SuperGen Marine Energy Research Consortium 2

Economic analysis of variability and penetration

1 October 2008

Grant Allan, Michelle Gilmartin, Peter McGregor, Kim Swales and Karen Turner

Fraser of Allander Institute and University of Strathclyde Economics Department
Centre for Public Policy for Regions (CPPR)

1. Introduction

Main objectives:

- Assessment of portfolio theory applications to energy issues:
  - Conventional approaches to comparing energy technologies: “levelised costs”
  - Limitations of levelised costs and the application of portfolio theory to energy issues
  - Explore role of wave and tidal in UK electricity generation portfolios

- Alternative energy futures:
  - Need for a system-wide approach
  - The importance of energy policy in influencing energy futures
  - The role of renewables in general and marine in particular

2. Levelised costs

- Important because widely used in discussions of energy policy
  - "Affordable" energy is one of goals of energy policy (Council of Economic Advisors)
  - Often used as a measure of the gap between renewable technologies and currently "commercial" generation (and to give an indication of the scale of public sector support that might be required for deployment)

- What are levelised costs? IEA (2005):

"the ratio of total lifetime expenses versus total expected outputs, expressed in terms of the present value equivalent"

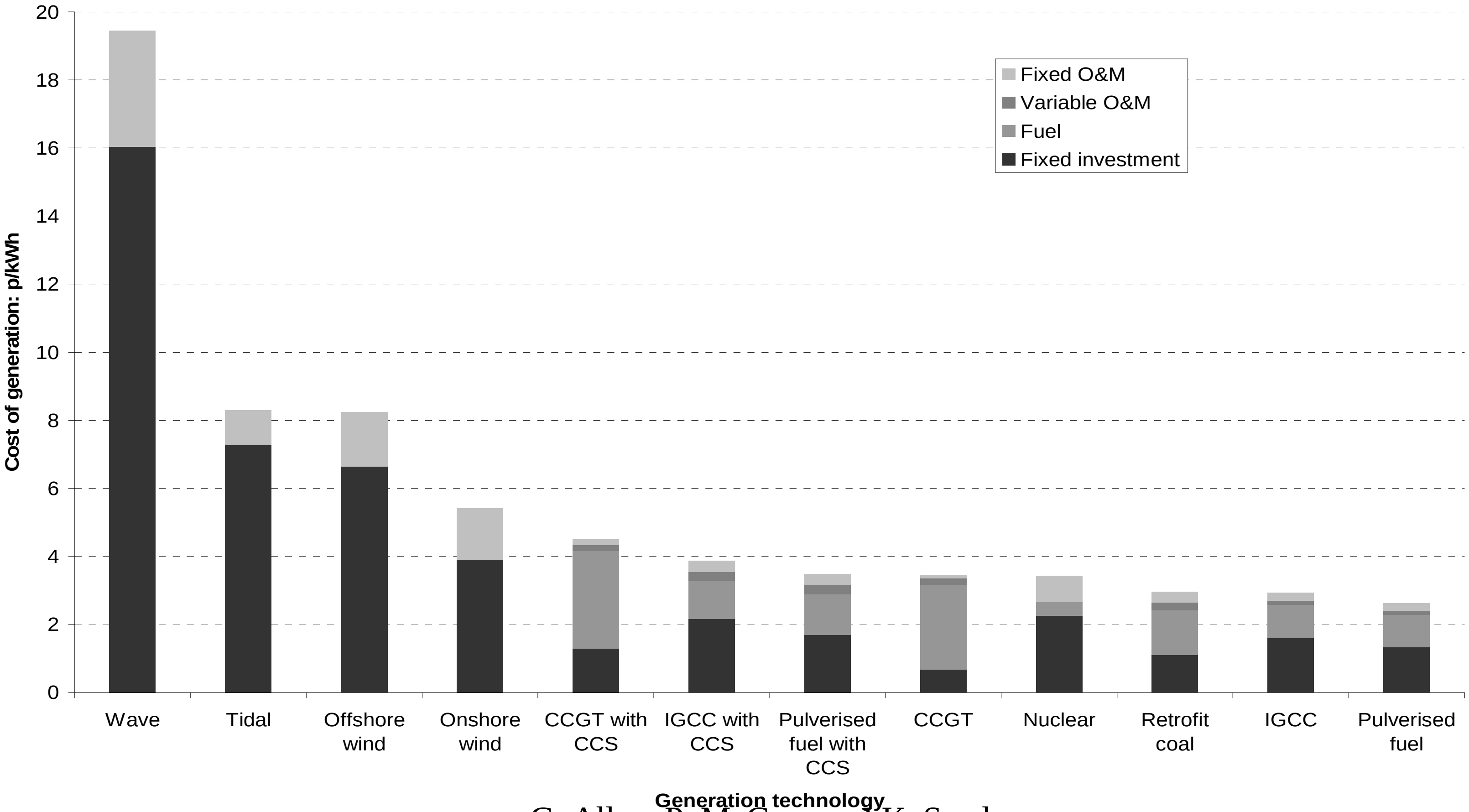
2. Levelised costs

- Two main methods used to compute levelised costs
  - Discounting (e.g. IEA ,2005; Carbon Trust, 2006)
  - Annuitising (e.g. BERR, 2007)

