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Providing rural communities with an integrated 10 MW liquid calcium dual hydride continuous Power plant

Additional submitted attachment is included below.

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EPIC 5: 2026 to 2030 Program

ADI Solar Corporation

Project Title: Providing rural communities an integrated 10 MW liquid calcium dual hydride continuous Power plant

Deliverables

This program integrates a continuous power solution using a combination of 18 hour energy storage combined with a down mirror central tower solar design integrated with a multi-fuel backup power. The system team has completed a detail techno-economic analysis which provides a $0.025/ kWhe value once the power plant is fully commercialized. Two 100 kW continuous solar power plants will be operational and validated prior to the program start. The first 100 kW power plant will be setup in the Tri-Cities eastern Washington State near DOE facilities on Stevens Way. The second 100 kW power plant will setup near Sacramento California. The lessons learned from these facilities allow an integrated 10 MW system. A 10 MW supercritical CO2 turbine is currently in the final development stages with GTI Energy at the SwRI test site in San Antonio and will be commercial in the next 2 years. This is a next generation energy conversion system with an operating efficiency of 50% thermal to electric.

Project team

ADI Solar Corporation is the organization providing the solar and storage technology along with integration of the 10 MW turbine. They are a US corporation focused on providing a competitive continuous power plant for the US and world market.

GTI Energy has been the focal for the 10 MW turbine and will provide commercial and technical integration of the power plant with the energy storage.

Southwest Research Institute is a nano coating lab that is providing the PEMS and HPIMS hermetic coatings used to contain both the liquid calcium and magnesium hydride storage systems.

The 10 MW site will operate near the existing Ivanpah commercial site which is closing in 2025. the site has grid integration hardware which will provide access to the California community grid. Several towns are located within the San Berardino County area which is over 8000 sq miles including: New Berry Springs, Keso, Cima, Fort Irwin, Ivanpah, Nipton, Goffs, Essex, Needles, Amboy, Cadiz, Rice, Vidal, Yermo, Landers, Daggett, Hoodge, and Ludlow.

The project has a total cost of $80M dollars which is shared between the DOE, ADI Solar Corporation, and the California Energy Commission. The project will last five years with the last two years operating the power plant; 2026 to 2030.

Technical Solution

ADI Solar would like the opportunity to propose a 10 MW continuous power plant integrated adjacent to the current Ivanpah facility located in San Bernardino county California. The site will integrate with the existing grid at Ivanpah due to the site closure in 2025. The plant will power the surrounding community around the Fort Irwin, Baker, and parts of Barstow area.

The 10 MW system meets the EPIC 5 requirements by providing a "next generation renewable continuous" energy system that will have two commercial power plants, of the 100 kW size, operational at a TRL level of 8 prior to the 10 MW phase construction planned for 2027.

The 10 MW system operates as a multi-fuel fully integrated power plant that utilizes natural gas, Dimethyl Ether (DME), and direct concentrated solar. The Ivanpah location receives 80 to 90% clear skies allowing solar power availability during these times of the year. ADI Solar has fully integrated a liquid calcium dual hydride storage system that provides 18 hours of 10 MW operation with 6 hours of sun. The power plant will have a LCOE of $0.05/kWhe from the start of operation and provide grid quality electricity over the plant operating life of 30 years.

The 10 MW supercritical CO2 turbine is currently in testing in San Antonio at the SwRI site and will be at a TRL 8 level operating on natural gas or DME by 2027. This provides assurances that the power plant will have nameplate power levels by 2028 when the 10 MW plant provides continuous power and is fully integrated into the grid. ADI Solar Corporation has been in discussions with GTI Energy to facilitate delivery of their 10 MW supercritical turbine meeting the EPIC 5 time requirements.

The storage reactor operates at 1000 C to 1050 C using a well established storage material of calcium metal reversibly combing with hydrogen gas. Hydrides have a proven history of cycling 1000's of times without performance degradation. The hydrogen is reversibly cooled through a stationary heat exchanger and reversibly stored in magnesium metal combining with the hydrogen at 300 C. The major storage materials are derived from calcium oxide and magnesium oxide which are extremely plentiful and low cost materials. A eutectic salt surrounds the magnesium tanks and provides a 300 C thermal heat reservour which absorbs and desorbs the thermal heat generated as magnesium and hydrogen combine and separate. This is a critical sub-element of the process as it maintains the magnesium storage at almost constant temperature without added energy inputs.

