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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.

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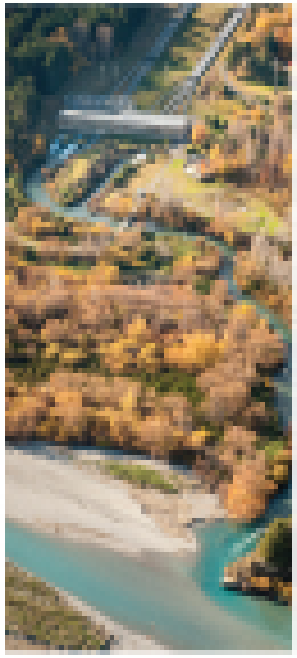
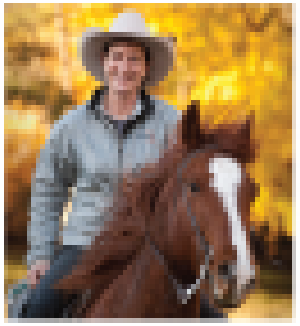
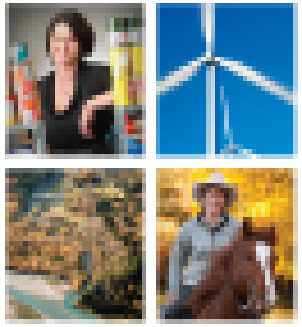




Modelling generation investment under uncertainty: UK experience

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

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Clients include utilities, banks, developers, policy makers and regulators

UK Renewables Consultation 2008

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.

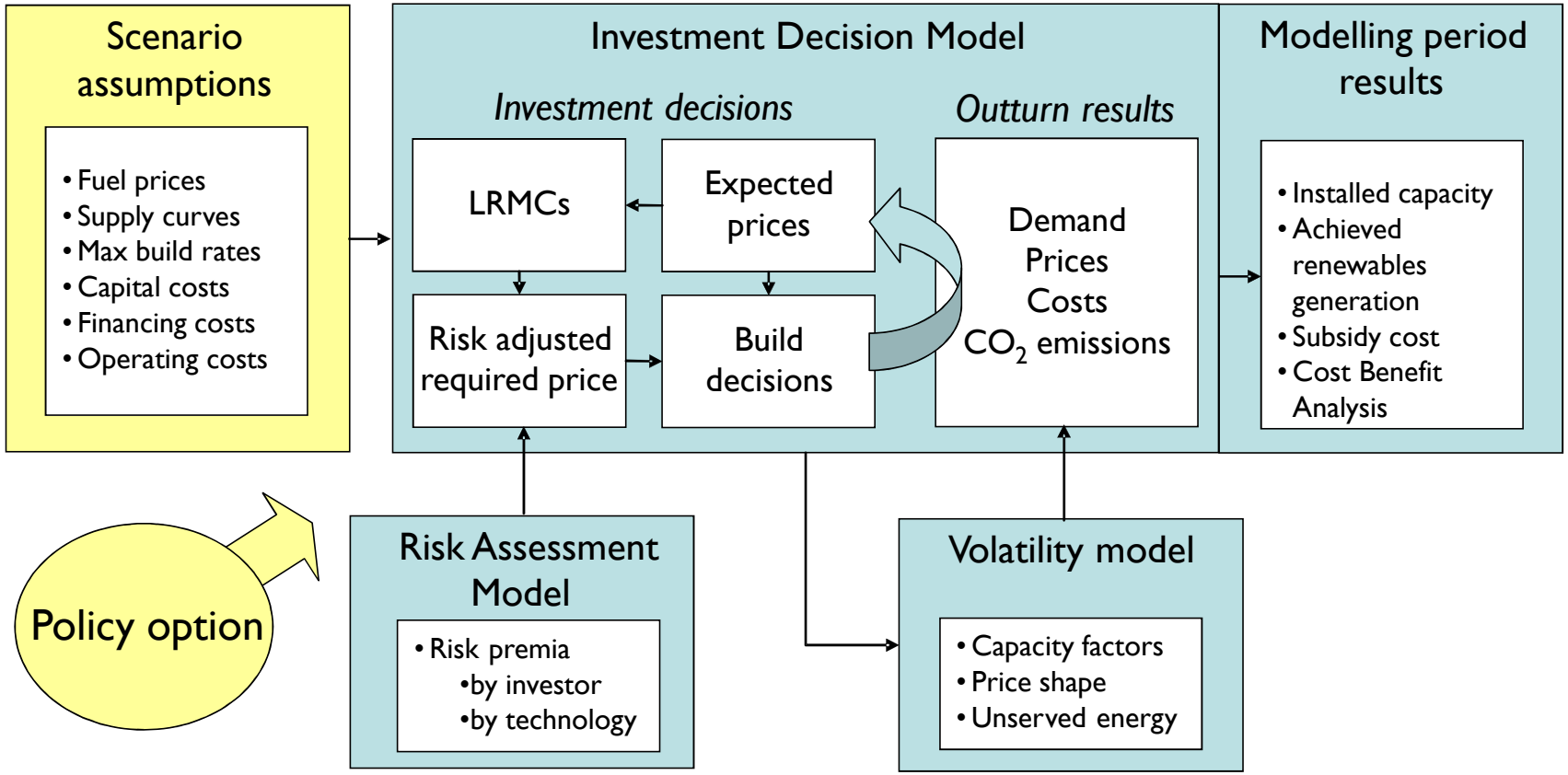
Trilemma UK (www.trilemma-uk.co.uk) provides clients with advice on regulatory, policy and strategic issues affecting UK and European energy markets.

