Diego Moya, PhD
https://diegomoya.me/

Energy Economics
Transition & Policy
PhD: GIS-ABM

Geospatial Big Data analytics and ABM to assess the long-term sustainable climate-energy-economy transition worldwide

GIS - Geographic Information System;
ABM - Agent-based modelling

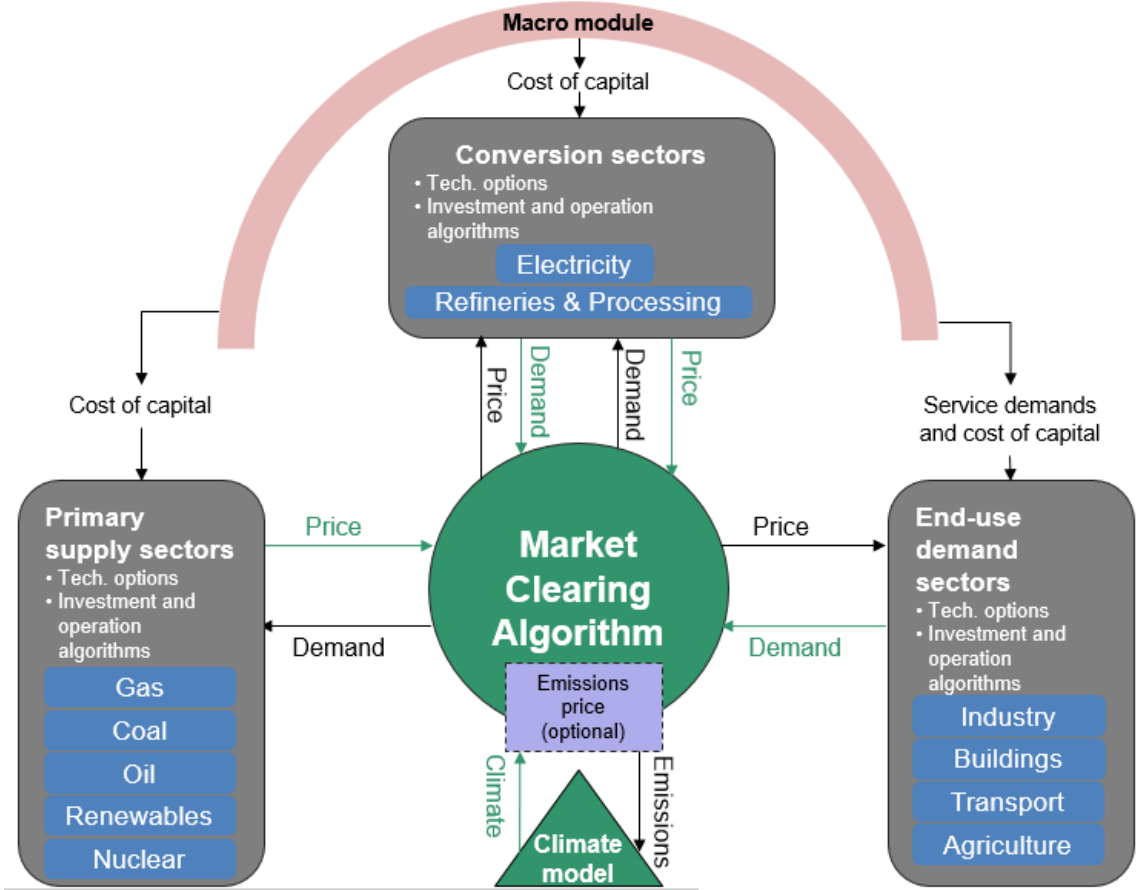
Alumnus: Imperial College London SSCP DTP — Centre for Process Systems Engineering

Founder: IIASUR — INSTITUTE FOR APPLIED SUSTAINABILITY RESEARCH

muse RASA

Mod**U**lar energy system **S**imulation **E**nvironment
Residenti**A**l **S**patially-resolved and temporal-explicit **A**gents

Unique climate-energy-economy system simulation tool to analyse the role of technologies in the global energy transition, integrating Geographic Information Systems (GIS) and agent-based modelling (MBA): space-time and human dimensions of the transition.

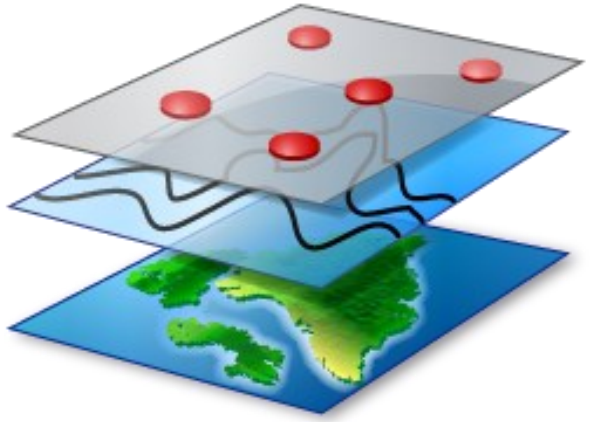


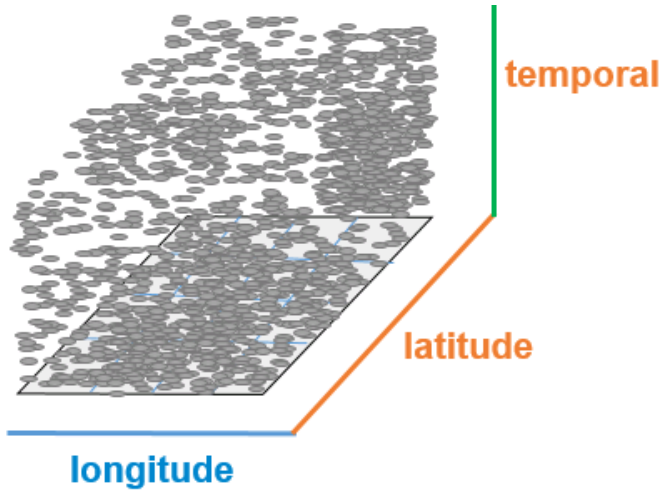
https://www.imperial.ac.uk/muse-energy/what-is-muse-/

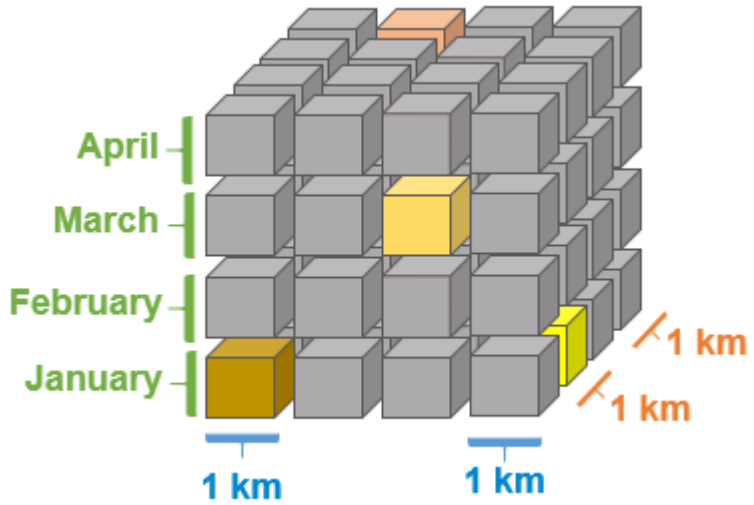
Geographical Information Systems:

Geospatial Datasets: Spatial and temporal dimensions

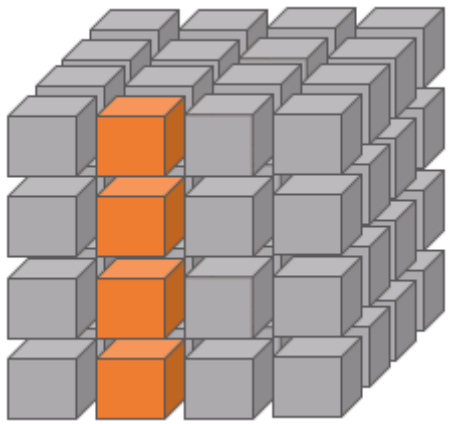
- **Outdoor temperature**
- **Population count**
- **Population density**
- **Heating/cooling demand**
- **Heating/cooling density**
- **GDP**
- **GDPpc**
- **HDI**



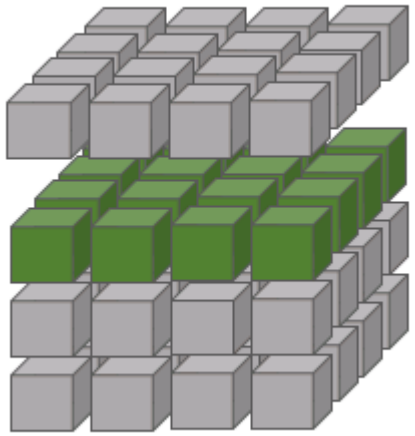




Time series



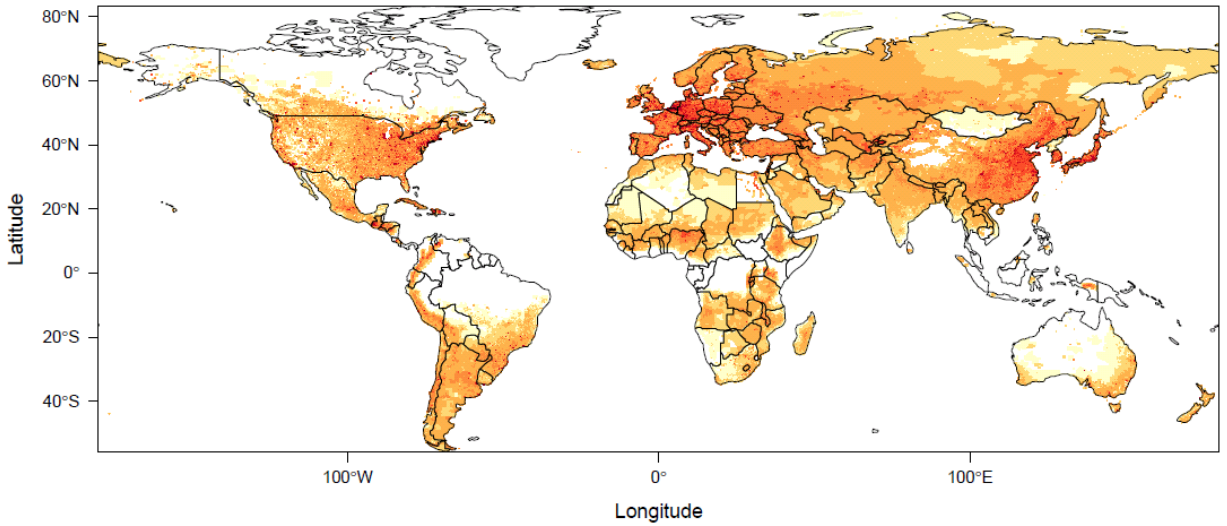
Time slice



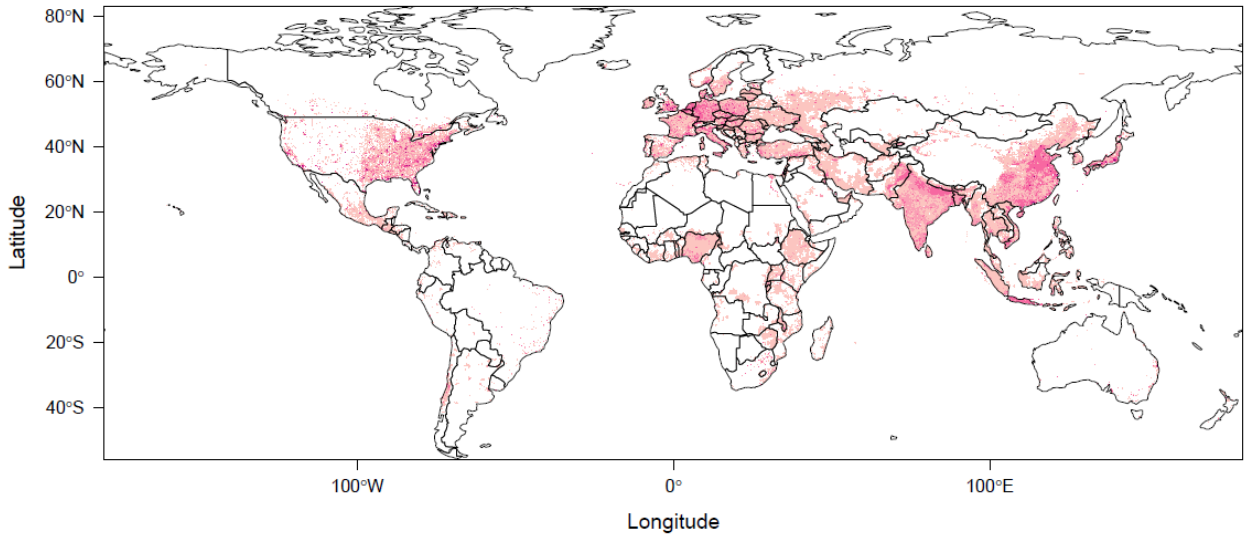
Geographical Information Systems:

