

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

**Screening Document:
Other energy types**

Final Report

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1 Context

This study, the first phase of a Newfoundland and Labrador energy innovation roadmapping exercise, was guided by a Steering Committee that was led by the Department of Natural Resources and included representatives from the Research & Development Corporation - Newfoundland and Labrador, Department of Innovation, Trade and Rural Development, Department of Business and Nalcor Energy. 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 project took place between September 2009 and March 2010, following a structure that narrowed down 31 energy types into innovation priority areas. The process, reflecting the difference between energy types, involved analyzing energy types based on both resource potential and opportunities for innovation in Newfoundland and Labrador that could add to value in overcoming barriers for local and/or external development.

The Energy Plan introduced the concept of an ‘Energy Warehouse,’ which featured several key resource types— onshore wind energy, hydroelectricity, and oil and gas, supported by transmission. Detailed evaluation has been applied to the areas of energy that fall within the Energy Warehouse concept.

The Energy Plan also identifies several other energy types that could offer opportunities for NL, though it is less specific about which should be priorities. A long list of energy types was initially assessed at high level for their fit with local physical and human resources, and the promising energy types were grouped into themes for further analysis. This screening and grouping process is the subject of this document.

The overall project process showing the context for this screening document is set out in Figure 1 below.

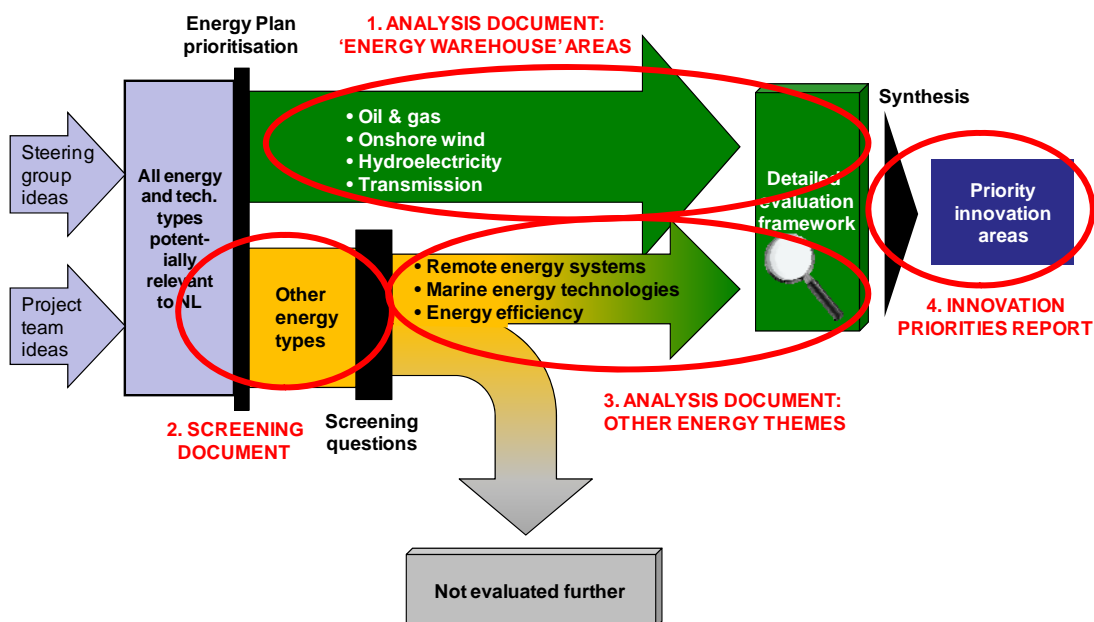


Figure 1: Overall project process and outputs

Methodology

1.1 Long list of energy types

A long list of energy types was drawn from the Energy Plan, noting all of the energy types mentioned which have potential relevance to NL, and from additional input by the consultants. The energy types cover energy resources, conversion processes and applications and also include energy efficiency. To qualify for the list, innovations within a given energy type needed to be conceivable in NL given the physical and economic context. So, for example, innovation in uranium extraction and processing was included, but nuclear fusion was not since the latter is very unlikely to be developed and deployed in NL and there is no base for such innovation. That is, it is not conceivable that innovations in nuclear fusion would occur in NL in the foreseeable future. However, depending on the economics, it is not inconceivable that innovations in uranium extraction and processing might occur within the province. The long list of energy types considered is shown in Figure 2 below.

Category	Energy type	Energy sub-type
Renewable Energy resources	Wind	<ul style="list-style-type: none"> •Offshore wind •Small-scale wind •Novel wind concepts
	Ocean	<ul style="list-style-type: none"> •Wave •Tidal (Stream) •Tidal (Barrage) •Novel
	Biomass	<ul style="list-style-type: none"> •Feedstock supply •Waste to energy •First generation biofuels •Lignocellulosic biofuels •Power generation •Small scale heat •Large scale heat/CHP •Biogas and synthetic natural gas
	Solar	
	Geothermal	
Novel Energy carriers	Hydrogen	<ul style="list-style-type: none"> •H2 production, bulk storage and distribution •H2 use
Non renewable energy	Uranium	<ul style="list-style-type: none"> •Uranium Exploration, Extraction and Pre-processing •Nuclear Power generation and Waste Treatment
	Peat	
	Oil shale	
Energy efficiency and conservation		

Figure 2: Long list of energy types for assessment against criteria

1.2 Screening criteria

The screening criteria chosen were reflective of the goals of the overall project – to identify areas of technological energy innovation in which NL could attain competitive advantage. Four questions were chosen:

Does NL have (or could NL have) sufficient local resources? This would include:

- Local *natural* resources (e.g., wind resources); and/or
- Existing local assets (e.g., docks, district heating system).

Is the energy type consistent with the Energy Plan? Does it facilitate or enable:

- Environmental leadership;
- Energy security;
- Sustainable economic development;
- Optimization of electricity export value;
- Optimization of long term value for oil and gas; and
- Effective governance.

Is technical innovation required? This would:

- Address whether the innovation that is required is technical (i.e., not market, company or regulatory); and
- Avoid producing solutions that are based on wishful thinking, rather than true market needs.

Is it feasible that NL has/could have appropriate capabilities to meet the challenge? This would consider:

- Existing capability (e.g., University department, industrial base, etc.); and
- International competitiveness.

The questions were answered based on information gathered in discussion with energy stakeholders in NL and through subsequent assessment by the consultants and the steering committee. Detailed primary analysis was not applied, however, because most of the answers became evident by inspection. In case of doubt, the assessment erred towards inclusion rather than exclusion. The main evidence used in answering the questions is shown in this report.

The answers to the screening criteria were summarised as yes (green) / maybe (amber) / no (red). Each of the questions was a 'gateway' so that a 'no' (red) against any energy type resulted in exclusion of the energy type. Colour codes denoting the answers have been applied to the questions in the sections that follow and these are also summarised in tabular form in section 6 of this report

The energy types that emerged from the screening were then considered to see if they had common features. Common themes were identified, as discussed in section 6, and these themes were carried forward for more detailed analysis (see 'Analysis document: other energy themes' above).

2 Renewable Energy Resources

2.1 Wind

2.1.1 Offshore Wind

Fundamentals /working principle

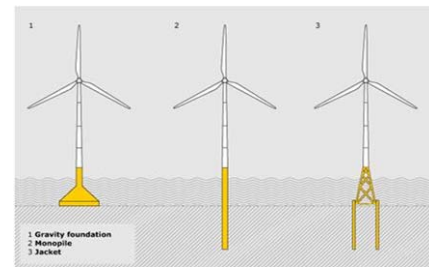
- Moving air causes rotation of the turbine blades which drive a generator. Extractable power varies as the wind-speed cubed
- Winds fluctuate with weather, season and time of day. This “intermittency” leads to variable wind power outputs. Winds are stronger at greater heights, and further offshore
- Use marinised onshore turbine designs, but usually larger (fewer height or visual impact restrictions), and foundations vary (e.g. gravity, monopile, lattice jackets, or floating)

Development status

- Offshore turbine technology is near commercial – but still comparatively expensive compared to onshore wind
- Cost increases (steel prices and project costs) from ~£1m/MW in 2004 to a peak of ~£3m/MW for planned projects today. Very large 5+MW turbines becoming more common offshore
- Globally, 1,473 MW was in operation at the end of 2008 (a growth rate of 30%), with more than 99% of this in Europe. UK leading market, followed by Denmark and Germany
- Reliability, survivability and ease of access in tough ocean conditions are major issues. Accessing deep water resources, grid connection costs and availability of construction facilities are among the major hurdles for developers



Source: ksitracker.mit.edu/2009/06/page/2/



Source: zueblin-offshore.de

Figure 3: Overview of offshore wind

1. Do we have (or could we have) sufficient local resources?

- Yes: world-class offshore wind resources. Also have large dock and shipping facilities

2. Is the energy type consistent with the Energy Plan?

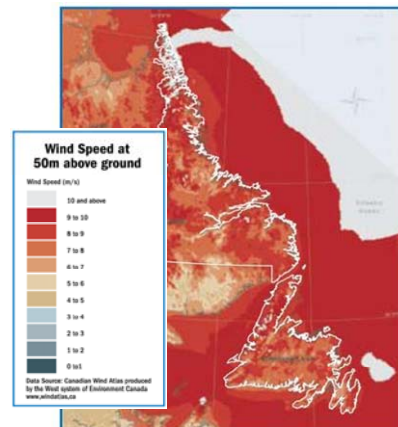
- Wind power is mentioned as playing a role of primary importance in NL, however, offshore wind is not mentioned – every mention of wind only refers to onshore resources since these are equally abundant, cheaper, and more accessible
- Remote communities are all coastal, close to offshore resource

3. Is technical innovation required?

- Innovation is required in larger MW designs, ease of installation, corrosion resistance, survivability, deep water foundations, and greater reliability / lower maintenance

4. Is it feasible that NL has/could have appropriate capabilities to meet the challenge?

- Vast majority of developers currently located in Europe
- NL are looking to utilize the skills and infrastructure developed in the manufacturing and fabrication sector to expand into wind power activities, e.g. making towers, bases, turbine blades in NL
- Offshore wind supply chain much smaller, less competition
- NL also have extensive offshore and iceberg knowledge from the oil and gas industry, and ocean expertise



Source: NL Energy Plan

Figure 4: Gateway questions – offshore wind

Conclusion: carry forward offshore wind for evaluation as skills and resources are strong.

