

EECA Peer Review for Canola Life Cycle Assessment

- Final
- 25 July 2008



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EECA PEER REVIEW FOR CANOLA/RAPSEED LIFECYCLE ASSESSMENT

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1. Introduction

1.1 Background

The Energy Efficiency and Conservation Authority (EECA) engaged Sinclair Knight Merz Limited (SKM) to review a Life Cycle Assessment (LCA) of rapeseed biodiesel undertaken by CRL Energy Limited (CRL) for Solid Energy New Zealand Limited.

CRL have indicated that the Rapeseed LCA was undertaken with a limited budget and therefore referred to a similar LCA for tallow based biodiesel undertaken by CRL for EECA. Where appropriate the tallow LCA has been referred to.

The scope for the review was as follows:

- To check the Rapeseed Life Cycle Assessment for consistency and logic; and
- To compare the approach adopted by CRL with the biofuel LCA methodology developed by E4Tech in the UK.
- To run the CRL data through the E4Tech calculator

This report sets out the results of the review including comments on the methodology and assumptions adopted by CRL and E4Tech.

1.2 Limitations

This report has reviewed a LCA of rapeseed base biodiesel undertaken by CRL Energy Limited. The comments offered have largely relied on the data and discussion contained in the CRL report, a LCA for tallow based biodiesel undertaken by CRL for EECA, publically available information on LCA and publically available information regarding the E4Tech greenhouse gas emissions calculator.



2. Definitions and Abbreviations

Allocation method	A method of Life Cycle Assessment in which the environmental impact or impacts to each input or output of the product system are divided according to how much the product costs or weighs.
Co-Product	A product produced together with another product.
Feedstock Energy	The heat of combustion of raw material inputs, which are not used as an energy source to a product system.
Functional Unit	The unit of comparison that assures that the products being compared provide an equivalent level of function or service.
GHG	Greenhouse Gas
HHV	Higher Heating Value
Higher Heating Value	(Also known as the gross calorific value or gross energy) The amount of heat released when a product initially at 25 °C combusts and then returns to 25 °C. Assumes the recovery of the heat from the latent heat of the water vapour formed.
LCA	Life Cycle Assessment
LHV	Lower Heating Value
Life Cycle Assessment	A cradle to grave assessment of environmental effects a product or service has during its lifetime.
Lower Heating Value	(Also know as the net calorific value) The amount of heat released when a product initially at 25 °C combusts and then returns to 150 °C.
MED	Ministry of Economic Development
Product System	Collection of materially and energetically connected unit processes which performs one or more defined functions.
RME	Rapeseed Methyl Ester
System Boundary	Interface between a product system and environment or other product systems.



System Boundary Expansion Method

A method of LCA where co-products are considered to be alternatives to other products on the global market. The system of the product that is replaced by the alternative is then assessed and negative value added to the environmental impact.

Unit Process

The smallest portion of a product system for which data are collected when performing a life cycle assessment.



3. RME Biodiesel Goal and Scope Comparison

3.1 CRL (New Zealand) Goal

CRL Energy Limited (CRL) prepared a Life Cycle Assessment (LCA) on the production of rapeseed methyl ester (RME) biodiesel produced from rapeseed oil (also known as canola) grown in Southland at the request of Solid Energy Ltd. The LCA was carried out in order to compare the greenhouse gas (GHG) emissions of RME biodiesel with fossil diesel (CRL Energy 2008).

3.2 E4tech (UK) Goal

The E4tech model was designed to provide a comparison of GHG emissions for a range of biofuels, including RME biodiesel, and fossil diesel or petrol. The default data is based on research conducted by an expert group established by E4tech. The calculator developed by E4tech was used to prepare the GHG emission estimates referred to in this report (E4tech et al. 2006).

3.3 CRL (NZ) Scope

The LCA prepared by CRL identified the system process as the production of RME biodiesel using NZ feedstocks and production facilities. The functional unit was identified as one kilogram of RME biodiesel.

The boundary established in the study can be described as 'well to wheel' although some inputs and outputs differ when compared with similar LCAs. These are described in Section 3 of this report. The system boundary included the initial crop production through to the exit of RME biodiesel from the biodiesel plant.

Although the 'system boundary expansion' analysis method is preferred by ISO 14040:2006 Environmental management-- Life cycle assessment--Principles and framework, CRL stated that there was not enough data available to use this method (CRL Energy 2007). The alternative 'allocation' analysis method was used for the CRL LCA. Economic, energy and weight allocations were used, which is the norm when analysing farm based process.

CRL calculated the energy and GHG emissions after first calculating a mass balance for the process. They apportioned a GHG emissions credit for the by-product rapeseed meal for both the cultivation and extraction modules based on both a weight and economic allocation. Glycerine was reported as a valuable co-product of the biodiesel production process and was credited throughout all modules at a 13% rate¹.

¹ i.e. 13% of the emissions from each module were 'allocated' to glycerine.



The CRL report calculates all GHG emissions on higher heating values (HHV) as is standard in New Zealand but not in the European Union (EU) and the guidelines of the Intergovernmental Panel on Climate Change (IPCC). CRL have reported that the difference in reporting the energy output to input ratios as HHV vs. LHV is minimal.

The CRL report does not provide any information concerning re-allocation of land use or competition for food crops.

CRL have noted that "the LCA was undertaken with a limited budget and therefore referred to an earlier tallow-derived biodiesel LCA where appropriate. The boundary was kept simple and erred on the conservative side to avoid debate. ..."

3.4 E4tech (UK) Scope

The E4tech model results for RME Biodiesel are based on the production of RME biodiesel using UK feedstocks and production facilities. The functional unit is identified as one kilogram of RME biodiesel consistent with the CRL report.

The boundaries for the E4tech model are similar to the CRL boundaries in the overall definition but do differ in certain inputs and outputs. This is discussed further in Section 4 of this report. The system boundary includes initial crop production through to RME biodiesel exit from the biodiesel plant. The E4tech analysis is also a 'well to wheel' style analysis.

It is not clear whether the E4tech model uses an 'allocation' or 'system boundary expansion' analysis. E4Tech do state that 'boundary expansion' was used as a default. It is clear from the calculator that economic allocation was used in co-product credits for the biodiesel conversion stage. However it is unclear what method was used in applying a credit for rapeseed meal in the extraction process.

The E4tech model appears similar to the CRL method in calculating GHG emissions based on mass balances. E4tech do not award credit for rapeseed meal economically, but actually provide an emission factor for rapeseed meal. This diverges from the NZ practice of applying an economic allocation across the crop production and extraction modules. Glycerine was not considered a valuable co-product and did not provide any credit while potassium sulphate was economically allocated a 1% credit in the UK model. The E4Tech model does not consider re-allocation of land use or competition for food crops.



It is not apparent whether lower heating values (LHV) or higher heating values (HHV) were used in the GHG determination. It has been assumed that E4Tech have followed the practice of using LHV as is the norm in EU analysis. GHG emissions based on HHV emissions will tend to be slightly less conservative than those based on LHV. In a pure scientific view the use of HHV is preferred as it follows the rules of physics. LHV arose as an easy practice for determining useable energy. However, the discrepancy is usually removed by using GHG emission factors that are altered to reflect whether an HHV or LHV values are used.



4. RME Biodiesel Life Cycle Assessment Comparison

4.1 General

The UK approach is based on the widely accepted E4Tech carbon intensity calculator (see appendix A.1). For comparison purposes, the data in the CRL report has been entered into the E4Tech carbon calculation model (see appendix A.2).

Rounding errors have resulted in some small differences in the NZ data but are not considered to be significant. It is important to note that many GHG emission factors for NZ are considerably lower than the equivalent UK GHG emission factors. This is backed by data provided from the MED and is most notably due to a higher ratio of low carbon or renewable electricity generation (e.g. hydro generation) in NZ.

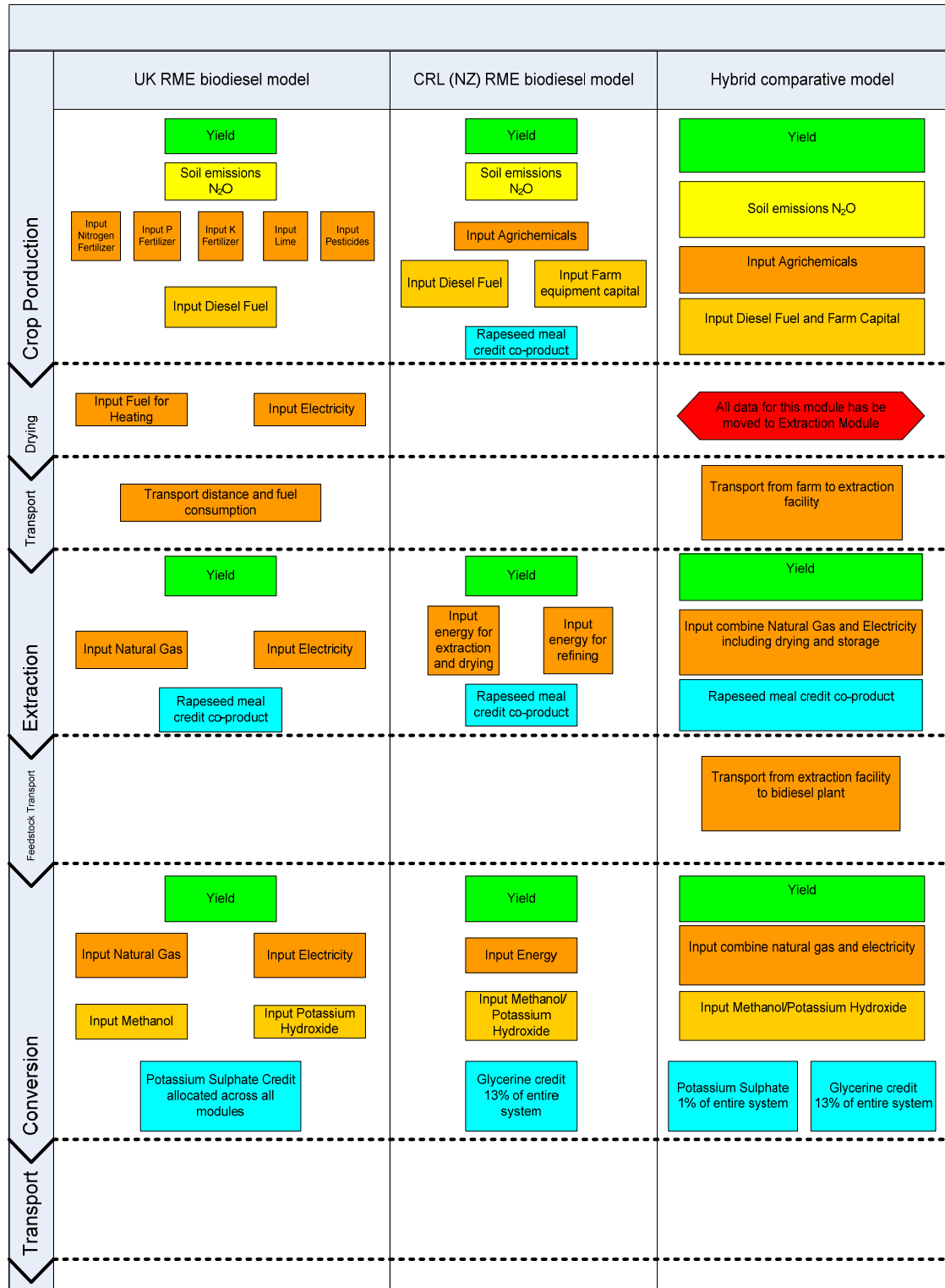
The life cycle inventory analysis of both the E4Tech model and the CRL report were broken into modules (synonymous with sub systems) to identify the sources of inputs, outputs and allocations of GHG emissions involved. This form of reporting GHG emissions is based on the Carbon Emission Calculator created by E4Tech. Each version (UK and NZ) has been displayed in their reported forms and then extrapolated to a comparative form. A description of the differences is provided in the remainder of this section. The calculation models in print form can be found in Appendix A.

