



# Docket 22805: Propane-Battery Hybrid Almond Harvesting Machine

## Terzo Power Systems

### APPLICANT INFORMATION

**Primary Contact:** Manuel Arciga, Chief Engineer

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**Amount Requested:** \$ 97,185

**Other Funding Organizations/Amounts:** Terzo Power Systems / \$ 234,506

**Start Date:** 04/15/2021

**PERC Team Leader:** Michael Newland

**Additional Vendors:** N/A

**Organization:** Terzo Power Systems

**Phone:** 916-245-9660

**Total Project Cost:** \$ 331,691

**End Date:** 12/31/2021

### EXECUTIVE SUMMARY

#### Project Summary

- *Describe the proposed product or idea, its importance, its benefits, and the market and/or audience it serves. Briefly outline the scope of work. If applicable, describe the key messages and deliverables, including who, what, where, and how they are delivered. Please limit response to 500 words.*

This project will demonstrate how propane can be paired with electric hybrid technology to offer ultra clean off-road solutions for agriculture and construction applications. This propane-electric hybrid technology will demonstrate the ability of propane to be in the clean energy solution conversation in the most stringent regulated states. This technology will be demonstrated in the agriculture sector and will have additional application in construction equipment and other off-road mobile applications.

Specifically, this project will demonstrate how a propane-battery powered almond harvesting machine functions as a cleaner alternative to its diesel-powered counterpart. The implementation of a propane engine functioning in this capacity is solely of a genset nature. It would be utilized to spin a generator, applying charge to a 400vdc battery pack. This in turn allows for direct and independent control of electric motors mated to the hydraulic pumps responsible for machine propulsion and harvesting duties.

With this approach, the machine can operate in "all-electric" mode until the battery voltage depletes to a predefined level. At which point, the propane engine will turn on to begin the battery charging process. This leads to benefits of reduced engine emissions and operating modes for different conditions. For example, in a machine-idle state or short-distance transport, the engine can turn off and capitalize on the benefits mentioned.

## Strategic Importance

- Describe how this initiative supports PERC's strategic plan.
- Describe how this initiative is important to the propane industry.

This project will further develop technology for PERC's strategic goal to impact the mobile ag sector. Not only does this project impact the nut production space, this project will be utilized as a demonstration project showing how propane-electric hybrid technology can impact any power fluid system. For that reason, this project has importance to the agriculture segment at PERC, but also crosses over to off-road applications and can show the possibilities of this technology in construction applications and beyond.

The ultimate result of this project will be to demonstrate propane-electric hybrid components and technology that can be utilized in a number of markets. This project will provide a platform for conversations with OEM manufacturers in agriculture, construction, off-road, state regulators and will serve as a backdrop for communications on how the propane industry is delivering new technology to fit today's carbon reduction environment.

These products (ag and construction) also tend to be off-peak season for agriculture grain drying and home heat. This fact adds to the opportunities to expand our non-peak season gallons.

## Budget Impact and Three-Year History for Similar Dockets

- Provide the budget market & activity this project will be impacting.

### Category:

Agriculture > Product Development

### Year Total:

\$1,105,500.00

### YTD Remaining:

\$1,105,500.00

### Remaining if Funded:

\$1,028,315.00

## Three Year Funding History for Similar Dockets

Year	Docket	Budget	Actual	Results
2013	18126	\$975,000	\$270,440	Proof of concept on New Holland T6 tractor completed. The unit was developed and demonstrated. We continue to work with New Holland on a commercialization plan and decision.

## Success Measures

- Describe the desired outcome of the project / measurement of success.

Success for this project includes delivering a reliable machine on-time and on-budget. The engineering on the electric components for this unit have already been completed by Terzo Power.



Delivering a final project to reveal to the OEM world that will run the time needed for orchard duty cycle will be key to this project.

A key launch date for this project is the World Ag Expo 2022 date. A successful project has a completed project that is able to be demonstrated and revealed to the OEMs and almond customers at that event.

