Report of the GHGenius Model Run of the HECO CT-1 Biodiesel Supply

1. Diesel Fuel Production

Diesel fuel for the comparison scenario is produced in a petroleum refinery in Hawaii and is based on publicly available information. This refinery sources its crude oil from southeast Asia, mostly from Vietnam, Thailand, China and Indonesia. The proportion of each country is shown in the following table (US EIA, 2007).

Table 1-1 Refinery Crude Oil Sources

Country	% of Total	Comments
Vietnam	55.2%	All offshore oil production
Thailand	26.9%	85% offshore. Chevron is a major producer
China	9.2%	85% onshore.
Indonesia	6.9%	Chevron is a major producer in the country

The oil from all of these sources is a light sweet crude oil. The average API gravity was 37.3 and the average sulphur was reported to be 0.1% (US EIA, 2007). Not each of the countries is included in GHGenius, so for modelling purposes the Thailand and Indonesian oil is aggregated and the Vietnam and China oil is combined.

Shipping distances are calculated based on Jakarta and Shanghai as the shipping ports and Honolulu as the receiving port.

It is assumed that the diesel fuel is shipped 30 km by truck between the refinery and the power plant. It is assumed that the diesel fuel is low sulphur diesel (500 ppm S).

GHGenius has been set up to reflect this crude oil input data. No other changes to the diesel fuel pathway have been made to the model. The refinery that is modelled is the average refinery in the western United States.

The GHG emissions for the production and use of this fuel in a large diesel fired stationary engine are shown in the following table. The emissions are shown on a higher heating value basis.

Table 1-2 Lifecycle Emissions Diesel Fuel

Fuel	Low Sulphur Diesel	
Feedstock	Crude oil	
	g CO_2 eq/GJ Fuel	Comments
Fuel dispensing	0	
Fuel distribution and storage	317	Emissions related to transportation from refinery to power plant
Fuel production	5,132	Refining emissions
Feedstock transmission	2,293	Crude oil transport emissions
Feedstock recovery	5,531	Energy related emissions from crude oil production
Land-use changes, cultivation	0	
Fertilizer manufacture	0	
Gas leaks and flares	2,936	Leaks and flares associated with crude oil production
CO_2, H_2S removed from NG	0	
Emissions displaced	-0	
Sub-Total	16,209	Emissions for fuel production
Combustion	76,490	Stationary diesel engines have relatively high N_2O emissions
Lifecycle emissions	92,699	Lifecycle emissions

The energy balance calculated by the model for this fuel production pathway is shown in the following table. For every unit of energy delivered to the power plant 0.17 units of energy are consumed producing, refining and transporting the fuel. The energy expended includes the energy used to produce the energy that is used in the process. The Net Energy ratio is the inverse of the energy consumed per unit delivered. In addition to the total energy balance the fossil energy balance is also shown. In this case, any renewable energy used in the production system is not included in the calculation. For the petroleum diesel fuel the differences are relatively small.

Table 1-3 Energy Balance Petroleum Diesel Fuel

Fuel	Diesel Fuel	Diesel Fuel
Feedstock	Crude oil	Crude oil
	Total Energy	Fossil Energy
	Joules consumed/Joule delivered	
Fuel dispensing	0.0000	0.0000
Fuel distribution, storage	0.0041	0.0038
Fuel production	0.0625	0.0599
Feedstock transmission	0.0255	0.0254
Feedstock recovery	0.0776	0.0698
Ag. chemical manufacture	0.0000	0.0000
Co-product credits	-0.0000	-0.0000
Total	**0.1697**	**0.1589**
Net Energy Ratio (J delivered/J consumed)	**5.8927**	**6.2932**

2. ANIMAL FAT BIODIESEL

The fuel for this assessment is animal fat biodiesel where the fuel is produced in the Midwest, and is then shipped to Hawaii.

