

# EABSS Workshop 2023

## Co-Creation of Agent-Based Social Simulation Models

**Case Study** (Zhang et al 2010)  
**Modelling Office Building Energy Consumption**

# Related Project: "Future Energy Decision Making for Cities: Can Complexity Science Rise to the Challenge?"

- Project research question: How do city level energy policy interventions (technological; behavioural; organisational) impact on overall energy consumption and energy user behaviour?
- Collaboration between several universities (researchers from different domains)
  - <https://gow.epsrc.ukri.org/NGBOViewGrant.aspx?GrantRef=EP/G059780/1>
  - <https://gow.epsrc.ukri.org/NGBOViewGrant.aspx?GrantRef=EP/G05956X/1>
- Task: Developing models to help decision makers define their current energy situation and then reach balanced decisions in their future energy planning to implementing UK sustainability targets

# Case Study: Context

- Office building energy consumption

- We focus on modelling electricity consumption
- Organisational dilemma
  - Need to meet the energy needs of staff
  - Need to minimise its energy consumption through effective organisational energy management policies/regulations



- Objective

- Test the effectiveness of different electricity management strategies, and solve practical office electricity consumption problems

# Case Study: Modelling

- Electricity consumption
  - Base electricity consumption: security devices, information displays, computer servers, shared printers and ventilation systems.
  - Flexible electricity consumption: lights and office computers.
- Current electricity management technologies
  - Each room is equipped with light sensors
  - Each floor is equipped with half-hourly metering system
- Strategic questions to be answered
  - Automated vs. manual lighting management
  - Local vs. global energy consumption information

# Case Study: Modelling

- We distinguishing base appliances and flexible appliance
  - Examples for **base appliances**
    - Security cameras
    - Information displays
    - Computer servers
    - Refrigerators
  - Examples for **flexible appliances**
    - Lights
    - Desktop computers
    - Printers



# Case Study: Modelling

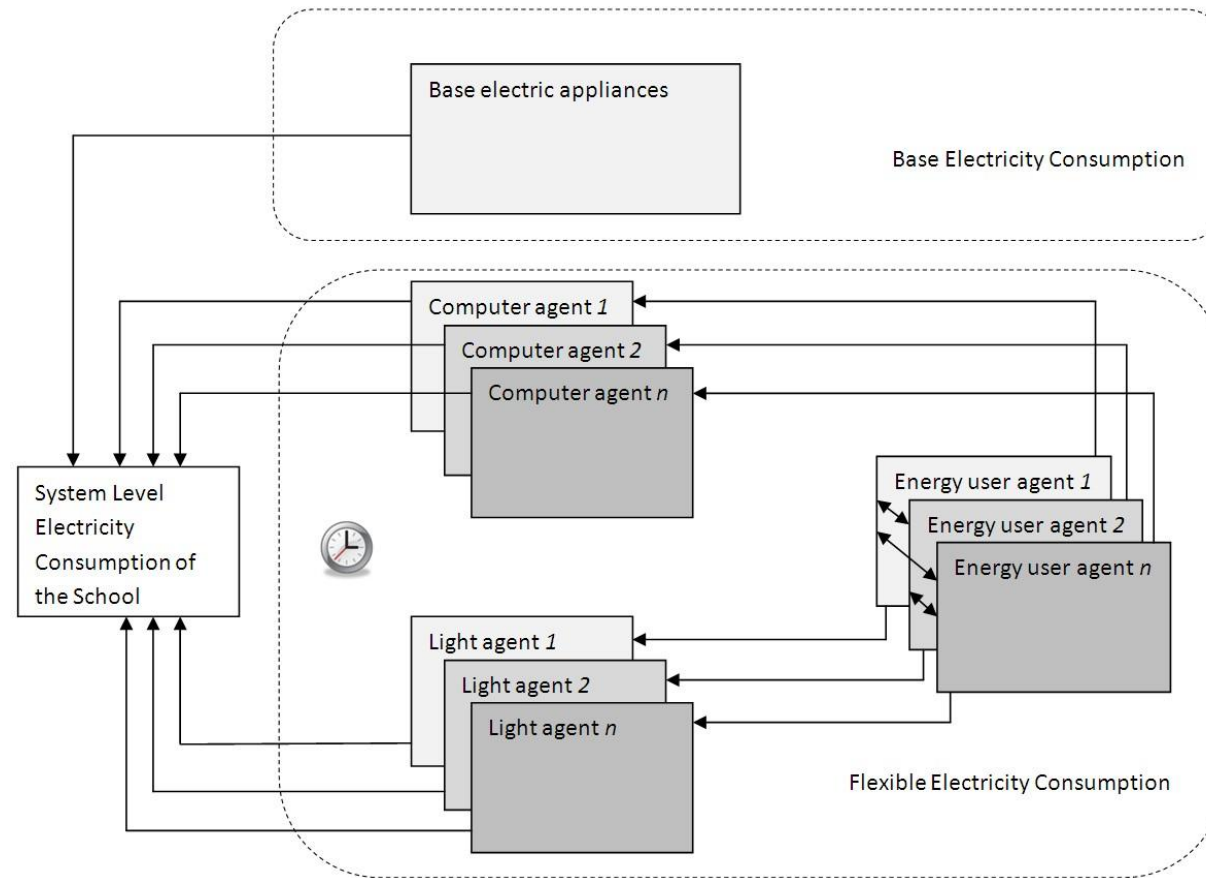
- The mathematical model
  - $C_{total} = C_{base} + C_{flexible}$ 
    - where  $C_{flexible} = \beta_1 * C_{f1} + \beta_2 * C_{f2} + \dots + \beta_n * C_{fn}$
    - and  $C_{f1} \dots C_{fn}$  = maximum electricity consumption of each flexible appliance
    - and  $\beta_1 \dots \beta_n$  = parameters reflecting the behaviour of the electricity user
      - $\beta$  close to 0 = electricity user switches flexible appliances always off
      - $\beta$  close to 1 = electricity user leaves flexible appliances always on
  - $C_{total} = C_{base} + (\beta_1 * C_{f1} + \beta_2 * C_{f2} + \dots + \beta_n * C_{fn})$