MUSE-RASA 〉 GIS

Initial calculations:



Global atlas of the SH+WH demand in the residential sector

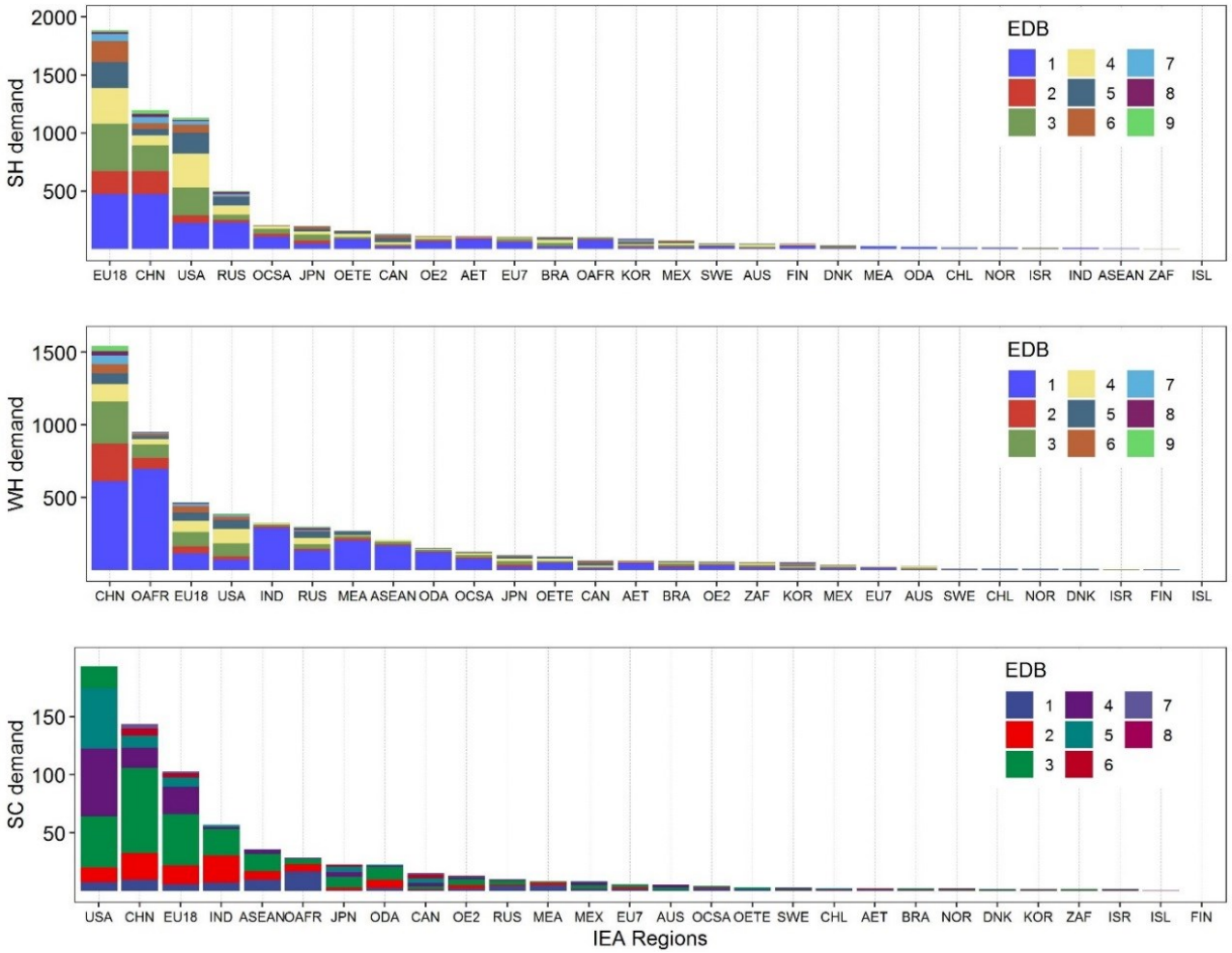


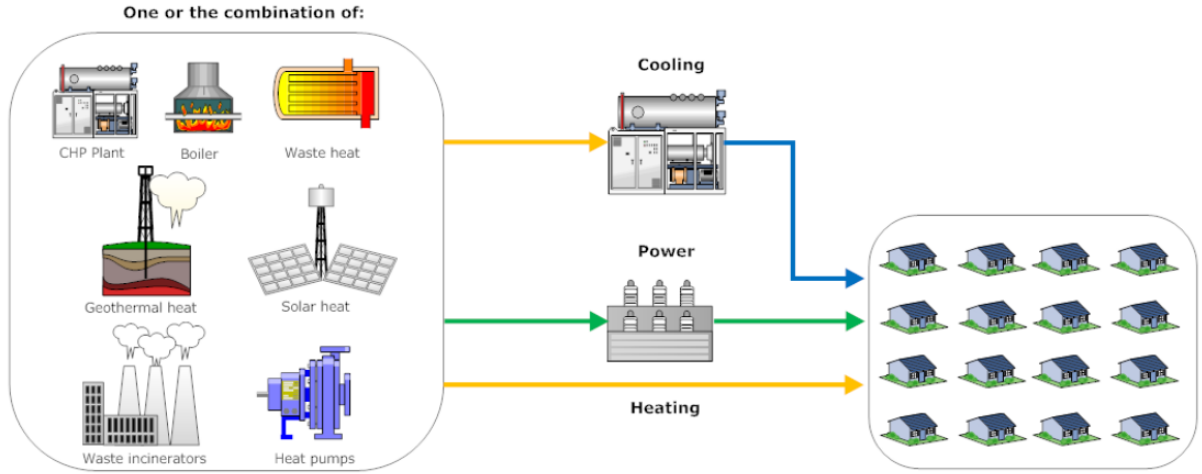
Global atlas of the end-use energy demand density

Sachs, J., Moya, D., Giarola, S., & Hawkes, A. (2019). Clustered spatially and temporally resolved global heat and cooling energy demand in the residential sector. *Applied Energy*, *250*, 48-62. https://www.sciencedirect.com/science/article/abs/pii/S0306261919308657

Global service demand

MUSE-RASA 〉 GIS





Distribution of energy density bands EDB in 28 world regions [TWh/y].

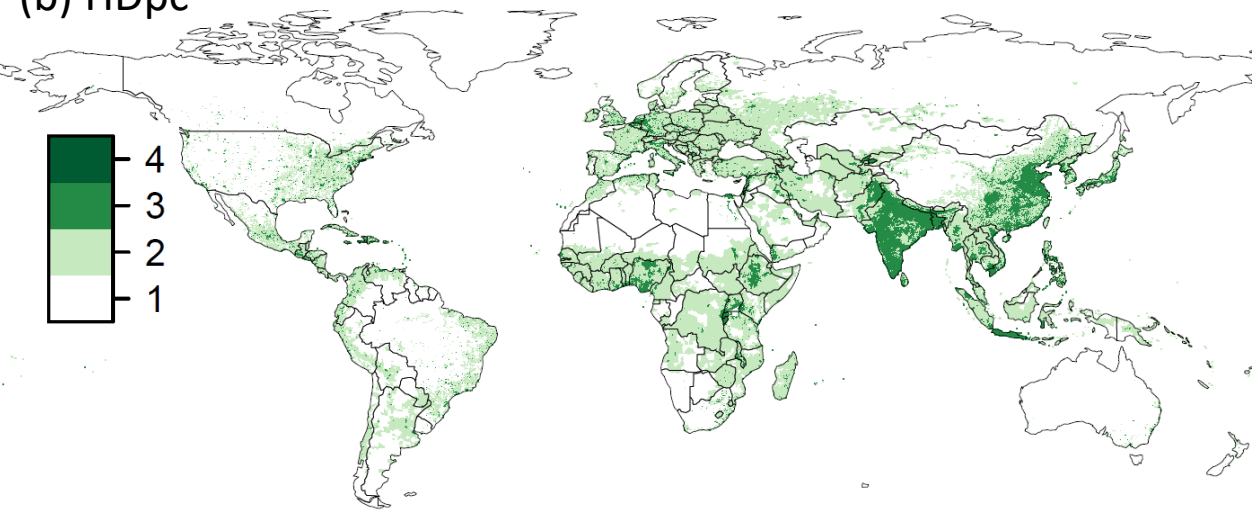
GIS: spatial clustering – machine learning

MUSE-RASA 〉 GIS 〉 ABM

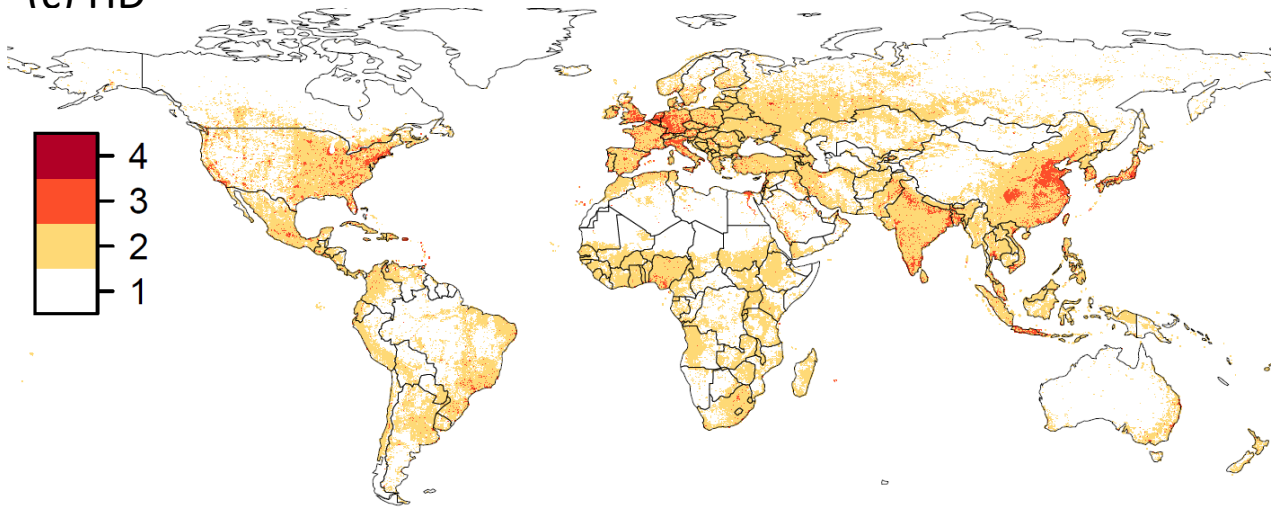
Unsupervised Machine Learning

(a) GDPpc

(b) HDpc



(c) HD



(d) Lower and upper limits

GDPpc [US$/y]			HDpc [MWh/cap]			HD [MWh/km^2]		
classes	lower	upper	classes	lower	upper	classes	lower	upper
1	min	500	1	min	0.9	1	min	1790
2	500	3785	2	0.9	3.2	2	1790	12080
3	3785	18215	3	3.2	5.3	3	12080	36927
4	18215	41667	4	5.3	max	4	36927	max
5	41667	75901						
6	75901	max						

