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Nuclear Power and the World Energy Outlook

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1st CeSSA Conference "Natural Gas, Nuclear Energy, and Security of Supply" – Berlin, 01 June 2007

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World Energy Outlook 2006

Approach & Scope of *WEO-2006*

- Quantitative assessment of global energy market prospects to 2030
- Two scenarios depict markedly different energy futures:
  - *Reference Scenario: No new government policies adopted*
  - *Alternative Policy Scenario: Energy-security & climate-change policies now under consideration are adopted*
- Additional analysis of special issues:
  - *Macroeconomic impact of higher energy prices*
  - *Current trends in oil & gas investment*
  - *Energy for cooking in developing countries*
  - ***Outlook for nuclear power***
- ***World Energy Outlook 2007:*** *China and India prospects – Implications for the World*

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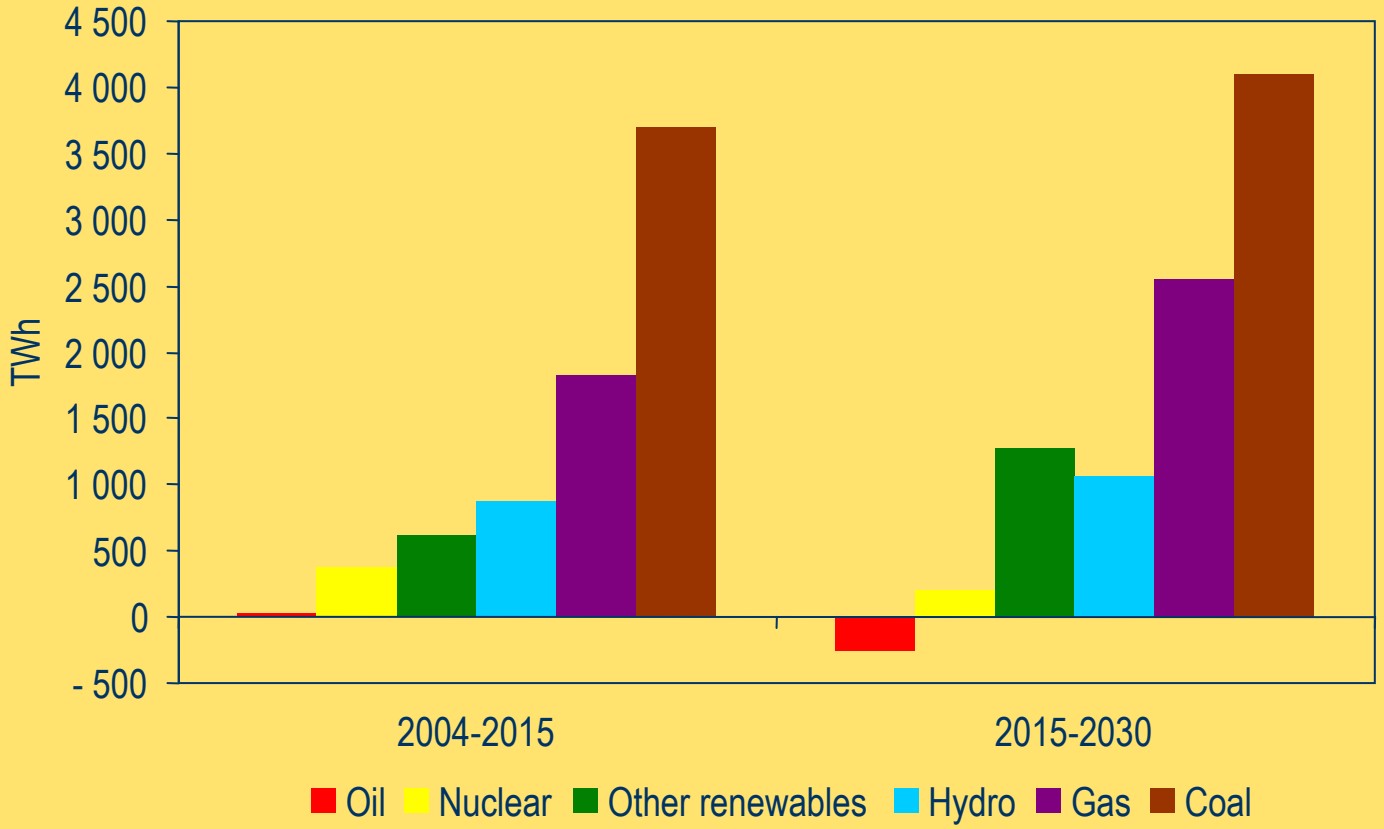
Reference Scenario:

World Incremental Electricity Generation by Fuel



Most of the additional demand for electricity is expected to be met by coal, which remains the world's largest source of electricity to 2030

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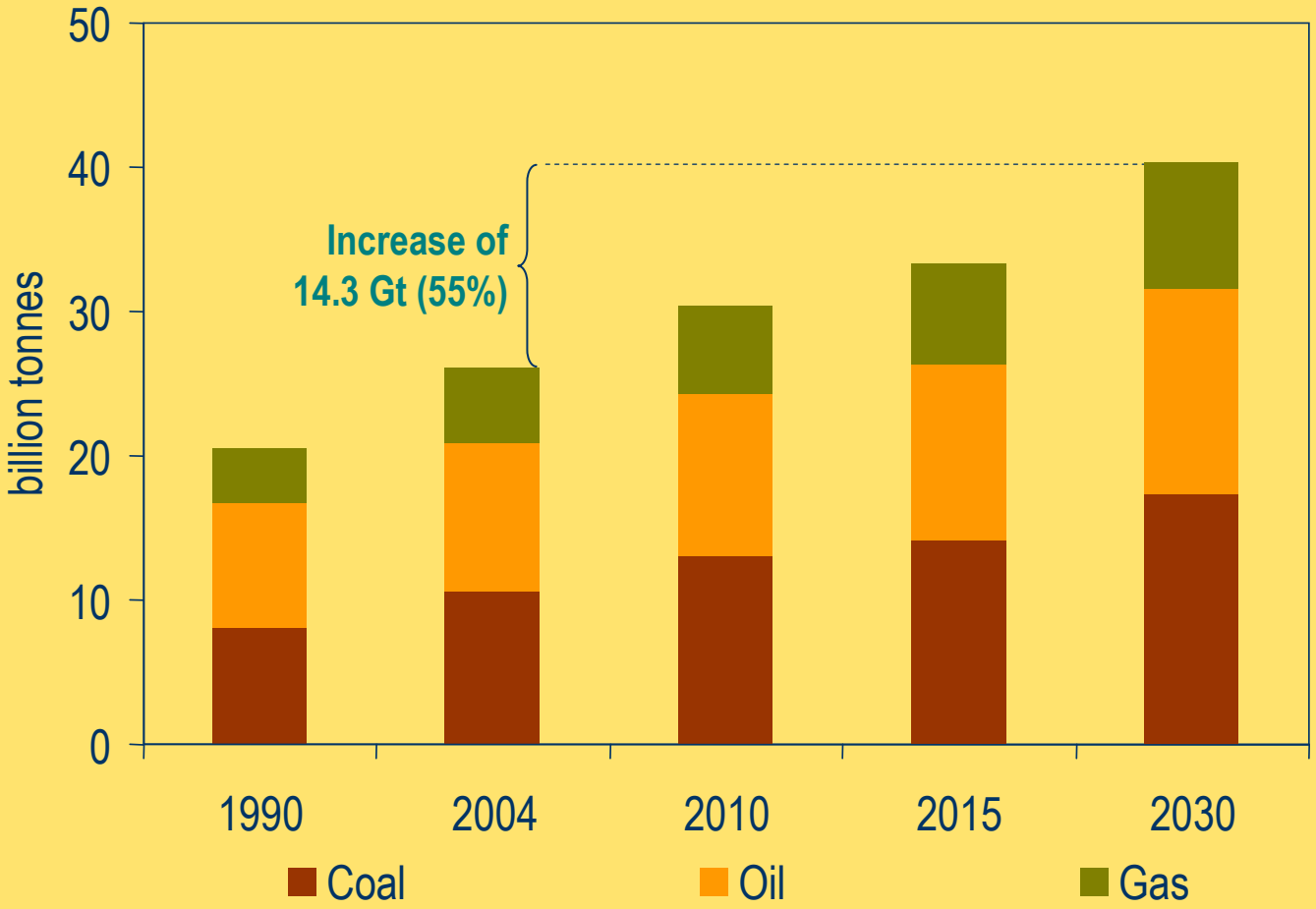
Reference Scenario: Energy-Related CO_2 Emissions by Fuel



Half of the projected increase in emissions comes from new power stations, mainly using coal & mainly located in China & India

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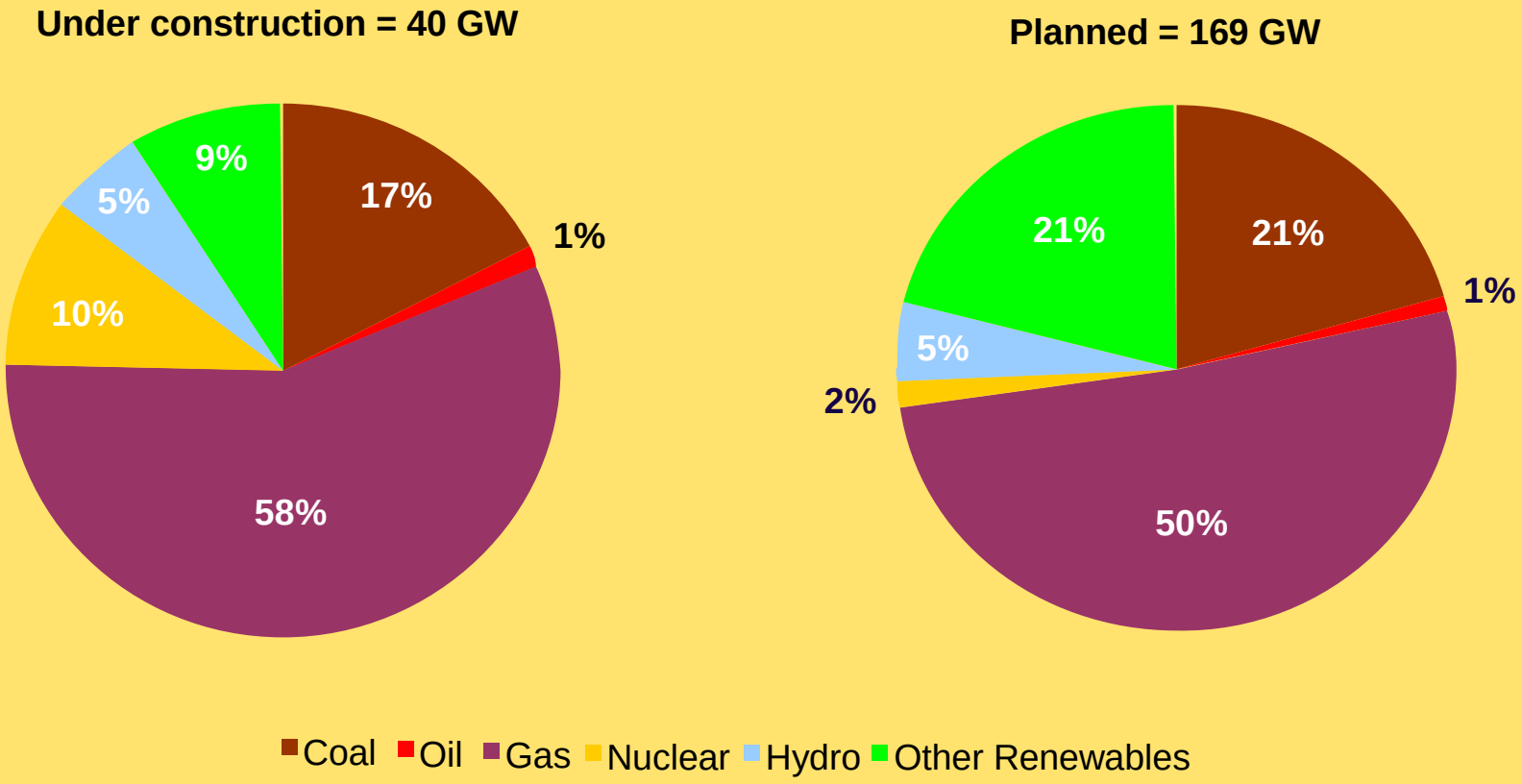
New Generation Capacity in the European Union



