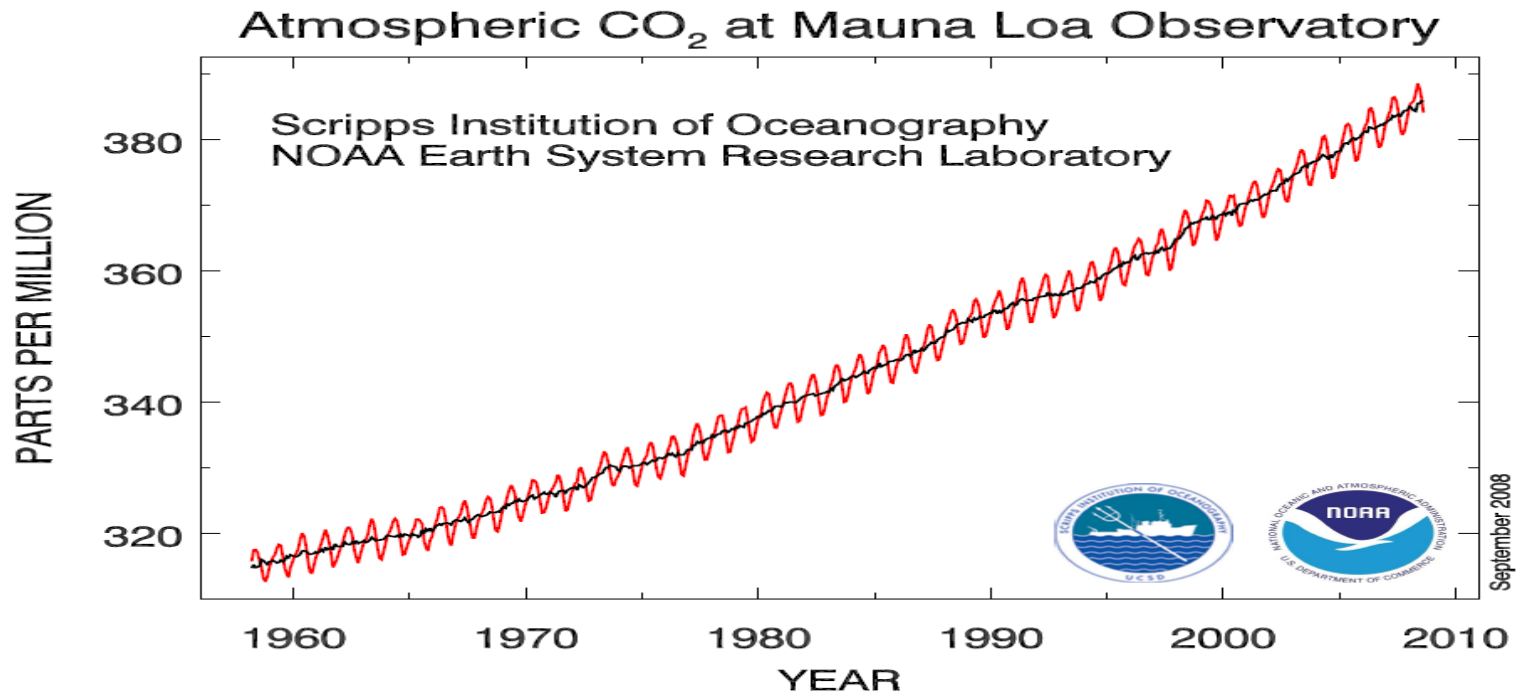




# Electricity Investment Behaviour in Response to Climate Policy Risk

Janne Kettunen

# Background and Motivation



- Policies are currently formulated to mitigate carbon emissions and global warming
- The feasibility of the carbon abatement targets, the implementation effectiveness and the willingness of the participating states are unclear
- This results in a significant policy uncertainty in the electricity generation market