The calcium reactor moves its reversible thermal-chemical energy, 20X of molten salts, into a supercritical CO2 turbine providing over 50% heat to electricity conversion at 715 C.

The central tower design, used for power tower systems, is replaced by a lower cost central ring tower design that supports an array of secondary mirror targets. These mirrors focus onto two thirty foot diameter 5 MW reactors with their twelve foot diameter elliptical heat pipes. The array provides 5000 suns to the two heat pipes maintaining the operating temperature during the day.

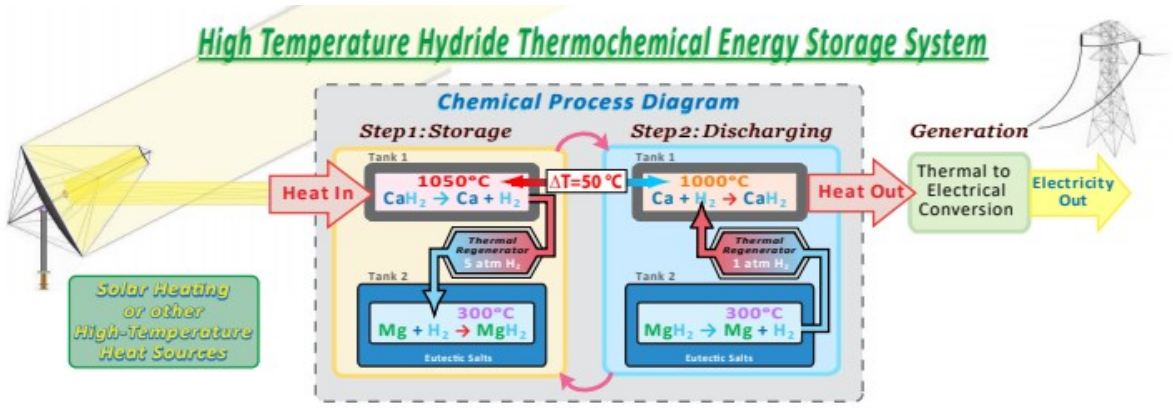

Figure 1: Diagram of the HYTES energy storage process

Through the reversible reaction cycles, at 1 to 3 atm H2, solar energy is stored as thermo-chemical energy and then produced as heat for thermal processes or electricity when needed through this simple and effective process. There are no valves or moving parts in the Ca/CaH_2-Mg/MgH_2 energy storage system. The storage and discharge of energy is controlled simply by raising and lowing the temperature of the Ca/CaH_2 tank 1 by 50C. The primary working material, liquid calcium hydride, has a 20X increased storage energy density relative to molten salt systems (sodium/potassium nitrate solar salt) and 10X increase in kilojoules per dollar of storage material cost relative to molten salt storage. Therefore, it has excellent economic scaling.

The 10 MW system, shown in figures 2 and 3, utilize two 5 MW reactors which are 30 feet in diameter each to power the 10 MW turbine. The two 5 MW processors are also shown in figure 3 which shows the 100 Acre field of 180 focusing heliostats. The design is a two mirror system. The primary mirrors are 60, 90, and 120 feet in diameter the secondary mirrors, 300 feet above the reactors, are 6, 9, and 12 feet in diameter in an annular ring of flat mirrors.

