Hydrogen and Ammonia Pathways Towards Net-Zero in the Northwest Territories

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1. Introduction

- The Northwest Territories (NWT) imports 89.3% of its energy in the form of fossil fuels (mainly diesel) to meet the demands of 45,132 people living in 33 communities[1]. Fossil fuel importation occurs despite the NWT having tremendous untapped hydroelectric potential and a year-round excess available on the Taltson hydro grid[2].

- This high demand for fossil fuels means that the NWT has per capita emissions of 35.0 metric tons CO_2e/year or ~1.8x the Canadian average of 19.6 metric tons CO_2e/year[1,3]. Fossil fuels account for 94% of the NWT's total greenhouse gas emissions[3].

- For the NWT to become net zero by 2050, drastic action must be taken in all sectors to reduce reliance on fossil fuels. Meaningful action will require the adoption of non-carbon energy carriers, such as hydrogen and ammonia, that can be produced using hydroelectricity.

- This research aimed to understand what a hydrogen and ammonia-based net-zero energy system would look like in the NWT.

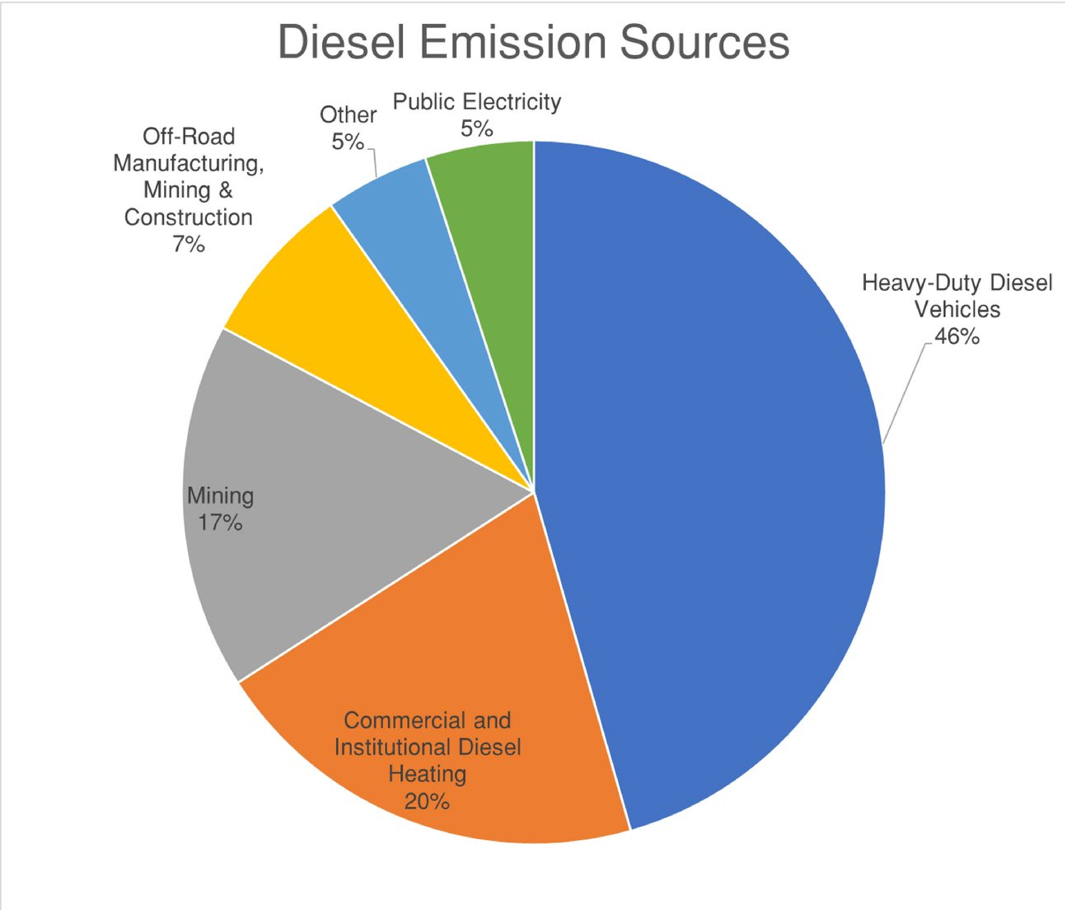

Figure 1. Diesel emission breakdown in the NWT for 2019, chart created using NIR data.

2. Methods

- This project used 2019 NIR data, literature review, and Government of NWT fuel tax data to characterize the NWT energy system.

