Italian National Agency for New Technologies,
Energy and Sustainable Economic Development

Building Energy Communities

A support framework for users and prosumers

1st June 2022, Forlì

Samuele Branchetti – TERIN-SEN-CROSS – ENEA Bologna Research Centre

Activities of the laboratory on CE

- **Energy Technologies and Renewable Sources Department**
  - **Smart Energy Division**
    - **Cross Technologies for Urban and Industrial Districts Laboratory**

ENEA – TERIN-SEN-CROSS laboratory, based in Bologna and active on Energy Communities in different areas:

- Definition of communication standards for data exchange (protocols, formats);
- Identification of the main technologies for Energy Communities such as:
  - Blockchain;
  - Definition of benchmarks, KPI;
  - Clustering of energy profiles;
  - Development of data models, aggregation and analysis tools;
  - Design of advanced tools for user interaction (APP, CruISE);
  - Development of business models and community management solutions.

- Projects:
  - COME-RES (www.come-res.eu)
  - GECO (https://www.gecocommunity.it)
  - Ricerca di Sistema Elettrico (www.smartenergycommunity.it – under construction)
  - Self-USER (https://www.selfuser.it).

Outline

1. The Energy Communities context

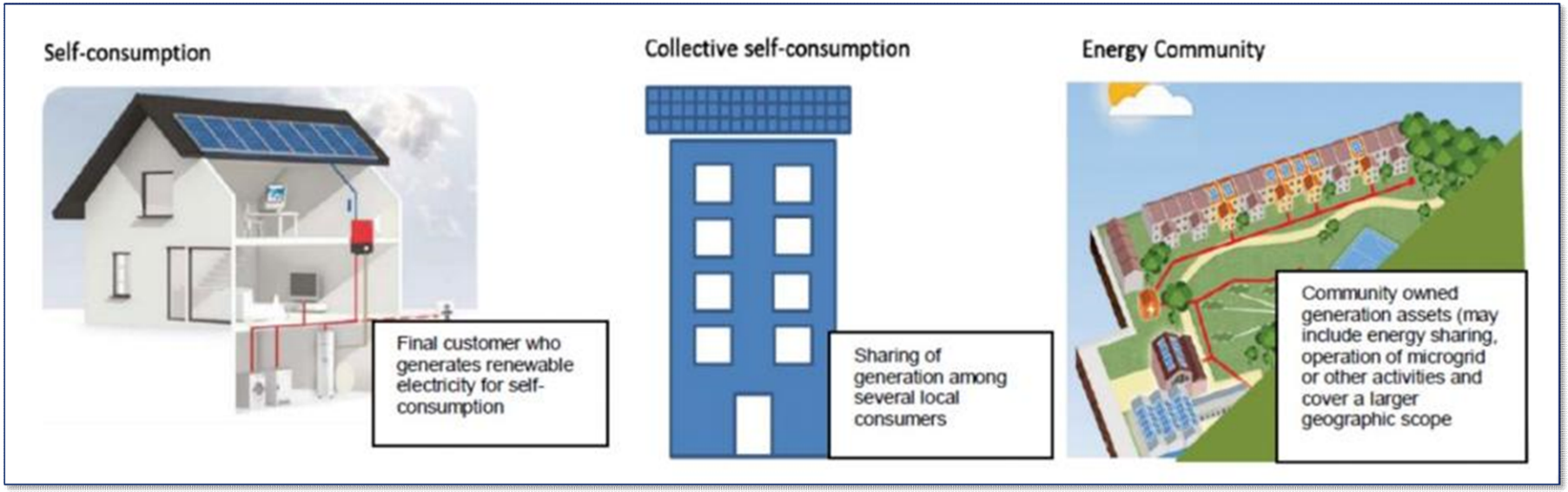
2. Open topics

3. The available tools

Energy Communities as a pillar for the sustainable development

- The concept of Energy Community is defined in the **Clean Energy Package** composed of 8 directive proposed by European commission. The cornerstone of the legislation is the *empowerment* of citizens.
- The Energy Community is a tool for the sustainable development as it combines the concept of local community, made up of people and institutions living in the area, with the idea of sustainability of the overall energy profile.
- As a matter of fact the fundamental factor of the Energy Community is its close link with the local territory.

The Energy Community configurations



Direct self-consumption: the producer directly consumes the produced energy and sells the surplus to the grid. When needed, it buys energy from the grid.

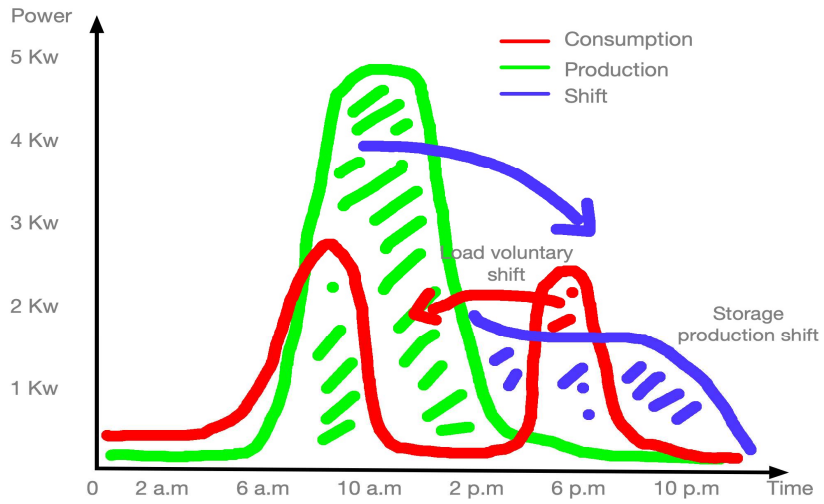
Collective self-consumption: the produced energy is consumed by several users who live in the same building.

Energy Community: the produced energy is consumed by several users who are connected to the same HV/MV substation**. The shared energy** is the minimum between the hourly produced energy and consumed energy by the community and **the reward** is calculated in relation to it.

The Renewable Energy Community

The Renewable Energy Community is a legal entity, which can access the enhancement and incentive service of shared electricity, producing important energy and economic implications:

- Investments on new energy production plants
- Sharing of energy production
- Changes in energy behaviours



Open topics

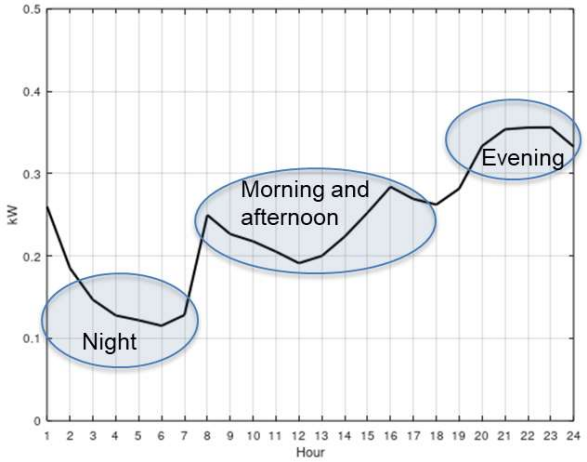
A. Energy data analysis / electrical load curves
   - How to retrieve complete and reliable data?
   - What info to extract?
   - How to make data accessible to users and decision makers?

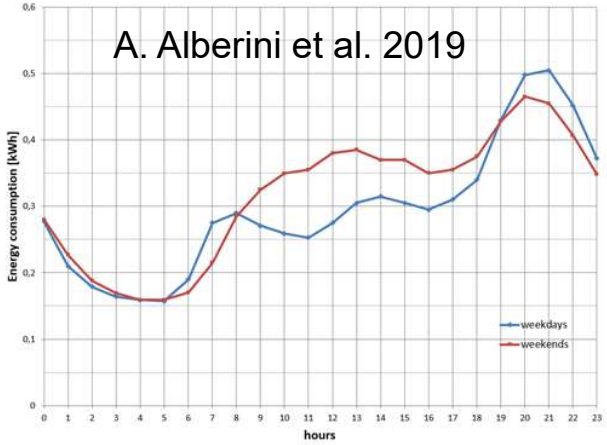
B. Modelling of energy communities
   - Which models to implement?
   - What accuracy to expect?
   - To plan or to manage?

