Technology choices in electricity markets: the impact of long term contracts

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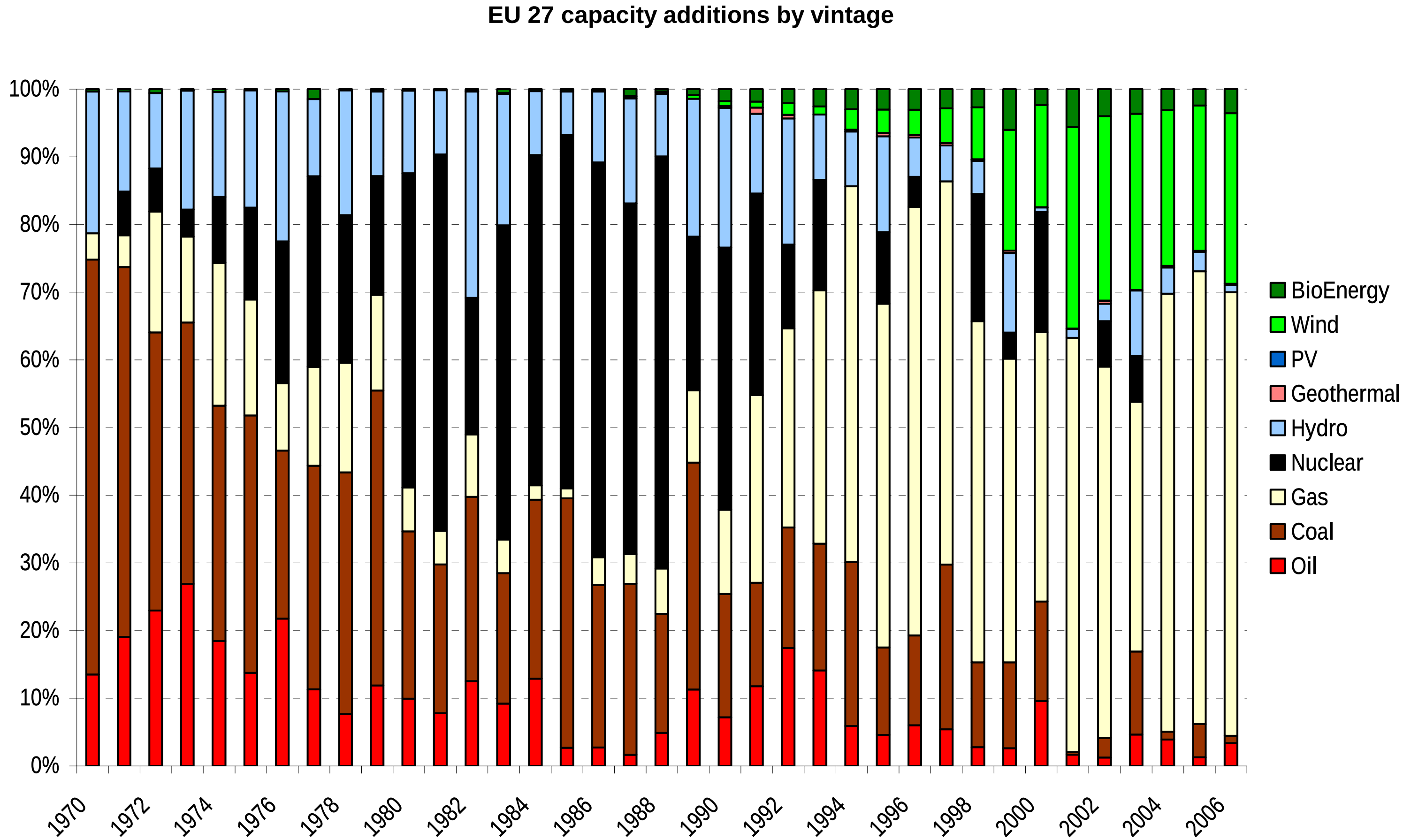
*The views in this presentation are based on work done while the author was with the EPRG and are those of the author alone.

Introduction - Technology choices in Europe



- CCGTs have been new entrants' generation choice in liberalised markets
  - Liberalisation accompanied by trend toward decreasing capital intensity since the 1980s
  - Deployment of low carbon technologies (renewables, nuclear, CC&S) will likely reverse this trend

  => What are the implications for contractual arrangements and industry structure evolution?

Introduction

- **Power generation technologies have different risk and returns characteristics**
  - Different exposure to market risks (electricity price, fuel price, CO2 price)
  - Different degrees of capital intensity (ratio of investment to operating costs)
  - ⇒ How do long term contracts affect the risks and returns and competitiveness of different technologies?

- **The vertical and horizontal market positioning of investors and the contractual arrangements affect technology choices**
  - Vertical integration / long term contracts - fuel sourcing and power purchase agreements
  - New entrants’ technology choices will likely diver from vertically integrated / portfolio utilities

⇒ **Industrial organisation and long term contracts affect technology choices and fuel mix**

⇒ **Which industrial structure and contractual arrangements will make possible the financing of capital intensive “green technologies” (nuclear, renewables, CC&S)?**

⇒ **What are the implications for competition and antitrust policies?**

Outline

Technology choices and investment risks allocation:

1. Vertical integration and/or long term contracts – impact for a new entrant

2. Portfolio diversification for large utilities

3. Optimal contract cover for new entrants / portfolio utilities

Technology choices with market risks – the case of a new entrant

- Assumption: IPP without significant vertical integration and without pre-existing plant portfolio
- Focus on market risks (power price, fuel prices, CO2 price)

