Energy Decision-Making for Cities

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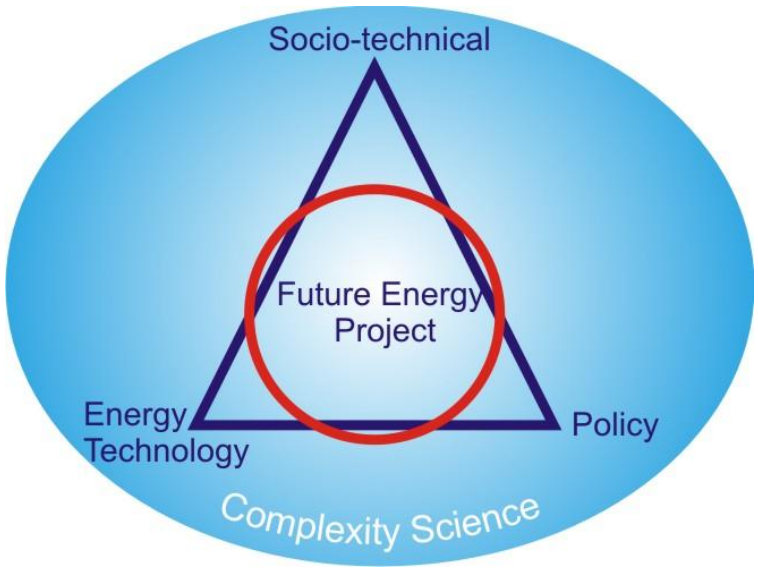
Future energy decision making for cities:

Can complexity science rise to the challenge?

- Using complex systems methods to understand energy decision-making at the city level

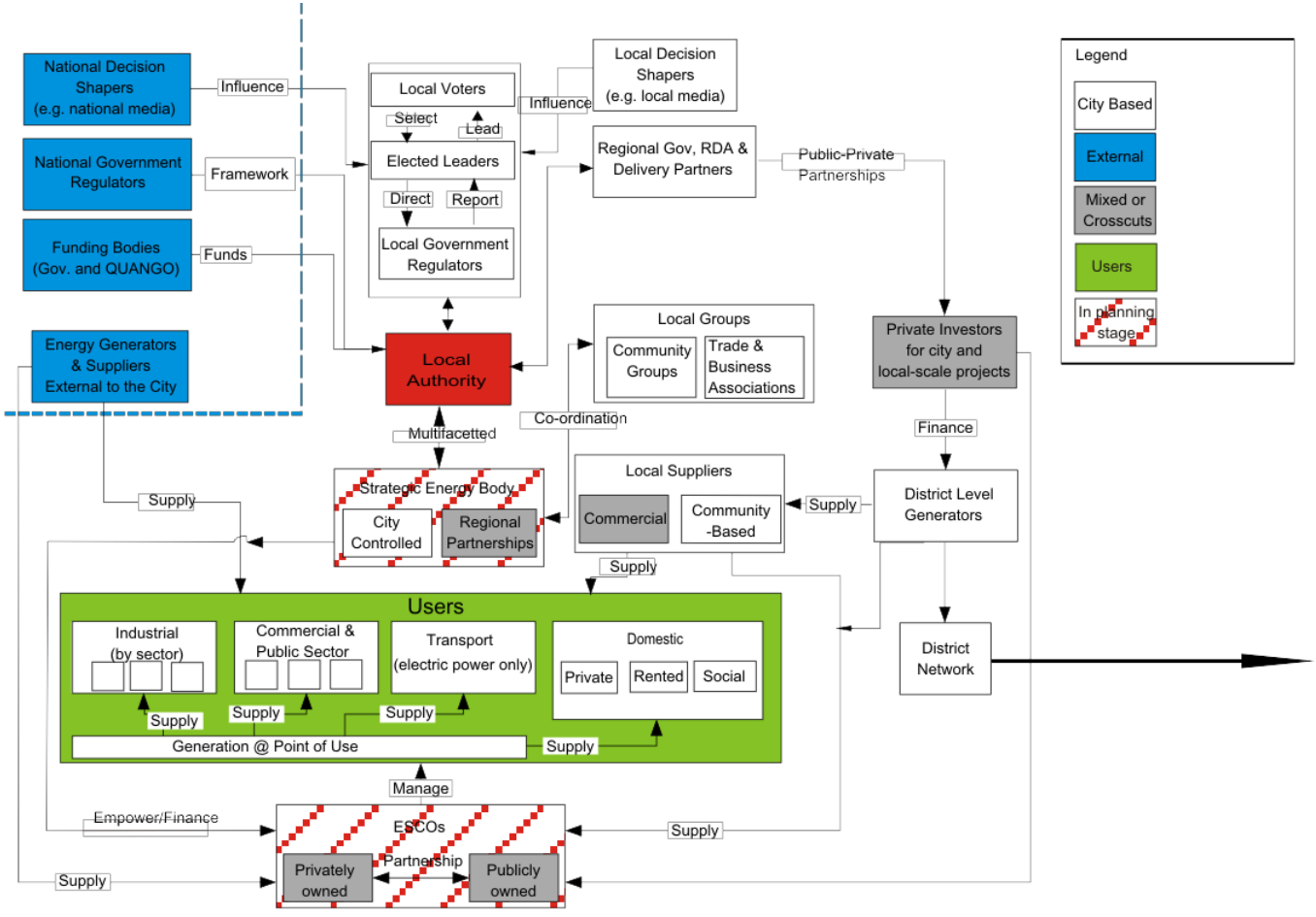
1. Network modelling
   - consumer behaviour models[1],
2. Agent-based simulation
   - Modelling electricity consumption in office buildings[2]



1: McCullen *et al.*, IJBC (2011)

2: Zhang *et al.*, Energy and Buildings (2011)

Background: local authority energy planning



- Local authorities (LAs) are willing to think strategically about energy interventions but need the tools to do so.

