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PIACER: a toolbox for RECs of the future



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LEAP scarl

CONTEXT

The European Renewable Energy Directive (RED II) and the European Union directives and regulations on electricity markets outline an ambitious vision of Renewable Energy Communities (RECs) that goes well beyond **current configurations, which are predominantly electricity-based and limited to the purely virtual sharing of energy**.

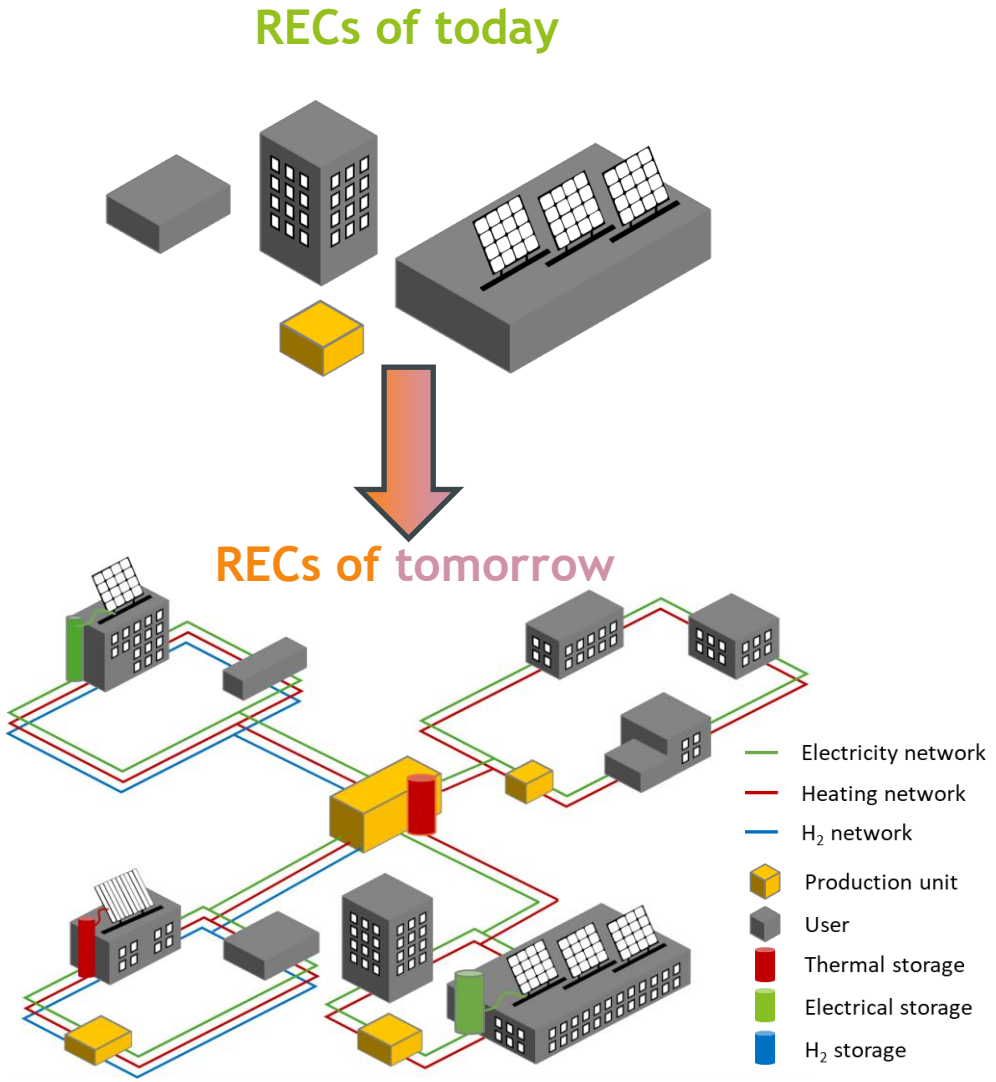
Two conceptual pillars define this forward-looking vision.

→ **MULTI-ENERGY AND MULTI-SERVICE RECs**

Multi-energy and multi-service integration transforms RECs from simple electricity networks into **integrated territorial hubs**. Besides connecting electricity, heat and sustainable mobility, RECs offer smart management of energy consumption, **grid flexibility** and shared charging services, generating economic, environmental and social value for the entire community

→ **USER CENTRALITY IN THE ELECTRICITY MARKET**

The final consumer is transformed from a passive subject (a mere buyer) into an **active player** (prosumer) within the energy system, adapting their consumption in response to **price signals** or **incentives** and providing **flexibility** to the energy community and to the grid.

