Uncertainty and IAMs: ongoing work at FEEM&CMCC

Massimo Tavoni
CMCC and FEEM

IAMC 5° annual meeting
Utrecth, Nov. 13° 2012

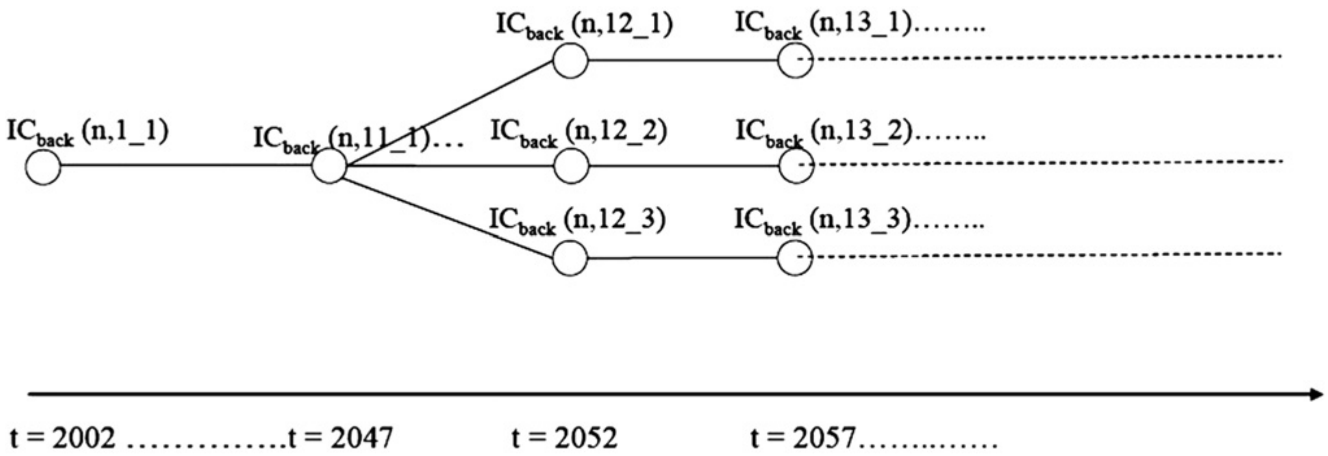
FONDAZIONE ENI ENRICO MATTEI

cmcc Centro Euro-Mediterraneo sui Cambiamenti Climatici

Uncertainty and IAMs: needs and challenges

Reasons for including uncertainty in IAMs	Challenges of including uncertainty into IAMs
Uncertainty is pervasive (climate, socio-economics, technology etc.)	For some drivers it is difficult to quantify (or has not been quantified)
Large multi model ensambles with a lot of scenarios	Scenarios cannot be interpreted statistically to provide uncertainty ranges
Better algorithms and faster computing (parallel)	Curse of dimensionality
Policy makers demand for robust strategies	Difficulty of communicating uncertain outcomes