2.1.2 Small-Scale Wind

Fundamentals/working principle

- Moving air causes rotation of the turbine blades which drive a generator. Extractable power varies as the wind-speed cubed
- Winds fluctuate with weather, season and time of day. This “intermittency” leads to variable wind power outputs. Winds are stronger at greater heights, and further from the turbulence caused by buildings & obstructions
- Turbine designs vary widely, with horizontal axis upwind or downwind concepts, differing numbers of blades (2 or more), vertical axis and helical concepts. Small-scale generally refers to <50-100kW, micro generally refers to <1kW: both can be on- or off-grid. Building mounted designs are rare

Development status

- US dominates the global market, in front of UK, Japan and Canada. 39MW (19,000 units) were sold in 2008: a growth of 53%, to \$156m in sales. Market momentum is now heavily in favour of grid-connected turbines
- Growth has been largely due to high demand, the availability of capital and inventory, and the evolution of manufacturing economies of scale. 23 manufacturers are present in Canada. Most provinces offer net metering, but consumer financial incentives are currently missing
- Globally, ¼ of 50-100kW turbines sold in 2008 were for remote wind-diesel hybrid systems, mainly in Alaska and Canada – incentives are increasing, and demand is very high. CanWEA is forecasting 30% annual growth in this segment of the Canadian small-scale wind market



Source: better generation, Google Images

Figure 5: Overview of small-scale wind

1. Do we have (or could we have) sufficient local resources?

- Yes: world-class onshore and coastal wind resources

2. Is the energy type consistent with the Energy Plan?

- Small-scale wind is mentioned in the Energy plan, although it plays a less prominent role when compared to hydro, oil and gas, and large onshore wind:

“A number of other technologies, including [...] small-scale wind, ... might be able to contribute to our electrical supply

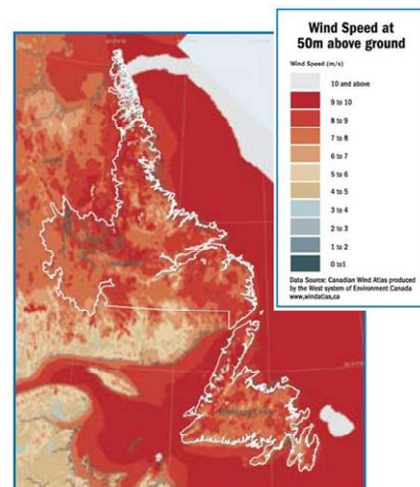
- Demand for clean, cheap energy in small isolated communities

3. Is technical innovation required?

- Innovation is required in site resource assessment technology, blade and alternator efficiency, larger rotors, fewer components, improved low wind performance, faster installation and the integration and control of hybrid systems

4. Is it feasible that NL has/could have appropriate capabilities to meet the challenge?

- NL are looking to utilize the skills and infrastructure developed in the manufacturing and fabrication sector to expand into activity related to the wind power industry
- Good fit with small-scale wind, since costs rely heavily on manufacturing techniques and volume (1000's units). However, limited NL experience, Canadian small wind manufacturers mainly based in ON and BC
- Ramea island experience: control and operation of wind-diesel system since 2004, and now design and construction of the expanded wind-hydrogen-diesel energy storage system



Source: NL Energy Plan

Figure 6: Gateway questions – small-scale wind

Conclusion: carry forward small-scale wind for evaluation as resources are strong and there are some skills in applications engineering.

2.1.3 Novel Wind Concepts

Rotating aerostat

- Magenn based in US & Canada. Prototype testing since 2006, manufacturing rollout planned to start by 2010
- Magenn Air Rotor System (MARS) operates at 300m altitude, 100kW rated power, balloon volume 5,700m³

Kites

- Kitegen, Italy. 30kW unit testing in 2006, generator will be installed near Asti at the end of 2009
- Two configurations: stem or carousel, altitudes 100-1,000m

Flying Electric Generator (FEG)

- Sky WindPower Corporation, USA. Tested twin 3.7m rotor at 20m, and designed a 240kW unit for altitudes of 5,000m+, weighing 520kg
- FEG tilts into the wind to maximise blade area, and can draw power to stay aloft if needed

Balloons in motion

- TWIND is a concept of Zanettistudios, Italy. Looking to define technical specifications, promote the product and develop test facilities and IP
- Operates at 800m altitude, 50kW rated power, weight 2,000kg

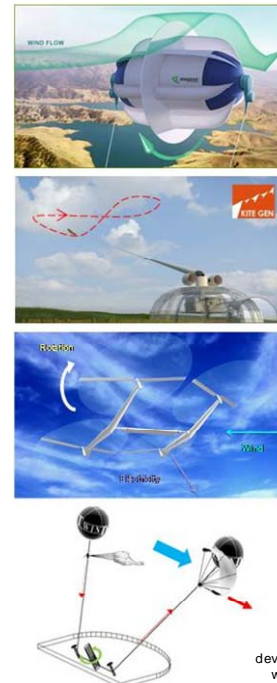


Figure 7: Overview of novel wind concepts

1. Do we have (or could we have) sufficient local resources?

- Yes: world-class onshore and coastal wind resources, which translates into even stronger winds at higher altitudes

2. Is the energy type consistent with the Energy Plan?

- Novel wind concepts are considered in the Plan
- Demand for clean, cheap energy in small isolated communities

3. Is technical innovation required?

- Innovation is required across the entire value chain, as the technologies are only at the prototype and demonstration stages

4. Is it feasible that NL has/could have appropriate capabilities to meet the challenge?

- The few developers are currently located in the USA and Italy – there is no previous NL experience
- NL are looking to utilize the skills and infrastructure developed in the manufacturing and fabrication sector to expand into activity related to the wind power industry – however, the materials for these novel concepts are quite different from the onshore wind industry (mainly light-weight, high tensile strength cables, and durable thin sails, as opposed to steel and fibreglass)

Figure 8: Gateway questions – novel wind concepts

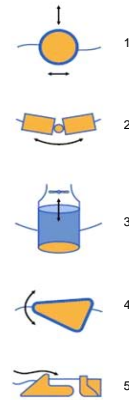
Conclusion: do not carry novel wind concepts forward as NL capabilities not suited to innovation needs.

2.2 Ocean

2.2.1 Wave

Fundamentals/working principle

- Wave power devices harvest energy from the surface motion of waves and/or from pressure fluctuations below the sea surface
- Five main types of devices can be identified
 - Point absorber. Floating structure that absorb energy through its movement at/near the surface
 - Attenuator. Floating device which works parallel to the wave direction and "rides the wave"
 - Oscillating water column. Partially submerged hollow structure where waves cause the water column to rise and fall and drive an air turbine
 - Oscillating wave surge converter. Pendulum like structure that extract the energy cause by wave surge
 - Overtopping device. Captured wave water in a reservoir generate electricity via low -head turbine



Source: OREG

Development status

- Technology still in its infancy
- No clear winner yet among device types and companies
- Reliability, survivability and ease of access in tough ocean conditions are major issues
- Need of extensive field testing and grid connection costs are among major hurdles for developers

Figure 9: Overview of wave energy

1. Do we have (or could we have) sufficient local resources?

- Some wave resources, but in general, lower resource when compared to West coast (see mean wave power on maps, right)

2. Is the energy type consistent with the Energy Plan?

- Wave is mentioned in the Energy Plan, although it plays a less prominent role when compared to hydro, oil and gas, and wind.

"Untapped potential also exists in other energy sources, such as wave and tidal energy, wood, peat, methane captured from landfills and solar energy in some areas."

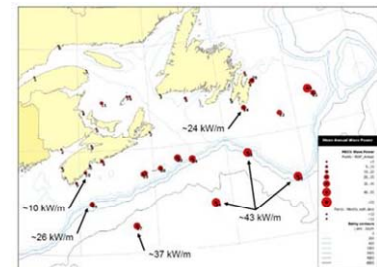
- Wave resources are far from isolated communities, so wave does not mitigate that issue

3. Is technical innovation required?

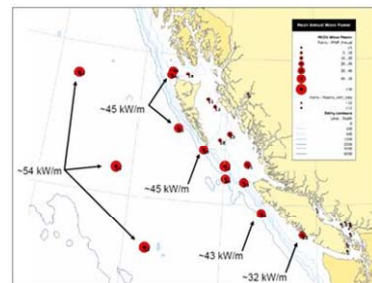
- Innovation is required across the entire value chain

4. Is it feasible that NL has/could have appropriate capabilities to meet the challenge?

- Most developers are currently located in the UK, USA, Norway. Some in Canada, but mostly in BC and NS



Annual mean wave power for sites in the NW Atlantic. Source: NRC



Annual mean wave power for sites in the NE Pacific. Source: NRC

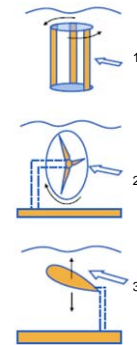
Figure 10: Gateway questions – wave energy

Conclusion: carry forward wave energy for evaluation as innovation required which may match local capabilities and there is some local primary resource.

