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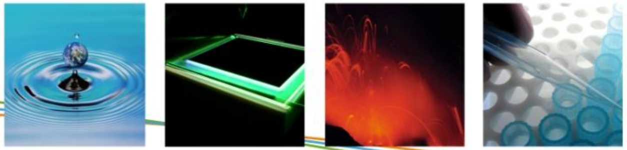

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Energy diversification through fuel price variation within TIMES

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tumatim

Motivation and goal

- Motivation
  - Some parameters like fuel prices will always be uncertain
  - Impossible to fully predict over time horizon

- Goal:
  - Single hedging strategy for the shorter term against risk aversion
  - Incorporating the uncertainty of future parameters by (almost) continuous distribution functions, taking into account covariances between the uncertainties

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Handling uncertainty

Near optimal

- Lower bound i.e. var.act
- Post-optimality analysis (SET BENCOST YES)
- Modeling to generate alternatives (MGA)
- Monte Carlo/Parametric programming

Hedging outside TIMES

- Make scenarios
- Monte Carlo/Parametric programming

Hedging within TIMES

- Robust Programming
- Stochastic Programming
- **Include the cost of variation in the objective**

New

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Conditions for good investment analysis

1. Irreversibility: OK
2. Uncertainty threats: Risk Averse
3. Uncertainty opportunities/ Adaptiveness/Flexibility:
    - Not OK when perfect foresight
        - “The traditional discounted cash flow approach assumes a single decision pathway with fixed outcomes without the ability to change over time.”
    - OK, when using stochastic to get better information
        - “By having the ability to make midcourse corrections when these uncertainties become known, decision-makers have essentially hedged themselves against any downside risks.”

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Diversification :

Not the single cheapest technology on average when

- **Risk aversion** (being risk neutral, you do not have diversification even with uncertain parameters in a model with a single decision path,~ NPV calculations)
- **Adaptiveness** (even when being risk neutral)
  - Example:
    - Alternative fuel @ 4 €/GJ
    - Gas fuel @ 5 €/GJ +- 3€/GJ
- **Variable demand**
  - Fixed versus variable costs
  - No cheap storage

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Some history...

Risk averse: Fearing uncertainty

- 1950: **Portfolio theory** Markovitz
- 1960: Sharpe, Miller

- Nobel Prize 1990

- 1970: **Option pricing models** Fischer Black, Myron Scholes, Robert Merton

- Nobel Prize 1997

Adaptiveness = Profiting from uncertainty

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An overview

1995: Columbia Business school

	Risk neutral	Risk averse
Non-adaptive	Classical approach	DEVUP, λ DEVUP, Minimax
Adaptive	Stochastic programming (Option theory, real option theory)	(*) A combination ? Capetown 2012

(*) Risk aversity for SOW today possible with Minimax Stochastic, Risk averse stochastic

