

# Incorporating Behavioural Responses within a Technology Optimization Energy Model

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BIEE Conference, Oxford  
20-21 September 2006

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# Outline

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- Introduction to UK MARKAL
- Modelling energy efficiency and conservation
  - Incorporation of barriers
  - Incorporation of behaviour
- Indicative modelling results
- Uncertainties and comments

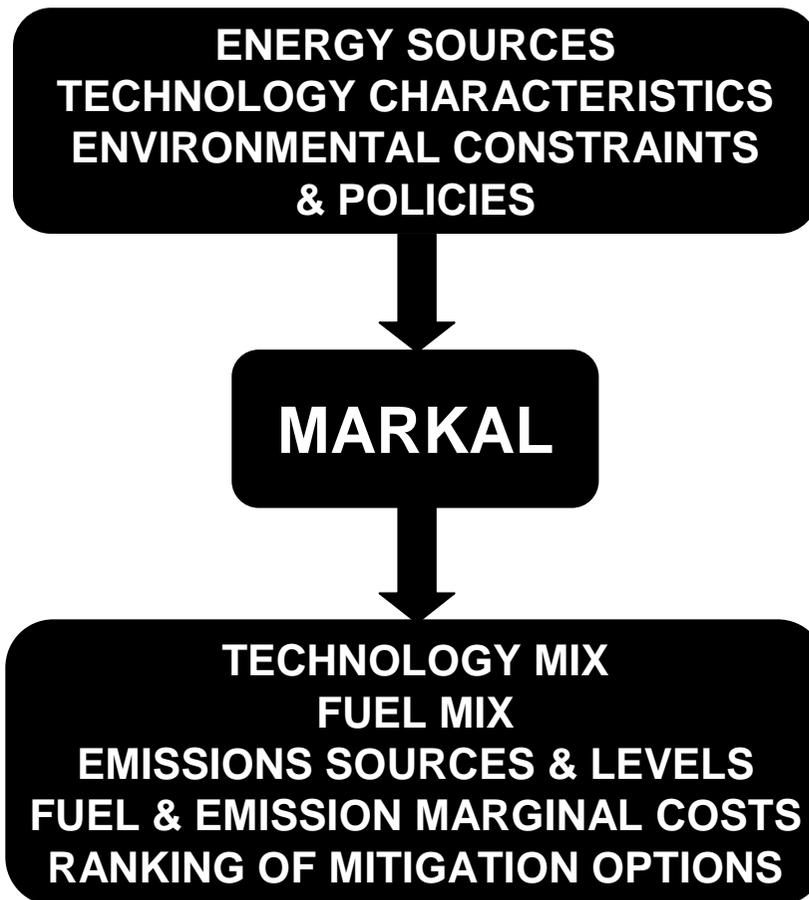
# Introduction: MARKAL

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- **MARKet ALlocation** dynamic optimization model
- A **least cost optimization** model based on life-cycle costs of competing technologies (to meet **energy demand services**)
- **Technology** rich bottom-up model (e.g. end-use technologies, energy conversion technologies, refineries, resource supplies, infrastructure, etc)
- An **integrated energy systems** model
  - Energy carriers, resources, processes, electricity/CHP, industry, services, residential, transport, agriculture
- Range of physical, economic and policy **constraints** to represent UK energy system

