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Centre International de Recherche sur l'Environnement et le Développement

# Global Sensitivity Analysis of an Energy-economy Model of the Residential Building Sector

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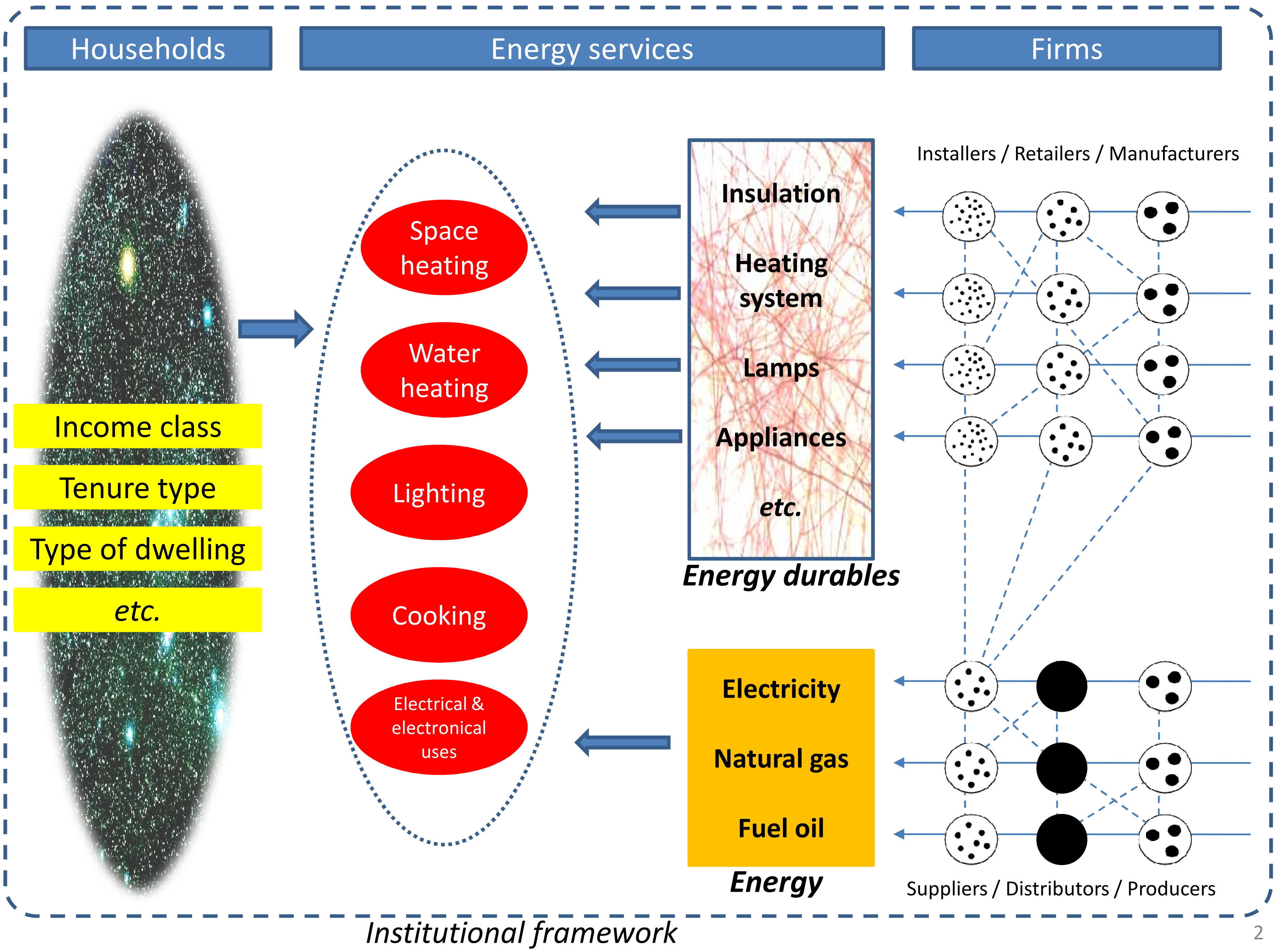
*International BE4 Workshop – London – April 20, 2015*


Households
Energy services
Firms
Income class
Tenure type
Type of dwelling
etc.
Space heating
Water heating
Lighting
Cooking
Electrical & electronical uses
Insulation
Heating system
Lamps
Appliances
etc.
Energy durables
Installers / Retailers / Manufacturers
Electricity
Natural gas
Fuel oil
Energy
Suppliers / Distributors / Producers
Institutional framework

→*Uncertainty associated with modelling such a complex system?*

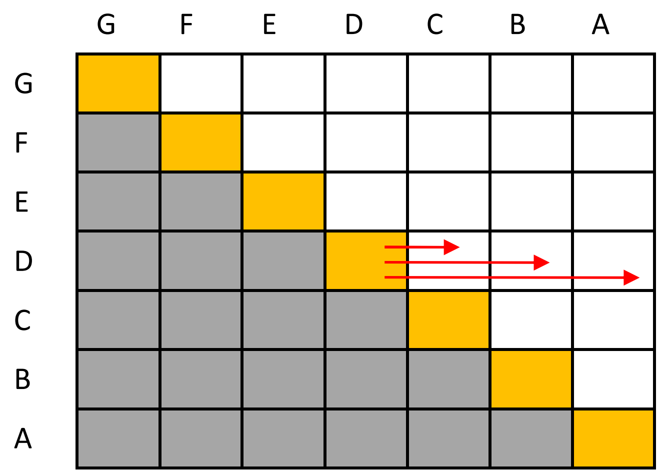
1. The Res-IRF model in a nutshell
2. Quantifying uncertainty: Monte-Carlo analysis
3. Characterizing uncertainty: the Morris Method