• Focus on 3 technologies: CCGT, Coal, and nuclear

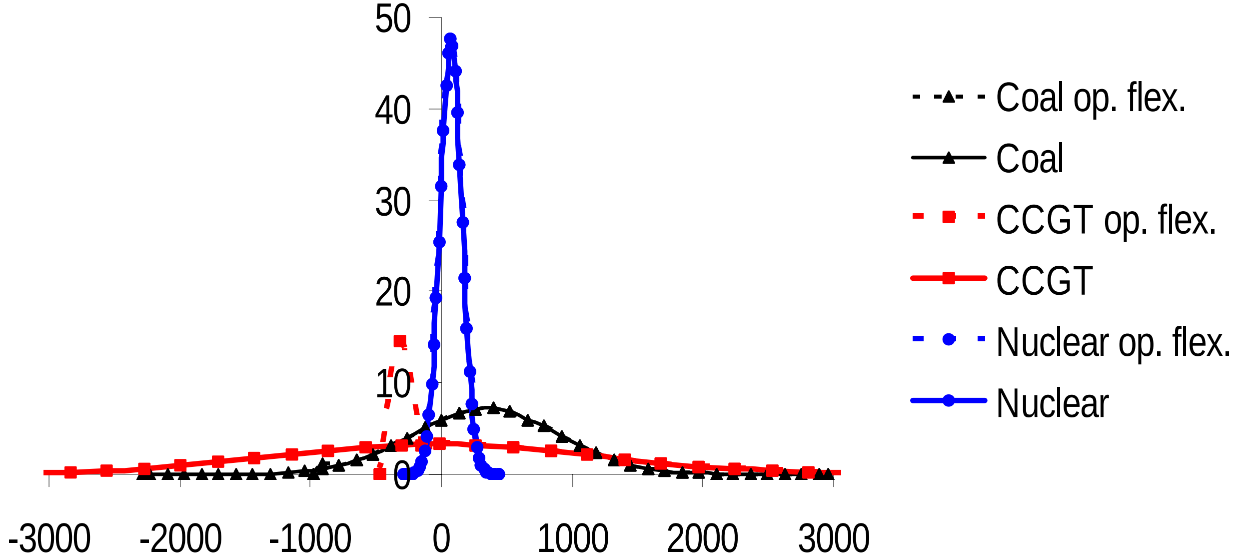
• NPV model parameters based on IEA/NEA (2005) & IEA (2006)

• Monte Carlo simulation of NPV – distributions based on UK historical data (2001-2005)

Parameters	Unit	Nuclear	Coal	CCGT
Technical parameters				
Net capacity	Mwe	1000	1000	1000
Capacity factor	%	85%	85%	85%
Heat rate	BTU/KWh	10400	8600	7000
Carbon intensity	kg-C/mmBTU	0	25.8	14.5
Construction period	years	5	4	2
Plant life	years	40	40	25
Cost parameters				
Overnight cost	€/Kwe	2000	1120	520
Incremental capital costs	€/Kwe/yr	16	9.6	4.8
Fuel costs	€/mmBTU	0.4	2	5.8
Real fuel escalation	%	0.5%	0.5%	0.5%
Nuclear waste fee	Mill€/KWh	1	0	0
Fixed O&M	€/Kwe/year	52	40	20
O&M real escalation rate	%	0.5%		
Financing parameters				
WACC	%	10%		
Government actions				
Carbon tax	€/tCO2	10		
Carbon price escalation	%	1%		
Revenues				
Electricity price	€cents/KWh	5.5		
Electricity escalation rate	%	0.5%		

Case Nb. 1:
Impact of fuel and CO2 price risks – electricity sold at fixed price through long term contract

NPV (€million/GW) probability distribution
Fuel price risk - fixed electricity price
(in 10^-4 for 100 000 simulations)



- CCGT more exposed to fuel (gas) price volatility than coal or nuclear plant
- Contractual flexibility to resell gas limits potential losses of CCGT plant

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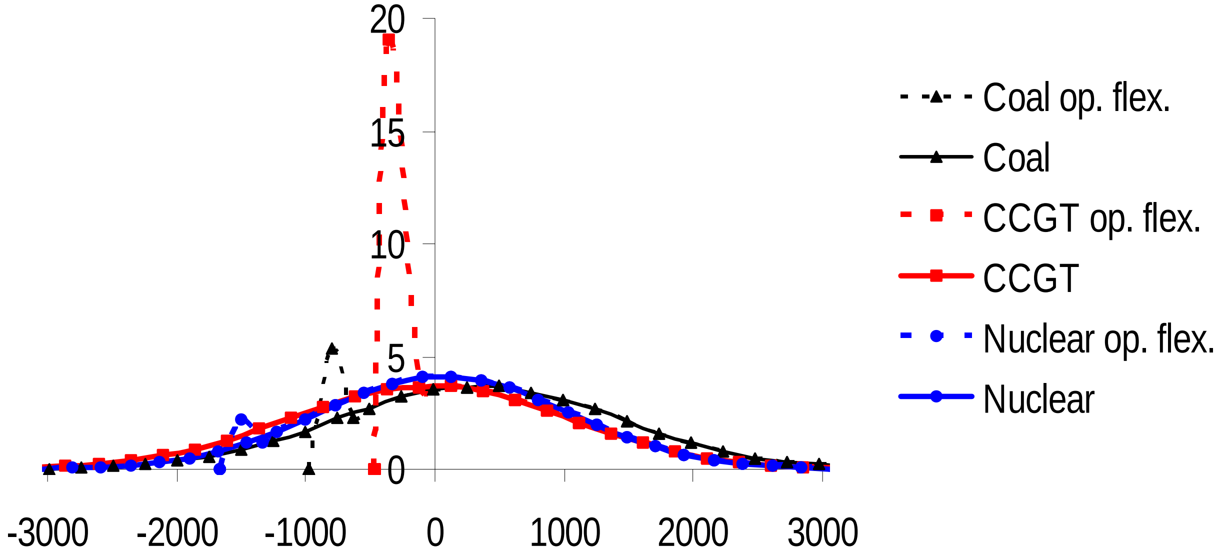
Case Nb. 2:
Impact of electricity and CO2 price risks –
long term fixed price purchase agreement for fossil fuel