C. Billing schemes for the shared energy
   - How to split the incentives for the shared energy?
   - How to link the incentive to the territorial context (local token economy)?

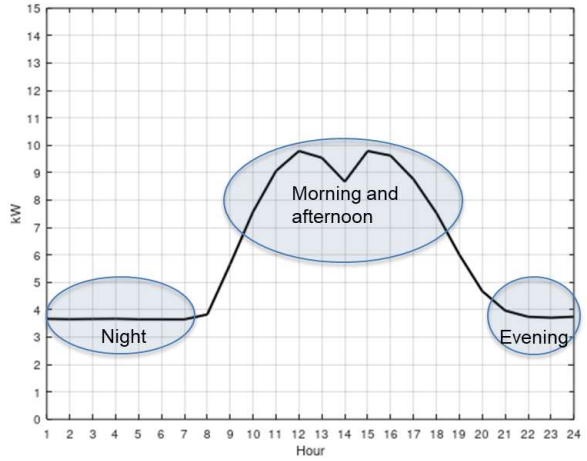
A. Energy data analysis / electrical load curves

Average hourly load curve during the day in <u>household</u>





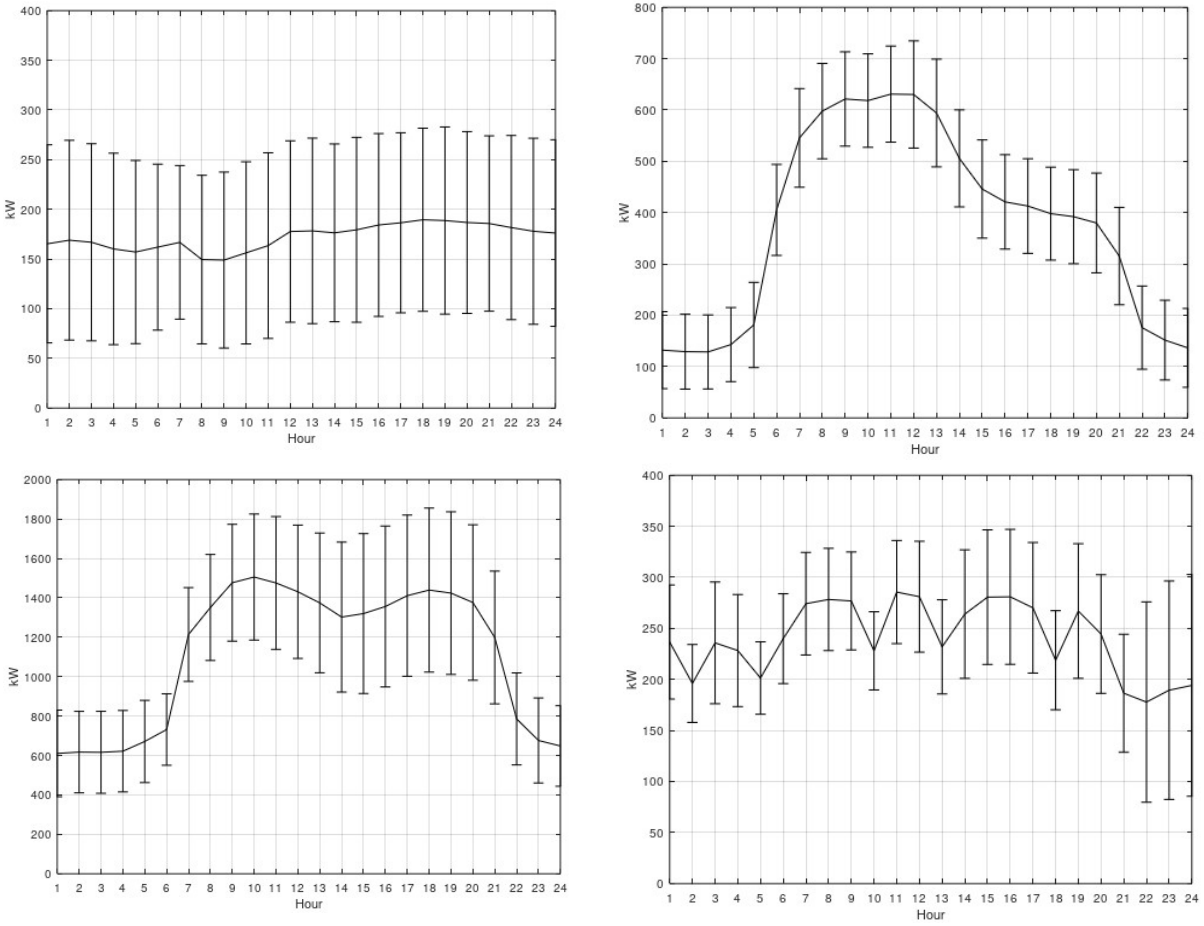
Average hourly load curve during the day in <u>office building</u>



Electricity consumption during weekends depends on the type of activity (e.g. school, office, shopping centre)

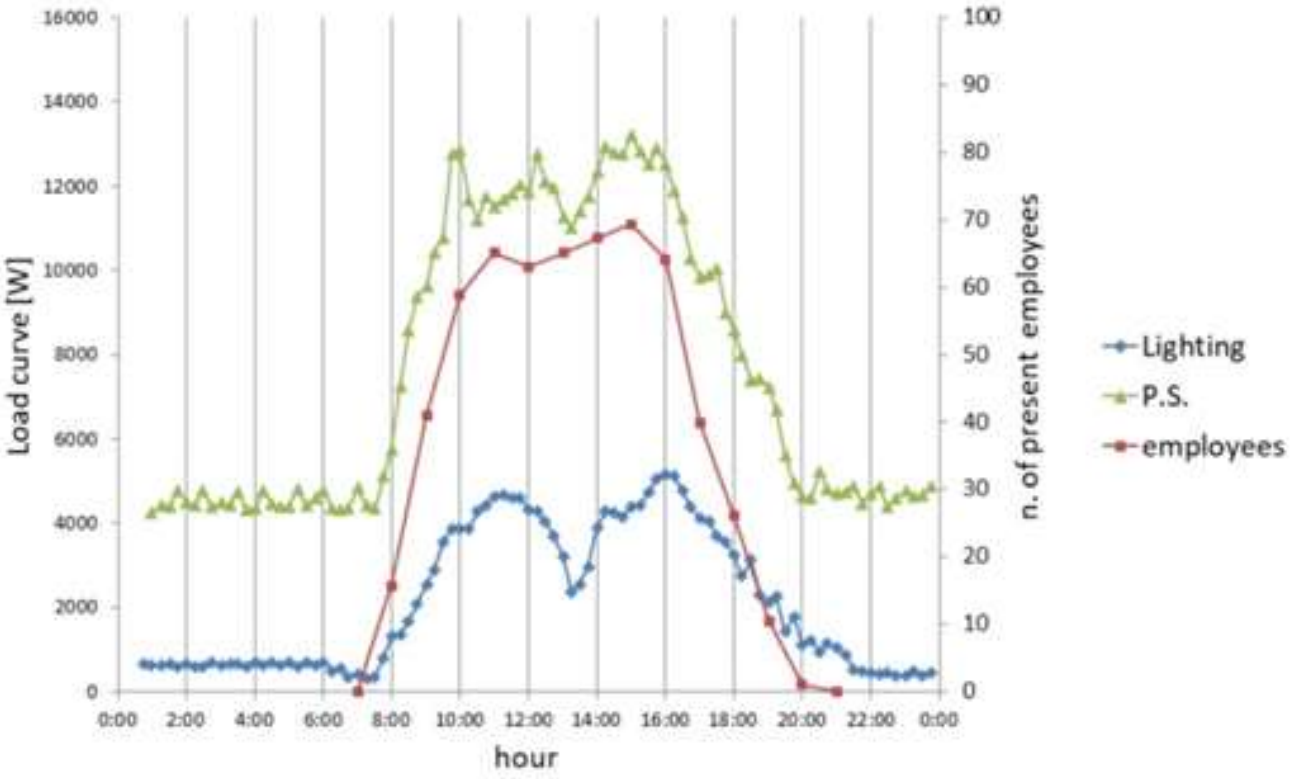
Electrical load curves in industry

Average hourly load curve during the working day



The direct self-consumption in industry depends on the hourly load profile of the specific company

Energy data analysis and context data



E.g. occupation of the workplace, etc.