CCGTs still dominate investors' plans in Europe

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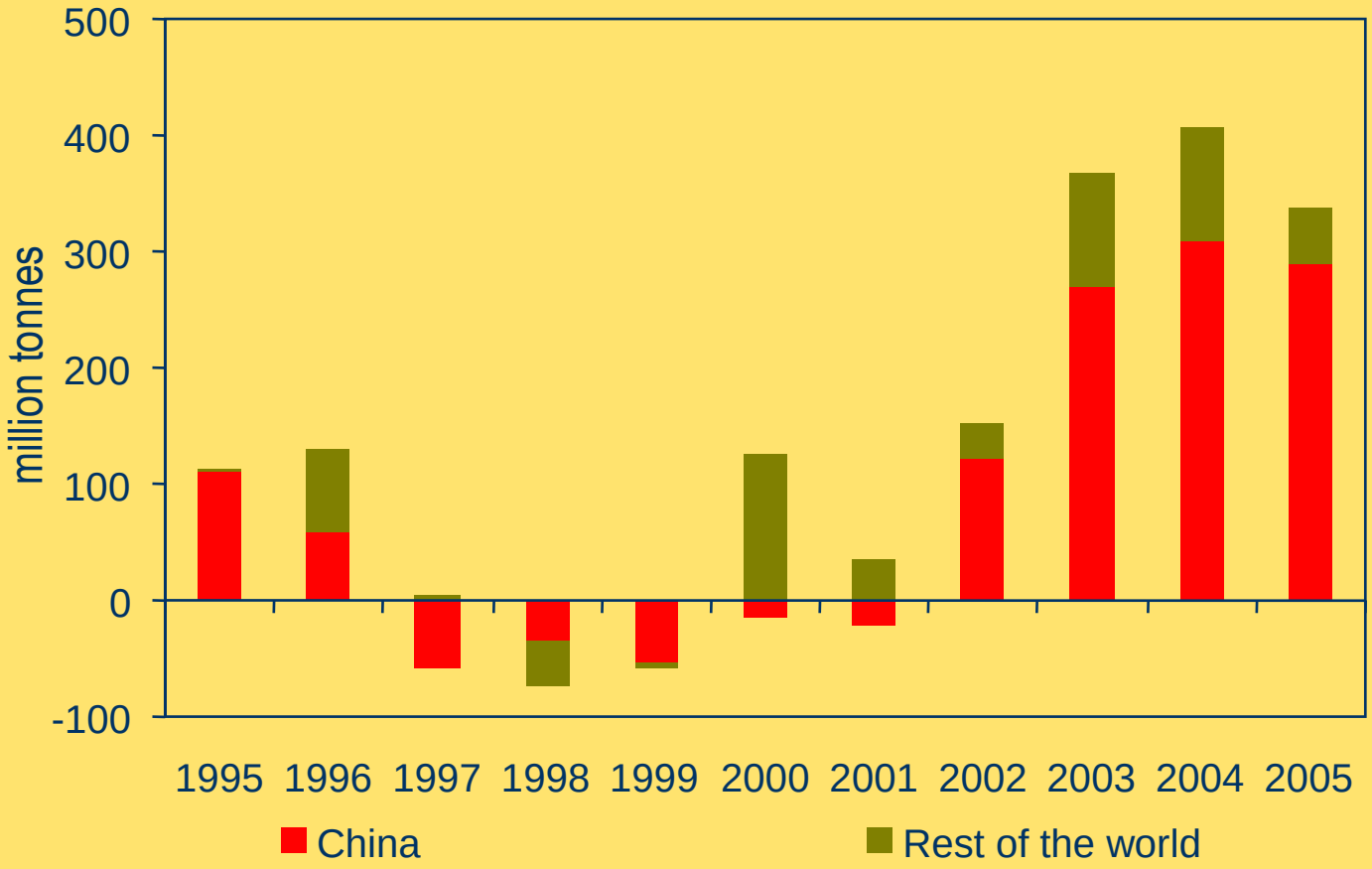
Annual Increase in Coal Demand



Global coal demand in the recent years has grown much faster than previously – mainly driven by China

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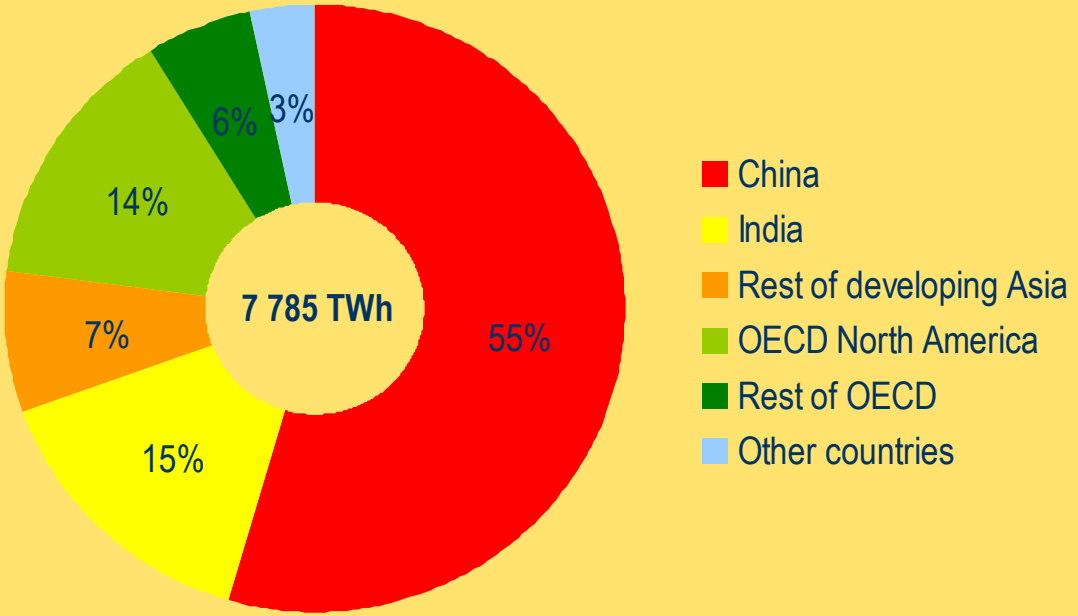
Reference Scenario:

Incremental Coal-fired Electricity Generation by Region



Over three-quarters of the increase in coal-fired generation is in developing Asia, based on ample coal reserves

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The background of a potential "Nuclear Renaissance"

- **Power sector key to 'decarbonise' the economy**
  - Nuclear (and renewables) would displace coal-fired generation in US & most developing countries
  - Europe specific case – nuclear competing with coal and gas fired generation
- **Investment over the next decade will lock in technology that will remain in use for up to 60 years**
  - Significant power generation asset replacements in OECD countries
  - Very large power generation investments in developing countries, particularly China and India

=> Nuclear and Renewables represent a unique opportunity to prevent lock in a carbon intensive power generation system

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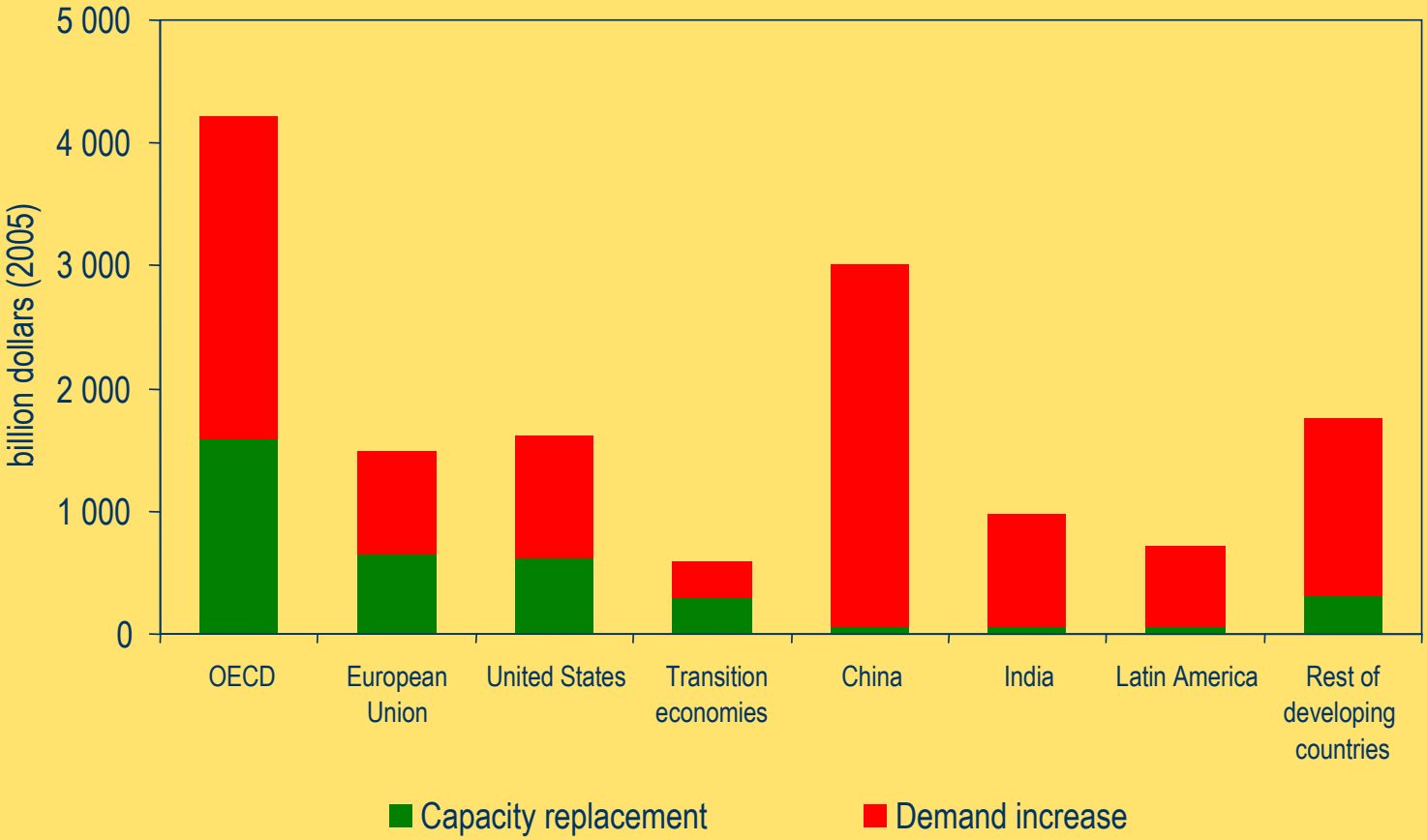
Reference Scenario:
Cumulative Power-Sector Investment, 2005-2030



