September 7, 2023

To Whom It May Concern:

Monarch Tractor is an innovative, mission driven company currently headquartered in Livermore, California developing and building driver optional electric tractors. We set out in 2018 to enable the adoption of clean, efficient, and sustainable farming practices globally. Monarch's flagship product, the MK-V compact tractor, combines a 100% electric powertrain, automation technology, and insightful data - giving farmers the tools needed to implement more productive, precise, and sustainable farming practices. The MK-V is commercially available today and is already decarbonizing farming operations in California.

Despite the potential for each electric compact tractor to abate [redacted] annually, these vehicles do not have an applicable Energy Economy Ratio (EER) under the current LCFS regulation. To help support the adoption of these impactful electrification technologies into the LCFS program portfolio, we have developed the Tier 2 pathway herein using 3rd party validated energy consumption data and real-world tractor fleet duty cycle information for your review.

Certain information in the application is a trade secret and is exempt from disclosure under the California Public Records Act. As such, we have provided a copy of our application with trade secrets redacted and we authorize release of this redacted version if the agency receives a public records request.

We look forward to your review and welcome any questions.

Warmly,

Jake Winters

Jake Winters
Head of Impact
Monarch Tractor

Pathway Summary

Zimeno Inc DBA Monarch Tractor submits this Low Carbon Fuel Standard Tier 2 fuel-vehicle pathway application for battery electric smart tractors to encourage adoption of these technologies in the agricultural sector, which contributes 11% of US GHG emissions[1]. With the review of this proposed pathway and corresponding EER, CARB will further encourage farmers and other tractor operators to electrify their operations in the historically difficult to decarbonize agriculture industry.

The flagship Monarch Tractor, the MK-V, is a no compromise compact-utility tractor capable of undertaking any workload traditionally completed by diesel tractors of the same class. Over the course of five years, four tractor iterations, and countless validation runs, Monarch now produces the MK-V commercially and has [redacted] on farms across California completing work previously performed by diesel tractors. It's best in class tractive power, hydraulics, and lift capabilities mean that farmers can perform mowing, raking, weeding, hauling, spraying, feed pushing, seeding, discing and additional operations while generating zero tailpipe emissions.

This report compares the test data completed at a third-party facility utilizing the University of Nebraska Tractor Test Lab methodology on the Monarch MK-V Tractor to publicly available Nebraska Tractor Test data of a New Holland Workmaster 50, a similar diesel-powered tractor. The processes outlined in this pathway application indicate that each Monarch MK-V tractor deployed will reduce [redacted] emissions annually. This estimate is based in part on a representative duty cycle generated from real world customer usage data through July 2023. This representative duty cycle is applied to lab measurements of the energy usage for both the New Holland Workmaster 50 diesel tractor and the Monarch MK-V electric tractor at various sustained power levels. This links lab test data to real world operating conditions for the most accurate efficiency and emission calculations.

The Electricity Lookup Table Fuel Pathway Code was utilized to acquire the Carbon Intensity (CI) of the CA grid mix electricity used by most Monarch Customers. Select Monarch customers generate renewable energy on site, however this is not always easy to determine, so we've limited this Tier 2 pathway to the standard CA grid mix. Our approach applies the Energy Efficiency Ratio (EER) generated through our side-by-side comparison of the equivalent diesel powered tractor that historically completed the on farm tractor work.

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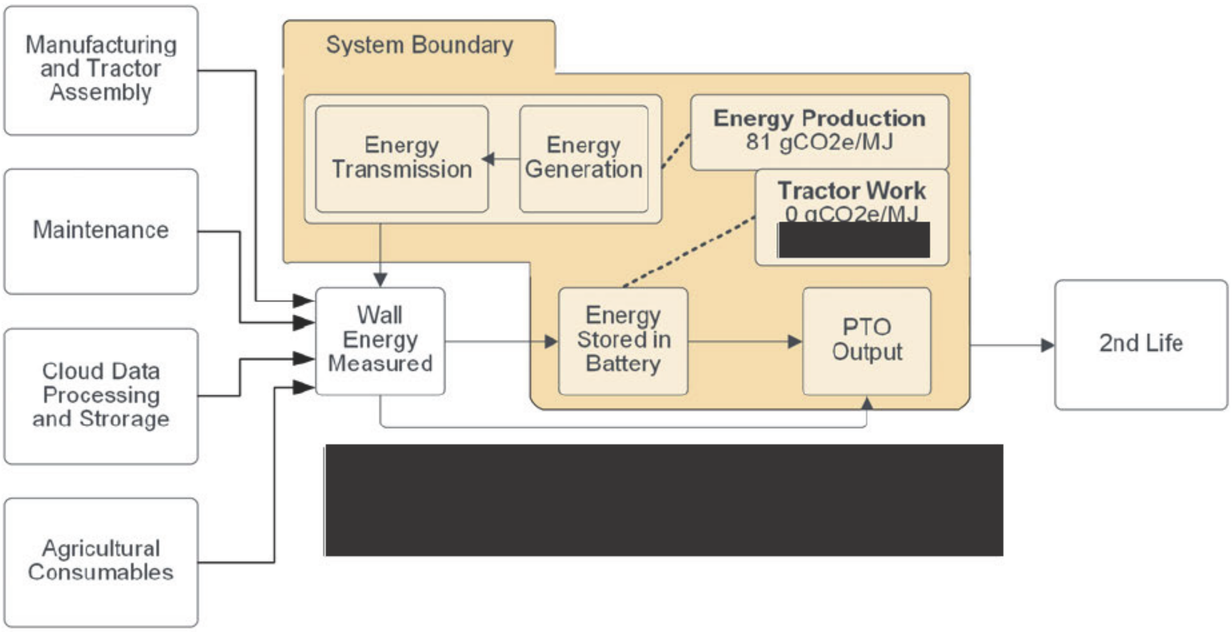
[1] Environmental Protection Agency: Total US Greenouse Gas Emissions by Economic Sector and Electricity End-Use for Agriculture (source)

