Multi-Dimensional Analysis of Seasonal Hydropower Generation and Energy Storage in an Alberta Irrigation Network

Kristina Pearson, P.Eng, MSc Student Sustainable Energy Development, University of Calgary

Supervisors: Dr. Blake Shaffer, Dr. Antony Ware, Trevor Helwig P.Eng

Introduction

What?

St. Mary's Irrigation Network moves water from March through October Irrigating Farmland between Lethbridge and Medicine Hat in Southern Alberta. **Is it economic to incorporate hydropower generation and pumped energy storage into their upcoming lifecycle repairs?**

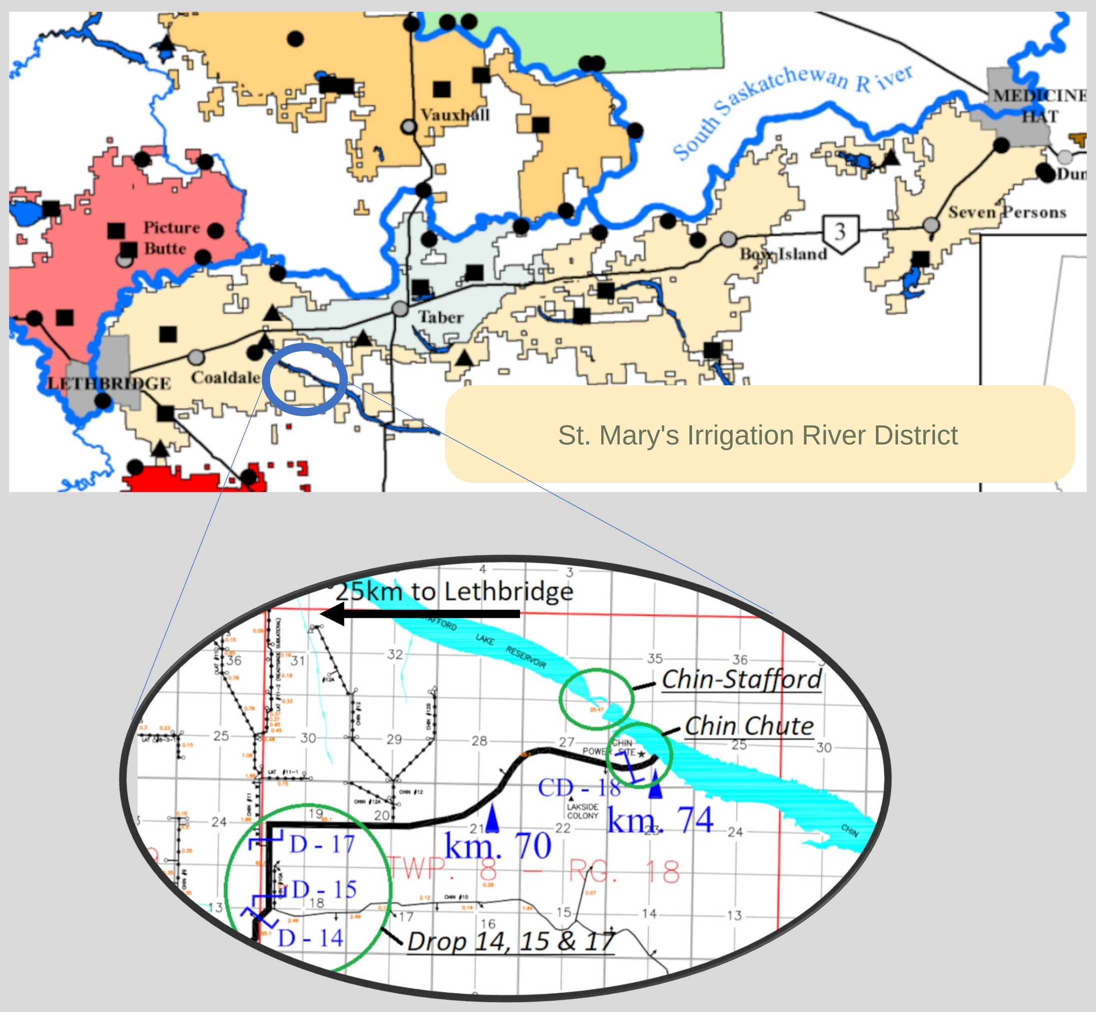
Why?

The additional **run-of-river (ROR)** hydropower energy would displace carbon-intensive electricity generation from the Alberta grid, reducing greenhouse gas emissions.

Electricity sold to the grid earns income and diversifies income streams for the irrigation district.