# UK MARKAL model

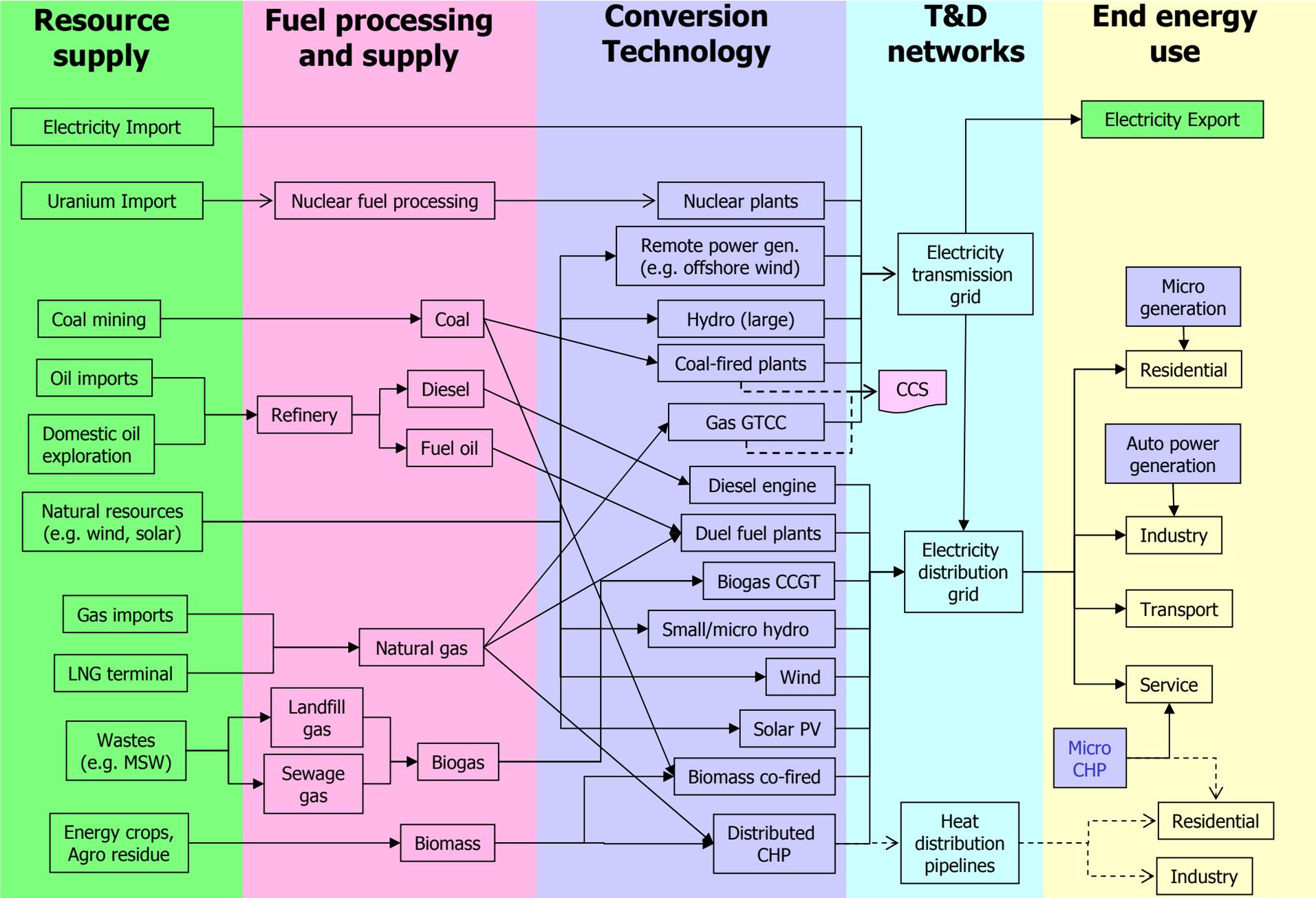
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Open and transparent  
Fully documented data sources  
Explicit sensitivity and uncertainty analysis

A key analytical input for the 2003 White Paper  
Model has been substantially updated for the 2006 Energy Review

