# Feasibility Study

## Production of hydrogen in Newfoundland by using windpower, transport to Europe and distribution

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## Executive Summary:

Global warming is a fact and cannot be any longer questioned. It is also known that the resources for oil, natural gas and coal are dwindling and that the western world depends on supplies from not always reliable countries. In a long term view higher prices for this energy must be expected. Wars to secure a supply of the needed supply have proven to be costly and unsuccessful. If the costs of a such a war would be added as a surcharge to the price of fossil fuels, hydrogen would be very competitive.
It seems to be better to invest in energy sources in friendly countries to guarantee employment and a high living standard also in the future.
This feasibility study deals with:

- the production of hydrogen using windparks  in Newfoundland, specially designed for using electrolysis
- storage and transport between the wind parks and Europe and distribution
- a suggested start up plan
- expected costs
- a possible work share between Europe and Canada

# 1. Table of Contents:

# 1. Abbreviations:

**BMW** Bayerische Motorenwerke
**DWV** Deutscher Wasserstoff- und Brennstoffzellenverband **(**German Hydrogen and Fuel Cell Association **)**
**ESRU** Energy Systems Research Unit's **(**UK)
**EST** Gesellschaft für Energiesystemtechnik mbH, Essen
**ETS** Emissions Trading Scheme (Europäisches Emisionshandelssystem)
**FMEA** Failure Modes and Effects Analysis
**HyFi®** Hydrogen Fuel Injection (Fa. Linde)
**IRR** Internal Rate of Return
**itc** international trading company
**MAN** Maschinenfabrik Augsburg Nürnberg
**m/s** meters per second
**PdM** Predictive Maintenance
**PM** Program Management
**VDMA** Verband deutscher Maschinen- und Anlagenbau
**WT** Wind Turbine
**ZBT** Zentrum für BrennstoffzellenTechnik
**ZEV** Zero Emission Vehicle

# 2. Purpose of the Study:

This feasibility study investigates:

- future use of hydrogen
- the production of hydrogen on the shores of Newfoundland by using windpower plants especially designed for this purpose by electrolysis
- the use of manganese dioxide coated electrodes for the electrolysis of seawater.
- the transport and storage of hydrogen within Newfoundland
- the transport from hydrogen from Newfoundland to Europe
- the distribution within Europe
- storage and service stations in Europe
- safety measures
- economical aspects
- risk evaluation
- recommendation how to proceed

# 3. Future Use of Hydrogen:

This study deals only with the use of hydrogen to power cars, busses, truck and aircrafts in the future.

## 3.1 Present status:

All the development efforts of the leading car manufacturers in the world are concentrated on the future use of electrical power.
This can be achieved by using batteries, eventually combined with the hybrid technique where kinetic energy can be recovered and stored in the battery.
The range of these vehicles is restricted and so far no solution is known to standardize the batteries and to allow a lease of the batteries to enable a fast exchange in service stations.
To extend the range of electrical powered cars attempts are made to use a combustion engine to recharge the battery during driving the car.

## 3.2 The next Step:

The hybrid technique which means that kinetic energy can be recovered and stored in a battery during slowing down a vehicle or driving downhill shall always be part of each new design. Street cars in Germany used this technique already in the thirties.
More and more cities will restrict the use of cars with hazardous exhaust gases. States in the USA, such as California, are considering seriously to make the use of ZEV's mandatory.
In Europe cities started already to ban certain vehicles from entering designated areas.
Battery powered cars are being considered to be one of the solutions to avoid pollution. However, the environmentally friendly production of the required electrical power is still in question.
Using fuel cells and hydrogen in a reverse electrolysis process to produce electrical power is a certain solution and almost all major car manufactures are working on this task. Test vehicles are in use for many years. And the progress achieved in reliability and cost reduction is so promising that the first companies will offer in the near future such vehicles on a lease basis to selected customers to gain more experience on a wider basis.
Independent from that and not so well known is the progress achieved with normal combustion engines using hydrogen.
MAN in Germany for example is running a test fleet of busses for public transportation and BMW did a presentation of hydrogen powered cars. The efficiency of these vehicles has also dramatically improved as well as the storage tanks in the vehicles and how to fill them up. The German company Linde is very active in this field.
This technique of using hydrogen combustion engines could become an intermediate alternative to the high efficient diesel powered vehicles with the advantage of less hazardous emission and the dependance of a fuel supply by countries in critical areas.
It also could give some marketing advantages to the European automotive industry when they spend more research on this intermediate technique until the fuel cell fulfills all the requirements.
A recommendation is to develop some kind of van which can serve as cab for intercity traffic which is using hydrogen as a power source. The size of the vehicle should allow enough room for passenger, their luggage as well as storage tanks in a size which allows an extended range without many stops for filling up the tanks.
Hydrogen should have also a future for air traffic. A new design of airplanes seems to be mandatory to accommodate the required larger tanks which should be preferable located above the passenger area to increase safety.
Extensive studies and even tests have already be performed to prove the use of hydrogen in aircrafts. (See under References)