NPV (€million/GW) probability distribution
Electricity price risk - fixed fuel price
(in 10^-4 for 100 000 simulations)



- Contractual flexibility to resell gas limits potential downside losses of CCGT plant to lower levels than coal and nuclear plants
  - CCGT 5% percentile reduced from -1817 to -474 €million/GWe
  - Coal 5% percentile reduced from -1432 to -976 €million/GWe
  - Nuclear 5% percentile unchanged at -1511 €million/GWe

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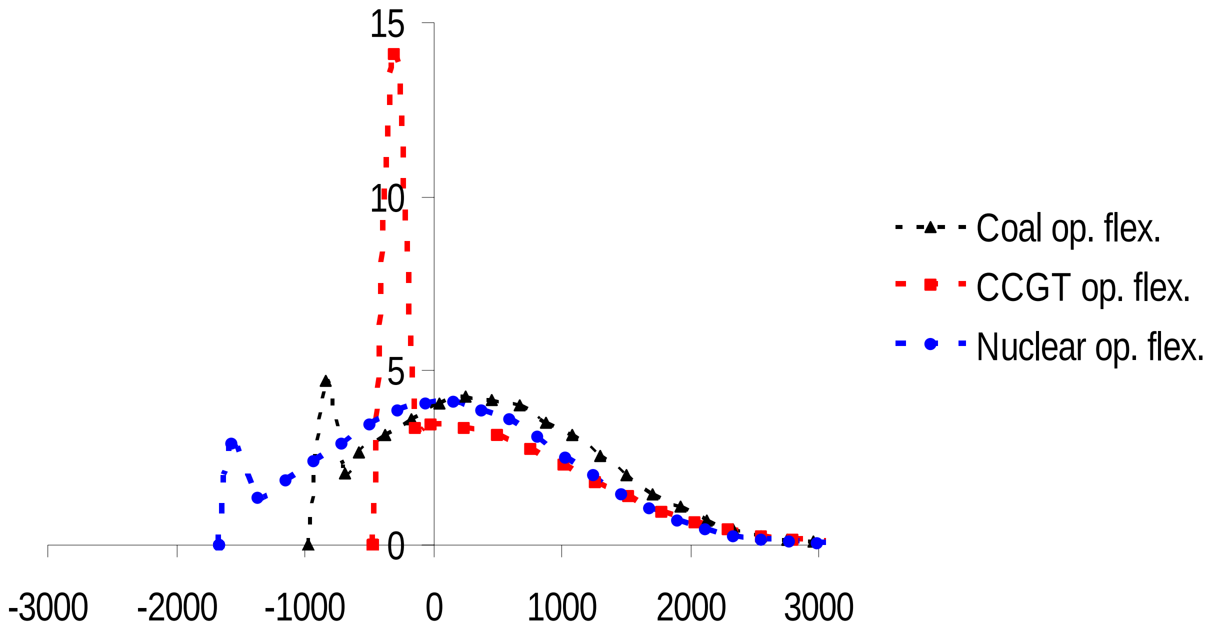
Case Nb. 3:
Impact of fuel, electricity and CO2 price risks

NPV (€million/GW) probability distribution (in 10^-4 for 100 000 simulations)



- Contractual flexibility to resell fuel and correlation between power and gas prices limit potential downside losses of CCGT

⇒ **For a new entrant, without vertical or horizontal integration, CCGT risk / return profile most interesting**

⇒ **CCGT returns are self-hedged through correlation between power and gas prices and power / gas markets arbitrage**

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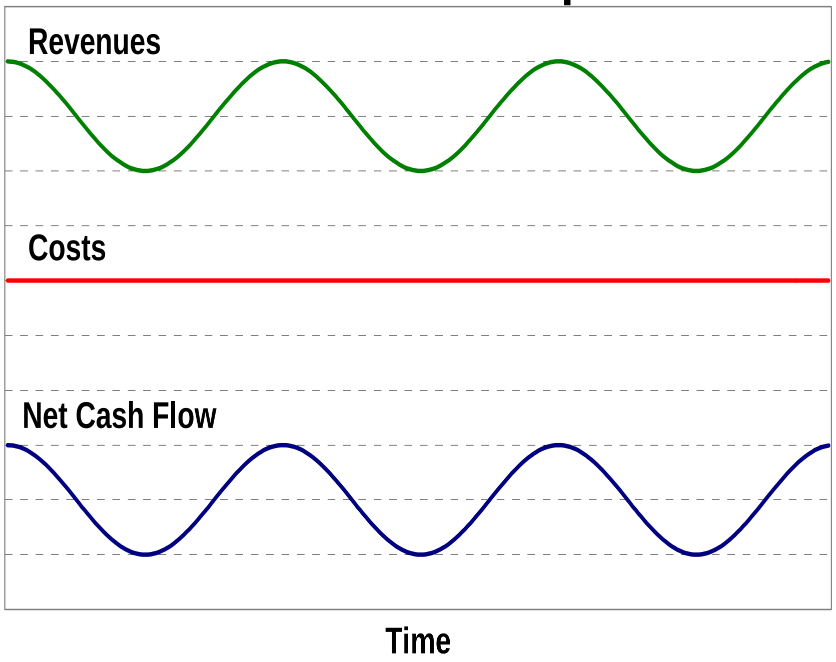
Marginal cost setting technology faces reduced market risks in liberalised markets