Substantial investment is needed in OECD countries to replace ageing power plants & networks

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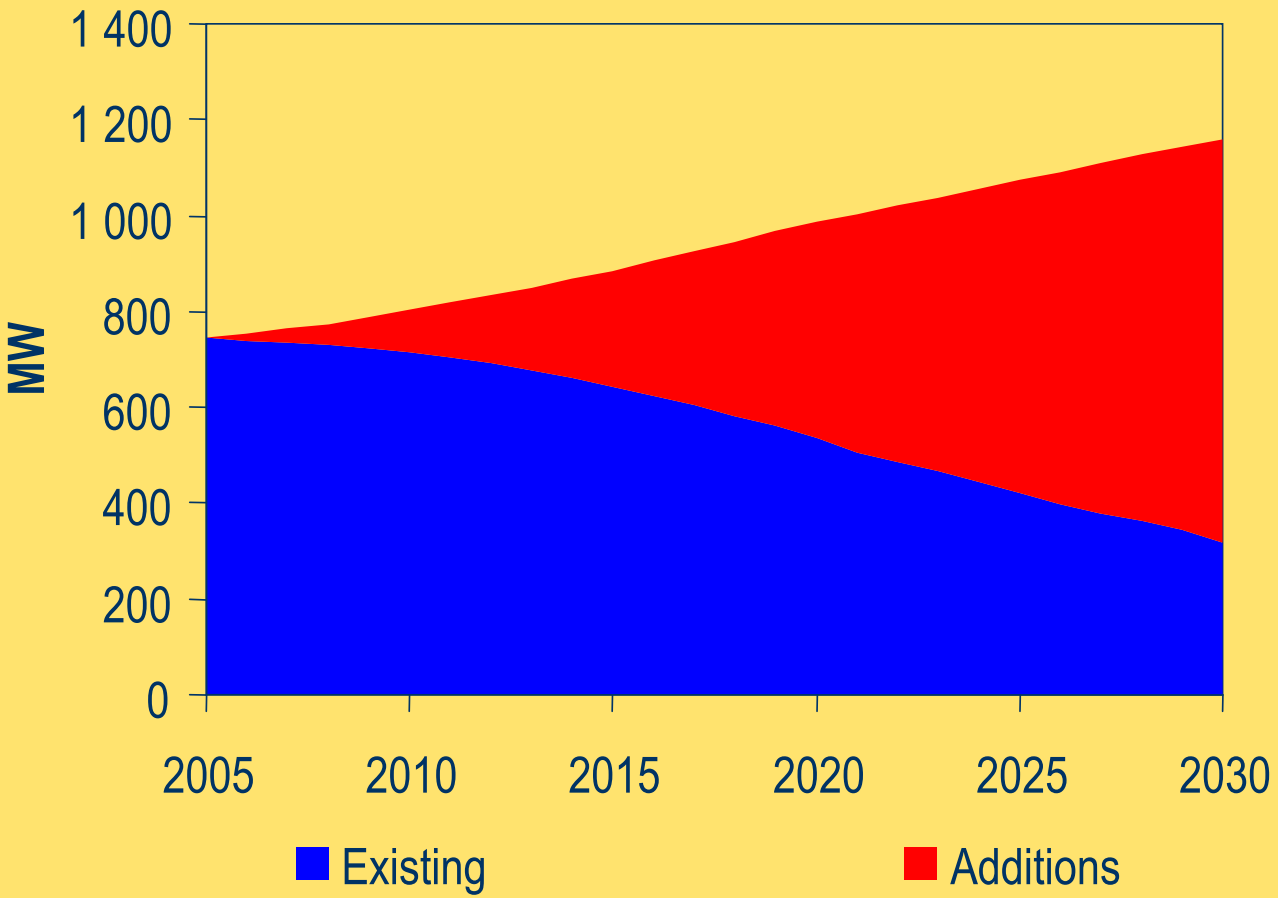
European Union : Power Generation Capacity Increases



Capacity additions until 2030 are larger than current installed capacity. By 2015 more than a quarter of today's coal fired plants will be retired.

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Prospects and challenges for Nuclear Power

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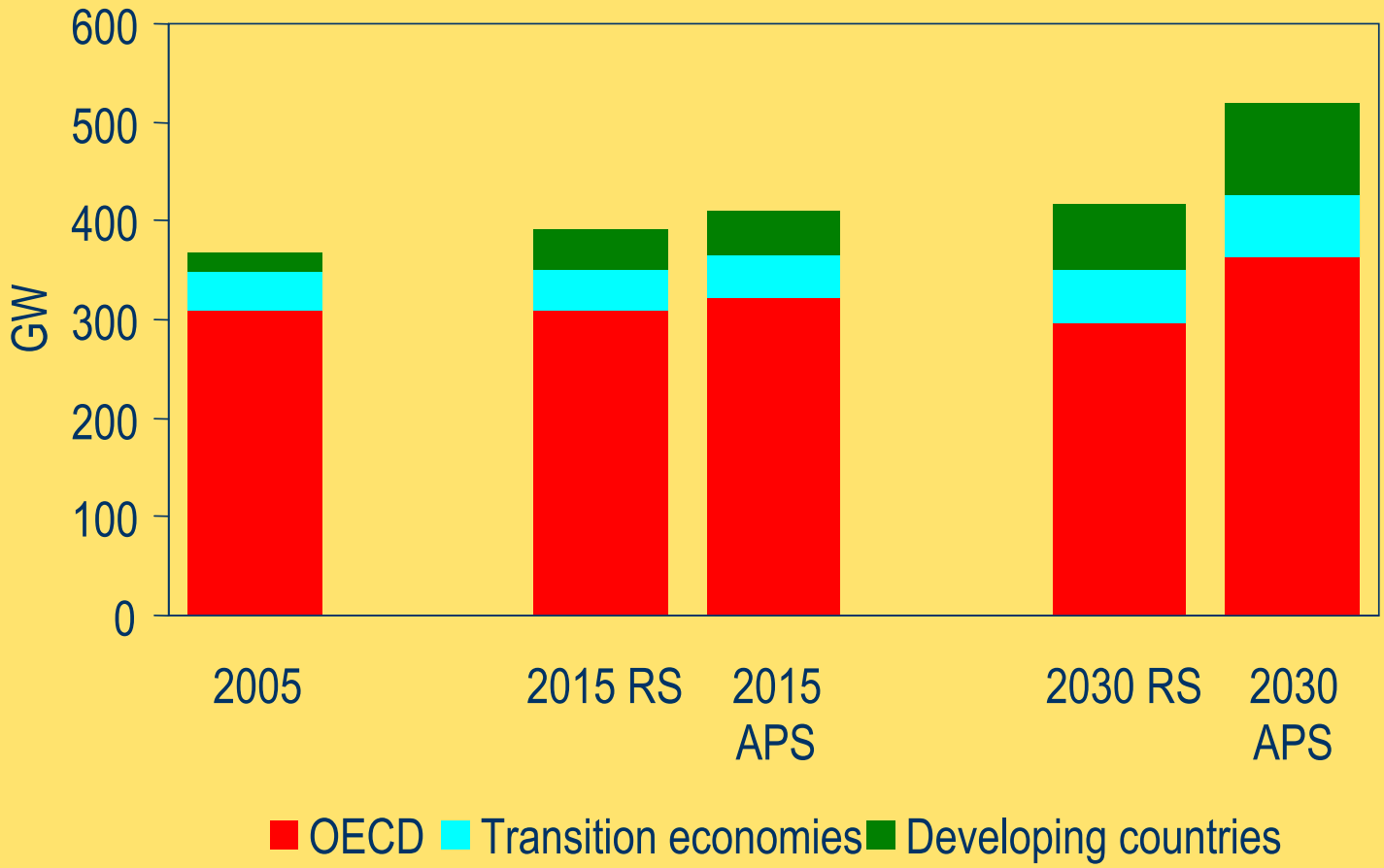
Outlook for World Nuclear Capacity



More favourable policies on nuclear could significantly accelerate the growth in global capacity

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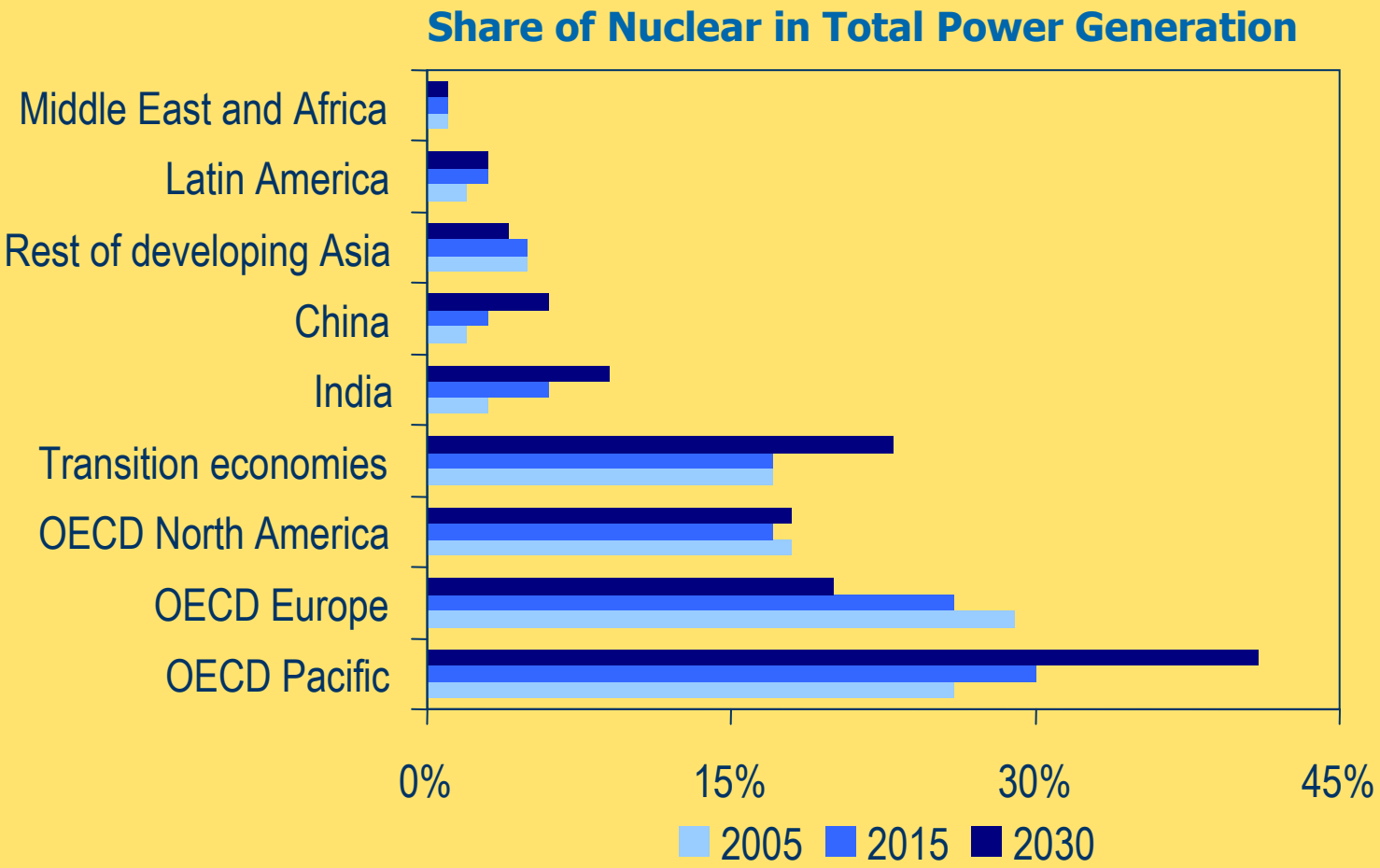
Outlook for Nuclear Power Generation in the Alternative Policy Scenario



