Applications of agent-based modelling in energy transitions for industrial networks and urban systems

Dr Koen H. van Dam
Imperial College London
Introducing complexity-oriented methods into life-cycle thinking
7th June 2024

Climate Compatible Growth

UKaid from the British people

"The views expressed in this material do not necessarily reflect the UK government's official policies."

University Partnership:

University of Cambridge
The Open University
Climate Parliament
University of Strathclyde Glasgow
University of Oxford
Centre for Global Equality
UCL
Loughborough University
STEER – Centre for Sustainable Transitions: Energy, Environment and Resilience
KTH Vetenskap och Konst
Imperial

ENERGY TRANSITION COUNCIL

MULTILATERAL PLATFORM

with over 40 governments, multilateral development banks, technical partners and other international organisations

RAPID RESPONSE FACILITY (RRF)

delivering prompt and demand-driven technical assistance to address transition barriers and unlock larger-scale, longer-term finance

Co-chaired by the UK and the Philippines

HIGH-TRUST DIALOGUE

mobilising, aligning and coordinating support for the clean energy transition

COLLABORATING

on key areas, including coal retirement, renewables deployment, energy efficiency and a just transition

DIALOGUES AND RRF SUPPORT set to continue to at least 2025

https://www.energytransitioncouncil.org/

ENERGY TRANSITION COUNCIL

15

ETC NATIONAL DIALOGUES

to identify energy transition priorities, shared challenges and sources of international support

8

ETC MINISTERIALS

to raise confidence that we are able to deliver on shared challenges; secure ministerial buy-in for the energy transition agenda; and foster senior-level, high-trust dialogue

100s

of smaller, focused strategy sessions and working groups to address and unblock specific technical challenges impeding the energy transition

30+ RRF TECHNICAL ASSISTANCE REQUESTS

about energy efficiency, just transition and clean cooking

with more in the pipeline across

11 ETC COUNTRIES

responded to by

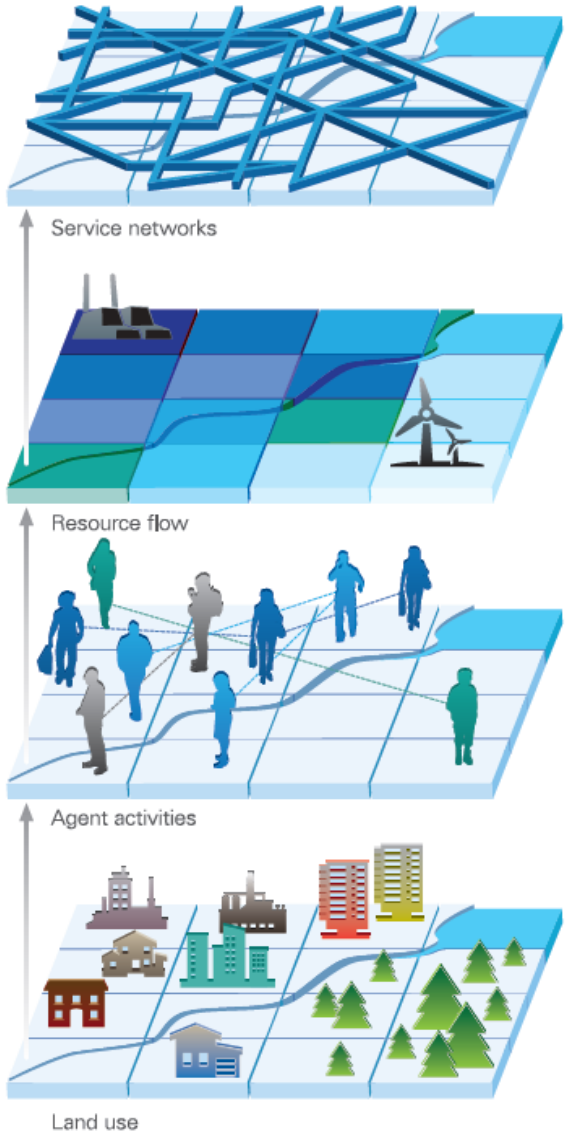
25+ DELIVERY PARTNERS

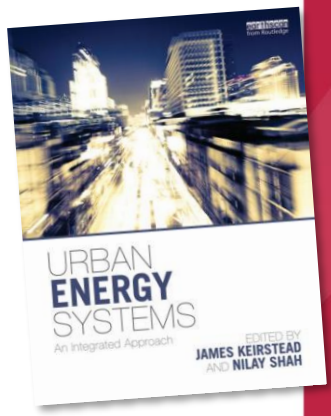
resulting in

significant clean energy commitments made by ETC partner countries, including through the COP26 Global Coal to Clean Power Transition Statement and the COP28 Global Renewables and Energy Efficiency Pledge

Context / Motivation

- Socio-technical systems:
  - Human activities leads to demand for services
  - Resources are used to meet that demand
  - Technologies convert resources
  - Networks to transport resources
- ABM + RTN
- Purpose:
  - Transition to a more sustainable future
  - Test impact of different policies
  - Evaluate alternative technology options, select locations
  - Explore role of behaviour change
- Optimise for costs, emissions, jobs created, etc
- Transitions involving multiple stakeholders
- Scales: national, regional, urban, industry





