Internet-of-Things software infrastructure for energy management

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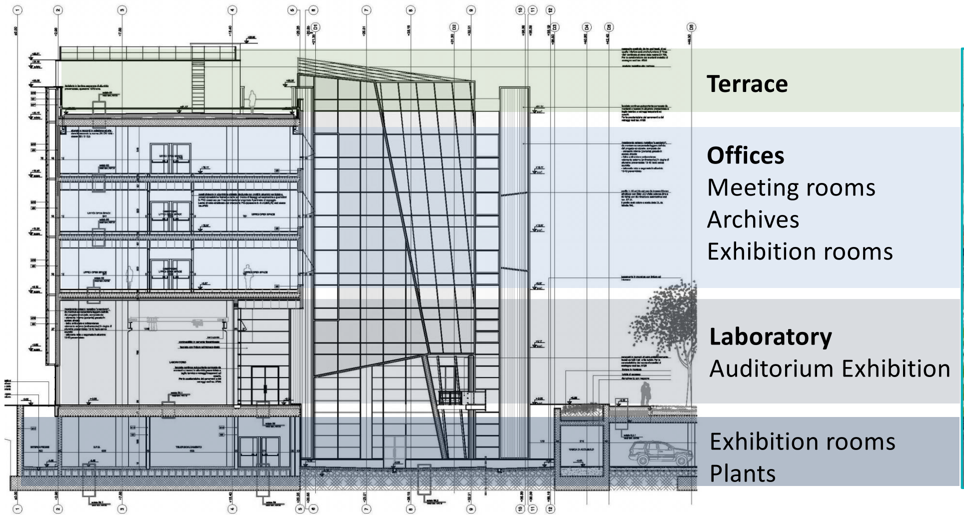
LAB

ENERGY CENTER

Energy Center Initiative

- Politecnico di Torino has launched since 2016 the **Energy Center Initiative (ECI)** to support and stimulate series of actions and projects that will provide support and advice to local, national and transnational authorities on energy policy and technology.



Energy Center Initiative

- The two pillars of the **ECI** are:

Energy Center House (EC-H)

Energy Center House (EC-H), a new building in the Politecnico di Torino campus, that will host companies, start-ups and public administrations who are active in the field of energy technology, R&D, management and policy.

Energy Center Lab (EC-L)

Energy Center Lab (EC-L), the Inter-dipartimental Center for Energy, that gathers a multi-disciplinary group of Politecnico faculty members who are devoted to discovering the best technical, economic, social and environmental solutions for a transition toward a more sustainable society.

It consists of

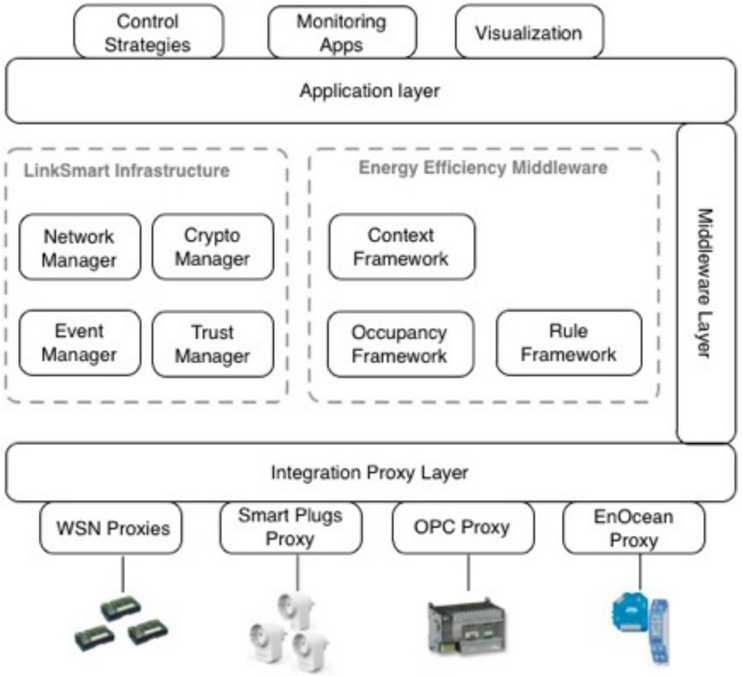
- 14 Faculty Members
- 11 Junior researchers.

Our Research

- Contexts
  - **Smart Building**
  - **Smart District**
  - **Smart Grid**
  - **Simulation and Prediction in Smart Context**
- Areas
  - **Cloud Platforms**
  - **Distributed Systems**
  - **Internet of Things (IoT) Technology**
  - **Machine Learning and Deep Learning Techniques**

Smart Building

- ***SEEMPubS*** is an Event-Driven User-Centric Energy Efficient Middleware to enhance existing buildings moving forward the Smart Building view



Benefits

- enhances the monitoring and management of energy consumption in buildings;
- enables the interoperability across heterogeneous IoT devices;
- increases energy user-awareness
- provides a set of rules to control both HVAC and lighting systems.

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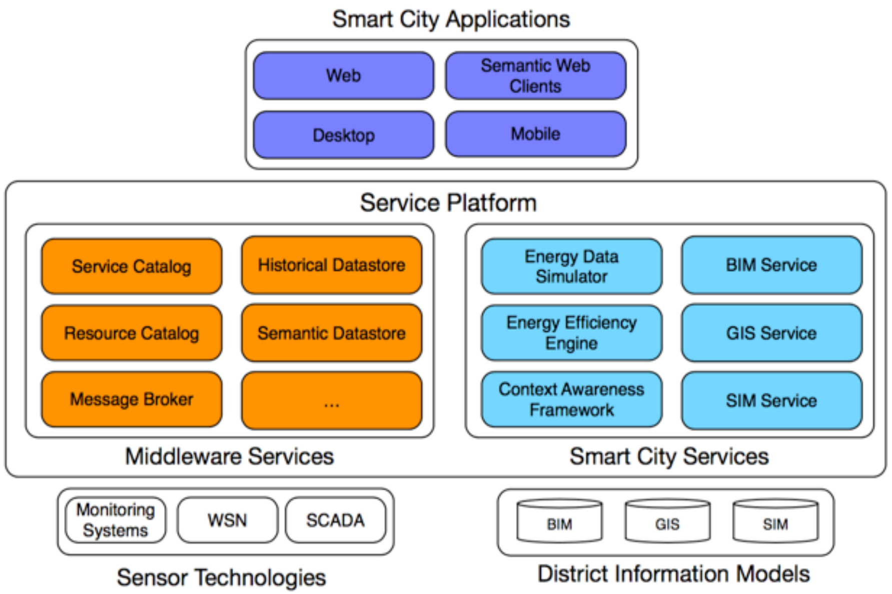
Smart City

- ***DIMMER*** allows access of multiple actors to heterogeneous data sources to provide new services at city district level. Provide tools to simulate energy policies in districts and cities

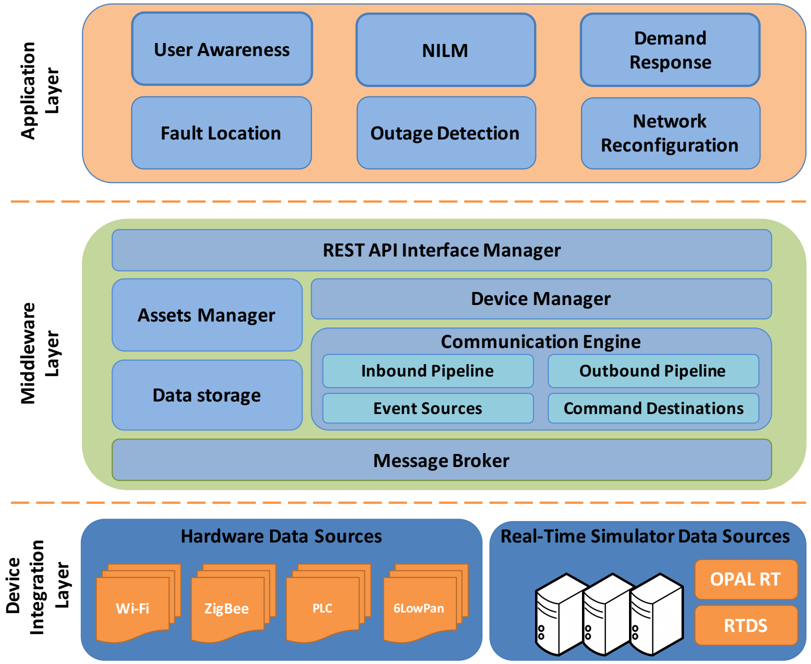


Benefits

- Smart Metering Architecture for heating and power networks
- Integrated simulation engine for thermal energy behaviours and optimization
- Services for different stakeholders

Smart Grid

- ***FLEXMETER***, a smart metering architecture aims at facilitating the access of multiple actors to relevant data to foster the spreading of various innovative services.



Benefits

- Multi-vector Smart Metering Architecture
- Integrated Co-simulation platform
- Services for different stakeholders

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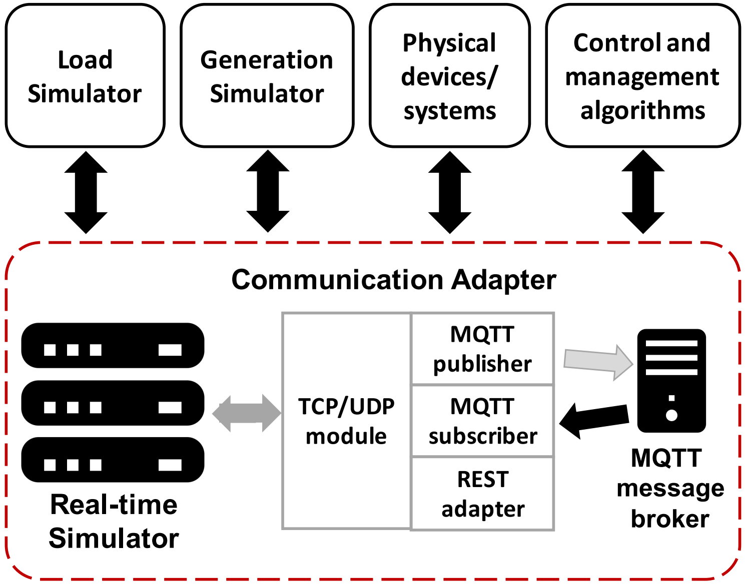
Simulation in Smart Cities

- ***Slack Co-Simulation Approach*** between OpalRT and other Simulation Software through (near) real-time communication approach

