CIRLEM

Enhancing Climate Resilience and Energy Flexibility of Buildings and Energy Systems by Combining Collective Intelligence and Reinforcement Learning

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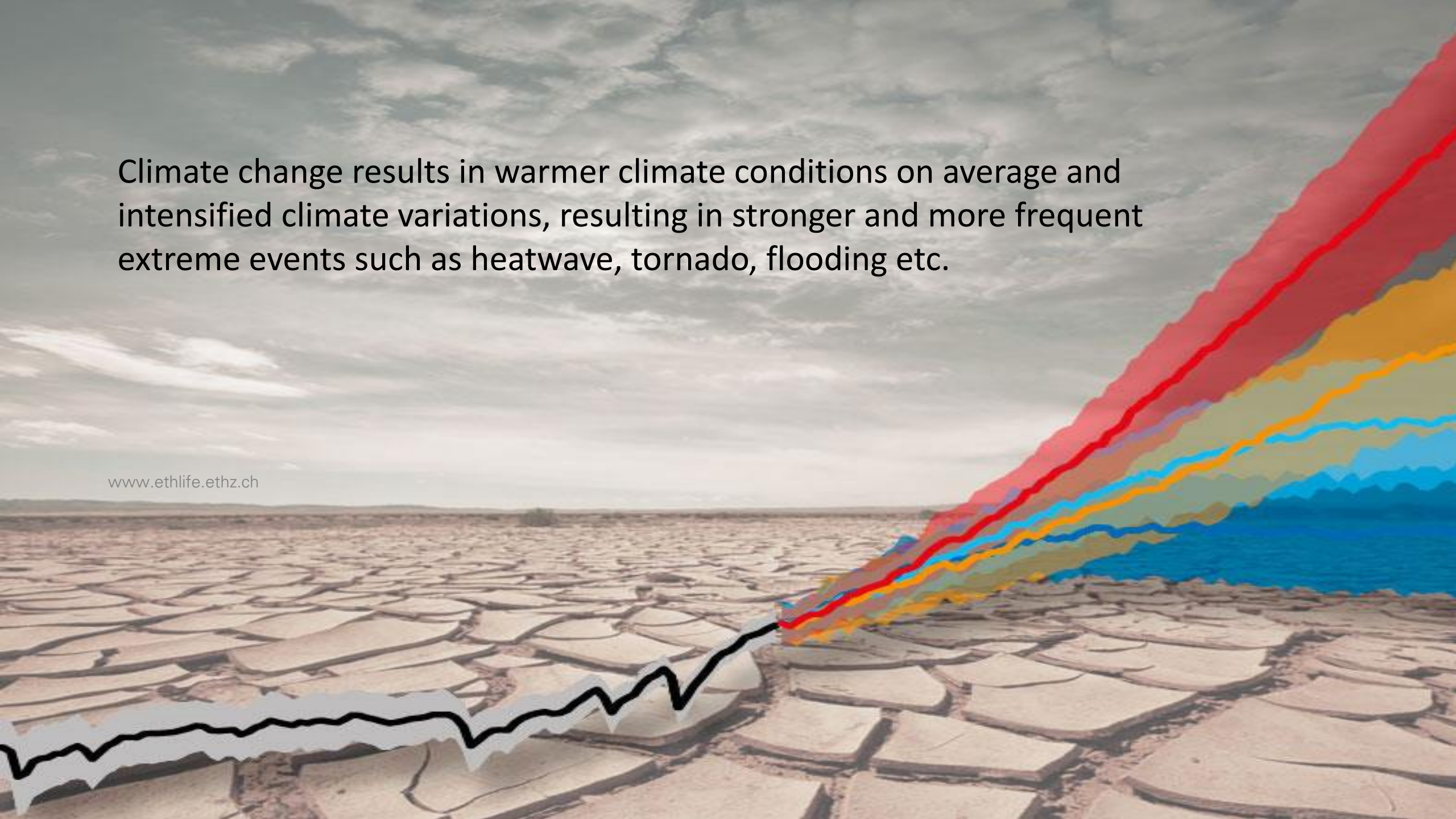
Climate change results in warmer climate conditions on average and intensified climate variations, resulting in stronger and more frequent extreme events such as heatwave, tornado, flooding etc.



Urban energy systems are complex systems, affected by several factors, such as building energy performance, user behavior, other urban utilities etc. Impact of extreme climate events can become much larger in complex systems such as urban energy systems, therefore we should increase the 'climate resilience' of such systems and make them more resistance and flexible for the future climate.

Nik VM, Perera ATD, Chen D. "Towards climate resilient urban energy systems: A review", National Science Review, March 2021, 8, 3. doi:10.1093/nsr/nwaa134.

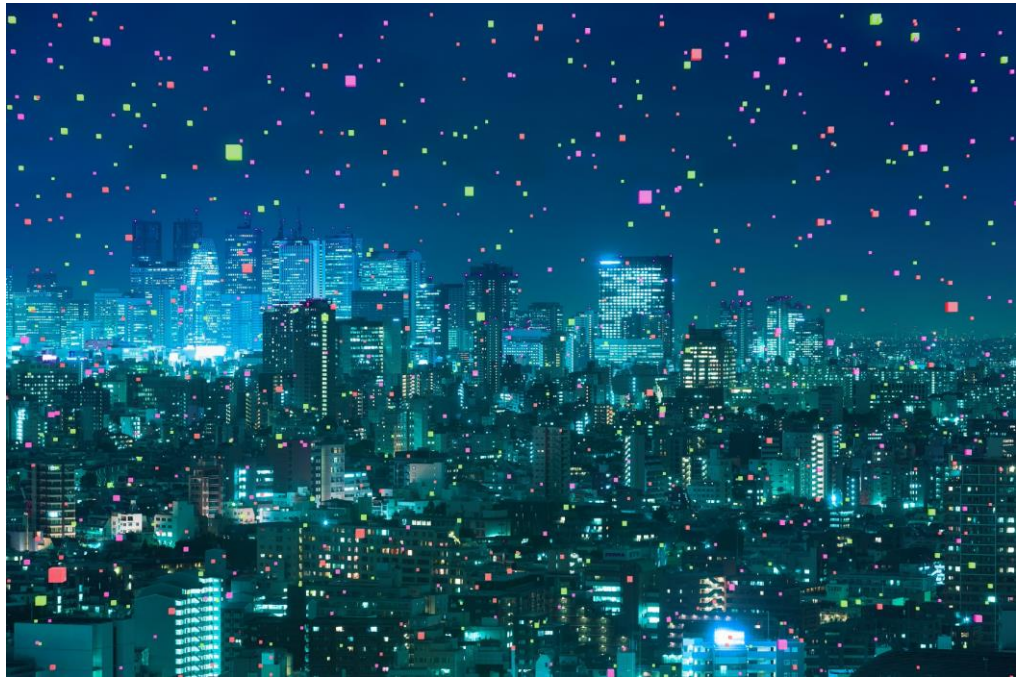
Need for innovative approaches for energy system design and control

→ White/Grey/Black-box modelling
→ AI-driven approaches
  → ML and RL approaches

What is CIRLEM

- Combined **C**ollective **I**ntelligence and **R**einforcement **L**earning in **E**nergy **M**anagement