Bale *et al.*, Energy Policy, (2012)

Network models: Role of social networks in domestic sector uptake of energy-efficiency innovations

N. J. McCullen.

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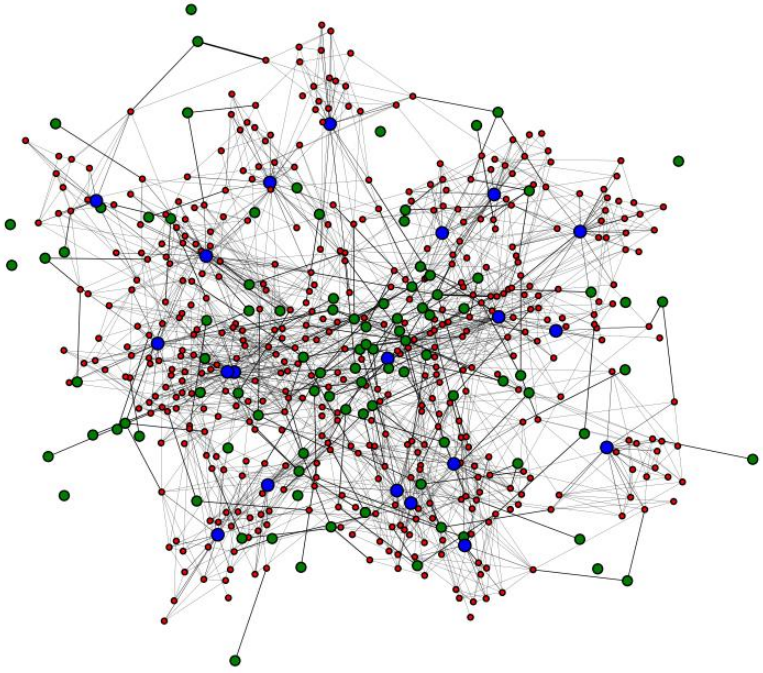
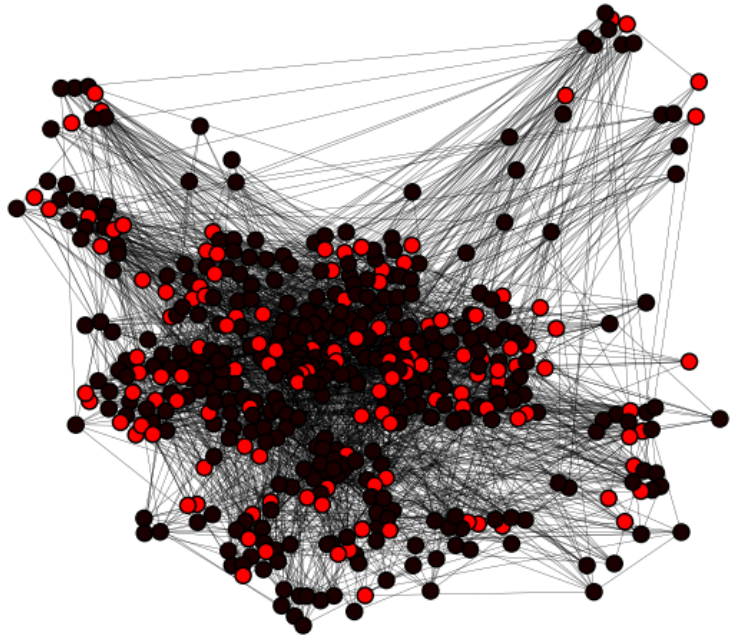
Role of social networks in domestic sector uptake of energy-efficiency innovations

- influence of social networks not previously considered.