Energy data analysis by clustering

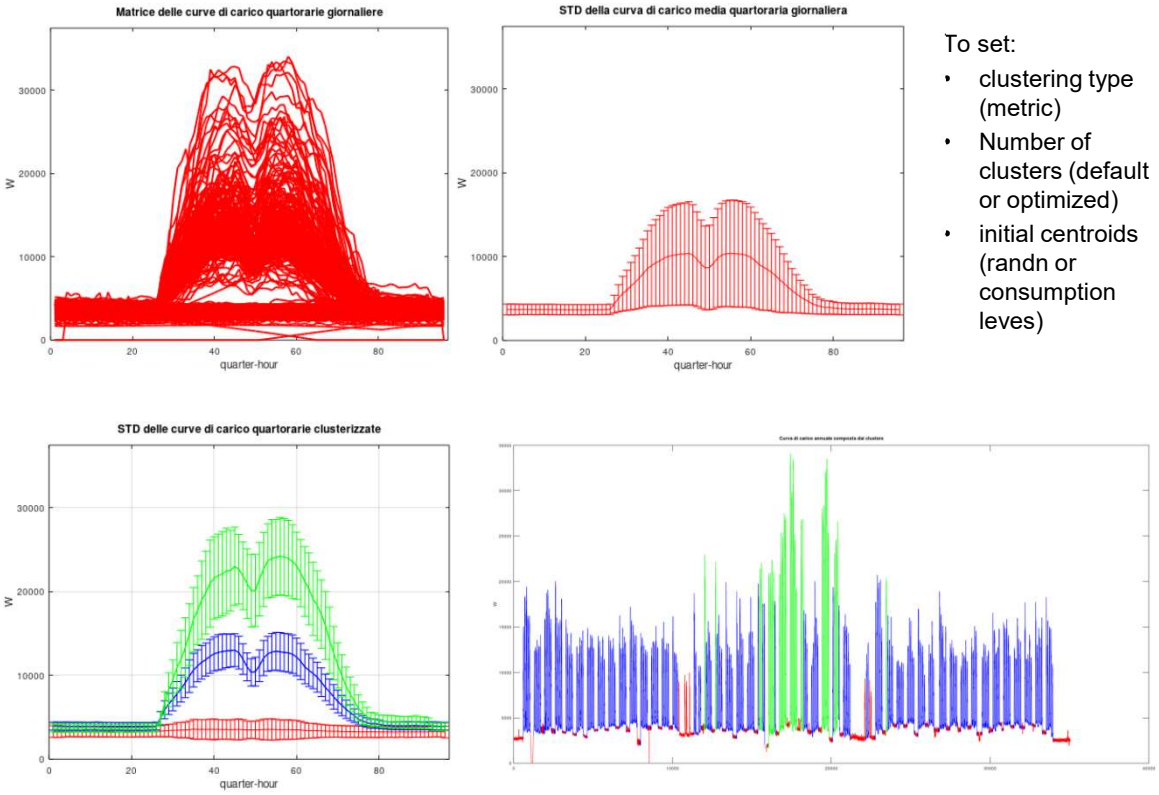
Literature:

Methods for electrical load pattern grouping.

Method
Adaptive vector quantization (AVQ)
Entropy-based (Renyi)
Follow-the-leader (FDL)
Fuzzy logic (FL)
Fuzzy and ARIMA
Fuzzy k-means (FKM)
Hierarchical clustering (HC)
Iterative refinement clustering (IRC)
k-means (KM)
Min–max neuro-fuzzy (MMNF)
Multivariate statistics (MANOVA)
Probabilistic neural network (PNN)
Self organizing map (SOM)
Support vector clustering (SVC)
Weighted evidence accumulation clustering (WEACS)

G. Chicco, Overview and performance assessment of the clustering methods for electrical load pattern grouping, Energy 42 (2012) 68-80

Example:

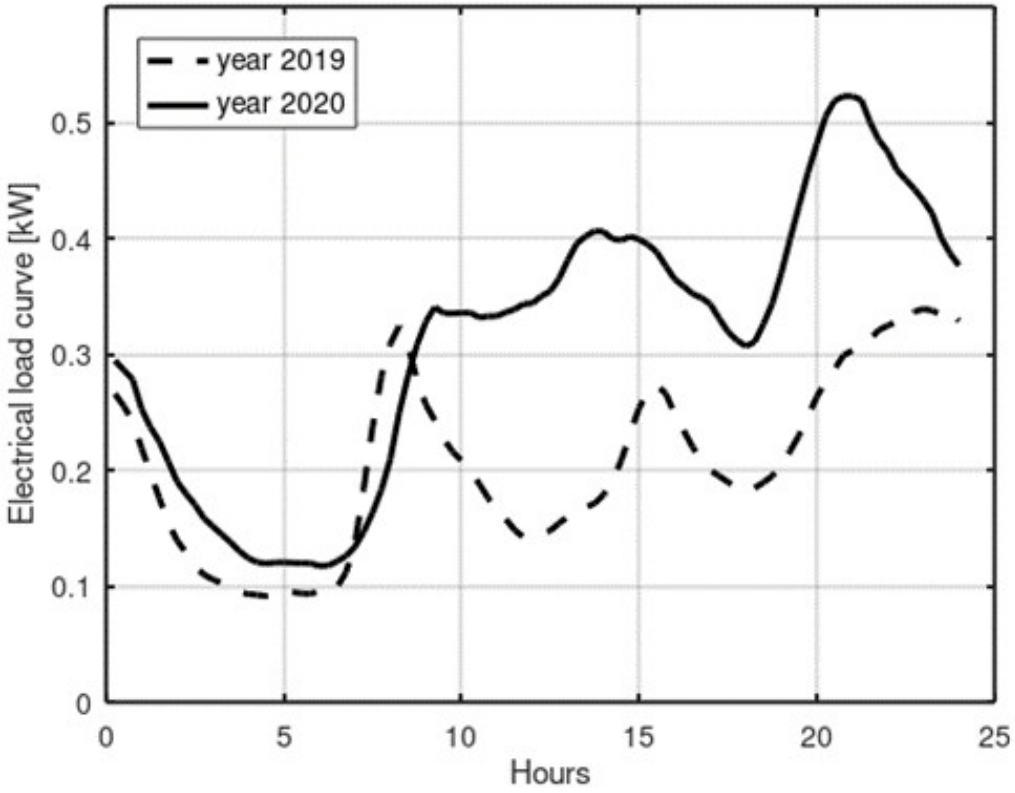


To set:

- clustering type (metric)
- Number of clusters (default or optimized)
- initial centroids (randn or consumption leves)

ENEA CROSS-TEC: clustering of quarter-hour electrical load curve during a day in office building (75 offices) over a whole year of data

Advanced scenarios on energy consumption



Variation of electrical load curves in household during working days in the lockdown period (March-May 2020)

Branchetti S., Petrovich C., Nigliaccio G., Paolucci F., The Lockdown and Smart Working Effects on Electric Energy Consumption: the Analysis for a Group of Employees https://doi.org/10.18280/ti-ijes.652-423