http://www.decc.gov.uk/en/content/cms/consultations/cons_res/rescon_support/rescon_support.aspx

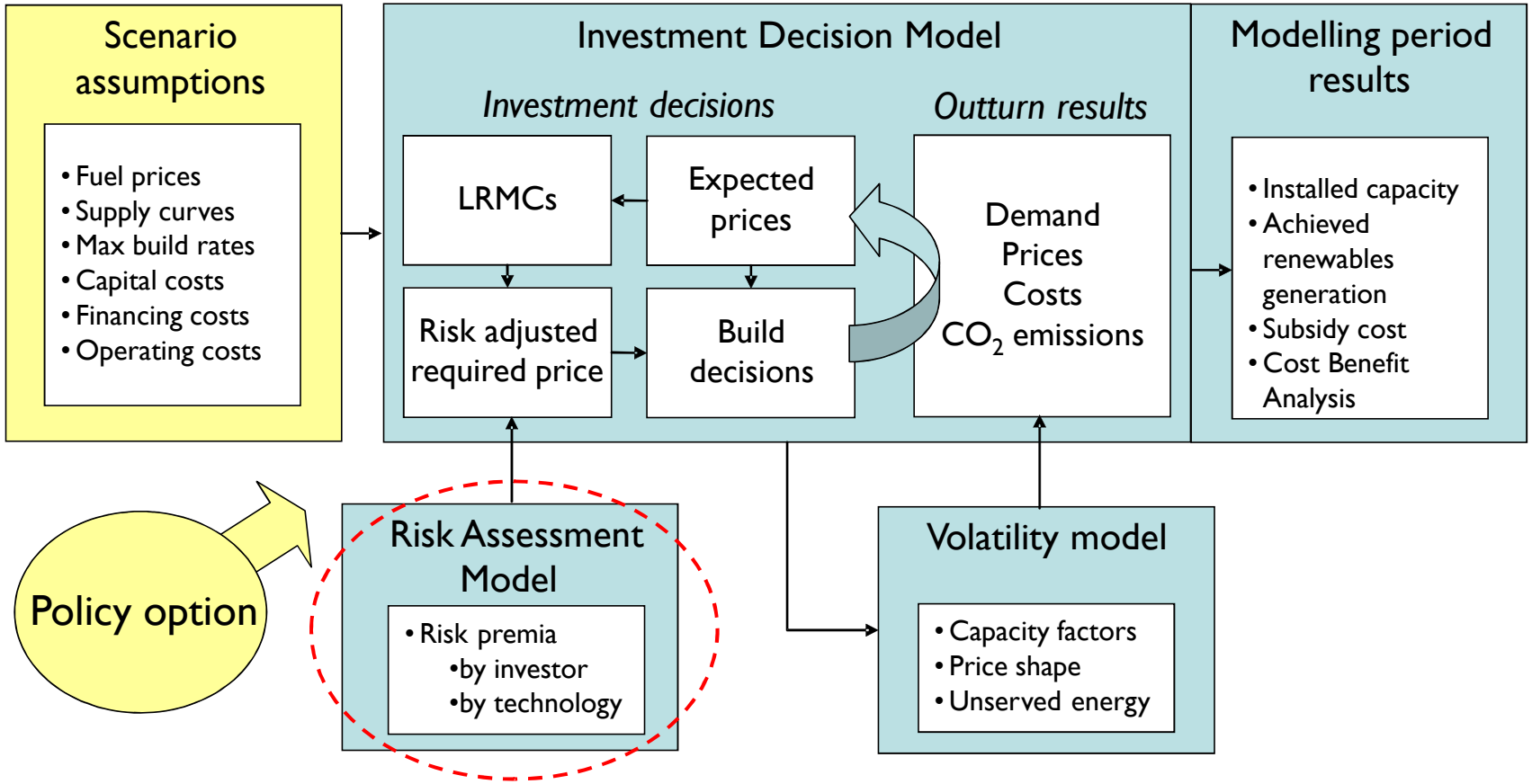
Modelling investment in liberalised markets

- 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



Risk Assessment Model



Risk Assessment Model

- 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

Risk Assessment Model

- The model is based on a Risk-Adjusted Return on Capital (RAROC) approach[1]
- 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

[1] See Prokopzuk, M., Rachev, S., Truck, S. (2004), 'Quantifying Risk in the Electricity Business: A RAROC-based Approach'. Universität Karlsruhe, Germany and University of California, USA

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

Risk factor	Obligation scheme	Feed in Tariff
Policy risk	X	✓
Subsidy risk	X	✓
Electricity price risk	X	✓
Forecasting/balancing risk	X	✓
Locational/transmission charging risk	X	✓
Project risk	X	X

