INTEGRATION OF FUTURE LARGE SCALE WIND ELECTRICITY SUPPLY: A CLEAN ENERGY PACKAGE

Alister Gardiner, Tana Levi, Rob Whitney and Jonathan Leaver
NZWEA Conference
22 March 2013

WIND GENERATION PROJECTIONS

Dispatchability and capacity factor are key issues for the growth of wind energy

WIND GENERATION PROJECTIONS

NZWEA Vision [ref.1]
- 3500MW by 2030, 20% of production (10,400GWh)
MED Energy Outlook reference scenario [ref.3]
- 888MW new by 2030, rising to 1287MW by 2040 (from 2011)
HCE (UniSyD) [ref.4]
- 11-33% of production depending on scenario (low GHG$ to high oil$)

The NZWEA vision implies ~34% wind generation capacity factor (MED 36%), so with a grid demand factor ~60%, wind could potentially supply:
- Total NZ demand during troughs with good wind conditions
- Minimal NZ demand during peaks with poor wind conditions
- There will be many times (ranging from minutes to days) when wind energy will be surplus to demand or need support from other generation. Its value will fluctuate widely.

Balancing future supply and demand
- The holy grail: large scale grid storage?
GRID BALANCING OPTIONS

Battery systems currently being assessed in various projects globally.

GRID BALANCING OPTIONS

Storage (+,-)
- Pumped hydro, CAES, flywheels
- Batteries incl. BEVs PHEVs (V2G)
- Capacitors, SMES, Hydrogen FC/ICE/FCVs (V2G)

Sectoral transfer
- Gas peaker gen (+)
- Diesel ICE gen (+)
- NG Microgen. (+)
- Hydrogen prodn (-)

Demand Side Participation
- Smart metering (+, -)
- Real time pricing (+)

A recent case study [Ref.5, 2012] compared storage options
- Pumped hydro, CAES, flywheels
- Batteries incl. Pb-acid
- Capacitors, SMES, (no H₂)

For
- Load shifting (3MW, 5hrs)
- Frequency/voltage support (10MW, 15 min)
- Power quality (10MW, 30s)
- Combined (10MW, 1.5hrs)

Results for the Combined case (US$)
- CAES showed overall lowest cost ($102/kW), pumped hydro next best ($307/kW)
- Advanced batteries way too expensive (Pb-acid best at $327/kW)
- Flywheels ($389/kW)

CAES, flywheels and Pb-acid offer the lowest costs in specific applications, with SMES only being competitive in power quality.

AN ENERGY TECHNOLOGY PACKAGE
WITH GRID BALANCING POTENTIAL

CoCo – a flexible Co-fuelled, Co-production energy process producing syngas, hydrogen and heat with generation and storage capability.

Co-fuels
Hydrocarbon feedstock \( H \_X, C \_Y, (O \_Z) \)
Water \( H_2O \)
Intermittently available electricity (eg wind sourced)

Co-products
Continuous Energy Production Process with Electricity “Storage” Capacity
Heat (incl. losses)
Syngas \( H_2, CO, CO_2 \)
Hydrogen \( H_2 \)
TECHNOLOGY PACKAGE OVERVIEW

See Ref. 6 for an explanation of the laboratory scale research project results.

Production of Synthetic Transport Fuels and Peaking Electricity

Gasification Plant

Lignite  Biomass  Water  Wind Energy

Pressure Electrolysis Plant

Chemical Energy Storage Buffer

H₂ store for Fuel cell vehicles or gas pipeline injection

H₂ for peaking gas and other purposes (e.g. CHP or F-T fuels)

Syngas for peaking gen and other purposes (e.g. CHP or F-T fuels)

CHP Process heat

ADVANCED GASIFICATION

Normally in advanced (IGCC) gasification:

- Oxygen is separated from air and used for partial oxidation of hydrocarbon feedstocks, reacting with steam in a reformer at around 800 degrees Celsius.
- Hydrogen, carbon monoxide, carbon dioxide are generated.

In a second step requiring catalysts (CO or water gas shift reaction):

- Some CO reacts with steam to create more CO₂ and more hydrogen.
- These catalysts are expensive and subject to contamination from by-products of the gasification process.

But, in this package:

- The use of electrolysis to produce the oxygen eliminates the WGS step, as hydrogen can simply be back blended with the output gas stream.

GASIFICATION PLANT

Experimental and modelled syngas production:

- Laboratory scale reactor:
  - Gasifier testing at 200kW therm with 30% oxygen:
    - Lignite:biomass (E. nitrens and P. radiata) 100:00 to 70:30
    - H₂:CO:CO₂:CH₄ ranged from 8-14%:10%:16%:12-15%:1-2%
**ADVANCED ELECTROLYSIS**

Single electrolysis cell

- Electrolysis:
  
  \[ \text{Electricity} + \text{H}_2\text{O} + \text{heat} = \text{H}_2 + \frac{1}{2} \text{O}_2 \]

> 100% electrical efficiency?

**ELECTROLYSIS PLANT**

Electrolysis splits water into oxygen and hydrogen:
- Oxygen forms on the positively charged electrode (anode)
- Hydrogen forming on the negatively charged electrode (cathode)
- A membrane between the anode and the cathode prevents the two gases from crossing over
- This process can be carried out under high pressure, allowing both gases to be directly stored at low cost with no additional energy consumption

Advanced electrolysers are being developed with very high efficiency (>80% system).

