Newfoundland & Labrador Energy Innovation Roadmap: Priority Identification (Phase 1)

Analysis Document:

Other Energy Themes (Remote energy systems, Marine energy technologies, Energy efficiency)

Final Report

August 2010

E4tech orioninnovations Wade Locke Economic Consulting

Contents

Glossary

Bespoke – Custom made to specifications

CNA – College of the North Atlantic (Newfoundland and Labrador)

DTU/RISO - Risø is the National Laboratory for Sustainable Energy at the Technical University of Denmark - DTU

EDF – (France) Energie du France, Large energy generator in France and the UK

EE – Energy efficiency

Eskom - generates, transmits and distributes electricity primarily in South Africa and into other parts of the continent

Gensets - fuel powered generators

ICE – Internal Combustion Engine

IEA – International Energy Agency (France)

MUN- Memorial University Newfoundland & Labrador

Nalcor - (Canada) generation and transmission of electrical power

NGO – Non-Governmental Organisation

NL – Newfoundland & Labrador

NREL- National renewable energy laboratory (USA)

R&D – Research and Development

RUV – remote underwater Vehicle

1 Context

This study forms the first phase of a Newfoundland and Labrador energy innovation roadmapping exercise, being undertaken under the guidance of the Department of Natural Resources in collaboration with the Department of Innovation, Trade & Rural Development, Department of Business, the Research & Development Corporation and Nalcorby. The purpose of this study is to identify priority innovation opportunities for Newfoundland and Labrador (NL) that merit detailed roadmapping in a subsequent phase of work.

The analysis and recommendations from this phase of work are contained in four separate reports, illustrated, in the context of the overall project, through Figure 1 below. Our findings and recommendations are presented in the Innovation Priorities Report which, in turn, draws upon the detailed analysis contained within three other supporting documents:

1. Analysis document: 'Energy Warehouse' areas (Oil & gas, Onshore wind, Hydroelectricity, Transmission)
2. Screening document: Other energy types (All other potentially relevant energy types)
3. Analysis document: Other energy themes identified through screening (Remote energy systems, Marine energy technologies, Energy efficiency)

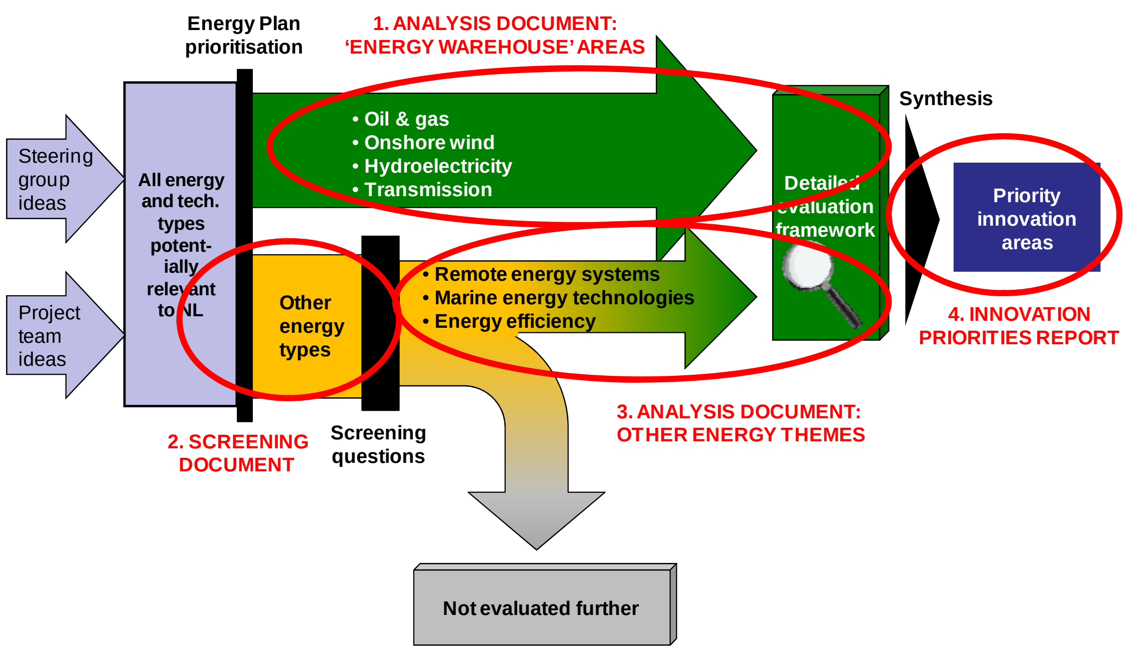

Figure 1: Overall project process and outputs

The Energy Plan introduced the concept of an 'Energy Warehouse' which featured several key resource types, namely onshore wind energy, hydroelectricity, oil and gas. The Energy Plan also identifies several other energy types that could offer opportunities for NL, though it is less specific about which are priorities. Using the overall objectives identified in the province's Energy Plan, the project team identified a long list of potential energy types. This list was screened against established criteria to produce a shortlist grouped under three themes that merit closer consideration (see document 2 for details of the screening process). The themes that were derived from this assessment were: Remote energy systems, Marine energy technologies and Energy efficiency. This current report (document 3) considers those three themes in more detail.

2 Overview

2.1 Analytical framework

A common framework has been adopted for the analysis of all energy types. It is based on the premise that innovation opportunities arise due to the need to overcome barriers that inhibit the commercialisation of particular energy resources or technologies. Prioritization of these innovation opportunities for this project has been based upon potential value and NL's current and/or future competitive position. However, insights developed during the course of the work meant that the framework was tailored and applied with appropriate modifications to each of the three themed areas addressed in this report.

2.2 Overview of findings

Remote energy systems

The markets and technologies associated with remote energy systems are emergent, hence the potential value and competitiveness related to any specific innovation is less well defined. As such, remote energy systems were considered as an area of potential option value[1] for NL, rather than as a specific priority need.

