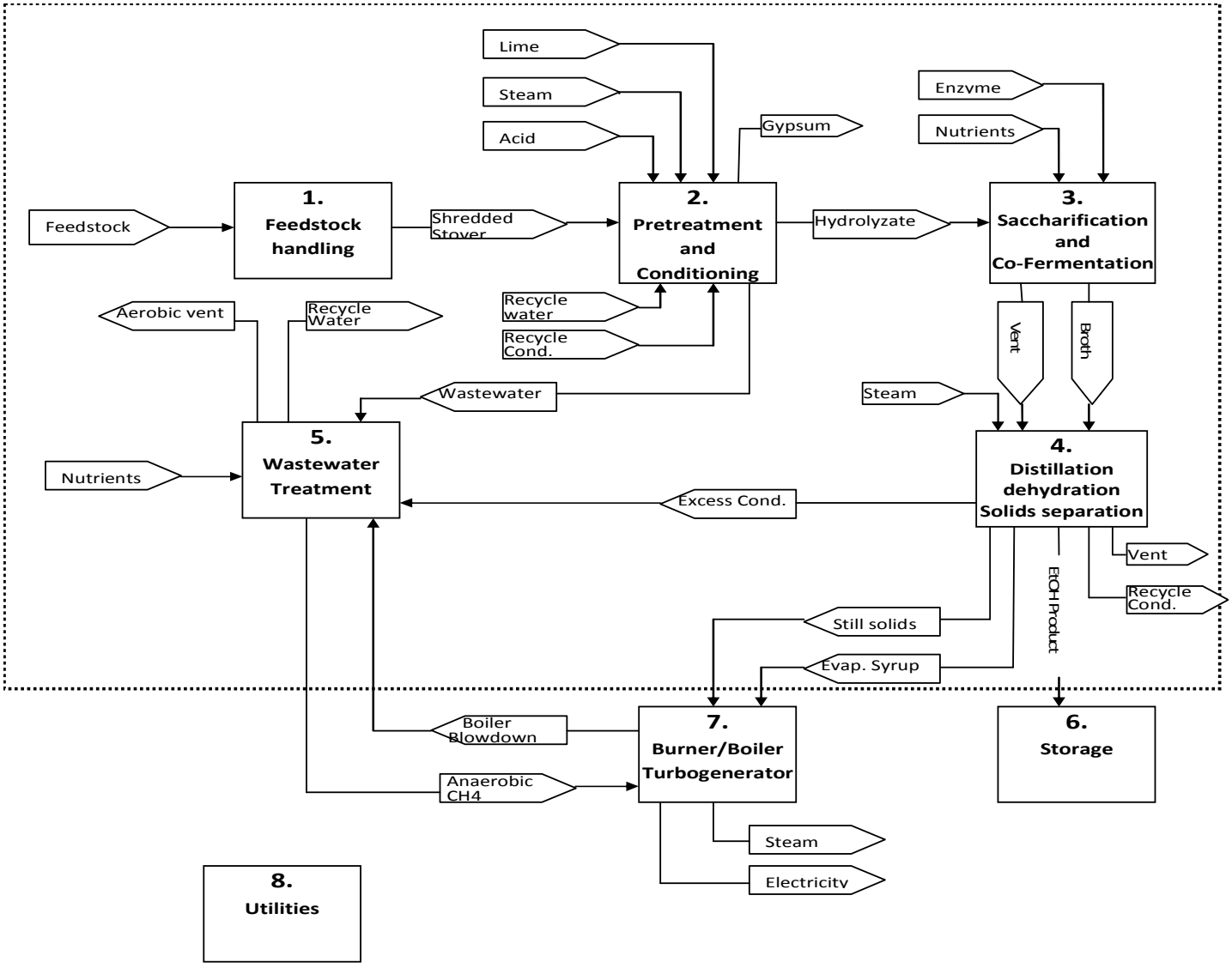
- Fossil fuels are used in the harvesting and processing of the crop, and in transporting between stages.

