<u>Comments on Topics raised during the Low Carbon Fuel Standard Public Workshop to Discuss Potential Regulation Revisions, October 14 & 15, 2020 (the "October Workshop")</u>

Dr. Michael R. Schuppenhauer

My comments concern four aspects raised during the October Workshop:

1. Inclusion of crop residues as key substrates for the production of carbon-negative biofuels
2. Application of methane-avoided credits, analog to manure methane-avoided credits, when using specific crop residues in co-digestion
3. Determination of carbon intensity of biofuels (biogas) as derivative of biomethane potential when co-digesting mixed substrates
4. Uncertainty and methods to increase accuracy of carbon and nitrogen emissions reductions as a function of land management practices

1. Crop Residues as Key Substrates (see attached 2019 presentation for more details)

A number of studies have documented the significant potential of crop residues for the production of domestic, sustainable and affordable biofuels (AGF 2011, Murray 2014), including but not limited to the Billion Ton Study (Langholtz 2016) and a recent study by LLNL (Baker 2020). However, most of the studies did not recognize the potential these substrates have for a biogas pathway (a cellulosic D3 renewable fuel under the Federal RFS), but instead, these studies assumed either a generic thermal (combustion/gasification) pathway, or a liquid cellulosic pathway.

Recent history has shown that, despite significant investments, the liquid cellulosic pathway continues to be challenged economically with factually no operating cellulosic biorefinery left in the United States, while the thermal/gasification pathway continues to be elusively at demonstration scale – since decades. Leaving biogas in fact as the sole D3 cellulosic fuel pathway in the United States, and the sole feasible pathway to zero/negative CI LCFS fuels. To support, the biomethane pathway has hundreds of successful full-scale reference plants globally, all of which operate as co-digesters of manure and cellulosic feedstocks, i.e., crop residues. In fact, the typical mix of a high-performing digester consists of a 50:50 to 70:25 mix of manure : crop residue/energy crop, thus blending the liquid and nitrogen containing manure with the high-carbon containing cellulosic material.

We performed several studies in 2014/2015 looking at key substrate availability and their biomethane potential for the U.S. down to county level, concluding that the U.S. could replace 8.8 quad or more than 50% of its transportation fuel demand, by using a mix of crop residues and energy crops, manure and waste streams. **80% of the U.S. potential originates from crop residues and energy crops**, 6% from manure, and less than 2% each from the classical substrates, such as wastewater, organic waste, landfills etc. For the State of California, we calculated a potential of more than 200 million MMBTU or 1.8 billion GGE from biogas using primarily crop residues <u>with</u> manure, based upon the amounts of substrate available. Similar numbers were independently calculated later and before by UC Davis, LBNL, and LLNL (Jenner 2012, Kaffka 2013, Breunig 2017 & 2018, Baker 2020). The

key point here is though that this significant potential, as well as the overall success of digesters in California (which thus far has seen a close to 50% failure rate), hinges (1) on the use of more higher-energy-containing substrates in digesters, i.e., the use of crop residues as substrate, as well as (2) the ensuing departure from lagoon type digesters, as those are not able to handle more than 2.5% of total solids in the incoming stream.
CARB should encourage and foster rules that treat co-digesters using mixed substrate streams equal to mono-digesters and assign proportionate LCFS CIs based upon each stream's proportionate contribution to energy production and CI reduction (or increase), including the application of the environmental credits from methane-avoiding practices.

2. **Credits for Methane-Avoided Management of Crop Residues** (see attached Methane-Avoided Memo for more detail)
Crop residues in the U.S. account for more than 350 million tons of unused biomass, manure accounts for 680 million tons (4.2 million tons and 5.4 million tons for California, respectively, USDA NASS 2014). Since the demise of the cellulosic ethanol efforts that tried to monetize corn stover (a crop residue), most residues (except wheat straw in parts) are left on fields to decompose under a mix of aerobic and anaerobic conditions, during the latter they will emitt short-lived climate pollutants / criteria pollutants, such as methane, that have significant short-term GHG potential. While the exact proportion and amount of these in-field GHG emissions from decomposition is largely not known due to lack of measurement during the fallow season, and lack of the expensive permanent sensor infrastructure, the emissions for certain crops and land management practices are known and have been found, when measured, to be significantly larger than previously estimated or modeled (Fitzgerald 2000, Merbold 2014, Martinez-Eixarch 2018, Romasanta 2017).