Combining GIS with Agent-based modelling: MUSE-RASA

MUSE-RASA 〉 GIS 〉 ABM

Geospatial data-driven, agent-based, technology-rich, bottom-up approach

7. Application of MUSE-RASA model framework

6. Eight scenario definition

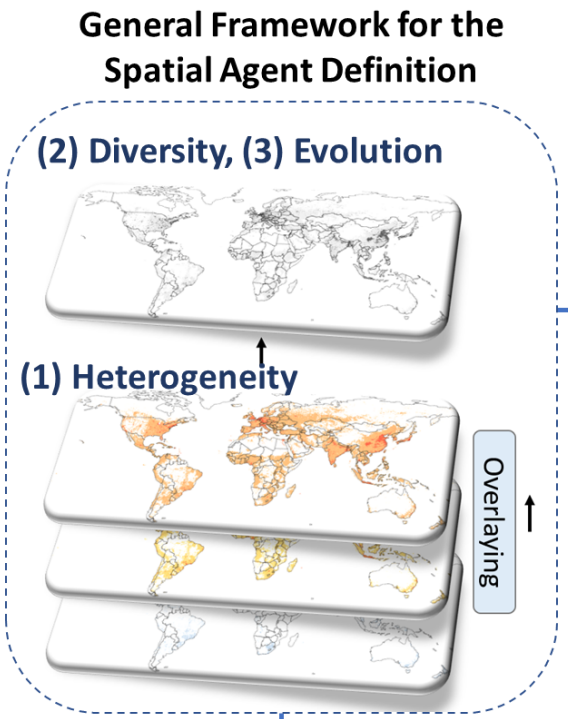
5. Spatial cross validation

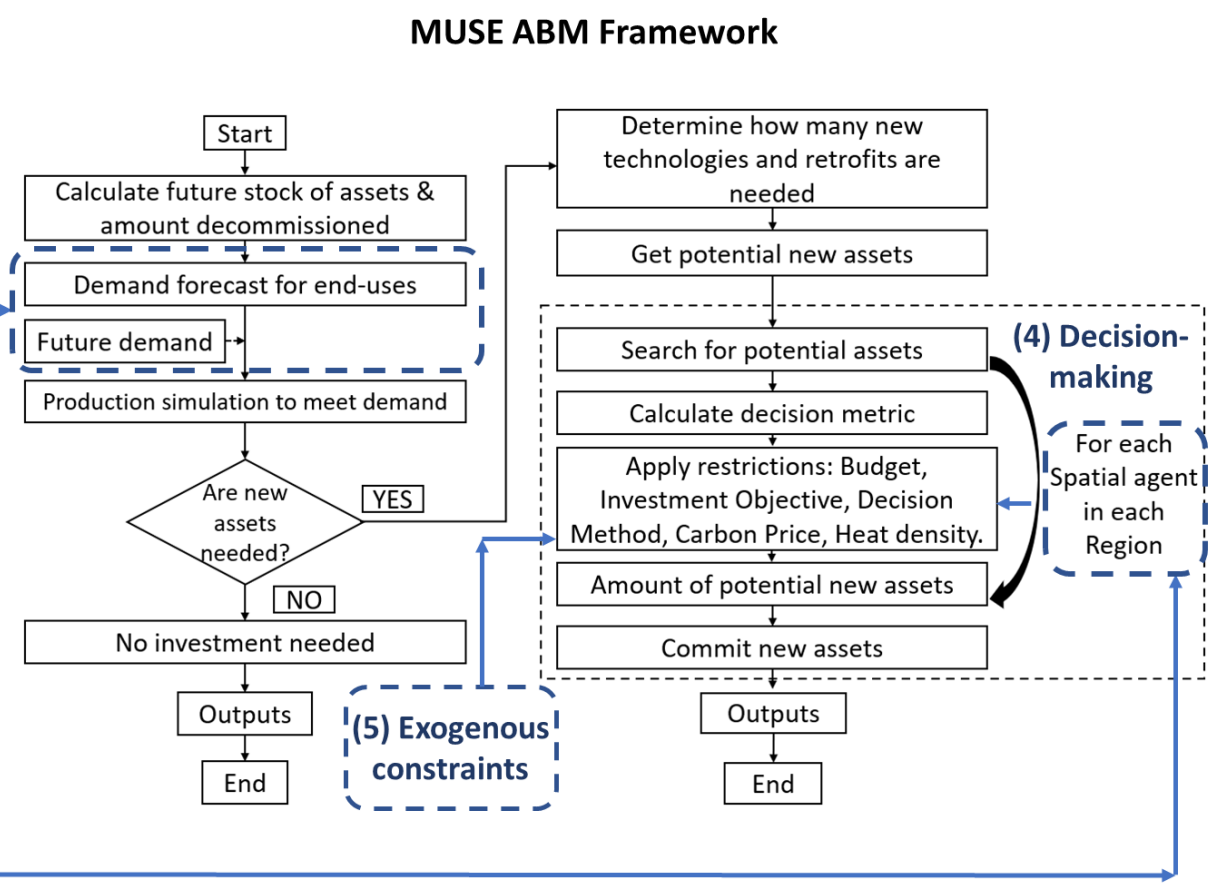
4. Geospatial Agent-Based Modelling Framework

3. Agent-based modelling

2. Geospatial Big Data Analytics

1. Collecting and handling data

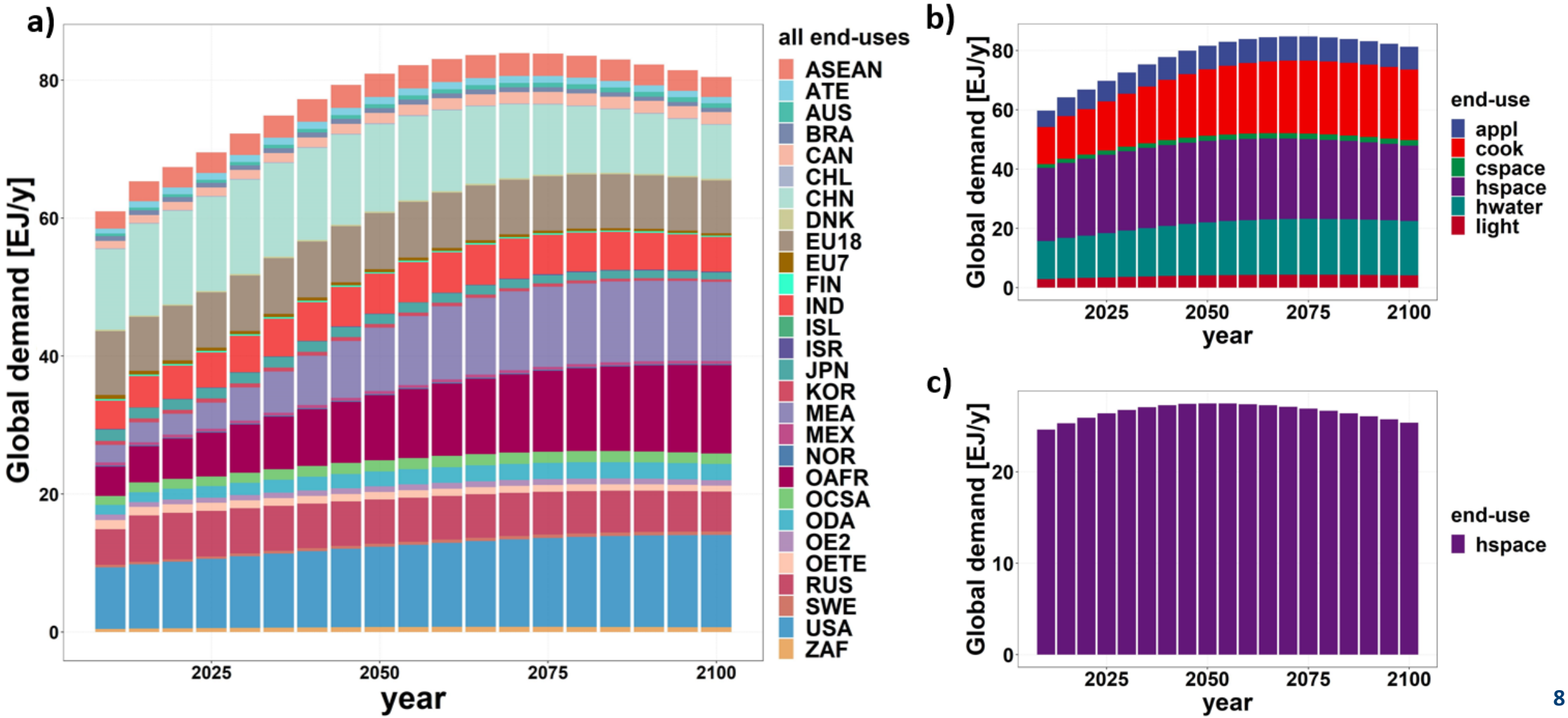




*RASA: ResidentiAl Spatially-resolved and temporal-explicit Agents

Global service demand, focus on space heating (hspace)

