Modelling generation investment under uncertainty: UK experience

James Tipping

Any analysis of future outcomes in a deregulated electricity market requires forecasts of the likely quantity, mix and operating behaviour of generation capacity on the system. Investment in such markets around the world is driven primarily by the profit-maximising intentions of market participants. However, their decision-making may not lead to capacity mixes and market operation that are consistent with the goals of policy makers, namely targets for security of supply, environmental standards and diversification of plant portfolios.

Modelling such behaviour requires a tool that is able to mimic the actual investment decision-making process. The tool must account for limited foresight on the part of investors, and interventions on the part of policy-makers. During time spent working with Redpoint Energy, a London-based energy consultancy, I was part of a team that developed a suite of tools for modelling the dynamic investment decision-making of market participants through time, as plant mixes, policies and pricing dynamics evolve. These tools operate in both the long and short term: investment (and retirement) decisions are made on an annual basis, in response to changes in pricing dynamics and security of supply metrics at an hourly level.

The tools have found frequent application in the Great Britain electricity market, for asset valuation, investment analysis and policy development. They have been used by the UK Government in several studies analysing different financial support mechanisms for renewable electricity, as well as in the analysis of different policies to promote security of electricity supply. In this presentation I describe the tools at a high level, and detail their application in the context of the British market, in which a significant level of subsidised investment in renewable technology is required.
Modelling generation investment under uncertainty: UK experience
Brief speaker background

2002 – 2006
PhD student (EMRG, Canterbury)
Market consultant (CRA International, Wellington)

2006 – 2009
Market consultant (Redpoint Energy, London)

2009 –
Strategic advisor (TrustPower, Tauranga)
Dynamic Simulation of Investment Decision-Making in Electricity Markets

IAEE Vienna 2009
8th September 2009

TO CLimb A NEW ROUTE SUCCESSFULLY FOLLOWING CAREFUL ANALYSIS AND PREPARATION
Redpoint Energy is a specialist energy consultancy, advising clients on investments, strategy and regulation across Europe’s liberalised power, gas and carbon markets.

Clients include utilities, banks, developers, policy makers and regulators.
Redpoint Energy (www.redpointenergy.com) is a specialist energy consultancy, advising clients on investments, risk, strategy, policy and regulation across Europe’s liberalised power and gas markets.

The Electricity Policy Research Group (www.electricitypolicy.org.uk) is based at the Faculty of Economics and at the Judge Business School, University of Cambridge. The group offers rigorous independent research output that informs public and private sector decision making in the electricity and energy industry.

Trilemma UK (www.trilemma-uk.co.uk) provides clients with advice on regulatory, policy and strategic issues affecting UK and European energy markets.

Modelling investment in liberalised markets

- Profit maximisation is the main driver of investment in deregulated electricity markets
- Decisions are made by multiple players
- Investment decisions are made with imperfect information (limited visibility of the future)
- Redpoint has developed a suite of tools which model the dynamic investment decision-making of market participants through time
Modelling suite overview

**Scenario assumptions**
- Fuel prices
- Supply curves
- Max build rates
- Capital costs
- Financing costs
- Operating costs

**Investment Decision Model**
- **Investment decisions**
  - LRMCs
  - Expected prices
  - Risk adjusted required price
  - Build decisions
- **Outturn results**
  - Demand Prices Costs
  - CO₂ emissions
- **Policy option**

**Risk Assessment Model**
- Risk premia
  - by investor
  - by technology

**Volatility model**
- Capacity factors
- Price shape
- Unserved energy

**Modelling period results**
- Installed capacity
- Achieved renewables generation
- Subsidy cost
- Cost Benefit Analysis
Risk Assessment Model

Scenario assumptions
- Fuel prices
- Supply curves
- Max build rates
- Capital costs
- Financing costs
- Operating costs

Investment Decision Model
- Investment decisions
- LRMCs
- Expected prices
- Build decisions
- Risk adjusted required price
- Demand Prices
- Costs
- CO₂ emissions

Outturn results
- Policy option
- Risk Assessment Model
- Risk premia
  - by investor
  - by technology
- Volatility model
  - Capacity factors
  - Price shape
  - Unserved energy

Modelling period results
- Installed capacity
- Achieved renewables generation
- Subsidy cost
- Cost Benefit Analysis
Individual projects are exposed to risks such as:

- Capital expenditure
- Construction time
- Power price risk
- Volume risk (load factor variation and outage risk)
- Policy risk (carbon market, subsidy schemes)

Investors recognize these risks by requiring a higher return on investment
The model is based on a Risk-Adjusted Return on Capital (RAROC) approach. The model uses a Monte Carlo simulation of the uncertain variables, resulting in a distribution of profitability outcomes for the project. A riskier project will have a wider distribution of NPV outcomes. We convert this to a hurdle rate for the project – a riskier project has a higher hurdle rate.

