A SPECIFIC REPORT

University of Ontario Institute of Technology

Prof. Dr. Ibrahim Dincer

Yusuf Bicer

Hydrofuel Inc.

Greg Vezina

Frank Raso

Summary of the Proposed Project
"Connection of Remote First Nation Communities in Northwest Ontario"

In many of the remote First Nation communities located in northwest Ontario, diesel fuel generators are used to provide electricity. Because of the drawbacks related with diesel generation, extending Ontario's transmission system to these communities is being proposed as an option. It is intended to establish the technical and economic feasibility of connecting remote First Nations communities in northwest Ontario to the provincial electricity grid.

There are 27 remote First Nation communities in northwest Ontario with electricity supply, of which are currently not connected to the provincial electricity grid and use local diesel generators for electricity. These remote First Nation communities are considered remote because of their distance from established transportation and / or energy infrastructure, with most relying on winter roads to transport goods and supplies. Two of these communities (Cat Lake and Slate Falls) were once supplied by diesel generation but have subsequently become connected to the Ontario electricity grid.

Because of forecast demand progress in these communities, the volume of fuel required for electricity generation is expected to increase radically in the 40 year planning period. This increase in fuel consumption will pose significant additional challenges in delivering fuel to remote communities. Therefore, the additional fuel that would be required in the communities is expected to increase the percentage of fuel that must be delivered by air tanker, as winter roads are highly utilized for fuel transport. The cost of transporting diesel by air tanker is many times higher than by trucking on winter roads.

The Ontario Power Authority and the representatives of the remote First Nation communities and tribal councils in the area drafted the 2012 Technical Report for the Connection of Remote First Nation Communities in Northwest Ontario. The updated analysis identifies that there is an economic case to connect up to 21 remote communities at this time. The remaining communities are not economic to connect at present, largely due to their relatively small size and distance from existing transmission infrastructure. First phase includes the new power transmission line to Pickle Lake. After that, connection of 16 remote First Nation communities will be conducted.

A report for the comparison of alternative options for powering these remote communities were prepared. The following remarks are taken from the report "Draft Technical Report And Business Case For The Connection Of Remote First Nation Communities In Northwest Ontario For Northwest Ontario First Nation Transmission Planning Committee" dated August 21, 2014:

- Research into other jurisdictions found that renewable generation can be economically integrated with diesel power systems to power remote communities either in regional micro-grids, where distances between communities and generation sites are not great, or as isolated individual community systems. These options could provide some cost and environmental risk reduction over the status quo and they may also create opportunities for more economically developing some renewable energy sites in remote communities.
- However, for the community electricity systems to remain isolated from the IESO controlled grid, development of the larger scale, more economic renewable sites would require the pooled demand of at least 3-5 communities. However, this would require 21 hundreds of kilometers of transmission and distribution line be built to connect the generation with sufficient load. This requirement adversely affects the overall economics of such projects.

- Furthermore, in all cases diesel generation would still be needed to meet demand when variable renewable resources are insufficient or unavailable, such as when run-of-river hydro sites have insufficient flow to meet demand or wind is not available. It is expected that even with efficiently sized renewable generation the community diesel generation units would need to provide at least 15% of the energy requirements in each community. While battery storage can eliminate some inefficient diesel operation (low load operation below the engine's optimal efficiency level), the technology is costly and the diesel units would need to run regularly to meet demand variations and maintain operability of the local system. This inefficient operation would limit the amount of diesel fuel that could be offset. As a result, it is expected that the long-term cost of renewable resources integrated with diesels in either micro-grids or isolated systems will remain high.
- The following table was presented in the report for comparison of powering options.

Table 1. Comparative average total cost of electricity supply for alternative supply technologies

	Average Total Cost of Supply to 2054 ($/kWh)		
	Low	**High**	**Remaining on Diesel Supply**
Diesel Generation	1.1	1.2	All
Isolated Wind Integrated with Diesel	0.85	0.95	All
Isolated Solar Integrated with Diesel	1.1	1.2	All
Isolated Wind and Solar Integrated with Diesel	0.85	0.95	All
Hydro Connected to Community Clusters	1.1	1.5	>10
Transmission Connection	0.4	0.5	<=5

Source: OPA

- It is seen in the report that they mainly propose a power transmission connection instead of using renewable energy. The option for using ammonia as alternative fuel for diesel generators is not considered.

