Universal Biofuels Private, Ltd LCA Analysis Report Portfolio:

In support of LCFS Fuel Pathway modifications for Biodiesel made from Tallow with high-energy rendering and UCO with "cooking" pretreatment

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I. Introduction

We are applying to add a new pathway to the California LCFS fuel carbon-intensity lookup table. This pathway is a modification to the current tallow to biodiesel pathway in CA-GREET model [1].

Except for the points of deviation summarized below, our pathway is identical to the default tallow to biodiesel pathway in CA-GREET model. The pathway differs from the default in only the following ways:

1) The feedstock and fuel are both produced in India and the fuel is shipped to California via ocean tanker for distribution and consumption
2) Electricity mix is specific to India
3) Heat for rendering tallow is generated by woody biomass
4) Values specific to the Universal Biofuels Private, Ltd (referred to as Universal hereafter) biodiesel facility, including the use of electricity, diesel fuel and biomass, are used in the calculation of fuel production energy use.

This application is for tallow collected and processed in India. Based on our modeling in CA-GREET, we find that the modified pathway has a carbon intensity of **55.42** $gCO_2e\ MJ^{-1}$.

II. Company Details

Universal Biofuels Private, Ltd is a biodiesel production facility located at Plot No 36, Industrial Park, Vakalapudi, Kakinada, Andhra Pradesh, India 533004. The facility commenced construction in October 2006 and completed construction in May 2008. The Universal biodiesel plant uses rice husks to generate steam for process heat. The technology provider is De Smet Chemfood Engineering.

Universal Biofuels Private, Ltd operates under an operating license issued by the Andhra Pradesh Pollution Control Board. This license limits production to 45,000,000 gallons of biodiesel per year (150,000 metric tons per year,). Based on this permitted capacity, registered permitted capacity under EPA's RFS program is estimated at 47,250,000 gallons per year (based on 150,000 metric tons per year X 1,000 kg per metric ton X 2.205 lbs per kg X 1 gal per 7.35 pounds biodiesel X 105%).

Under EPA's RFS program, the Universal biodiesel facility is capable of producing biodiesel (Fuel Code 20) under a renewable fuel D code of 4 utilizing waste oils/fats/greases (Feedstock Code 160) via transesterification, in a dedicated renewable biomass facility (Process Code 180). The facility intends to produce D4 biodiesel via transesterification utilizing waste oils/fats/greases (Feedstock Code 160). Because the facility meets grandfathering provisions, it is also capable of producing biodiesel (Fuel Code 20) under a renewable fuel D code of 6 utilizing stearin, Feedstock (not listed) used

at a grandfathered facility (Feedstock Code 888) via transesterification, in a dedicated renewable biomass facility (Process Code 180).

Tallow rendering takes place in the same location as the slaughter of animals. Crushed bones and other wastes from slaughter are cooked in a cooker for 3 hours. No chemical inputs are added to the process. After 3 hours, the animal fats (tallow) float to the top and the solids settle on the bottom. The animal fat is decanted, centrifuged and collected in a storage tank and transported to the biodiesel plant by truck. [redacted]

The Universal biodiesel facility adopts a typical transesterification method for biodiesel production. Tallow feedstock is fed into [redacted] Glycerin that separates out as bi-product is treated to be freed from the methanol and is then sent to storage. The biodiesel obtained from transesterification is settled by gravity, [redacted] Washed biodiesel is distillated to free it from methanol and moisture before it is sent to storage.

EcoEngineers conducted an on-site 3rd party Engineering Review of the Universal biodiesel facility on February 11, 2014, as required under 40 CFR Part 80, section 1450 to register under the EPA's Renewable Fuels Standard. EcoEngineers met with Mr. E.A. Srikirishna, Jr, Production Manager. The on-site review included a review of information provided by the facility prior to the visit and a tour of the quality control laboratory and renewable fuel production facility.