Stochastic programming in the WITCH IAM

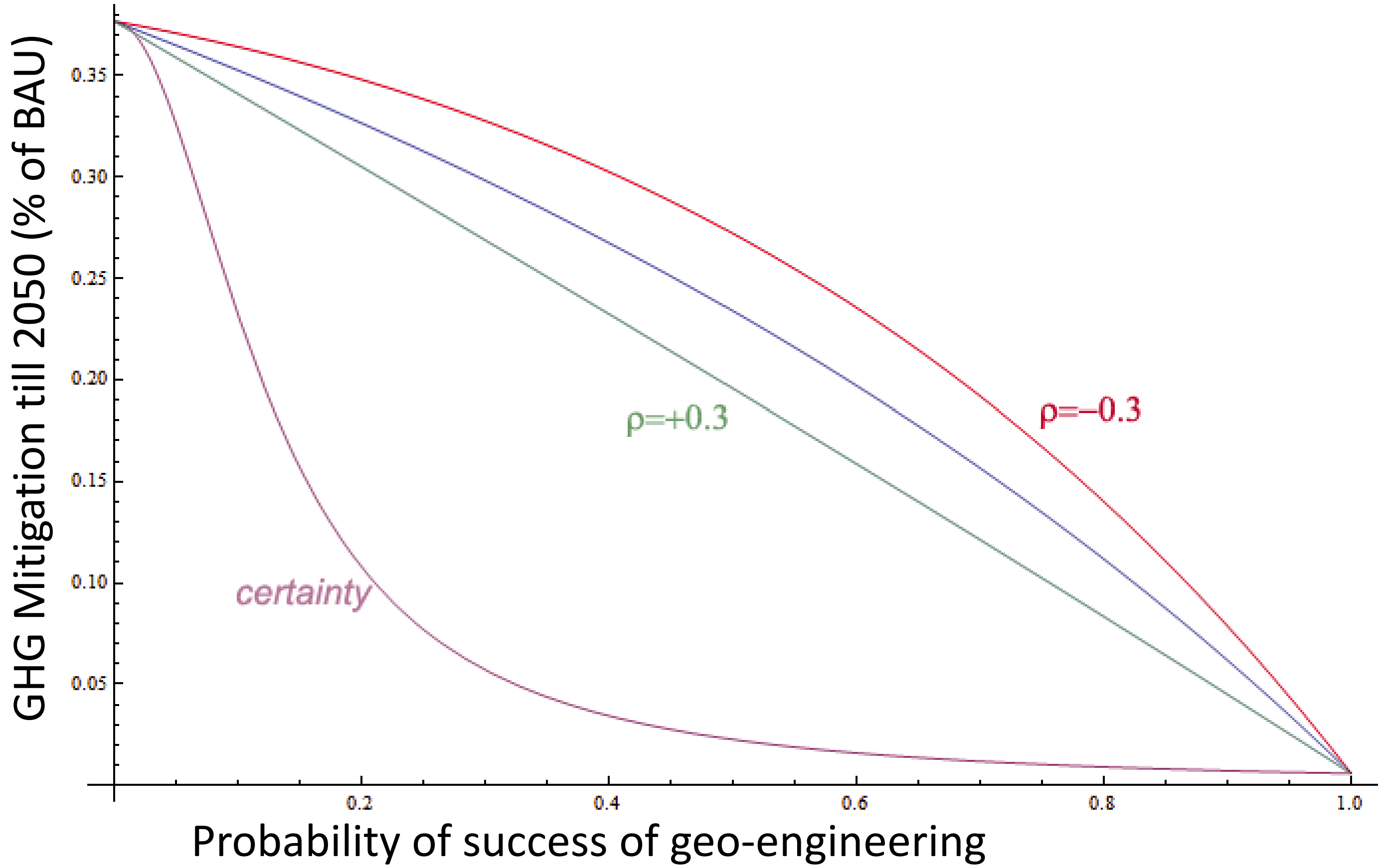


Model redefined on nodes of the scenario tree. Non anticipativity is implicitly defined through characterization of predecessor/successor relationships among nodes.

Parallel computing	Cooperative solution (joint optimization)	Competitive solution (single region optimization and iterations)
Deterministic	9 hrs	5 mins
Stochastic (2 SOW)	30 hrs	20 mins

