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Techno-Economic Opportunities for Integrating Renewable Energy into Saskatchewan Irrigation Projects Using HOMER †

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Abstract: Sophisticated irrigation agriculture may be required for global food security. In Saskatchewan, irrigation requires a large electrical input, and within the current electrical utility landscape, any new demand exacerbates the use of fossil fuels. With cost decreases, renewable energy is increasingly techno-economically viable. Using HOMER Pro software (Version 3.16.0), this study aims to quantify the viability of renewable energy to support irrigation projects. The evaluation includes the modelling of the three following scenarios: conventional, optimized and 100% renewable. Further, sensitivity has been considered for utility rates, grid interaction and carbon pricing. The lowest cost systems propose the inclusion of some renewable energy. Depending on the system architecture, the analyzed energy systems can be as low as \$0.02/kWh or as high as \$1.12/kWh. The efficacy of renewable integration is particularly dependent on the sensitivity surrounding grid interaction.

Keywords: renewable energy; irrigation; Saskatchewan; HOMER Pro

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1. Introduction

Food is a necessity, and as the global population grows, there will be an increasing need for agricultural products. As such, improving agricultural efficiency and productivity is important. Irrigation is a pathway for efficiency improvement. Globally, irrigation requires more water than any other sector as well as considerable amounts of energy to pump water. In Saskatchewan, irrigation relies on the electrical grid, which exacerbates the usage of fossil fuel [1]. Inclusion of renewable energy technologies (RE) may mitigate a portion of these environmental concerns.

Although past research has not identified RE as competitive, there have been price declines in recent years, and RE is increasingly a favourable alternative. The Levelized Cost of Electricity (LCOE) offers a means to compare costs between different types of generation. LCOE calculations consider the ratio of total costs to total electrical energy produced. Iterative LCOE analyses have been undertaken [2]. Recent publications increasingly identify the competitiveness of utility-scale solar and onshore wind energy [2]. Though LCOEs provide some insight, it must be noted that not all energy is equal; conventional energy is often dispatchable, while RE is often intermittent.

There has been a rapidly accelerating utilization of solar PV in irrigation. India is covering canal lengths under its Solar Power Project [3]. Spain has successfully implemented a solar PV prototype for large-scale irrigation [4]. California is also implementing solar PV in irrigation [5] and covering large portions of their own canal network [6]. In Saskatchewan, irrigation development has recently been re-invigorated by a governmental commitment to develop up to 200,000 hectares around Lake Diefenbaker [7]. Despite its considerable potential, Saskatchewan's irrigation development is limited by the pumping requirements of surface water resources. In Saskatchewan, there exist productive onshore wind and solar PV resources [8], yet there are technological challenges for RE inclusion due to intermittency.

Though there have been many HOMER Pro Software (HOMER) techno-economic studies for the incorporation of RE in agriculture and rural energy systems, previous RE work cannot be generalized since energy system costs are undergoing major disruption, and further, the technical merits of RE are project-specific. HOMER has identified RE as techno-economically competitive for rural, agricultural and irrigation energy systems in Nigeria [9], India [10–12] and Bangladesh [13]. In Canada, HOMER RE analysis of rural energy systems has shown less competitiveness [14].

Contributions and Study Objectives

This study considers the viability of RE utilization for Saskatchewan irrigation projects. The assessment uses HOMER [15] to evaluate opportunities. The sensitivity treatment of grid interaction, utility rates and carbon pricing offers unique study contributions. Research applicability is most relevant for irrigation systems within the Canadian Prairies with considerable pumping requirement but may also be applicable for other northern climates.

2. Materials and Methods

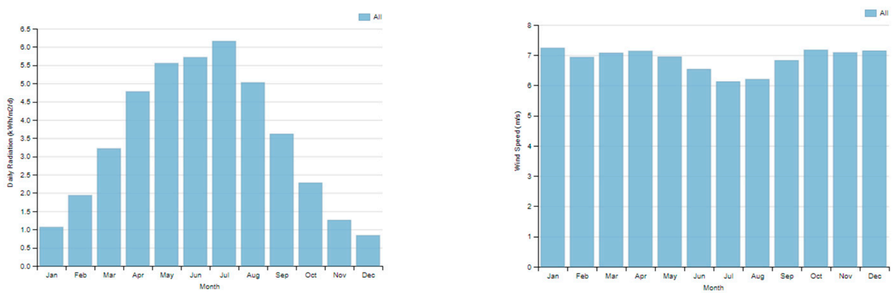
Without the opportunity for experimentation, the system analysis of energy mixes often depends on modelling software and computational optimization. Academics, the government and institutions develop energy models and scenarios to transform the current energy system. However, there exist many software and selection should be task-specific.