III. Changes to baseline CA-GREET model inputs for Universal biodiesel facility

The modified input values to CA GREET spreadsheet are all listed in Table 1, and in the "1.0 Changes made to CA GREET" tab of a separate spreadsheet named "Universal Original Data File" as well. CI calculation results can be found in the "Tallow BD Results" tab of the modified CA-GREET spreadsheet.

Table 1. Changes made to CA GREET model

Parameter	**Cell location**	**Default BIOD008value**	**Universal Tallow value**	**Units**
Region for analysis	Regional LT!C2	US Average	India	
Res. oil electric generation	Regional LT!J83	2.7%	0.2%	%
Natural gas electric generation	Regional LT!J84	18.9%	42.9%	%
Coal electric generation	Regional LT!J85	50.7%	50.0%	%
Nuclear electric generation	Regional LT!J86	18.7%	0.0%	%
Biomass electric generation	Regional LT!J87	1.3%	0.0%	%
Other (renewables) electric generation	Regional LT!J88	7.7%	6.9%	%

Glycerin coproduct yield	Tallow RD!C39	0.213	CBI	lb/lb BD
Diesel commercial boiler	Tallow RD!C150	0	CBI	%
Biomass used for biodiesel transesterification	Tallow RD!D188	0	CBI	lb rice husks/lb BD
Diesel fuel for biodiesel transesterification	Tallow RD!D185	0	CBI	btu/lb BD
Electricity for biodiesel transesterification	Tallow RD!D190	47	CBI	btu/lb BD
Energy consumed for rice husks production	EtOH!BP144	612,700	0	btu/ton
Transport distance for purchased rice husks	T&D!FZ93	75	CBI	miles
Fuel Transported for BD plant use	T&D!AD4	Forest Residue	Rice Husks	
Payload of Truck	T&D!AD7	17	CBI	
Biodiesel Ocean tanker transport distance	T&D!GB93	NA	CBI	miles
Biodiesel truck transport distance	T&D!GC93	50	CBI	miles
Biodiesel pipeline transport distance	T&D!GE93	400	CBI	miles
Biodiesel ocean tanker payload	T&D!V5	--	CBI	tons
Biodiesel ocean tanker horsepower requirement	T&D!T12	--	CBI	hp
Ocean tanker fraction diesel power	T&D!GB95	--	CBI	%
Ocean tanker fraction residual oil power	T&D!GB96	--	CBI	%
Ocean tanker outbound energy intensity	T&D!GB108	--	CBI	btu/ton-mile
Fraction of biodiesel transported by ocean tanker	T&D!CL138	0	CBI	%
Fraction of biodiesel transported by truck	T&D!CL142	80	CBI	%
Fraction of biodiesel transported by pipeline	T&D!CL140	0	CBI	%
Tallow transport distance truck	T&D!IF93	10	CBI	miles
Tallow transport distance rail	T&D!IG93	1400	0	miles
Combustion process	Tallow RD!A158	Coal industrial boiler	Biomass industrial boiler	
Share of combustion process type	Tallow RD!C158	0	CBI	%
Solid fuel type	Fuel_Specs!A57	Corn stover	Rice Husks	
LHV	Fuel_Specs!B57	14,075,990	CBI	btu/ton

NG used for tallow rendering	Tallow RD!B187	4,956	5,355	btu/lb tallow
Tallow used for tallow rendering	Tallow RD!B198	399	0	btu/lb tallow

IV. Basis for the Input Values

This pathway is similar to the published CA GREET model for default tallow biodiesel, with changes in the following areas as further detailed below.

1. Electricity generation mix (2.0 Electricity Mix)
2. Fuel production and energy use (3.0 Electricity Use and BD, 4.0 Diesel Fuel, 6.0 Rice Husks Use)
3. Transport modes and distances (5.0 Transportation)

Next to each item in parentheses is the supporting documentation reference in the "Universal Original Data File" reference.

The modified CA-GREET spreadsheet is included in the application package; results can be found in the "Tallow BD Results" tabs.