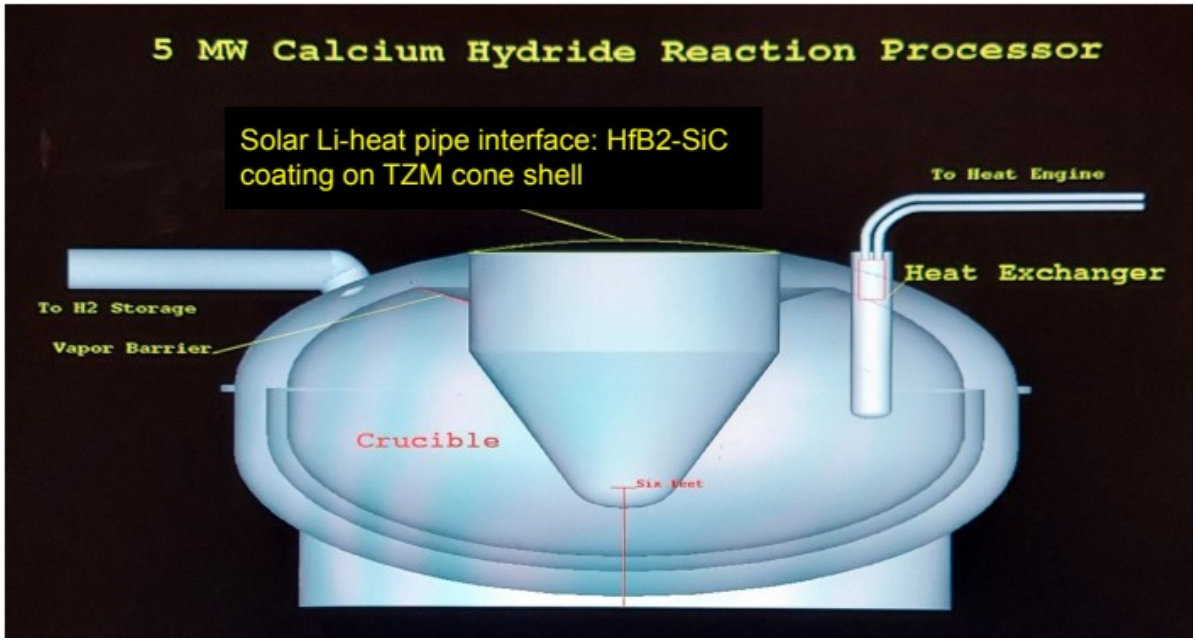

Figure 2: 5 MW Calcium Reactor

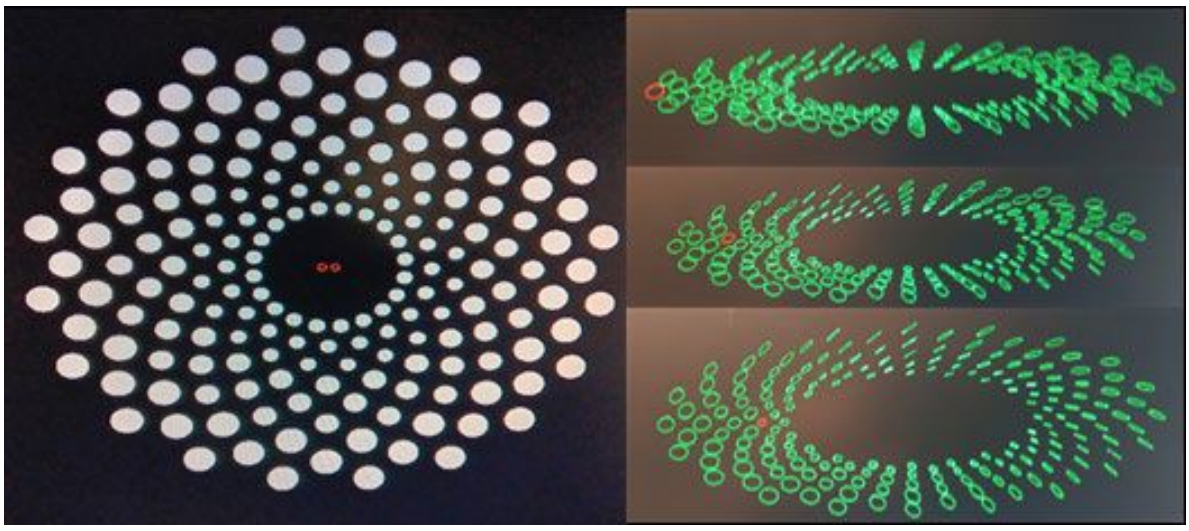

Figure 3: 10 MW Solar mirror array and down mirrors

Business Case

This project will provide significant immediate benefits to the area serviced by the 10 MW power plant. The Ivanpah site had costs which were significantly above market power rates which resulted in the site being closed prematurely. The ADI Solar power plant provides continuous power at a LCOE of $0.05/kWhe which is under the local market price. The plant has a projected maintenance cost of $500,000 per year due to the significant increase in site automation. The economics will allow a competitive power purchase agreement. The new site will provide a higher level of power stability and reliability. The local area benefits from the multi-fuel feature allowing both a clean environmentally conscious solution and economic.

