# How we treat behaviour in energy system optimisation models

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International $BE_4$ Workshop, London, April 20th 2015

1. Parameters which capture behaviour in ESOMs

2. Use of hurdle rates

3. Sensitivity analysis of hurdle rates

4. An empirical basis for hurdle rates

# Parameters which capture "behaviour" in ESOMs

- Energy system optimisation models
- Whole-energy system depiction
- Technology explicit/detailed
- Linear programming basis:
  - Minimising costs, or
  - Maximising surplus
- "Social planner" perspective


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# Parameters which capture "behaviour" in ESOMs

## Energy service demand

**Passenger kilometers, lumens, heat, etc.**

1. *Demand driver*

Source:

Simple econometric models
Government/authoritative projections
Other models

2. *Elasticity of demand*

Demand response to price
Determined by income, substitutability and necessity of good, etc

## Technology uptake & use

3. *Discount and hurdle rates*

- Whole-energy system depiction
- Technology explicit/detailed
- Linear programming basis:
  - Minimising costs, or
  - Maximising surplus
- "Social planner" perspective

# Discount & hurdle rates

- Global discount rate:
  - Applied globally across the model
  - Prescriptive/"ethical" discounting: 0.11%-3.5%
    - Represents value society attaches to present over future consumption or utility
  - Descriptive/behavioural: 10%
    - Reflects real market risk, required rate-of-return

- Technology-specific discount rate, "hurdle rate"
  - Applied to specific sectors or technologies
  - Can differentiate the agent making investment
    - Private cost of capital 7-10%
    - Business borrowing costs: 3-7%
    - Government: 1%?
  - Can also represent
    - the required rate of return on investment (10-15%?)
    - the perceived energy-efficiency gap of individuals => 25%
    - Other uses for representing behaviour

# Use of hurdle rates

- One study (global HR 10%, end-use 25%)
  - Market investment rate. "to reflect commercial UK market rates of return"
  - "higher technology-specific discount or hurdle rate to account for market risks and consumer preferences”
  - "imperfect knowledge and non-cost preferences"
  - "market risk, information deficiencies and other market imperfections in the uptake of end-use conservation options"

- Another study:
  - Hurdle rates are “used for both the cost of finance and for social discounting. The first is … in accordance to an annual return on investment. Social discounting is used to reflect the valuation on well-being in the near future versus well-being in the longer term”

# Use of hurdle rates (cont'd)

- A third:
  - High hurdle rates are used for new/unproven technologies: "a factor of 15% to reflect a higher risk in investing in unproven technologies and infrastructures"
  - "meant to mimic hesitancy on the part of the purchaser to invest in a newer technology over an established technology"

- "Hurdle rates of 25, 20, and 15% are applied, graded on dates of commercial availability, the severity of perceived market barriers, and the uncertain requirements of new infrastructures"

# Average hurdle rates for residential energy efficiency investments

| Study | End-Use Type | Average rate |
|---|---|---|
| Arthur D Little (1984) | Thermal shell measures | 32% |
| Cole and Fuller (1990) | Thermal shell measures | 26% |
| Goett (1978) | Space heating system and fuel type | 36% |
| Berkovec, Hausman and Rust (1983) | Space heating system and fuel type | 25% |
| Hausman (1979) | Room air conditioners | 29% |
| Cole and Fuller (1980) | Refrigerators | 61-108% |
| Gately (1980) | Refrigerators | 45-300% |
| Meier and Whittier (1983) | Refrigerators | 34-58% |
| Goett (1983) | Cooking and water heating | 36% |
| Goett and McFadden (1982) | Water heating fuel type | 67% |
| **Source(s): Sandstad *et al.* (1995); Train (1985).** | | |

Manion et al., 2006 "Strategic Investments in Residential Energy Efficiency: Insights from NE MARKAL"