MUSE-RASA | GIS | ABM | Results - cases



Global supply of service demand

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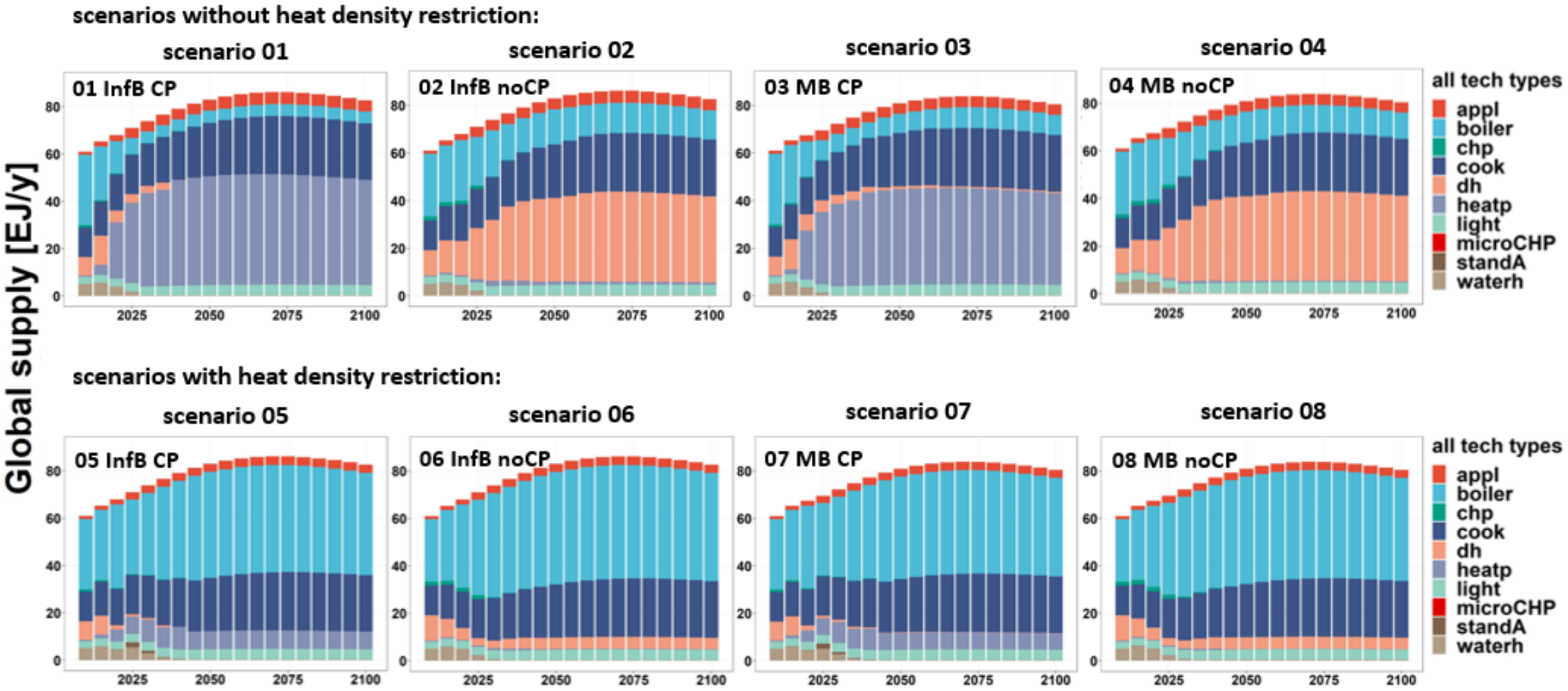
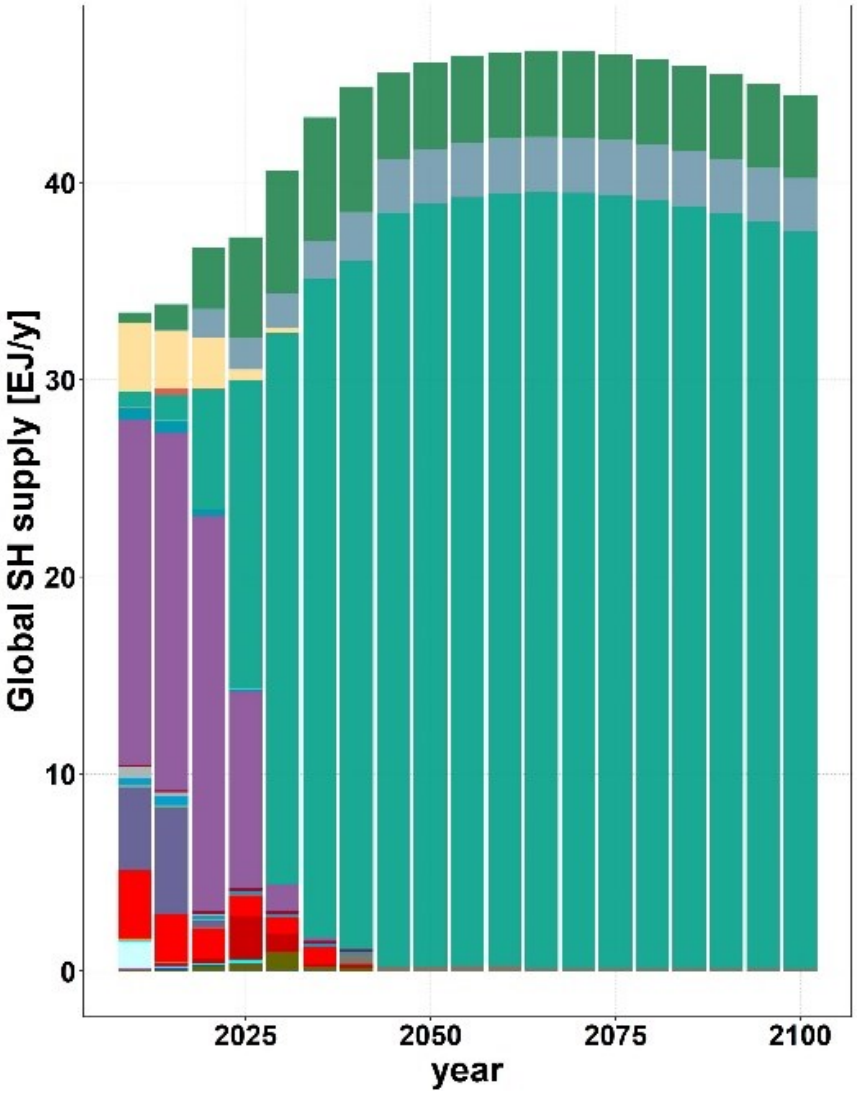
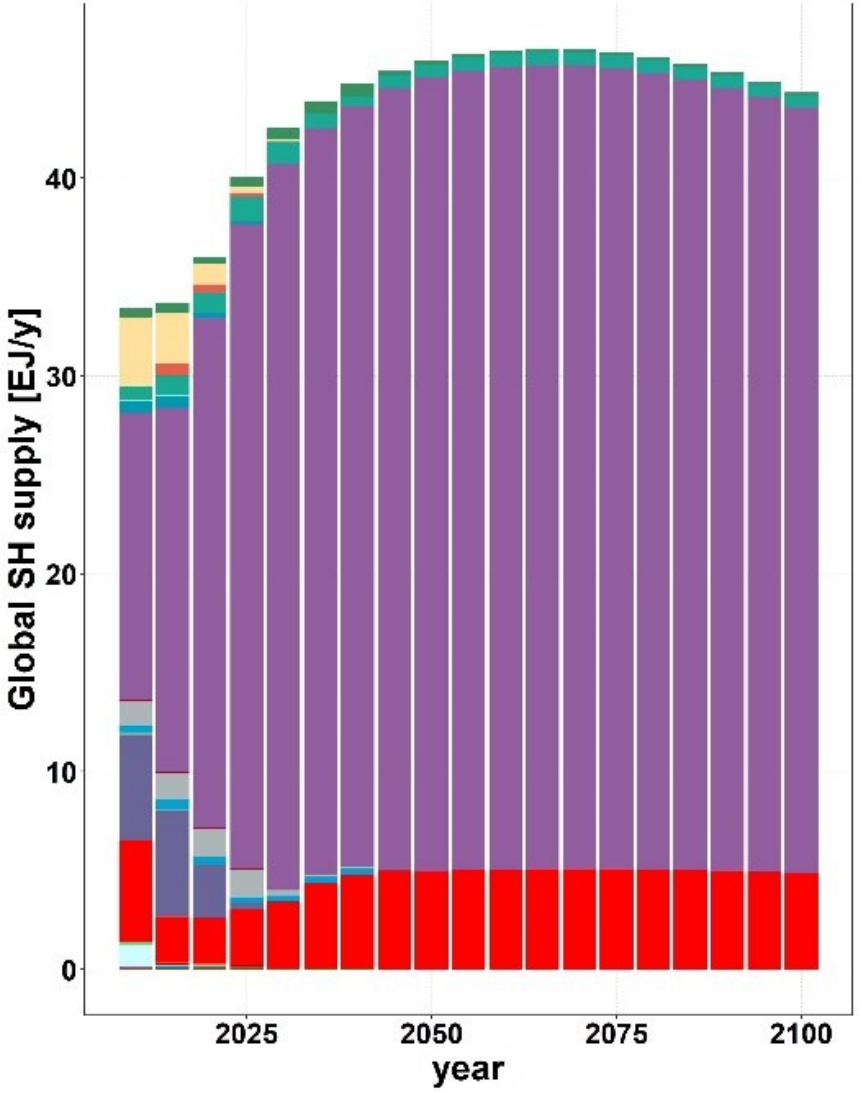


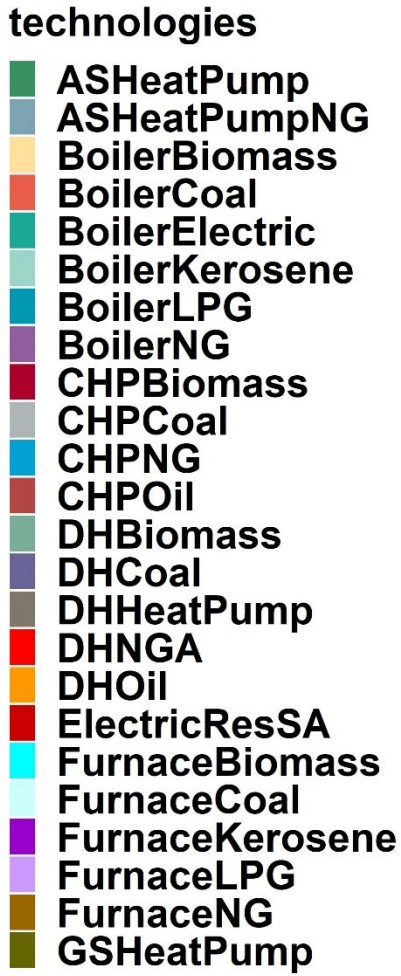
Global SH supply by technology disaggregation: 2 scenarios

Scenario 07: MB, CP, HDR.