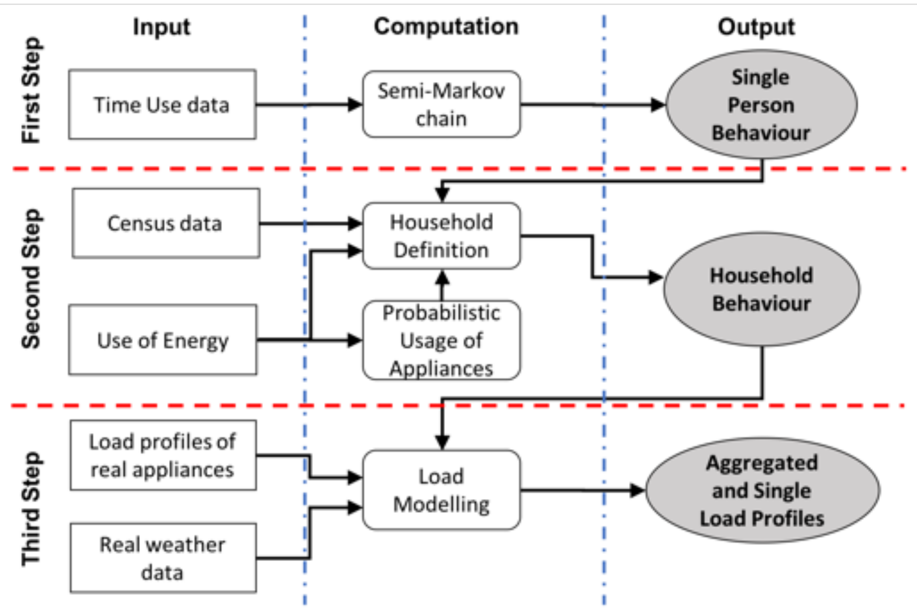


Benefits

- Simulate new power systems
- Study interoperability among different services
- Exploiting (near-) real-time data from smart meters via SMI

Simulation in Smart Cities

- ***LoadSIM*** is a realistic multi-scale model to simulate energy consumption trends with different spatial-temporal resolutions



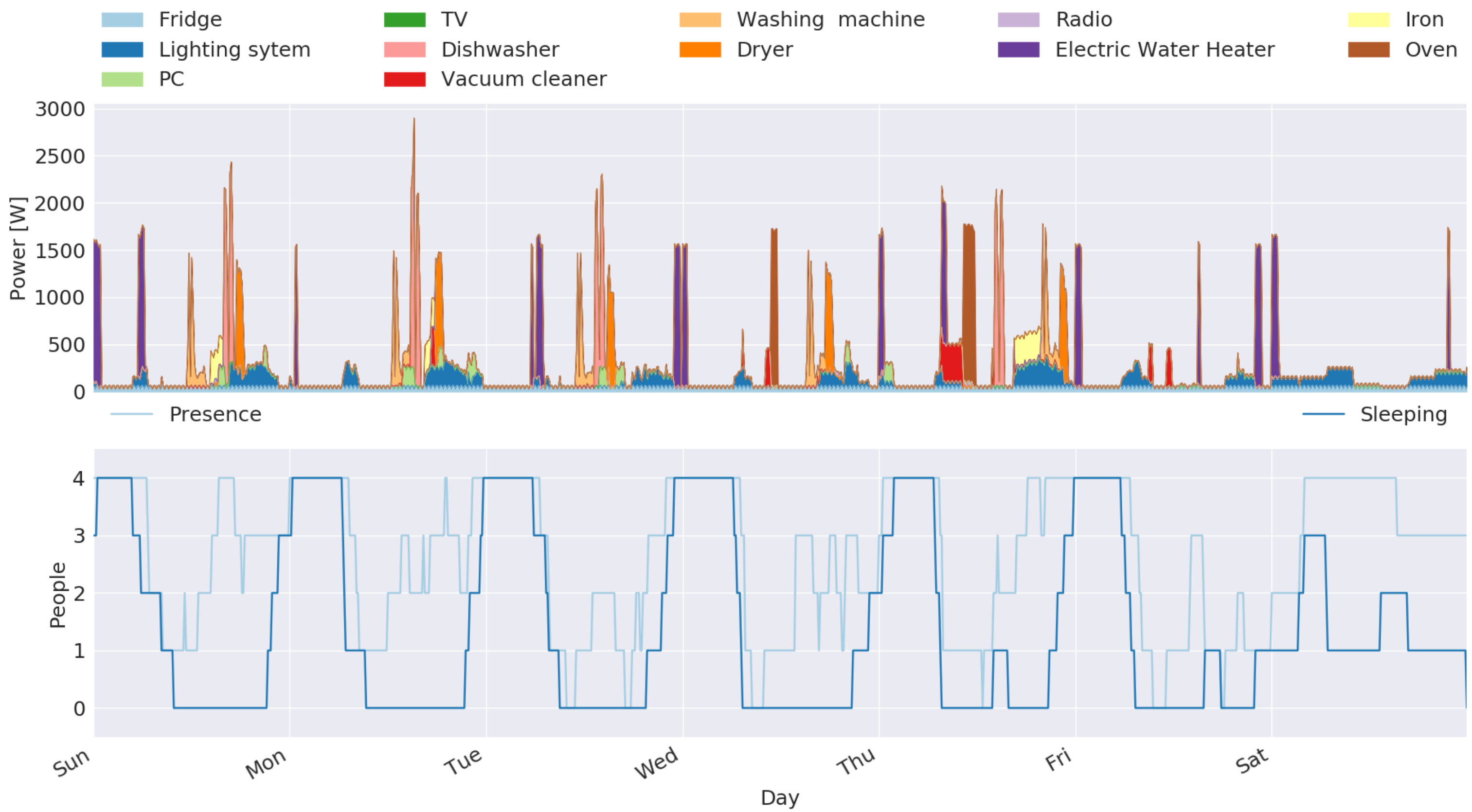
Benefits:

- Simulation different scenarios (e.g. definition of households composition with different users and appliances);
- inclusion of appliances information impacting load trend;
- inclusion of domestic end-uses affecting load trends (e.g. domestic hot water and specific electricity appliances)
- generation of multi-level aggregate results (e.g. house- hold, district and city);