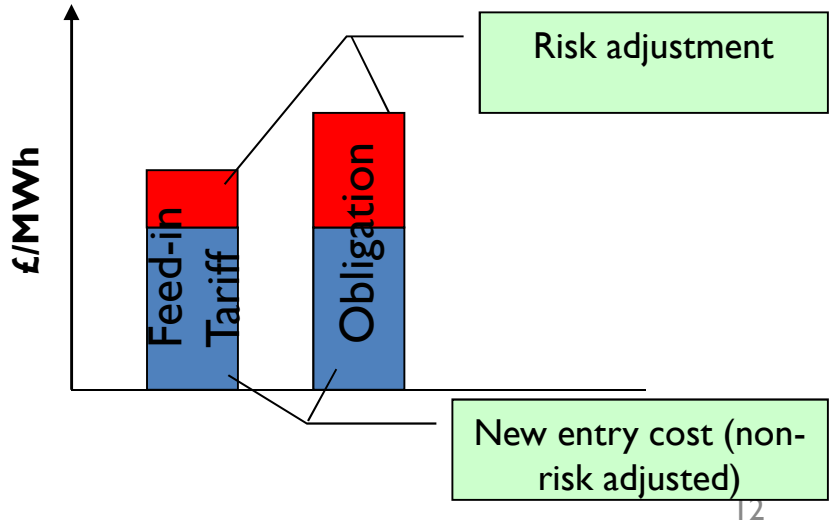
Risk Assessment Model: Renewables Support Schemes

- Risk reduction under Feed in Tariff has a significant impact on hurdle rates
- This has a direct impact on the costs of new entry

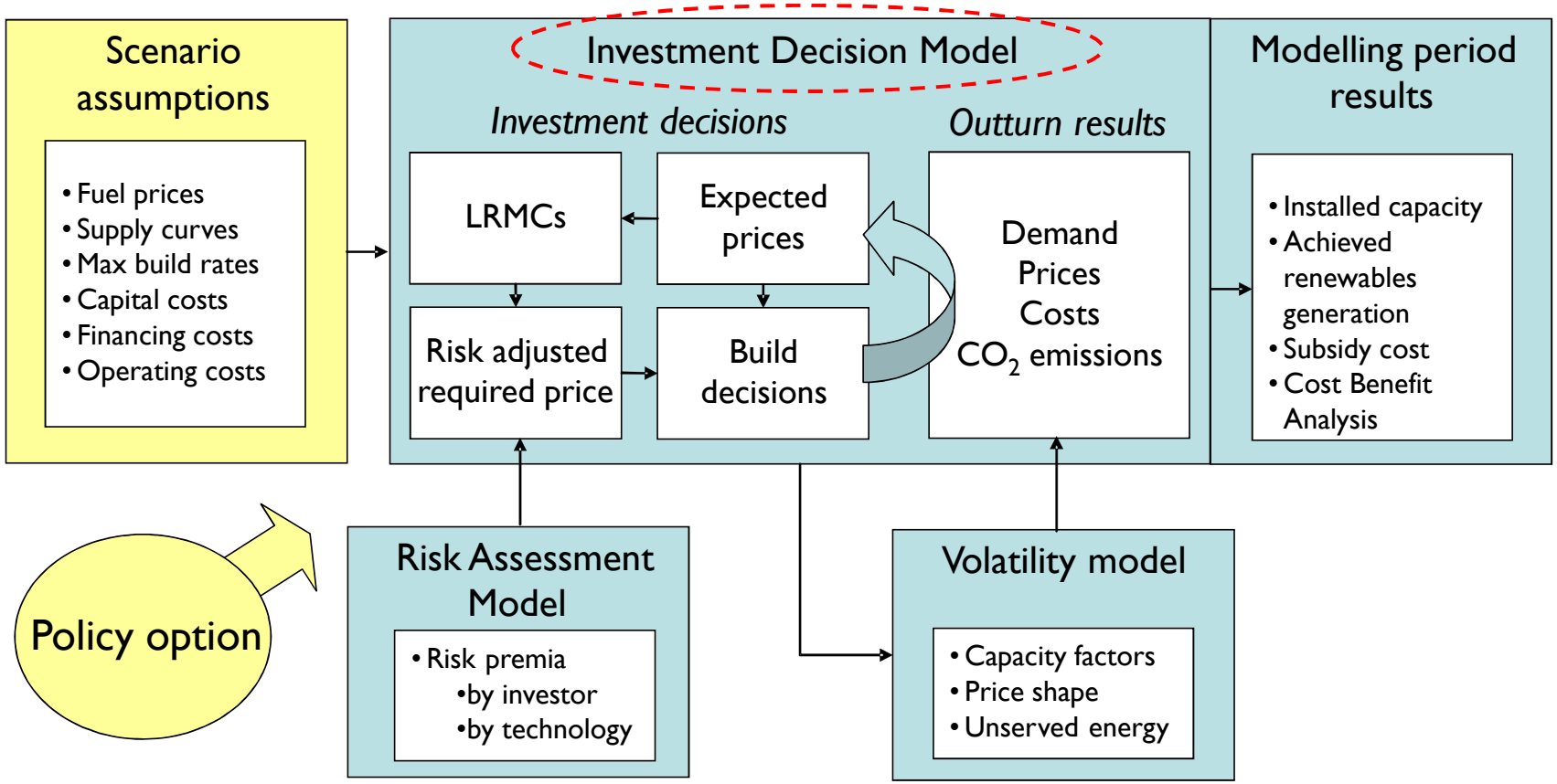
Modelled increase in hurdle rate under Obligation scheme

Technology	Percentage point increase
Onshore wind	1.1% - 1.8%
Offshore wind	1.7% - 2.7%
Biomass	3.3% - 3.8%
Wave	0.5% - 0.7%
Tidal Stream	0.7% - 1.0%
Tidal Range	0.5% - 0.7%