Alternative Solutions

1) Ammonia fueled generators for stand-alone power production by transporting ammonia via tanker trucks

Diesel engines are simply compression-ignition engines, and can operate on a variety of different fuels, depending on configuration and location. Where a gas grid connection is available, gas is often used, as the gas grid will always remain pressurized even during almost all power cuts; in more rural situations, or for low load factor plant, diesel fuel derived from crude oil is a common fuel; it is less likely to freeze than heavier oils.

Ammonia is the only carbon-free chemical energy carrier (other than hydrogen) suitable for use as a transportation fuel. Furthermore, ammonia has a high octane rating (110–130), can be thermally cracked to produce hydrogen fuel using only ~12% of the higher heating value , presents no explosion danger when properly transported and stored, has a well-established production and distribution infrastructure, and has zero global warming potential (GWP). In addition to its attractive qualities as a fuel, ammonia is widely used as a NO_x reducing agent for combustion exhaust gases using selective catalytic reduction (SCR), and its capacity as a refrigerant can be applied to recover and further utilize engine heat that would otherwise be lost. In terms of environmental sustainability, ammonia can be produced using either fossil fuels, or any renewable energy source, using heat and/or electricity, which allows for evolution of ammonia production methods and technologies in parallel with sustainable development.

Ammonia can also be used in the following applications in remote communities:

- Fertilizers in the agriculture
- Fuel for farm tractors
- Heavy trucks
- Vessels
- Heavy duty engine fuel
- Off peak and excess power storage and distributed power generation

Advantages

- Ammonia is currently second largely synthesized chemical in the world. It is already being transported in large quantities using tanker trucks.
- Ammonia can be used as duel fuel with diesel, propane, hydrogen etc.
- Power transmission line is eliminated by using distributed power generation.
- Zero GHG during utilization in diesel cycle generators.
- Ammonia transportation pipelines can be installed which can also be used for natural gas, propane etc.
- Using solar energy, ammonia can be used for combined heat and power production.
- Reduced use of diesel for electricity generation will also have significant effects on the environmental impact of power generation in the communities. It will improve environmental quality within the communities by limiting diesel fuel spills, pollution resulting from combustion and noise pollution of the diesel system. Diesel generation creates significant emissions in remote communities, causing local pollution and greenhouse gas releases

Disadvantages

- Transportation of ammonia using tanker trucks may bring additional costs and maintenance requirements for the roads.
- Since lower heating value of ammonia is lesser than diesel, the transportation requirement is higher.
- Without power transmission lines, power generation for the provincial grid would not be possible which can provide a revenue source for communities.

2) Renewable energy based on-site ammonia production and utilization in ammonia fueled generators for stand-alone power production

Any renewable energy source can be used for on-site ammonia production. Northern Ontario has rich hydropower, wind and solar energy sources. In order to compensate the intermittency problem of solar and wind energy, an integrated system coupling these renewable resources can be simply utilized.

Advantages

- Ammonia can be produced from renewable energy resources on site. Canada has more than 10 large scale ammonia production facilities. Currently, steam methane reforming method is utilized for ammonia production. However, water can be dissociated into hydrogen and oxygen using renewable energy and then produced hydrogen can be combined with nitrogen from air to produce ammonia.
- Power transmission line is eliminated by using distributed power generation.
- Zero GHG during utilization in diesel cycle generators.
- There are also a number of potential hydroelectric sites 18 in the area in potential size up to about 30 MW which can be utilized for on-site ammonia production.
- Ammonia fuel may provide an alternative to electricity for transmission, annual-scale firming storage, and energy supply integration.
- Converting stranded, curtailed, or spilled renewable energy source electricity, at the sources, to ammonia fuel, allows harvest, transmission, and storage of this stranded renewable energy, for a degree of community energy independence.

Disadvantages

- Usage of only one renewable resource may cause storage problems because of intermittency.
- Siting of ammonia storage tank or tank farm for preferably at a distance downwind of the community may be needed to prevent any large accidental ammonia leak.

I. Cost Comparisons

In this section, alternative diesel generator fuels are comparatively assessed in terms of yearly and lifetime (40 years) period.

Table 2. Current market prices of ammonia, diesel and hydrogen

Fuel	Cost (US$/kg)
Ammonia	0.28
Hydrogen	3.2
Diesel	0.85

For a 2000 kW diesel generator, the following fuel consumptions are considered for cost analyses:

Table 3. Comparison of diesel generator operation for various fuels

Fuel	**Lower Heating Value (kJ/kg)**	**Fuel Mass Flow Rate in Diesel Engine (kg/s)**	**Unit Cost (US$/kg)**	**Daily Cost (US$/day) (24 hours)**	**Yearly Cost (US$)**	**Life Time Cost (US$) (40 years)**
Ammonia	18,646	0.32	0.28	7741.44	2,825,625	113,025,024
Hydrogen	120,210	0.05	3.2	13824	5,045,760	201,830,400
Diesel	42,791	0.1396	0.85	10252.22	3,742,061	149,682,470

As seen in Table 3, the operation of diesel generators fueled with ammonia yields the lowest cost.