## DETAILED BUSINESS CASE

### Product

- *Describe the proposed product and its benefits.*
- *What is the expected cost per unit?*
- *How will the cost of the product compare to current options (first cost, operating cost)?*
- *To whom is the product directed? Define target audience, industry, and region.*
- *Will this project potentially lead to additional products, partnerships, or uses?*
- *Describe whether patents are required and their status.*

The product in question is described as a hybridized almond tree shaker. Hybridization defined as a varied energy source for supplying power for machine work duties. In this instance, those duties are actuation of hydraulic functions responsible for machine propulsion, positioning and clamping the shaking implement, and the act of spinning an eccentric weight to shake the trunk of an almond tree. The varied energy sources in this case are a propane engine coupled to a generator to supply charge to a 400vdc battery pack. Benefits of the concept come in the form of the intrinsic properties of propane and the modified modes of operations that an electrified platform allows. Immediate benefits from such an architecture include reduced greenhouse gas emissions, all-electric mode of operation, power-on-demand, and increased overall efficiencies during energy conversion stages.

Expanding on the benefits mentioned, a propane-battery hybrid system provides benefits of various degrees at various stages throughout the supply chain. At an air quality regulatory level, the concept represents a solution for non-attainment areas. For the end user, operating cost reduction is realized at fill-up for example. Historically, propane has been ~30% less expensive per gallon of gas and ~50% less than diesel. There is currently no competitor in the agricultural marketplace offering a propane-electric solution.

The piece of equipment is aimed at the agriculture and farming community who have a keen interest in sustainability and desire to stay ahead of their competition in next-gen technology.

To be price competitive, full system cost is expected to be \$30k-\$60k. The variation comes from the fact that the system will be designed to be machine agnostic and scalable in performance to target a wide range of equipment.

### Market

- *Describe the market and the need for the proposed product.*
- *Describe: (cite source of market information)*
  - *The size of the market.*
  - *The rate of growth for the market.*
  - *The degree of competition in the market.*
  - *Ability to penetrate the market.*
  - *Main competitors*

- *Is propane currently present in this market? With what applications? How will this product affect sales on the existing propane offerings?*

There exists a massive effort to go to full-electric solutions across various industries. For many applications in the agriculture/off-road mobile market, a full-electric solution is not feasible. The pieces of equipment in question are purpose built for high-power demanding duties. Full electrification would consist of an immensely sized battery pack to provide the power and energy capacity for a full day of work. In some instances, the price of the battery alone, has the potential to cost more than the machine itself.

The original equipment manufacturer of the almond tree shaking machine that will be used in this project, estimates yearly sales of 100-200 machines. The potential does not end there. Because of the system’s design, the same platform can be extended to be used in other types of machines. In almond harvesting, there are at least three other types of machines (all utilizing diesel engines) designated as support vehicles. This project will serve to highlight the propane-electric hybrid technology for other equipment OEMs in agriculture and in the off-road construction markets.

### Project Scope

- *Describe the proposed project per task and the work entailed to complete the project.*
  - *Include product development and demonstration plans.*
  - *Describe data to be collected.*
  - *Highlight areas of Propane Council involvement.*
- *Describe what is not covered by this scope of work.*

A Propane-Battery powered almond harvesting machine functions as a cleaner alternative to its diesel-powered counterpart. The implementation of a propane engine functioning in this capacity is solely of a genset nature. It would be utilized to spin a generator, applying charge to a 400vdc battery pack. This in turn allows for direct and independent control of electric motors mated to the hydraulic pumps responsible for machine propulsion and harvesting duties. Work required to complete the project includes removal of existing engine and fuel storage equipment, temporary removal of supporting equipment such as cooling system, electrical wiring, etc. Once removed, engineering design is needed for new fuel storage solution, assessment of low-voltage electrical system, logic programming, vibration isolation, etc.

Once engineering is complete and all new systems accounted for, assembly of the new fuel storage tank system, engine and electronic programing will be completed.