Impact on new entry costs



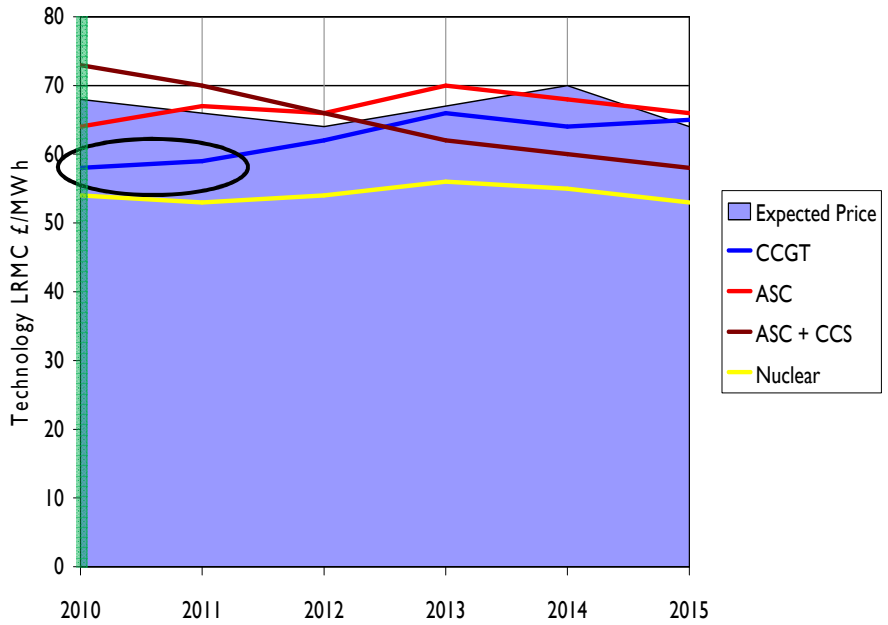
Investment Decision Model



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

In the Money (therefore in planning)	2010	2011	2012	2013	2014	2015
CCGT	Y	Y	Y	Y	Y	N
ASC	Y	N	N	N	Y	N
ASC + CCS	N	N	N	Y	Y	Y
Nuclear	Y	Y	Y	Y	Y	Y

Committed

Committed	2010	2011	2012	2013	2014	2015
CCGT			Y	Y	Y	Y
ASC						
ASC + CCS						
Nuclear				Y	Y	Y

In Operation

In service	2010	2011	2012	2013	2014	2015
CCGT						Y
ASC						
ASC + CCS						
Nuclear						