Lignocelluloses to ethanol

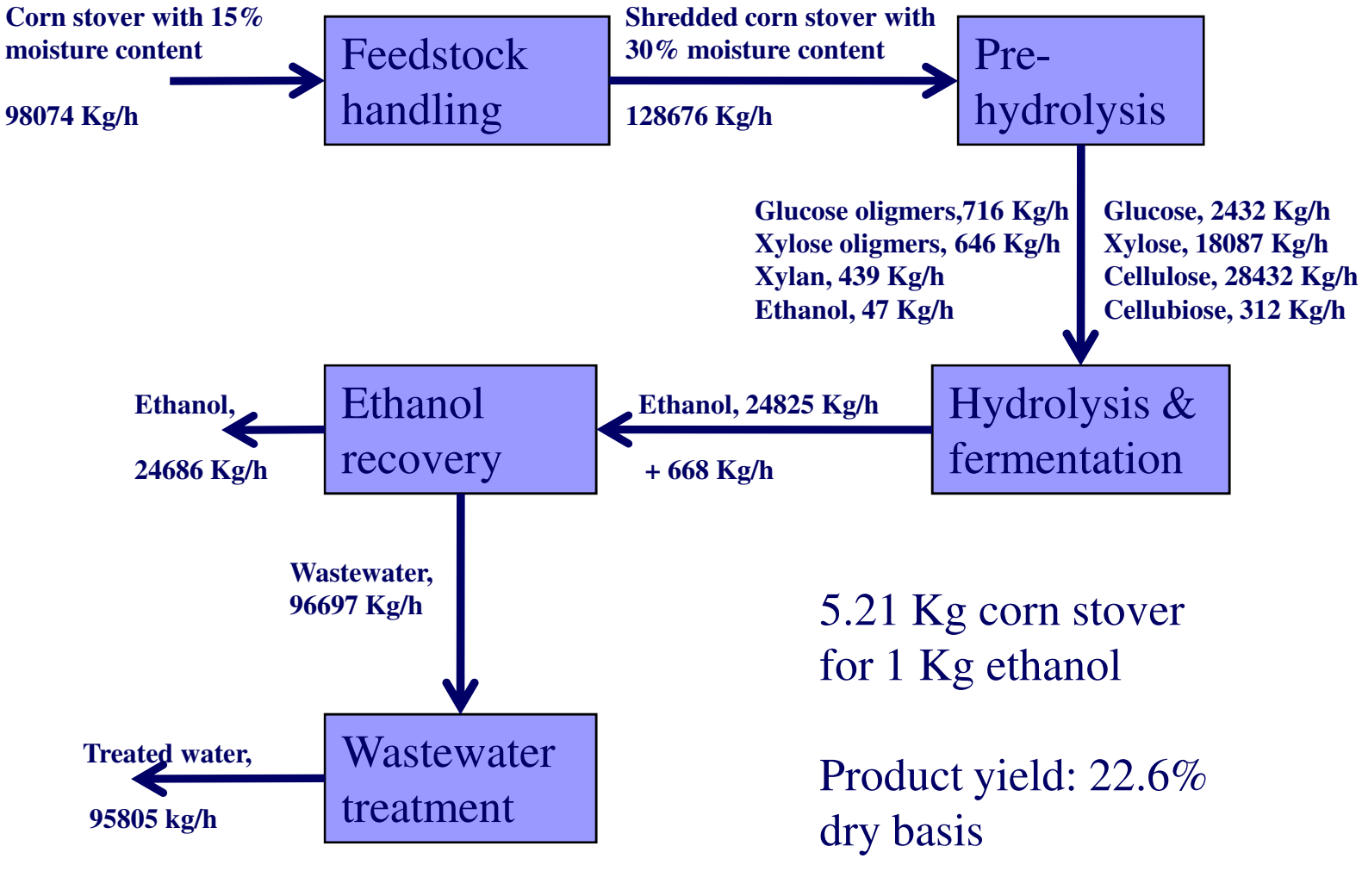




Ethanol conversion process



Material flow



5.21 Kg corn stover for 1 Kg ethanol

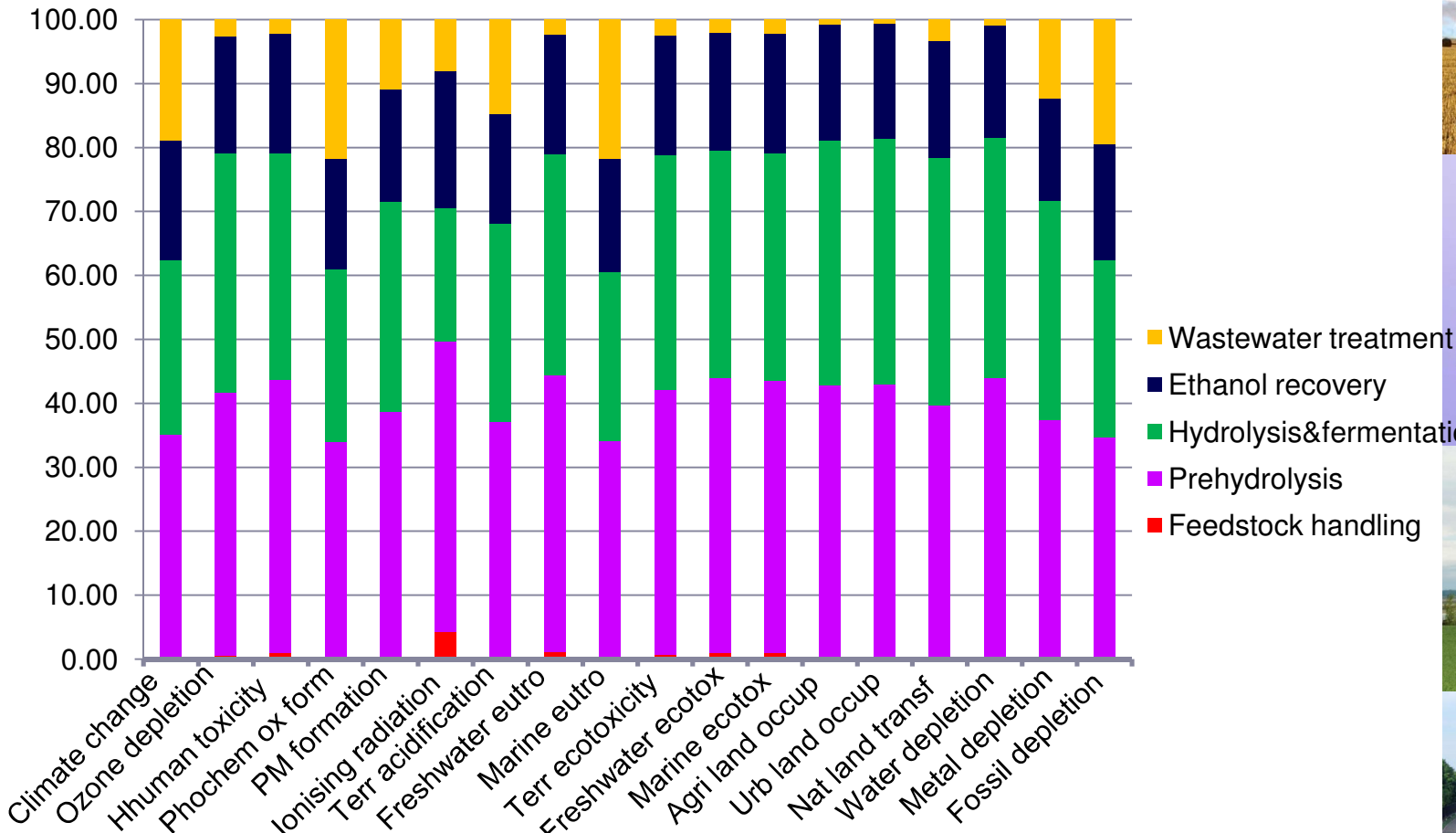
Product yield: 22.6% dry basis

Characterisation results

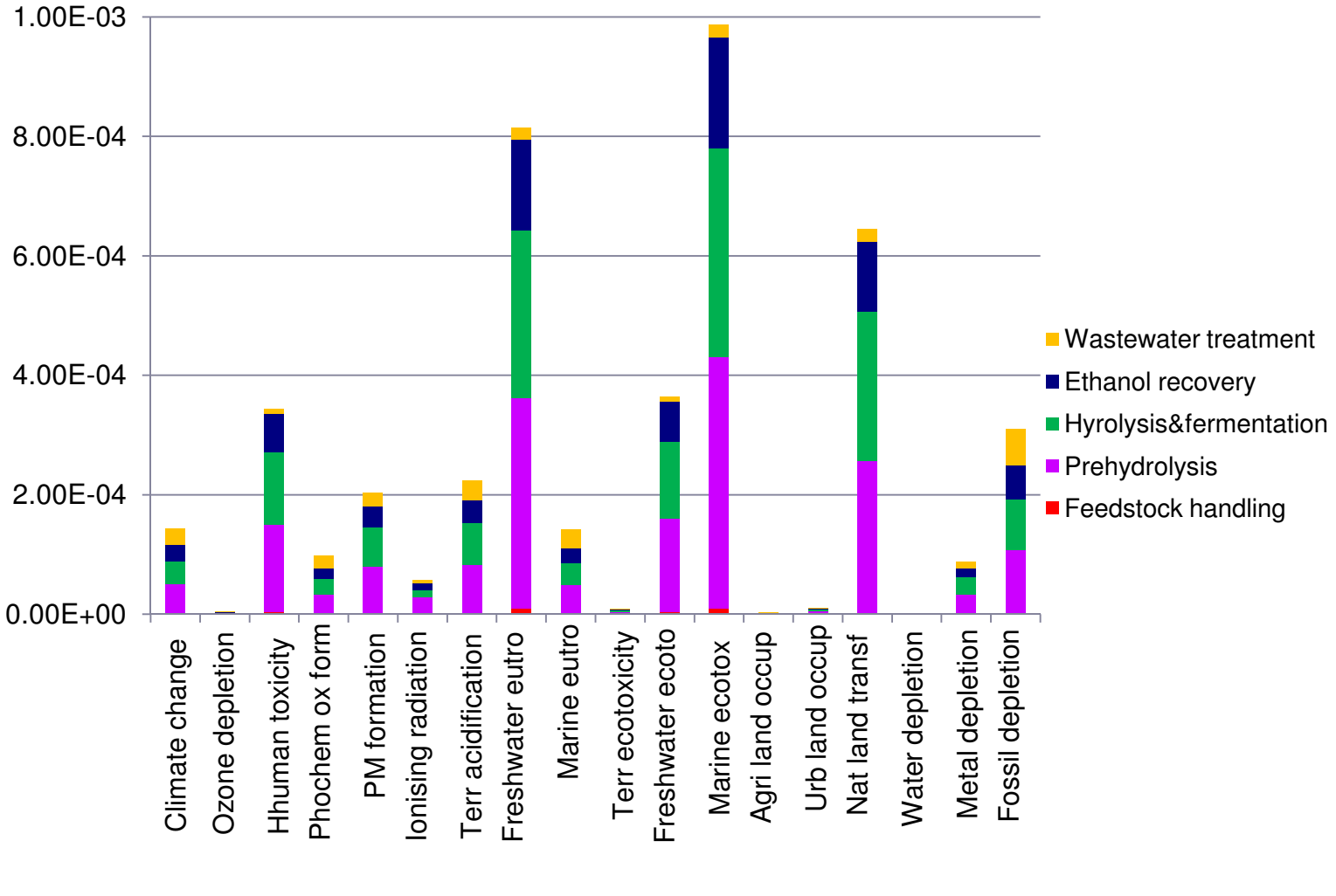
Impact category	Unit	Total	Feedstock handling	Prehydrolysis	Hydrolysis & fermentation	Ethanol recovery	Wastewater treatment
Climate change	kg CO2 eq	1.61E+00	0.002892	5.62E-01	4.38E-01	2.99E-01	3.04E-01
Ozone depletion	kg CFC-11 eq	7.56E-08	4.04E-10	3.11E-08	2.82E-08	1.38E-08	2.04E-09
Human toxicity	kg 1,4-DB eq	2.08E-01	0.002116	8.86E-02	7.37E-02	3.90E-02	4.52E-03