Marine energy technologies

The prioritization of innovation opportunities for Energy Warehouse energy types is based primarily on local value and secondarily on international competitiveness and export potential. NL has undoubted innovation resources and capabilities in the area of marine energy technologies (e.g., offshore wind, wave and tidal energy). However, in the views expressed by many of the stakeholders during our consultations, NL is not likely to be a suitable location for deployment. In this particular case, the opportunity for NL is not through innovation for local deployment, but through service provision to innovators outside NL who may wish to make use of NL skills and facilities. Consequently, analysis and prioritization within marine energy technologies is less important than the development of an appropriate service-export plan.

Energy efficiency

Non-technical barriers to deployment have been identified for all energy types, but only technical barriers have been examined in detail for innovation prioritization and roadmapping purposes. All the identified barriers to deployment of energy efficiency solutions are non-technical so energy efficiency should be addressed in energy planning activities, rather than being considered further for technology innovation prioritization purposes.

[1] Option value arises when an activity does not directly create economic value, but where it positions the holder of the option to capture value at some point in the future as a result of changing circumstances.

3 Remote Energy Systems

3.1 Definition

During the screening of energy types (described in document 2), several types of primary energy resource, energy conversion technology and energy system emerged which could be deployed in remote, off-grid applications. In most instances, the distinguishing feature related to the system integration and its application, rather than to the energy source or conversion technology. It was therefore decided to address these in a technology-neutral fashion by evaluating the remote energy sector as a whole, rather than any individual component.

The one exception to this technology neutrality is the use of fish oil in gensets, where the resource and the application are key to one another[2].

3.2 Energy opportunity

The availability of reliable and durable power in settings where the electricity grid is unavailable is a constraint to economic and social development worldwide. By some estimates, over 2 billion people live without access to reliable grid supplies of electricity.

In general, there are few solutions to the need for power in remote settings. For low power applications (e.g., remote sensing devices, single lights), batteries are dominant, while in some cases renewable energy is the primary source. For larger power applications (e.g., building power, outdoor power, minigrids), larger scale gensets are dominant. In all cases, the functioning of the system is constrained by the availability of energy (fuel or battery charge), which, in turn, enhances the attraction of a system that can make use of the various forms of energy available in the vicinity, whether solar, kinetic (wind, marine) or chemical (fish oil).

Telecommunications companies have a particular interest in finding off-grid sources of electricity and reliable backup power for base stations in remote areas. At the GSMA Mobile World Congress in Barcelona, the GSM Association presented findings from their 'Green Power for Mobile' programme which concluded that 'solar and wind technologies, including hybrids, were currently the most attractive technologies for powering remote base-station sites in terms of reliability, operational expense and resource availability'[3]. The program also showed that 39% of operators with an interest in the developing world have tested green-power sites.

NL has a wide variety of settings where grid power is unavailable and the alternative is expensive. Applications vary from a few milliwatts (marine condition monitoring devices) to watts (marker lights, communications towers) up to tens of kilowatts (offgrid dwellings, fish processors and outport communities).

It would be grandiose to suggest that, in the context of satisfying its own needs, NL could develop technologies that could solve the world's remote energy problems. However, it is clear that systems

[2] Fish oil is a byproduct of fish processing. It can be cleaned and used in internal combustion engines as a diesel blend or substitute. It can also be processed to improve its combustion properties.

3http://www.ericsson.com/ericsson/events/2009/mwc09/news/articles/090218-green-power.shtml; http://gsmworld.com/our-work/mobile_planet/green_power_for_mobile/index.htm#nav-6 which are applicable to even a small fraction of the global remote energy market could be very valuable export opportunities for NL.

3.3 Innovation needs and associated opportunities

There are a number of challenges to the development and deployment of cost-effective remote energy solutions. These include:

Energy source:

- Securing and harnessing energy sources which are predictable, of consistent quality, and cost competitive with fossil fuel alternatives.

Integration:

- Designing and engineering systems that integrate renewable energy sources and energy storage devices, while simultaneously and cost-effectively satisfying remote energy needs.

Operation:

- Designing and engineering systems that operate reliably and cost-effectively under a range of demand conditions.

The specific barriers (and, therefore, innovation opportunities) associated with each of these challenges are shown in Figure 2 below.

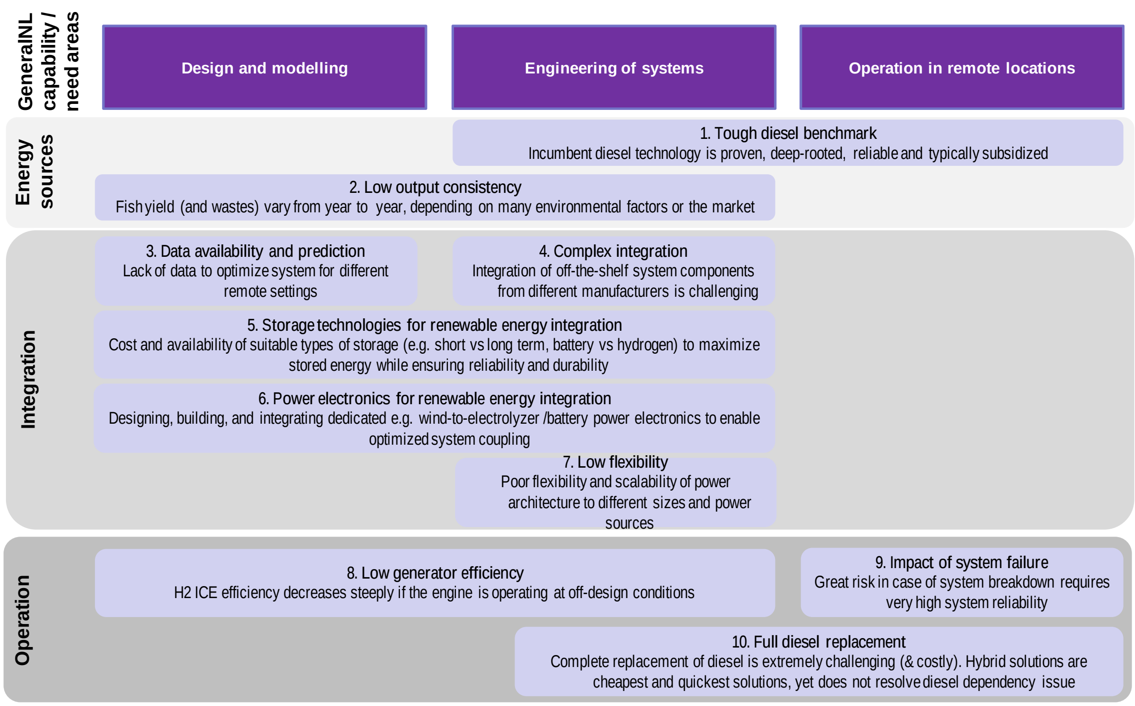

Figure 2: Remote energy systems – Key barriers matching general areas of NL capability

3.4 International innovation landscape

The principal players involved in innovation in remote energy systems are utilities, energy and telecommunications companies; research centres and universities; system design and installation businesses; and international aid agencies and NGOs. Fish oil and biodiesel innovation often involves the waste producers, such as fish processing companies.