# 4. Why Newfoundland?

- Newfoundland is located very close to Europe. See picture 1
- Newfoundland is not surrounded by any critical countries and is very stable
- Newfoundland has along and rocky coastline with excellent wind conditions. No expensive off-shore installations are required
- Canada is looking for a closer partnership with Europe
- Newfoundland has a small population and less problems with certain regulations can be expected
- similar to Europe Canada is interested in creating or securing jobs and not depend on investors of only one country
- I learned that people in Newfoundland are very reliable, honest and friendly
- Newfoundland has created a so called "Ambassador Program" which seems to help the province in creating new jobs
- it can be expected that certain government funding may be available if the project is properly presented and a long term success can be seen.


Picture 1

# 5. Project Details:

In order to get this project going it is mandatory that the automotive and aerospace industry as well as the governments of the involved countries work together and do a proper planing.
The automotive and the aerospace industry shall be interested because hydrogen powered vehicles seem to be the best solution for individual ground traffic to meet the upcoming standards for ZEV's and to make air travel independent from fossil energy.
Because of time required to create the required infrastructure for a sufficient supply with hydrogen it is recommended that the automotive industry starts with smaller series of buses and cabs powered with hydrogen combustion engines. This is a great chance to gain the required experience for a later mass production when the fuel cells have been fully developed.
A pilot facility installed in Newfoundland would reduce the risk of a major failure and wrong investment.
This feasibility study does not replace the required detailed specifications and evaluations which must be done after the study has been completed.
Especially during the present economical problems it is mandatory to start a project which has exceptional chances to gain economical strength again and secure jobs and our living standard in an healthier environment.

## 5.1 Why Wind Power?

Naturally, there are more possibilities to produce hydrogen with an environmentally friendly processes, such as using water or solar power.
However, the potential of wind power seems to be world wide much bigger and it can be used even in countries with less sunny days but known as reliable partners.
Cooperation with local companies for production of components for the WT's, the required construction work and the maintenance will be a requirement and can be beneficial for both sides. For certain large components, such as the towers, this may even become a cost saving element because of lower transportation costs.

## 5.2 Concept of the proposed WT's:

The WT's should be designed only for the production of hydrogen by using electrolysis of sea water and to provide the required electrical power for the operation of all required subsystems.
They should not delivery any energy to the public grid to avoid any interference with local suppliers and to minimize the costs of this facility.
The life span of a WT is presently approximately 20 years of continuos operation, except short maintenance periods.
It is assumed that the costs and operating costs for WT's can be further reduced by mass production and product improvements.

### 5.2.1 Size of the proposed WT's:

The size of the WT's is affected by the wind conditions. These wind conditions must be evaluated in detail if potential locations on the east coast of the island Newfoundland are determined.
For this study a mean wind speed of 10 m/s at a height of 80 m has been assumed based on data available from the "Canadian Wind Atlas".
The actual value will be probably higher.
This justifies the installation of large units. Expertises of suppliers are needed.

### 5.2.2 Comparison - WT's with gear unit versus gearless concept:

Both systems are being used and both have advantages and disadvantages.

***The advantages of gearless WT's are:***
- no gear box is required between rotor and generator. In the past reliability problems with gear boxes have been experienced
- less expensive
- low speed operation which may improve reliability and reduce wear

***The disadvantages of variable speed WT's are***:
- size and weight of the generator increase which makes installation more costly
- total efficiency seems to be lower

***The advantages of WT's with gear unit are:***
- can capture more energy under most wind conditions
- will supply power at constant voltage and frequency while the rotor speed varies. This is essential

when electrical power is supplied to the grid which is not intended for this project.