2.1. HOMER Pro Software

Many scientific papers utilize HOMER for RE system simulation. In HOMER, the user inputs microgrid components, electrical loads, existing energy grid information and resource availability. HOMER simulates different configurations of components to output technical merits and optimized results. Working effectively with HOMER requires an understanding of its three core capabilities, simulation, optimization and sensitivity analysis [16].

2.2. Site Description

The location of the hypothetical irrigation project is the Lake Diefenbaker area. Not only is the surrounding land considered suitable for irrigation, but the also reservoir reduces pumping requirements. Solar radiation and windspeed data (Figure 1) are selected from NASA's surface meteorology and solar energy database using HOMER [17].



(**a**) (**b**)

Figure 1. Regional resources for: (**a**) Average daily solar radiation; (**b**) Average daily wind speed.

2.3. Load Assessment

A simplified project layout has been adopted for modelling. For this analysis, a typical irrigation project has been modelled (one major pump station; one distribution canal; 10 identical secondary distribution pump stations; one distribution piping to farmer turnouts). A total of 20,000 hectares has been adopted as a realistic size for development.

Each crop has a unique water demand, and the irrigation load is a function of regional precipitation, regional evapotranspiration and crop mix. Based on past irrigation data (R. Husband, personal email communication with provincial irrigator, October 2023), daily water demands have been determined for a common provincial crop mix.

Total irrigation energy requirements include the primary pumping out of Lake Diefenbaker and the subsequent secondary distribution re-pumping to producers. Specifically, energy requirements include an initial lift of 30 m from Lake Diefenbaker and then a secondary 60 m for distribution. Daily loads fluctuate throughout the year (Figure 2). For most months, only a small portion of peak flow is required.

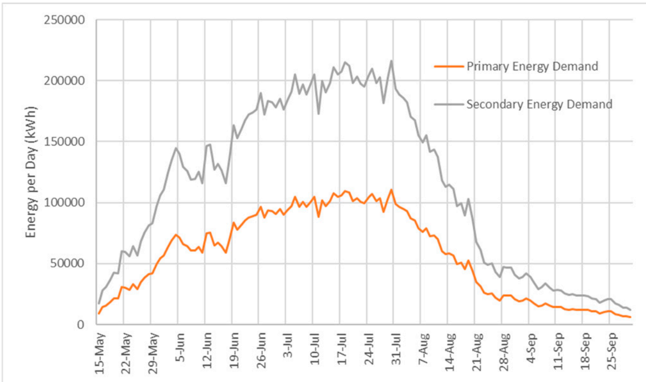


Figure 2. Irrigation load.

The primary load possesses some operational flexibility since all water must be pumped in advance of the final demand at distribution turnout. HOMER is capable of detailed load modelling. Certain loads must be met immediately, but there is also an opportunity to model a deferrable load that requires a certain amount of energy within a time period. For analysis, the primary lift has been considered deferable, with a finite storage capacity afforded by the irrigation canal.

2.4. Grid Assessment

HOMER allows the modelling of the grid interaction in several ways. For grid interaction, baseline analysis is informed by the rates as defined by SaskPower [18]. In Saskatchewan, major pumping and irrigator pumping is approximately \$0.12/kWh and \$0.08/kWh, respectively. An average cost of \$0.10/kWh has been applied. There are no restrictions on the amount of purchasable energy, but the transmission capacity is set at peak demand. In addition to purchases, there will be excess RE power generation and an opportunity for energy sellback to the grid. For small power producers, SaskPower currently permits sellback at approximately half the chargeable rate. For the baseline analysis, the sellback rate has been assumed at \$0.05/kWh. There are no restrictions on the amount of sellable energy and the transmission capacity is constant. There is CAPEX associated with grid interconnection.

2.5. System Components

In addition to the grid component, HOMER includes many energy alternatives. Those considered include solar PV modules, wind turbines and lithium-ion batteries (Table 1). All intermediary components for system operability are implicitly modelled.

Table 1. RE component assumptions.