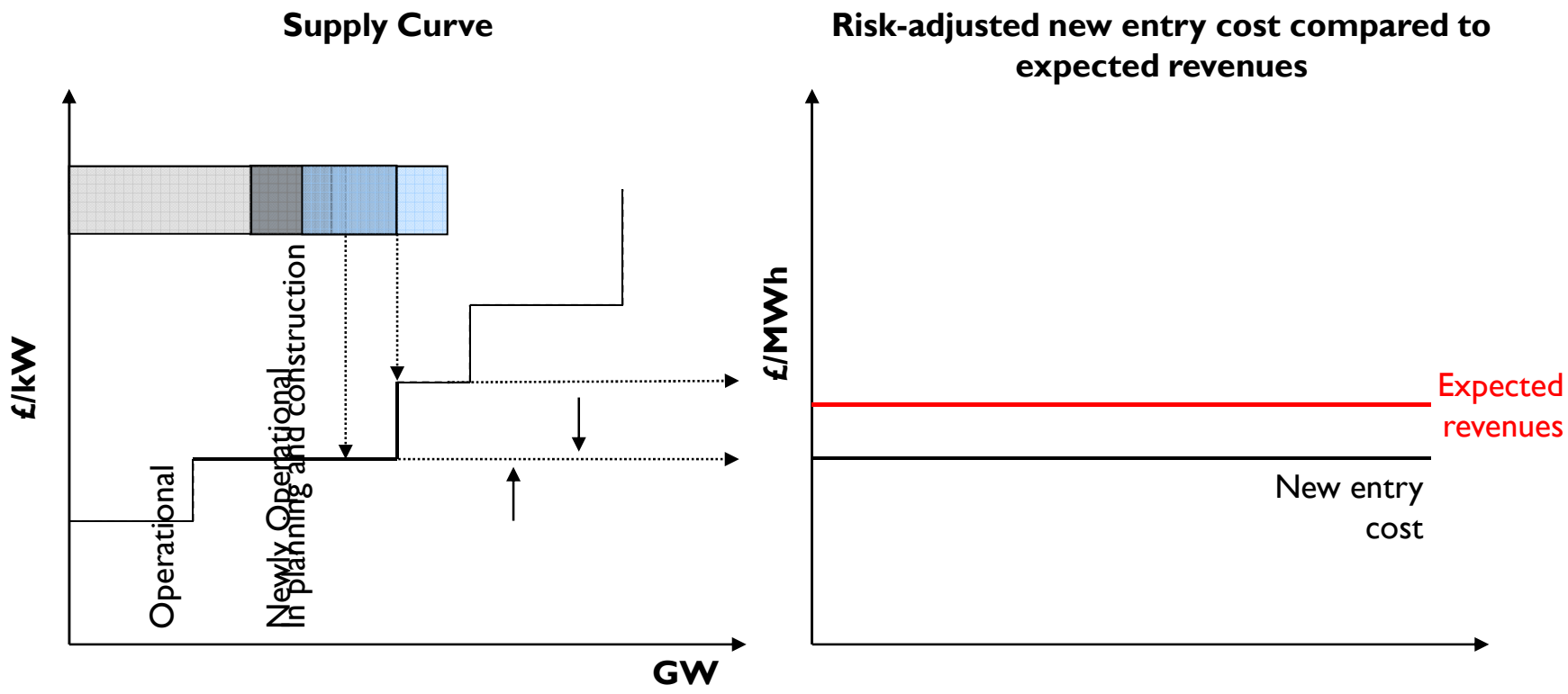
Parameters

	Planning Time	Build Time
CCGT	2	3
ASC	3	4
ASC + CCS	3	4
Nuclear	3	6

Dynamic Renewable Technology Costs

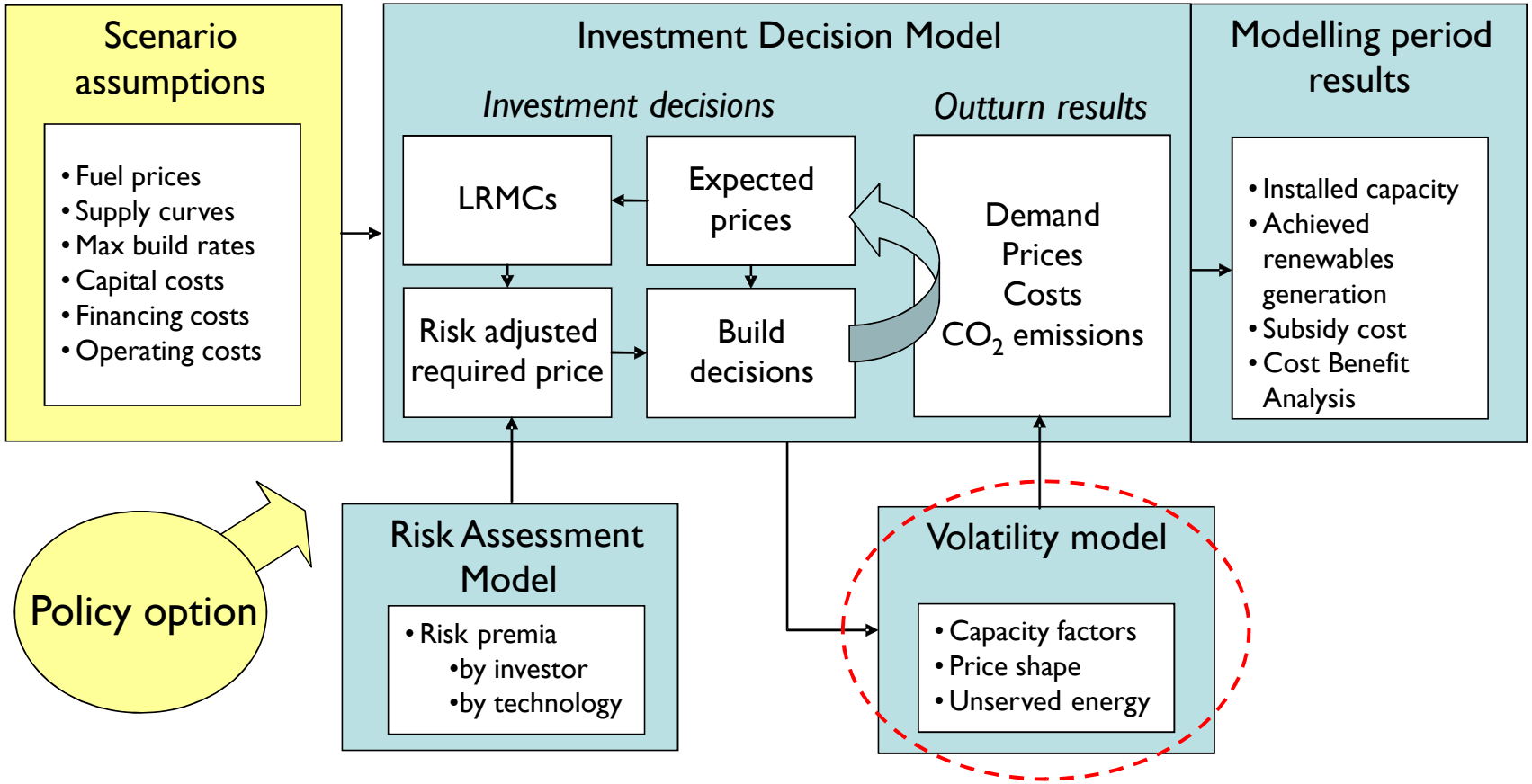
- Investment costs for conventional generation (e.g. CCGT) often show little variation across projects
- Renewable investments are often location specific
- Resource availability is limited and varies by location
- Emerging technologies may have a technological learning curve
- The model captures these effects dynamically