Globally, the share of nuclear power drops only slightly, from 15% in 2005 to 14% in 2030

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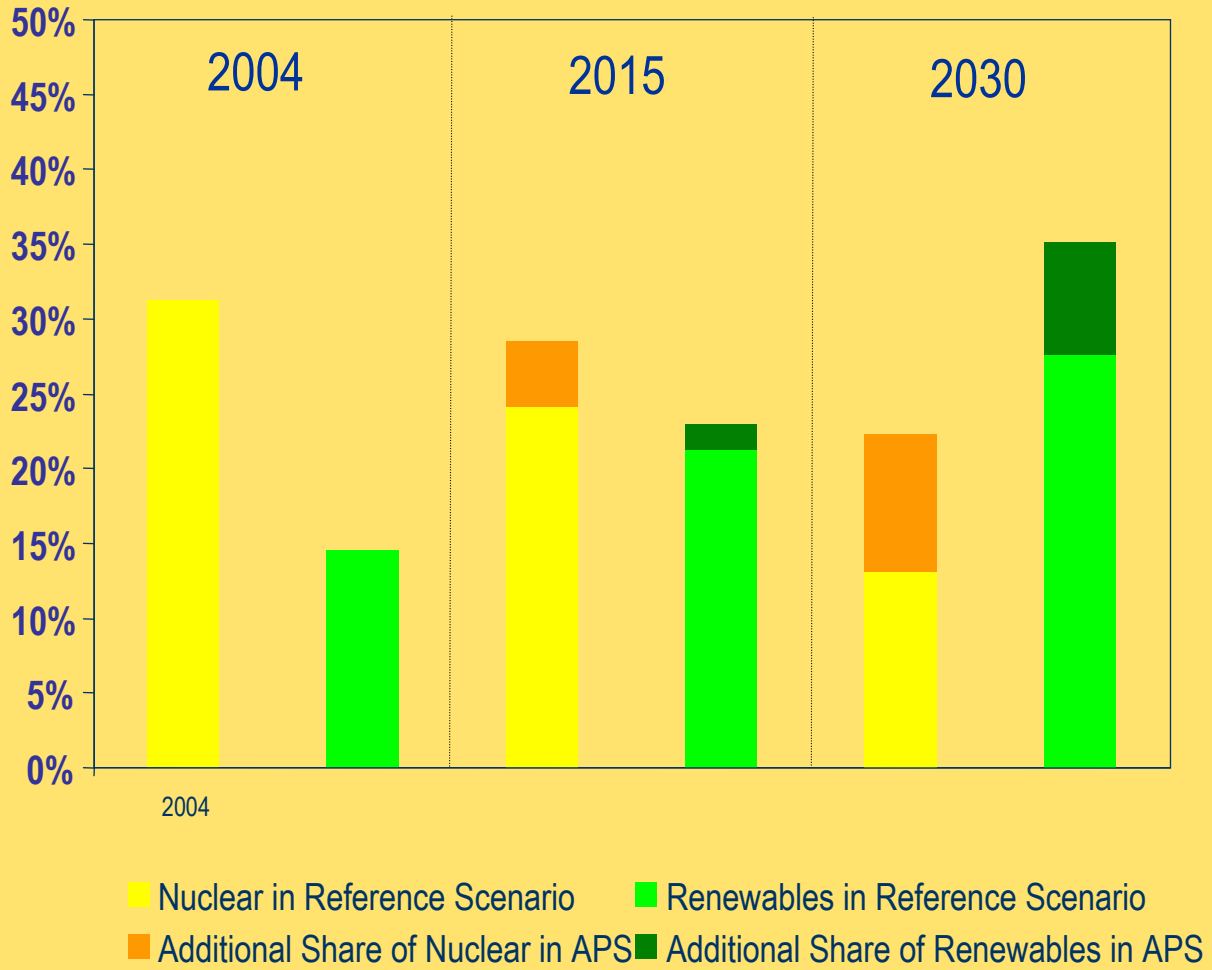
European Union: Share of Nuclear & Renewables



The share of carbon free power generation will increase from 46% today to 58% in APS in 2030, while it declines to 41% in the Reference Scenario

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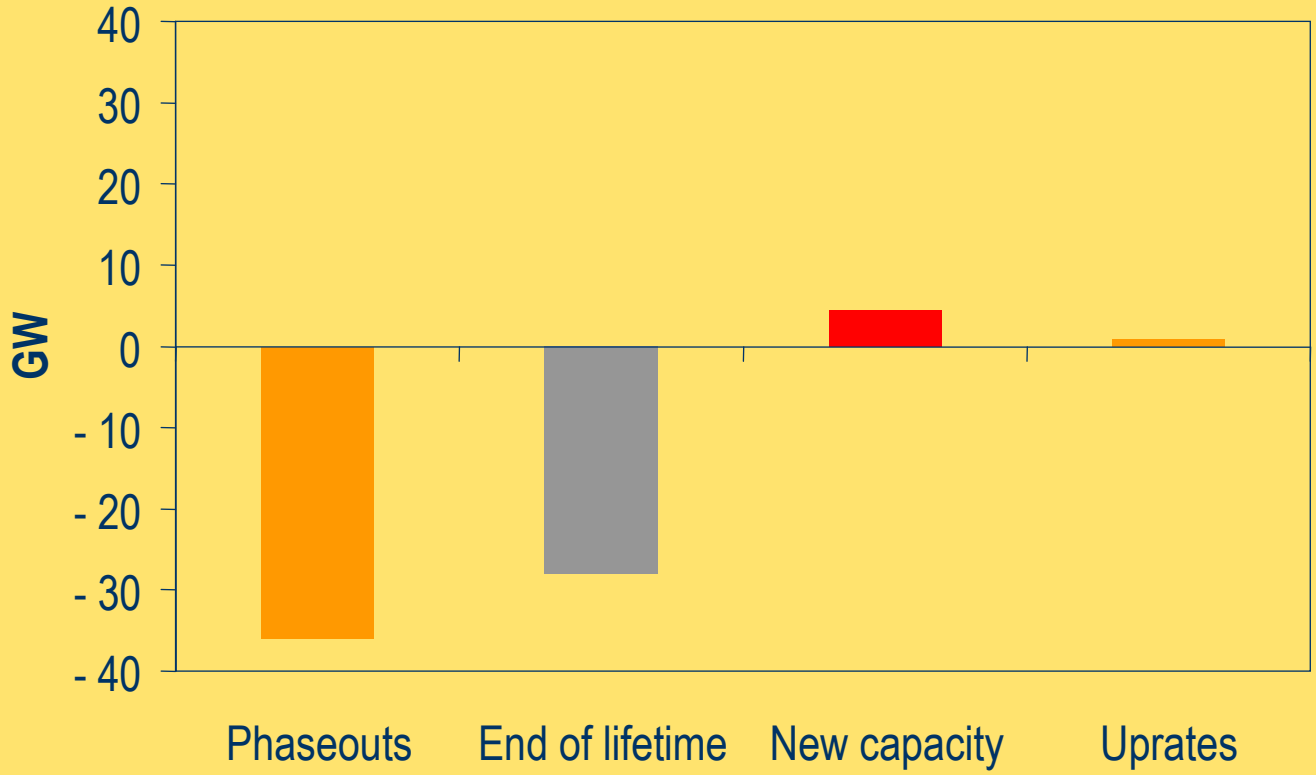
European Union : Nuclear Plant Retirements in Reference Scenario, 2005 to 2030



Installed nuclear capacity decreases from 131 GW today to 74 GW in 2030

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Potential hurdles to the development of nuclear power

- **Public opinion and proliferation issues**
  - **Nuclear Waste**
  - **Proliferation concerns**
- **Nuclear fuel supply/Uranium reserves**
- **Regulatory uncertainty and contruction risks**
- **Economics and financing in liberalised markets**

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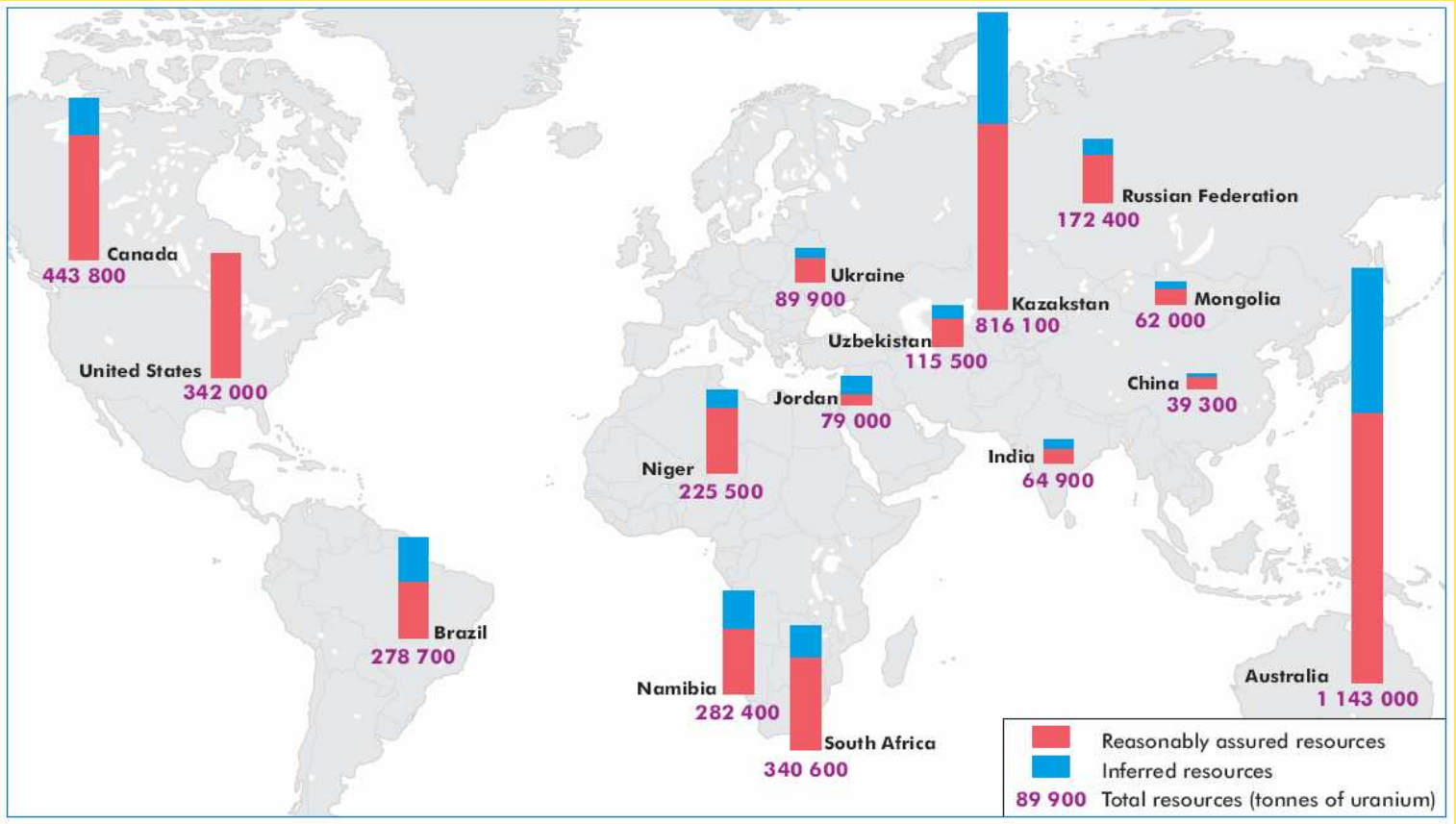
Global Distribution of Uranium Resources:
Top 15 Countries – 95% of total resources