For the rendering of tallow, steam and electricity are consumed. [redacted]

In India, instead of using natural gas and tallow to render tallow, steam boilers fired by wood are usually used to provide the process steam. However, because no detailed demonstrable usage data is currently available, the default usage values of NG, tallow and electricity have been adopted for this pathway. [redacted]

At Universal's facility, there are two different processes: BD production and refinery of self-produced and purchased glycerine. The energy consumptions (including grid electricity, diesel, and rice husks, see below for details) are split into two fractions to reflect the use in these two processes. However, in this application, we allocated all energy use to biodiesel production and therefore ensure a most conservative CI output.

Grid electricity is typically used by the facility for the conversion of tallow to biodiesel in the Universal biodiesel facility. However, sometimes when grid power is unstable or unavailable, diesel fuel is used on-site to generate electricity needed. [redacted] Universal will notice CARB in case there is significant change of this operation in the future. And quarterly reports will also provide additional information in the future.

Rice husks are combusted to provide the processing heat. [redacted] based on peer-reviewed literature [3], "…only a small quantity of RH is utilized for the energy generation and other application such as silica production and composting at present." Therefore, we drew the conclusion that the rice husks market is not constrained and will

not be constrained in the near future because that Universal uses it for process heat at the biodiesel plant.

[redacted] The changes of the fraction of GREET formula to calculate the emissions from use of rice husks are shown in Table 1.

Total grid electricity and diesel fuel consumption from January 2012 to March 2014 is provided in the "Universal Original Data File." The current electricity generation mix in Andhra Pradesh, India is 50.0% coal, 19.5% natural gas, 1.6% nuclear, 0.2% diesel, 0% biomass, and 28.7% others [6]. The nuclear and hydro power is marginalized as natural gas, and the diesel is modelled as residual oil as it is typical in GREET, so the electric mix used is 0.2% residual oil, 50.0 coal, 42.9% natural gas, 0% biomass, 0% nuclear, and 6.9% other renewables. Biodiesel produced is transported by pipeline from the biodiesel plant to the Kakinada port, and then shipped via ocean tankers from the Kakinada port to the CA port, and is finally distributed in CA using trucks. The distance between Kakinada and Oakland is 10,391 miles [7].

The way the ocean tanker transport of biodiesel is modeled as follows:

[redacted]Default values of chemical inputs in CA-GREET model are adopted for Universal's facility. This is reasonable as Universal runs a typical transesterification process for biodiesel production. Universal attests these values are accurate and representative of the facility operation. Universal will inform CARB if these values change significantly in the future.

Energy use values in the submitted pathway are based on facility data from January 2012 to March 2014. This application is only for a new pathway for tallow biodiesel at the Universal biofuel facility, which has a carbon intensity of **55.42 $gCO_2e\ MJ^{-1}$**.

V. CA-GREET Model Output

Table 2: Fossil energy use and emissions from tallow biodiesel produced in the U.S. and in India, separated by life cycle stage. Figures are rounded.

	Tallow, Fuel produced in the U.S.		**Tallow, Fuel produced in India**		**% difference**	
	Fossil Energy (BTU/MMBTU BD)	**Emissions (gCO2e/MJ)**	**Fossil Energy (BTU/MMBTU BD)**	**Emissions (gCO2e/MJ)**	**Fossil Energy (BTU/MMBTU BD)**	**Emissions (gCO2e/MJ)**
Rendering of Tallow	256,379	17.14	[redacted]	[redacted]	[redacted]	[redacted]

Tallow Transport (after rendering)	18,665	1.44	[redacted]	[redacted]	[redacted]	[redacted]
Biodiesel Production	158,852	4.95	[redacted]	[redacted]	[redacted]	[redacted]
Biodiesel Transport	9,596	0.74	[redacted]	[redacted]	[redacted]	[redacted]
Total (Well To Tank)	**443,492**	**24.27**	**[redacted]**	**[redacted]**	[redacted]	**[redacted]**
Total (Tank To Wheel)	**0**	**4.48**	**[redacted]**	**[redacted]**	[redacted]	**[redacted]**
Total (Well To Wheel)	**443,492**	**28.75**	**[redacted]**	**[redacted]**	[redacted]	**[redacted]**