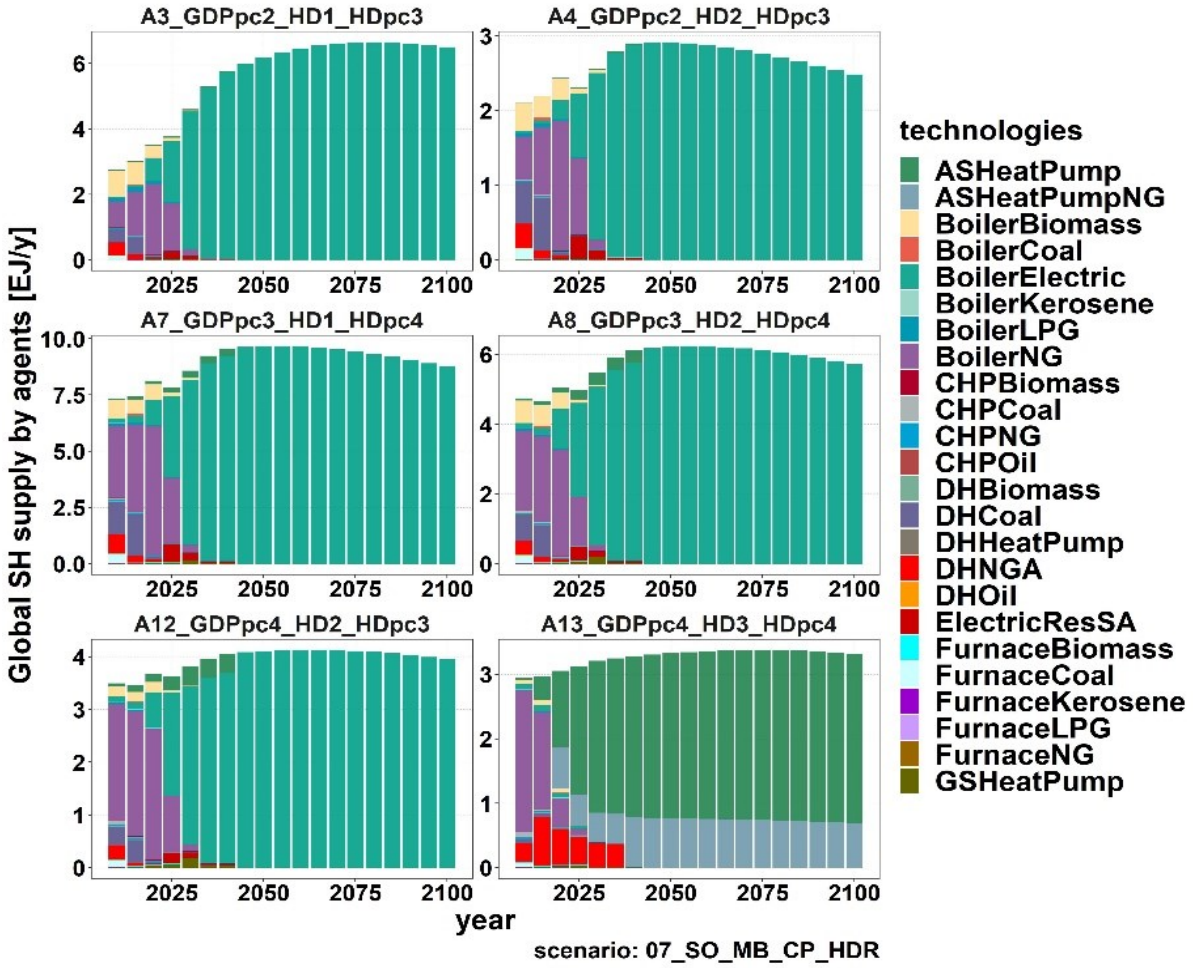
Scenario 08: MB, noCP, HDR.

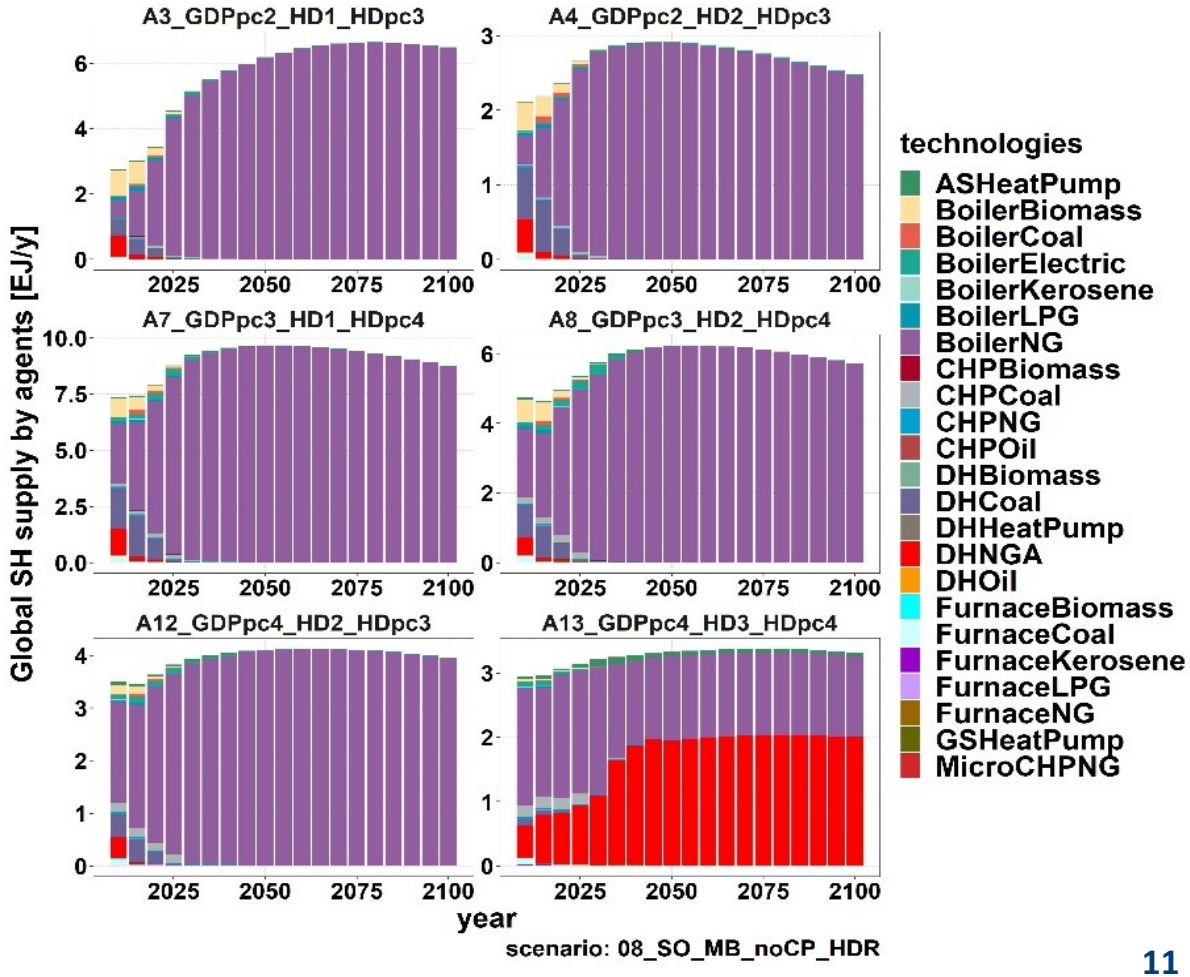




Global SH supply in the 6 topmost consuming agents

Agents/consumers under a range of socio, technical and economic characteristics:

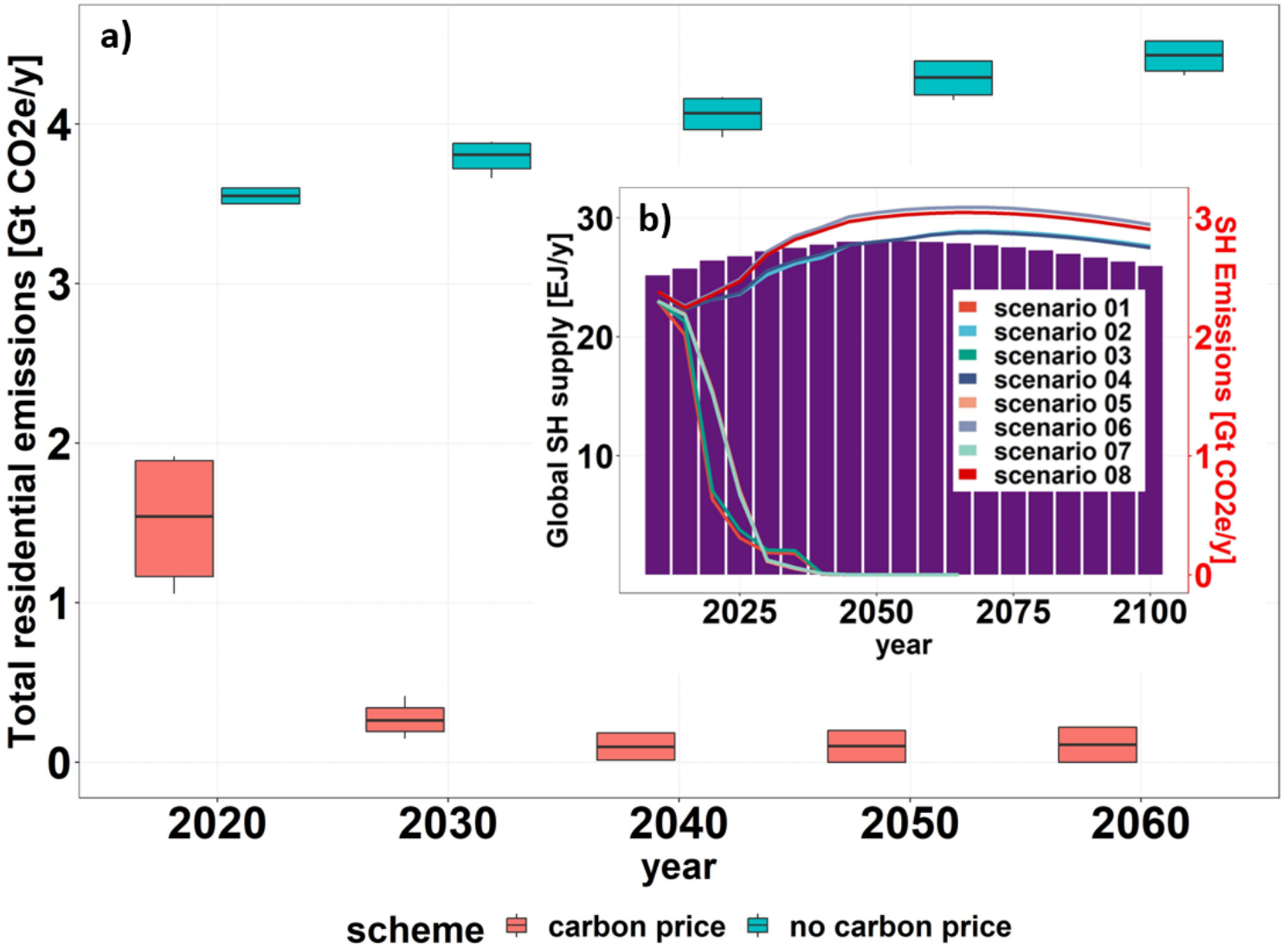




Global emissions

(a) Global related CO2 emissions distribution among the eight scenarios for all end-uses.

(b) Global SH CO2 emissions profiles in scenarios without carbon prince: 02, 04, 06, 08; and with carbon prince: 01, 03, 05, 07.



