

# DOPTTEST: District Optimization Testing Framework

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Expert Meeting at DTU  
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IBPSA Project 2



# Outline

- Motivation
- Concept
- Modeling
- Simulation example
- Developments
- Outlook

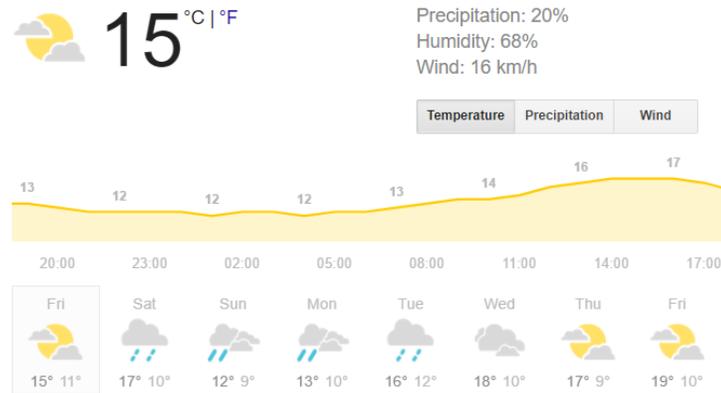
# Motivation

# Motivation

- Let's be **predictive**
  - To enhance energy efficiency in buildings
- Let's get **connected**
  - To enable demand response in buildings

⇒ Optimal predictive control

⇒ System integration in districts: Positive Energy Districts (PEDs)



Google weather forecast



<http://www.justinbrownphotography.com/>

# Motivation

System integration deals with:

- Different **energy vectors**
- **Energy agents** with competing objectives

**\*Note!**

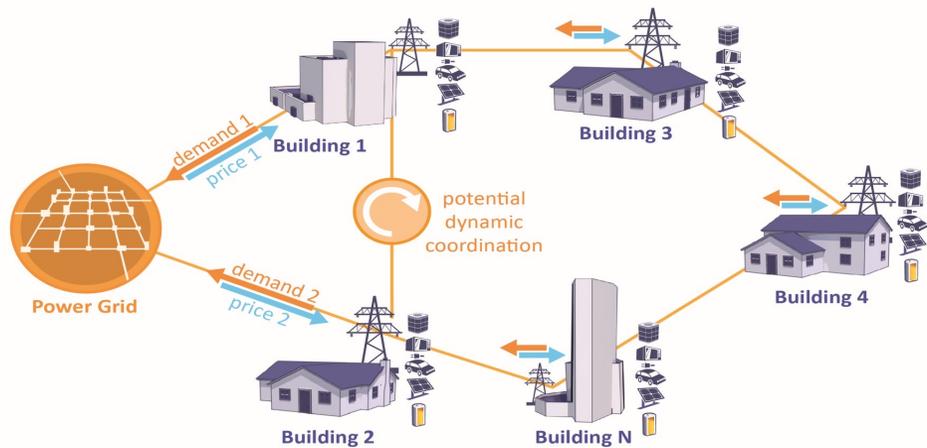
An **energy agent** any entity able to exchange energy with its surroundings and that is assigned a bill for the exchange.



**There is no unified framework for evaluating **system integration strategies** in districts**

# Motivation

**CityLearn:** OpenAI-Gym simulation-based framework for testing RL algorithms for DR at an urban scale

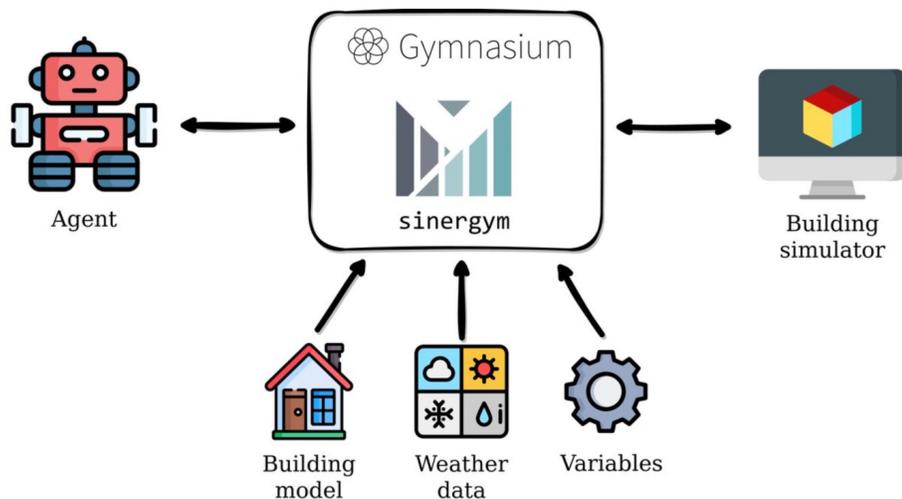


<https://www.citylearn.net/>

- ✓ District simulation and benchmarking
- ✓ Gym interface
- ✓ Established contest
- ✗ Not detailed emulators
- ✗ Not generic interface
- ✗ Linear electricity price model

