



JISEA

Joint Institute for
Strategic Energy Analysis



Clean Energy in Oil & Gas Consortium: Compressor Station Case Study

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Clean Energy for Oil & Gas Consortium

JISEA established a collaborative program for the identification, development, modeling & analysis, and demonstration of clean power for oil and gas operations. The program will:

- Support the identification, development, and adaptation of **highly reliable, cost-effective clean energy solutions** for oil and gas operations
- Perform techno-economic analysis and **site-specific optimization** of combinations of renewable and conventional generation, storage, and energy conservation
- With industry partners, **demonstrate the most promising technologies** for validation of performance in a variety of field environments, while analyzing optimization scenarios.



Value Proposition

- **Demonstrate reliable, affordable, clean power for oil & gas operations**
- **Reduce risk to operations**
- **Collaboratively identify ‘best practices’ to reduce cost**
- **Access to unique, world class capabilities**
- **Leverage research/testing dollars**

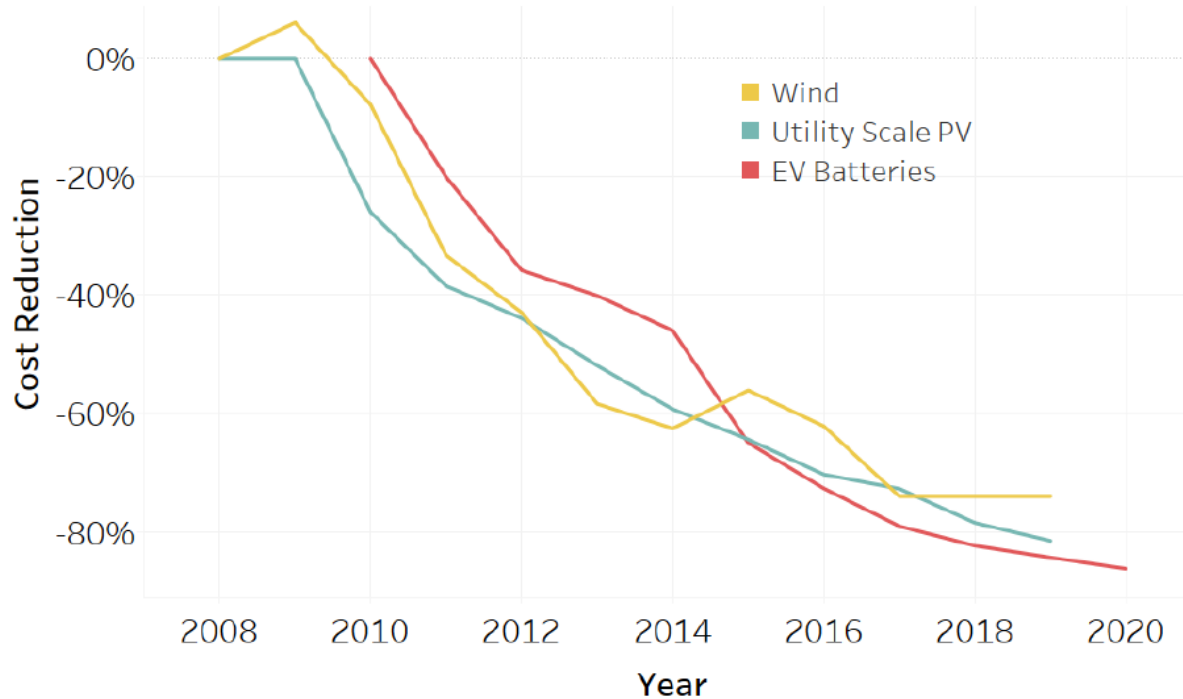
Clean Energy for Oil & Gas Project Status

Current members:

- Baker Hughes
- Extraction Oil and Gas
- INGAA Foundation
- Conoco Phillips
- Kinder Morgan

- We have completed and published analysis for Kinder Morgan compressor sites in Texas and North Dakota. We will present on the Texas site today.
- We have completed analysis and begun the publication process for an upstream site from Conoco Phillips.

