Climate Change AI

NEURAL INFORMATION PROCESSING SYSTEMS

A Configurable Pythonic Data Center Model for Sustainable Cooling and ML Integration

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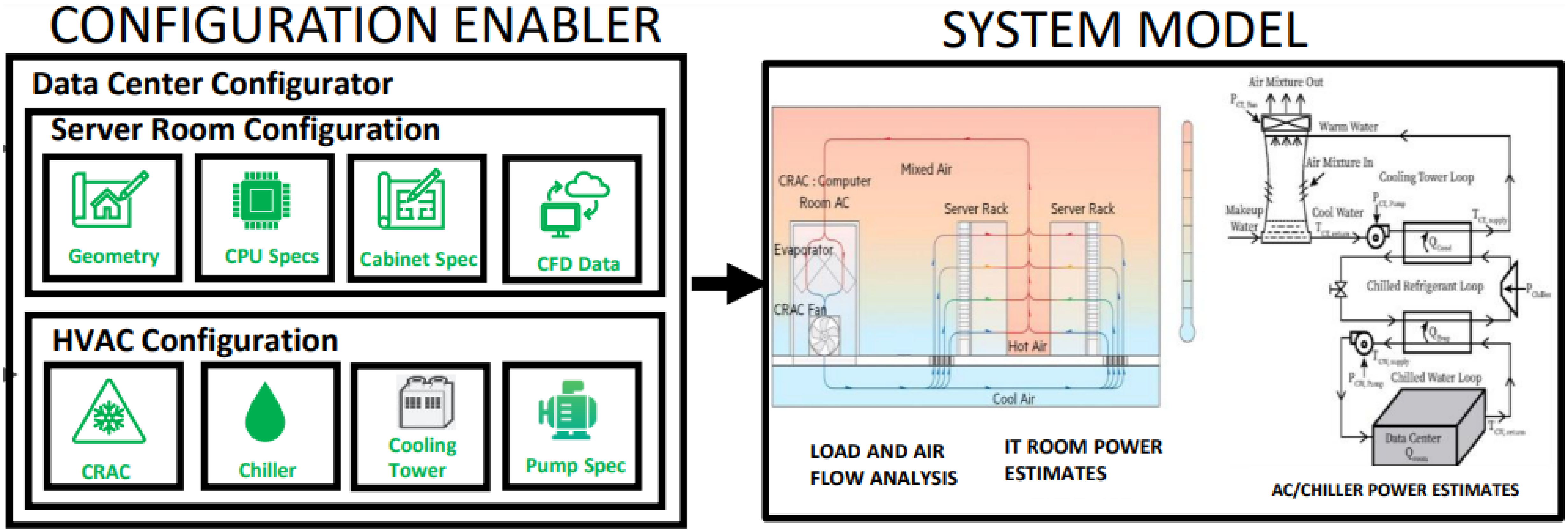
Architecture Overview