# Res-IRF in a nutshell

# Res-IRF: Scope

- Energy use covered
  - Space heating (2/3 of French household demand)
  - Electricity, natural gas, fuel oil

- Energy efficiency improvements
  - New constructions (standard/low energy/passive)
  - Retrofitting of existing dwellings (including fuel switch)



# Res-IRF's Main Innovations

- All margins of energy use are endogenous
  - Intensity of retrofits
  - Number of retrofits
  - Utilization adjustments (Rebound effect)

- Some barriers to energy efficiency
  - Static: split incentives (discount rates)
  - Dynamic: learning-by-doing, information acceleration

# Intensity of Retrofits

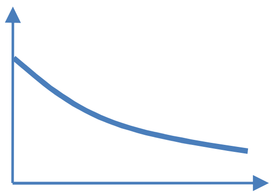
$$PR_{i,f} = \frac{LCC_{i,f}^{\ -\nu}}{\sum_{h>i} LCC_{i,h}^{\ -\nu}}$$

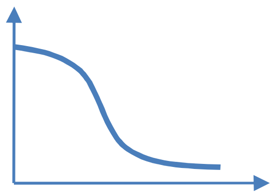
Heterogeneous discount rates across landlords and tenants

$$LCC_{i,f} = CINV_{i,f} + CENER_{f} + IC_{i,f}$$

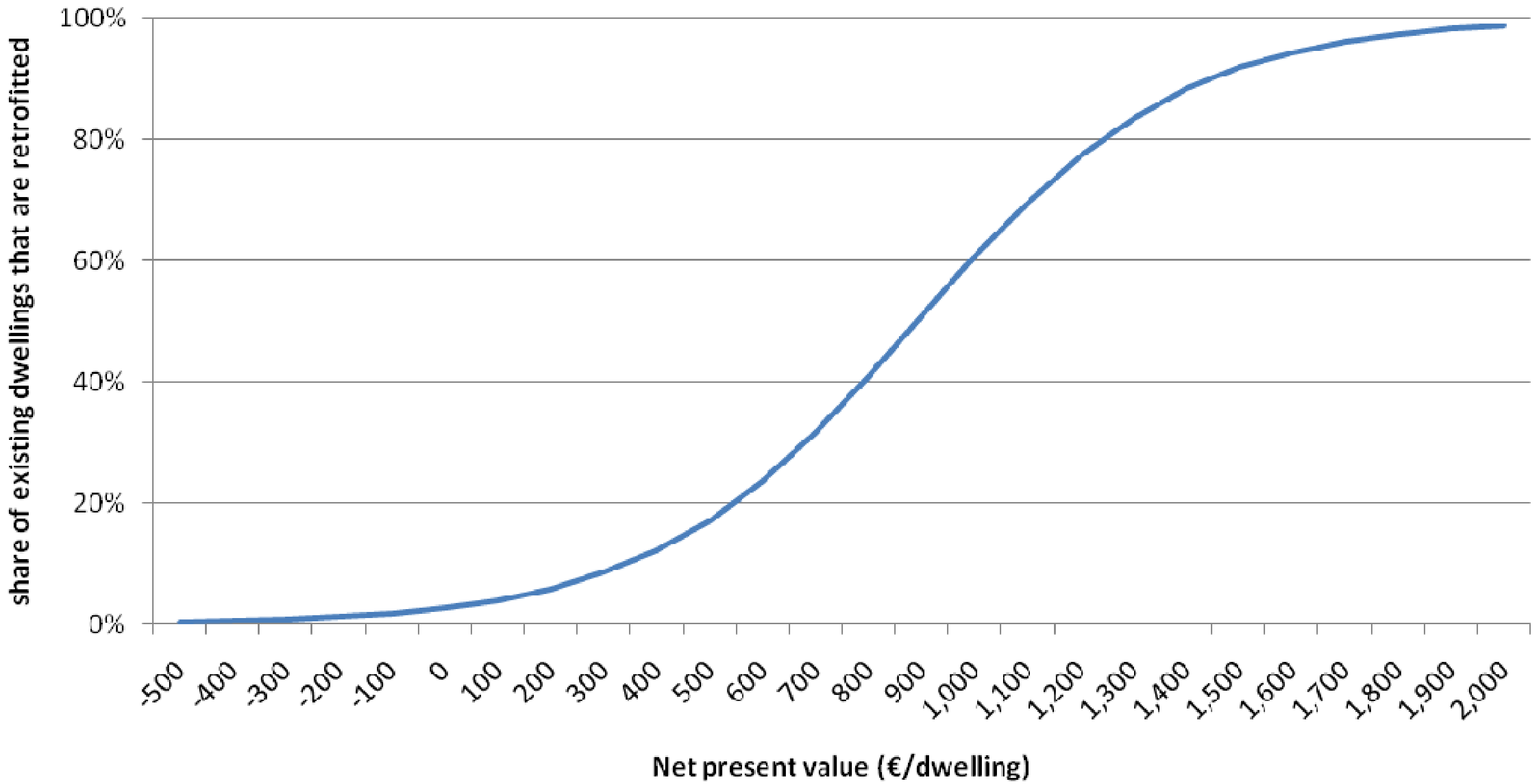
Subject to endogenous decrease (learning-by-doing)

Subject to endogenous decrease (peer effects)