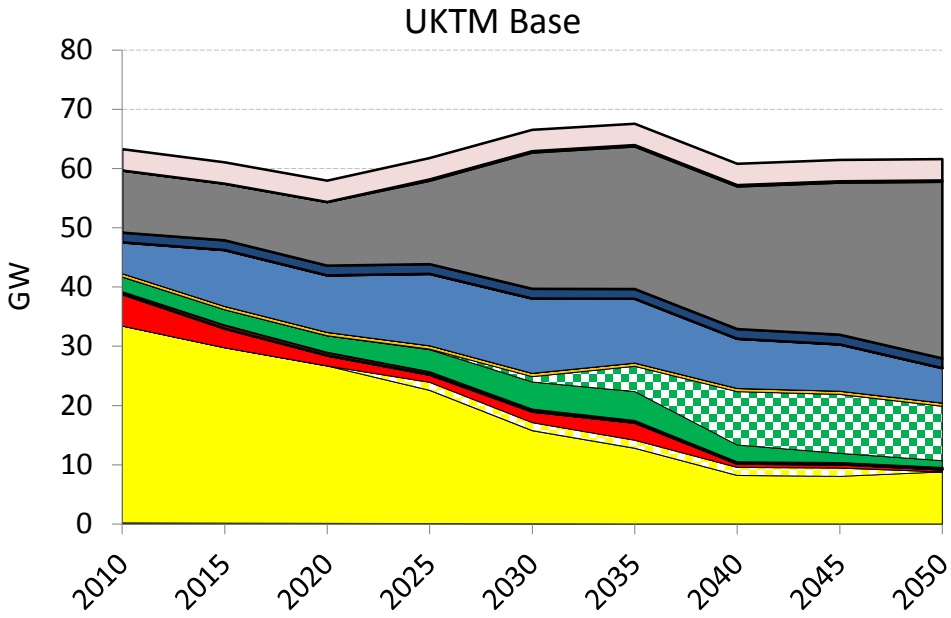
| | UKTM | ESME | PRIMES/JRC TIMES | UK MARKAL/MACRO | DECC DDM |
|---|---|---|---|---|---|
| Upstream / Processes | 10% | 8% | 7% | 10% | 10% |
| Power sector | 10% | 8% | 9% | 10% | 5-19% |
| Agriculture | 10% | 8% | 12% | 10% | 10% |
| Industry | 10% | 8% | 12% | 10% | 10% |
| Services | 10% | 8% | 12% | 10% | 10% |
| Residential | 5% | 8% | 18% | 25% | 5% |
| Cars | 5% | 8% | 18% | 25% | 5% |
| Public transport | 7% | 8% | 8% | 25% | 7% |
| Road freight | 10% | 8% | 12% | 9% | 10% |
| Aviation | 10% | 8% | 8% | 4% | 10% |
| Shipping | 10% | 8% | 12% | 4% | 10% |

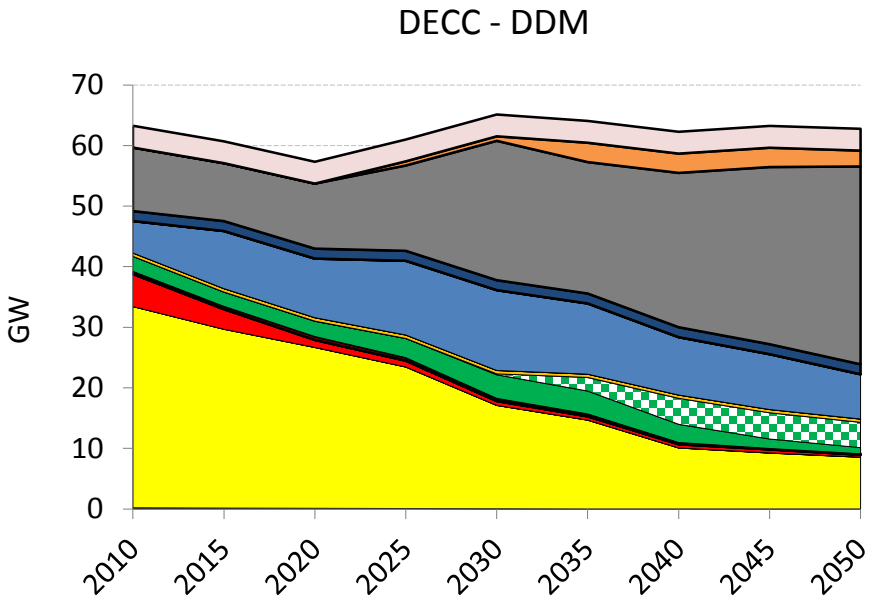
Inconsistency in the portrayal of:

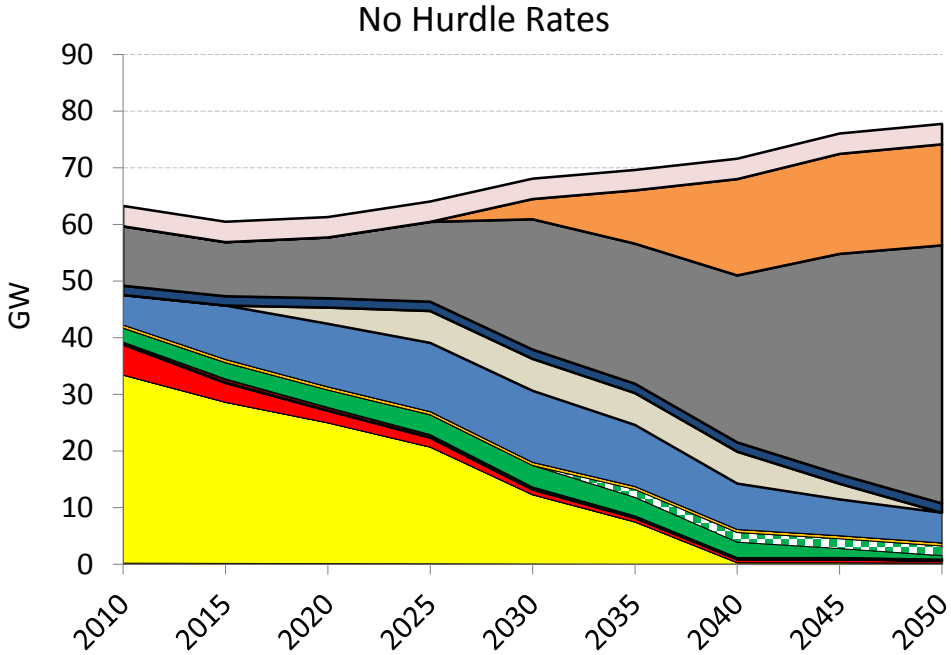
- Individual purchaser behaviour – Energy Efficiency gap, vs low cost of borrowing
- Novel technologies
  - High cost of uncertainty, vs “technology agnostic”

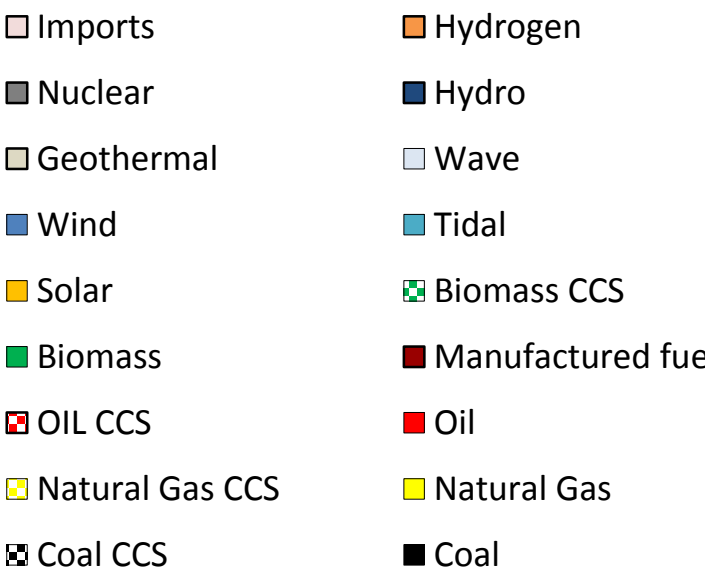
# Sensitivity analysis with the UK TIMES Model (UKTM)