- **CI**→ Collaborative Behavior
- **RL**→ Performance Enhancement



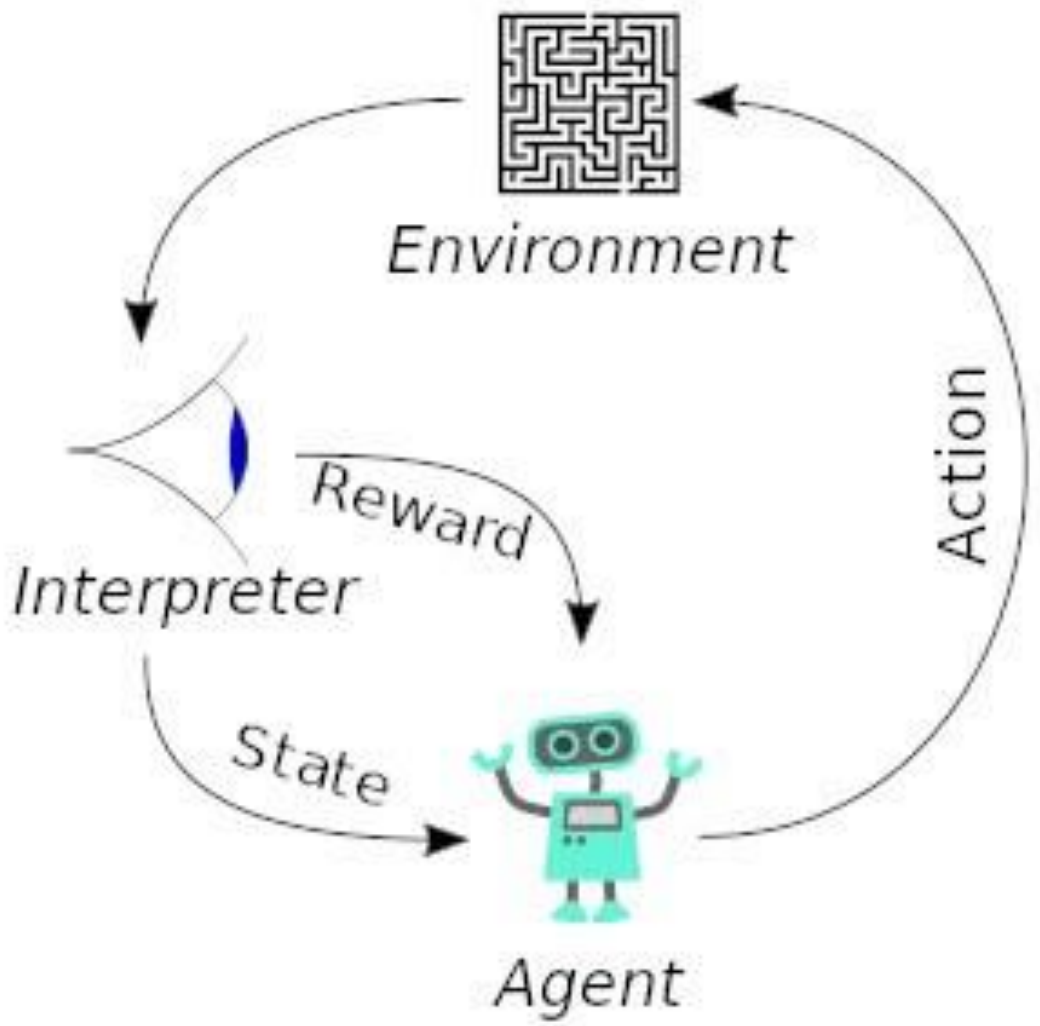
Collective Intellligence

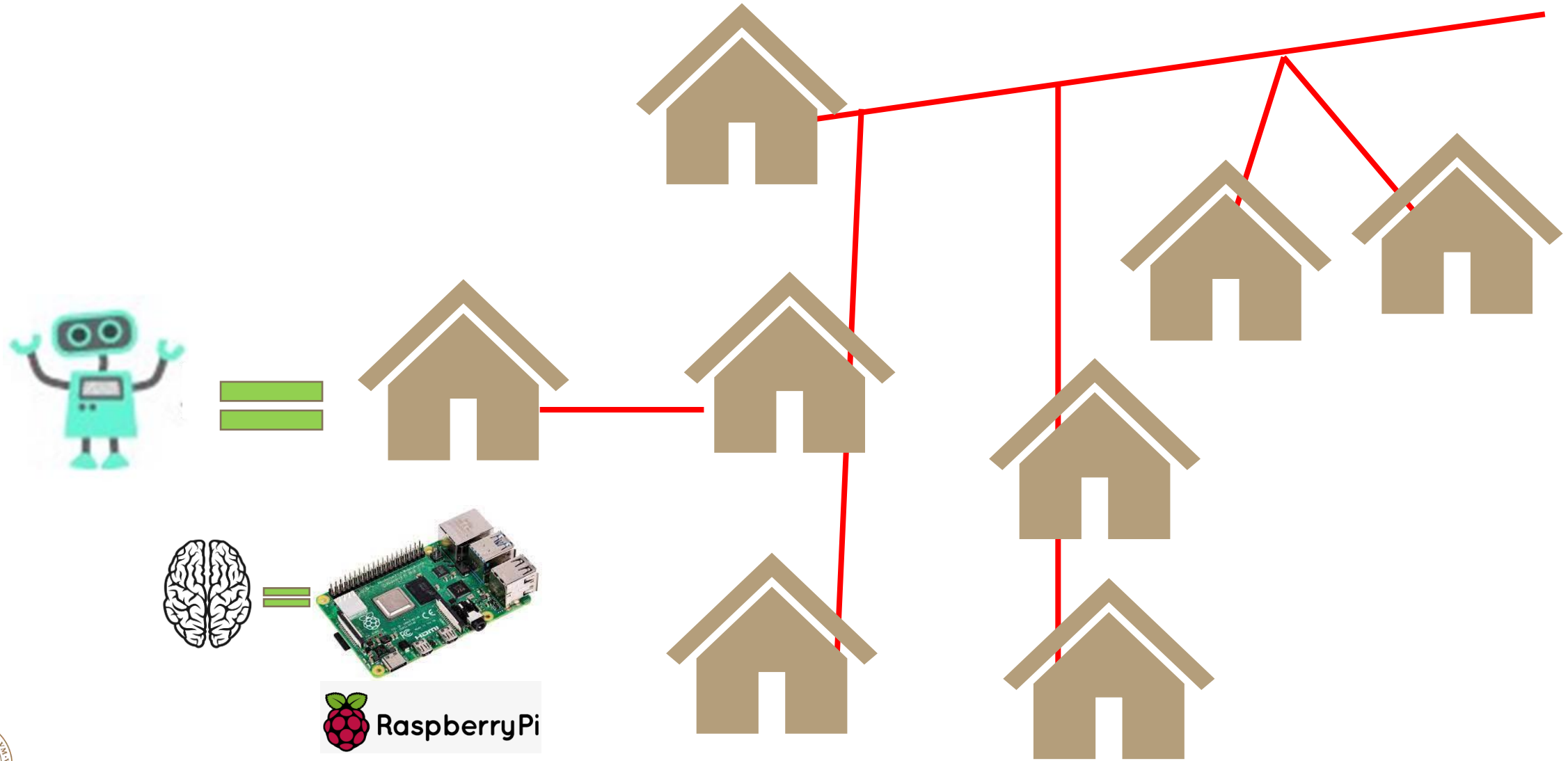
In natural ecosystems:

- Enables teams and entire ecosystems to overcome shocks
- No need for leadership
- Minimum data gathering and information sharing
- Enhances over time (self-learning)