- Costs typically would include: investment (including decommissioning); operations and maintenance; fuel

- But neglect:
  - business issues (revenues and ROCs?)
  - externalities
  - system factors

Point estimates of levelised costs
(DTI 2007, Strathclyde 2008)



G. Allan, P. McGregor, J.K. Swales
and K. Turner

2. Levelised costs

- While significant uncertainties, seems little doubt that wave and tidal currently have higher levelised costs, but recall
  - carbon not priced in these costs (externalities to explore levelised social costs of technologies?)
  - though nor is intermittency (resource to grid)

- But is it legitimate to focus simply on "standalone" levelised costs of individual technologies?

- In fact, marine would be introduced as part of a portfolio of electricity generating assets: should be assessed in terms of its overall contribution - to energy *portfolio* costs and risks.

3. Portfolio theory

• Markowitz (1952) and Roy (1952) – “co-Fathers” of modern mean-variance portfolio theory MVPT

Expected return for two-asset risky portfolio is:

$$E(r_P) = X_1 E(r_1) + X_2 E(r_2)$$

Portfolio risk (as measured by standard deviation) is:

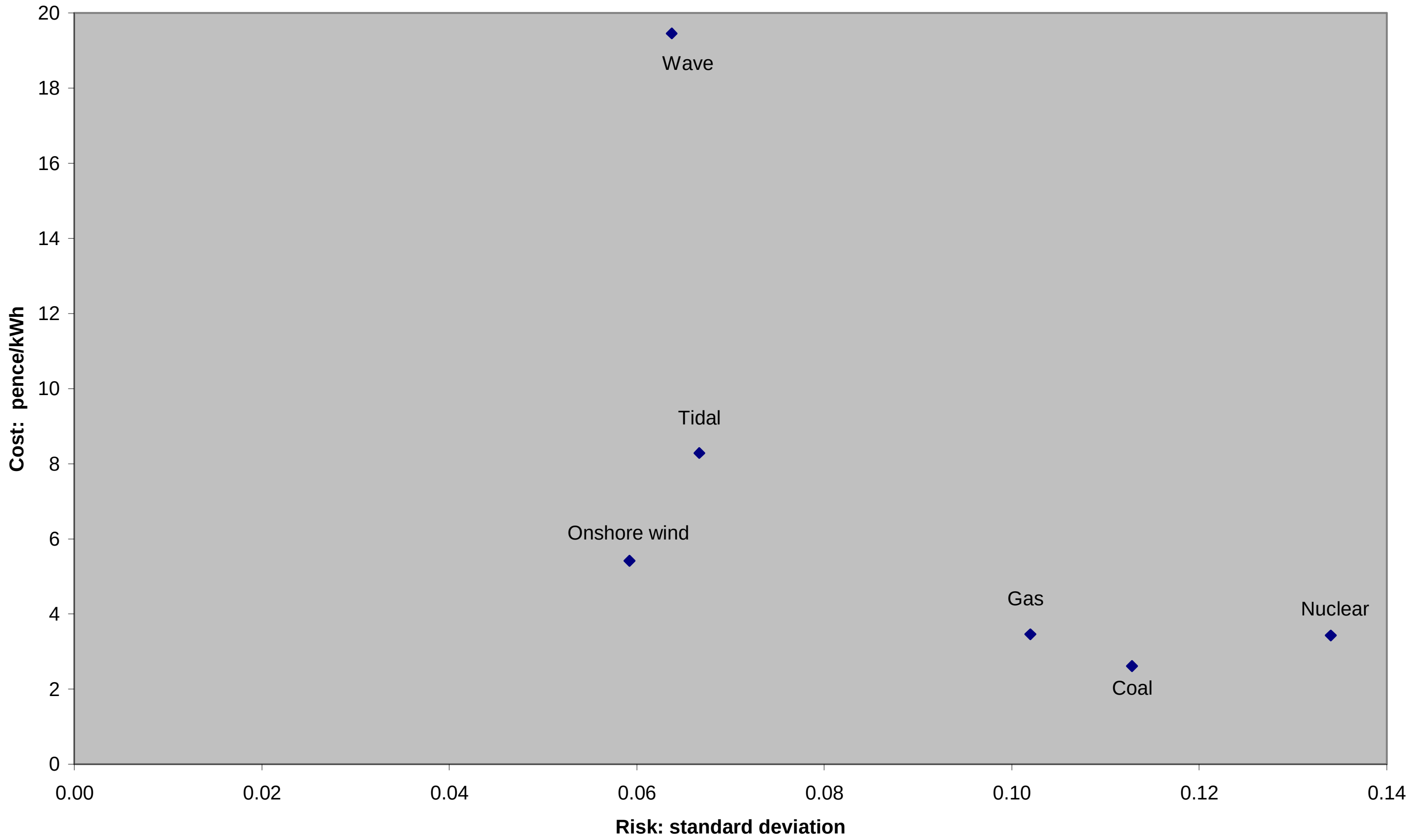
$$\sigma_P = \sqrt{X_1^2\sigma_1^2 + X_2^2\sigma_2^2 + 2X_1X_2\rho_{12}\sigma_1\sigma_2}$$