Photochemical oxidant formation	kg NMVOC	5.50E-03	6.5E-06	1.86E-03	1.49E-03	9.47E-04	1.20E-03
Particulate matter formation	kg PM10 eq	3.04E-03	4.41E-06	1.17E-03	9.97E-04	5.31E-04	3.32E-04
Ionising radiation	kg U235 eq	3.53E-01	0.015195	1.60E-01	7.39E-02	7.51E-02	2.85E-02
Terrestrial acidification	kg SO2 eq	7.71E-03	1.19E-05	2.85E-03	2.39E-03	1.32E-03	1.14E-03
Freshwater eutrophication	kg P eq	2.05E-04	2.48E-06	8.87E-05	7.06E-05	3.83E-05	4.89E-06
Marine eutrophication	kg N eq	1.76E-03	2.53E-06	5.98E-04	4.67E-04	3.13E-04	3.83E-04
Terrestrial ecotoxicity	kg 1,4-DB eq	6.84E-05	4.69E-07	2.83E-05	2.52E-05	1.28E-05	1.68E-06
Freshwater ecotoxicity	kg 1,4-DB eq	3.94E-03	3.88E-05	1.69E-03	1.40E-03	7.31E-04	7.83E-05
Marine ecotoxicity	kg 1,4-DB eq	4.08E-03	3.98E-05	1.74E-03	1.45E-03	7.63E-04	8.82E-05
Agricultural land occupation	m2a	1.38E-02	5.24E-05	5.84E-03	5.27E-03	2.49E-03	1.07E-04
Urban land occupation	m2a	4.34E-03	1.18E-05	1.86E-03	1.67E-03	7.75E-04	3.03E-05
Natural land transformation	m2	1.04E-04	4.07E-07	4.11E-05	4.04E-05	1.91E-05	3.47E-06
Water depletion	m3	2.99E-02	0.000103	1.31E-02	1.12E-02	5.28E-03	2.63E-04
Metal depletion	kg Fe eq	6.24E-02	0.000159	2.31E-02	2.14E-02	9.96E-03	7.73E-03
Fossil depletion	kg oil eq	5.88E-01	0.000844	2.03E-01	1.63E-01	1.07E-01	1.15E-01