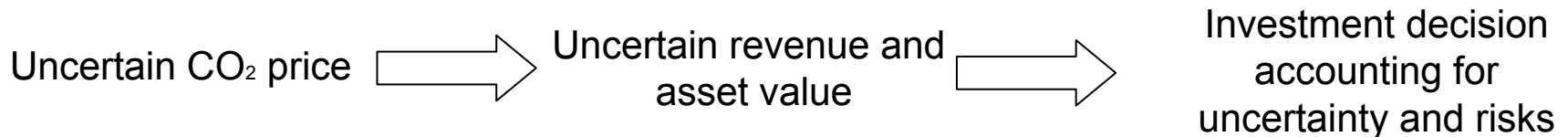
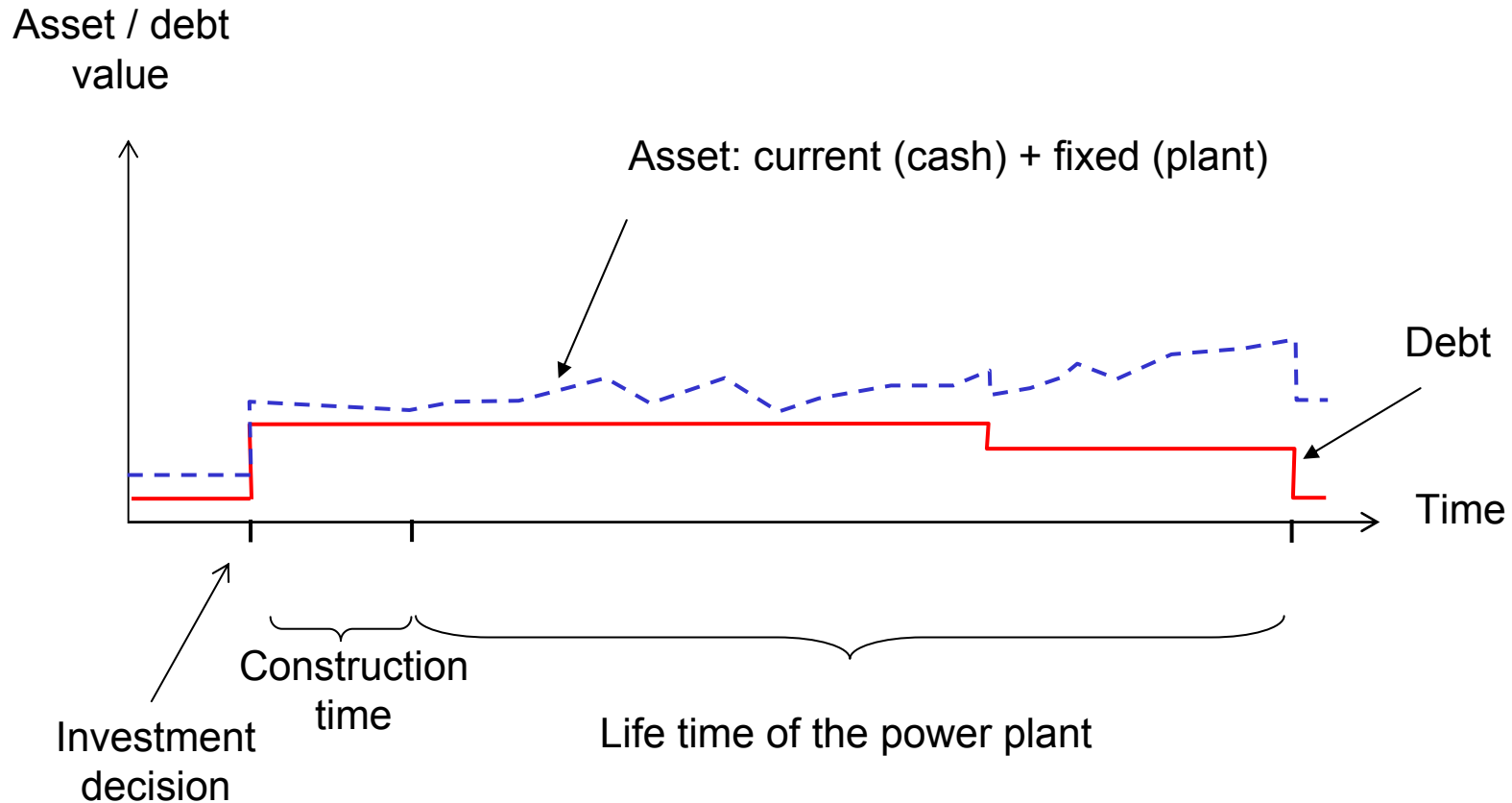
# Investment Behavior