Reinforcement Learing

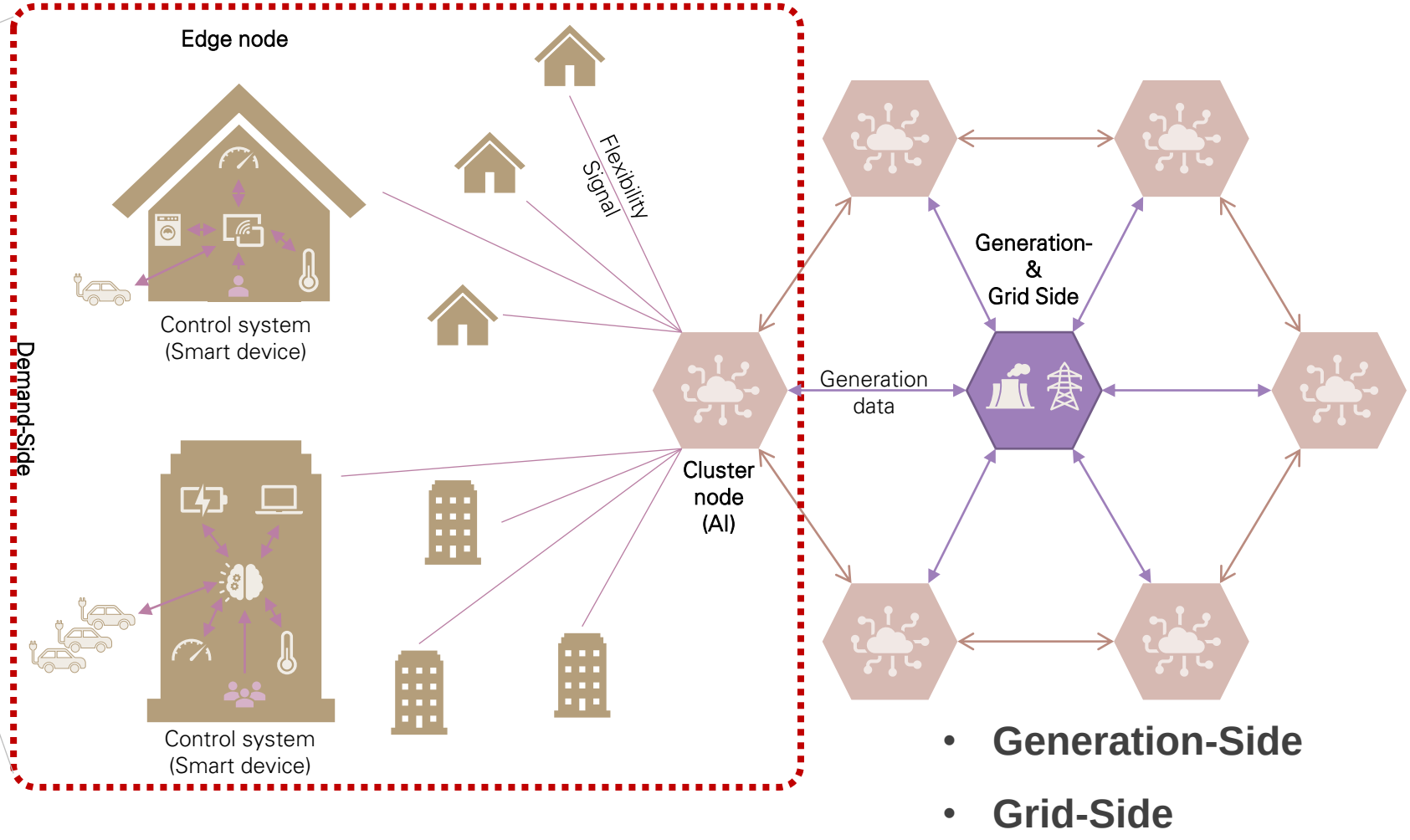
- Learning by doing
- Learning without requiring historic data
- Maximizing the reward by keeping the state close to the defined conditions
- Low computation




RaspberryPi

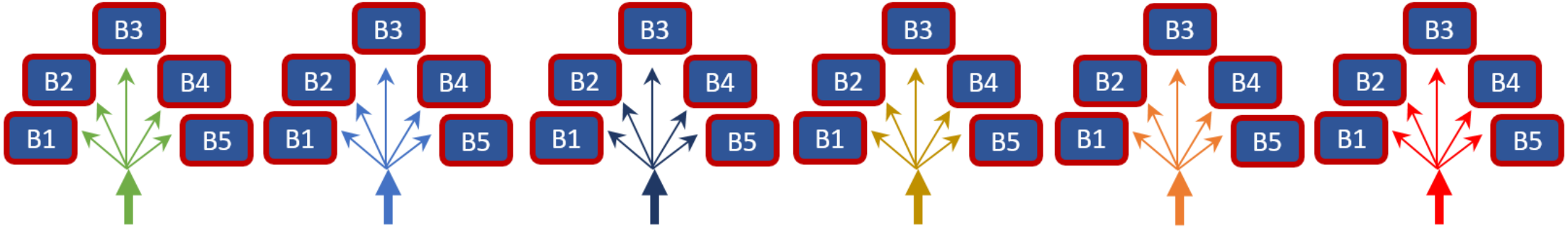
A network of agents that work in a collaboratiove manner with a minimum amount of data comminucation.