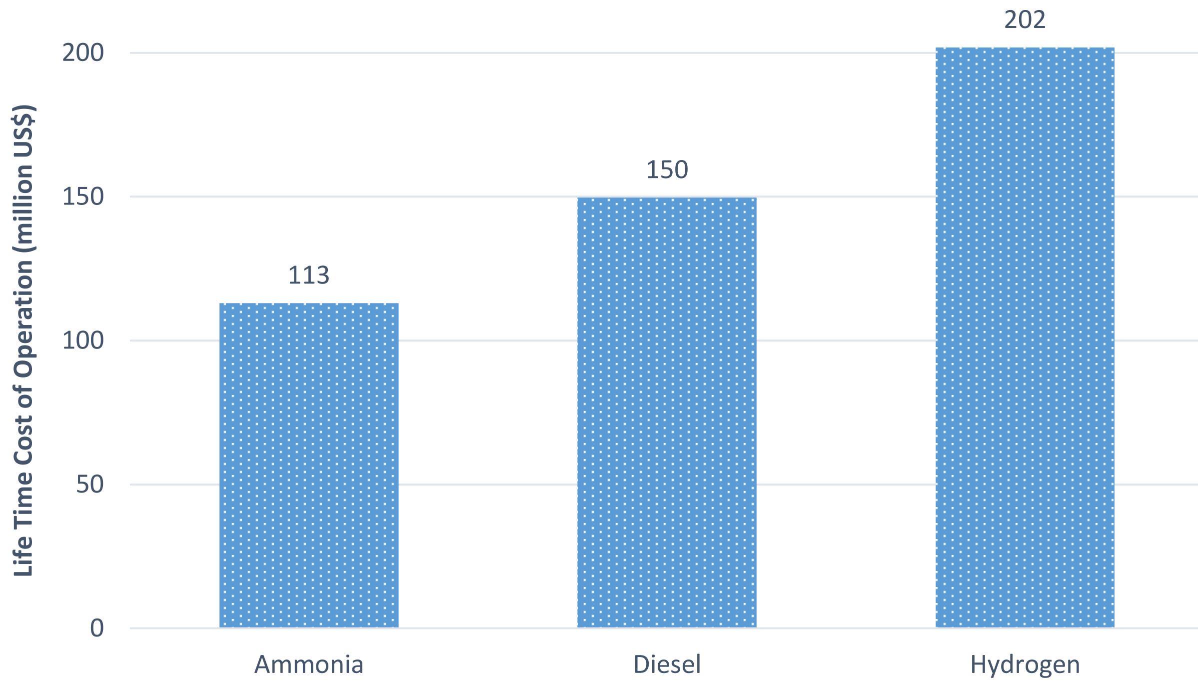

Fig. 1. Life time (40 years) cost comparison of diesel generator operations driven with various fuels

Table 4. Estimated per-km truck cost for sample fleet in GTA

Truck Type	**Per Kilometer Costs**		**Congestion Premium**
	With Congestion	**Without Congestion**	
Straight	CA$2.97	CA$2.53	17%
Tractor-trailer	CA$3.58	CA$3.12	14.5%

These results are for a specific fleet operating within primarily within the GTA and for 16,000 average kg of payload capacity. The cost terms are in Canadian dollar here. The congestion premium noted would obviously be less for fleets that operate for longer periods of time in noncongested traffic areas. The truck transportation cost values are taken from the report of "Transport Canada Economic Analysis Directorate, Estimation of Costs of Heavy Vehicle Use Per Vehicle-Kilometer In Canada".

Table 5. Fuel and transportation requirements

Fuel	**Fuel Mass Flow Rate in Diesel Engine (kg/s)**	**Required Fuel Mass in 1 Year (ton)**	**Required Fuel Mass in 40 Years (ton)**	**Required Number of Truck Transportation in 1 Year**	**Required Number of Truck Transportation in 40 Years**
Ammonia	0.32	10,091	403,660	631	25,229
Hydrogen	0.05	1,576	63,072	99	3,942
Diesel	0.1396	4,402	176,097	276	11,007

If 1500 km distance is considered for fuel transportation using tractor-trailer type trucks, the following calculations are obtained:

Table 6. Cost of transportation for various fuels

Fuel	**Required Number of Truck Transportation in 1 Year**	**Required Number of Truck Transportation in 40 Years**	**Transportation Cost (US$/km)**	**Cost of Transportation (US$/year)**	**Life Time Cost of Transportation (US$/40 years)**
Ammonia	631	25,229	2.4375	2,307,093	92,243,531
Hydrogen	99	3,942	2.4375	361,968	14,412,937
Diesel	276	11,007	2.4375	1,009,125	40,244,343

The life time cost of ammonia transportation is calculated more than diesel because of lower heating value and more mass requirement. However, the major advantage of ammonia is that it can be produced on-site which eliminates the transportation costs. However, diesel cannot be generated on-site for utilization in remote regions. In addition, there are many more alternative ways for power production using ammonia such as gas turbines.

II. Environmental Impact Comparison

The following figures present the environmental impacts of ammonia and diesel production processes per kg of fuel. Fig. 2 is obtained using life cycle tool of SimaPro via Eco-Indicator 99 method. It allows the environmental load of a product to be expressed in a single score (1000 mPt=1Pt). The absolute value of the points is not very relevant as the main purpose is to compare relative differences between products or components. The scale is chosen in such a way that the value of 1 Pt is representative for one thousandth of the yearly environmental load of one average European inhabitant. Whereas, Fig. 3 is obtained via CML 2001 environmental impact assessment method. In this method, the results are given in terms of CO_2 equivalent. As seen in the Figs. 2 and 3, the production of ammonia from hydropower, which is an abundant source of renewable energy in remote communities, yield the lowest environmental impact. The current steam methane reforming option produces even lesser impact than diesel production. This means that central production of ammonia and transportation via tanker trucks will be more environmentally benign option instead of diesel production and transportation.

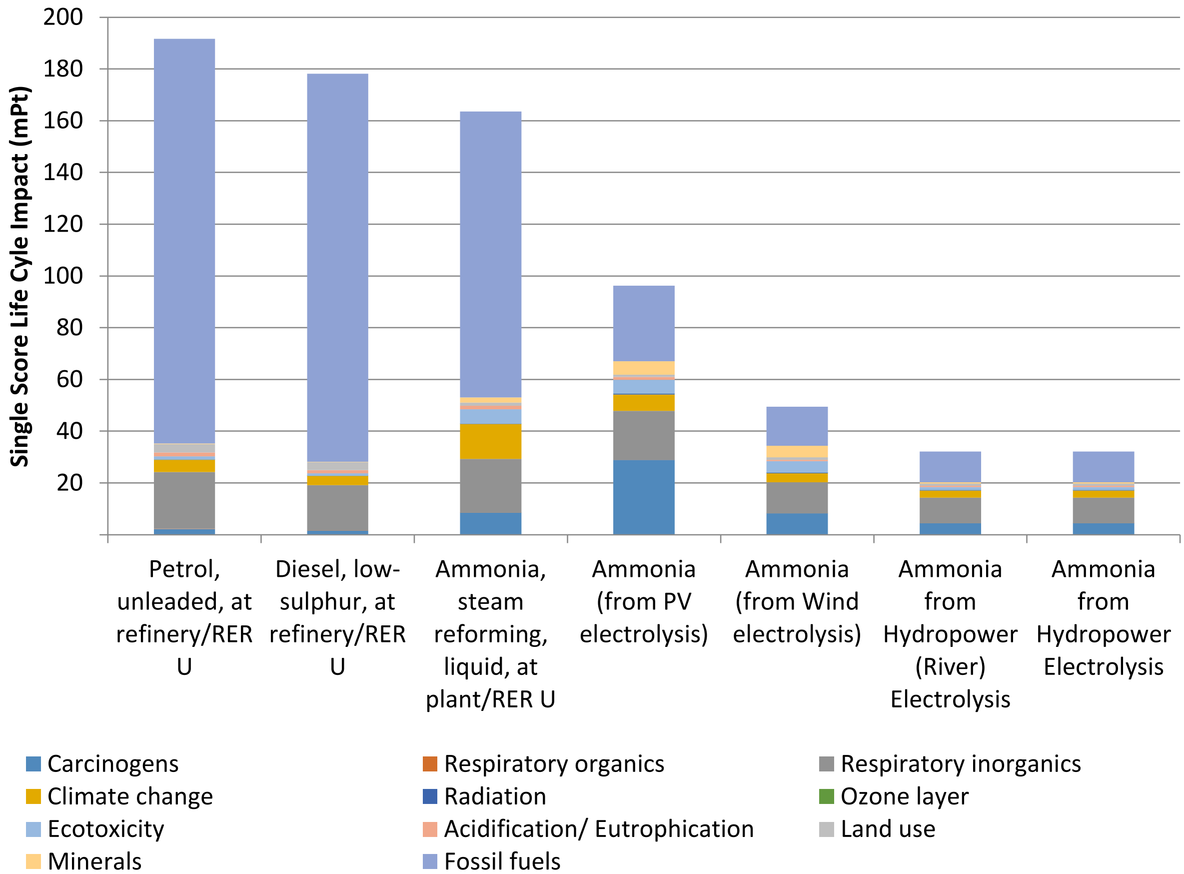

Fig. 2. Overall environmental impact comparison of 1 kg of ammonia, petrol and diesel production