Site Specific Inputs

Based on the unique nature of Tier 2 LCFS pathways, the site specific inputs for the Monarch Tractor application are proposed on the basis of the system boundary below. This includes first the energy generation and transmission stage, defined by CARB for the CA grid. And second, the pathway specific battery to Power Take Off (PTO) stage, where energy from the battery is delivered through a spinning shaft at the back of the tractor to power attached implements, and ultimately perform work. This system boundary is expected to be consistent between individual user sites within CA.



The following sections outline the steps to quantify the energy efficiency of the tractor system, and arrive at a proposed EER value:

1. Comparable Equipment Methodology
2. Compact Utility Tractor Duty Cycle
3. Energy Consumption of Monarch MK-V Electric Tractor (kWh)
4. Energy Consumption of Compact Utility Diesel Tractor (kWh)

In the following application components, we have detailed how this data has been collected, analyzed, and scaled to reflect an accurate comparison of the emissions savings generated by the replacement of diesel fuel in the agriculture sector. Data is measured on board the tractor and is capable of being reproduced for any set of parameters in accordance with CARB requirements and LCFS reporting standards.

Comparable Equipment Methodology

Energy in and out of MK-V Tractor was tested at varying power bands to provide an understanding of the energy draw relative to the comparable diesel tractor across the operational spectrum. A full report from UTAC has been included in this pathway applications to support the forthcoming calculations. The raw data from this testing is contained in the table below.

[redacted]

University of Nebraska Tractor Test Laboratory provides publicly available tractor test data that we have leveraged as the comparable equipment database. The Nebraska Tractor Test data is contained within the table below.

POWER TAKE-OFF PERFORMANCE

Power HP (kW)	Crank shaft speed rpm	Gal/hr (l/h)	lb/hp.hr (kg/kW.h)	Hp.hr/gal (kW.h/l)	Mean Atmospheric Conditions
MAXIMUM POWER AND FUEL CONSUMPTION					
Rated Engine Speed—(PTO speed—545 rpm)					
46.59 (34.60)	2600	3.72 (14.09)	0.561 (0.341)	12.46 (2.46)	Fuel used during active exhaust regeneration - na (see note 1 page 2)
Standard Power Take-off Speed(540 rpm)					
40.50 (34.72)	2370	3.70 (13.99)	0.533 (0.338)	12.00 (2.48)	
VARYING POWER AND FUEL CONSUMPTION					
46.59 (34.60)	2600	3.72 (14.09)	0.561 (0.341)	12.46 (2.46)	Air temperature
39.85 (29.72)	2626	3.48 (13.16)	0.610 (0.371)	11.46 (2.26)	72°F (22°C)
30.35 (22.63)	2664	2.95 (11.16)	0.679 (0.413)	10.50 (2.03)	Relative humidity
20.36 (15.18)	2682	2.43 (9.18)	0.834 (0.507)	8.39 (1.65)	10%
10.26 (7.65)	2702	1.94 (7.34)	1.322 (0.804)	5.29 (1.04)	Barometer
0.66 (0.49)	2711	1.53 (5.79)	16.245 (9.882)	0.43 (0.08)	28.85"Hg (97.70 kPa)

Maximum Torque - 112 lb.-ft. *(151 Nm)* at 1750 rpm
Maximum Torque rise - 19.1%
Torque rise at 2080 engine rpm -8%
Power increase at 2576 engine rpm - 0.1%

Data Scaling

Since testing was completed at slightly different Hp levels, data scaling was necessary to compensate for the greater than 5% difference in some tested Hp values. Monarch MK-V data has been scaled to meet that of the Nebraska Tractor Test Laboratory recordings. The formula used to scale the data is as follows:

Raw MK-V Hp(Diesel Comparison Hp / Raw MK-V Hp)=Scaled MK-V Hp*

With this approach applied to each power band, the following table was produced.

