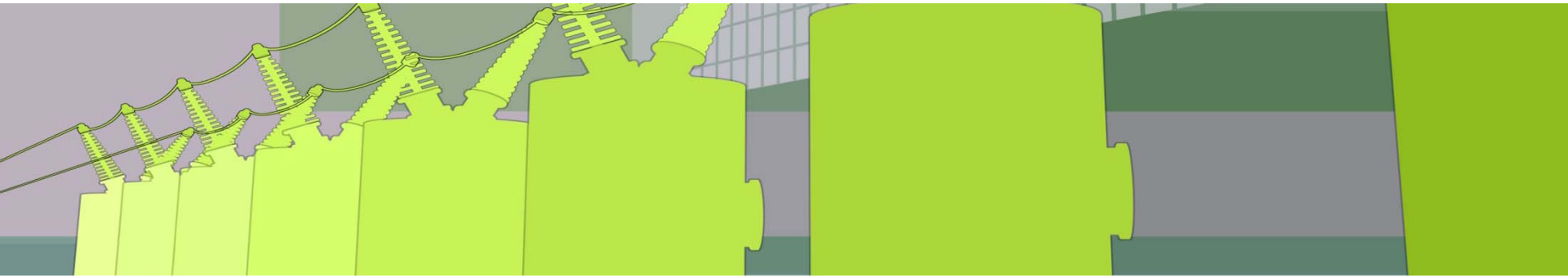

Systematic Review of Life Cycle Analysis for Bioenergy and Biofuels

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March 08,

Outline

- Brief introduction to LCA
- Need for LCAs
- Problems with current LCAs
- Aims of current review
- Methods used
- Conclusion and recommendations

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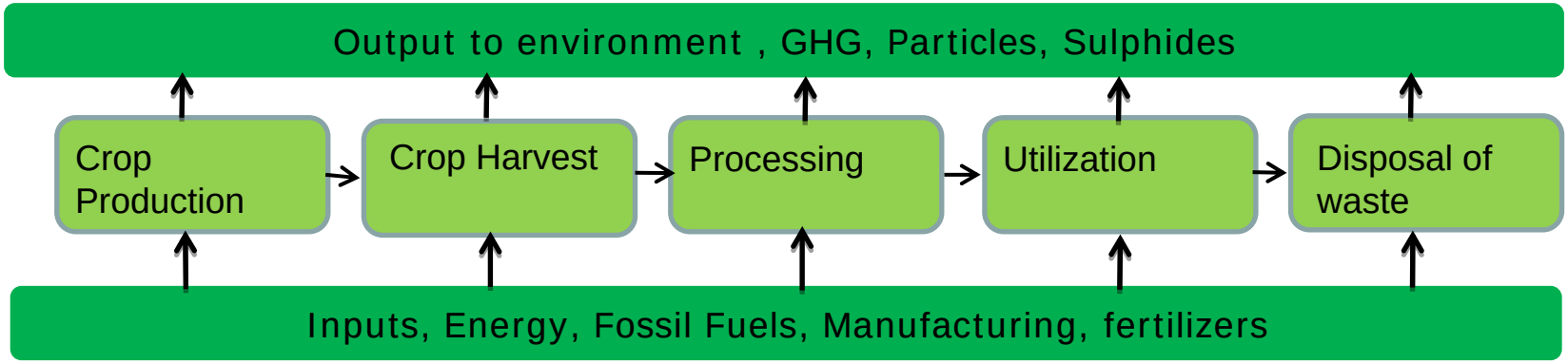
Life Cycle Analysis

- Life Cycle Analysis: A Cradle to Grave assessment of the environmental impact of a product.



- Impact Categories
  - Global warming potential
  - Energy conservation
  - Acidification
  - Smog
  - Ozone layer depletion
  - Human-toxicological pollutants
  - Eutrophication
  - Eco-toxicological

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ISO 14040 (2006): Environmental management - Life cycle assessment -Principles and framework, International Standard Organization (ISO), Geneve
ISO 14044 (2006): Environmental management - Life cycle assessment -Requirements and guidelines, ISO, Geneve

Role of LCAs in Bioenergy

- Accreditation of Sustainability
  - Allow assessment and comparison of all impact
  - Global warming potential
    - The Roundtable on Sustainable Biofuels, “Biofuels shall contribute to climate stabilization by reducing GHG emissions as compared to fossil fuels”. Assessed by LCA.
- Production chain improvements

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Aims and Problems

- The primary aim of this review is to compare GHG emission and energy efficiencies of bioenergy (heat and power) and biofuels in the UK context
- Reported figures in LCA however vary widely making simple direct comparison of final figures unreliable
  - LCA report in a range of figures, gCO_2 equiv. /MJ, gCO_2 equiv. /ha/yr, gC /KWH
  - Variation in system boundaries selected, and subsection included
  - Variation in conversion efficiencies.