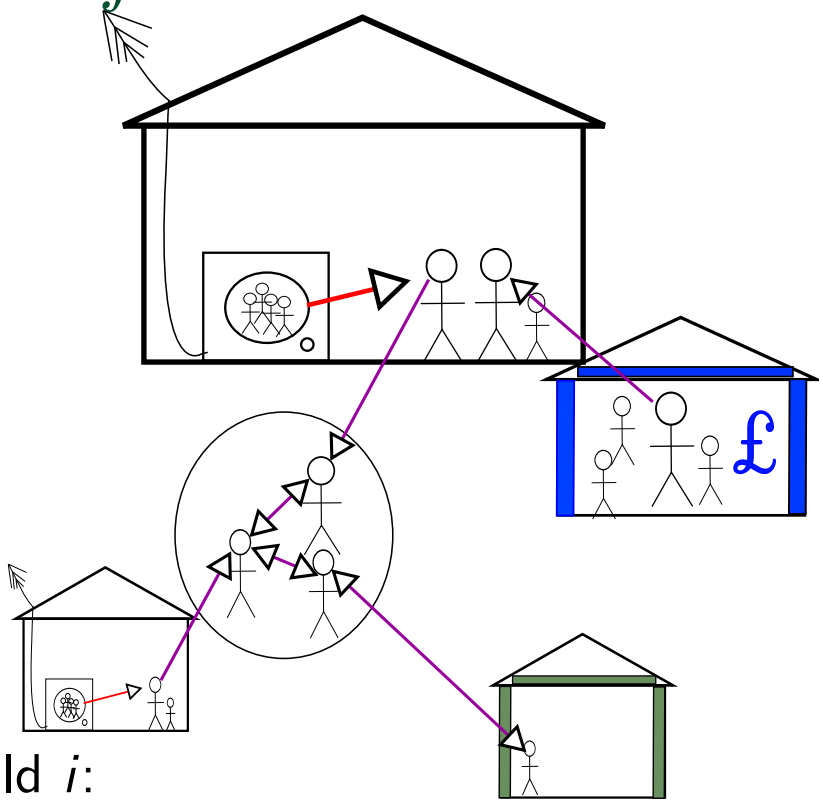


- We use complex networks to model innovation diffusion mediated via social network interactions.

Modelling adoption of innovations

Households are *nodes*.

Links represent **interactions**.



- Households adopt based on various factors:
  - personal + social benefit[a].
- Intrinsic benefits to household.
- Social benefit combination of both[b]:
  - personal social network,
  - mainstream social norm.

- Total *utility* to individual household i:

$$u_i = \alpha_i p_i + \beta_i s_i + \gamma_i m \quad (1)$$

  - p_i, s_i, m: personal, peer-group and societal influence.
  - $\alpha_i, \beta_i, \gamma_i$: relative weightings given to each factor.
  - Adoption occurs if u_i exceeds a *threshold* θ_i.

[a]Delre *et al.* (2010); [b]Valente (1996)

(1) from: McCullen *et al.*, in prep. for SIADS, (2012)

Parametrising the models using survey data

- Survey data including info on behaviours.
  - Over 1050 valid responses received from residents of Leeds.
- Data used as a guide rather than definitive source,
  - used to narrow choice of structure and parameter values,
  - also to illustrate potential applications.

Model element	Parameter	Question / Data
Network	number of active individual / group connections.	Q. on who talks to whom about energy.
Threshold	θ	Q. on house type, tenancy and income.
Node archetypes	α, β, γ	Defra types of pro-enviro. behaviour

Modelling Scenarios

- Different **scenarios** studied by varying *dynamical model* and *network parameters*.

	Baseline	Seeded	Community	Incentives	Snowball
Model Param.	Do Nothing	Give efficiency measure to some (random) individuals	Give efficiency measure to whole communities.	Advertise a money off scheme.	Recommend-a-friend discount voucher scheme.
Links	Data based	–	–	–	**Increase**
Threshold	Data based	–	–	**Lower**	**Lower**
Initial Seed	Unforced	**Random**	**Target**	–	–

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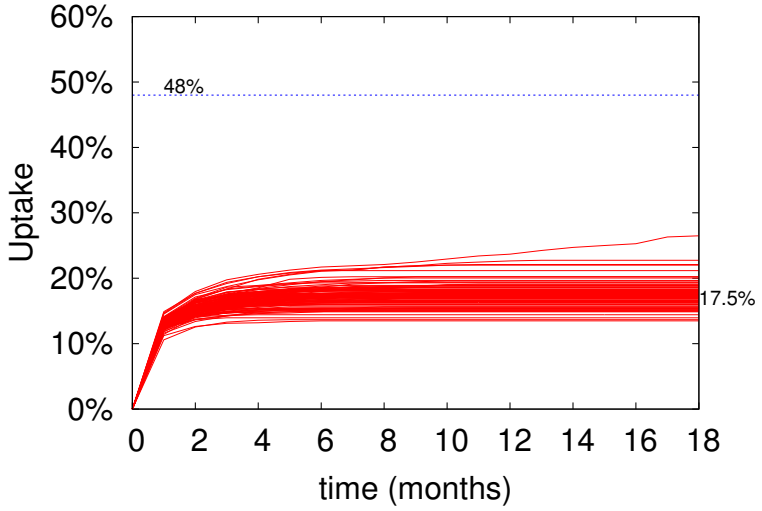
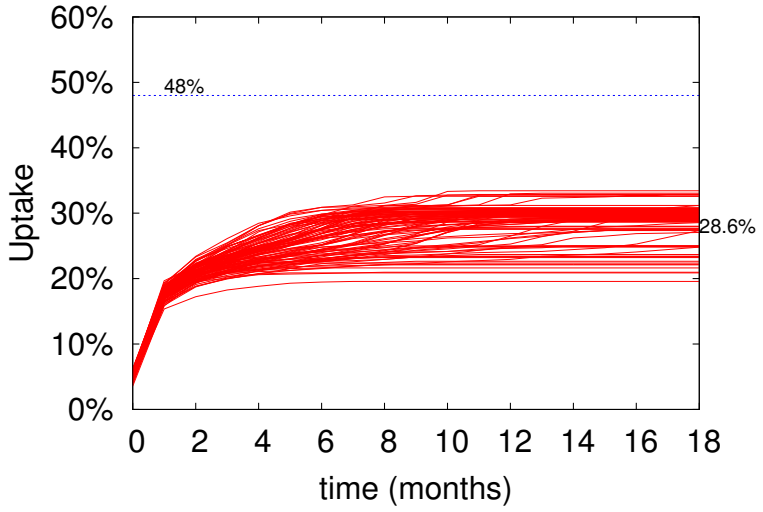
Example model results