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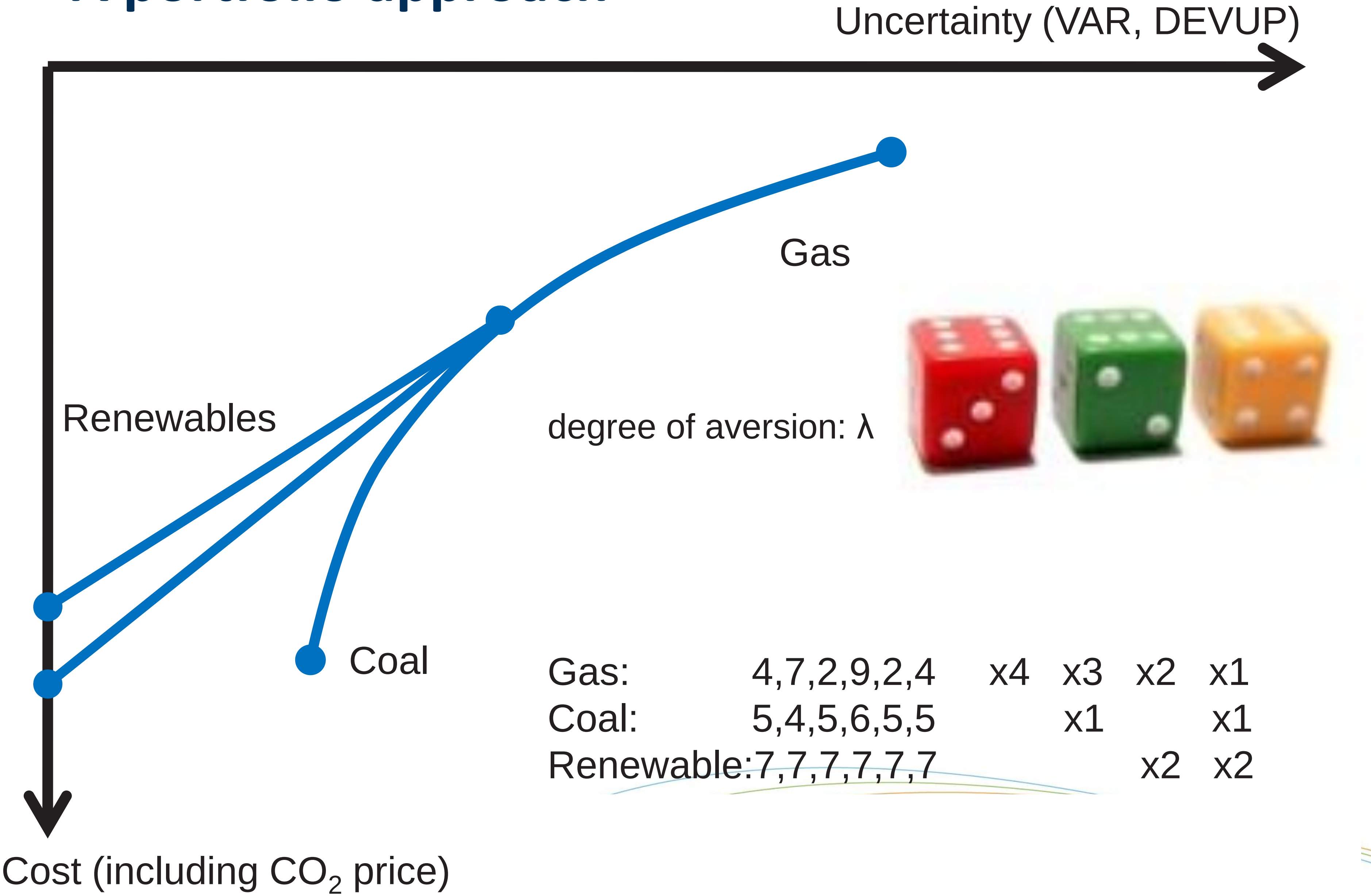
A portfolio approach



degree of aversion: λ

Gas:	4,7,2,9,2,4	x4	x3	x2	x1
Coal:	5,4,5,6,5,5		x1		x1
Renewable:	7,7,7,7,7,7			x2	x2

Upward deviation

Var (cost)	☹
UpAbsDev	☹
DownAbsDev	😎

- Mean variance

  Where λ = the risk aversion factor

  var(cost) = actual price variation

$$\min\{E(cost) + \lambda\, var(cost)\}$$

- Adapted to the linear model (smaller model to validate lambda)

$$\min\{E(cost) + \lambda \text{ UpAbsDev } (Cost)\}$$

Where $UpAbsDev\,(cost) = \sum_j p_j \{cost_j - E(cost)\}^+$

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Fuel price variation

- Fuel price scenarios constructed using expected growth rates and covariance matrix

	Oil	*Coal*	*Gas*
Oil	0.047666		
Coal	0.015483	0.046052	
Gas	0.022898	0.018412	0.046349

- 150 price scenarios generated for the period 2010-2050 through Monte Carlo simulations