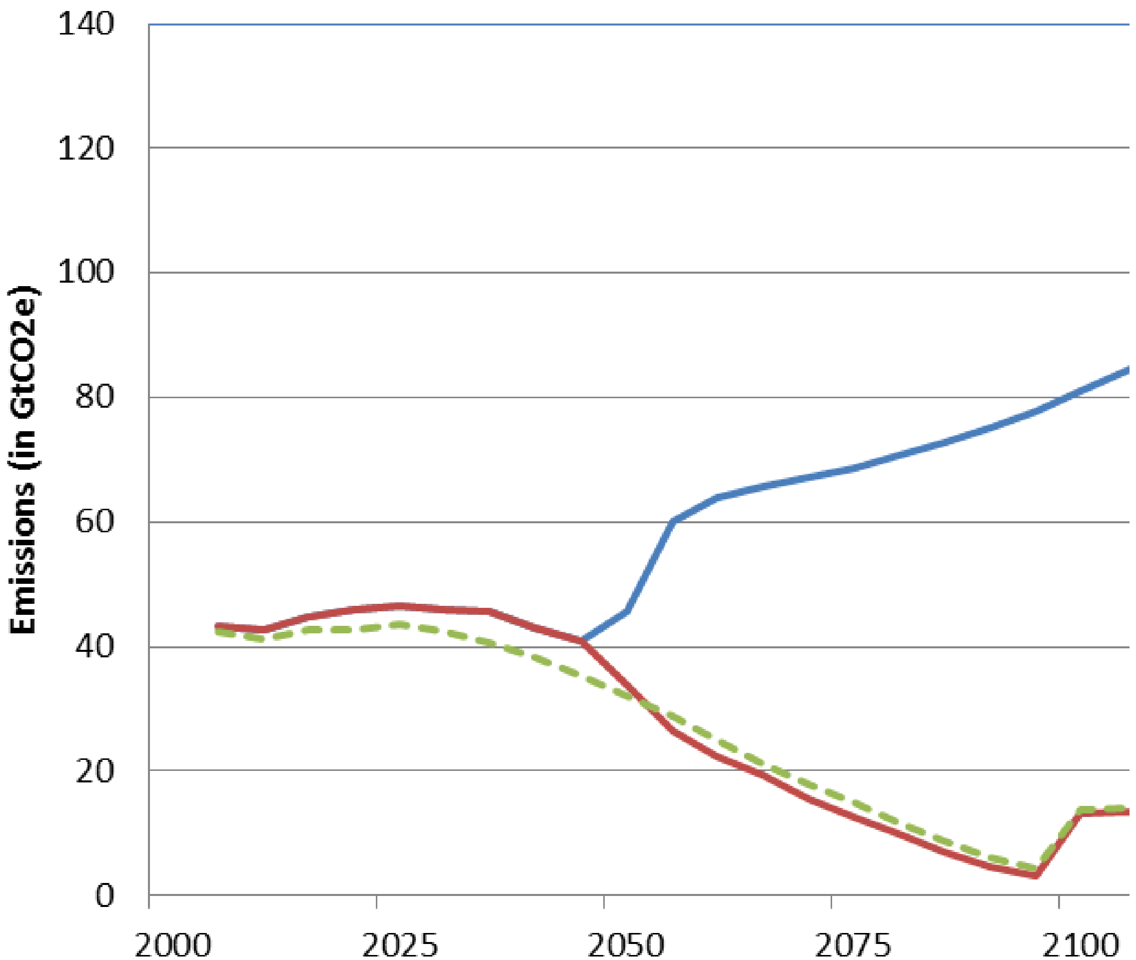
SP application: SRM (solar radiation management)

SRM is economical but potentially disruptive: assume it is viable on a large scale from 2050 onward with a given probability. Would this hamper mitigation?



