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wholeSEM 3rd annual conference

Session 2a: Integrating society within energy systems modelling

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Integrating social practice and economic rationality principles in household energy demand modelling

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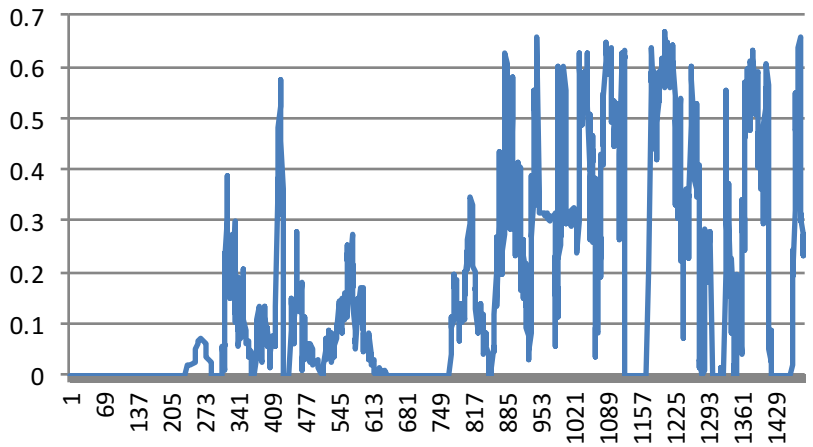
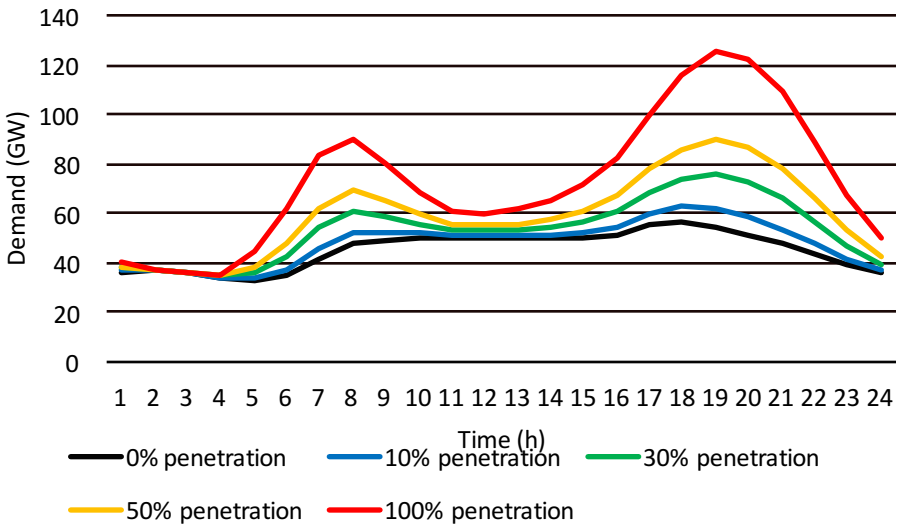
Structure of the presentation

- Emerging challenges for power systems
- Role of demand side in emerging setting
- Economic rationality / utility maximization framework
- Social practice framework
- HOPES model
- INPUTS project

Emerging challenges for power systems



- Under-utilised conventional generation needs to remain in the system as a “back-up” energy source and flexibility provider



- Under-utilised generation and network capacity needs to be built in order to cover new demand peaks

COST EFFICIENCY?

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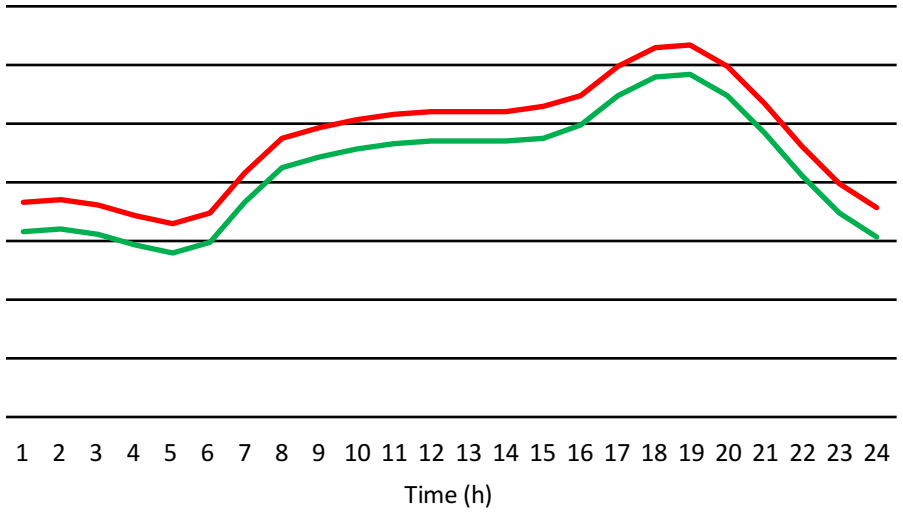
Role of demand side in addressing emerging challenges

