Techno-Economic Feasibility Assessment of Waste Heat Recovery for Greenhouse Operation in Northern B.C.

Stuart Mills – University of Calgary

Dr. Aggrey Mwesigye – University of Calgary, Schulich School of Engineering
Adam Leece – Integrated Sustainability

Introduction

British Columbia has approximately 2350 active oil and gas facilities. These operations produce a significant amount of waste heat. A typical compressor station produces exhaust gas between 330-550°C and a mass flow rate of 18,000 kg/h per unit.
Heating in Canadian greenhouses accounts for 10% - 35% of total production costs and 70-80% of greenhouses' energy demands.

Research Question: Is it technically and economically feasible to meet a greenhouse's supplemental heating and electricity requirements in Northern British Columbia with waste heat from a natural gas compression station?

Methodology

Study Component	Analysis Tool
Technical Feasibility Assessment	TRNSYS – building energy modeling
Economic Viability Assessment	Payback Period, Internal Rate of Return, and Net Present Value
Environmental Impacts	CO_2 emissions avoided

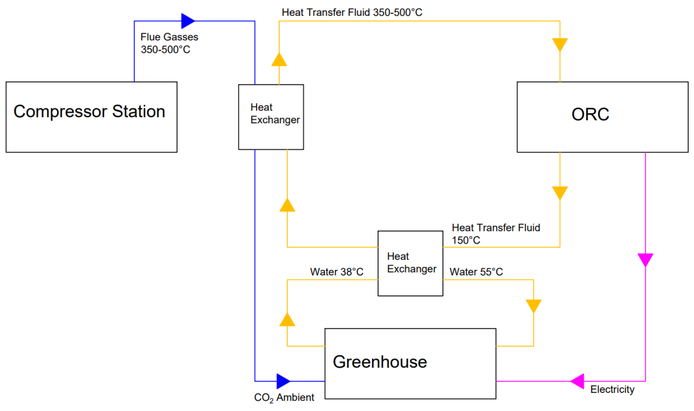

Figure 1: System Block Diagram

Energy Model

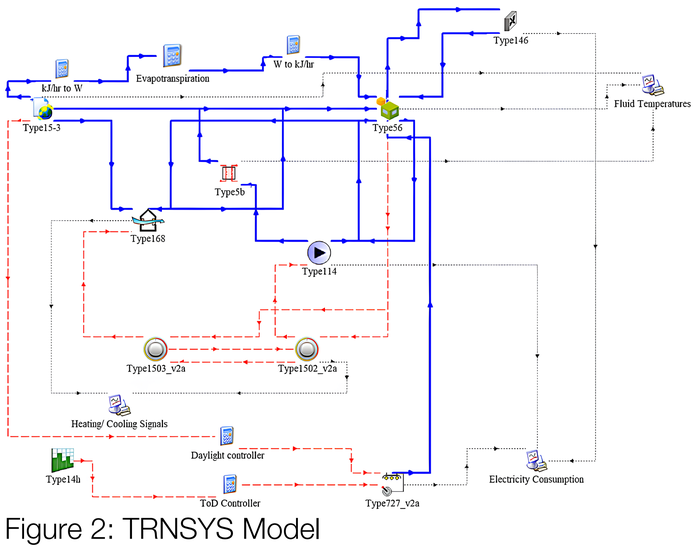

Figure 2: TRNSYS Model

Results

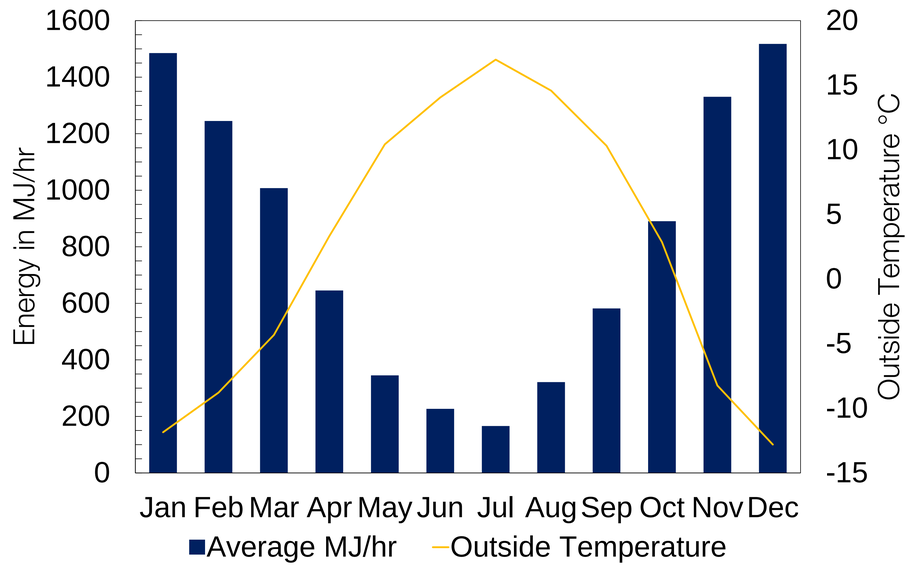

Figure 3: Average Hourly Supplemental Heating Requirement

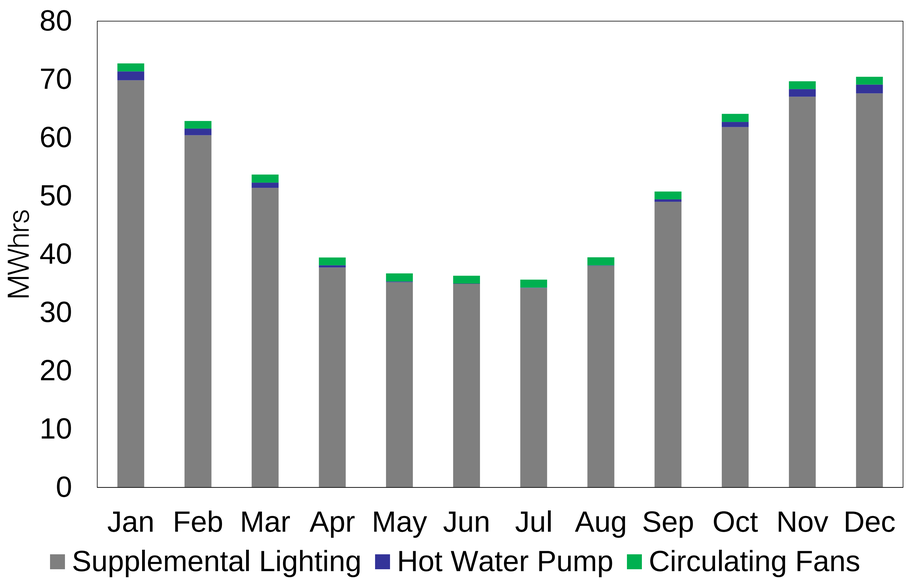

Figure 4: Average Hourly Supplemental Heating Requirement

Table 1: Economic Performance Compared to a Natural Gas Greenhouse

Waste heat greenhouse				**Natural gas greenhouse**			
Cash Flow	**CAD 1000$**	**Indicator**		**Cash Flow**	**CAD 1000$**	**Indicator**	
Capital Cost	540	Pay Back Period	4.5 yrs	Capital Cost	740	Pay Back Period	6.3 yrs
Annual Cost	619	20-year NPV	CAD 1241 k	Annual Cost	869	20-year NPV	CAD 869 K
Gross Revenue	847	20-year IRR	31%	Gross Revenue	540	20-year IRR	24%

Table 2: Economic Performance Compared to a Natural Gas Greenhouse

Emission Source	**Intensity kg CO_2eq / kg tomatoes**	
	Present Study	**NG Heated Greenhouse**
Electricity	0	0.04
Natural Gas, Supplemental Heating	0	1.94
Captured CO_2	-0.04	-0.04
Total	-0.04	1.94

Conclusion

