# Linking energy systems models to real systems: model calibration and emulation

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Complex mathematical models are widely used for decision support in planning of energy systems and determining public energy policy. Examples in decreasing order of scope and increasing order of engineering detail include: whole energy economy models such as MARKAL/TIMES; whole electricity sector models such as those developed across various projects by Imperial College; models for projecting generation investment and costs of low carbon support schemes as used by DECC in the electricity market reform process; and models used for assessing generation adequacy risk on a planning timescale which underpin electricity capacity mechanisms.

All these models have in common a high dimensional input space, with considerable uncertainty over both the appropriate values of inputs and over the relationship between the model structure and the real world. Careful analysis of uncertainty in the relationship between model outputs and the real world is thus necessary if decisions are to be taken in a systematic way using the model as a support tool.

For most such energy systems models, standard statistical techniques for sensitivity analysis and parameter calibration are not applicable, as the models are too computationally expensive for the necessary number of runs to be performed. Nevertheless such analysis must be carried out in order to link the model to the real world, and thus the limited number of evaluations which is possible becomes another uncertainty in the modelling process. In order to treat this systematically, it is possible to introduce a statistical emulator of the full computer model, which encodes the uncertainty in the output of the model at all points in the input/parameter space where it has not been evaluated.

This presentation will summarise the technical steps involved in carrying out uncertainty analysis and calibration of complex computer models, including the Gaussian process emulator structure which is typically used. Exemplars will include uncertainty analysis of results from the “Dynamic Dispatch Model” (DDM) used by DECC and National Grid as a decision support tool in the Electricity Market Reform process and subsequent operation of the Capacity Mechanism and incentives for low carbon technologies; calibration of a model for projecting investment in new generating capacity; and network infrastructure investment decision making under uncertainty.

This is joint work with Amy Wilson, and Michael Goldstein (Department of Mathematical Sciences, Durham University), and draws on the work of Meng Xu and Antony Lawson at Durham for exemplars. The authors acknowledge the support of EPSRC Grant EP/K03832X/1, and National Grid and DECC’s assistance through the use of DDM as an exemplar.

**Biography**

Dr. Chris Dent is Senior Lecturer in Energy Systems Modelling at Durham University. He holds an MA in Mathematics (Cambridge, 1997), PhD in Theoretical Physics (Loughborough, 2001) and MSc in Operational Research (Edinburgh, 2006). Since 2007 he has worked full time in energy systems analysis, with interests including reliability analysis, economic modelling, renewables and storage integration, and decision making under uncertainty. Since 2011 he has worked with National Grid on design of technical modelling for the GB Electricity Capacity Assessment Study. He was the 2012 recipient of the IET Mike Sargeant Young Engineer Career Achievement Award, and is a Senior Member of the IEEE and Associate Fellow of the OR Society.