Uranium resources are widely distributed around the world

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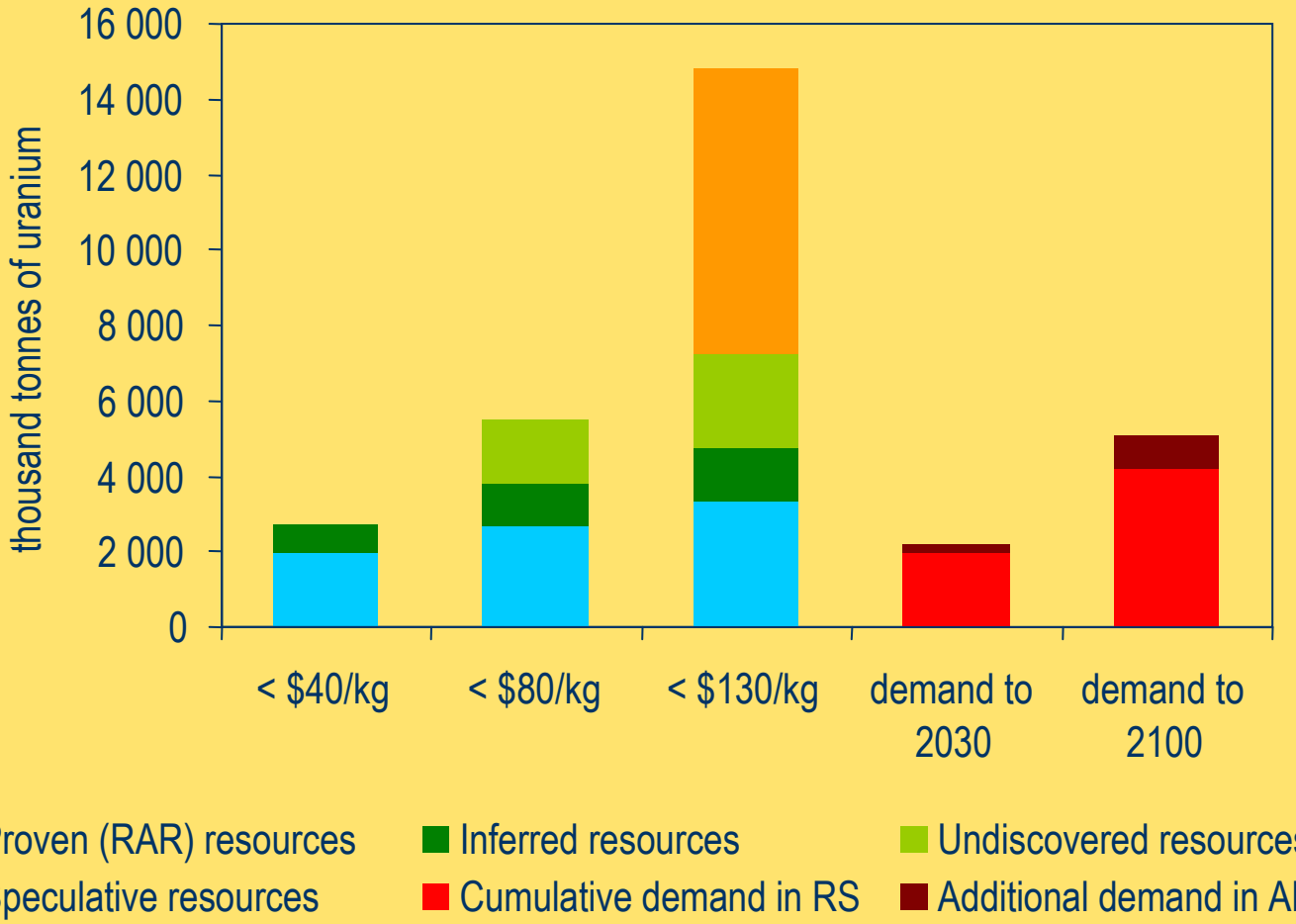
Uranium Resources versus Cumulative Uranium Demand



Identified conventional uranium resources are sufficient for several decades of operation at current usage rates

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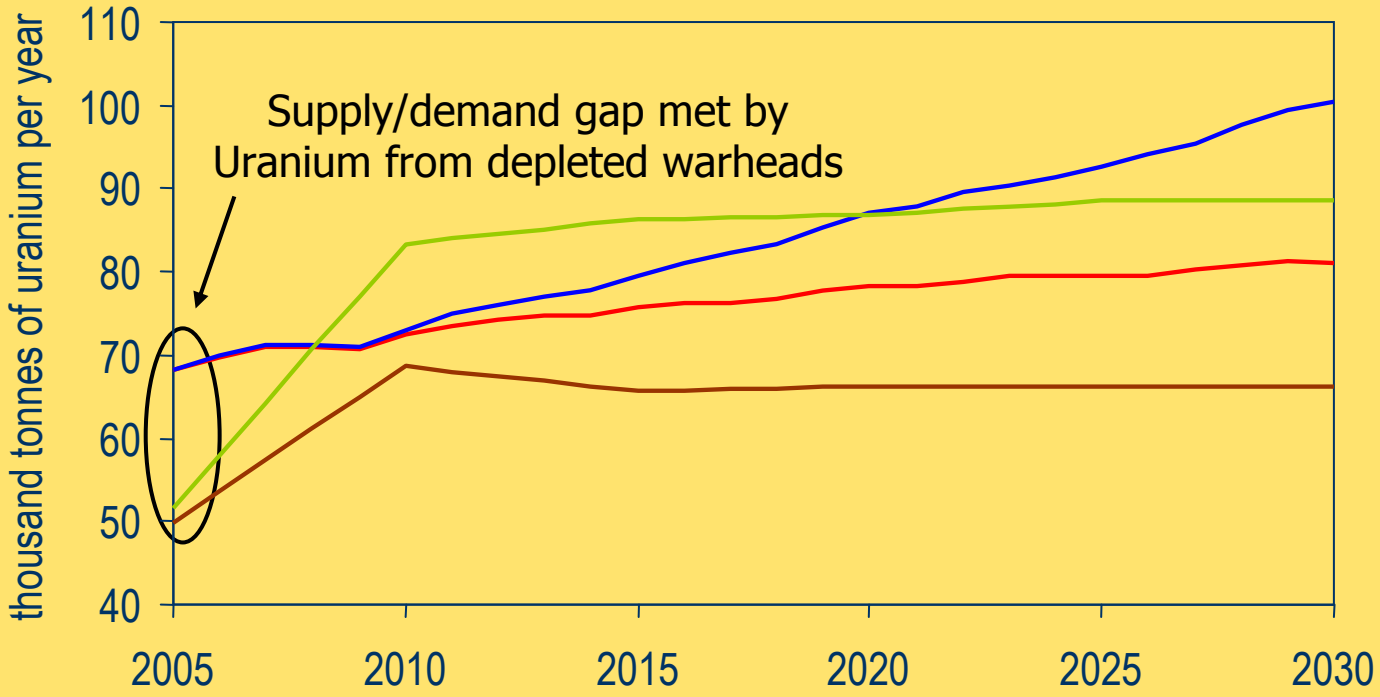
World Uranium Production Capability & Reactor Requirements



Despite the significant additions expected in the coming years, primary production capability will require further expansion after 2015

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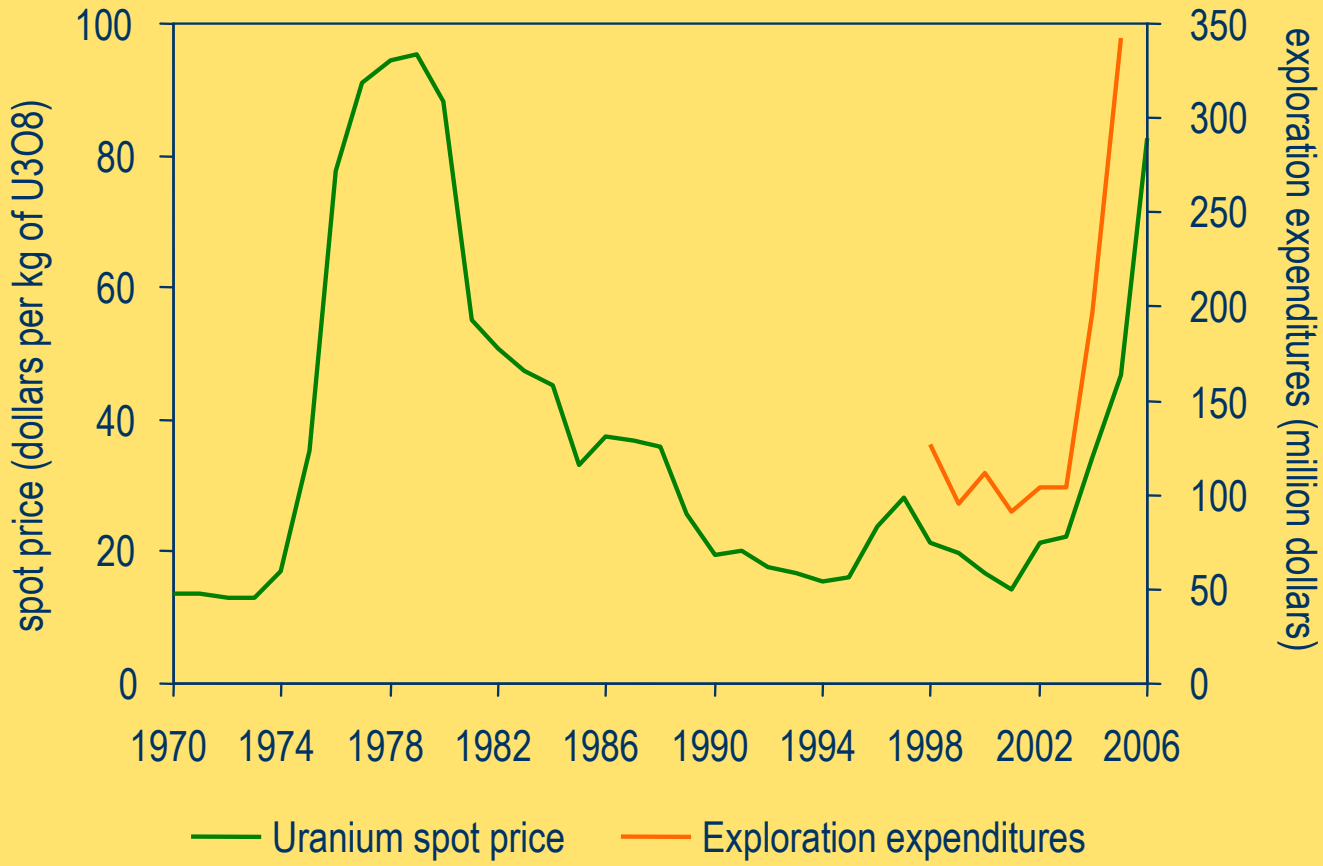
Uranium Spot Prices & Planned Uranium Mining Capacity Additions