A LCA flow chart (Figure 1) of the individual subsystems or modules in the different LCAs of RME biodiesel can be found on the following page. This demonstrates the difference between the CRL and E4Tech approach. The third column illustrates how the data from the two models has been used to develop a like for like comparison. The details of this comparison are discussed in the remainder of Section 3 above.

Table 1 is a summary of the original GHG emissions calculations and the comparative version for each. The third column describes the changes made to the original data in order to carry out a comparison.



■ Figure 1 - LCA Flowchart for RME Biodiesel





■ **Table 1 GHG Emissions For Each Module Of The Production Of RME Biodiesel**

Module	E4Tech UK RME Biodiesel	CRL NZ RME Biodiesel	Modified E4Tech UK RME Biodiesel	Modified E4Tech NZ RME Biodiesel	Explanation of changes
Crop Production	2185	1490	2204	2050	1, 2, 3
Drying and Storage	327	NA	NA	NA	4
Feedstock Transport	32	NA	32	0	No changes
Oil Extraction	NA	250	NA	NA	5
Oil Refining	NA	40	NA	NA	5
Conversion (extraction)	-201	NA	127	-413	1, 2, 3, 4
Feedstock Transport	NA	NA	NA	NA	No changes
Conversion	519	250	523	254	1, 2,
Fuel Transport	NA	NA	NA	NA	No changes
Potassium Sulphate credit	Allocated throughout all modules	NA	NA	NA	1
Glycerine Credit	NA	Allocated throughout all modules	NA	NA	2
Potassium Sulphate/Glycerine credit	NA	NA	-25	-254	1, 2
Total with Potassium Sulphate/ Glycerine Credit	2862	1770	2861	1770	
Total without Potassium Sulphate/Glycerine Credit	NA	NA	2886	2024	

1. The potassium sulphate credit was removed from the UK emissions and included in the final Potassium Sulphate/Glycerine credit.

2. The glycerine credit was removed from the NZ emissions and included in the final Potassium Sulphate/Glycerine credit.

3. The rapeseed meal credit was removed from the NZ emissions and included in the conversion module.

4. The UK emissions for drying and storage were moved to the conversion (extraction) module.

5. The NZ emissions were moved to the conversion (extraction) module.



4.2 Crop Production CRL (NZ) Vs. UK

Rapeseed yield in New Zealand was reported at 3.2 t/ha.a and was similar to yields in Germany and France but was higher than those in the UK (3.03 t/ha.a). NZ rapeseed yields were based on an un-irrigated crop and info was not provided concerning irrigation qualification of the UK data.

The nitrous oxide emission factor for NZ was presented in a short report by Andrew Barber and Glenys Pellow with AGRILINK NZ. Their report is one of the first estimates done on GHG potentials for un-irrigated canola crop grown in Southland (to the farm gate). Some rounding issues in Andrew Baber's AGRILINK report made it difficult to adapt the data for use in the E4Tech calculator.

The farming inputs for NZ did not distinguish the types of fertiliser nor did it keep the carbon dioxide emissions for pesticides separate from those for fertilisers. AGRILINK's report presented a summary of all farming inputs but included the capital inputs separately. This makes it difficult to directly compare total emission factors for production used by CRL with those used by E4Tech for UK production. It is possible to compare emissions factors for total agrichemicals. The higher agrichemical inputs in the UK (297.1 kg/ha in the UK versus 160 kg/ha in NZ) could be attributed to the generally higher use of nitrogen fertilizer in the UK.

Farming capital was included as an input in the NZ report but was not included in the UK report. This is most likely due to the relatively small contribution of farming capital to the overall process and it is common practice with most LCA to exclude capital for most farm gate inventories.

Fuel use was higher in the NZ report. Possible explanation for the discrepancy could include less fuel efficient machinery and differences in farming practices.

The overall difference in carbon dioxide equivalent emissions between the two Crop Production modules, approximately 125 kgCO₂/t biodiesel less for NZ, appears reasonable and can be feasibly attributed to lower fertiliser use and lower carbon intensity of fertiliser production in NZ.

4.3 Drying and Storage

Drying and storage of rapeseed is a necessary step in the production of biodiesel from rapeseed. Drying and storage of rapeseed has been assessed separately in the UK report while the NZ report has included the GHG emissions for drying in the oil extraction module. This makes it difficult to directly compare this module between the two reports and so this module has been removed in the comparative calculation and the emissions calculated in this model by E4Tech have been added to the oil extraction module.



4.4 Feedstock Transport from Farm to Oilseed Crusher

The GHG emissions of the transport of rapeseed to oil extraction facilities was not included in the NZ report as it was determined to be less than 1% of the total carbon emissions. The UK report has included the transport. Although the carbon emissions from the drying process have been combined with those for the extraction process the rapeseed is still assumed to be transported in a dry state.

4.5 Conversion (Oil Extraction)

The original calculation from the NZ report included drying and storage GHG emissions in the conversion module while the UK report did not. For comparison purposes the drying and storage emission in the UK report have been moved from the separate drying and storage module to this module.

If we do not consider the rapeseed meal credit we find that the GHG emissions for drying, extraction and refining of rapeseed are 20% higher in the UK than for NZ. Some of the discrepancy can be attributed to the difference in GHG emissions factors for electricity, however only 5 -10% can be attributed directly to electricity use. It is possible that the processes differ in their ratio of electricity and gas use contributing to the remainder of the difference.

CRL used economic allocation and referenced data from the Canadian Canola Council to determine an allocation factor of 0.28 for rapeseed meal and 0.72 for rapeseed oil. When these factors were applied to the GHG emissions for crop production, drying and extraction of rapeseed CRL derive a plausible and referenced credit approximately 2 times the credit utilised in the UK calculator. It is possible that the discrepancy can be attributed to the use of system boundary expansion versus economic allocation methodology. Further research is required to produce better side by side comparison of the rapeseed meal credit.

When viewing the module total for conversion (oil extraction) the value reported by CRL is 381 kgCO₂/t biodiesel lower when compared with the UK data. The majority of the discrepancy is attributed to the higher meal credit given in the NZ data.

4.6 Transport (From extraction facility to biodiesel plant)

Neither study includes GHG emissions for the transport of rapeseed oil from extraction facility to the biodiesel plant. In the NZ report the actual GHG emissions for overall transportation involved in the complete process were less than 1% and considered to have an insignificant impact on the total GHG emissions.

4.7 Conversion (Biodiesel production)

The CRL report references another CRL Report on tallow based biodiesel (CRL Energy 2007) and assumes the GHG emission for biodiesel production from tallow is the same as that from rapeseed. The E4Tech GHG emission rates for tallow and rapeseed conversion to biodiesel are the same i.e.



E4Tech appear to have made the same assumption. CRL's report on biodiesel production from tallow based the GHG emissions for conversion of tallow on reports and data involving the production of biodiesel from soy and rapeseed stocks. All of the GHG emissions for the NZ rapeseed report are directly based on these calculations and data.

CRL have not clearly separated the GHG emissions from electricity and natural gas usage in conversion of refined rapeseed. The E4Tech model separated the GHG emissions for electricity and natural gas inputs and for comparison purposes the two values have been combined to give emissions for energy. When the differences between the CRL and E4Tech GHG emissions for the overall energy input are assessed, only a small difference is apparent. This is likely to be due to the lower emission factors for NZ electricity.

Two additional inputs in the conversion module are methanol and potassium hydroxide. Both chemicals carry a GHG emission in the E4Tech model but only methanol is represented in the CRL report. The contribution of GHG emission from potassium hydroxide was not considered to have significant impact in the CRL report although it was mentioned. The CRL report noted that even when the GHG emissions from potassium hydroxide were added to the GHG emissions from methanol, the resulting total was 16% lower in one study (Beer et al. 2001) and 45% higher in another study (Sheehan et al. 1998). The NZ GHG emission factor for methanol was considerably lower than the UK value but could be partially attributed to the lower GHG emissions related to NZ methanol production. Further research needs to be conducted to derive an appropriate emissions factor for methanol in NZ.

The data from the E4Tech model gives credit based on economic allocation for the co-production of potassium sulphate but does not give any credit for glycerine. The CRL report makes no mention of the co-product potassium sulphate but includes a rather substantial credit, based on economic allocation, for glycerine. The market value for glycerine in the NZ report is comparable with recent market value of glycerine and it is surprising that the E4Tech model does not give any value, or allocate any of GHG emissions, to glycerine.

The relatively low GHG emissions for biodiesel production in NZ when compared to the UK are mostly related to the lower GHG emission factor for methanol and the inclusion of a glycerine credit in the CRL approach.

4.8 Liquid Fuel Transport and Storage

Neither study includes GHG emissions for the transport of biodiesel from the biodiesel plant to the blending facility. In the NZ report the actual GHG emissions for overall transportation involved in the complete process were less than 1% and considered to be of insignificant impact on the total GHG emissions.



5. Comparing RME Biodiesel and Fossil Diesel

CRL reported a GHG emission of 3.80 kgCO₂/kg fossil diesel in their report on NZ tallow biodiesel and referenced this figure in their RME biodiesel report when comparing with fossil diesel (CRL Energy 2007). They also note that 1.08kg of biodiesel has the same energy content as 1.00 kilogram of fossil diesel. Using the GHG emissions from 3.2 t/ha.a yield NZ RME biodiesel without a glycerine credit we find a 42% reduction in GHG emissions when compared with fossil fuel. CRL has reported a 47% decrease in both Table 1 and Table 6 of the RME biodiesel report (CRL Energy 2007). It appears the energy content factor has not been applied when calculating the GHG emissions reduction for all permutations.

If we use the same factors above with the GHG emissions for UK RME biodiesel we find a 19% reduction in GHG when comparing neat RME biodiesel and neat fossil diesel. This is a considerable difference but has been attributed to the higher rapeseed meal credit and lower carbon intensive energy sources for NZ RME Biodiesel. CRL report further savings involving higher yield crops and glycerine credits in their report and discussed further in their section on sensitivity analysis.