***The disadvantages of WT's with gear unit are***:

- expensive power electronic is needed
- in the past problems with gear boxes have been experienced

For this project preference is given to the gearless drive system

## 5.2.3 The Tower:

Each WT used for this project will need a tower. The following concepts of towers should be coinsidered for this project:

### 5.2.3.1 Tubular Steel Towers

***The main features of tubular steel towers are:***

- most commonly tubular steel towers are used with a concrete foundation.
- special cut steel plates are rolled to cones and welded
- several of these cones are welded together to a size which still allows transportation
- on the location of the planned WT these segments are either welded or bolted together
- all critical welding seams must be inspected
- either a service lift or a ladder can be inside the turbine tower
- transportation on roads can cause problems. Therefore the route gas to be checked carefully
- these towers are mostly selected

It seems to be feasible to use qualified shipbuilders in Newfoundland to involve them later in the manufacturing process. Investments are certainly required as well as proper training. Based on my experience this basic training should take place in Europe. The language may be a barrier because the English spoken in Newfoundland is almost a separate language.

### 5.2.3.2 Lattice towers

***The main features of lattice steel towers are:***

- less problems with transportation because they are constructed using steel profiles, welded together
- design reduces costs
- they are well know and accepted for hydro lines and the best known lattice tower can be found in Paris, France. Beauty and visual appearance can also not be used as an argument against them
- either a service lift or a ladder can be installed inside the turbine tower

In order to minimize the risk for the pilot project the use of a lattice tower is proposed. However, the effects of ice build up must be evaluated before a final decision is made.

### 5.2.3.3 Concrete towers

***The main features of concrete towers are:***

- a new Canadian project, called the "Slip-Form Concrete Tower Wind Turbine Project" is planned for 2009. It uses a slip-form pouring method and the progress should be obeyed
- many of them use are part of a "hyprid system'" which combines elements of a conical steel tower with concrete design

The progress in development, test results and the actual building of these kind of towers shall be monitored.

### 5.2.4 The Nacelle:

The size, the weight and the design of the complete nacelle depends from the selected concept of the WT - with gear units or gearless.

- for fixed speed operation a gear drive is used the nacelles are smaller and lighter
- for variable speed operation no gear drive is required but a bigger generator which adds weight and size
- in order to provide proper lightning protection metall shall be used for the housing and the cover of the nacelle. This allows that it works as a so called “Faraday cage”
- for the installation of the nacelle to the WT heavy cranes are required.

#### 5.2.4.1 The Housing:

#### 5.2.4.2 Rotor Blade Controls:

#### 5.2.4.3 Brake System:

#### 5.2.4.4 Generator:

Low-speed synchronous generators are used for gearless operation by WT manufacturers such as Enercon GmbH and also by Siemens for a new project.
It is estimated that for this project such a solution would be the best with respect to lower operating costs. However, further evaluation is needed.

#### 5.2.4.5 Anemometer and Wind Vane:

Both are used to measure wind speed and direction. These information are required for the control system of the WT. They should be protected against icing by sensors nd heating devices.

#### 5.2.4.6 Monitoring System:

A monitoring system with computer link to a service center where all data are monitored is mandatory. This remote sensing is also a prerequisite for a PdM program. Optimizing maintenance is an essential cost saving measure and will affect the IRR of the project!

### 5.2.5 The Rotor Blades:

Commonly the rotor blades are manufactured using composite material. For the majority of WT’s three blades are used.
State of the art know how, excessive quality control and testing are required to guarantee a long and trouble free operation.
The transport route must be carefully planned when selecting the location of the WT’s.

#### 5.2.5.1 Deicing System:

The need for a rotor blade deicing system has toe be carefully evaluated after the actual location of the WT’s has been determined. It has to be checked wether the required sensors can be installed in the rotor blades. This seems to be the preferable location and also redundancy is provided.
If a rotor blade deicing system is needed the WT’s must be located in an arrangement that hazard to

people and facilities on the ground is eliminated. Also ice fragments should not damage a neighbouring WT.

#### 5.2.5.2 Lightning Protection:

Proper lightning protection for the rotor blades, as well as for the compete WT must be provided. This includes the required grounding.

### 5.2.6 Safety Measures:

A FMEA should be performed to identify possible failures of the complete system which can cause a hazard to the public, the environment or can cause the destruction of the WT. In addition applicable regulations such as applicable for air traffic must be met.