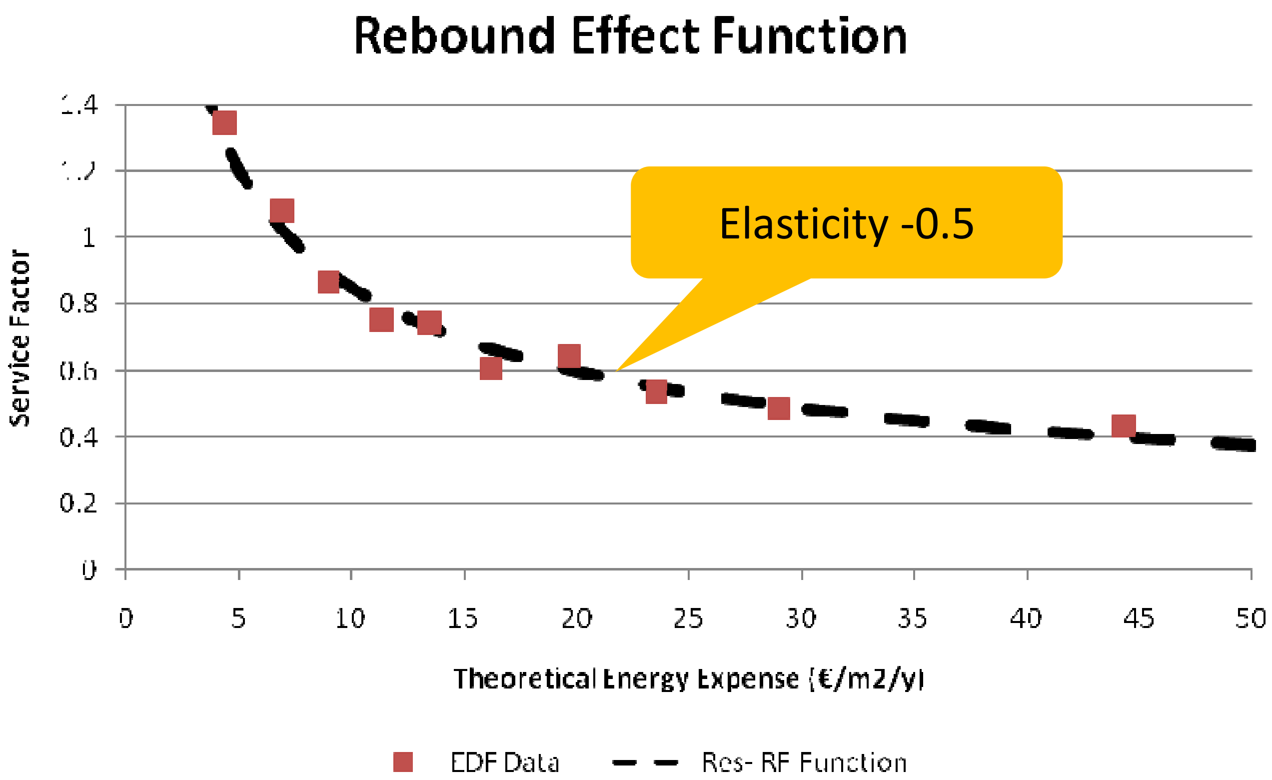


# Number of Retrofits



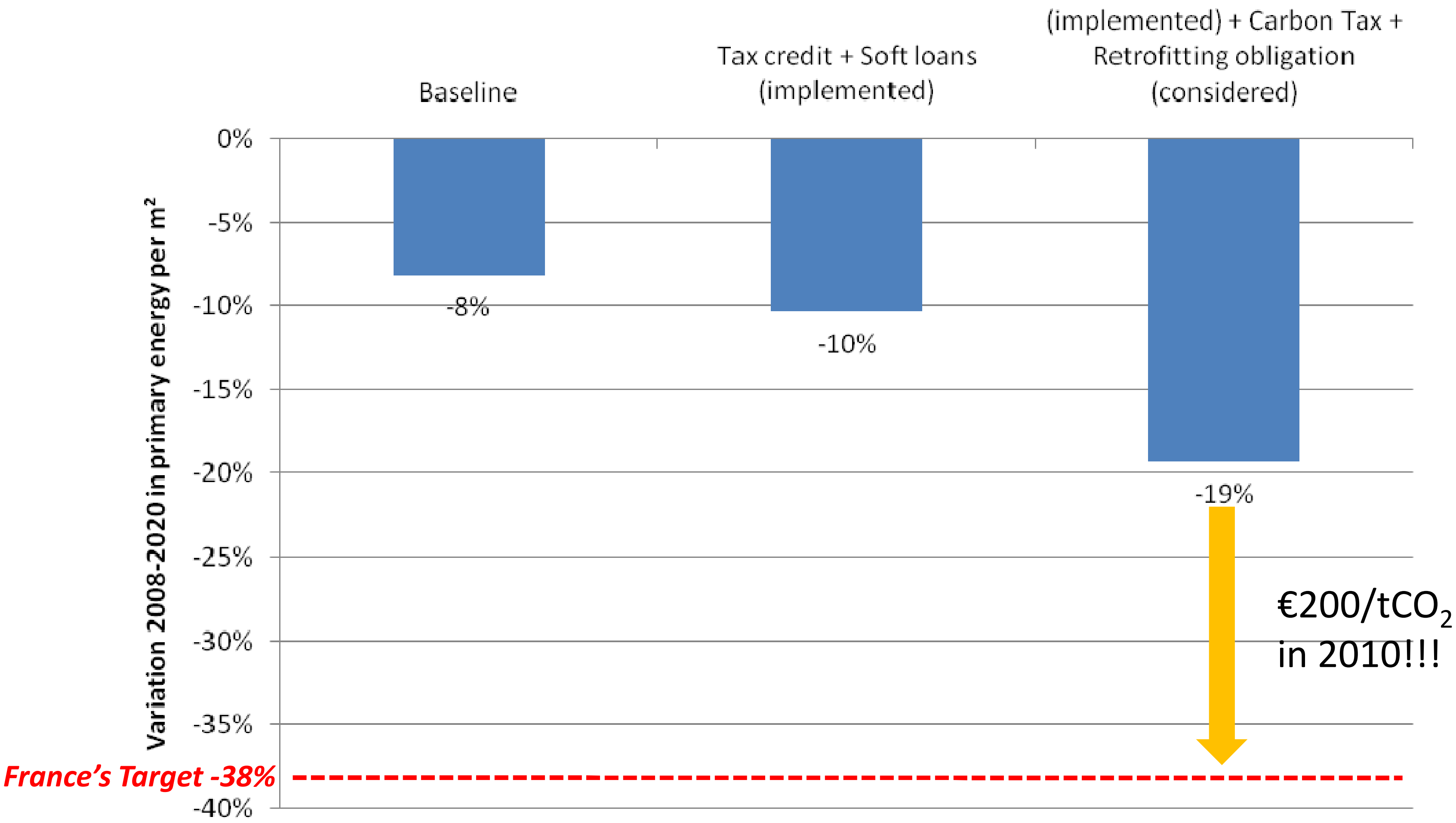

Captures heterogeneity in preferences for heating (e.g. sensitiveness to cold)