# Motivation

**Sinergym:** OpenAI-Gym simulation-based framework for testing RL algorithms in individual buildings



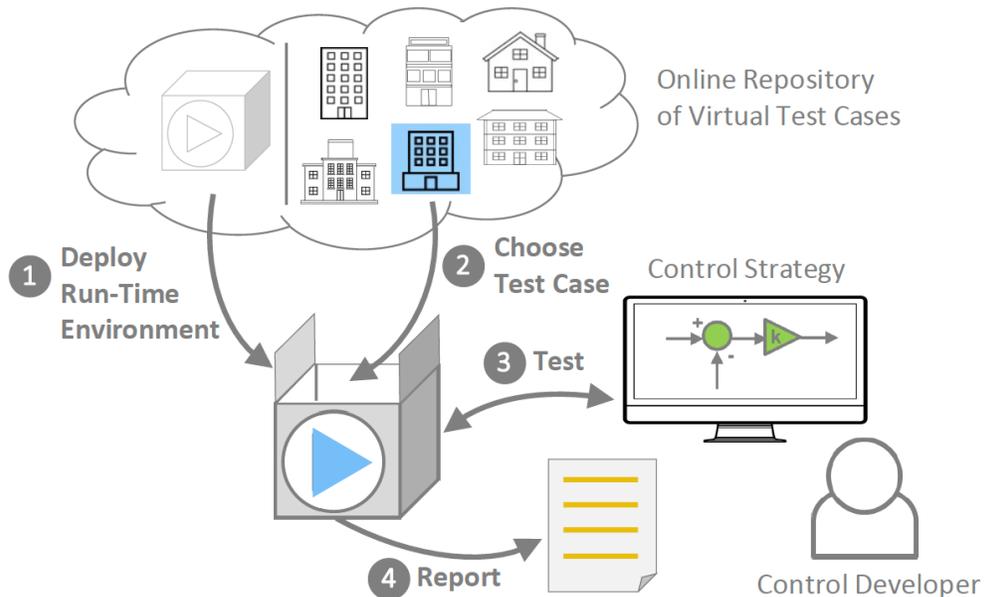
<https://ugr-sail.github.io/sinergym/compilation/main/index.html>

- ✓ Building simulation and benchmarking
- ✓ Gym interface
- ✓ Detailed emulators (EnergyPlus)
- ✗ Individual buildings
- ✗ Not generic interface
- ✗ No pricing model

# Concept

# Concept

**BOPTTEST = Building optimization testing framework**



Main stakeholders :