Can evaluate all risk-return payoffs for possible portfolios containing (two) assets:

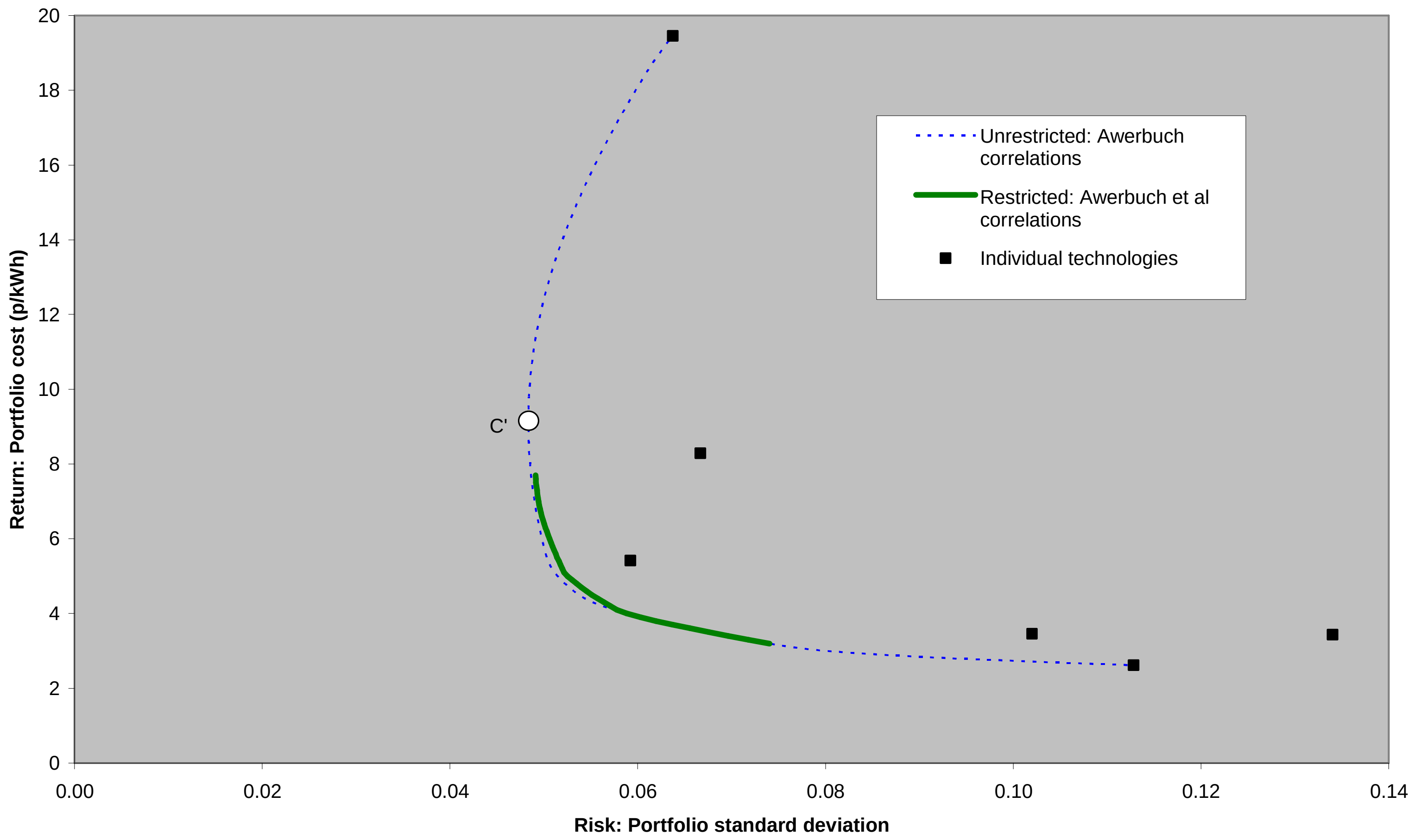
• Can ignore all possible combinations of n-assets, and focus only on those lying on “efficient frontier” – i.e. “set of efficient mean-variance combinations”

• Efficient frontier given by possible portfolios where risk can’t be decreased while holding return constant, and return can’t be increased while holding risk constant