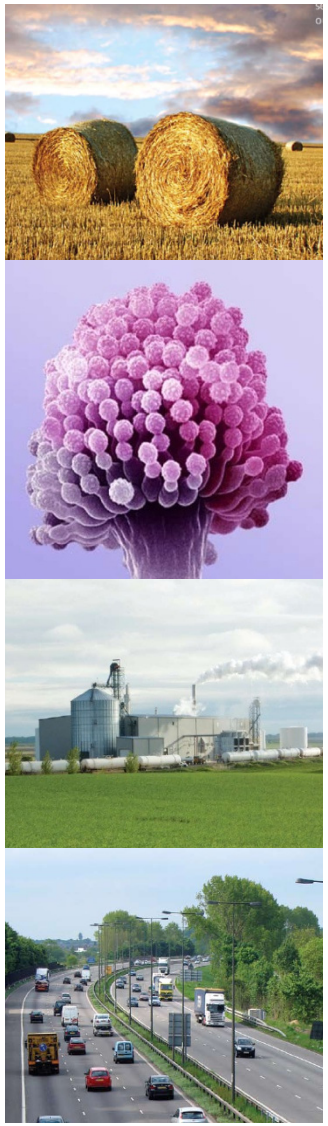



Characterisation results



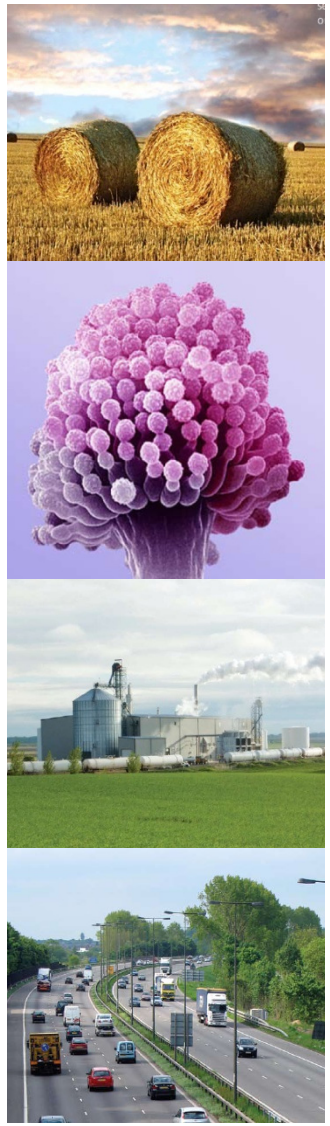
Normalisation results





Conclusions

- An LCA analysis of ethanol conversion process was carried out taking account of feedstock handling, pre-hydrolysis, hydrolysis and fermentation, bioethanol recovery, and wastewater treatment.
- Among the ethanol conversion processes, the pre-hydrolysis step contributes significantly to the environmental burdens.
- The use of sulphuric acid and process steam, as well as electricity, are identified as the main sources for the environmental burdens that contribute to climate change and ozone depletion.



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Thank You for Your Kind Attention

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The University of Nottingham

Impact assessment method
ReCipe