Investment Decision Model: Renewable Supply Curves

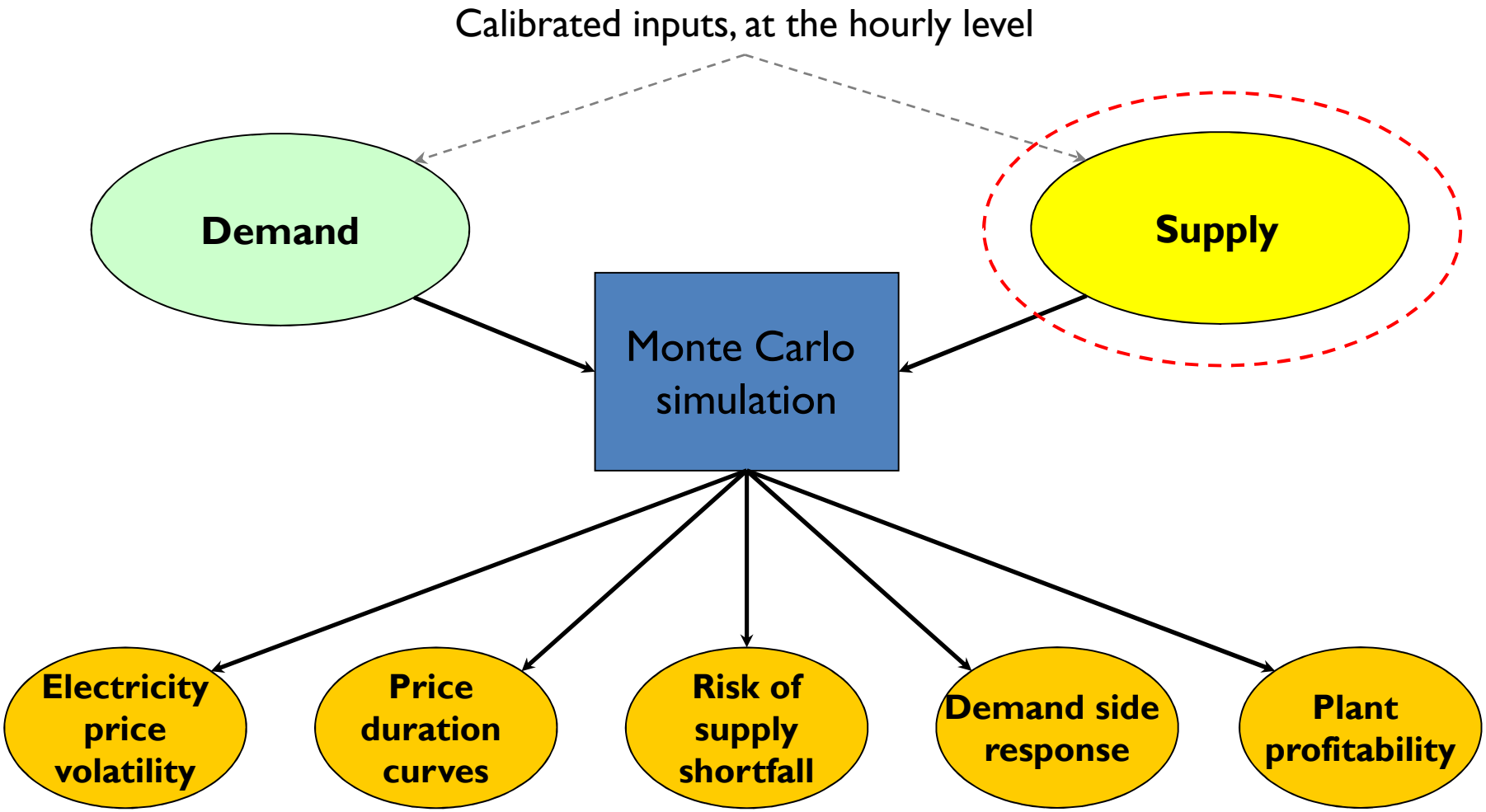


Moving up the supply curve increases LRMC

Volatility Model

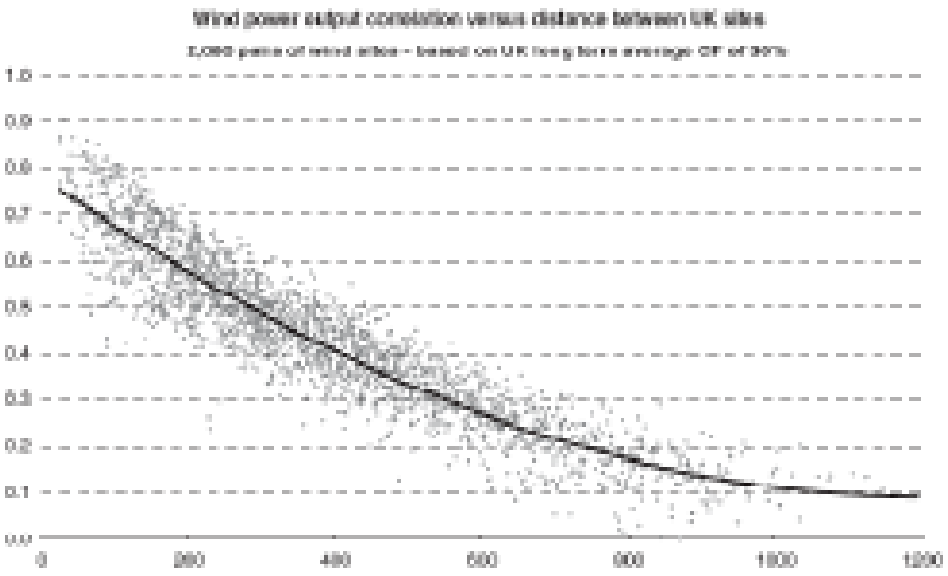


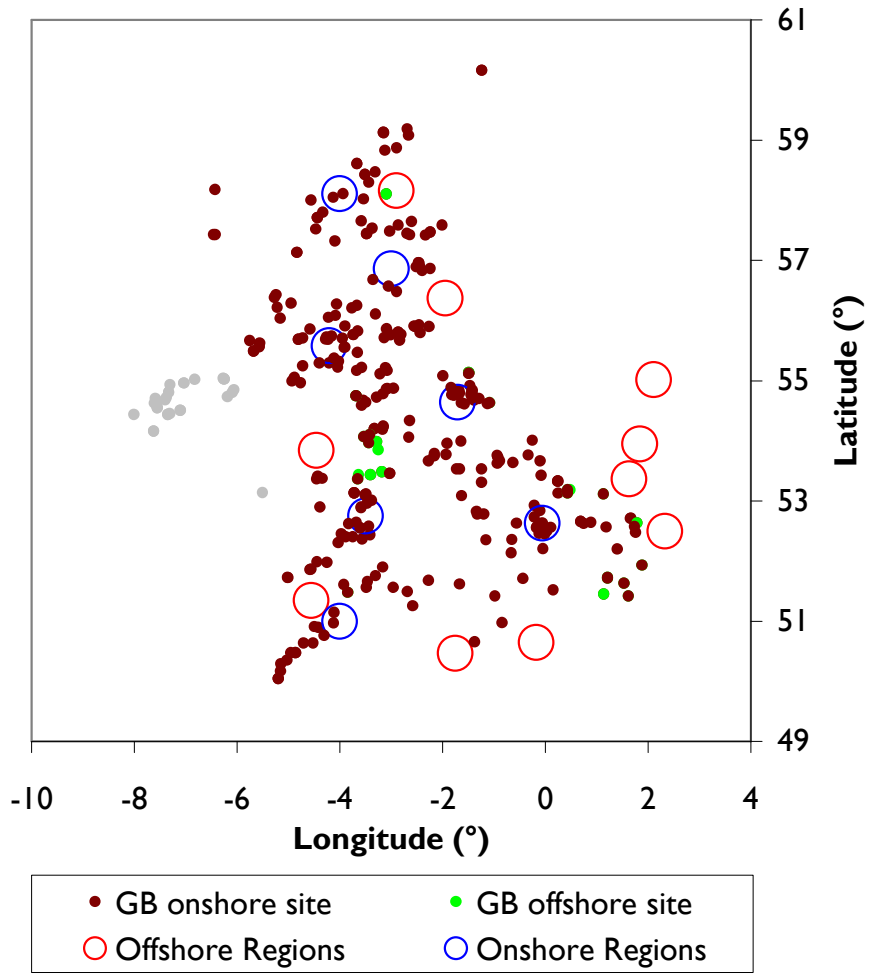
Volatility Model: Overview