Opportunity: Decline in Clean Energy Technology Costs

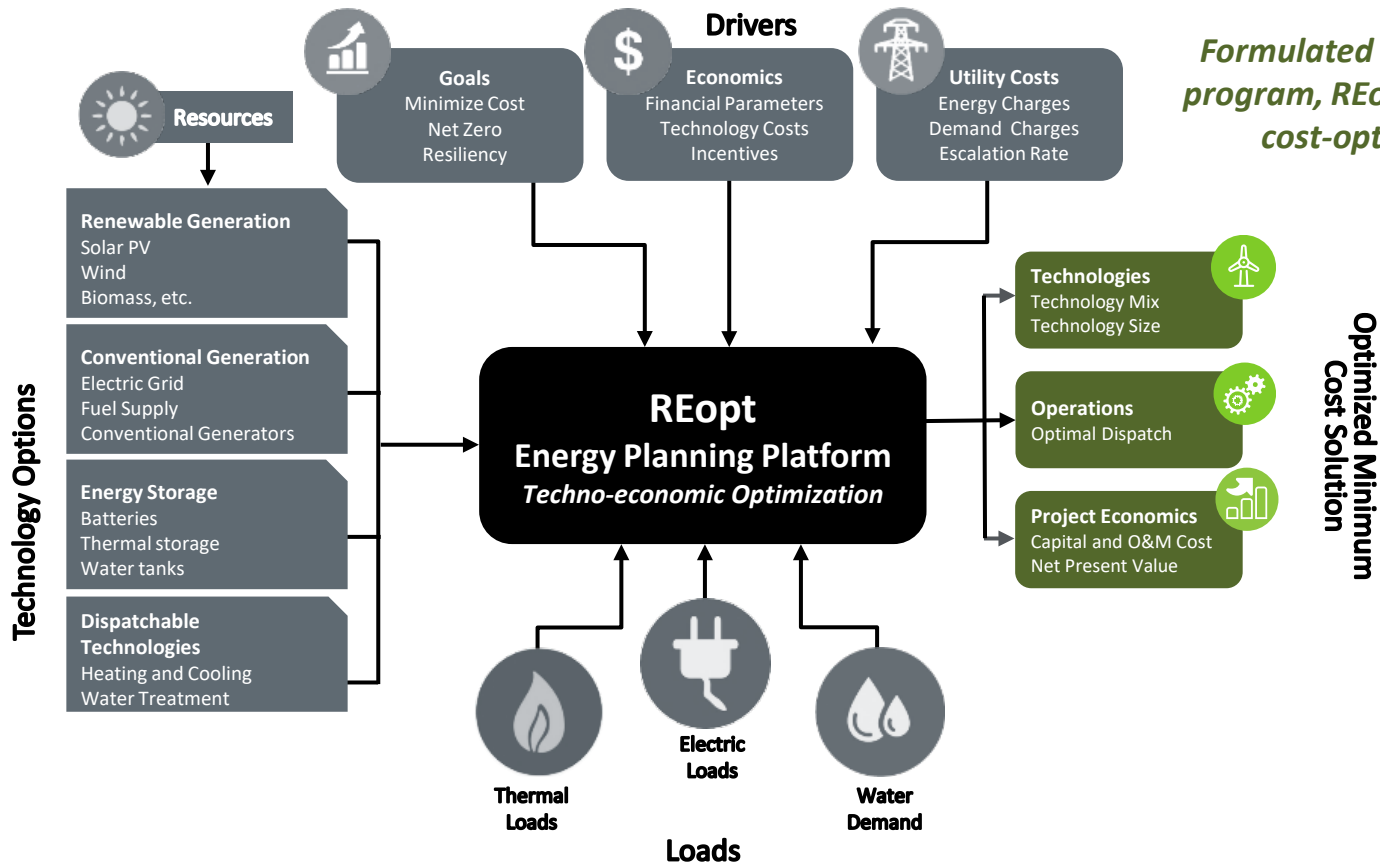


Incorporating renewable and low-emissions energy sources into oil and gas operations may reduce costs and emissions.