VI. Discussion of Results

Table 2 compares energy use and emissions from the proposed pathway to those from reference [1] for tallow biodiesel produced in the U.S. For the Universal pathway, the most energy consuming and GHGs intensive step is the rendering of the tallow, followed by tallow transport, biodiesel transport, and biodiesel production. It needs to be mentioned that the low-energy rendering is the default case in CA-GREET for US pathway. Both the transport of tallow and biodiesel in the proposed pathway have much higher (over 500%) GHGs emissions than in the default pathway. This is reasonable as the distance of transport is much longer in the proposed pathway.

Overall, the Universal biodiesel process has 93% higher GHGs emissions than that of the U.S. Tallow rendering and transporting tallow feedstock and biodiesel product generate more GHG emissions from the proposed pathway than from the default pathway in US.

VII. Production Range of the Universal biodiesel facility

The new pathway should be applicable to the Universal biodiesel facility for 100% (45,000,000 gallons/year) of the Permitted Capacity issued by the Andhra Pradesh Pollution Control Board.

VIII. Sustainability of the Universal biofuel facility

The Universal biodiesel facility was designed and constructed using well-established modern designs and equipment and is managed by professional, well-qualified staff to ensure that the energy efficiency of and emissions from the facility do not deteriorate over time. Any deterioration in efficiency would result in a less profitable business. Thus the sustainability of the plant is well aligned with the business objectives of the owners.

IX. Impact on Land Use

Since the raw material discussed is tallow, a waste stream from food industry, there is no land use impact.

X. Conclusion

Based on our modeling in CA-GREET and the available data, we find that biodiesel produced from tallow at the Universal biodiesel plant has a carbon intensity of **55.42 $gCO_2e\ MJ^{-1}$**.

XI. References

1. *CA-GREET 1.8b. Dec. 2009. Available at: http://www.arb.ca.gov/fuels/lcfs/lcfs-background.htm (Accessed June 20th, 2014).*
2. *California Environmental Protection Agency, Air Resource Board, 2009. Detailed California-Modified GREET Pathway for Co-Processed Renewable Diesel Produced from Tallow (U. S. Sourced) Version 2.0. September 23, 2009. Available at: http://www.arb.ca.gov/fuels/lcfs/092309lcfs_tallow_rd.pdf (Accessed Nov. 21st, 2014)*
3. *Pode R. 2016. Potential applications of rice husk ash waste from rice husk biomass power plant. Renewable and Sustainable Energy Reviews 53: 1468–1485. doi:10.1016/j.rser.2015.09.051*
4. *http://www.knowledgebank.irri.org/step-by-step-production/postharvest/milling/what-is-rice-husk*
5. *Quaak. P., Knoef, H., Stassen, H., 1999. Energy from Biomass: A Review of Combustion and Gaification Technologies. World Bank Technical Paper No. 422 Energy Series.*
6. *Monthly All India Installed Generation Capacity Report. http://www.cea.nic.in/installed_capacity.html. (Accessed June 3rd, 2015).*
7. *Farnel Capital Incorporated. Port to port distances, 2013. Available at: http://www.searates.com/reference/portdistance/ (Accessed June 20th, 2014).*
8. *Detailed California-Modified GREET Pathway for Biodiesel Produced in California from Used Cooking Oil. Version 2.0. California Environmental Protection Agency Air Resources Board, 2009.*

XII. Data supporting Annual Quantities of electricity, diesel fuel use and biodiesel production

The data supporting the annual quantities of electricity, diesel fuel use and biodiesel production, as well as the modifications to the CA-GREET model and methanol calculations are documented in a separate spreadsheet named "Universal Original Data File".