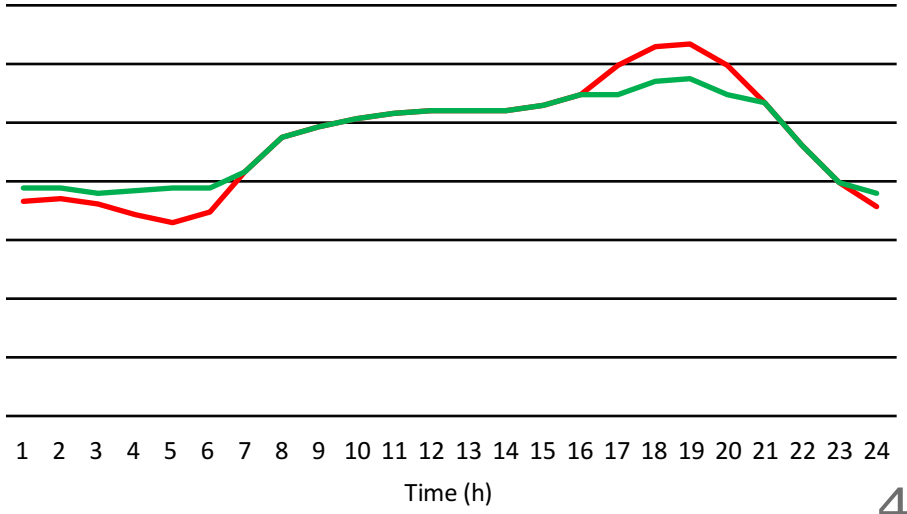
- **Energy efficiency**
  - ➢Improved insulation of buildings
  - ➢Use of efficient electrical appliances
  - ➢Changes in consumers' behavior

Overall reduction of generation and network requirements



- **Demand flexibility / redistribution**
  - ➢Shift operation of appliances in time
  - ➢Use appliances with storage components > decouple acquisition and consumption of energy

