From Wells to Watts: Enhancing Upstream Oil and Gas Sustainability with Solar PV

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Abstract

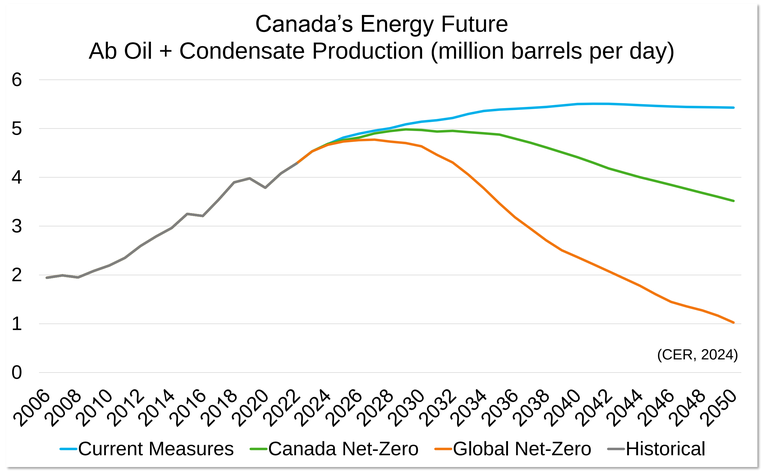
Alberta's oil and gas (O&G) industry is responsible for 60% of the province's greenhouse gas (GHG) emissions, and CO_2, primarily from fuel combustion, makes up 76% of the 158 million tCO_{2e} emitted by the industry. In 2022, Alberta's conventional O&G industry emitted twice as much GHG per barrel of oil than the global average due to high energy inputs during production. Fortunately, the province also has Canada's largest solar photovoltaic industry due to high solar irradiance and favourable regulations. This research explores the synergistic opportunity of solar PV microgeneration with O&G production to reduce emissions economically. Utilizing the oil production greenhouse gas emissions estimator tool and public O&G data, over 200 wells across 276 km^2 are analyzed. The analysis demonstrates that an emissions reduction of 8,062 tCO_{2e} from 94% of the wells investigated is possible with positive economic returns.

Research Question

What is the potential for solar PV microgeneration to decrease upstream O&G GHG emissions in Alberta?

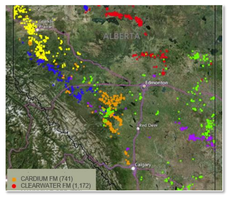
Introduction

Alberta's O&G production may not peak until the 2040s, with related GHG emissions making up 60% of the province's total emissions in 2022. Alberta's conventional O&G industry's GHG intensity is double the global average per barrel produced. However, Alberta's growing solar PV industry, driven by a strong resource and unique market, offers opportunities to reduce O&G emissions by electrifying new and existing sites with renewable energy.



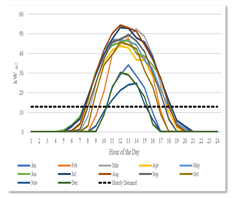
Methodology

1) Data Collection



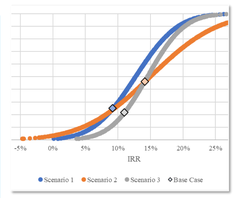
- Oil and gas: AER's OneStop and Petrine public data, industry and industry associations
- Includes production data, well details, surface equipment, and more
- Solar PV: NREL, AESO, IEA, IRENA, Lazard, RenuWell, ATCO, and Fortis
- Cost, design, and PV model information

2) Data Analysis



- Well screening and distribution distance measurements – mapped in Cartofact
- Well level fuel consumption allocations from ST60B
- Solar PV modelling in System Advisor Model
- Production analysis using OPGEE and equipment analysis for well site energy demand

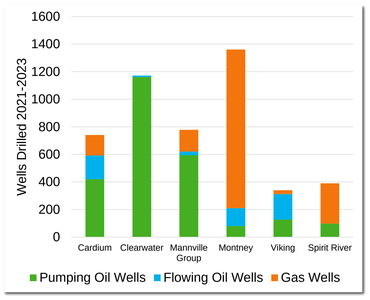
3) Economic Analysis



- Three before tax economic scenarios modelled: new, existing fuel conversions with PV adds, existing grid connected sites with PV adds
- First-year and lifetime emissions reduction calculations
- Local one-at-a-time sensitivity analysis
- Uncertainty analysis