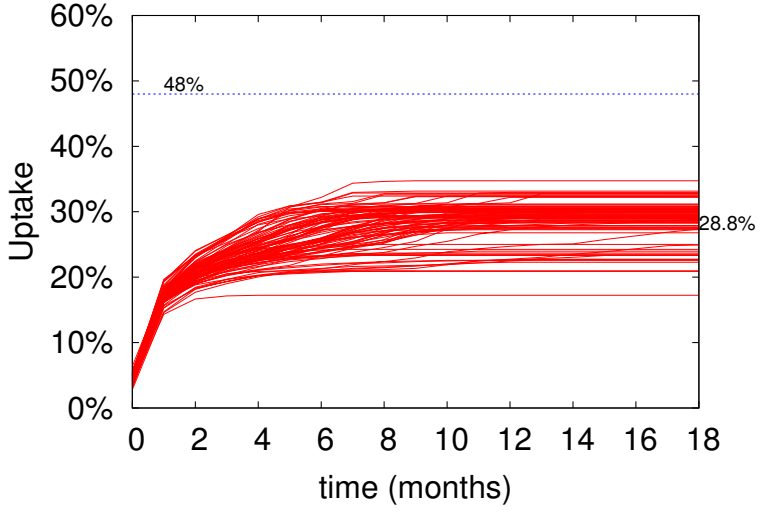
Baseline



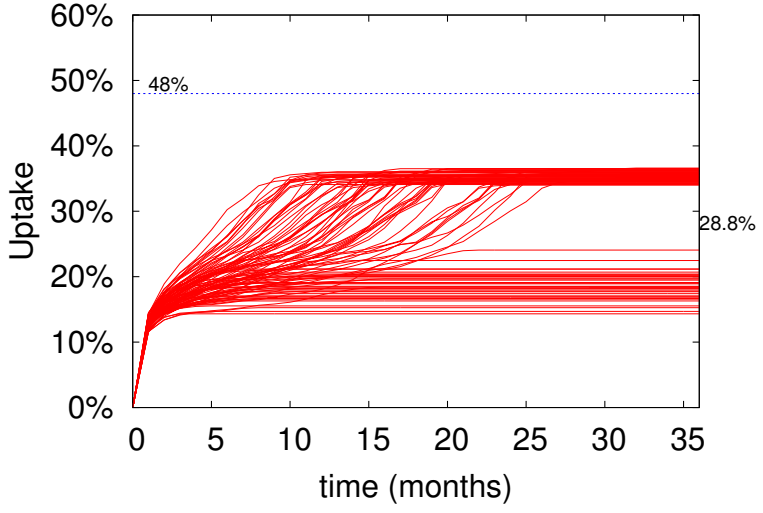
Seeded



Community

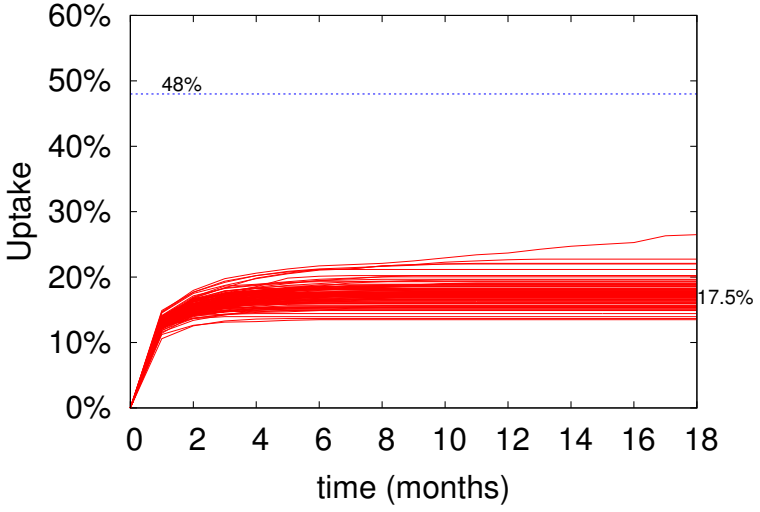


Incentives

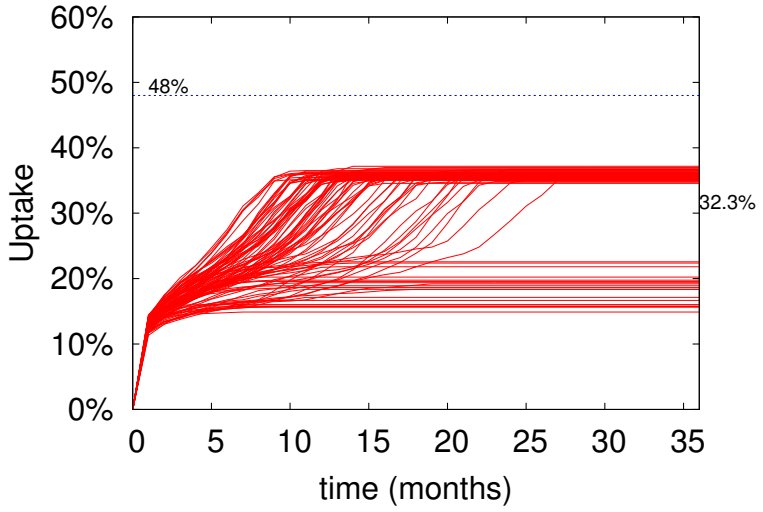


Example model results

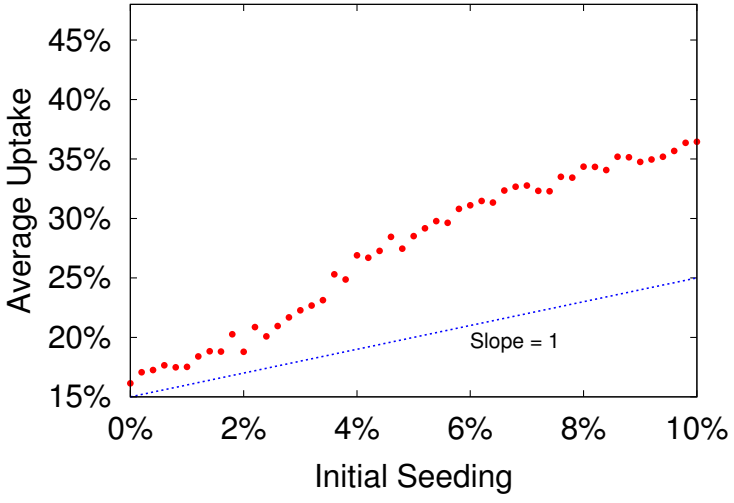
Baseline



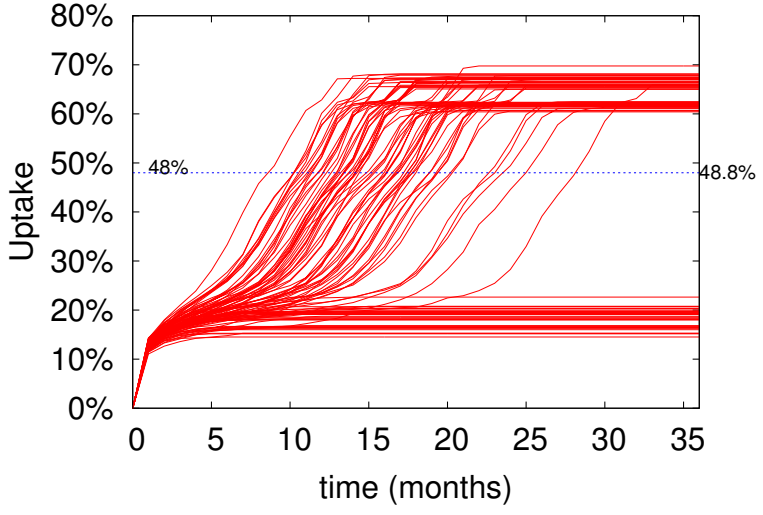
Snowball



Seeding Level



Snowball + Extra



Agent Based Simulation: Role of user learning in council-led smart meter deployment

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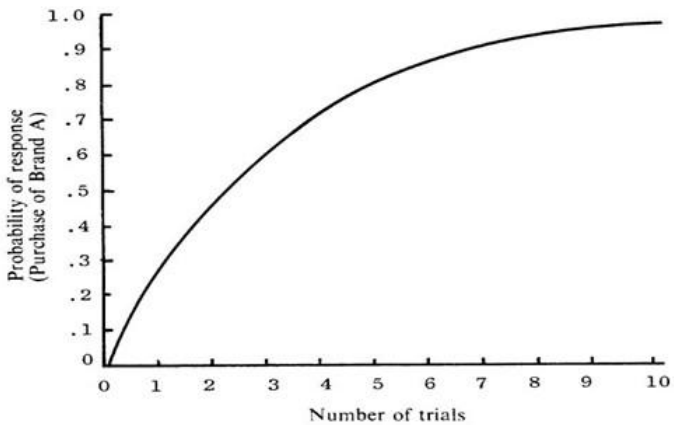
Role of user learning in council-led smart meter deployment

- Smart metering is one of the key interventions that local authority can take to manage and control the energy consumption in Leeds.
- Deploying smart meters to council-owned properties is a type of authoritative technology adoption.
- User learning (i.e. transit from zero knowledge about smart meters to making the best use of them) is very important in this process.

Theoretical Basis[1]

- Technology adoption decisions:
  - Optional Innovation-Decision
  - Collective Innovation-Decision
  - Authority Innovation-Decision