More efficient utilisation of generation and network assets



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Flexible demand appliances

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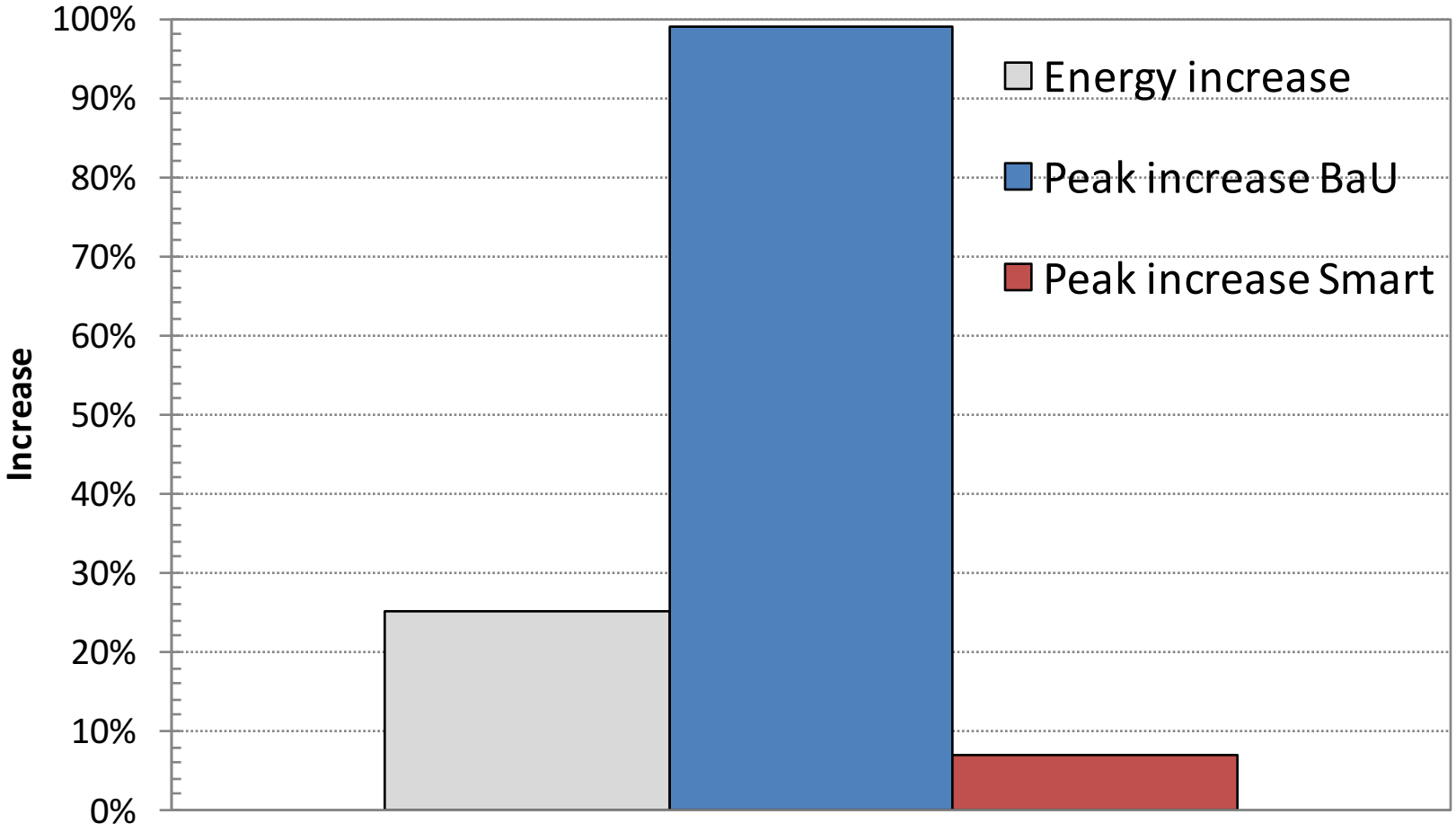
Example: Impact of smart charging of EV

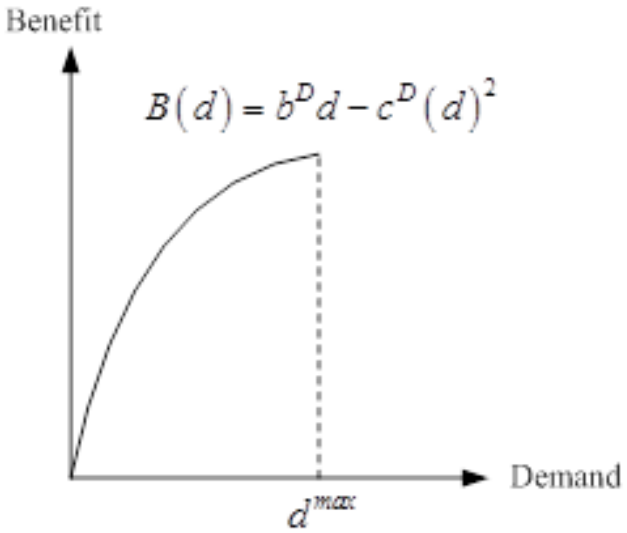


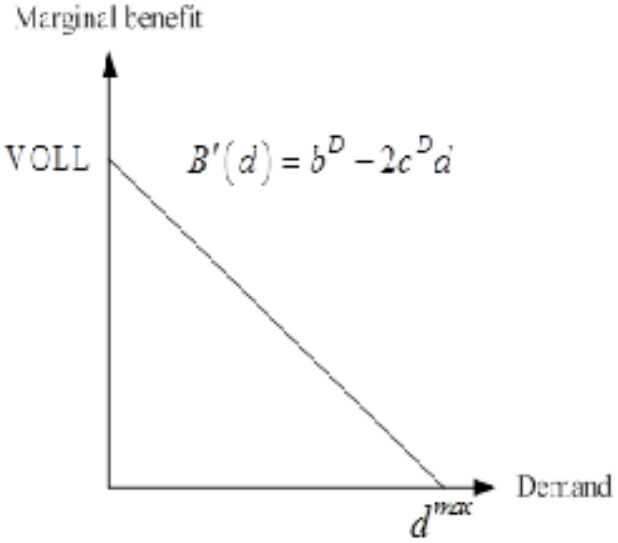
Economic rationality / utility maximisation framework