**ELECTROLYSIS PLANT**

Projected electrolyser performance improvements

Source: Hydrogenics

**PROCESS BENEFITS**

Energy efficiency:
- Input electricity simultaneously produces both hydrogen and process oxygen at high efficiency
- Minimal WGS is required so gasification plant efficiency is higher than normal

Carbon footprint:
- Biomass and wind electricity both reduce the carbon footprint of the syngas (grid electricity - about 65% clean in NZ is not used)
- Less GHG CO2 is emitted because CO is not processed to CO2

Simplified process, more stable syngas composition:
- Lower gasification plant costs
- Low CO2 content without removal
- Direct combustion in GTs [Ref.8]
- Hydrogen content adjustable to suit state of the art DLN GT burners
**PROCESS BENEFITS**

What we have found

- Advanced (oxygen rich) gasification of blends of woody biomass and lignite combined with hydrogen from electrolysis produce a flexible high quality syngas
- High efficiency (>80%) electrolysers in development will substantially reduce present costs for water splitting
- Low biomass feedstock costs and high daily variation in electricity costs are needed for good economics
- The process is flexible, allowing different mixes of feedstocks, co-fuels and co-products depending on circumstances and requirements
- The process may be suitable for smaller scale (distributed) plants of 10MW thermal upwards

---

**ENERGY SYSTEM MODELING**

Use of hydrogen as a mobility fuel makes this package more attractive. Results from extensive Unitec scenario modelling [Ref.4] show:

- Substantial numbers of alternative vehicles on the road by 2020
- HEV and PHEV become popular (fuel cell plugins were not modelled)
- Fuel cell vehicle (FCV) uptake is dependent on the price of hydrogen
- Penetration of EVs (battery only) into the light vehicle fleet is low

---

Two other outputs from this study [Ref.4] are shown below, illustrating that:

- A large component of wind generation is anticipated by 2050
- The initial market for mobility H2 is addressed with electrolysis, followed by a slow transition to biogasification as process expertise grows
- The UniSyD model does not yet simulate the co-production package described in this presentation (ie, simultaneous use of biomass and electricity to produce H2)

---

As a comparison, the UKH2Mobility project [ref.2] expects by 2030:

- 1.6 m FCVs on the road in the UK
- Demand for hydrogen for FCEVs will be 254,000 tonnes p.a.
- Hydrogen fuel cost reduced by 20% due to a high uptake of wind generation results in continued use of large scale electrolysis
ENERGY SYSTEM APPLICATIONS

Conceptual use of hydrogen for storing surplus renewable energy generation

POTENTIAL FOR APPLICATION IN NEW ZEALAND

Resource Availability
- Electricity - wind resource is only limited by the build rate
  - Why not overbuild wind generation to create an environment for the integration of future storage technologies?
  - Lowest average cost, but highest price variation?
- Lignite >1000yrs under likely use
  - Low cost
  - GHG?
- Biomass - sustainable purpose grown forests (+15-20 years) or arisings
  - Cost?
  - Efficiency vs liquid biofuels?

POTENTIAL FOR APPLICATION IN NEW ZEALAND

Value for grid storage and sectoral transfer
- Ancillary services - power quality and frequency supports
- Improved utilization of generation and T&D assets
- Higher renewable generation mix
- Slightly greener gas infrastructure
- Resilient low carbon transport option
- Energy security/independence

Help address two problems which will characterise New Zealand’s future energy system:
- Electricity grid balancing
  - Include sectoral transfer in the options
- Cost and availability of transport fuels
  - Include FCVs within the electric vehicle portfolio

OVERSEAS STATUS OF HYDROGEN TECHNOLOGIES

Transport Infrastructure
Results from stage 1 of the UKH2Mobility project [Ref.2]
- Potential for 1.6 million vehicles on UK roads by 2030
- Annual sales more than 300,000
- Initial rollout of just 65 hydrogen refuelling stations, growing to 1150 sites by 2030.
- The hydrogen refuelling network will cover its operating costs by the early 2020s, and reach breakeven in the late 2020s.
- Total financing needed up to breakeven is £418 million (US$655 million), with £62 million ($97 million) required before 2020.
OVERSEAS STATUS OF HYDROGEN TECHNOLOGIES

Hydrogen Vehicles
FCVs
- Alliances are being formed to reduce costs/take advantage of the best stack technology on show
  - Daimler/Nissan/Ford
  - BMW/Toyota

OVERSEAS STATUS OF HYDROGEN TECHNOLOGIES

Grid/network generation - hydrogen storage
- IEA H2A Task 18: DISCO H2 has identified more than 35 hydrogen storage projects
Examples follow:

OVERSEAS STATUS OF HYDROGEN TECHNOLOGIES

Electrolysis as a controllable load for grid frequency regulation
Source: Hydrogenics

OVERSEAS STATUS OF HYDROGEN TECHNOLOGIES

HYDROLICA
Project duration: operate
Partners: Basal, Enovis, INERCO, AIDIA
GREENPOWER,
Hydrogenics
Location: Cadiz, Spain
Data availability: -

The aim of this project is to optimize the energy use of wind farms with integrated production of hydrogen and electricity.
OVERSEAS STATUS OF HYDROGEN TECHNOLOGIES

MYRTE
Project duration: 2009-2015
Partners: IEC, HELION, CEA, RAFFALI
Location: Corse, France
Data availability: OK
- 40Nm3/hr 30 bar electrolyser
- 350kWp PV plant
- 200kW fuel cell plant

REFERENCES
1. NZWEA Wind Energy to 2030 http://windenergy.org.nz/resources/resources
2. Synopsis of UKH Mobility Phase 1 results: http://tinyurl.com/ukh2mobility-phase1