Inventory and Impact Assessment Uncertainty in Coal-Based Power Generation

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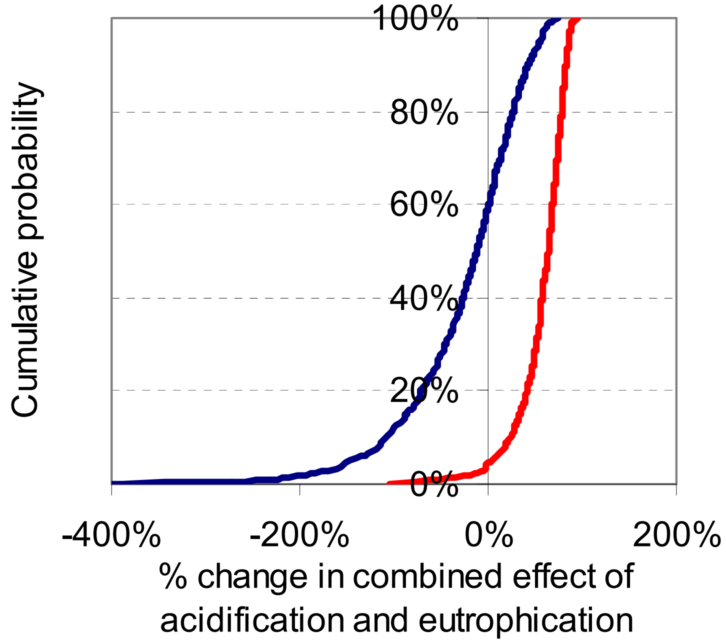
Overview

- Key features of uncertainty analysis framework
  - Emphasis on different sources of uncertainty and their respective methods for reducing and assessing uncertainties.
  - Iterative procedure, starting from a coarse level of analysis and refining as appropriate.
  - Uncertainty incorporated at lowest possible level of modelling.
- Enhanced interpretation of LCA results demonstrated with reference to a case study
  - An investigation into the combustion of discard coal as an option for reconditioning old power stations.
- Specific focus on presentation and analysis of uncertain results
  - Use of principal component analysis (PCA) to present and analyse large data sets.
  - Use of an uncertainty "audit trail" to identify key parameters, determine meaningful selection criteria, and guide further analysis.

Graphical Analysis of Uncertainty: Cumulative Probability Plots

- Displays the probability that a quantity lies in specific intervals
  - e.g. within specific fractiles or confidence intervals.

- Plot of normalised difference between two options enhances interpretation
  - Y-intercept shows at what probability one option is always preferred to the other.
  - Normalisation required to eliminate correlations between the two options (provided the two options have been generated from identical uncertainty samples).
  - Limited to pair-wise comparison.