[redacted]

Data Interpolation Accuracy Maximization

As highlighted in red text in the table above, [redacted] To account for this outlier, a linear interpolation was used with the higher and lower power level results to generate and estimated scaled data point for this item. The linear interpolation formula and corresponding input data are as follows:

[redacted]

$$
\begin{aligned}
y &= y_0 + (x - x_0)\frac{y_1 - y_0}{x_1 - x_0} \\
&= \frac{y_0(x_1 - x_0)}{x_1 - x_0} + \frac{y_1(x - x_0) - y_0(x - x_0)}{x_1 - x_0} \\
&= \frac{y_1 x - y_1 x_0 - y_0 x + y_0 x_0 + y_0 x_1 - y_0 x_0}{x_1 - x_0} \\
&= \frac{y_0(x_1 - x) + y_1(x - x_0)}{x_1 - x_0},
\end{aligned}
$$

[redacted]

The resulting value in the data set is [redacted] highlighted in green text, resulting in the above adjusted table, is reflective of the Hp test ranges undergone by the Nebraska Tractor Test Laboratory, and includes the linear interpolation of [redacted].

[redacted]

The scaled and interpolated data set was extracted into the separate table above for clarity.

Compact Utility Tractor Duty Cycle

Monarch developed a standard compact utility tractor duty cycle by analyzing the power consumption of the Monarch MK-V customer fleet across the State of California. This data is comprised of PTO power output over a full month of use for the California MK-V customer fleet. Energy in and out of the tractor was measured for this testing automatically via the onboard telematics system. [redacted] The results are represented by the following histogram.

[redacted]

This showcases the distribution of tractor PTO power demand [redacted]

[redacted]

This breakdown is representative of the typical duty cycle for any tractor in the compact utility classification regardless of engine type, utilizing 540rpm at the PTO. Operations include but are not limited to: mowing, raking, weeding, hauling, spraying, feed pushing, seeding and discing.

Energy Consumption of Monarch MK-V Tractor

We have taken a conservative approach and assumed that all operations occurring within each power band require the maximum energy consumption of the power band. [redacted]

We look to test at additional data points between the existing power bands in order to increase the resolution of energy draw measurements. The kilowatthour per hour (kWh/hr) value is then multiplied by the corresponding distribution of tractor PTO power demand from Monarch customers. These values are then summed for the entire duty cycle to produce the average kWh/hr rating for work completed by Monarch MK-V tractors in representative operating conditions.

[redacted]

Electric Smart Tractor As The Meter

The Monarch MK-V tractor unit is equipped with on board vehicle monitoring and telematics. This includes a high fidelity measurement of the energy into and out of the battery pack as well as connectivity capabilities to automatically offload data to the cloud. [redacted]

[redacted]

Using the vehicle to measure emissions reductions at the location where the emissions are abated creates visibility into the populations actually receiving the air quality benefits. Tractors are often moved from site to site and across 1000s of acres to perform their work, which results in air emission reductions in a variety of areas, not just the charger location.

On vehicle energy reporting also enables accuracy advantages in increasingly frequent scenarios where a single EVSE is used to charge several different electric vehicles. Emerging EVs, especially in the off road space, have varied EER values, making measurement at the charging site inadequate. Many Monarch customer farms offer EV charging to their patrons, charge med/heavy duty trucks, tractors, ATVs, and other off-road electrified equipment often utilizing the same EVSE. [redacted]

Monarch has seen on vehicle telematics reporting be highly effective for other California Zero-Emission programs focused on quantifying GHG emissions in SB 151 Priority Population areas such as the California Clean Off-Road Equipment (CORE) voucher program. In the supporting documents we have included a sample of a report produced for CORE for reference.

[redacted]

[redacted]

[redacted]

[redacted]

Energy Consumption of Comparable Diesel Tractor

The same University of Nebraska Tractor Test Lab procedures were used for both tractors and recordings were taken. For the diesel powered tractor, energy in was measured in gallons of fuel, and energy out was measured in Hp at PTO in the same power bands as the Monarch MK-V Tractor. The diesel gallons per hour expenditure at each power level was multiplied by the same percentage of duty cycle from the real world fleet data that was used in the Monarch calculations, shown in the following table to ensure equivalency.