- User learning

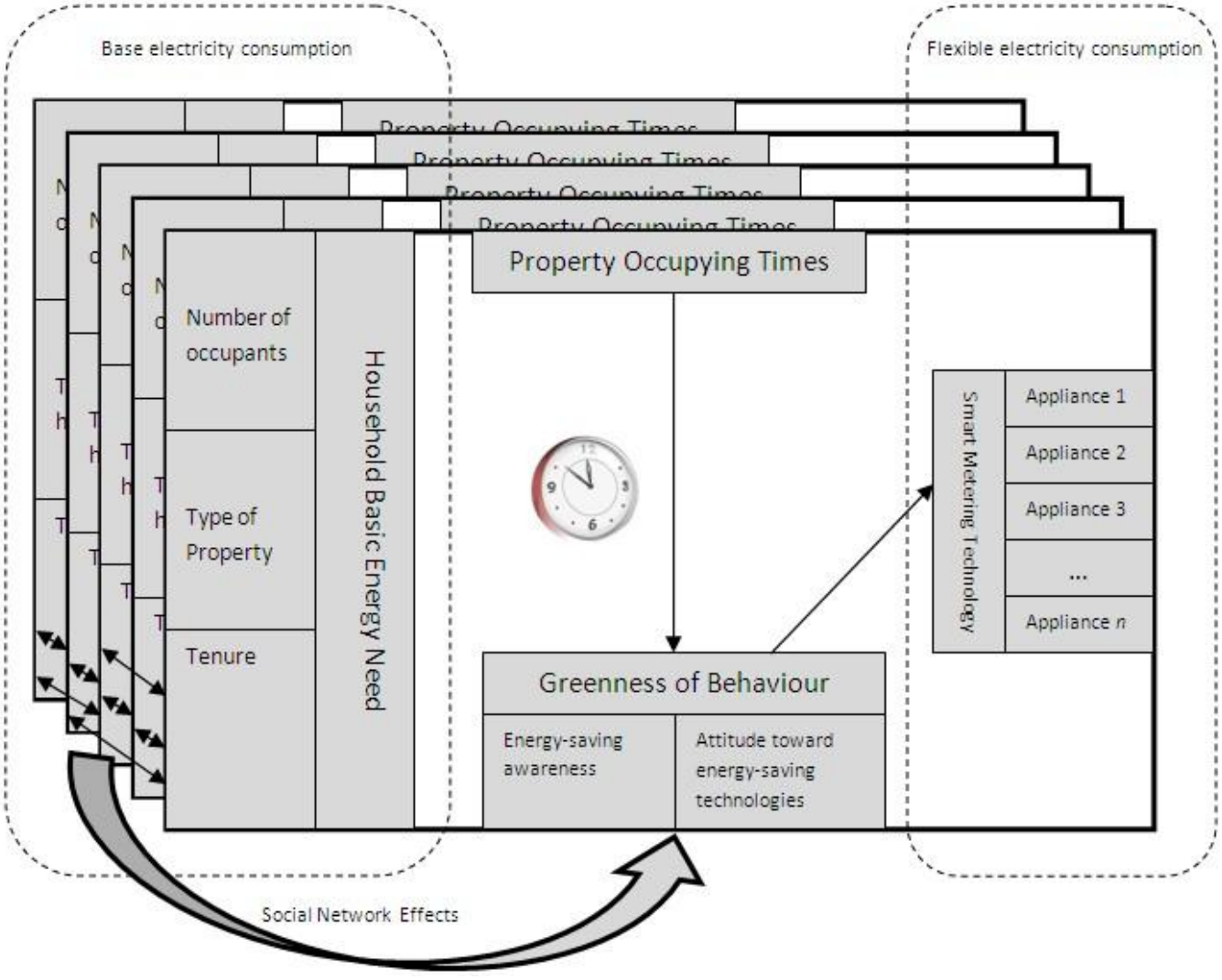


The form of the function is
$P_A = M(1 - e^{-kt})$, where:

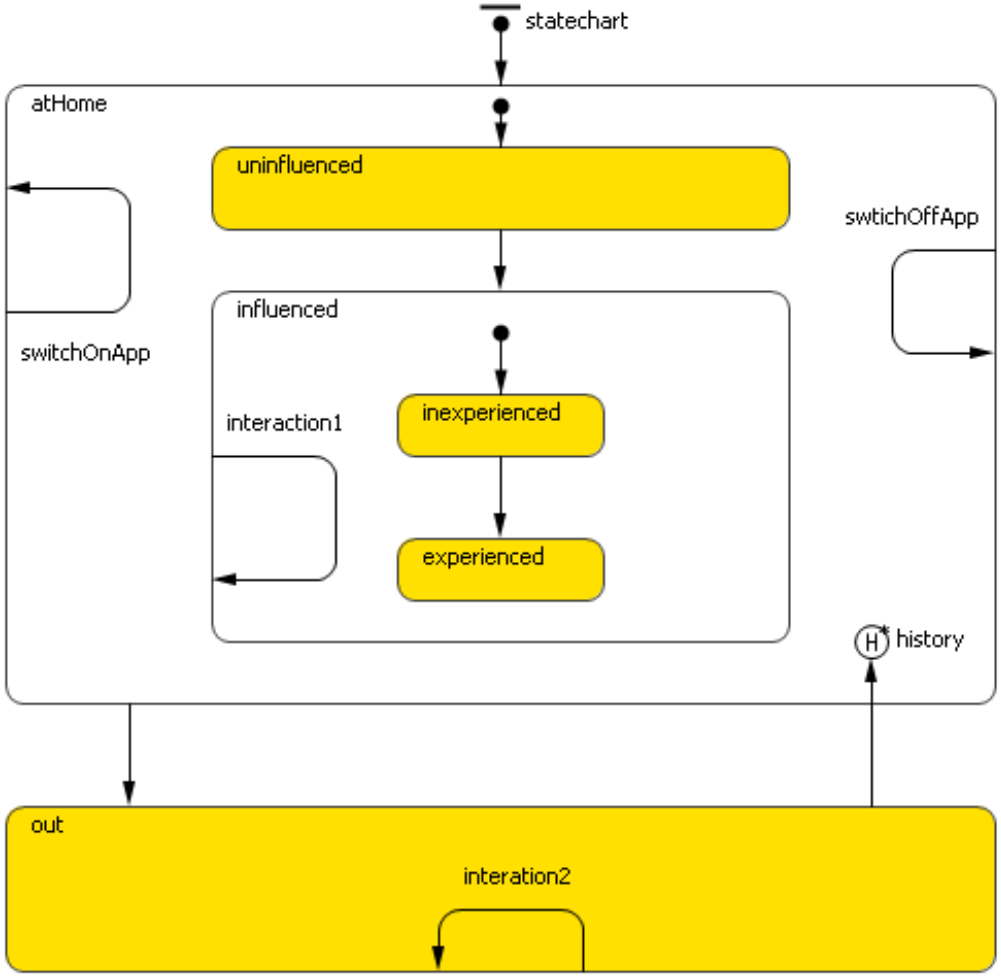
P_A is the probability of purchasing **Brand A**,
M is the maximum attainable loyalty to **Brand A**,
k is a constant expressing the learning rate,
t is the number of reinforced trials