Wind: plant location and capacity factors

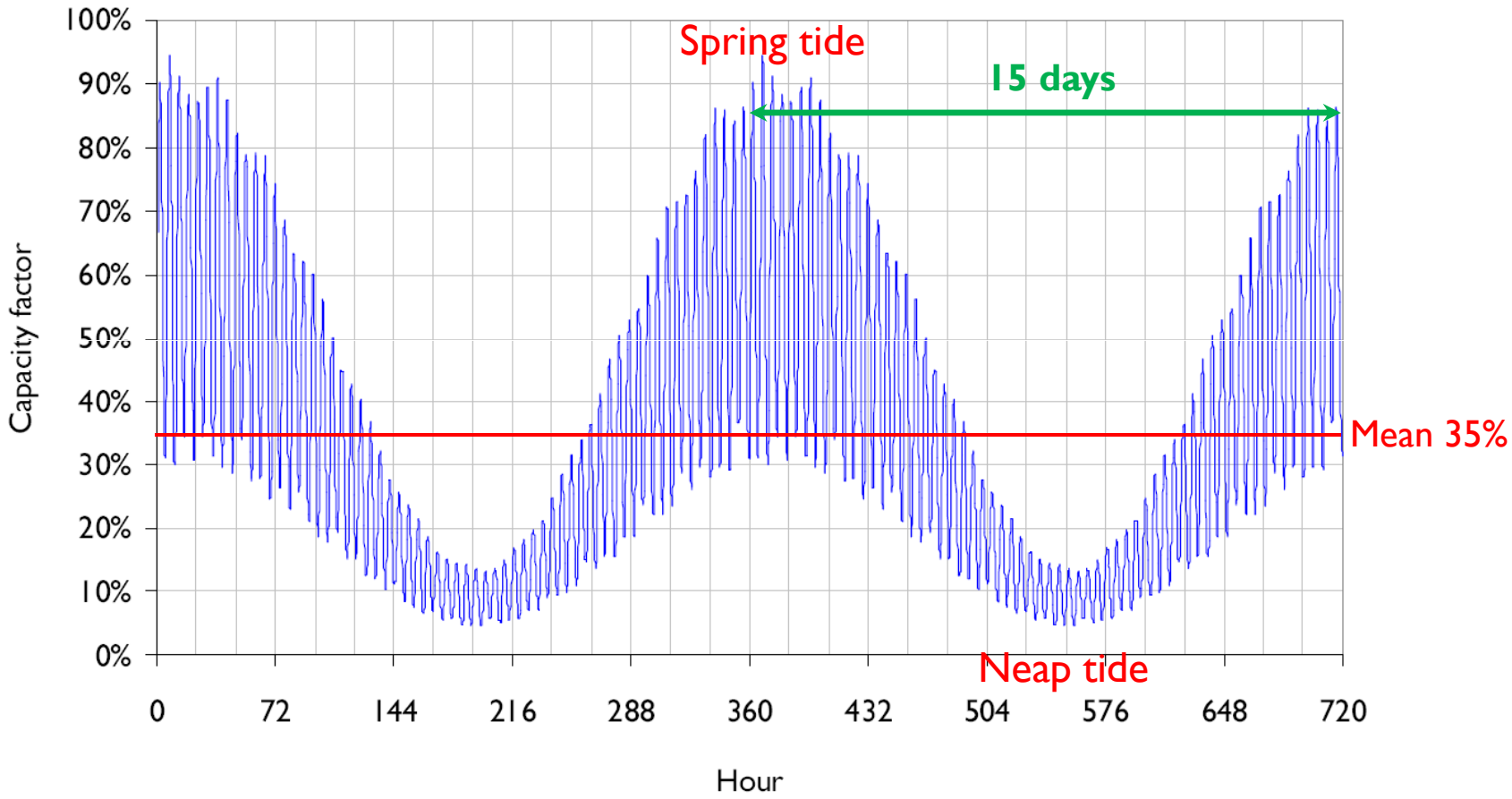
- Regional location of new plant assumed based on existing and forecast development
- Half-hourly capacity factors for each "region" simulated based on long-term correlations