3.4.1 Remote energy

Innovation within the utilities and energy companies arises from a need to serve remote communities, where connection to the grid is not economically viable. Most large utilities seeking to serve remote communities engage in innovation related to remote energy systems. This includes, for example, Eskom and EDF, the two largest utilities serving Africa. Telecoms infrastructure companies also have an active interest in applying solutions for remote power.

A great many research centres and universities conduct research that has a bearing on remote energy solutions, often addressing two or more parts of a complete system (for example, hydrogen storage and electrolyser optimization at DTU/RISO in Denmark). These research institutions are less frequently focussed on complete system integration, optimization and operation, though there are a number of exceptions related in particular to complete wind/hydrogen hybrid energy systems. Examples include NREL in the US and the Fraunhofer Institute in Germany. Further examples and details are given in the appendix to this document.

There are numerous businesses that have expertise in the bespoke design and installation of hybrid systems, using available technology. Many of these have a focus on a single primary power source, generally solar or wind, and the majority use battery storage. Examples include Energy Development Co-operative Ltd,[4] which specialises in off-grid solar and wind power design, and SunEnergy Inc,[5] which specializes in solar energy solutions for both remote and island resorts and local communities. Further examples and details are given in the appendix to this document.

Implementation of remote hybrid energy systems is considered a key factor in reducing poverty and improving the well-being of many rural communities in the developing world. There are a number of aid agencies and NGOs that have considerable experience on the ground in supporting innovation in the deployment of such hybrid systems (often solar based). For example, the Alliance for Rural Electrification[6] promotes and provides efficient renewable solutions for rural electrification in developing countries, and the World Bank[7] and GVEP (Global Village Energy Partnership)[8] are also active in supporting projects (primarily through funding and promoting partnerships) associated with improving access to energy for rural communities. Further examples and details are given in the appendix to this document.

National and international large-scale collaborative programmes have been initiated in order to support innovation in remote energy systems. The IEA Wind to Hydrogen, and the Alliance for Rural Electrification (mentioned above) are two examples.

Within Canada, the Integrated Community Energy Solutions (ICES) 'roadmap for action' (2009)[9] sets out to improve community energy performance, while simultaneously contributing to federal,

---

[4] http://www.solar-wind.co.uk/

[5] http://www.sunenergy.com.au/index.php

[6] http://www.ruralelec.org/

[7] http://www.worldbank.org/

[8] http://www.gvepinternational.org/

9 Council of Energy Ministers, Integrated Community Energy Solutions, A Roadmap for Action, Sept 2009.

provincial and territorial governments' energy efficiency and climate change objectives. That particular roadmap focuses all sectors that influence the production and consumption of energy (including generation, distribution, transport, buildings and industry), but notes that ICES can be scaled to meet all needs, including remote rural communities. The roadmap, therefore, contains a strong endorsement for the use of local renewable energy resource potential, district energy systems, decentralized energy systems, grid management initiatives and community thermal and electrical storage.

3.4.2 Fish waste to energy

A number of fish processing companies, such as UniSea Inc and US Seafood, use fish oil-diesel blends as a straight substitute for diesel fuel. For example, in 2003, Unisea used more than 1 million gallons of 50:50 fish oil-diesel blends at its Unalaska Powerhouse[10]. There is also interest in converting fish-oil to biodiesel (via initial conversion to a methyl-ester) for use in power generation and transport applications. According to Biofuels Digest[11], Ocean Nutrition Canada sells biodiesel made from fish oil (although it is not possible to find mention of this on ONC's own website[12]).

The Aquafinca (Tilapia Farm) in Honduras[13] is fully sustainable, using bio-diesel made on site to run 10 generators that power the whole plant plus electricity for housing. The plant uses up 1,368 Kw a day and produces 11,000 litres of fish oil, from which 6,000 litres of bio-diesel can be made.

South East Asia and China, the global hub of fish processing, are also becoming increasingly interested in biodiesel from fish waste.

The efficient use of fish oil from fish waste in a diesel blend, or converted to bio-diesel, is the subject of research by a number of institutions around the world. The Alaska Energy Authority (AEA) has an entire biomass energy program[14], of which fish oil and biodiesel are important parts. Further examples and details are given in the appendix to this document.

3.5 NL competitive position

NL has a wide variety of settings where grid power is unavailable and the alternative is expensive. An example is Flowers River Lodge in Labrador, which recently announced the installation of a wind-solar-battery system to replace a diesel genset. Ramea also serves as an example of an outport with a clear off-grid energy need. At smaller scale, there are numerous marine applications for which small-scale power is needed. Interestingly, the Marine Institute is launching a project to evaluate subsea microgeneration systems. Even more ambitiously, MUN researchers are assessing the creation of a renewably-powered subsea recharging network for RUVs. If successful, all of these could open up large markets within NL, but, more significantly, beyond NL since the techniques would be widely applicable.

---

[10] The Potential for Biomass District Energy Production in Port Graham, Alaska – Final Report, May 2008, EERC, U.S. Department of Energy Tribal Energy Program.