### Risk Assessment

- *Identify 3-5 potential risks to the successful completion of the project or inability to meet outcome targets, how likely those are to happen, impact on the project, and how to resolve those risks.*
- *Indicate low, medium, or high for “Likelihood” and “Impact.”*

Risk	Likelihood	Impact	Risk Resolution and/or Contingency Plan(s)
Technology does not work	LOW	HIGH	Technology has been deployed on similar equipment

Emissions profile not advantageous	LOW	MEDIUM	Technology would still outperform current Tier 4 versions
CARB pushes for all electric	MEDIUM	MEDIUM	Push marketing message to OEMs and end users. Electric will not offer adequate duty cycle for this application.

### Vendor Capabilities

- *Describe why applicant is suited to complete the work, including technical capabilities.*
- *Describe ability to commercialize the product (production, distribution, warranty)*
- *Discuss similar work completed.*
- *Identify personnel expected to work on this project*

Terzo Power Systems has established itself as a leading electric-hybrid technology company. Key members of the Terzo Power team are in the final stages of completing a CNG-Battery powered almond nut harvesting machine for the state of California Energy Commission.

Key members of the Terzo Power team have recently finalized key deliverables of a CNG-Battery powered almond nut harvesting machine for the California Energy Commission. Previous experience to the CNG-Battery project was a Gas-Battery electric snow grooming machine. This places emphasis on experience with electrification of heavy equipment in addition to handling of alternative gas fuels and integration into heavy equipment. In-house skillsets include advanced degrees in mechanical engineering, electrical engineering, PCB assembly, and custom electronics design.

### Cost/Benefit Analysis

- *What is the potential impact? (i.e., new gallons, units sold, persons trained, propane industry resource savings, etc.)*
  - *Provide five-year estimated sales projections for the product (if applicable) and a list of factors that may influence the estimates.*
  - *How many gallons of propane does the product use per unit per year?*
- *What are the potential risks to achieving the impact? (i.e. fuel price; regulatory, environmental, or legislative considerations; propane marketer support)*

This opportunity offers completely new gallons for this segment which has been outlined by Council as a Strategic Priority for agriculture.

Sales projection in the almond segment could approach 200 units per year or more depending on performance and CARB acceptance and support through the Carl Moyer program of California. The Moyer program offers incentives for equipment purchases that significantly change the level of emissions in any given segment.

Potential for impact include:

- \* Exposure of propane use to new industries.
- \* New education opportunities on the use of propane.
- \* The “machine agnostic” approach in the Terzo topology means there’s a cross-platform compatibility between other types of machines.
- \* Positive contributor to California’s reduction efforts of greenhouse gasses.

Potential challenges to realizing impacts are some that have come across from Terzo Power Systems' experience from working with alternative fuels. Namely, fueling infrastructure, machine run-time before fueling, and availability of varying fuel storage capacity options.

### Budget

- Outline cost per task, including estimated cost share (cash and in-kind).
- If applicable, indicate hourly rates, including overhead

Terzo Power has developed all components of the system and purchased the 2018 Shockwave Sprint, battery system, hydraulic sub-system and all electrical sub-systems.

Propane Retrofit Labor materials estimate		Labor rate	\$150		
<u>CNG Engine Removal Activities</u>		Materials (\$)	Estimates Labor (hr)	Labor (\$)	Notes
Drain coolant	-		2	\$300	
Disconnect and cap engine coolant hoses	\$100.00		1	\$150	Hose plug(s) needed
Remove machine top covers	-		2	\$300	
CNG engine ECU electrical removal	-		4	\$600	
Vaporizer solenoid electrical removal	-		1	\$150	
CNG tank solenoids electrical removal	-		1	\$150	
Pressure regulator electrical removal	-		1	\$150	
Pressure regulator removal	-		1	\$150	
CNG gas line removal	-		1	\$150	
Generator removal	-		5	\$750	
Inverter removal	-		3	\$450	
Generator high voltage wire disconnect	-		1	\$150	
Inverter high voltage wire disconnect	-		1	\$150	
Remove and cap cooling/heating lines from CNG tanks	\$100.00		1	\$150	Hose plug(s) needed
Disconnect and remove high pressure hose line from CNG tanks	-		2	\$300	
Remove rear frame	-		6	\$900	
CNG engine removal	-		6	\$900	
Disconnect air intake hose	-		0.5	\$75	
Remove and cap inverter cooling lines	\$50.00		0.5	\$75	
Disconnect and cap generator cooling lines	\$50.00		0.5	\$75	
<b>TOTALS</b>		<b>\$300.00</b>	<b>40.5</b>	<b>\$6,075</b>	
<b>PARTS/LABOR TOTALS TO REMOVE</b>		<b>\$6,375.00</b>			
<u>Propane Engine Installation Activities</u>		Materials (\$)	Estimates Labor (hr)	Labor (\$)	Notes