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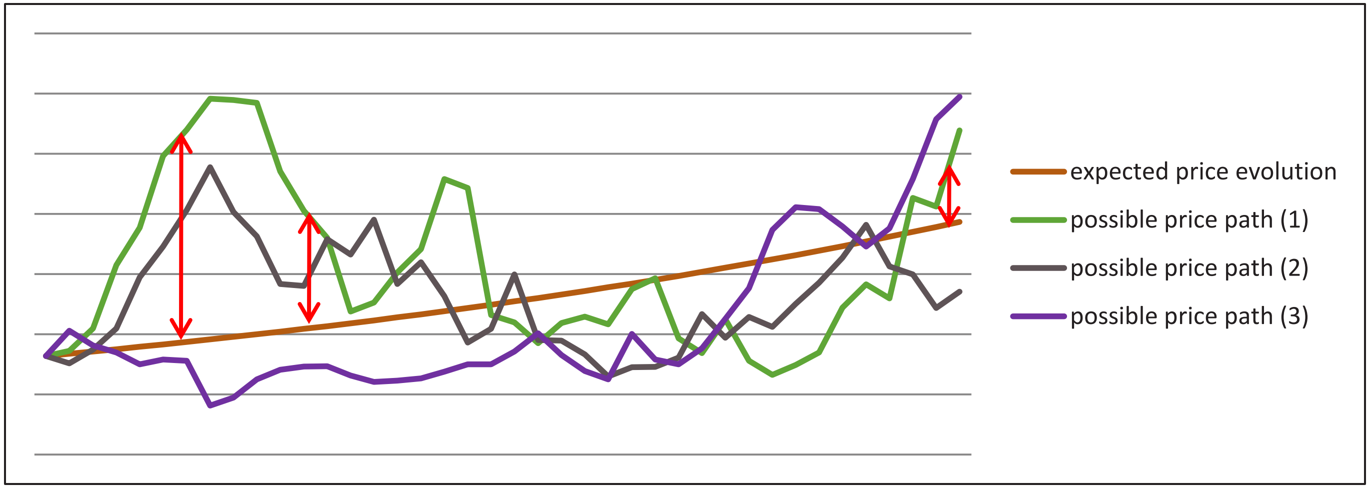
Fuel price variation

- Example of price volatility:



- In TIMES, DEVUP is taken for each price path and for the total of fossil fuels.

Implementation within TIMES: Why you don't need 150 objective functions

$OBJ = 1500\ I_W + 500\ I_G + 1300\ I_C + 900\ I_O + 5\ F_G + 7\ F_C + 8\ F_O$ Average OBJ

$OBJ^2 = 1500\ I_W + 500\ I_G + 1300\ I_C + 900\ I_O + 3\ F_G + 8\ F_C + 23\ F_O$

$OBJ^3 = 1500\ I_W + 500\ I_G + 1300\ I_C + 900\ I_O + 14\ F_G + 6\ F_C + 12\ F_O$

$OBJ^4 = 1500\ I_W + 500\ I_G + 1300\ I_C + 900\ I_O + 7\ F_G + 9\ F_C + 6\ F_O$

…

OBJ^{150}

Subtract for each price path

$$OBJ^{DEVUP} = 1500\ I_W + 500\ I_G + 1300\ I_C + 900\ I_O + 5\ F_G + 7\ F_C + 8\ F_O$$

$$+ \lambda/4.\ [\ \{-2F_G + 1F_C + 15F_O\}^+ + \{9F_G - 1F_C + 4F_O\}^+ + \{\ 2F_G + 2F_C - 2F_O\}^+]$$

DEVUP is dependent on fuel choices and is not known in advance.

It is more than just adding an extra cost to each fuel !

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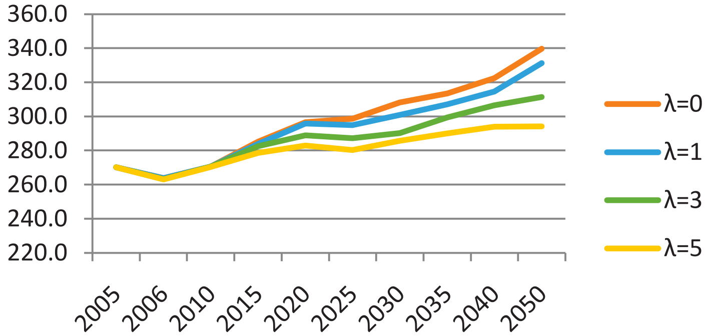
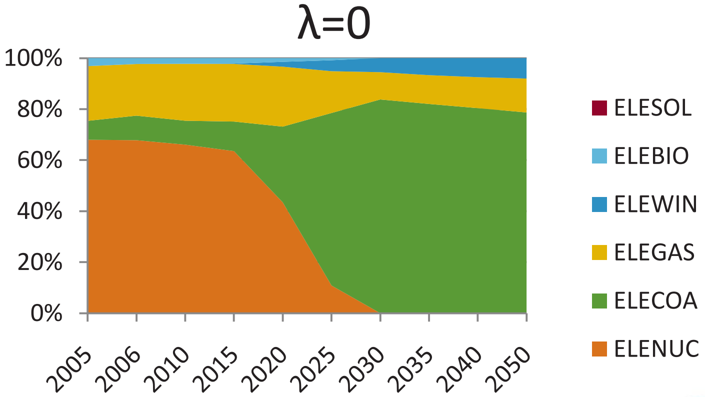
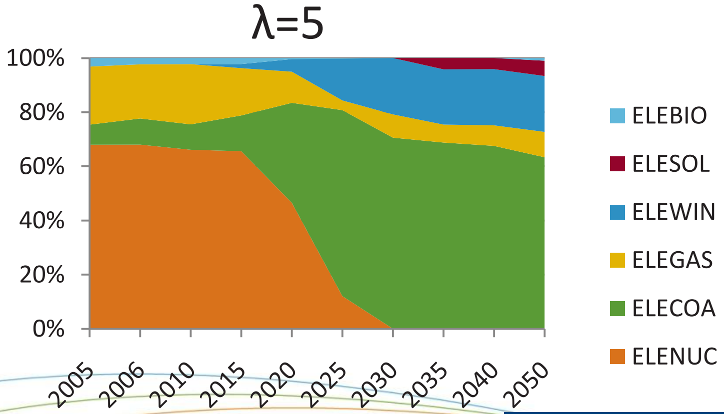
Fuel price variation: Results

