Modeling Case Study:

The Use of Transportable Batteries to Power Vehicle Charging Stations

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Harvesting solar power from remote locations and transporting it to travel corridors via electric battery 'vehicles' could provide a low-cost, flexible, and scalable business alternative to grid interconnections.

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Transportable Battery Energy Storage Systems to Power Vehicle Charging Stations

Demand charges from grid connections eat into the profits of vehicle charging stations and the wallets of drivers. Yet many of the best locations for charging stations are in dense urban areas where there is no room for solar contributions to help with costs. Can a fleet of electric battery transporters provide an economic electric 'pipeline' between affordable solar sites and driver demand?

By: Brian D. Kuhn, C.E.O., Founder, Associated Energy Developers, Plymouth, MA

As the chicken and egg problem of matching the number of electric charging stations with vehicle adoption rates continues, station operators are increasingly seeking to lower costs. Placing charging stations closer to the traffic corridors draws more cars but creates issues with electric interconnection capacity for both power and energy. The power needed to charge thousands of cars during the morning and evening commutes is large and increasing as charger sizes grow. This strains electric utility lines and creates large 'demand' charges - making many station operators rely on large scale, expensive Battery Energy Storage Systems (BESS) to try to buffer the power needs over the day. Can that BESS be offered as a remote 'service'?

With the world careening towards electrification as a Rosetta Stone of energy carriers (electricity can be made from many sources) the public policy expectation is that the electricity used for vehicle charging should increasingly be coming from solar and other renewable resources. But prime service station locations are not usually located next to vacant land where solar arrays could be erected economically. Even if they were, the sun's timing as crosses the sky does not match up with the demand of the vehicles, requiring batteries to buffer the energy in some fashion.

As a US solar developer which has been asked to help design many 'solar powered charging stations', AED has considered how effectively and economically electric charging stations could be supplied with power from remote solar power arrays using transportable BESS configurations. These solar farms could supply many charging stations and yet be miles away where land prices are more affordable.

This paper describes work AED has done to show that a fleet of 'electric transport vehicles' (trucks with a large battery on them) could be used as an alternative to the electric utility lines to provide the energy (kilowatt-hours) needed by the cars while buffering the power (kilowatts) needed to charge many vehicles at the same time. It depicts this information from the point of view of a 'Special Purpose' company ("DevCo") which owns and operates the Solar project and fleet of battery vehicles and sells this electricity to a local charging station.

The end result of the modeling is the production of a 25 year Proforma income statement using AED's proprietary *FOCUS*© financial modeling software for Microgrids, which calculates all of the revenues and expenses of DevCo for both solar production and storage discharge in 15 minute intervals over the year, including its unleveraged (unfinanced) Internal Rate of Return as an investment ranking.

The Base Case for Modeling:

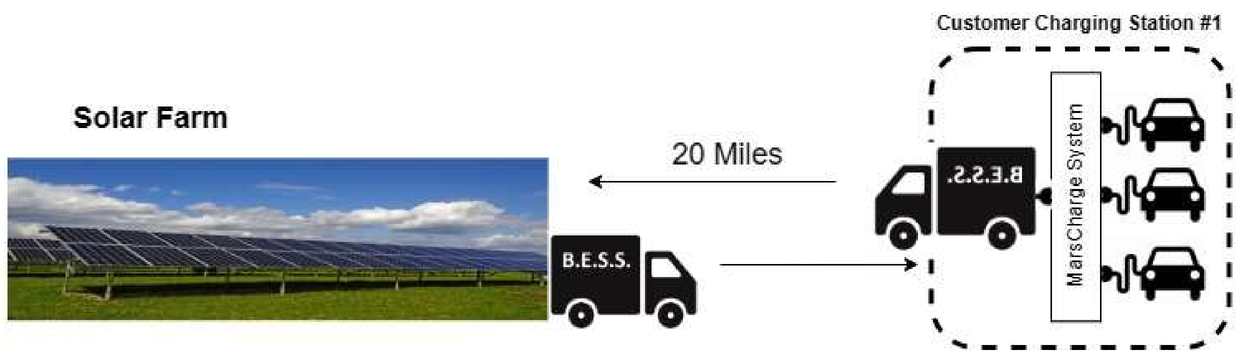
The following describes the simplified scenario and assumptions that were used to create the base case modeling exercise:

1. The project developer (DevCo) has leased land in central California for the purpose of developing an off-grid (non-interconnected) solar PV array which will be used to supply electricity to charging stations. DevCo has 4

commercial customers who act as 'off-takers' and purchase DevCo's energy under a 20 year 'Take or Pay' Power Purchase Agreement. The Customers then resell the power and energy to the retail electric vehicle market through charging stations. Each Customer owns and operates one recharging station. Each station is located 20 miles or less from DevCo's solar land site.