- **Demand-Side**
  - Edge Node
  - Cluster Node



- **Generation-Side**
- **Grid-Side**

CIRLEM - ENC



Signal: 0

$E^t \leq E^t_{Reference\ 1}$

Signal: 1

$E^t > E^t_{Reference\ 1}$

Signal: 2

$E^t > E^t_{Reference\ 2}$

Signal: 3

$E^t > E^t_{Reference\ 3}$

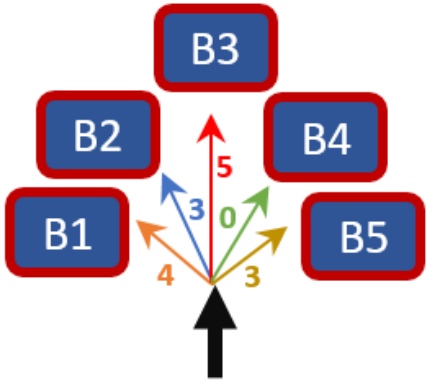
Signal: 4

$E^t > E^t_{Reference\ 4}$

Signal: 5

$E^t > E^t_{Reference\ 5}$

CIRLEM - ECC

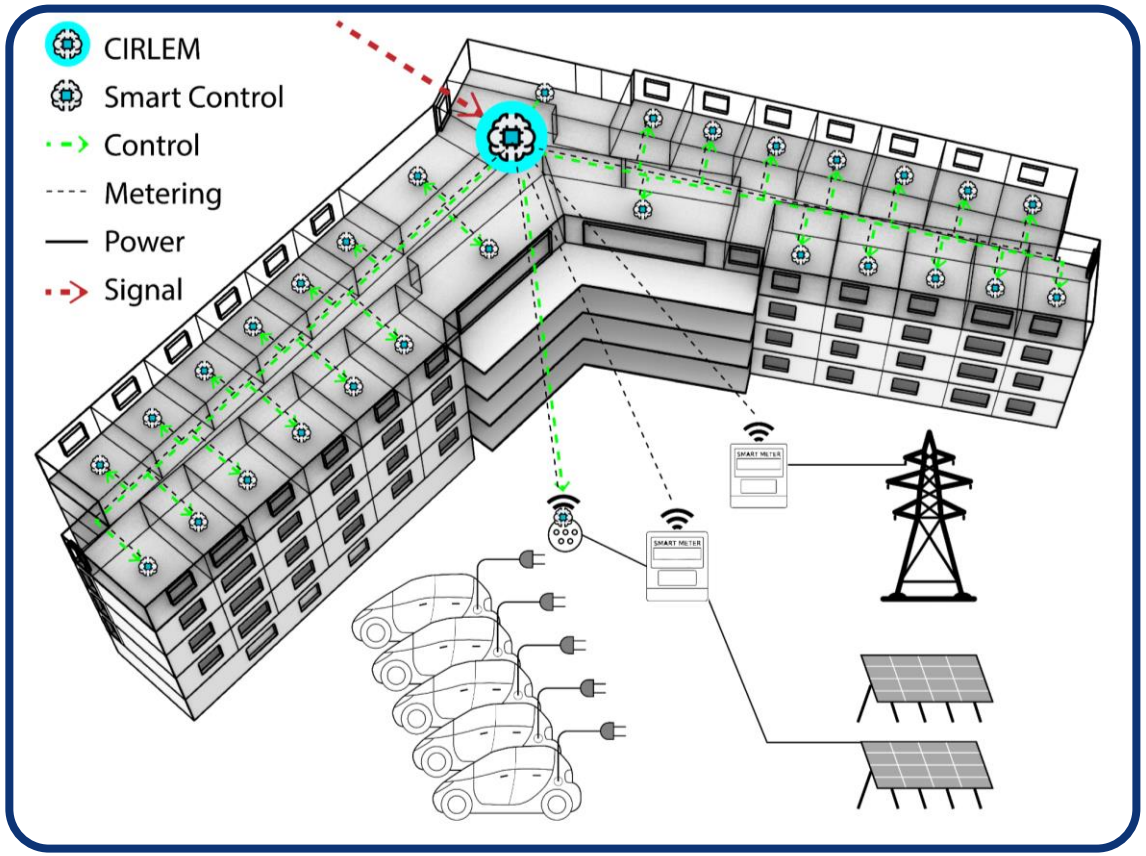


Signals

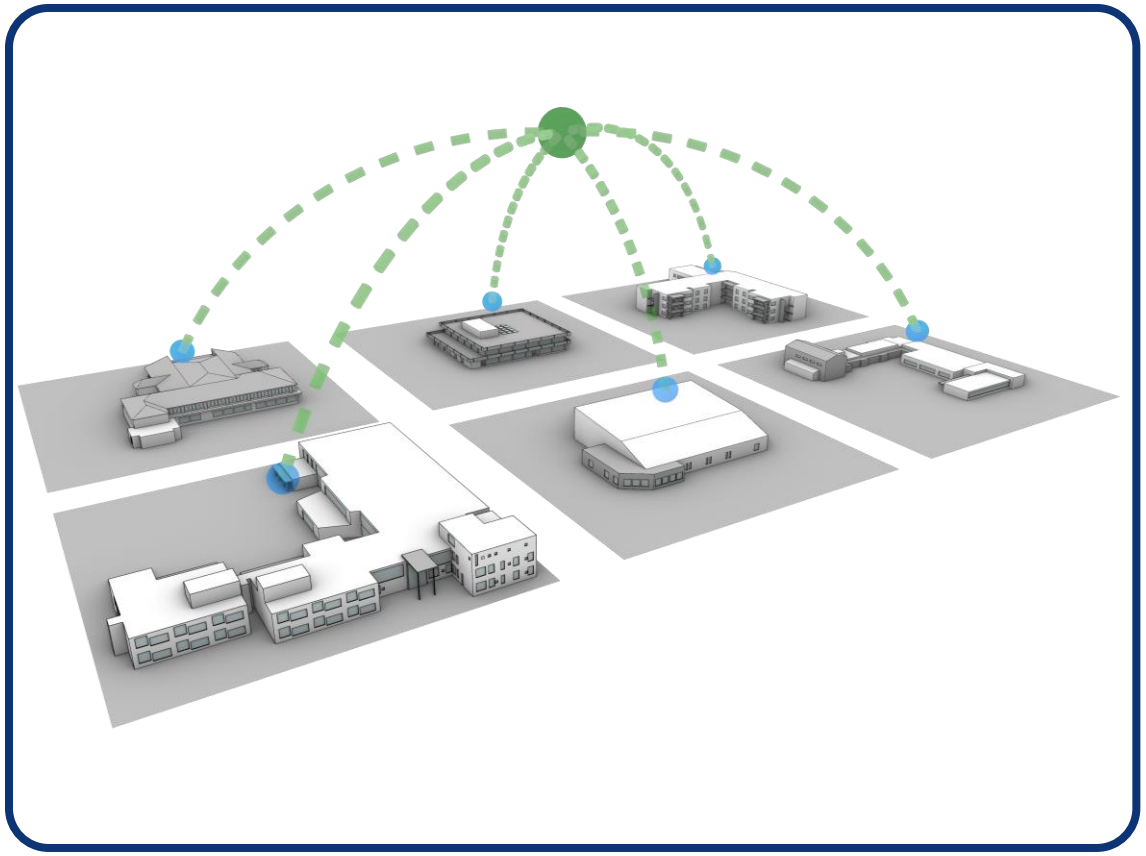
$E^t > E^t_{Reference}$

Nik VM, Hosseini M. "CIRLEM: a synergic integration of Collective Intelligence and Reinforcement learning in Energy Management for enhanced climate resilience and lightweight computation", Appl Energy 2023;350:121785. doi:10.1016/j.apenergy.2023.121785.

CIRLEM Framework

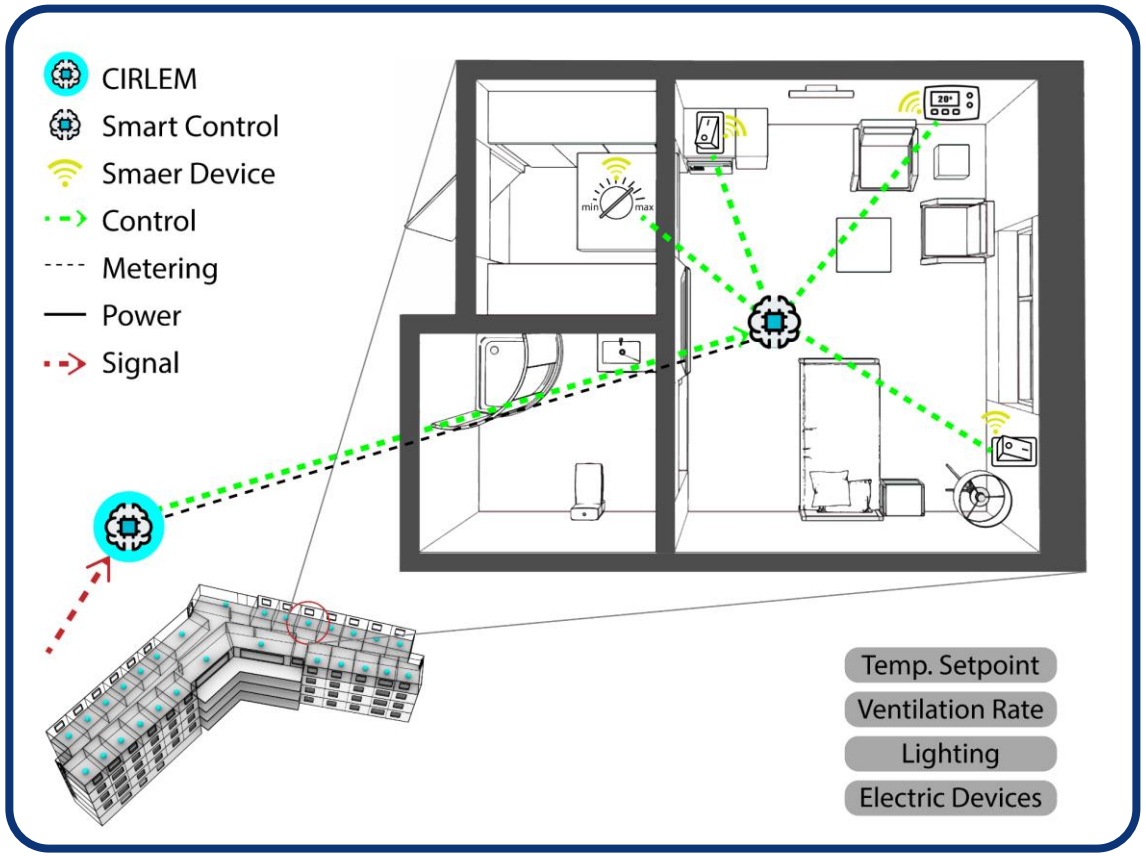


Edge Node (Building Level)