2.2.2 Tidal (stream)

Fundamentals/working principle

- Tidal currents occurs when seabed forces the water to flow though narrow channel (flow and ebb current)
- Distinct advantage of being highly predictable
- Three main engineering approaches to tidal energy converters (TEC)
 1. Vertical Horizontal axis turbine
 2. Horizontal axis turbine
 3. Oscillating hydrofoil



Source: OREG

Development status

- Tidal current turbines is still in its infancy
- Several full-scale and down scaled demonstration devices installed, but only few built and successfully tested in harsh tidal currents.
- All full-scale operational tidal currents demo devices are horizontal axis turbine, suggesting this might be the optimal configuration
- UK is by far the leading country in tidal current, followed by USA, Canada (mainly West coast), and Norway
- Reliability, survivability and ease of access in tough ocean conditions are major issues
- Need of extensive field testing and grid connection costs are among major hurdles for developers .



SeaGen, first commercial tidal stream device in operation Source: Sea Generation Limited

Figure 11: Overview of tidal (stream)

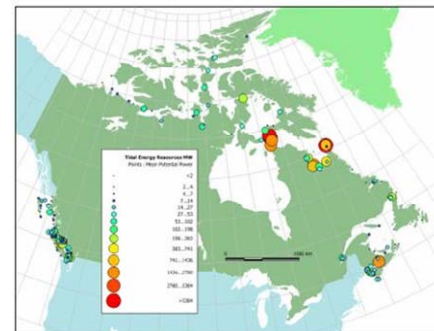
1. Do we have (or could we have) sufficient local resources?

- Some clear tidal stream resources (Strait of Belle Isle, Forteau, Pointe Armour, Pike Run)
- Lower resource in general when compared to Hudson Strait, Nova Scotia, and Vancouver Island Mainland

2. Is the energy type consistent with the Energy Plan?

- Tidal is mentioned in the Energy Plan, although it plays a less prominent role when compared to hydro, oil and gas, and wind.

"Untapped potential also exists in other energy sources, such as wave and tidal energy, wood, peat, methane captured from landfills and solar energy in some areas."



Leading potential tidal current power sites in Canada. Source: NRC

3. Is technical innovation required?

- Yes, Innovation is required across the entire value chain, particularly in testing for reliability and survivability.

4. Is it feasible that NL has/could have appropriate capabilities to meet the challenge?

- Most developers are currently located in the UK, USA, Norway. Some in Canada, but mostly in BC and NS

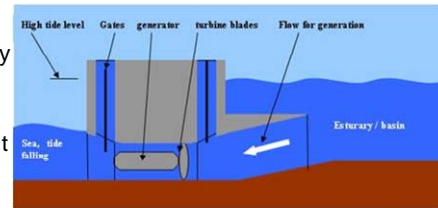
Figure 12: Gateway questions – tidal (stream)

Conclusion: carry forward tidal (stream) for evaluation as innovation required which may match local capabilities and there is some local primary resource

2.2.3 Tidal (Barrage)

Fundamentals/working principle

- A tidal barrage is typically a dam built across an estuary or a bay with significant tidal range
- Electricity generation from tidal barrages is based on the same principle of hydroelectric generation (except that the tidal current flows in both directions)
- There are two types of tidal barrage systems



1. Single basin tidal barrage.
Depending on the design, it can operate in different mode: ebb generation, flood generation, and two way generation
2. Double-basin tidal barrages
It is an ebb generation system in which a proportion of the electricity generated is used to pump water into a second basin, allowing for an element of energy storage

Development status

- Tidal barrage technology is considered fairly mature and reliable. However, due to the size (and related high construction costs) and the environmental impact of the plant, there are only four operational plants worldwide. However, various feasibility studies exist about new facilities.
- The largest operating tidal barrage power plant is in La Rance (France) . Built in 1967, it has a rated power of 240 MW.
- The most promising sites currently undergoing feasibility study include the Severn Estuary (UK) and the Bay of Fundy (Canada)

Figure 13: Overview of tidal (barrage)

1. Do we have (or could we have) sufficient local resources?

- No adequate site exists in Newfoundland and Labrador to harness tidal energy with barrages.

2. Is the energy type consistent with the Energy Plan?

- Tidal is mentioned in the Energy Plan, but appears to be more oriented to tidal stream than tidal barrages

3. Is technical innovation required?

- Innovation is mostly required in the area on environmental impact understanding and mitigation

4. Is it feasible that NL has/could have appropriate capabilities to meet the challenge?

- Some overlap with hydroelectric industry, although no specific capability in the tidal barrage sector

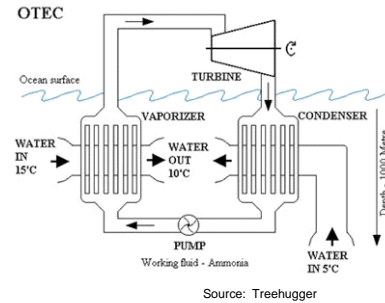
Figure 14: Gateway questions – tidal (barrage)

Conclusion: do not carry forward tidal (barrage), mainly as no suitable sites – in particular in comparison with other locations

2.2.4 Novel concepts

Ocean Thermal Energy Conversion

- The temperature difference between the warm surface water and the cold deep water can be used to run a heat engine
- Total resource is immense, yet practical considerations (sufficient temperature difference for efficient heat engine operation, distance from shore, and ultimately, cost) strongly limit its current exploration
- Although OTEC has been attempted since the 19th century, it is still in its early stage of development. Currently a few pilot operating plants in Micronesia, Hawaii, and India.



Osmotic Power (Salinity Gradient Power)

- The salinity difference between river water and sea water can be used to produce energy by harnessing the associated osmotic pressure. This pressure can be then used in a power generating turbine.
- Total resource is very large, although the high cost of the membrane has been the major hurdle to its deployment so far.
- The development of the technology is in its infancy. The first pilot osmotic power plant will be opened by Statkraft at the end of November 2009 in Norway

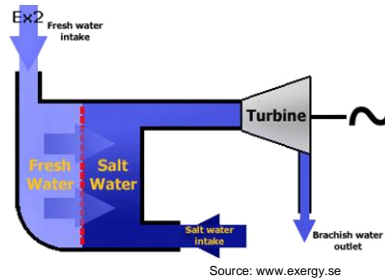


Figure 15: Overview of novel concepts

1. Do we have (or could we have) sufficient local resources?

- OTEC - No technically exploitable resources (these are mainly in subtropical regions)
- Osmosis - Potentially good resources due to large number of rivers. In practice, limited due to Marine Protected Areas and impact on fish and fishery.

2. Is the energy type consistent with the Energy Plan?

- Novel ocean technologies are not addressed in the Energy Plan.

3. Is technical innovation required?

- Innovation is mainly required in:
 - Balance of system (OTEC)
 - Development of low cost membrane (Osmosis power)

4. Is it feasible that NL has/could have appropriate capabilities to meet the challenge?

- Likely not

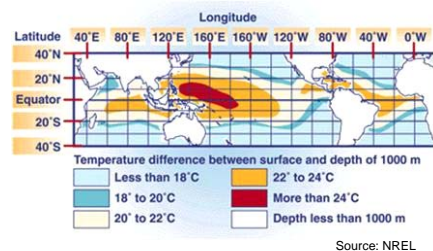


Figure 16: Gateway questions – novel concepts

Conclusion: do not carry forward novel ocean energy concepts as limited basis to innovate and compete.

2.3 Biomass

- Bioenergy involves the conversion of biomass feedstocks to one or more energy products
- Biomass feedstocks are plant or animal based materials
- They can be converted by thermal, chemical or biological processes, to produce heat, power, and transport fuels, at a range of scales

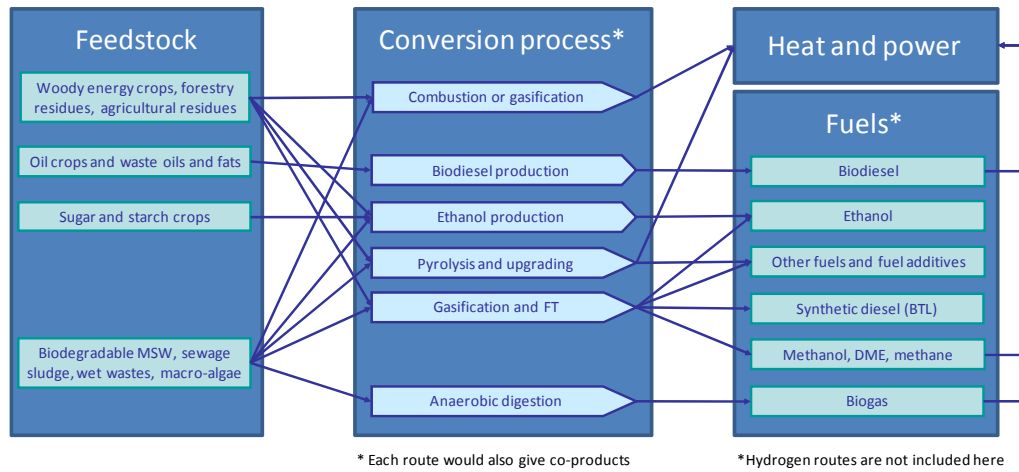


Figure 17: Overview of Bioenergy

2.3.1 Feedstock Supply

Fundamentals/working principle

- From the biomass feedstocks possible, here we focus on forestry products:
 - Low farmland areas exclude crops grown for energy
 - Low levels of agricultural residues
 - Wastes covered separately
- Types of biomass from forestry are
 - Stemwood
 - Residues - tops, branches
 - Wood processing residues – sawdust, offcuts
 - Paper industry residues - spent sulfite liquor, black liquor
- Wood can be used as chips, or densified through pelletising or torrefaction, to reduce transport costs for export



