Sustainable Arctic Communities: A proposal for the Early Introduction of Smart Electric microGrids, Renewable Energy and Electric Transportation in Remote Arctic Communities

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1.0 Summary and Outline of Proposal

A key element in creating sustainable and secure communities in the Arctic is a local renewable energy supply and a mode of transportation that does not require imported fuel. Prior to contact with southern cultures, Arctic communities were sustainable and in the harsh climate of the Arctic had invented and perfected a tool set and life-style of incredible self-sufficiency, but now Arctic communities have energy and transportation demands that necessitates expensive imported fuels and dependency on the south. This proposal is intended to initiate the return of self-sufficiency to the Northern peoples of the Arctic based on local renewable energy supplies. This proposal also suggests that there is a solution that will enable remote Arctic communities to lead the way globally in creating economically viable sustainable energy and transportation systems. The key economic driver is the high and growing costs of the conventional approach using imported diesel fuel for electrification of the village grid and imported gasoline for transportation within the village and in the surrounding area. Technological enablers are the development of smart electric grids capable of accepting power from renewable sources such as wind, tide, and ocean and river currents that can be combined with energy storage on-board new generations of electric vehicles (EVs) that are bi-directionally connected to the grid; i.e. the EVs can be charged from the grid as well as providing power back to the grid from their stored electrical energy. The total system would be controlled through a wireless network. All the components of the proposed system are already commercially available, although some are still in an early stage of development. To demonstrate this sustainable solution in jurisdictions with existing massive electric grids and a very minor component of electric vehicles in the transportation sectors is problematic, but to trial the approach and demonstrate it in the micro-grid of Arctic villages is not only feasible but is economically attractive based on studies carried on in California (1).

This Position Paper provides a review of the present situation with regard to the technologies required to create this sustainable energy and transportation system for Arctic communities. A proposed approach to develop the concept is then suggested followed by a discussion of the institutional and other barriers and research opportunities to the suggested approach.

A situation has developed in which remote Arctic communities may be in a position to lead globally in the demonstration of a sustainable energy and transportation future with potential for commercial advantages to the local communities and their industrial partners as they will be the first family of experts created by adopting these sustainable solutions.

2.0 The Present Situation

The Concept

The use of both imported diesel fuel for the generation of electric power as well as gasoline for transportation creates environmental, security and an economic problems in Arctic communities. The recent extraordinary rise in the price of crude, which according to many energy experts is structural and not market cycle based, is causing even more serious problems for Arctic communities than for the rest of the world. Fuel costs were already much higher in the Arctic due to transportation costs and the short period when shipping is feasible for many locations. The emissions from burning fossil fuels for generating electric power or for powering vehicles in Arctic villages are often released close to or within villages which constitutes a health hazard for the inhabitants. Internal combustion engines are often left running since they are difficult to start at low temperatures experienced in the Arctic. At present there also exists an energy security problem when sea ice conditions prevents or delays the annual delivery of fuel. This proposal offers a novel solution to these three serious problems:

- High and growing cost of imported fuels
- Risks of depending on insecure delivery of fuels from the south

- Health risks from emissions from diesel generators and from vehicles operating in Arctic winter conditions

The basic idea is that of implementing an electric vehicle-to-grid (V2G) system within a smart grid which is combined with renewable energy sources that are local to the communities. Due to the high costs of delivered fossil fuel in these communities, this concept could be demonstrated first in the Arctic before being adopted more generally. The concept of electric V2G systems has already been researched and is now being tested in California under the sponsorship of the California Air Resources Board (CARB).(1)