# Simplified & Partial MARKAL Reference Energy System (RES)

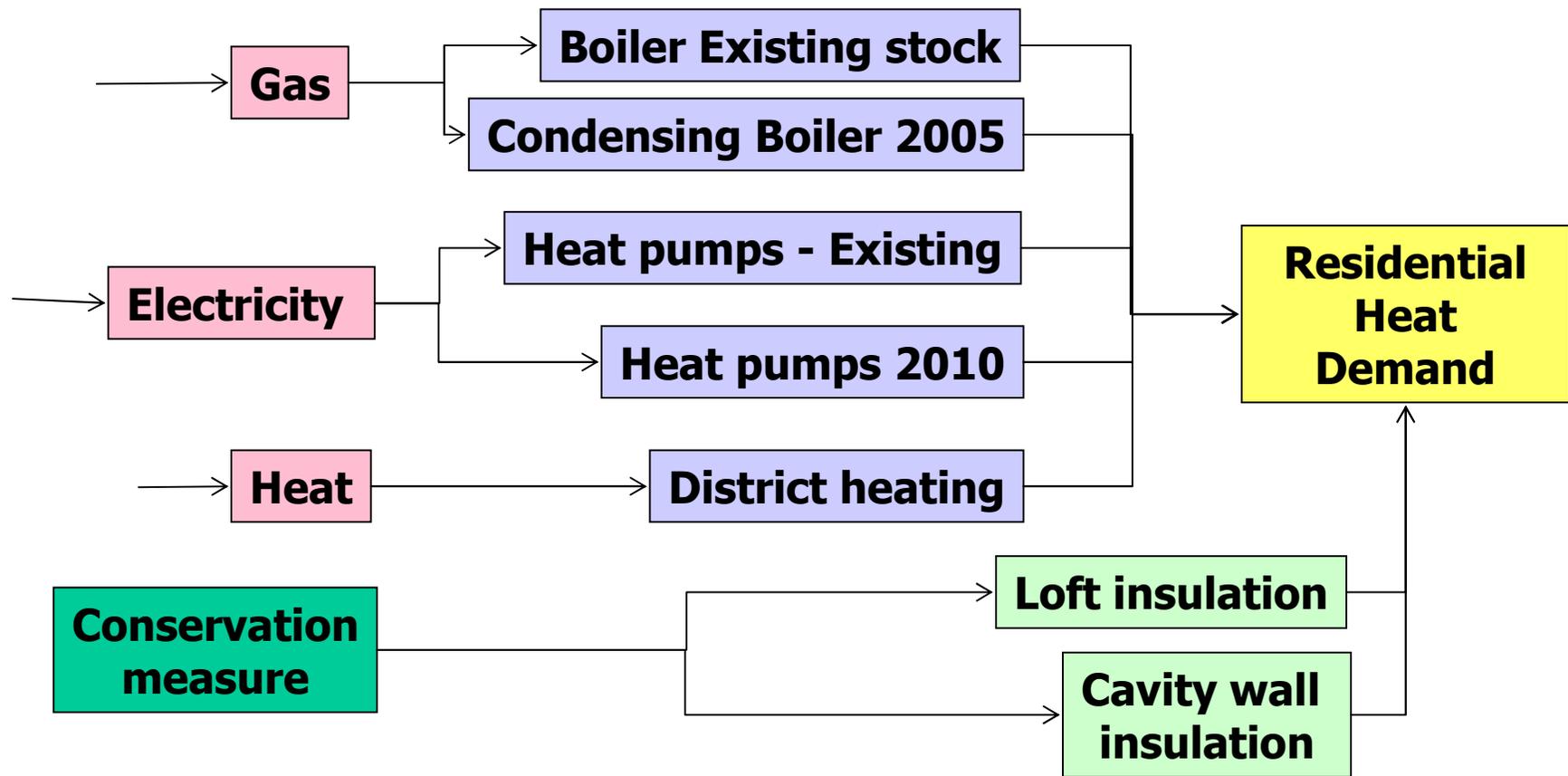


# Modelling energy efficiency and conservation

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- Energy efficiency options are represented through efficient/advanced technologies
  - Efficiency improvement
  - Cost reduction (vintages vs. learning curves)
  - Constraints on uptake
- Conservation measures
  - Mimic reduction of energy service demand from a given conservation measure using dummy technology that **deliver desired energy service without using any input energy**
  - Capital and O&M cost are represented
  - Incentives, subsidies, opportunity costs can be incorporated

