Good or bad bioenergy? The validity of comparing biomass and biofuels using life cycle assessment

This content has been downloaded from IOPscience. Please scroll down to see the full text.

2009 IOP Conf. Ser.: Earth Environ. Sci. 6 192006

(<http://iopscience.iop.org/1755-1315/6/19/192006>)

View [the table of contents for this issue](#), or go to the [journal homepage](#) for more

Download details:

IP Address: 152.78.150.219

This content was downloaded on 31/03/2014 at 11:10

Please note that [terms and conditions apply](#).

S19.06

Good or bad bioenergy? The validity of comparing biomass and biofuels using life cycle assessment

Jeanette Whitaker(1), K Ludley(1), S Ryder(1), R Rowe(2), J Chapman(2), G Taylor(2), D Howard(1)

(1) Centre for Ecology and Hydrology, Lancaster, UK

(2) University of Southampton, Southampton, UK

Renewable energy technologies should contribute towards the mitigation of climate change impacts through reduction in the emission of greenhouse gases (GHG) such as carbon dioxide. One alternative to fossil fuels is the use of biomass to generate heat, power and liquid transport fuels. Whilst the use of this renewable energy source is rapidly expanding its environmental sustainability and the role that its deployment can play in climate change mitigation has recently been called into question (Crutzen et al., 2008; Searchinger et al., 2008). Life Cycle Assessment (LCA) is one approach that enables the energy requirements, GHG balance and other impacts of bioenergy production chains (biomass and liquid biofuels) to be calculated, and should allow their accurate comparison. However, concerns have been raised that published data on energy and GHG balances of bioenergy show wide variability leading to conflicting conclusions on their environmental sustainability. Objectives: The objectives of this study were three-fold: (1) to complete a systematic review of energy and GHG data from LCA studies of bioenergy; (2) to use the results to compare the relative merits of bioenergy production chains for heat and power with those for liquid transport fuel; and (3) to assess whether LCA provides a valid and accurate comparison of the environmental sustainability of bioenergy, and what the limitations of the method are. Methods: We selected nine bioenergy production chains (defined by feedstock and fuel type, see Table 1) from across the heat, power and transport fuel sectors. A systematic literature review resulted in the selection of ~150 LCA type studies. From these publications, data on energy and GHG balances were systematically calculated for each process step, e.g. fertiliser production and feedstock drying, within each chain. The review included information on the production of the final fuel (e.g. biodiesel or solid biomass), but not on its use. Data were consistently collated and converted into standard units, along with information on the system boundaries and assumptions used in each publication. This rigorous process then enabled a comparison of biomass and biofuels to be made. Results: Results from the analysis revealed that using biomass for heat and power generation results in significantly lower average GHG emissions and energy requirements than using biomass for liquid transport fuels, including both first and second generation biofuels (Table 1). For example, the average GHG emissions from six LCA studies of woody crop biomass for electricity were 4.47 g CO₂ eq MJ⁻¹, whilst the average from 26 studies of bioethanol production from wheat-grain was an order of magnitude higher (61.41 g CO₂ eq MJ⁻¹). Within the transport biofuel chains, 2nd generation fuels (ethanol from wheat straw/woody crops and Fischer-Tropsch diesel from woody crops) had substantially lower average energy requirements and GHG emissions than 1st generation fuels (ethanol from wheat grain and sugarbeet, and biodiesel from oilseed rape). However, whilst the average values appear to present a clear picture of the energy and GHG balances of the various chains, the data are highly variable, particularly for transport biofuels (Table 1). For example the energy requirement for bioethanol from woody crops ranges from -0.19 to 1.5 (Table 1). The variability in all the chains had a number of main sources: (1) the source of electricity and heat used for fuel conversion; (2) variations in cultivation methods and parameters e.g. crop yields and soil N₂O emissions; (3) variable definitions of system boundaries (4) methods of co-product allocation. These factors had major consequences for the interpretation of the chains environmental sustainability. Conclusions: A number of conclusions can be drawn from the average energy and GHG balance figures calculated. We can conclude that using biomass to generate heat and power is significantly more efficient in its energy balance and leads to considerably lower GHG emissions than converting biomass to transport biofuel. We can also conclude that 2nd generation transport fuels have lower average energy requirements and GHG emissions than 1st generation fuels. The data also shows that in the majority of studies biomass and biofuels outperform fossil fuels by a substantial margin in their average GHG and energy balances. However, when the range of values is considered, it is clear that variations in methodology and system boundaries can lead to very large variations in results making these conclusions less clear-cut. Further conclusions which can be drawn are that there are a number of limitations in current LCA studies, particularly in relation to variations in system boundaries, and that there are areas where empirical data is lacking e.g. N₂O emissions from soil. There is global interest in developing a sustainability assessment protocol for bioenergy chains and our analysis suggests that strict adherence to defined methodology and transparency in reporting will be crucial for this to succeed.

Table 1. Average GHG emissions and (non-renewable) energy requirement ratios for a range of bioenergy production chains calculated from life cycle assessment publications.

Fuel	Feedstock	Energy requirement (MJ _{in} :MJ _{fuel} *)	Min	Max	GHG emissions (g CO ₂ eq MJ ⁻¹)	Min	Max
Bioethanol	Wheat	0.686	0.01	0.06	61.41	1.50	9.11
Bioethanol	Sugarbeet	0.741	0.02	0.30	59.31	1.32	9.75
Bioethanol	Wheat straw	0.161	0.03	0.28	25.47	1.70	14.03
Bioethanol	Woody crops	0.323	-0.19	1.50	27.62	21.86	112.7
Biodiesel	Oilseed rape	0.633	0.15	1.86	55.39	13.68	91.51
Diesel (Fischer Tropsch)	Woody crops	0.214	0.04	0.30	19.48	8.92	72.2
Biomass	Woody crops	0.036	0.03	1.12	4.47	4.90	48.15
Biomass	Grasses	0.060	0.27	1.49	3.84	38.97	87.60
Biomass	Forest residues	0.082	0.02	0.64	7.09	2.42	57.20
Unleaded petrol		1.17			84.5		
ULS Diesel		1.18			81.9		
Coal (electricity)		1.06			96.2		

* fuel is defined as liquid transport fuel, prepared biomass (e.g. wood chip) or coal for heat and power generation.

References

- Crutzen, P.J., Mosier, A.R., Smith, K.A., Winiwarter, W. Atmospheric Chemistry and Physics Discussions, 2008, 8, 389-395.
Searchinger, T., Heimlich, R., Houghton, R.A., Dong, F., Elobeid, A., Fabiosa, J., Tokgoz, S., Hayes, D., Yu, T.-H. Science 2008, 319, 1238-1240.