An early analysis by Adams *et al* (2) based on data from a group of remote Arctic communities in Canada indicated that in these high fuel price situations, even as early as the 1970s, it was possible to save considerable fuel and make a solid economic case for the installation of storage batteries for load leveling the diesel electric generating systems. In this proposal, the storage batteries would be located in the electric vehicle fleet modified for Arctic operation which would be part of the microgrid rather than requiring a dedicated load leveling storage battery installed as part of the electric power system. The concept of V2G connected electric vehicles has gained considerable support lately as plug-in hybrid electric vehicles are being suggested as a source of back-up power locally in the case of power failures in the grid. In fact, the V2G concept has been extended to consider the possibility of power flowing both to fleets of EVs and from the fleets in bi-directional connections throughout the grid itself. If the control of the connections is shared by the power company and the owners of the EVs through the use of a “smart micro-grid” such as is described by Kroposki *et al* (3), then a mutually beneficial situation arises whereby the power company has both an electricity storage and an electricity generation opportunity while the owners of the EVs will be paid to make their EVs available to the Power Company which reduces the transportation costs of the EV owners. Modern wireless communications technology makes the central control of the V2G connections and identification of the vehicle and its state of charge for billing purposed etc on the microgrid possible. Wireless phones already have location functions included and it will be relatively simple to adapt this technology to the V2G application. The major car manufacturers are already including wireless systems in their vehicles such as the “On Star” system in GM vehicles. In studies by W. Kempton et al (4) which was sponsored by the California Air Resources Board

(CARB) and others, these researchers looked at the case of California where the analysis indicated that the yearly cost of the EVs could be greatly reduced to the EV owners while the V2G system would be of great benefit to the power companies. There is much recent interest in the concept (see updates in ref. 4). Intermittent renewable energy sources such as wind or solar add further benefits to this concept, since energy storage increases the percent utilization of these intermittent sources and reduces the use of fossil fuels and the generation of greenhouse gases.

Advantages of a Sustainable Energy and Transportation System for the Arctic

- Reduced use of diesel and gasoline with cost and environmental benefits
- The security of energy and transportation in the villages would be enhanced
- Electric vehicles (EVs) do not require any special features to operate in the cold and are emission free. They also save on expensive maintenance, oil changes, and other parts required for conventional engines. EVs can be designed for extreme conditions e.g. new army vehicles are being developed that will be electric or hybrid with off-road capabilities, while the battery industry is rapidly developing batteries which will enable vehicle performance equivalent to gasoline fueled vehicles. These EVs are now being demanded by consumers upset over the cost and possible availability of gasoline in the future.
- Arctic communities could be self-sustaining and not (or at least less) dependent on southern support with regard to energy and transportation
- Arctic communities and their partners that initiated and implemented these concepts could potentially obtain commercial spin-off opportunities as early adopters of technology that will likely only enter the mainstream in the south 10 or 20 years from now.
- The requirement for skilled and educated personnel to implement, operate, and maintain these systems will offer employment opportunities for Arctic residents where unemployment is a serious issue

Status of Component Technologies

Energy Storage and Conversion

Advances in energy storage and energy conversion technology are rapidly evolving and are one of the keys to replacing fossil fuel dependency and reducing global oil consumption. Lead acid batteries were invented over 150 years ago and are still the cheapest type of rechargeable batteries. However due to the weight of lead acid batteries, nickel metal hydride batteries developed in the 1970s were introduced and are now in service in hybrid vehicles such as the Toyota Prius, but are themselves about to be replaced. New generations of large format lithium ion batteries which are being developed from lithium ion batteries that first entered service for cell phones and computers only about ten years ago, will be entering commercial EV use beginning this year. The energy density in these new batteries will be about five to ten times that of lead acid so that vehicle ranges will be able to meet nearly all the requirement of vehicle users. In addition, there are developments in the area of supercapacitors which will enable fast charging of EVs and even more efficient EV propulsion systems. There are also other energy storage and conversion technologies being studied such as flow batteries and fuel cell/electrolyzer/hydrogen storage systems which can be used in distributed power systems with renewable energy sources to store energy for periods when the renewable source is unavailable. However, these systems are not readily adapted for on vehicle energy storage. It is worth commenting that companies such as Ballard Power in Vancouver that initially promoted fuel cells for transportation in automobiles have now concluded that the vehicle market (other than buses) for fuel cells is too far in the future due to the high costs of building a hydrogen supply infrastructure and the realization that using fuel cells in vehicles suffers poor overall energy efficiency (see ref.5 on this topic). All major automobile manufacturers in North America and elsewhere have begun to make strategic alliances with battery developers so that they will be able to make the change from gasoline engines to electric propulsion over the next decade.