The existing infrastructure can be used for **pumped hydro energy storage (PHES),** increasing electrical grid stability and enabling off-season winter income for the district.

Where?



The Three Projects:

<u>Drop 14, 15, 17</u> – Three drop structures combined for irrigating season hydropower generation (3-5 MW). No energy storage capability.

<u>Chin Chute</u> – Add a 1 MW Pump-as-Turbine to the existing 10 MW Turbine. Allows for 3 hours of energy storage in the winter, and some irrigating season hydrogeneration with excess water.

<u>Chin-Stafford</u> – Two reservoirs separated by an elevation drop. Allows for 28 hours of energy storage in the winter, and either ROR hydropower generation or **daily shaping (DS)** of hydropower (3-5 MW) – where water can be 'held up' in the upper reservoir and flow concentrated into a few hours of the day to capture higher power prices during the irrigation season.

Objectives

Energy – Electricity produced and cycled for each project given the variable irrigation season lengths and flow rates.

Environment – The greenhouse gas impacts for each project.

Economics – The expected payback and rate of return for each project, given the variable electricity generation and power pricing.

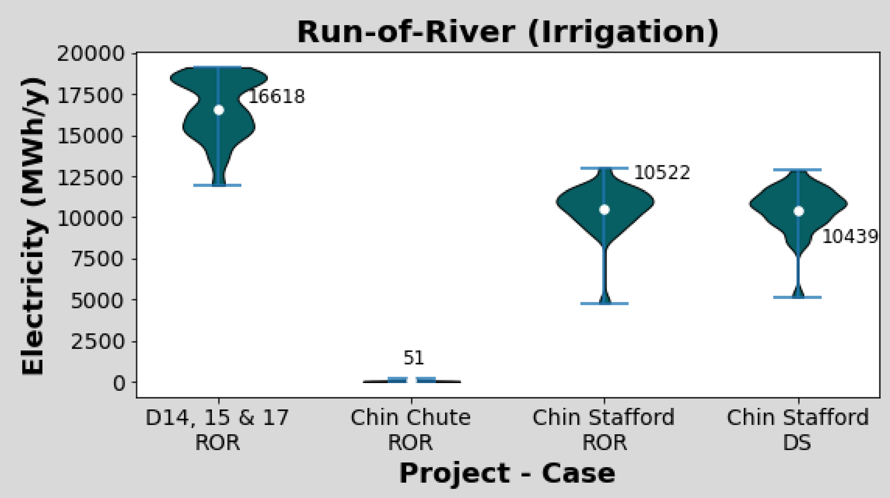
Methodology

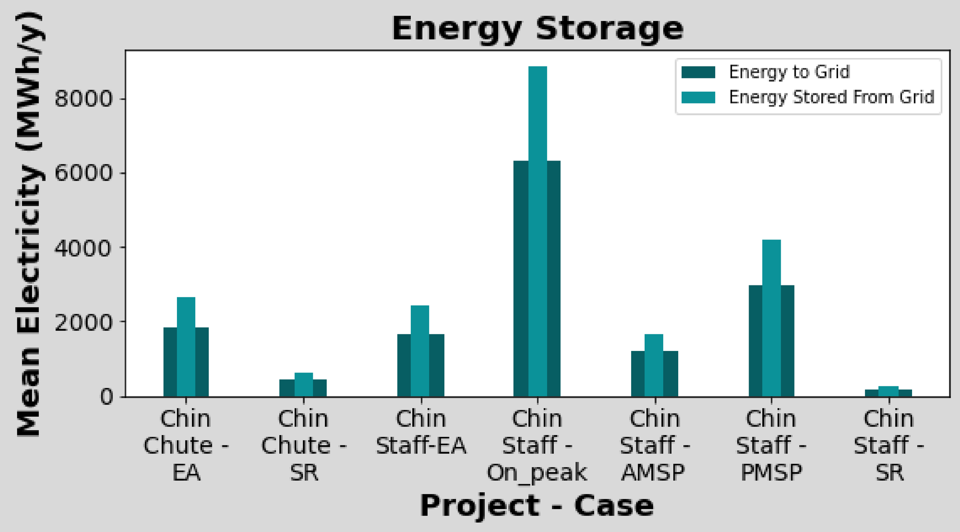
1. Find the ROR electricity generation for each project using 23 years of daily irrigation flow rates.
2. Estimate the ROR electricity revenue for each project using the electricity calculated and 23 years of hourly pool pricing for the Alberta Electricity Grid.
3. Evaluate the energy storage revenue potential under three operating strategies:
   a) **Energy Arbitrage (EA)** – Buy power when prices are low (Nighttime hours). Sell power when prices are high (Daytime and Evening hours).
   b) **Regulating Reserve (RR)** – Earn regulating reserve revenue (on top of energy production revenue) by allowing the system operator to adjust your production to respond to demand and generation fluctuations, thus ensuring a stable operating grid. RR reserve allows for market bids for the morning super peak (AMSP), evening super peak (PMSP), and daytime (On peak). Nighttime (Off-peak) was not considered as it is when charging occurs.
   c) **Spinning (Contingency) Reserve (SR)** – Earn spinning reserve revenue for being available to produce power on short notice to respond to larger demand and generation fluctuations. Note: No regular energy revenues are earned under this operating mode.
4. Using 2021 Alberta electricity grid generation data, determine the expected displaced carbon emissions using the calculated mean hourly carbon intensity (g CO2eq/KWh)*.
5. Optimize the equipment selection and storage operating mode to maximize expected revenues. Calculate the nominal internal rate of return and expected payback, including the value of the carbon credits from the displaced carbon emissions.