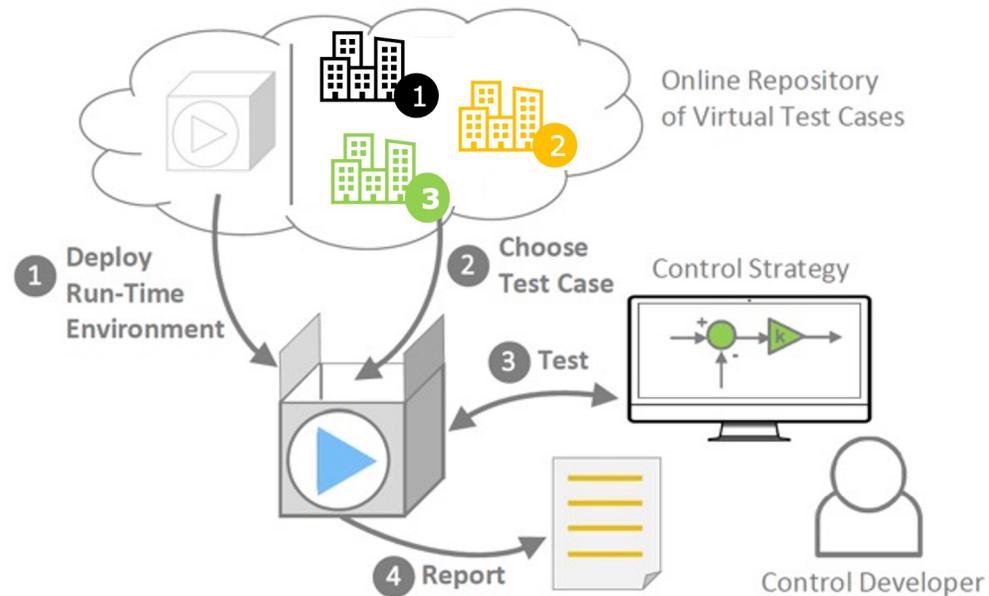
- Building owners
- Facility managers

<https://github.com/ibpsa/project1-boptest>

*D. Blum et al. Journal of Building Performance Simulation, 14(5), 586-610*

# Concept

From **BOPT**EST to → **DOPT**EST = District optimization testing framework



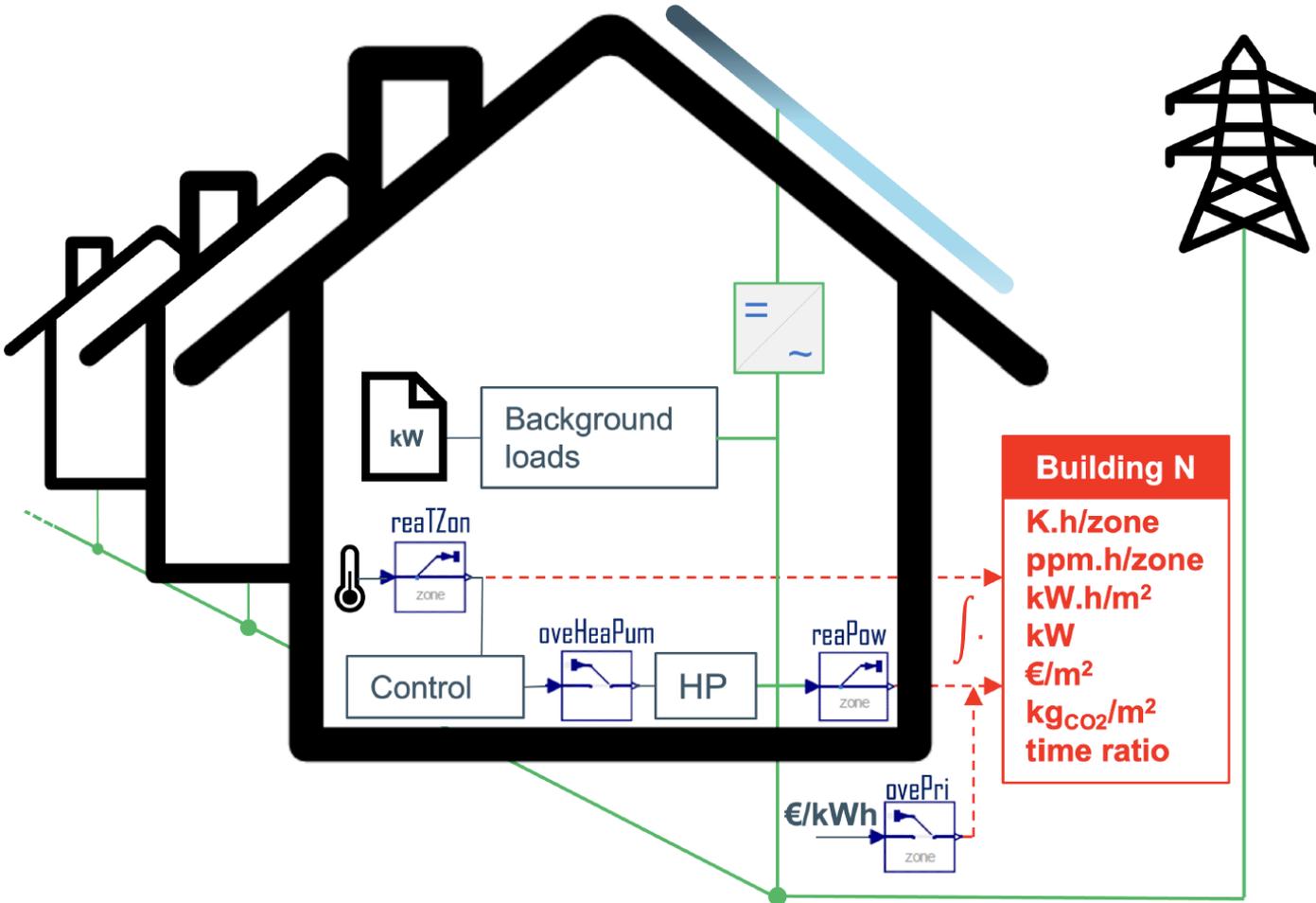
Main stakeholders :