- Based on literature, various efficiencies were assumed for each sector, and useful/lost energy totals were ascertained for each category.

- Estimates of technology adoption were made based on technology readiness level and practicalities of operations in the north.

- To model demand, net-zero technology efficiencies were used from literature to understand the total amount of hydrogen, ammonia, biofuels, and electricity needed to power the energy system that would provide the same useful energy currently required.

- The total additional hydroelectric capacity required was calculated based on literature values for hydrogen and ammonia production, and a carbon reduction potential was calculated based on direct CO_2 emissions.

3. Existing NWT Energy System

Overall, the NWT energy system in 2019 used 21,478 TJ of energy with the following observations:

- Fossil fuels make up 19,186 TJ or 89.3% of the total primary energy demand .
- Diesel fuel is the most combusted fuel and provides 67.7% of total energy.
- The most energy intensive end-use sector was freight (combined off-road and on-road heavy hauling which accounted for 39.3% of energy used in the NWT.
- Energy efficiencies vary widely between end-use sectors, with the lowest being internal combustion engines, and the highest efficiencies were found in the building sector.
- Overall, the NWT energy system was found to be 52.4% efficient.

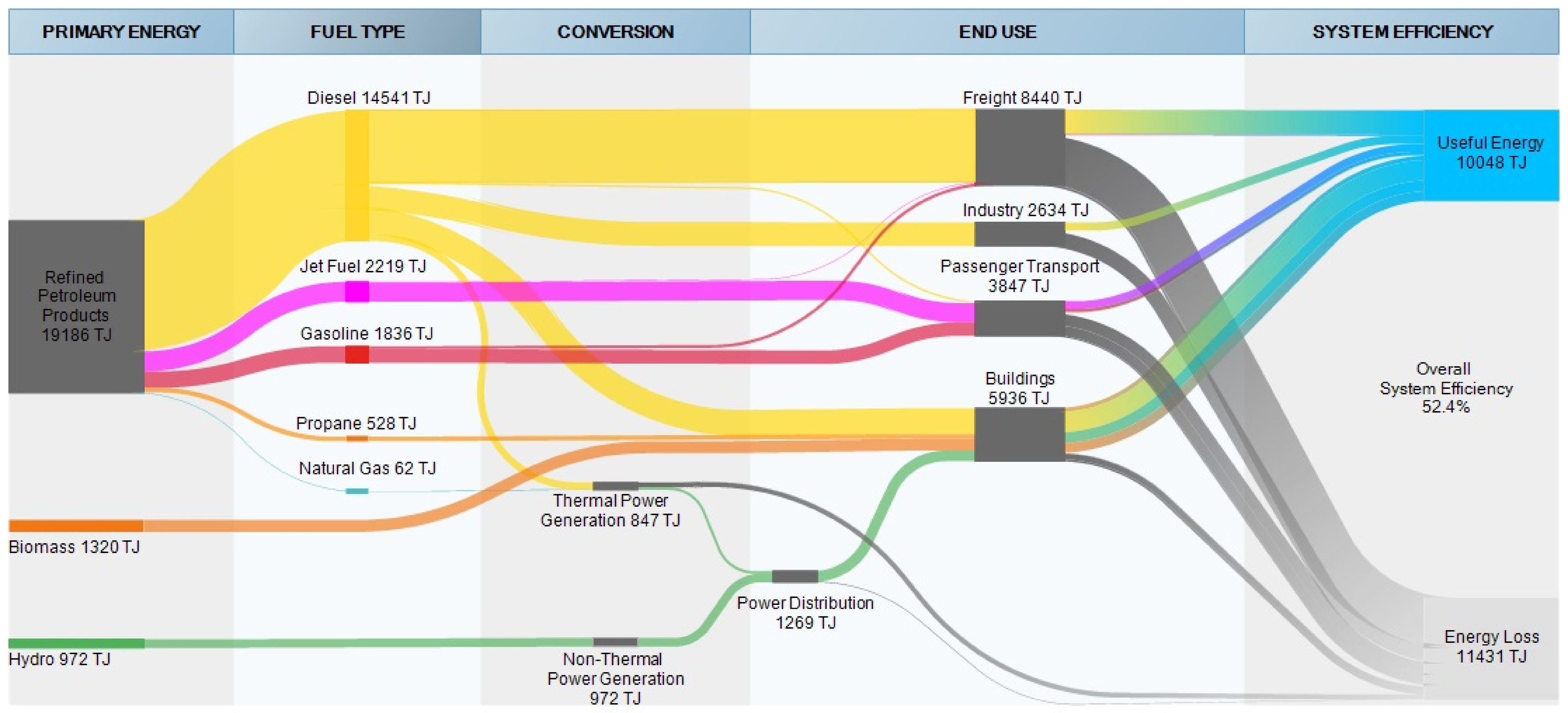

Figure 2. Sankey diagram of the 2019 NWT energy system, created using NIR and GNWT fuel tax data

