bwRSE4HPC

eCoSimHPC: Scaling up sector-coupled energy system analysis with RSE support

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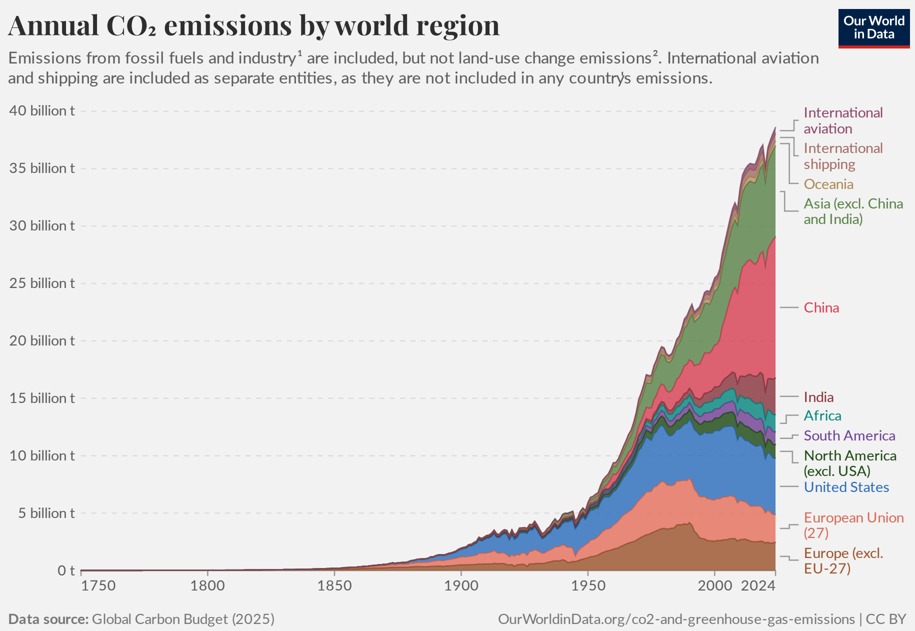
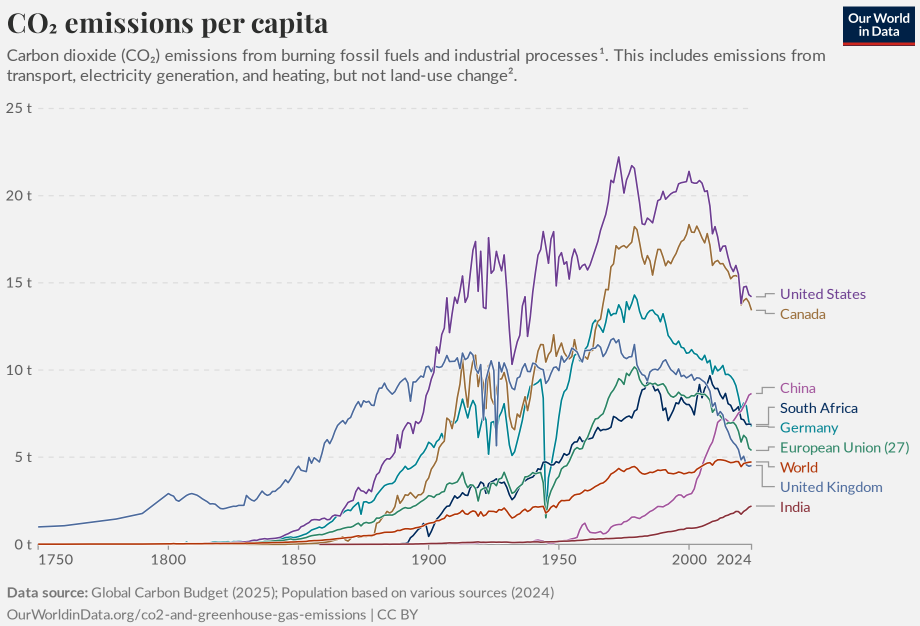
Towards carbon neutrality

Paris Agreement 2015: “hold the increase in the global average temperature to well below 2°C above pre-industrial levels and pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels.”