- Aggregators
- Grid operators

*Modified from D. Blum et al. Journal of Building Performance Simulation, 14(5), 586-610*



# Concept



- **Goal:** Evaluation and benchmarking of system integration strategies in districts through simulation

- **Requirements:**

1. Widely used technologies & RWs

2. Substations to wider grids

3. Coherent weather & emissions & pricing

4. Testing scenarios & KPIs

5. Control & pricing signals

6. Price maker (inside) vs. Price taker (outside)



# Concept

- Overview of selected core Key Performance Indicators (KPIs):

We want to obtain the least possible ...

Thermal discomfort

Indoor air quality discomfort

While minimizing ...

Energy use

Peak power

CO<sub>2</sub> emissions

Operational cost

And keeping an eye on ...

Computational time ratio

-- Profit --

$$\kappa_{prof} = \frac{\sum_{a \in \mathcal{A}} \sum_{v \in \mathcal{V}_a} \int_{t_s}^{t_f} \lambda'_{av}(t) P_{av}(t) dt}{A} - \kappa_{cost} \cdot 100$$

- Distinguish between “**cost**” and “**bill**” of using an energy vector



# Modeling

# Modeling

- **MoPED** = Models of positive energy districts
- MoPED **INTEGRATES** component models for **dynamic district energy simulations**
- We are users of:
  - OpenModelica v1.23.0-dev
  - Buildings v9.1.1
  - IDEAS v3.0.0

OpenModelica

# Modeling

<https://gitlab.kuleuven.be/positive-energy-districts/moped>



Positive Energy Districts > MoPED

**M** **MoPED** Project ID: 7745

🔔 Unstar 2 🍴 Fork 6

🔗 1,670 Commits 🌿 12 Branches 🏷️ 0 Tags 📄 355.6 MiB Project Storage

Library of positive energy district models.

pipeline passed

Merge branch 'issue127\_removeReadBlock' into 'main' d1857626

Javier Arroyo authored 5 days ago

main ▾ moped / + ▾ Find file Edit ▾ ↓ ▾ Clone ▾

README Lawrence Berkeley National Labs BSD variant license CI/CD configuration Add CHANGELOG Add CONTRIBUTING

Add Kubernetes cluster Add Wiki Configure Integrations

Name	Last commit	Last update
📁 .devcontainer	Update vscode files.	1 week ago
📁 .vscode	Use relative paths for launch.json	1 week ago
📁 MoPED	Remove read block.	5 days ago
📁 bin	Add test-networks not makefile. Not added yet to .gi...	10 months ago
🔥 .gitignore	Remove fmu source files from version control.	7 months ago
🔥 .gitlab-ci.yml	Roll back to Buildings v9.1.1. to be consistent with in...	6 days ago