[11] http://www.biofuelsdigest.com/blog2/2007/11/02/canadas-ocean-nutrition-canada-sells-fish-oil-biodiesel-could-reduce-ocean-dumping-of-waste-fish-extract/

[12] http://www.ocean-nutrition.com/

[13] http://aquaticbiofuel.files.wordpress.com/2009/08/fishwaste-biodiesel.pdf

[14] http://www.akenergyauthority.org/programsalternativebiomass.html

General areas of relevant NL capability and current innovation include the following:

- *Design and modelling*: Researchers at MUN, Marine Institute and CNA, for example, are active in identifying energy requirements and designing and simulating systems that meet these needs in concept.
- *Engineering of systems*: The Nalcor-led project to install a wind-hydrogen-diesel system at Ramea has required the development of bespoke control systems to integrate diverse components. At a more conventional level, Nalcor has developed a broad range of diesel genset systems for outport communities.
- *Operation in remote locations*: Nalcor has extensive experience in operating power systems in outport communities. In addition, fish oil production and genset operation in remote settings is well-understood across NL.

3.6 Priority NL innovation opportunities

We recommend that NL prepare a high-level innovation roadmap for the remote energy systems sector. The roadmap should be flexible to the high level of uncertainty regarding the performance and availability of the relevant technologies, avoiding being overly prescriptive. NL has a number of remote energy needs, such as in off-grid outport communities, that would benefit from innovative, remote energy systems. There is also a very large international market opportunity to be exploited and the local market could provide a platform upon which to build.

Although there are numerous businesses and research institutions globally that are focused on remote energy system research, the 'race' has only just begun. It is still possible to acquire a globally competitive position and there are numerous opportunities for national and international collaboration.

NL has a number of strategic advantages. It combines 'developed world' technical skills, with remote energy challenges that are more common in the 'developing world'. It also has some existing innovation activity on which to build. This is focused on the design, modelling, engineering and operation of remote energy systems.

The remote energy systems sector as a whole, and NL's activities in particular, are too immature for us to be prescriptive about priority innovation opportunities. We recommend that the roadmap allow for NL to build options within the sector and that these options be refined and prioritized as the sector and NL's activities mature. An illustration of an options approach is found in the technology development programs of many industrial companies, where a range of competing technology paths are followed in parallel until it becomes clear that some will not be successful and so they are closed off.

4 Marine energy technologies

4.1 Definition

During the screening of energy types, marine energy technologies were mentioned numerous times. The main types that emerged as of potential relevance were offshore wind turbines, wave energy converters and tidal lagoons or barrages (see the screening document). All of these technologies are under development worldwide and, in the case of offshore wind, in the rapid growth phase of commercial deployment in some markets.

4.2 Capabilities and barriers

The relevance of marine energy for NL was strongly debated during our consultations with NL energy stakeholders. Proponents pointed to the local capabilities in system design and testing, detractors referred to the hostile marine environment which makes it unlikely that such devices will be deployed in NL ahead of other more favourable marine locations, or before more readily accessible (onshore) NL resources have been exploited.

What is clear is that NL has a range of proven skills and facilities for marine energy technology design and testing, and these have already come to the attention of developers outside NL who have made use of them. The general NL capability areas were characterised as follows:

- *Design for harsh environment*: World class capabilities resulting from oil and gas industry experience in particular
- *Marine safety*: Vessels and oil and gas installations have been the focus of such skills over many years
- *Autonomous and intelligent systems*: NL skills are increasingly been applied to data gathering and interpretation for marine facilities, with a particular focus on ocean and ice conditions
- *Infrastructure & processing*: Design, simulation and test of supporting infrastructure for marine systems is a core strength
- *Environmental science*: The identification of effects in the marine environment is another strong area

These areas of general capability were combined with our understanding of barriers to marine energy technology commercialisation, as follows.

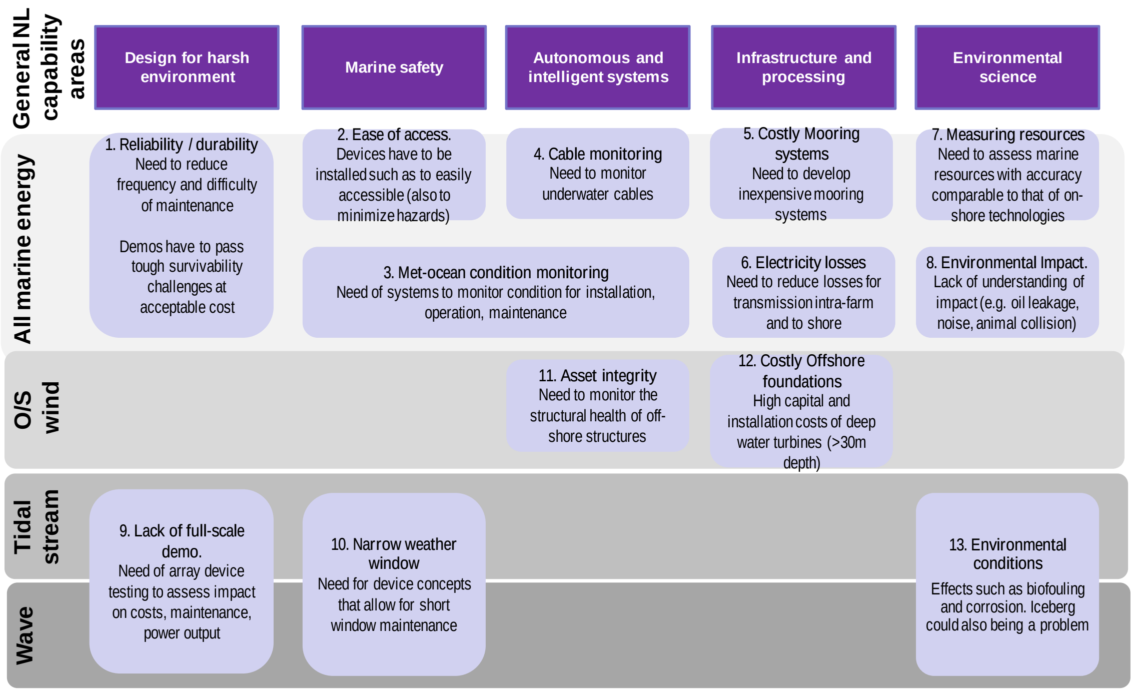

Figure 3: Marine energy technologies - Key barriers matching general areas of NL capability

4.3 Opportunity

The need for innovation in marine energy technology is large. In the case of wave and tidal devices, basic survivability has yet to be achieved at acceptable cost and scale. For offshore wind, there will be incremental challenges as the industry tackles larger and more hostile (i.e., windy) environments.