- Carbon emission costs get passed through into the wholesale market  
(Fezzi and Bunn 2008)
- Companies tend to delay their capacity investments until carbon policies are reset  
(eg. Reedman et al. 2006, Blyth et al. 2007)
- Yet many energy models assume homogenous companies which make investments whenever NPV is positive  
(eg. Caramanis 1982, Schumacher and Sands 2006)

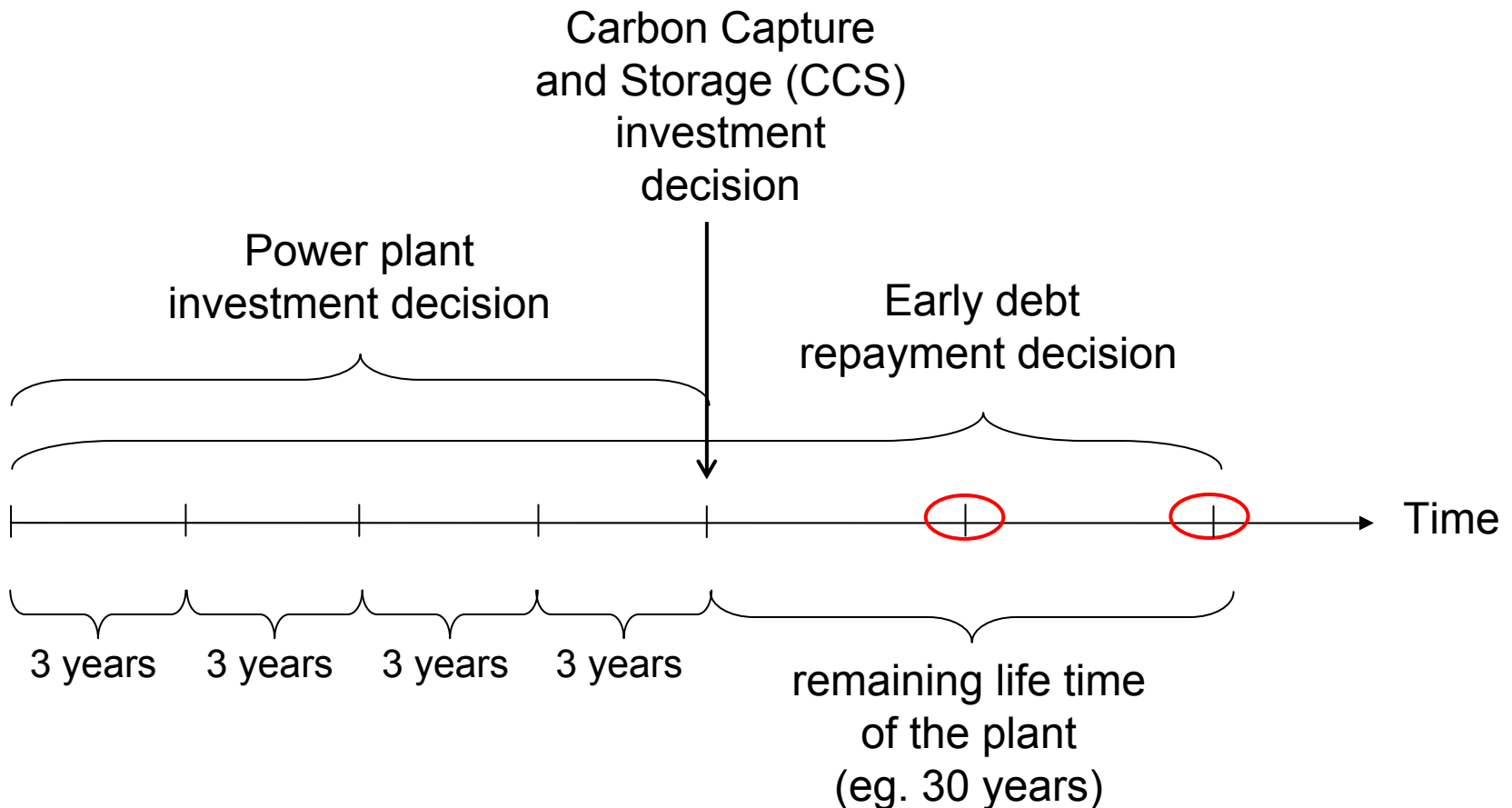
# Key Questions

1. How does carbon policy uncertainty, manifested in carbon price, impact the investment propensity of companies?
2. What are the effects of the carbon policy uncertainty on the evolution of market structure?
3. How does carbon policy uncertainty influence the technology mix of a company?