UK generation technologies

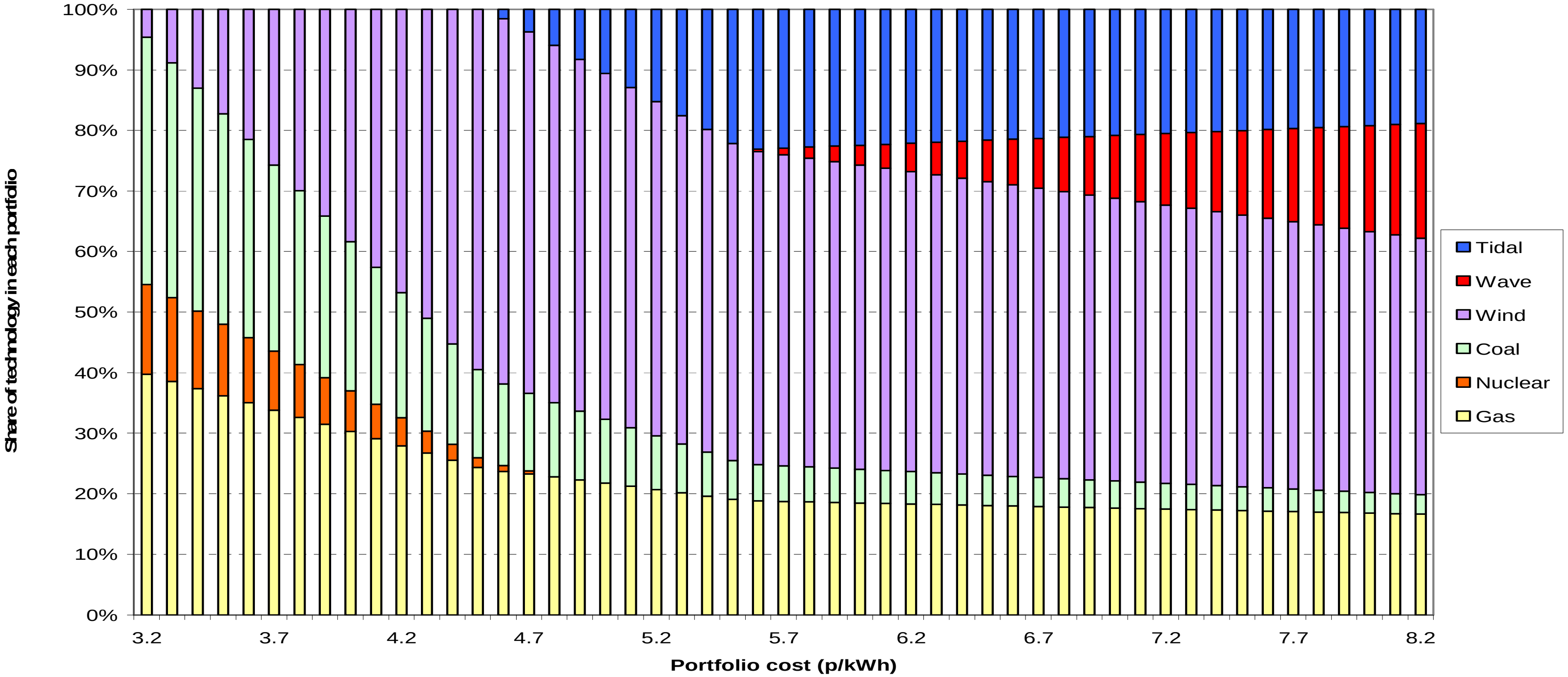


Application of theory to UK generation



Composition of efficient generation portfolios

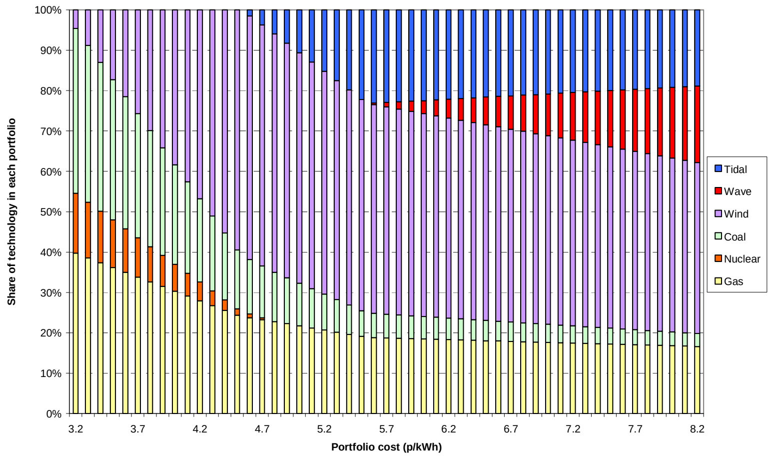
Shares of generation technologies along the unrestricted efficient frontier (3.2<p/kWh<8.2)



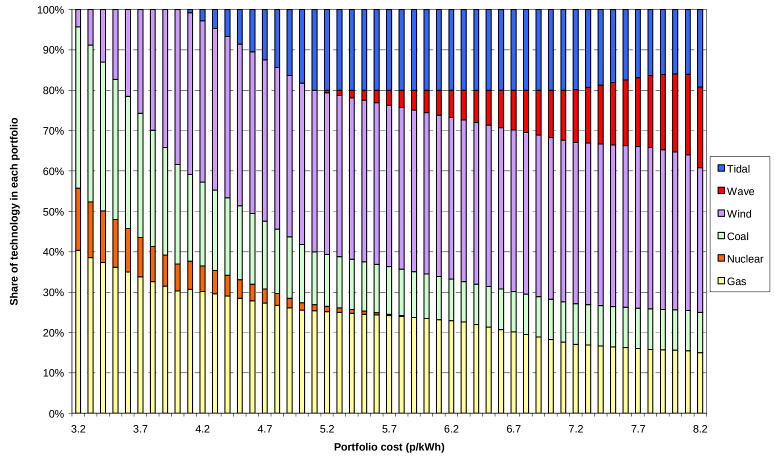
Composition of restricted efficient portfolios

Shares of generation technology under restricted and unrestricted efficient frontiers

Unrestricted



Restricted



Efficient portfolios containing tidal generation arise at lower portfolio costs under the "restricted" scenario.