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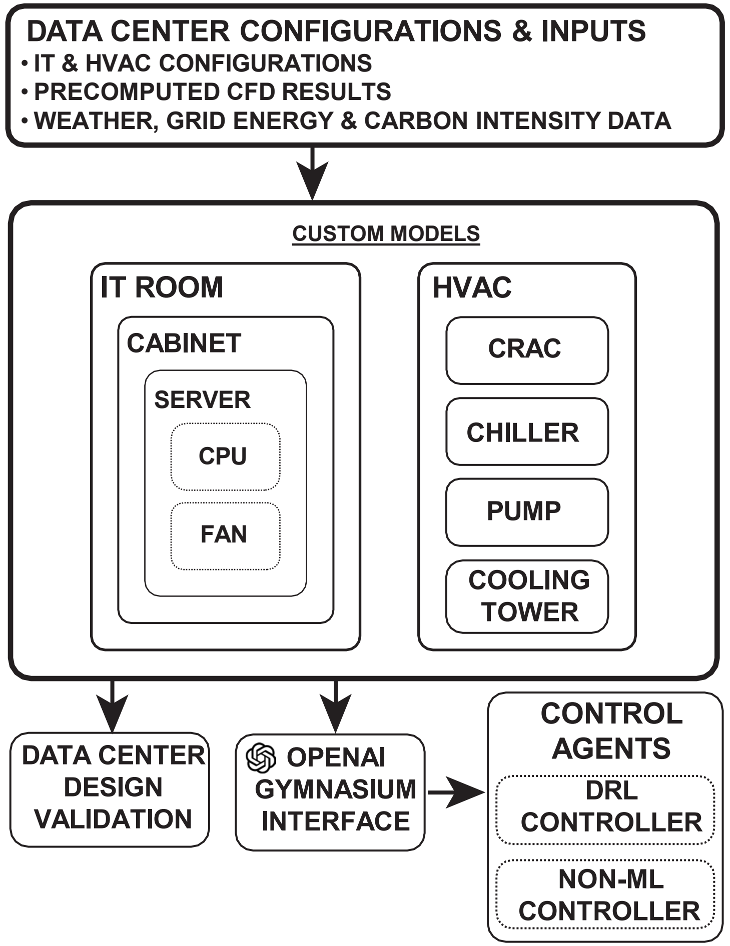
Architecture Details

- **JSON enabled Customization**
  - IT Room Geometry and Parameters
  - IT And HVAC System Parameters
  - Precomputed CFD measurements
- Python enabled
  - **Hierarchical Modeling** of IT and HVAC systems
  - **Visualization**
- **Control Agents**
  - Open AI gym **interface** with support for Multiagent Reinforcement Learning
  - **Traditional controllers** like MPC
- Vectorized calculations to facilitate high **scalability** and **faster execution** on limited resources for simulation



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Comparison with Current Data Center Model Implementations

Characteristics / Current Implementations	IT Room Customization	HVAC Customization	Open AI interface for RL Control	Integrate CFD Results	Temperature Visualization	Scalability	Execution Speed
CFD Based	🟢	🟢	🔴		🟢	🔴	🔴
Energy Plus and Open Modelica	🟡	🟡	🟡	🟢	🟡	🟡	🟡
Our Work	🟢	🟢	🟢	🟢	🟢	🟢	🟢

🟢 Includes these features

🟡 Limited work

🔴 Lacks these features

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Customizability

- Parameter values assigned via dictionary →Any parameter can be updated
- CFD Datasets: Any arrangement of data center provided the “supply” and “approach” temperatures are precomputed

Parameter	Description	Example Value
NUM_ROWS	# of rows in the data center	5
NUM_RACKS_PER_ROW	# of racks per row	10
CPUS_PER_RACK	# of CPUs per rack	40
RACK_SUPPLY_ APPROACH_TEMP_LIST	Supply temperatures for each rack	[22, 22.5, ...]
C_AIR	Air properties	1006
CHILLER_COP	Chiller’s coefficient of performance	6.0
IT_FAN_AIRFLOW_ RATIO_LB	LB Fan airflow ratios for IT equipment	[0.0 0.6]
IT_FAN_AIRFLOW_ RATIO_UB	UB Fan airflow ratios for IT equipment	[0.7 1.3]