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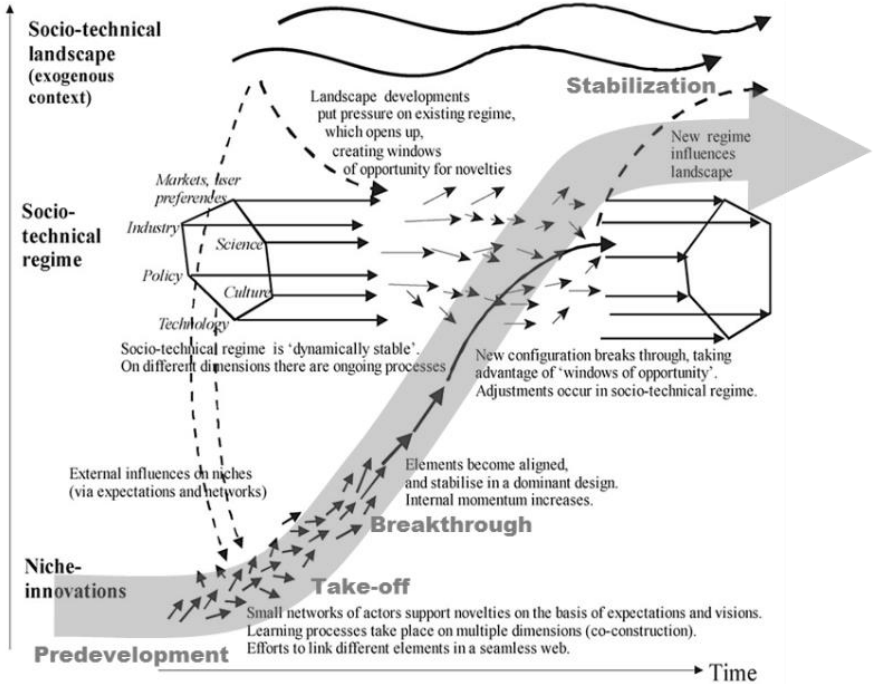
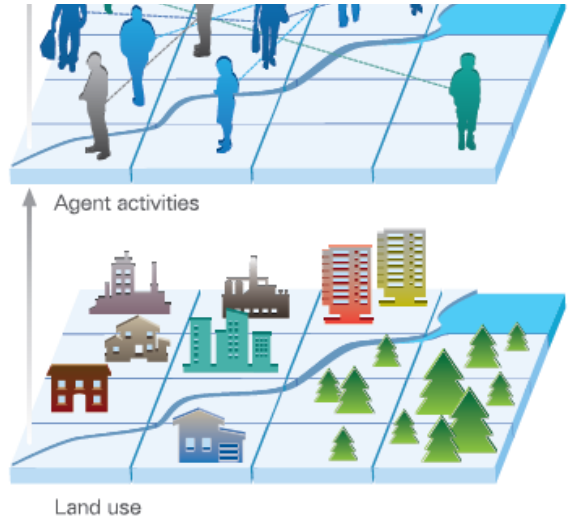
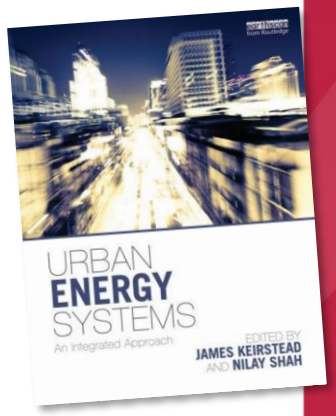
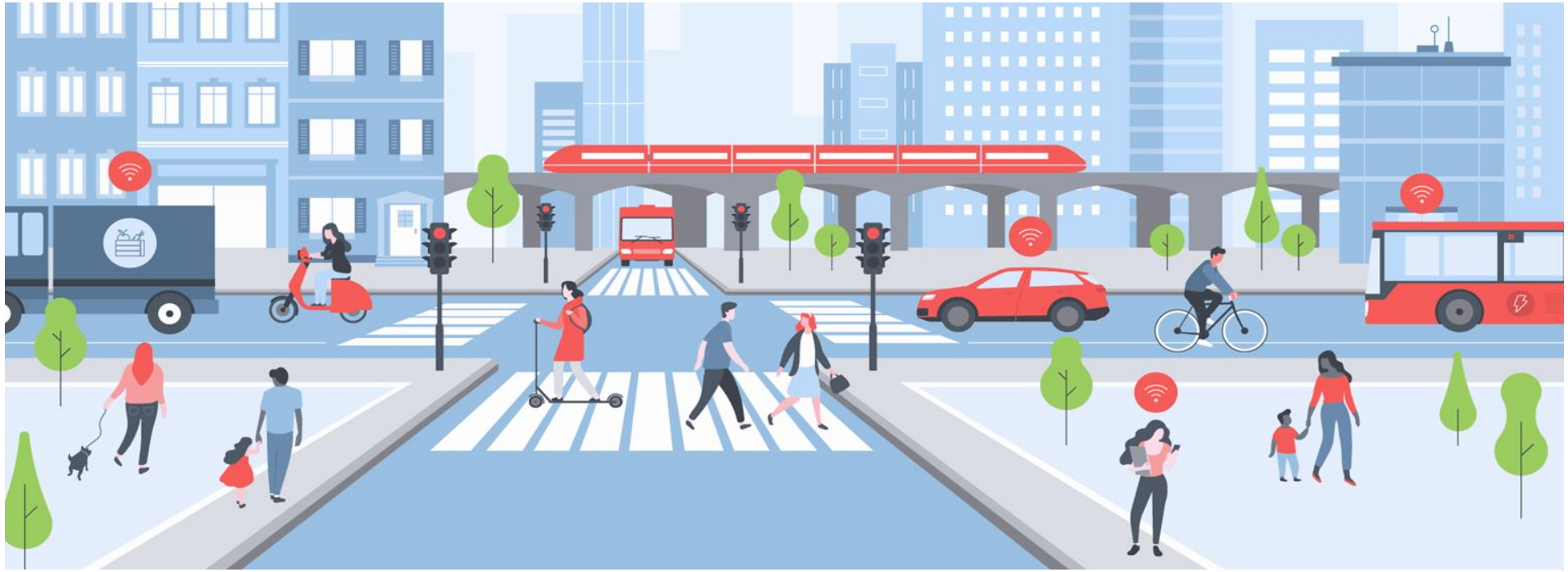
Geels (2002)