- The consumers determine the schedule of their appliances by maximizing their perceived utility
  - Based on microeconomics foundations
  - Most common approach in power systems / energy economics literature
- Maximize U = B – λ*P subject to operational constraints
  - U : perceived utility (expressed in monetary terms e.g. £)
  - B : perceived benefit or satisfaction from the use of the appliances, expressing consumers' preferences and requirements (£)
  - λ : electricity price at each time period (£/kW)
  - P : electrical power consumed at each time period (kW)
  - λ*P : electricity payment (£)

Economic rationality / utility maximisation framework

- Benefit function B is a non-decreasing, concave (usually quadratic) function of the instantaneous power demand
- Marginal benefit B' function is a linear decreasing function of instantaneous power demand
  - ➢As the level of demand increases, the extra satisfaction that a consumer perceives is reduced



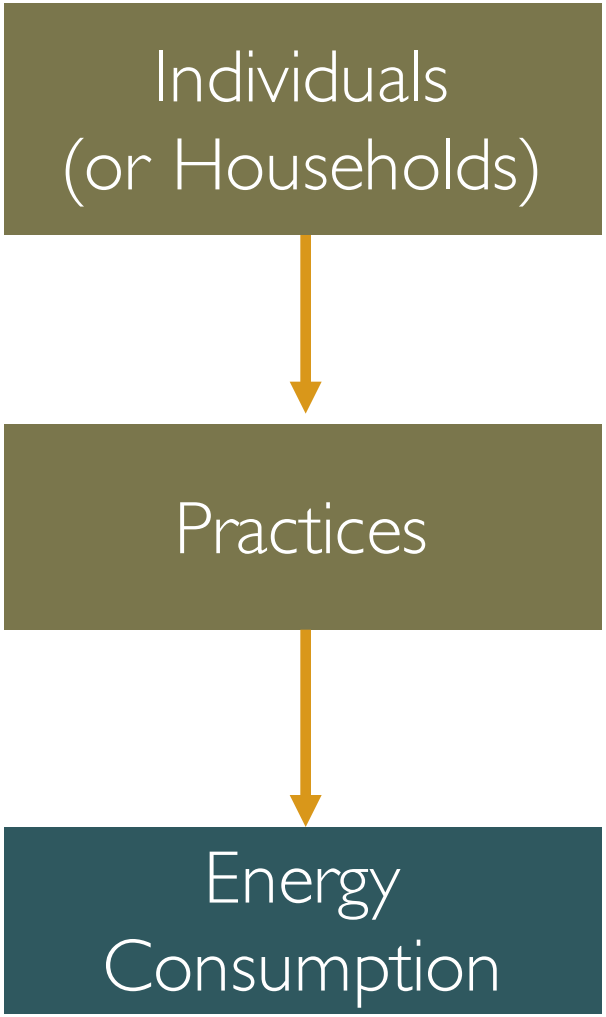


Economic rationality / utility maximisation framework

- Insights from sociology
  - Satisfaction is not a function of electrical power > the satisfaction that the consumers perceive depend on the service quality and is appliance-specific
  - Satisfaction cannot be accurately expressed in monetary terms, even by the consumers themselves
  - Human consumers do not generally behave economically rationally > they do not always consciously think about energy use
  - A number of other factors drive consumers' behavior > perceptions, habits, social interactions etc

Social practice framework

- **Practices**: repeated activities undertaken by people in their daily lives (cooking, cleaning, washing, etc.)
- Individuals are carriers of social practices
- Energy use is driven by the daily rhythms of practices performed in households
- Not only have appliances changed over the years, but the ways in which appliances are used have also changed over the years. This in turn influences energy use