Analysis Overview

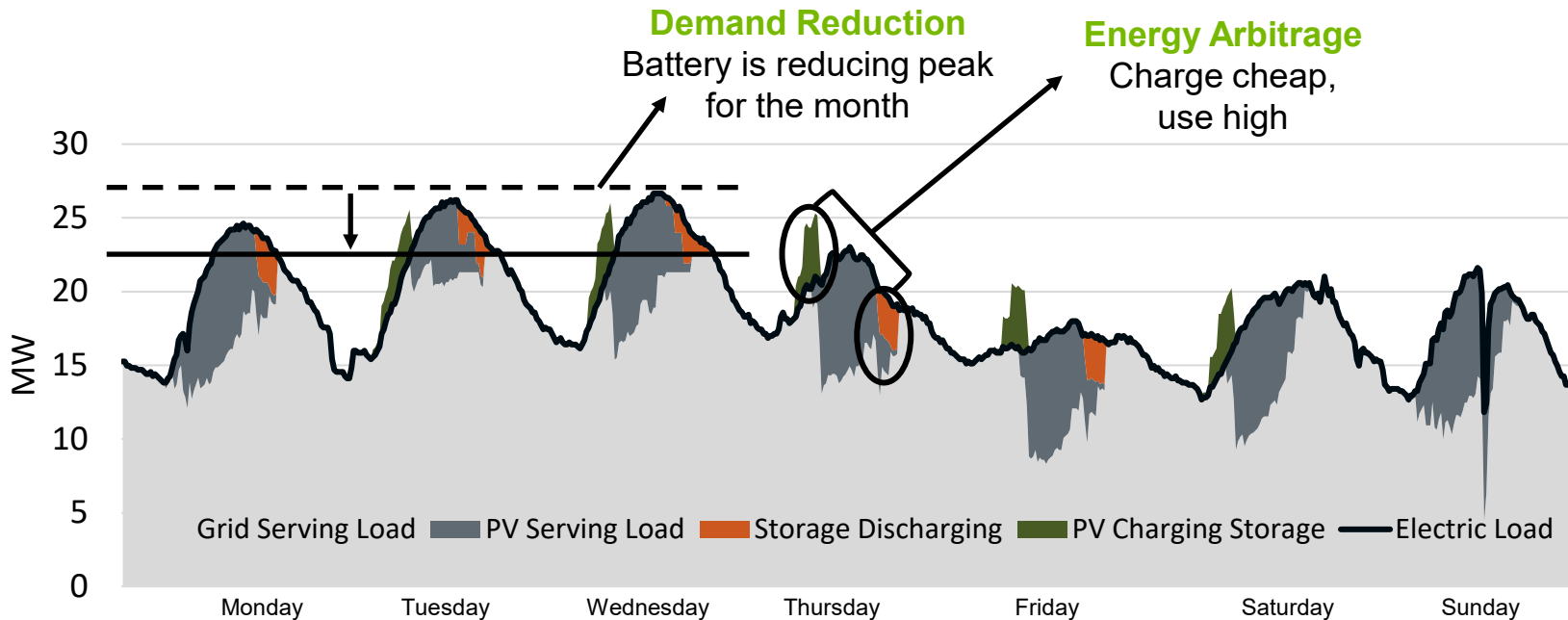
- Analysis conducted to evaluate technology and economic potential of incorporating low-emissions energy sources into various oil & gas operations in different locations to assist industry decision making
- NREL is using a software tool called REopt to evaluate the techno-economic potential of various clean energy technologies for specific case study oil & gas locations
- The case study analysis presented here evaluates renewable energy (RE) opportunities at a Kinder Morgan all electric compressor station located in Texas
- This presentation also shows preliminary results for sensitivities of that study and the addition of the net zero carbon Allam cycle technology

REopt Platform Inputs and Output



Formulated as a mixed integer linear program, REopt provides an integrated cost-optimal energy solution

How Does REopt Lite Work?