# Energy efficiency vs. conservation



# Representation of barriers

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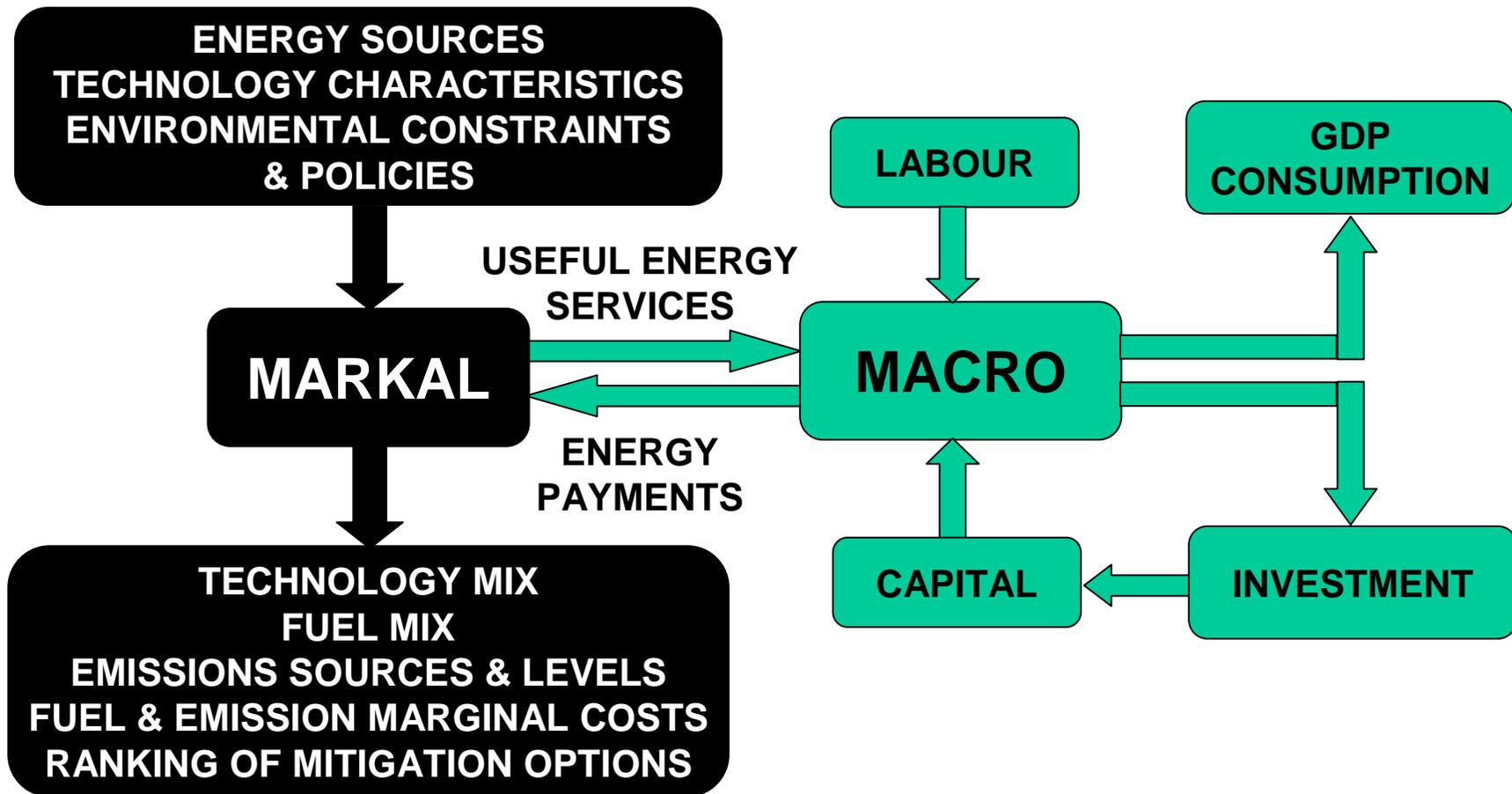
- Cost optimization models tend to choose all cost-effective technologies and measures
- But many barriers prevent the penetration of energy efficiency and conservation
  - Lack of information
  - Uncertainty in performance
  - Principal agent issues
  - Sensitivity to upfront costs
  - .....
- **How is this incorporated in MARKAL?**

# Modelling of behavioural change

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- Energy efficiency
  - Constraining technology mix - historical take-up of technologies (*e.g. bell shape distribution of labeled appliances*)
  - Upper and lower limits (or diffusion curve) on technology penetration (to prevent overnight booming)
  - Introducing high hurdle rate (25%) to delay investment decision
  - Inclusion of subsidies or hidden costs
  - Partial access to end-use sector
- Conservation measures
  - Upper bounds for take-up of conservation
  - Calibrated to near-term policy effectiveness