4. Hydrogen-Based Net-Zero NWT Energy System

In a hydrogen and ammonia-based net-zero energy system, the total primary energy demand is 24,139 TJ with the following observations:

- Fossil fuels do not play a role in a hydrogen-based energy system; however, drop-in biofuels make up 17.0% of energy demand in this scenario, with the largest user being the aviation sector.
- Hydroelectricity is the largest primary energy source, providing 15,967 TJ of energy or 66.1% of total demand, an overall increase of ~16.4x compared to current production.
- Ammonia production is the largest user of energy, being 38% of primary energy demand.
- A decrease in overall system efficiency was observed due to the conversion losses of generating hydrogen and ammonia.

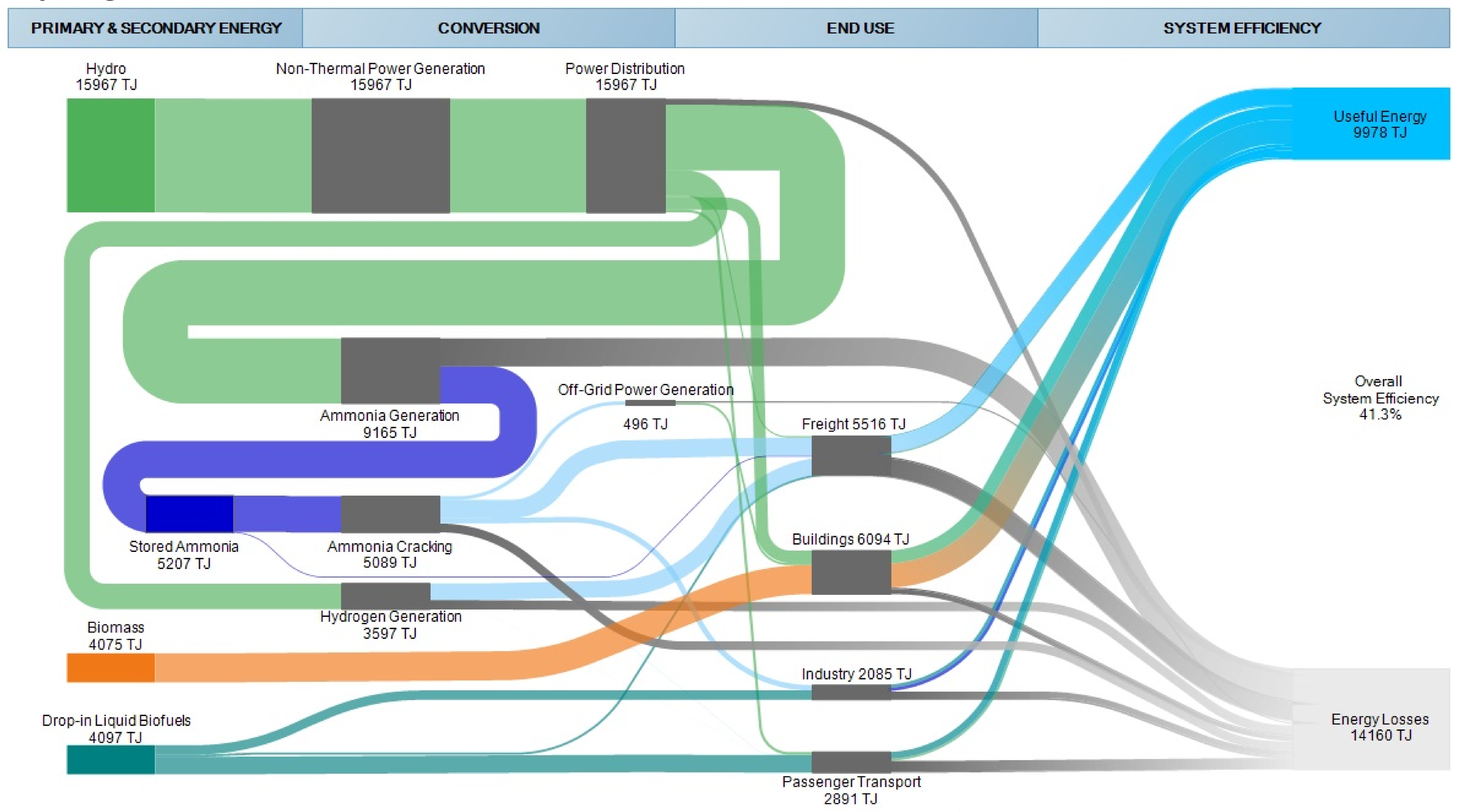

Figure 3. Sankey diagram of a theoretical net-zero NWT energy system that utilizes a hydron and ammonia backbone