# Utilization Adjustments




*Data: EDF R&D (see Cayre et al., 2011, ECEEE Proceedings)*

# Insights into French Policy

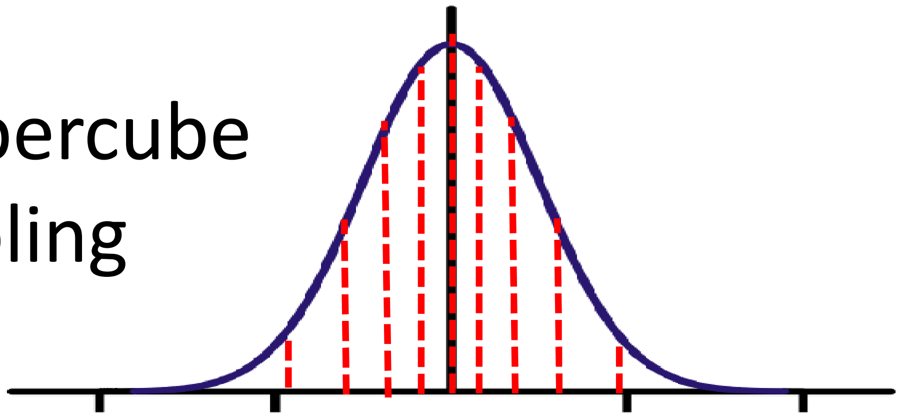


# Quantifying Uncertainty: Monte-Carlo Analysis

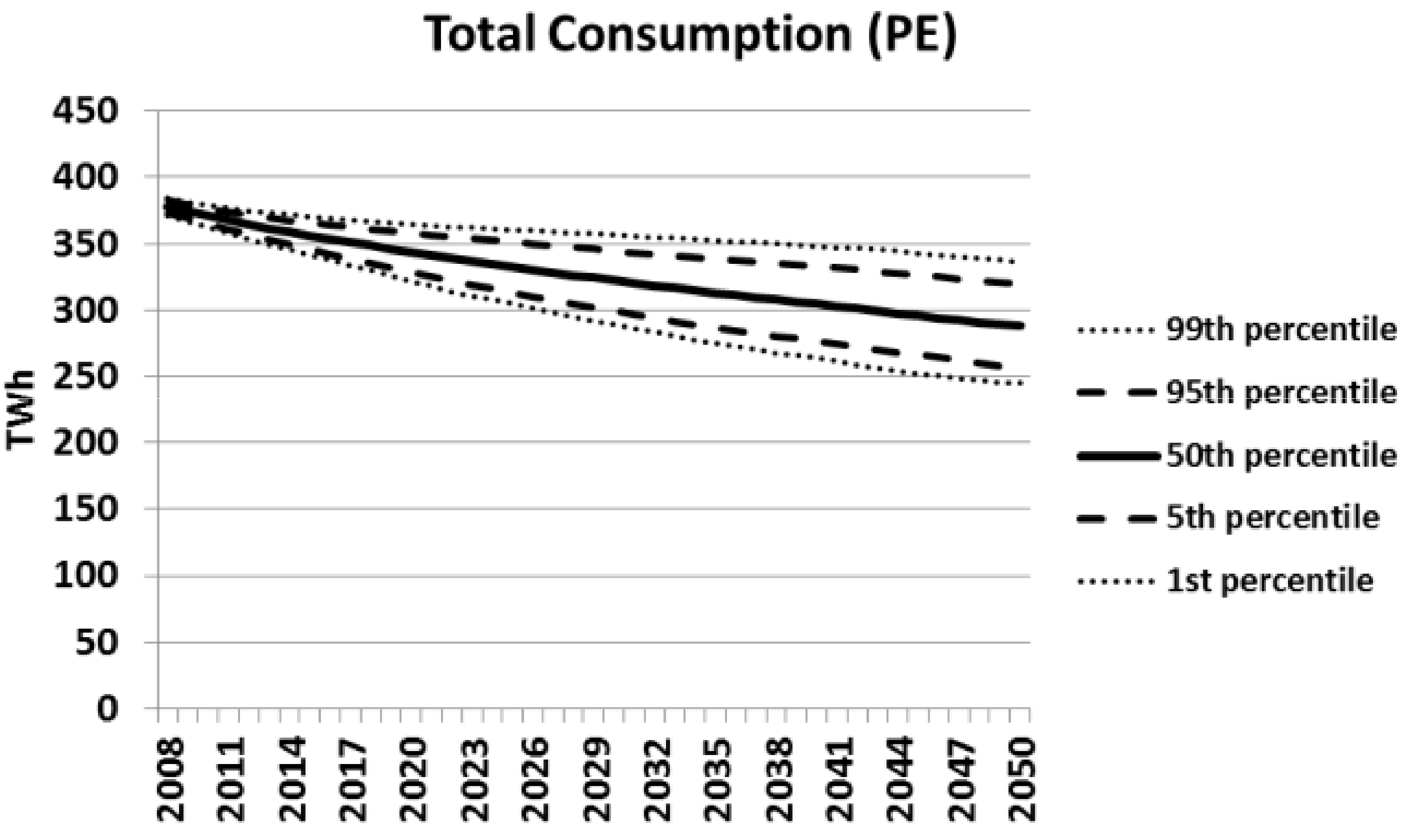
# Protocol

~~Randomly pick parameters~~