	Solar PV	Wind Turbine (1.5 MW)	Lithium-Ion Battery
Capital	\$2500/kW	\$3,000,000	\$550/kW
Replacement	\$2500/kW	\$3,000,000	\$550/kW
O&M	\$10/Year*kW	\$30,000/Year	\$10/Year*kWh

2.6. Economic Constants

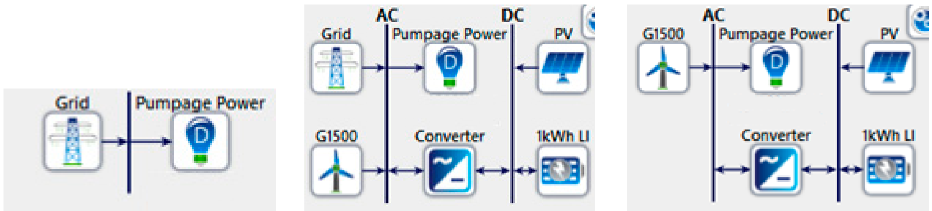
To evaluate the LCOE, HOMER projects cash flows for all costs and revenues (for energy sellback). Cash flow from year-to-year cannot be directly compared due to the earning power of money. In accounting for earning power, a discount rate converts all earnings to their present value. Inflation can also inhibit cash flow comparisons across years. The major financial assumptions are provided (Table 2).

Table 2. Major financial modelling assumptions.

Modelling Component	Assumption
Annual Real Interest Rate	3%
Discount Rate	5%

3. Results

RE penetration has been varied from 0% to 100%, considering the following three scenarios (Figure 3): a grid-tied conventional system; a grid-disconnected 100% RE system; and an optimized system. To meet the load, each scenario follows a different approach. The conventional scenario exclusively purchases energy from the grid. The optimized scenario cooperatively uses RE sources with grid purchases as backup. When surplus RE exists, the optimized scenario sells energy to the grid. The 100% RE scenario does not interact with the grid and relies on excessive RE infrastructure.



(**a**) (**b**) (**c**)

Figure 3. Energization scenarios for: (**a**) Conventional; (**b**) Optimized; (**c**) 100% RE.

Scenario results and low-cost systems are summarized (Table 3). The optimized scenario achieves the lowest costs. The conventional scenario has minimal CAPEX but high OPEX due to ongoing fuel purchases. Without an outlet to sell energy, the 100% RE is prohibitively expensive.

Table 3. Baseline result summary.

	Conventional Scenario	Energy Optimization Scenario	100% RE Scenario
Solar PV (kW)	0	0	50,460
1500 kW Wind Turbine	0	14	17
Battery (kWh)	0	0	201,001
Total Grid Capacity (kW) [1]	15,000	15,000	0
LCOE ($/kWh)	0.15	0.02	1.12

[1] Includes grid capacity for major and distribution pump stations.

3.1. Sensitivity Treatments

Sensitivity targets parameters with a possibility for change and examines how potential changes may impact results. Parameters targeted by this research include carbon pricing, SaskPower's utility rates and grid interaction (Table 4). Canadian governments intend to increase the cost of carbon pollution to $170/tonne*$CO_2$e by 2030 [19]. In addition, a future with higher commodity prices is a possibility and would likely impact

SaskPower rates. Currently, SaskPower's net metering programme purchases excess energy from small energy producers, the baseline grid purchase rate has been altered in the sensitivity treatment.

Table 4. Sensitivity treatment.

Sensitivity Parameter	Baseline	Treatment 1	Treatment 2
Carbon and Utility Pricing	\$20/tonne CO_2; \$0.10/kWh	\$170/tonne CO_2; \$0.10/kWh	\$20/tonne CO_2; \$0.20/kWh
Grid Sale Interaction	\$0.05/kWh	\$0.01/kWh	Prevent all Grid Sales

3.2. Sensitivity Results

Though each scenario has been subjected to all sensitivity treatments (Figure 4), the scenarios do not necessarily respond to the treatment. The conventional scenario does not respond to any changes in grid sellback rates since the system does not sell electricity. As a grid-disconnected system, none of the treatments impact the 100% RE Scenario. The relative impacts of sensitivity treatment are summarized.