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Secondary Aims

- To devise a **means** to cross compare the impacts of different methods of energy production, be it for transport fuel, heat or power
- Identify and highlight areas of greatest variation, within method employed.
- To develop a set of guidelines for LCA reporting for the bioenergy sector.

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Method

- Selection of publications
- Extraction of information
- Conversion of all units to comparable form
- Formation of summary figures between which comparisons can be made.
- Explanation and development of recommendations

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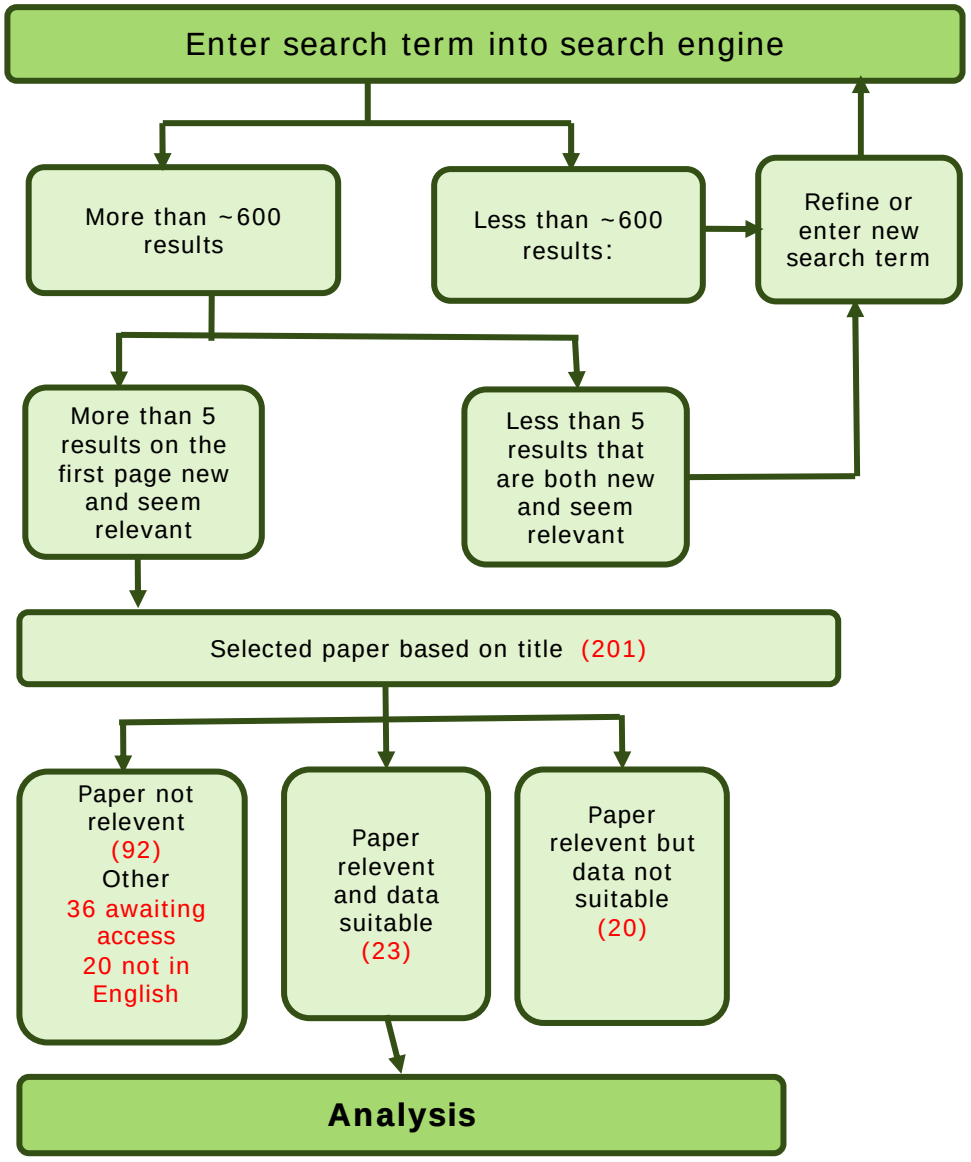
Selection of Publication