2. It is assumed that each of the recharging stations services 50 vehicles per day, and each recharge requires an average 30kWhrs of electricity. The stations all make use of a local charger/storage management system similar to [redacted] electric vehicle chargers, which are designed to handle a multitude of station charging and discharging configurations and include on-site storage capabilities. Therefore the management of the vehicle charging is removed from DevCo's responsibilities, and DevCo simply acts as a transportable energy provider to the 4 charging center owners. The DevCo energy transporter parks at and 'plus into' the customer's recharge center and supplies a total of 1500 kWhrs of energy/day to run the [redacted] chargers at a maximum discharge rate of 400kW/hr. The DevCo energy transporter vehicle is exchanged every day with a fully charged BESS.
3. For each set of 4 customer charging stations being serviced, DevCo owns two transportable BESS trucks that have the equivalent of 20' containerized Lithium Ion (phosphate) Battery Energy Storage Systems (BESS) mounted on them. The trucks spend alternate days charging at the solar site and discharging at the Customer's charging station. The trucks are electrically powered. In the future these might be autonomous vehicles which would further reduce costs, but for now DevCo employs human drivers to drive the trucks.

This scenario is depicted in Figure 1 below.



Assumptions:

A number of assumptions are used to model the system. The model makes use of the primary assumptions and metrics found in Tables 1 below to calculate its economics.

Item	**Value**
Cost of Solar Array	$2.11/watt
Cost of Energy Transporter	$320/kW, includes truck
Cost of Site/Land	$10,000/year
Investment Tax Credit	Yes, 30%
Combined Tax Bracket	28%
Storage capacity of 20' container	1,600 kWhrs
Taxes (PILOT)	$10,000/yr

Table 1 - Various assumptions used in the model

Other assumptions include:

1. The Energy Transporter is an electric truck chassis on which is mounted a battery energy storage system (BESS) as a 'payload'. A 2 hour 'exchange time' is assumed for each charging station, which are 20 miles

away. This allows for drive time and the time for the driver to uncouple the previous spent Transporter and connect the freshly charged Transporter. Therefore 4 charging centers can be serviced by a single driver in an 8 hour work day. The model analyzes the economics of servicing just ONE of those charging centers.

2. Two BESS payloads are needed to perform the swap out each day at the Customer's charging station. An extra Transporter is kept at the solar array to be shared around various stations if needed for servicing and to absorb extra solar energy during peak hours of charging instead of 'stranding' sunlight during periods of seasonal solar variations. Charging logic ensures that one BESS is completely charged before the backup BESS starts charging.
3. The annual vehicle load was considered a constant across the year at 1500kWhrs for the retail vehicles, plus 100kWhrs/day of 'parasitic use' by the electric transporter.
4. The model includes $40,000/year of General and Overhead expenses for the Devco for each Customer Station serviced. This yields a G&A budget of $160,000 per central solar array serving 4 Customer recharging stations. The G&A provides for 1 – 2 additional non-specialty personnel and misc office fees.
5. Drivers are budgeted at the rate of $30/hr including payroll burden and work an 8 hour day to service 4 stations, therefore each station is charged for 2 hours of drivers per day.
6. The land that the solar array and BESS charging project is located on is leased at the rate of $10,000/year and requires approximately 2 acres. Note that this is just the pro-rata share for the array that services ONE Customer charging station, which is what the economic analysis was run on. A cost is also provided for property taxes in the form of a Payment in Lieu of Taxes (PILOT) for the facility.
7. The size of the array and land area and the number of transporters would be 4 times as large when serving the 4 Customer charging stations. This would result in a proforma profitability analysis which is also 4 times as large, although there should be some positive effect on the overall IRR due to economies of scale.
8. In order to depict the ability to finance the project, a 'placeholder' financing plan consisting of 10% equity and 90% debt over 20 years at an annual interest rate of 7.5% was used in the model.