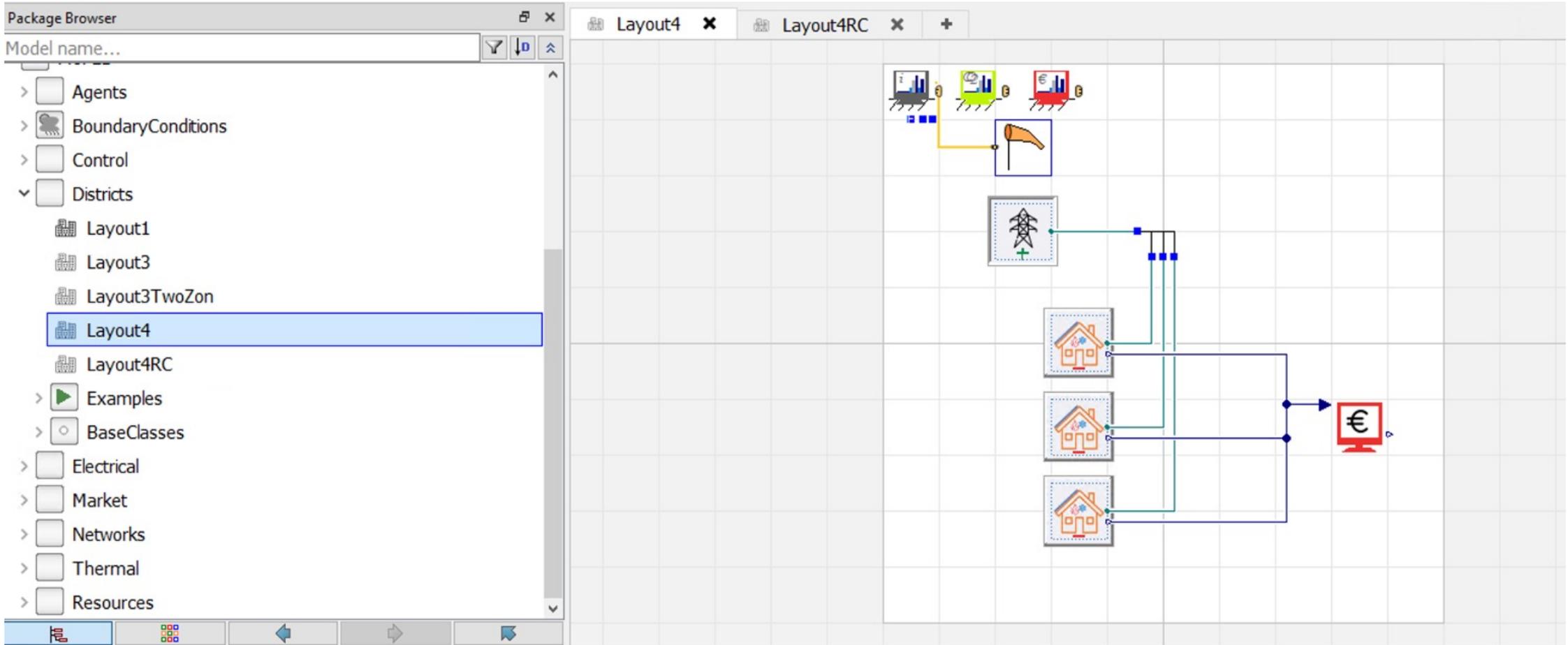
- 📁 Agents
- 📁 BoundaryConditions
- 📁 Control
- 📁 Districts
- 📁 Electrical
- 📁 Market
- 📁 Networks
- 📁 Resources
- 📁 Thermal
- 📄 package.mo
- 📄 package.order

# Modeling

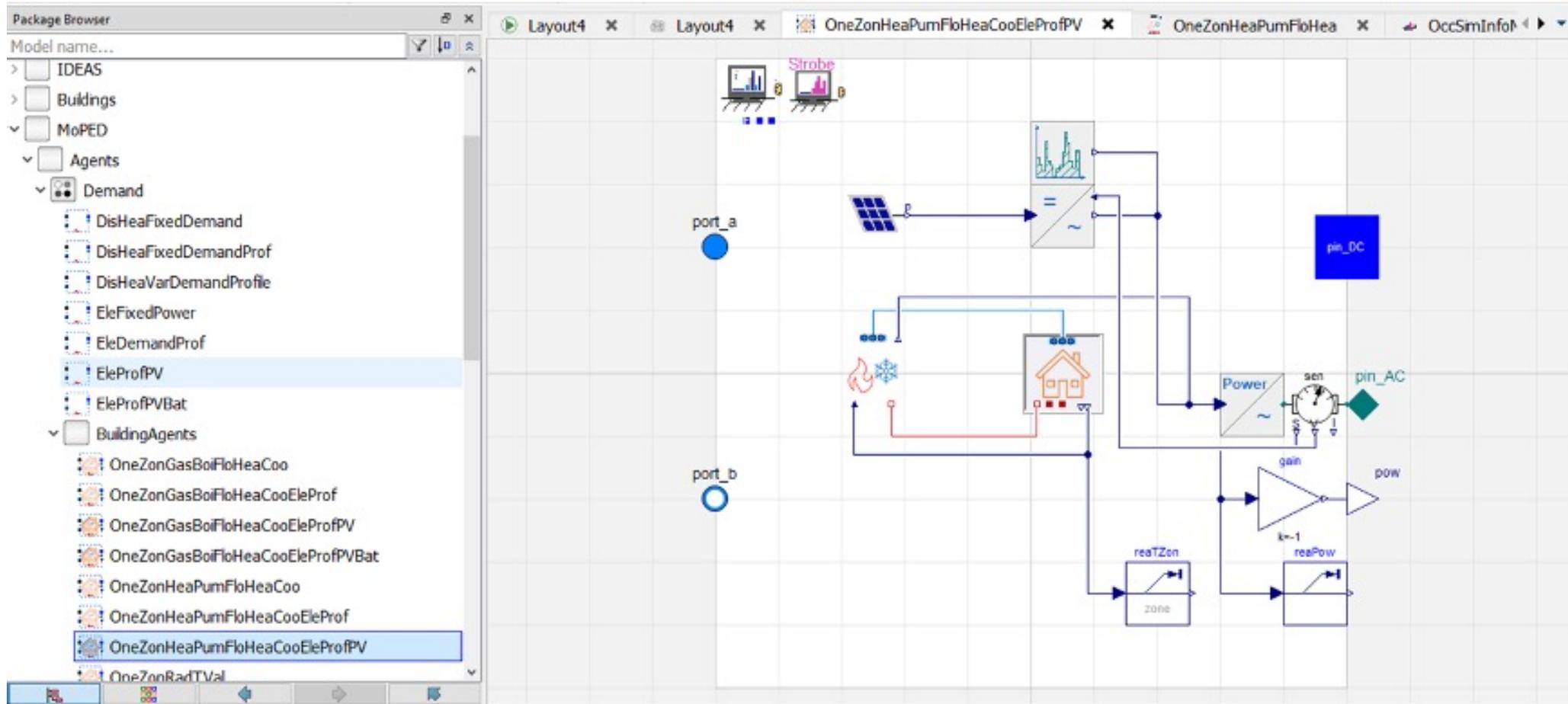
<https://gitlab.kuleuven.be/positive-energy-districts/moped>