New engine isolator analysis and procurement	\$200.00	5	\$750.00
New propane thermal cooling requirement analysis	-	8	\$1,200.00
New propane thermal cooling requirement possible procurement	\$2,000.00	0	\$0.00
New exhaust design	-	16	\$2,400.00
New exhaust procurement	\$2,000.00	0	\$0.00
Generator installation	-	8	\$1,200.00
Inverter installation	-	5	\$750.00
Inverter-to-generator mounting bracket design	-	5	\$750.00
Inverter-to-generator mounting bracket procurement	\$200.00	0	\$0.00
IQAN program modification for propane engine	-	40	\$6,000.00
New electrical wiring for propane engine	\$100.00	32	\$4,800.00
Coolant lines needed for propane engine	\$200.00	0	\$0.00
Cooling line installation to propane engine	-	4	\$600.00
Propane/generator flywheel installation	-	4	\$600.00
Propane engine ECU wiring	\$100.00	8	\$1,200.00
Propane solenoid wiring (if applicable)	\$50.00	3	\$450.00
Fill with coolant	-	1	\$150.00
Kubota Propane engine	\$10,000.00		
Propane tank engineering and custom fabrication	\$10,000.00	5	\$750.00
Fill with oil	\$60.00	1	\$150.00
New rear frame for propane tank housing?	\$6,000.00	0	\$0.00
Connect cooling lines to inverter and generator	\$100.00	4	\$600.00
Install machine top panels	-	2	\$300.00
Design engine-to-chassis isolator brackets	-	8	\$1,200.00
Procure engine-to-chassis isolator bracket	\$750.00	0	\$0.00
Engine flywheel coupler and plate	\$1,600.00	0	\$0.00
Engine flywheel coupler and plate installation	-	6	\$900.00
Shop parts and supplies	\$500.00		
Misc. Part and engineering	\$2,000.00	8	\$1,200.00
Final testing and validation	-	60	\$9,000.00
Emissions Testing			\$15,000.00
Transportation - World Ag Expo and Testing			\$5,000.00
<b>TOTALS</b>	<b>\$35,860.00</b>	<b>233</b>	<b>\$54,950.00</b>
<b>PARTS/LABOR TOTALS TO INSTALL</b>	<b>\$90,810.00</b>		
<b>OVERALL TOTAL</b>	<b>\$97,185.00</b>		



<b>Major Components/Sub-systems</b>	<b>Cost</b>
2018 Shockwave Sprint	\$109,206.00
CNG Engine and Fuel Storage Sub-system	\$33,500.00
Ruggedized Battery Sub-system	\$62,700.00
Electro-Hydraulic Sub-system	\$23,400.00
Master Controller Sub-system	\$5,450.00
Cab Comfort Sub-system	\$20,200.00
High Voltage Safety Sub-system	\$14,500.00
<b>TOTAL</b>	<b>\$268,956.00</b>
Retrofit Parts and Labor	\$97,185.00
<b>GRAND TOTAL</b>	<b>\$366,141.00</b>

<b>CNG Engine and Fuel Storage Sub-system</b>	<b>Cost</b>
CNG Engine	\$10,000.00
CNG Tanks/Rear Frame	\$10,000.00
GVM Generator	\$5,300.00
GVM Encoder cable	\$300.00
Rhinehart Inverter	\$6,800.00
High-voltage cables	\$200.00
Electronics cooling pump	\$600.00
Stainless Flanges for exhaust	\$300.00
<b>TOTAL</b>	<b>\$33,500.00</b>

