The Scottish renewable resource assessment and implications for the grid

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Background

• Scottish renewable target: 40% by 2020, recently upgraded to 50%, interim milestone of 31% by 2011
• In 2004, the (then) Scottish Executive commissioned a report to appraise of the extent to which Scotland could meet the 40% target
• The aim: realistic assessment of Scotland’s renewable potential (wind on- and off-shore, tidal and wave resource)
• The Scottish target is now 50% but the assessment of the resource still stands
What’s unique?

• Temporal resolution: one-hour for wind and 3 hours for wave
• Spatial resolution: 1 km²
• Physical modelling using WAsP and WindFarmer: calculate wind at turbine height (80 m agl.) in each 1 km² cell from met station data, elevation data and surface roughness description
• Eliminate no-go areas and take limits into account
• Rank sites according to costs
• Full report available from: http://www.scotland.gov.uk/Publications/2006/04/24110728/0
The Challenge

MEC Load

Network

Supply

Demand

Time

Time
Study Area

• Spatial resolution: 1 km²
• Use of British National Grid coordinates

Source: Ordnance Survey
Political

- International limit (200 nmi, 12 nmi)
- National limit
- Fishing limit (6 nmi)
- Planning authorities
- Local regulations

Sources: OS, UKHO
Physical

- Water depth
- Slope
- Lakes
- Rivers
- etc.

Example:
Average slope > 15% in a 1 km by 1 km square.

Sources: OS, BGS, BODC, SRTM
Environment

- Recreation interests (high sensitivity)
  - National Scenic Area
  - National Park
  - Regional park

- Biodiversity interests (high sensitivity)
  - Natura 2000, SSSI, ...

- Medium sensitivity areas
  - AGLV, LNR, ...

Sources: OS, SNH, SEGIS
Aviation Interests

- **Civil radars**
  - 15 km exclusion zone
  - 30 km consultation zone
  - NATS high impact
  - NATS lower impact
- **Military radars**
- **Met Office radars**
- **Low Flying System**
  - Tactical Training Area

Sources: OS, DTI, CAA, BWEA
Further Constraints

- Urban areas
  - Cities, towns, villages

- Navigational risk
  - very high
  - medium
  - very low

- Seismological measurements
  - Eskdalemuir

- Ammunition dumping

- Distances, etc.

Sources: OS, DTI, CAA, BWEA
Onshore Wind Resource

Average wind speed in each 1 km\(^2\) cell at 80 m height agl. calculated from met station data using WAsP and WindFarmer

10 years data (1994-2003)

| 4 | 10 | 16 m/s |

Meteorological station (21 + 3)

Sources: OS, Met Office
Offshore Wind Resource

Average wind speed at 80 m height asl.

4  10  16 m/s

Water depth, 5 km offshore

- 0 ... 30 m
- 30 ... 40 m
- 40 ... 50 m

+ Met Office Simulation Point (11)

Sources: OS, DTI, Met Office
Wave Resource

3 hour data: March 2000 – Nov 2004

Wave power per metre crest length

5 30 55 kW/m

Water depth, 5 km offshore

□ 50 ... 100 m

+ Met Office Simulation Point (84 + 11)

Sources: OS, DTI, Met Office
Tidal Current Resource

Variable but deterministic

Average spring tide velocity (surface)

| 0.5 | 1.5 | 2.5 m/s |

Water depth

- 30 ... 50 m

Sources: OS, DTI, Robert Gordon Univ.
Contents

Future Generator Locations

Constraints
Long-term resource

GIS
Project costs
Selection criteria
Generator locations
Resource time series

Macro

Scenario

Network

Key figures

Results

Converter

Renewable generation

Demand

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The Scottish renewable resource assessment and implications for the grid
16 May 2008
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Cost Calculation

<table>
<thead>
<tr>
<th>Step</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remove “no go” cells</td>
<td>e.g. cities, NSAs</td>
</tr>
<tr>
<td>Calculate annual energy output</td>
<td></td>
</tr>
<tr>
<td>Calculate (initial) levelised project cost (LPC) per cell</td>
<td>Excluding grid connection costs</td>
</tr>
<tr>
<td>Remove “expensive” cells</td>
<td>e.g. &gt; 10 p/kWh</td>
</tr>
<tr>
<td>Check capacity limit in consultation areas</td>
<td>e.g. by 100 km² area, remove more cells</td>
</tr>
<tr>
<td>Cluster to projects (for cost sharing)</td>
<td>neighbouring cells, total capacity limit</td>
</tr>
<tr>
<td>Calculate (final) LPC per cell</td>
<td>Including grid connection costs per area; capacity or cost limit</td>
</tr>
<tr>
<td>Select cells</td>
<td></td>
</tr>
</tbody>
</table>
Project Costs

Example:
Estimated onshore wind project costs including connection to existing network

- low cost
- medium cost
- high cost

- “no go” zone

Assumptions:
- 3 x 2.5 MW per km²
- 80 m hub height
- 20 years, 8 % discount rate
Contents

Creating Power Time Series

- Constraints
- Long-term resource
- GIS
- Project costs
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- Renewable generation
- Network
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- Converter
- Key figures
- Results
- Scenarios
- Macros
- Resource time series
- Conversion

