EquiMar: Work Package 7
Economic Assessment of Large-Scale Marine Energy

8th European Wave and Tidal Energy Conference (EWTEC)
9th September 2009

EU FP7 ENERGY.2007.2.6.3
Tim Stallard¹, Gareth Harrison², Pierpaolo Ricci³ and Jose-Luis Villate³

¹JOULE Centre, University of Manchester, UK.
²Institute of Energy Systems, University of Edinburgh, UK.
³TECNALIA-Energia ROBOTIKER-Tecnalia, Spain.

Equitable Appraisal of Marine Energy Systems

To deliver a suite of protocols for the equitable evaluation of marine energy converters
– Both tidal and wave energy.

These will harmonise testing and evaluation procedures including
– site selection,
– device engineering design,
– scaling up of designs,
– deployment of device arrays,
– environmental impact, and
– economic issues.
Equimar: Economic Assessment

Objectives:
NOT to state cost of electricity
NOT to propose a new method for assessment

To identify the key stages of an assessment to allow fair comparison of marine energy technologies accounting for:
- stage of development
- deployment scale

Learn from early developer experience

Review of motives and methods for conducting economic assessment of marine energy
- Brief review of literature
- Feedback from stakeholders
- Objectives of economic assessment
- Economic criteria
- Project assessment
- Technology assessment
- Limitations
Background

- EPRI (2005-7)
- Ernst & Young (2007) Impact of Banding the ROC
- Renewables Advisory Board (2007) Marine Renewables

Reasons for conducting Economic Assessment

Facilitate fair comparison of alternative marine technologies for large-scale deployment.

A
- To provide a summary measure of economic viability to allow comparison to alternative project options.
  - Economic Assessment of a Project
    - Standard procedure for determining economic indicators
    - Identify the underlying processes that influence cost and revenue
    - Account for uncertainty consistent with the level of development

B
- To provide comparison between electricity generating options (e.g. between individual wave or tidal technologies).
  - Economic Assessment of a Technology
    - Quantify limits to performance and cost reductions
    - Quantify range of possible cost variations
Economic Indicators

Payback period (years):
- Capital cost of the project divided by the average annual average return.

Return on investment (%):
- Average annual return / capital cost

Levelised cost of Electricity (COE):
- Present value of all expenditures / Present value of electricity production

... all neglect or simplify future revenue ...

Net Present Value (NPV):
- Sum of present values of all future income and all future expenditures.

Benefit/Cost ratio:
- Present value of all income / Present value of all costs over project life

Internal Rate of Return (IRR):
- Value of discount rate that gives a Net Present Value of zero.

Benefit/Cost ratio: 
- Present value of all income / Present value of all costs over project life

Portfolio theory ... (Supergen Marine II)

Net Present Value

\[ \text{Annual cash flow} \]

\[ \text{Lifetime cash flow} \]

\[ \text{Project Net Present Value} \]

\[ \text{Discount Rate} \]

\[ \text{Operating Life} \]

\[ \text{Ex. Decom.} \]

\[ \text{CAPEX} \]

\[ \text{OPEX} \]

\[ \text{Revenue} \]

\[ \text{Other Cash Flows: Feed-in tariff} \]
Economic Measures

COE widely used
Capital cost and Installation costs assumed less important
Operating cost of particular importance to Policy Makers

Stallard, T., Harrison, G.P., Ricci, P. and Villate, J-L.

Capital Cost

Stallard, T., Harrison, G.P., Ricci, P. and Villate, J-L.
### Capital Cost

#### Indicative percentage contributions to CAPEX

From Equimar workshop & Survey

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Installation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Station-keeping</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E&amp;M equipment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### From Equimar workshop & Survey

Stallard, T., Harrison, G.P., Ricci, P. and Villate, J-L.