<b>Ruggedized Battery Sub-system</b>	<b>Cost</b>
SPEAR Battery Modules	\$61,000.00
Custom Battery Enclosure	\$1,500.00
High-voltage cabling	\$200.00
<b>TOTAL</b>	<b>\$62,700.00</b>

<b>Electro-Hydraulic Sub-system</b>	<b>Cost</b>
Shaker pump GVM	\$7,000.00
Auxiliary pump GVM	\$3,500.00
Mounting brackets	\$300.00
GVM Encoder cables (2x)	\$600.00
Rhinehart inverter (for shaker pump)	\$6,800.00
Rhinehart inverter (for auxiliary pump)	\$5,200.00
<b>TOTAL</b>	<b>\$23,400.00</b>

<b>Master Controller Sub-system</b>	<b>Cost</b>
MD4-5 controller touchscreen display	\$1,400.00
MC43 Expansion modules (2x)	\$2,200.00
Telematics	\$1,000.00

Low-voltage wiring materials	\$500.00
Fuse block	\$100.00
Fuse breaker	\$100.00
Contactora	\$150.00
TOTAL	\$5,450.00

### **Cab Comfort Sub-system**

High-voltage compressor	\$1,500.00
ABS Custom housing	\$3,000.00
Refrigerant machine	\$4,300.00
Condenser	\$300.00
Evaporator	\$300.00
High-voltage wires	\$200.00
Kubota cab	\$1,000.00
Kubota cab extruded aluminum frame	\$1,500.00
Extruded aluminum frame test bench	\$5,000.00
ABS Tee's for testing	\$2,000.00
Instrumentation sensors for initial tests	\$500.00
Blower fans	\$600.00
TOTAL	\$20,200.00

### **High Voltage Safety Sub-system**

ABS Custom housing	\$3,000.00
Custom Designed DCM modules	\$1,000.00
Custom active cooling plates (for DCMs)	\$500.00
High-voltage electronics PCB board design	\$10,000.00
TOTAL	\$14,500.00

### **Timeline**

- *Provide a detailed timeline of all activities, tasks, and milestones.*
- *Include commencement and completion dates.*
- *List most responsible person for each task.*

Major milestone timelines:

1. Propane engine installation – 7/2/2021
2. Propane-Battery machine testing commencement – 9/6/2021
3. Propane-Battery machine testing complete – 12/31/2021
4. Display at World Ag Expo 2022 - 02/2022

## COMMERCIALIZATION PLAN

### **Positioning Strategy**

- *Outline a possible positioning strategy for the commercial launch of the new product.*
- *Share how current leaders are positioned in the market.*

This project will be a technology demonstration project. The hybridized almond tree shaker will be the backdrop for conversations with CARB, OEM manufacturers, OEMs in other markets, and end users at farm shows and private events. This project will strengthen our standing with CARB and show our industry is part of their solution to improve California's agriculture "footprint".

### **Potential distribution and channel approach(es)**

- *State the possible challenges in reaching the market.*
- *Describe the distribution channels of partners/manufacturers.*
- *Identify opportunities to leverage existing marketing/outreach channel(s).*

Possible challenges to overcome in this demonstration project include product performance. We need to meet run time requirements of orchards with available on-board storage of propane. The ability of this machine to have enough on-board fuel for a real-world day length cycle will be critical.

Another challenge can be CARB and how they look upon this technology in their grant programs. That determination will only happen with a completed machine and testing.

Upon successful completion of the project, this orchard market is a fairly small one with 5-6 companies building this exact type of machine. The Terzo technology is applicable to all manufacturers and translates to other pieces of equipment built by these same manufacturers for the orchard segment.

Beyond orchard equipment, Terzo's technology translates to other fluid power equipment including the light construction market where that equipment has a very similar duty cycle to the orchard equipment and would be a prime opportunity for expansion.