The Smart Microgrid and Wireless Control of V2G Charging

In military developments there is a term called network enabled operations in which soldiers in the field are fully integrated with local commanders and with their headquarters and have available information on their surroundings in real-time from a wide range of sensors and platforms. The hardware and software required for this mode of operations which uses wireless connectivity is also being developed for civilian applications in a wide range of areas including the electric utility industry where the term “smart” grid means that the operator of the grid can control all functions of the grid to ensure the optimum operation of the grid including control of any embedded energy generators such as photo voltaic (PV) or other renewable energy sources or situations where customers may have excess power available to sell back into the grid(see ref. 3). Technically there are no barriers to implementing a system in which each EV when plugged into the grid anywhere in a village would be in wireless contact with a central station which would control the charge process and ensure that that vehicle was ready and charged for the owner when required. This smart microgrid would also make use of the energy storage capacity in these connected EVs when excess renewable energy was being generated from the renewable sources such as wind. When renewable energy was not available then energy would be extracted from the EV fleet to an extent based on individual vehicle owners wishes to meet some or all of the needs of the village. It is unlikely that the renewable energy sources could meet all requirements under all conditions so a hybrid renewable/conventional energy system will be required such as exists in some Arctic communities already e.g. Kotzebue in Alaska.

There are technical issues associated with the conversion of energy and the charging of EVs in that battery charging requires DC power while the grid operates on AC power thus there will have to be conversion between AC and DC power as well as voltage adjustments. These issues are becoming less difficult as power electronic technology is making rapid advances in new devices and designs.

Electric Vehicle Technologies

EVs are not new and were the dominant form of vehicle propulsion until early in the 20th century when the internal combustion engine with electric start became the preferred system. There was a renewed interest in EVs in the 1970s when there was a spike in oil prices combined with a reduction in global oil supplies controlled by the OPEC countries. The auto manufactures in this period however did not seriously support the development of EVs. Moreover battery technology at the time was lead acid or nickel/cadmium which could not provide adequate energy storage at a reasonable weight to enable the EVs to achieve ranges suitable for most consumers. In the 1980s battery technology was evolving rapidly and farsighted automotive companies continued to develop the EV concept including GM in North America as well as the major Japanese companies. One of the major events in the late 1980s was the Australian solar car competition whereby electric cars fueled only by the sun using PV systems integrated into the car bodies competed to cross the vast deserts of Australia from the north to the southern coast. GM produced a winning design that lead to their EV1 electric car (now made famous by the movie "Who Killed the Electric Car") produced to meet California's strict regulations to curb emissions from conventional vehicles. Unfortunately for the North American car industry, short sighted management at GM cut this program and leadership has moved to the Japanese companies who continued a vigorous program of development and now dominate the global EV and hybrid market. In North America, GM is playing catch-up with a massive (estimated to be over $1 billion US) development program to commercialize a plug-in hybrid electric vehicle named the VOLT which they expect to begin marketing in 2010. This vehicle will provide a battery electric range of 40 miles using an on-board charger that can be plugged into a conventional 110VAC household outlet and includes a small gasoline engine generator that charges the battery and enables the vehicle to have a gas/electric range of many hundreds of miles. A vehicle such as this would be suitable for the suggested Arctic program, but it would be even better if the battery were sized to provide a larger range. Toyota is also developing and plans to market a plug-in version of the popular Prius which has now sold over one million units globally and 600,000 in North America.

Other electric propulsion systems are being developed for bicycles, scooters, and motorcycles and are proving to be very popular especially in Asian countries. Electric mowers and many types of power tools are entering commercial development as advanced battery technology developers can now provide light weight powerful battery packs at a rapidly reducing cost. It can be expected that in the next few years there will be electric all terrain vehicles (ATVs) and snowmobiles and certainly electric trucks of all descriptions.

Renewable energy systems

In discussions with northern communities there is often a desire expressed for use of renewable energy options such as wind. Many village locations have excellent wind regimes and offer good potential. Similarly, tidal, ocean and river currents offer opportunities although winter ice conditions create challenges. All these energy sources are to some extent variable and intermittent, but even solar can be used in special circumstances above the Arctic circle e.g. in Canada for communication towers in very remote areas. Experience is now being gained in a number of circumpolar countries with wind as well as geothermal and ocean thermal energy sources. These early adopters are providing the essential demonstrations within which the technology is being improved and made suitable for the Arctic. Perhaps even more important, local residents are being trained to manage and maintain and to recognize the benefits of the renewable energy systems. The present proposal offers a method of extending the value of the investment in renewable energy sources by enabling the excess energy to be stored for use when the renewable source is not available and extending its use into the transportation sector.