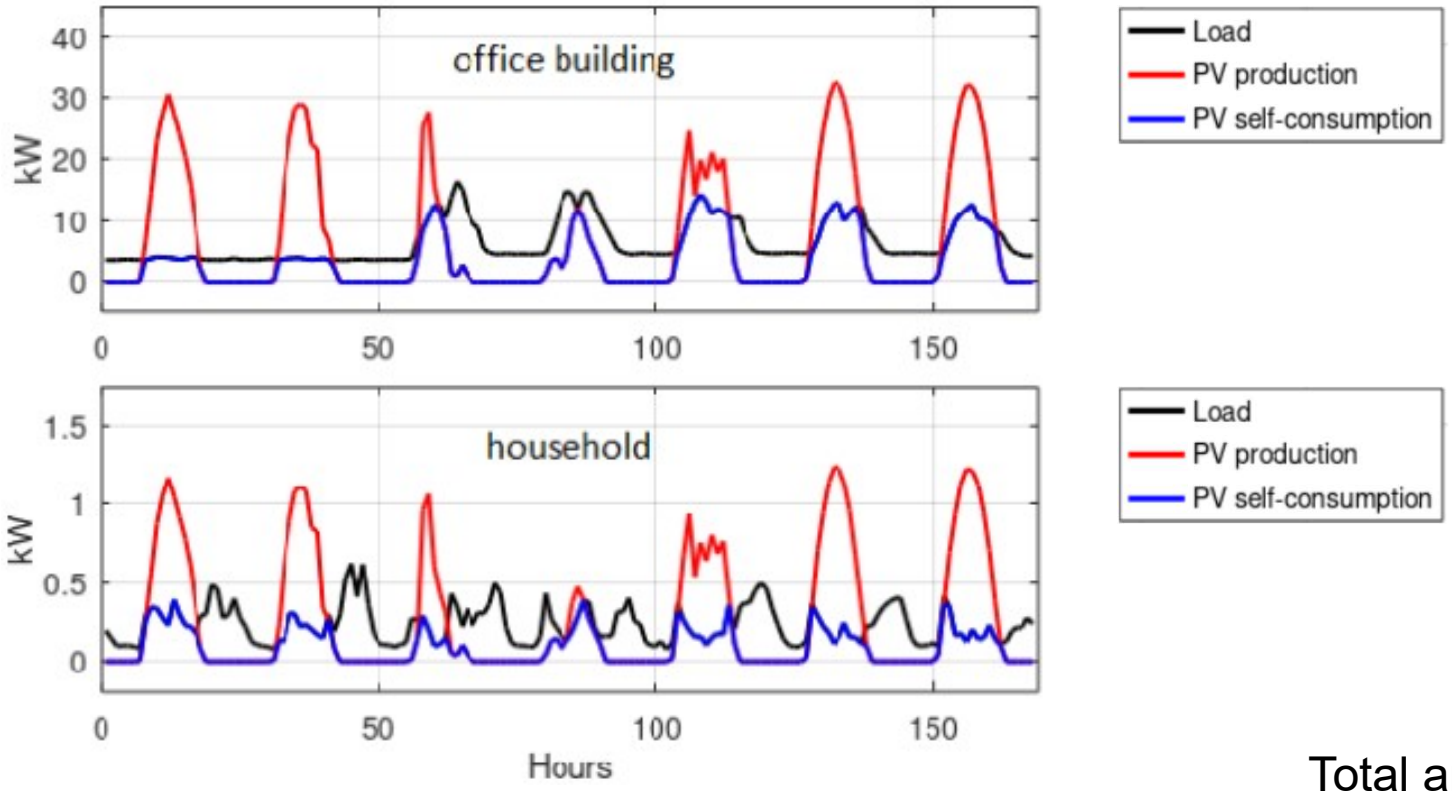
B. Modelling of energy communities

- Electricity consumption in different kinds of users:
  - Residential
  - Tertiary
  - Industrial

- Simplified energy models to calculate production, storage, self-consumption and shared energy

Component	Model
Photovoltaic production	$P_{gen} = P_{stc} \frac{I_t}{G_{stc}} \eta_{rel}(I_t, T_m)$
Energy storage	$SOC(t_i) = SOC(t_{i-1}) + \frac{P_{bat} \cdot \Delta t}{C_{bat}}$
Etc.	

Production and consumption of renewable energy

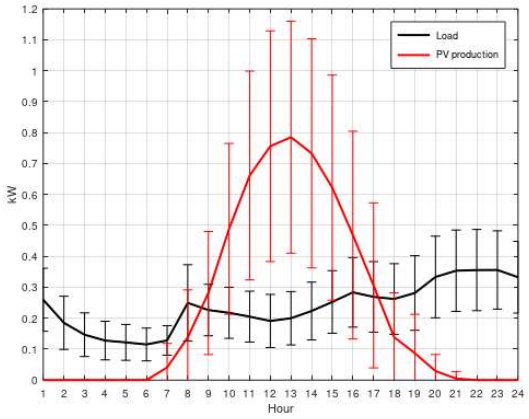


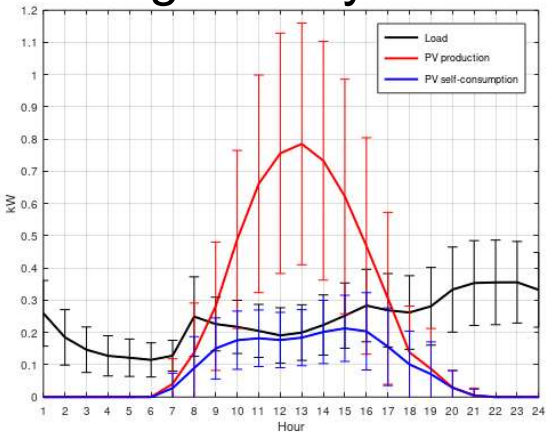
$$Absolute\ self consumption(t) = min\{Load(t), P_{gen}(t)\}$$

Total annual production equal to total annual consumption but ...

Electricity consumption and PV production

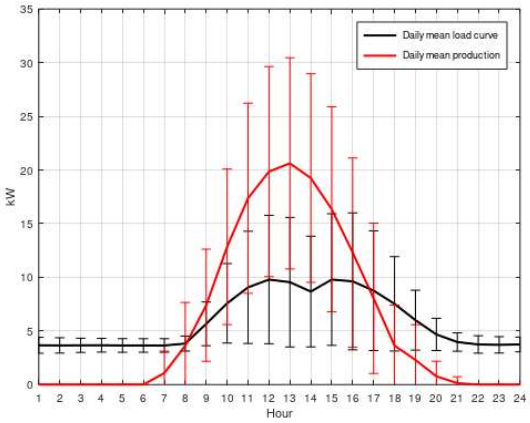
Average hourly profiles during the day over one year of data in household

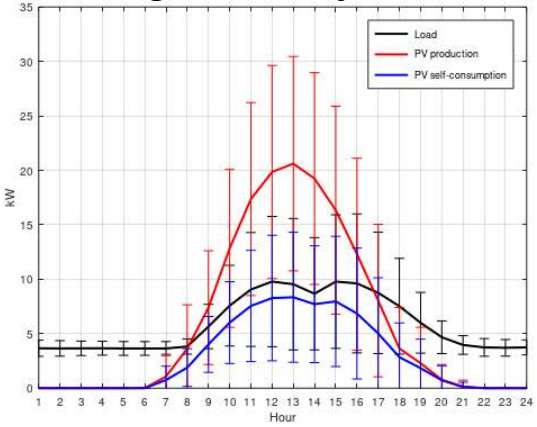




Only 30-35 % of photovoltaic production will be self-consumed directly

Average hourly profiles during the day over one year of data in office



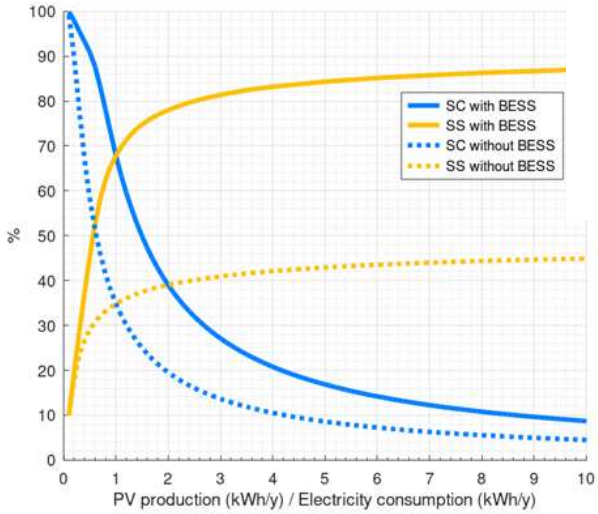


A greater share (e.g. 50%) of photovoltaic production will be self-consumed directly