Comparing portfolios

	Share of generation mix (%)		
	DTI 2020	*Equal cost/lower risk*	*Same risk/cost but greater marine*
Gas	60	36	37
Nuclear	7	12	12
Coal	21	35	43
Wind	12	16	5
Wave	0	0	1
Tidal	0	1	2
Portfolio cost	3.514	3.514	3.514
Portfolio risk	0.0731	0.0679	0.0731
Portfolio diversity	1.075	1.325	1.273

Comparison of energy portfolios

DTI (2006):

- Portfolio cost is 3.514 p/kWh
- Portfolio standard deviation is 0.0731
- Shannon-Wiener measure of diversity is 1.075

Same cost/lower risk:

- Positive shares for tidal generation, and more renewable
- Gas still modal, but more coal
- Diversity under this scenario is greater at 1.325.

Same risk and cost:

- Same portfolio cost and risk can be obtained but with greater penetration of wave and tidal sources.
- Diversity is also greater under this scenario.

Portfolio approach: future research

- Number of issues still to be resolved, but finding that marine could form part of an efficient UK energy portfolio significant.

- Range of possible extensions (beyond further sensitivity analysis):

    - Definition of feasible ranges for each technology?

    - Extend costs to social costs of generation – include externalities, such as pollution, job creation, and system impacts (intermittency)

    - Extend to liberalised markets incorporating revenue side e.g. Roques *et al* and explore the role for policy in achieving socially efficient/desirable scenarios

4.Alternative Energy Futures

- Our analyses of alternative energy futures rooted in an approach, which recognises:

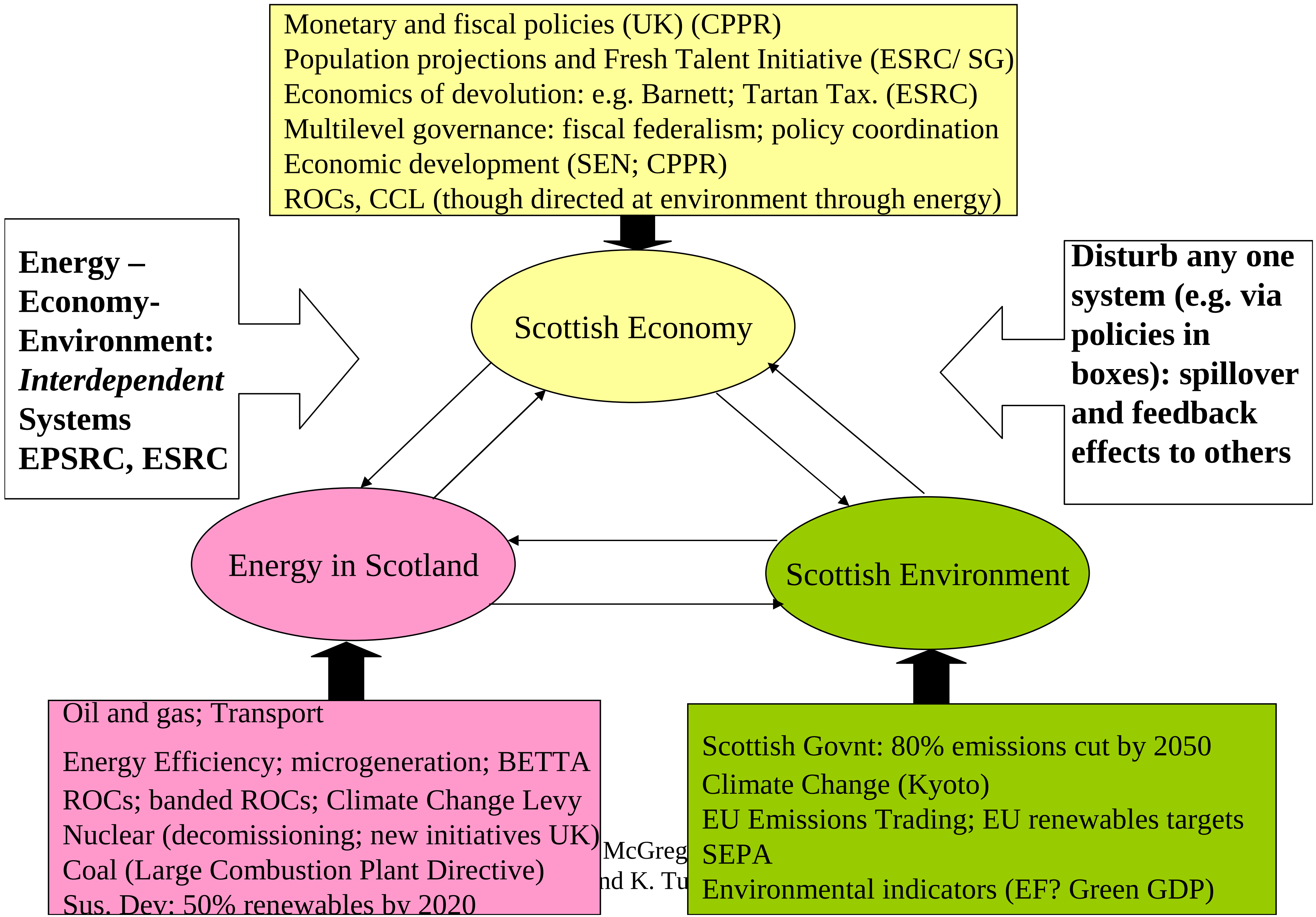
  - The interdependence of the energy- economy-environmental sub-systems