5. Carbon Reduction Potential

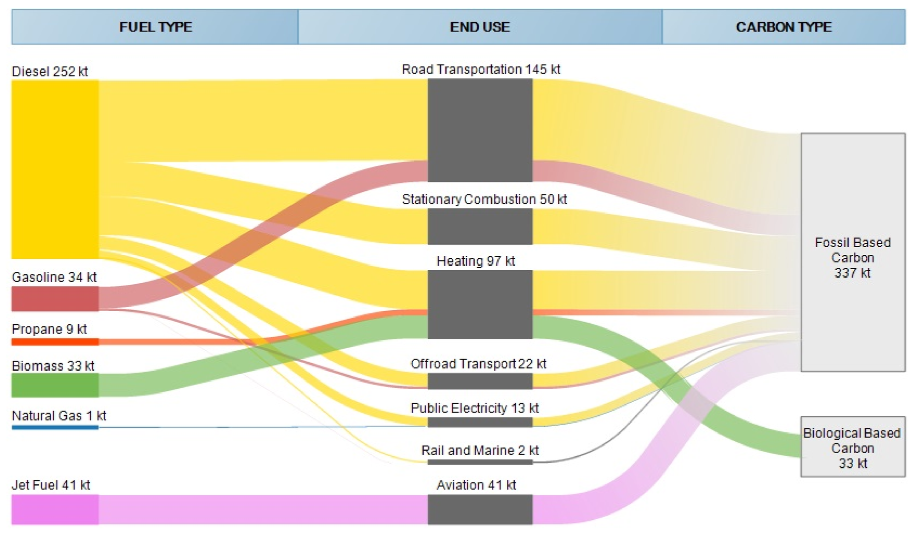

Figure 4. Elemental carbon Sankey diagram of 2019 NWT energy system

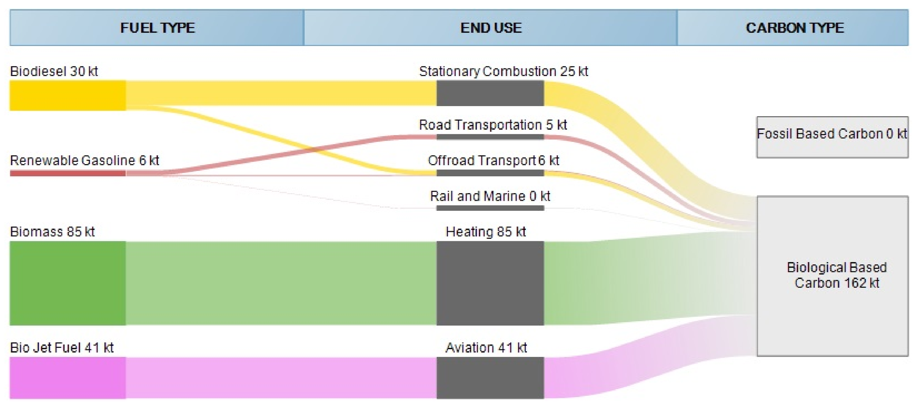

Figure 5. Elemental carbon Sankey diagram of net-zero NWT scenario

6. Hydrogen Production Potential

It was clear early in the project that the current NWT excess hydro capacity was inadequate to provide enough electricity to produce hydrogen on a system scale.

To demonstrate this, the excess hydro production potential was graphed against the largest hydrogen end-use sector - freight.