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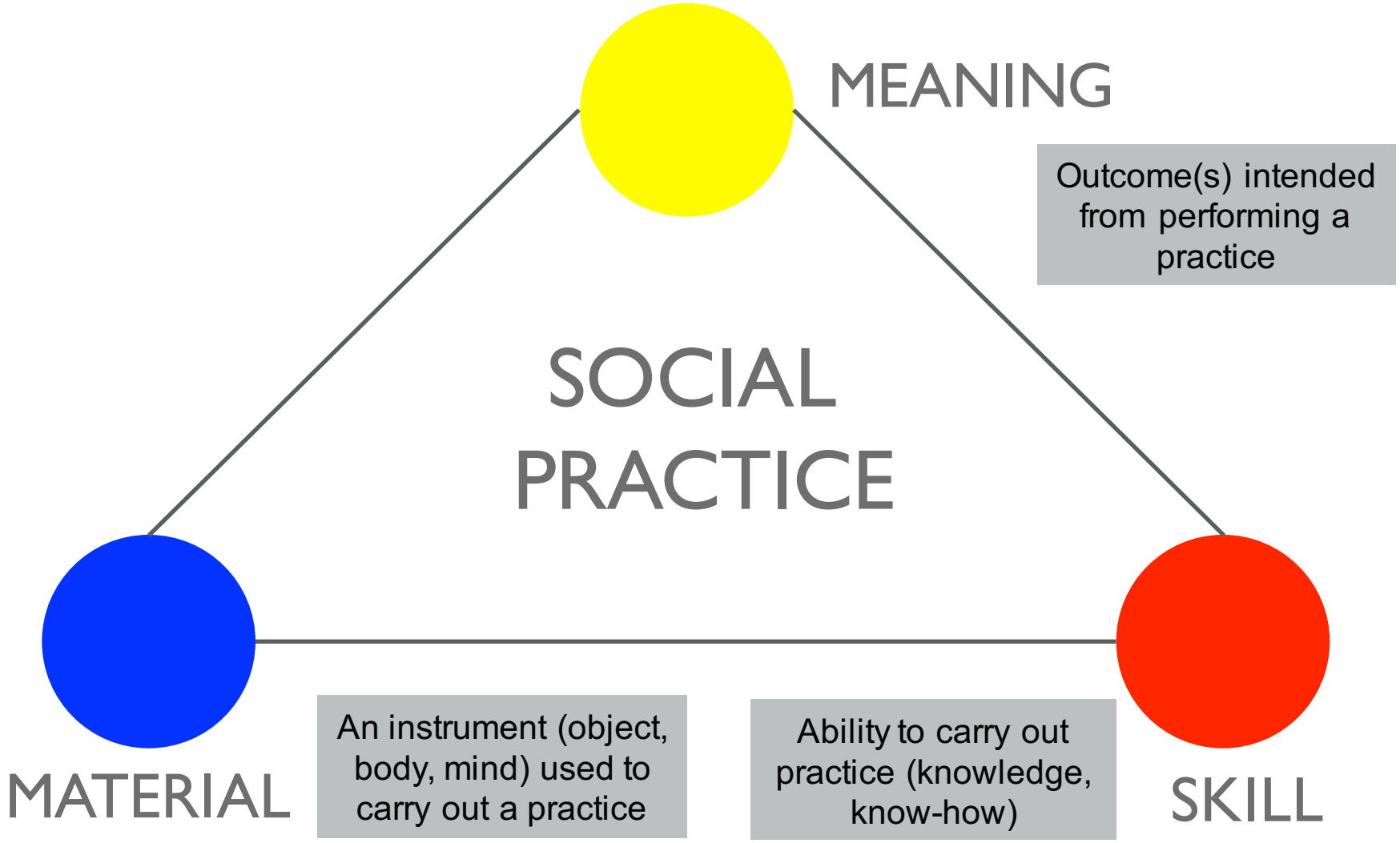
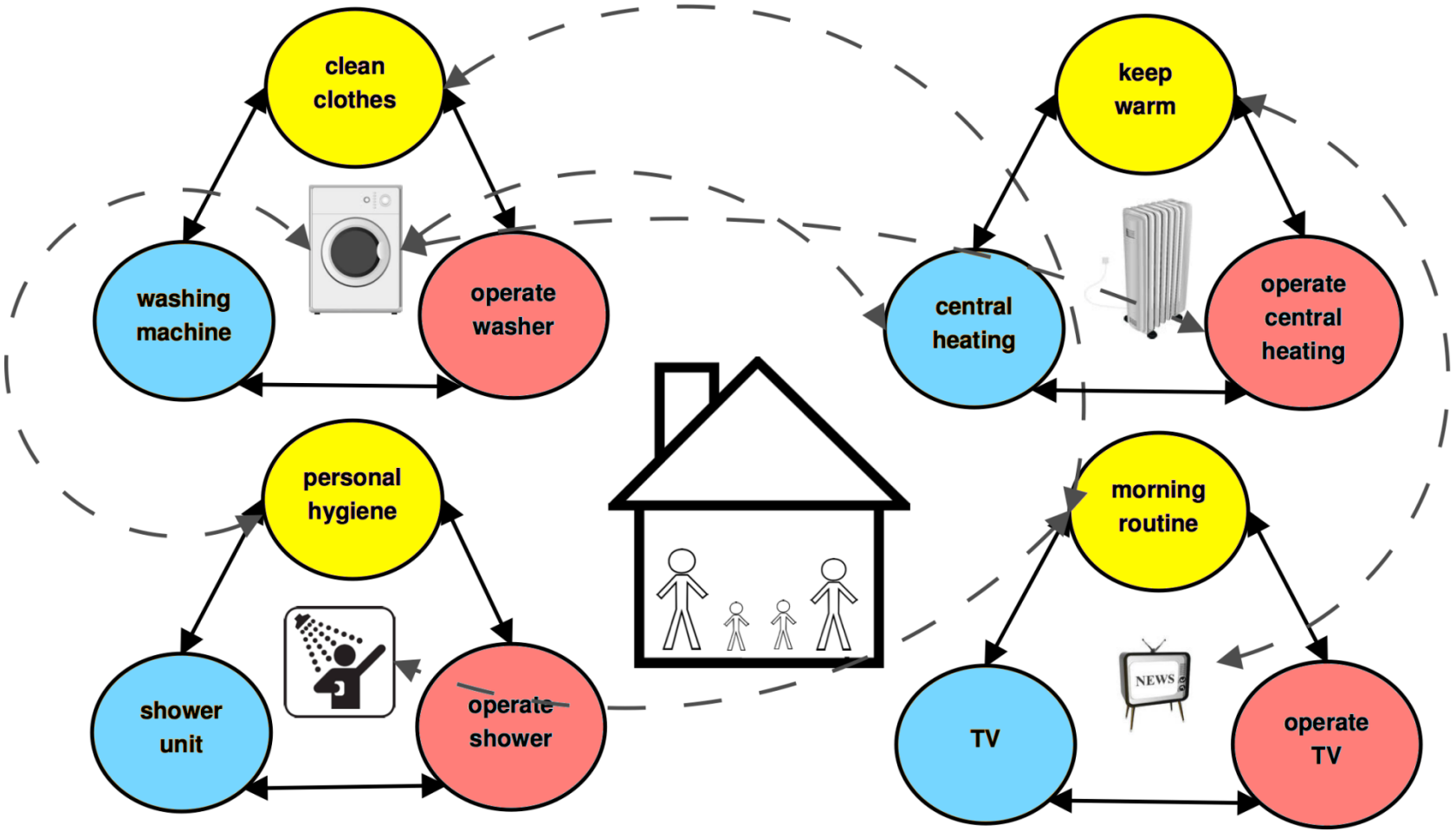
Social practice framework