Emmerling and Tavoni, 2012

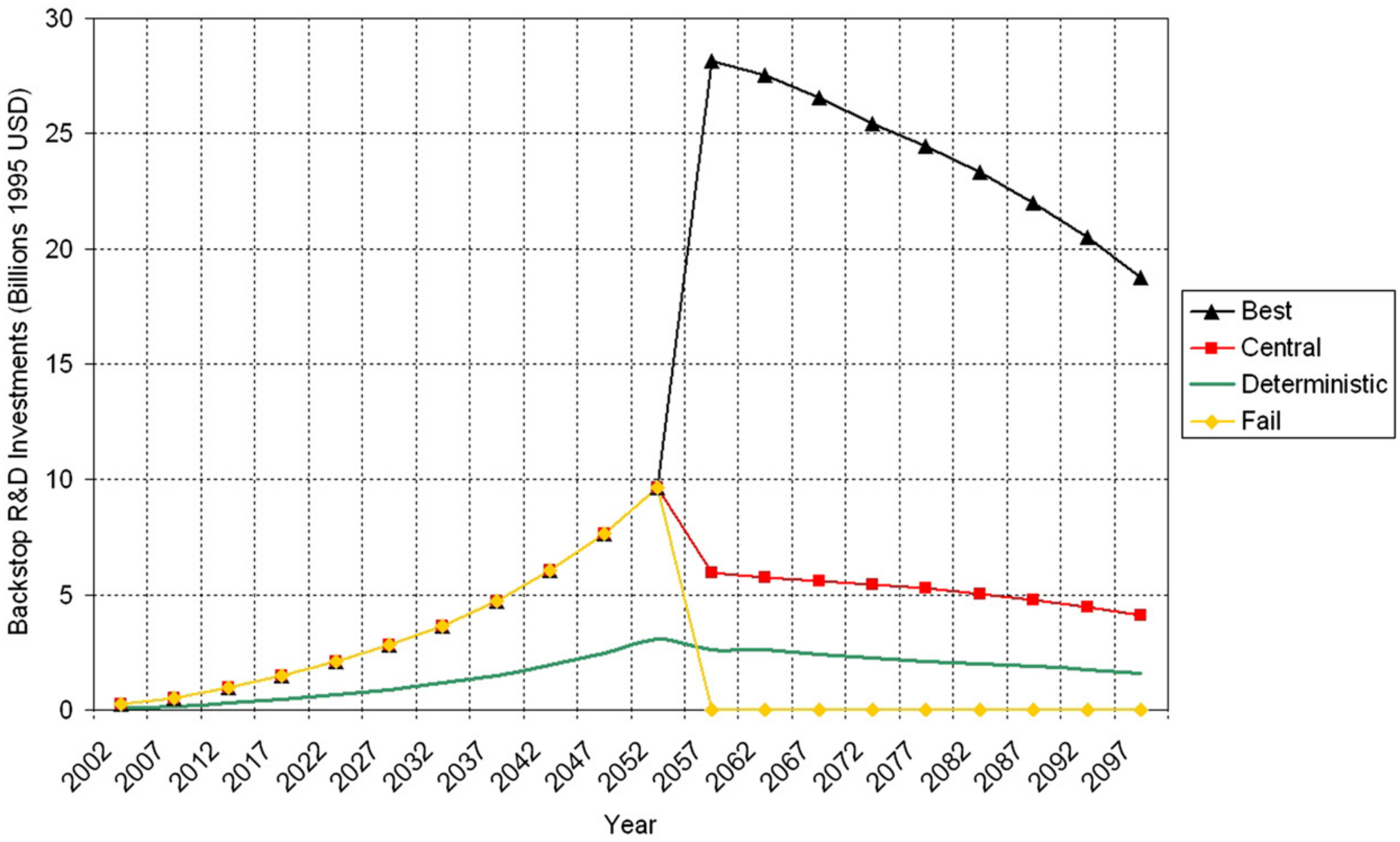
SP application: SRM (solar radiation management)



Emmerling and Tavoni, 2012

SP application: breakthrough R&D in low carbon technology

Uncertainty on the effectiveness of an R&D programme to develop a carbon free ‘breakthrough’ technology:

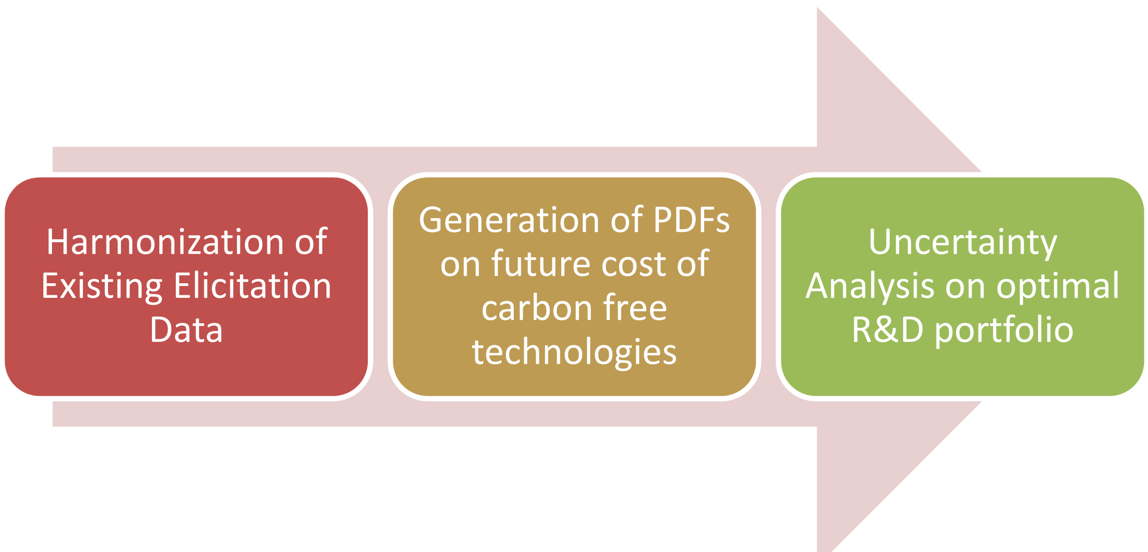


Bosetti and Tavoni, 2009

TEaM project

The purpose of this project is to develop a framework for:

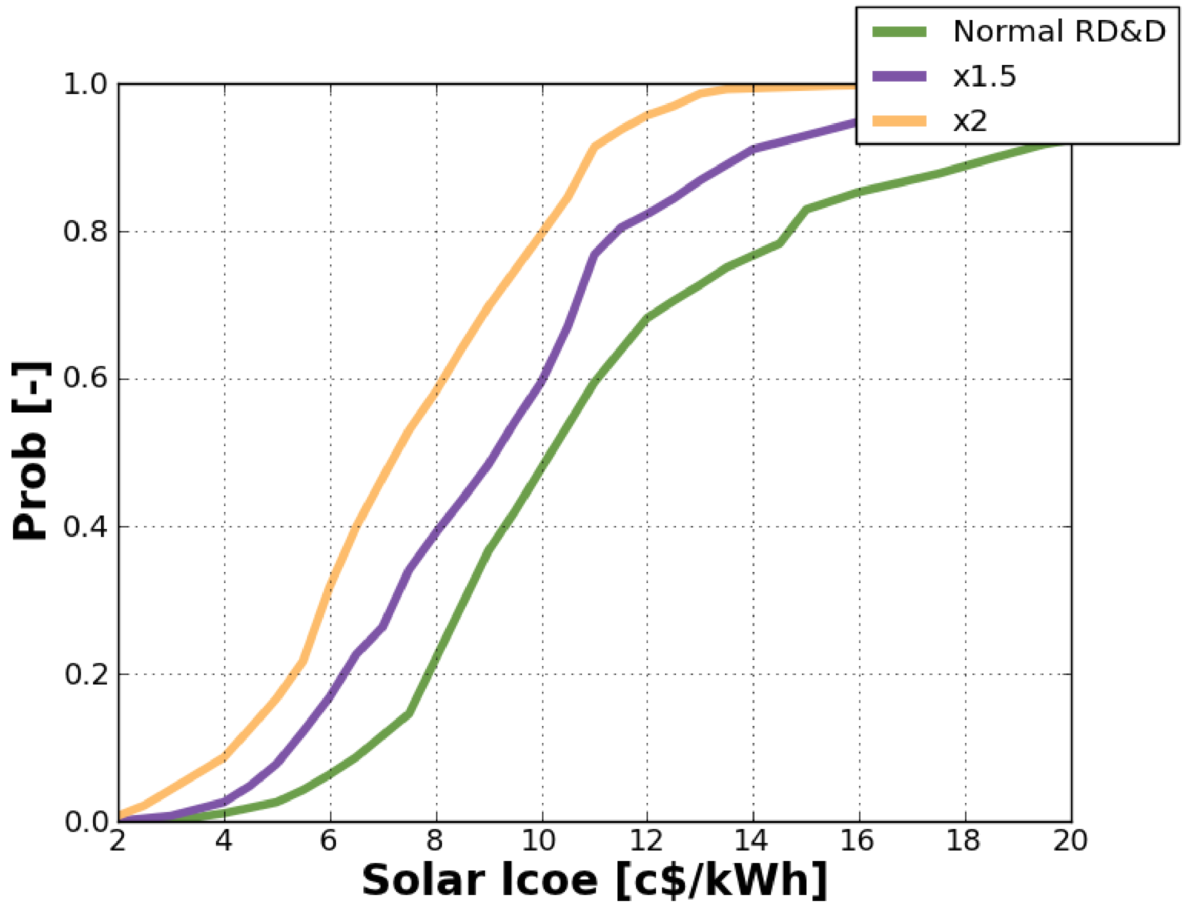
1. Integrating the large and growing data sources on technology supply derived from expert elicitations
2. Communicating the integrated data in a way that is useful to policymakers and IAM modelers.
3. Study the effect of uncertain technical change in IA models



Expert judgment of technology prospects: DB

Technology:	CCS	Solar	Nuclear	Biofuel s	Electricity from biomass	Battery/ Elec vehicles	Utility scale storage	Wind, geother mal, hydrogn	Building energy eff	IGCC
UMass	**X**	**X**	**X**	**X**	**X**	**X**				
Harvard	**X**	**X**	**X**	**X**	**X**	**X**	**X**		**X**	
FEEM/CMCC	**X**	**X**	**X**	**X**	**X**					
DOE EERE	X	X		X	X	X		X	X	
CMU	X	X	X							
NAS	X									X
Chung et al	X									