# Modeling



# Modeling

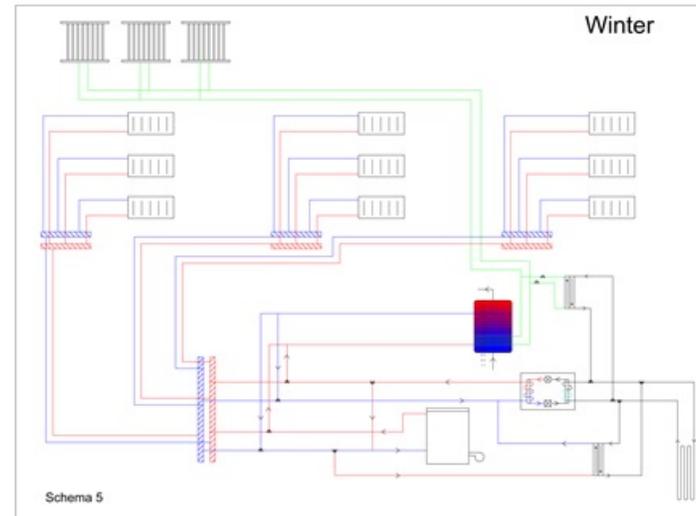




# Simulation example

# Simulation example

The **tiny cluster use case**: preliminary idea was launched and pre-explored in combined student master thesis work of Ghent University and KU Leuven in 2020-2021-2022\*



\* Gommers & Meessens & Van Regenmortel, supervised by prof Boydens & Helsen

# Simulation example

The tiny cluster use case: simulation example with baseline control

	House 1 (small)	House 2 (medium)	House 3 (large)
Length [m]	10	8	10
Width [m]	10	8	10
Height [m]	2.8	5.6	5.6
Windows (N-E-S-W*) [m <sup>2</sup> ]	3 - 3 - 3 - 5	4 - 6 - 8 - 6	6 - 10 - 10 - 10
Occupancy ****	FTE+PTE	FTE+PTE+SCH	FTE+PTE+SCH+SCH
Installed heating** - cooling*** power [kW]	3 - 1	4 - 1.5	6 - 3.5
PV installation [kW]	3.7, W	5.2, S	6.6, S

\*N = north, E = east, S = south, W = west

\*\*Gas boiler, \*\*\*Air-to-air heat pump

\*\*\*\* FTE = Full-Time Equivalent, PTE = Part-Time Equivalent, SCH = Schoolgoing child