Integrating renewable sources

- Power required for a Stuttgart-sized city : ~180MW
- Large wind turbines can produce a few megawatts each.
- Connecting a wind farm to the electrical grid can overload the grid unless proper preparations are made.
- Simulations are required to demonstrate the impact renewables have on the power grid and identify where changes are needed.

Components of Coupled Energy System Simulations

- Structural components
  - Electrical, heat and gas grids
  - Sector coupling: P2X/X2P
  - Buildings (PV, batteries, heat pumps)
  - Transportation: electric vehicles, charging stations
- Variable components
  - Occupancy
  - Time of day
  - Weather


Photo by Brett Sayles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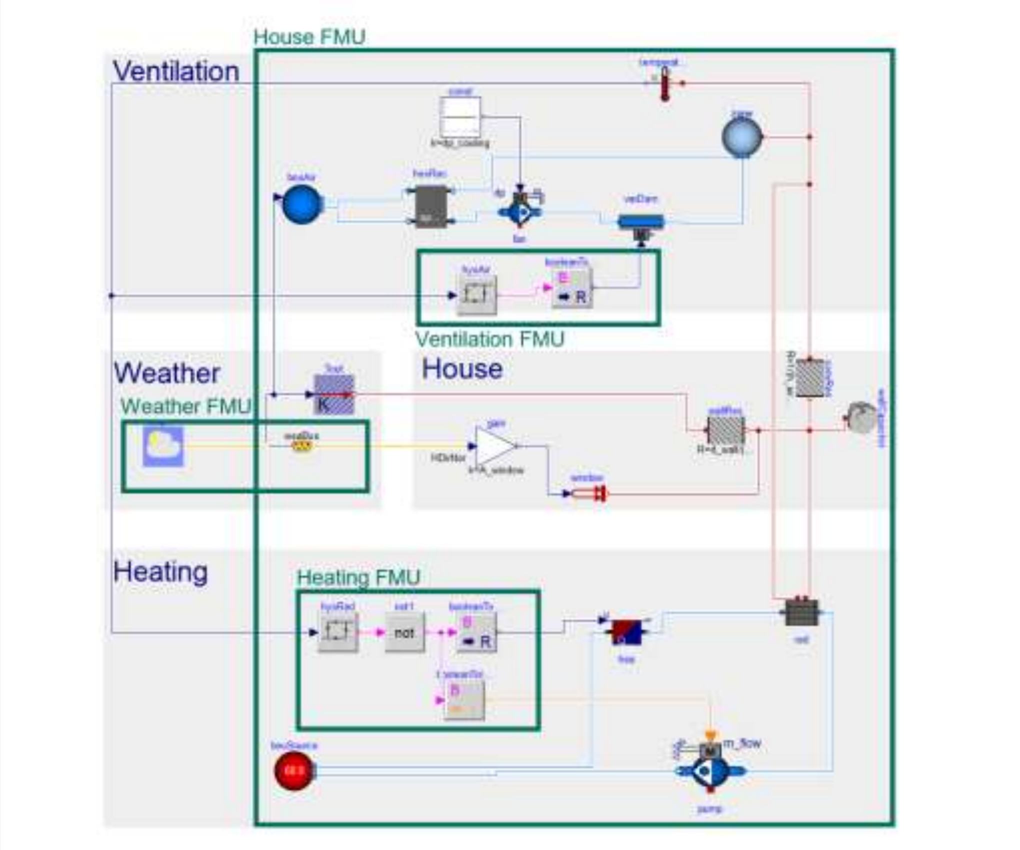
eCoSim: Energy System Co-simulation

- A co-simulation framework for controlling and executing simulators. (Çakmak et al. 2019).
- Enables data communication between different simulators.
- Integrates into existing data visualisation software – *e*ASiMOV (Kyesswa et al. 2017).