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XIII. Introduction

We are applying to add a new pathway to the California LCFS fuel carbon-intensity lookup table. This pathway is a modification to the current Midwest used cooking oil (UCO) to biodiesel pathway in CA-GREET model [9].

Except for the points of deviation summarized below, our pathway is identical to the default Midwest UCO to biodiesel pathway in CA-GREET model. The pathway differs from the default in only the following ways:

1) The feedstock is imported from other countries including China, Thailand and Saudi Arabia, is converted to biodiesel in India, and the fuel is shipped to California via ocean tanker for distribution and consumption
2) The electricity mix for biodiesel production is specific to India
3) Values specific to the Universal Biofuels Private, Ltd (referred to as Universal hereafter) biodiesel facility, including the use of electricity, diesel fuel and biomass, are used in the calculation of fuel production energy use.

This application is for UCO imported and processed in India. Based on our modeling in CA-GREET, we find that the modified pathway has a carbon intensity of **24.21** $gCO_2e\ MJ^{-1}$.

XIV. Company Details

Universal Biofuels Private, Ltd is a biodiesel production facility located at Plot No 36, Industrial Park, Vakalapudi, Kakinada, Andhra Pradesh, India 533004. The facility commenced construction in October 2006 and completed construction in May 2008. The Universal biodiesel plant uses rice husks to generate steam for process heat. The technology provider is De Smet Chemfood Engineering.

Universal Biofuels Private, Ltd operates under an operating license issued by the Andhra Pradesh Pollution Control Board. This license limits production to 45,000,000 gallons of biodiesel per year (150,000 metric tons per year,). Based on this permitted capacity, registered permitted capacity under EPA's RFS program is estimated at 47,250,000 gallons per year (based on 150,000 metric tons per year X 1,000 kg per metric ton X 2.205 lbs per kg X 1 gal per 7.35 pounds biodiesel X 105%).

Under EPA's RFS program, the Universal biodiesel facility is capable of producing biodiesel (Fuel Code 20) under a renewable fuel D code of 4 utilizing waste oils/fats/greases (Feedstock Code 160) via transesterification, in a dedicated renewable biomass facility (Process Code 180). The facility intends to produce D4 biodiesel via transesterification utilizing waste oils/fats/greases (Feedstock Code 160). Because the facility meets grandfathering provisions, it is also capable of producing biodiesel (Fuel

Code 20) under a renewable fuel D code of 6 utilizing stearin, Feedstock (not listed) used at a grandfathered facility (Feedstock Code 888) via transesterification, in a dedicated renewable biomass facility (Process Code 180).

The UCO feedstock entering the Universal biodiesel facility is collected by 3rd party companies and imported from other countries including China, Thailand and Saudi Arabia by ocean tanker. The water in the raw UCO collected is removed before entering the facility. Due to the lack of the energy consumption data for UCO rendering, the high energy that is associated with UCO cooking in the default Midwest CA-GREET model is adopted, as well as the energy shares [9]. The transport distance of UCO by ocean tanker is assumed at 11,500 miles. This conservative assumption ensures Universal to be able to purchase UCO from any countries in the world. We have modified the electric mix based on a previous discussion with CARB staff. Now the electric mix is 5% residue oil, 15% natural gas and 80% coal. This should be conservative enough to cover different locations where the UCO is cooked.

The Universal biodiesel facility adopts a typical transesterification method for biodiesel production. UCO feedstock is fed into [redacted]. Glycerin that separates out as by-product is treated to be freed from the methanol and is then sent to storage. The biodiesel obtained from transesterification is settled by [redacted] Washed biodiesel is dried to free it from methanol and moisture before sent for storage.

EcoEngineers conducted an on-site 3rd party Engineering Review of the Universal biodiesel facility on February 11, 2014, as required under 40 CFR Part 80, section 1450 to register under the EPA's Renewable Fuels Standard. EcoEngineers met with Mr. E.A. Srikirishna, Jr, Production Manager. The on-site review included a review of information provided by the facility prior to the visit and a tour of the quality control laboratory and renewable fuel production facility.