Safety measures should include:

- automatic shut off system for the WT in case of:
  - to high wind
  - overheating of gear box if used
  - any foreseeable other failures which can occur and cause serious damage
- testing of storage containers for hydrogen before filling them. Proper handling procedures must be established.
- environmental protection against spilling of chemicals needed for th electrolysis process
- security of the complete plant against sabotage etc.
- proper warning devices for air traffic

### 5.2.7 Applicable Regulations:

All applicable regulations for the intended location and use of the WT’s shall be compiled and accomplished by documentation which demonstrates that they are met.

### 5.2.8 Construction / Installation of a WT:

The location of the planned WT’s will probably be in a remote area which does not have the needed infrastructure for transport and erecting the towers.
This will affect the costs and changes in the design of the complete WT’s shall be considered to minimize these costs.

# 6. Electrolysis of Seawater:

The electrolysis of seawater to produce hydrogen seems to be a new challenge. The manufacturers of electrolyzers will be contacted for detailed expertises.
No hazardous byproducts must be released into the environment.

# 7. Handling of the produced Hydrogen:

Hydrogen can be stored either in liquid form at very low temperatures or under high pressure. The most economical process shall be used even for the pilot project considering;

- filling of suitable containers at the wind power facility
- transportation by truck to a harbour
- transportation of these containers by ship to European destinations

- distribution within Europe to further processing, such as liquefying if required or direct to filling stations

## 8. Start-up Plan:

- To minimize the risk and to gain the required experience a work group which represents all the involved industries as well as governments should be formed.
- A shared pilot project should be planned to produce hydrogen with a specific designed WT for this purpose and electrolysis units using sea water.
- Included shall be filling process of suitable containers
- The testing and operation will deliver important information for improvements and later expansion of the facility
- The outcome of the pilot project will also allow to make a sounder cost calculations for the proposed supply of hydrogen to Europe. All alternatives must be considered which will allow to stop global warming and secure the present living standard.
- These costs are certainly also required by the automotive and the aerospace industry as well as by the governments to make the right decisions for the future grow of the economy and to meet the market demands
- Naturally a realistic schedule and control measure to initiate corrective actions are mandatory for the success

## 9. Workshare Proposal:

It is essential to define the workshare and responsibilities at the beginning of this project. Later a details schedule must be added.
The involvement of itc is to support the project as an extended arm in Canada. To do this it is mandatory that itc familiarizes itself with basic technical details and can get required technical support when needed,

| # | Main Task | Sub Task | Resp. |
|---|---|---|---|
| 1 | Feasibility study - draft | | itc |
| 1.1 | | Support WT's | Industry |
| 1.2 | | Support electrolysis | Industry |
| 1.3 | | Support storage containers | Industry |
| 1.4 | | Support shipping to Europe | Industry |
| 1.5 | | Support distribution in Europe | Industry |
| 1.6 | | Support automotive industry | Industry |
| 1.7 | | Forecast of required hydrogen | Industry |
| 1.8 | | Selection of the most suitable location for the WT's | Industry<br>itc |
| 1.9 | | Updates | itc |
| 1.1 | | Approval | DWV<br>Industry |

| | | | |
|---|---|---|---|
| 2 | Presentation of Feasibility Study | To governments | DWV Industry |
| 2.1 | | Follow up in Canada | itc |
| 2.2 | | Contacting potential Canadian business (subcontractors) | itc |
| 3 | Review of feed back and incorporation of applicable changes in a development program | | All |
| 5 | Cost evaluation and analysis | Presentation together with development program to involved governments for approval and / or required changes. | DWV Industry |
| 6 | Incorporate of all inputs in program and add proper control measures to allow fast corrective measures in case of problems | | DWV Industry |
| 6.1 | Establish a responsible program management group | | DWV Industry |
| 7 | Preparation of detailed specifications | | DWV Industry |
| 7.1 | Contact potential international subcontractors | | Industry |

## 10. References used or to be considered:


Danish Wind Industry Association — Web Site

E4tech — The Economics of an European Hydrogen Automotive Infrastructure

ENERCON GmbH — Web Site

ESRU (University of Strathclyde Energy Systems Research Unit) — Web Site for electrolysis of seawater

Linde Gas — Web Site

New Energy World — Developing New Energy for the future: Europe launches a 1 billion Euro project to get into pole position for the Fuel cells and Hydrogen race

Power Engineering — Web Site, Wind Turbines: Designing With Maintenance in Mind

Siemens AG — Pictures of the Future - Web Site

3G Energy Corp — Slip-Form Concrete Tower Wind Turbine Project (Canadian)