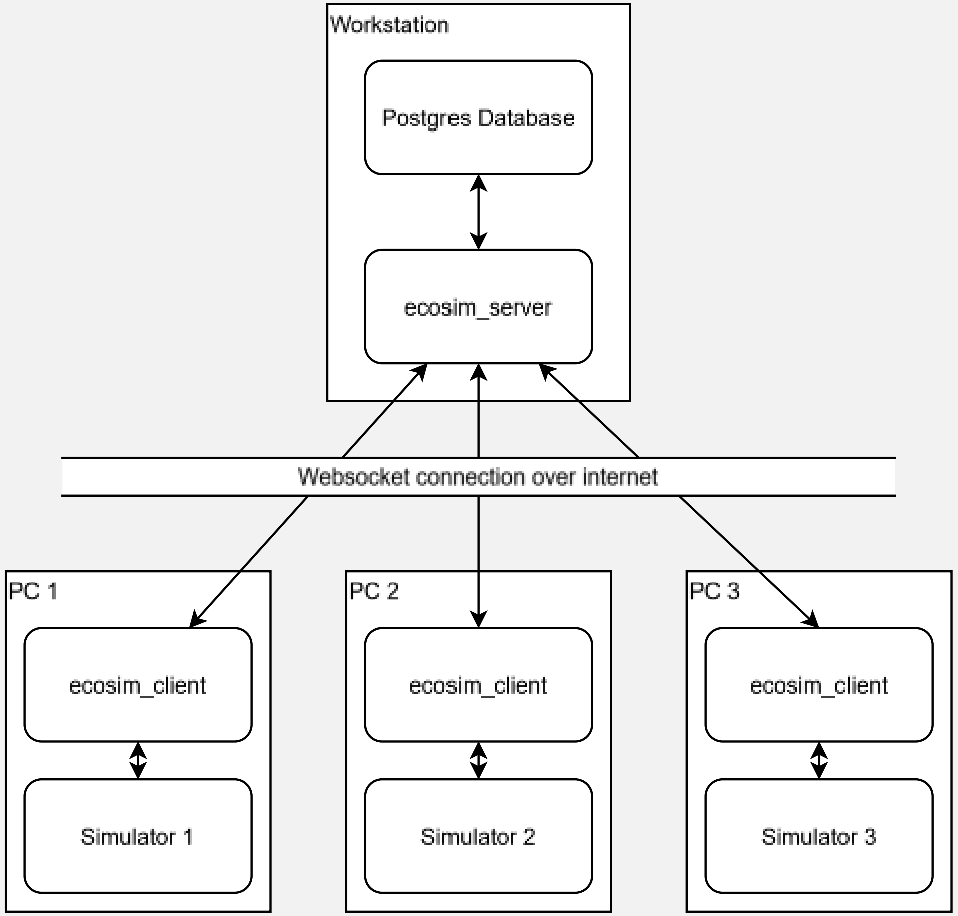


Kocher et al. 2024

Software stack

- Written primarily in Python.
- Data transfer through TCP communication with Python’s native socket package.
- Data storage with PostreSQL and sqlalchemy.
- Simulators can be created in Python, MatLab or compiled into a Functional Mock-up Unit (FMU).

eCoSim design:



eCoSim RSE history

eCoSim: Java based

(2019)

(2024)
Converted to Python

Python simulator compatibility

(2024/25)

(2025/26)

eCoSimHPC:

Dask backend

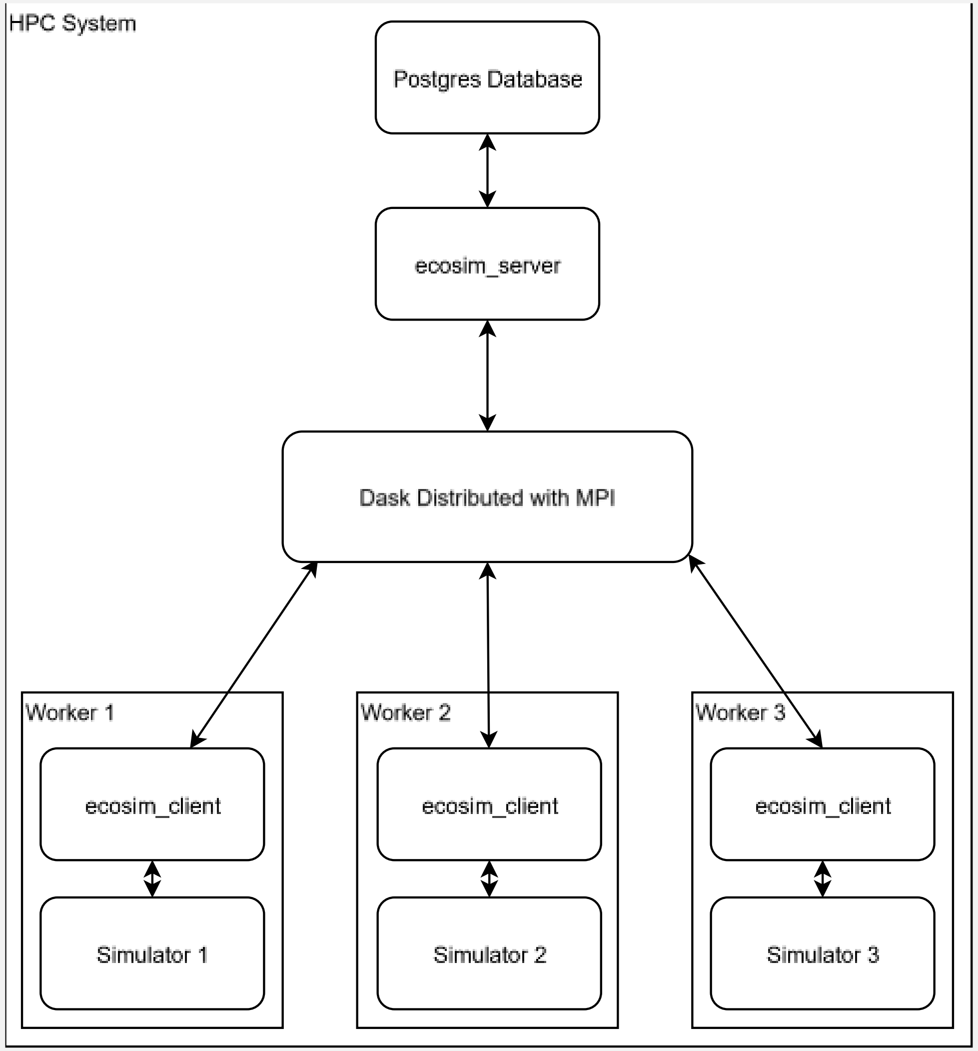
From eCoSim to eCoSimHPC

- In order to simulate a city’s energy grid, > 50000 simulators are needed! -> HPC Systems required.
- Need a way to distribute the simulators across multiple nodes whilst maintaining compatibility with existing software structure.
- Single executable for simpler user experience.

Development

1. Make use of abstraction methods to maintain compatibility.
2. Make use of Dask Distributed and Dask-MPI for distribution and communication.
3. Adapting existing tests to the new Dask-based back end.

eCoSimHPC design



Runtime comparison

Using the IceLake dev nodes on bwUniCluster:

Test	eCoSim runtime (s)	eCoSimHPC runtime (s)
Single Client	10.19	7.46
Three Clients	10.07	2.13
Matrix Transfer	10.39	17.94
Codependent	10.6	25.98
Batch steps (5 test range)	10.03 – 10.05	1.5-1.91

- eCosim contains unneeded sleep statements when running on a single machine

Larger scale testing

- 43 simulators (42 FMUs and 1 Python)

eCoSim:

- System: 12 core workstation
- Runtime for 44638 timeteps: 2hrs 13mins
- Runtime per timestep: 0.17s

eCoSimHPC:

- bwUniCluster3 Compute Node using 96 cores
- Runtime for 100 timesteps: 11mins 20sec.
- Runtime per timestep: 6.8s

=> Processing of messages on ecosim-server currently runs sequentially.

Next steps

- Resolve the concurrent message processing issue.
- Investigate and solve context switching issues (reduce the number of cores needed).
- Test other kinds of larger scale simulations to better gauge scalability and performance, including ones that require more computing resources than one workstation or node.
- Publish eCoSim and eCoSimHPC as open source software.

Summary

- eCoSim is a Python based co-simulation program designed for simulating energy systems.
- With the implementation of Dask, simulators can be distributed whilst maintaining compatibility with existing code.
- RSE support has enabled the code to expand, supporting more simulators and running larger co-simulations.