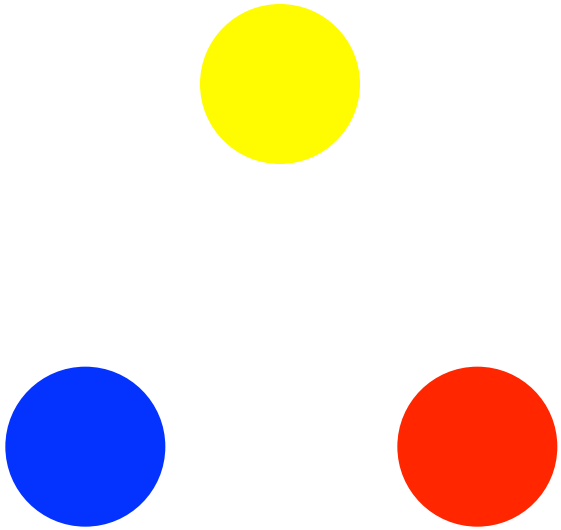
Social practice framework



Agent-based modelling

An approach used to situate an initial population of **agents** (autonomous and heterogenous entities) in a relevant **environment**; allow them to interact according to **simple rules**, and thereby **generate (or 'grow') a macroscopic phenomenon** from bottom-up (Epstein 1999:42)