### **Potential Marketing, Communications, and Promotional Requirements**

- *Describe how the message(s) will be conveyed to the market.*
- *Identify opportunities to leverage existing channel(s). (i.e. ongoing outreach programs in other markets)*
- *Outline the marketing collateral that likely will be required.*
- *List any external agencies that will be utilized and identify the purpose for which they will be needed.*
- *Describe the timeline for the activities above for the first three years.*
- *Identify 3-5 features and benefits the product or service will provide from a customer perspective.*

The initial marketing of this technology will be to three groups: 1. OEM manufacturers in this space making orchard equipment. We will also market this to OEMs in off road applications where they have similar duty cycles and needs. 2. Regulators at CARB to move propane into the "clean" conversation. 3. End users at trade shows.

A case study will be utilized to tell the story of this unit developed with the assistance of Terzo Power and PERC by Swanson Russell. This case study will be distributed throughout our propane industry and also used externally to tell the story of this propane-electric hybrid and the performance of this unit.

The marketing and collateral development will begin as we near completion of the unit. Terzo has agreed to allow this unit to be displayed at World Ag Expo 2022 (WAE) in Tulare, CA. This show is a very good show as it focuses on California agriculture and agriculture equipment. This unit will be displayed and promoted at the Western PGA booth and will garner attention from OEMs, almond growers, regulators and media. We will need a completed marketing piece at WAE 2022 due to the attention I expect this unit will receive.

Benefits for the customer for a unit with this technology are the lack of DEF systems on the diesel engine, fuel that is safe and secure, fuel that is clean for the environment and your employees, meeting requirements of CARB, potential incentives from CARB for new equipment purchases.

### **Preliminary Training Needs**

- *Identify which groups will require training (for example, propane marketers, customer service staff, maintenance, and channel and distribution partners).*
- *What type of training is required? (i.e. marketer, safety, user training)*

There will be significant training for the end user on this product. There are multiple systems within the unit, all requiring specialized training. In addition, there will be a new fueling system that the end user will need safety training. The local propane marketer will need safety training on the unit due to the electrical system integration.

We will utilize Terzo Power for the bulk of this training and our internal PERC team for the propane safety training and material generation.

### **Customer service and support needs**

- *Identify the potential customer service and ongoing commercialization support requirements.*
- *List the resource that will likely be required for sustained support*

Terzo Power will provide long term customer support on the physical units with the local propane marketer providing fuel and fuel system support as needed. Long term PERC support will include continued promotion of the units and promotion of the technology to other OEMs and other segments.

### **Expected Launch Date**

- *State the target launch date/outreach kickoff*

Expected Launch Date: 12/31/2021, Q1 2022

## **MEASUREMENT & EVALUATION**

### **Project Metrics**

- *Detail how success will be measured for this project overall and by tactic, what the metric is, and when it will be achieved.*

Project Deliverable Metrics	Metrics	By When (Date)
Project Kick Off	Council Vote	05/01/2021
Engine Installation	Completion	06/02/2021
Propane-Battery Testing Commencement	Validation	09/06/2021
Final Product Testing/Confirmation	Validation	12/31/2021

Market Outcomes	Metrics	By When (Date)
Marketing Rollout Piece Development	Completion	12/31/2021
OEM Invitation Only Event at WAE 2022	Invitations made to OEMs	1/20/2022
California Almond Growers Event at WAE 2022	Invitations made to organization	1/20/2022

### Partner Selection

- *What was the basis for selecting the recommended contractor?*
- *If the basis for selection is not via a competition, describe the unique qualifications this vendor possesses.*
- *For time and material work arrangements, list or attach the Principal Hourly Rates and the basis used to determine that the rates are competitive.*
- *How will matching funds be verified?*

Terzo Power was a company sought out by PERC staff from research. Terzo Power offers a unique solution to the electrify movement by utilizing an internal combustion engine for power generation. This system will allow propane to enter places in the agriculture off-road space that we have not yet been able to enter. The system will leverage the electric hybrid movement already underway in on-road application in the US and will leverage the movement to move to cleaner energy in agriculture.