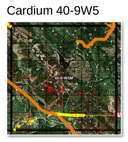
Results

Wells by Recovery Type

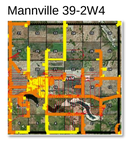


Investigated Focus Areas

Cardium 40-09W5



Mannville 39-2W4



Viking 35-8W4

Focus Areas' Energy Demands

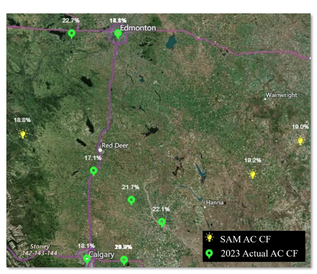
- 145 pumping wells on 62 of the 85 investigated surface locations emitted 14.7 thousand tCO_{2e} in 2022 from fuel combustion
- Only 17 of the locations are currently grid connected

Parameter	Unit	Cardium 40-09W5	Mannville 39-02W	Viking 35-08W4
Surface Locations	#	19	23	43
Wells	#	66	67	92
Pumpjacks	#	9	48	68
Progressive Cavity Pumps	#	3	17	0
2022 Total Fuel Emissions	tCO_{2e}	4,267	3,649	6,773
2022 Total Oil Production	m^3	146,379	120,974	72,627
2022 Total Water Production	m^3	2,118	777,579	166,370
OPGEE Pump Demand Total	kW	116	703	187

Focus Areas' Solar PV Analysis

Base Case Model Parameters	Unit	Cardium 40-09W5	Mannville 39-02W	Viking 35-08W4
Baseline PV Array Size	kW_{DC}	150	150	150
Tilt Angle	°	38	37	37
Annual AC Energy in Year 1	MWh	190	192	194
Ratio of Hourly AC Generation Above Avg. Site Demand	%	63.3	64.5	63.5
AC Capacity Factor	%	18.8	19.0	19.2
Array Area	m^2	790	790	790

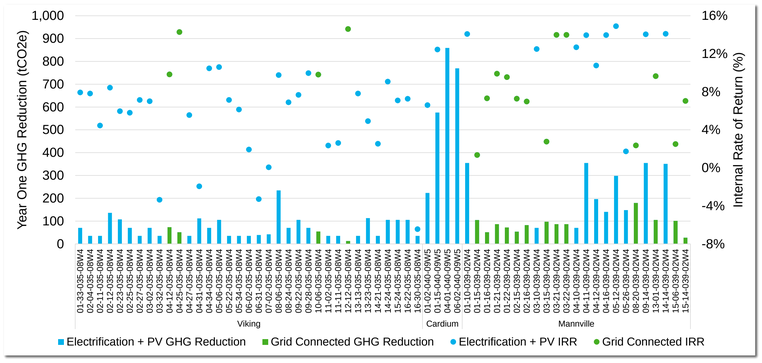
Focus areas' solar PV generation potential reinforces the opportunity for renewable electrification, even in non-ideal locations.



Note: Comparison of model results to utility scale solar PV sites

Results Continued

Economic Results

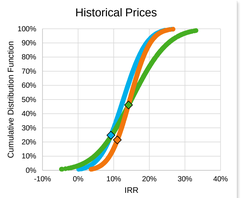


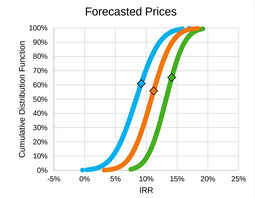
Opportunities for impactful GHG reductions and economic returns, but site selection is critical to maximize both.

Economic Uncertainties

Economic Input	Unit	Lower Bound	Base Case	Upper Bound
PV Capex	$/kW	1,547	1,750	2,045
Demand Decline	%	0.0	0.04	10.0
PV O&M	$/kW-year	16.0	31	54.0
Interest Rate	%	2.3%	5.2%	5.6%
Distribution Capex	$/km	23,500	29,375	35,250
Pump Drive Capex Factor	%	80%	100%	120%
Pump Drive O&M Factor	%	80%	100%	120%
Nat. Gas Hist.	$/GJ	1.24	2.59	8.23
Electricity Hist.	$/kWh	0.018	0.098	0.133
Nat. Gas Fcst.	$/GJ	1.43	2.59[1]	4.81
Electricity Fcst.	$/kWh	0.094	0.098[1]	0.102

[1] Price forecasts: AESO 2021 Long-term Outlook and AER's AECO-C Base





- 1000 model runs per scenario for each of the historical and forecast electricity and natural gas prices compared to base case results
- Base case model results are conservative compared to potential range of IRRs in the historical price range environment

Conclusion

Significant emissions reductions are achievable through combining PV microgeneration and pump drive electrification, with first-year emissions reductions of 8,062 tCO_{2e} (55% reduction) from the investigated wells. This would add 5 MW_{DC} of distributed PV microgeneration, with potential for conversion to long-term small-scale generation.

Limitations and Future Research

- Limited focus areas, estimated pumping energy demands, pumping demand only, generic PV design, and no clean technology investment tax credit evaluated
- Single PV site supplying multiple sites through common feeder, additional heating fuel combustion replacement demand, and a full field detailed evaluation of PV filling pumping energy demand

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