Simulation in Smart Cities

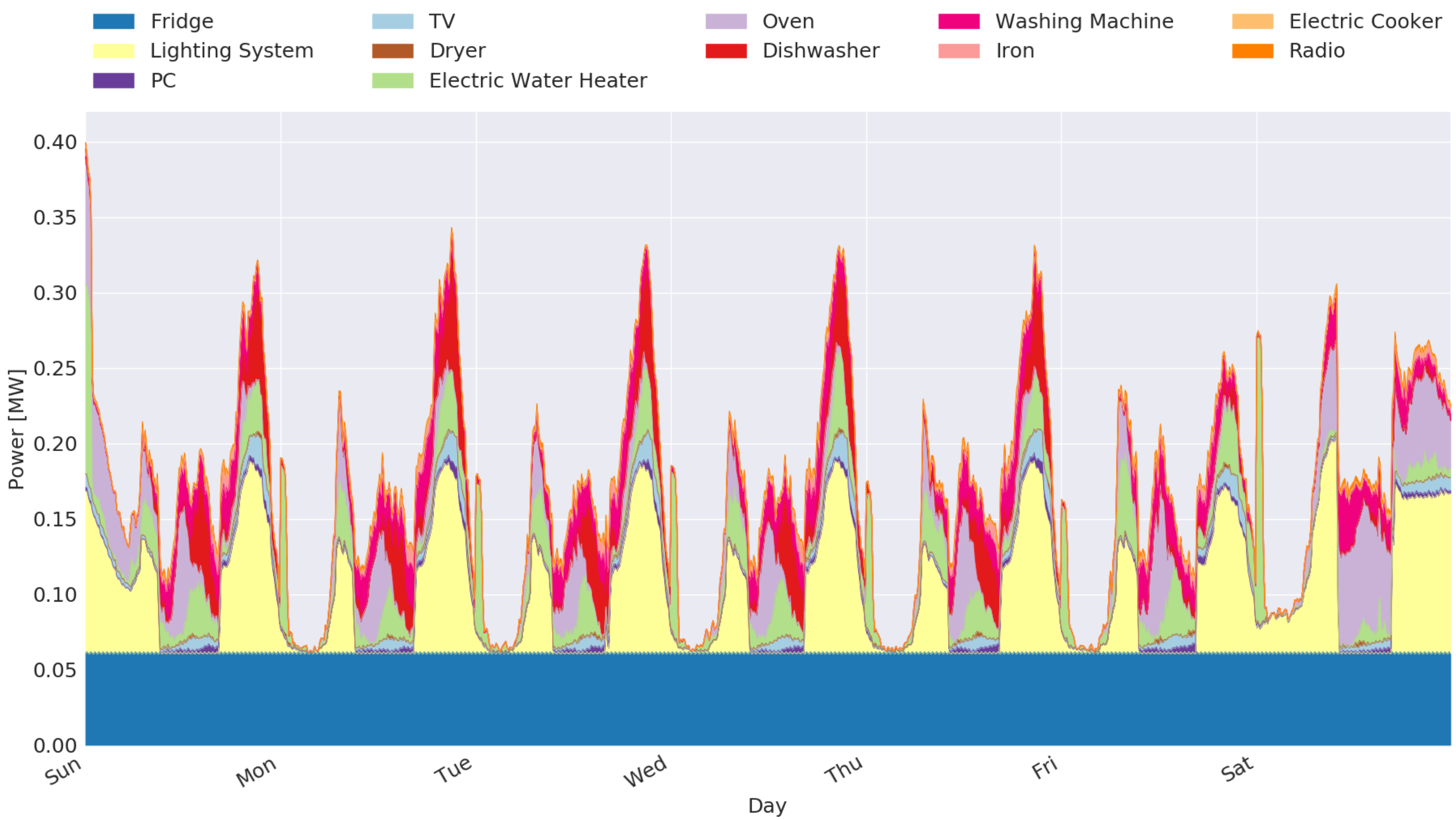
Family with 2 persons

Simulation in Smart Cities



Family with 4 persons

Simulation in Smart Cities



Virtual district with 1000 persons

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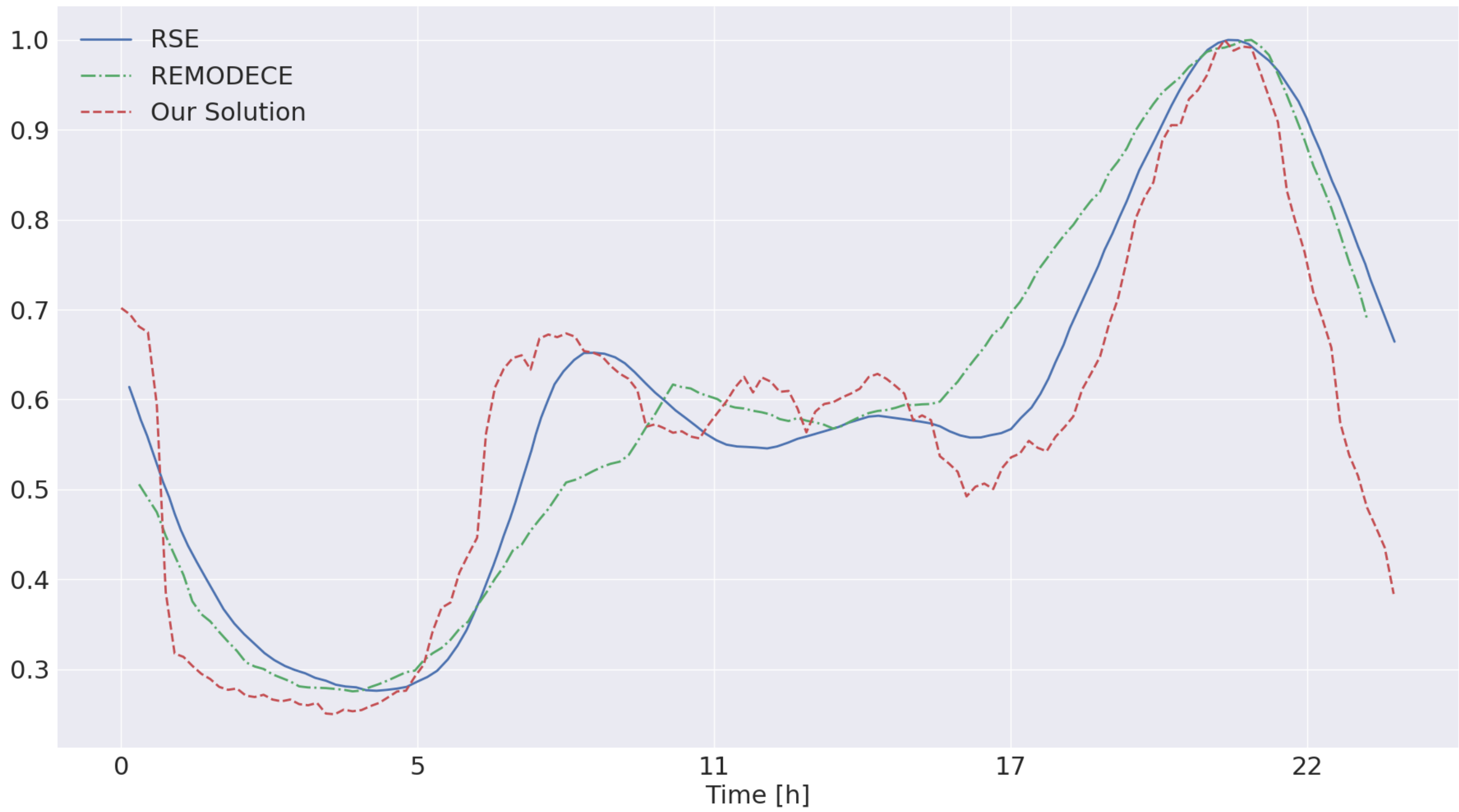
Simulation in Smart Cities



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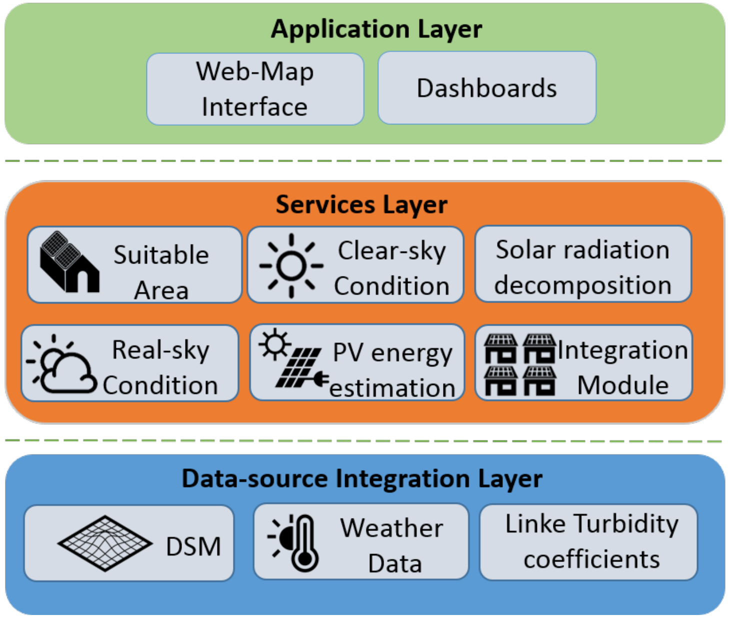
Simulation in Smart Cities

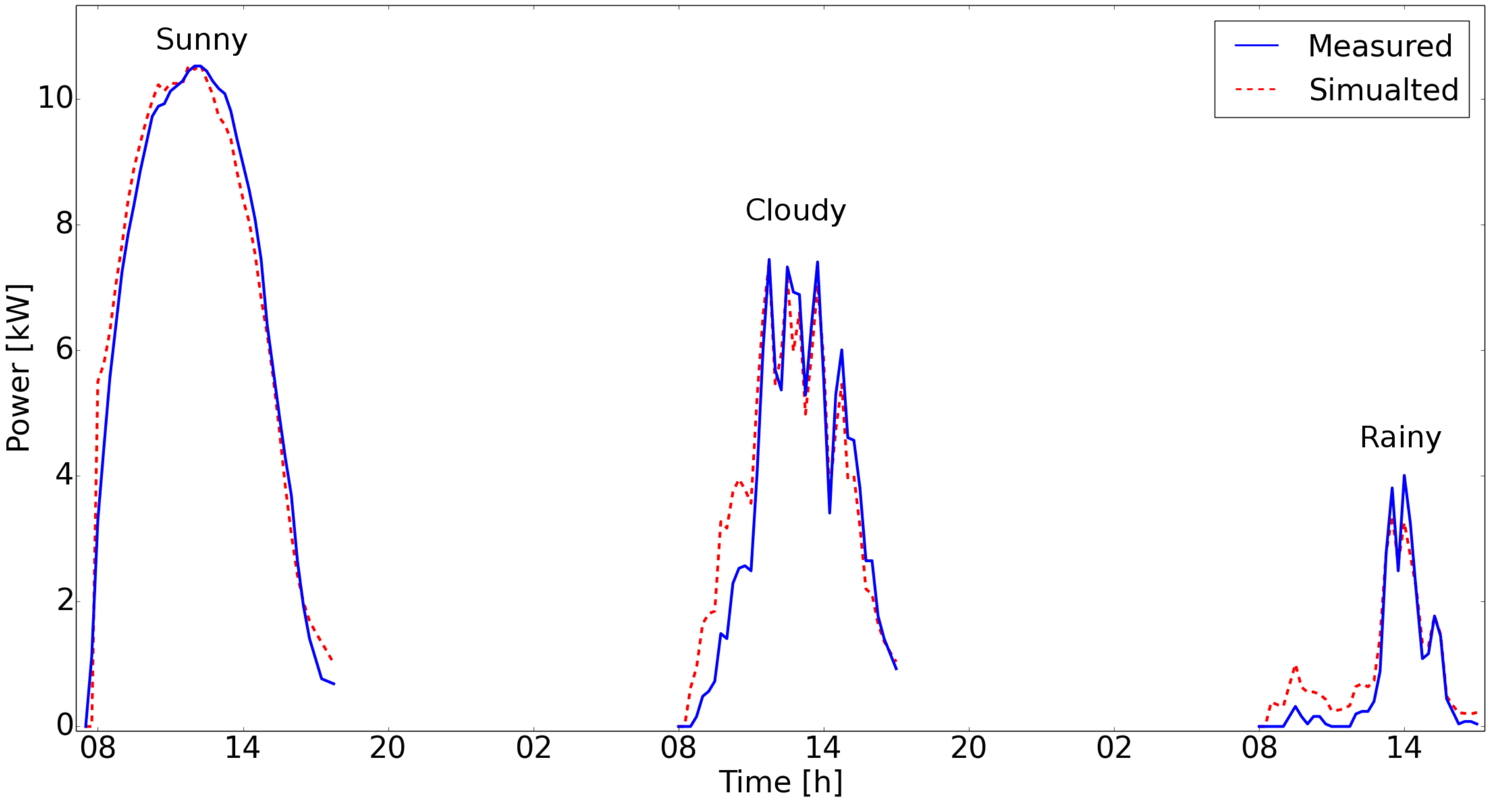
- ***PVSIM*** performs simulations in a spatio-temporal domain exploiting GIS and meteorological data to estimate PV generation profiles in real operating conditions.



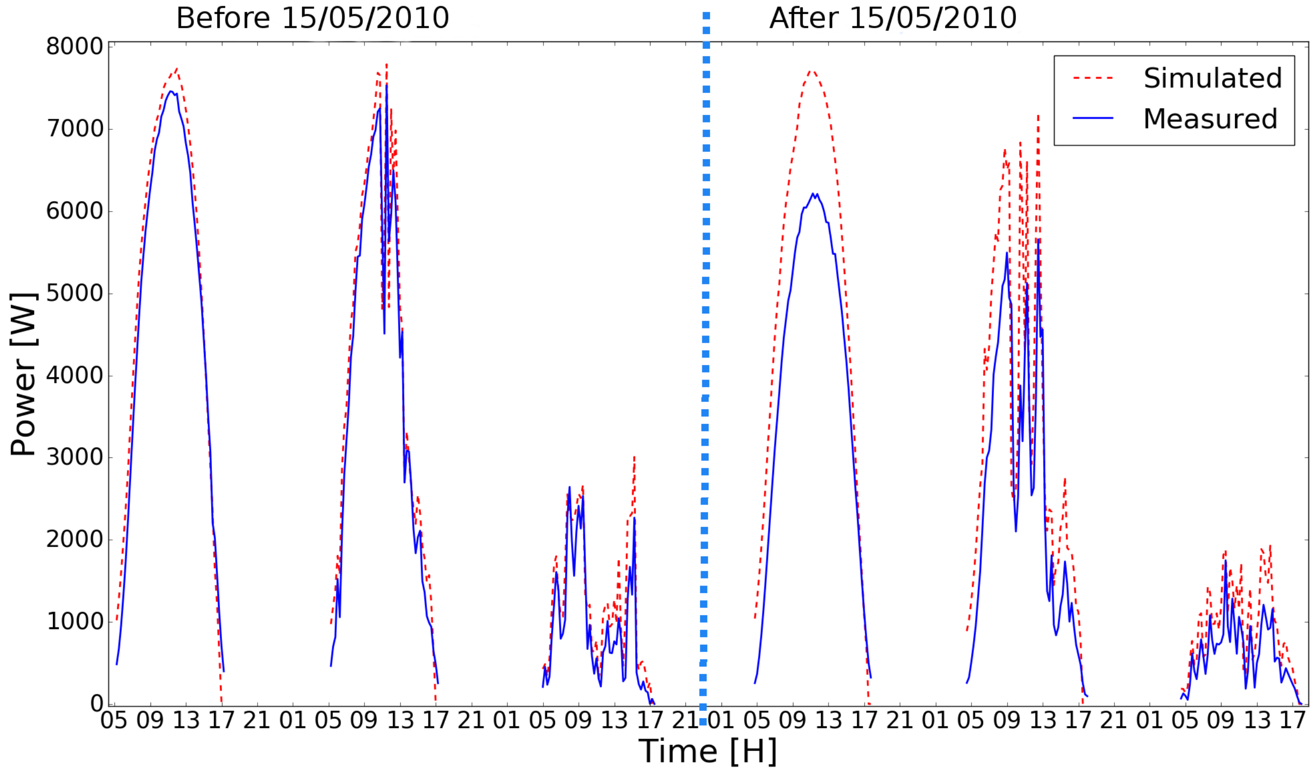
Benefits

- Identification of real suitable areas for PV deployment in rooftops
- Integration of weather stations
- Sub-hour clear- and real-sky simulations
- Distributed and modular architecture