XV. Changes to baseline CA-GREET model inputs for Universal biodiesel facility

The modified input values to CA GREET spreadsheet are listed in Table 3, and in the "1.0 Changes made to CA GREET" tab of a separate spreadsheet named "Universal UCO to BD Original Data File" as well. CI calculation results can be found in the "UCO BD Results" tab of the modified CA-GREET spreadsheet.

Table 3. Changes made to CA GREET model

Parameter	Cell location	Default BIOD002	Universal UCO value	Units

		value		
Select Region for Analysis	Regional LT!C2	Midwest	India	
Fuel phase electric generation mix				
Res. oil electric generation	Regional LT!J83	2.7%	0.2%	%
Natural gas electric generation	Regional LT!J84	18.9%	42.9%	%
Coal electric generation	Regional LT!J85	50.7%	50.0%	%
Nuclear electric generation	Regional LT!J86	18.7%	0.0%	%
Biomass electric generation	Regional LT!J87	1.3%	0.0%	%
Other (renewables) electric generation	Regional LT!J88	7.7%	6.9%	%
Feedstock phase electric generation mix				
Res. oil electric generation	Regional LT!J83	2.7%	5%	%
Natural gas electric generation	Regional LT!J84	18.9%	15%	%
Coal electric generation	Regional LT!J85	50.7%	80%	%
Nuclear electric generation	Regional LT!J86	18.7%	0.0%	%
Biomass electric generation	Regional LT!J87	1.3%	0.0%	%
Other (renewables) electric generation	Regional LT!J88	7.7%	0%	%
Diesel fuel for UCO transesterification	UCO BD!F187	0	CBI	btu/lb BD
Glycerin coproduct yield	UCO BD!C41	0.105	CBI	lb/lb BD
Diesel commercial boiler	UCO BD!D152	0	CBI	%
Electricity for UCO transesterification	UCO BD!F192	47	CBI	btu/lb BD
Biomass used for biodiesel transesterification	UCO BD!F190	0	CBI	lb rice husks/lb BD
Energy consumed for rice husks production	EtOH!BP144	612,700	0	btu/ton
Transport distance for purchased rice husks	T&D!FZ93	75	CBI	miles
Fuel Transported for BD plant use	T&D!AD4	Forest Residue	Rice Husks	
Payload of Truck	T&D!AD7	17	CBI	
Biodiesel Ocean tanker transport distance	T&D!GB93	NA	CBI	miles
Biodiesel truck transport distance	T&D!GC93	50	CBI	miles
Biodiesel pipeline transport distance	T&D!GE93	400	CBI	miles
Biodiesel ocean tanker payload	T&D!V5	--	CBI	tons
Biodiesel ocean tanker horsepower requirement	T&D!T12	--	CBI	hp
Ocean tanker fraction residual oil power	T&D!GB96	--	CBI	%

Ocean tanker outbound energy intensity	T&D!GB108	--	CBI	btu/ton-mile
Fraction of biodiesel transported by ocean tanker	T&D!CL138	0	CBI	%
Fraction of biodiesel transported by truck	T&D!CL142	80	CBI	%
Fraction of biodiesel transported by pipeline	T&D!CL140	0	CBI	%
UCO transport distance by ocean tanker	T&D!IJ93	--	11,500	miles
Combustion process	UCO BD!A160	Coal industrial boiler	Biomass industrial boiler	
Solid fuel type	Fuel_Specs!A57	Corn stover	Rice husks	
LHV	Fuel_Specs!B57	14,075,990	CBI	btu/ton
UCO transport distance by truck	T&D!II93	50	110	miles
Share of residual oil for ocean tanker	T&D!IJ96	--	100%	%
Ocean tanker energy intensity				
Ocean tanker back-haul energy intensity	T&D!IJ109	--	CBI	
Share of UCO ocean tanker transport	T&D!DP138	--	CBI	

XVI. Basis for the Input Values

This pathway is similar to the published CA GREET model for default Midwest UCO biodiesel, with changes in the following areas as further detailed below.