Note: Self-consumption values always depend on the specific application

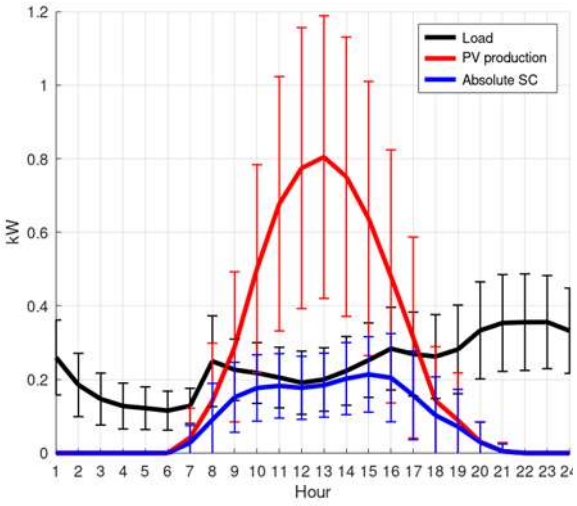
The energy storage increases performance

Average hourly profiles during the day over one year of data in household without and with BESS (Battery Energy Storage Systems)

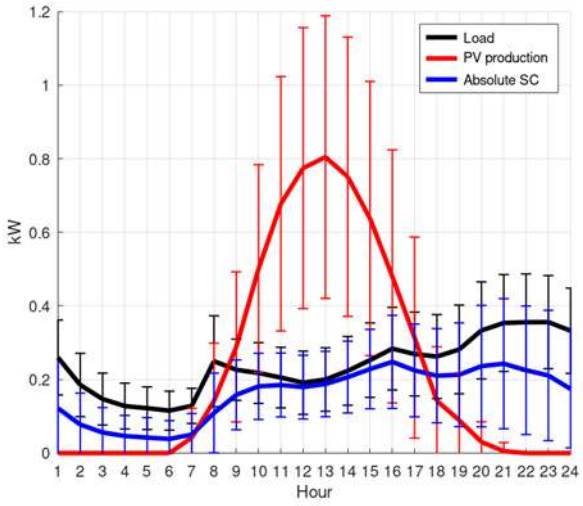


Branchetti S., Petrovich C., Naldi R., Paponetti I.M., Nigliaccio G., Paolucci F., PV Self-Consumption and Self-Sufficiency for Household and Office Users: the Lockdown Effects During the COVID-19 Pandemic https://doi.org/10.18280/ijsdp.170231

without BESS



with BESS



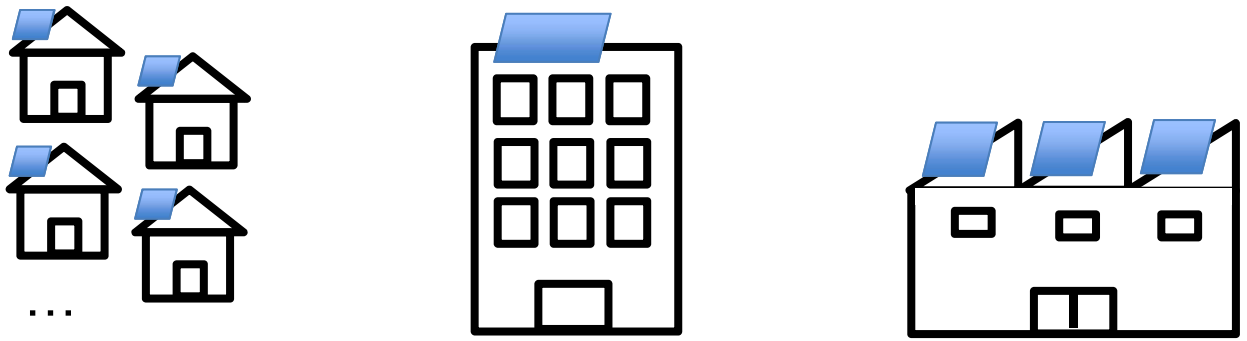
$$SelfConsumption\ rate = \frac{\int_{t=t_1}^{t_2} A(t)dt}{\int_{t=t_1}^{t_2} P_{gen}(t)dt}$$

$$SelfSufficiency\ rate = \frac{\int_{t=t_1}^{t_2} A(t)dt}{\int_{t=t_1}^{t_2} Load(t)dt}$$

Both rates should be evaluated

The Energy Community increases performance

Example of prosumers involved for a REC of about 287.5 kWp

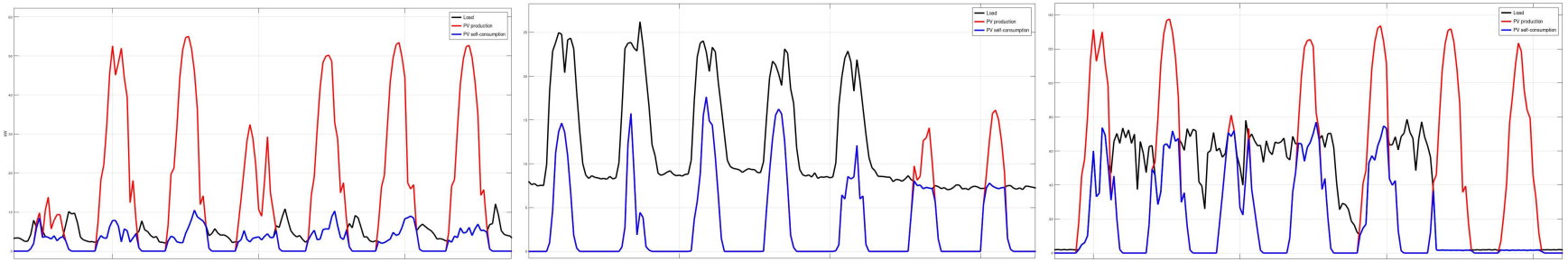


Kind of user	Residential	Tertiary (e.g. office/school)	Industry (SME)
Prosumers	25	1	1
Total consumption	52000 kWh/year	105000 kWh/year	224000 kWh/year
Available space	600 m^2	200 m^2	1500 m^2
Rated power	75 kWp	25 kWp	187.5 kWp
Production	95000 kWh/year	32000 kWh/year	237000 kWh/year
Direct self-consumption	20000 kWh/year	27000 kWh/year	80000 kWh/year

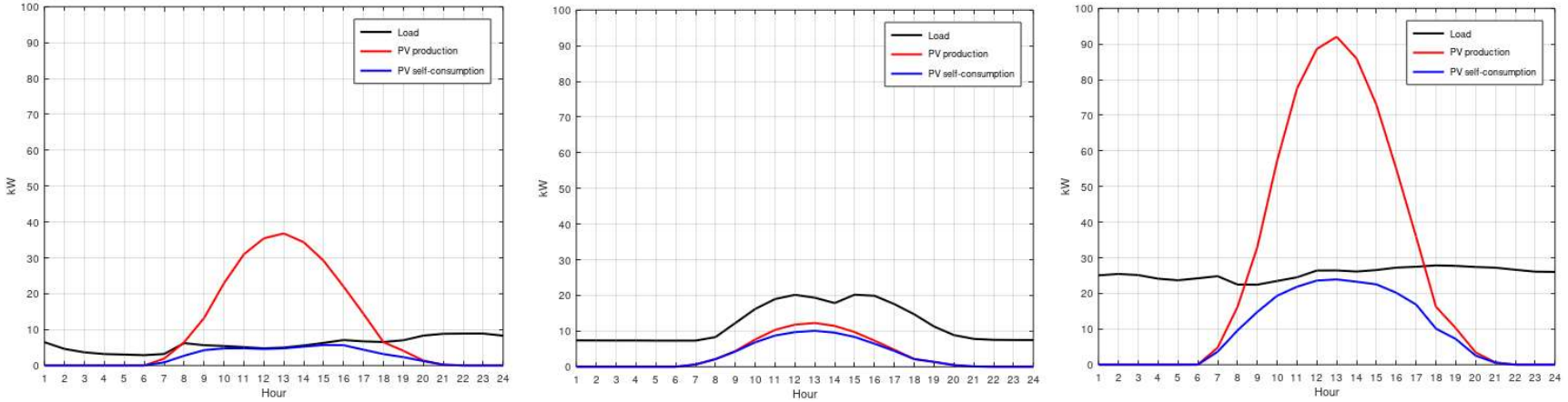
The Energy Community increases performance