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Energy Converters

On/Offshore Wind

- 3-bladed horizontal axis turbine with pitchable blades
- 80 / 120 m diameter
- 2.5 / 5 MW
- 80 m hub height
- Offshore: < 40 m water depth

Waves

- Semi-submerged articulated structure
- 180 m long
- 1.5 MW
- 50 ... 150 m water depth

Tidal Currents

- Twin-rotor horizontal axis turbine with pitchable blades
- 20 m rotor diameter
- 2 x 500 kW
- 30 ... 50 m water depth

Source: Nordex, OPD, MCT
Contents

Generation vs. Demand

Constraints

Long-term resource

Generator locations

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Project costs

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Macro

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Converter

Key figures

Results

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Scenarios

Macro

Renewable generation

Demand

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Demand - Daily

Example: 2002/03

Source: SP and SSE 2003 Seven Year Statements
Demand - Annual

Source: SP 2002 and 2003 Seven Year Statements
Sample Area
Demand Matching January, July 2003

Tidal currents
Waves

Offshore wind
Onshore wind
(a) Orkney
(b) Mainland

40%, 100% demand

0 40 80 120 (MW)

Jan-20 Jan-21 Jan-22 Jan-23 Jan-24 Jan-25 Jan-26 Jan-27

16 May 2008
Key Figures and Results

Contents

- Constraints
  - Long-term resource
  - Project costs
    - GIS
      - Selection criteria
        - Generator locations
          - Resource time series
            - Macro
              - Resource generation
                - Converter
                  - Demand
                    - Network
                      - Scenarios
                        - Key figures
                          - Results
Results

After application of geographical constraints it could be possible to develop at least

– 6 GW of onshore wind
– 3 GW of offshore wind
– 3 GW of wave and
– 1 GW for tidal current

or any combination of these technologies.
Results

Annual plant capacity factors derived from production time-series all exceed 30%

- They reduce as the capacity increases by adding less energetic higher cost sites.
- Seasonal values for wind and wave power are significantly higher in winter than in summer.

<table>
<thead>
<tr>
<th>Plant capacity factor (%)</th>
<th>3 GW</th>
<th>6 GW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onshore-wind</td>
<td>33.9</td>
<td>32.7</td>
</tr>
<tr>
<td>Offshore-wind</td>
<td>35.8</td>
<td>-</td>
</tr>
<tr>
<td>Wave</td>
<td>31.7</td>
<td>-</td>
</tr>
<tr>
<td>Tidal-current (750 MW)</td>
<td>(30.0)</td>
<td>-</td>
</tr>
<tr>
<td>75-10-10-5% mix</td>
<td>34.7</td>
<td>33.5</td>
</tr>
</tbody>
</table>
Results

Onshore wind or the mixed technology portfolio of 6 GW would on average meet at least 40% of the electricity demand in 2020.

Potential to increase the penetration to 50% or more.

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<table>
<thead>
<tr>
<th>Technology</th>
<th>3 GW</th>
<th>6 GW</th>
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</thead>
<tbody>
<tr>
<td>Onshore wind</td>
<td>21.8</td>
<td>41.5</td>
</tr>
<tr>
<td>Offshore wind</td>
<td>23.0</td>
<td>-</td>
</tr>
<tr>
<td>Wave</td>
<td>20.4</td>
<td>-</td>
</tr>
<tr>
<td>Tidal-current (750 MW)</td>
<td>(4.8)</td>
<td>-</td>
</tr>
<tr>
<td>75-10-10-5% mix</td>
<td>22.3</td>
<td>42.7</td>
</tr>
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</table>
Results

Coincident hours best describe ongoing hourly match as a histogram.

There is about 29 hours/year when the demand > 90% of the peak while on-shore wind provides less than 10% of its capacity.

Diversification by using a portfolio of renewable generation reduces that number to 20 hours/year.

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<tr>
<td>Onshore-wind</td>
<td>29</td>
<td>29</td>
</tr>
<tr>
<td>Offshore-wind</td>
<td>14</td>
<td>-</td>
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<tr>
<td>Wave</td>
<td>19</td>
<td>-</td>
</tr>
<tr>
<td>Tidal-current (750 MW)</td>
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<td>75-10-10-5% mix</td>
<td>18</td>
<td>20</td>
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Network Access

Generally weak network in Scotland

Competition for network access

Full development of the more remote onshore and most of the offshore resource would require completion of planned network upgrades in northern and western Scotland.
Need for network upgrades

Current developments: review of GB Security and Quality of Supply Standard (SQSS) and Transmission Access Review (TAR)

Controversy regarding scaling factor for wind for network planning purposes (currently 60%)

Need for upgrades could be reduced if control schemes were more widely used (quad boosters, intertrips)
Summary

The study has refined understanding of characteristics and availability of renewable resource in Scotland through detailed physical modelling using geographical and surface roughness data.

Realistic assessment by eliminating no-go areas and including limits to renewable generation.

Diversification of renewable energy sources helps to manage variability of renewable input but a strong interconnected transmission system is required.

SuperGen FlexNet projects will extend the study to the whole GB although in less detail.