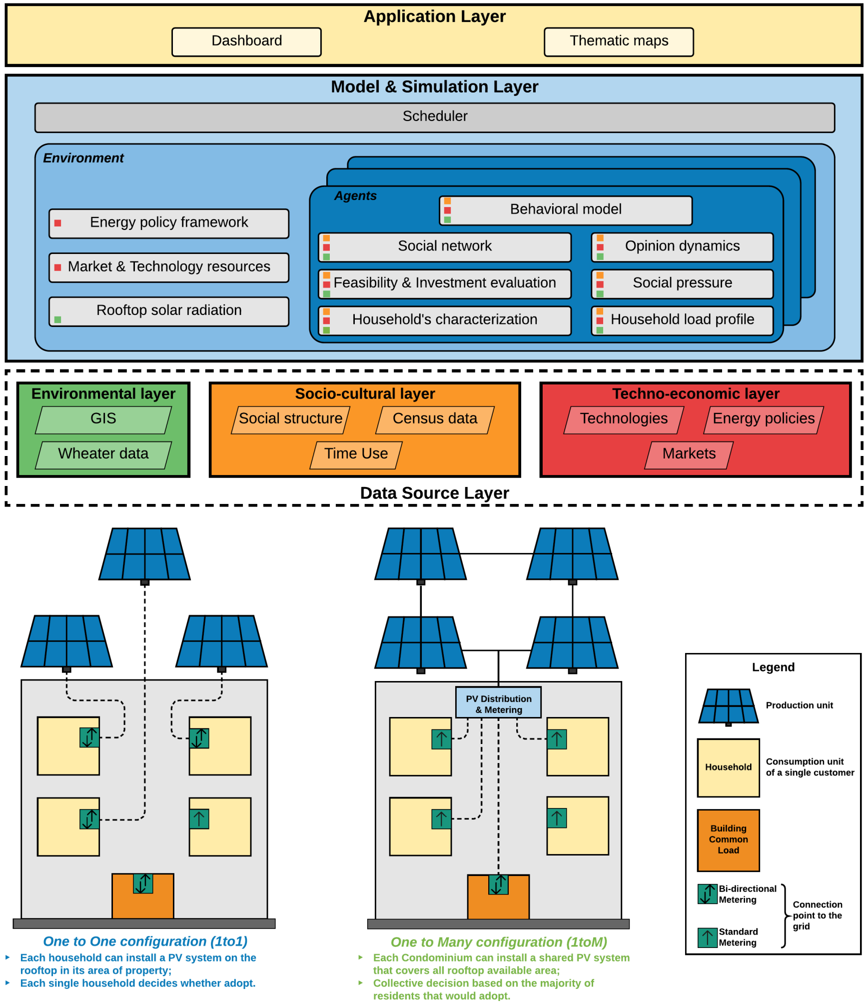
Simulation in Smart Cities



Simulation in Smart Cities



Simulation in Smart Cities



AMB simulation of Photovoltaic penetration in smart cities under different regulatory framework.

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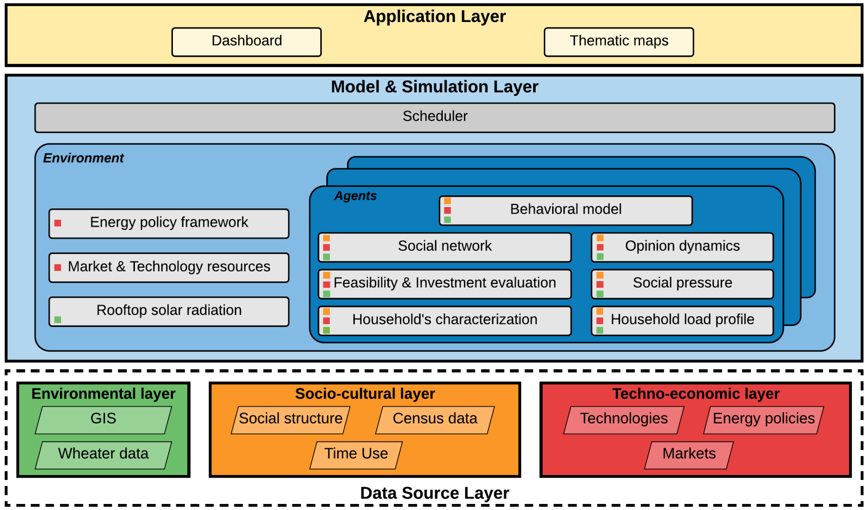
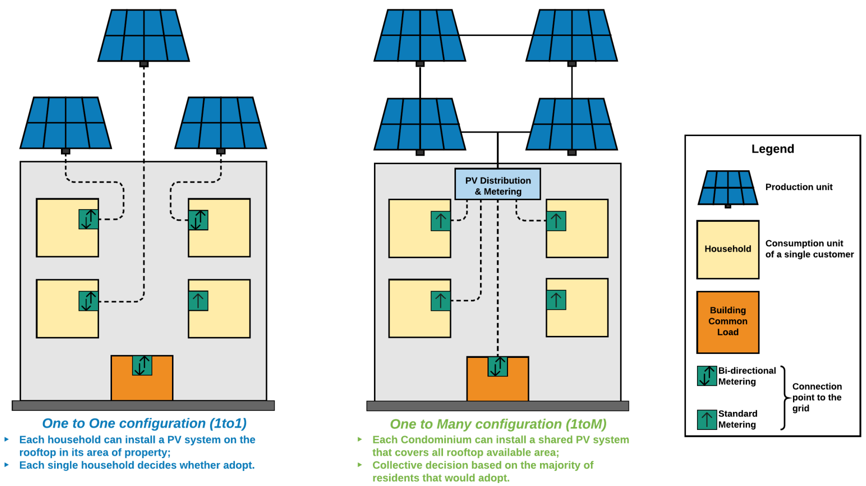
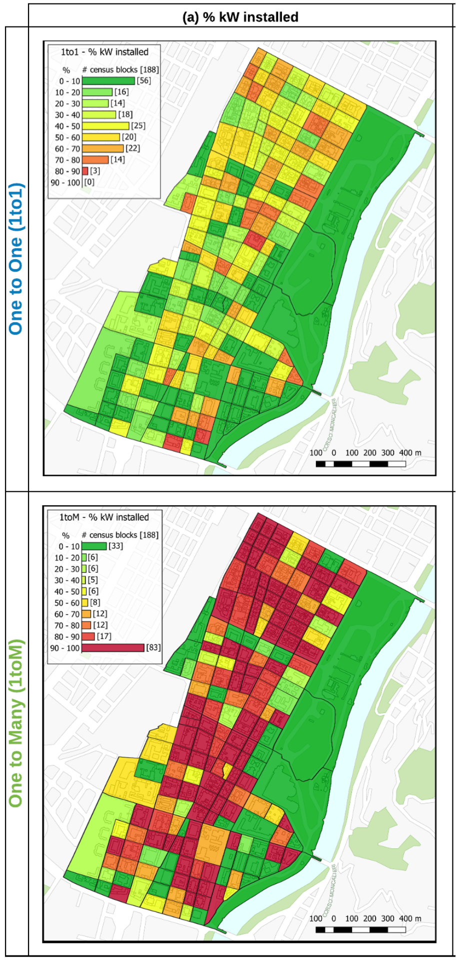
Simulation in Smart Cities



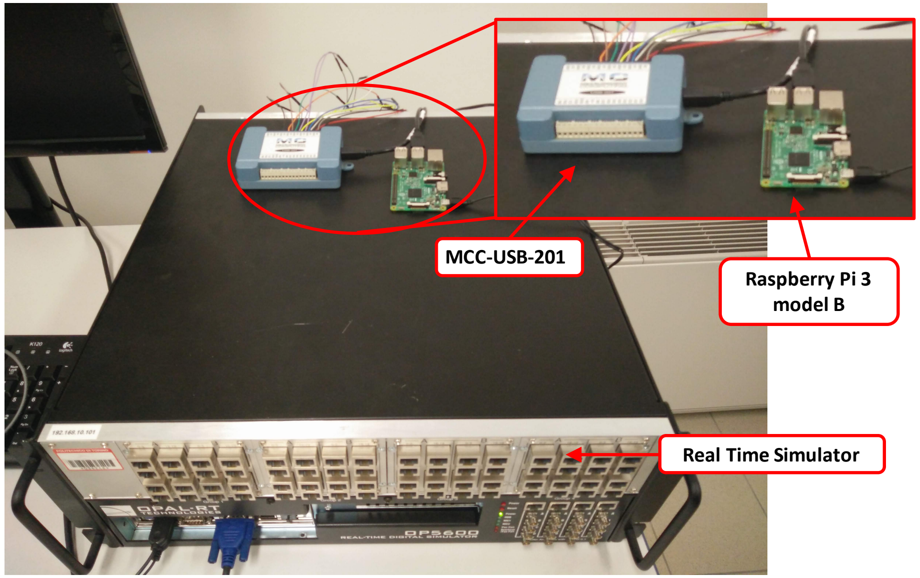




AMB simulation of Photovoltaic penetration in smart cities under different regulatory framework.

Simulation in Smart Cities

- ***3-SMA*** is a three-phase smart meter to support and provide the self-healing distribution systems.