Latin Hypercube Sampling



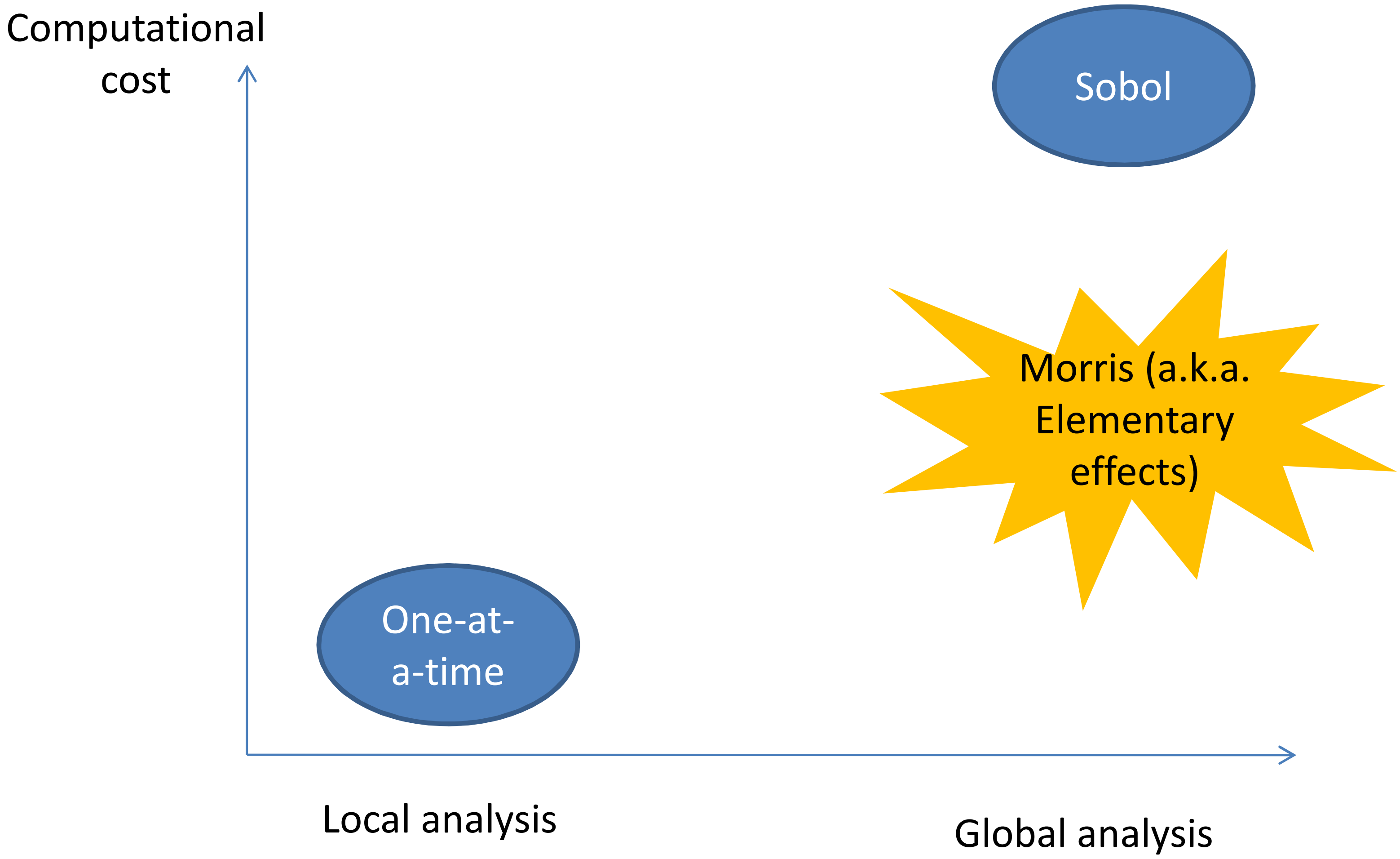
# Overall Uncertainty



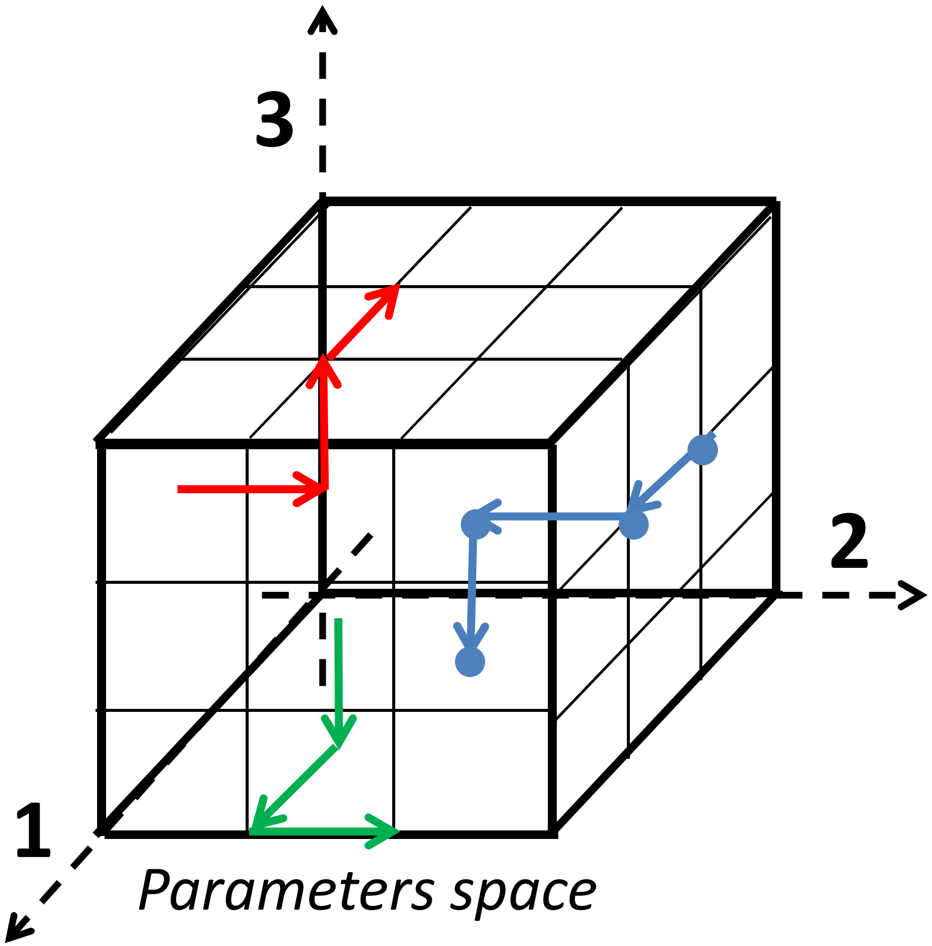

25% around the median value

# Characterizing Uncertainty: the Morris Method

# Methods of Sensitivity Analysis



# The Morris