Productive forest area (in green).
Dept of Natural Resources



Development status

- Stemwood and processing residues are widely used for energy, and are traded globally as chips and pellets. Use has been predominantly for heat and power, with current development of transport fuel routes
- The paper industry has used black liquor for energy for decades, and is now developing processes for fuel and electricity production from black liquor (via gasification) and spent sulfite liquor (ethanol)

Figure 18: Overview of feedstock supply

1. Do we have (or could we have) sufficient local resources?

- Resources include: forestry residues (likely to be large), wood chips from sawmills if not used by the pulp and paper industry (estimated up to 500,000 -700,000 m³) and other sawmill residues
- Sawmills have few markets for residues: chips and some bark are sold to the pulp and paper industry, planer shavings and bark are often landfilled. The forest sector strategy estimated that the overall harvest on the Island would yield total sawdust, shavings and bark volumes of approximately 300,000 m³ annually (equivalent to a 12MW_e plant or a large pellet plant)
- Potential in Labrador for chips and pellets at a scale suitable for local use only

2. Is the energy type consistent with the Energy Plan?

- Wood is mentioned in the Energy plan, although it plays a less prominent role when compared with hydro, oil and gas, and wind.
- Discussed in detail in forest sector strategy – alternative markets for wood and residues are needed, and alternatives to overcome the decline of some forest sectors

3. Is technical innovation required?

- Chip and pellet production is commercially developed. New densification technologies (pyrolysis, torrefaction) and some conversion technologies are at the pilot or demonstration stage

4. Is it feasible that NL has/could have appropriate capabilities to meet the challenge?

- Large forestry sector (2-2.5% of the economy of NL, excluding offshore oil and mining)
- Several companies active in pellets production and distribution: Cottles Island Lumber Company, Holson Forest Products, Exploits Pelletizing

Figure 19: Gateway questions - feedstock supply

Conclusion: do not carry forward bioenergy as a feedstock supply as there is very limited innovation required – may be an opportunity for provincial businesses though.

2.3.2 Waste to Energy

Fundamentals/working principle

- Municipal solid waste includes domestic waste, commercial & industrial waste, and construction & demolition waste
- A high proportion of the waste is biomass – i.e. paper, food and wood waste – which can be used to produce energy with low greenhouse gas (GHG) emissions
- Waste can be used to produce power, heat and transport fuels directly, or via intermediates such as biogas and synthetic natural gas
- Using waste for energy also provides an alternative disposal route to those to be phased out under the provincial waste management strategy – e.g. landfill and teepee incinerators



Development status

- Waste to energy is used commercially in many countries worldwide
 - power and heat through gasification or incineration with energy recovery
 - anaerobic digestion of wet wastes to produce biogas, for heat, power or transport fuel
- There is considerable interest in most countries in increased separation of wastes, and in new conversion technologies that are currently at the demonstration or early commercial stage, such as new types of gasification, and routes to fuels

Figure 20: Overview of waste to energy

1. Do we have (or could we have) sufficient local resources?

- Newfoundland and Labrador generates around 400,000 t waste per year.
- Assuming that paper is recycled, and that half of the other organic waste could be used, this would give around 60,000t per year that could be used.
- For some technologies (e.g. pyrolysis), this is the size of one relatively small plant, for others (e.g. anaerobic digester), around 10 small plants

MATERIAL TYPE	PER CENT OF TOTAL WASTE
Paper	37
Organic	30
Metal	9
Plastic	8
Glass	6
Inorganic	4
Other	6

Waste generated in the Province.
Source: Newfoundland and Labrador Waste Management Strategy (2002)

2. Is the energy type consistent with the Energy Plan?

- Biomass is mentioned, but no routes discussed in detail
- Is consistent with the Waste Management Strategy target for landfill diversion

3. Is technical innovation required?

- Yes, for some technologies, such as transport fuels and synthetic natural gas, but not for heat and power

4. Is it feasible that NL has/could have appropriate capabilities to meet the challenge?

- There is no current NL activity in waste to energy
- There is work at Memorial University on uses for waste products from fish processing e.g. chitin from shellfish to high value products (not energy) and on fish oils to biodiesel

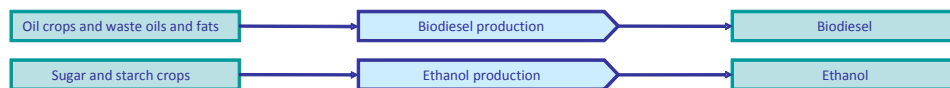
Figure 21: Gateway questions - waste to energy

Conclusion: do not carry forward waste to energy as modest resource level and limited innovation base.

2.3.3 First Generation Biofuels

Fundamentals/working principle

- 'First generation' biofuels are normally considered to be
 - Ethanol produced from sugar or starch crops through hydrolysis and fermentation
 - Biodiesel produced from vegetable oils, waste cooking oil or tallow through transesterification. These oils can also be blended with diesel directly
 - Biogas produced by anaerobic digestion of wet wastes or crops (covered separately)



Development status

- Ethanol production is a mature technology, with significant production worldwide, particularly from sugar cane in Brazil and corn in the US
- Biodiesel production by transesterification is also mature, with production predominantly in Europe, from vegetable oils. An alternative route (hydrogenation) is at the early commercial stage

Figure 22: Overview of first generation biofuels

1. Do we have (or could we have) sufficient local resources?

- Newfoundland and Labrador has low levels of agricultural production
- Waste fish oils are a potential biodiesel feedstock - currently used in Alaska

2. Is the energy type consistent with the Energy Plan?

- Biomass is mentioned, but no routes discussed in detail

3. Is technical innovation required?

- These routes are mature

4. Is it feasible that NL has/could have appropriate capabilities to meet the challenge?

- There is a project at Memorial University on fish oils to biodiesel, but this opportunity may be small as a result of the composition of fish waste and remoteness of fish processing plants in NL - producing the biodiesel for export is likely not feasible. The most likely option for fish biodiesel is on-site production for blend in the diesel engine for energy.
- There is also waste oil collection from Compass Group food services for biodiesel production by Rothsay biodiesel in Montreal

Figure 23: Gateway questions – first generations biofuels

Conclusion: carry forward first generation biofuels for evaluation using fish oil as resource and need are strengths, but not bio crops.

2.3.4 Lignocellulosic biofuels

Fundamentals/working principle

- Lignocellulosic biofuels are those produced from lignocellulosic materials e.g. wood, straw, and wastes. They are often called second generation biofuels, although this isn't clearly defined!
- They are:
 - Lignocellulosic ethanol or butanol - produced by biological routes (hydrolysis and fermentation) or by gasification
 - FT fuels – produced by gasification followed by Fischer-Tropsch (FT) synthesis of the gas produced. Also commonly called 'synfuels' and biomass to liquids 'BTL'
 - Pyrolysis-derived fuels – produced by pyrolysis to form an oil, then upgrading of the oil, or incorporation into an oil refinery
- The main reasons for interest in second generation biofuels are the potential for lower cost, lower lifecycle GHG emissions, greater range of feedstocks with less competition for food, and better performance in vehicles and infrastructure

Development status

- Lignocellulosic ethanol production is at the pre-commercial stage, with commercial scale demonstration plants being built, in the US, Canada (Iogen, Lignol) and Europe. Butanol is slightly further off
- BTL is at an earlier stage, with several demonstration plants in operation. Many of the individual technologies are nearing commercialisation, but integrating these requires further demonstration
- Whilst pyrolysis itself is at the early commercial stage, upgrading to a fuel is at the demonstration stage

Figure 24: Overview of Lignocellulosic biofuels

1. Do we have (or could we have) sufficient local resources?

- Biofuel plants are being developed that could use forestry resources, and in some cases use wastes such as Municipal Solid Waste

2. Is the energy type consistent with the Energy Plan?

- Biomass is mentioned, but no routes discussed in detail

3. Is technical innovation required?

- Each of the routes has challenges in demonstration and scale up and there is ongoing fundamental and applied R&D underway to improve the processes

4. Is it feasible that NL has/could have appropriate capabilities to meet the challenge?

- No industry activity in NL. A pyrolysis company (Dynamotive) signed an MOU with Cottles Island Lumber Company in 2004 for bio oil production, but no further news on this
- No apparent research on these routes
- Green chemistry capability at Memorial University (Kerton and Kozak group) has skills relevant to advanced biofuels: use of bio-derived molecules, extraction techniques

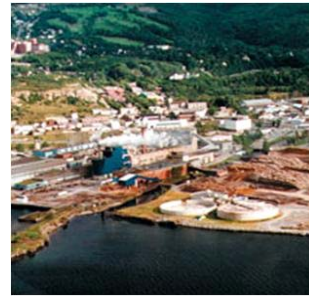
Figure 25: Gateway questions – Lignocellulosic biofuels

Conclusion: do not carry forward lignocellulosic biofuels as limited basis to innovate and compete.