# Behavioural response via UK MARKAL MACRO model



# UK MARKAL: Conservation options

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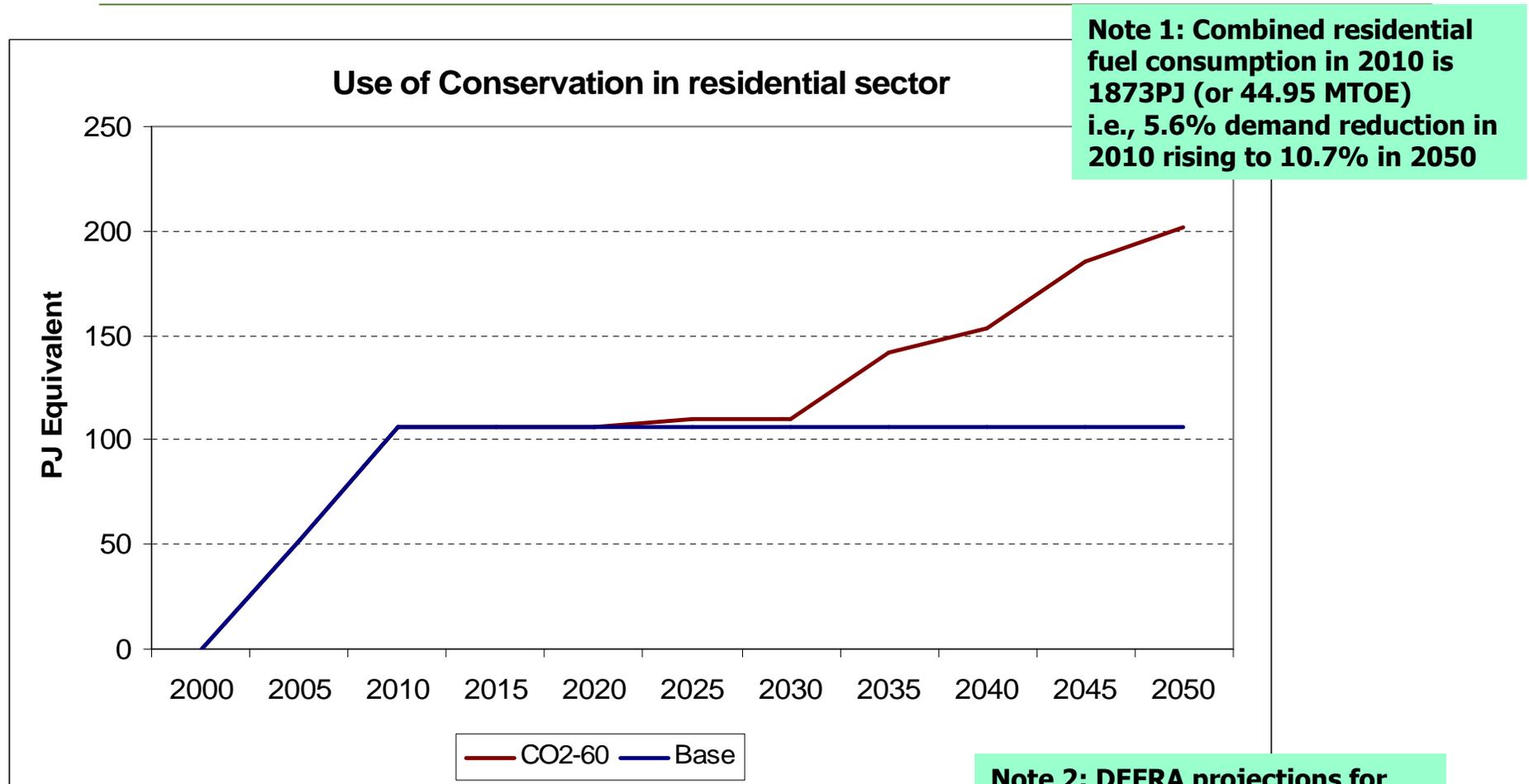
- Selected residential sector conservation measures
  - Loft insulation of various thickness
  - Cavity insulation (pre & post 76)
  - Solid wall insulation
  - Double glazing windows
  - Hot water cylinder insulation of various thickness
  - Floor insulation
  - .....
- Selected service sector conservation measures
  - Double glazing
  - Cavity wall insulation
  - External wall cladding/insulation pitched roof insulation
  - Programmable thermostats optimising
  - Heating start times
  - .....
- Industrial sector aggregated conservation
  - Chemical, iron & steel, paper & pulp, ferrous metals, other industry
  - By fuel: coal, oils, natural gas, derived fuels)