- ***Uranium market highly cyclical***
- ***Recent price increases have triggered more exploration & major new production projects***

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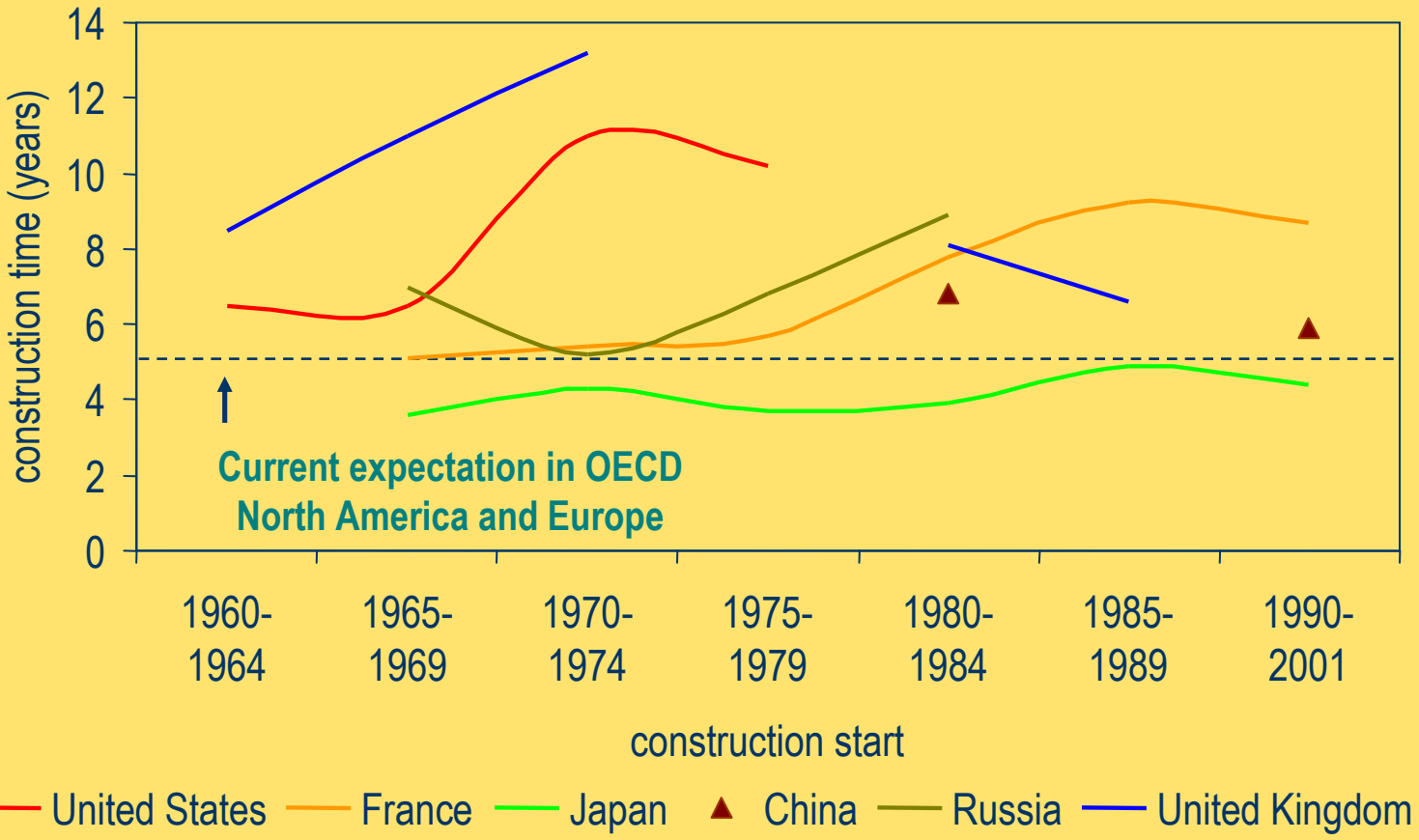
Construction Time of Future Nuclear Power Plants?



Overcoming the legacy of the past: Investors will need to be convinced that construction times can be reduced in the future in some countries

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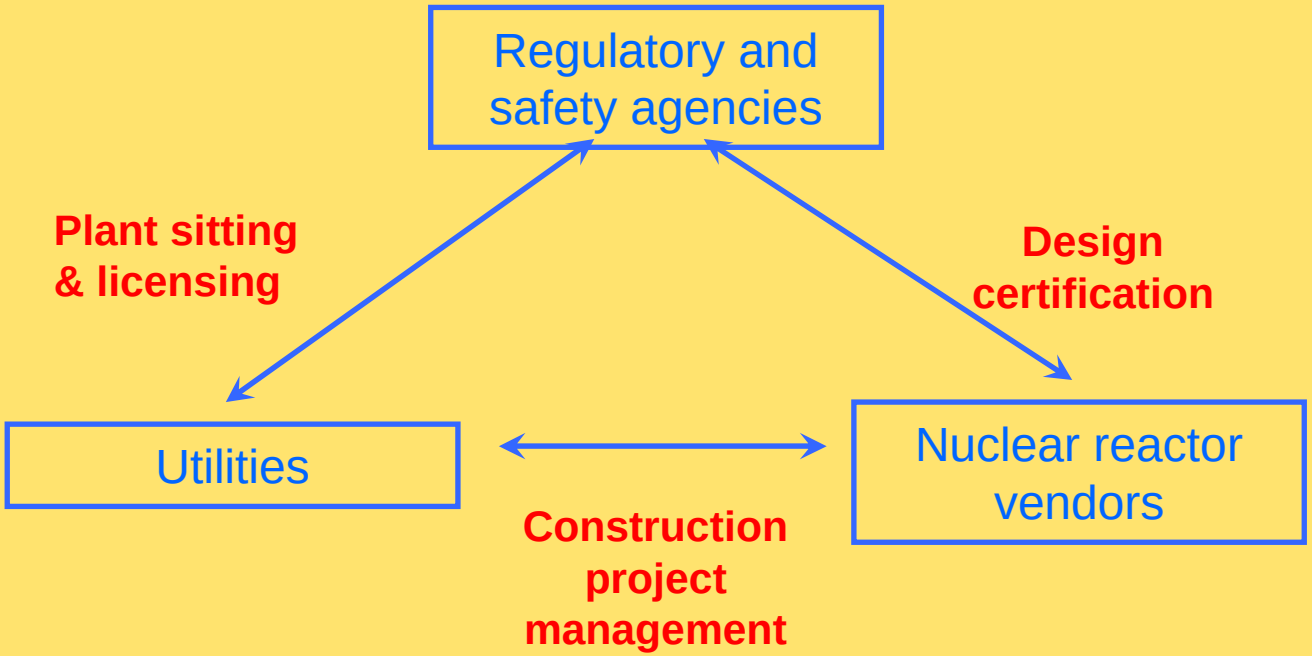
Regulatory and construction risks



- **Great differences in institutional and industrial organisation in various countries**
  - **e.g. comparative study USA/France by Lester and McCabe (1993)**
  - **Technology standardisation, institutional and industrial organisation to mitigate construction and operating risks**
- **Learn from most successful experiences**
  - **Reduce regulatory uncertainty (streamlining of licensing procedures)**
  - **Plant vendors to assume construction risk (e.g. Finnish EPR Turn key contract)?**

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Economics of nuclear power

- **Depend critically on:**
  - time and cost to build
  - prices of coal, gas, CO_2 and hence electricity
  - discount rate, hence financing

- **A closer look at market price risks:**
  - Impact of correlation between elec./gas/coal/ CO_2 prices
  - who should bear the risks? =>impact of long term contracts and financing arrangements

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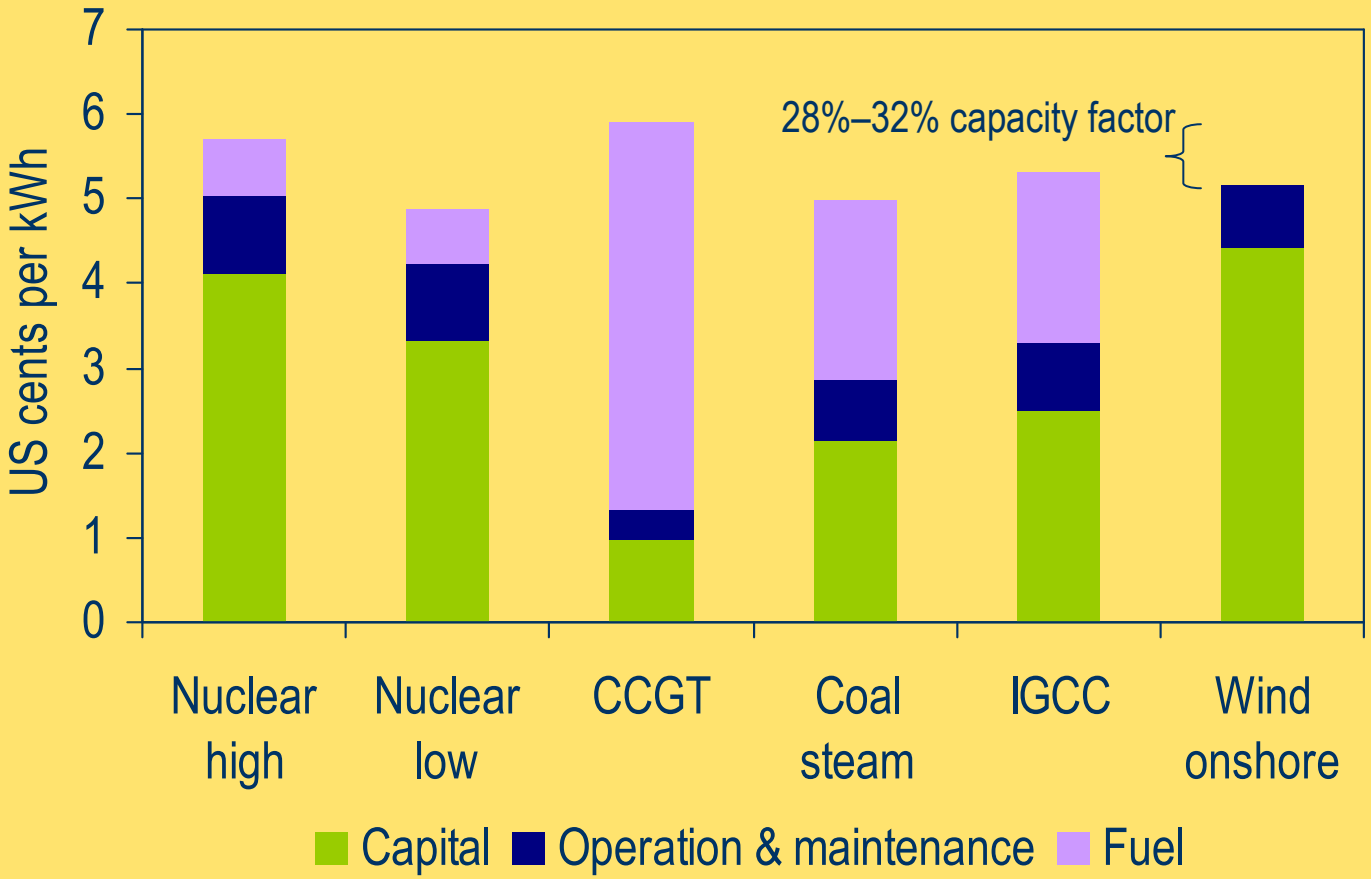
Electricity Generating Costs: Low Discount Rate