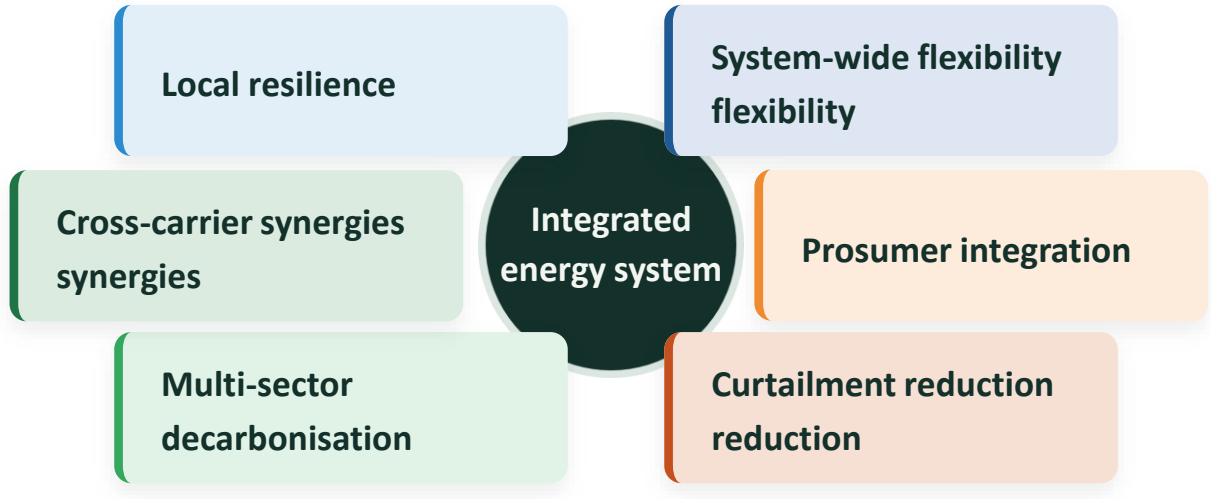


CHALLENGES AND OPPORTUNITIES

This shift represents one of the most profound transformations of the modern energy system and introduces new benefits for each member.

Challenges and opportunities for the PIAC(ER)^2 project

Sector coupling and user centrality introduce **multiple subsystems** which, to interact effectively, require **advanced coordination and planning tools**.



The multiplicity of energy carriers and services increases the number of **degrees of freedom** of the system. → Opportunity: it is possible to exploit synergies and activate more advanced **efficiency** and **flexibility** mechanisms. Risk: greater scope for **errors** and inefficiency in the design or management phase, and for failing to correctly identify faults.

Active user involvement in the planning and management of the REC implies, on the one hand, the possibility of exploiting **peer-to-peer interaction** mechanisms among individual members to increase the **collective benefit** and, on the other, the need to preserve the **autonomy**, **privacy** and **objectives** of individual members (to motivate them to remain in the REC).

THE SOLUTION



GOAL: To create a **toolbox** (PIACER) designed to deliver the **energy, economic, environmental and social benefits of a 3.0 REC (*multi-energy and multi-service*)**, generating value from the data made available by the devices within a REC or by external platforms/sources.

Academia

LEAP – Politecnico di Milano

Università degli Studi di Ferrara | IN4 | CIRI Fonti Rinnovabili, Ambiente, Mare ed Energia - FRAME – Alma Mater Studiorum Università di Bologna

ENEA CROSS-TEC

CIDEA Centro Interdipartimentale per l'Energia e l'Ambiente – Università di Parma

Industry

SMARTDOMOTICS easy living

GETEC

Siram by Veolia

PIACER TOOLBOX

Long-term strategic decisions | **Operational actions and responses**

Optimised design

Multi-objective algorithms to **size the energy assets of a REC**, considering the number of members, consumption profiles and available resources. They also calculate the **redistribution of the incentive** among members.

Sector coupling

Models and manages multiple energy carriers (electricity, heat, cooling) and their interconnections. Simulates and **optimises future scenarios**, identifying cross-carrier synergies.



Asset diagnostics

Monitors the health of distributed assets and identifies whether and where a fault has occurred. Integrates two approaches: a **data-driven** one, based on a **NARX neural network**, to identify the faulty subsystem, and a **physical model** to estimate the magnitude of the fault.

Smart Management

Integrates deep learning for **accurate load forecasting** and **optimises day-to-day management**, maximising economic performance while preserving the privacy and autonomy of the members.