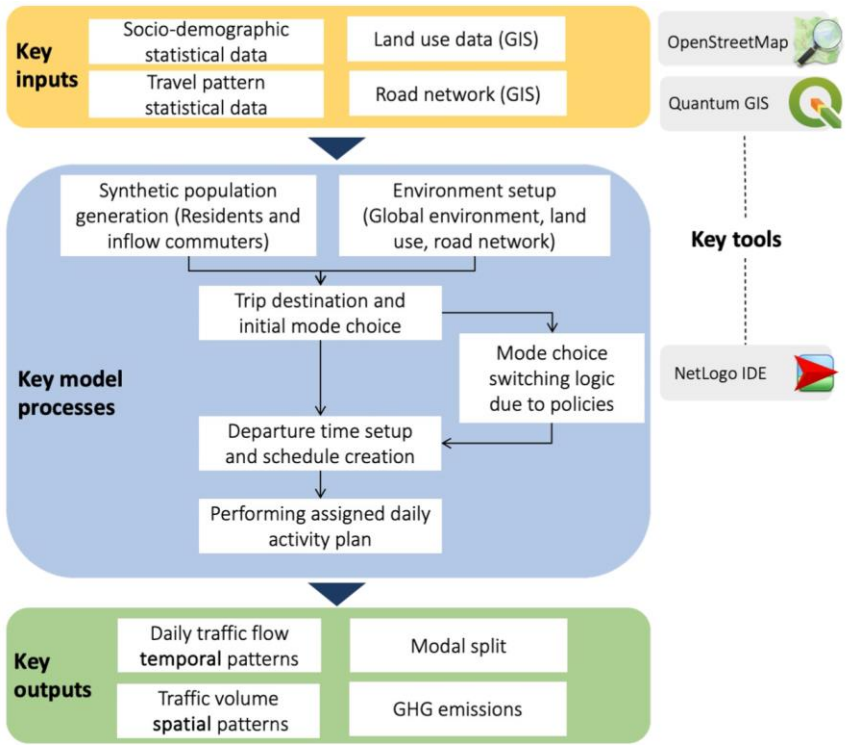




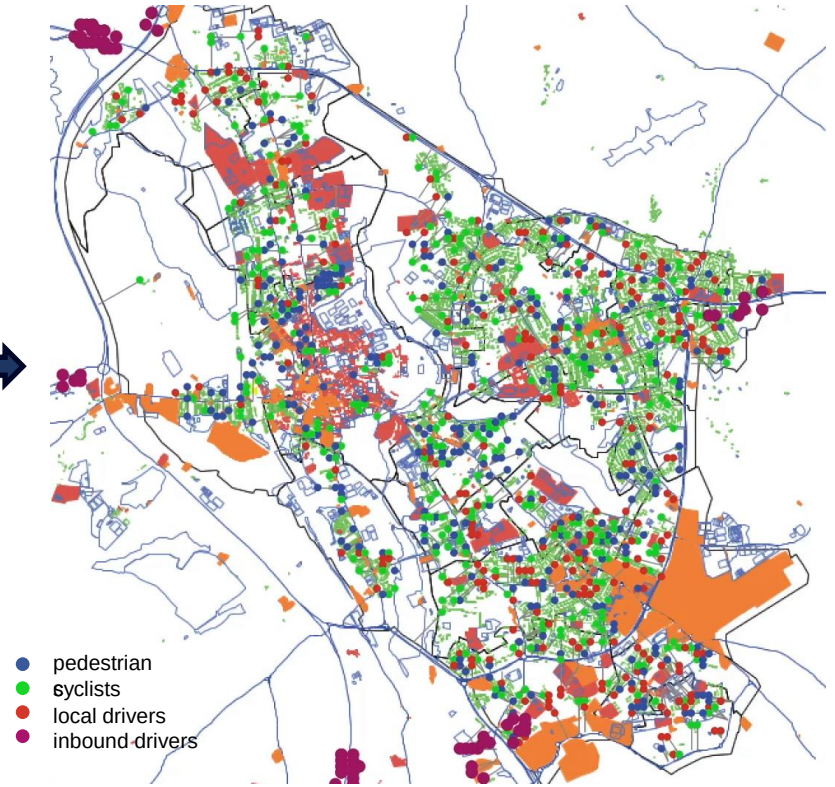
Supporting decision-making for sustainable urban transport systems via agent-based modelling: a case study on policy impact assessment in Oxford

Maiia Sagdieva, Liu Yang, and Koen H. Van Dam, presented at the
8th International Conference on Integrated Land-Use Transport Modeling (ILUTM-8), December 2023