The opportunity for NL is not local resource development, but service export. The requirement is, therefore, for NL to develop and promote its undoubtedly strong skills and facilities to innovators worldwide. This could take the form of a service export plan or strategy for the sector, involving trade promotion and other means to attract innovators.

Since this opportunity does not constitute an innovation opportunity for NL innovators, it was not evaluated further for the purpose of establishing energy innovation priorities for roadmapping. The innovation benefits will accrue to the users of NL services, though NL will gain greater skills and knowledge in the field – enhancing the value of its services.

5 Energy Efficiency

5.1 Definition

There is a set of applications and disciplines that serve to reduce the need for heat and power ('energy conservation') and the rate of their use ('energy efficiency'). For simplicity, these are both referred to as energy efficiency in this document.

Energy efficiency can be applied to buildings, transport and industry. In the NL context, transport could be air, sea and/or road. The efficiency of air and road vehicles is largely controlled by decisions beyond NL, so these were set aside. The efficiency of (small and medium) marine vessels is an area that NL has some influence over – for example, in the installation of bulbous bows for fishing vessels. However, this was seen by most as an area that has more to do with overall marine strategy than with energy strategy and, as such, was not pursued here.

5.2 Barriers

The two areas that remain in scope – buildings and industrial efficiency - face numerous barriers. It is well understood that many efficiency technologies exist, and are available 'off the shelf', yet are not adopted. To illustrate this, below is a cost curve for energy efficiency measures that profiles the average cost of energy (i.e., the cost of doing nothing). While most measures are significantly cheaper, they remain unimplemented.

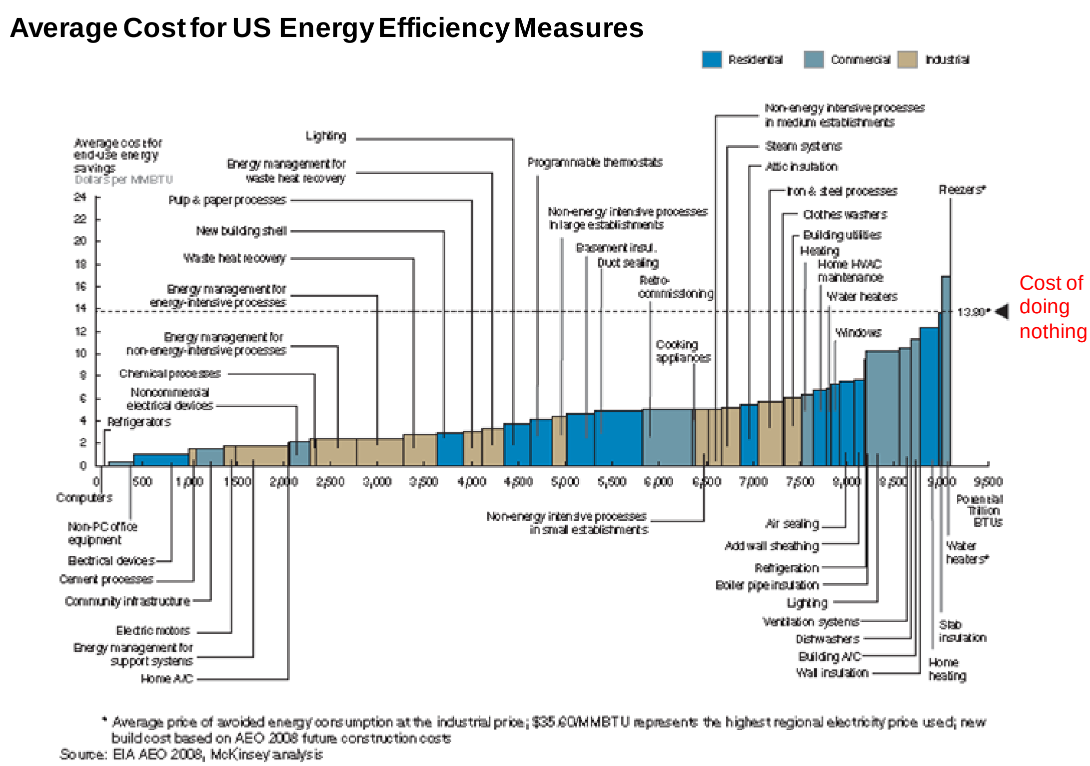

Figure 4: Average cost of energy efficiency measures compared with average energy cost (US)

The reasons for the lack of implementation are explained by the barriers below.

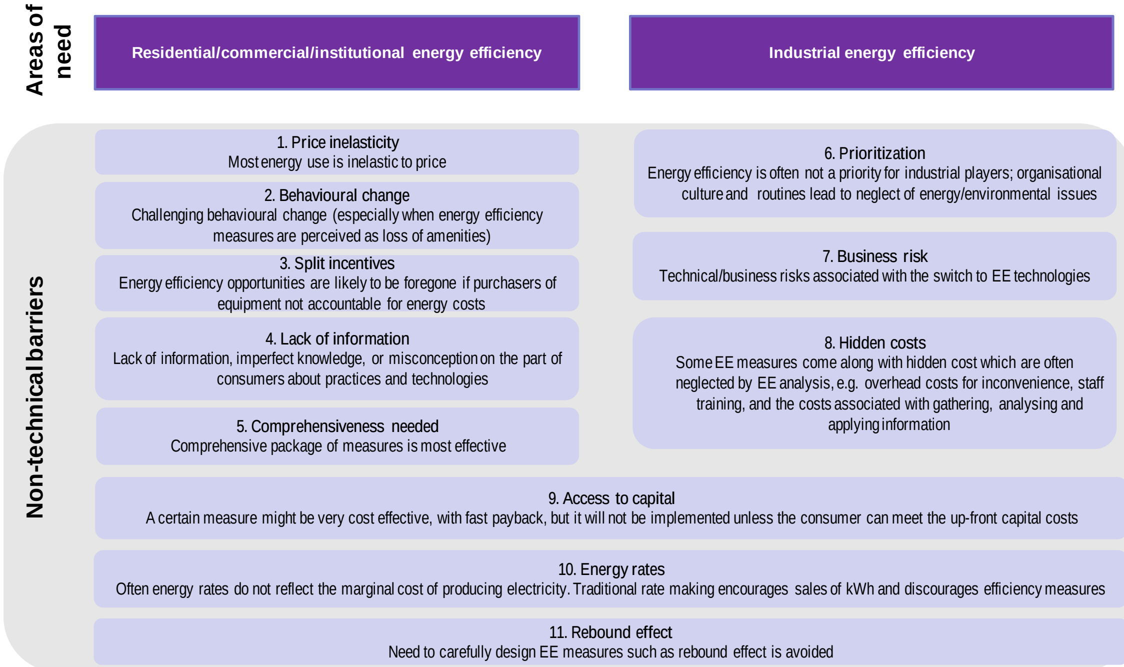

Figure 5: Energy efficiency – Common barriers to buildings and industrial efficiency