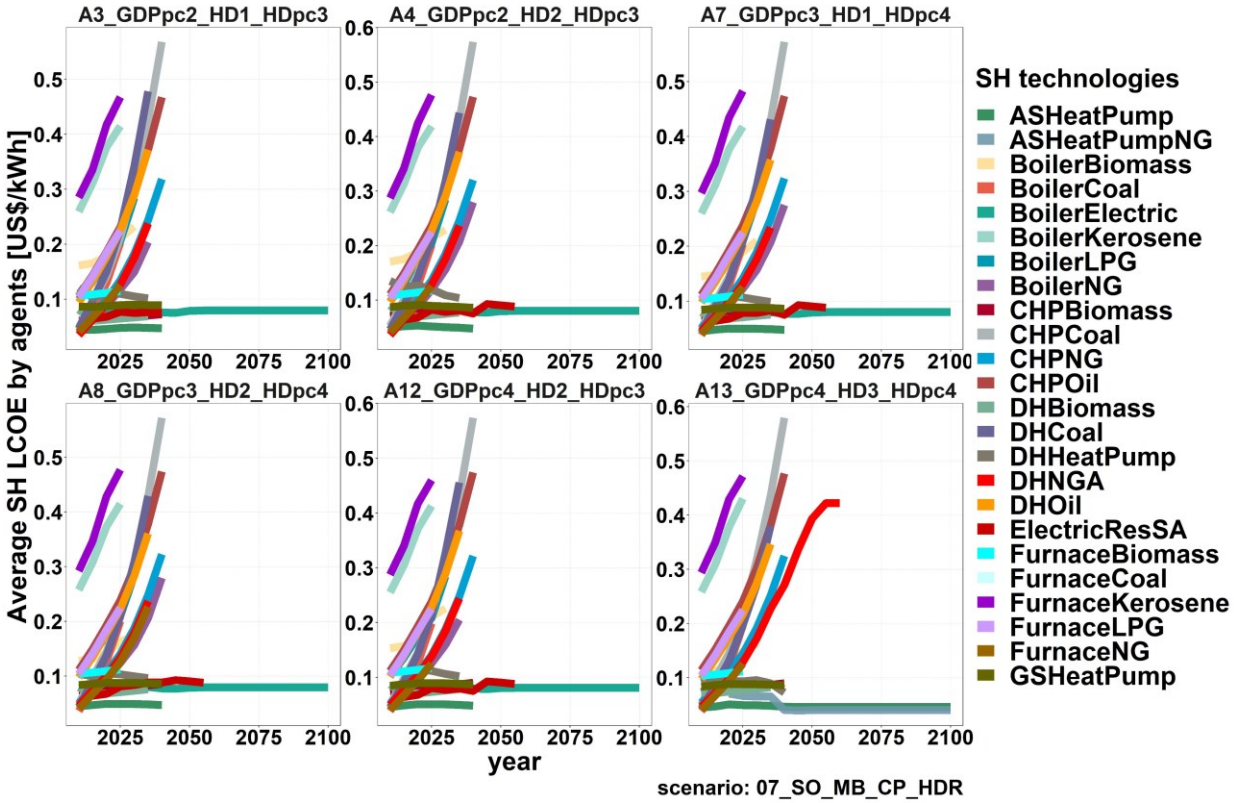
Transition costs and emission summary

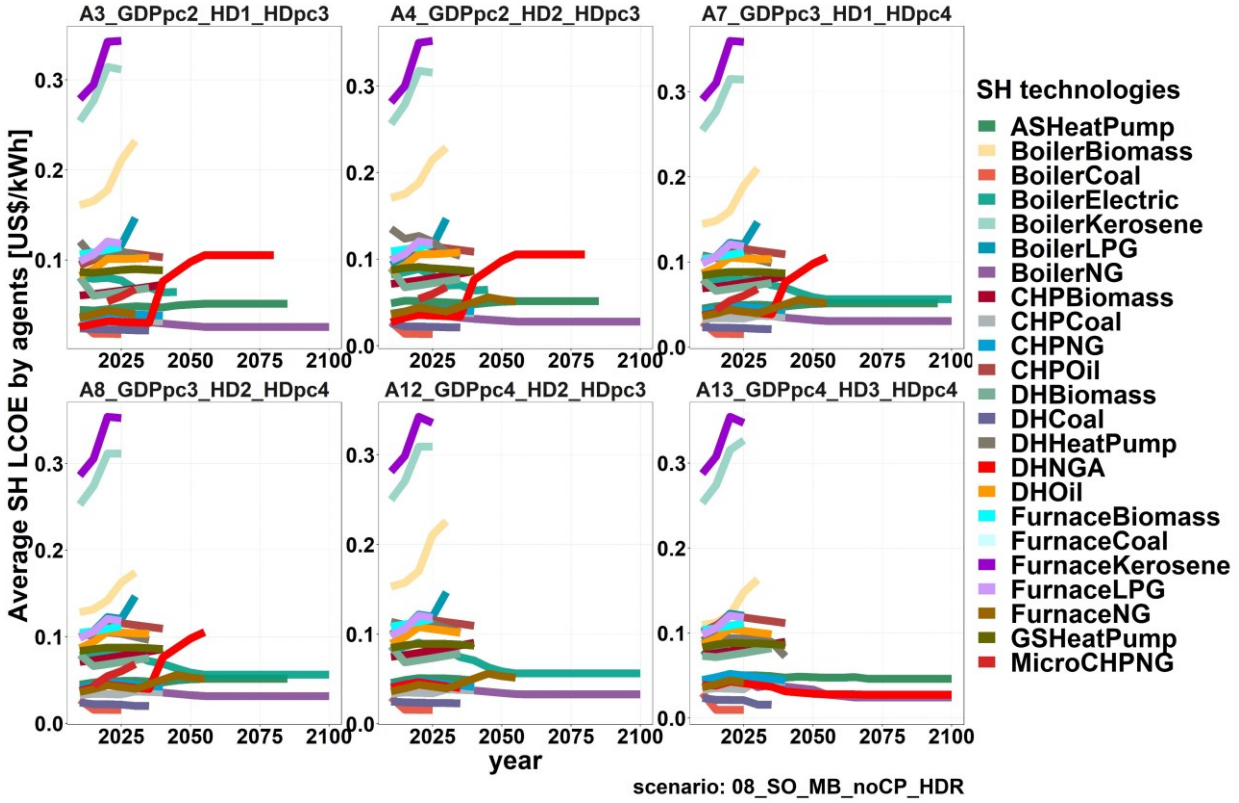
Values are estimated for 30 years, between 2020 and 2050.

Agent	Characteristics	NZE by mid-century		Current consumption path		
		Reduced emissions with CP	CAPEX under CP	Produced emissions without CP	CAPEX without CP	Carbon tax to pay (if)
		[$GtCO_2$]	[TN USD]	[$GtCO_2$]	[TN USD]	[TN USD]
A3	GDPpc2, HD1, HDpc3	0.28	0.87	2.44	1.03	0.61
A4	GDPpc2, HD2, HDpc3	0.21	0.37	1.32	0.41	0.31
A7	GDPpc3, HD1, HDpc4	0.64	1.26	4.33	1.41	1.03
A8	GDPpc3, HD2, HDpc4	0.33	0.86	2.7	0.97	0.65
A12	GDPpc4, HD2, HDpc3	0.26	0.61	1.86	0.7	0.44
A13	GDPpc4, HD3, HDpc4	0.15	1.81	1.44	0.55	0.34

Levelised cost of energy - LCOE

MUSE-RASA › GIS › ABM › Results - cases





Global average LCOE for space heating supply by agents for a scenario with multiple restrictions: budget restriction, heat density restriction and with/without carbon price. Results are provided by technology disaggregation for topmost six consuming agents.

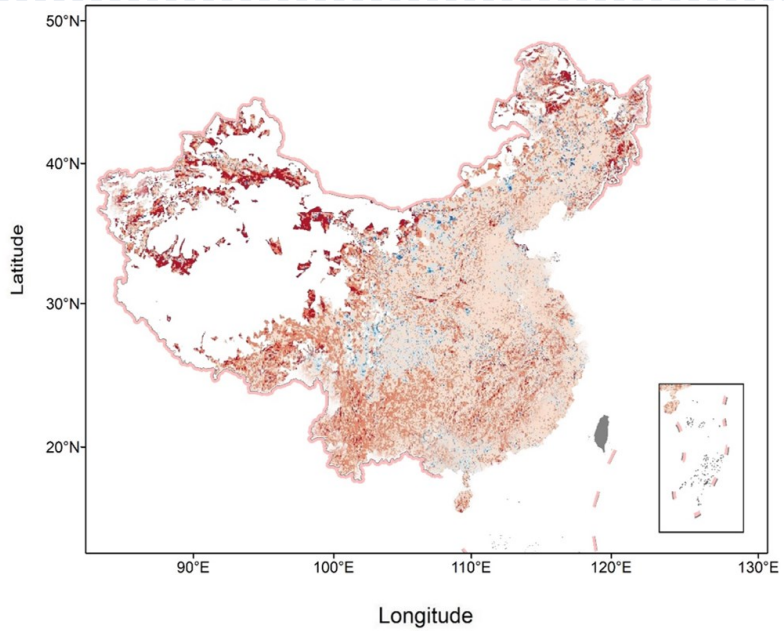
China case study

MUSE-RASA | GIS | ABM | Results - cases

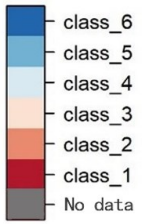
Nationwide survey

Agent characterization

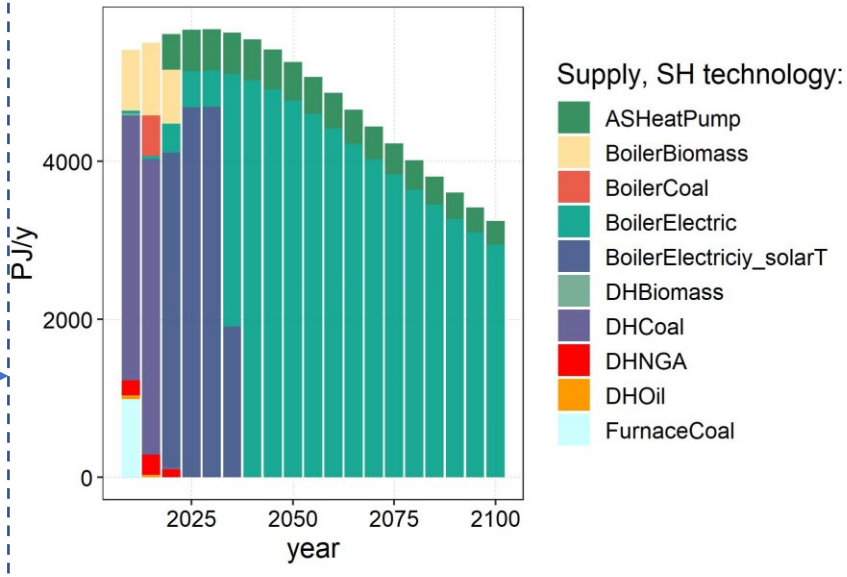
Geospatial location of agents



Classes	Per capita income (USD/y)
1	<500
2	500-3,785
3	3,785-18,215
4	18,215-41,667
5	41,667-76,000
6	>76,000