Source: Sinden, G. (2007). Characteristics of the UK wind resource: Long-term patterns and relationship to electricity demand. *Energy Policy* **35**(1), 112-127.

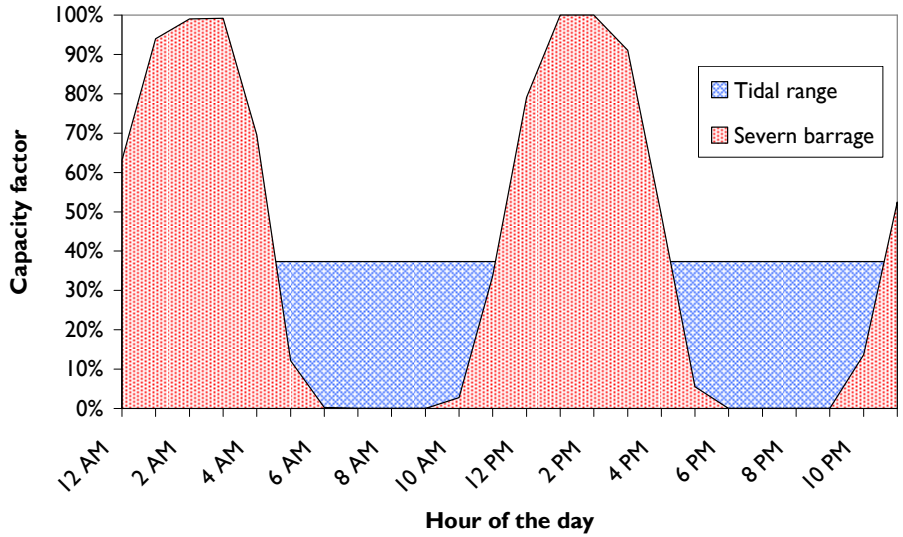
Capacity factors: aggregate tidal stream capacity



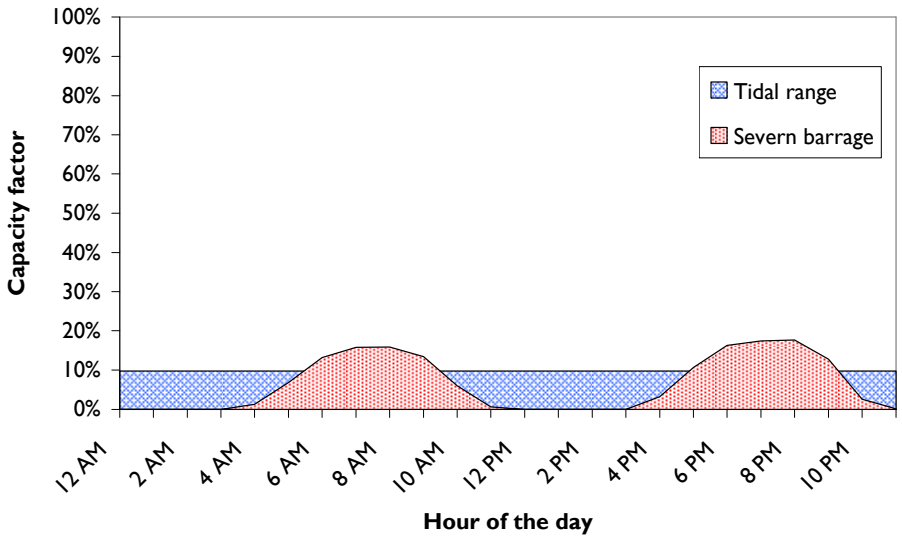
Tidal stream development concentrated in certain regions, especially the Pentland Firth

Capacity factors: the Severn Barrage

Spring tides



Neap tides



- 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:
  http://www.decc.gov.uk/en/content/cms/consultations/cons_res/rescon_support/rescon_support.aspx
- Benefits of marine technologies within a diversified renewables mix:
  http://www.bwea.com/pdf/marine/Redpoint_Report.pdf
- UK Renewable Energy Strategy:
  http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/renewable/res/res.aspx
- UK Consultation on a framework for the development of clean coal:
  http://www.decc.gov.uk/en/content/cms/consultations/clean_coal/clean_coal.aspx
- UK Committee on Climate Change – 1st Annual Progress Report:
  http://www.theccc.org.uk/reports/1st-progress-report

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