2.3.5 Power Generation

Fundamentals/working principle

- Biomass can be used to generate power through:
 - Combustion with steam turbines
 - Gasification with gas and steam turbines
 - Pyrolysis, followed by combustion or gasification of pyrolysis oil
- This can be in dedicated plants, or through co-firing with fossil fuels such as coal and oil
- Heat and power production together is referred to as cogeneration or combined heat and power (CHP)



Corner Brook (NL) Cogeneration Plant and feedstock (Kruger)

Development status

- Combustion is a mature technology
- Gasification and pyrolysis are at the early commercial stage.



Figure 26: Overview of power generation

1. Do we have (or could we have) sufficient local resources?

- Biomass power plants could use forestry resources, and wastes such as MSW

2. Is the energy type consistent with the Energy Plan?

- Biomass is mentioned, but no routes discussed in detail

3. Is technical innovation required?

- Combustion and some gasification technologies are mature; there is scope for innovation in other gasification technologies and in pyrolysis routes

4. Is it feasible that NL has/could have appropriate capabilities to meet the challenge?

- Corner Brook Pulp and Paper has had a biomass cogeneration (combined heat and power) system in operation since 2003. The plant uses bark, sludge, and sawmill shavings, with a capacity of 15MW_e which is sold to NL Hydro for distribution
- A pyrolysis company (Dynamotive) signed an MOU with Cottles Island Lumber Company in 2004 for bio oil production, but no further news on this
- No apparent research in biomass to power or companies active in new technologies

Figure 27: Gateway questions – power generation

Conclusion: do not carry forward biofuels for power generation as technically mature and limited innovation base.

2.3.6 Small Scale Heat

Fundamentals/working principle

- Biomass can be used to generate heat in small scale applications e.g. for domestic use through stoves and furnaces
- These often use wood pellets, as a result of ease of handling and high storage density, but can also use wood chips and logs, particularly for larger systems
- Liquid biofuels such as biodiesel or pyrolysis oil derived fuels could also be used, blended with heating oil



Pellet boiler (source: Planet Energy) and pellets (source: Balcas)

Development status

- Stoves and furnaces are mature technologies



Figure 28: Overview of small scale heat

1. Do we have (or could we have) sufficient local resources?

- Feedstock can be made from forestry resources, including pellets from sawmill residues and bark

2. Is the energy type consistent with the Energy Plan?

- Biomass is mentioned, but no routes discussed in detail

3. Is technical innovation required?

- Biomass heating is mature technology

4. Is it feasible that NL has/could have appropriate capabilities to meet the challenge?

- NL has capabilities here, but the technology is mature
 - In 2003, wood and other solid fuels were the primary heating source for 19% of households in Newfoundland and Labrador (with around 50% electricity and 30% heating oil)
 - Pellets are already used for heating in NL, and supported by the Residential Wood Pellet Appliance Rebate program (25% rebate to homeowners buying an energy efficient wood pellet appliance)

Figure 29: Gateway questions – small scale heat

Conclusion: do not carry small scale heat forward – technically mature and innovation already dominated by others.

2.3.7 Large Scale Heat/CHP

Fundamentals/working principle

- Biomass can be used to generate heat or heat and power in larger scale applications, e.g. for schools, leisure centres, hospitals, commercial and industrial sites, and for district heating
- These systems generally use wood chips, but can also use pellets, or liquid fuels such as pyrolysis oils
- Combustion or gasification-based technologies can be used



Biomass boiler using forestry wastes at hospital site
(North West Wales NHS Trust)

Development status

- Biomass combustion systems are mature
- Small scale gasification systems are at the early commercial stage, with a need to prove reliability

Figure 30: Overview of large scale heat/CHP

1. Do we have (or could we have) sufficient local resources?

- Feedstock can be from forestry resources

2. Is the energy type consistent with the Energy Plan?

- Biomass is mentioned, but no routes discussed in detail

3. Is technical innovation required?

- Biomass heating and combustion CHP are mature technologies. Some development is required in gasification based systems and use of pyrolysis oils

4. Is it feasible that NL has/could have appropriate capabilities to meet the challenge?

- Corner Brook Pulp and Paper has had a biomass cogeneration (combined heat and power) system in operation since 2003. The plant uses bark, sludge, and sawmill shavings, and exports 15MW_e
- A pyrolysis company (Dynamotive) signed an MOU with Cottles Island Lumber Company in 2004 for bio oil production, partly for use by local companies as fuel oil, but no further news on this
- No apparent research in biomass to power or companies active in new technologies

Figure 31: Gateway questions – large scale heat/CHP

Conclusion: do not continue with large scale heat/CHP as technically mature and innovation already dominated by others.

2.3.8 Biogas and Synthetic Natural Gas

Fundamentals/working principle

- Wet biomass such as food waste, sewage sludge and animal manures can be anaerobically digested to produce biogas, and a fertiliser. Methane from biogas can then be used to generate heat and power, or as a transport fuel
- Gasification and methanation can be used to convert biomass into synthetic natural gas (SNG). Again, this can be used as a transport fuel, or put into natural gas networks



Anaerobic digestion (Hull CC)

Development status

- Anaerobic digestion is a well established commercial technology, although its economic case strongly relies on the availability of very cheap or free feedstock
- Synthetic natural gas routes are at the demonstration stage
- Use of methane from biogas or SNG in boilers, engines and vehicles is mature.

Figure 32: Overview of biogas and synthetic natural gas

1. Do we have (or could we have) sufficient local resources?

- There are suitable resources for both routes
 - Biogas feedstocks in NL are predominantly food wastes, though animal manures could also be used
 - Synthetic natural gas feedstock can be from forestry resources and wastes.
- However, as there is no natural gas network in NL, only systems using the gas on site or in refueling onsite would be viable

2. Is the energy type consistent with the Energy Plan?

- Biomass is mentioned, but no routes discussed in detail

3. Is technical innovation required?

- Anaerobic digestion is a mature technology.
- Development is required in SNG production

4. Is it feasible that NL has/could have appropriate capabilities to meet the challenge?

- No apparent research or company activity in biogas or SNG

Figure 33: Gateway questions - biogas and synthetic natural gas

Conclusion: do not continue with biogas and synthetic natural gas as no gas grid and limited innovation base.

2.4 Solar

Fundamentals/working principle

- There are three modes to use solar energy
 1. As thermal energy for space conditioning in buildings
 - Passive system. It uses building orientation and location, as well as the natural characteristics of certain building materials to capture and store heat and or transmit light
 - Active system. Used to provide hot water, heating and air conditioning to buildings. It employs collectors to capture solar energy and transfer it to a working fluid
 2. As thermal energy, collected in solar concentration and then converted into electricity (a.k.a. Concentrated Solar Power, CSP)
 3. By direct conversion into electricity by using the photovoltaic (PV) effect



Source: Jenny Nelson

Development status

- Solar heating for domestic and commercial application (e.g. swimming pools) are robust and reliable and are currently attractive options. Still room for improvement in cost effectiveness and durability
- PV technologies are about reaching grid parity in Southern Europe. Intense R&D activity in low cost, high efficiency cell
- Utility scale pilot plants for CSP being deployed in “sunny” region (e.g. Spain, California)

Figure 34: Overview of solar

1. **Do we have (or could we have) sufficient local resources?**
2. Modest annual solar radiation in Newfoundland, low in Labrador
- Low irradiation would not justify deployment of solar thermal electricity system.
- Photovoltaic generation could make sense only on peculiar off-grid applications, with high seasonality for example.
- Passive energy for building is a very logical approach, but is not a major opportunity.

2. Is the energy type consistent with the Energy Plan?

- Mentioned in the plan:

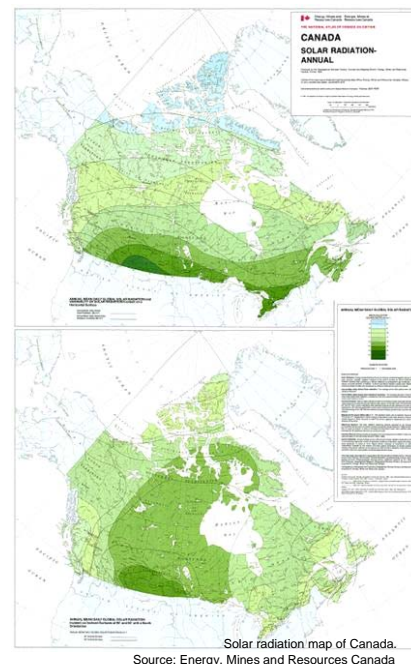
“Untapped potential also exists in other energy sources, such as [...] solar energy in some areas”

3. Is technical innovation required?

- Very active innovation arena worldwide in solar thermal power and PV, much less in thermal energy for buildings.

4. Is it feasible that NL has/could have appropriate capabilities to meet the challenge?

- Some capability in forced convection solar heating



Solar radiation map of Canada.
Source: Energy, Mines and Resources Canada

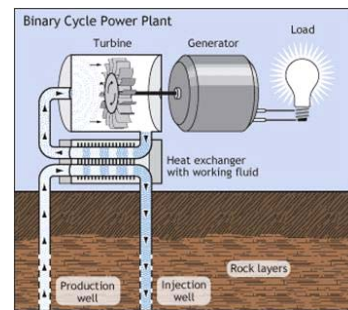
Figure 35: Gateway questions – solar

Conclusion: do not carry solar forward – modest resource and limited innovation base.