[1] Bennett and Mandell (1969)

Overview of the ABS model



Behaviour of Residential Energy Consumer Agents

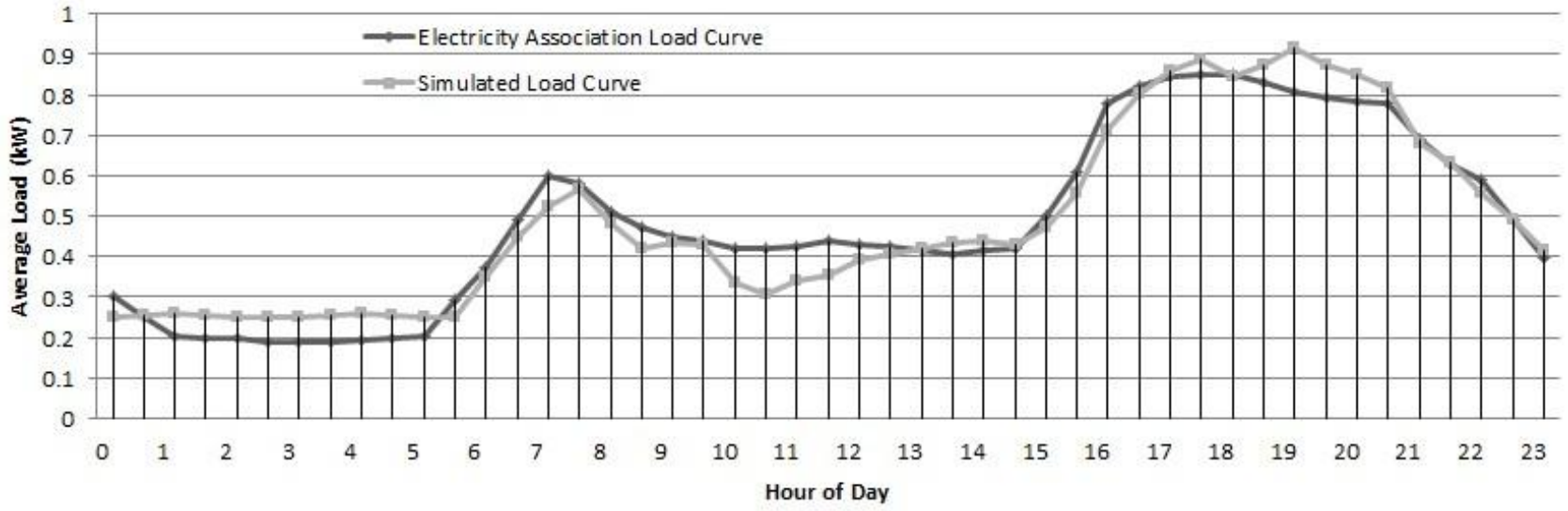


- Empirical data for the simulation model from Leeds survey.
- Developed archetypes of residential energy consumers[2].