Example of optimal dispatch of PV and BESS

Compressor Station

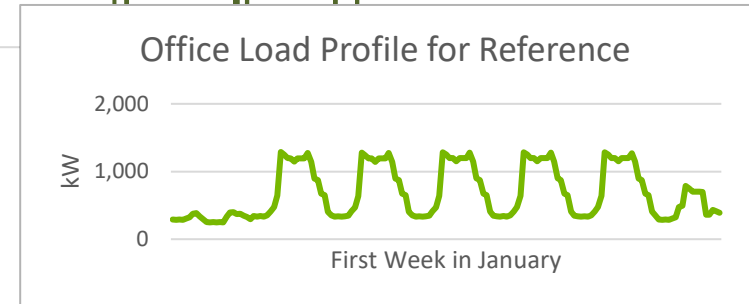
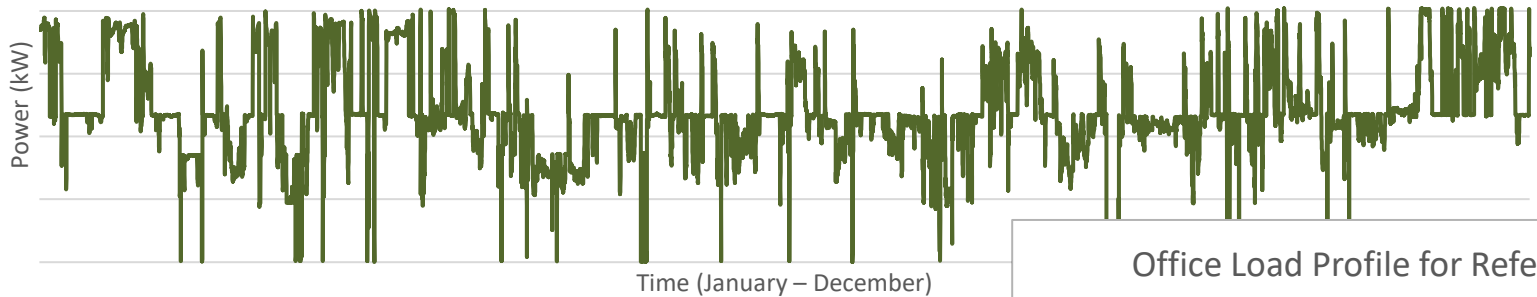


Compressor stations play an important role in transporting natural gas from the well to end users by sustaining the pressure and flow of natural gas. Note the pictured compressor station was not the one modeled in the study. Photo courtesy of Kinder Morgan

Interval Data

- 30-minute interval data from 2019 was received for the Texas site, shown in the chart below.
- Load-shape seems to indicate 3 load-levels (two units that are either on or off) and is very different from typical commercial building (highlighting the importance of using actual load data and not simulated data).

30-Minute Interval Data



Industrial Electric Rate

SECTION III RATE SCHEDULES

Page 12.1

ENERGY TEXAS, INC.
Electric Service

Sheet No.: 26
Effective Date: Service on and after 10-17-18
Revision: 7
Supersedes: LIPS Effective 4-1-14
Schedule Consists of: Two Sheets

SCHEDULE LIPS

LARGE INDUSTRIAL POWER SERVICE

I. APPLICABILITY

This Schedule is applicable under the regular terms and conditions of the Company to Customers who contract for not less than 2,500 kW of electric service at Company's available line voltage.

II. NET MONTHLY BILL

A.	Customer Charge	\$2,500.00 per month	
		Billing Months of	
		May-October	November-April
B.	Billing Load Charge All kW per month	\$8.15 per kW	\$ 7.58 per kW
C.	Energy Charge*		
	1 st 584 kWh/kW of Billing Load	\$ 0.004867 per kWh	\$ 0.004867 per kWh
	Additional kWh	\$ 0.003262 per kWh	\$ 0.003262 per kWh

*Plus the Fixed Fuel Factor per Schedule FF and all applicable riders.

D. Delivery Voltage Adjustment

The Delivery Voltage below represents the voltage of the line from which service is delivered or, if applicable, the voltage used in determining the facilities charge under Schedule AFC. When service is metered at a voltage other than the Delivery Voltage, metered quantities will be adjusted by 1.5% for each transformation step to the Delivery Voltage.