2.5 Geothermal

Fundamentals/working principle

- Geothermal energy consist of thermal energy stored in the earth's crust
- Geothermal resources are varied and include Hydrothermal (i.e. spontaneously producing hot fluids), Geo-pressured systems (sediment-filled reservoirs containing fluids), Hot dry rock, Magma.
- Geothermal energy can be used for various applications
 - Power generation
 - Soil warming
 - District heating
 - Building heating and cooling (with geothermal heat pumps)
 - Power drying
 - Leisure



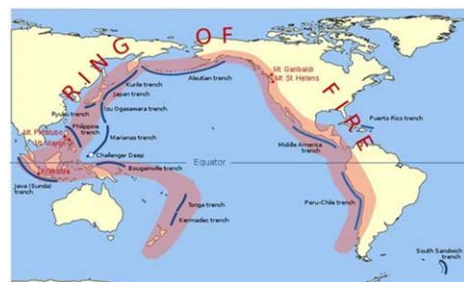
Schematic of a geothermal power plant. Source: EERE

Development status

- At the present only a very small percentage of the geothermal resources are used and geothermal plants have been built only where high temperature material is available relatively close to the surface (e.g. typically the edges of tectonic plates or other hot spots)
- Several miles below the Earth's surface, geothermal resource are enormous and ubiquitous. Prospects for geothermal energy lie in developing technology to deep drill, reach hot dry rock heated by magma underneath, inject cold water and draw it off warm for power generation.

Figure 36: Overview of geothermal

- 1. Do we have (or could we have) sufficient local resources?**
 - Very limited easily accessible resources
- 2. Is the energy type consistent with the Energy Plan?**
 - Geothermal is not mentioned in the Energy plan
- 3. Is technical innovation required?**
 - Limited for current geothermal system. Technology is very mature, although some innovation is needed in low cost drilling and improved power plant efficiency.
- 4. Is it feasible that NL has/could have appropriate capabilities to meet the challenge?**
 - Unlikely as requires different skills



Distribution of the highest quality geothermal resources.
Source: Canadian Geothermal Energy Association

Figure 37: Gateway questions – geothermal

Conclusion: do not carry geothermal forward as no resource, limited innovation need and no basis to innovate.

3 Novel Energy Carriers

3.1 Hydrogen

- Hydrogen can be used as an *energy carrier*, to link primary energy sources to energy services, such as light, heat and transport
- Like electricity, hydrogen must be generated using a different form of energy. Hydrogen can be generated from hydrocarbons and biomass, from electrolysis of water, and through several novel routes
- Hydrogen can then be used to carry the energy to where it is needed. Note that hydrogen can be stored more easily than electricity.
- Hydrogen can then be combusted in a fuel cell or an engine to provide an energy service, such as transportation, heat or useful power. Note that the combustion of hydrogen produces only water.

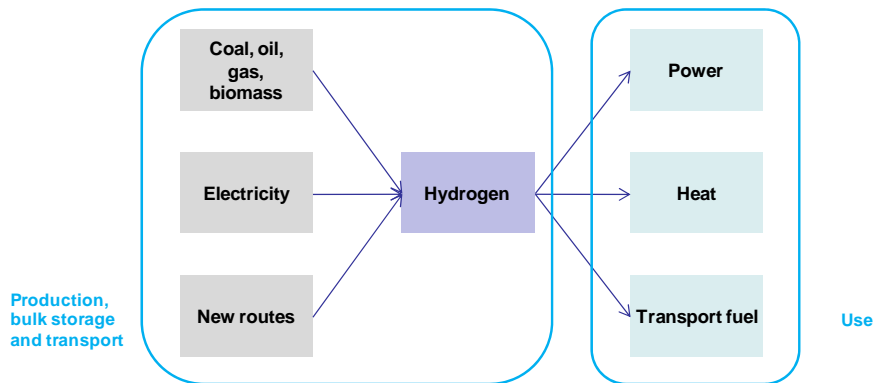


Figure 38: Overview of hydrogen

3.1.1 Hydrogen Production, Bulk Storage and Distribution

Fundamentals/working principle

- Hydrogen can be produced
 - from hydrocarbons, such as natural gas, biomass and coal, through gasification (for solid materials) and reforming (for gases)
 - from electrolysis of water, using electricity from renewable, nuclear or fossil sources
 - via new production routes, for example using hydrogen producing bacteria, or splitting water using heat from solar or nuclear energy.
- Reforming of gases, and electrolysis can be done on site at the point of use, all other routes would be done at a centralized point
- If produced in a centralized system, the hydrogen would then need to be transported to the point of use, which can be done as a compressed gas, in tube trailers or pipelines, or as a liquid in cryogenic tank.



Electrolyser (Wikimedia Commons)



Tube trailer (Doug McKenzie)

Development status

- Centralized hydrogen production from coal and natural gas, and through large scale electrolysis, are mature technologies used for many years
- On site production systems such as small reformers and electrolyzers are commercially available
- There are only a few demonstration systems using the output of intermittent renewables, such as wind
- New production routes range from the basic R&D stage through to applied research
- Bulk transport and storage are mature technologies, though liquefaction could be improved

Figure 39: Overview of H₂ production, bulk storage and distribution

1. Do we have (or could we have) sufficient local resources?

- Large local resources: low carbon routes (hydro, wind, and biomass) and natural gas, though on-site natural gas reforming limited by lack of gas grid

2. Is the energy type consistent with the Energy Plan?

- Yes - *"The province's abundant wind and hydroelectric resources provide us with a natural advantage for the clean production of hydrogen using electrolysis powered by renewable energy"*

3. Is technical innovation required?

- Although on site production systems such as small reformers and electrolyzers are commercial, there is ongoing work on cost reduction
- Need for further work on design and control of systems using intermittent renewables
- New production routes require further R&D and demonstration

4. Is it feasible that NL has/could have appropriate capabilities to meet the challenge?

- Experience with hydrogen production from wind from the Ramea project (see right) – partners include:
 - Memorial University – M. Tariq Iqbal group - expertise in wind and hybrid power systems
 - NL Hydro. Also has become a member of the North Atlantic Hydrogen Association (NAHA), which undertakes research and development projects

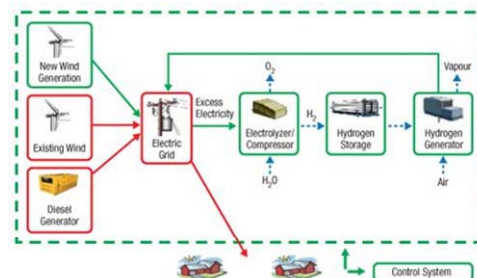


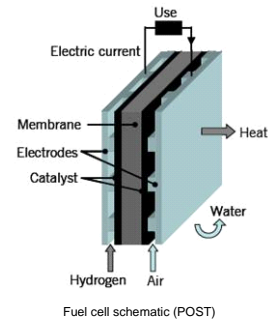
Figure 40: Gateway questions - H₂ production, bulk storage and distribution

Conclusion: do not carry hydrogen forward as large scale infrastructure and market access lacking, limited innovation base.

3.1.2 Hydrogen Use

Fundamentals/working principle

- Hydrogen can be used to provide
 - Electricity and CHP, via an IC engine, turbine or fuel cell
 - Heat, via a burner, or a catalytic heater
 - Energy for transport, via a fuel cell or IC engine – e.g. cars, buses, forklifts
- Each use also has particular storage requirements, generally
 - Compressed gas storage for stationary applications
 - High pressure compressed gas, liquid, or within a metal hydride for transport or some portable applications
- Note that portable devices using fuel cells generally use liquid fuels such as methanol rather than hydrogen, as a result of increased energy density



Development status

- All applications using fuel cells are at the demonstration/early commercial stage, with the furthest advanced being applications such as forklifts, telecoms power and backup, and small CHP, and with vehicle applications being further from commercialization
- Stationary engines for power generation, and heat applications such as burners and catalytic burners for cooking are also at the demonstration stage
- Compressed bulk storage is mature, but high pressure storage for vehicles, and liquid and metal hydride systems are at the applied R&D/ demonstration stage

Figure 41: Overview of H₂ use

1. Do we have (or could we have) sufficient local resources?

- Large local resources coupled with demand from small communities for energy storage systems
- Cold climate could be a barrier or an opportunity for demonstration of fuel cell systems

2. Is the energy type consistent with the Energy Plan?

- Yes - *"The province's abundant wind and hydroelectric resources provide us with a natural advantage for the clean production of hydrogen using electrolysis powered by renewable energy"*

3. Is technical innovation required?

- Further RD&D is needed in fuel cells, for cost reduction and performance improvement, and in their integration into systems such as vehicles and CHP
- Further demonstration is needed of combustion based systems
- There is also need for investigation and optimization of systems using hydrogen e.g. in remote communities
- Further development is needed for on board hydrogen storage for vehicles.

4. Is it feasible that NL has/could have appropriate capabilities to meet the challenge?

- Experience with use of hydrogen from the Ramea project
- Memorial University has capability in materials chemistry related to fuel cells: Peter Pickup (Head of Chemistry) has worked on membranes and catalysts for fuel cells using hydrogen, ethanol, methanol and formic acid

Figure 42: Gateway questions – H₂ use

Conclusion: carry forward hydrogen use for evaluation of stationary applications in conjunction with renewable energy – other uses lack basis to innovate and compete.