6. Comparing E4Tech and CRL Results for Tallow

CRL Energy (CRL) prepared a Life Cycle Assessment (LCA) on tallow derived biodiesel produced in New Zealand from New Zealand based feedstocks. E4tech conducted LCA for tallow based biodiesel produced in the UK from UK feedstocks. The LCAs were carried out in order to compare and contrast the greenhouse gas emissions of tallow derived biodiesel with fossil diesel.

The boundaries defined in each study are quite different and make a comparison between the two in their original forms impractical and prone to misrepresentation. Both versions define their functional unit as 1 kg of biodiesel. The system boundary for the CRL assessment includes inputs and outputs from the pasture (well) to the exit of the biodiesel plant gates while the E4tech model only includes inputs and outputs from the exit of the rendering facility to the exit of the biodiesel plant. E4tech based this approach on a policy position in the UK excluding farm and rendering processes from LCA for tallow. The results from CRL report were reduced to fit the boundaries of the E4tech model in attempt to provide some meaningful comparison. The results are presented in Table 2 along with the original CRL data.

■ Table 2 GHG Emissions For The Production Of Tallow Derived Biodiesel

Module	CRL original GHG emissions kgCO ₂ / t biodiesel	E4tech GHG emissions kgCO ₂ / t biodiesel	CRL reduced boundary GHG emissions kgCO ₂ / t biodiesel
Farming and Meat Processing	770	NA	NA
Rendering	920	NA	NA
Feedstock Transport	23	8	20
Conversion	250	519	221
Liquid fuel transport	NA	NA	NA
Subtotal	1960	NA	270
Glycerine credit	-263	NA	Allocated throughout modules
Total	1750*	526	242

* Values may differ slightly from actual results due to rounding

When the CRL boundary is reduced for comparison, the conversion and feedstock values are smaller because the glycerine credit is applied to each module. As for the RME Biodiesel comparison the methanol emissions factor also contributes to the difference.



7. Conclusions

7.1 The CRL Approach to LCA for Biofuels

As for all LCA, the most important stage is putting in place appropriate system boundaries and key assumptions. The difficulty in assessing any LCA is that decisions on boundaries and assumptions are a judgement call. CRL have made an assessment very simple by clearly laying out each assumption and enabling the source of data to be identified.

Table 3 sets out our key conclusions on the CRL approach to LCA for biodiesel. The first column makes a general comment on each issue – have the decisions taken been appropriate, logical and defensible. The second column of comments considers the link to the E4Tech calculator and issues that may arise in linking to LCA undertaken internationally based on that model.

■ Table 3 Key Comments CRL LCA Approach

	General Comments	Linking to E4Tech Calculator
System Boundary	The selection of a system boundary reflecting the 'well to wheel' approach for both RME and tallow Biodiesel is appropriate.	The 'well to wheel' boundary for RME Biodiesel links well with the E4Tech approach. The inclusion of on farm processes for tallow biodiesel is at odds with the E4Tech approach.
Allocation Method	The allocation method adopted has been clearly set out however it would be ideal to collect enough data to use "system boundary expansion" methodology.	While it not always clear what method E4Tech have used for each process the approach adopted by CRL is broadly comparable. The differing results are in most cases due to different assumptions used in the allocation rather than a different method being employed.
Assumptions/Inclusions	Potassium hydroxide should be included (or dismissed on the basis of forming a small part of overall GHG emissions). The data on methanol should be examined further based on the significant difference compared to the figure used in the E4Tech model. Given the EU convention to use LHV it may be helpful to provide a conversion methodology or to use LHV as a basis for the LCA.	The lack of accounting for potassium hydroxide and the by-product made comparison with E4Tech difficult. Assigning a market value to glycerine was a different approach to that adopted by E4Tech, although the calculator does allow for allocating some GHG emission to glycerine on an economic basis.



7.2 Comparison of CRL and E4Tech Approach

As noted above, LCA can provide a large range of 'correct' answers. In this context it is useful to compare the results of an LCA on RME and Tallow Biodiesel using the CRL and E4Tech approaches.

Key differences include:

- The CRL approach for RME biodiesel will produce a lower figure than the E4Tech approach if the same figures are used;
- When the CRL figures for RME Biodiesel are adapted and used in the E4Tech calculator they return a lower figure than that using UK defaults. The largest contributions to this difference include GHG emission factors for electricity, glycerine value, rapeseed meal credit and upstream GHG emissions for methanol production;
- The CRL approach for tallow based biodiesel will produce a higher figure than the E4Tech approach due to the inclusion of on-farm and rendering inputs in the system boundary;
- When the CRL figures for tallow based biodiesel are used in the E4Tech calculator they return a lower figure than the UK defaults. The largest contributions to this difference are the value of glycerine and the upstream GHG emissions for methanol production;
- The CRL approach suggests RME and tallow based biodiesel result in comparable GHG emissions from well to wheel. The E4Tech approach suggests RME has significantly higher GHG emissions from well to wheel, largely due to differences in system boundaries for the two feedstocks.

All of the LCA undertaken suggest that biodiesel produces less 'well to wheel' GHG emissions than fossil diesel.

7.3 Recommendations

As for any LCA, both the E4Tech and CRL approaches to assessing the 'well to wheel' GHG gas emissions of biodiesel could be modified. Rather than modifying the two approaches it is probably more worthwhile to consider some of the issues raised in this report and develop a preferred approach, and NZ dataset, for future biofuel LCA in New Zealand. Accordingly, it is recommended that:

- A policy/agreed approach is developed on system boundaries for biofuel LCA in NZ be developed, potentially as part of the regulation development process associated with the Biofuel Bill.
- A NZ specific data set for biofuel LCA is developed. This would cover a range of issues including emissions factors for on-farm and processing steps as well as a basis for allocation of emissions to by-products such as rapeseed meal, glycerine and potassium sulphate.