Developing an agent-based model for policy impact assessment

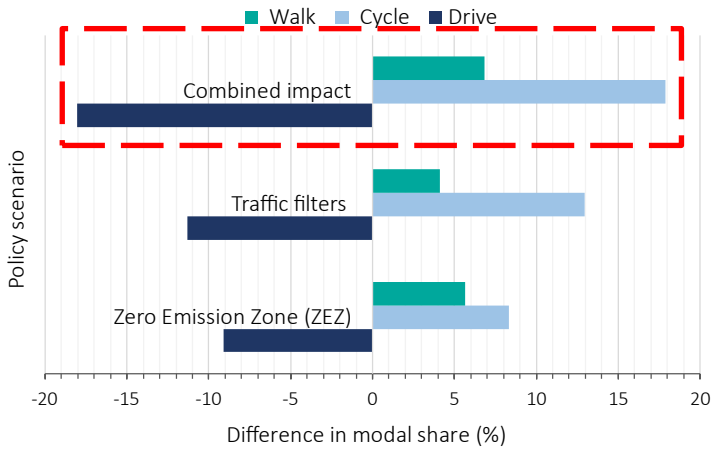


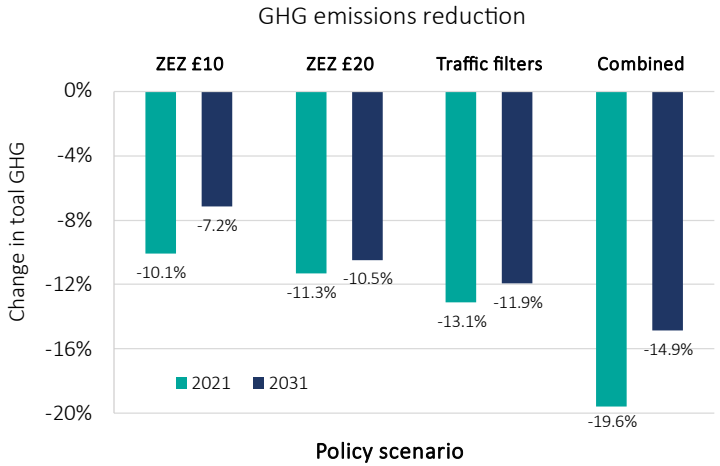
ABM for Oxford, UK



Supporting decision-making for sustainable urban transportation systems via agent-based modelling