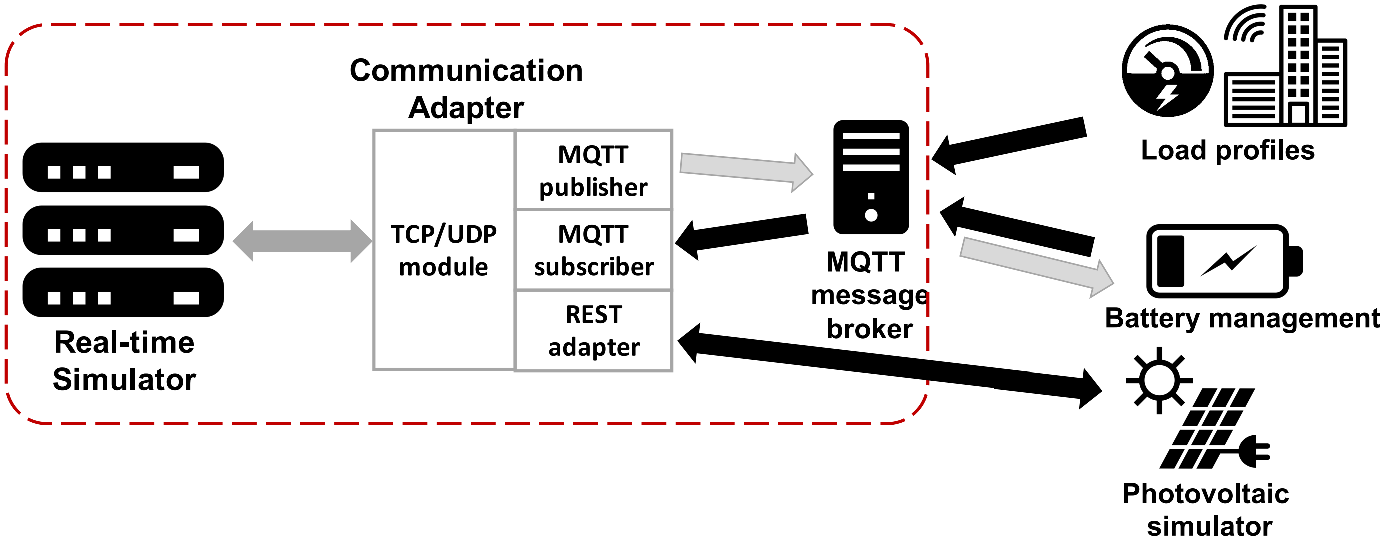


Benefits

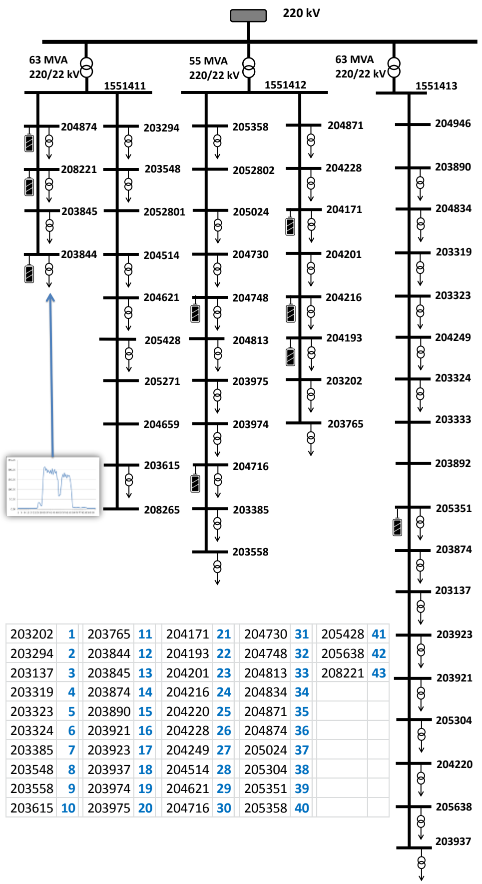
- low-cost and open-source 3-phase smart meter
- Internet-connected device
- Self-configurable according to the portion of distribution network it monitors

Simulation in Smart Grids

Implementation example of Photovoltaic penetration in cities with distributed storage management



Simulation in Smart Grids



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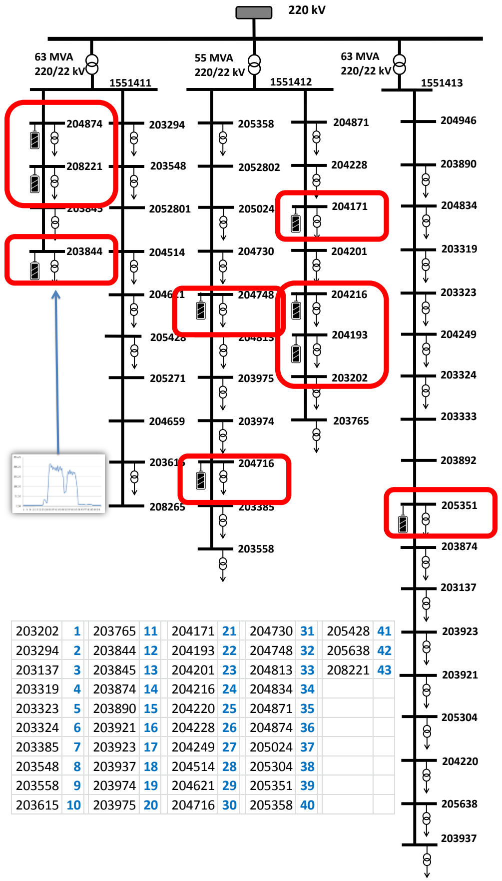
203137	3	203845	13	204201	23	204813	33	208221	43
203319	4	203874	14	204216	24	204834	34		
203323	5	203890	15	204220	25	204871	35		
203324	6	203921	16	204228	26	204874	36		
203385	7	203923	17	204249	27	205024	37		
203548	8	203937	18	204514	28	205304	38		
203558	9	203974	19	204621	29	205351	39		
203615	10	203975	20	204716	30	205358	40		

MV distribution grid
(RTS)

Simulation in Smart Grids



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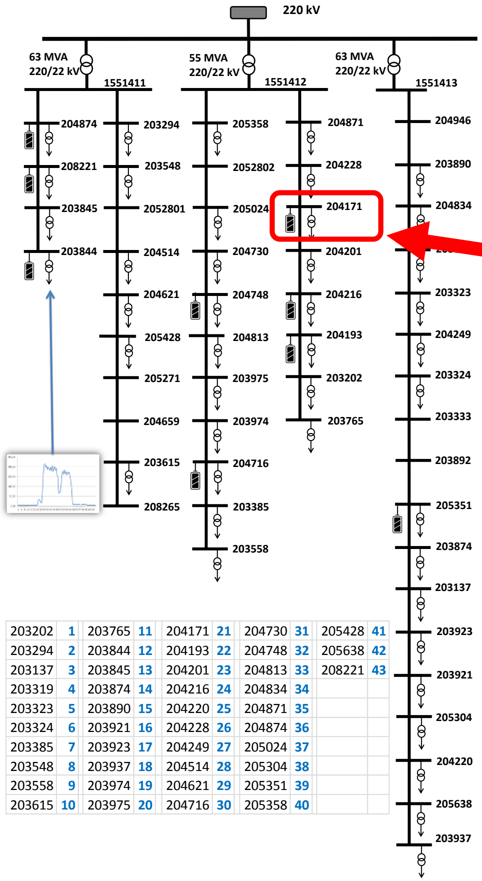

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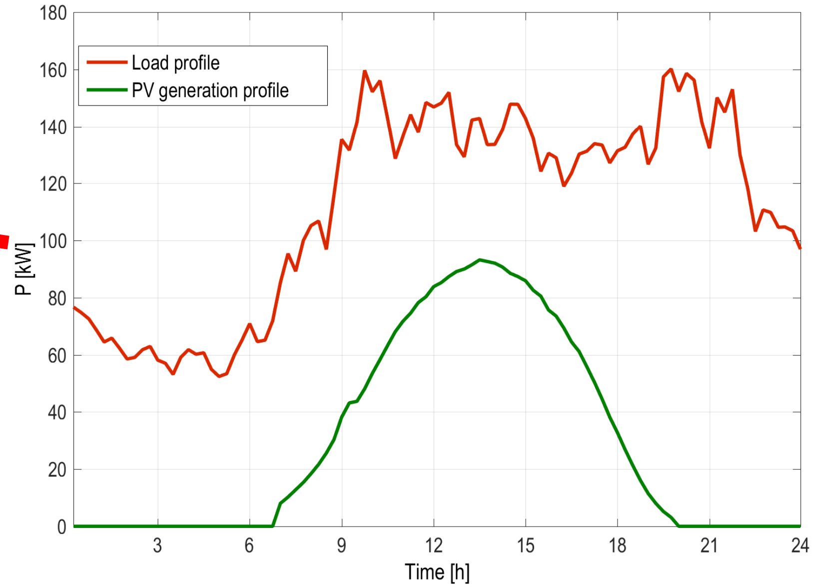

Input for substation
(Load and PV simulators)

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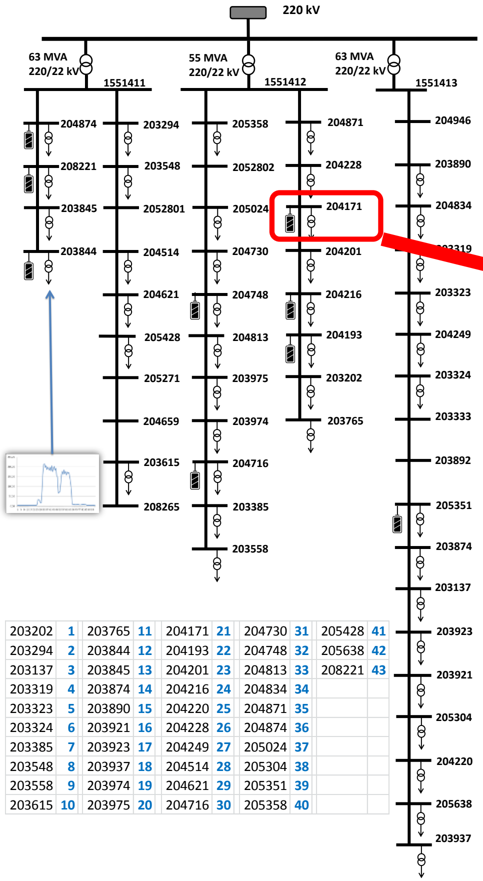
Simulation in Smart Grids



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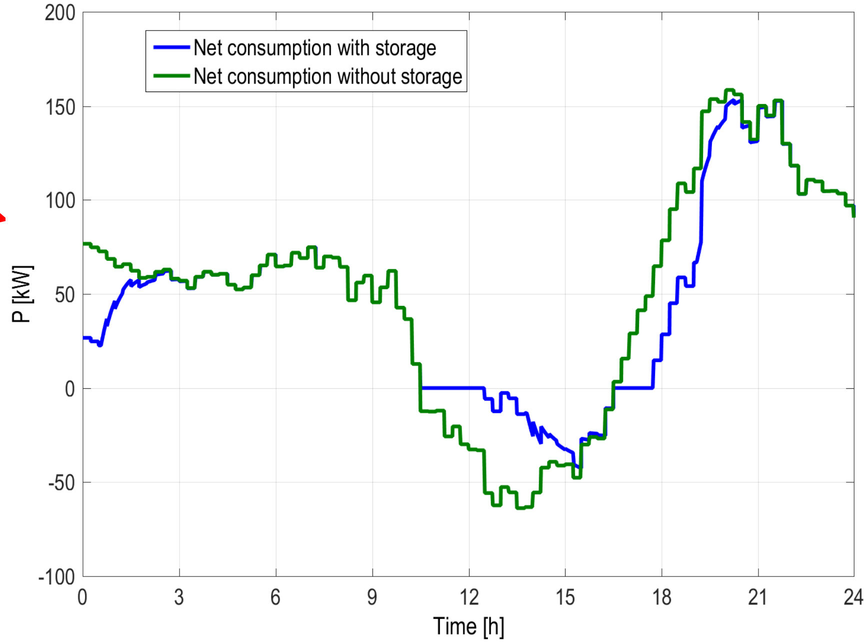
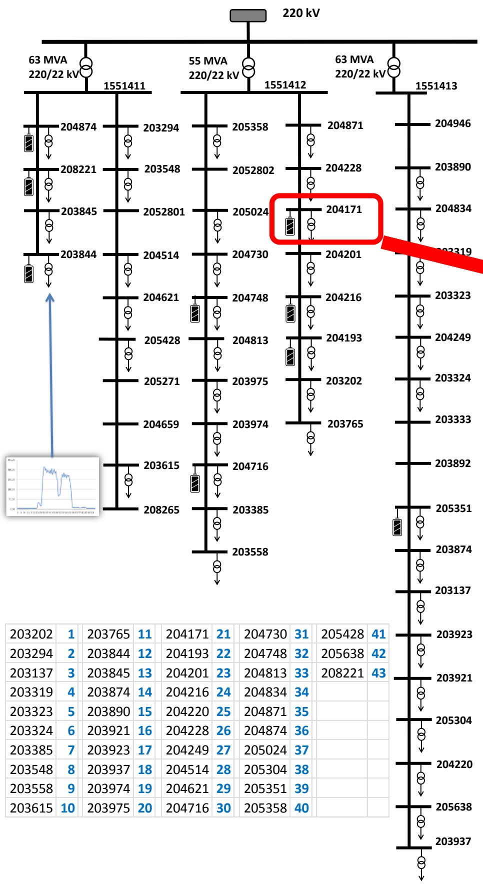
MV distribution grid (RTS)