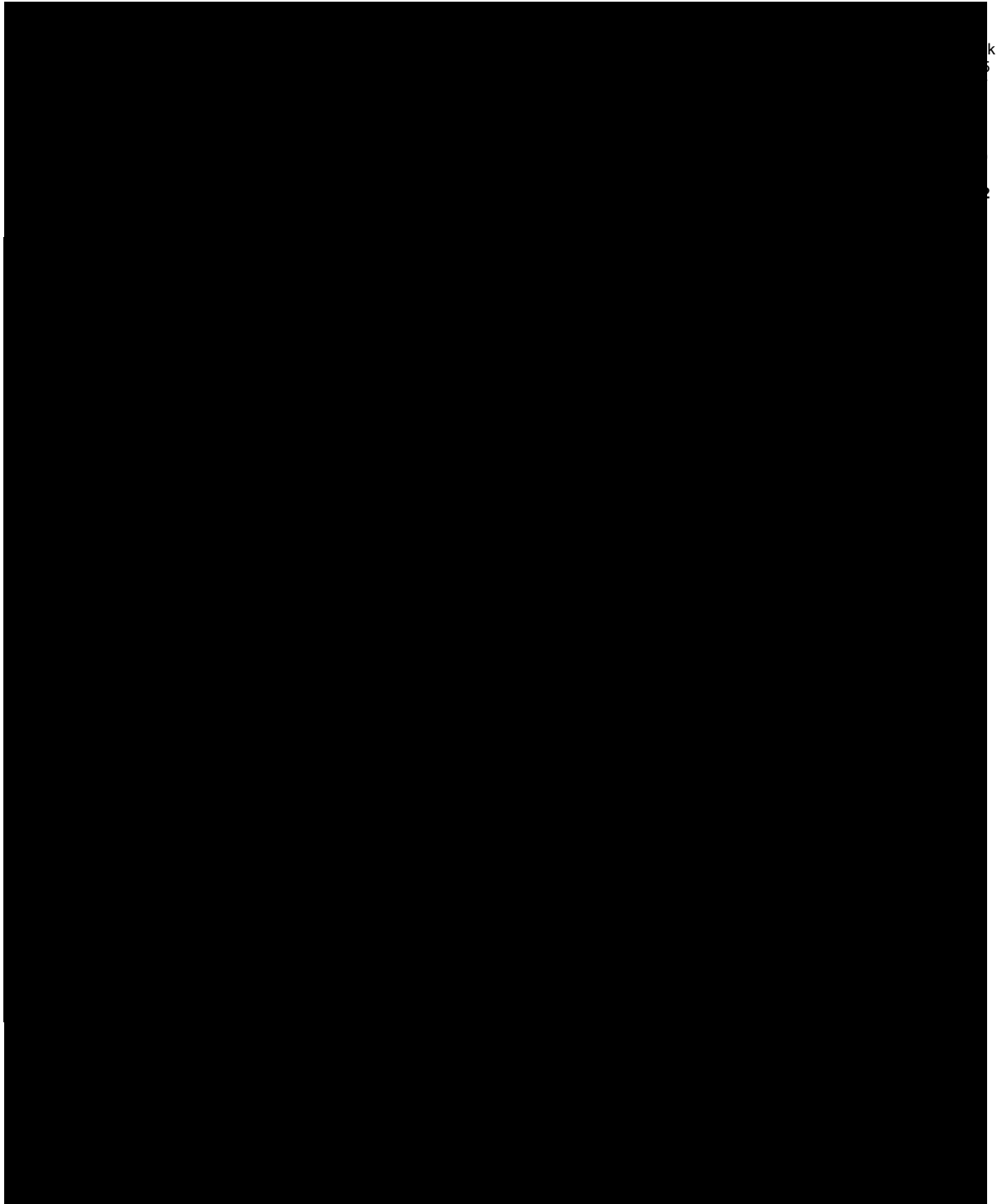
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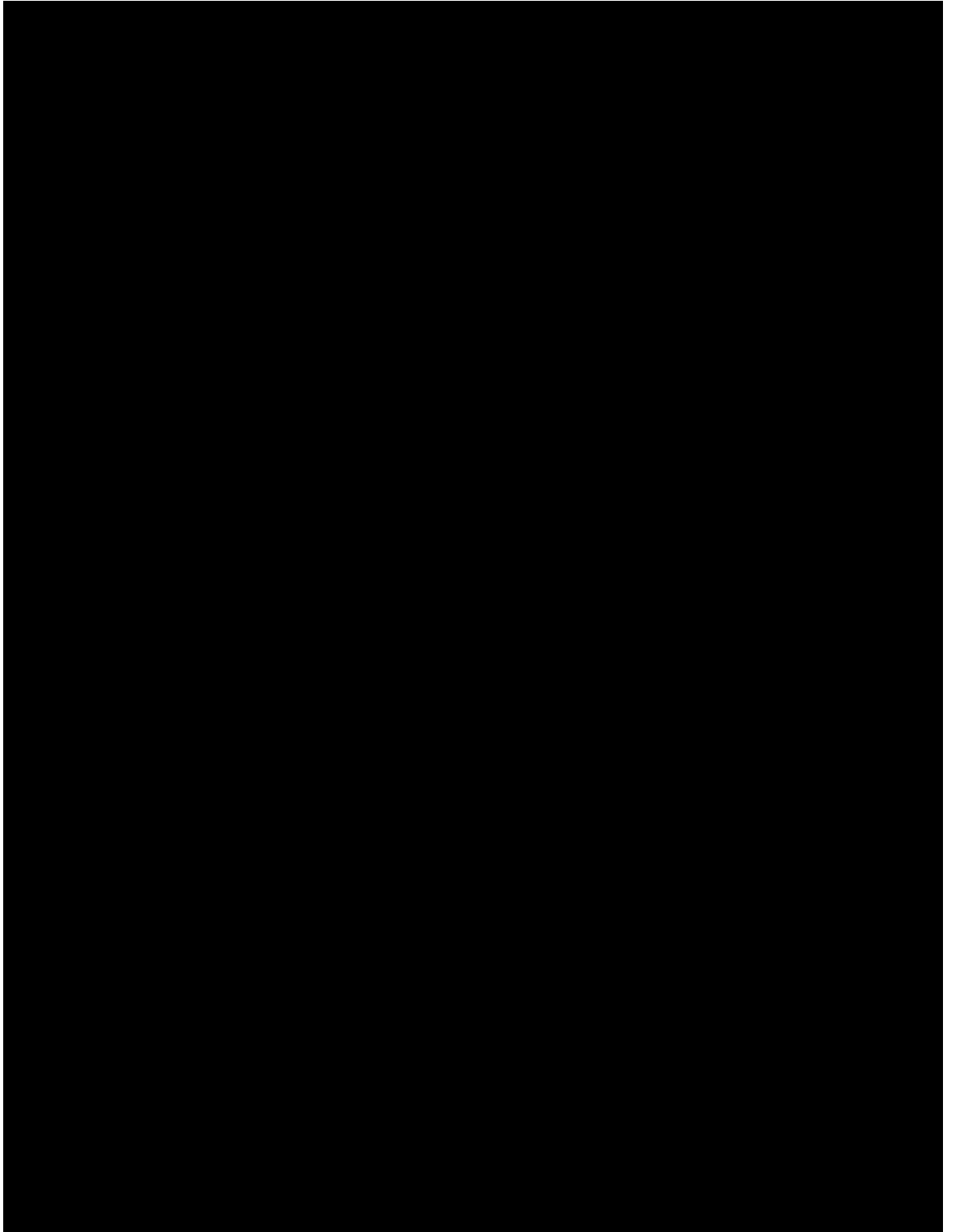
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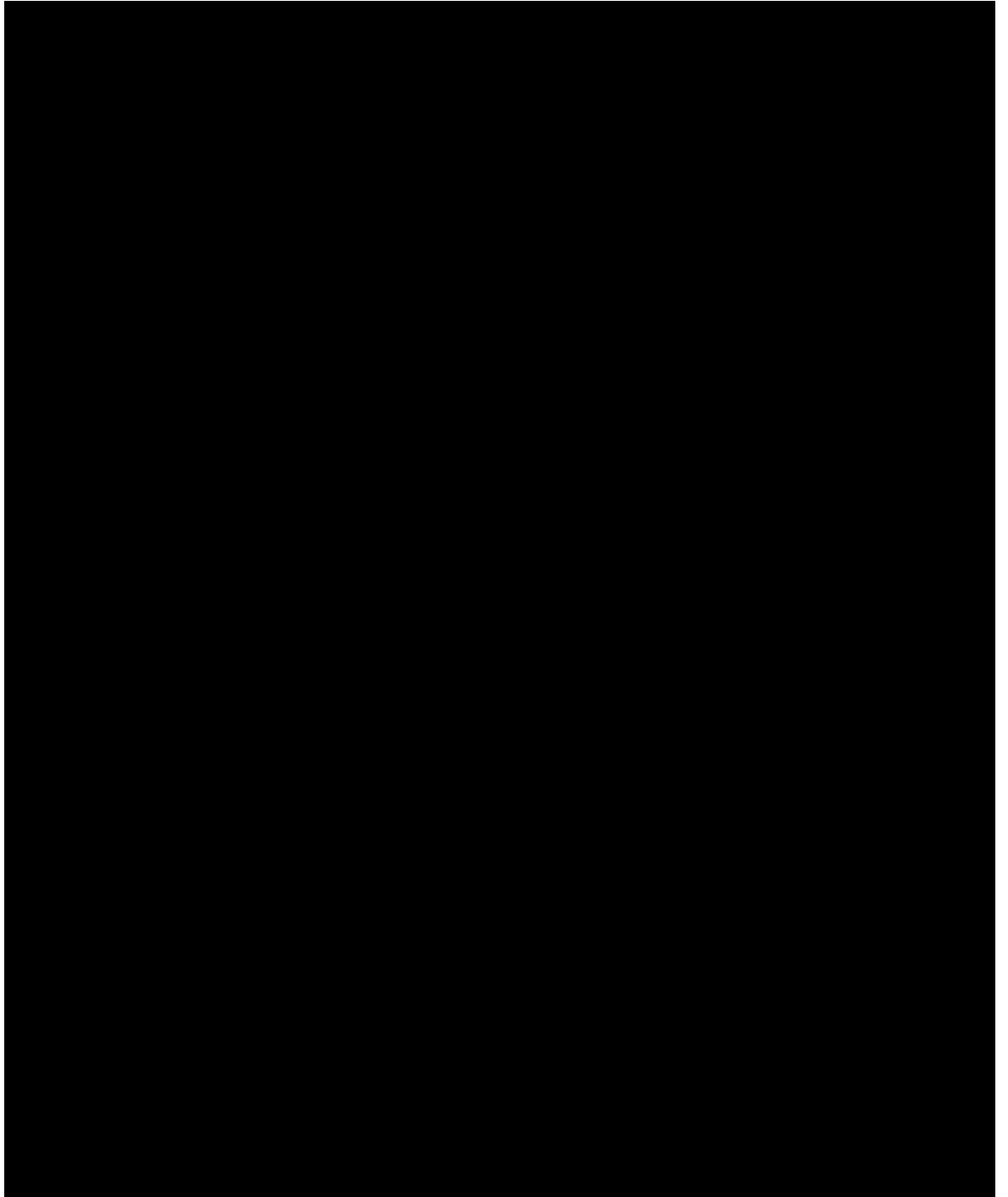