[redacted]

To produce a result that is directly comparable in terms of energy output to the Monarch MK-V, the gal/hr value was converted first to MJ/hr and then into kWh/hr using values from the CARB Greenhouse Gas Quantification Methodology[2]. The tested gal/hr value is multiplied by the CARB established energy density for diesel fuel in MJ/gal and then converted to kWhs.

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[2] Energy Density Table B-1 found on page 16 states Diesel energy density is 134.47 MJ/gal https://ww2.arb.ca.gov/sites/default/files/auction-proceeds/carb_oratd_finalqm_16-17.pdf

[redacted]

Table B-1. Fuel-Specific Energy Densities[2]

Fuels (units)	Energy Density
CARBOB (gal)	119.53 (MJ/gal)
CaRFG (gal)	115.83 (MJ/gal)
Diesel (gal)	134.47 (MJ/gal)

Energy Economy Ratio (EER)

The following table summarizes the measured intakes of energy required to perform the same amount of work, completed in a third-party lab UTAC testing facility or the Nebraska Tractor Test Lab and measured on a dynamometer.

[redacted]

[redacted] As we refine the engineering, design, and system compatibility of the Monarch MK-V tractor, we seek to increase the efficiency of this pathway.

The current EER value generated by a Monarch MK-V tractor when compared to an equivalent diesel tractor is [redacted]

Carbon Intensity of Electric Tractors

Since Monarch Tractors are fully electric, generate zero tailpipe emissions, and therefore equate to 0 gCO2e/MJ within the established system pathway, California grid electricity generation is the extent of the carbon intensity scoring. For the purposes of this pathway application, Monarch is using the code ELC000L00072023 value of 81 gCO2e/MJ[3] given to California grid electricity as the carbon intensity score of the total pathway.

Expected CO_2e Reductions/Credit Generation

To calculate the expected emission reductions, we prepared the value on a per tractor basis. We calculated the emissions from the comparable diesel piece of equipment and subtracted the emissions from the proposed pathway to find the delta which represents the emissions abated by replacing equivalent diesel tractors with Monarch MK-V tractors.

To determine this value, we have taken the kWh/hr calculated for the Monarch MK-V [redacted] and the comparable diesel [redacted] and [redacted] Annual tractor usage is highly varied between crops and farm size, the following numbers represent one example.

[redacted]

These products are then multiplied by the result of converting the CARB carbon intensity (CI) values for diesel and grid energy to gCO2e/kWh which is accomplished utilizing the gCO2e/MJ value and multiplying by 3.6, the established MJ to kWh conversion factor. Converted values are listed below.

Emissions Conversions		
	Diesel	**CA Grid**
gCO2e/MJ	100.45	81
gCO2e/kWh	361.62	291.6

[3] CA grid mix carbon intensity values
ww2.arb.ca.gov/sites/default/files/classic/fuels/lcfs/fuelpathways/comments/tier2/2023_elec_update.pdf?_ga=2.255330381.430057548.1693245120-1089177057.1690839791

The above table is used to produce the annual g/CO_2e values being reported which are then divided by 1,000,000 to convert grams to tonnes resulting in the number of annual tonnes of CO_2e generated at each point of measurement. Converted values are listed below.

[redacted]

[redacted] annual tonnes of CO_2e abated. This value is also the number of credits generated annually per tractor, in the duty cycle scenario presented.

[redacted]

For reference, the g/CO_2e value saved per hour of tractor use [redacted] when compared to operations completed with a diesel tractor.

[redacted]

Reporting and Registration

Monarch Tractor currently produces a monthly report for all tractors that are financed in part by the California CORE program administered by CALStart in conjunction with CARB. This report contains data on the cumulative time in use and cumulative energy used (in kWh) for each tractor. All data from this report is generated from the Monarch MK-V Tractor and uploaded to our cloud data management system and exported for reporting and emission reduction quantification.

We propose and adapted version of this report as the quarterly reporting requirement for LCFS credit generation [redacted] However, this data can be provided in a myriad of forms at CARBs discretion. Monarch will also aggregate the data on a fleetwide basis and looks forward to opportunities enabled by CARB for this data to be automatically uploaded.

Commitment to Improvement

Monarch Tractor has been conservative in many of the estimates within this LCFS application and anticipate improvements will be made within the system boundary established throughout this application. Tractor work capability will expand as we continue to improve the MK-V tractor and we anticipate charging efficiency and energy generation to improve alongside it. A portion of Monarch customers also utilize renewable energy to generate their own electricity to further increase the level of emission reduction made possible by the Monarch MK-V.

Such iterations will be included in future submissions of LCFS pathways, and we look forward to collaborating with CARB to improve the understanding of off-road agricultural electrification within California and the suite of benefits it provides.