Methodology:

FOCUS© financial modeling software for Microgrids (www.AssocEnergy.com/Focus) was used to model the business unit profitability. From the assumptions FOCUS© was used to set up a microgrid topology for the solar array and transporters and all associated costs incurred in servicing one of the charging centers. FOCUS© then simulated the operation of the system using data from TMDY solar data in 15 minute increments to analyze how the central solar array charges the transporter vehicles, as well as the economics of delivering the transporters to the charging stations where they are swapped out for the depleted transporter vehicles. Because a 'Take or Pay' PPA contract is assumed to be in place with the Station Owner, DevCo may assume that the entire battery becomes fully discharged by this event and the 'empty' transporter is returned to the solar array for recharging.

The business has been modeled from the point of view of DevCo, which owns just the solar array and electric transporter vehicles as a business unit. The product being sold is the electricity delivered to the customer's charging station. The market risk of selling the electricity to vehicles belongs to the charging station owners. The costs associated with the business unit include all costs of Capital, Financing, Operations, Labor and O&M placed upon the business unit consisting of the solar arrays and the transporter vehicles, and pro-rated for delivery of energy to just one of the charging centers. The location of the solar array was assumed to be in Central California, which exhibited an annual solar capacity factor of 20.3%. Inverter replacement was considered at 10 years.

FOCUS© was first used to optimize the comparative size of the solar array vs. BESS storage available so that 100% of the solar energy provided would be usable and not stranded. The combination of the 2 available BESS systems on the transporters absorbed the seasonal variability of the solar output.

The sales price of the energy sold to the Customers (Charging Station Owners) under the PPA was varied to depict a range of Internal Rates of Return upon which the business unit could be evaluated as an investment. A 25 year proforma income statement was generated using FOCUS© for a mid-range price of energy which was thought to be both profitable and affordable. No demand (power) charges are assessed to the charging stations.

Conclusions:

The FOCUS© analysis shows that the optimum size solar system to service one charging center would be a 360kW DC (273 kW AC) solar array which would produce 640,656 kWhrs of energy per year. This compares to the 584,000 kWhrs required by the annual load from the transporters at a given rate of 1,500kWhrs/day x 365 days/year plus the parasitic transportation energy.

The transportable batteries are charged on alternate days and driven to a vehicle charging station 20 miles away where they are left to discharge and swapped out the next day with the other freshly charged battery. Four such customer locations could be serviced by the same driver.

All of the attendant costs of such a charging arrangement were considered for a fictitious company named DevCo, whose role is to own the solar array and BESS charging equipment and truck the electricity to their customer's charging station. The total Capital expenditure for DevCo's optimized solar/BESS facility is calculated to be on the order of $1.78M USD. At a sales price of $.75 per kWhr to the Customer, with NO demand charges for power, such a business operation is very profitable, yielding a 20 year unlevered Internal Rate of Return of some 37%! Assuming just the proportional costs of the driver and G&A, the EBITDA for servicing one customer location would be approximately $360,000 per year on annual energy sales of $477,000. An Investment Tax Credit for $536,000 is available from the CapEx of the project. The following page shows a 25 year Proforma Income Statement depicting a sales price of $.75/kWhr.

Of note is that the operations stay profitable (IRR above 20%) down to a price point of just $.45/kWhr. Conversely, in markets where energy can be sold to the charging center at $1.05/kWhr (with no demand charges) the 20 year IRR reaches 50.5 %!

This exercise shows that a profitable business could be created by using Transportable Battery Energy Storage Systems to deliver energy to remote urban charging stations instead of using the electric grid which creates additional costs in terms of Demand Charges and interconnection costs.

25-YEAR FINANCIAL PROFORMA : TRANSPORTBLE ENERGY TEST - , Avenal, CA

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FOCUS

Notes:	**Transportable BESS Scenario to service ONE Customer Recharging Center**
Prepared For:	Driving on Sunshine
Prepared By:	Brian Kuhn, Founder, CEO
Contact Info:	1(888) 800-2381 | Brian.Kuhn@AssocEnergy.com
Report Date:	11/30/2023 11:23
Annual Load Usage:	584,000 kWh
Renewable Production:	639,952.60 kWh
Offset %:	109.6%

	Source 1	Source 2	Source 3	Energy Storage	Ancillary Svc.	Totals
Generation Type:	Ground SolarPV			Energy Storage System	N/A	
Size (dc):	360.360 kWdc					360.360 kWdc
Size (ac):	273.000 kWac			3,200.000 kWac		3,473.000 kWac
Net Output:	639,953 kWh			N/A		639,953 kWh
Cost ($):	$762,216.00			$1,025,000.00		$1,787,216.00
Cost ($/W):	$2.115 /Wdc			$0.320 /Wdc		$4.960 /Wdc
Tax Ineligibles:	$0.00			$0.00		$0.00
Investment Tax Credit:	$228,664.80			$307,500.00		$536,164.80
Depreciation Cash Value:	$168,449.74			$226,525.00		$394,974.74