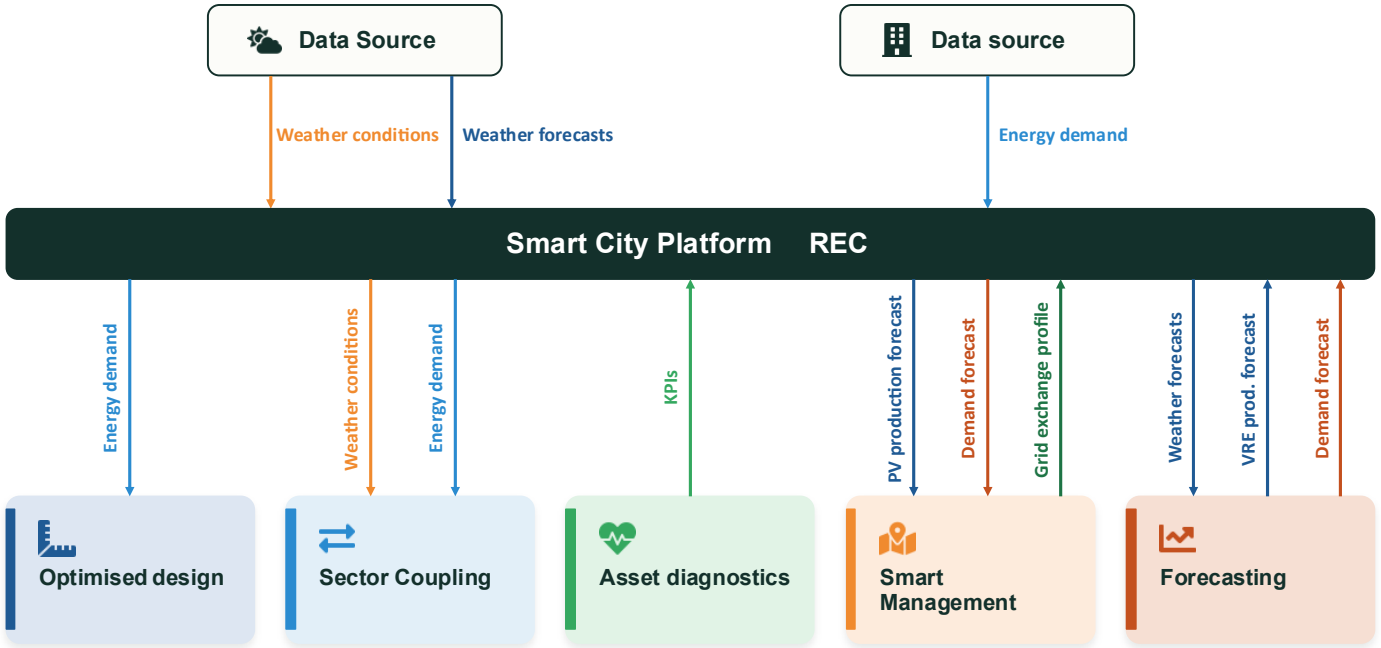
Interoperability

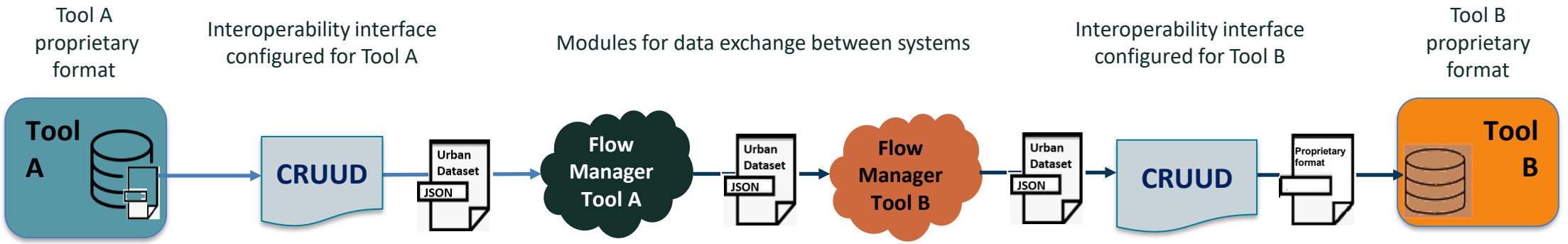
Ensures the cohesive integration of all tools. Defines common standards, communication protocols and standardised interfaces. Data representation syntax and semantics are based on **UrbanDataset formats**, part of the Smart City Platform Specification (SCPS).