# Investment under Carbon Policy Uncertainty



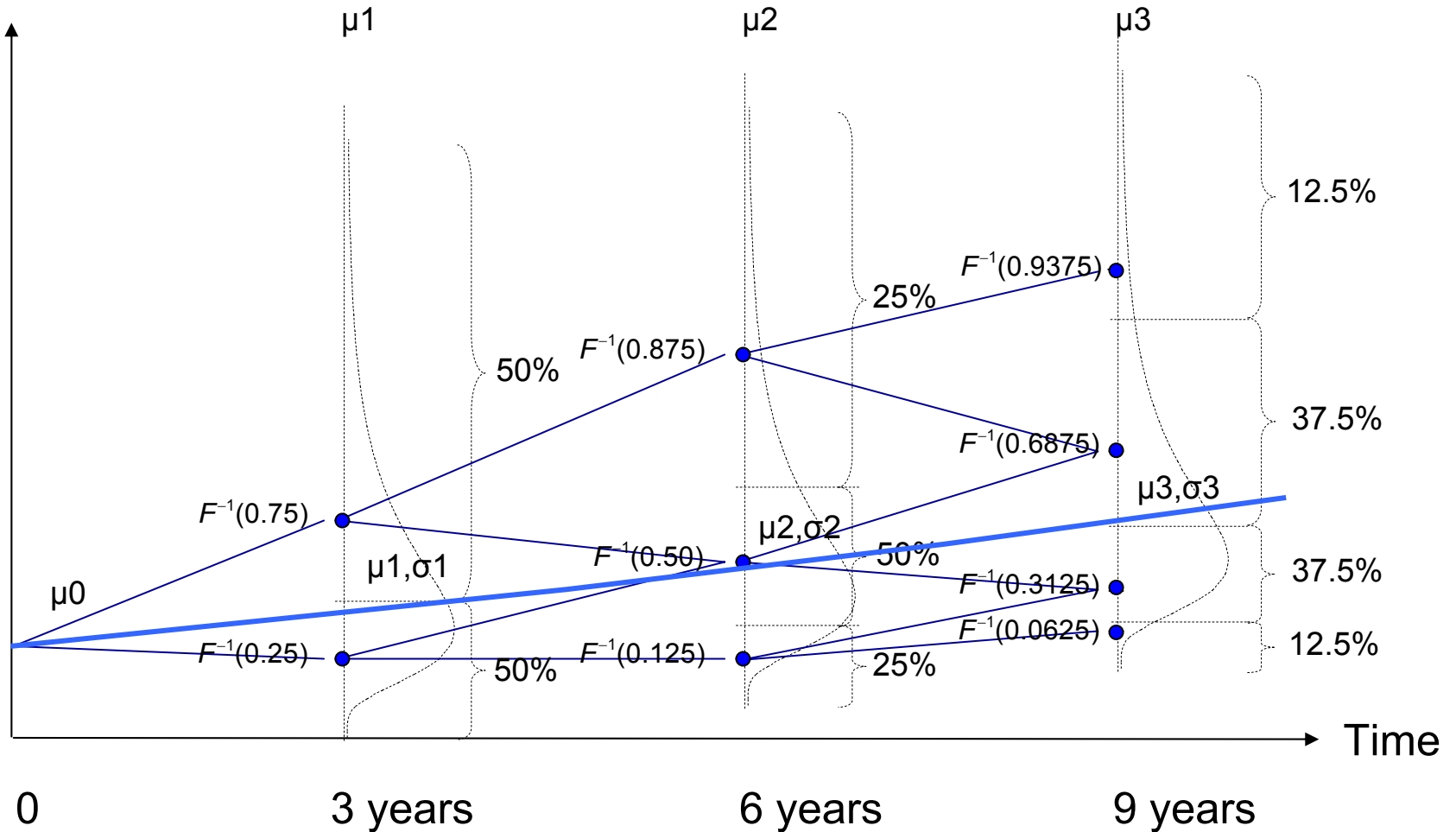
# Discrete Time Decision Making Model



○ Risk

# CO<sub>2</sub> Price Scenarios

CO<sub>2</sub> price



# Optimization Model

$$\max \frac{\sum_{s^T \in S^T} p(s^T) \text{cash}(s^T)}{(1 + r(1 - \text{tax\_rate}))^T} - \alpha \text{risk\_level}$$