Revenue (Cash Basis)									Gross	Operating Expenses								EBITDA	Financing		Results	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Year	Src1: SolarPV - M1 BTM Revenue at Grid Rate of: $0.00000 /kWh				Additional Revenue BESS kWhrs Exports	Utility Incentive Revenue		Depreciation and Fed ITC Depreciation at 26.0% Tax Rate ITC Shown as Revenue (Year 1)	Gross Revenue	Site Lease / Site Purchase	Insurance Coverage $47.62/kWdc with 1% escalator	Operations & Maintenance $17.76/kWdc with 1% escalator	Miscellaneous Expenses 000	G&A Portion Management $111.00/kWdc with 1% escalator	Drivers Costs $60.77/kWdc with 2% escalator	Down Payment / Interest Reserve 10.0% Down Payment	PILOT / Property Taxes $27,750/MWdc with 1% escalator	Total Net Revenue (before financing)	Total Payments (P & I) 90.0% LTV 7.50% Interest Loan Principal of $1,608,494.4	Debt Service Coverage Ratio 1.25 (suggested minimum)	Annual Net Cash Flow	Cumulative Net Cash Flow
0																-$178,722		-$178,722			-$178,722	-$178,722
1					$383,522			$1,314,705	$1,698,227	-$10,000	-$17,160	-$16,650		-$40,000	-$21,900		-$10,000	$1,582,517	-$155,495	1.72	$1,427,022	$1,248,301
2					$387,357			$90,148	$477,505	-$10,000	-$17,332	-$16,618		-$40,400	-$22,338		-$10,100	$360,718	-$155,495	1.74	$205,223	$1,453,523
3					$391,231			$54,089	$445,319	-$10,000	-$17,505	-$16,586		-$40,804	-$22,785		-$10,201	$327,439	-$155,495	1.76	$171,944	$1,625,467
4					$395,143			$32,453	$427,596	-$10,000	-$17,680	-$16,554		-$41,212	-$23,240		-$10,303	$308,607	-$155,495	1.78	$153,112	$1,778,579
5					$399,094			$32,453	$431,548	-$10,000	-$17,857	-$16,522		-$41,624	-$23,705		-$10,406	$311,433	-$155,495	1.79	$155,938	$1,934,517
6					$403,085			$16,227	$419,312	-$10,000	-$18,035	-$16,491		-$42,040	-$24,179		-$10,510	$298,056	-$155,495	1.81	$142,561	$2,077,077
7					$407,116				$407,116	-$10,000	-$18,216	-$16,460		-$42,461	-$24,663		-$10,615	$284,702	-$155,495	1.83	$129,206	$2,206,284
8					$411,187				$411,187	-$10,000	-$18,398	-$16,429		-$42,885	-$25,156		-$10,721	$287,598	-$155,495	1.85	$132,103	$2,338,386
9					$415,299				$415,299	-$10,000	-$18,582	-$16,398		-$43,314	-$25,659		-$10,829	$290,517	-$155,495	1.87	$135,022	$2,473,408
10					$419,452				$419,452	-$10,000	-$18,768	-$16,367	-$144,366	-$43,747	-$26,173		-$10,937	$149,094	-$155,495	0.96	-$6,401	$2,467,007
11					$423,647				$423,647	-$10,000	-$18,955	-$16,337		-$44,185	-$26,696		-$11,046	$296,428	-$155,495	1.91	$140,933	$2,607,940
12					$427,883				$427,883	-$10,000	-$19,145	-$16,306		-$44,627	-$27,230		-$11,157	$299,419	-$155,495	1.93	$143,924	$2,751,863
13					$432,162				$432,162	-$10,000	-$19,336	-$16,276		-$45,073	-$27,774		-$11,268	$302,434	-$155,495	1.94	$146,939	$2,898,802
14					$436,484				$436,484	-$10,000	-$19,530	-$16,246		-$45,524	-$28,330		-$11,381	$305,473	-$155,495	1.96	$149,978	$3,048,781
15					$440,848				$440,848	-$10,000	-$19,725	-$16,216		-$45,979	-$28,897		-$11,495	$308,537	-$155,495	1.98	$153,042	$3,201,823
16					$445,257				$445,257	-$10,000	-$19,922	-$16,186		-$46,439	-$29,475		-$11,610	$311,626	-$155,495	2.00	$156,131	$3,357,954
17					$449,709				$449,709	-$10,000	-$20,121	-$16,156		-$46,903	-$30,064		-$11,726	$314,739	-$155,495	2.02	$159,244	$3,517,197
18					$454,207				$454,207	-$10,000	-$20,323	-$16,127		-$47,372	-$30,665		-$11,843	$317,877	-$155,495	2.04	$162,382	$3,679,579
19					$458,749				$458,749	-$10,000	-$20,526	-$16,097		-$47,846	-$31,279		-$11,961	$321,039	-$155,495	2.06	$165,544	$3,845,123
20					$463,336				$463,336	-$10,000	-$20,731	-$16,068		-$48,324	-$31,904		-$12,081	$324,227	-$155,492	2.09	$168,735	$4,013,858
Subtotals:					$8,444,768			$1,540,075	$9,984,843	-$200,000	-$377,846	-$327,090	-$144,366	-$880,760	-$532,112	-$178,722	-$220,190	$7,123,757	-$3,109,898	1.85	$4,013,858	$4,013,858
Additional Years' Performance																						
21					$467,969				$467,969	-$10,000	-$20,938	-$16,039		-$49,789	-$32,542		-$12,202	$326,459			$326,459	$4,340,317
22					$472,649				$472,649	-$10,000	-$21,148	-$16,010		-$50,287	-$33,193		-$12,324	$329,688			$329,688	$4,670,005
23					$477,376				$477,376	-$10,000	-$21,359	-$15,981		-$50,789	-$33,857		-$12,447	$332,942			$332,942	$5,002,947
24					$482,149				$482,149	-$10,000	-$21,573	-$15,953		-$1,129,728	-$34,534		-$12,572	-$742,210			-$742,210	$4,260,737
25					$486,971				$486,971	-$10,000	-$21,789	-$15,924			-$35,225		-$12,697	$391,336			$391,336	$4,652,073
Totals:					$10,831,883			$1,540,075	$12,371,958	-$250,000	-$484,653	-$406,997	-$144,366	-$2,161,353	-$701,464	-$178,722	-$282,432	$7,761,971	-$3,109,898			$4,652,073