Search Terms	
Bioenergy	**Liquid Transport fuels**
life cycle +bioenergy	Life cycle
lifecycle +Biomass	LC*
LCA + Biomass	Externalities
LCA +Bioenergy	Biofuel
LC* +Biomass	Alternative fuel
LC* +Bioenergy	Bioethanol
Externalities	Biobutanol
Externalities +biomass	Biodiesel
Externalities +bioenergy	Ethanol fuel
balance +energy +carbon +GHG	E85
Balance +energy +carbon +biomass	Balance (+energy, + carbon, +GHG)
Balance +energy +carbon +Bioenergy	Budget (+energy, + carbon, +GHG)
budget +energy +carbon +biomass	Impact (+energy, + carbon, +GHG)
budget +energy +carbon +bioenergy	Cradle to (+energy, + carbon, +GHG)
impact +energy +carbon +GHG	Footprint (+energy, + carbon, +GHG)
Cradle to +energy +carbon +GHG	Markal
Cradle to +energy	+emissions
Cradle to +biomass	+sustainability
footprint +energy +carbon +GHG	+audit
footprint +energy +bioenergy	+inventory
footprint +energy +biomass	+environmental
footprint +energy +carbon	

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Extraction and Conversion

- Visual Summaries of System boundaries of each paper/report were created.
- Figures convert to:
  - gCO_2 equiv.MJ^{-1} of fuel (biodiesel ready for use, or woodchips ready for use)
  - Energy requirements (Fossil energy **in**/fuel energy **out**)
- Examples:

  100g CO_2MWH^{-1} /3600 = 0.027g $CO_2MJ^{-1}_{fuel}$

  100g $CO_2MJ^{-1}_{elec}$ X 36%(conversion efficiency of plant)= 36 CO2 MJ^{-1}_{fuel}.

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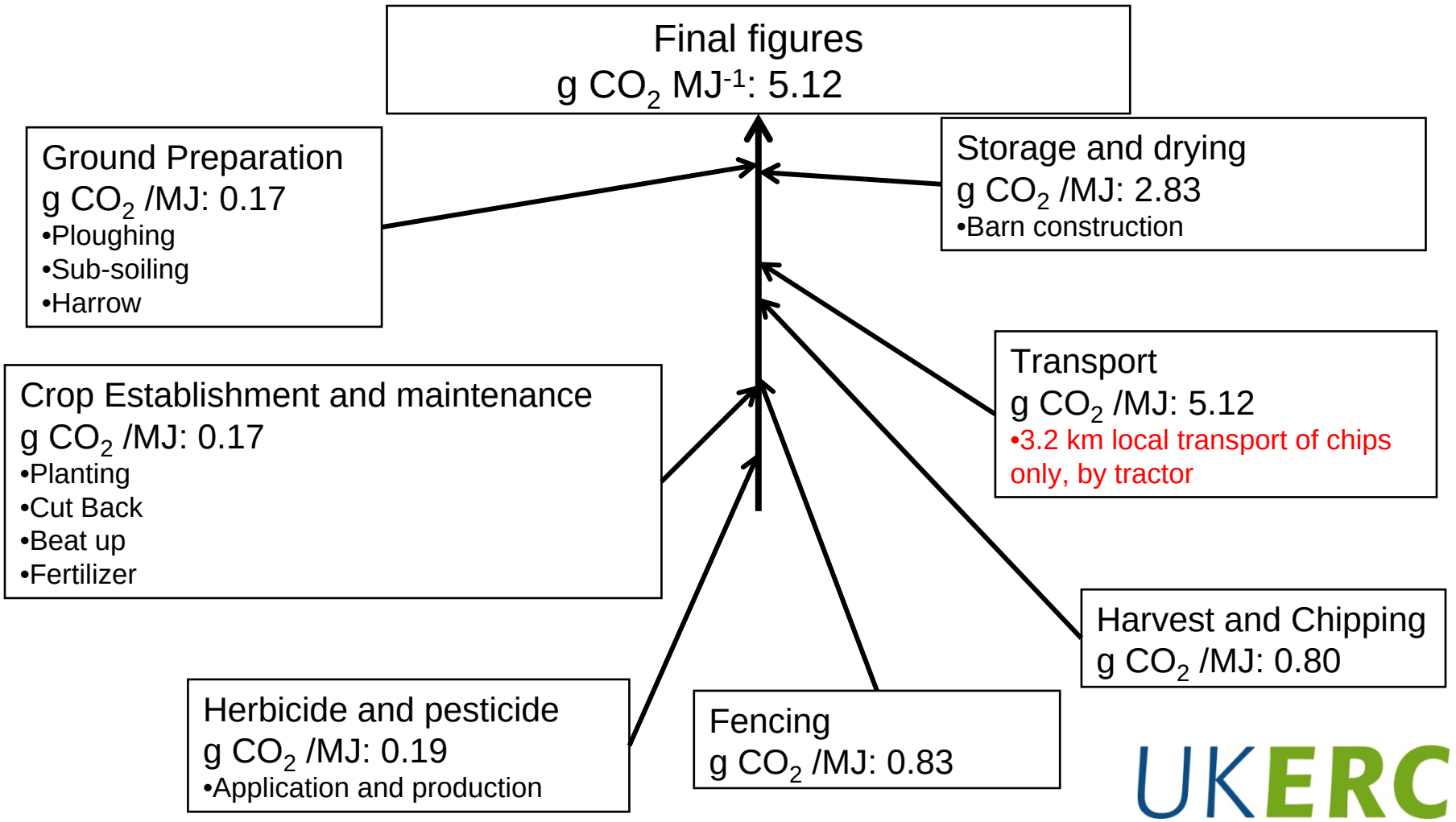
R.W. Matthews: Modelling of energy and carbon budgets of wood fuel coppice systems Biomass and Bioenergy 21 (2001) 1–19