Delivery Voltage	Adjustment
Less than Transmission (69kV)	\$1.42 per kW of Billing Load
Transmission (69kV)	\$0.05 per kW of Billing Load
Transmission (138kV)	(\$0.29) per kW of Billing Load
Transmission (230kV)	(\$0.75) per kW of Billing Load

The site is served by Entergy under rate schedule Large Industrial Power. The rate has a demand charge (slightly higher in summer than winter), and an energy charge component

- Demand based on maximum usage during 30-minute interval of current month
- Rate: https://www.entergy-texas.com/userfiles/content/price/tariffs/eti_lips.pdf
- Fuel Factor: <https://www.entergy-texas.com/userfiles/content/price/fuel/fa-tx-ff.pdf>

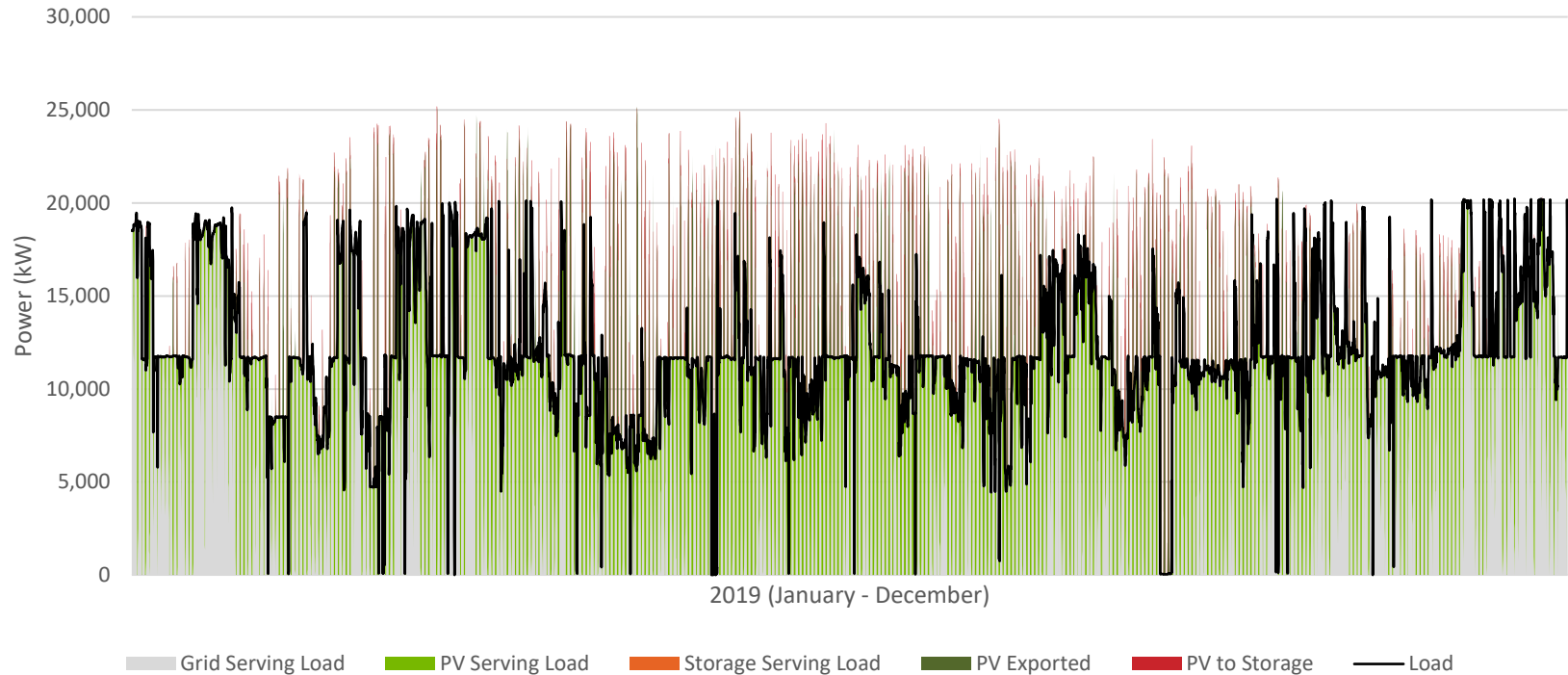
	Summer (May – Oct)	Winter (Oct – Apr)
Energy	\$0.03/kWh	
Demand	\$8.15/kW	\$7.58/kW