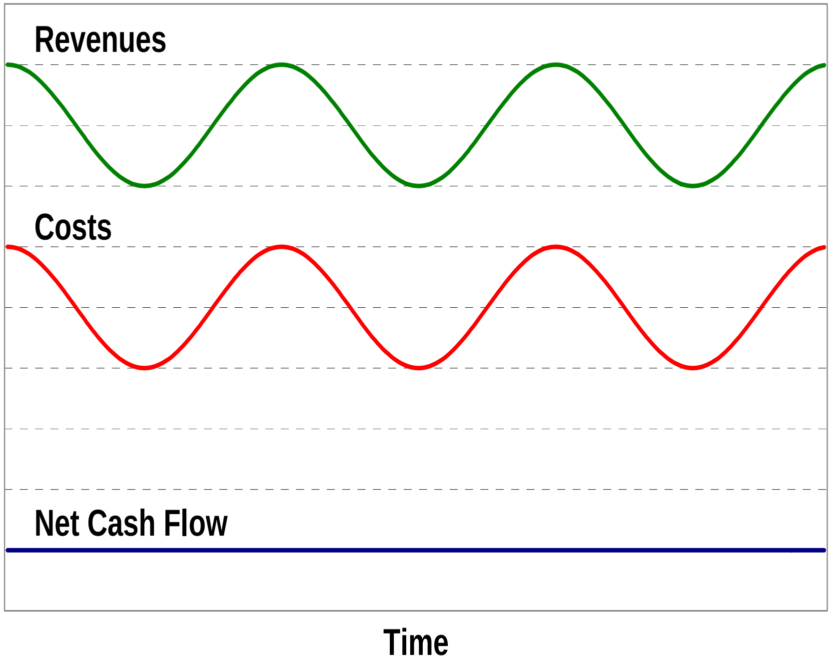
- "***self hedged***" bc. of correlation btw. elec. & gas/CO2 prices

- ***self reinforcing externality***: the more investment in CCGT, the more correlated elec&gas prices, the less risky the cash flow of already operating plants.

Nuclear/Renewable plant



Gas plant



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Technology choices and market risks - The case of a large utility with a portfolio of plants

- **Besides a strong balance sheet, an existing and varied portfolio of plants provides a hedge against fuel and CO_2 price risks**

- **Markowitz Mean Variance Portfolio theory** defines efficient portfolios as the ones which have the smallest attainable portfolio risk for a given level of expected return (or the largest expected return for a given level of risk).

- The **expected return** $E(r_p)$ of portfolio P containing N assets i [expected return, $E(r_i)$, SD, σ_i] in proportion X_i is the weighted average of the expected returns of the N assets:

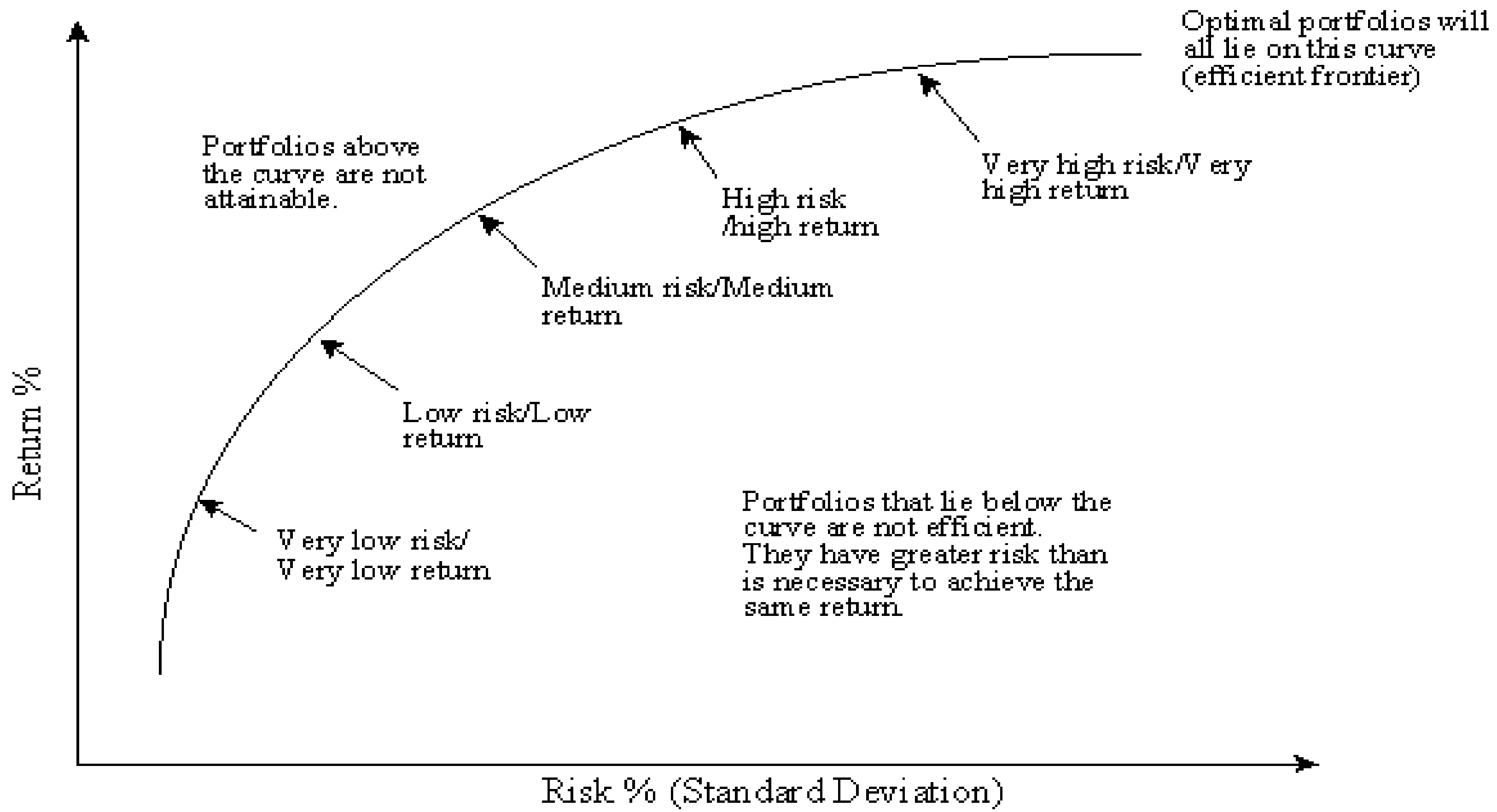
$$E(r_p) = \sum_{i=1} X_i E(r_i)$$

- The portfolio **standard deviation** σ_p is defined by:

$$\sigma_p = \sqrt{\sum_{i=1}^{NP} X_i^2 \sigma_i^2 + \sum_{i=1}^{N} \sum_{\substack{j=1 \\ i \neq j}}^{N} X_i X_j \rho_{ij} \sigma_i \sigma_j}$$

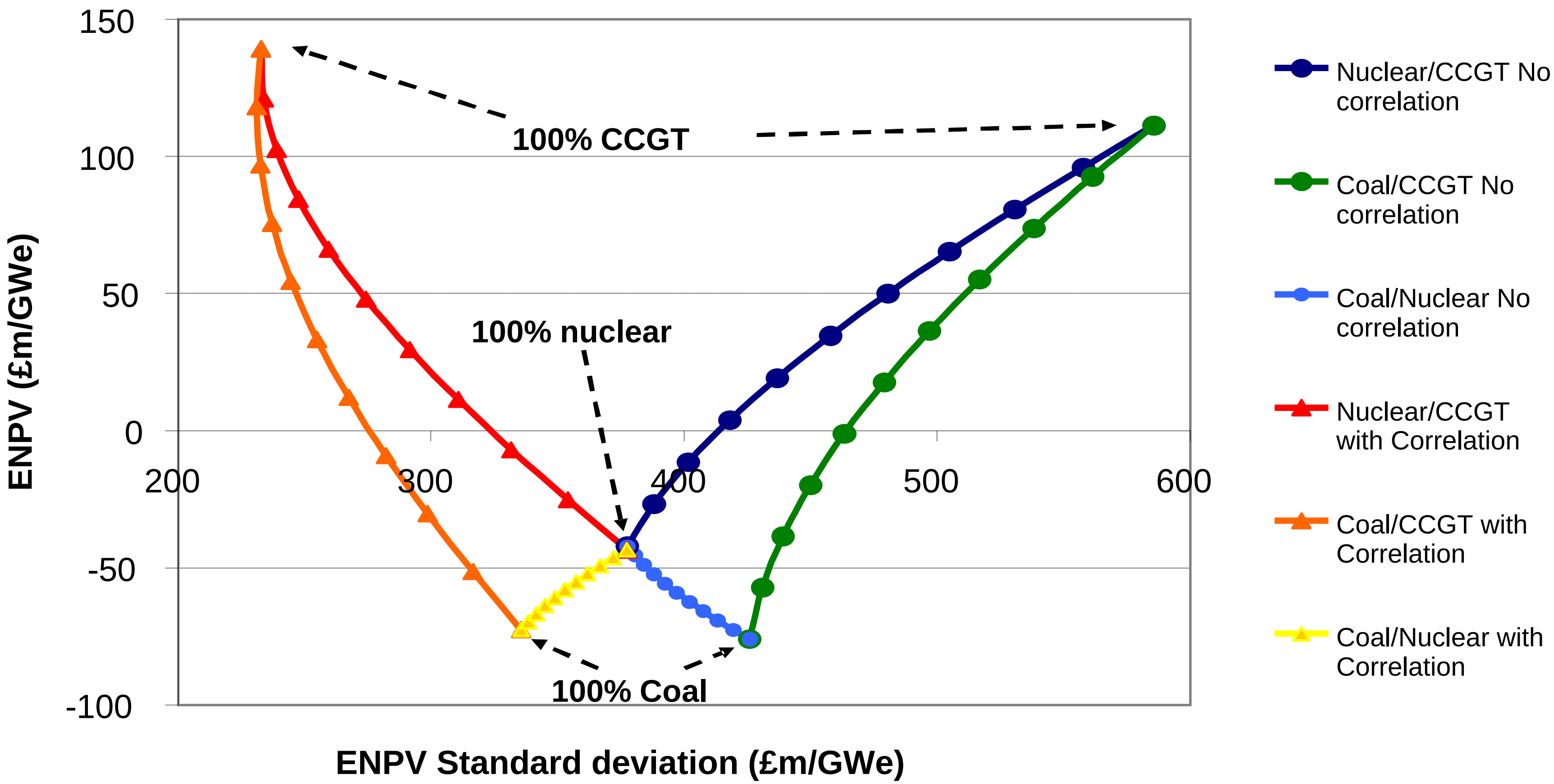
where ρ_{ij} represents the correlation between the returns r_i and r_j of the two assets