Method: Design

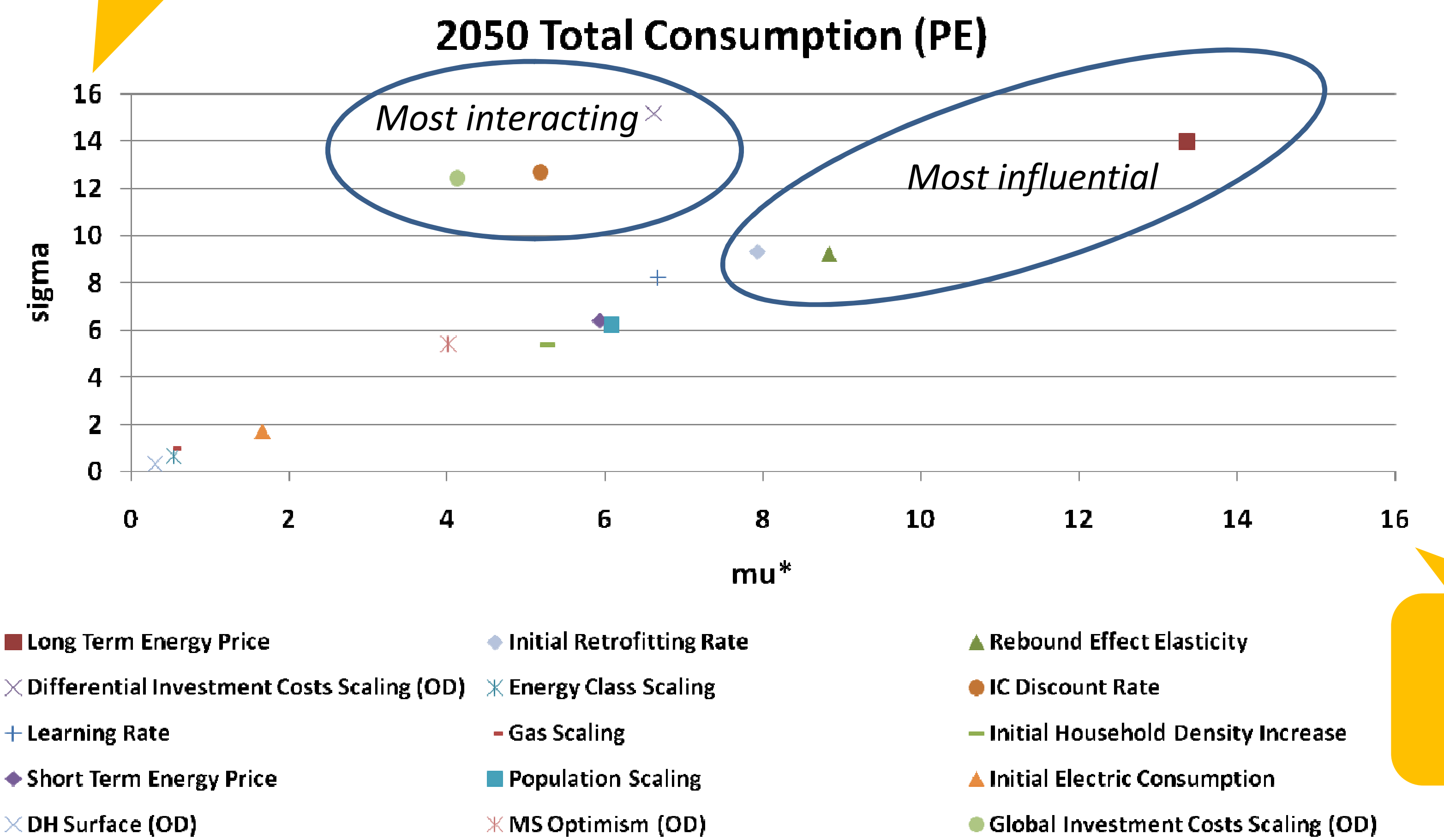



k+1 simulations
→k elementary effects

We repeat the operation for r trajectories
→r*(k+1) simulations

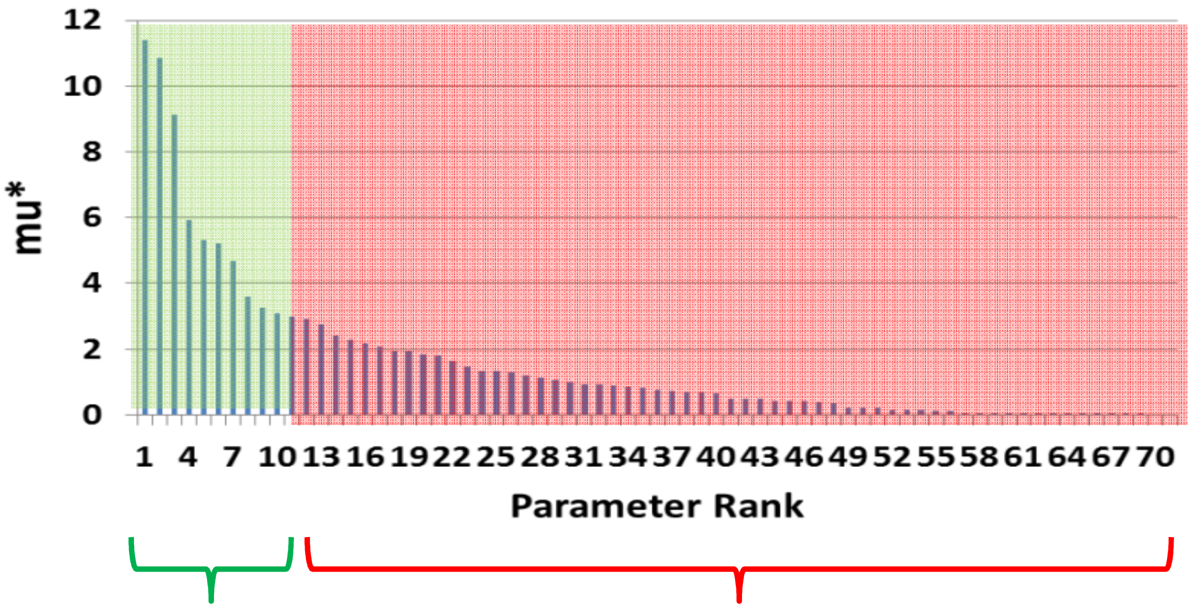
# Results: Morris Diagram

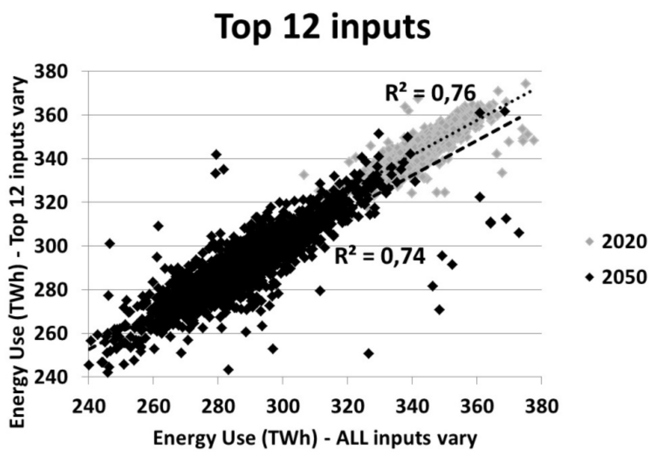