CDF on future (2030) costs of technology for different levels of R&D



ICARUS survey, Bosetti et. al 2012

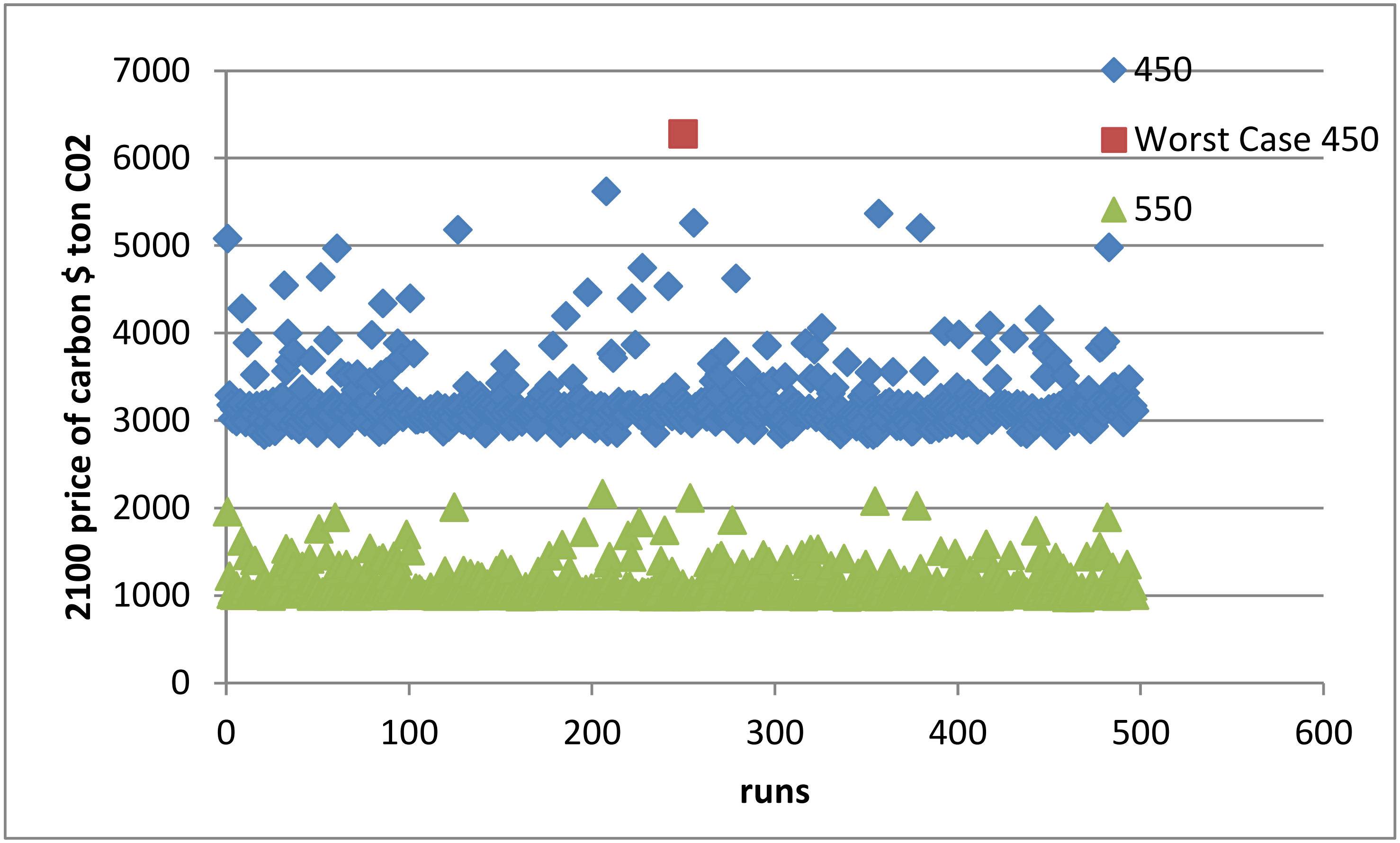
TEaM Pilot project

Research Question: What is the optimal/robust energy R&D portfolio?