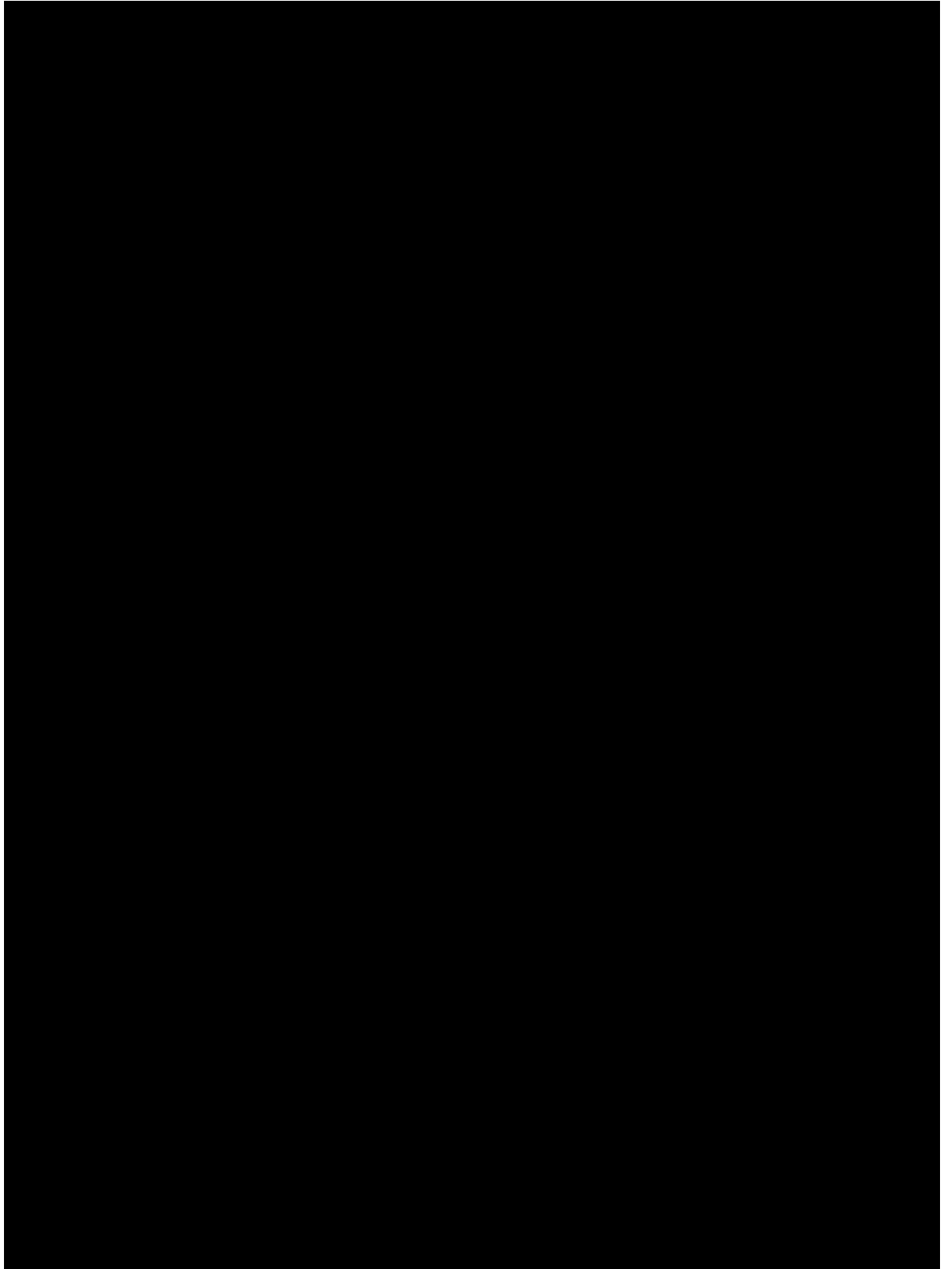
Appendix A RME Biodiesel Calculations

A.1 Original E4Tech RME Biodiesel Calculations



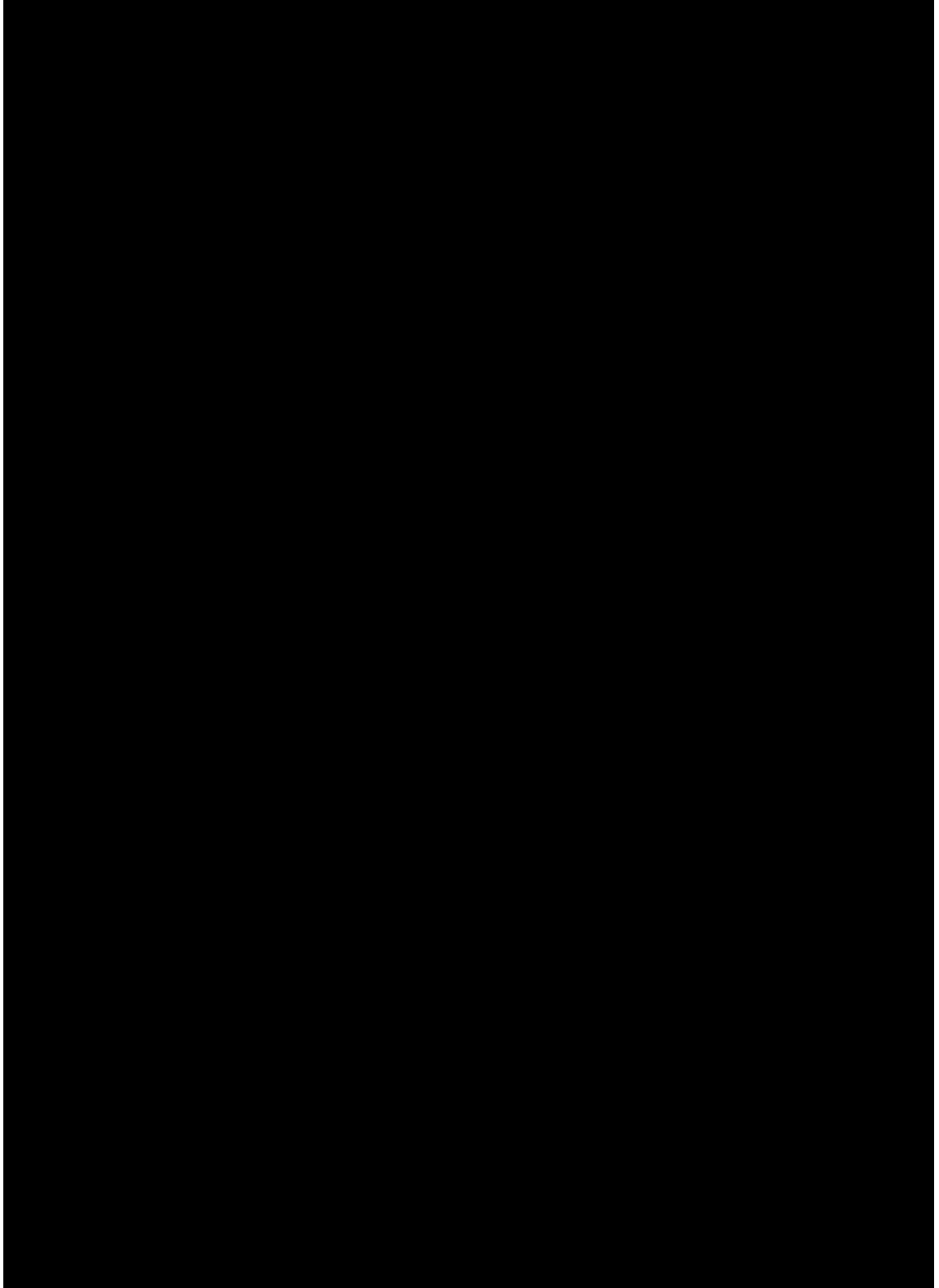


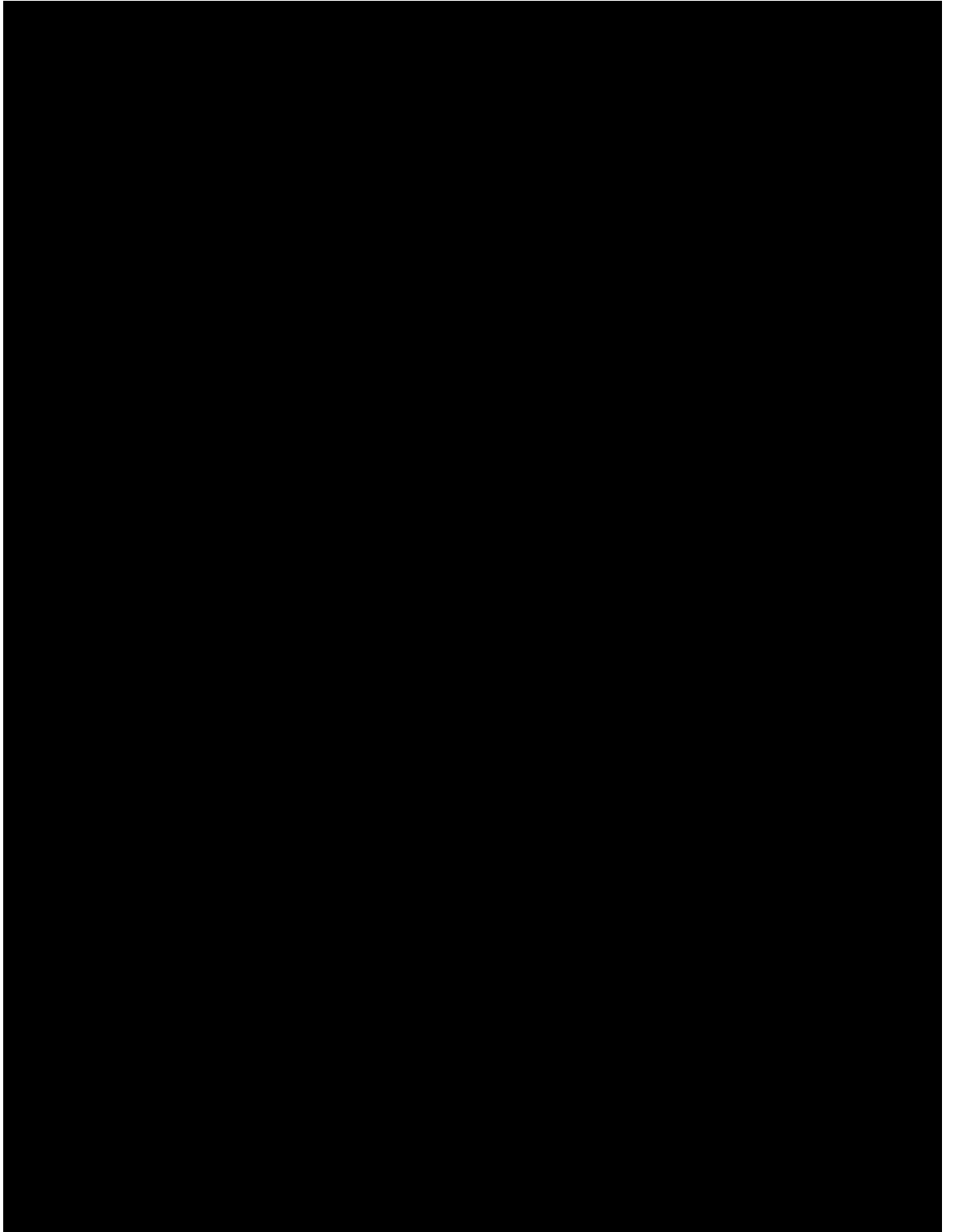


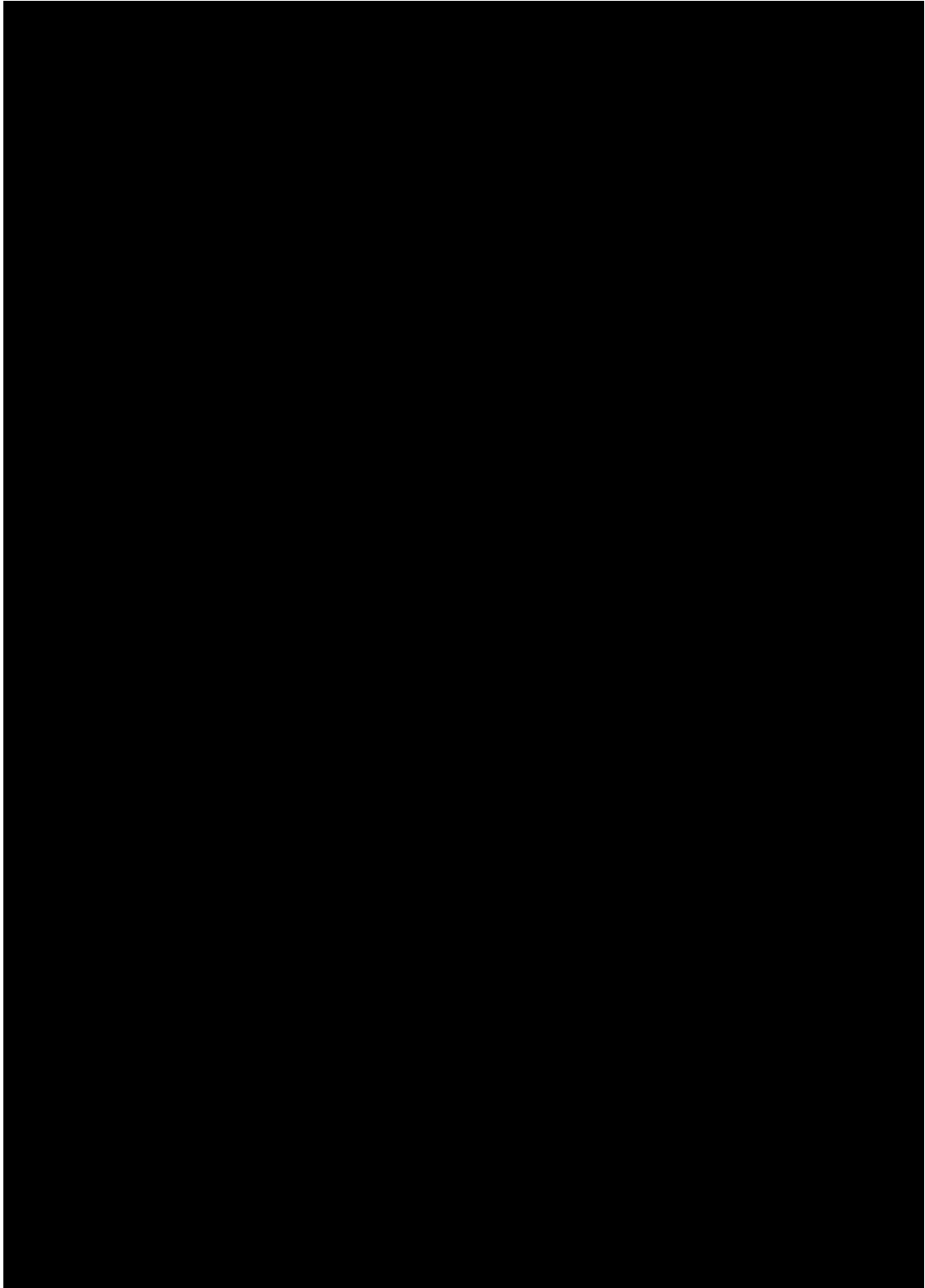


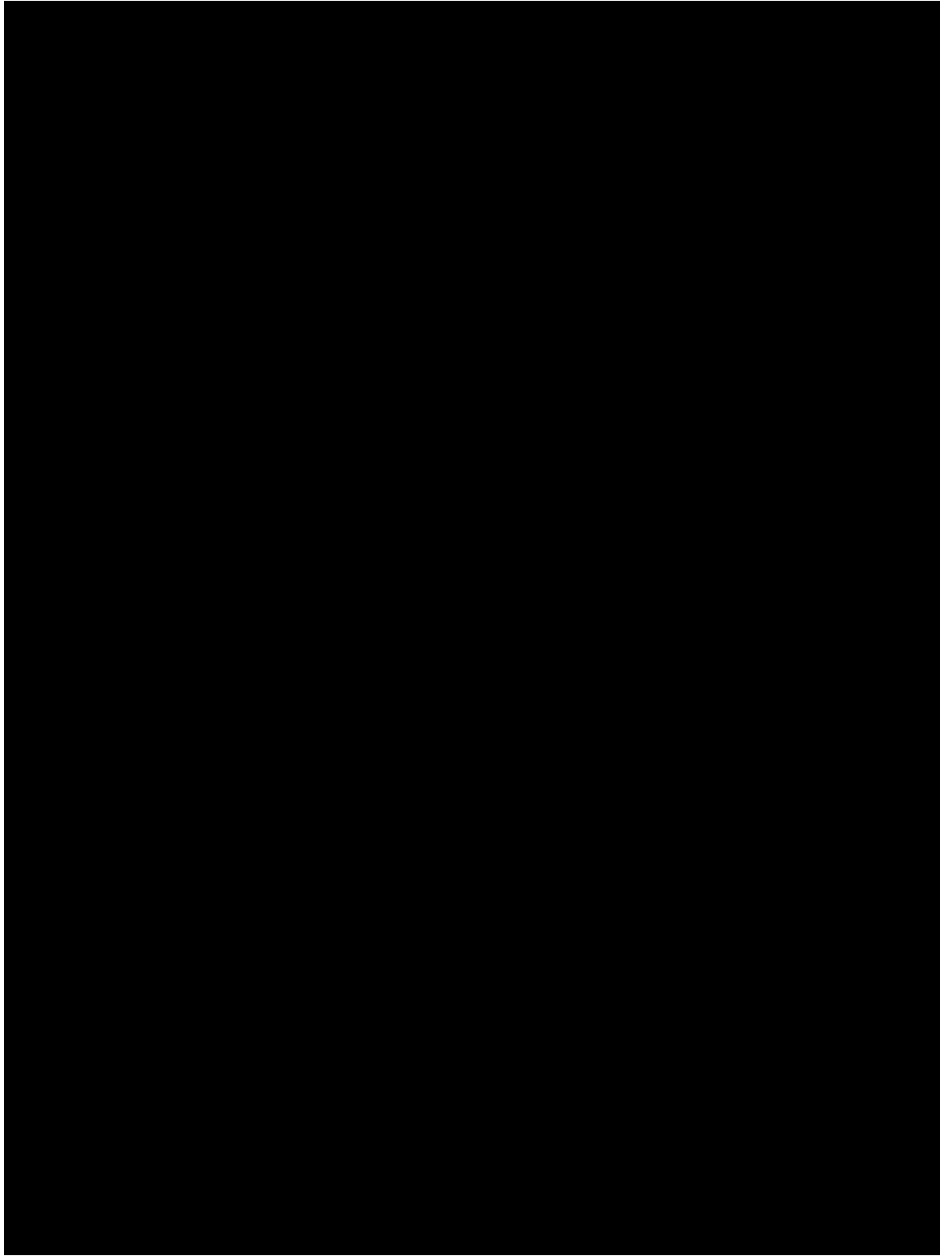


A.2 Original CRL RME Biodiesel Calculations









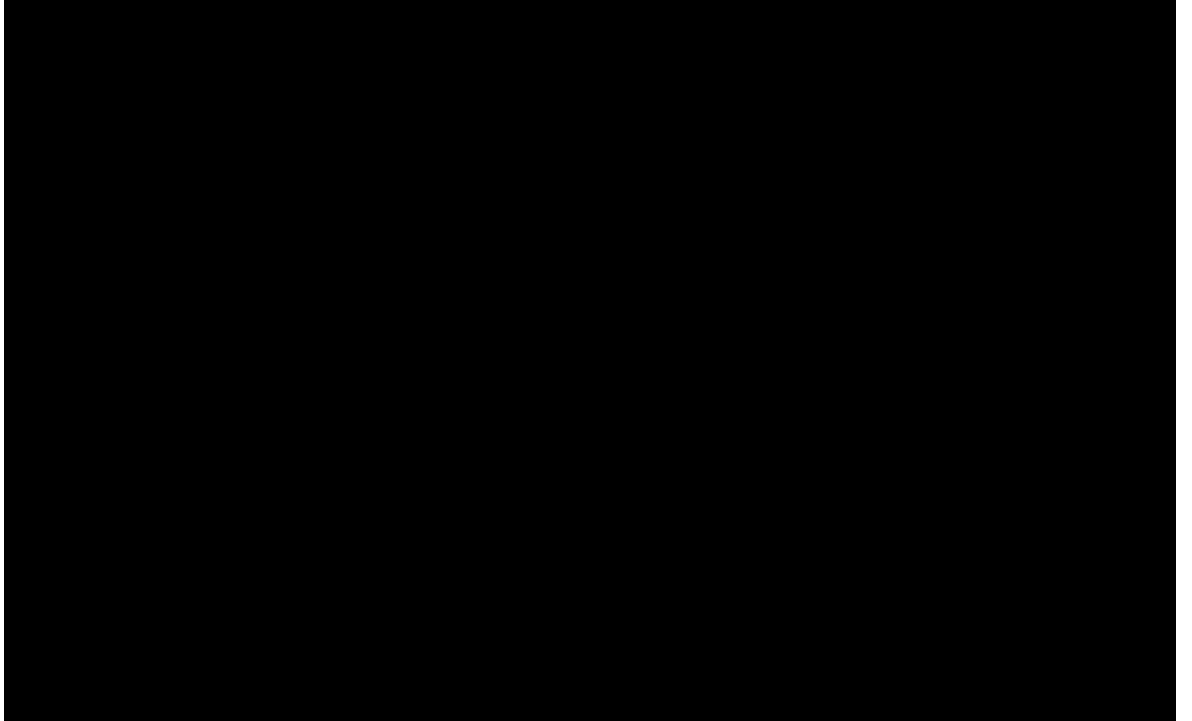


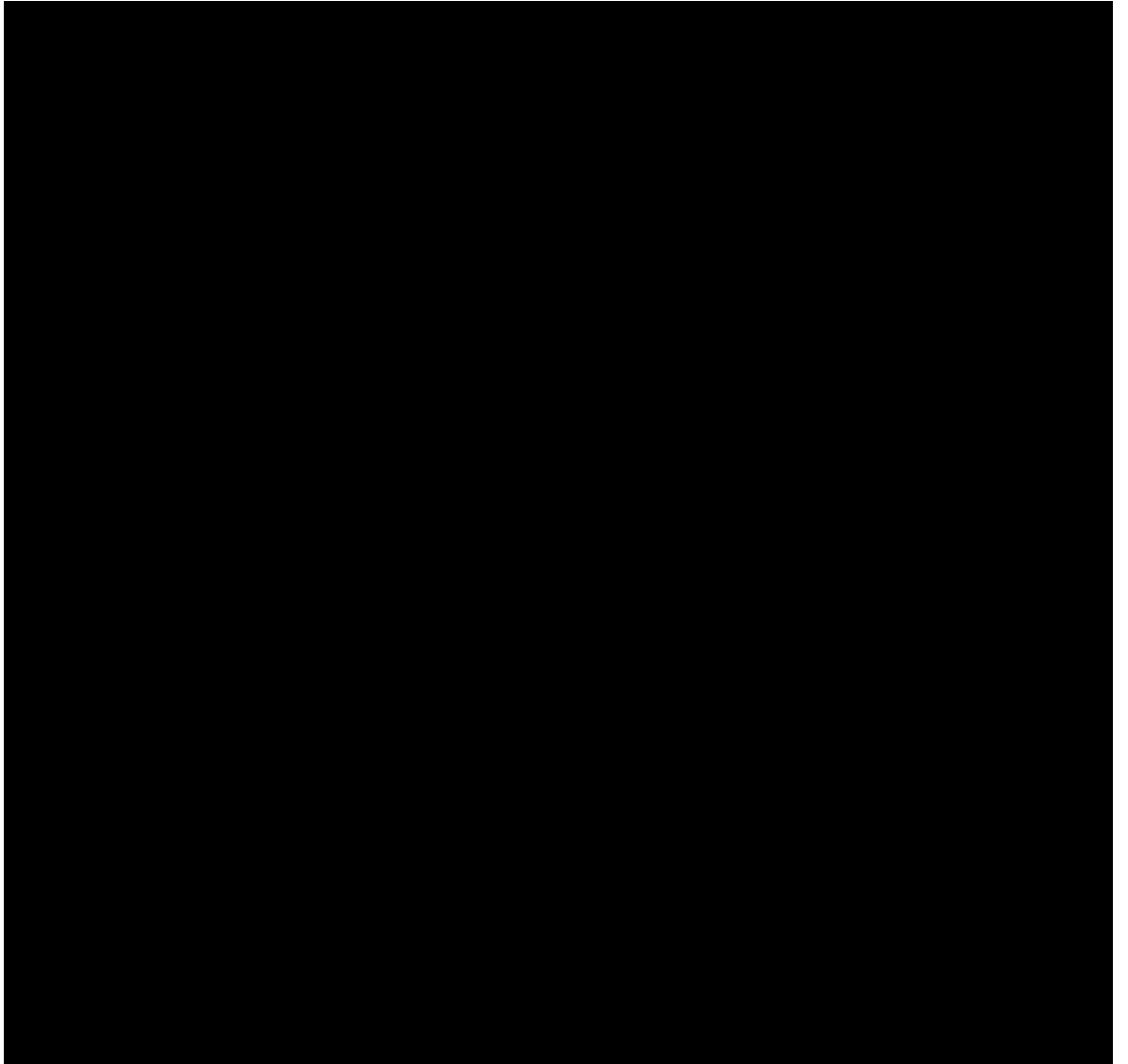
A.3 Comparative E4Tech and CRL Data

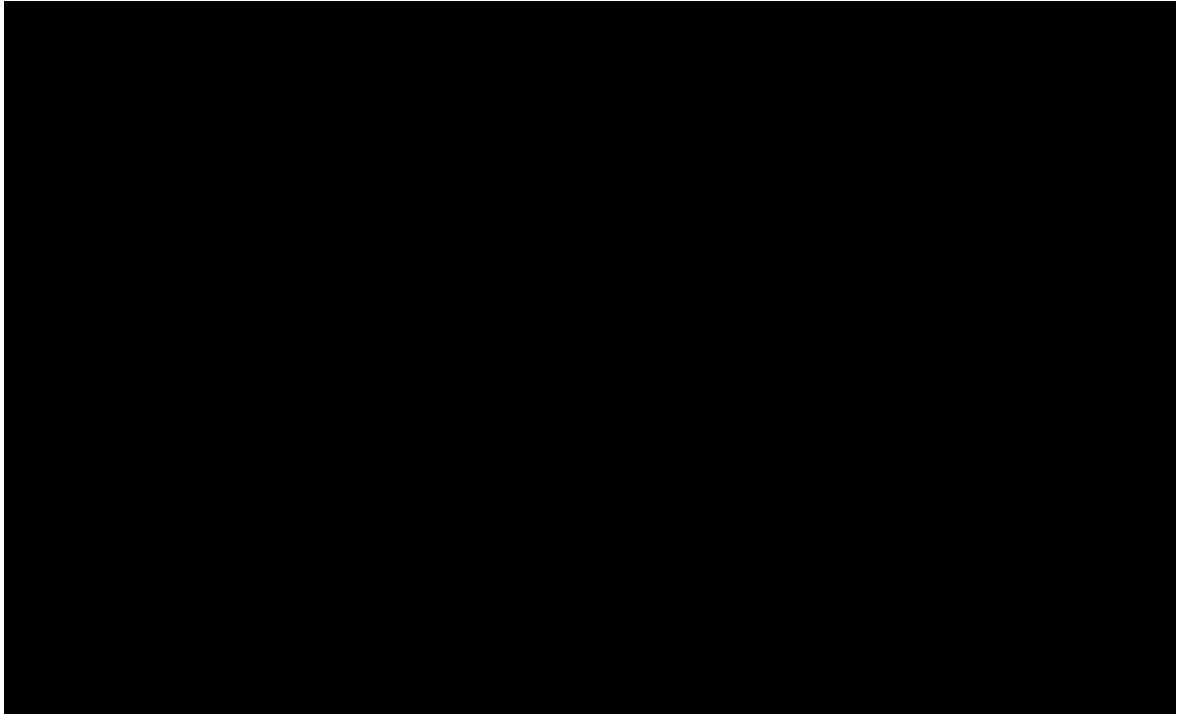
Fuel chain summary Module	Carbon intensity [kg CO ₂ / t biodiesel]						UK Active link	NZ Active link
	Australia	Canada	France	Germany	Poland			
1 - Crop production	2139	2058	1802	1809	1667	2204	2050	
2 - Drying and storage	0	311	302	328	339	0	0	
3 - Feedstock transport	24	120	96	96	96	32	0	
4 - Conversion (crushing)	-162	-225	-239	-198	-182	127	-269	
5 - Feedstock transport	400	95	8	12	27	0	0	
6 - Conversion (esterification)	519	519	519	519	519	523	254	
7 - Liquid fuel transport and storage	0	0	0	0	0	0	0	
Total w/o glycerine/potassium sulphate credit	2920	2877	2488	2566	2465	2887	2034	
Total with glycerine/potassium sulphate credit						2005	1770	
Feedstock origin:	Default (UK)							

Stage 1 - Crop Production							
Description		Cultivation and harvesting of oilseed rape					
Basic Data							
	Units						
UK	Yield @ traded moisture content	[t/ha.a]	3.03	Y			
NZ	Yield @ traded moisture content	[t/ha.a]	3.20	Y			
UK	Traded moisture content	%	9				
NZ	Traded moisture content	%	6				
Soil Emissions							
	N ₂ O emissions			Emissions factor (kgCO _{2e} /ha)		Total Emissions (kgCO _{2e} /t OSR)	
UK				1140	÷ Y =	376	UK
