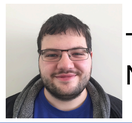
Hydrogen Fuel Cells for Freight Transport

Using Alberta's Renewable Energy Potential

UNIVERSITY OF CALGARY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INTRODUCTION

Concerns about climate change and Canada's 76 Mt CO_2e/yr emissions arising from diesel consumption in freight transport have both increased interest in vehicle electrification[1], and threatened the economy of fossil-fuel rich Alberta.

A solution to reshape freight transportation to reduce diesel emissions is to use Hydrogen Fuel Cells (HFC) to provide on-board electricity generation that will meet the power and distance requirements for heavy transport[2]. This study explores Alberta's large wind and solar potentials to provide the fuel energy needs for heavy transport at the scale of the industry across Canada.

METHODS

Data from the literature[1,2,3,4] were used to quantify the energy flows needed to provide 1 km of heavy transport (Figure 1). For the HFC Scenario, the AB solar (30%) and wind (70%) resource were used to power an Alkaline Electrolyzer (Fig. 2) that produced H_2 gas which was compressed for on-board use in a PEM Fuel cell (Fig. 3) to produce the electricity to drive the wheels of the truck.

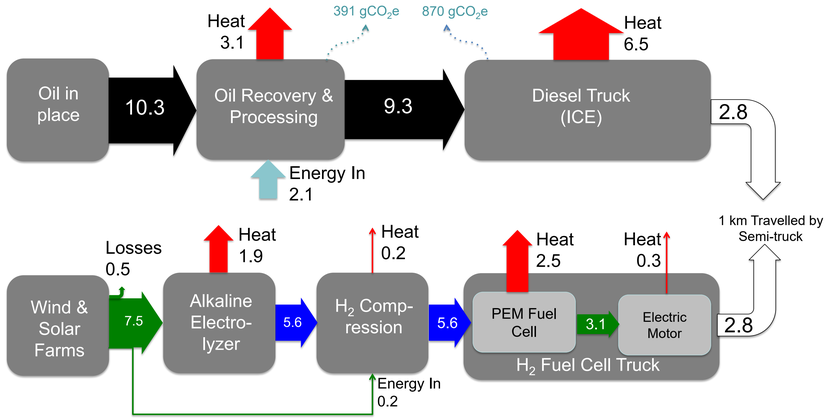


Fig. 1. Energy flows associated with Diesel and HFC trucking (MJ/km)

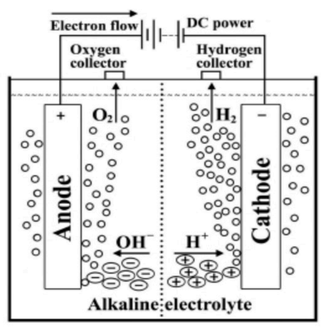


Fig. 2. Alkaline Electrolyzer [4]

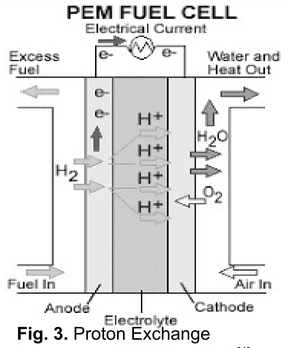
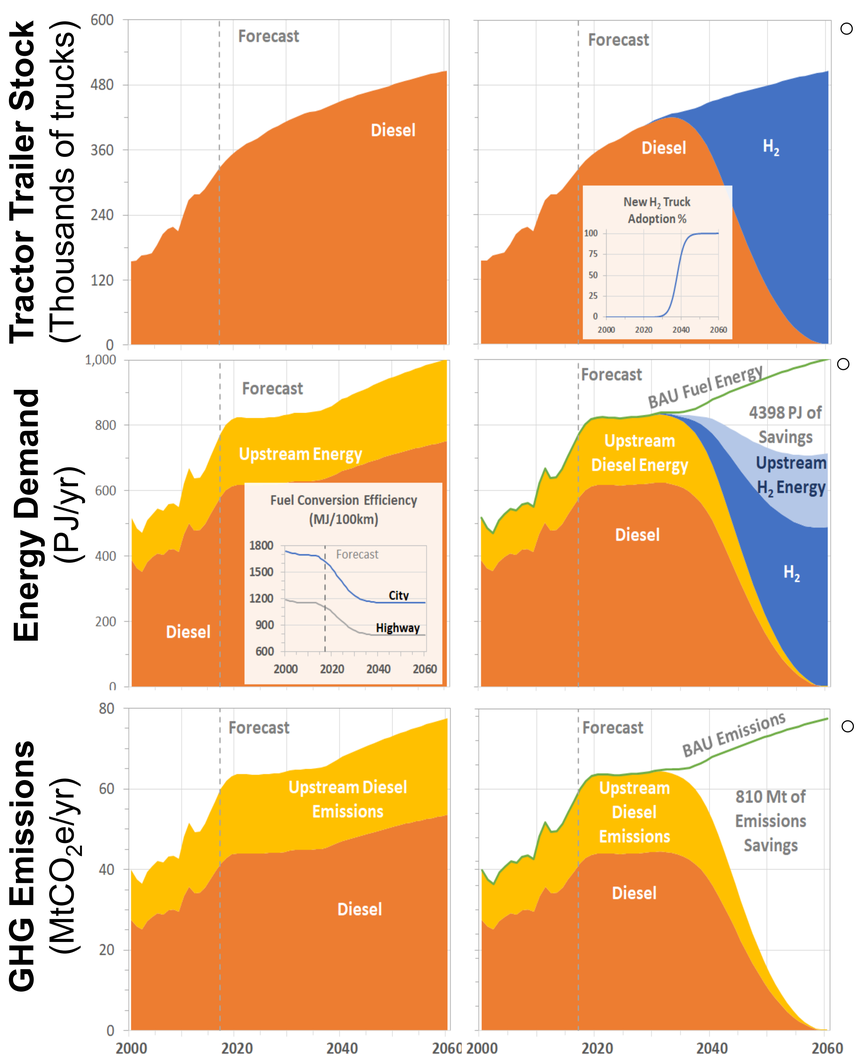


