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Fuel Cell Power as a Primary Energy Source for Remote Communities

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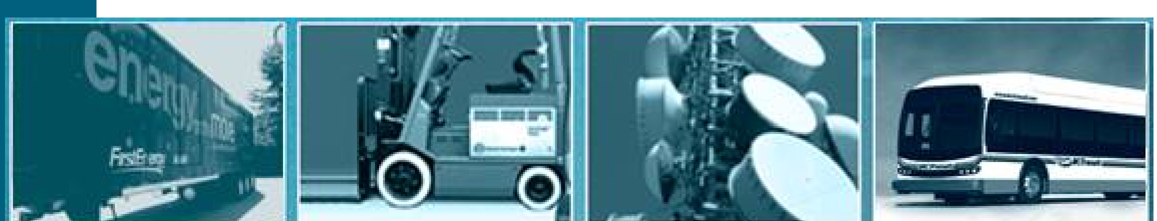

SITUATION

Around the world there are many remote communities not connected to a large, stable electrical grid. Canada, for example, has approximately 300 of these remote communities[1] and it is estimated there are up to 4,000 such communities globally. Typically, these small, isolated sites having unstable grid connectivity generate much or all of their electricity using diesel generators.

While diesel generators may have a relatively favourable capital cost, they have exceptionally high operating costs due to their low efficiency, combined with the high cost of transporting diesel fuel to remote sites, often under very difficult circumstances. Diesel fuel prices are expected to increase further in the coming years. In addition, diesel generators have extremely poor efficiency as they turn down in power. As a result, remote communities typically employ multiple diesel generators to meet their average and peak power demands.

Moreover, diesel generators create greenhouse gas (GHG) emissions that are harmful to local residents and the environment. Many remote communities are interested in improving utility service to support social well-being while, at the same time, reducing their dependence on diesel-powered electricity for social and environmental reasons. In addition, many governments are looking at ways to create job opportunities in these remote communities, leveraging alternative energy for job creation.

SOLUTION

Renewable sources of electricity, such as wind, hydropower and solar are particularly attractive for remote communities since they offer a clean source of power in locations that cannot be economically served by means of a grid extension.

While renewable power systems typically have relatively high capital cost, their operating costs are very low in comparison to diesel generators. Therefore, they have lower life-cycle cost and associated levelized cost of energy. Short term payback periods for renewable power systems relative to diesel systems are achievable, when combined with fuel cells.

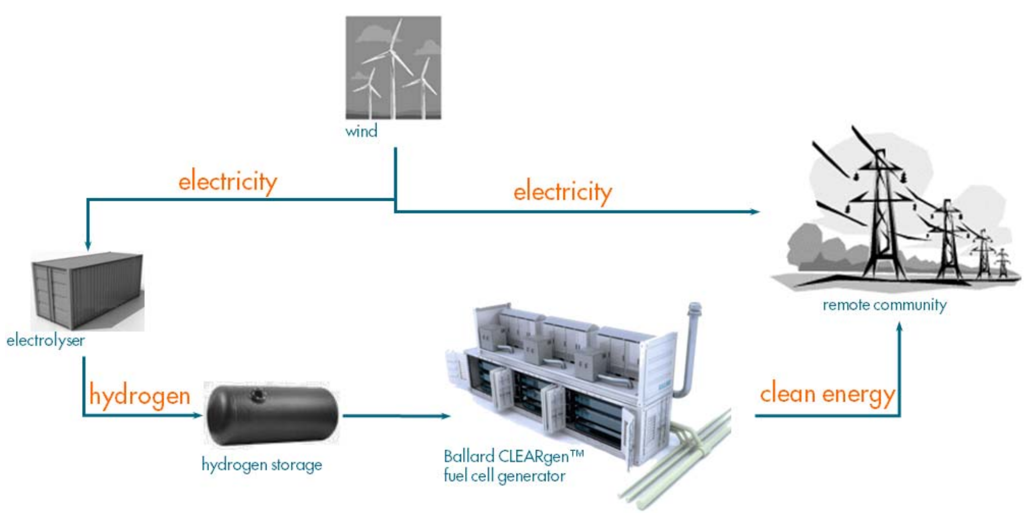

Figure 1: Renewable power system for a remote community.

Significant issues with renewable power systems are their intermittency (or low capacity factor) and unpredictability. These systems cannot be relied up on to meet 100% of the power demand – there will be times when available renewable power is less than power demand.

These issues of intermittency and reliability can be effectively addressed by storing surplus off-peak power for use during peak power periods. Off-peak energy can be stored in the form of hydrogen (produced using renewable energy and electrolysers), which will produce power during peak times by means of a fuel cell system. This allows the renewable power system to meet a very high percentage of power demand.

