October 24, 2014

Cal/EPA Headquarters Building
1001 “I” Street
Sacramento, CA 95812

RE: Comments on the LCFS Program – CA-GREET 2.0

Mr. Ingram and Mr. Pham,

National Sorghum Producers (NSP) is a trade association representing the interests of over 50,000 sorghum producers on issues related to legislative and regulatory policy in Washington as well as various state capitals. NSP led efforts to secure an advanced biofuel pathway for sorghum under the RFS2 and has performed extensive analysis on several models and datasets over the last four years, including several datasets similar to those used by the Argonne National Laboratory (ANL) as well as the ARB in modeling the CI of sorghum ethanol.

NSP applauds the ARB for undertaking an extensive update of the LCFS, but we have serious concerns about several of the assumptions underlying the portions of the GREET model used to estimate sorghum CI. We have been in close contact with personnel at the ANL regarding these concerns and present them in the attached comments. In brief:

- Sorghum yield
    - Sorghum yield has been lowered based on data gathered in a historic drought. Sorghum yields are unlikely to ever again be as low as they have been over the last few years, so this value should be left unchanged.
- Sorghum farming energy use
    - The energy use value should ultimately reflect the fact that a large percentage of producers practice no tillage agriculture which correlates to significant fossil fuel savings on-farm as well as the fact that grain sorghum is not dried using fossil fuels.
- Nitrogen application rate
    - Nitrogen application rates have not changed. This is due to fertilizer recommendations remaining the same and a grain sorghum harvest ratio calculation error. With forage sorghum acres excluded from the NASS-published acreage figures, the nitrogen application rate is similar to that used by the ARB in the 2010 pathway.
- N_2O emissions from sorghum stover
    - This area is especially concerning, as it has very significant CI effects and its applicable model portions are based on sorghum genotypes *not used in commercial sorghum production.* As a result, these genotypes have yields and harvest indices completely unlike anything that would be found in modern sorghum production, leading to a much higher score in this area. Using alternative data from actual hybrids used in commercial sorghum production results in an N_2O emissions from stover value much lower and closer to the one used by the ARB for corn, which would be expected given the two crop’s compositional similarities.

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Thank you for the opportunity to provide feedback and make suggestions. We feel with these changes, sorghum ethanol can play an even larger role in helping California meet the greenhouse gas reduction goals set by the LCFS while at the same time promoting the use of water-sipping crops like sorghum.

Please do not hesitate to let me know if you have any questions.

Regards,

John

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Discussion of Data and Accounting for Sorghum-Based Ethanol Pathway I

The Cai et al. journal article published in the June issue of Biotechnology for Biofuel, entitled *Life-cycle energy use and greenhouse gas emissions of production of bioethanol from sorghum in the United States*[1] provides a comprehensive overview of energy intensity and greenhouse gas intensity values associated with the many sections of various sorghum-based ethanol pathways. It also forms the basis of current ARB modeling efforts. Sorghum Checkoff (USCP) staff provided feedback and additional data to the authors at Argonne National Lab (ANL) in areas where the authors denoted a lack of sufficient information.

In August of 2014, USCP staff traveled to ANL and met with Hao Cai to discuss various aspects of the paper. A summary of the discussion, supporting data, and literature referenced during the meeting is provided below.

I. Farming

Sorghum Yield

CA GREET 2.0 value:	Not provided in Draft Version
GREET1 2013 Pathway I value:	3.4 tonnes/ha (54.2 bu/ac)
CA GREET 1.8bvalue:	4.3 tonnes/ha (69.2 bu/ac)
Industry value:	2010 ARB value of 4.3 tonnes/ac

- Based on discussions with Hao Cai, the 3.4 tonne/ha value was derived from 2011 NASS data, which represents one of the worst drought years on record.
- National average sorghum yields are unlikely to ever again be as low as they were in 2011 and 2012, as consecutive droughts crippled the Sorghum Belt. This can be seen in the U.S. Drought Monitor image immediately below from mid-May 2014, taken almost three years into the drought and just prior to widespread rains over the plains.
- Yields are lower during drought, but this is a definite anomaly. For this reason, we feel the yield should be left at the yield used in the 2010 pathway.

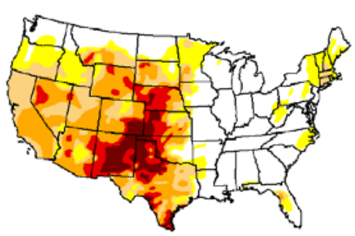

Figure 1 U.S. Drought Monitor May 2014

[1] Cai et al. **Life-cycle energy use and greenhouse gas emissions of production of bioethanol from sorghum in the United States.** Biotechnology for Biofuel 2013, 6:141.