Fig. 3. Proton Exchange Membrane (PEM) Fuel Cell [4]

RESULTS & DISCUSSION



Data provided by CANESS and whatIf? Technologies [1][2]

- Assuming market share shown in inset figure, HFC trucks reach 100% of stock by 2060.
- From 'Well to wheels', HFC trucks use about 34% less energy than a vehicle using diesel from oil sands bitumen.
- GHG emissions were reduced by 66% between 2005 and 2050, but achieved 100% reduction by 2060.

Alberta Solar and Wind Potential

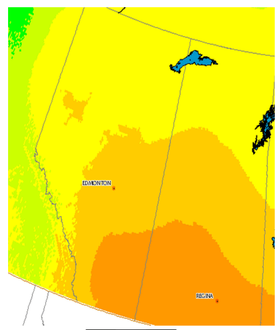


Fig. 4. Photovoltaic potential of Alberta[5]

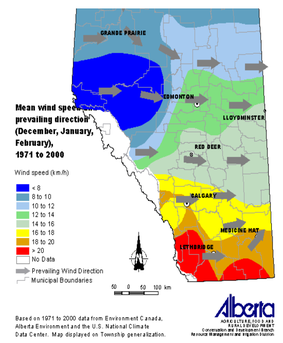


Fig. 5. Mean Wind speed of Alberta[6]

Alberta has an incredibly large renewable energy potential, enough to power the electrolysis needed to meet our H2 needs. In southern Alberta, the solar potential is on average 1400MW with the rest of the province having between 1200-1400MW. Alberta also has an approximate 1500MW wind capacity with average wind speeds at 18 km/hr.

CONCLUSION

By 2060, 78 km^2 of solar and 1200 km^2 of wind turbines will be required to provide enough energy to power the electrolysis. Approximately 28 Mm^3 of H_2O will be required for producing H_2 through water electrolysis. This accounts to a 0.7%[7] increase in Alberta's current water usage. The molecular oxygen produced from electrolysis can be sold to aid with counteracting costs.

This research is similar to previous studies done by Nikola Motors[8], Toyota[9] and Kensworth[10] all of which have announced hydrogen fuel cell powered class 8 transportation trucks.

Replacing our total stock of 15 tonne freight trucks from diesel trucks to HFC trucks with our given alternative adoption scenario, we see a possible reduction of 77.5MtCO_2e equivalent per year in Canada by 2060. A total of 810MtCO_2e is saved between 2020 and 2060.

REFERENCES

[1] Dr. B. Straatman et al "dieselUseAndStock_170926+graphs", Excel Spreadsheet provided by the professors of SCIE 529. D2L. October 17, 2017.

[2] whatIf? Technologies Inc., 2014. Canadian Energy Systems Simulator (CanESS) - version 6, reference scenario. www.caness.ca

[3] "Energy Requirements for Hydrogen gas compression and liquefaction as related to vehicle storage needs", *DOE Hydrogen and Fuel Cells Program Record*. 2009. [Online]. Available: https://www.hydrogen.energy.gov/pdfs/9013_energy_requirements_for_hydrogen_gas_compression.pdf.

[4] "Fuel Cell Fundamentals, Third Edition", *O'Hayre R, Colella W, Cha S, Prinz F.* John Wiley & Sons Inc. New Jersey, 2016.

[5] "Alberta's Potential", *Neighbor Power.* 2017. Available: http://neighbourpower.com/alberta-solar-potential/

[6] "Mean wind prevailing direction", *Alberta Govt*. 2003. Available: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/sag6450?opendocument

[7] Dr. D Layzell et al "Calculations for Teams 3-5", Excel Spreadsheet provided by the professors of SCIE 529. Nov 22, 2017.

[8] "Nikola One", *Nikola Motor Company*, 2017. Available: https://nikolamotor.com/one.

[9] "Here's the Technoloy Behind 'Project Portal,' Toyoya's Fuel Cell Truck", *Trucks.com, 2017*. Available: https://www.trucks.com/2017/04/19/toyota-project-portal-fuel-cell-truck-technology/.

[10] "Kensworth Advances Low – Zero Emission Prototype", *Kensworth*, 2017.

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