Biomass production only of SRC assuming 5ha field, 10 000 stools ha-1, 3 cutting cycle, 16y coppice life, yield 8 ha-1 yr-1 in year one, 12 odt ha-1 yr-1 for all subsequent cycles.



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Dubuisson et al :Energy and CO_2 Balances in different power generation routes using wood fuel from short rotation coppice. Biomass and Bioenergy 15 (4-5) 379-390. 1998

Three production methods low, medium and high considered and three conversion method small scale electricity only, CHP and co-firing (yields low 10 ODT ha^{-1} yr^{-1}, medium 12 odt ha^{-1} yr^{-1}, High 15 odt ha^{-1} yr^{-1},) 25 year life cycle

Utilization

	CO_2/MJ
Peak power production:	**26.41**
Local CHP:	**10.64**
Co Firing:	**44.01**

•Construction included but water use and chemical used during conversion excluded
•Low energy ratio explained in paper.

Ground preparation

CO_2/MJ
Medium Input: 3.00

•Fencing
•Ploughing, sub soiling, Harrowing

Crop removal

CO_2/MJ
Medium Input 0.06

Biomass Production, Storage and Transport

CO2/MJ
Medium Input: 9.17 (6.16)
Figures for production only ()

Included in overall figures and in each box below:
•Machinery production (a proportion related to use)
•Fuel/ oil (used plus production cost)

Crop Establishment

CO_2/MJ
Medium Input: 0.19

•Planting, Herbicide, mechanical weeding, cut back

Regional Transport

CO_2/MJ
Medium Input: 1.40
30km by truck

Storage and drying

CO_2/MJ
Medium Input: 1.42
•Forced ventilation

Crop maintenance

CO_2/MJ
Medium Input: 1.87
•Herbicide
•Fertilizer

Harvest and chip

CO_2/MJ
Medium Input: 0.97

Local transport

CO_2/MJ
Medium Input: 0.18

•Within farm 5km

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Summary Figures

- 10 supply chain option were defined
  - Bioenergy
    - Woody crops, Grasses, Forestry residue and Waste (includes Biogas production)
  - Biofuels
    - Bioethanol wheat, Bioethanol Sugar beet, Lignocellulosic ethanol, Biodiesel Oilseed rape, biodiesel waste oil, Fischer Tropsch biodiesel from wood
- Summary slides showing GHG emission and energy requirements for each chain are to be produced.