Real hourly load curve during the day for a single week

Residential	Tertiary (e.g. office/school)	Industry (SME)



Average hourly load curve during the day elaborated over a whole year

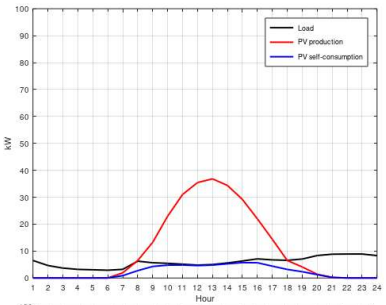


Self-consumption	21%	Self-consumption	87%	Self-consumption	34%
Self-sufficiency	39%	Self-sufficiency	26%	Self-sufficiency	36%

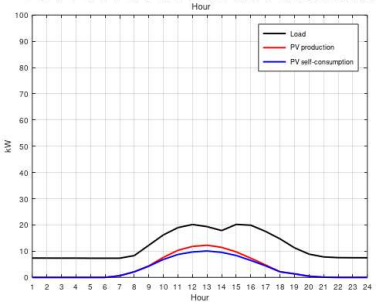
The Energy Community increases performance

Single «prosumer»

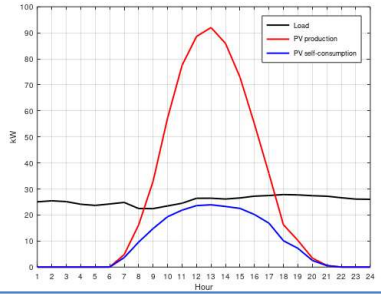
Residential (25)



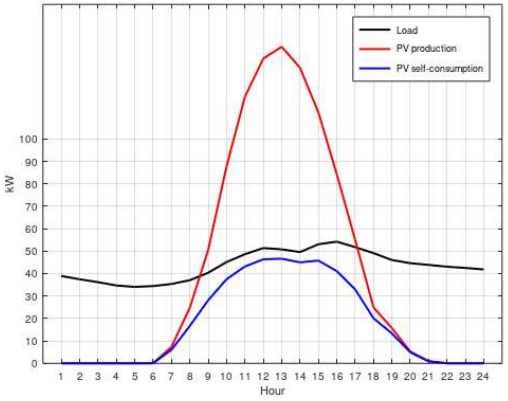
Tertiary (1)



Industry (1)

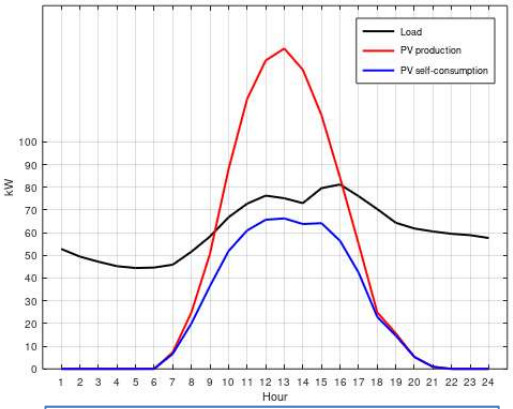


Self-consumption
127.000 kWh/year



Self-consumption
156.000 kWh/year
that is +23%
(in the example)

Adding «passive» users
(further 25 residential and 1 tertiary)

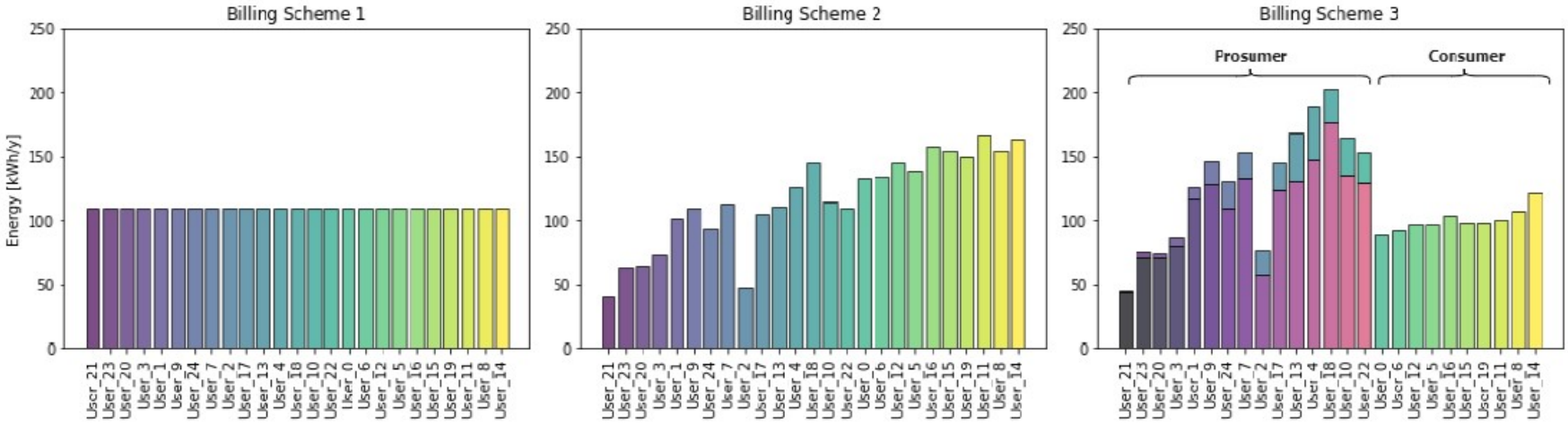


Self-consumption
211.000 kWh/year
that is +66%
(in the example)

C. Billing schemes for the shared energy

Different schemes can be use to split the reward for the shared energy among the members of the Energy Community and the chosen scheme can be included within the EC agreement.

We have defined a set of scenarios based on the energy behaviours should be promoted.



POLITO models for ENEA (GECO project)

Shared energy model based on blockchain

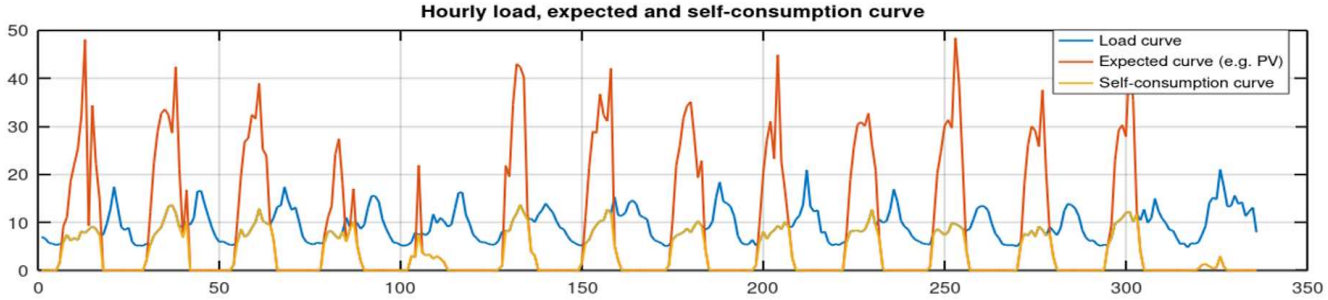
1. to maximize the shared energy

If the community has photovoltaic systems, more the produced energy is made available and it is consumed within the community, more the community will be rewarded.