# Power Generation Mix

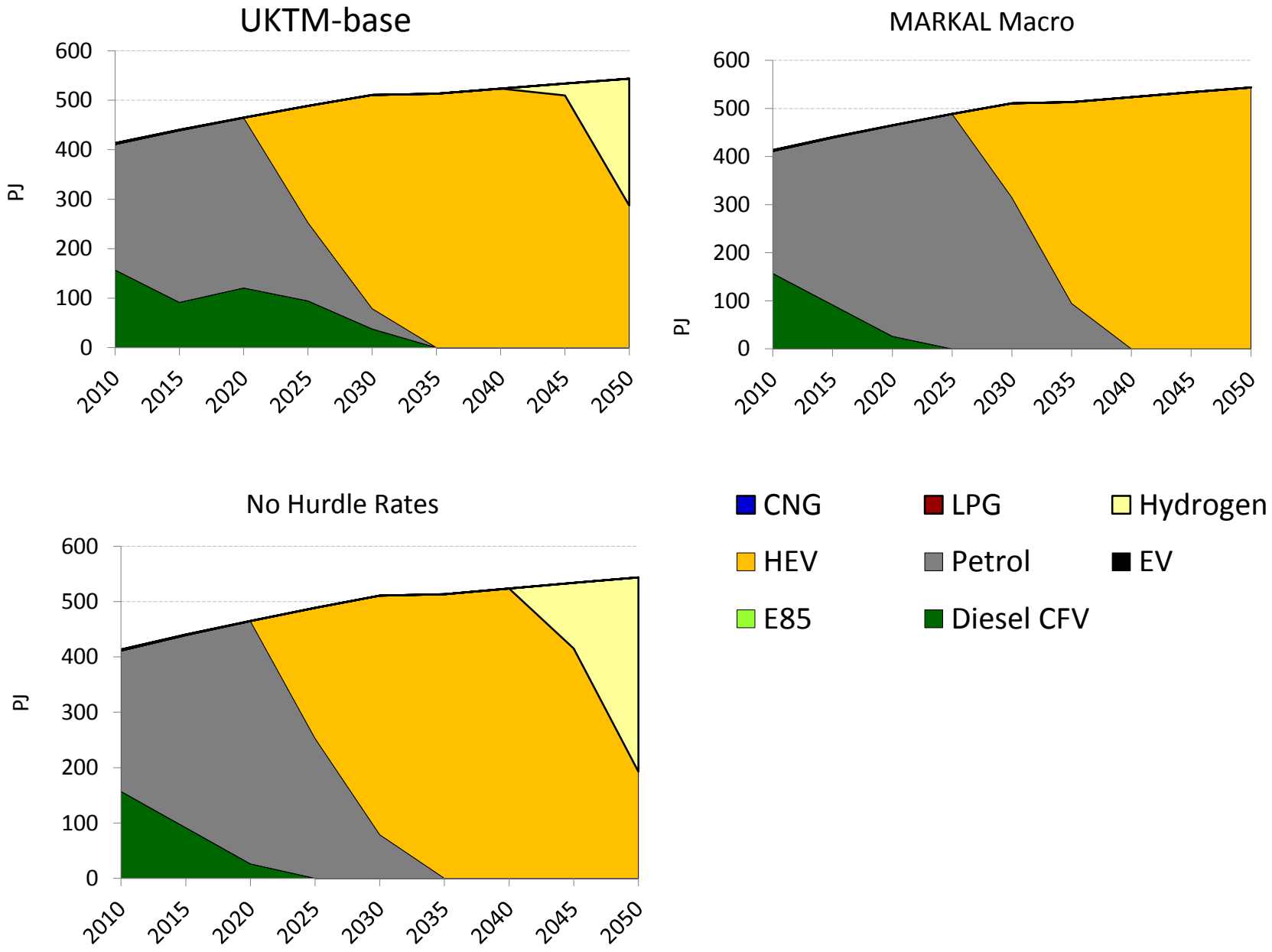


# Passenger car fuel consumption



# Conclusions

- Hurdle rates have the potential to substantially change optimal technology pathways
- Our narrative for what our model is saying should be consistent with use of hurdle rate
  - Are we being prescriptive (normative), “this is the optimal energy system”
    - In which case, are we missing out on real-world barriers to technology uptake and being overly optimistic?
  - Descriptive (positive), “this is a realistic scenario for the next 50 years”
    - In which case, is the use of hurdle rates pre-determining technology deployment?
- There should be *consistent rationale* for using HRs across different technologies
- This rationale, and HRs used in a study, should be transparent

# WholeSEM Household Questionnaire: Deriving an empirical basis for hurdle rates

Which central heating would you choose?

| | Gas | Electric storage | Heat pump | Solid fuel |
|---|---|---|---|---|
| Upfront cost | £2,000 | £2,000 | £3,000 | £3,000 |
| Annual cost | £500 | £750 | £750 | £750 |
| $CO_2$ savings | -20% | -40% | -40% | -100% |
| Lifetime | 15 | 20 | 15 | 20 |
| Effort for servicing, fuelling | Low | Medium | High | Low |
| Operation effort | Low | Medium | Medium | High |

→ Ask people to trade off preferences for different heating attributes
→ Technology attributes are derived from UKTM

→ Develop a discrete choice (MNL) model of heating selection
→ Derive hurdle rates which differentiates costs, novelty, hassle
→ Differentiate hurdle rates for different population segments