Measure of **interaction**

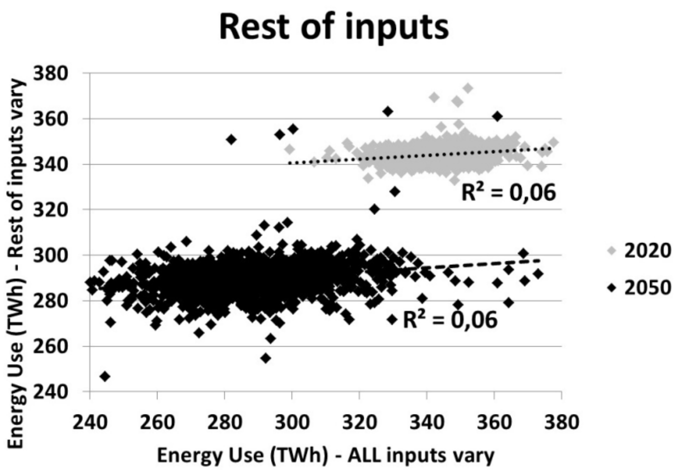



Measure of **influence**

# Parameters Ranking



# Important Parameters: Comment

- Energy price

  *Somewhat reassuring that the model is sensitive to its main input…but very uncertain parameter in practice!*