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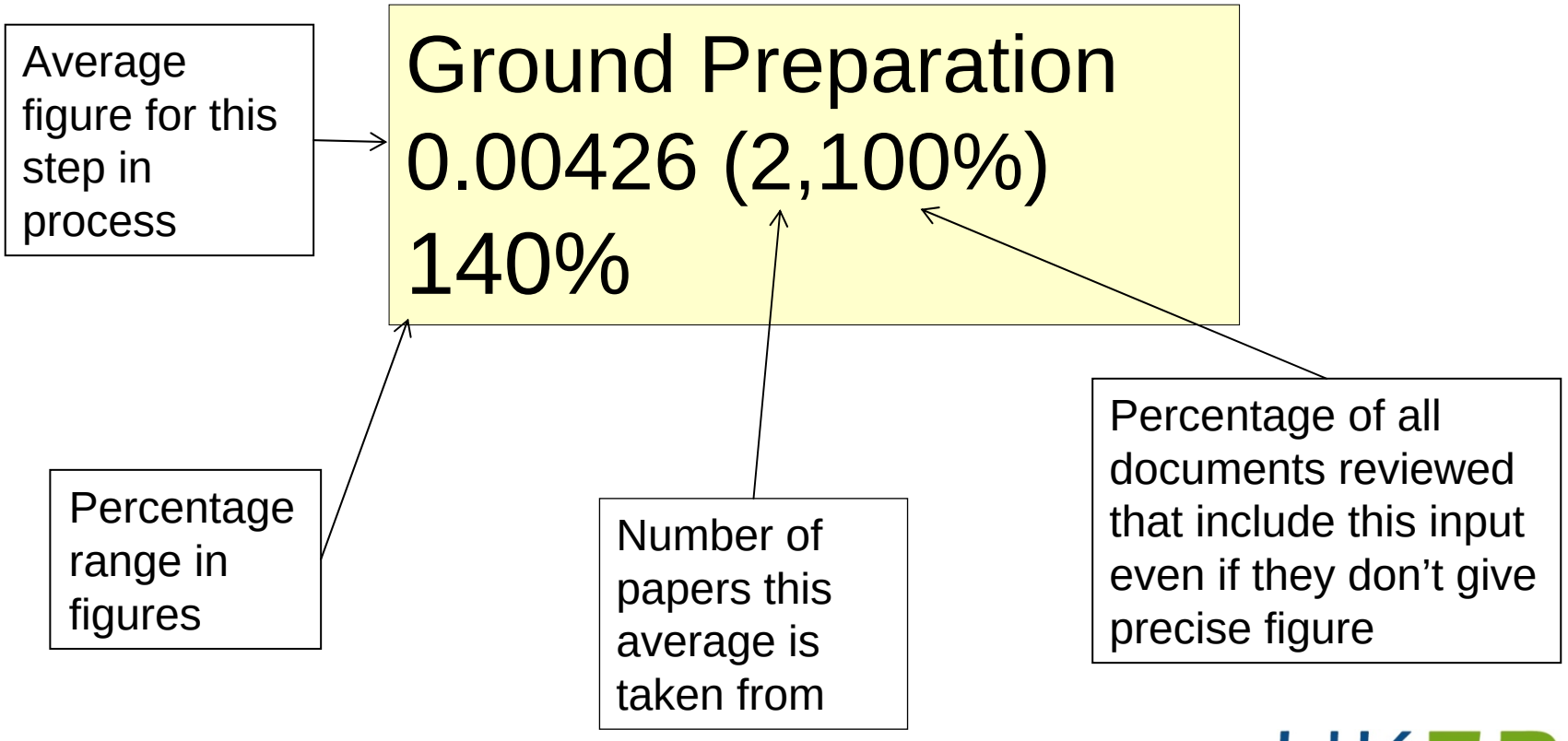
Summary Figures Data