Net consumption power with and without storage (Battery Management)

Simulation in Smart Grids



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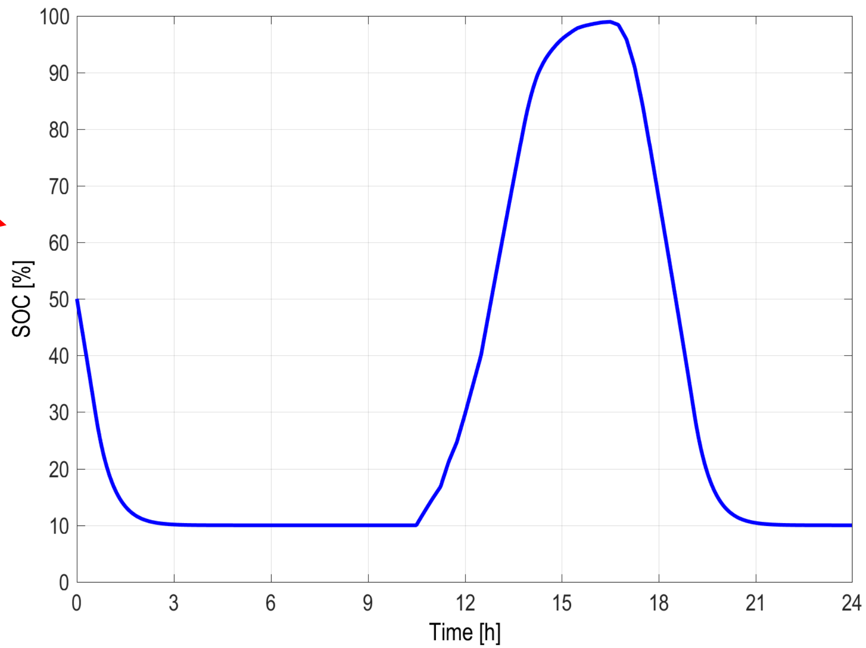

State Of Charge profile of storage
(Battery Management)

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Prediction in Smart Cities

- ***Smart Grid***:
  - Neural networks to forecast Solar radiation
- ***Smart Building***:
  - Neural networks to forecast indoor temperature in buildings
  - Kalman filters to evaluate thermal energy profiles in buildings

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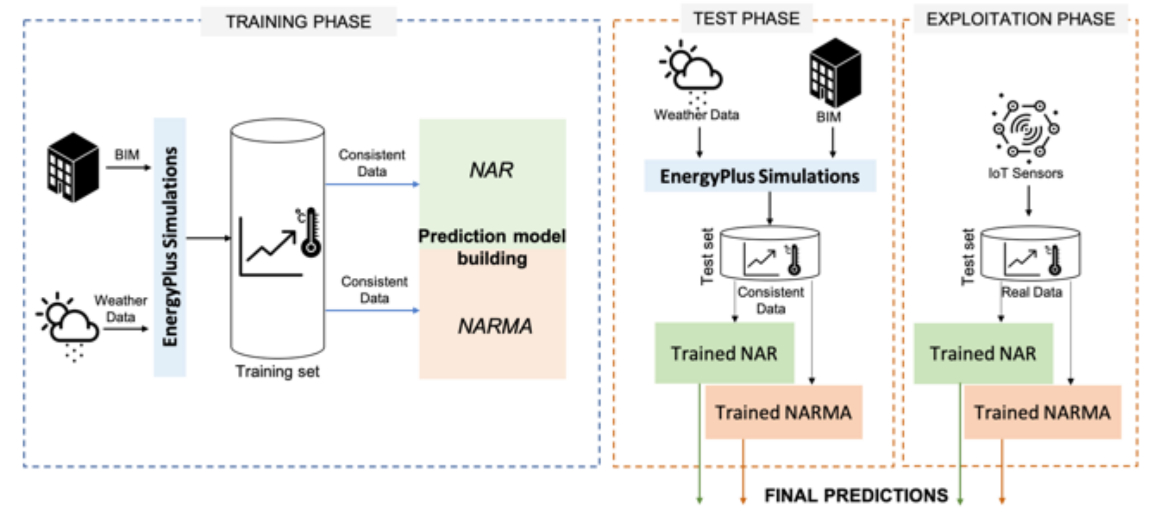

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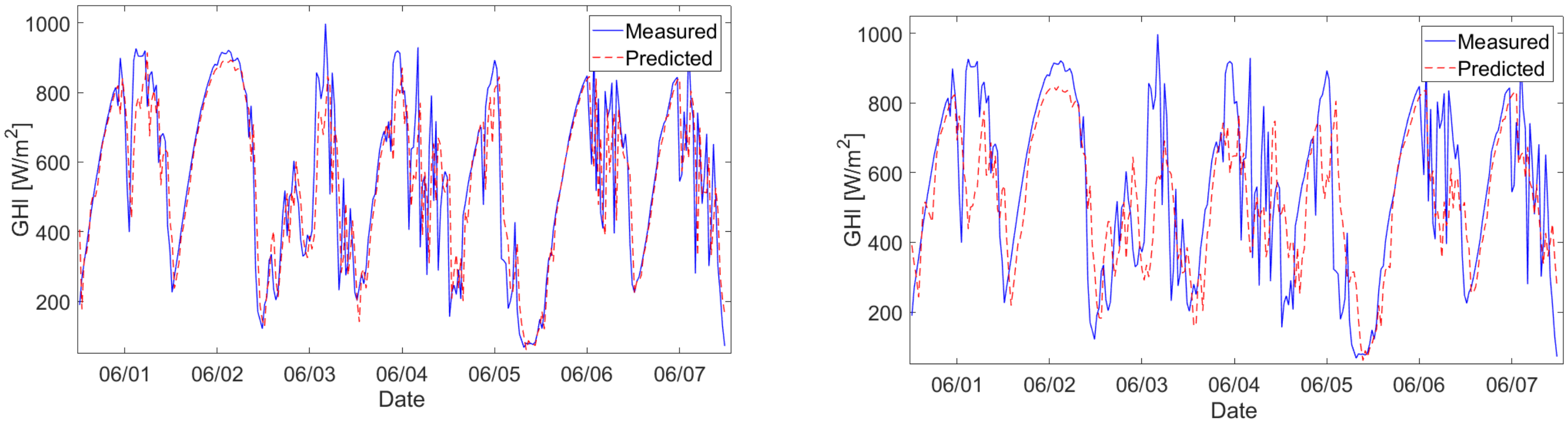
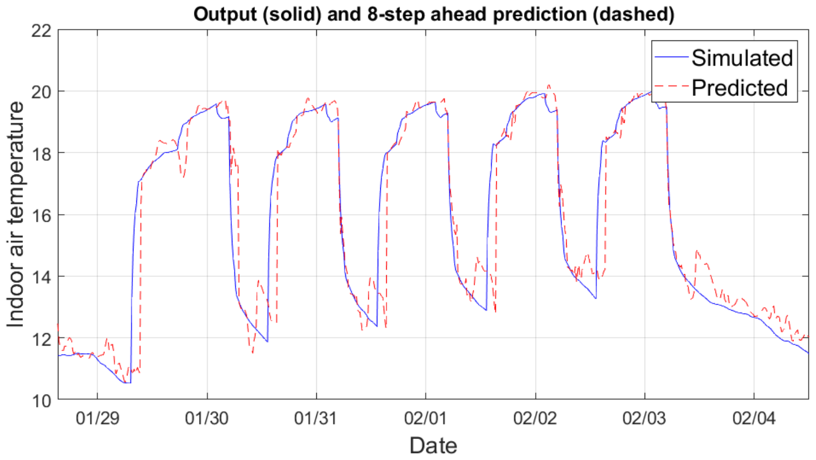
Prediction in Smart Cities

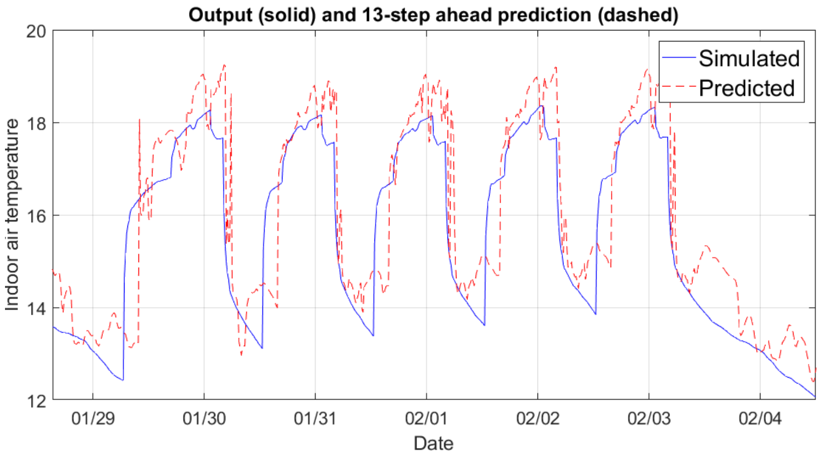
Neural network for Solar Radiation forecast