Scenarios Evaluated

1. Base case: Lifecycle cost of electricity, assuming site continues to purchase all electricity from utility grid
2. No net metering
 - A. Minimum lifecycle cost: Size of RE that would provide the lower lifecycle cost of electricity
 - B. 50% RE: Size of RE to meet a 50% RE generation on an annual basis
3. Net metering at (energy portion of) retail rate
 - A. Minimum lifecycle cost: Size of RE that would provide the lower lifecycle cost of electricity
 - B. 50% RE: Size of RE to meet a 50% RE generation on an annual basis

Hourly Dispatch of PV, Storage, Grid

Hourly Dispatch for 50% RE Generation



Summary Results (See printed report)

	1. Base Case	2. No Net Metering		3. Full Net Metering	
		A. Minimum Lifecycle Cost	B. 50% RE Generation	A. Minimum Lifecycle Cost	B. 50% RE Generation
PV Size (kW)	--	196	34,202	261	34,167
Battery Size (kW)	--	362	1,020	378	386
Battery Size (kWh)	--	628	4,264	671	804
Battery Size (hours)	--	1.73	4.18	1.78	2.08
Wind Size (kW)	--	0	0	0	0
Total Capital Cost (\$)	\$0	\$577,780	\$37,558,640	\$664,635	\$36,625,680
Electricity Purchases (kWh)	104,530,173	104,232,832	67,399,537	104,136,003	68,341,079
Percent RE generated based on generation (%)	0%	0.3%	50%	0.3%	50%
Reduction in Grid Purchases (kWh)	0	297,355	37,130,650	394,184	36,189,108
Annualized CO2e offset based on reduction in grid purchases (tCO2e)	0	116	14,481	154	14,114
Cost of Emissions Reduction offset based on reduction in grid purchases (\$/tCO2e)	-	--	\$69.37	--	\$38.02
RE Generated Annually (kWh)	0	299,215	52,319,787	398,860	52,265,601
Annualized CO2e offset based on RE generated (tCO2e)	0	117	20,405	156	20,384
Cost of Emissions Reduction based on RE generated (\$/tCO2e)	-	--	\$49.23	--	\$26.33
Year 1 Energy Costs (\$)	\$3,135,905	\$3,126,985	\$2,021,986	\$3,123,974	\$1,567,967
Year 1 Demand Costs (\$)	\$1,838,009	\$1,805,752	\$1,738,730	\$1,803,505	\$1,789,661
Year 1 Energy Savings (\$)	\$0	\$8,921	\$1,113,920	\$11,931	\$1,567,938
Year 1 Demand Savings (\$)	\$0	\$32,256	\$99,278	\$34,503	\$48,347
Lifecycle Cost of Electricity (\$)	\$65,634,225	\$65,544,807	\$78,895,025	\$65,543,833	\$72,718,192
Net Present Value (\$)	\$0	\$89,411	-\$13,260,807	\$90,385	-\$7,083,973

Summary Results

PV Size (kW)
Battery Size (kW)
Battery Size (kWh)
Battery Size (hours)
Wind Size (kW)
Total Capital Cost (\$)
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Year 1 Energy Costs (\$)
Year 1 Demand Costs (\$)
Year 1 Energy Savings (\$)
Year 1 Demand Savings (\$)
Lifecycle Cost of Electricity (\$)
Net Present Value (\$)

- The results indicate that smaller size renewable energy technologies (generating <1% of the site's load) are cost-effective.
- A 196 kW PV system coupled with a 360 kW (~2-hour) battery could be cost effective and would reduce both energy (\$9 thousand) and demand charges (\$32 thousand) by reducing grid purchases. The net present value (NPV) over the analysis period is \$89 thousand.
- The model could (but did not) select to build wind turbines driven by the installed cost and wind resource in at the location.