  - Potentially critical role of UK (and Scottish) energy policies

  - Proceed by use of a suite of multisectoral models (Input – Output (IO) and computable general equilibrium (CGE) models)

  - provide a number of examples of such analyses...

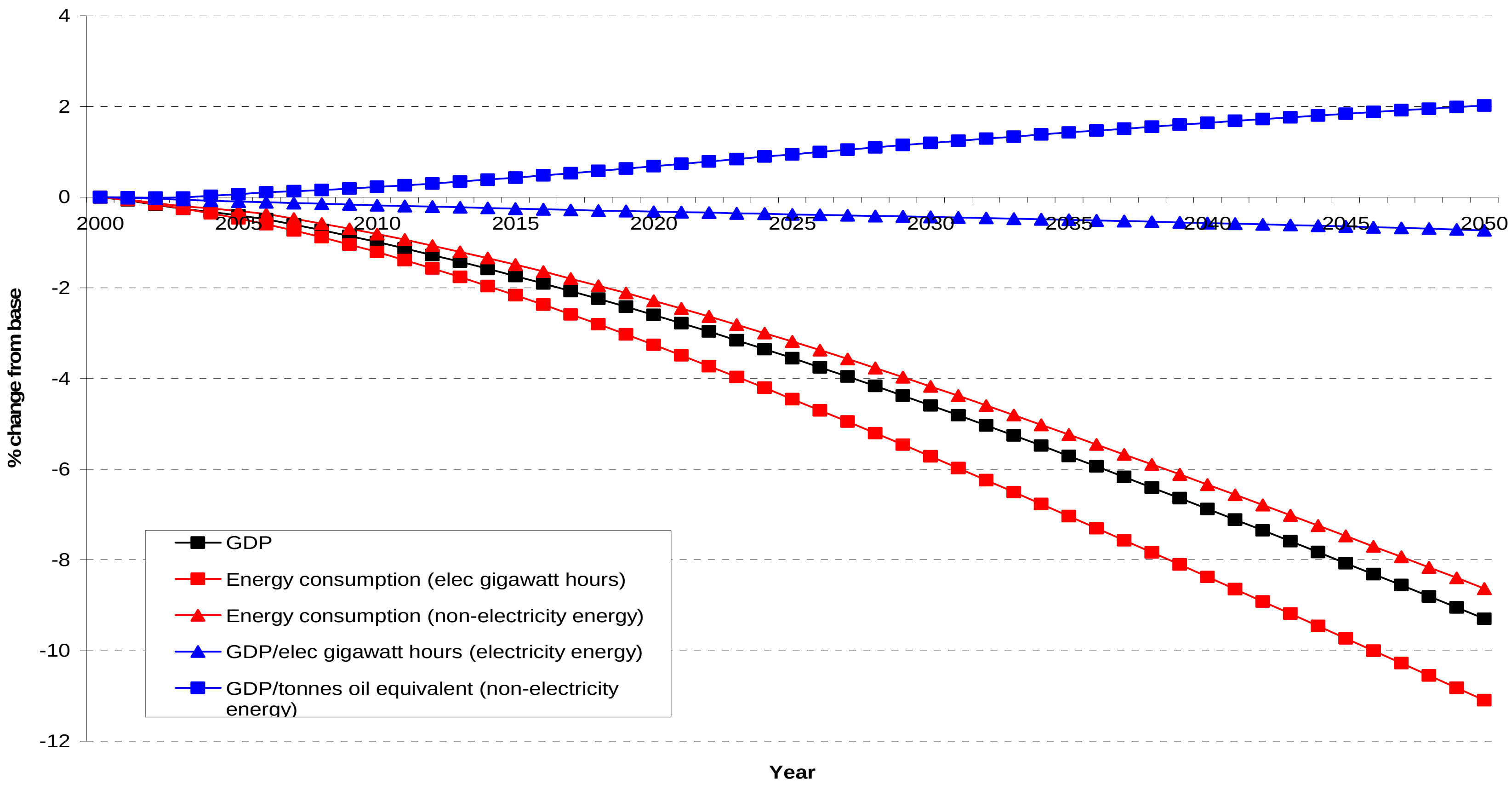
The interdependence of the Energy-Economy-Environment Systems