# Case Study: Modelling

- Knowledge gathering
  - Consultations with the school's director of operations and the university estate office
  - Survey amongst the school's 200 PhD students and staff on electricity use behaviour (response rate 71.5%)
- User stereotypes
  - Working hour habits
    - Early birds, timetable compliers, flexible workers
  - Energy saving awareness
    - Environment champion; energy saver; regular user; big user

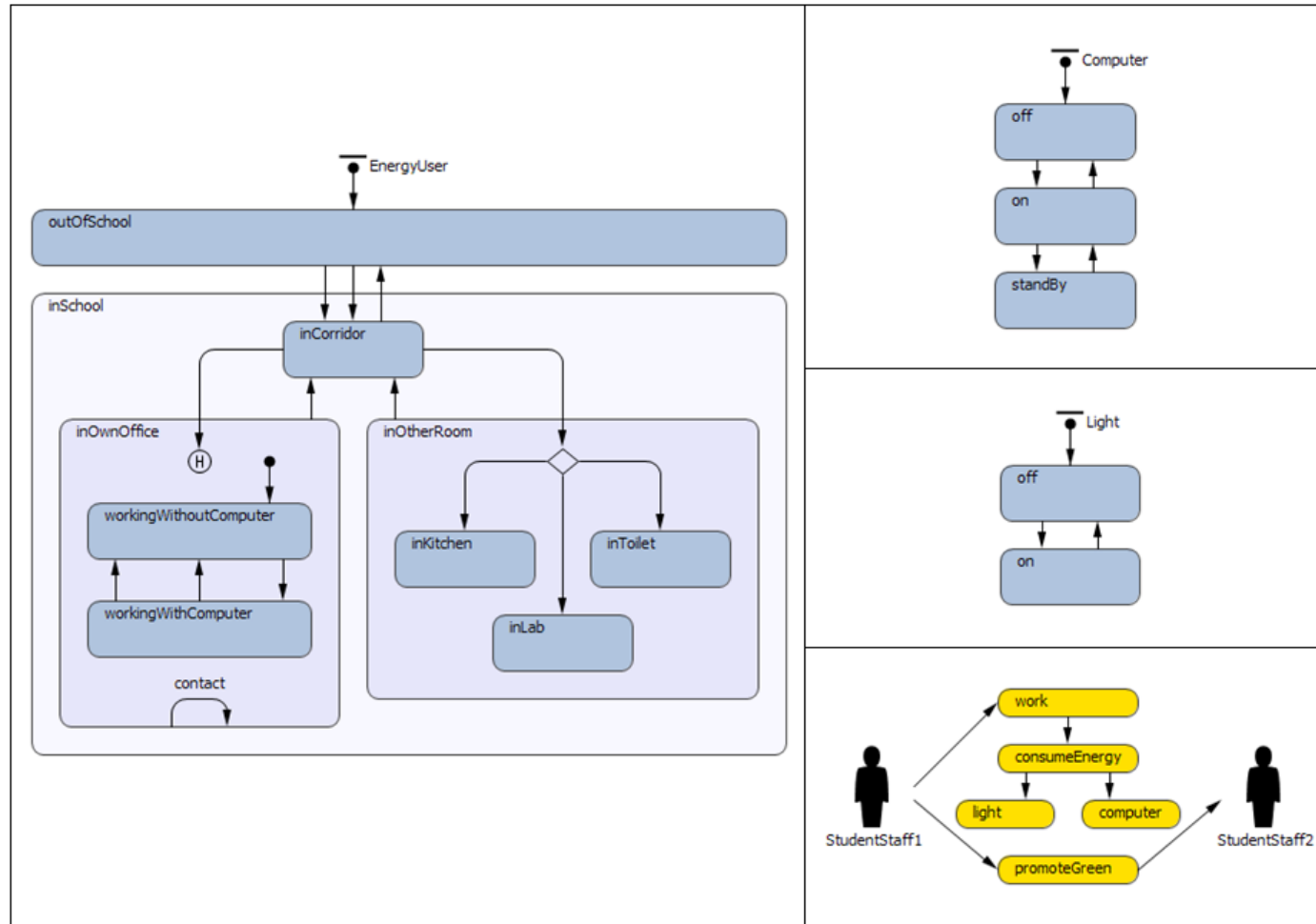
# Case Study: Modelling

- Conceptual model





# Case Study: Modelling



# Case Study: Implementation

The screenshot displays the AnyLogic University [EDUCATIONAL USE ONLY] interface. The main workspace shows a statechart with three states: 'vacant', 'partlyInUse', and 'fullyInUse'. Transitions are labeled 'statechart'. The 'vacant' state is connected to 'partlyInUse', and 'partlyInUse' is