PIACER TOOLBOX

Interoperability

1. Identification, and customisation for the REC domain, of specifications for interoperability in data exchange between tools
   - ➢ UrbanDataset format, part of the Smart City Platform Specification (SCPS) for Interoperability Layer: provides the reference data representation syntax and semantics
2. Design and development of an interface for the transformation from proprietary formats to UrbanDataset format and vice versa.
   - ➢ CRUUD application
   - ➢ Activation of data exchange between tools through the Smart City Platform (SCP)





PIACER TOOLBOX

Optimised design

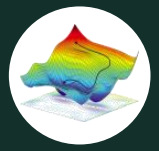
CSV

Disturbances
external conditions, energy demands, costs…

JSON

System characteristics
components, size constraints, energy and installation costs…

Generalised MILP optimisation framework



Optimal sizing of energy components
PV, heat pumps, boilers, batteries…

CSV

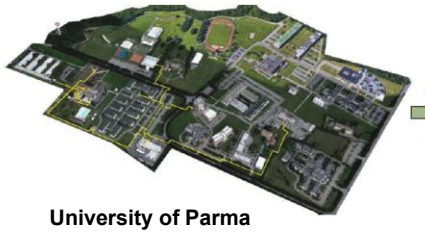
Optimised management over the forecast horizon
management of storage and conversion units, exchanges with the grids…

CSV

GOAL: To optimise the sizing of the energy components and to automatically calculate the redistribution of the incentive among the members



Validation at the University of Parma Campus REC



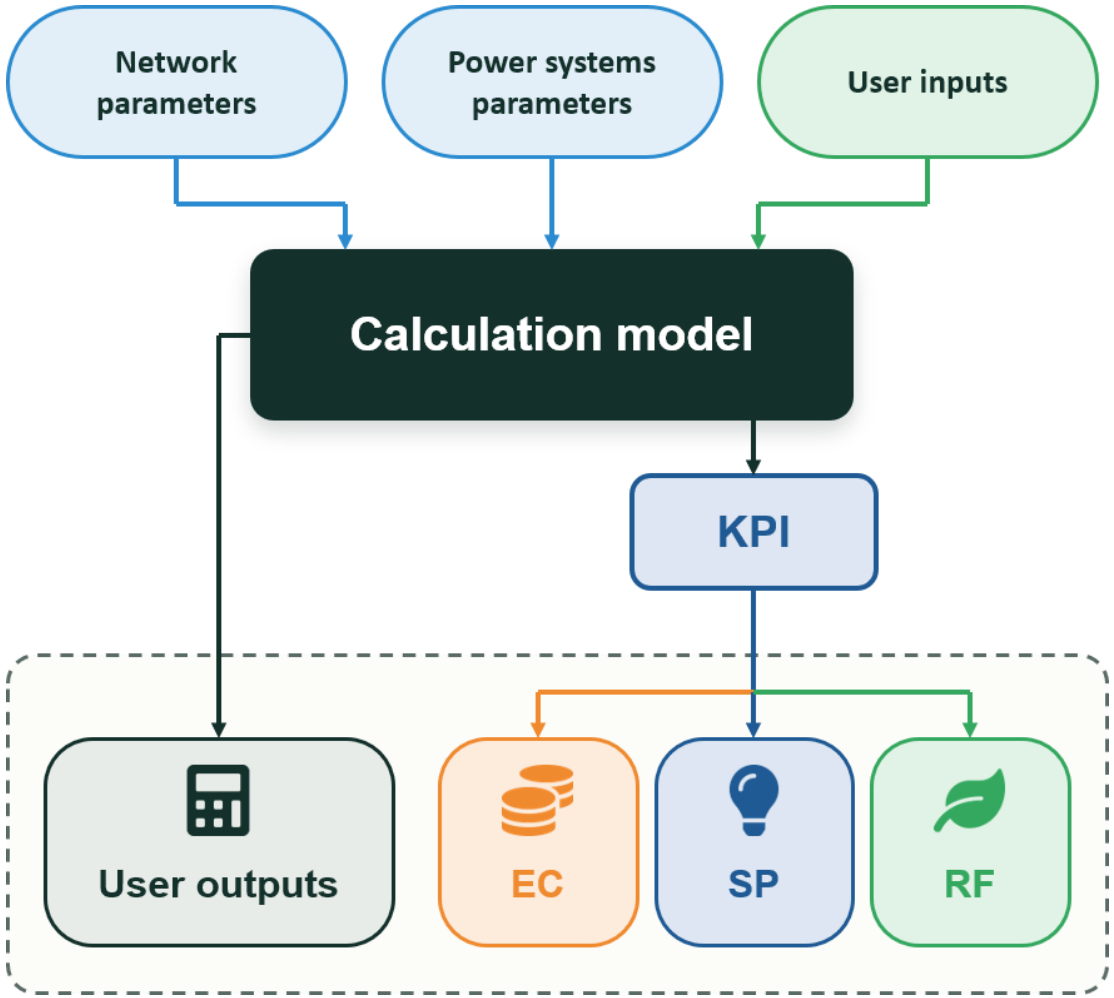
University of Parma Campus



CNR-IMEM (Institute of Materials for Electronics and Magnetism

PIACER TOOLBOX

Sector coupling - ECOS 7.1 (Energy Communities Optimizer Software)