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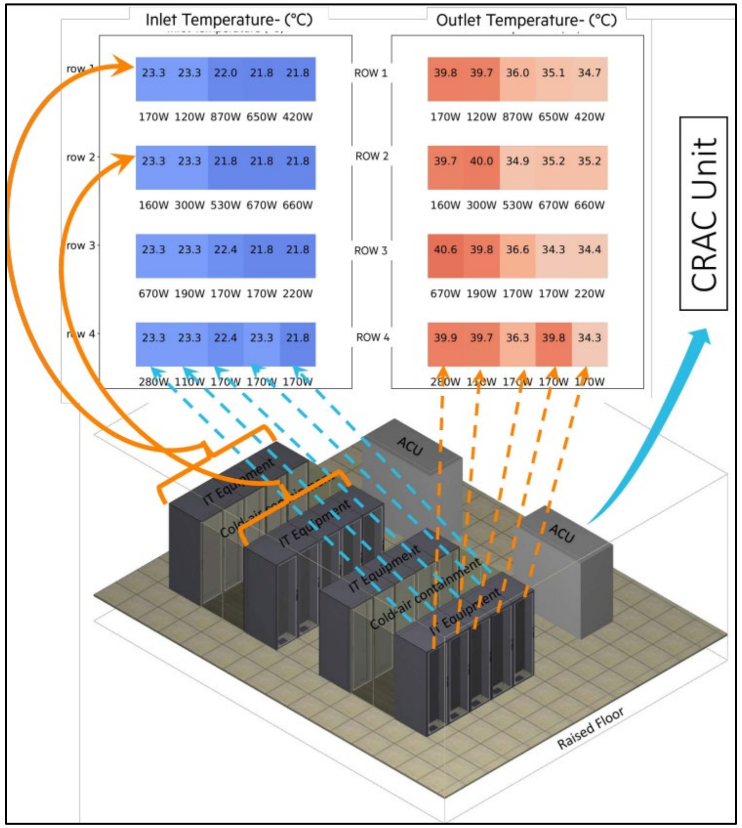
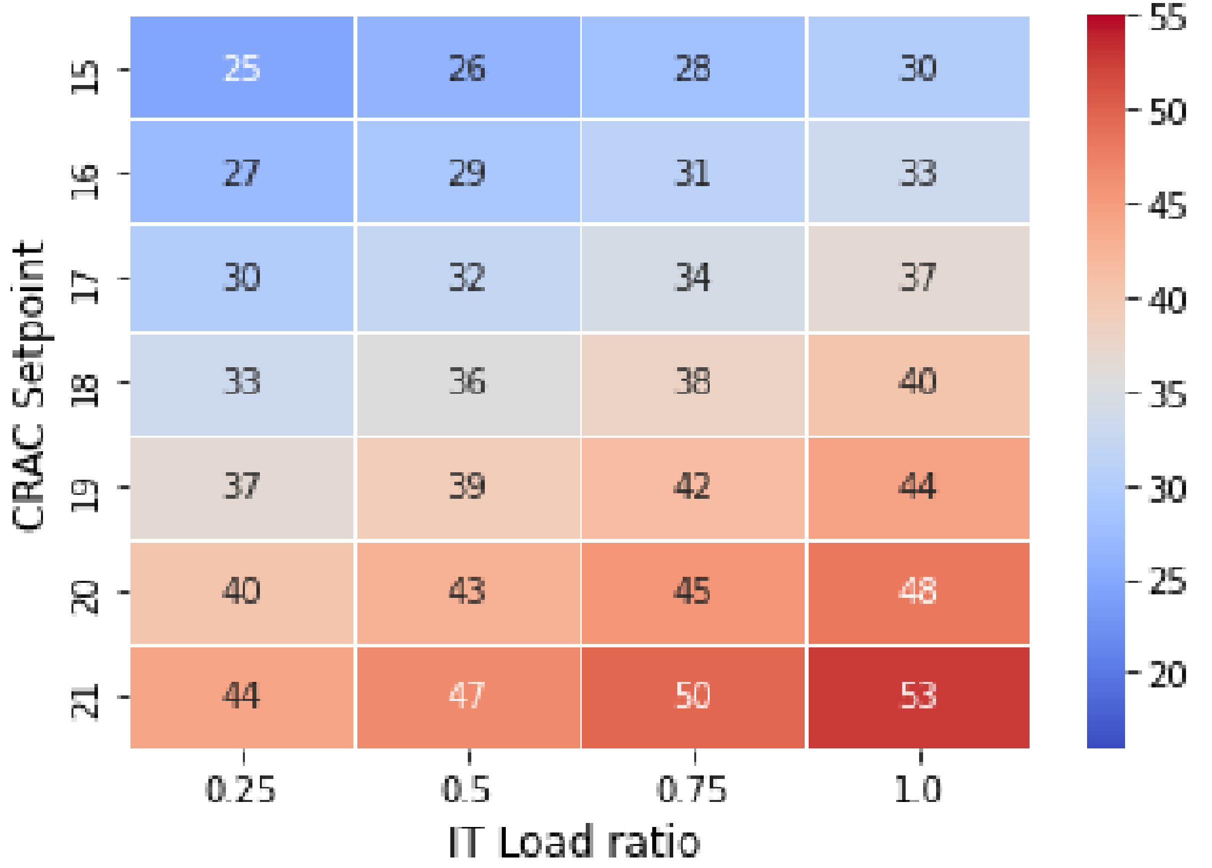
```
{
    "data_center_configuration" :
    {
        "NUM_ROWS" : 4,
        "NUM_RACKS_PER_ROW" : 5,
        "RACK_SUPPLY_APPROACH_TEMP_LIST" : [
                                        5.3, 5.3, 5.3, 5.3,
                                        5.0, 5.0, 5.0, 5.0,
                                        5.0, 5.0, 5.0, 5.0,
                                        5.3, 5.3, 5.3, 5.3
                                        ],
        "RACK_RETURN_APPROACH_TEMP_LIST" :  [
                                        -3.7, -3.7, -3.7, -3.7,
                                        -2.5, -2.5, -2.5, -2.5,
                                        -2.5, -2.5, -2.5, -2.5,
                                        -3.7, -3.7, -3.7, -3.7
                                        ],
        "CPUS_PER_RACK" : 300
    },
    "hvac_configuration" :
    {
        "C_AIR" : 1006,
        "RHO_AIR" : 1.225,
        "CRAC_SUPPLY_AIR_FLOW_RATE_pu" : 0.00005663,
        "CRAC_REFRENCE_AIR_FLOW_RATE_pu" : 0.00009438,
        "CRAC_FAN_REF_P" : 150,
        "CHILLER_COP" : 6.0,
        "CT_FAN_REF_P" : 1000,
        "CT_REFRENCE_AIR_FLOW_RATE" : 2.8315,
        "CW_PRESSURE_DROP" : 300000,
        "CW_WATER_FLOW_RATE" : 0.0011,
        "CW_PUMP_EFFICIENCY" : 0.87,
        "CT_PRESSURE_DROP" : 300000,
        "CT_WATER_FLOW_RATE" : 0.0011,
        "CT_PUMP_EFFICIENCY" : 0.87
```