connected to 'fullyInUse'. The 'fullyInUse' state is also connected back to 'partlyInUse'. The 'vacant' state is also connected to 'partlyInUse'.

The left sidebar shows a project tree for 'EnergyProject2\*' with sub-projects: Computer, Light, Main, Office, User, WriteToFile, and Simulation: Main. The 'Office' sub-project is selected.

The central workspace lists variables and functions for the 'Office' sub-project:

- officeName
- officeSize
- numberOfComputers
- numberOfLights
- timeOfficeUnoccupied
- energyConsumption
- Boundaries of office
- shape\_line
- Users in this office: users
- Computers in this office: computers
- lights in this office: lights
- SwitchOffLights
- calculateEnergyConsumption
- animation
- joinOffice
- leaveOffice

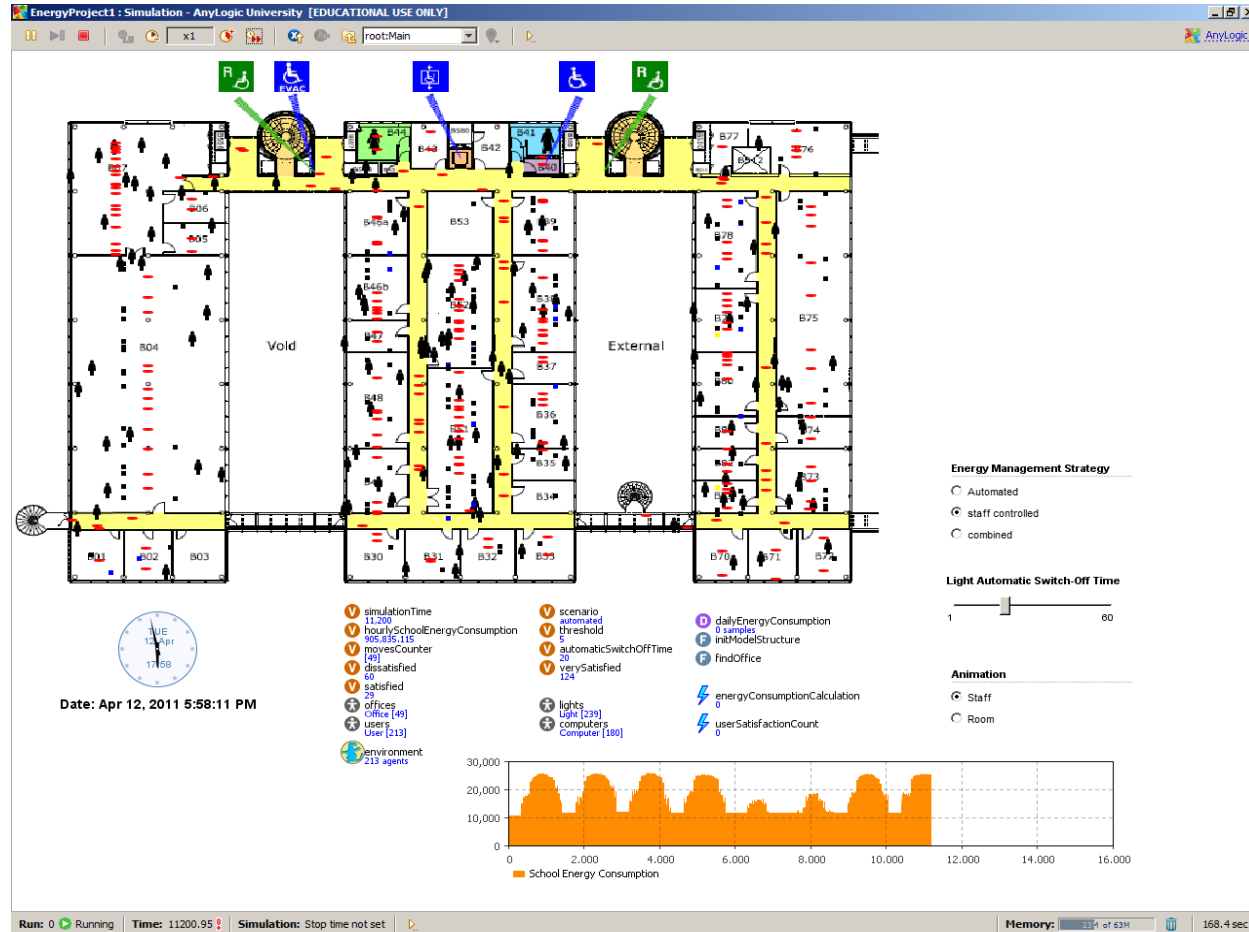
The bottom panel shows the configuration for the 'SwitchOffLights - Event':