Oxford's Transport Strategy shows great potential but…





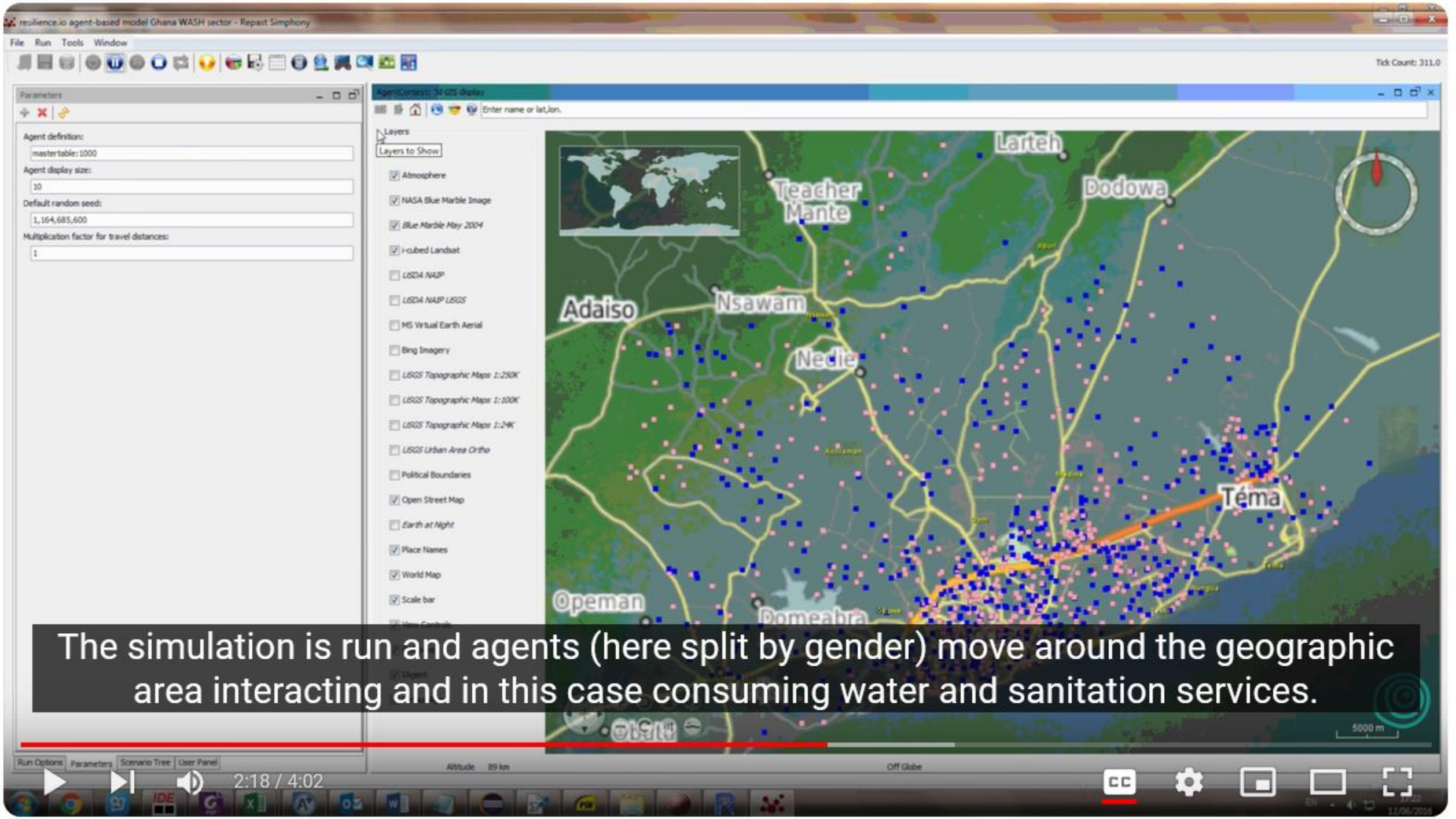
18%
maximum feasible modal shift

20%
potential GHG emission reduction

25%
reduction in policy benefit by 2031

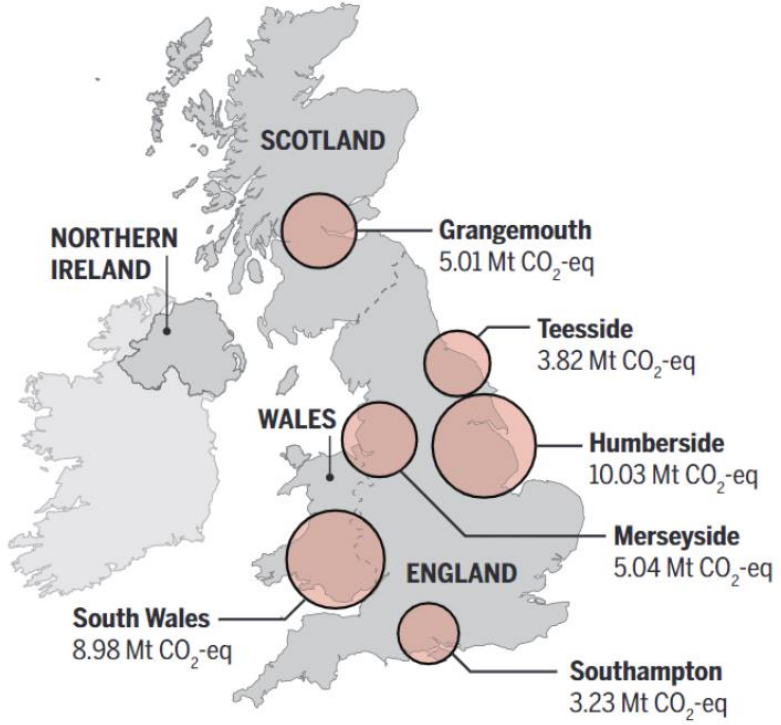
Supporting decision-making for sustainable urban transportation systems via agent-based modelling

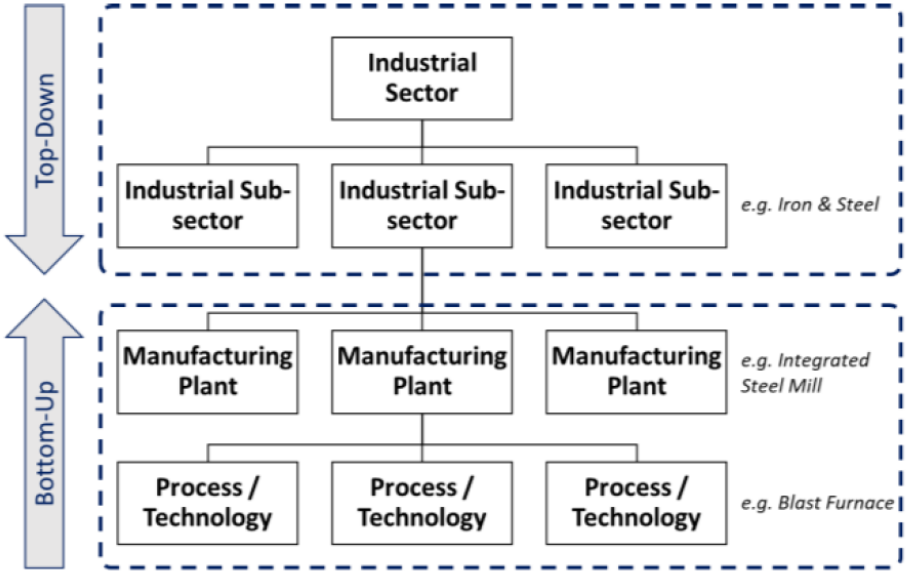
…does everyone benefit from these measures?


resilience.io agent-based model Ghana WASH sector - Repast Simphony
File Run Tools Window
Tick Count: 311.0
Parameters
Agent definition:
mastertable: 1000
Agent display size:
10
Default random seed:
1,164,685,600
Multiplication factor for travel distances:
1
Layers
Layers to Show
Atmosphere
NASA Blue Marble Image
Blue Marble May 2004
i-cubed Landsat
USDA NAIP
USDA NAIP USGS
MS Virtual Earth Aerial
Bing Imagery
USGS Topographic Maps 1:250K
USGS Topographic Maps 1:100K
USGS Topographic Maps 1:24K
USGS Urban Area Ortho
Political Boundaries
Open Street Map
Earth at Night
Place Names
World Map
Scale bar
Larteh
Teacher Mante
Dodowa
Adaiso
Nsawam
Nedie
Téma
Opeman
Domeabra
5000 m
Run Options
Parameters
Scenario Tree
User Panel
Altitude 89 km
Off Globe
The simulation is run and agents (here split by gender) move around the geographic area interacting and in this case consuming water and sanitation services.
2:18 / 4:02
CC