Risk averse investor minimizes risk ( $\alpha \approx \infty$ )

Risk neutral investor maximizes E[NPV] ( $\alpha \approx 0$ )

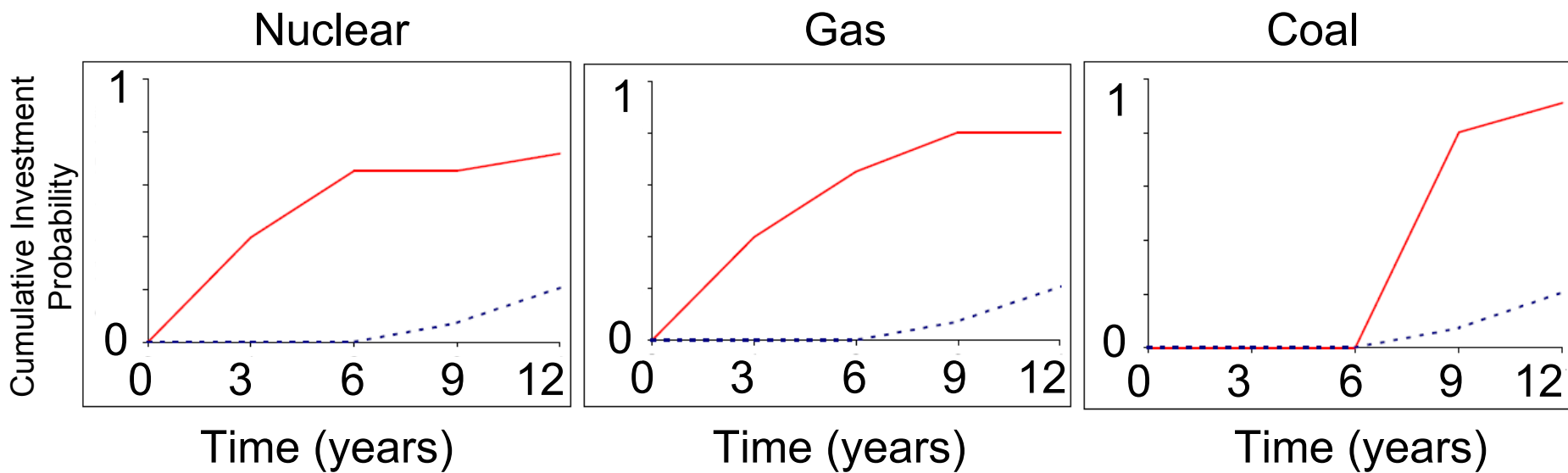
*with*

- Electricity price (stylized stack model depending on carbon price)
- Risk measure (conditional cash flow at risk)
- Cash flow constraints (revenue, tax, depreciation, and debt)
- Decision consistency constraints (irreversible investment decision)

# Benchmarking of Model

	<b>Nuclear</b>		<b>Coal</b>		<b>Gas</b>	
	NPV	ROCE	NPV	ROCE	NPV	ROCE
<b>Conventional</b> Investment in power plant at $t = 0$ and CCS at $t = 12$	-304	-20%	-168	-24%	-66	-19%
<b>Real options</b> Possibility to invest in power plant $t \in \{0..12\}$ and CCS $t = 12$	91	38%	123	73%	120	102%
<b>Real options and financial details</b> As above plus optimization with tax, depreciation, and debt repayments	349	54%	249	91%	197	131%