2.1 ANIMAL FAT BIODIESEL PRODUCTION

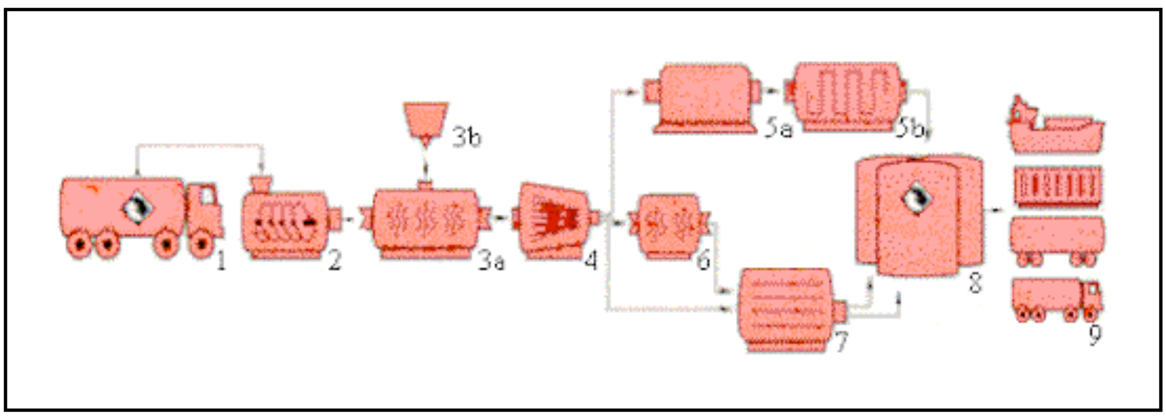
Approximately 90% of the animal fat for this project is obtained directly from slaughter facilities. The other 10% is obtained from rendering facilities. The rendering process recycles animal and poultry by-products, including bones, trim, fat, offal and feathers, and waste cooking oils into a broad range of commercial tallow (animal/vegetable fat) and protein products (meat and bone, poultry, feather, blood, fish and porcine meals). Bypassing the rendering facility has a significant impact on the energy requirements and GHG emissions of the overall process.

To be consistent with the other waste feedstocks the only input required for the feedstock production stage is the transportation of the feedstock to the rendering plant. The feedstock for tallow production is the animal wastes and by-products. The energy requirements for this stage are calculated automatically in the model based on the transportation distances and the material properties. The feedstock is assumed to have a high moisture of content of approximately 64%. It has been assumed that the animal carcasses are transported and average of 100 km by truck to the rendering facility.

2.1.1 Feedstock Production

The process steps involved in the rendering process are shown in the following figure.

Figure 2-1 Rendering Process



The individual steps in the process are described below:

1. Trucks: collection from suppliers.
2. Grinder: each type of raw material is processed separately, starting with crushing

3a. Cooker: releases natural proteins and oils of the animal by-products; feathers are hydrolyzed
3b. Air purifier: ensures the highest standard of air quality

4. Press: all materials are pressed to separate solids from liquids

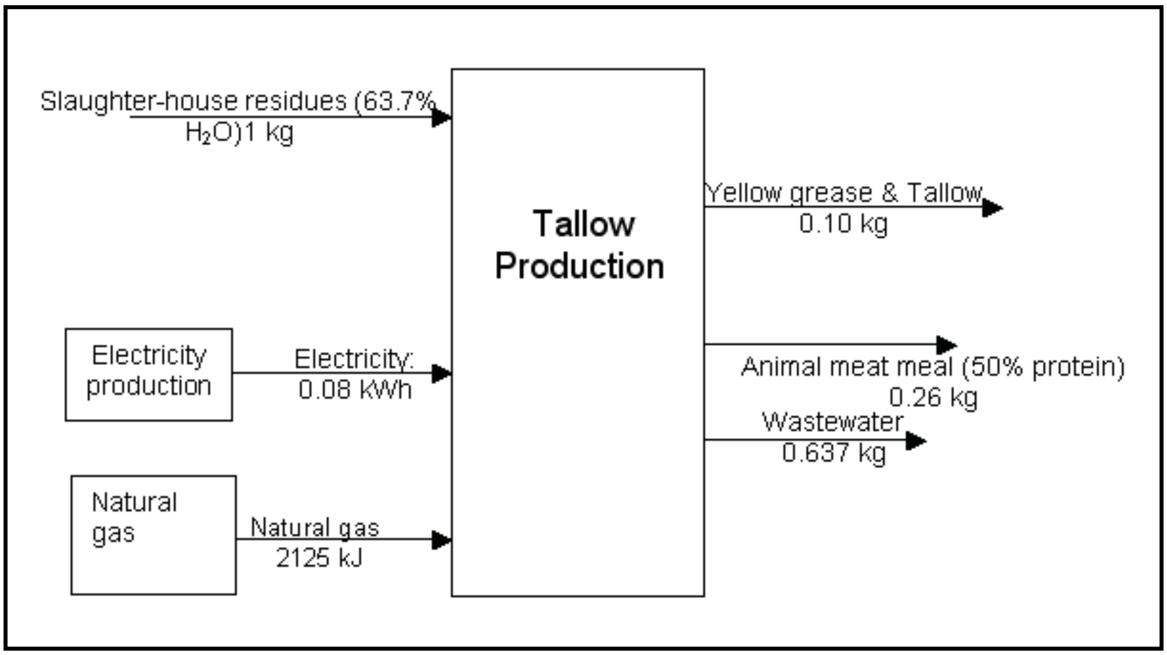
5a. Centrifuge: fats and oils are centrifuged to remove any remaining solids; blood is collected through coagulation and centrifuging
5b. Polisher: fats and oils are further refined, filtered and processed

6. Dryer: fish solids and feathers are dried separately
7. Mill: protein meals are milled separately
8. Storage: all meals, fats and oils are stored in tanks until shipped
9. Transport: meals, fats and oils are delivered via truck, rail, container or ship.