#### Expected CAPEX for increased deployment scale

TOTAL Reduction:
- A: -20.6%
- B: -9.7%
- C: -18.0%
- D: -10.5%

From Equimar workshop & Survey

Stallard, T., Harrison, G.P., Ricci, P. and Villate, J-L.
Operating Costs

Most significant components of operating cost

<table>
<thead>
<tr>
<th>Rank</th>
<th>Operating Cost Category</th>
<th>Score</th>
<th>Uncertainty</th>
<th>Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Vessels for transportation &amp; on-site maintenance</td>
<td>9</td>
<td>30%</td>
<td>14%</td>
</tr>
<tr>
<td>2</td>
<td>Maintenance &amp; monitoring personnel</td>
<td>5</td>
<td>30%</td>
<td>19%</td>
</tr>
<tr>
<td>3</td>
<td>Insurance</td>
<td>3.5</td>
<td>30%</td>
<td>21%</td>
</tr>
<tr>
<td>4</td>
<td>Costs related to inaccessibility</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Replacement parts</td>
<td>2.5</td>
<td>30%</td>
<td>14%</td>
</tr>
<tr>
<td>6</td>
<td>Organisation and finance</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From Equimar workshop & Survey
Risk Assessment

Technology Risk
- Mismatch between predicted- and actual behaviour
- Mitigated by warranties, technology qualification

Project Risk
- Unexpected events that influence viability

Generally modelled through discount rate
- Company’s weighted average cost of capital
- Reflects risk of a company’s typical projects rather than specific technology

Uniform (Carbon Trust, 2006; EPRI, 2005)
- Typically 8-15 % used, higher rates account for greater uncertainty

Cash-flow dependent (Awerbuch, 2003)
CAPM industry sector (Gross & Chapman, 2003) – comparison to broad set of industries
CAPM technology specific (Harrison et al. 2003)

Revenue

Power production is sole driver of project revenue

Technology Uncertainty – device output, array output
- Varies with development stage (qualified by other protocols)

Environment Uncertainty
- Wave and tidal stream predictability and variance

Market value: volatile, long term uncertainty

![Price Graph](www.elexon.com)
Cost variation with development

Industry wide-learning of 10 – 15% (Carbon Trust; EPRI) by ... (Junginger, 2005)
- searching (R&D, new technologies)
- doing (fabrication and installation processes)
- using (early stage learning from niche markets)
- interacting (across sectors and within industry)
- upsizing, or downsizing (economies of PROJECT scale)
- economies of scale (economies of TECHNOLOGY scale)

Limitations -
- Difficult to transfer between industry sectors (IEA, 2006),
- Rates are time-varying (Junginger, 2004; Ferioli, 2009),
- Not applicable at early development stage (Jeffery et al. 2008).

Does not differentiate between technologies – component rates

Cost Reduction Mechanisms

Increase revenue: increased value per kWh
- increased availability
- increased performance

Reduce OPEX: reduced maintenance
- reduced insurance
- increased reliability

Reduce CAPEX: manufacturing processes
- installation processes
- material quantities
- material cost
Ongoing activities

Increase revenue:
Review of technical limits to capture element and array performance

Reduce OPEX:
Duration of accessible conditions for large farm installation and maintenance

Reduce CAPEX:
Technical limit to number of devices - limits scope for learning
Change of civil infrastructure with scale of deployment
- Supporting structures,
- Mooring configurations,
- Bed connections

Summary

Two distinct types of economic assessment can be identified:

• For Project assessment
  – Several quantitative measures discussed
  – Indicative CAPEX and OPEX components and ‘expected’ trends
  – Highlighted links between environmental uncertainties and financial risk

• For Technology assessment
  – Methods for estimating cost changes outlined
  – Learning curves briefly discussed
  – Limits due to device performance, deployment scale and accessibility

• Ongoing Equimar work
  – cost drivers for infrastructure
  – site accessibility
  – performance limitations
Thanks for listening

For more information:

www.equimar.org

Wiki site: https://www.wiki.ed.ac.uk/display/EquiMarwiki/EquiMar

E-mail: equimar.contact@see.ed.ac.uk