Here, and **of particular importance to California** (and the overall agricultural GHG emissions balance) **are the methane emissions from anaerobic decomposition of crop residues in rice paddies during flooding, as flooding creates an anaerobic environment that is emitting methane** (similar to open lagoons filled with dairy manure). Annually in California between 1.1 and 2.5 million dry tons of rice straw are anaerobically decomposed in flooded fields during the fallow season after harvest in September/October and are releasing between 3 – 6 million t CO_2eq. The magnitude is rivaling the methane emissions from dairy manure in size, placing rice straw decomposition on the #2 spot for GHG from agriculture in the state. Globally, of course, rice is the most important grain crop for the largest part of the world population, while on the other side sharing the top methane emissions spot from agriculture with enteric and manure emissions from animal husbandry.

While there are only very few year-round measurement stations (and all in Arkansas) tracking those GHG emissions in rice fields, **it is obvious that the removal of the causative, decomposing biomass from the open-pond paddies would reduce the GHG potential significantly**.

In fact, the California State Treasurer implicitly confirmed that removal of rice straw is a pollution mitigating activity, by allowing the issue of a $235 million tax-exempt bond from the California Pollution Control Financing Authority, for the financing of the CalPlant I facility in Willows, CA (Application 17-SM059, CUSIP 130536QY4, 130536QZ1, 130536RA5). The Independent Consultant report submitted with the tax-free bond issuance documents (Appendix S of the CalPlant I Limited Offering Memorandum, "LOM") provided a range of methane-emissions avoided through the collection of rice straw (0.25 to 0.625 tons methane avoided per acre straw collected). The LOM thus provides legal precedence and cover to apply the same methane-avoided model for the removal and digestion of rice straw for the purpose of CI calculation when using the CA-GREET model and a Tier 2 pathway, as it is already used for the calculation of methane-avoided through dairy and pig manure digesters.

This precedence is in addition to the Rice GHG Abatement protocol issued by CARB and the voluntary protocols by CAR and ACR, which all lay out and confirm the fact that rice straw under current practice in California is left to decompose under anaerobic conditions in open fields and emits significant methane. Yet, these **existing voluntary protocols, as previously in the case of dairy manure, have resulted in no GHG abatement project in rice fields**. This is going back to the establishment of the 1998 Rice Straw Diversion Plan, which proposed diversion of 50% of straw with no results. Increasingly in other regions, where post-harvest straw burning is also prohibited due to concerns over PM2.5 emissions (Po Delta, Ebre Delta), the same significant GHG emissions from fallow season rice paddies become apparent and of great concern (Fitzgerald 2000, Martinez-Eixarch 2018, Romasanta 2017).

A simple first approximation to determine methane-avoided would be to equate the methane-avoided to the methane-produced in a rice straw fed lab or full-scale digester. For this approach we found lab values of on average 185 m_N^3 CH_4 per ton dry matter. Martinez-Eixarch (2018) found values in the range of 195 m_N^3 CH_4 per ton dry matter of straw decomposing in flooded fields, and Romasanta (2017) implied 119 m_N^3 CH_4 per ton dry matter emissions in open fields. The CalPlant I LOM implied methane potential of 500 to 1,250 lbs. per 2.75 tons of straw harvested per acre, or 244 to 612 m_N^3 CH_4 per ton dry matter of straw. **I believe a conservative value of 185 m_N^3 CH_4 per metric ton dry matter is well supported mechanistically, within the context of other studies and materials, and supported through several independent lab studies, in several independent labs.**

While there are valid concerns to ensure enough wetlands for the Pacific Flyway, the removal of straw is unrelated to winter flooding to maintain such wetlands, nor is straw collection reducing available feed for shore and water birds. In fact, it was found that straw collection increases the available feed for shore birds and winter fowl (Matthews 2016).

CARB should develop and encourage Tier 2 and Design pathways that use substrates, beyond only manure, which otherwise are responsible for GHG emissions / short-term climate pollutants. Specifically, this should include the classification of the removal of crop residues (straw) after harvest as a methane-avoiding practice, as it reduces the biomass that is causing the GHG emissions, if they otherwise decompose anaerobically in fields. These practices shall be assessed using a combination of recent GREET Farm to

Gate extensions, and methane-avoided calculations based upon BMP measurements of the removed substrates.