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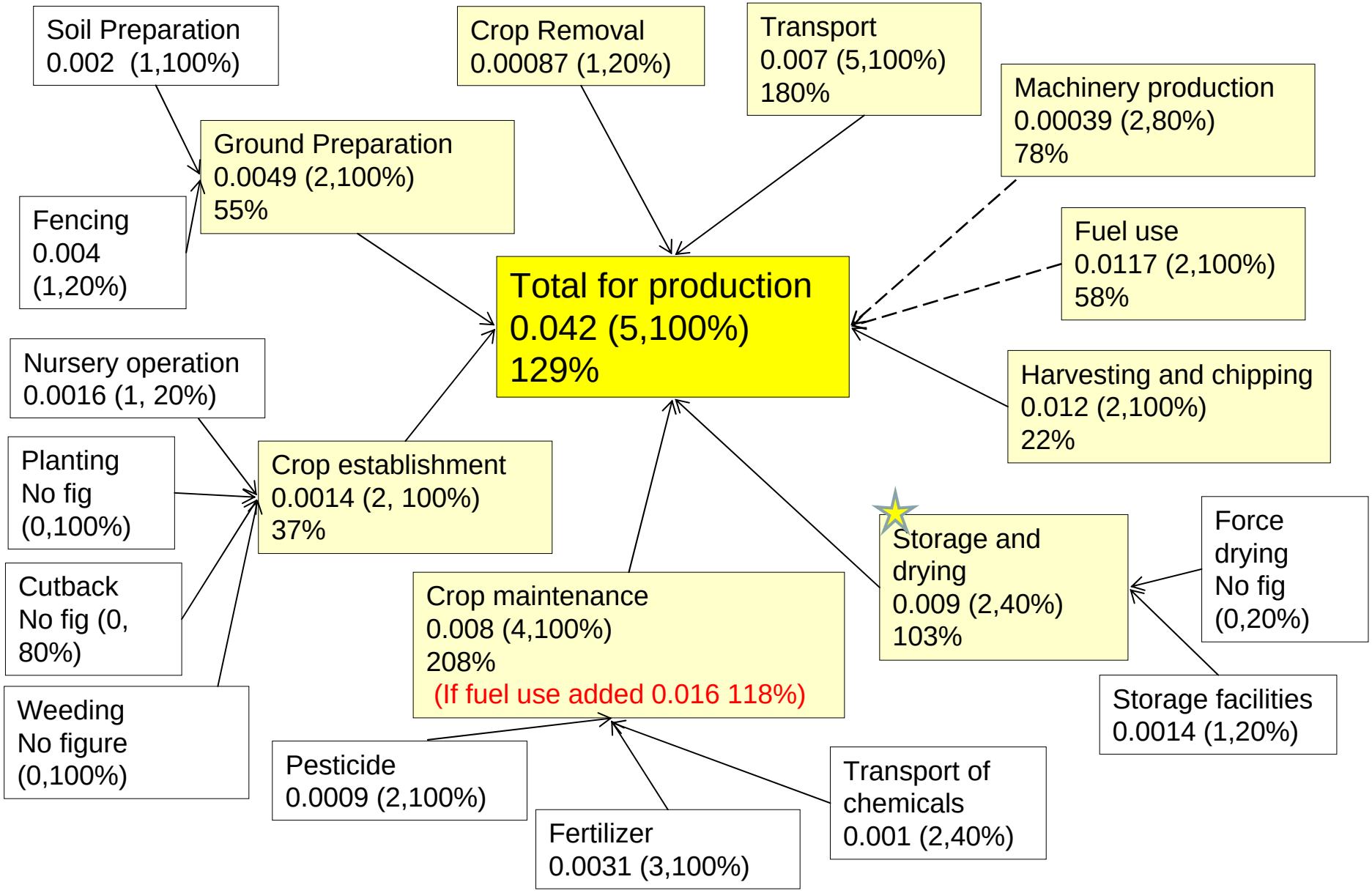
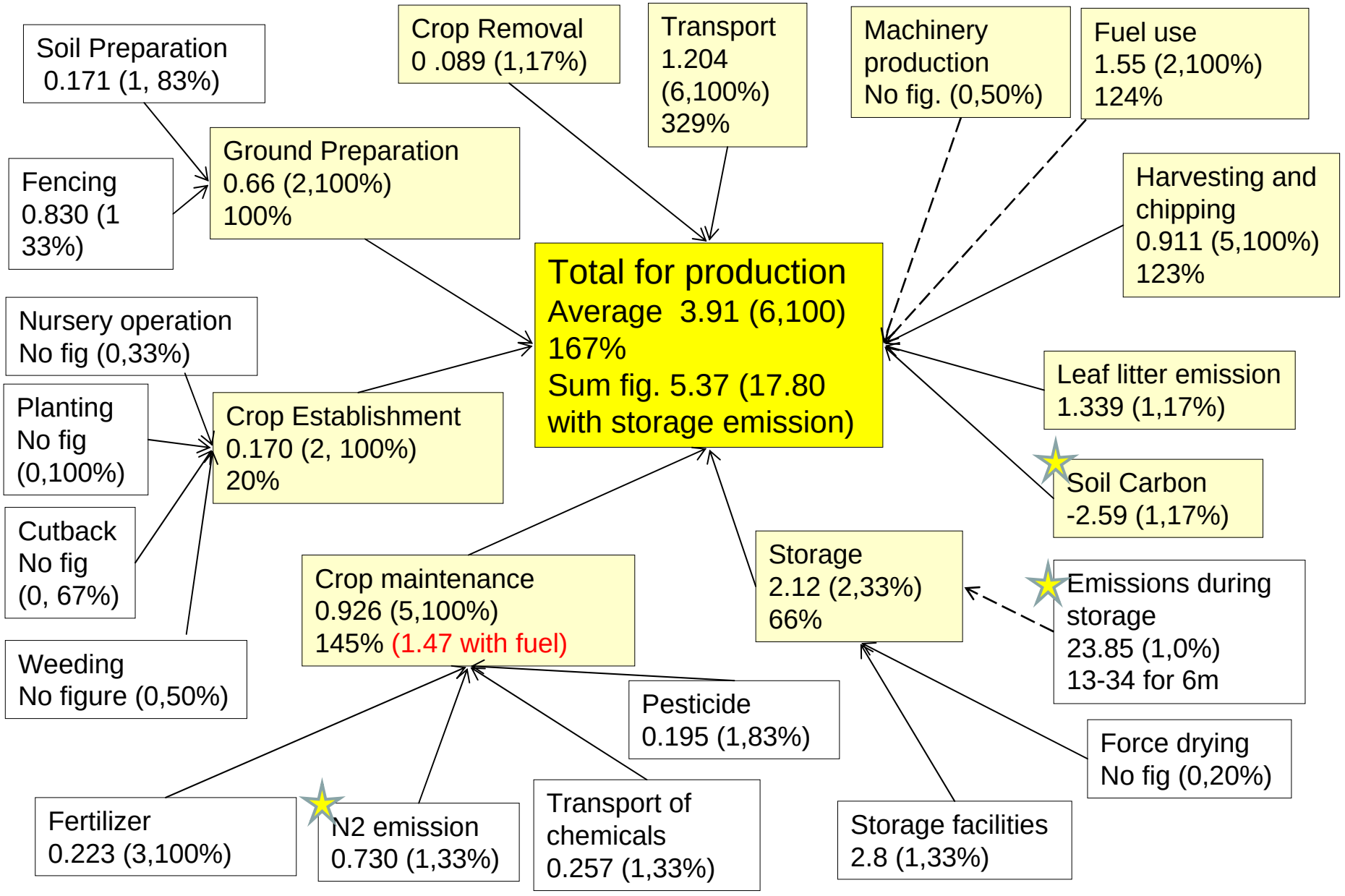
Energy requirement Summary figure Woody crops production