The aim is to increase the energy virtuosity of users day by day and to reward virtuous behavior with community tokens.

a) counting of "Number of tokens assigned to the community thanks to the percentage of self-consumption"
b) distribution of tokens among users, based on their consumption hour by hour during the day

Further ENEA models



Elaboration on Gessa and Branchetti document for «Ricerca di Sistema»

Peak reduction model based on blockchain

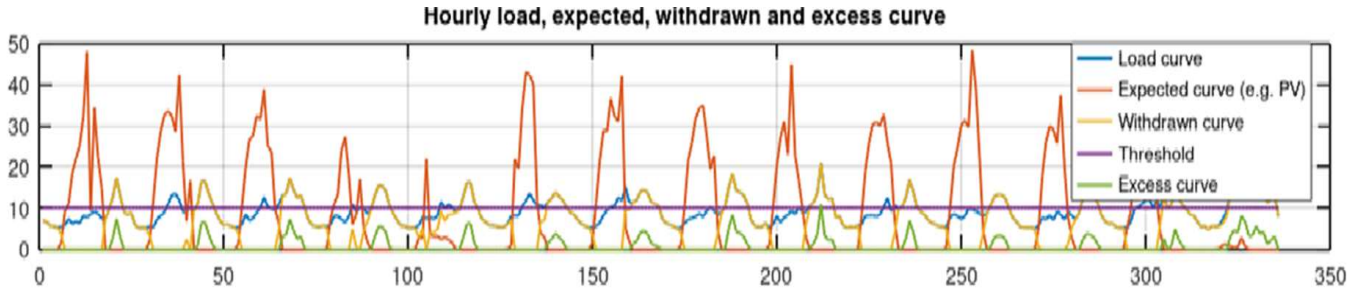
2. to limit the load peaks in energy consumption

A consumption load threshold not to be exceeded is set, and the community is rewarded when it manages to stay below this threshold.

The aim is to reward virtuous behavior in not creating load peaks.

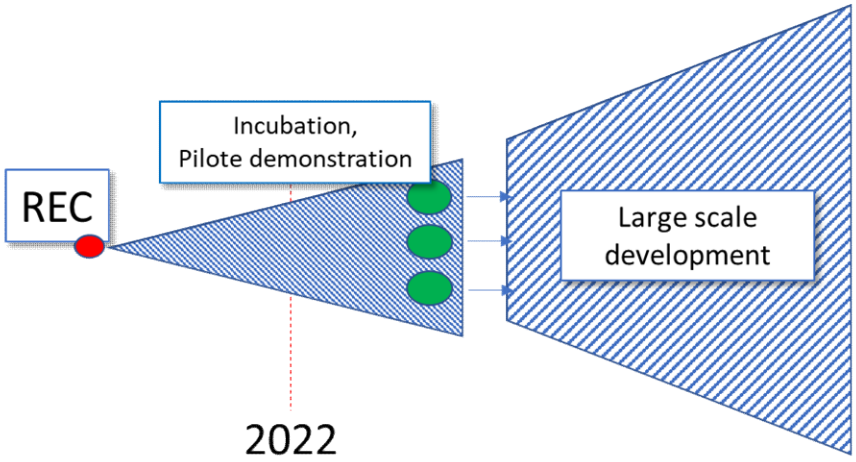
a) counting of "Maximum number of assigned tokens if the threshold is never exceeded"
b) Decreasing of assigned tokens for each peak and redistribution of remaining ones according to consumption

Further ENEA models



Elaboration on Gessa and Branchetti document for «Ricerca di Sistema»

The vision of ENEA for the Energy Communities

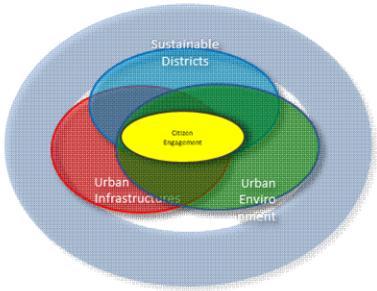


Information

Dissemination

New policies

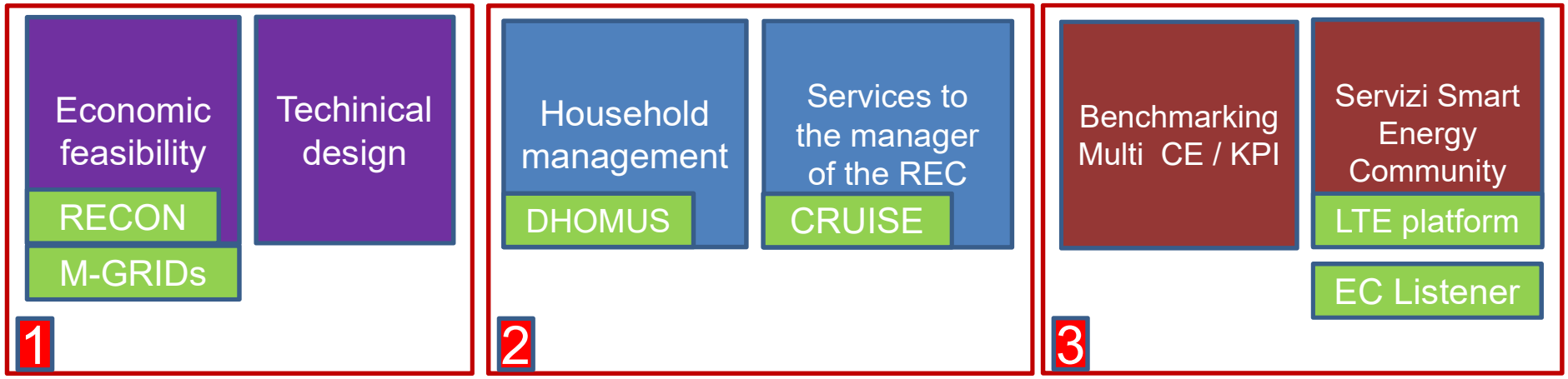
Juridical
models



Enabling
technologies

Business
Models

Life cycle of an energy community and ENEA tools



The life cycle of an Energy Community includes:

- a phase of economic feasibility analysis and technical design, 1
- an implementation and management phase, 2
- a phase of enhancement and networking with other realities. 3

ENEA is developing a set of tools and services to support the different phases of this life cycle for the Local Energy Community.

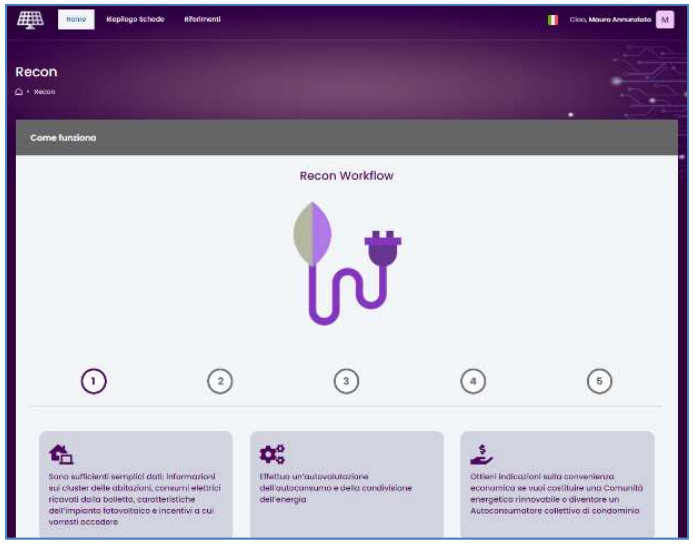
RECON: Energy Community Simulator

- Analysis and reconstruction of community consumption profiles
- Project feasibility and calculation of investment / management costs
- Estimate of photovoltaic production profiles
- Analysis of collective self-consumption and shared energy profiles
- Analysis of economic scenario (investment, eco-bonus, superbonus, shared energy)
- Cash flow analysis, payback, ROI, etc ...

https://recon.smartenergycommunity.enea.it/

Partners
- Polytechnic of Turin (Energy Center)
- Polytechnic of Milan (Energy Strategies)
- LUISS (LabGov)
- JRC (PVGis)