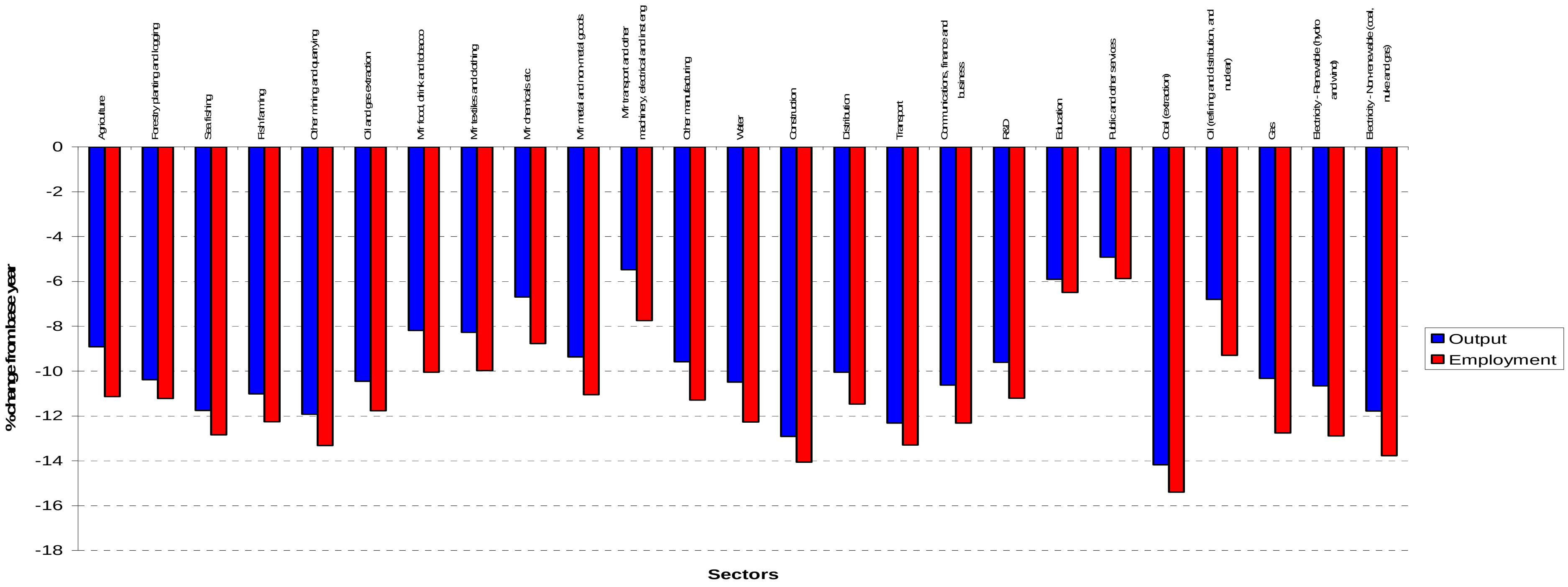
4.Alternative Energy Futures

- One important constraint on energy policies is the potential trade-off between policy goals:
  - Perhaps the most obvious is the potential trade-off between economic growth (and population growth) and environmental goals (emissions targets)
    - Number of simulations of projected population growth in Scotland and the impact of this on carbon emissions
  - Can this be resolved through policies e.g.
    - To improve energy efficiency?
    - To stimulate growth in renewables?
    - By other means (e.g. CCS)

4. Energy impact of population decline



4. Sectoral impact of population decline



4.Energy efficiency improvements?

Arguments that increases energy productivity reduce burden of economic activity on environment are now widespread - and influential in policy formulation.

In a system-wide context, however, not straightforward, since e.g. a 5% increase in energy efficiency lowers effective price of energy and:

- Will typically result in a less than 5% reduction in energy demand (“rebound”) and may even increase energy demand (“backfire”)
- Research suggests rebound and backfire more likely in Scottish context than UK:
  - Scotland net exporter of electricity
- More open than UK economy and more sensitive to changes in competitiveness

But not necessarily bad news: always possible to employ other policies in a coordinated manner to improve sustainable development

- Rebound and backfire reflect the role of energy efficiency improvements in providing a stimulus to economic activity
- But are other policy instruments available? (carbon tax; ETS)

4.Stimulating renewables?

Attractions:

- Big concentration of renewable resource in Scotland
- Potential to increase economic growth and reduce carbon emissions?

But is this potential equal across renewables?

Growth in new renewables mainly through ***onshore wind***, but impact on economy?