	2. No Net Metering		3. Full Net Metering	
	A. Minimum Lifecycle Cost	B. 50% RE Generation	A. Minimum Lifecycle Cost	B. 50% RE Generation
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Summary Results

- Larger systems (generating 50% of the site's load) offset significant amounts of CO₂, but at an added cost with a negative NPV.

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Year 1 Demand Costs (\$)
Year 1 Energy Savings (\$)
Year 1 Demand Savings (\$)
Lifecycle Cost of Electricity (\$)
Net Present Value (\$)

- The cost of emission reduction could be compared to a carbon tax. The values shown are the break-even numbers, or the cost of carbon that would result in a \$0 NPV for the renewable energy systems recommended, based on reduction in grid purchases.
- For example, if a carbon tax of \$69/tCO_{2e} were enacted, it would cost the same to install the 34 MW of PV (with a small battery) as it would to pay the carbon tax in the scenario without net metering. If the carbon tax increased to values over \$69/ tCO_{2e} it would be more cost-effective to install renewable energy technologies to provide carbon reductions.

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Cost of Emissions Reduction based on RE generation	
Year 1 Energy Costs (\$)	
Year 1 Demand Costs (\$)	
Year 1 Energy Savings (\$)	
Year 1 Demand Savings (\$)	
Lifecycle Cost of Electricity (\$)	
Net Present Value (\$)	

- If net metering is available (scenario 3), the economics of the 50% RE scenario improve significantly, because the electricity that is generated above the load is compensated at the retail value
- The break-even point decreases to \$38 tCO_{2e} should the site be able to fully net meter the solar PV system
- The minimum lifecycle cost solution (smaller sizes) are not impacted because the resulting electricity generation rarely, if ever, exceed the site load.
- Note that results for another location result in similar take-aways

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Emerging Zero Emission Technology

- At the request of the consortium advisory committee members, JISEA/NREL also modeled the techno-economics of an emerging technology that uses the Allam-Fetvedt Cycle, which burns natural gas with pure oxygen. The resulting high-pressure CO₂ is used through the cycle and then captured, along with other industrial gas coproducts (argon and nitrogen) that are salable.
- Based on information provided by the company, NREL evaluated the economics of a 25-megawatt power plant sited behind the meter at a hypothetical compressor station and able to sell power generation on the Electric Reliability Council of Texas (ERCOT) wholesale market, valued at 2018 ERCOT west hub pricing.
- Initial analysis shows potential for the technology to provide cost savings, largely driven by the value of selling gas generation (nitrogen, oxygen, argon, and CO₂) associated with this technology (about 45%). Additional savings come from avoided utility costs and sales to the wholesale market.

Conclusion - Insights for Industry

- This study explored the potential for cost-effective clean energy implementation at an all-electric compressor station in Texas.
- The results indicate that smaller size renewable energy technologies are cost-effective; larger systems (generating 50% of the site's load) offset significant amounts of CO₂, but at an added cost.
- NREL calculated the cost of emissions reduction (\$/tCO₂e) based on renewable energy generated and found that this could improve the economics of onsite renewable energy in the event of a carbon tax.
- A technology using the Allam-Fetvedt Cycle could be cost-effective for producing power and reducing emissions, but more information is needed to fully understand its market potential.
- As a large energy user, a compressor station benefits from low costs of grid electricity purchases, making the economics of large-scale renewable energy integration challenging however, large-scale renewable energy technology costs continue to decrease across the country.
- Although there is variability in renewable energy resources across the United States, it is likely that the avoided cost of electricity (coupled with current or existing policy environments) may drive prioritization and implementation of clean energy projects.



Thank you!