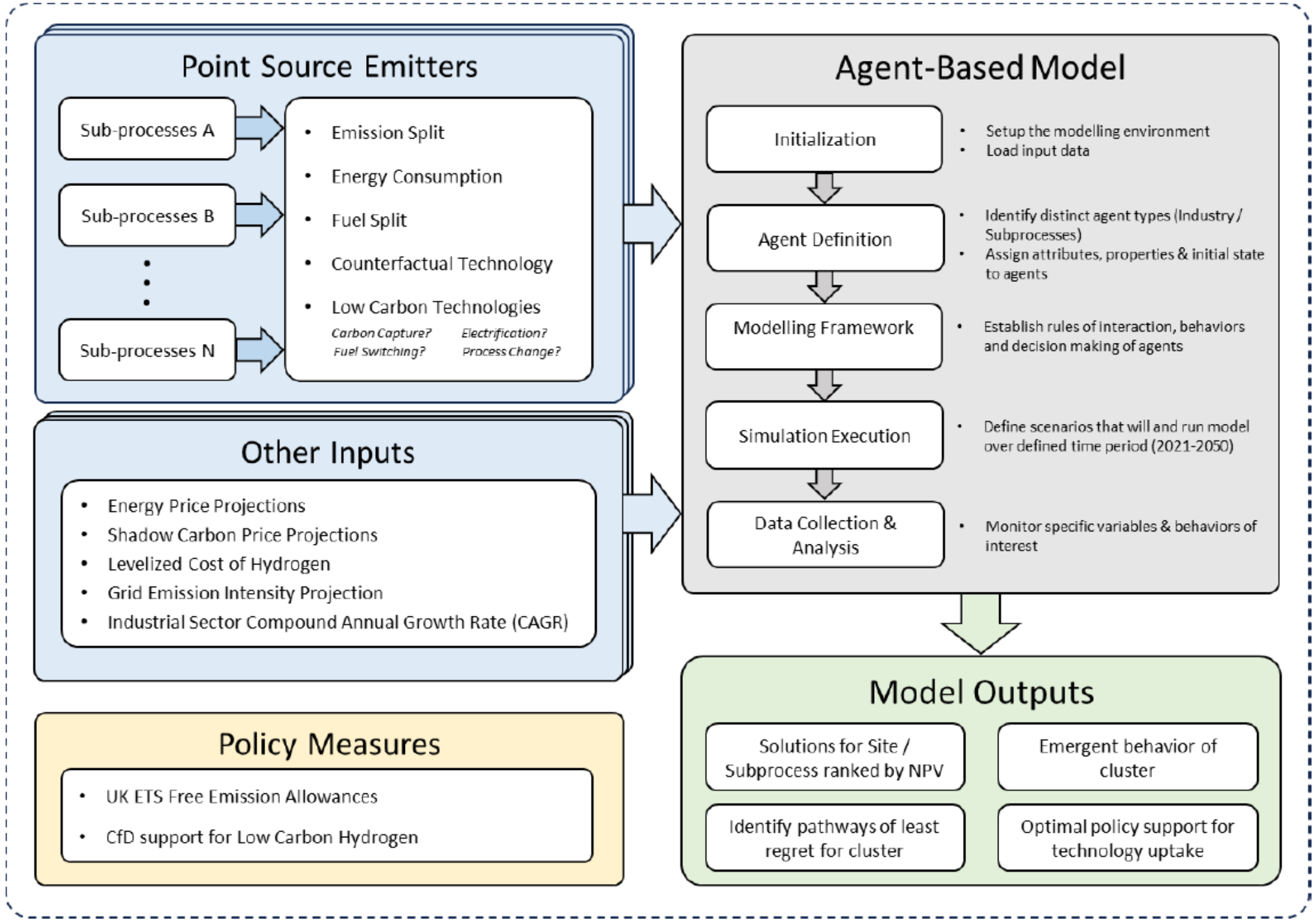
Modelling the transition of industrial clusters

- Multi-level decision-making:
  - Individual businesses
    - Operation
    - Investment
    - Long-term strategy & risk
  - National government
    - Growth
    - Climate policy
  - Cluster
    - Shared infrastructure (e.g. transport, natural gas, hydrogen, CCS)
    - Local economy