- Total electricity production decreases



- Share of renewables increases





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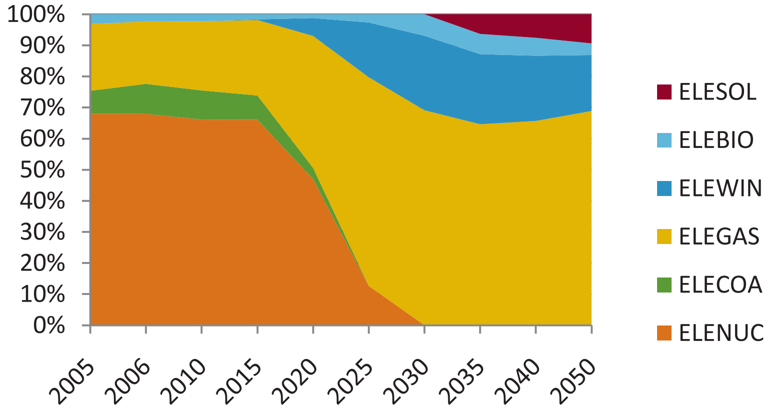
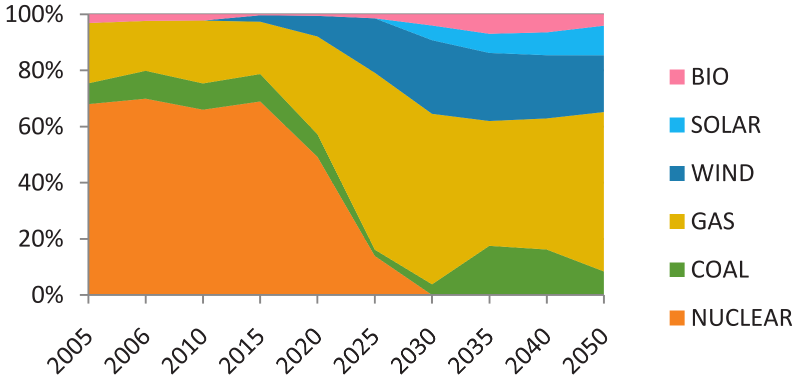
Fuel price variation: Results

- Comparison in a scenario with CO2 constraint

λ=0



λ=3



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Results with fuel price variation

- Price variation of fossil fuels leads to
  - The introduction of renewables in the electricity mix
  - Less electricity / energy demand
  - Diversification for high values of λ (under the assumption of limited technologies without variability)

- The effect when CO_2 constraint is binding
  - The effect of uncertainty is significantly reduced alternative options are reduced: all renewables already exhausted
  - More demand reduction
  - Shift towards coal as diversification policy

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Conclusions and future work

1. The test case leads to diversification and other changes for a more robust energy system.
2. Advantages of the approach: it is within TIMES, covariances are included and it is fast.

1. Include CO_2 price uncertainty (possibly with shocks)
2. Include Minimax strategy (implementation is only slightly different)
3. Put risk aversion at a lower level, at least sectoral level:
   - The smaller the covered system, the larger the variability
   - But could be neutralised by hedging with options
4. Further develop to combine real options approach with portfolio approach within TIMES.

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