Prediction in Smart Cities

Neural network for indoor air temperature forecast





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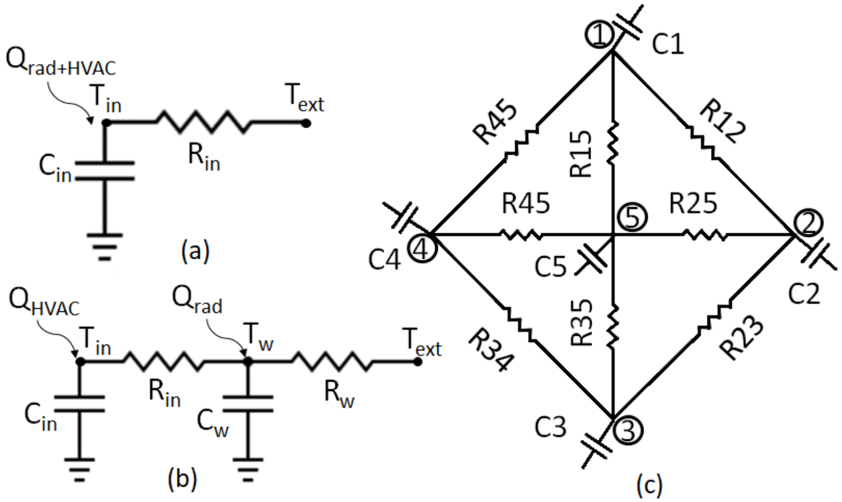
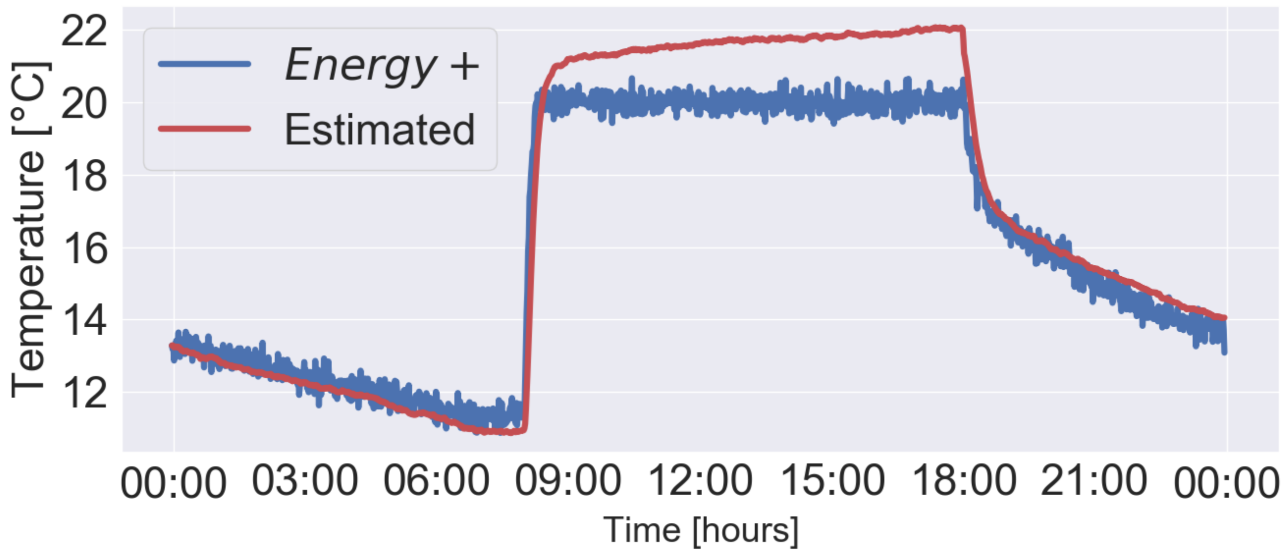
Prediction in Smart Cities

Kalman Filters



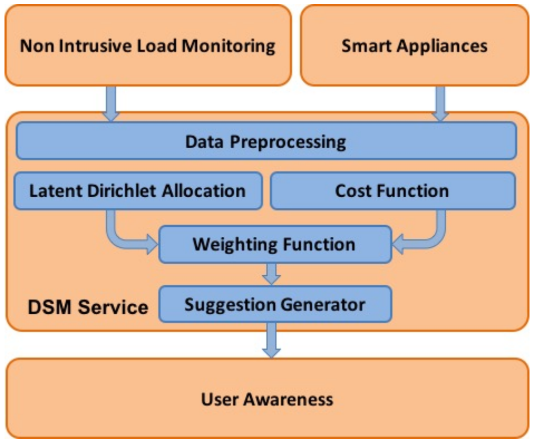
Prediction in Smart Cities

Kalman Filters



Prediction in Smart Cities

- ***Appliance Usage Behaviour Prediction***:
  - Latent Dirichlet Allocation to learn usage pattern behavior of shiftable appliance for Demand Side Management service



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Prediction in Smart Cities

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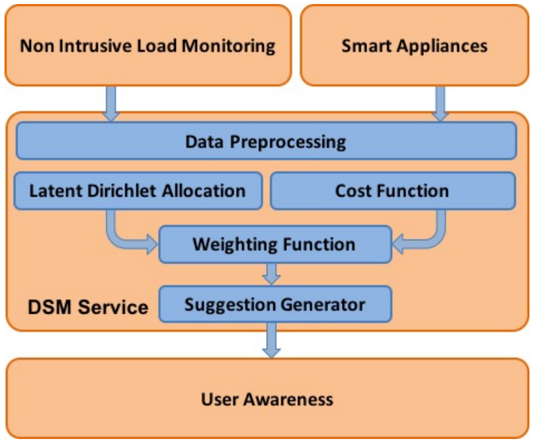
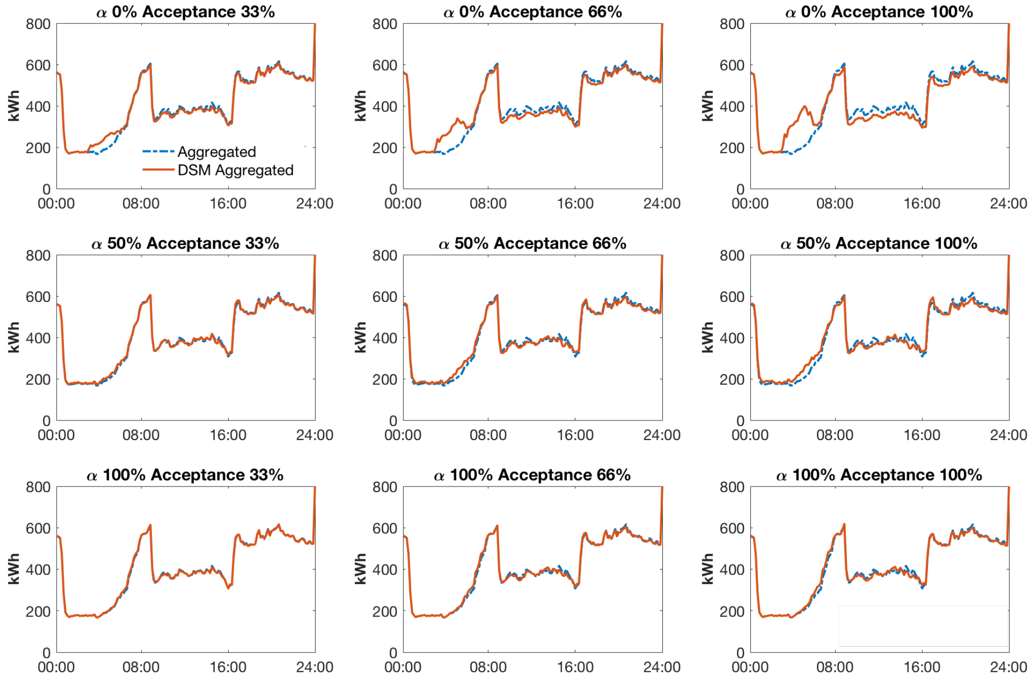
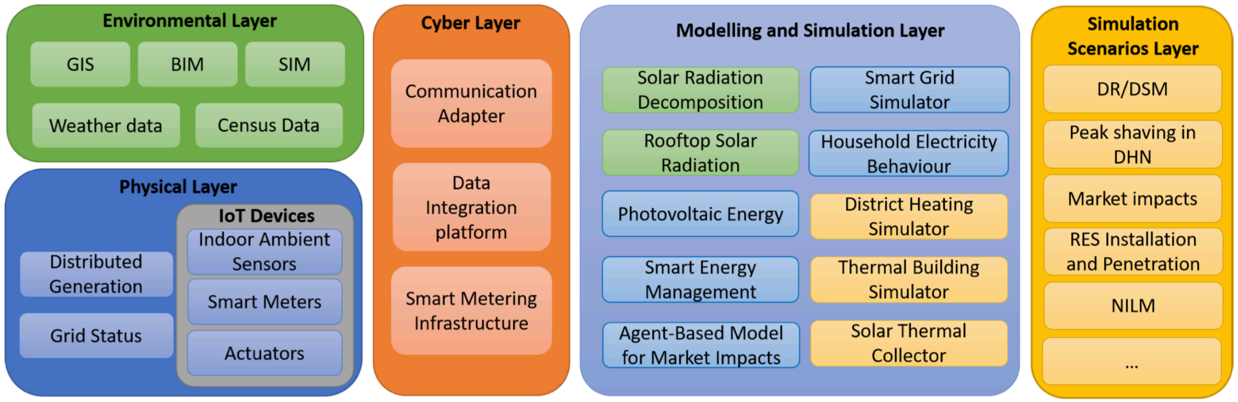


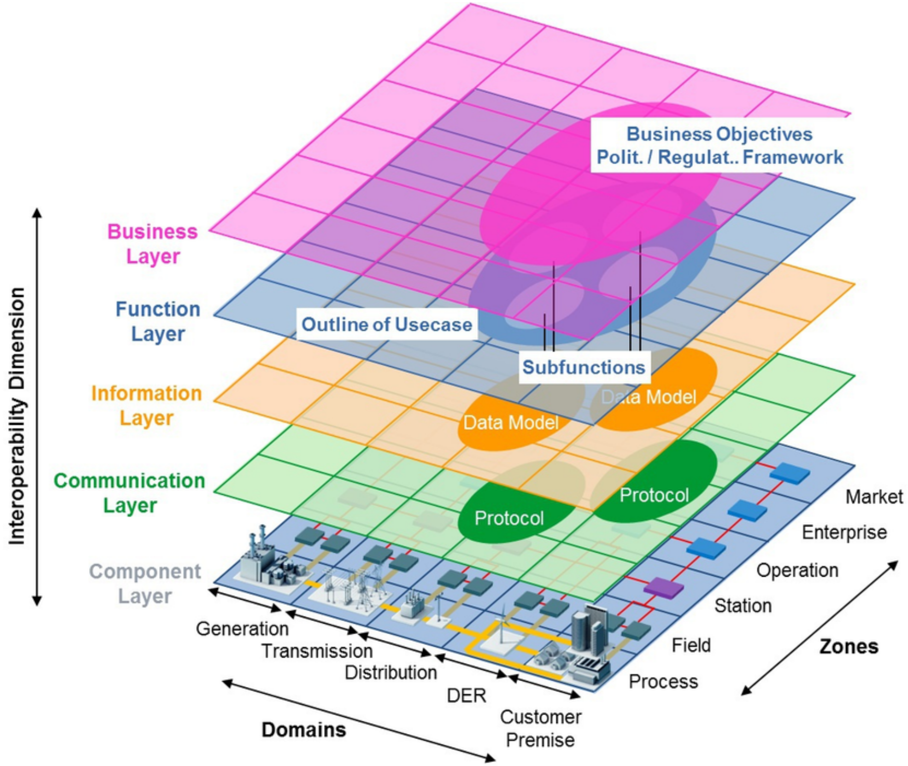


Energy Center Lab

- **Main Objective**
  - Design of a co-simulation platform for Multi-Energy System Analysis (SIL, HIL, PHIL)
    - Operational Control **VS** Energy Planning
    - Grid Balancing and Management
    - Technology Diffusion and Competition
    - Demand Side Management and Demand Response
    - Energy Policy and Security