# UK MARKAL: End-use data sources

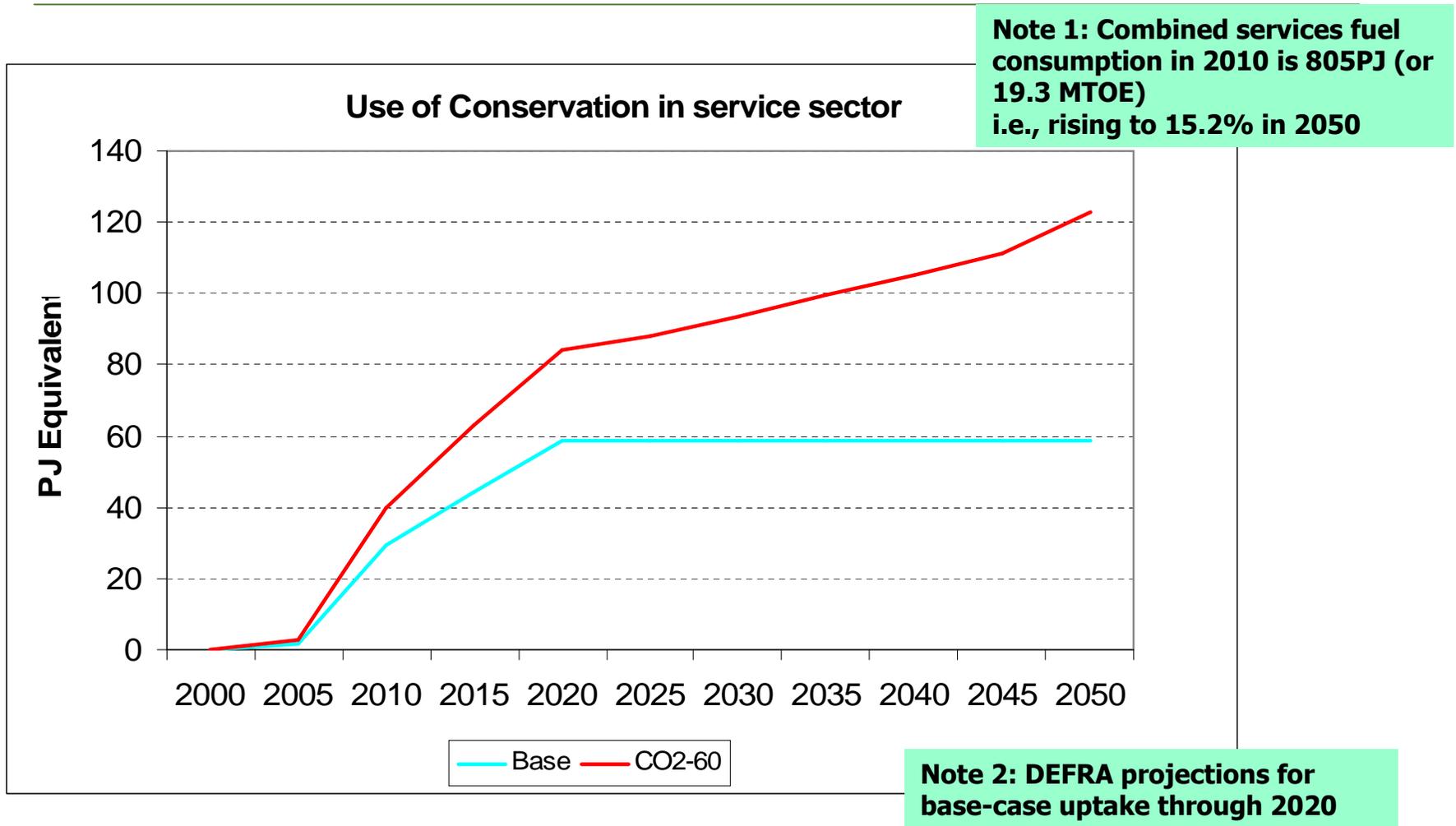
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- Key data sources for residential and service sectors conservation measures
  - BRE
  - DTI/DEFRA
  - Environmental Change Institute, University of Oxford (e.g. 40% house, Carbon futures for European households)
  - Market Transformation Programme
  - Energy Saving Trust
- Policies incorporated
  - EEC (Energy efficiency commitments), building regulations
  - EU-ETS, RTO, REO, Climate levy etc