All of these barriers are non-technical and so technological innovation is not the key to addressing them. They are not a recommended innovation priority area therefore.

Resolution of these barriers relies upon a range of measures, many of which have policy at their root. Examples include:

- Data to encourage a shift in attitudes amongst consumers, including real time energy metering;
- Information programmes about the available options for energy efficiency;
- Energy price adjustment, for example through taxation, to motivate change. This revenue can be recycled back to assist with other measures;
- Regulation to enforce efficiency by, for example, landlords who would otherwise have no incentive;
- Loans, subsidies and grants for energy efficiency measures; and
- Measures to ensure that energy cost savings through efficiency do not result in consumers using more energy (e.g. raising heating temperatures after insulating houses). This is known as the ‘rebound effect’.

6 Appendix: Leading remote energy systems innovators worldwide and their research priorities

The principal players involved in innovation in remote energy systems have been profiled in Section 3.4 above. More detailed information is given for selected areas below.

6.1.1 Remote energy

Utilities, energy and telecommunications companies

Within Canada, there has been considerable interest from governments and utilities in wind-diesel systems for remote communities, although it appears that capital and operating costs remain significant barriers to more widespread adoption. Whereas manufacturers and developers believe that these systems are technically viable, there also appears to be less certainty on the part of the utilities.[15] Moreover, there may be opportunities to replace diesel with hydrogen-based systems in the future.

Yukon Energy[16] (Yukon's publicly owned electrical utility), for example, produces most of its electricity from Hydro plants, but the utility is continuously investigating ways in which to reduce the use of diesel as back-up power. The Yukon Energy Portable Solar-Hybrid demonstration unit (battery storage) can provide enough power to run common household items, well pumps and power tools, and is currently being trialled at various locations within the territory.

Outside of Canada, ***Gas Natural***[17] is one of the largest European energy multinationals and the largest global LNG operator in the Atlantic basin. The company has a particular emphasis on supporting the use of hydrogen as a future energy vector: the website home page states 'bringing together electricity and hydrogen isn't a step, it's a leap'. In February 2008, in order to demonstrate the feasibility of hydrogen for power balancing, the company launched a new hydrogen production and storage plant at the Sotavento wind farm in Galicia.

Research centres and Universities

Selected research centres that conduct research into complete wind/hydrogen hybrid energy systems are given in the table below:

Location	Institution	Examples of research areas relating to remote energy systems
Colorado	NREL	NREL – Xcel Energy Wind to Hydrogen project[18] (W2H2) demonstration project at the National Wind Technology Centre: optimisation of wind turbines and PV array coupling to electrolyser systems and stacks
PEI, Canada	WEICan/PEI Energy Corporation	Wind-Hydrogen village. A hydrogen production system consisting of a load regulator, electrolyser, gas holder, compressor, gas control panel, storage tanks, genset package and control systems required to integrate all components

[15] Energy Policy, Volume 36, Issue 5, May 2008, Abstract, Stakeholders' perspectives on barriers to remote wind–diesel power plants in Canada

[16] http://www.yukonenergy.ca/

[17] http://portal.gasnatural.com

[18] http://www.nrel.gov/hydrogen/proj_wind_hydrogen.html

Massachussettes, US	University of Massachussettes; Centre for Energy Efficiency and Renewable Energy (CEERE)	The Renewable Energy Research Laboratory (RERL)[19]. Focus includes hybrid power systems and renewable energy software development. For example, Hybrid2 is a probabilistic/time series computer model, using time series data for Loads, Wind speed, Solar insolation, Temperature and the power system designed or selected by the user, to predict the performance of the hybrid power system. The hybrid systems may include three types of electrical loads, multiple wind turbines of different types, photovoltaics, multiple diesel generators, battery storage, and four types of power conversion devices
North Dakota, US	University North Dakota: Energy and Environmental Research Centre (EERC)	The EERC is home to the National Center for Hydrogen Technology (NCHT). Areas of expertise include: producing clean hydrogen from renewable resources; economic hydrogen production at ethanol plants; fuel cell development; integration of hydrogen production and fuel cells; demonstrating the production of hydrogen from wind power; hydrogen production from renewable fuels; innovative wind storage and hydrogen technologies
Minnesota, US	University of Minnesota	Hybrid Energy System Study: a partnership project between the University of Minnesota Rochester and Rochester Public Utilities which focused on integrating fuel cells, geothermal energy, and digital system controls into a complete alternative energy system. The total project cost, including the value of the laboratory, was $375,000
Germany	ISE (Fraunhofer Institute for Solar Energy Systems)	The largest solar energy research institute in Europe, with a focus on the developing systems, components, materials and processes in the fields of thermal use of solar energy, solar building, solar cells, electrical power supplies, chemical energy conversion, energy storage and energy efficiency. The institute develops develop stand-alone power supply systems based on photovoltaics (PV), fuel cells, wind energy and hydroelectricity in applications ranging from portable appliances through to stationary technical power supplies and the rural electrification of huts and villages The institute has approx 900 staff and an operating budget of EUR52 m (CAN$75 m)
Greece	Centre for Renewable Energy Sources (CRES)	CRES undertakes applied research and provides technical support in the following sectors: wind energy, biomass, PV, mini-hydro, geothermal, renewable energy/hydrogen technologies and emerging renewable technologies Activities include the implementation of integrated applications of renewable energy; energy systems analysis and the development and management of information systems, databases and energy models The wind park at CRES contains a pilot unit for hydrogen production from wind incorporating a 500 kw Enercon wind turbine; a 25kw alkaline electrolyser; novel metal hydride storage tanks; a hydrogen filling station and a central control and data recording unit. The unit was developed in the context of the EC funded RES2H2 project in co-operation with other partners including C. ROKAS SA (compressor, filling station) and FIT in Cyprus (metal hydride storage tanks)
UK	Loughborough University (CREST)	Research activities cover a range of technical applications, including wind power, solar PV, energy in buildings, grid connection & integration and energy storage (including hydrogen).