Proposed Representation of MES



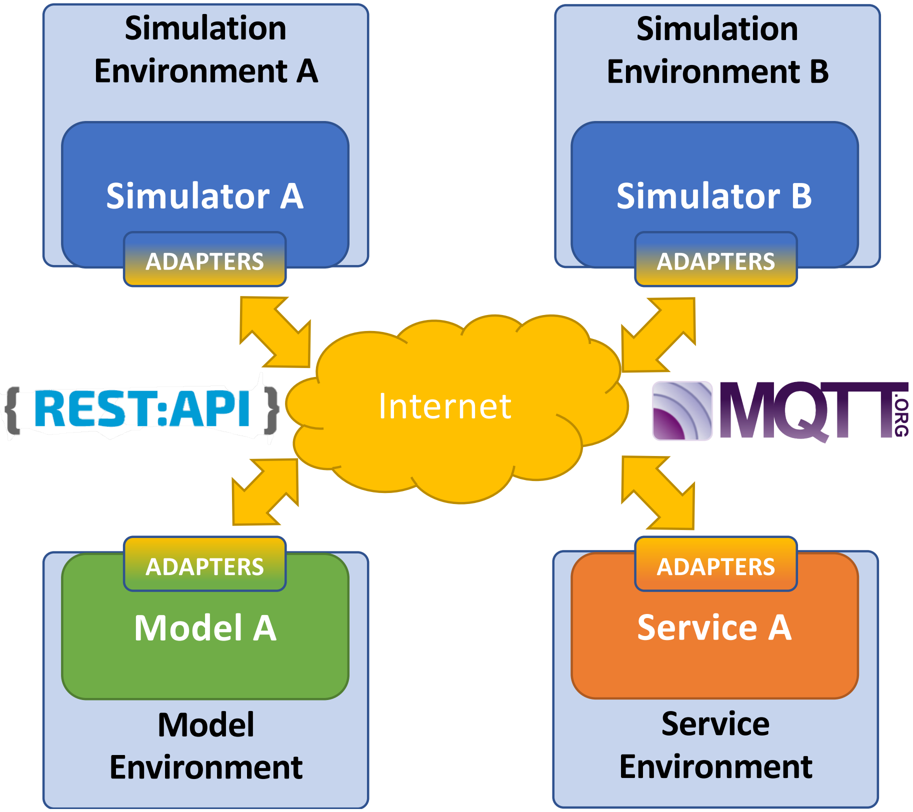
Extend **SGAM** (Smart Grid Architectural Model) to Multi Energy Systems

- What are physical components required?
- How should the information be exchanged?
- What should data be communicated?
- What are functions needed?
- What are business and regulatory constraints to be applied?

Previous Works

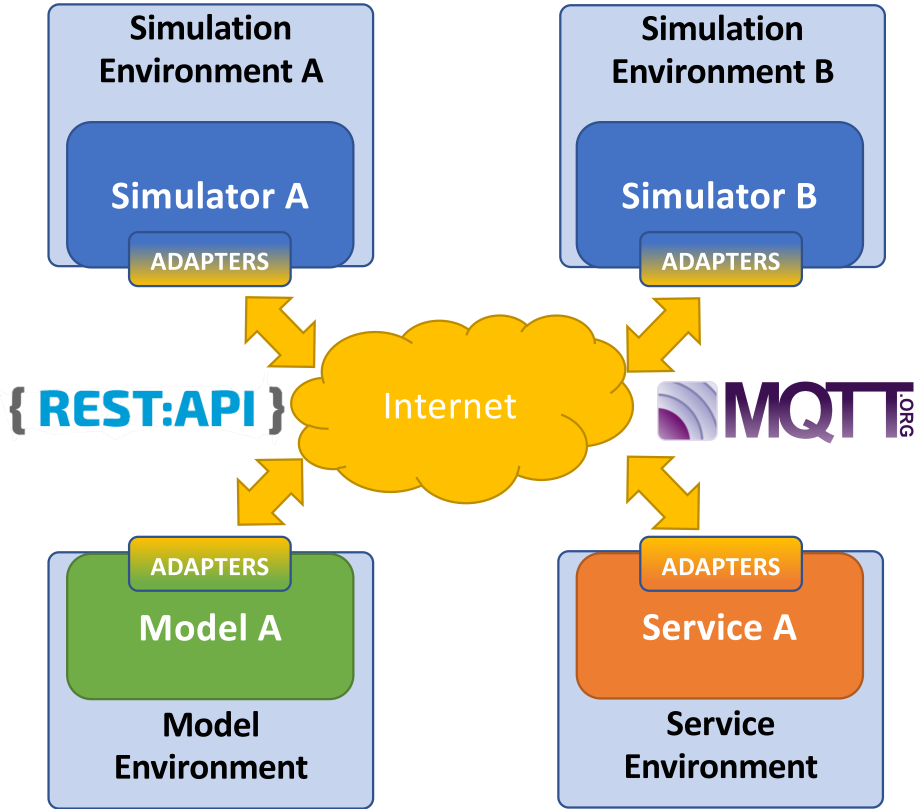
- Interdisciplinary approach to couple models, simulators, and software:

- Common Data Model (i.e. JSON)
- Ad-hoc interface (i.e. adapters)
- Communication protocol based upon different approach:
  - **request-response (i.e. HTTP REST)**
  - **publish-subscribe (i.e. MQTT)**
- Collect, store, and supply information to application that are in charge to manage, analyze, optimize and control the overall complex system



Weakness

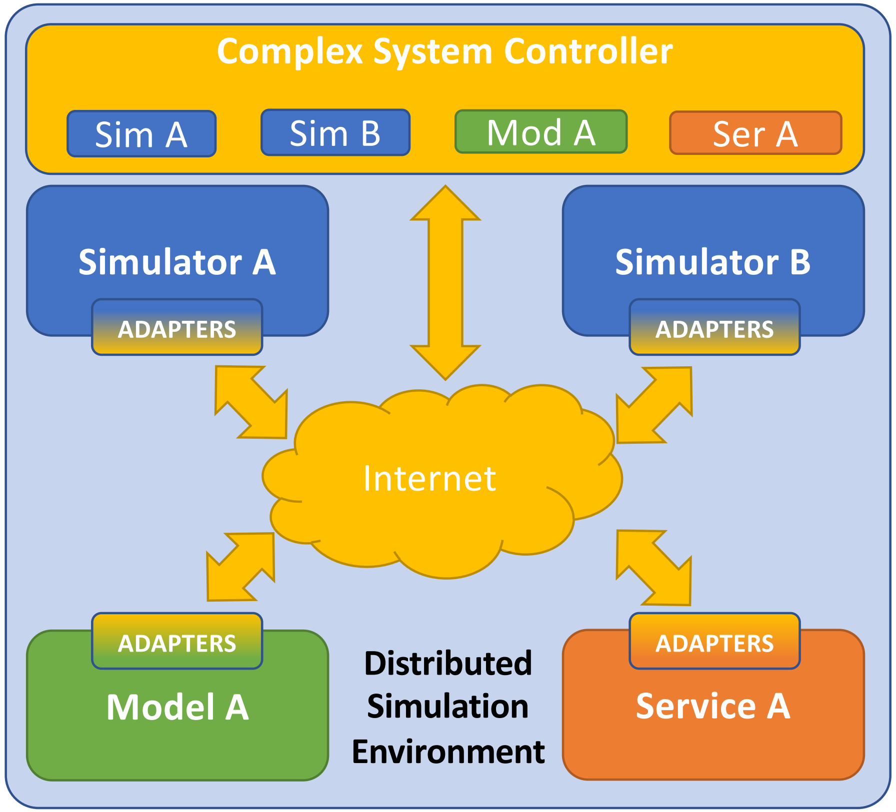
- Interdisciplinary approach to couple models, simulators, and software:



- Each interconnected environment manteins its typical variable and time-step management
- Each new simulator, model, and service must be customized to let it communicate with other entities
- Each simulator, model, and service must be customized once a new node is added
- Slack approach of time synchronization, considering the real world clock as the time of the overall complex system (near-real-time approach)
- Low extensibility and modularity of the overall infrastructure

Our Perspective

- Cosimulation approach to couple models, simulators, and software :
  - Use of co-simulation techniques (HLA, FMI, DDS) to create a Distributed Simulation Environment to share variable and entities
  - Harmonized, simple, and plug-and-play coupling of new models, simulators and softwares in an existent complex system simulation
  - Foster the distribution of the model across a cloud of hardware resources



Enabling technologies

- Cosimulation techniques:
  - **Functional Mock-up Interface (FMI)**
  - **High Level Architecture (HLA)**
  - **Data Distribution System (DDS)**
  - **Mosaik**

Challenges

- Improve Time Management, Synchronizations and Regulation
  - Time Scales and Time Resolution (Time Based Simulation)
  - Multi-Rate and Adaptive-Rate Simulations (Event Based Simulation)
- Definition and management of common Distributed Object for Data Exchange
- Management of Distributed Simulation and Orchestration
- Allow Simulation with Hardware-, Humans-, and Systems-in-the-loop
- Integration of Communication Network Simulators
- Modelling, Simulating and Experimentation Requirements

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Challenges

- Providing monitoring, control, and debugging tools
- Providing advanced analysis support
- Make the platform scalable to allow a distributed deployment

Energy planning: integrating planning and operational dimensions

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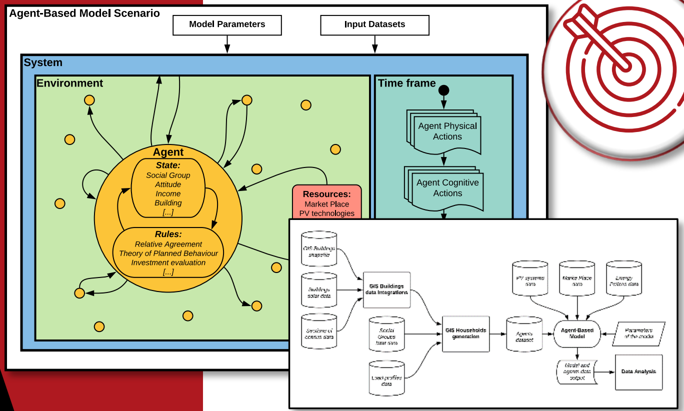

Main Goal - Development of a comprehensive methodology for the diffusion of sustainable communities based on the interoperability of sub-models at different functional layers. The proposed framework will allow to set up and solve different energy scenarios at the urban context with the aim of supporting decision makers toward effective energy policies and interventions.

Task 1 - Development of a modelling framework incorporating planning and operational dimensions, for supporting the deployment by decision makers of effective energy interventions and policies in cities.

Task 2 - Exploitation of the agent-based approach to study the interactions between the different functional layers.

Task 3 - Scenarios for sustainable urban energy planning in collaboration with the EC_lab activities.

Task 4 - Early implementation of energy policies at the urban level in collaboration with the Municipality of Torino.

Contacts

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Publications:
http://eda.polito.it/edoardo-patti/
Google scholar: https://goo.gl/gARx7B
YouTube: https://goo.gl/Jyqqwx