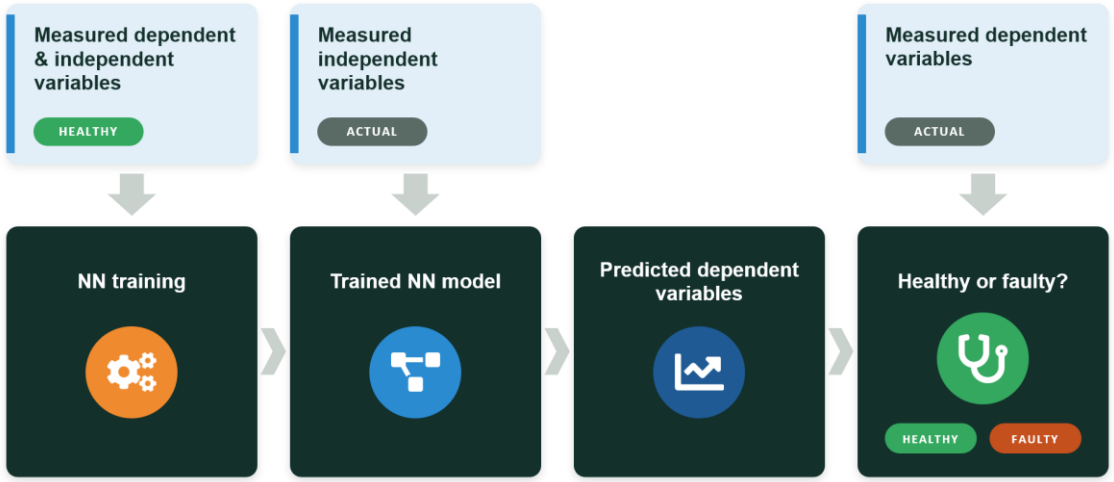
- **Network parameters:** number of users, type of loads, energy prices and the season in which the behaviour of the energy network is analysed.
- **Energy system parameters:** technical details of each user's energy system, such as the energy efficiency and the size of the photovoltaic or solar thermal systems.
- **User inputs:** variable conditions including the energy production mix and the sizing of the energy systems for each user.
- **Calculation model:** this model processes the inputs and parameters to determine the system outputs.
- **Key Performance Indicators (KPIs):** Extra Costs (EC), Self-Production (SP) and Renewable Fraction (RF).
- **User outputs:** represent the simulation results for each user, divided into two categories: **economic outputs** (e.g. daily costs, CAPEX) **and energy outputs** (e.g. energy consumption, daily energy production).