4 Non Renewable Energy

4.1 Uranium

4.1.1 Uranium Exploration, Extraction and Pre-processing

Fundamentals/working principle

- Uranium is relatively ubiquitous on the Earth, found in rocks and seawater. However, only in some areas its concentration is sufficiently high to be economically recoverable
- The main methods to extract uranium are:
 - Open pit mines
 - Underground mines. This method is used when the uranium ore is too below the surface for open pit mining
 - In-situ leaching (ISL). This method consists in pumping a leaching liquid through the ore in order to transport the uranium to the surface. ISL can be applied if the ore is located in a permeable rock confined by non-permeable rock.
- Uranium mined in open pit and underground mines is first crushed and then leached in a chemical plant (uranium mill) to produce an 80% uranium concentrate (yellow cake).
- Due to low concentration of uranium in the ore (typically between 0.1%-0.2%), uranium mining is a volume intense activity. Uranium mill tailings, which are typically dumped as a sludge in special ponds or piles, amount to nearly the same as that of the ore milled (See Figure).



Development Status

- Due to the advantage of reduced tailings, ISL extraction is becoming the preferred uranium extraction technology. However, ISL poses risks of ground water contamination.
- Uranium extraction is a mature industry with some innovation occurring in exploration (e.g. prompt fission neutron detector), extraction (e.g. recovery of uranium from phosphate rocks and golden ores) and pre-processing (heap leaching with microorganism-based leaches)

Figure 43: Overview of Uranium Exploration, Extraction and Pre-processing

1. Do we have (or could we have) sufficient local resources?

- The Central Mineral Belt is one of the most prolific areas for uranium mineralization in eastern Canada
- However, typically much lower grade mines (0.1%) compared to Saskatchewan (where grade often exceeds 10%)

2. Is the energy type consistent with the Energy Plan?

- Uranium is mentioned in the Energy Plan, but only as a fuel for export

"The Government of Newfoundland and Labrador will encourage exploration and development of our uranium resources."

- Moratorium on the development of any new uranium mine until (at least) 2011 by the Nunatsiavut Government

3. Is technical innovation required?

- Most of the innovation is required in the mine decommissioning phase (remediation, restoring and reclamation, ground water restoration, etc.), and unmanned extraction process.

4. Is it feasible that NL has/could have appropriate capabilities to meet the challenge?

- With ca. 4,000 people employed, mining industry plays a major role in NL economy
- However, no uranium production occurring at the moment in NL
- Also, few transferrable skills and expertise from other mining industries to uranium

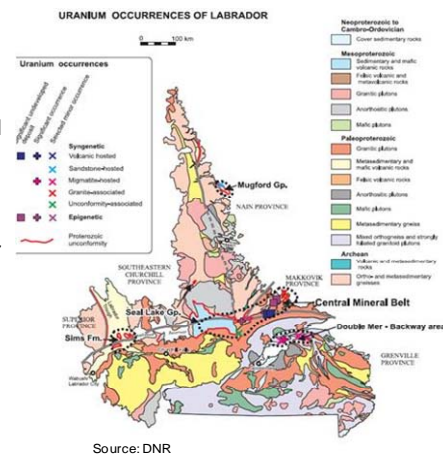


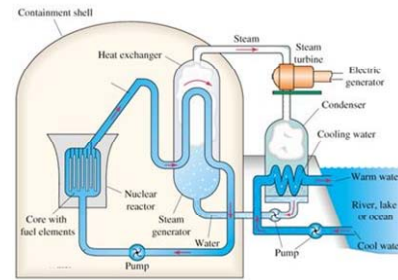
Figure 44: Gateway questions - Uranium Exploration, Extraction and Pre-processing

Conclusion: do not carry uranium forward as limited basis to innovate and compete.

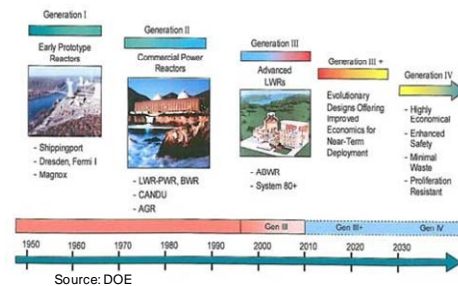
4.1.2 Uranium Power Generation and Waste Treatment

Fundamentals/working principle

- Nuclear fission reactors generate electricity by means of the energy released when atomic nuclei are split
- The heat associated with the nuclei split is used to generate water steam, which is then used to generate electricity
- There are different commercial reactor design, which mainly differs on the coolant and moderator materials
- Nuclear fuel material is typically enriched uranium (i.e. Uranium with higher concentration of the fissile isotope) and plutonium. Plutonium is generated in the reactor during the fission of uranium
- Spent nuclear fuel contains unconverted uranium and other fission product material with high radioactivity. Spent nuclear fuel can be reprocessed to recover uranium and plutonium for reuse



Source: Imperial College



Source: DOE

Figure 45: Overview of Uranium power generation and waste treatment

1. Do we have (or could we have) sufficient local resources?

- Local uranium resources in Labrador
- Potential land availability for waste management and temporary storage

2. Is the energy type consistent with the Energy Plan?

- From the Energy Plan:

"No role is foreseen for nuclear generation in the province. Even if provincial legislation prohibiting nuclear generation were not in place, more cost-effective and flexible hydro alternatives are already available to us and are well understood."

- The "Act to regulate the electrical power resources on Newfoundland and Labrador (2004)" states that:
"planning for future power supply of the province shall not include nuclear power"

3. Is technical innovation required?

- Innovation is needed in next generation reactors that will provide:
 - Advance passive features and reinforcement against airplane crash
 - Reduced waste
 - Proliferation resistant reactor
 - Combination with hydrogen production via water electrolysis

- Geological repository for medium/high level waste

4. Is it feasible that NL has/could have appropriate capabilities to meet the challenge?

- Size and effort to meet the challenges go well beyond the NL human and financial capabilities

Figure 46: Gateway questions – Uranium power generation and waste treatment

Conclusion: do not carry uranium power generation and waste treatment forward as limited basis to innovate and compete.

4.2 Peat

Fundamentals/working principle

- Peatlands globally represent a significant store of soil Carbon that has been accumulated over millennia.
- Peatlands impact the global balance of three main greenhouse gases (GHG) - carbon dioxide, methane and nitrous oxide. In their undisturbed, natural state, peatlands remove CO₂ from the atmosphere via peat accumulation and emit methane.
- There is indeed a broad consensus among the scientific community that, in terms of GHG managements, the preservation of peatlands as large store of soil C should be a priority for policy makers.
- According to IPCC, peat emissions amount to 106 gCO₂/MJ and are therefore higher than those of coal (94.6 gCO₂/MJ)



Turf cutting. Source: markjhandel (Flickr)

Development status

- Peat is currently used for horticulture, in the food industry (e.g. to dry barley for whisky), for domestic use (cooking and heating), as an oil absorber, and for heat and power generation (co-fired with coal on its own)
- Peat use for power and heat production is particularly widespread in countries such as Ireland and Finland, where peat amount to ca 30% of primary energy consumption of both countries.
- Peat fuel is produced by extraction and drying of peat. There exist different extraction technique (e.g. milled peat, sod peat, etc.). Peat fuel is sometimes pelletized before final use.

Figure 47: Overview of peat

1. Do we have (or could we have) sufficient local resources?

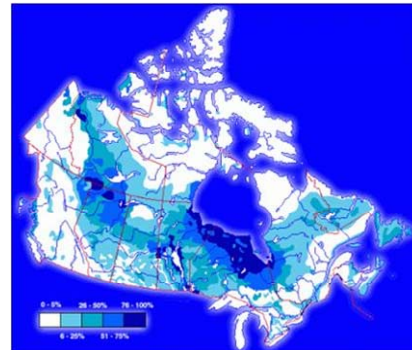
- Newfoundland and Labrador has large sphagnum peat moss reserves

2. Is the energy type consistent with the Energy Plan?

- Peat is mentioned in the Energy plan, although it plays a less prominent role when compared to hydro, oil and gas, and wind.

“Untapped potential also exists in other energy sources, such as wave and tidal energy, wood, peat, methane captured from landfills and solar energy in some areas.”

- Best used of peat is co-firing in coal plants, yet NL does not have coal plants.



Map of wetlands in Canada. Source: ?

3. Is technical innovation required?

- Peat fuel for power generation is fired in plant operating on conventional steam cycle for which no technical innovation can be envisaged.
- R&D opportunities exist mostly in the area of understanding the role of wetlands in global climate as a soil C stock.

4. Is it feasible that NL has/could have appropriate capabilities to meet the challenge?

- Peat Resources Limited is a Toronto based company that operates a small scale facility in Stephenville producing peat fuel pellets.

Figure 48: Gateway questions – Peat

Conclusion: do not carry peat forward – limited innovation need and some questions about sustainability remain.

4.3 Oil Shale

Fundamentals/working principle

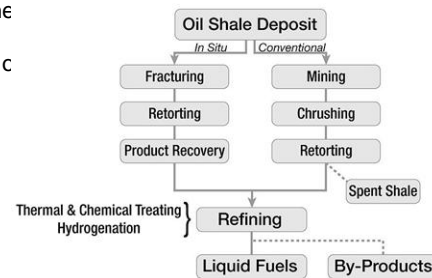
- Oil shale comprise a host rock andkerogen
- Kerogen is an organic matter that has not gone through (yet) the phenomena of high temperature and pressure necessary to generate oil
- Global resources of oil shale are comparable to the original world endowment of conventional oil
- The most common production technology so far has been surface mining followed by above-ground retorting. Although simple, this approach requires expensive facilities and generate a vast amount of waste rocks.
- An alternative process is the “in situ” conversion. In this case, the deposit is drilled, the reservoir is heated so that thekerogen is converted into a mid-distillate refinery feedstock on a time scale c months

Development status

- Conventional oil shale extraction (mining + retorting) is a well established technology
- In situ conversion is an emerging technology. Few pilot scale plants exist and it is not clear yet which specific extraction method will be the best.