The ORC can generate between 2600 and 8000 MWh of electricity annually; after the ORC, the waste heat can provide 31536 GJ annually. The analysis showed that the proposed greenhouse consumed 7100 GJ of supplemental heating and 1138 MWh of electricity annually.

The greenhouse was economically viable with an expected payback period of 4.5 years, a 20-year NPV of CAD 1241 K, and a 20-year IRR of 31%.

The proposed greenhouse will save 1.94 kg CO_2 eq/ kg tomato compared to a conventional greenhouse heated with natural gas, representing 335 tonnes of CO_2eq annually.

Recommendations for Future Work

- Assess other economic opportunities to utilize the waste heat and compare their financial performance to that of a greenhouse.
- Conduct a social cost-benefit analysis of the greenhouse focusing on its impact and benefits to Indigenous people.
- Conduct a formal LCA of the greenhouse to establish the full scope of its environmental impacts and compare it to field-grown tomatoes.

Acknowledgments

I want to acknowledge Dr. Aggrey Mwesigye for his guidance and advice and Adam Leece for his expertise and support on this project as my industry sponsor.

References

1. Ahamed, M. S., Guo, H., Taylor, L., & Tanino, K. (2019). Heating demand and economic feasibility analysis for year-round vegetable production in Canadian Prairies greenhouses. Information Processing in Agriculture, 6(1), 81–90. https://doi.org/10.1016/J.INPA.2018.08.005
2. Ahmadpour, M., Roshandel, R., & Shafii, M. B. (2024). The effect of organic Rankine cycle system design on energy-based agro-industrial symbiosis. Energy Efficiency, 17(5). https://doi.org/10.1007/s12053-024-10221-0
3. Andrews, R., & Pearce, J. M. (2011). Environmental and economic assessment of a greenhouse waste heat exchange. Journal of Cleaner Production, 19(13), 1446–1454. https://doi.org/10.1016/j.jclepro.2011.04.016
4. Castilla, N. (2013). Greenhouse Technology and Management, 2nd edition Nicolás Castilla ; translated by Esteban J. Baeza ; reviewed by A. P. Papadoupoulos. CABI.
5. Choab, N., Allouhi, A., El Maakoul, A., Kousksou, T., Saadeddine, S., & Jamil, A. (2019). Review on greenhouse microclimate and application: Design parameters, thermal modeling and simulation, climate controlling technologies. In Solar Energy (Vol. 191, pp. 109–137). Elsevier Ltd. https://doi.org/10.1016/j.solener.2019.08.042