II. Farming Energy

CA GREET 2.0 value:	16,741 Btu/bu
GREET1 2013 Pathway I value:	16,741 Btu/bu
CA GREET 1.8b value:	27,257 Btu/bu

- We have reviewed the data included in Table 1 of the 2009 Nelson et al. Journal of Environmental Quality article[2], from which the 16,741 Btu/bu value for on-farm energy use is derived. The table provides information of the type of tillage practiced and on-site energy consumption per crop per tillage method (i.e. conventional plow till, reduced till, and no till). The 16,741 Btu/bu value is the product of the weighted average of energy use on-site based on the number of acres practicing either conventional, reduced, or no till methods. We appreciate the updated values that reflect the lower energy intensity of grain sorghum production. As more data can be collected on the tillage practices of grain sorghum producers, we can provide updated tillage practice information that impacts our energy intensity.
- In addition, the value representing energy use for sorghum farming should not include fuel used for grain drying. The drying of grain sorghum is not practiced by the majority of producers in the U.S. as evidenced by two attached letters attesting to this fact.

III. Fertilizer & Chemical Production

Nitrogen Application Rate

CA GREET 2.0 value:	626 g/bu
GREET1 2013 Pathway I value:	610 g/bu (*24 g N/kg grain*)
CA GREET 1.8b value:	433 g/bu
Industry value:	433 g/bu

- The following summarizes approaches to calculating nitrogen application rates:

  1. **Industry standard equation** – Growers determine their application rates based on the formula described in a July 2014 letter authored by Rick Kochenower, Grain Sorghum Specialist in the Division of Agricultural Sciences & Natural Resources at Oklahoma State University[3]. The equation is provided below. The aforementioned letter detailing N application rate requirements by Kochenower provides a final recommendation of 0.95 pounds per bushel, which is almost identical to the 2010 rate.

     N_{Rec}=[YG x 1.25] STA – PCA – PYM – PNST

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[2] Nelson et al. **Energy Use & Carbon Dioxide Emissions from Cropland Production in the United States, 1990-2004**. Journal of Environmental Quality 2009, 38:418.

[3] "Grain Sorghum Nitrogen Requirements." Letter to Wes Ingram from Rick Kochenower. 28 July 2014. Filename: kochenower_n_requirements.pdf.

Where,

N_{Rec} = N recommendation in lbs/ac
YG = Realistic yield goal in bu/ac
STA = Soil texture adjustment of 1.1 (sandy soil) or 1 (medium & fine soil)
PCA = Previous crop adjustment (=0 unless previous crop was a legume)
PYM = N left from previous year's manure application
PNST = N remaining in soil via the Profile Nitrogen Soil Test

2. **Historical data from government agencies**– The nitrogen application rate can also be derived from historical values of application rates, acreage receiving N, acreage planted, and acreage harvested. The equation used to quantify nitrogen application, provided in the supplemental document to Cai et al. 2013 article in Biotechnology for Biofuels is provided below:

$$NR = \frac{NR_{AR} \times AR\%}{\frac{Area_{harvested}}{Area_{planted}}}$$

Where,

NR = Actual nitrogen application rate
$NR_{AR=}$ = Nitrogen application rate
AR% = Ratio of planted area receiving N fertilizer
$Area_{harvested}$ = Acreage harvested
$Area_{planted}$ = Acreage planted

The source of the primary data utilized in this equation has significant implications. Cai et al. 2013 report a ratio of $Area_{harvested}/Area_{planted}$ equivalent to 87%. This value is erroneous as it is based on the NASS dataset for acreage planted, which includes *all* sorghum planted, not just grain sorghum. Thus forage sorghum acres—that are not being used for ethanol production—and the associated N fertilizer application quantities, are included in the final value that is intended to represent only nitrogen fertilizer quantities for grain sorghum. Raising the average harvest ratio by eliminating these acres lowers the N application rate significantly. Note that the NASS *harvested acreage* data specifically excludes all but grain acres.

As an alternative to NASS acreage planted data, we recommend primary data published by the Farm Service Agency. Using FSA certified crop acreage, we calculate the true average grain sorghum harvest ratio to be about 94 percent per the table below. Note there is one year where more acres were reported harvested than planted. This is because sorghum is often planted as an uninsured wildcat crop behind a failed primary crop, so it sometimes goes uncertified. For the N application discussion, it is important to remember that these wildcat acres are rarely if ever fertilized, meaning a significant amount of sorghum acres are not fertilized and never show up on an N application survey such as ARMS, the survey on which Cai bases its N application figures. We feel this is another reason the N application rate should be held at the 2010 default rate.

Table A Harvest Ratio Value Excluding Non-Ethanol Grain Acreage

USDA Grain Sorghum Acreage			
	FSA Planted Grain Acres	NASS Harvested Grain Acres	Harvest Ratio
2009	5,541,432	5,520,000	99.61%
2010	4,657,673	4,813,000	103.33%
2011	4,744,730	3,929,000	82.81%
2012	5,384,741	4,955,000	92.02%
2013	7,059,351	6,530,000	92.50%
Average Harvest Ratio		94.06%	

N_2O Emissions from Sorghum Stover

CA GREET 2.0 value:	10,000 g N/tonne grain (254 g N/bu)
GREET1 2013 Pathway I value:	10,000 g N/tonne grain (254 g N/bu)
CA GREET 1.8b value:	5,591 g N/tonne grain (142 g N/bu)
Industry value:	5,153 - 6,830 g N/tonne grain (131 - 173 g N/bu)

- The following summarizes multiple references to nitrogen content quantification in sorghum stover:

  Laboratory analysis of N content via acid digestion and colorimetric analysis of plant matter – This technique is the standard and reliable assay for determination of various elements including nitrogen in biomass. The resulting value of nitrogen retained in plant tissue is highly dependent on the strain of crop analyzed. The following references report significantly different values of mass of nitrogen per unit mass of grain.