Oil shale extraction
Source: Red, Green, Blue



Oil shale process diagram
Source: DOE

Figure 49: Overview of oil shale

1. Do we have (or could we have) sufficient local resources?

- Potentially, but not widely explored

2. Is the energy type consistent with the Energy Plan?

- Not mentioned in the plan
- May not be compatible with sustainability goals

3. Is technical innovation required?

- Innovation is required in efficient in situ conversion technologies

4. Is it feasible that NL has/could have appropriate capabilities to meet the challenge?

- Thermal processing is not a current area of strength
- Challenges are already being tackled by other actors in other area of Canada/the world.



Canada oil shale deposits
Source: United States Geological Survey

Figure 50: Gateway questions – oil shale

Conclusion: do not carry oil shale forward – limited basis to innovate and questionable sustainability.

5 Energy Efficiency and Conservation

Fundamentals/working principle

- Difference between efficiency and conservation
 - **Efficiency**: to use less energy to provide the same (or even improved) energy service.
Examples: energy saving lamps, energy efficiency appliances, better insulated buildings
 - **Conservation**: to use less energy by decreasing the demand of an energy service
Examples: decrease demand for travel, less space heating, less use of light

Development status

- Many technologies for an efficient energy use cover multiple areas of energy service (both domestic and industrial), are already mature, and often pay back the initial investment in a relatively short time
- Energy efficiency has been mainly driven so far by regulation
- Implementation of energy efficiency measures should always take into account the rebound effect
- Energy conservation is driven by behavioural change (and by those technologies that help behavioural change to happen – e.g. comparative billings, smart metering, etc.)



Figure 51: Overview of energy efficiency and conservation

1. Do we have (or could we have) sufficient local resources?

- Energy efficiency and conservation measure/technologies are low hanging fruits to achieve emission reduction AND savings

2. Is the energy type consistent with the Energy Plan?

- One goal of the energy plan is to:

"[...] invest[ing] in energy efficiency and conservation programs"

3. Is technical innovation required?

- Some, though more focus needed on implementation than technology

4. Is it feasible that NL has/could have appropriate capabilities to meet the challenge?

- Some experience with industrial efficiency
- Relatively limited residential efficiency activities, historically
- One smart meter technology company

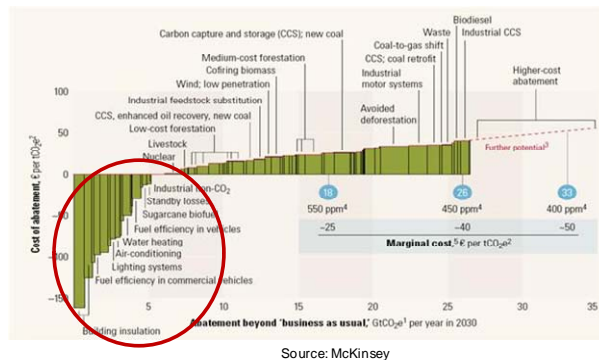


Figure 52: Gateway questions – energy efficiency and conservation

Conclusion – carry forward energy efficiency for evaluation – good opportunities to apply, though modest innovation base.

6 Summary of screening results

The results of the screening are summarised below.

Energy Type	Energy sub-type	Gateway questions				Summary	Next step
		Suitable local resources?	Consistent with Energy Plan?	Technical innovation required?	Can NL meet the challenge?		
Wind	Off-shore					Marine engineering skills could be applied, though deployment in NL unlikely before long term	Assess as part of marine energy systems theme
	Small scale					Significant device innovation unlikely in NL. Integration in hybrid systems could be a strength	Assess as part of remote energy systems theme
	Novel concepts					Limited basis to innovate and compete	Do not continue
Ocean	Wave					Marine engineering skills could be applied, though deployment in NL unlikely before long term	Assess as part of marine energy systems theme
	Tidal (stream)					Marine engineering skills could be applied, though deployment in NL unlikely before long term	Assess as part of marine energy systems theme
	Tidal (barrage)					No suitable resource	Do not continue
	Novel					Limited basis to innovate and compete	Do not continue
Biomass	Feedstock supply					Opportunity to provide wood products for NL and export markets, but not for major innovation	Consider for deployment (not innovation) strategy
	Waste as a feedstock					Modest resource base and limited innovation base	Do not continue
	First generation biofuels					Potential related to fish processing waste oils, but not conventional biofuels	Assess as part of remote energy systems theme
	Lignocellulosic biofuels					Limited basis to innovate and compete	Do not continue
	Power generation					Technically mature and limited basis to innovate	Do not continue
	Small scale heat					Technically mature, supply already dominated by others	Consider for deployment (not innovation) strategy
	Mid/large scale heat & CHP					Technically mature, supply already dominated by others	Do not continue
	Biogas and Synthetic Natural					Very limited market (no gas grid), limited innovation base	Do not continue
Hydrogen	Production, bulk storage and					Large scale infrastructure and market access lacking, limited innovation base	Do not continue
	Automotive application use					Limited basis to innovate and compete	Do not continue
	Stationary application use					Energy storage development needed for remote applications, some innovation base	Assess as part of remote energy systems theme
	Portable application use					Limited basis to innovate and compete	Do not continue
Uranium	Exploration, Extraction and					Limited basis to innovate and compete	Do not continue
	Power generation (fission and					Limited basis to innovate and compete	Do not continue
	Waste treatment					Limited basis to innovate and compete	Do not continue
Others	Geothermal					Modest resource base and limited innovation base	Do not continue
	Solar					Modest resource base and limited innovation base	Do not continue
	Peat					Need to prove sustainability. If satisfactory then peat export possible, but limited innovation	Consider for deployment (not innovation) strategy
	Coal and oil shale					Modest resource base and limited innovation base	Do not continue
	Energy efficiency					Good opportunities to apply (including offshore), though modest innovation base	Assess as part of energy efficiency theme

Gateway questions ('No' = do not continue):



Figure 53: Summary of screening results by energy sub-type

In considering these results it became clear that there were three overall groups of energy sub-types, defined by common themes.

1. *Marine energy technologies*, which have are all renewable generation technologies with common technology characteristics and where there appear to be relevant local innovation capabilities

2. *Remote energy systems*, which are defined more by application and capability than by specific technology. The applications include anywhere that off-grid electricity is required – at device, building or small community level. The capabilities that are common to these are an understanding of small scale generation from ambient energy sources (e.g., small scale wind), integration of devices in small systems (e.g., matching generation with storage), and operation of such systems in remote settings (e.g., in outports).
3. *Energy efficiency* which has a clearly articulated need in the Energy Plan and for which there is high potential, but is not currently an area of significant innovation in the province.

The results of the screening were logically grouped under these three themes therefore, as described in figure 54.

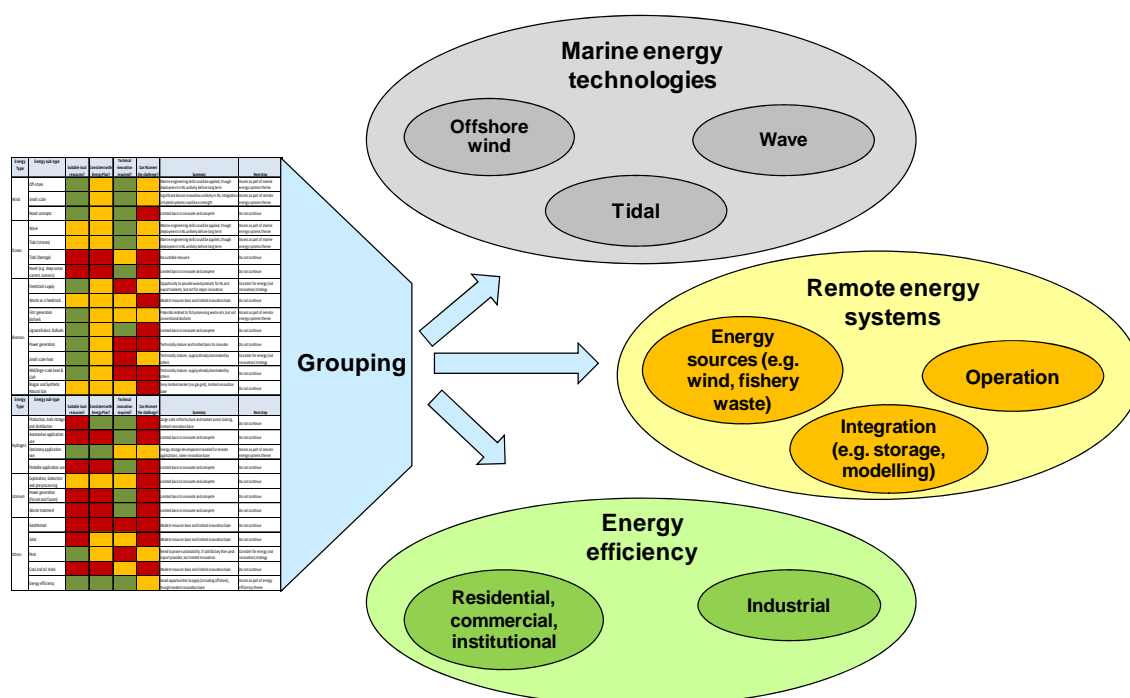


Figure 54: Grouping of screening results under three themes

These three themes were carried forward for more detailed evaluation in the rest of the project, as described in '3. Analysis document: other energy themes'.