Portfolio Theory efficient frontier



- MVP theory does not prescribe a single optimal portfolio combination, but a **range of efficient choices**.
- Investors will choose a risk-return combination based on their **own preferences and risk aversion**.

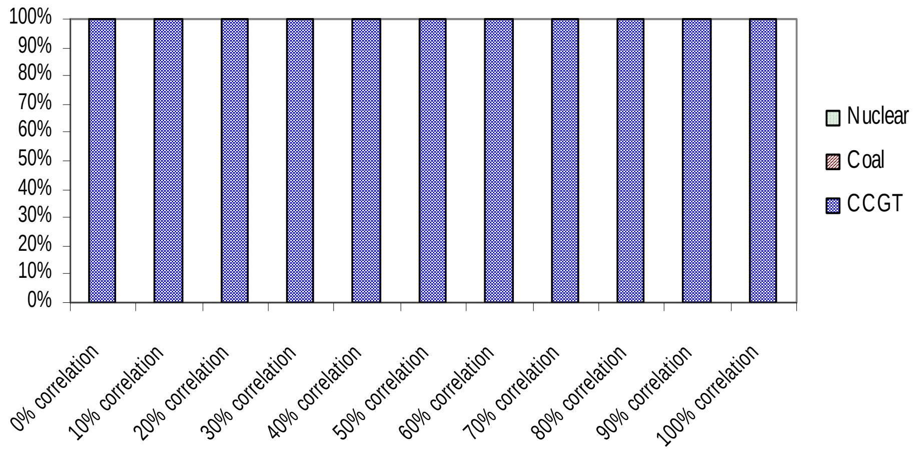
Optimal Portfolios of Nuclear, Coal and CCGT plants with & w/o correlation btw. elec., fuel, & CO2 prices



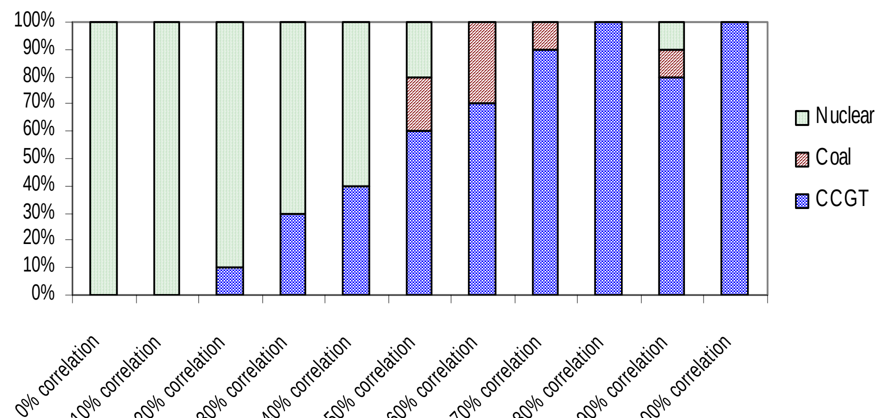
- **Correlation btw. gas, elec.& CO2 prices reduces incentive to diversify away from CCGTs in coal and nuclear**