---

Risk Assessment Model: Renewables Support Schemes

- Feed in Tariff
  - Generator receives a fixed price for output
- Obligation scheme
  - Generator sells power into the market
  - Generator receives ‘Green certificates’

### Risk management afforded by different support schemes

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Obligation scheme</th>
<th>Feed in Tariff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Policy risk</td>
<td>✗</td>
<td>✓</td>
</tr>
<tr>
<td>Subsidy risk</td>
<td>✗</td>
<td>✓</td>
</tr>
<tr>
<td>Electricity price risk</td>
<td>✗</td>
<td>✓</td>
</tr>
<tr>
<td>Forecasting/balancing risk</td>
<td>✗</td>
<td>✓</td>
</tr>
<tr>
<td>Locational/transmission charging risk</td>
<td>✗</td>
<td>✓</td>
</tr>
<tr>
<td>Project risk</td>
<td>✗</td>
<td>✗</td>
</tr>
</tbody>
</table>
• Risk reduction under Feed in Tariff has a significant impact on hurdle rates

• This has a direct impact on the costs of new entry

<table>
<thead>
<tr>
<th>Technology</th>
<th>Percentage point increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onshore wind</td>
<td>1.1% - 1.8%</td>
</tr>
<tr>
<td>Offshore wind</td>
<td>1.7% - 2.7%</td>
</tr>
<tr>
<td>Biomass</td>
<td>3.3% - 3.8%</td>
</tr>
<tr>
<td>Wave</td>
<td>0.5% - 0.7%</td>
</tr>
<tr>
<td>Tidal Stream</td>
<td>0.7% - 1.0%</td>
</tr>
<tr>
<td>Tidal Range</td>
<td>0.5% - 0.7%</td>
</tr>
</tbody>
</table>

*Impact on new entry costs*

*Modelled increase in hurdle rate under Obligation scheme*
Investment Decision Model

Scenario assumptions
- Fuel prices
- Supply curves
- Max build rates
- Capital costs
- Financing costs
- Operating costs

Investment Decision Model
Investment decisions
- LRMCs
- Expected prices
- Risk adjusted required price
- Build decisions

Outturn results
- Demand
- Prices
- Costs
- CO₂ emissions

Modelling period results
- Installed capacity
- Achieved renewables generation
- Subsidy cost
- Cost Benefit Analysis

Risk Assessment Model
- Risk premia
  - by investor
  - by technology

Volatility model
- Capacity factors
- Price shape
- Unserved energy

Policy option
Investment Decision Model

- Agent-based simulation – each investor an independent agent

- Investors annually assess investment opportunities, comparing risk-adjusted new entry costs to an expected annual wholesale power price

- Investors do not have perfect foresight of future market conditions:
  - Fuel prices
  - Future capacity changes
  - Demand growth
### Investment Decision Model: Capacity development

#### In Planning

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CCGT</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>ASC</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>ASC + CCS</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Nuclear</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
</tbody>
</table>

#### Committed

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CCGT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASC + CCS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nuclear</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### In Operation

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CCGT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASC + CCS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nuclear</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
• Investment costs for conventional generation (e.g. CCGT) often show little variation across projects
• Renewable investments are often location specific
• Resource availability is limited and varies by location
• Emerging technologies may have a technological learning curve
• The model captures these effects dynamically
Investment Decision Model: Renewable Supply Curves

Supply Curve

Risk-adjusted new entry cost compared to expected revenues

Moving up the supply curve increases LRMC
Volatility Model

Investment Decision Model

Scenario assumptions
- Fuel prices
- Supply curves
- Max build rates
- Capital costs
- Financing costs
- Operating costs

Policy option

Risk Assessment Model
- Risk premia
  - by investor
  - by technology

Modelling period results
- Installed capacity
- Achieved renewables generation
- Subsidy cost
- Cost Benefit Analysis

Volatility model
- Capacity factors
- Price shape
- Unserved energy

Investment decisions
- LRMCs
- Expected prices
- Risk adjusted required price
- Build decisions
- Demand
- Prices
- Costs
- CO₂ emissions
Calibrated inputs, at the hourly level

- Demand
  - Electricity price volatility
  - Price duration curves
  - Risk of supply shortfall

- Supply
  - Demand side response
  - Plant profitability

Monte Carlo simulation
Wind: plant location and capacity factors

• Regional location of new plant assumed based on existing and forecast development

• Half-hourly capacity factors for each “region” simulated based on long-term correlations

Capacity factors: aggregate tidal stream capacity

Tidal stream development concentrated in certain regions, especially the Pentland Firth
Capacity factors between Spring and Neap tides are scaled to ensure that both the Barrage and tidal range each have an annual simulated capacity factor of 23%
Summary

- Redpoint has developed a complete suite of internally-consistent models for investment and dispatch.
- Investment decisions are made by multiple agents, without perfect foresight, with dynamically evolving costs, and taking full account of the associated risks.
- We have used the modelling suite in analysis for policy makers and investors, to support real life decision-making.
- We believe that this is a novel application of these techniques within European power markets.
References to applications of the modelling suite

- **UK Renewables Consultation 2008:**

- **Benefits of marine technologies within a diversified renewables mix:**

- **UK Renewable Energy Strategy:**

- **UK Consultation on a framework for the development of clean coal:**

- **UK Committee on Climate Change – 1st Annual Progress Report:**
  [http://www.theccc.org.uk/reports/1st-progress-report](http://www.theccc.org.uk/reports/1st-progress-report)
Contacts:

Oliver Rix
oliver.rix@redpointenergy.com

www.redpointenergy.com

James Tipping
james.tipping@trustpower.co.nz