The photograph below shows a renewable power system installed in Bella Coola, a remote community in Northern British Columbia, Canada. The main source of power for this community is a run-of-river generator, whereby the natural flow and elevation drop of a local river are used to generate electricity. The surplus energy from the run-of-river generator is stored in a flow battery and is also used to produce hydrogen from water by means of electrolysis. To combat intermittency issues during periods of high water demand, the stored hydrogen is fed into a fuel cell system to generate electricity for the community.

Figure 2: Renewable power system at Bella Coola, British Columbia, Canada.

Fuel cells are capable of high power turn down and have higher efficiency at all power levels than conventional technologies, such as diesel generators. The fuel cells themselves release zero harmful emissions from their operation. Further efficiencies and reductions in GHG emissions can be realized when the waste heat from a fuel cell system is utilized for district heating.

CASE STUDY

A techno-economic analysis was performed comparing a renewable wind-hydrogen power system to conventional diesel generators for a hypothetical remote community. Assumptions include: 30 year study period; 7.5% annual real interest rate; 162 kW annual average power demand; 392 kW peak power demand; $2/L diesel fuel cost; 8 m/s wind speed.[2]

Renewable Power System

System architecture

Wind turbine	1,000 kW
325kW Diesel	325 kW
160kW Diesel	160 kW
Fuel Cell	200 kW
Inverter	200 kW
Rectifier	200 kW
Electrolyzer	1,000 kW
Hydrogen Tank	1,000 kg

Cost summary

Total net present cost	$ 11,254,168
Levelized cost of energy	$ 0.671/kWh
Operating cost	$ 415,795/yr

Electrical

Component	Production (kWh/yr)	Fraction
Wind turbines	2,705,259	80%
325kW Diesel	126,583	4%
160kW Diesel	111,764	3%
Fuel Cell	453,313	13%
Total	3,396,918	100%

Emissions

Pollutant	Emissions (kg/yr)
Carbon dioxide	234,446
Carbon monoxide	780
Unburned hydrocarbons	86.4
Particulate matter	58.8
Sulfur dioxide	471
Nitrogen oxides	6,959

Diesel Generator

System architecture

325kW Diesel	325 kW
160kW Diesel	160 kW

Cost summary

Total net present cost	$ 18,051,900
Levelized cost of energy	$ 1.076/kWh
Operating cost	$ 1,359,144/yr

Electrical

Component	Production (kWh/yr)	Fraction
325kW Diesel	940,825	66%
160kW Diesel	480,438	34%
Total	1,421,263	100%

Emissions

Pollutant	Emissions (kg/yr)
Carbon dioxide	1,321,134
Carbon monoxide	3,261
Unburned hydrocarbons	361
Particulate matter	246
Sulfur dioxide	2,653
Nitrogen oxides	29,098

Figure 3: Wind-hydrogen vs. diesel generator-only power systems for a hypothetical remote community (All currencies in US funds)

While the wind-hydrogen system requires 3.2x more capital dollars, the levelized cost of energy for this renewable system is 38% lower than for the diesel generator (ie. $0.671/kWh vs. $1.076/kWh). With an annual operating cost savings of over $900,000, a five-year payback is achieved for the renewable system.[3] In addition, the renewable system reduces CO2 emissions by 82%, removing almost 1,200 tonnes (US) of CO2 from the atmosphere annually.

CONCLUSIONS

Energy storage in the form of hydrogen (using renewable sources and electrolyser technology) combined with power production using a fuel cell system can enable remote communities to meet all – or a significant proportion – of their power needs in a highly economical manner.

The adoption of renewable energy production and fuel cells provides a number of meaningful benefits for remote communities, including:

- improved air quality and reduced GHG emissions;
- economic development, including creation and retention of high-value jobs needed to plan, commission and manage renewable and fuel cell power installations; and
- movement toward energy independence and economic self-sufficiency.

REFERENCES

1. Renewable Energy in Canada's Remote Communities, Kim Ah-You and Greg Leng, Renewable Energy for Remote Communities, Natural Resources Canada (http://canmetenergy-canmetenergie.nrcan-rncan.gc.ca/fichier.php/codectec/En/1999-26-27/1999-27e.pdf).

2. All modeling performed using HOMER, The Optimization Model for Distributed Power, Version 2.68 Beta (https://analysis.nrel.gov/homer/, http://www.homerenergy.com/).

3. Note that the renewable (wind-hydrogen) power system scenario assumes the diesel generator stays in-place to satisfy marginal demand at the peak period only. This reduces its use by 93% relative to the diesel generator-only scenario.