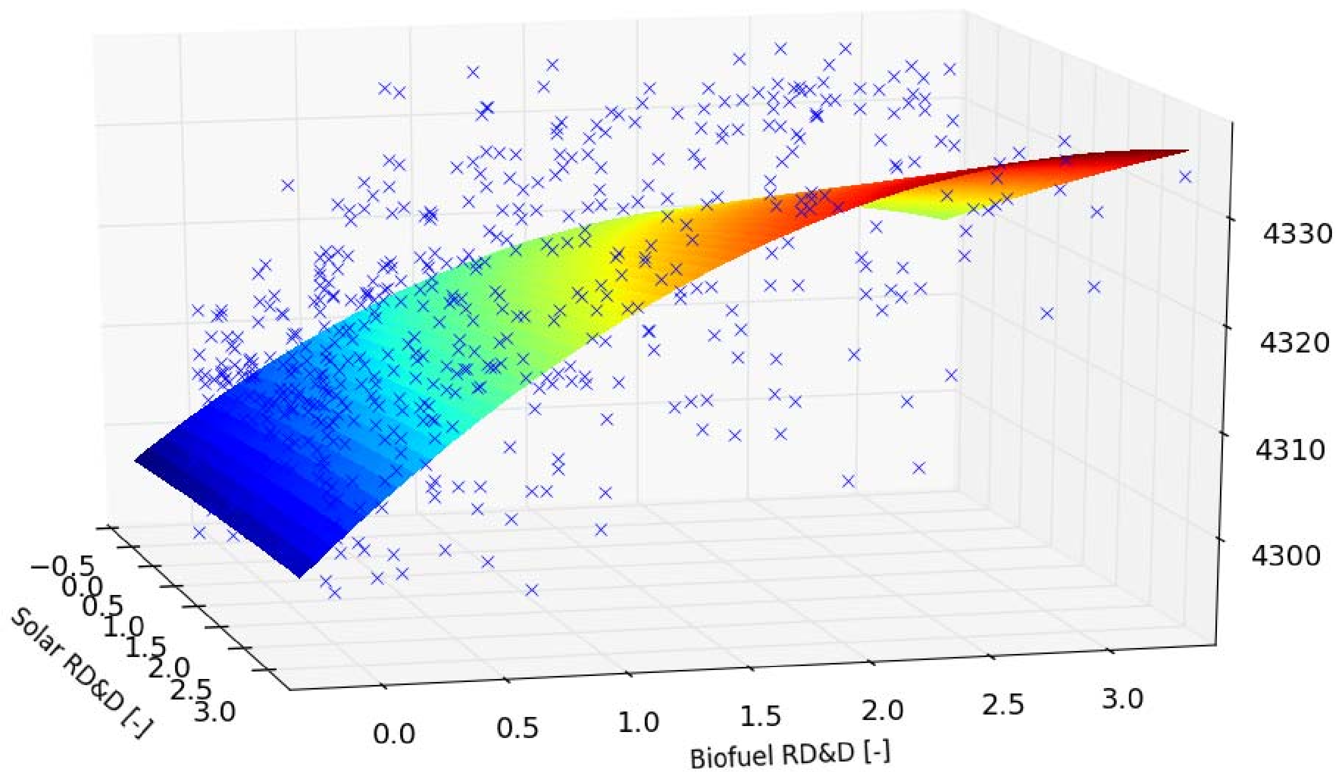
- **Data**: Elicitation from FEEM/CMCC, Harvard, Umass on Solar PV, Nuclear, CCS, Liquid fuels from biomass, Electricity from biomass
- **Modelling tools**: GCAM, Markal US, WITCH
- **Type of Analysis**: MonteCarlo analysis with post-processing to generate pdfs
- **Scenarios**: unconstrained , 450, 550ppm climate policies

- **Assess IAMs payoffs for different technology costs (and associated R&D expenditures) and devise optimal R&D allocation**

Example of WITCH sampling outcome



Approximate Dynamic Programming in WITCH



Alternative: use Hermite interpolation (Cao and Judd, 2012) to fit value function and then run a SP programme