[19] http://www.ceere.org/rerl/index.html

The IEA's Implementing Agreement for Hydrogen[20], also encompasses areas of research of relevance to remote hybrid systems. Of particular interest is Task 24: ***Wind Energy and Hydrogen Integration*** (2006-2009)[21]. Specific subtasks included 'Technology development on main equipment and system integration concepts' and 'Wind energy management within the wind & hydrogen full integration concept'. The task incorporates a wide range of applications from stationary devices and off-grid systems to transportation and large-scale wind farms. Planned tasks include 'Hydrogen infrastructure and mass storage'. The W2H2 project, Wind-Hydrogen Village and RES2H2 project (see table above) all contributed to Task 24.

System design and installation businesses, and specialist consultancies

There are numerous businesses that have expertise in the bespoke design and installation of hybrid systems using available technology. Many of these have a focus on a single primary power source (generally solar or wind) and the majority use battery storage. Examples are:

Energy Development Co-operative Ltd[22] specialises in off-grid solar and wind power design, and since 1998, has installed over 5,000 independent power systems worldwide. Storage systems are based on batteries.

SunEnergy Inc.[23] specializes in solar energy solutions for remote and island resorts as well as local communities. Their business is based around the design and manufacture of solar inverters with advanced communications and remote management capabilities, and are suitable for military use. The company also provides large hybrid solar systems incorporating solar, diesel, wind, battery, fuel cell and other technologies.

Isofoton[24] was set up in 1989 as a solar photovoltaics manufacturing and design company, based in Malaga, Spain. The company now operates a Research and Manufacturing Centre with a focus on renewable energy and energy efficiency. The TINA[25] project was set up to demonstrate a solar PV/hydrogen fuel cell hybrid system, in order assess reliability, safety and economics of the installation.

The ***Beijing Bergey Windpower Co,***[26] serving as the main R&D base for the Bergey Windpower Company (BWC, Oklahoma), provides tailor made solutions for hybrid systems using PV, wind, diesel and batteries with applications in telecommunications, and for rural electrification.

IT Power[27] is a UK-based consultancy providing practical and quality advisory services in sustainable energy and climate change. IT Power has in-house technical expertise covering the whole range of sustainable energy technologies including hybrids and cogeneration. Unlike many

20 http://www.ieahia.org

21 http://task24.hidrogenoaragon.org/

22 http://www.solar-wind.co.uk/

23 http://www.sunenergy.com.au/index.php

24 http://www.isofoton.com/energy-solutions/products/

25 http://www.isofoton.com/energy-solutions/developments/solar-hydrogen/

26 http://www.bergey.com.cn/english/Index.asp

27 ITPower.co.uk

installers/manufacturers, the company offers independent advice, without affiliation to any project developers or equipment suppliers.

Innovation Energie Développement[28] provides a range of services covering the entire project cycle associated with decentralized rural electrification (DRE), such as

- Strategic development programming;
- Demonstration and information dissemination;
- Project and impact assessments;
- Financial evaluations and financial engineering;
- Assistance to private project developers;
- Feasibility, engineering and project execution studies;
- Technical assistance to project execution;
- Project management; and
- Project identification and development.

Technical knowledge covers all generation options for DRE systems, including diesel, solar PV, wind, and hydro.

Hydrogenics[29] designs, manufactures and installs commercial hydrogen systems around the world, including hydrogen storage systems (electrolysis plus fuel cells) for remote renewable power generation**.**

The ***Pure Energy™ Centre***[30], a renewable hydrogen system developer specialising in renewable energy, hydrogen and embedded electricity technologies. The centre grew out of the PURE (Promoting Unst Renewable Energy) demonstration project for a self contained wind/hydrogen remote energy system. The centre now offers training, consultancy and project management as well as a range of facilities for R&D (e.g., logging and performance monitoring; hydrogen electrolyser (data-logged); hydrogen storage (high pressure and low pressure); fuel cells (data-logged); wind to heat system (continuous monitoring); renewable energy generating plant test equipment).

Their own scalable Hydrogen Production Module (HyPOD) combines alkaline electrolyser technology with either Grid, Solar, Wind, Hydro, Wave and/or Tidal power, and can be used for applications ranging from small community owned, public or government sites to large-scale commercial and industrial installations.

International aid agencies, NGOs

There are a number of aid agencies and NGOs that have considerable experience in supporting innovation in the deployment of remote-powered systems (often solar-based). These include:

The ***Alliance for Rural Electrification***[31] which promotes and provides efficient renewable solutions for rural electrification in developing countries. A number of working groups within the organization

[28] http://www.ied-sa.fr/

[29] http://www.hydrogenics.com/about/

[30] http://www.pure.shetland.co.uk/html/index.html

[31] http://www.ruralelec.org/

focus on different challenges to rural electrification. In 2008, the Working Group on Technological Solutions produced a position paper entitled 'Hybrid power systems based on renewable energies: a suitable and cost-competitive solution for rural electrification', and the group is now focusing on providing support schemes for renewable energy projects in developing countries. This will include support for the training of local staff in operation and maintenance.