Example JSON script for configuring data center

Visualization



Temperature Distribution with Cold Air Containment



Rack Outlet Temperature($°C$) as a function of IT load ratio and CRAC set point

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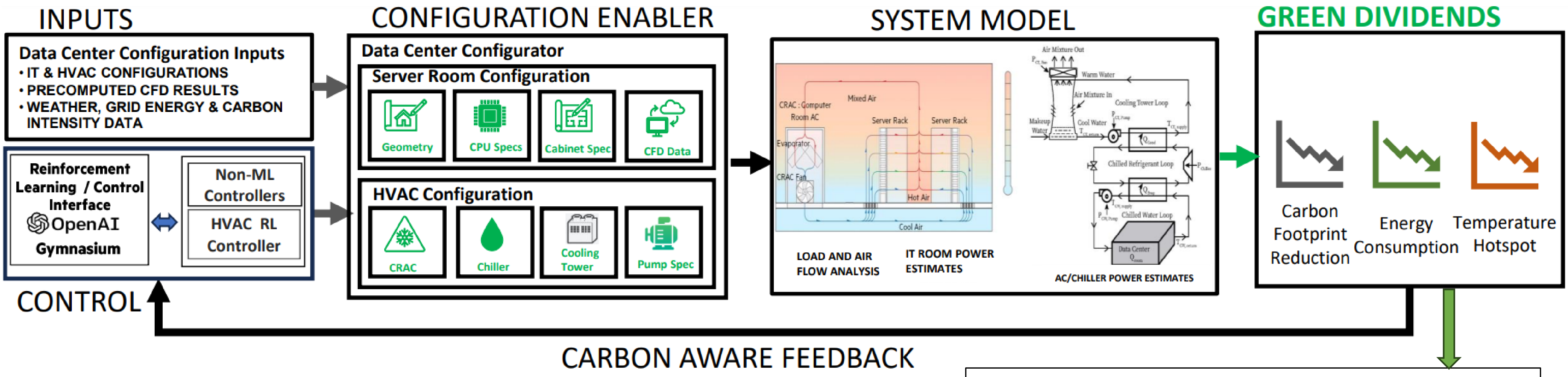
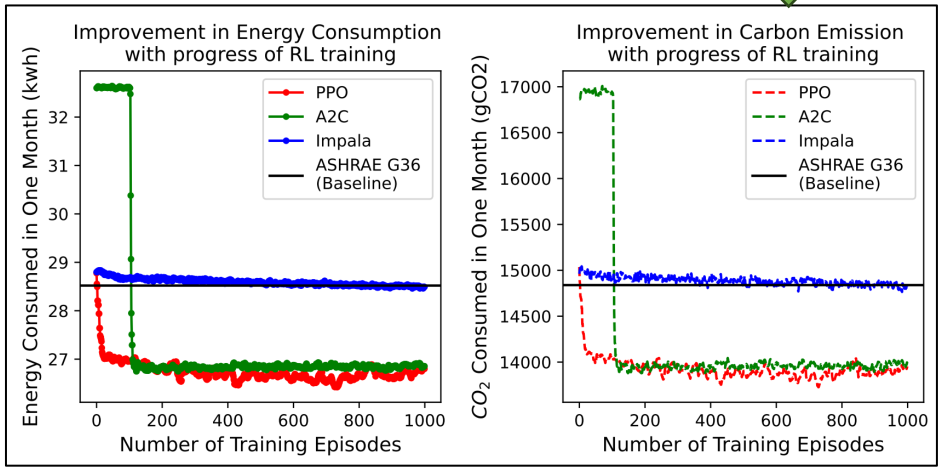
Control





7.63 % savings in energy consumed

7.23% savings in carbon footprint

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Speed and Scalability

Comparison of method timings between implementations in EnergyPlus and PyDCM. Mean ± std. dev. of 10 simulations

Method	EnergyPlus	PyDCM	Reduction (%)
init	1.05s ± 23.6ms	1.57ms ± 60.4µs	99.85
reset	2.67s ± 23.8ms	0.03ms ± 0.25µs	99.99
step	0.46ms ± 98.38µs	0.13ms ± 15.84µs	71.33

Total simulation time comparison between implementations in EnergyPlus and PyDCM for different RL episode lengths. Mean ± std. dev. of 10 simulations

Episode	EnergyPlus	PyDCM	Reduction (%)
30 days	3.33s ± 91.20ms	0.34s ± 42.20ms	89.79
7 days	2.64s ± 34.39ms	0.09s ± 1.86ms	96.77

Comparison of Performance Metrics between implementations in EnergyPlus and PyDCM for RL Environments. Mean ± std. dev. of 10 simulations

Metric	EnergyPlus	PyDCM	Reduction (%)
Wait. Time	1.48s ± 0.22s	0.27s ± 0.48ms	81.55
Sample Time	9.28s ± 0.51s	3.95s ± 16.20ms	57.34

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Conclusions

- Developed a data center modeling and control-enabling framework
- Demonstrated it resource effectiveness and speed compared to current implementations

Future Work

- Add Cooling technologies like liquid cooling
- Load-shifting workloads and battery optimization presents a further refinement with multiagent RL

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Thank you!
Questions?

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