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 **JISEA** Joint Institute for
Strategic Energy Analysis

Economic Analysis Assumptions

Input	Assumption
Objective	Minimize lifecycle cost
Ownership model	Direct Ownership
Build year	2020
Analysis period	25 years
Site's discount rate (nominal)	8.3% per NREL ATB ¹
Electricity cost	Entergy Large Industrial Power (per Kinder Morgan)
Natural gas cost	\$1.81/MMBtu (September 2020 per Kinder Morgan)
Electricity cost escalation rate (nominal)	2.49% per EIA (2020-2045 for west south-central region – industrial) ²
Natural gas cost escalation rate (nominal)	3.68% per EIA (2020-2045 for west south-central region – industrial) ²
Inflation rate	2.5% per NREL ATB
¹ https://atb.nrel.gov/ ² https://www.eia.gov/outlooks/aeo/data/browser/#/?id=3-AEO2020&region=1-7&cases=ref2020&start=2018&end=2050&f=A&linechart=ref2020-d112119a.3-3-AEO2020.1-7&map=ref2020-d112119a.4-3-AEO2020.1-7&sourcekey=0 ; https://www.eia.gov/consumption/commercial/maps.php	

Analysis Assumptions for Solar PV

Input	Assumption
System type	Ground mount, single axis tracking
Technology resource	TMY2 weather file from National Solar Resource Database (NSRDB) ¹
Installed capacity density	6 acres/MW
Tilt	Tilt = 0
Azimuth	180° (south-facing)
DC to AC ratio	1.2
Capital costs	\$1.06/W-dc (1-axis tracking utility scale) per NREL ATB ²
O&M costs	\$13/kW/yr per NREL ATB
Incentives	26% ITC ³ ; 5-yr MACRS ⁴
¹ https://rredc.nrel.gov/solar/old_data/nsrdb/	
² https://atb.nrel.gov/	
³ http://programs.dsireusa.org/system/program/detail/658	
⁴ http://programs.dsireusa.org/system/program/detail/676	

Analysis assumptions for Wind Turbines

Input	Assumption
Technology resource	AWS Truepower database ¹
Installed capacity density	30 acres/MW
Capital costs	Large (>1,000 kW): \$3.450/W-AC 2018 distributed wind market report ²
O&M costs	\$40/kW/yr per NREL distributed wind cost analysis ³
Incentives	5 year MACRS; PTC expired in 2019 ⁶

¹ <https://aws-dewi.ul.com/>

² <https://www.energy.gov/sites/prod/files/2019/08/f65/2018%20Distributed%20Wind%20Market%20Report.pdf>

³ <https://www.nrel.gov/docs/fy17osti/67337.pdf>

⁴ <http://programs.dsireusa.org/system/program/detail/658>

⁵ <http://programs.dsireusa.org/system/program/detail/676>

⁶ <http://pograms.dsireusa.org/system/program/detail/734>

Analysis Assumptions for Battery Storage

Input	Assumption ¹
Battery type	Lithium-ion
DC-DC round trip efficiency	89.9%
Minimum state of charge	20%
Capital costs	\$420/kWh + \$840/kW
Replacement costs (year 10)	\$200/kWh + \$410/kW
Incentives	26% ITC; 5-yr MACRS (assumes grid cannot charge BESS)
https://reopt.nrel.gov/tool/REopt%20Lite%20Web%20Tool%20User%20Manual.pdf	

Analysis Assumptions for Emissions

Input	Assumption
Region	SERC Mississippi Valley (SRMV) ¹
Total Output Emissions Rate	809.6 lb. CO ₂ e/MWh; 5.1% grid loss = 0.39 tCO ₂ e/MWh ²
¹ https://www.epa.gov/egrid/power-profiler#/SRMV	
² https://www.epa.gov/sites/production/files/2021-02/documents/egrid2019_summary_tables.pdf	
Annual cost (or savings) = Net present value (\$) / present worth factor	
Annual tCO ₂ e offset = Reduction in grid purchases (MWh) * emissions factor (tCO ₂ e/MWh)	
Cost of emissions reduction = Annual cost (\$) /Annual tCO ₂ e offset (tCO ₂ e)	