3. **Determination of Carbon Intensity and Biomethane Potential for Mixed Substrate Streams**
   As digesters produce a biogas that is on one side more expensive than fossil natural gas, but on the other side has inherent environmental attributes (values), its economics are dependent on the correct valuation and verification of these attributes, which in turn are innate to the feedstock and proportionate to its quantity used.

   The solution to account in mixed streams for the substrate specific environmental attributes, such as methane avoided, carbon sequestered, nitrous oxide reduced, and substrate specific energy content, would be on one side a calculation of the carbon intensity through the CA-GREET 3.0 model with an extension developed and proposed by Argonne National Lab (Liu 2020), and on the other side the use of a substrate stream and location specific biomethane potential (or generally speaking bioenergy) test, per the internationally recognized VDI 4630 standard (Liebetrau 2016, VDI 2006) performed in independent laboratories.

   Over time a collection of reproducible, organic Total Solid (oTS) specific biomethane potentials (BMP), based upon actual site-specific values, will emerge that allows a proportionate calculation of energy yield, carbon intensity and "cellulosicness" per RFS2 per proportionate sub-stream in a set of mixed streams of substrates. The VDI4630 Test is actually used by all leading digester EPCs to establish performance criteria and warranties for new plants. Equipment to perform such test as routine control on site is below $10,000 (ANKOM, Bioprocess Control). As the substrate specific BMP is oTS dependent, short-cut calculations can be based upon simple TS and oTS determinations when consistent mono-substrates are used, and thus only moisture correction is needed. From an operations perspective these types of feedstock tests should be part of regular digester operations and control and are easy to perform and low cost.

   CARB should codify the use of the VDI 4630 procedure together with routine performance of Forage Analysis per Weender / van Soest together with the GREET 3.0 Farm to Gate model in order to establish a proportionate calculation of CI for mixed substrate digesters when they use energy crops and crop residues as substrate.

4. **Uncertainties and Methods to Increase Accuracy for GHG Emissions from Land Management Practices**
   While there are currently several geospatial *models* in use, including but not limited to DayCENT, DNDC, Ecosys, CALAND et al., that claim to provide various land management practice dependent sustainability metrics and outputs, these models, including their assumptions, are highly dependent on calibration with *correctly* measured observations. Significant weaknesses have been identified in all of these models, either because they lack mechanistic models for subsystems (such as soil nitrogen or soil carbon cycles), or because they extend beyond the boundaries of the original measurements used to tune the models

(such as vegetation periods, or incomplete crop data), within others. In fact, when measuring actual fluxes, deviations from model predictions by two orders of magnitude are not uncommon (Merbold 2014, Linquist 2018).

Recognizing these defects in models, and to ground-truth the sustainability of bioenergy crop to fuel pathways, the U.S. Department of Energy embarked on the ARPA-E SMARTFARM effort. In fact, the ARPA-E DE-FOA-0002250 precisely lays out the issues around accuracy of these models in its Program Objectives (Chapter I.C. of the FOA).

The DOE ARPA-E SMARTFARM effort led by Dr. David Babson, will through its five awardees establish 15 Phase I references sites in 2020/2021 of which three are based in California, and six are managed by the author serving as PI. These sites are heavily instrumented and probed year-round including with state-of-the-art laser based eddy covariance flux measurement towers. The data stream from these fields will be analyzed through AI and machine-learning tools, including those from ARVA Intelligence Corp., who is the lead award recipient, managing six sites together with LBNL. These sites will for the first time allow to demonstrate tools that are site and pathway specific and accurate enough to measure on a continuous basis methane, nitrous oxide and carbon dioxide, while also providing temporal and spatial accuracy metrics. Results from this $14 million effort are expected for 2024 and will provide for the first time and only for the selected 15 sites the full set of year-round farm emissions and sequestrations for methane, nitrous oxide, carbon dioxide and soil carbon for all major bioenergy crops and pathways, including crop residues, corn, soy and sorghum.

However, ARVA Intelligence will iteratively update its sustainability metrics using an ensemble approach of *all* the above-mentioned models, calibrated against emerging field data, as well as feeding CA GREET outputs for the entire U.S. through remote sensing data.

CARB should closely monitor the data stream and variance information from these SMARTFARM reference sites and resulting validation ofabive-mentioned models to update methane-avoided, GHG footprint and soil carbon sequestration approaches as the data becomes available during the 2021-2024 timeframe, and enables true-up of previous calculations and models when discrepancies emerge.

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