- Research suggests little "multiplier impact" on Scottish economy
- Also, little potential for supply-side benefits
- Can be important locally (but depends on revenue sharing/ ownership)

Most recent emphasis on economic development opportunities has been on ***marine*** (wave and tidal):

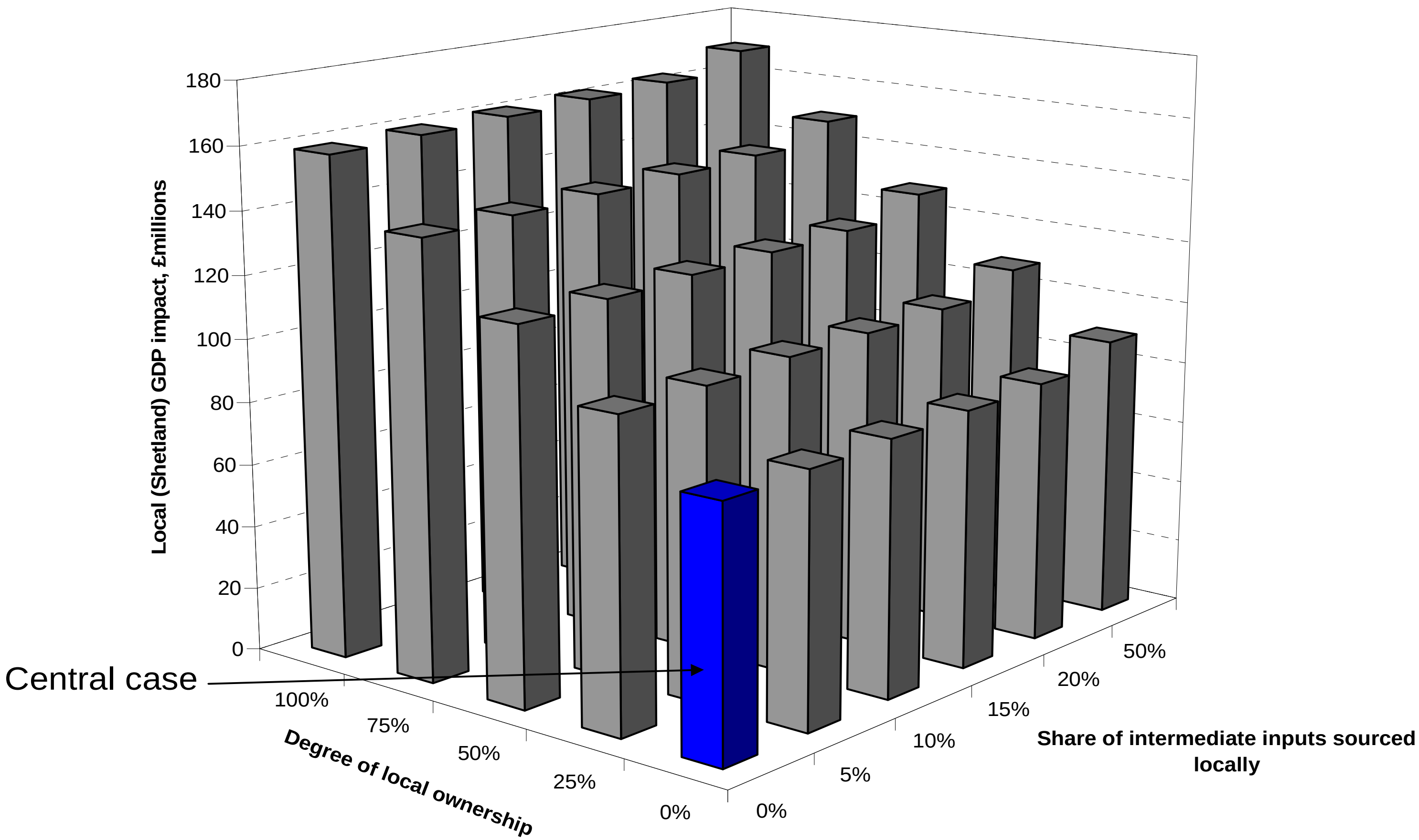
- Unit costs currently too high to compete without support, but learning and new ROCs?
- Portfolio arguments (from Scottish Government perspective)
- External benefits for economy and environment
- Research suggests potential for economic development with lower emissions

Alternative scenarios

Scenario A is "high marine" (10%, rather than 5%) with 50% renewables target met by 2050 (and no nuclear)

		Scenario A	Scenario B
Type 1	Change in GDP (£millions)	263.24	153.69
	Change in employment (000s, FTE jobs)	24,984	13,172
	Change in CO_2 emissions, % from base year	-3.52	-3.59
Type 2	Change in GDP (£millions)	416.41	247.78
	Change in employment (000s, FTE jobs)	29,572	15,957
	Change in CO_2 emissions, % from base year	-5.69	-5.89

4. BUT windfarms (and other renewables) may matter for local economic development – especially if partly locally-owned (Shetland social accounting matrix (SAM) example)



G. Allan, P. McGregor, J.K. Swales
and K. Turner

5.Conclusions

- Exercise caution in the use of levelised cost analyses (CEA)
- Application of portfolio theory holds considerable promise.
- Analysis of energy futures best informed by system-wide framework that recognises interdependence of energy-economy-environment
- Policy goals often subject to trade-offs: e.g environment and economic and population growth
  - *Some* renewables may benefit both goals (may depend e.g. on ownership)
  - Energy efficiency no magic bullet
  - But need systematic analysis of policy initiatives