Optimal generation portfolios for low, medium and high risk aversion

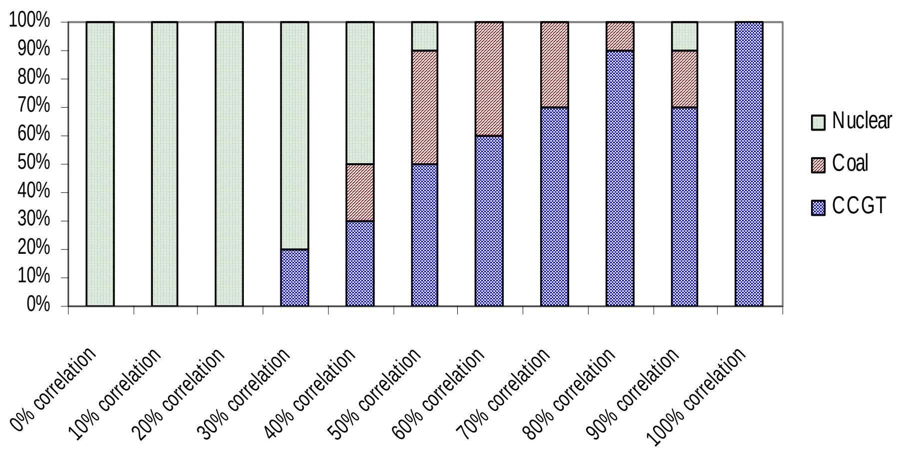
Low risk aversion



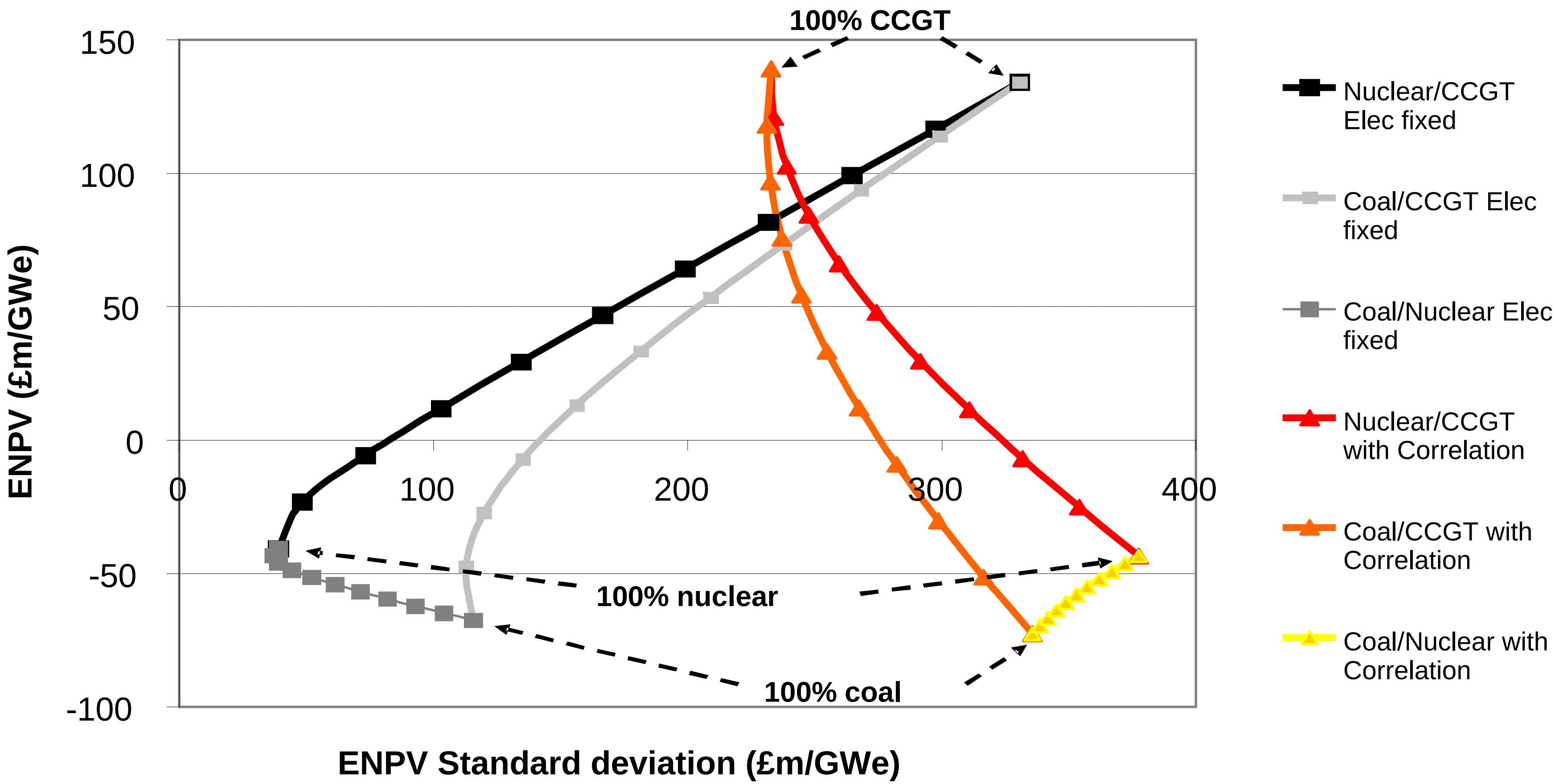
Medium risk aversion



High risk aversion



Optimal Portfolios of Nuclear, Coal and CCGT plants – Impact of long term contracts



- **Long term fixed price power purchase agreement greatly improve incentives to diversify away from CCGT by investing in coal or nuclear plants**