# Results: Base Case without Pre-Existing Portfolio

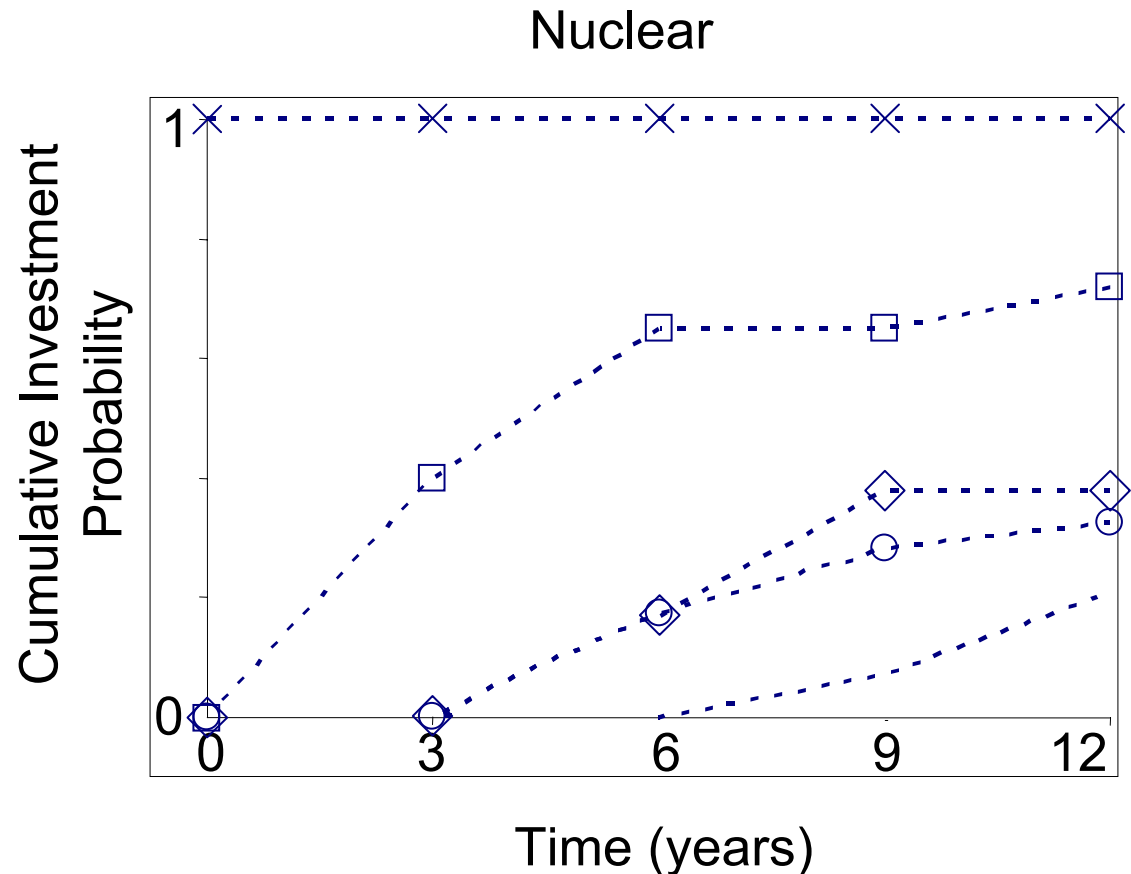
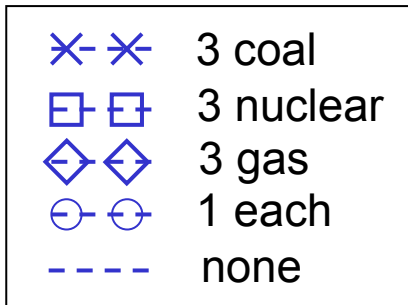


— risk neutral investor  
- - - risk averse investor

# Results: Pre-Existing Portfolio

H7: Existing portfolio encourages risk averse investor to invest **Confirmed**

Pre-Existing Portfolio



# General Conclusions

- Firm-level impacts:
  - Financial details, real options, and uncertainties make a significant difference in valuation
  - Existing asset portfolios result in path dependent investments
- Broader economic impacts:
  - Impacts of carbon policies and market instruments depend on company size, funding conditions etc.
  - Policy uncertainty leads to more concentrated and less competitive markets

# Modelling Contributions

- Innovative scenario tree generation to model CO<sub>2</sub> price uncertainty
- Extensive real options analysis including
  - Timing of power plant investment
  - CCS investment
  - Financial details (debt repayment optimization, tax, depreciation)
- Incorporating different company behaviors
  - Risk aversion
  - Financial strength
  - Pre-existing portfolio