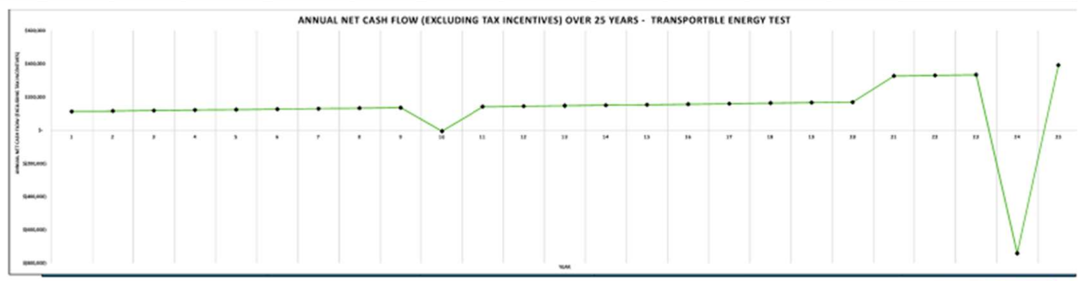
Key Financial Metrics

Internal Rate of Return (IRR)

20-Year Unlevered IRR:	*36.79%*
25-Year Unlevered IRR:	*36.82%*

Project Notes

- Ground SolarPV modeled using 30% ITC. Depreciation modeled at 26% Tax Bracket. Year One Tax Benefit ROIC of 735.62%.



About the FOCUS Software:

The FOCUS software used to model the system in this exercise has been developed over the past 12 years for use in depicting the financial performance of various kinds of renewable energy and microgrid systems, including combinations of solar, wind, CHP, energy storage, natural gas gensets, and other resources within a microgrid environment. It has been used by developers, investors and financial institutions to model the financial performance of over 1000 energy systems around the world.

About the Author

Brian D. Kuhn is the Founder and a Principal of both Associated Energy Developers *and* Aeronautica Windpower *of Plymouth, MA, and a 40 year veteran of the Renewable Energy industry. Associated Energy Developers is a renewable energy project analysis and development company specializing in solar and wind systems for clients in the Commercial and Industrial as well as Utility scale markets. Brian may be reached at* Brian.Kuhn@AssocEnergy.com*, or 508-364-9489.*