- Initial retrofitting rate

  *Illustrates that calibration is a critical step*

- Rebound effect elasticity

  *Importance of behaviours*

The model is more sensitive to how the different margins of energy use are disaggregated than to how barriers to energy efficiency are introduced

# Discussion

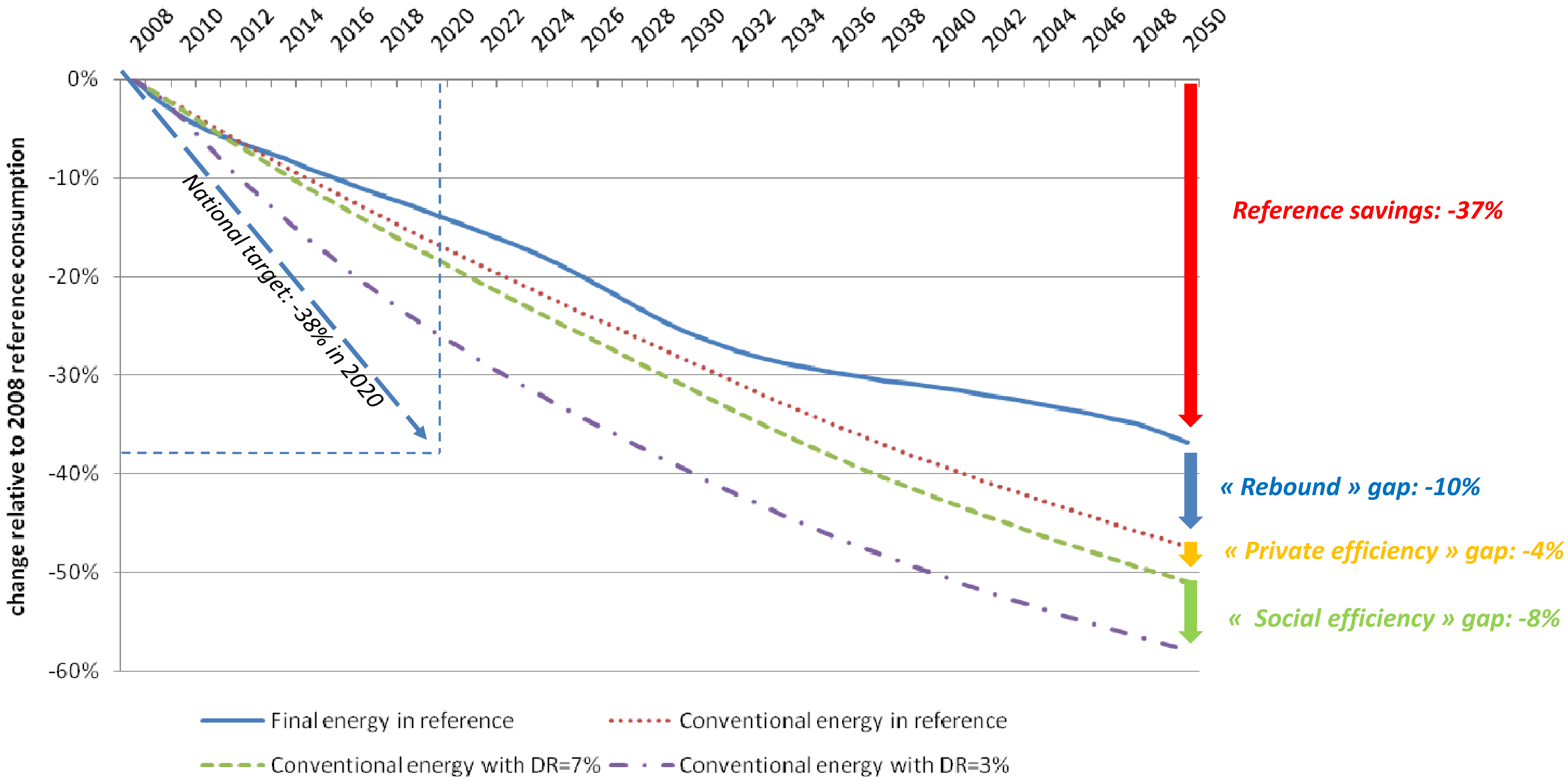
*Overall, we were quite happy with the results. But…*

- Even though all inputs are taken into account, analysis still dependent on the choice of the probability distributions
- Sensitivity specific to one particular output (energy use)
- Sensitivity analysis only captures uncertainty about model quantities, not about model forms

# REFERENCES


- **Branger et al. (2015) Global sensitivity analysis of an energy-economy model of the residential building sector, forthcoming, Envionmental Modeling & Software**
- **Giraudet et al.** (2011). Comparing and combining energy saving policies. Will proposed residential sector policies meet french official targets? Energy Journal, 32 (SI 1):213–242
- **Giraudet et al.** (2012). Exploring the potential for energy conservation in french households through hybrid modeling. Energy Economics, 34 (2):426–445.
- **Morris, M. D.** (1991). Factorial sampling plans for preliminary computational experiments. Technometrics, 33(2):161–174.
- **Saltelli et al** (2008). Global Sensitivity Analysis: The Primer. John Wiley & Sons.
- **Van Asselt, M. B. A. and Rotmans**, J. (2002). Uncertainty in integrated assessment modelling. Climatic Change, 54(1):75–105.

# Potential for energy conservation in French dwellings




Giraudet, L.-G., Guivarch, C., Quirion, P., 2012. Exploring the potential for energy conservation in French households through hybrid modeling. Energy Economics 34, 426–445. doi:10.1016/j.eneco.2011.07.010