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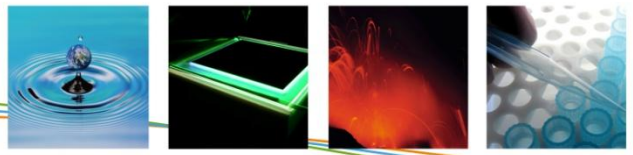

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Investment decisions under fixed and flexible operational conditions, a first comparison.

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With the aid of Denise Van Regemorter, Wim Benoot, Pernille Seljom and Antti Lethila

Motivation and goal

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

- Goal:
  - Single hedging strategy for risk aversion
  - Incorporating the uncertainty of future parameters by (almost) continuous distribution functions, taking into account covariances between the uncertainties
  - Better solutions than using a deterministic model

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**
- **Stochastic SPINES**

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."

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)
- **Recourse actions / 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

An overview

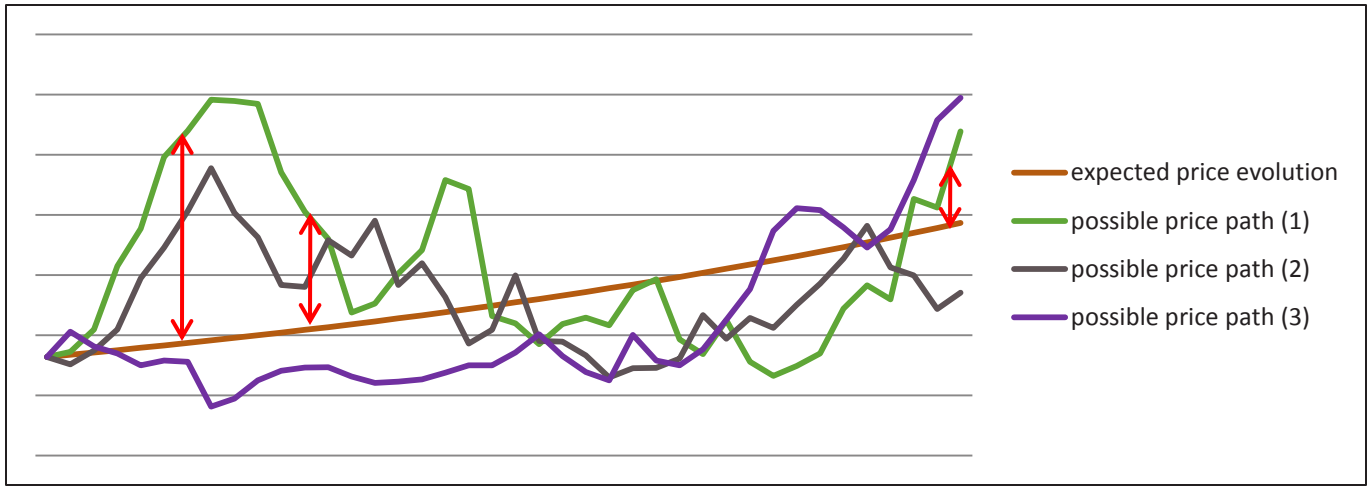
	Risk neutral	Risk averse
Single stage	Classical approach	DEVUP, λ DEVUP, Minimax
Recourse only for non-capacity var.	Stochastic SPINES	λ Minimax
Full recourse	Stochastic	λ Minimax

Two approaches

- Single-stage or “portfolio approach”
  - Together with Denise Van Regemorter, Wim Benoot and Joris Morbee
  - Within TIMES by using Excel files, but not in the code
  - Enables the modeler to put an extra cost on upward variation of the total fuel costs (not just the separate ones).
  - The main advantage is that covariances are taken into account and that a high number of future price paths can be included.
- “Operational recourse”
  - Already in the TIMES code: SPINES as a variant of STOCHASTIC
  - An explanation of the implementation is written in the User Control Switches

Fuel price variation

» Example of price volatility:



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

$$\sum_{time} (P_{gas} - E[P_{gas}])Q_{gas} + (P_{coal} - E[P_{coal}])Q_{coal} + (P_{oil} - E[P_{oil}])Q_{oil} > 0$$

Results with Portfolio approach and 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
  - More demand reduction
  - Shift towards coal as diversification policy
  - The effect of uncertainty is significantly reduced alternative options are reduced: all renewables already exhausted
  - !!! Reference is different

First results when using SPINES

- It is able to give an expected cost (and not only a cost)
- It gives an energy system that, when using the criterium of expected cost is robust for the different fuel paths (or other uncertainties).
- SPINES size of the model is lower than the classical stochastic approach, cfr some variables non SOW specific
- It migth not be necessary to have a very dense decision tree

Sow	OBJ	Difference with DET
	2113025	-10682
1	2074017	-49689
2	2122978	-728
3	2142078	18372
	2120895	-2811
1	2084798	-38908
2	2125643	1937
3	2152244	28538

Conclusions and future work

1. Portfolio approach is fully working and can be further improved for different risk levels (total energy system, sectoral or even lower)
2. The test case shows a different (more robust) energy system is chosen.
3. Further analysis is need to better see differences (if any) between real options approach and a stochastic approach.
4. Working out examples in the electricity sector that show that for large shares of intermittent sources (for example wind and solar), there is a main advantage in running a model by using a set of possible weather futures, rather than using an annual or seasonal AF.
5. Compare model results of deterministic/portfolio/operational recourse/full recourse models by including the ability to change operation or both operation and investment over time.