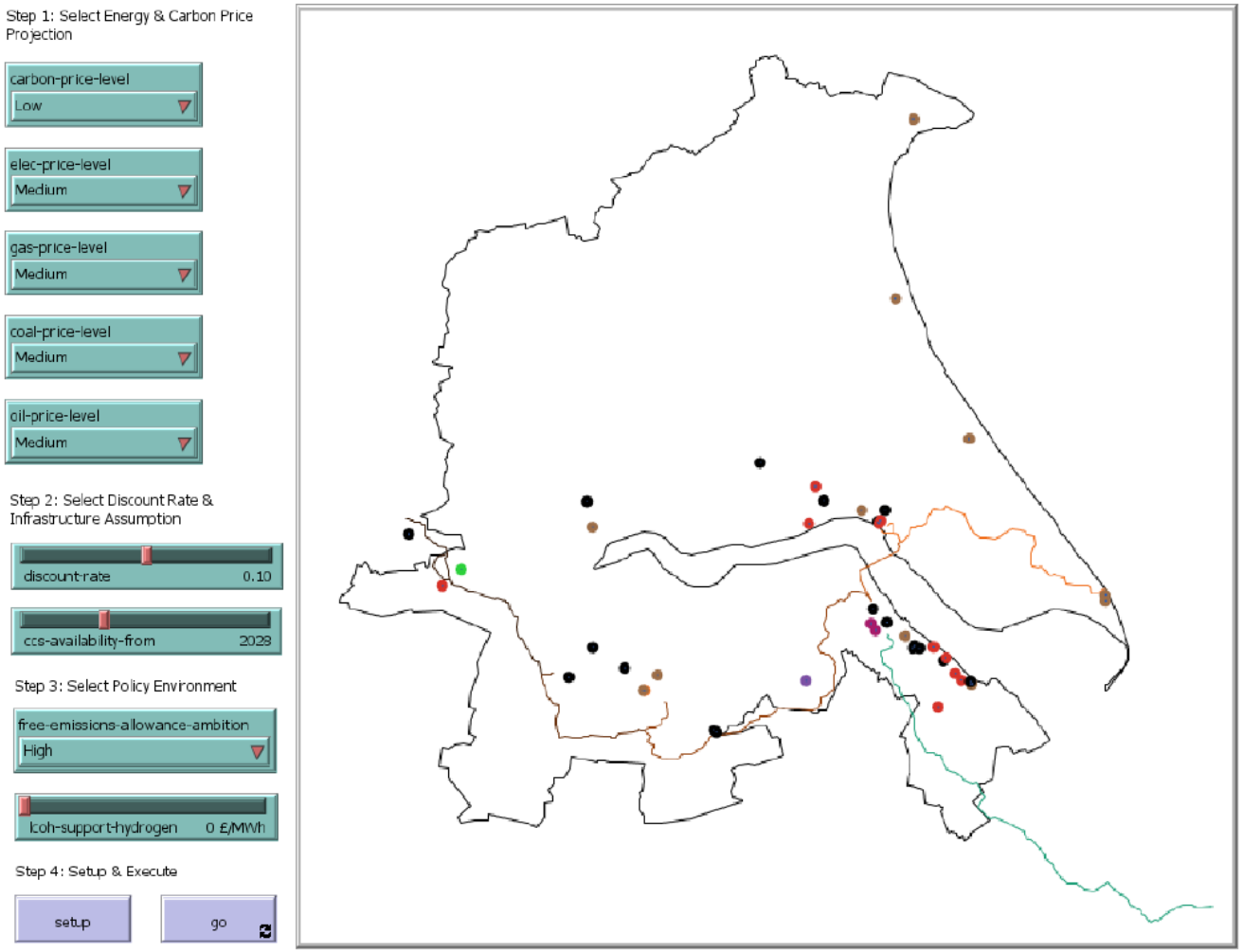




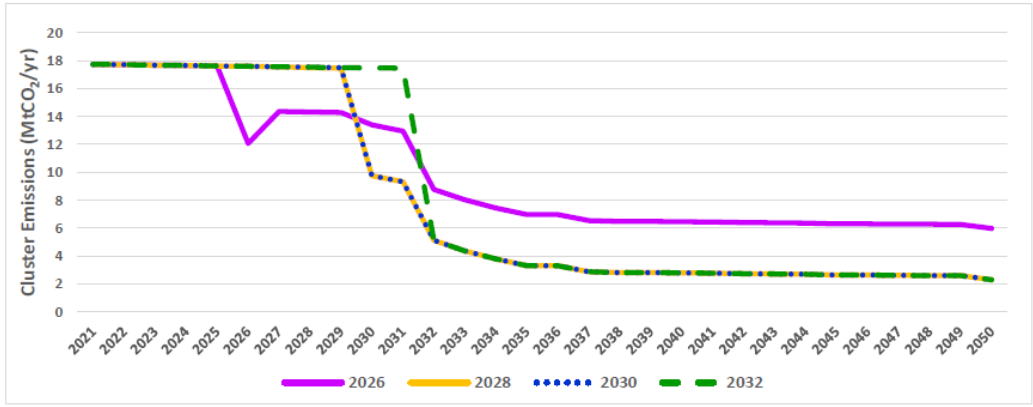
Shahroz Zami Ansari (2023) Strategy development for net-zero industrial clusters using an agent-based model, SEF, Imperial College London


Point Source Emitters
Sub-processes A
Sub-processes B
Sub-processes N
Emission Split
Energy Consumption
Fuel Split
Counterfactual Technology
Low Carbon Technologies
Carbon Capture?
Electrification?
Fuel Switching?
Process Change?
Other Inputs
Energy Price Projections
Shadow Carbon Price Projections
Levelized Cost of Hydrogen
Grid Emission Intensity Projection
Industrial Sector Compound Annual Growth Rate (CAGR)
Policy Measures
UK ETS Free Emission Allowances
CfD support for Low Carbon Hydrogen
Agent-Based Model
Initialization
Setup the modelling environment
Load input data
Agent Definition
Identify distinct agent types (Industry / Subprocesses)
Assign attributes, properties & initial state to agents
Modelling Framework
Establish rules of interaction, behaviors and decision making of agents
Simulation Execution
Define scenarios that will and run model over defined time period (2021-2050)
Data Collection & Analysis
Monitor specific variables & behaviors of interest
Model Outputs
Solutions for Site / Subprocess ranked by NPV
Emergent behavior of cluster
Identify pathways of least regret for cluster
Optimal policy support for technology uptake

