



M. Repetto
"Recoupled. . ."

Introduction

Recoupled
procedure

KPI

Case studies

Conclusions

Recoupled

A Simulation Tool for Renewable Energy Communities coupling Electric and Thermal Energies

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Resources, Environment,
Energy and Networks



April 6, 2022



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Introduction

Recoupled
procedure

KPI

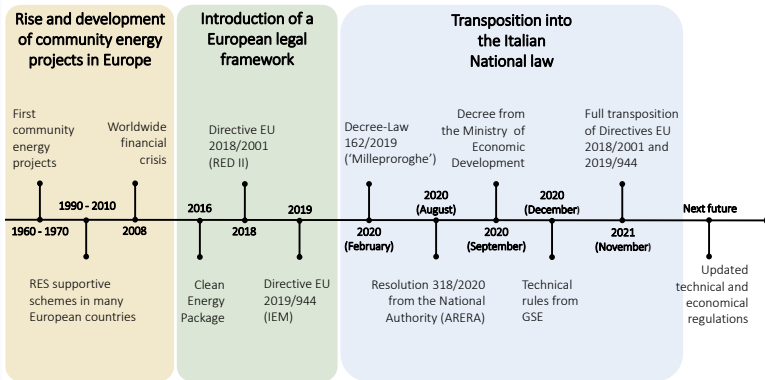
Case studies

Conclusions

- 1 Introduction
- 2 Recoupled procedure
- 3 KPI
- 4 Case studies
- 5 Conclusions



RECs evolution over time^{a, b}



^a Hewitt, R. J. et al., (2019), Social innovation in community energy in Europe: a review of the evidence. *Frontiers in Energy Research*, Volume 7.

^b Energy & Strategy Group, (2020), *Electricity Market Report*. Politecnico di Milano. (In Italian).

M. Repetto
"Recoupled. . ."

Introduction

Recoupled procedure

KPI

Case studies

Conclusions



M. Repetto
"Recoupled. . ."

Introduction

Recoupled
procedure

KPI

Case studies

Conclusions

Environmental

- promote the use of RES
- reduce CO₂ and local pollutants emissions

Energy-related

- increase efficiency
- raise awareness about energy use

Social

- fight energy poverty
- energy democracy
- low-income families

- electricity sharing is **virtual**, through the public distribution grid
- RECs should not pursue financial profits directly, however they can conduct economical activities (e.g. take action in energy markets, . . .)



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Renewables in Cities 2021 Global Status Report



DRIVERS FOR RENEWABLES IN CITIES

Clean air
and a healthy
environment

Climate change
mitigation and
adaptation

Local economic
development



Energy justice and
democracy

Stable and secure
energy supply



Poverty alleviation
and improved
energy access

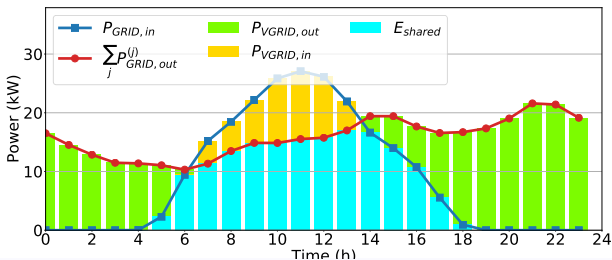
Reducing expenses
and managing costs



economic incentives on E_{shared}

- "is the minimum value, during each hour, between the total injections and total withdrawals from the users"

$$E_{shared}(t_h) = \min \left(P_{grid,in}(t_h)\Delta t; \sum_{j=1}^{N_j} P_{grid,out}^{(j)}(t_h)\Delta t \right), \forall h = 0, \dots, N_h$$





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"Recoupled. . ."