1. Electricity generation mix (2.0 Electricity Mix)
2. Fuel production and energy use (3.0 Electricity Use and BD, 4.0 Diesel Fuel)
3. Transport modes and distances (5.0 Transportation)

Next to each item in parentheses is the supporting documentation reference in the "Universal UCO to BD Original Data File" reference.

The modified CA-GREET spreadsheet is included in the application package; results can be found in the "UCO BD Results" tabs.

For the rendering of UCO, steam and electricity are consumed. [redacted]

At Universal's facility, there are two different processes: BD production and refinery of self-produced and purchased glycerine. The energy consumptions (including grid electricity, diesel, and rice husks, see below for details) are split into two fractions to

reflect the use in these two processes. However, in this application, we allocated all energy use to biodiesel production and therefore ensure a most conservative CI output.

Grid electricity is typically used by the facility for the conversion of UCO to biodiesel in the Universal biodiesel facility. However, sometimes when grid power is unstable or unavailable, diesel fuel is used on-site to generate electricity needed. [redacted] Universal will notice CARB in case there is significant change of this operation in the future. And quarterly reports will also provide additional information in the future.

Rice husks are combusted to provide the processing heat. [redacted] based on peer-reviewed literature [10], "…only a small quantity of RH is utilized for the energy generation and other application such as silica production and composting at present." Therefore, we drew the conclusion that the rice husks market is not constrained and will not be constrained in the near future because that Universal uses it for process heat at the biodiesel plant. [redacted]

Total grid electricity and diesel fuel consumption from January 2012 to March 2014 is provided in the "Universal UCO to BD Original Data File." The current electricity generation mix in Andhra Pradesh, India is 50.0% coal, 19.5% natural gas, 1.6% nuclear, 0.2% diesel, 0% biomass, and 28.7% others [13]. The nuclear and hydro power is marginalized as natural gas, and the diesel is modelled as residual oil as it is typical in GREET, so the electric mix used is 0.2% residual oil, 50.0 coal, 42.9% natural gas, 0% biomass, 0% nuclear, and 6.9% other renewables. Biodiesel produced is transported by pipeline from the biodiesel plant to the Kakinada port, and then shipped via ocean tanker from the Kakinada port to the CA port, and finally distributed in CA using trucks. The distance between Kakinada and Oakland is 10,391 miles [14].

The way the ocean tanker transport of biodiesel is modeled as follows:
[redacted]
When calculating the CI for feedstock phase and the fuel phase, the electric mixes are different. The way to handle it is as follows:

[redacted]Default values of chemical inputs in CA-GREET model are adopted for Universal's facility. This is reasonable as Universal runs a typical transesterification process for biodiesel production. Universal attests these values are accurate and representative of the facility operation. Universal will inform CARB if these values change significantly in the future.

Energy use values in the submitted pathway are based on facility data from January 2012 to March 2014. This application is only for a new pathway for UCO biodiesel at the Universal biofuel facility, which has a carbon intensity of **24.21 $gCO_2e\ MJ^{-1}$**.

XVII. CA-GREET Model Output

Table 4: Fossil energy use and emissions from UCO biodiesel produced in the Midwest U.S. and in India, separated by life cycle stage. Figures are rounded.

	UCOME Cooking Required, Fuel produced in the Midwest		**UCOME Cooking Required, Fuel produced in Universal, Inida**		**% difference**	
	Energy (BTU/ MMBTU BD)	**Emissions (gCO2e/ MJ)**	**Energy (BTU/MMBTU BD)**	**Emissions (gCO2e/MJ)**	**Energy (BTU/MMBTU BD)**	**Emissions (gCO2e/MJ)**
UCO Transport to Rendering Plant	0	0.00	[redacted]	[redacted]	[redacted]	[redacted]
Rendering of UCO	88681	5.69	[redacted]	[redacted]	[redacted]	[redacted]
UCO Transport (after rendering)	3912	0.30	[redacted]	[redacted][redacted]	[redacted]	[redacted]
Biodiesel Production	174956	6.06	[redacted]	[redacted]	[redacted]	[redacted]
Biodiesel Transport	28384	2.19	[redacted]	[redacted]	[redacted]	[redacted]
Total (Well To Tank)	**295933**	**14.24**	**[redacted]**	**[redacted]**	[redacted]	**[redacted]**
Total (Tank To Wheel)	**1000000**	**4.48**	**[redacted]**	**[redacted]**	[redacted]	**[redacted]**
Total (Well To Wheel)	**1295933**	**18.72**	**[redacted]**	**[redacted]**	[redacted]	**[redacted]**