NZ				1203	÷ Y =	376	NZ
Farming Inputs							
		Mass of input		Emissions co-efficient [kgCO _{2e} /kg nutrient]		Total emissions	
UK	Agrichemicals	185	x		÷ Y =	457	UK
NZ	Agrichemicals	160	x		÷ Y =	279	NZ
Machinery Inputs							
UK	Diesel fuel consumption	[litres/ha.a]	67	x	3.1	÷ Y =	68 UK
NZ	Diesel fuel consumption	[litres/ha.a]	80	x	3.1	÷ Y =	77 NZ
UK	Capital					0	UK
NZ	Capital					41	NZ
Totals							
UK	Module total					900	UK
NZ	Module total					773	NZ
Total Emissions [kgCO _{2e} /t biodiesel]							
UK	Contribution to fuel chain					2204	UK
NZ	Contribution to fuel chain					2050	NZ

Country	Yield [t/ha]	N Fertiliser	P Fertiliser	K Fertiliser
Australia	1.2	61	16	12
Canada	1.5	75	20	15
Default (UK)	3.0	185	45	48
France	3.2	155	45	80
Germany	3.4	170	45	90
Poland	2.4	102	35	44
United Kingdom	3.0	185	45	48









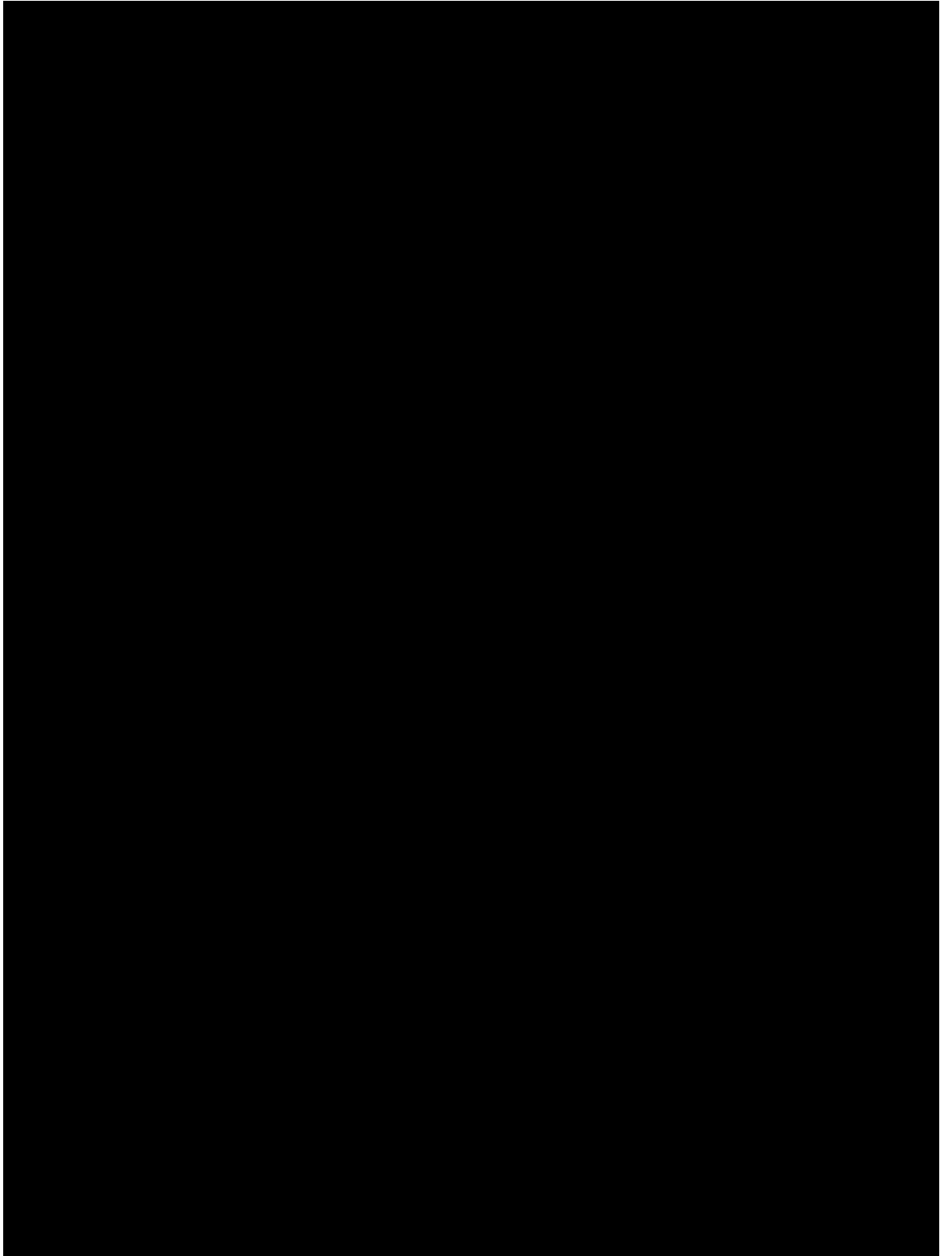
Stage 5 - Conversion						
Description		Biodiesel plant				
Basic data						
UK	Plant yield	[t biodiesel / t rapeseed oil]	0.95	(z2)		
NZ	Plant yield	[t biodiesel / t rapeseed oil]	0.965	(z2)		
Conversion Inputs						
					Emissions factor (kgCO _{2e} /MJ)	Emissions (kgCO _{2e} /t ethanol)
UK	Natural gas	[MJ/t biodiesel]	1690	x	0.062	105
NZ	Natural gas	[MJ/t biodiesel]	0	x	0.062	0
UK	Electricity imported	[MJ/t biodiesel]	335	x	0.131	44
NZ	Electricity imported	[MJ/t biodiesel]	0	x	0.131	0
UK	Gas and electricity reported combine					0
NZ	Gas and electricity reported combine					134
					Emissions factor (kgCO _{2e} /kg)	
UK	Methanol	kg/t biodiesel	113	x	2.8	311
NZ	Methanol	kg/t biodiesel	100	x	1.2	120
UK	Potassium hydroxide	kg/t biodiesel	26	x	2.4	63