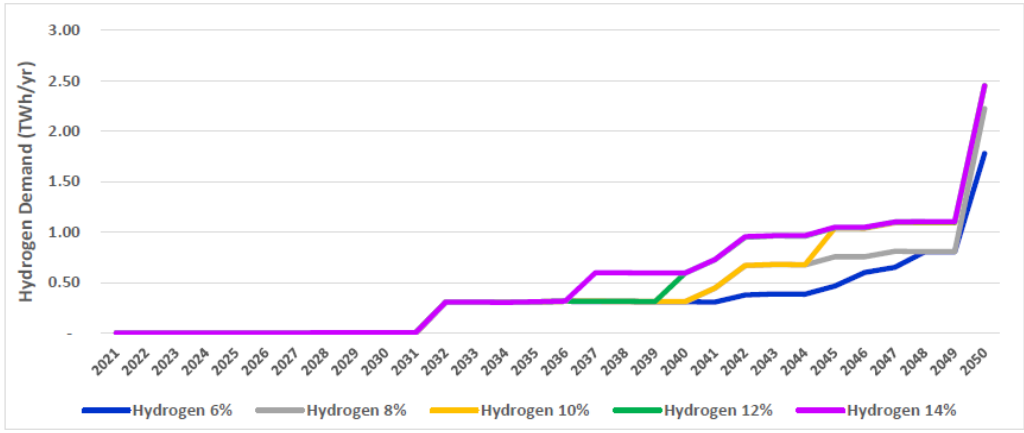
Model and illustrative outcomes



ABM implemented in NetLogo



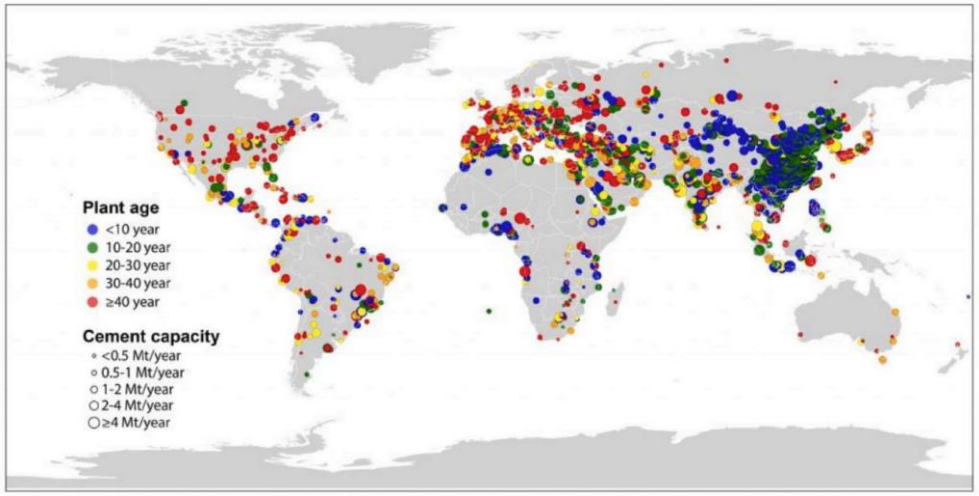
CO_2 emissions depending on CCS infrastructure availability



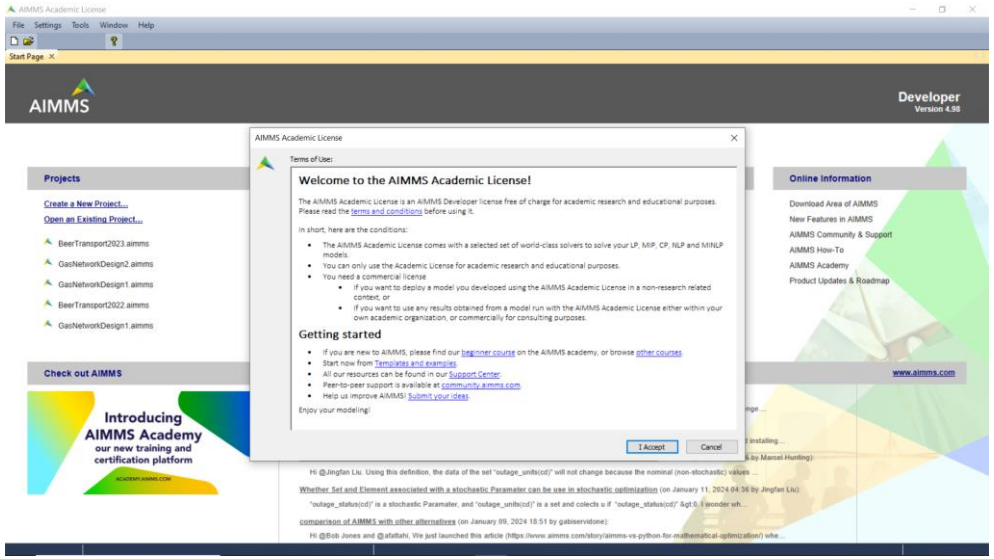
Projected hydrogen demand at various discount rates

Lessons learned

- Context-specific outcomes
- Use of open data and closed data
  - Easier for residential, harder for industrial/commercial?
- Business decision-making is the hardest part of modelling
  - Stakeholder engagement
  - Questionnaires
  - Academic literature e.g. on business models
- Using GIS in combination with ABM helps with data input as well as visualisation of results
- Not everything has to be done within the ABM... Combine agent-based simulation with other tools (e.g. Excel, AIMMS, OSeMOSYS)



Cement plants – Global Infrastructure Emissions Database



AIMMS optimisation software (free academic license)

Energy and Transport Starter Data Kits

Dataset and **data note** (with simple investment models) on energy for **70 countries**

- Capital cost projections for renewables
- Fuel price projections
- Carbon dioxide emissions
- Renewable energy potential
- Final demand projection, etc.

Transport data sets available too

https://climatecompatiblegrowth.com/starter-kits/

Acknowledgements: Naomi Tan and Carla Cannone

CCG Courses

The Climate Compatible Growth OpenLearn Collection provides all the necessary materials for anyone to learn how to use the various tools and build capacity in partner countries to address the fundamentals of planning for climate compatible growth.

Introduction to CLEWS (Climate, land-use, energy and water systems) (open.edu) (Nov 2023 update)
Windows

Infrastructure and Climate Resilience (open.edu) (Nov 2023 update):
Windows

Agent-based energy systems modelling: MUSE (open.edu) (Nov 2023 update):
Windows

Modelling, Policy, and Political Economy (open.edu) (Nov 2023 update)
Windows

climatecompatiblegrowth.com/openlearn-courses/

Outlook

- Two industrial cluster case studies, using ABM to evaluate different policies and technology options:
  - Humber Industrial Cluster (England)
  - Lekki Free Zone (Nigeria)
- Regional development
  - Neath Port Talbot (Wales)
  - Building a systems model to support sustainable development for the wider region and inform decarbonisation strategies
- Support for energy transitions from CCG and Energy Transition Council partners
  - e.g. Kenya, Laos, and India
  - Capacity building and technical assistance
  - Data-to-Deal (https://doi.org/10.33774/coe-2024-21xv4-v3)
- A review paper of state-of-the-art systems models

Thank you

www.climatecompatiblegrowth.com

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