Long-term energy planning



China case study

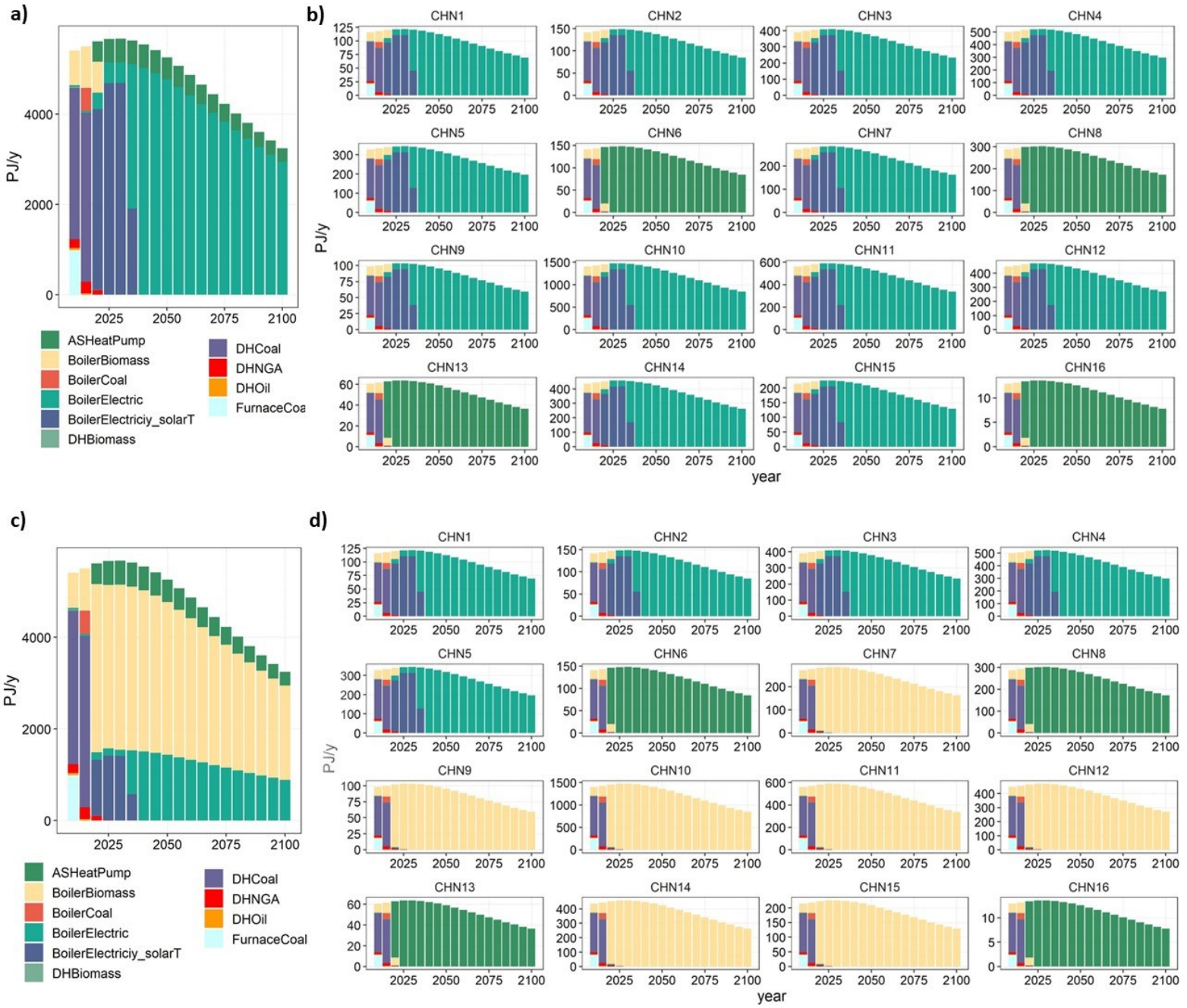
MUSE-RASA 〉 GIS

Survey-based scenarios of SH technology to supply heat in Chinese RS.

(Top) Scenario with a multi budget system, heat density restriction and excluding biomass-based technologies from the analysis: a) aggregated, b) agent-based disaggregated.

(Bottom) Scenario with a multi budget system, heat density restriction and including biomass-based technologies in the analysis: c) aggregated, d) agent-based disaggregated.

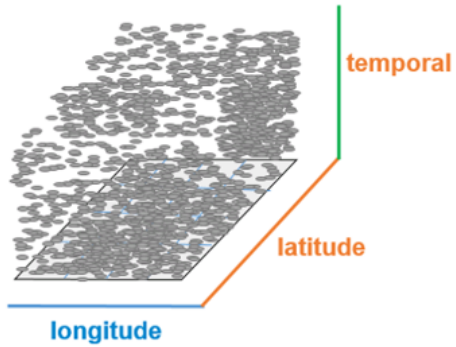
Both scenarios with carbon price schemes.



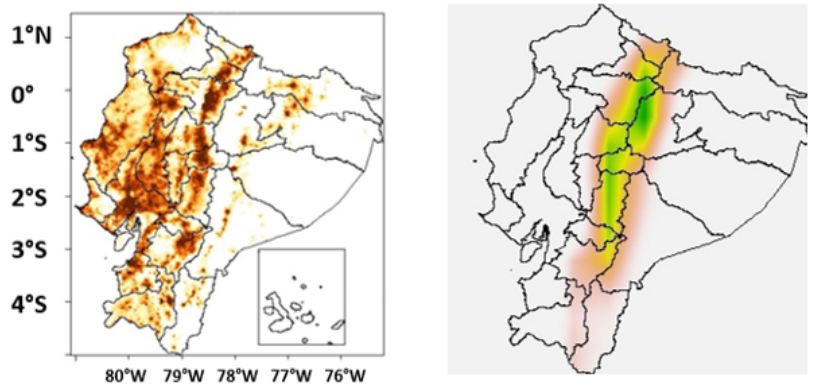
Ecuador case study

MUSE-RASA | GIS | ABM | Results - cases

1. **Public available data**
   (a) Local: INEC, ARCONEL, BCE
   (b) International: NASA MERRA2, CIESIN



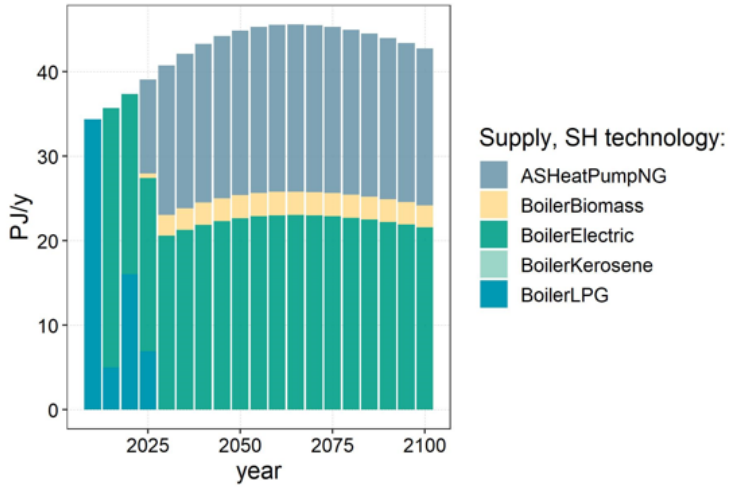
2. GIS-survey-based calculations 2010-2020



3. Gridded Energy consumption drivers, 2010-2020:

(1) Population
(2) Space heating
(3) Space cooling
(4) Water heating
(5) Gross domestic product
(6) GDP per capita
(7) Human Development Index

4. Long-term energy planning:



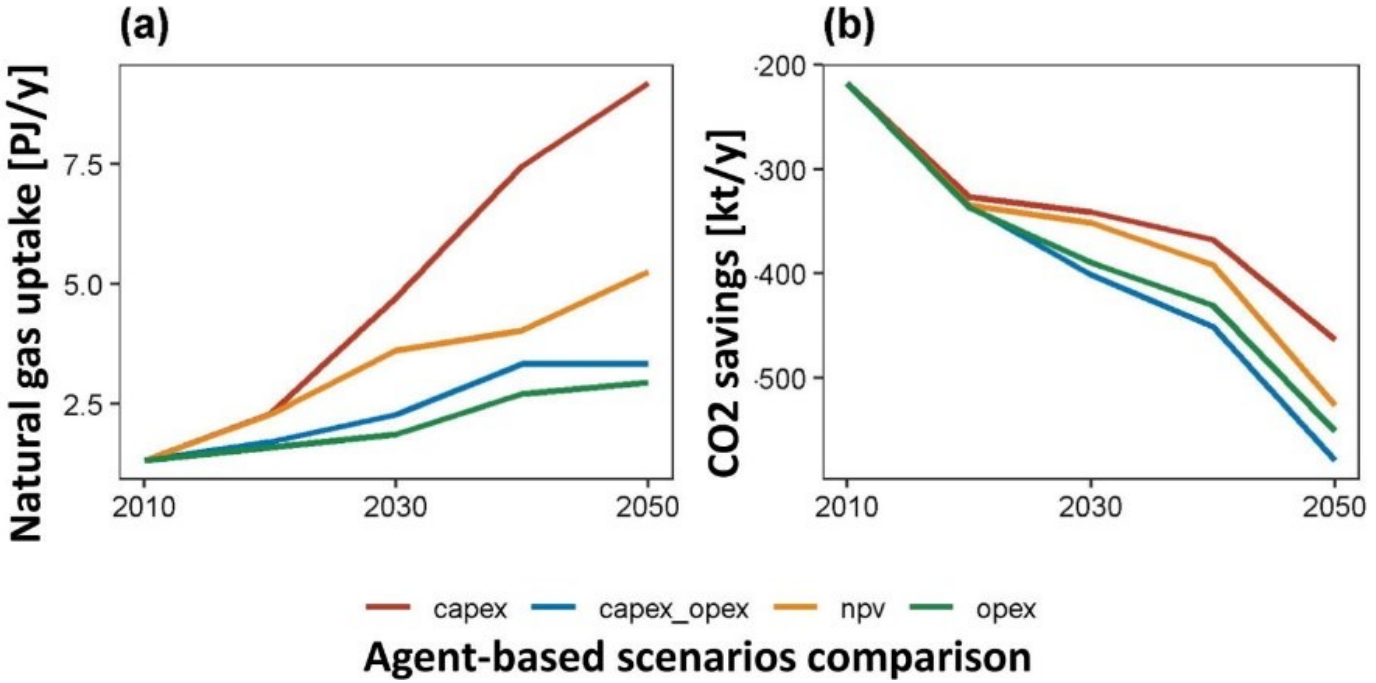
Graphical abstract of the approach conducted in Ecuador.

India case study

MUSE-RASA | GIS | ABM | Results - cases

On-site survey in
405 Indian heavy industries
108 iron and steel plants

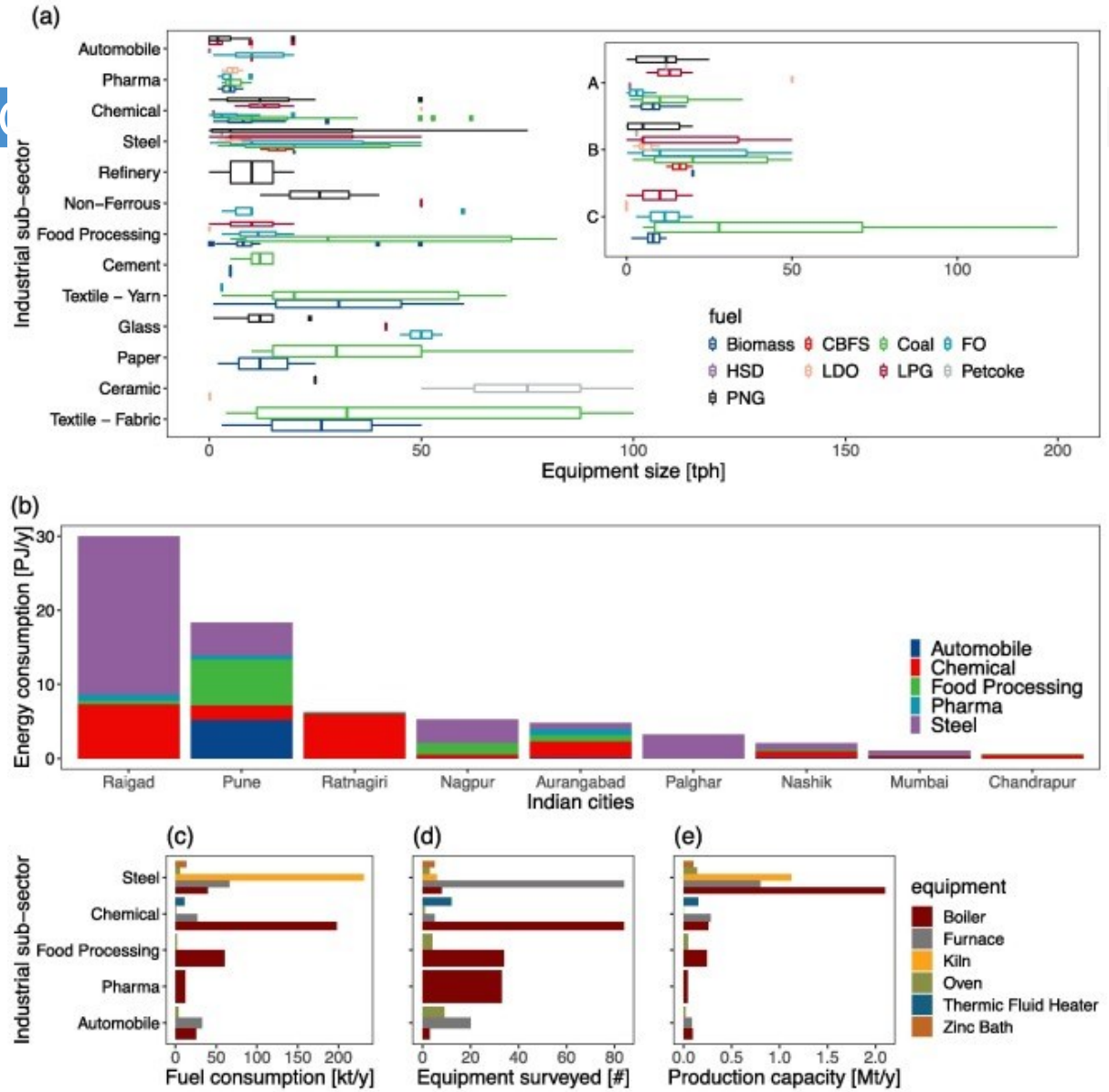
AB-IAM: MUSE
Industry Sector
Agent-based scenarios



Agent-based scenarios comparison for assessing fuel-switching investment in long-term energy transitions of the India's industry sector.