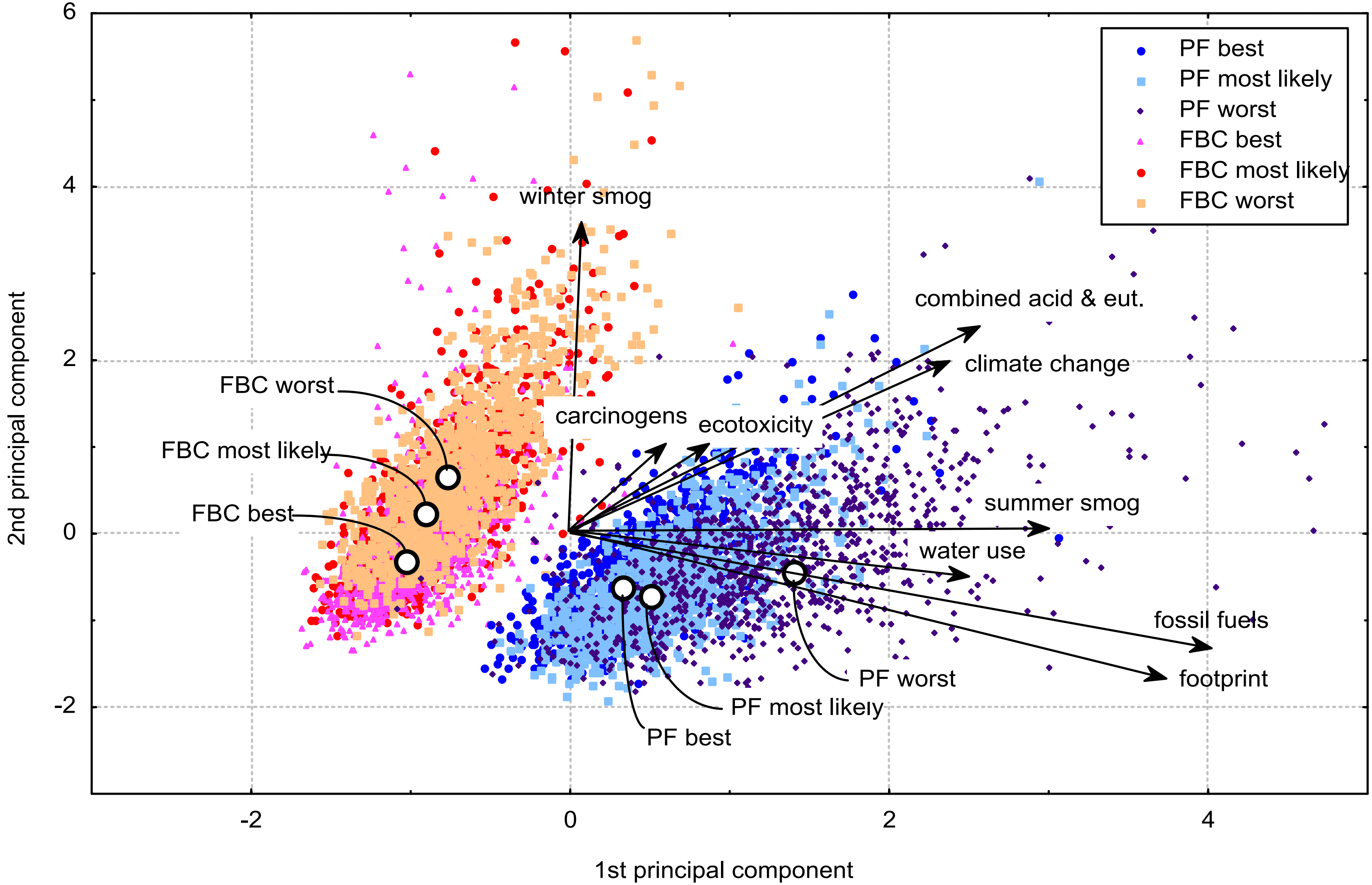
Graphical Analysis of Uncertainty: Principal Component Analysis

- Provides a solution for viewing large multi-dimensional data sets
  - Reduces the dimensionality of the data set by providing a planar view of the data.
  - Able to provide an overview of the results not possible with probability density plots.
  - Particularly powerful tool for scenario analysis.

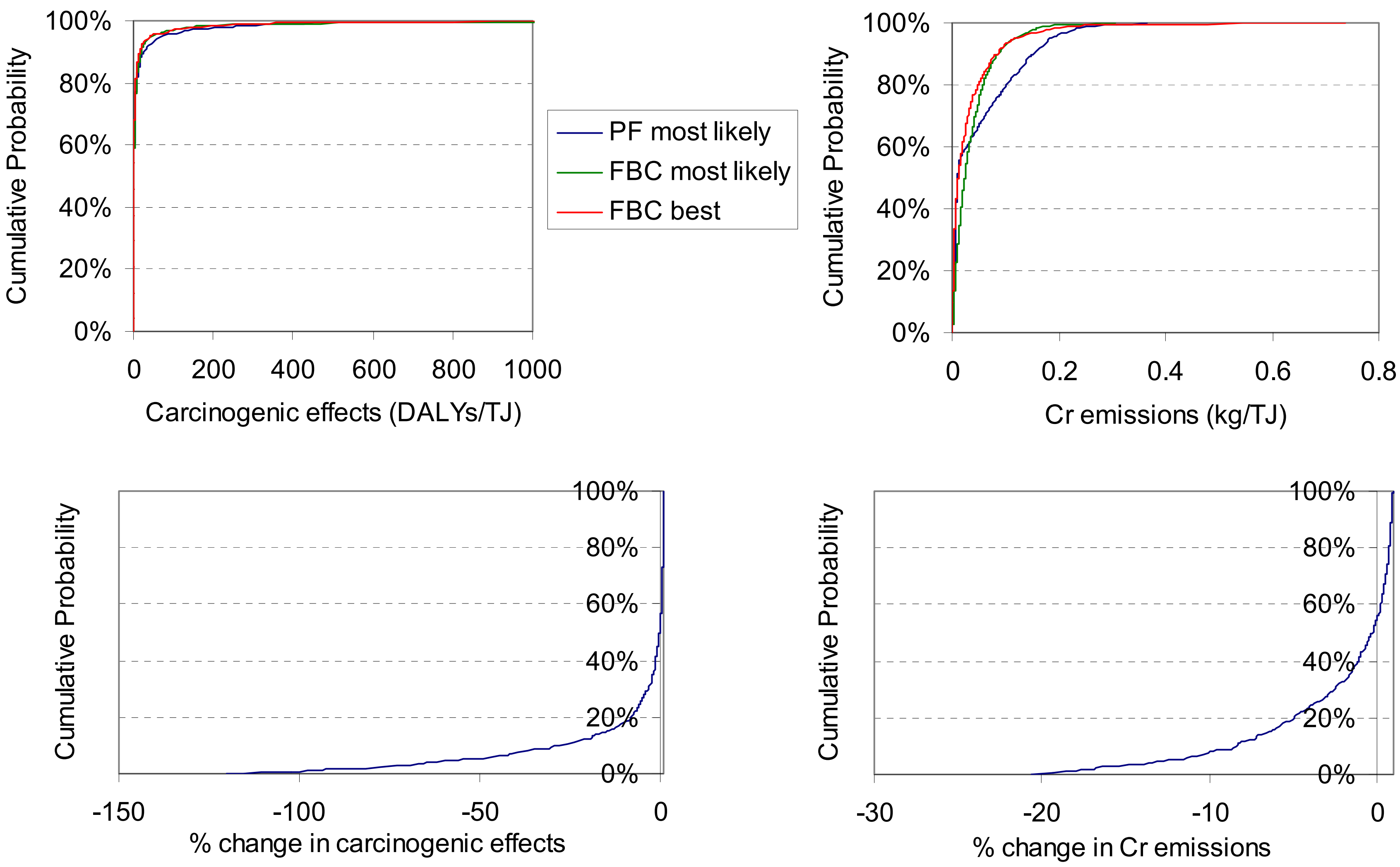
- Provides significant insights into the structure of the data set
  - Identifies highly correlated (and therefore redundant) selection criteria.
  - Identifies the most influential variables