Validation on the Turin district heating network

PIACER TOOLBOX

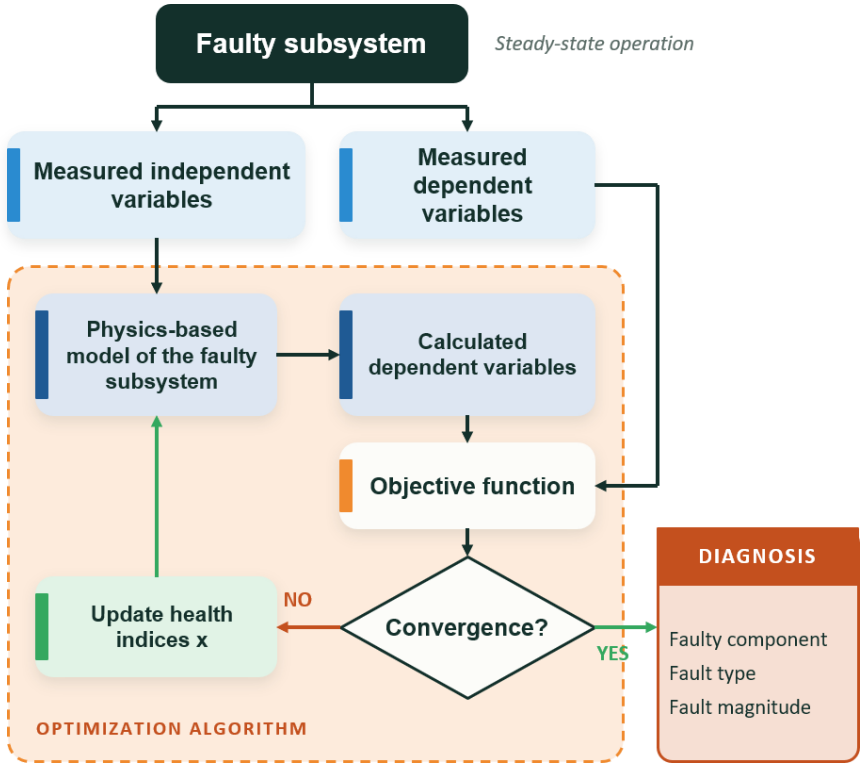
Asset diagnostics

Data-driven approach (NARX neural network) to identify the faulty subsystem



This synergy ensures effective monitoring and rapid troubleshooting, optimising the performance and stability of RECs in the multi-energy context, where achieving them is inherently more complex than in an isolated system (e.g., a cogenerator)

Physics-based approach to identify the magnitude of the fault

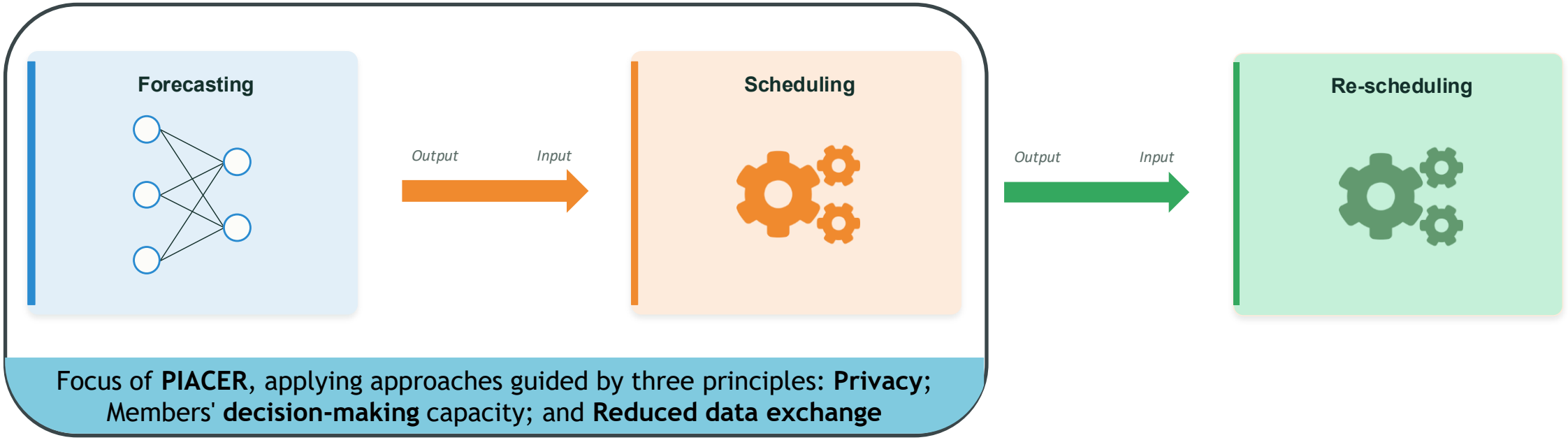


Validation on the Parma Campus (34 datasets, 33 of which contain faults)

PIACER TOOLBOX

Smart management

To optimise day-to-day management, provide services to the grid and make informed decisions on buying, selling or storing electricity (in a **multi-service**, **multi-market and multi-energy** perspective), it is essential to build an **advanced pipeline:**



Focus of **PIACER**, applying approaches guided by three principles: **Privacy**; Members' **decision-making** capacity; and **Reduced data exchange**



Research Question: What is the cost (both economical and in terms of performance loss) of forgoing data centralisation and sharing to protect the privacy of REC members?