Introduction

Recoupled
procedure

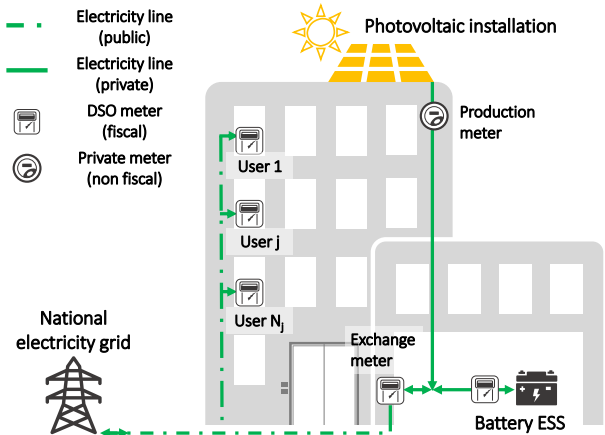
KPI

Case studies

Conclusions

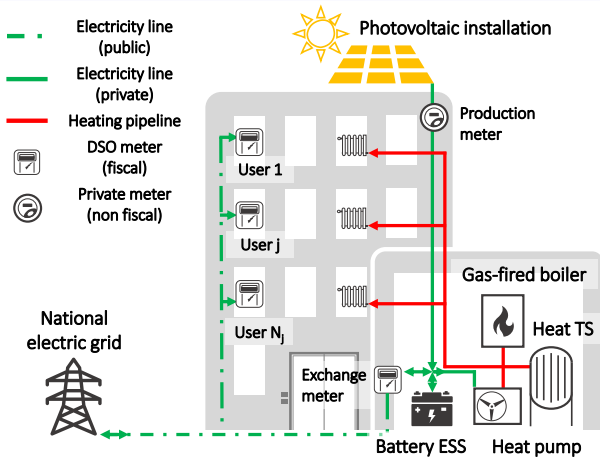
Collective Self Consumption

Electricity only





Electricity coupled with heating



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"Recoupled. . ."

Introduction

Recoupled procedure

KPI

Case studies

Conclusions



M. Repetto
"Recoupled..."

Introduction

Recoupled procedure

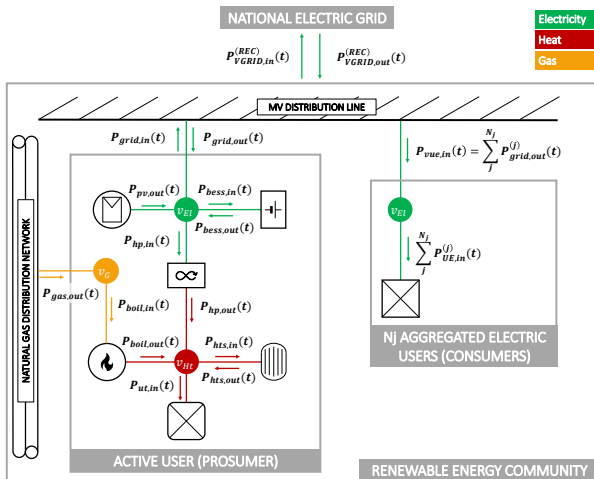
KPI

Case studies

Conclusions

Recoupled procedure

Multiple energy nodes





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Introduction

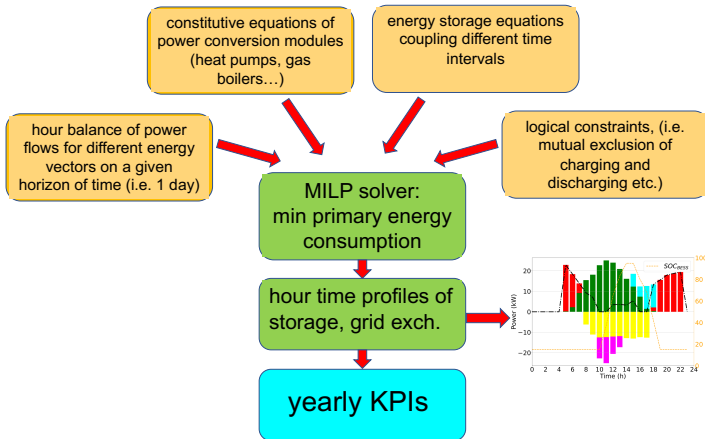
Recoupled
procedure

KPI

Case studies

Conclusions

Recoupled procedure





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Introduction

Recoupled
procedure

KPI

Case studies

Conclusions

Energy-related

- Self-Consumption, SC, i.e. self-consumed over total locally-produced energy (e.g. electricity):

$$SC_{el} = 100 - \frac{\sum_h P_{vgrid,in}^{(REC)}(t_h)\Delta t}{\sum_h P_{pv,out}(t_h)\Delta t} 100$$



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"Recoupled. . ."

Introduction

Recoupled
procedure

KPI

Case studies

Conclusions

Environmental

- Percentage reduction of yearly CO_2 emissions (Σ_{CO_2}) w.r.t. a base case scenario, Δ_{CO_2} :

$$\Delta_{\text{CO}_2} = \frac{\Sigma_{\text{CO}_2}^{(0)} - \Sigma_{\text{CO}_2}^{(REC)}}{\Sigma_{\text{CO}_2}^{(0)}} 100$$

- energy from external sources (e.g. electricity, gas from National grids) is multiplied by their emission factors;
- life-cycle emissions are considered the technologies (e.g. PV and battery ESS)
- in the base case (0), the whole electricity demand is supplied by the National grid, all heating demand by the gas-fired boiler



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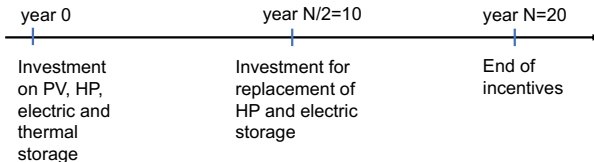
Introduction

Recoupled
procedure

KPI

Case studies

Conclusions



Economic

- CAPEX includes all technologies "added" in the REC configuration (PV, BESS, HP, HTS) with fiscal incentives
- OPEX includes O&M for the technologies, electricity and gas bills, taxes, REC's management
- Revenues account for shared energy incentive and injected energy are used to compute Percentage Cost Reduction (PCR) of bills



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"Recoupled. . ."