ADI Solar will use local contractor groups to provide both site setup and on-going maintenance. All of the 10 MW components are pre-fabricated and trucked to the site. The solar heliostat integration has been designed to minimize ground disturbance during setup so that the natural environment is maintained.

The project provides a benefit to both the local area and the state of California. The California Energy Commission will be integrated with the planning and development. It is anticipated that the site will provide an example of next generation continuous energy production so that multiple sites will be integrated to benefit the state. ADI Solar has a commercialization plan to privately fund an additional 50 MW of these solar hybrid sites adjacent to the initial site adding further value to the local area and specifically to the grid. The DOE program and 10 MW site provide valuable data on power flexibility and automation. It is anticipated that this site will serve as a US center of excellence demonstration site providing a demonstration and economic viability for multi fuel energy design optimization.

The economics of the power plant are summarized in the techno-economic analysis provided for the 10 MW system. The continuous power system is projecting a system price reduction due to commercial scaling with a fully integrated price of $24M.

Fuel Production

In parallel with the 10 MW power plant ADI Solar Corporation is planning to integrate a continuous di-methyl ether production facility powered by the solar facility with the goal of refining the process for low cost continuous renewable fuel production. Idaho National Lab has developed a solid oxide high temperature co-electrolysis system that uses steam, CO_2, and electricity as inputs. The solid oxide cell produces H_2 and CO as products at extremely high system efficiency. An existing catalyst process is used to directly convert the hydrogen and carbon monoxide into di-methy ether. DME is a storable fuel that can be shipped to any location in California having energy density and performance characteristics similar to propane.

Techno-Economic Analysis for 10 MW Dual Hydride Solar Power Facility

A detail techno-economic analysis was completed for the ADI Solar 10 MW system relative to competing storage systems projected to 2030 availability. All the system trades use the supercritical turbine and a similar solar field cost per sq meter. **The liquid calcium dual hydride shows ½ the LCOE relative to the ceramic bricks for baseload power of $.025/ kw-hr vs $.048/ kw-hr.** This significant benefit was the result of three factors:

1) A 29% system cost reduction:

This is primarily due to: ½ the tower and receiver cost, ½ the storage system cost, and ¼ the site construction cost

2) A 12.5% increase in Kwhr delivered:

This is primarily due to an increase in the solar multiple from 2.75 to 3.5 allowing a 15 MW power output during the six hour daytime interval relative to the 10 MW baseline.

3) A 20% increase in storage duration:

This is due to the significantly higher energy storage density available from the liquid calcium hydride system allowing 18 hours relative to 14.

Techno-Economic Analysis Summary Results Achieving DOE Targets by 2030

	Current Tech-nology		2030 Vision	2030 ADI Solar Vision
	Molten Salt		Ceramic Bricks	Liquid Calcium Dual Hydride
	Steam		sCO2	sCO2
	550°C TiT		700°C TiT	700°C TiT
Net Capacity / MWe	100		100	100
Operating Mode	Baseload		Baseload	Baseload
Receiver HTF	Molten Salt		Liquid Sodium	Lithium Vapor
LCOE / $/kWeh	**0.081**		**0.048**	**0.025**
Solar Multiple	2.75		2.75	3.5
TES Storage / hours	14		14	18
DNI / W/m2	850		850	850
Cycle Efficiency	41%		52%	52%
TES Round-Trip Efficiency	90%		95%	95%
Receiver Efficiency	85%		92%	92%
Field Efficiency	55%		70%	70%
Site Preparation / $/m2	10		10	10
Collector Field / $/ m2	75		50	50
Power Block / $/kWe	900		694	694
Tower and Receiver / $/kWth	150		60	25
TES System / $/kWthh	26		30	15.28
Construction/ Contingency Cost Factor	21%		20%	5%
Financing	7%		7%	7%
Lifetime / years	30		30	30
Capacity Factor	70.30%		70.30%	70.30%
O&M Factor / $/kWe-year	40		40	40

Team

ADI Solar Corporation has been building a technical/commercialization team over the past 10 years in order to bring the largest skill base for creating the path to market and making sure the product meets the requirements for the largest benefit to society. The founder, Wayne Bliesner, has been focused almost entirely on finding a solution to the US and world energy storage needs. The current design provides a synergistic solution guided by performance optimization trades, material trades, and manufacturing process trades to create a practical design that has an LCOE at ½ the DOE goal of $0.05/kWe. This will create a path to $0.025/kWe which was in the detail techno-economic analysis listed in the technical section.