Individual rendering operations can have variations in the process shown above. The variations can include the cooking temperature, the degree of heat recovery employed and the types of feedstocks process. There does not appear to be any industry wide statistics kept on energy use in the industry.

The mass and energy balance for a typical rendering operation has been provided by the National Research Council (2004) and it is shown schematically in the following figure. The energy requirements are based on a theoretical calculation of a plant without any energy recovery. This is typical for North American facilities.

Figure 2-2 Mass and Energy Balance for Animal Rendering



The overall yield is summarized in the following table.

Table 2-1 Typical Animal Fat Rendering System

	Metric
Inputs	
Animal Residue	10 kg
Outputs	
Tallow	1.0 kg
Meat and Bone Meal	2.6 kg
Water	6.4 kg

The operation also produces protein meals as co-products. This material typically has a protein content of 50%. It will be assumed that it is a direct displacement for soybean meal on a kilogram for kilogram basis.

The feedstock for tallow production has a high water content, which requires heat to dehydrate. The energy requirements to produce the oil for one litre of tallow are summarized in the following table. The natural gas requirements are based on the theoretical energy required to evaporate the water present with no provision for energy recovery.

Table 2-2 Energy Requirements for Rendering Operations

	Per Litre of Tallow
Electricity	0.67 kWh
Natural gas	429.3 L

For this project, only 10% of the animal fat is rendered and 90% is collected directly from the slaughter facilities. This has been modelled by changing the energy and mass balance of the rendering process. The revised mass and energy balance data is summarized in the following table.

Table 2-3 Mass and Energy Data for Modelling

	Input	Output
Carcasses	1.0 kg	
Animal Fat from Slaughter Facilities	0.9 kg	
Total	1.9 kg	
Natural Gas	42.9 l	
Electricity	0.067 kWh	
Tallow		1.0 kg
Meat and bone meal		0.26 kg

2.1.2 Biodiesel Production

The conversion of animal fats to biodiesel uses the animal fat esterification step in the model. The values that will be used for the modelling are shown in the following table. The biodiesel manufacturer has supplied the power and gas requirements for their process. The energy requirements are higher than they are for a vegetable oil biodiesel plant and reflect the different feedstock characteristics. This biodiesel plant energy is assumed to include any pretreatment of the feedstock that is required prior to the biodiesel production steps.

Table 2-4 Esterification Input for Modelling

	Power	Fuel	Methanol	Sodium Hydroxide
GHGenius	0.06 kWh/litre	43.6 L NG/Litre	0.108 litre/litre	0.009 kg/litre

The conversion process is highly efficient but the yields of biodiesel per gallon of feedstock will vary with the quality of the feedstock. The biodiesel manufacturer has provided information on the feedstock requirements of 0.96 kg of animal fat per litre of biodiesel. This is a reasonable feedstock rate for high quality animal fat.

2.1.3 Transportation

The transportation assumptions for animal fat biodiesel are shown below. The animal fat is shipped an average of 160 km by truck from the renderers to the biodiesel plant. The biodiesel is shipped by rail to Los Angeles and then by ship to Honolulu.

Table 2-5 Transportation Assumption for Animal Fat Biodiesel

	Feedstock average kilometre shipped
By Rail	0
Domestic water	0
Truck	160
	Finished fuel average kilometre shipped
By Rail	2,780
International water	4,130
Truck	30

2.1.4 Biodiesel Co-Products

The biodiesel process also produces glycerine. The biodiesel plant sells the crude glycerine and it is assumed that once this product is refined it will displace synthetic glycerine. The energy and emission credit that is provided is for the materials that produce synthetic glycerine not the energy required for the process. It is assumed that the energy required to refine the crude glycerine is the same as the energy required for the synthetic glycerine process.

2.2 RESULTS

The results of the analysis of the animal fat biodiesel scenario based on the inputs described above are shown in the following table.

Table 2-6 Lifecycle Emissions Animal Fat Biodiesel

Fuel	Animal Fat Biodiesel	
Feedstock	Animal Carcass	
	g CO_2 eq/GJ Fuel	Comments
Fuel dispensing	0	
Fuel distribution and storage	2,492	Emissions related to transportation from animal fat biodiesel plant to power plant
Fuel production	9,465	Animal fat Biodiesel production emissions
Feedstock transmission	1,329	Emissions related to animal fat collection to biodiesel plant
Feedstock recovery	0	Energy related emissions from animal carcass production
Land-use changes, cultivation	0	Emissions related to fertilizer use
Fertilizer manufacture	0	Emissions related to fertilizer manufacture
Gas leaks and flares	0	Leaks and flares associated with crude oil production
CO_2, H_2S removed from NG	0	
Emissions displaced	-18,202	Co-product credit for meat and bone meal and glycerine
Sub-Total	-4,916	Emissions for fuel production
Combustion	8,627	Stationary diesel engines have relatively high N_2O emissions. No carbon related emissions from biofuels.
Lifecycle emissions	3,711	Lifecycle emissions

The energy balance information for this scenario is shown in the following table. Both the total energy balance and the fossil energy balance are presented.