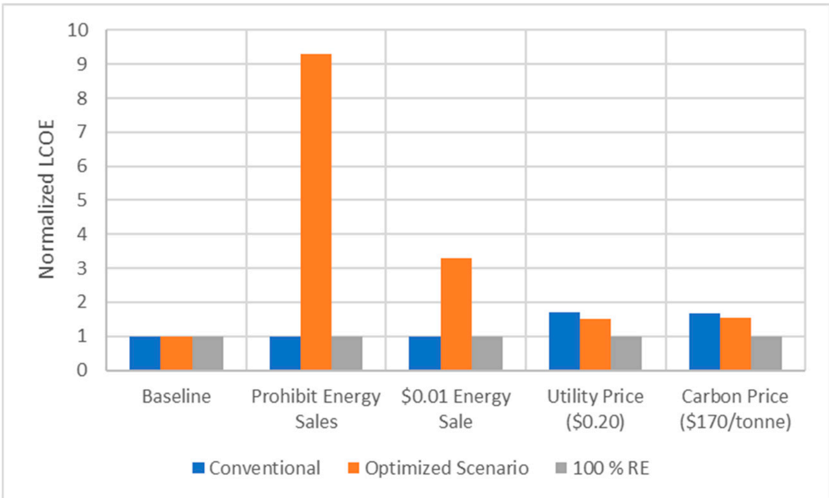


Figure 4. Relative impact of sensitivity.

4. Discussion

As long as energy can be sold, HOMER maximizes RE efficiency. Even at a \$0.01/kWh (10% of purchase rate), an optimized scenario is much less expensive than the conventional scenario (Table 5). On the other hand, the prohibition of electricity sales completely disrupts the capabilities of RE to generate energy at a low cost. By preventing grid sellback, RE becomes non-competitive. In preventing sellback, the optimal system becomes the conventional system.

Table 5. Energy sellback at \$0.01/kWh.

	Conventional Scenario	Optimized Scenario (at \$0.01/kWh Sellback)
LCOE	\$0.15/kWh	\$0.06/kWh

Any increases to the utility or carbon price increases the costs of grid-connected scenarios. However, the cost increase is correlated with the presence of RE. For the optimized scenario, the absolute cost increase is less than the conventional (Table 6).

Table 6. Absolute LCOE price increase in a carbon charge.

	Conventional Scenario	Optimized Scenario
LCOE (Baseline)	$0.15/kWh	$0.02/kWh
LCOE (Carbon Charge Increase to $170/tonne)	$0.25/kWh	$0.03/kWh
Absolute Price Increase	$0.10/kWh	$0.01/kWh

For the optimized system, HOMER is highly incentivized to include RE but depends on energy assurance from the grid; 100% RE systems remain cost-prohibitive.

Limitations

This study acknowledges the difficulty to characterize feasible energy alternatives with minimal input data and engineering design. To fully characterize energy systems, site data, design and operational strategies would be required. A limitation is the oversimplification of the relative cost and benefit shares for irrigators or SaskPower.

This study aims to represent the possibility for RE integration in irrigation and considers parameters impacting success. This investigation has undertaken the independent manipulation of each parameter—which departs from reality where several parameters would change simultaneously.

5. Conclusions

This research has evaluated LCOEs for a hypothetical Saskatchewan irrigation project. The report acknowledges the complexities of RE intermittency but has identified the economic benefits of RE in systems as long as a grid interconnection is maintained (Table 7). Interconnection provides dispatchable electricity during minor intermittent shortages but also accepts surplus RE to minimize curtailment. The viability of RE is enhanced with increases in utility rates, carbon pricing and competitive grid sellback. These findings are significant in Saskatchewan where irrigation has been delayed due to considerable pumping demands. This research identified the ongoing infeasibility of 100% RE as a stand-alone energy source for irrigation projects.

Table 7. Baseline results summary.

	Conventional Scenario	Energy Optimization Scenario	100% RE Scenario
LCOE ($/kWh)	0.15	0.02	1.12

While this research considers the RE opportunities for an isolated irrigation project, this research does not provide any insight into the functioning of RE integration within the broader electrical grid. Future studies should consider the entire provincial grid to evaluate the strategies for RE integration. Future studies should consider the capabilities of SaskPower to integrate new intermittent RE, and further, what techno-economic opportunities arise from RE integration.