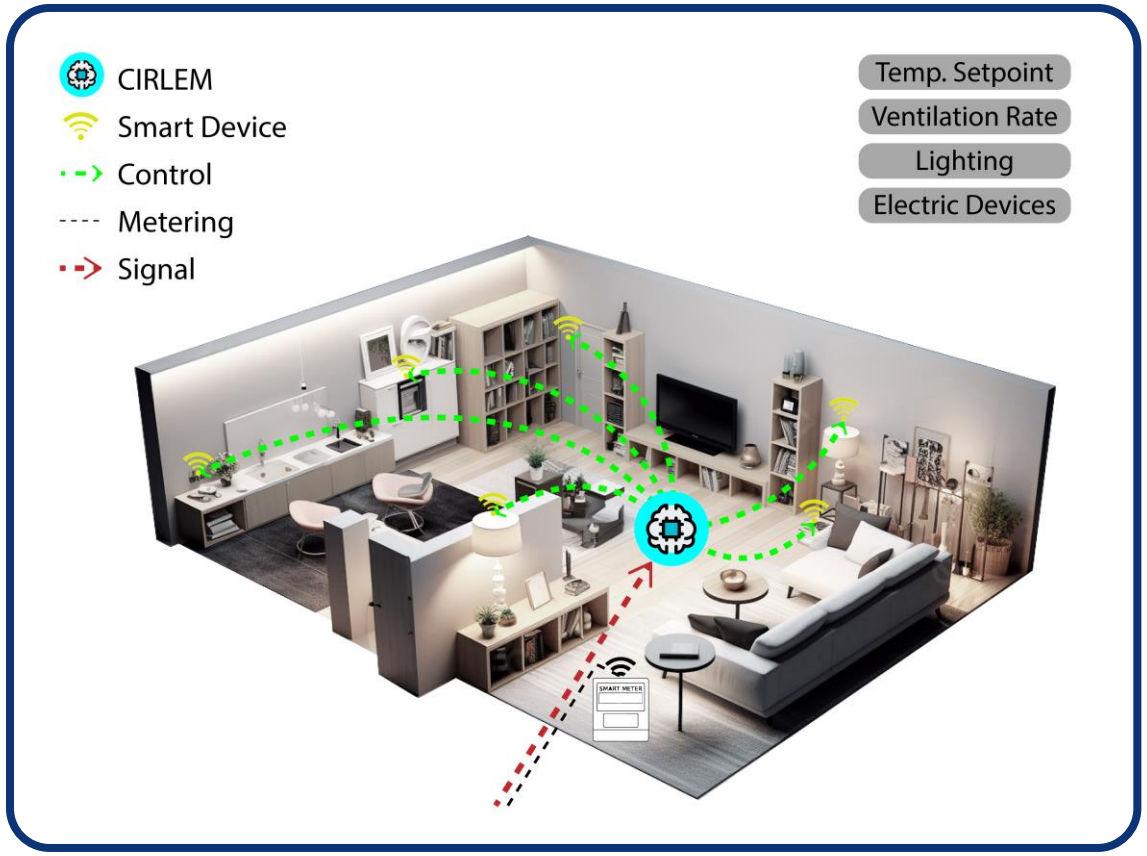


Cluster Node (Urban Scale)

CIRLEM Framework (EN)

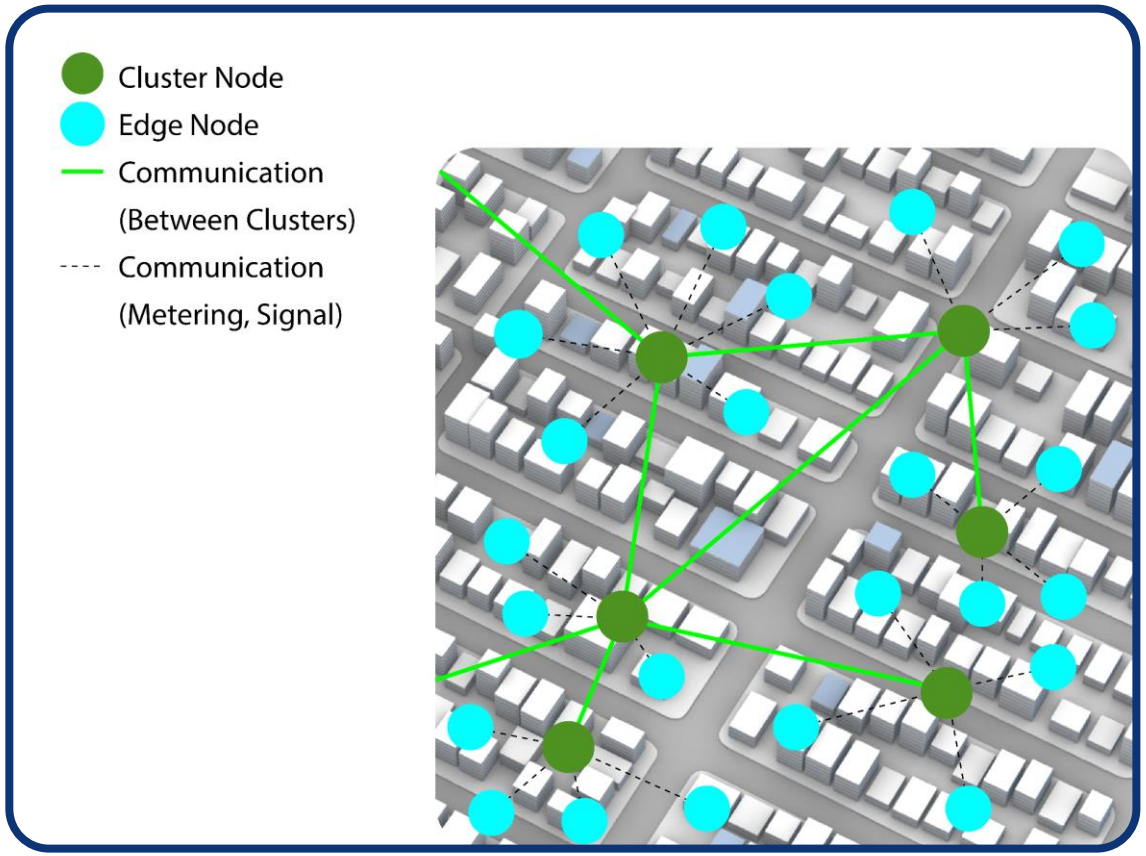


Edge Node (Multiple units)