At a low discount rate, nuclear is competitive with gas & coal too, if a coal-fired station costs less than $2000 per kW to build

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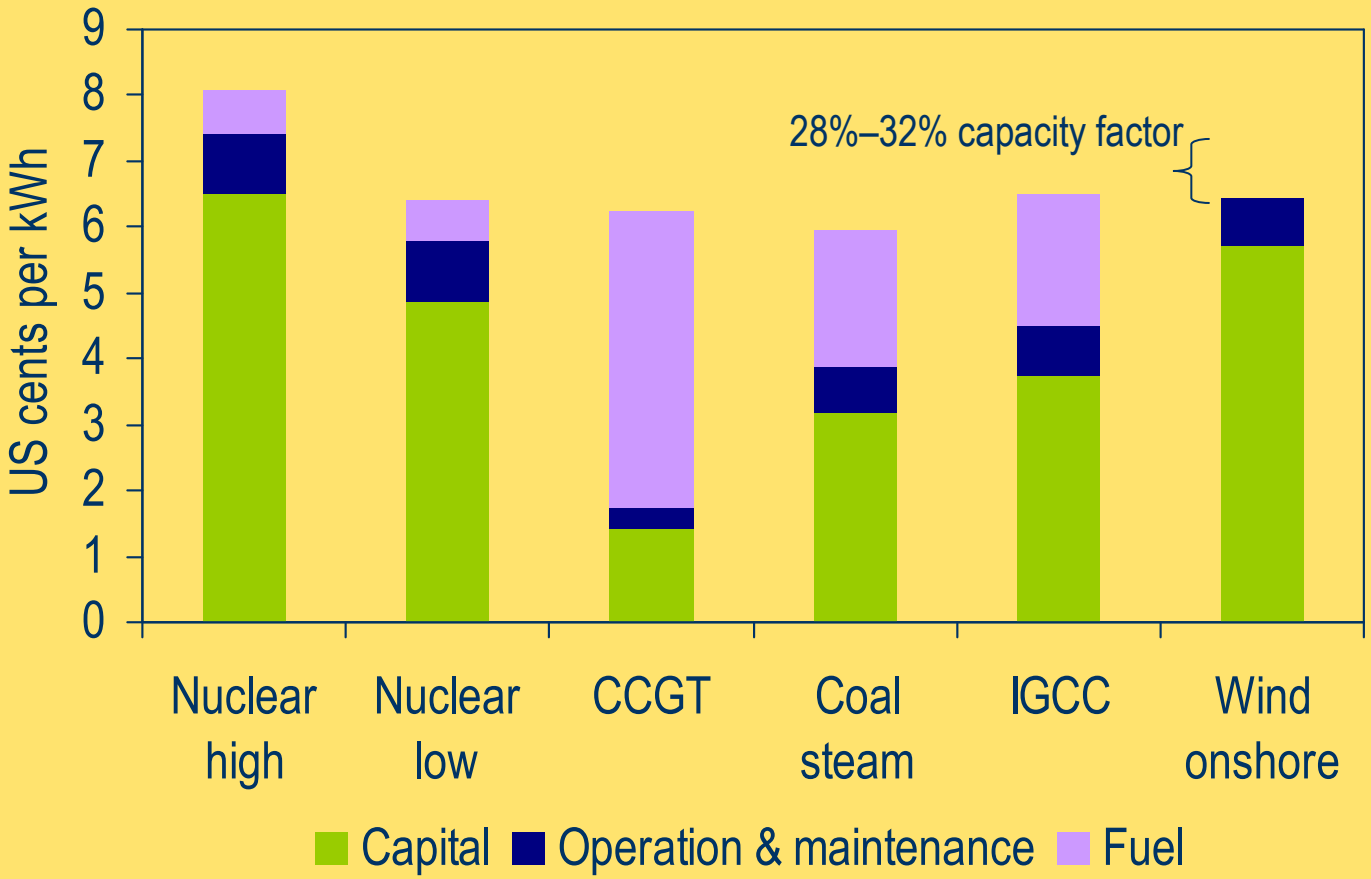
Electricity Generating Costs: High Discount Rate



At a high discount rate, the cost of building a nuclear plant would need to fall to less than $2000 per kW – in the absence of a carbon value

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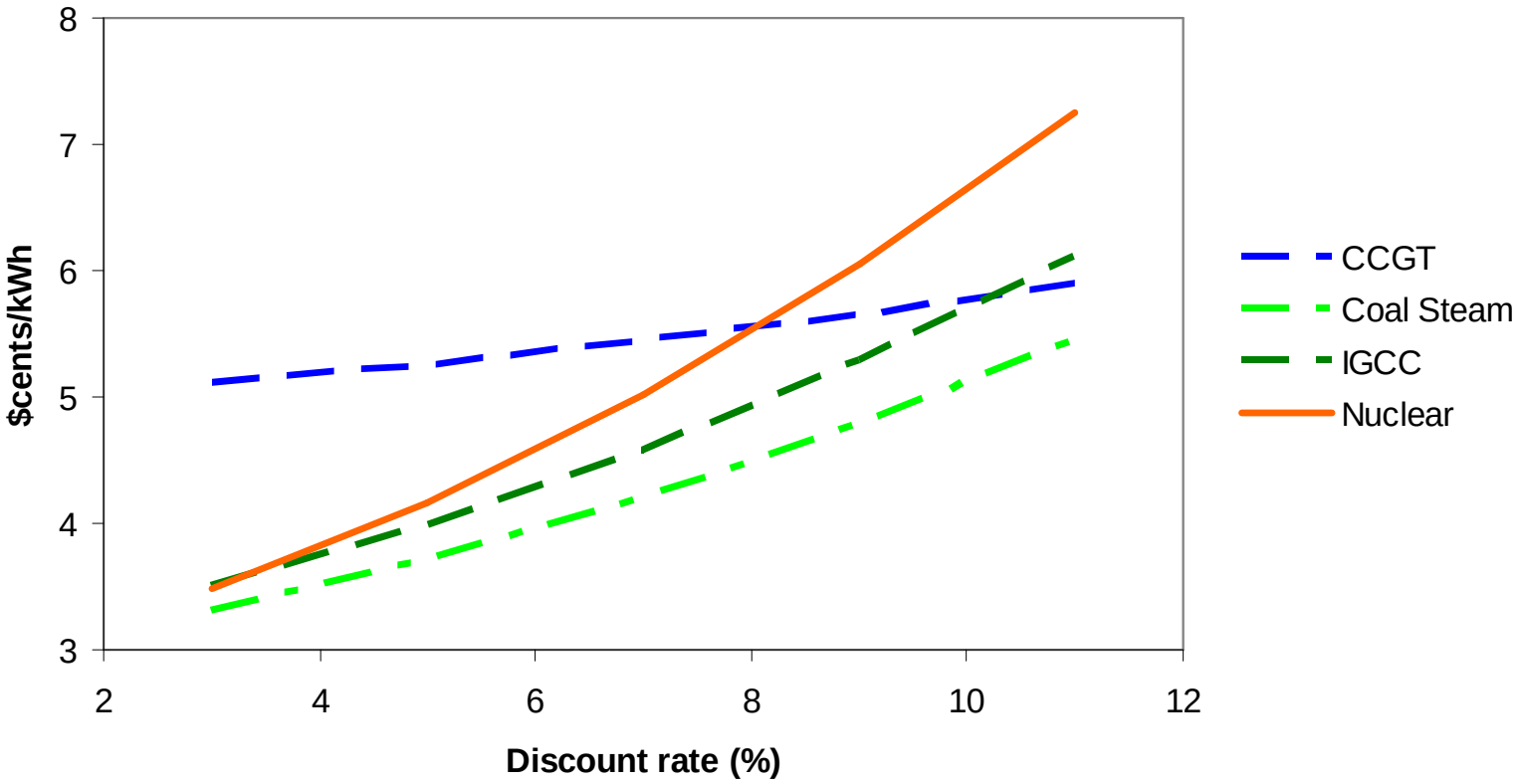
Sensitivity of generating costs to discount rate