Introduction

Recoupled
procedure

KPI

Case studies

Conclusions

General assumptions

apt. block building
40 apartments, 8 floors 2800m²
heating and electric load simulated
roof area 400m²

parametric analysis

PV panel up to 0.15kW_p/m²
max heat pump size for peak
demand
battery and heat storage for daily use





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"Recoupled. . ."

Introduction

Recoupled
procedure

KPI

Case studies

Conclusions

Case studies (continued)

Design space

Unit	Size min	Size max	Step	
PV	30	60	10	kW _p
HP	0	180 ¹ , 120 ² , 90 ³	30 ¹ , 20 ² , 15 ³	kW _{th}
BESS	0	135	45	kWh _{el}
HTS	0	150	50	kWh _{th}

¹ North, ² Centre, ³ South

Environmental parameters, kgCO₂/kWh

National grid ¹	Gas-fired boiler ¹	PV ¹	BESS ²
0.2686	0.224	0.050	175

¹ In terms of energy produced/consumed ² Related to nominal capacity



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"Recoupled. . ."

Introduction

Recoupled
procedure

KPI

Case studies

Conclusions

Economic parameters

- investment and operational costs of REC components

Unit	CAPEX ¹		OPEX	
PV	810	€/kW _p	12.5	€/kW _p /year
HP	700	€/kW _{th}	28	€/kW _{th} /year
BESS	350	€/kWh _{el}	8.75	€/kWh _{el} /year
HTS	20	€/kWh _{th}	-	-

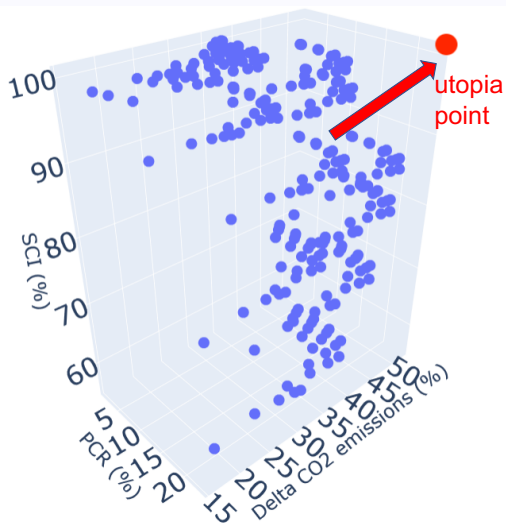
¹ Reduced by Ecobonus 50% for PV and BESS, 65% for HP and HTS

- energy prices

Natural gas (€/m ³)	Electricity (€/kWh)		
	Purchased	Injected	Shared
0.90	0.20	0.05	0.110



representation in Pareto space



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"Recoupled. . ."

Introduction

Recoupled
procedure

KPI

Case studies

Conclusions



M. Repetto
"Recoupled. . ."

Introduction

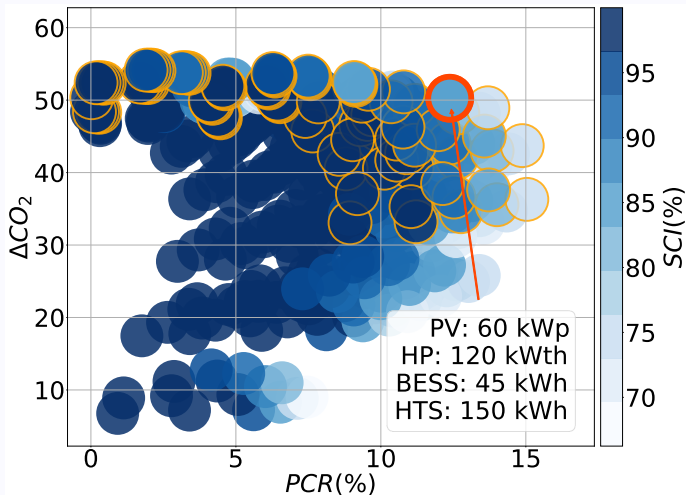
Recoupled
procedure

KPI

Case studies

Conclusions

North





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"Recoupled. . ."