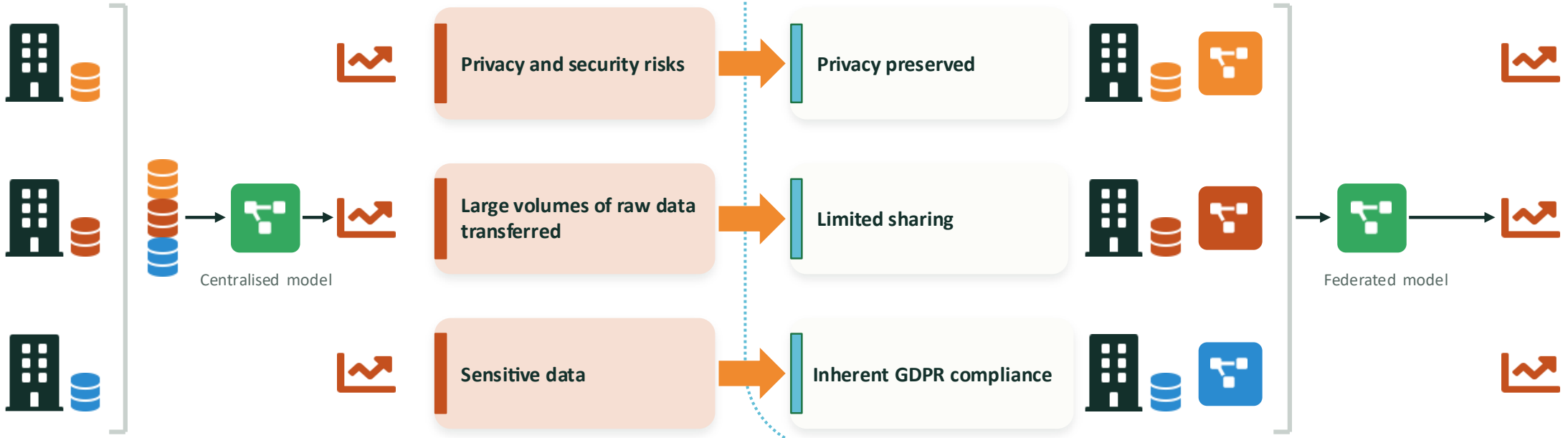
PIACER TOOLBOX

Conventional approach

All users' raw data are sent to a single central server, which processes them and trains a single centralised model.

PIACER approach

Federated Learning architecture offers a novel alternative. Each user trains their own model with their own data and shares only the model updates with the central server



Validation on 4 Politecnico di Milano campuses

Hybrid CNN-LSTM approach: CNN for short-term local patterns, LSTM for long-term trends

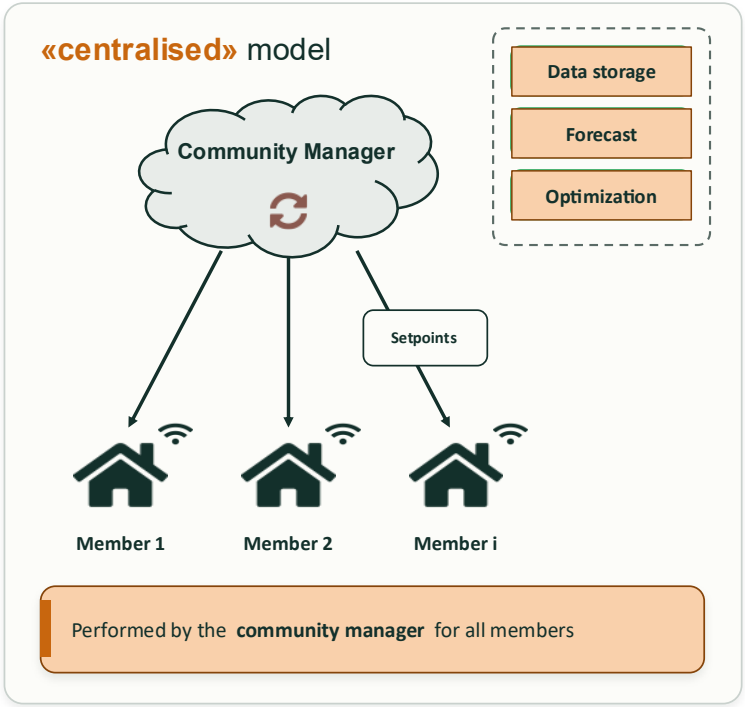
1. **Historical users:** the federated model is almost as accurate as the local models (MAE +2%).
2. **New users:** it solves the problem of the lack of initial data, offering more accurate forecasts (+62% for data <6 months).