  Analysis of Experimental Strains

  - The Mahama 2012 thesis[4] referenced in Cai et al. 2013 details that nitrogen content was assayed via digestion of leaves, stems, and grain with sulfuric acid-hydrogen peroxide. The extract was then analyzed via colorimetric procedures using RFA meth A303-5072 (pg 30 of Mahama 2012). While this approach to assaying for nitrogen content is reasonable, the tissue samples that were assayed do not represent strains of sorghum that are produced commercially today in the U.S. In studying the thesis, we discovered that six of the twelve genotypes examined were noncommercial hybrids, including two experimentals, while the other six are inbred lines. Inbred lines are used exclusively to produce hybrid seed and are never commercially planted to be used in the production of ethanol. Sections of the thesis detailing harvest results, beginning with Table 18 on page 167, report yields and harvest indices that are strikingly low and commercially unviable. The average yield in the thesis is 49 bushels per acre, which is 44 percent lower than the 87-bushel average from the Kansas State hybrid trials *in the same locations over the same years.* Similarly, the average harvest index for the entire study is 0.36, which is to be expected with noncommercial hybrids and particularly inbred lines, which when used for hybrid seed production yield very low despite a large stature and

[4] Mahama, George Y. *Variation Among Grain Sorghum Genotypes in Response to Nitrogen Fertilizer*. Thesis. University of Ghana / Kansas State University, 2012.

ample N application. In Table 9 of Plevin et al.[5], grain sorghum is estimated to have a harvest index of 0.44. The average of the harvest index in the Hons et al. [6] (see Table 4 for ATx623 x RTx430 at "84 N") and Powell et al. [7] (see text page 934) papers is 0.51.
- The data utilized in the thesis do not accurately reflect the hybrids utilized by the commercial sorghum industry in the U.S. The selection of sorghum genotypes in the Mahama thesis displayed inherently lower grain yields and much higher stover N accumulation than what is encountered in commercial sorghum production.

Analysis of Commercial Strains

- In comparison, a research group from the Department of Soil & Crop Sciences at Texas A&M University focused on characterizing sorghum stover as a potential source for biomass-based energy has published extensively on N content in all portions of the sorghum plant. The common grain cross in both papers was a commercial grain hybrid.[8]
- The two papers cited above report nitrogen content values of 6,830 g N/tonne of grain and 5,153 g N/tonne of grain. The calculations for each paper are below based on the total stover content of the plant:
  - Hons et al.
    i. 6.32 g/kg of N in biomass (stover) – Table 5 for ATx623 x RTx430
    ii. 6,300 kg/ha of biomass (stover) – Table 4 for ATx623 x RTx430 at "84 N"
    iii. 5,830 kg/ha of grain – Table 4 for ATx623 x RTx430
    iv. 6,830 g N/tonne = (6.32 x 6,300 / 5,830) x 1,000
  - Powell et al.
    i. 6.00 g/kg of N in stover – Table 1 for total stover in ATx623 x RTx430
    ii. 5,221 kg/ha of stover – Text page 934 [11.3 Mg/ha x (1 – 0.538)] to account for total dry matter yield and harvest index of ATx623 x RTx430
    iii. 6,079 kg/ha of grain – Text page 934 (11.3 Mg/ha x 0.538) to account for total dry matter yield and harvest index of ATx623 x RTx430
    iv. 5,153 g N/tonne = (6.00 x 5,221 / 6,079) x 1,000

IV. Summary

Both ANL and USCP staff agreed to continue to work together to ensure that future versions of the sorghum pathway be revised to reflect recent, accurate, and conservative primary data inputs. ANL acknowledged that the proposed revisions to yield, farming energy, nitrogen application, and nitrogen in stover were appropriate and would be considered.

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[5] Plevin et al. "Agro-ecological Zone Emission Factor (AEZ-EF) Model", http://www.arb.ca.gov/fuels/lcfs/lcfs_meetings/aezef-report.pdf

[6] Hons et al. "Applied Nitrogen and Phosphorous Effects on Yield and Nutrient Uptake by High-Energy Sorghum Produced for Grain and Biomass". Agronomy Journal. 78:1069-1078 (1986)

[7] Powell et al. "Nutrient and Carbohydrate Partitioning in Sorghum Stover". Agronomy Journal. 83:6 933-937 (1991).

[8] National Sorghum Producers. (2014). *Grain Sorghum Yields at Selected Locations for Top Hand TA and ATx623 x RTx430 1979-1985* (Yield values for test plots of hybrid strains).Information from Texas A&M Extension variety trials. Filename: Top Hand TA (623 x 430) yields.pdf