- Name: SwitchOffLights
- Show name:
- Ignore:
- Show at runtime:
- Trigger type: Timeout
- Mode: Cyclic
- First occurrence time (absolute): 0
- 26.02.2010 12:44:01
- Recurrence time: 1
- Action:

```
if (timeOfficeUnoccupied + get_Main().automaticSwitchOffTime
    for (Light lgt : lights) {
        lgt.lightOn = false;
```

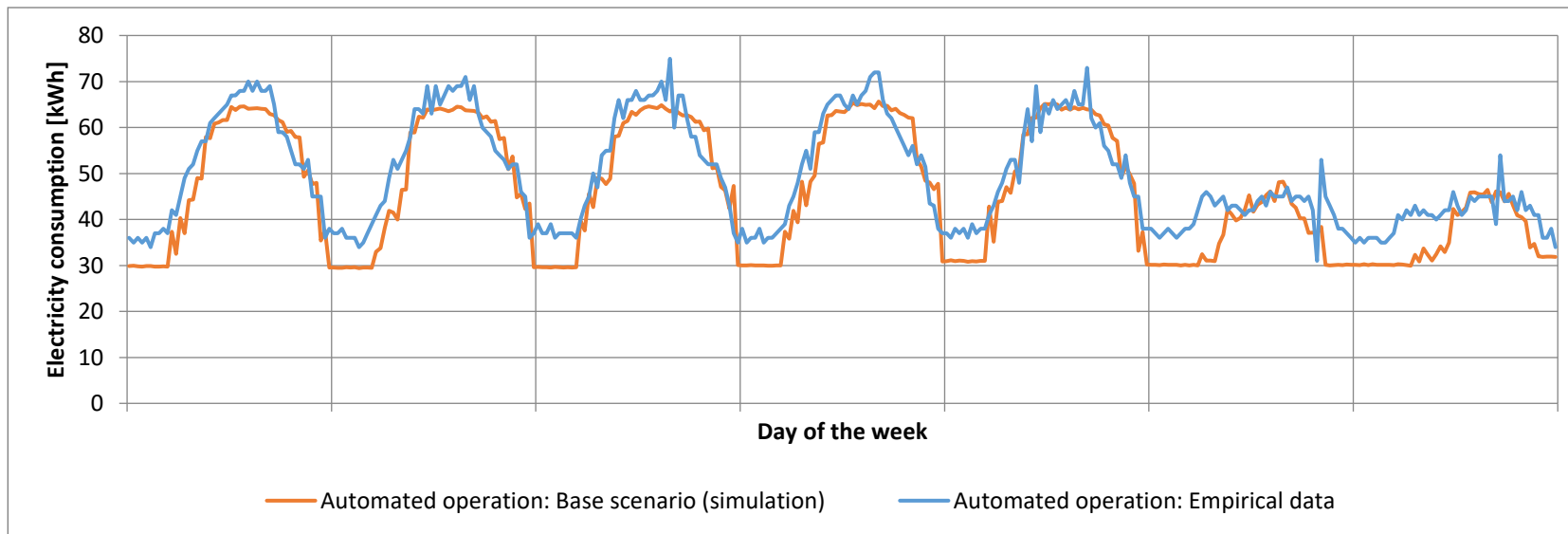
The bottom status bar shows 'SwitchOffLights - Event', 'Selection', and 'X=445, Y=258'.