India case study

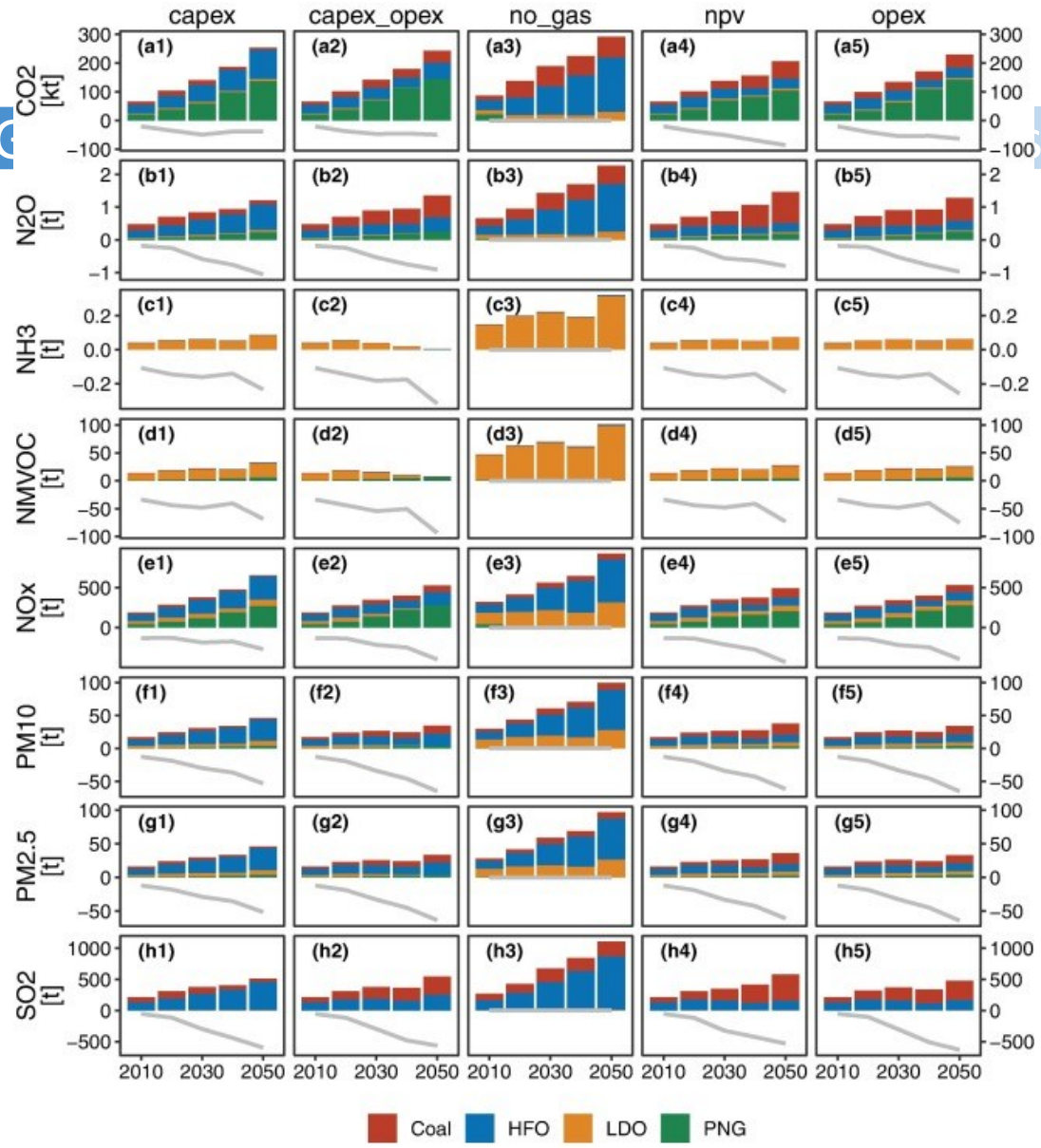
MUSE-RASA



Rationale to select the iron-steel sub-sector as a key case study to apply the agent-based MUSE framework. In Figure (a), A: Chemicals; B: Iron-steel; C: Food processing. Additional, PNG: Piped Natural Gas; HFO: Heavy Fuel Oil; CBFS: Carbon Black Feed Stock; LPG: Liquefied Petroleum Gas; LDO: Light Diesel Oil. Source: on-site surveys.

India case study

MUSE-RASA



Emission production and emission savings comparison of boilers on (a) CO2, (b) N2O, (c) NH3, (d) NMVOC, (e) NOx, (f) PM10, (e) PM2.5, and (f) SO2 for five scenarios (1) CAPEX-based, (2) CAPEX-OPEX-based, (3) NO-GAS-based, (4) NPV-based, and (5) OPEX-based. The line in grey represents the total emission savings in each scenario.

Conclusion – Overview

Abstracting from the real world to the RASA-MUSE model, outcomes and implications:

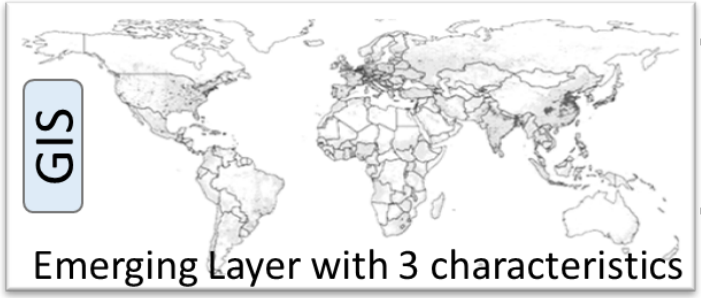
Macro-environment:

- GDP growth
- Population growth
- Commodity prices
- **Carbon tax schemes (5)**
- Productivity
- Climate-energy-economy system

Micro-environment:

(1) Heterogeneity: shaping structure

GIS



Emerging Layer with 3 characteristics

→ **(3) Evolution:** 2 spatiotemporal profiles

→ **(2) Diversity:** 8 shaping attributes

ABM

(4) Decision-making process:

- Choice/investment objectives
- Search rule (technoeconomics)
- Decision strategy
- Limited foresight

165 countries, 28 regions, 20 agents, 8 scenarios.

Long-term transition:

- Global service demand
- Global demand supply
- Global fuel consumption
- Global emissions
- Global CAPEX
- Global LCOE

Policy implications:

- Agents/regions that drive the consumption/CO_2
- Socioeconomics of where, who, how to target the decarbonisation
- Cost of the transition
- R&D prioritisation

Future work and services

Other regions: Global South and Global North

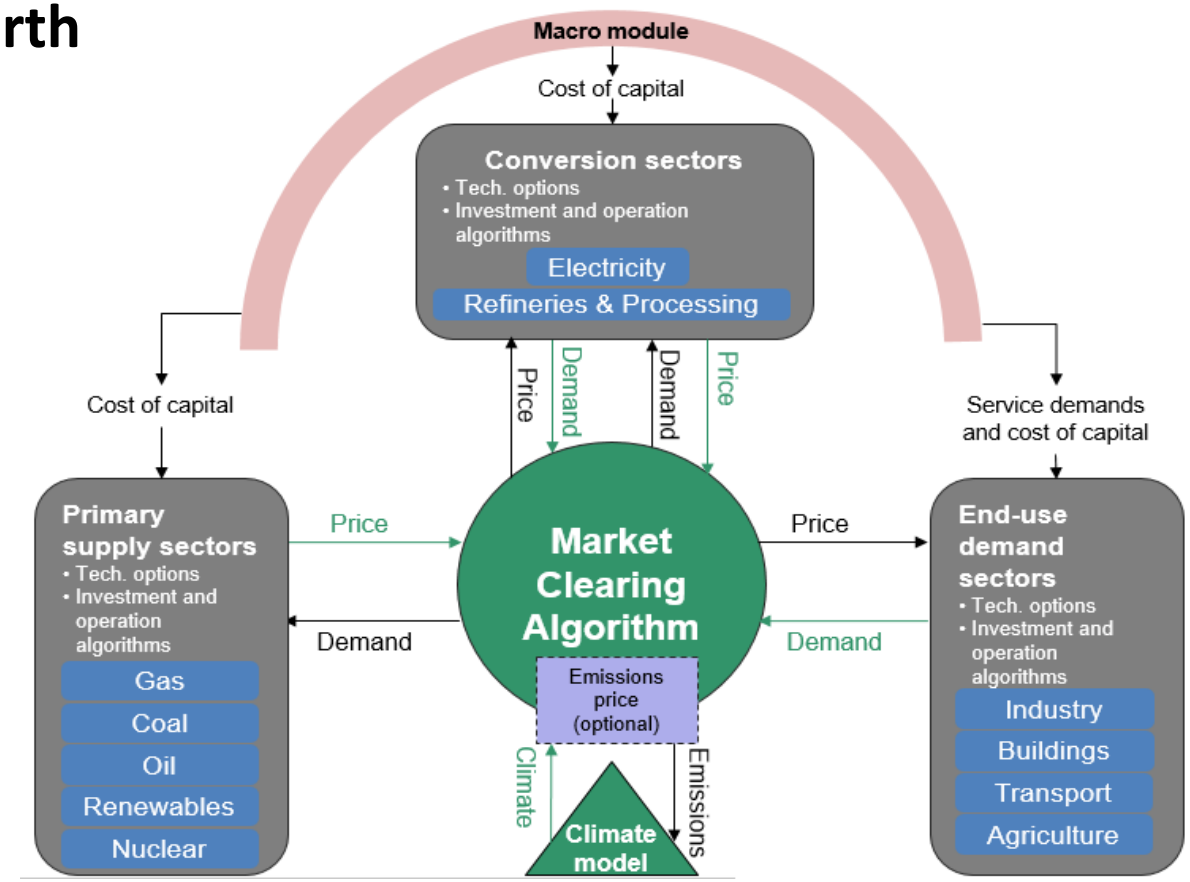
- Latin-American
- Africa
- Middle east
- China, India

Other technologies

- Hydrogen, biofuels
- Solar, wind
- Geothermal, waste to energy

Other sectors

- Transport, Industry, refineries, primary



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Founder:

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INSTITUTE FOR APPLIED SUSTAINABILITY RESEARCH