The **World Bank**[32] and **GVEP (Global Village Energy Partnership)**[33] are also active in supporting projects (primarily through funding and promoting partnerships) associated with improving access to energy for rural communities. Although not directly related to technological innovation, these help improve the availability of data regarding reliability, ease of maintenance, etc. Two examples of World Bank projects are:

Mongolia – Renewable Energy for Rural Access	Project aims are to increase access to electricity and improve reliability of electricity service among the herder population and in off-grid soum centers by: (i) assisting the development of institutions and delivery mechanisms; (ii) facilitating herders' investments in Solar Home Systems (SHSs) and small Wind Turbine Systems WTSs; and (iii)rehabilitating mini grids in selected off-grid soum centers
Nicaragua – off-grid rural electrification	Project aims are assisting the Government of Nicaragua (GON) in designing and implementing its national rural electrification strategy; (b) implementing innovative public/private offgrid electricity delivery mechanisms in several pilot sites, for later replication on a national scale; and (c) demonstrating, in the pilot areas, how sustainable targeted rural microfinance and business development services (BDS) can significantly increase the development impact of rural electrification

Collaborative organisations and programmes

National and international large-scale collaborative programmes have been initiated in order to support innovation in remote energy systems. The IEA Wind to Hydrogen, and the Alliance for Rural Electrification (described above) are two examples. Another interesting example is the **Foundation for the Development of New Hydrogen Technologies**[34] in Aragon. This not-for-profit organisation, founded in 2004, is made up of 62 partners from Industry, research centres and the Aragon Administration. It is responsible for engineering and consultancy services, as well as R&D that is focused on hydrogen generation, storage and fuel cell integration.

Within Canada, the **Integrated Community Energy Solutions** 'roadmap for action' (2009)[35] sets out to improve community energy performance, while simultaneously contributing to federal, provincial and territorial governments' energy efficiency and climate change objectives. The roadmap focuses all sectors that influence the production and consumption of energy (including generation, distribution, transport, buildings and industry), but notes that ICES can be scaled to meet all needs, including remote rural communities. The roadmap therefore contains a strong endorsement for the use local renewable energy resource potential, district energy systems, decentralized energy systems, grid management initiatives and community thermal and electrical storage.

---

[32] http://www.worldbank.org/

[33] http://www.gvepinternational.org/

[34] http://www.hidrogenoaragon.org/

[35] Council of Energy Ministers, Integrated Community Energy Solutions, A Roadmap for Action, Sept 2009.

The roadmap also highlights the need for co-operation between wide range of stakeholders, including federal, provincial, territorial and local governments; developers and private enterprises; energy companies, utilities and regulators.

Existing case studies for small communities from Canada include:

Hairy Hill Integrated BioRefinery, Vegreville, Alberta, a technology pilot using anaerobic digestion to produce biogas from manure obtained from a large feedlot. The biogas is used in turn to generate electricity and, soon, to manufacture ethanol.

Oujé-Bougoumou District Heating, Oujé-Bougoumou, Quebec, provides village-wide heating to efficient homes and buildings using wood waste (biomass) as the fuel source and hot water as the energy transfer medium. This technology forms part of the ongoing community revitalization and self-sufficiency efforts.

6.1.2 Fish waste to energy

The efficient use of fish oil from fish waste in a diesel blend, or converted to bio-diesel is the subject of research by a number of institutions around the world. Some examples are given in the table below.

Location	Institution	Examples of research areas relating to remote energy systems
Alaska	University of Alaska Fairbanks	This university was involved in the AEA biodiesel study, and has a major focus on fisheries and ocean science. Research within the Fishery Industry Technology Centre is focused on 'harvesting technology, processing technology, seafood quality and safety, contaminants and collaborative ecosystems research directed towards building the prudent and sustainable utilization of Alaska's fisheries resources'. [36] This includes project 'to determine the effectiveness of enzymatic hydrolysates made from fish waste as a nitrogen source in biogas generation. The biogas could be used to lower electrical costs at remote locations.'
North Dakota	University North Dakota: Energy and Environmental Research Centre (EERC)	The EERC incorporates the Centres for Renewable Energy and Biomass Utilization[37] which conducts research, development, demonstration, and commercial deployment of technologies utilizing biomass, wind, solar, geothermal, and hydroelectric energy sources. In 2007, the EERC conducted a study into the The Potential for Biomass District Energy Production in Port Graham, Alaska [38], concluding that utilization of a fish oil–diesel fuel in existing energy infrastructure was economically viable, alongside the installation of indoor wood boilers for the Chugachmiut communities
Vancouver, BC	Clayoquot Biosphere Trust	The Clayoquot Biosphere Trust (CBT) is responsible for running the Clayoquot Sound UNESCO Biosphere Reserve[39]. In 2007, they commissioned a report from the Sustainable Community Enterprises to conduct to conduct an initial feasibility study on the production of fish oil into biodiesel. The report[40] concluded that that at a price of $1.10 per liter of biodiesel, the payback time for

[36] http://www.sfos.uaf.edu/fitc/

[37] http://www.undeerc.org/programareas/renewableenergy/default.asp

[38] The Potential for Biomass District Energy Production in Port Graham, Alaska – Final Report, May 2008, EERC, U.S. Department of Energy Tribal Energy Program.

[39] http://www.clayoquotbiosphere.org/

[40] A Feasibility Study for Fish Oil Biodiesel Production – Final Report, Sustainable Community Enterprises for the Clayoquot Biosphere Trust, November 2007

		a self-built biodiesel processor, producing 250,000 liters per year for 4.2 years, and that biodiesel production was in keeping with the reserve's environmental and sustainability policies
Taiwan	National Taiwan Ocean University	Responsible for 2009 article in 'Fuel Processing Technology',[41] 'Engine performance and emission characteristics of marine fish-oil biodiesel produced from the discarded parts of marine fish'
Finland	VTT	ENERFISH, a three year project, launched in collaboration with Hiep Thanh Seafood JSC in Vietnam (2008) to produce bio-diesel from catfish waste, with plans for 120,000 litres of bio-diesel a day. The project aims to demonstrate the latest biodiesel production equipment
Spain	Anfaco-Cecopesca	In 2007 The National Technological Centre for the Canning of Fish Products in Spain (Anfaco-Cecopesca**)**, investigated ways in which fish fat which is found in waste water generated by the canning industry can be used for the manufacture of bio-diesel. A regional government grant of EUR 111 119 (US$ 152 134.45) was given to the project which was being carried out in Galicia[42]

[41] Fuel Processing Technology, Volume 90, Issues 7-8, July-August 2009, Pages 883-888

[42] http://aquaticbiofuel.files.wordpress.com/2009/08/fishwaste-biodiesel.pdf