Impact on Non- Renewable (locally based) energy options

There are some Arctic communities located close to natural gas developments (an example is Inuvik in Canada) that have been linked by pipeline so that they are able to generate power and provide heating to the community using natural gas. In fact, the natural gas reserves in the Canadian Arctic are estimated to be enormous and could support the local population for hundreds of years. Gas distribution by barge and sled could spread this option to most of the high arctic and liquefaction may not be necessary (6). Even in these situations, an electric transportation system could provide advantages since it reduces dependency of the community on southern gasoline deliveries. Ideally these communities would also adopt the use of renewable energy as well and create hybrid renewable/natural gas based grids for additional energy security and reduction in greenhouse gases.

Nuclear energy has also been suggested especially for Arctic communities in Russia where small portable nuclear electric power generators are being proposed to provide electric power for remote communities in Siberia. Galena Alaska is looking seriously at installing one or two Japanese-designed fast reactors to provided local a power supply. Again as in the case of the use of local natural gas, there are advantages to having energy storage in the operation of nuclear power systems which the proposed system could provide.

3.0 The Near Term Prospects

This proposal will have to be implemented in several phases. I suggest for discussion that the following phases be considered:

Phase I

Paper studies will be made to review the state of the art in EVs, V2G and smart microgrids including renewable components. The economic impact of such an approach should be explored and Arctic communities throughout the region assessed as to their electric power and transportation requirements. A work plan will be prepared based on a limited demonstration of the concept for a small remote community in the Arctic such as Kotzebue in Alaska in which the economic and environmental advantages of this approach will be quantified. The selection of the community is critical and requires that the electric utility operator be familiar with renewable energy as well as with electric vehicle technology. Kotzebue qualifies in both of these areas, but there are likely other communities that also would qualify.

Phase II

The work plan will be widely promoted and partners found from industry, academia and government. Funding will be sought to conduct a demonstration of the concept.

Phase III

An electric vehicle fleet with a V2G smart microgrid system will be demonstrated in an Arctic community where renewable energy is already in use.

4.0 Current Opportunities for and Barriers to Research Development and Demonstration for the Proposed Technological Approach in the Arctic

Opportunities

- Economic research is required to quantify the short and long-term financial consequences of implementing the proposed sustainable system for various village sizes and energy and transportation requirements in different regions of the Arctic

- System engineering research is required to identify and specify the elements of a smart grid that will be required to network the renewable energy sources with the electrified transportation system for village minigrids
- Research and development is required on specific elements of the proposed system to create components designed for Arctic use e.g. electric vehicles of various types and ranges to replace conventional gasoline engine powered trucks, snowmobiles and all-terrain vehicles
- Social policy research is required to identify the key issues for the village, governments and industrial players that will be required to support the development and implementation of the proposed sustainable system
- Industrial capabilities developed in this program could lead to opportunities for sale of expertise from the Arctic communities into southern markets where this approach to energy and transportation will likely occur on a wide scale only after oil prices have again doubled or tripled which is certain (due to the rise in demand especially in China and India and shrinking supply) within the next 10 to 20 years, but may be implemented initially in small southern communities or in distributed power elements of smart grids as they are rolled out throughout the world

Barriers

- Social and institutional barriers exist both in the private sector and in governments when new untested approaches are attempted
- Ensuring that there are sufficient local educated and skilled people to install and then operate and maintain the proposed sustainable system in the Arctic villages
- Convincing academic funding agencies that the proposed approach is possible and desirable so that they supply the required resources for the background engineering, R&D, and social/economic analyses needed
- Creating the required industrial research and development activity to meet the goals of the proposed program by finding sufficient commercial economic incentives to justify the required investment

5.0 Conclusions and the Way Forward

A feasible sustainable energy and transportation system for Arctic communities has been outlined and justified based on social, economic, environmental, and security arguments.

It is the hope of the author that the concepts outlined in this proposal will stimulate others to take the ideas and "*make it so*" as Jean-Luc Pickard says so often in Star Trek – The Next Generation.

6.0 References

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6.4 W. Kempton and S. Letentre on EV energy storage, see http://www.udel.edu/V2G/docs/Kempton-Letendre-97.pdf and for updates, see http://www.udel.edu/V2G/

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