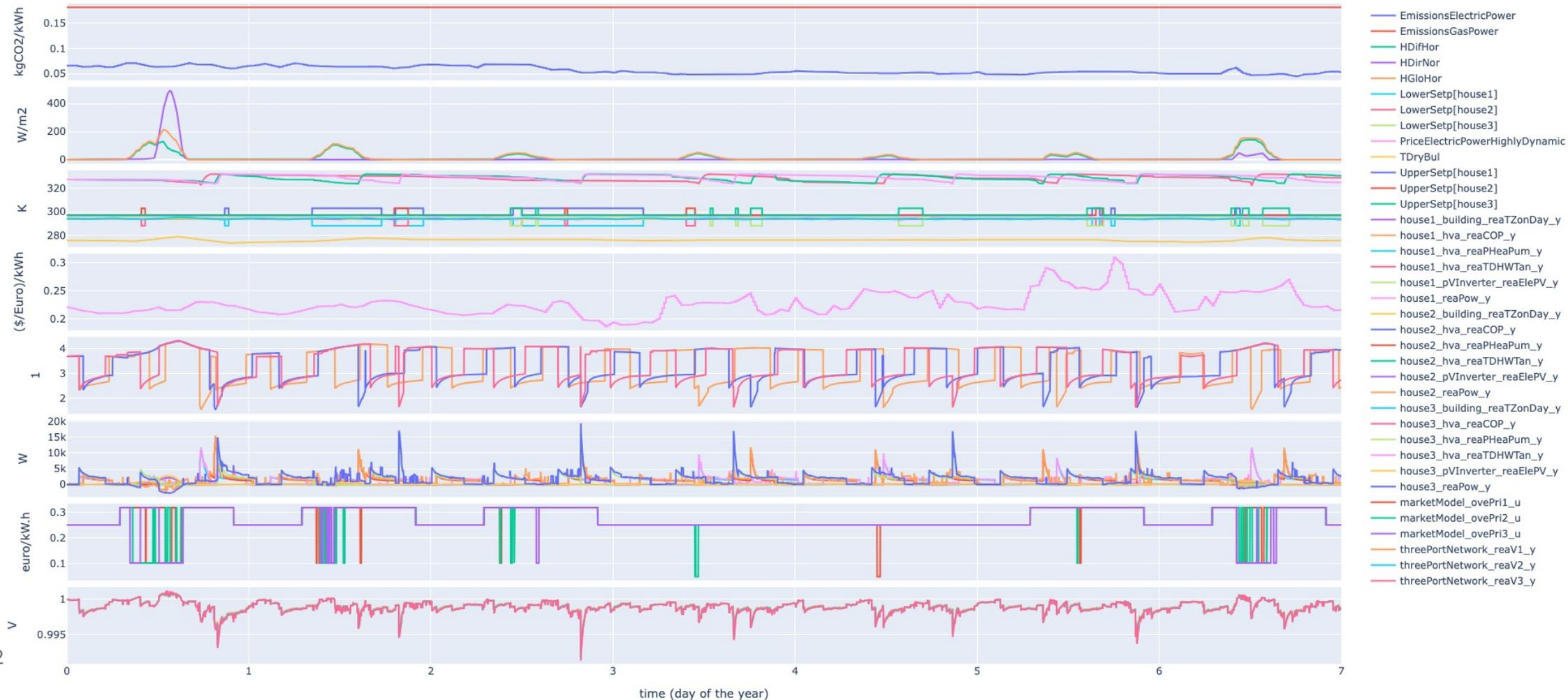
	Peak	Off-peak
Offtake price (c€/kWh)	31.96	25.12
Injection price (c€/kWh)	10.35	5.00

# Simulation example

```
Total time to simulate 7.0 days is: 54.880577087402344 seconds
{'bill_tot': 0.17941202258388217,
 'cost_tot': 0.14334060145597216,
 'emis_tot': 0.03531947912325251,
 'ener_tot': 0.6268034696588982,
 'idis_tot': 0.0,
 'pdih_tot': None,
 'pele_tot': 0.020436378327840767,
 'pgas_tot': None,
 'tdis_tot': 22.359550673197504,
 'time_rat': None}
```

- Tutorial to run this example in:

[https://gitlab.kuleuven.be/positive-energy-districts/moped/-/blob/main/MoPED/Resources/Scripts/fmu/tutorial.py?ref\\_type=heads](https://gitlab.kuleuven.be/positive-energy-districts/moped/-/blob/main/MoPED/Resources/Scripts/fmu/tutorial.py?ref_type=heads)