XVIII. Discussion of Results

Table 4 compares energy use and emissions from the proposed pathway to those from reference [9] for UCO biodiesel produced in the U.S. For the default pathway, the most energy consuming and GHGs intensive step is the biodiesel production, followed by the rendering of UCO, biodiesel transport, and UCO transport. [redacted] Both the transport of UCO and biodiesel in the proposed pathway have much higher GHGs emissions than

in the default pathway. This is reasonable as the transportation distance is much longer in the proposed pathway.

Overall, the Universal UCO biodiesel process has 29% higher GHGs emissions than that of the UCO biodiesel produced in Midwest U.S. Transporting the UCO feedstock and the final biodiesel product generate more GHG emissions from the proposed pathway than from the default pathway based in the US.

XIX. Production Range of the Universal biodiesel facility

The new pathway should be applicable to the Universal biodiesel facility for 100% (45,000,000 gallons/year) of the Permitted Capacity issued by the Andhra Pradesh Pollution Control Board.

XX. Sustainability of the Universal biofuel facility

The Universal biodiesel facility was designed and constructed using well-established modern designs and equipment and is managed by professional, well-qualified staff to ensure that the energy efficiency of and emissions from the facility do not deteriorate over time. Any deterioration in efficiency would result in a less profitable business. Thus the sustainability of the plant is well aligned with the business objectives of the owners.

XXI. Impact on Land Use

Since the raw material discussed is UCO, a waste stream from food industry, there is no land use impact.

XXII. Conclusion

Based on our modeling in CA-GREET and the available data, we find that biodiesel produced from UCO at the Universal biodiesel plant has a carbon intensity of **24.21 $gCO_2e\ MJ^{-1}$**.

XXIII. References

9. *California Environmental Protection Agency, Air Resource Board, 2012. Detailed California-Modified GREET PathwayFor Biodiesel Produced in the Midwest fromUsed Cooking Oil (UCO) and Used in California. Last updated February 21, 2012. Available at: http://www.arb.ca.gov/fuels/lcfs/2a2b/internal/15day-mw-uco-bd-022112.pdf (Accessed Dec 4th, 2014)*

10. *Pode R. 2016. Potential applications of rice husk ash waste from rice husk biomass power plant. Renewable and Sustainable Energy Reviews 53: 1468–1485. doi:10.1016/j.rser.2015.09.051*

11. *http://www.knowledgebank.irri.org/step-by-step-production/postharvest/milling/what-is-rice-husk*

12. *Quaak. P., Knoef, H., Stassen, H., 1999. Energy from Biomass: A Review of Combustion and Gaification Technologies. World Bank Technical Paper No. 422 Energy Series.*

13. *Monthly All India Installed Generation Capacity Report. http://www.cea.nic.in/installed_capacity.html. (Accessed June 3rd, 2015).*

14. *Farnel Capital Incorporated. Port to port distances, 2013. Available at: http://www.searates.com/reference/portdistance/ (Accessed Dec. 4th, 2014).*

XXIV. Data supporting Annual Quantities of electricity, diesel fuel use and biodiesel production

The data supporting the annual quantities of electricity, diesel fuel use and biodiesel production, as well as the modifications to the CA-GREET model are documented in a separate spreadsheet named "Universal UCO to BD Original Data File".