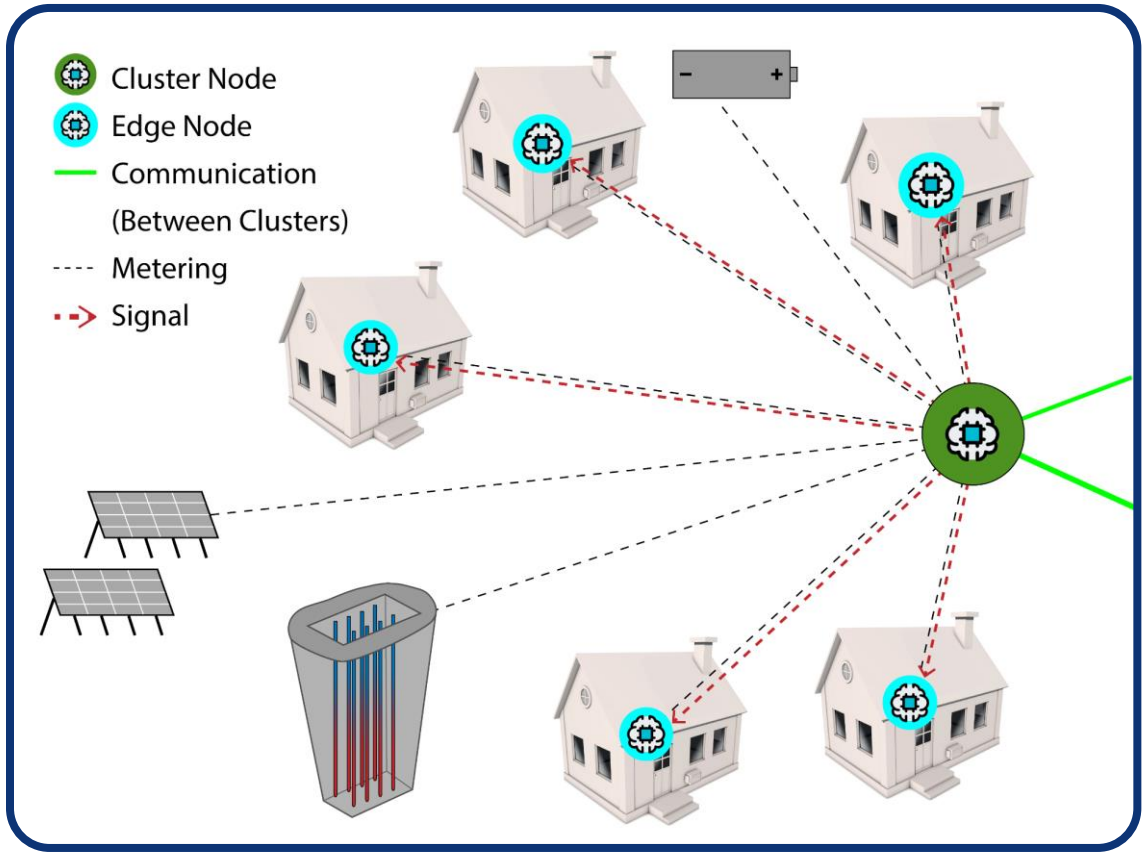


Edge Node (Single units)

CIRLEM Framework (CN)



Cluster Node (Between clusters)



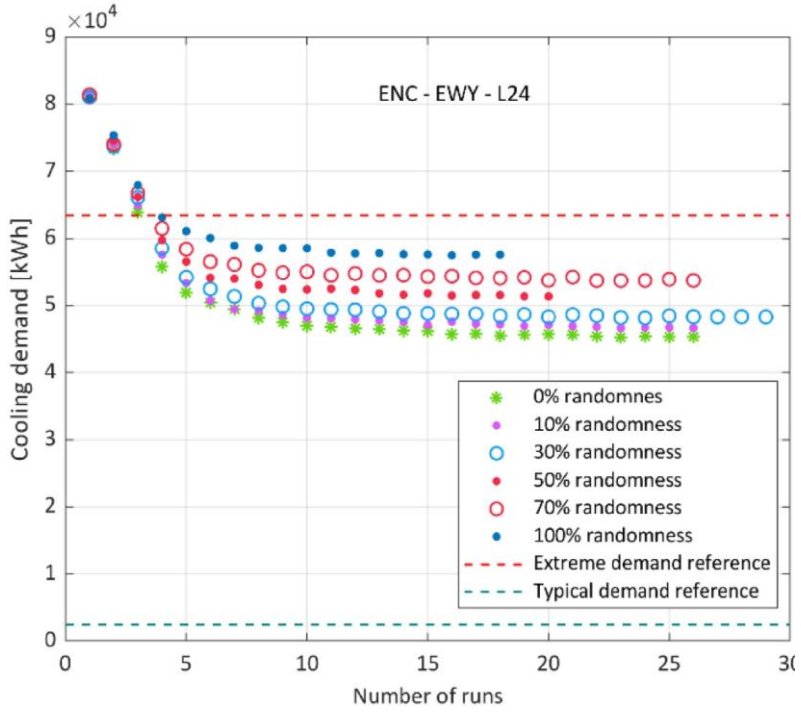
Cluster Node (Within a cluster)

Signal in CIRLEM

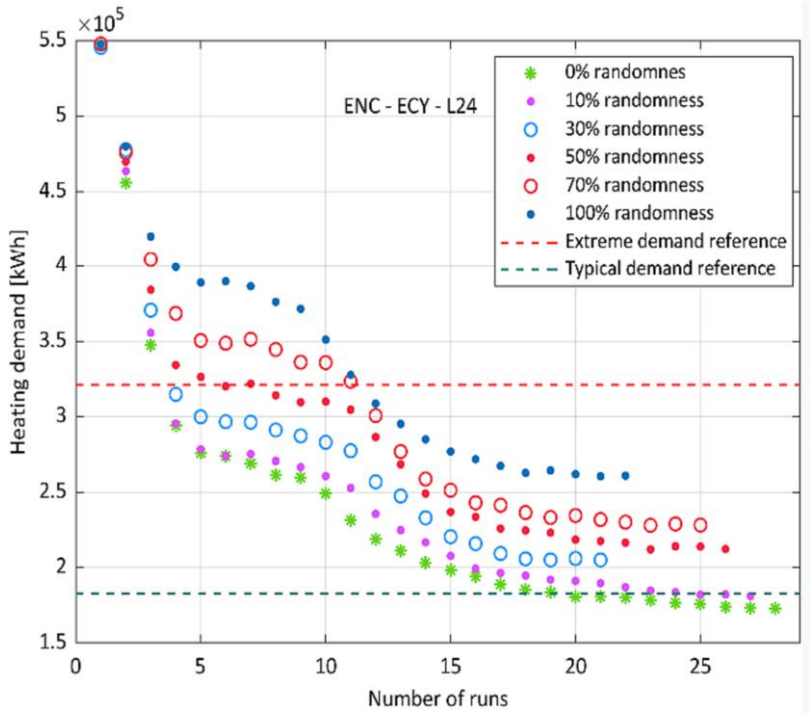
- Price
- Energy demand
- Weather
- Political issues
- Natural disasters
- Other Customized functions