[2] Zhang *et al.*, 2012

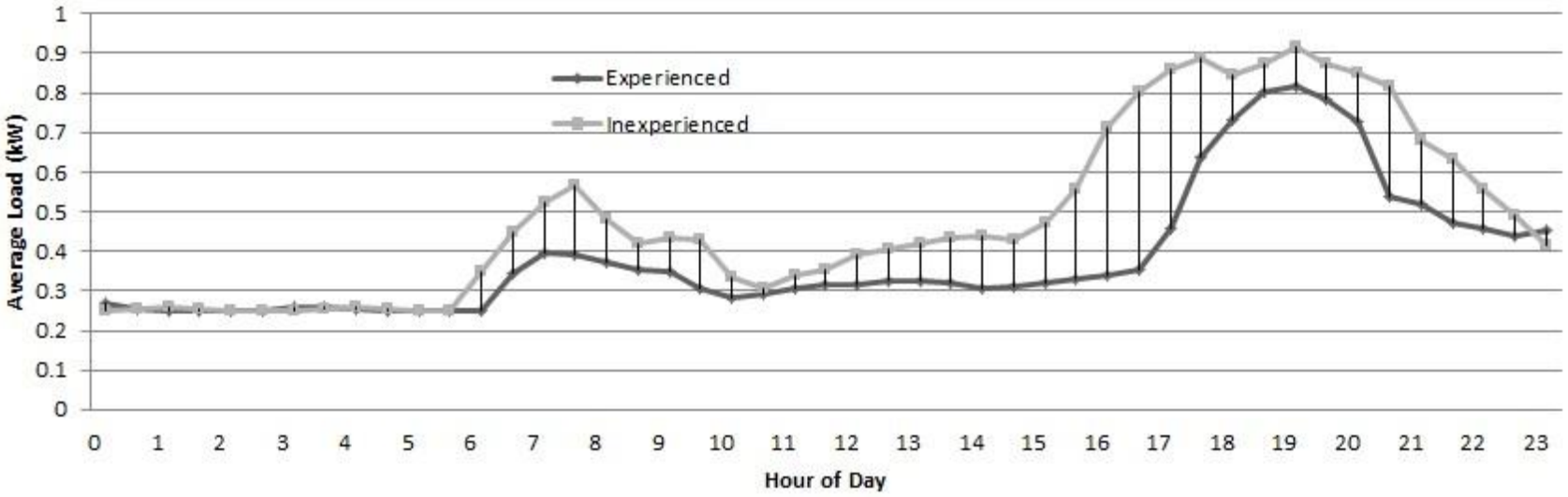
Simulation Experiments

- Simulated Load Curve vs. Real Load Curve:



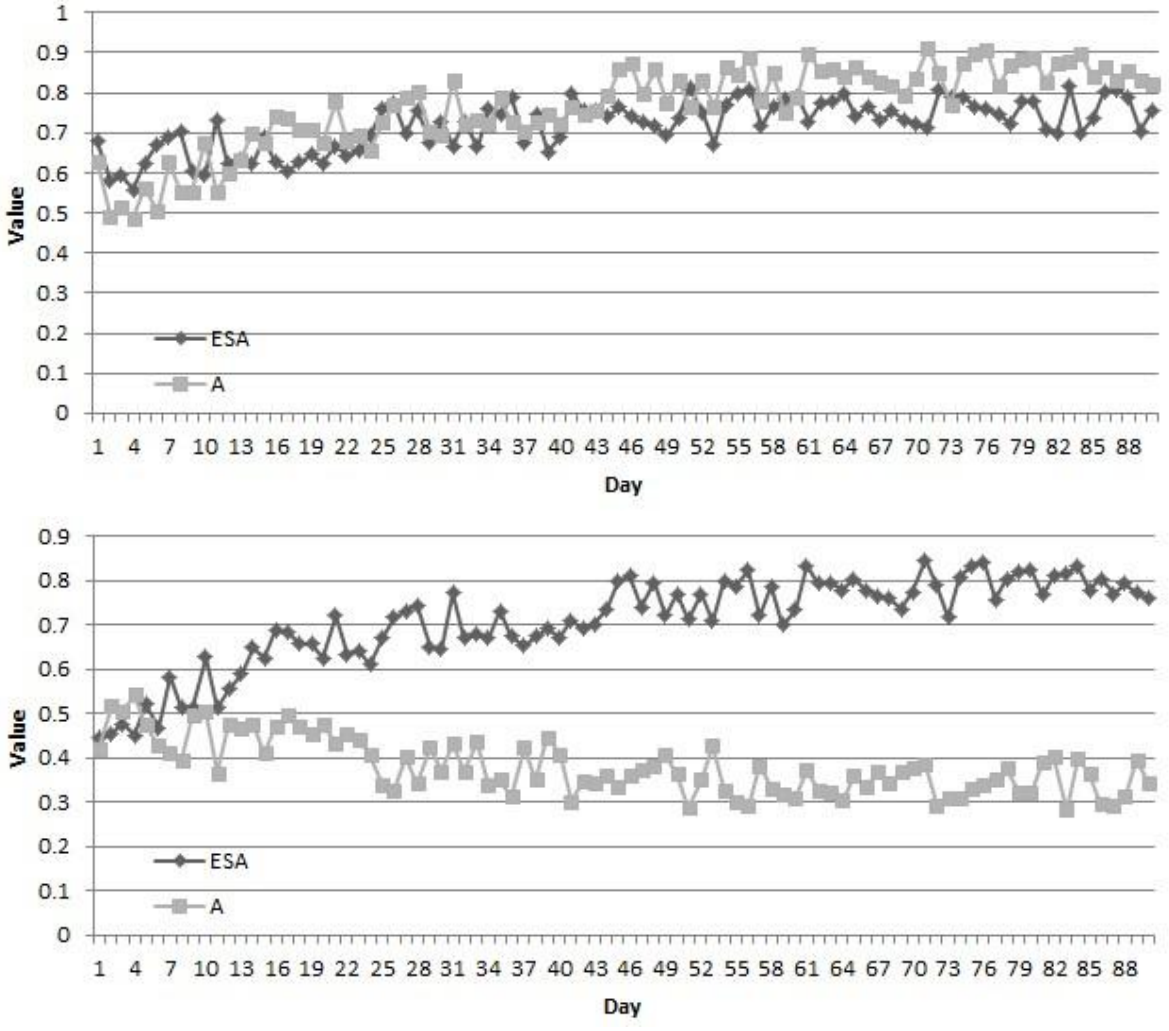
Simulation Experiments

- The effect of smart metering



Simulation Experiments

- Continuers vs. Discontinuers



Insights and lessons learned

- Developed complexity science models of city level domestic energy users:
  - network and ABS models of different aspects,
  - populated with data from real-world.
- Network models comparative rather than predictive.
  - social network interactions are important,
  - trust in various sources of information matters.
- ABS can produce simulation results to reflect real-world,
  - use to predict future effect of smart metering,
  - can look at possible effect of discontinuers.
- Complex systems models could be used for aiding policy decisions.

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