Heading the High Lift Aerodynamics research group at Boeing for 20 years provided the experience to gain technical expertise in multidisciplinary optimization along with "real world" lessons from the monthly meetings and interactions with vice president and senior engineering staff within the Boeing commercialization programs. This experience carried over to real world design trades and system optimization requirements that are key to a practical design solution. Work at Boeing also provided direct interactions in the commercialization decisions, processes, and documentation requirements to create the world class aircraft at Boeing: such as the 737, 757, 767, 777, and 787. Five years at Boeing in their geometry group led to the optimization and use of 3-D design software which significantly enhanced the ability to create "state of the art" designs as referenced by the international patent on the 777 for its leading edge system, shape, and integrated hardware. As lead for the international wind tunnel design program in high lift Aerodynamics time was spent both in testing facilities and international business trips to Japan for coordination.

GTI Energy has been the focal for the supercritical 10 MW CO2 turbine and has been working with ADI Solar integrating the turbine as a key power plant for the system. Discussions with Michael McDowell at GTI Energy provide coordination with the turbine testing and the 10 MW commercialization team. Integration work over the next several years will provide build-up of the manufacturing for the turbine for deliveries that meet the ADI Solar rollout production targets for the 10 MW system.

Southwest Research Institute is key to providing nano coating processes using their HPIMS/PEMS systems.

The team brings both National Lab, non-profit, and private corporations together to create a "world class" group that has both the experience and the networking to exceed all the goals set by this program. Our partner from GTI Energy lives in the San Bernardino county area and provides direct knowledge of the local user needs. In addition we will add a team member from EPRI to serve as utility and grid tie-in and who has energy storage experience.

Project Plan

The ADI Solar team is 100% focused on the commercialization and growth of the 10 MW power plant system. A commercial factory will be ramping in parallel with the 10 MW commercial facility. A factory staffing level of several hundred are available in Washington State and can provide the critical site setup and field expertise as needed. Added part inventory will be available if needed to maintain commercial power plant operation.

Site risks will be kept to a minimum by providing sufficient design and industry tie-in so that all the hardware and processes conform to industry reliability standards. It is critical for the ADI team to provide rapid consistent and documented processes in place so that risks can be forecast and prevented.

The table below provides a detail commercialization plan with growth rates, performance, and costs specific to the 10 MW system size and growth.

Commercialization Revenue Forcast Detail for 10 MW

Income Statement	(thousands)										
Sales Assumptions	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
Sales	0	1	5	50	200	500	1000	2000	6000	20000	50000
Sales Price		-	50,000	50,000	47,500	40,000	35,000	30,000	27,500	25,000	24,000
Production cost	0.0	80,000	50,000	40,000	35,000	30,000	25,000	22,000	21,000	20,000	20,000
Price per KW (in $)	0	0	5,000	5,000	4,750	4,000	3,500	3,000	2,750	2,500	2,400
Factories				1	4	10	20	40	120	400	1000
Revenue			250,000	2,500,000	9,500,000	20,000,000	35,000,000	60,000,000	165,000,000	500,000,000	1,200,000,000
Profit			50,000	5,000,000	1,900,000	4,000,000	7,000,000	12,000,000	33,000,000	100,000,000	240,000,000

Community and Workers

The 100 kW solar power plant operates with an extremely small footprint and can be integrated as a distributed power resource within the community. The system operates with zero noise and pollution without the need for continuous monitoring. This gives it similar features to a grid sub-station which operates autonomously.

Both the 10 MW and 100 kW systems integrate with 95% thermal processing needs for customer applications such as cement, steel, fuel reforming, or aluminum processing while providing a clean high temperature heat source for processes. The US energy grid infrastructure will have a strong and rapid market pull as the two power plant solutions integrate into multiple applications. ADI Solar will be working with the local community to understand if there are any specific needs and priorities.

ADI Solar has done an assessment of potential bird impact of the down beam solar power plant configuration. The solar concentration pattern utilizes a two mirror design that allows birds to fly through the beams without harm due to the focus regions and power plant design.