CIRLEM Performance

Extreme Warm Summer



Extreme Cold Winter



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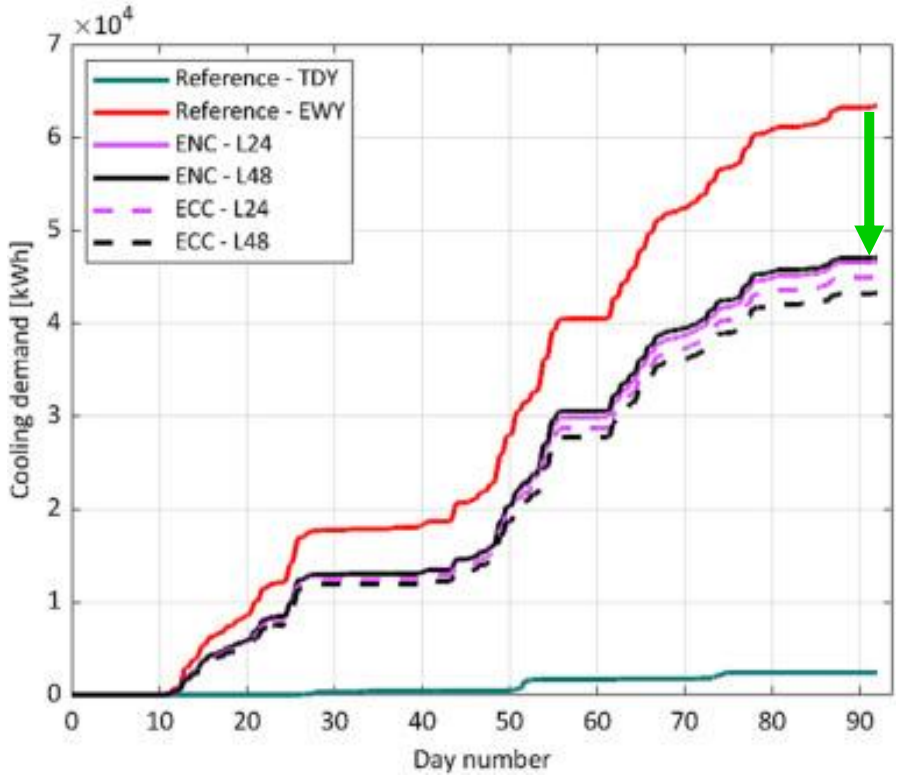
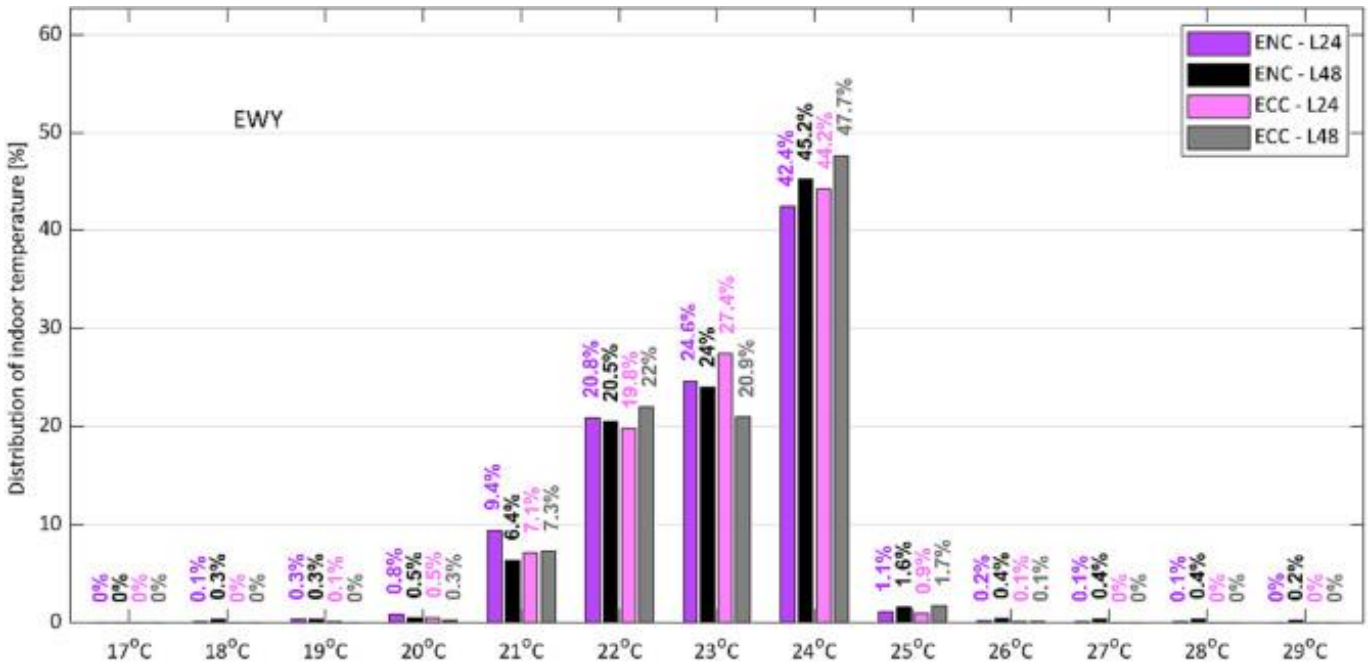
Extreme Warm Summer during 2040-2070