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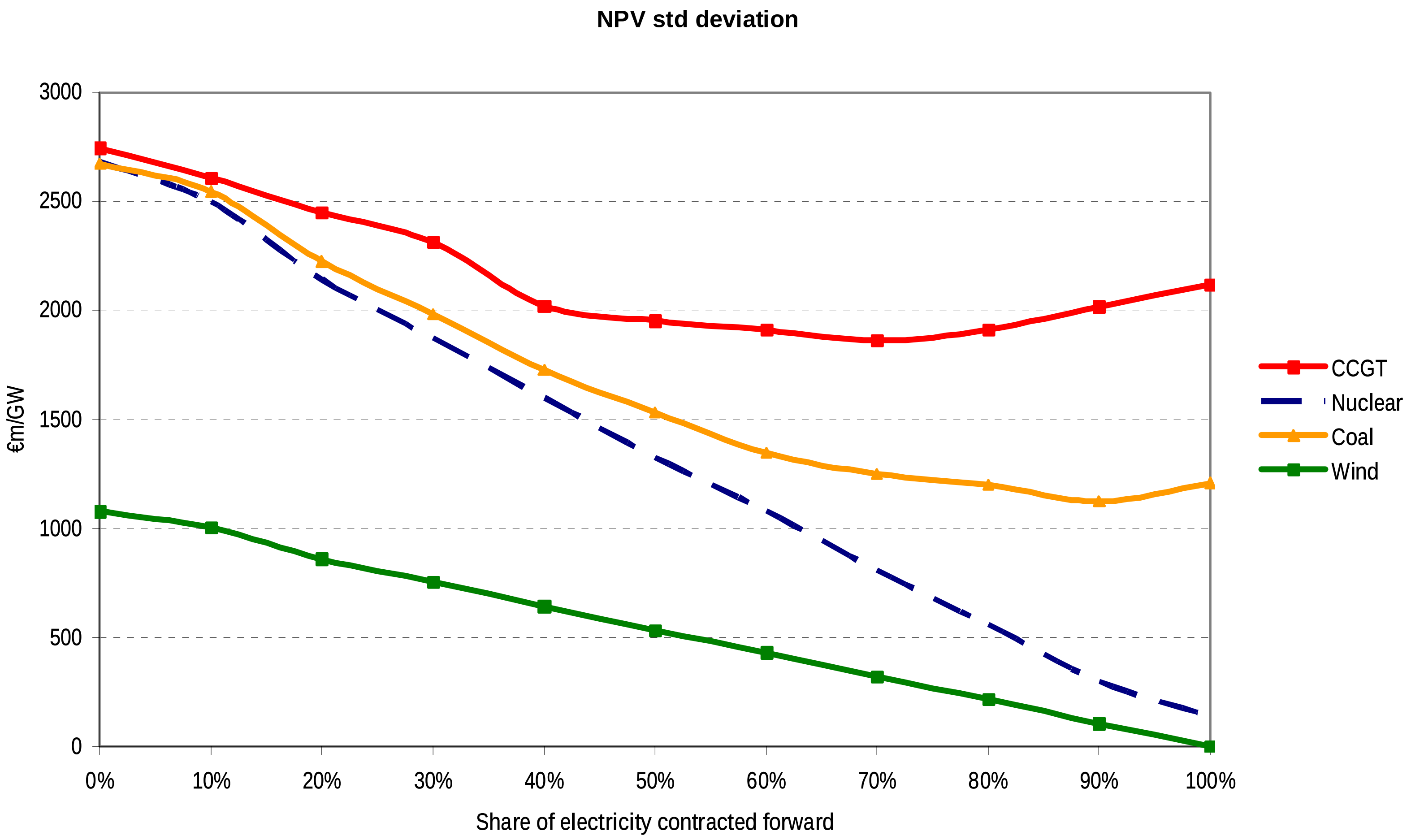
Which proportion of electricity to lock into long term contracts?

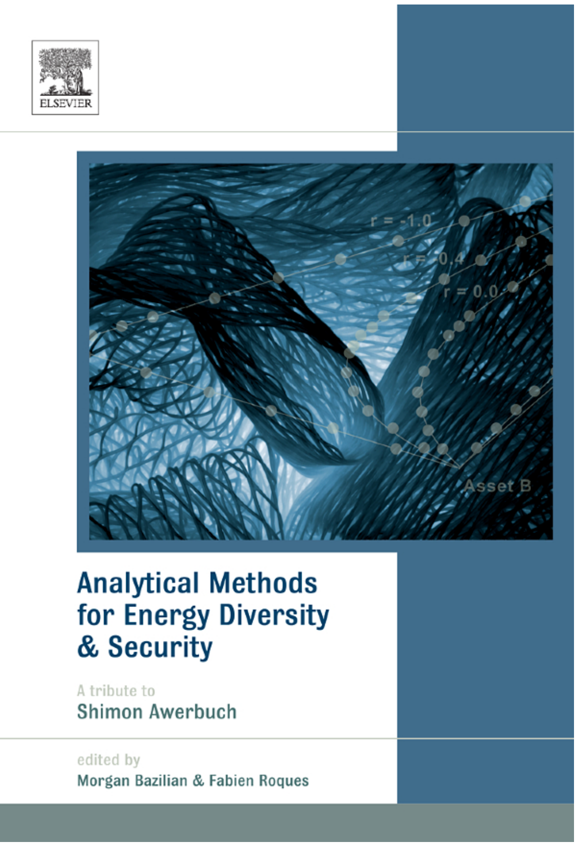


- Capital intensive technologies NPV standard deviation decreases with increasing degree of contract cover
- CCGT plant: trade off as contractual flexibility/spot market sales valuable to arbitrage between gas and power markets

Conclusions

- Industrial organisation and long term contracts affect technology choices and fuel mix
- Marginal cost setting technology cash flow “self hedged” by correlation btw. elec/gas/CO2 prices
- Incentives for private investors to diversify their technology mix towards capital intensive low carbon technologies can be improved by vertical integration / long term contracts
- Need for large scale deployment of capital intensive “green technologies” (nuclear, renewables, CC&S) to be taken into account when considering industrial structure and contractual arrangements in liberalised markets

Analytical Methods for Energy Diversity and Security - Bazilian & Roques (2008)



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Thank you for your attention

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Références:

Fabien A. Roques, David M. Newbery, William J. Nuttall (2007). Fuel mix diversification incentives in liberalized electricity markets: A Mean–Variance Portfolio theory approach. Energy Economics, Vol 30/4 pp 1831-1849. DOI information: 10.1016/j.eneco.2007.11.008

Also available as working paper EPRG 06/26:

http://www.electricitypolicy.org.uk/pubs/wp/eprg0626.pdf

Fabien A. Roques (2008). Technology Choices for New Entrants in Liberalised Markets: The Value of Operating Flexibility and Contractual Arrangements. Utilities Policy, in Press.

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