Table 2-7 Energy Balance Animal Fat Biodiesel

Fuel	Animal Fat Biodiesel	Animal Fat Biodiesel
Feedstock	Animal Carcass	Animal Carcass
	Total Energy	Fossil Energy
	Joules consumed/Joule delivered	
Fuel dispensing	0.0000	0.0000
Fuel distribution, storage	0.0291	0.0287
Fuel production	0.1528	0.1390
Feedstock transmission	0.0167	0.0166
Feedstock recovery	0.0000	0.0000
Ag. chemical manufacture	0.0000	0.0000
Co-product credits	-0.1675	-0.1298
Total	**0.0311**	**0.0545**
Net Energy Ratio (J delivered/J consumed)	**32.1543**	**18.3486**

3. DISCUSSION

There is a significant difference in the lifecycle GHG emissions between petroleum derived diesel fuel and animal fat biodiesel. Most of the difference is caused by the renewable nature of the animal fat derived fuel.

3.1 FINDINGS

In the following table, the GHG emissions for the animal fat biodiesel scenario is presented and compared to the petroleum diesel case.

Table 3-1 Comparison of the Lifecycle GHG Emissions of Petroleum Diesel and Animal Fat Biodiesel

Fuel	Petroleum Diesel	Biodiesel
Feedstock	Crude Oil	Animal Fat
Manufacturing Location	Hawaii	Midwest
	g CO_2 eq/GJ Fuel	
Fuel dispensing	0	0
Fuel distribution and storage	317	2,492
Fuel production	5,132	9,465
Feedstock transmission	2,293	1,329
Feedstock recovery	5,531	0
Land-use changes, cultivation	0	0
Fertilizer manufacture	0	0
Gas leaks and flares	2,936	0
CO_2, H_2S removed from NG	0	0
Emissions displaced	-0	-18,202
Sub-Total	16,209	-4,916
Combustion	76,490	8,627
Lifecycle emissions	92,699	3,711
% Reductions		96.0
Reductions per litre of biodiesel used, kg CO_2 eq		3.10

The GHG emissions for the animal fat biodiesel scenario are 96.0% less than the petroleum pathway emissions. The use of animal fat biodiesel saves 3.10 kg of CO_2 eq GHG emissions for every litre of biodiesel produced and consumed.

The total energy balances for the two cases considered are shown in the following table. The animal fat biodiesel case is considerable better than the petroleum diesel.

Table 3-2 Total Energy Balance Comparison

Fuel	Diesel Fuel	Animal Fat Biodiesel
Feedstock	Crude oil	Animal Carcass
Manufacturing Location	Hawaii	Midwest
	Joules consumed/Joule delivered	
Fuel dispensing	0.0000	0.0000
Fuel distribution, storage	0.0041	0.0291
Fuel production	0.0625	0.1528
Feedstock transmission	0.0255	0.0167
Feedstock recovery	0.0776	0.0000
Ag. chemical manufacture	0.0000	0.0000
Co-product credits	-0.0000	-0.1675
Total	**0.1697**	**0.0311**
Net Energy Ratio (J delivered/J consumed)	**5.8927**	**32.1543**

The fossil energy balance for the two cases is shown in the following table. The biodiesel pathway is considerably better than the petroleum diesel case.

Table 3-3 Fossil Energy Balance Comparison

Fuel	Diesel Fuel	Animal Fat Biodiesel
Feedstock	Crude oil	Animal Carcass
Manufacturing Location	Hawaii	Midwest
	Joules consumed/Joule delivered	
Fuel dispensing	0.0000	0.0000
Fuel distribution, storage	0.0038	0.0287
Fuel production	0.0599	0.1390
Feedstock transmission	0.0254	0.0166
Feedstock recovery	0.0698	0.0000
Ag. chemical manufacture	0.0000	0.0000
Co-product credits	-0.0000	-0.1298
Total	**0.1589**	**0.0545**
Net Energy Ratio (J delivered/J consumed)	**6.2932**	**18.3486**

4. REFERENCES

Energy Information Administration. 2007. http://www.eia.doe.gov/pub/oil_gas/petroleum/data_publications/company_level_imports/historical/2007/data/impa07d.xls

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National Research Council. 2004. Life Cycle Analysis of Biodiesel. November 2004.