*This is expected to be approximately 10% lower than actual displaced emissions, which would be from the marginal plant on the merit curve (Olmstead & Yatchew, 2022).

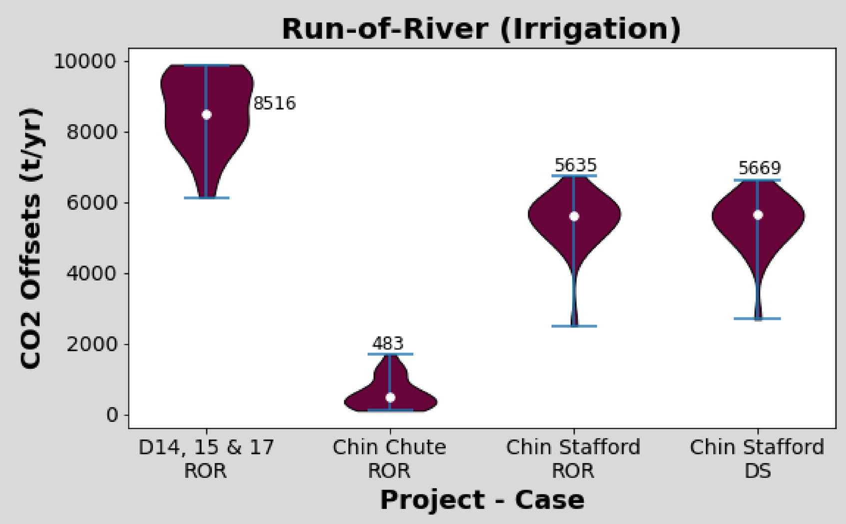
Results & Analysis

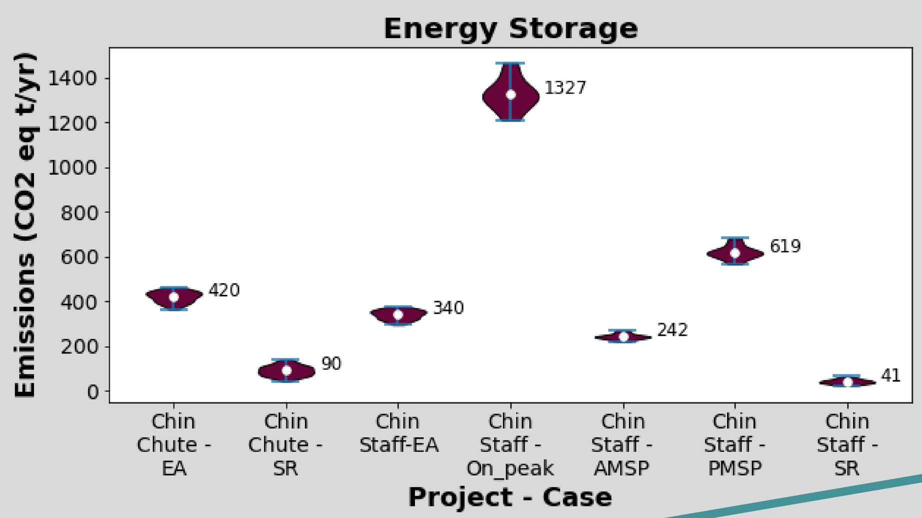
Energy



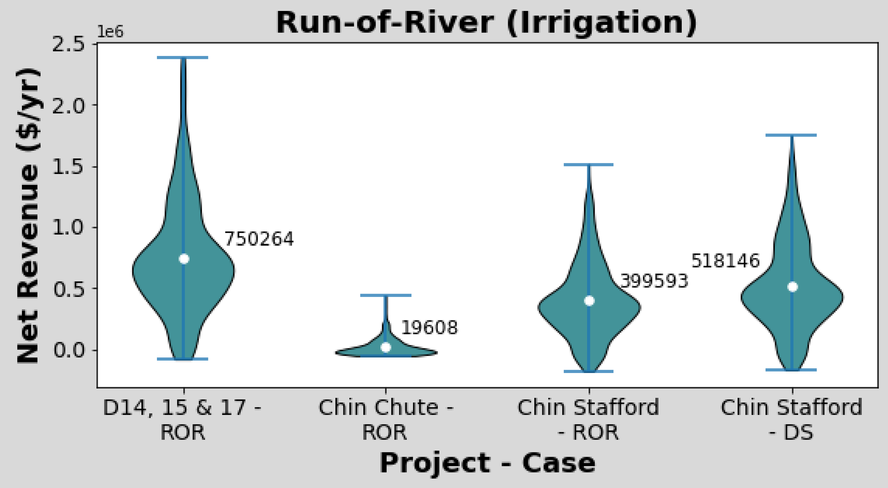


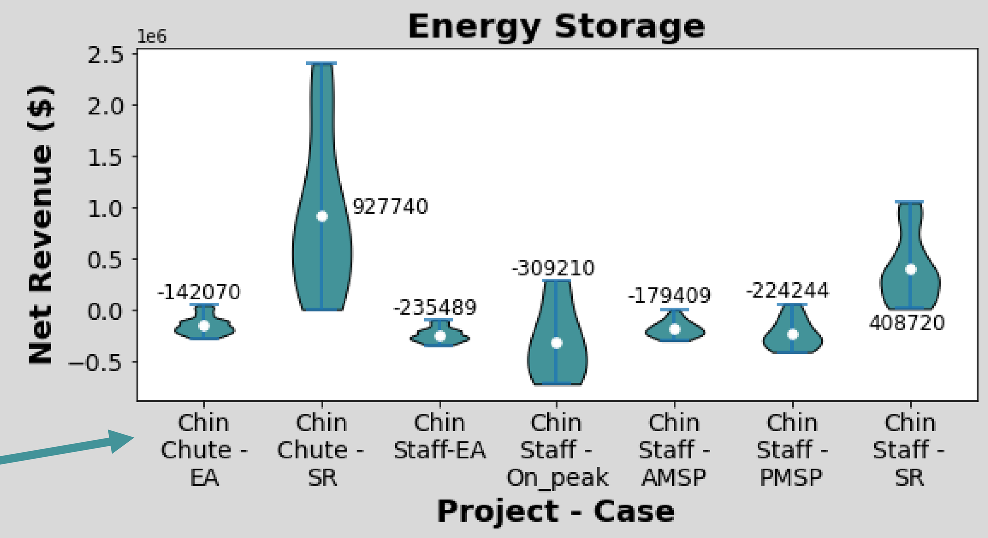
Environment





Economics





Scenario	Economics Combined Projects					
	D14, 15, & 17	Chin Chute		Chin-Stafford		
		ROR Only	ROR + PHES	ROR Only	DS	DS + PHES
Nominal Internal Rate of Return (Pre-Tax)	6.7%	-2.3%	27.8%	2.3%	3.4%	4.7%
Nominal Internal Rate of Return (After-Tax)	5.8%	n/a	24.1%	2.0%	2.9%	4.1%
Payback (yrs)	11	n/a	3.6	31.8	23.2	17.9

** Using Spinning Reserve Energy Storage Revenues

Q: Why are many of the energy storage revenues negative?

A: The **demand transmission tariffs (DTS)** are calculated based on the maximum load charging rate (pump size). Spinning reserves cycle less energy allowing for a smaller installed pump and greatly reducing the tariffs.

Future Research: Evaluate the benefits of charging directly from an onsite generator (wind or solar) to avoid load transmission charges.

Conclusions

- **Chin Chute has the best economic return, but D14, 15 & 17 has the best environmental impact, displacing the most greenhouse gases.**
- **Energy storage economics and operating strategies are heavily impacted by the current DTS formula***.**
- **Energy storage charged from the Alberta Grid is a net carbon emitter.**

*** The Alberta Utilities Commission is currently reviewing the tariffs structure.

References

Olmstead, D. E., & Yatchew, A. (2022). Carbon pricing and Alberta's energy-only electricity market. *The Electricity Journal*, *35*(4), 107112. https://doi.org/10.1016/j.tej.2022.107112.

Image Credit: Irrigation District Water Quality Project, Government of Alberta

Image Credit: *SMRID Distribution Map with Flows*, by the St. Mary's Irrigation District, 2008

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