Preferences

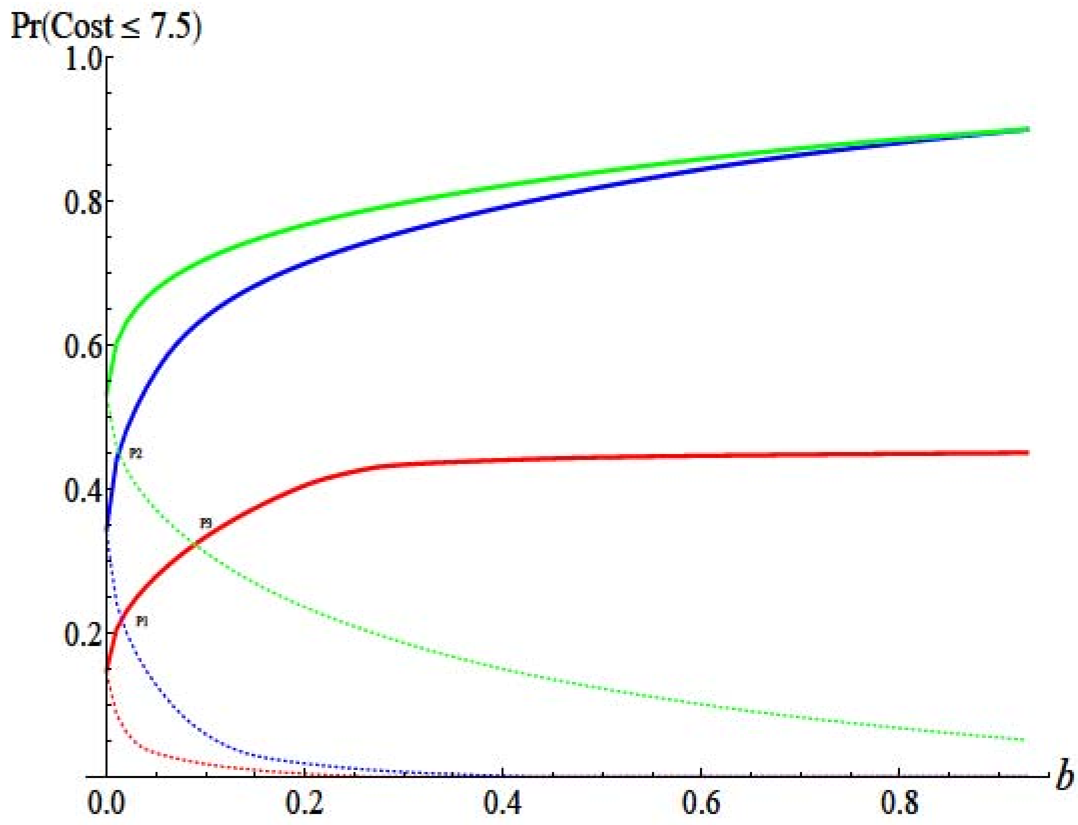
$$Social\ Welfare = \sum_{t=0}^{\infty} \beta^t \frac{C_t^{1-\alpha}}{1-\alpha}$$

Restricts the coefficient of relative risk aversion (“CRRA Coefficient”) to equal the inverse of the elasticity of intertemporal substitution (“EIS”). More aversion to climate risks, implies a higher discount rate and greater disinterest in the future.

$$U_t = \frac{1}{1-f}\left((1-\beta)C_t^{1-s} + \beta((1-f)E_t U_{t+1})^{\frac{1-s}{1-f}}\right)^{\frac{1-f}{1-s}}$$

Generalize utility function to separate time preference and risk aversion (Epstein and Zinn, 1989). Recently introduced into IAMs (Kaufmann, 2012, Ackerman, 2012). Introduced in the stochastic WITCH with limited additional computational burden.

Ambiguity over experts opinion



Athanassoglu, Bosetti and de Maere 2012

Way forward

Research to further integrate uncertainty into IAMs:

- Advanced stochastic programming techniques (e.g. ADP)
- Global sensitivity analysis
- Alternative decision models to expected utility (ambiguity aversion, minmax regret, etc)
- Simplified models which can summarize large model ensamble runs and build meta-models upon them

Activities and projects:

- ADVANCE project: 2013-2017, PIK (Coordinator), FEEM, IIASA, PBL, JRC, ..
  - Work-package on technical change and uncertainty: FEEM/CMCC to develop uncertainty module applicable to IAMs