# Developments

# Developments

- DOPTTEST dev [issue](#) and [branch](#)
- Differences with master in this [Draft PR](#)
- Main differences with BOPTTEST:
  - Capacity to **overwrite pricing**
  - Needed to parse **agent's identifier**
  - Read power for KPIs ONLY at **agent's feeder**
  - Euler solver with **60s interval** defining ncp
  - Return **absolute & disaggregated KPIs** → Draft in [this PR](#) (needs to fix conflicts)

```
{'bill': {'house1_reaPow_y': 61.41475731252235,
          'house2_reaPow_y': 69.39232166088244,
          'house3_reaPow_y': 84.20028889111963},
'cost': {'house1_reaPow_y': 49.93405707539428,
          'house2_reaPow_y': 55.431167713365156,
          'house3_reaPow_y': 66.4141519960776},
'emis': {'house1_reaPow_y': 12.208109084980915,
          'house2_reaPow_y': 13.551563037561136,
          'house3_reaPow_y': 16.567191658763765},
'ener': {'house1_reaPow_y': 217.26268008553865,
          'house2_reaPow_y': 241.38994778121193,
          'house3_reaPow_y': 292.5086501724731},
'idis': {},
'pdih': None,
'pele': {'house1_reaPow_y': 1.8509435653660729,
          'house2_reaPow_y': 9.553783212436187,
          'house3_reaPow_y': 13.08622901028212},
'pgas': None,
'tdis': {'house1_building_reaTZonDay_dTlower_y': 22.626828527835826,
          'house1_building_reaTZonDay_dTupper_y': 0.0,
          'house2_building_reaTZonDay_dTlower_y': 20.862638839534807,
          'house2_building_reaTZonDay_dTupper_y': 0.0,
          'house3_building_reaTZonDay_dTlower_y': 23.589184652221874,
          'house3_building_reaTZonDay_dTupper_y': 0.0}}
```

# Developments

- New KPIs needed:

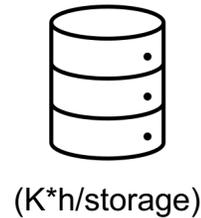
## Bill

(!= cost)



$$\kappa_{bill} = \frac{\sum_{a \in \mathcal{A}} \sum_{v \in \mathcal{V}_a} \int_{t_s}^{t_f} \lambda'_{av}(t) P_{av}(t) dt}{A}$$

## DHW discomfort



$$\kappa_{dwh} = \frac{\sum_{a \in \mathcal{A}} \sum_{s \in \mathcal{S}_a} \int_{t_s}^{t_f} \delta_{T,s}(t) dt}{\sum_{a \in \mathcal{A}} |\mathcal{S}_a|}$$

$$\delta_{T,s}(t) = \begin{cases} \underline{T}_s(t) - T_s(t), & \text{if } T_s(t) < \underline{T}_s \\ 0, & \text{if } T_s(t) \in [\underline{T}_s, \bar{T}_s] \\ T_s(t) - \bar{T}_s(t), & \text{if } T_s(t) > \bar{T}_s \end{cases}$$

VS.



$$\kappa_{dwh} = \frac{\sum_{a \in \mathcal{A}} \sum_{tap \in \mathcal{T}_a} \int_{t_s}^{t_f} \delta_{T,tap}(t) \dot{m}_{tap}(t) dt}{\sum_{a \in \mathcal{A}} |\mathcal{T}_a|}$$

$$\delta_{T,tap}(t) = \begin{cases} \underline{T}_{tap}(t) - T_{tap}(t), & \text{if } T_{tap}(t) < \underline{T}_{tap} \\ 0, & \text{if } T_{tap}(t) \in [\underline{T}_{tap}, \bar{T}_{tap}] \\ T_{tap}(t) - \bar{T}_{tap}(t), & \text{if } T_{tap}(t) > \bar{T}_{tap} \end{cases}$$

## EV discomfort

(As kWh not served?)



# Developments

- Possibilities to showcase functionality:
  1. Overwrite the heat pump **supply water temperature** of each building separately using MPC to minimize individual operational cost and discomfort.
  2. Overwrite buffer **tank water temperature** using RL with BOPTTEST-Gym to minimize individual operational cost.
  3. Overwrite **pricing signals** to minimize district peak power to minimize district's emissions.
  4. Overwrite **EV charging schedules** to minimize the district's emissions.

# Developments

- Current main HANDICAPS:
  - Unstable initialization and simulation with OpenModelica
  - Related ongoing OpenModelica issues:  
[#11657](#), [#10790](#), [#11373](#), [#10711](#), [#10745](#)
  - Hard-coded bill KPI in current implementation.
  - Lack of time and resources.

# Outlook

# Outlook

- Coordinate with **BOPTTEST refactoring**
  - Fix conflicts of KPIs disaggregated branch with new service architecture
  - Create a dedicated repo: ibpsa/boptest-doptest → but treat it as “another test case” with the functionality integrated into the core boptest repo
- Implement **district KPIs** → Needs:
  - To distinguish between agents (which may have zones)
  - New enumeration entries in read blocks for KPI calculation
- Implement **price-reactive building agents**
- Implement **EV charging**
- Go to **larger clusters**
- Benefit from **FMU-less wrapping** (see [here](#))

# Thank you!

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