NZ	Potassium hydroxide	kg/t biodiesel	0	x	2.4	0
Co-products						
	Description	Treatment				
	Co-product 1:	Crude glycerine sold as chemical Allocation - by market value				
	Co-product 2:	Potassium sulphate Allocation - by market value				
Co-products treated by allocation by market value						
Co-product 1: Glycerine						
					Market value [£ / t glycerine]	
UK	Quantity of crude glycerine produced	[t glycerine / t biodiesel]	0.1	x	0	0
NZ	Quantity of crude glycerine produced	[t glycerine / t biodiesel]	0.1	x	500	50
Co-product 2: Potassium sulphate						
					Market value [£ / t potassium sulphate]	
UK	Quantity of potassium sulphate produced and sold as chemical	[t potassium sulphate / t biodiesel]	0.04		75	3
NZ	Quantity of potassium sulphate produced and sold as chemical	[t potassium sulphate / t biodiesel]	0.00		75	0
Primary product: biodiesel						
					Market value [£ / t biodiesel]	
UK	Market value of biodiesel				340	340
NZ	Market value of biodiesel				340	340
Total market value of products						
UK	Total market value	[£ / t biodiesel]				343
NZ	Total market value	[£ / t biodiesel]				390
UK	Allocation factor (%age of emissions attributable to biodiesel)	%		Credit moved to cell h279		100
NZ	Allocation factor (%age of emissions attributable to biodiesel)	%		Credit moved to cell h280		100
Totals						
						Total Emissions [kgCO _{2e} /t biodiesel]
UK	Module total					523
NZ	Module total					254
UK	Contribution to fuel chain					523
NZ	Contribution to fuel chain					254
	Glycerine/potassium sulphate credit			Based on economic allocation		-29
	Glycerine/potassium sulphate credit			Based on economic allocation		-264