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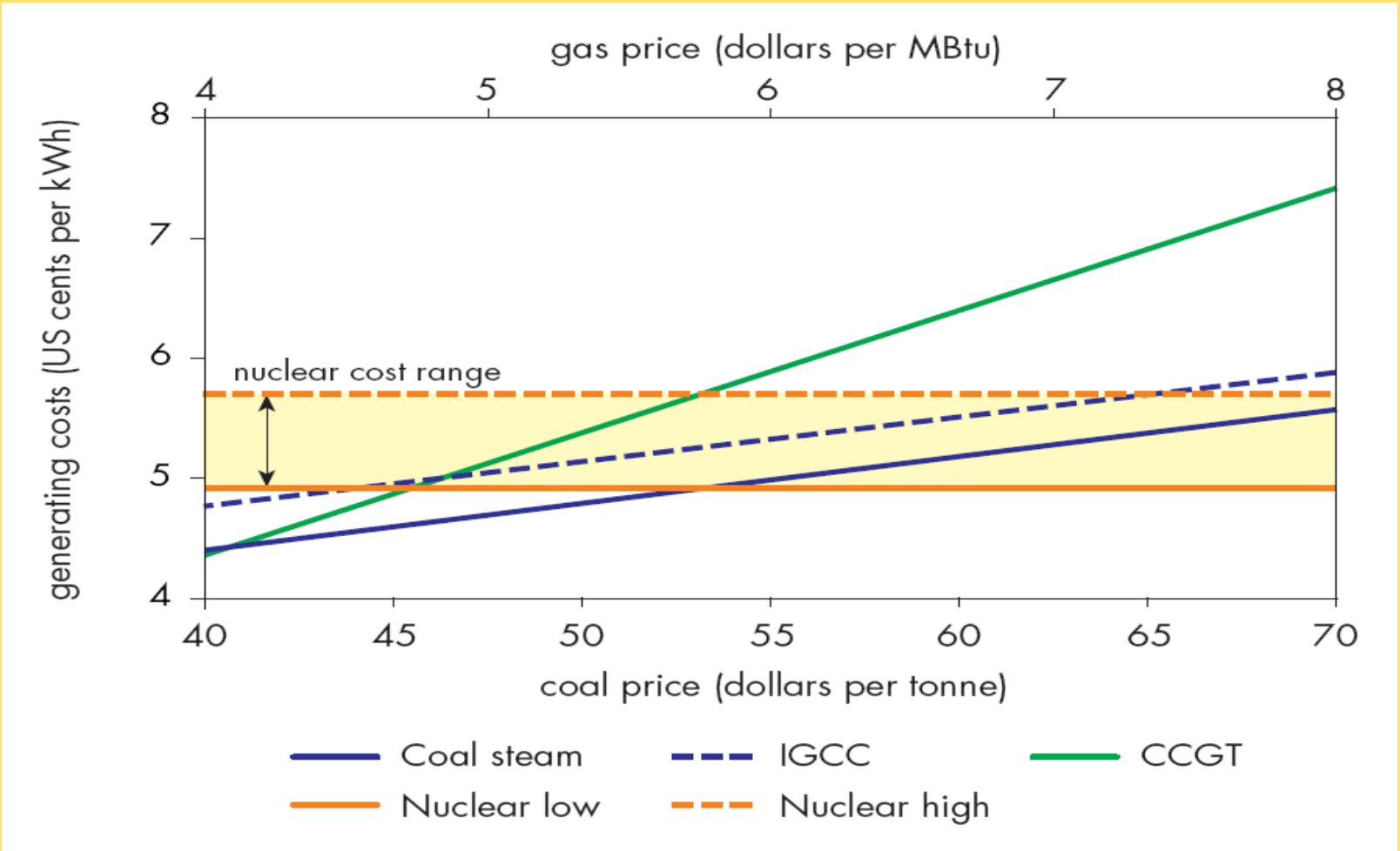
Sensitivity of generating costs to fossil-fuel prices



Nuclear can compete with gas at a gas price above $5.70/MBtu – corresponding to $40-$45 per barrel of oil

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Market risk and nuclear power: Who should bear the risk?

- **Merchant nuclear investment is risky**
- **Some consumers (e.g. electricity intensive) might prefer stable elec. prices**
  - hold shares in nuclear companies
  - sign long-term nuclear contracts
    - Finland: EPR output sold at production cost to TVO shareholders
    - France: Exeltium consortium of electricity intensive consumers – 15 to 20 years contract
- **Large European companies can finance new plant with own cash flows and transfer (part of) the electricity price risk to consumers**
  - Vertical integration and 'sticky consumers'

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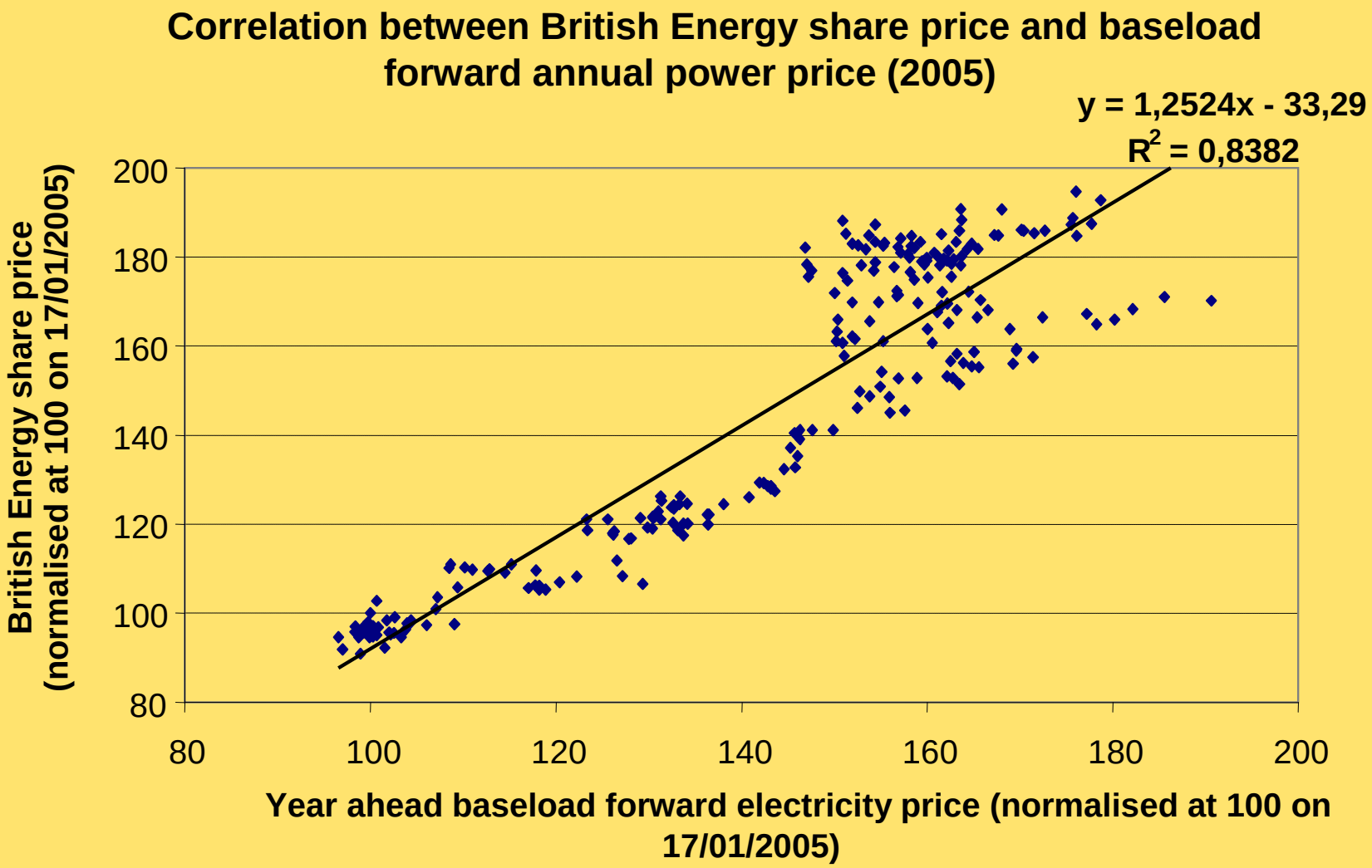
British Energy share 91% correlated with UK elec. price in 2005



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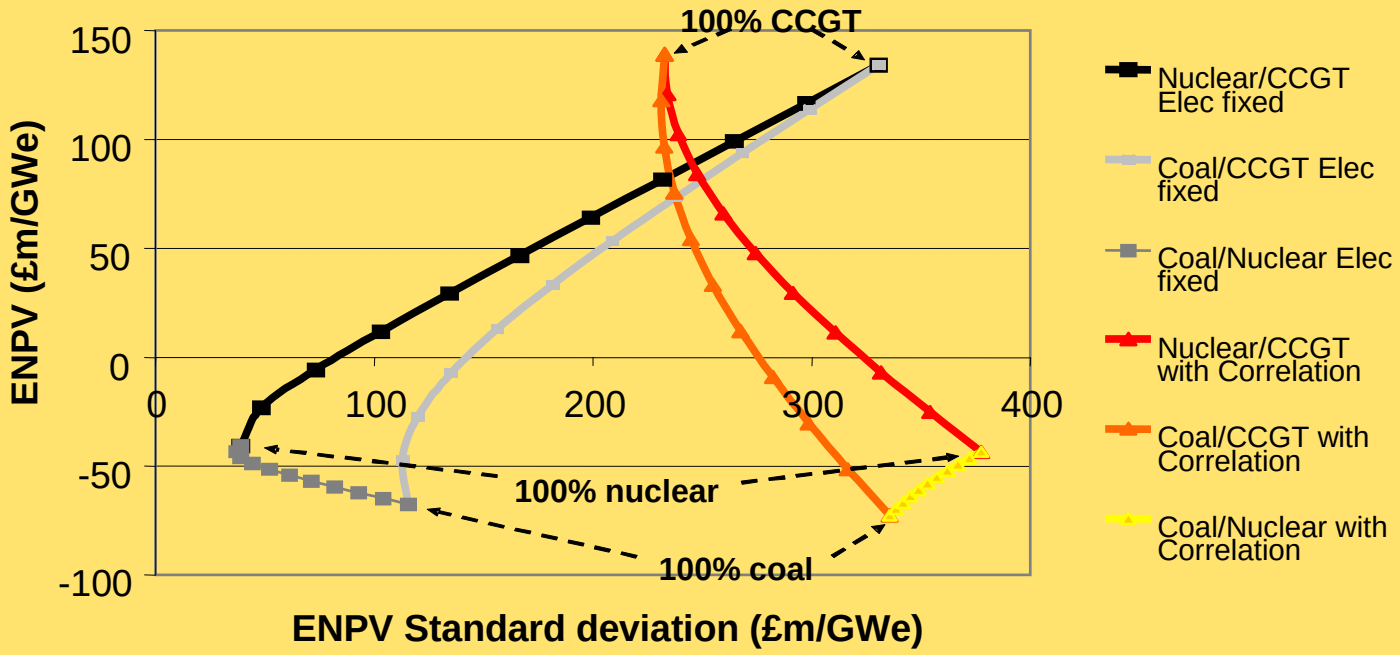
Impact of long term contracts on optimal generation portfolios

Roques, Newbery, Nuttall (2006)

Portfolios of Nuclear, Coal and CCGT plants with fixed and uncertain electricity prices (10% d. rate)



Long term fixed price power purchase agreement greatly improve incentives for mixed portfolios containing coal or nuclear plants

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Summing Up

- **Timing of potential nuclear renaissance critical**
  - Considerable investment in both OECD and developing countries over next 10 years
- **Uranium resources are not a constraint on the development of nuclear power**
- **Public concerns over safety, nuclear waste disposal & risk of proliferation must be addressed**
- **Nuclear power would mostly displace coal outside EU**
  - can help reduce emissions but contribution to lower gas import dependence debatable
- **Nuclear power can be competitive in liberalised markets, but only if**
  - construction & operating risks are well managed
  - financial penalties on CO_2 emissions are introduced

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Discussion

- **Allocation of risks through contracts, industrial structure and institutional arrangements critical**
  - to create a level playing field for capital intensive technologies in liberalized markets
  - and ensure adequate fuel mix diversification

- **Significant macroeconomic benefits of fuel diversity**
  - BUT CCGT cash flow "self hedged" by correlation btw. elec/gas/CO2 prices…
  - ⇒ misalignment between private investors' fuel-mix diversification incentives and socially optimal diversification?

- **Incentives for private investors to diversify their fuel mix by investing in nuclear power can be improved by:**
  - "Cheap financing"
  - Long term contracts
  - Vertical integration of energy utilities

=> New nuclear build in liberalised markets likely to be financed by (large) vertically integrated companies…

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