Total number of papers: 5



GHG Summary slide Woody crops production (g CO_2 equiv. MJ^{-1} fuel)

Total number of papers: 6



Conversion of energy crops

Conversation method	**Number of papers**	**Conversion efficiency** %	**Final Figures (form paper)** MJin:MJout	**Cost of plant construction and maintenance** MJin:MJout	**Estimate energy requirement based on "average" production** MJin:MJout
Gasification	3	37.2 – 36%	0.08-0.0643	Taken from LCA	= (production-construsction) / conversion efficiency
Biomass Burner	1	27.7	0.10		
Co -Firing	3	33.17-35.14	2.93-2.92 0.184		
CHP	1	64.1	0.088		
Coal reference		33.7	3.8981		

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Conclusion

- Comparison between LCA is extremely difficult.
- Large numbers of papers had to be rejected due to lack of transparency
- Even with conversion of units and division of sub-section large variation still exist between LCAs due do differences in expected yield, fertilizer requirements, storage methods, allocation of co-products, and production methods.
- LCAs do have the potential to aid in the accreditation of biofuels but they will need to be carefully assessed in each case.

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Recommendations

- Give **defined units** that can be mathematically manipulated, such as energy ratio or energy requirement and not weighted values, relative figures or energy savings (without giving original energy/carbon/fossil fuel requirements values!).
- **System boundaries** must be clearly defined.
- For bioenergy **conversion** efficiency of plants should always be stated, as should yield assumptions and time scale of the study.
- Do not give one final figure, but **give figure for sub-systems**, including productions, utilisation and transport (with defined system boundaries).
- **Compare** own figures with published work in same area explaining differences.

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