Introduction

Recoupled
procedure

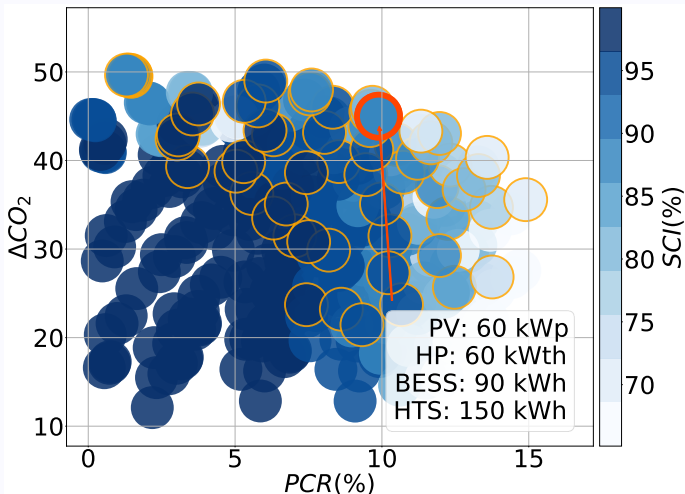
KPI

Case studies

Conclusions

Results (continued)

Centre





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"Recoupled..."

Introduction

Recoupled
procedure

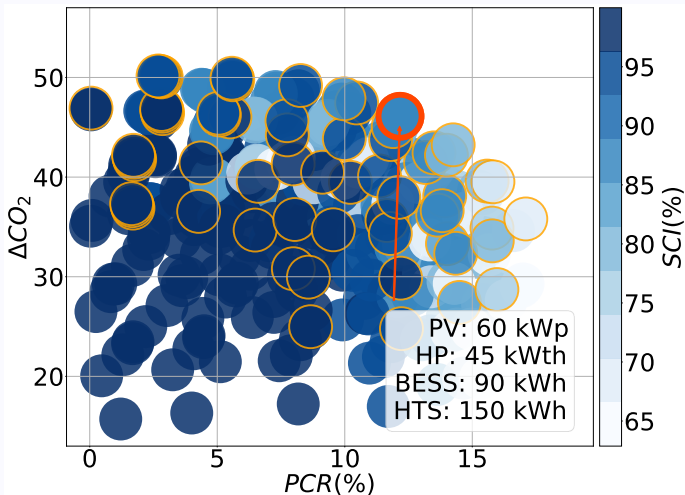
KPI

Case studies

Conclusions

Results (continued)

South





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"Recoupled..."

Introduction

Recoupled
procedure

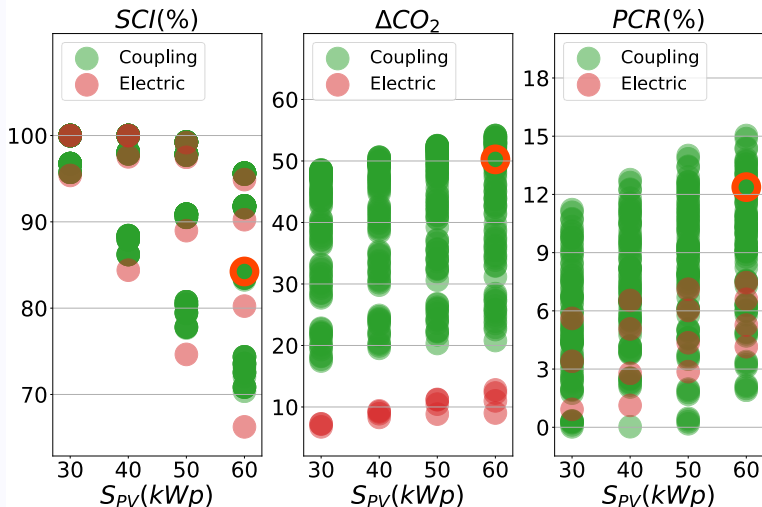
KPI

Case studies

Conclusions

Results (continued)

Comparison coupling vs electric, North case





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"Recoupled..."

Introduction

Recoupled
procedure

KPI

Case studies

Conclusions

highlights...

- different KPIs are generally in contrast \Rightarrow REC design is a multi-objective problem
- coupling of electric and heating demands in a collective SC context represents a valuable option for decarbonisation in residential contexts
- storage solution allow size reduction of conversion technologies (e.g. heat pump) by increasing their duty cycle
- simulation is of primary importance due to dynamic of energy prices...



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"Recoupled. . ."

Introduction

Recoupled
procedure

KPI

Case studies

Conclusions

. . . in renewable energy communities coupling is crucial...