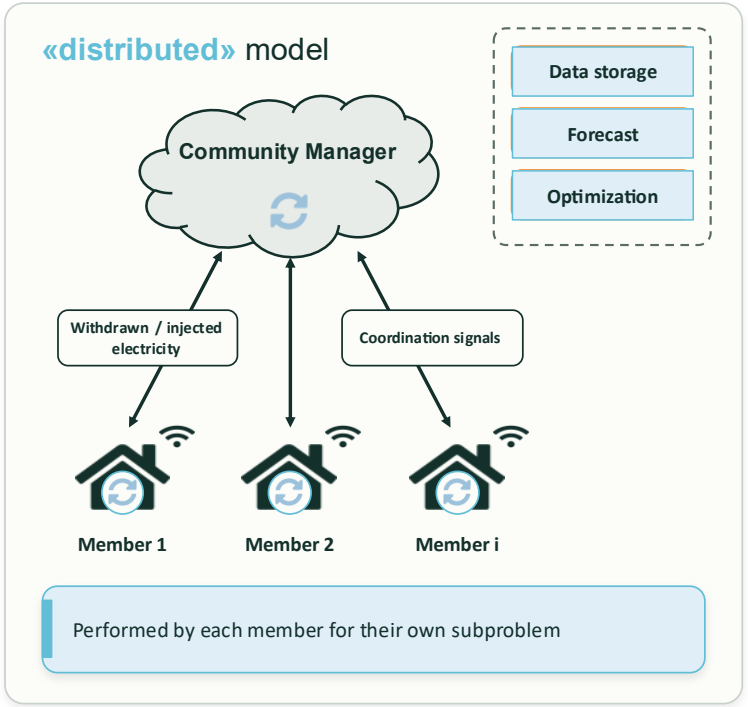
PIACER TOOLBOX

Centralised (classical) optimisation **collects all members' data** (e.g., production profiles, consumption habits, supply contracts), computes the optimal schedule and, **potentially, directly controls the assets**, thereby limiting members' autonomy .

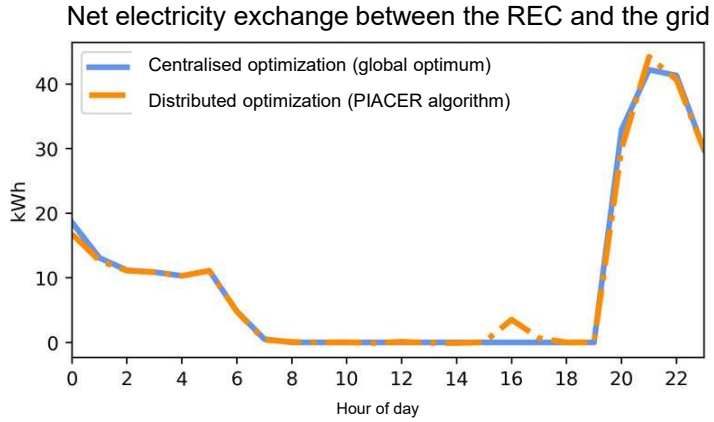
Solution: decomposition technique (ADMM):

- The global problem is decomposed into several local sub-problems, *one for each REC member*.
- Through a minimal exchange of coordination information with the Community Manager, the algorithm converges towards the global optimal solution (iterative process).





Validation: 72 residential PODs; 68 kW PV; 85 kWh BESS



Suitable for large RECs
Limited data exchange

Local optimum

BUSINESS MODEL: LOCAL FLEXIBILITY MARKETS

To assess the economic and financial viability for companies joining a REC, given an investment in renewable sources (PV) and storage (BESS), enabled by participation in Local Flexibility Markets (LFMs).

Business Model 1

Costs

- PV Capex & Opex
- GSE charges
- PIACER fee

Revenues

- Energy sales to the grid
- Incentive on shared energy

Business Model 2

Costs

- PV Capex & Opex
- GSE charges
- Aggregator fee (LFM)
- PIACER fee

Revenues

- Energy sales to the grid
- Energia condivisa
- Availability and activation on LFM

Business Model 3

Costs

- PV and BESS Capex & Opex
- GSE charges
- PIACER fee

Revenues

- Energy sales to the grid
- Incentive on shared energy

Business Model 4

Costs

- PV and BESS Capex & Opex
- GSE charges
- Aggregator fee (LFM)
- PIACER fee

Revenues

- Energy sales to the grid
- Incentive on shared energy
- Availability and activation on LFM

Preliminary results

- In all the identified BMs, the investment shows **an IRR > 10%**. The presence of the LFM (BM2) slightly increases the profitability of the investment compared with the PV-only case (BM1).
- Adding the battery alone (BM3) reduces the IRR because of the higher CAPEX. However, enabling the battery for LFM services (BM4) brings the IRR back to a value comparable to BMs 1 and 2.
- **Future outlook:** investment in the battery will become an attractive business model **once local flexibility markets move beyond the experimental phase and the activation rate reaches at least 8.2%**.

SAVE THE DATE



Thank you for your attention!

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