- Visual tool for guiding iterative refinement
  - Uncertainty samples plot as confidence zones ("clouds" of points).

“Best”, “Most likely” and “Worst” scenarios for re-commissioning an old 400 MW_e power station using either reconditioned pulverised fuel boiler units or fluidised bed boilers burning discard coal (a coal beneficiation waste stream).



An analysis based on carcinogenic effects versus an analysis based on chrome emissions



Uncertainty Importance Analysis

Top Contributing Parameters to Carcinogenic Effects (FBC system)

Input parameter	Correlation coefficient	Input CV
Cr equivalency factor	0.80	5
Partitioning of Cr in boiler fly ash	0.31	0.2
Ni equivalency factor	0.19	5
Discard coal quality	0.18	0.1
Fuel used in coal mining	0.14	0.5
Partitioning of Hg in fly ash	0.13	0.2
As from sulphuric acid production	0.13	1.4

- ⇒ Cannot state with greater than 56% confidence that the FBC system will have a lower contribution to carcinogenic effects than the PF system (output CVs of 1.7).
- ⇒ Cannot state with greater than 65% confidence that the FBC system will have lower Cr emissions than the PF system (output CVs of 0.5).

Uncertainty of Inventory-level vs Impact-level Information

Environmental Interventions	Foreground CV	Background CV
Cr	0.96	0.81
Ni	1.10	0.91
NMVOCs	0.55	0.99
CH_4	0.83	0.94
SO_2	0.41	1.20
NO_x	0.80	0.94
TSP	0.71	1.10
CO_2	0.16	1.00
Pb	0.86	0.86
Land transformation	0.41	0.88
Hard coal reserves	0.56	0.95
Oil reserves		0.80
Water use	0.15	0.70
Waterborne sulphates	0.70	0.98

uncertain equivalency factors

Impact Categories	CV
Carcinogenic effects on humans (DALYs)	5.6
Respiratory effects on humans caused by organic substances (summer smog) (DALYs)	2.2
Respiratory effects on humans caused by inorganic substances (winter smog) (DALYs)	1.8
Climate change (DALYs)	0.46
Ecotoxic emissions ($PDFxm^2xyr$)	3.8
Combined effect of acidification and eutrophication ($PDFxm^2xyr$)	0.53
Land occupation ($PDFxm^2xyr$)	1.1
Extraction of fossil fuels (MJ surplus energy)[1]	0.56

Conclusions

- Generally a signficiant increase in uncertanty in move from inventory to impacts
  - High equivalency factor uncertainty counter-acts the averaging effect of aggregating environmental interventions.
  - Dilemma that as the relevance of the information increases so the ability to distinguish between the systems decreases.
  - In systems with already high inventory uncertainty extending the inventory data to a consideration of impacts may yield such high uncertainty that no significant differences between the systems will be discernible.
- Different representations of uncertain results provide different types of information
  - PCA provides a powerful “graphical summary” of the results, and provides guidance on the selection of meaningful criteria for comparison.
  - Cumulative probability plots coupled with a rank-order correlation analysis provides a mechanism to direct effort back into the inventory model to guide the refinements required to achieve a desired degree of confidence.