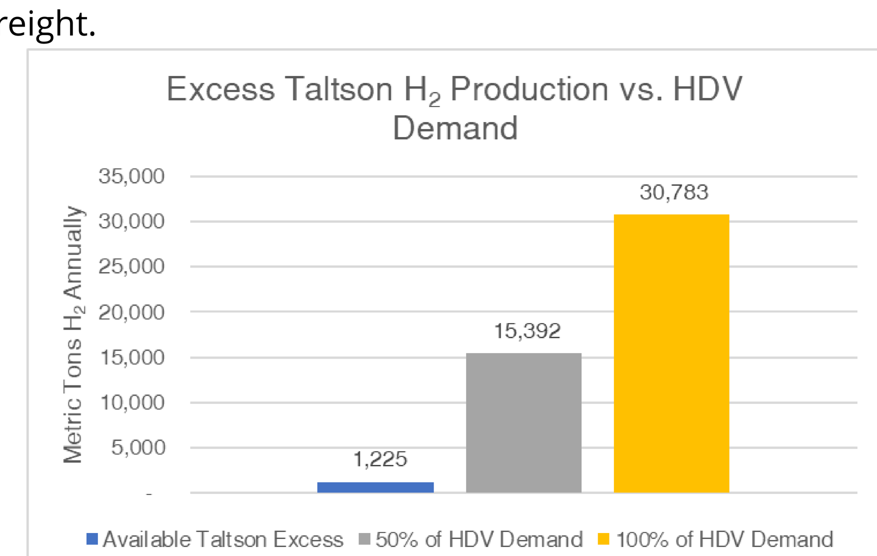

Figure 6. Excess hydroelectric hydrogen production potential

7. Biofuel Makeup

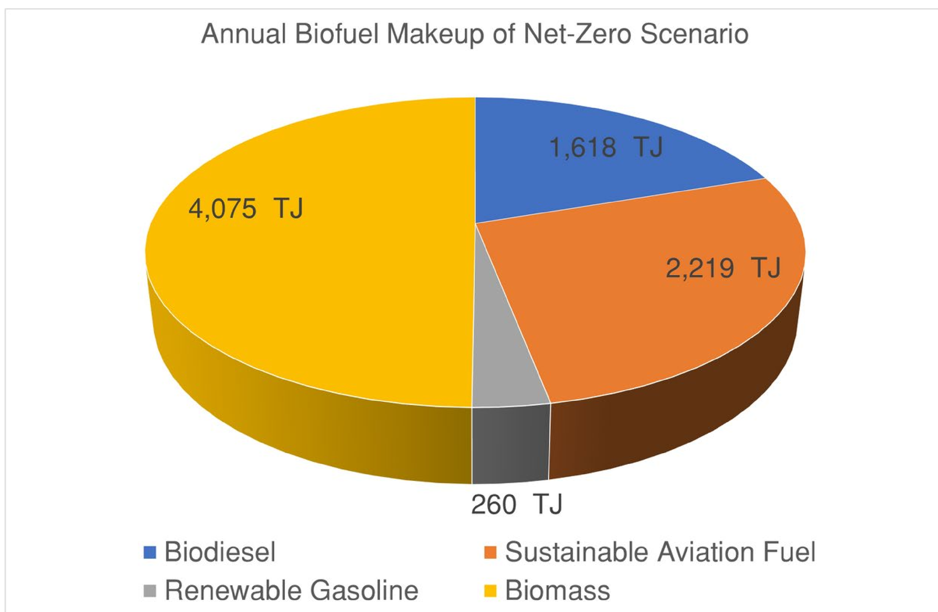

Figure 7. Net-zero biofuel demand projections

8. Limitations

- Communities were considered only to be hydro-connected or using hydrogen fuel cell generation only when, in practice, other local energy sources should be considered, such as wind, solar, and run-of-river hydro.
- GNWT fuel tax data only provides insight into sales, not combustion of fuel.
- Fuel emission factors used to model carbon Sankey diagrams only considered direct CO_2 emissions, not N_2O or CH_4, which have higher warming potentials.
- Life cycle emissions were not considered.
- Efficiency factors of technology were static and based on current technology but should be considered to be dynamic in a long-term model.

9. Conclusions

- A 100% hydrogen and ammonia powered NWT is not practical due to low population density and limitations of technology in sub-arctic and arctic environments.
- Biofuels will play a large role in the future of the NWT, especially in the heating sector.
- A total of an additional 731 MW of hydro at 53% capacity is required to generate the hydrogen and ammonia to be net-zero. Including passenger electrification, 781 MW is needed.
- Implementing an advanced energy system in the NWT is not only an engineering challenge but also a workforce challenge.

References

[1] Statistics Canada. (2021). Table 17-10-0009-01 Population estimates, quarterly. https://doi.org/https://doi.org/10.25318/1710000901-eng

[2] Government of Northwest Territories. (2021a). Northwest Territories - Energy Initiatives Report. https://www.inf.gov.nt.ca/sites/inf/files/resources/3894_-_gnwt_enr_-_energy_initiatives_report_-_2021_-_final_-web.pdf

[3] Environment and Climate Change Canada. (2022a). National Inventory Report 1990–2020: Greenhouse Gas Sources and Sinks in Canada.