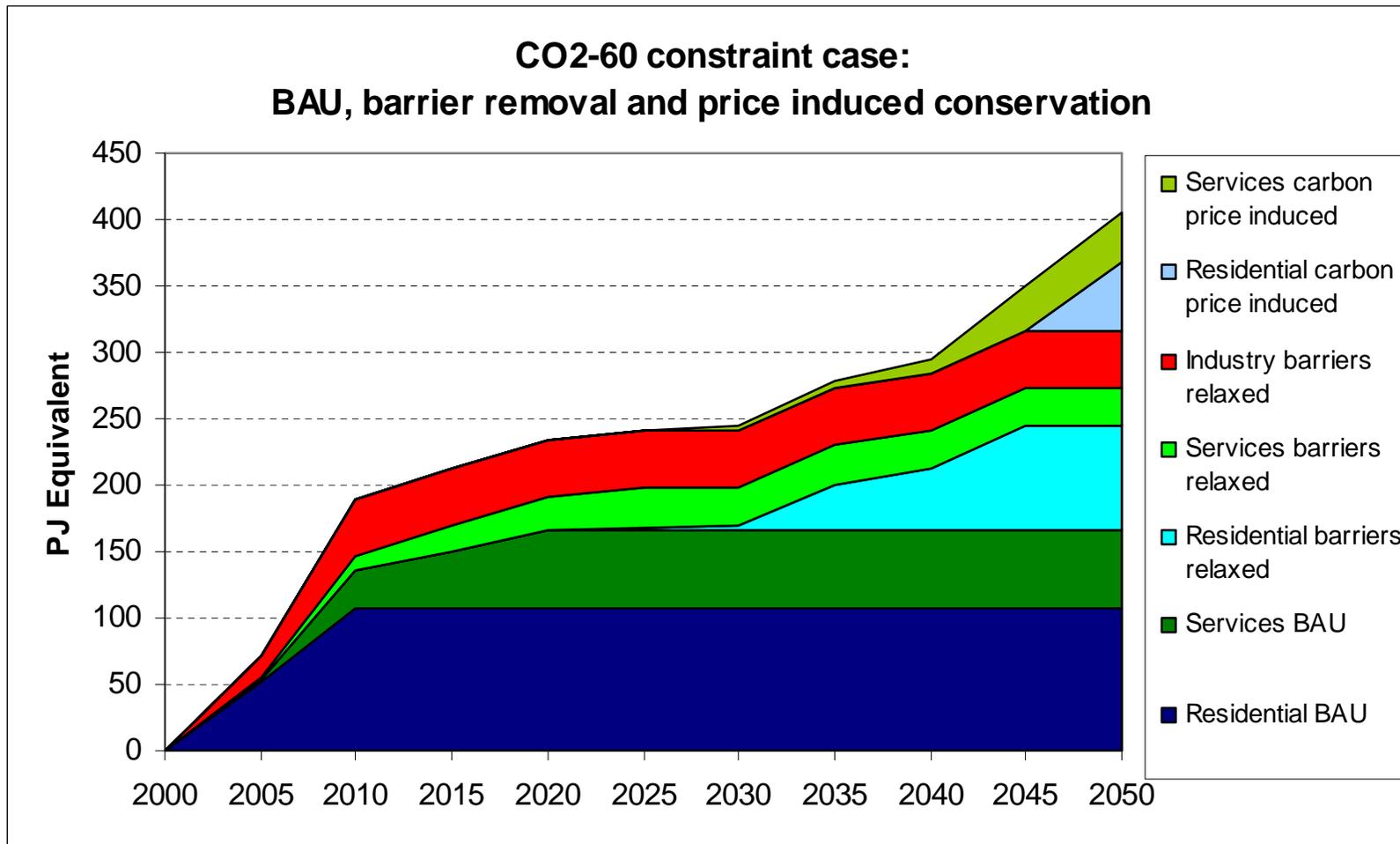
# Residential sector conservation uptake



# Service sector conservation uptake



# Overall conservation measures



# Uncertainties and closing comments

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- Models are not truth machines. They are intended to stimulate thought and deliver insights into complex realities
- Uncertainty/sensitivity analysis
  - Ranges for input data (rather than point estimates)
  - Tipping points and trade-offs via a set of runs rather than rely on one model output
- Optimisation issues
  - *Cost* optimization is NOT *price* optimization
  - Short term trends are not necessarily comparable with other model outputs
  - Simplified consideration of non-market barriers and behavioural responses
- Efficiency/conservation cost considerations are **essential**
- Energy system interactions are **essential**

# Thank you

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