# Case Study: Experimentation



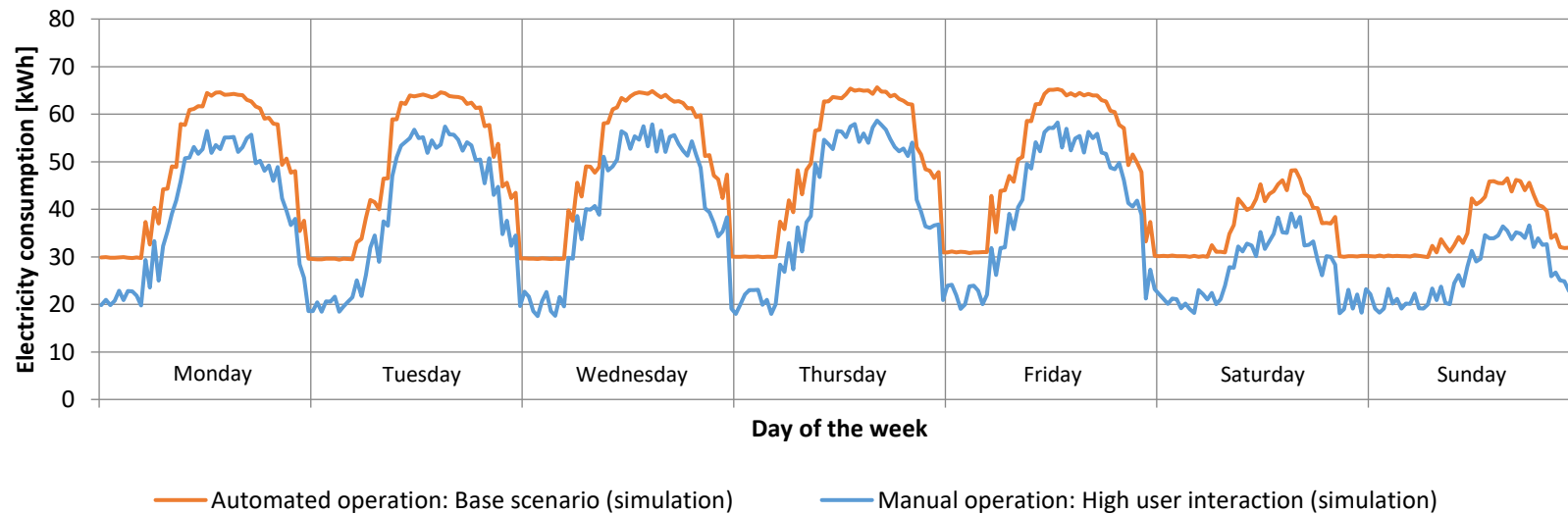
# Case Study: Experimentation

- Validation
  - Comparing **simulation** and **empirical results**



# Case Study: Experimentation

- Scenario #1
  - Comparing **automated** and **manual operation** (high user interaction)



Any Questions?



# References & Related Publications

- References

- Zhang T, Siebers PO and Aickelin U (2010) 'Modelling Office Energy Consumption: An Agent Based Approach'. In: Proceedings of the 3rd World Congress on Social Simulation (WCSS2010), 5-9 September, Kassel, Germany

- Related Publications

- Zhang T, Siebers PO and Aickelin U (2011) 'Modelling Electricity Consumption in Office Buildings: An Agent Based Approach'. Energy and Buildings, 43(10) pp. 2882-2892
- Zhang T, Siebers PO and Aickelin U (2012) 'A Three-Dimensional Model of Residential Energy Consumer Archetypes for Local Energy Policy Design in the UK'. Energy Policy, pp. 102-110
- Zhang T, Siebers PO and Aickelin U (2016) 'Simulating User Learning in Authoritative Technology Adoption: An Agent Based Model for Council-led Smart Meter Deployment Planning in the UK'. Technological Forecasting and Social Change, 106, pp.74-84
- Siebers PO and Klügl F (2017) 'What Software Engineering has to offer to Agent-Based Social Simulation'. In: Edmonds B and Meyer R (Eds). Simulating Social Complexity: A Handbook - 2e