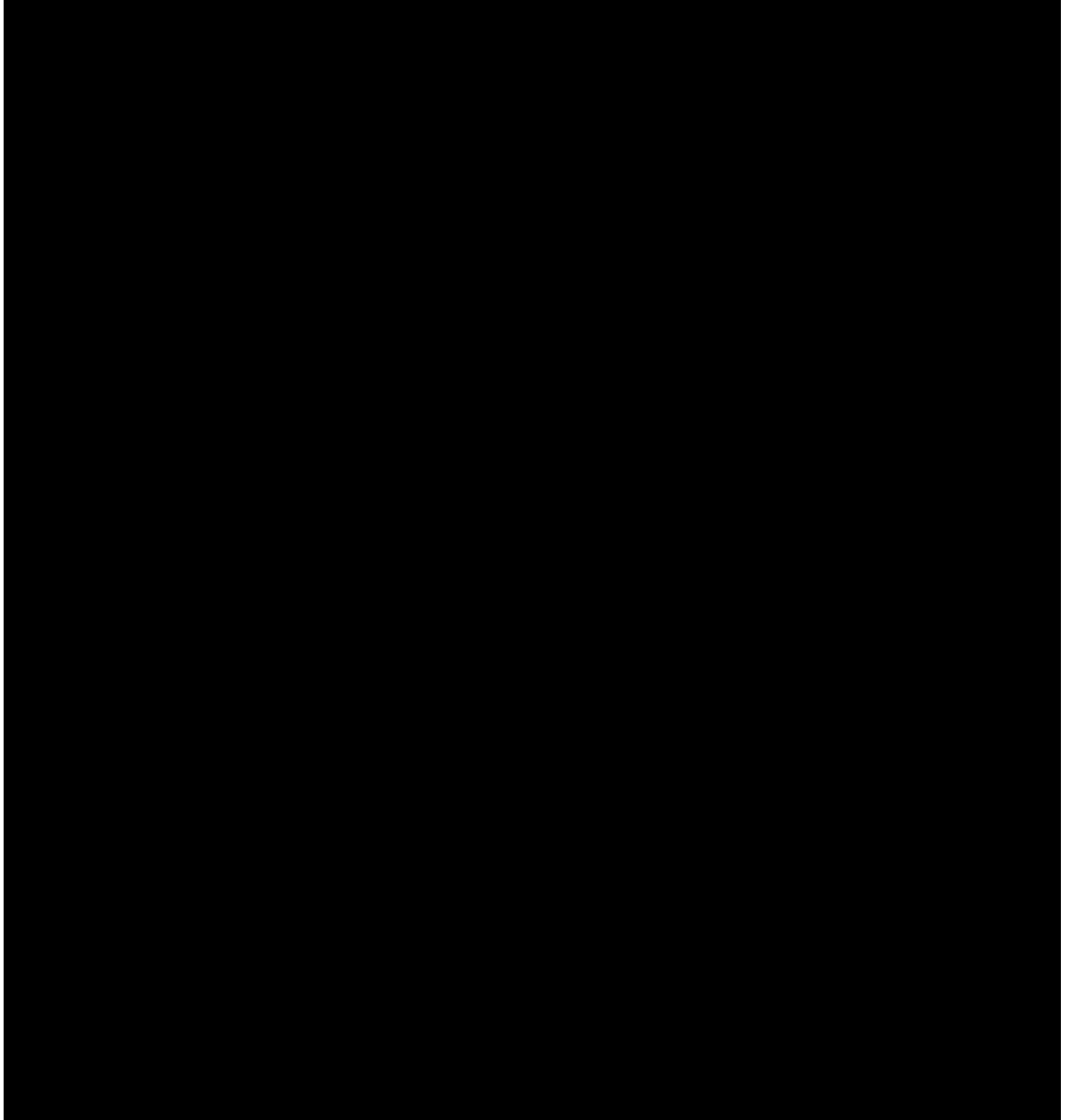
A.4 E4Tech tallow derived biodiesel calculations





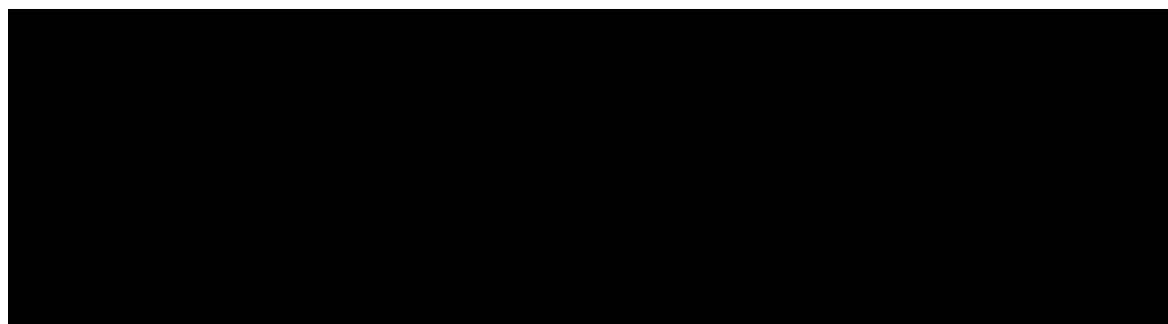


A.5 CRL tallow derived biodiesel calculations





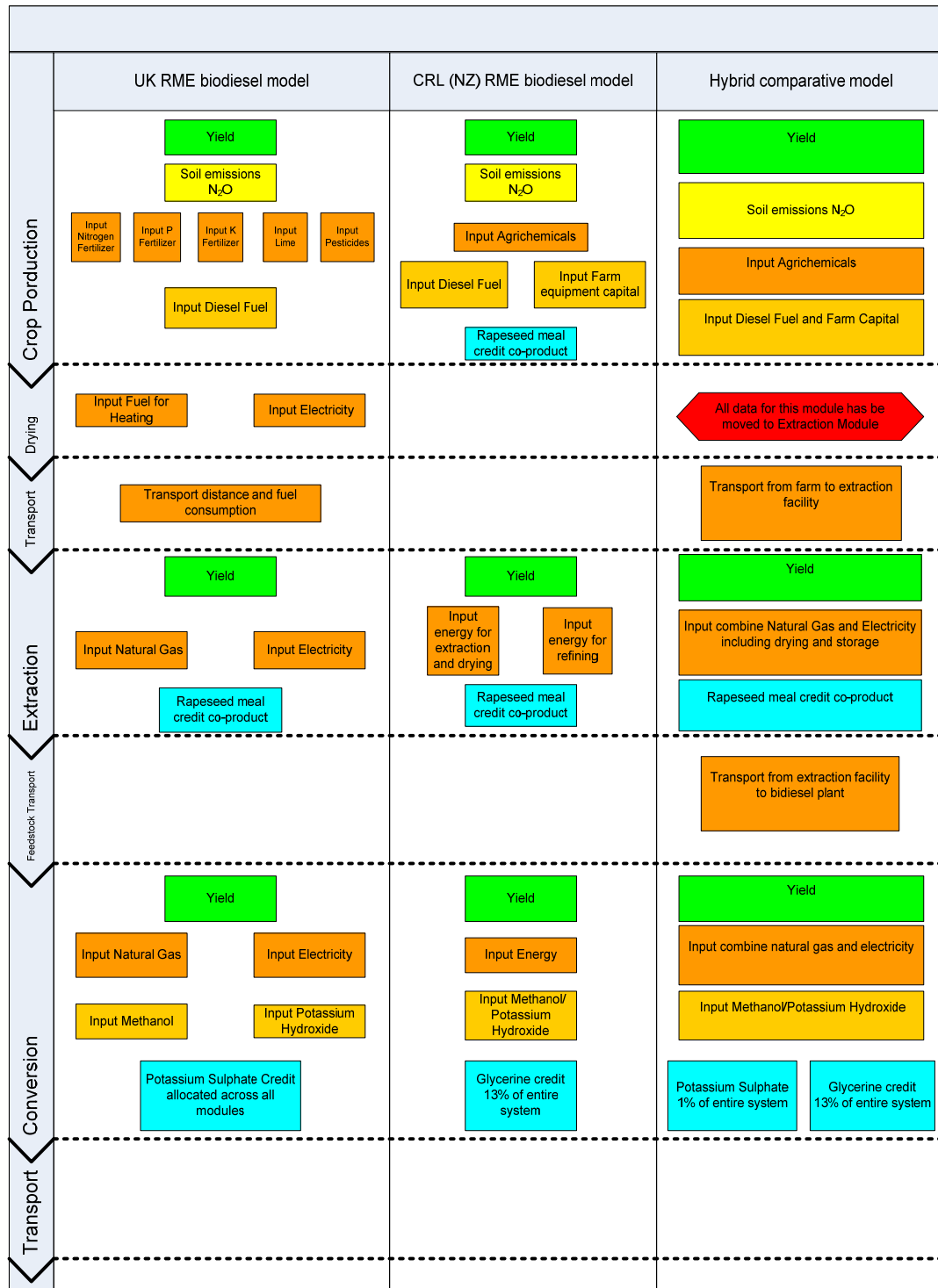
Stage 4 - Conversion						
Description		Biodiesel plant				
Basic data						
Plant yield	[t biodiesel / t UCO or tallow]	1.000	(z1)			
Conversion Inputs						
Natural gas and electricity	[MJ/t biodiesel]		x	Emissions factor (kgCO _{2e} /MJ)	=	Emissions (kgCO _{2e} /t biodiesel)
						130
Methanol	kg/t biodiesel	100	x	Emissions factor (kgCO _{2e} /kg)	=	120
Potassium hydroxide	kg/t biodiesel	0	x	2.4	=	0
Co-products						
Co-product 1:	Description	Treatment				
	Crude glycerine sold as chemical	Allocation - by market value				
Co-product 2:	Potassium sulphate	Allocation - by market value				
Co-products treated by allocation by market value						
Co-product 1: crude glycerine						
Quantity of crude glycerine produced	[t glycerine / t biodiesel]	0.1	x	Market value [\$ / t glycerine]	=	92
				920		
Co-product 2: Potassium sulphate						
Quantity of potassium sulphate produced and sold as chemical	[t potassium sulphate / t biodiesel]	0.00		Market value [€ / t potassium sulphate]	=	0
				75		
Primary product: biodiesel						
Market value of biodiesel				Market value [€ / t biodiesel]	=	616
				616		
Total market value of products						
Total market value	[€ / t biodiesel]					708
Allocation factor (%age of emissions attributable to biodiesel) %						100
Totals						
Module total						Total Emissions [kgCO _{2e} /t biodiesel]
						250
Contribution to fuel chain						250
Glycerine credit						-263





Appendix B Flow Charts

B.1 E4Tech and CRL LCA flow charts for RME biodiesel





B.2 E4Tech and CRL LCA flow chart for tallow derived biodiesel