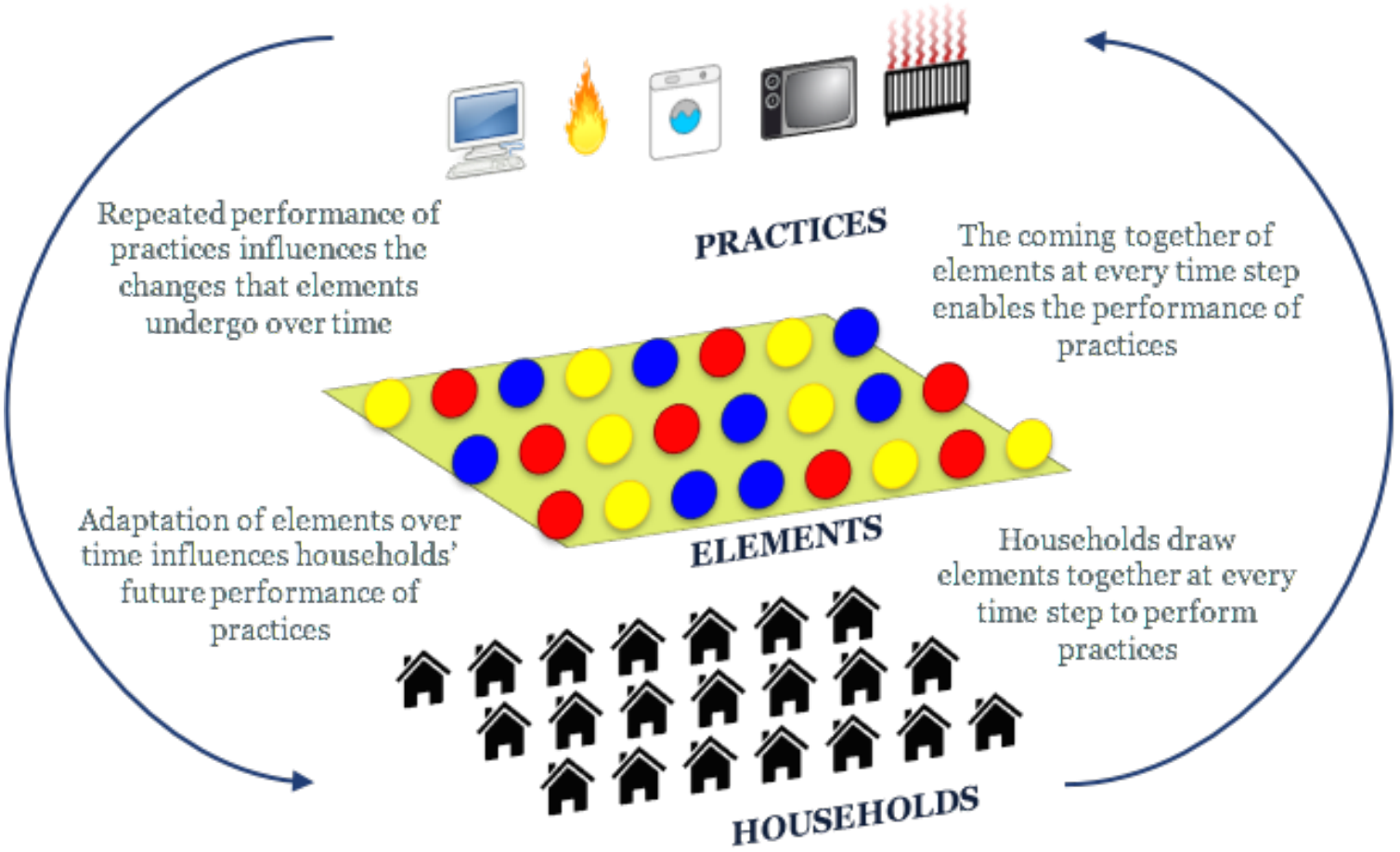
Households



Elements

Practices

Interactions among agents



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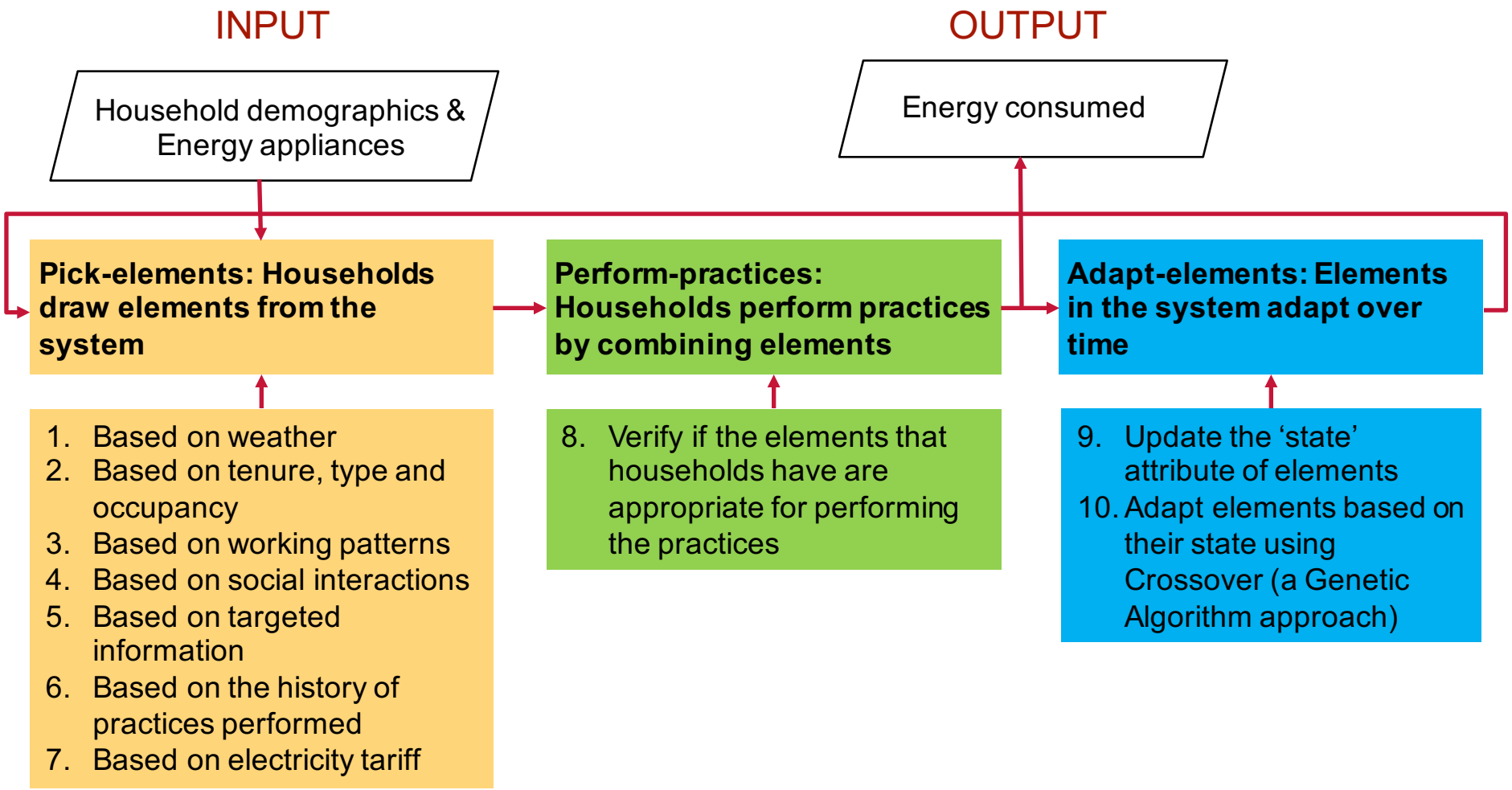
HOuseholds and Practices in Energy consumption Scenarios (HOPES) model



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INtegrated Practice and Utility based perspectives on demand Time Shifting (INPUTS)

- How can we integrate the electricity price in the social practice modeling framework?
- Which data to use in order to calibrate HOPES model?
- How does this more detailed demand side model affect power system outcomes at the operational and planning timescale?
- How does this difference in outcomes depend on:
  - The evolution of the power system: Level of renewables, electrification level of heat and transport sectors etc
  - The electricity market arrangements: how many different prices communicated to the consumers
  - The level of system considered: national level with a very large number of diverse consumers against local neighborhood level with a small number of consumers

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Comments / Questions ?