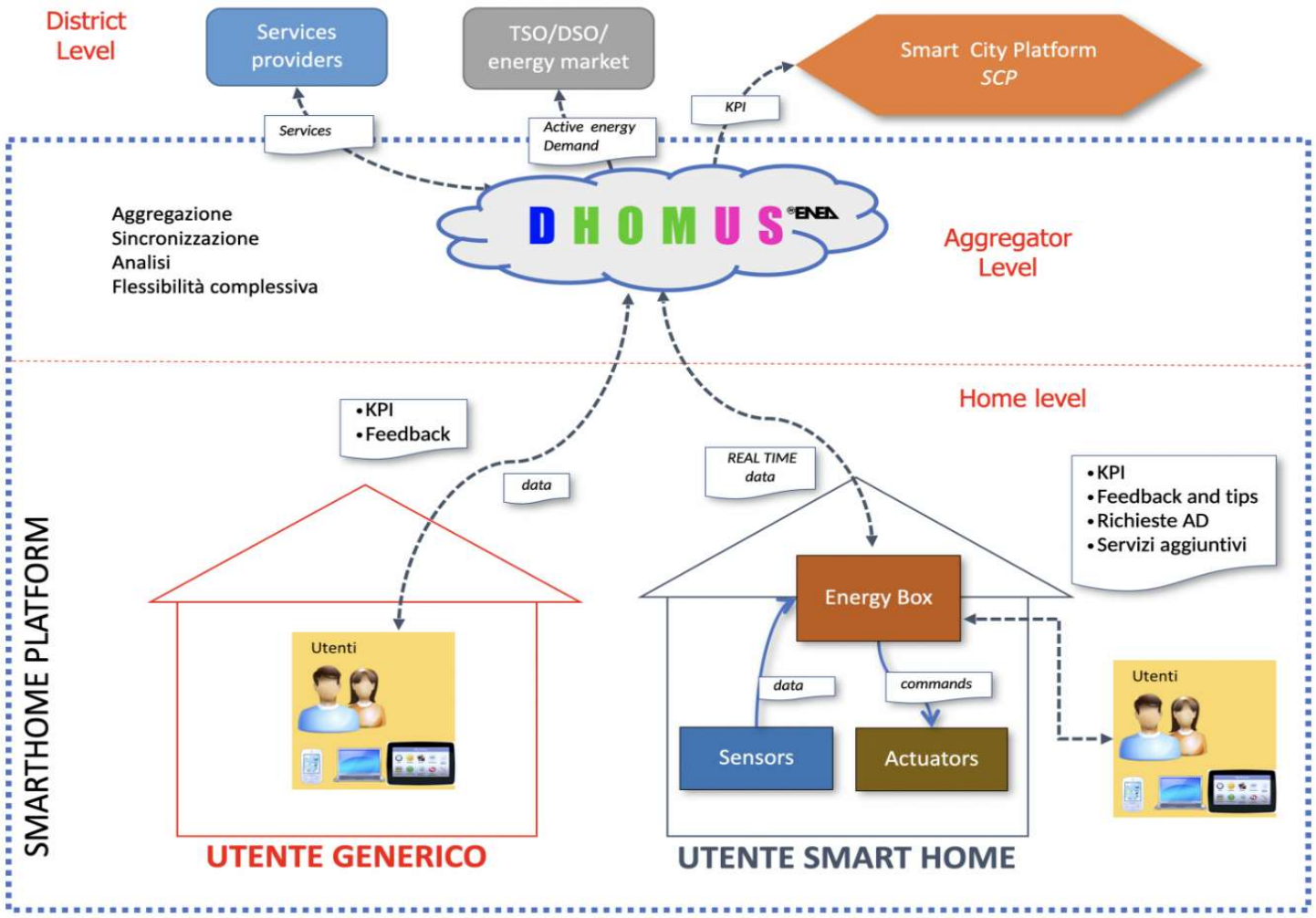
- Collaboration with GSE



RECON: Energy Community Simulator

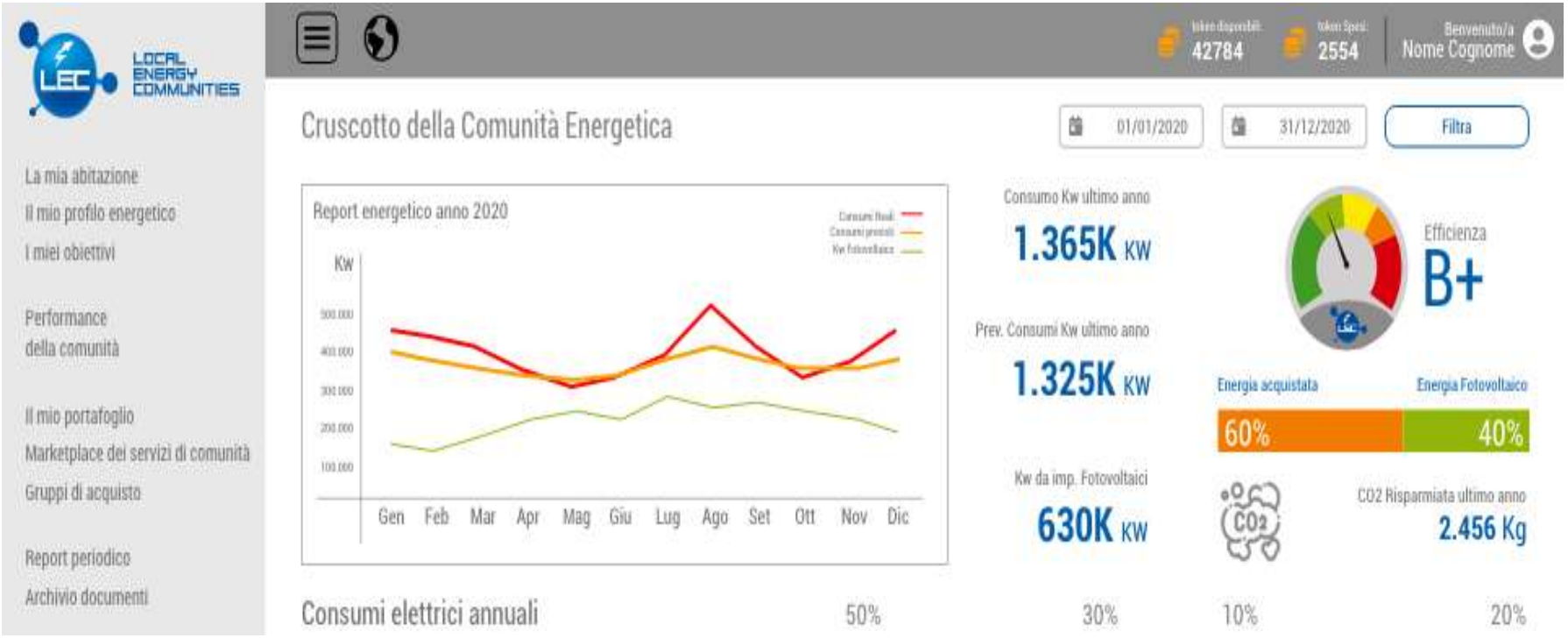
Main outputs:
- Cash Flows
- Estimated production and consumption
- KPI

DHOMUS: Support for homes



DHOMUS: Support for homes

CRUISE: dashboard for the management of energy communities



The mathematical **models** for data analysis allow us to understand different aspects relating to the Energy Community:

- the **optimal size** based on the actual consumption of the members;
- the actions to increase the shared energy;
- the **billing schemes** to share the benefits according to the member agreement underlying the Energy Community.

Towards an environmentally neutral community: sharing economy in the EC

The evolution of the energy community towards the sharing of **goods and services** in a **Smart Energy Community** that:

- supports a local economy that **recovers value** by putting unused assets, knowledge and spaces back into circulation in the community (**sharing economy**);
- realizes the sharing community through a local economy based on "**tokens**" that are exchanged for goods and services;
- allows the use of ***local* tokens** for the purchase of other goods or services.

Samuele Branchetti
samuele.branchetti@enea.it