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References

1. SaskPower. Current Reports. Annual Report 2022–23. Available online: https://www.saskpower.com/about-us/Our-Company/Current-Reports (accessed on 3 November 2023).
2. Lazard. 2023 Levelized Cost of Energy+ | Lazard. Available online: https://www.lazard.com/research-insights/2023-levelized-cost-of-energyplus/ (accessed on 3 November 2023).
3. Sunder, K. The 'Solar Canals' Making Smart Use of India's Space (Sunder, 2020). BBC Future Planet. Available online: https://www.bbc.com/future/article/20200803-the-solar-canals-revolutionising-indias-renewable-energy (accessed on 4 October 2023).
4. Narvarte, L.; Fernández-Ramos, J.; Martínez-Moreno, F.; Carrasco, L.M.; Almeida, R.H.; Carrêlo, I.B. Solutions for Adapting Photovoltaics to Large Power Irrigation Systems for Agriculture. *Sustain. Energy Technol. Assess.* **2018**, *29*, 119–130. [CrossRef]
5. Calderon, J.; Cureg, J.; Diaz, M.; Guzman, J.; Rudd, C.; Le, H.T. Smart Agriculture: An Off-Grid Renewable Energy System for Farms Using Wind Power and Energy Storage. In Proceedings of the 2019 IEEE Power & Energy Society Innovative Smart Grid Technologies Conference (ISGT), Washington, DC, USA, 18–21 February 2019; pp. 1–5. [CrossRef]
6. McKuin, B.; Zumkehr, A.; Ta, J.; Bales, R.; Viers, J.H.; Pathak, T.; Campbell, J.E. Energy and Water Co-Benefits from Covering Canals with Solar Panels. *Nat. Sustain.* **2021**, *4*, 609–617. [CrossRef]
7. Government of Saskatchewan. Saskatchewan Announces $4 Billion Irrigation Project at Lake Diefenbaker | News and Media. Available online: https://www.saskatchewan.ca/government/news-and-media/2020/july/02/irrigation-project (accessed on 4 October 2023).
8. Barrington-Leigh, C.; Ouliaris, M. The Renewable Energy Landscape in Canada: A Spatial Analysis. *Renew. Sustain. Energy Rev.* **2017**, *75*, 809–819. [CrossRef]
9. Akinyele, D. Techno-Economic Design and Performance Analysis of Nanogrid Systems for Households in Energy-Poor Villages. *Sustain. Cities Soc.* **2017**, *34*, 335–357. [CrossRef]
10. Amutha, W.M.; Rajini, V. Cost Benefit and Technical Analysis of Rural Electrification Alternatives in Southern India Using HOMER. *Renew. Sustain. Energy Rev.* **2016**, *62*, 236–246. [CrossRef]
11. Krishan, O.; Suhag, S. Techno-Economic Analysis of a Hybrid Renewable Energy System for an Energy Poor Rural Community. *J. Energy Storage* **2019**, *23*, 305–319. [CrossRef]
12. Sawle, Y.; Jain, S.; Babu, S.; Nair, A.R.; Khan, B. Prefeasibility Economic and Sensitivity Assessment of Hybrid Renewable Energy System. *IEEE Access* **2021**, *9*, 28260–28271. [CrossRef]
13. Shoeb, M.A.; Shafiullah, G.M. Renewable Energy Integrated Islanded Microgrid for Sustainable Irrigation—A Bangladesh Perspective. *Energies* **2018**, *11*, 1283. [CrossRef]
14. Rahman, M.M.; Khan, M.M.U.H.; Ullah, M.A.; Zhang, X.; Kumar, A. A Hybrid Renewable Energy System for a North American Off-Grid Community. *Energy* **2016**, *97*, 151–160. [CrossRef]
15. HOMER Pro Software (Version x64 3.16.2). UL Solutions. Available online: https://homerenergy.com/index.html (accessed on 3 October 2023).
16. HOMER Pro. "HOMER Pro Software Manual." HOMER Pro 3.13. Available online: https://www.homerenergy.com/products/pro/docs/3.13/index.html (accessed on 5 October 2023).
17. National Aeronautics and Space Administration [NASA]. ASDC | Projects | SSE. EarthData Atmospheric Science Data Center. Available online: https://asdc.larc.nasa.gov/project/SSE (accessed on 13 October 2023).
18. SaskPower. Apply for Net Metering. Available online: https://www.saskpower.com/Our-Power-Future/Our-Electricity/Connecting-to-the-Power-Grid/Net-Metering/Apply-for-Net-Metering (accessed on 3 November 2023).
19. Canada, Environment and Climate Change. Update to the Pan-Canadian Approach to Carbon Pollution Pricing 2023–2030. Guidance—Legislative, 5 August 2021. Available online: https://www.canada.ca/en/environment-climate-change/services/climate-change/pricing-pollution-how-it-will-work/carbon-pollution-pricing-federal-benchmark-information/federal-benchmark-2023-2030.html (accessed on 5 November 2023).