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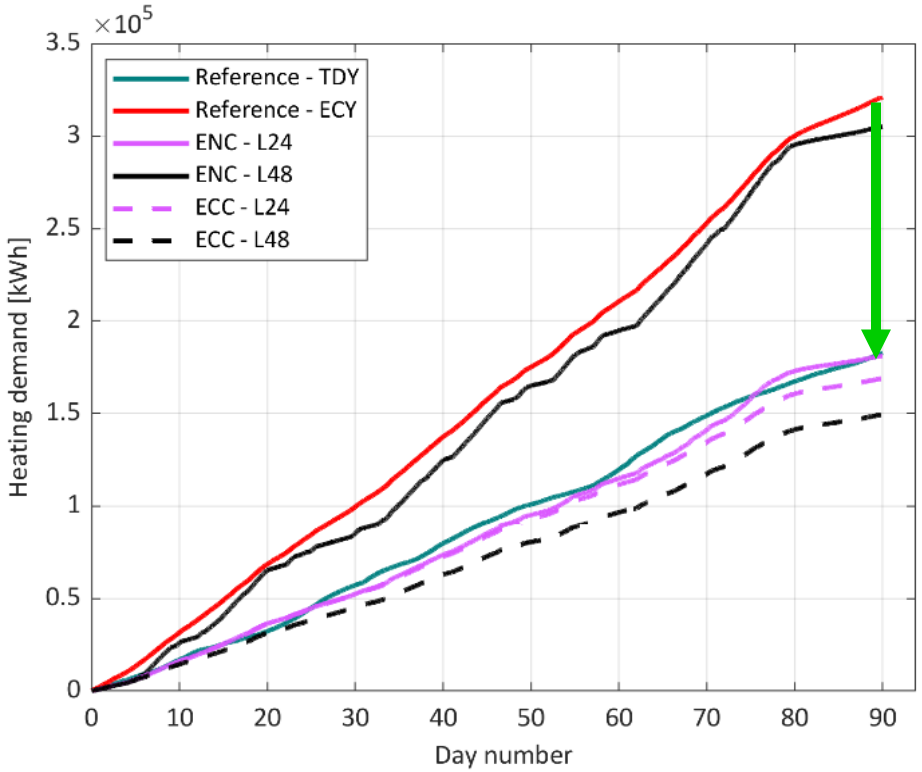
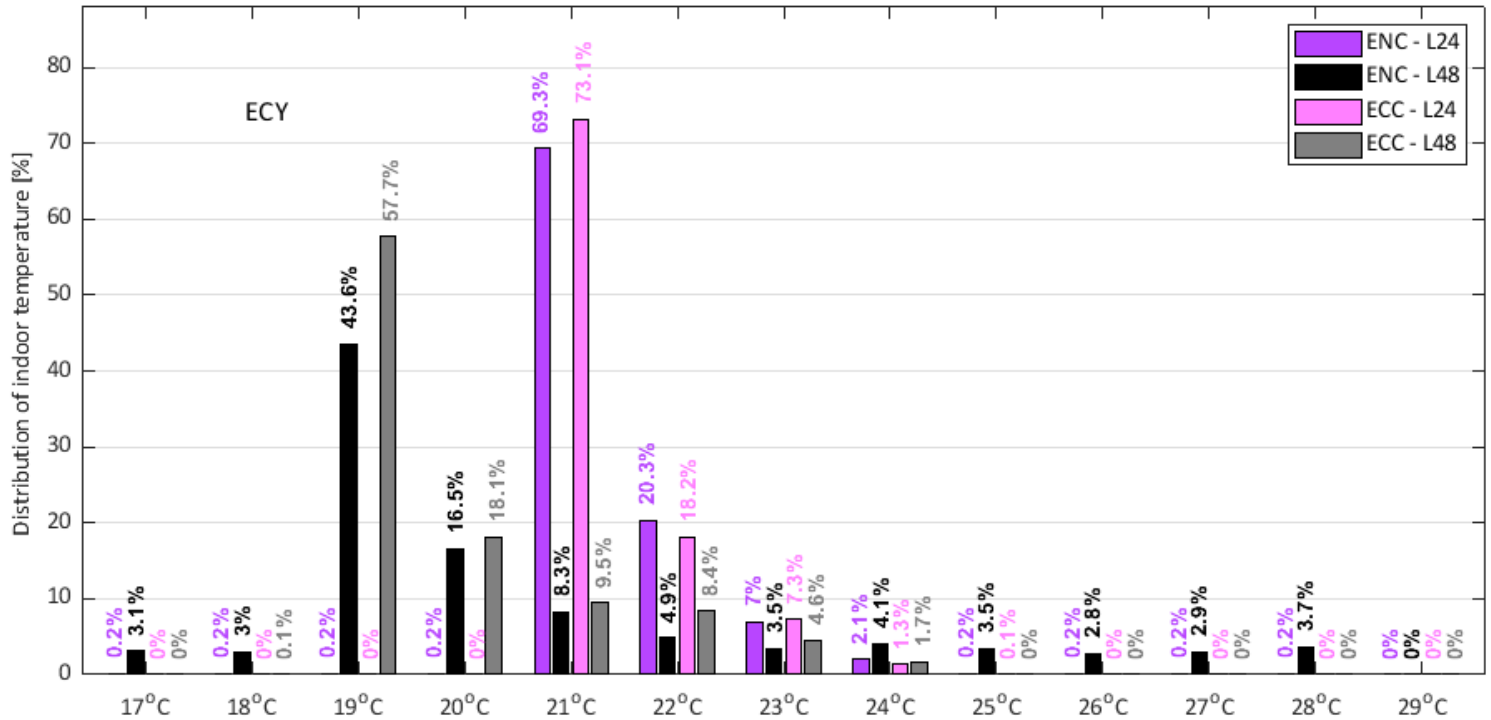
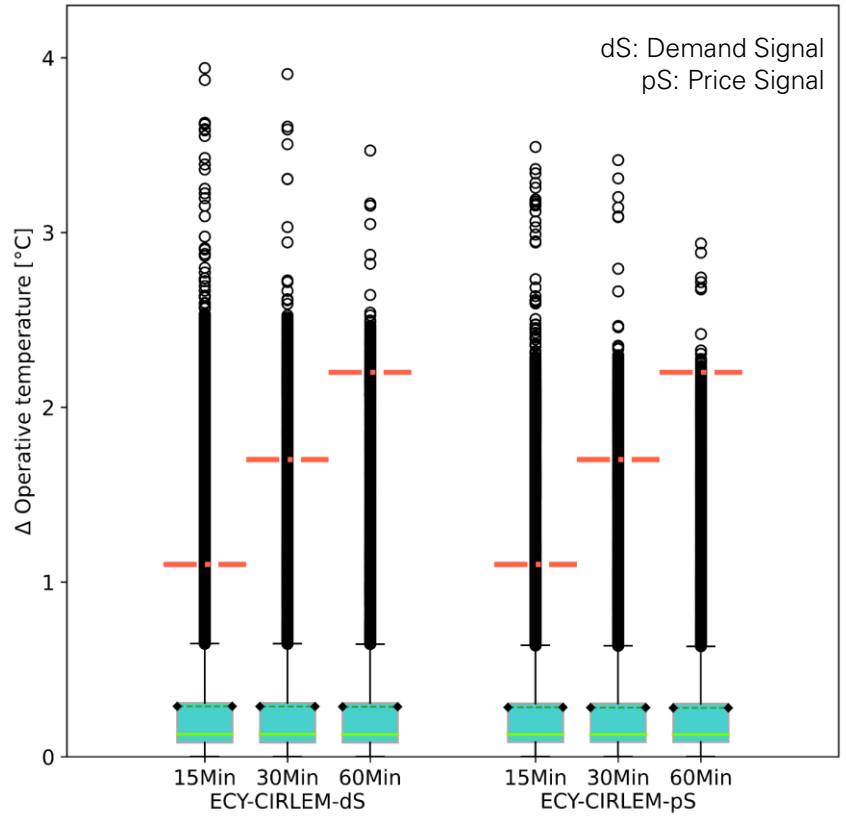
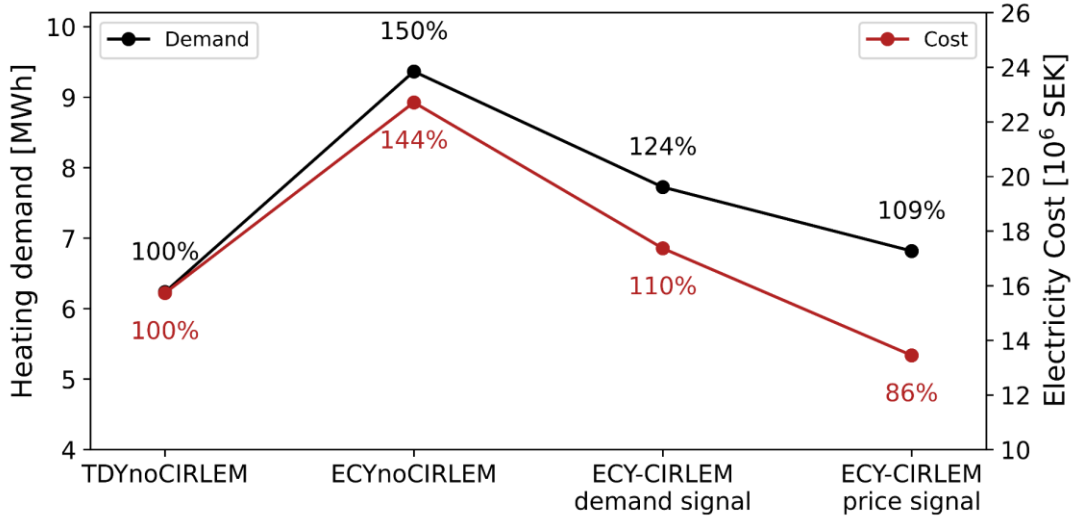






Thermal comfort



Cost saving

Implementation

Experiment in a pilot regular building with legacy equipment using Raspberry Pi

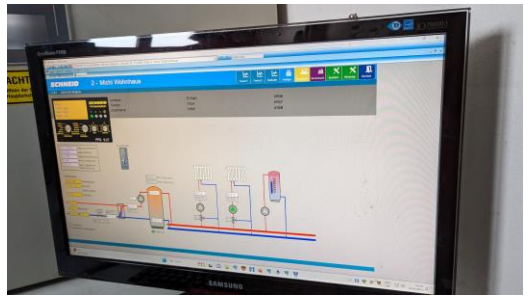
(in progress)

DigiCiti

Smart Energy Systems ERA-Net

Maria Laach, Austria

Osby, Sweden



LUND UNIVERSITY

- Our solution could considerably decrease the energy demand during extreme climate events while keeping the indoor temperature mostly at the comfort level.
- Enables the entire ecosystem to overcome shocks
- No need for central control
- Minimum data gathering and information sharing
- Enhances over time (self-learning)
- High performance in complex energy systems
- Tailor-made reward function for each building use type
- Inclusion of user preferences
- Operating on different modes depending on the conditions and user preferences

Thank you!

CRAFTCIRLEM

CARUACI

DigiCiti

COLLECTiEF

This work was supported by the Swedish Research council for Sustainable Development, Formas (project ID: 2022-01120 - CRAFTCIRLEM), the Crafoord Foundation under CARUACI project, the Joint ERA-Net Call 2020 (MICall20) on digital transformation for green energy transition under DigiCiti project (project ID: 108807), and the European Union's Horizon 2020 research and innovation programme under grant agreement for the COLLECTiEF (Collective Intelligence for Energy Flexibility) project (grant agreement ID: 101033683).