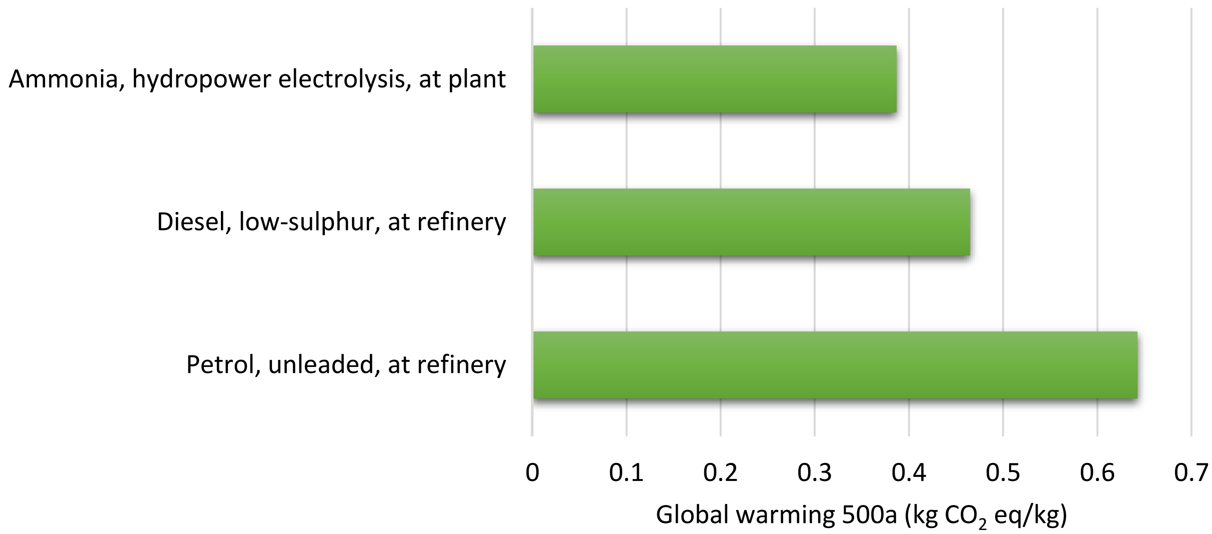

Fig. 3. Greenhouse gas emissions during production of 1 kg petrol, diesel and ammonia

Conclusions

The following remarks are noted based on the calculations and investigations.

- As the global warming and energy issues become important topics to be considered for the future of remote communities, alternative solutions for power and heat generation need to be investigated.
- Currently, diesel generators running on diesel are utilized for Northwestern Ontario remote communities. This is one of the most expensive and environmentally damaging option.
- First Nations request and propose a 1,500 km power transmission line to the remote communities instead of diesel generators which is a high cost investment.
- The significance of distributed power generation is emphasized in many studies throughout the world. Hence, producing power and heat via stand-alone facilities are being encouraged by the governments and decision makers.
- As an alternative and sustainable fuel, ammonia, can be utilized in the diesel generators by minor modifications. Ammonia has no greenhouse gas emission during utilization in the diesel generators. Hence, it is the most environmentally benign fuel among other alternatives.
- Transportation and storage of ammonia is already available and well-known since it is the second largest produced chemical in the world. This implies that instead of diesel, ammonia can easily be transported and stored.
- Ammonia can be produced on-site using renewable energy resources such as wind, solar and hydropower which are already available in these remote communities. This brings minimum transportation cost. However, diesel needs to be transported for long distances.
- The operation of diesel engines with fuel ammonia has the lowest cost based on the current market prices. Considering the technology development of ammonia production, the cost of ammonia will continue to decrease which will bring additional reductions in total cost.
- Production and utilization of ammonia in diesel generators have significantly lower environmental impacts in terms of climate change and global warming.
- As a result, ammonia usage in remote communities for power and heat production will bring significant cost and environmental benefits together with public satisfaction.