Università degli Studi di Padova
Dipartimento di Ingegneria Industriale

Energy and Buildings

Smart Buildings in the Energy Transition

Smart buildings in the energy transition

energy flexibility

prosumers

demand response

thermal comfort

privacy/cyber security/annoyance

efficiency

renewable energy

energy communities

distributed generation

Content

Multi-source energy systems for buildings
Prosumers
Energy flexibility of buildings
Energy communities
Urban-scale analysis of buildings

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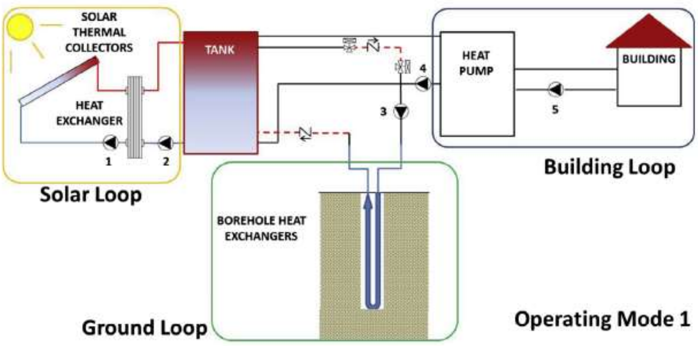
Multi-source Energy Systems for buildings

Solar assisted ground source heat pumps in cold climates (Emmi et al, 2015)

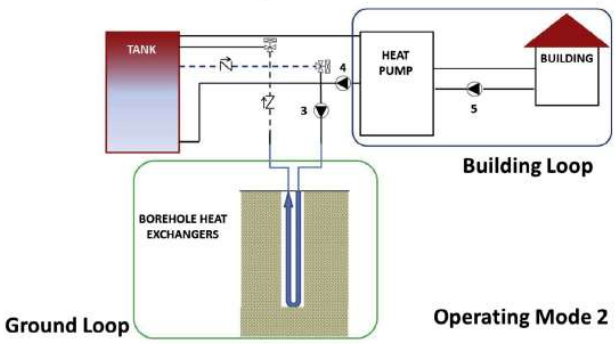


(a)

Smart Buildings in the Energy Transition

Multi-source Energy Systems for buildings

Solar assisted ground source heat pumps in cold climates (Emmi et al, 2015)



(b)

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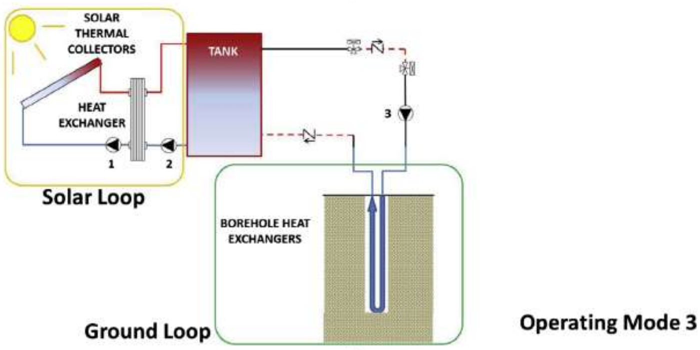
Multi-source Energy Systems for buildings

Solar assisted ground source heat pumps in cold climates (Emmi et al, 2015)



(c)

Smart Buildings in the Energy Transition

Multi-source Energy Systems for buildings

Solar assisted ground source heat pumps in cold climates (Emmi et al, 2015)

- Building load profiles are usually **heating dominated** in cold climates, but when common ground source heat pump systems are used only for heating, their performance decreases due to an unbalanced ground load: the **seasonal energy performance of the heat pump decreased by about 10% at each of the locations over the ten year period**.
- **Solar thermal collectors** can help to ensure that systems installed in cold zones perform more efficiently: the total borehole length was unmodified and the **seasonal energy efficiency was constant over time**. The ratio between the heat collected by the solar thermal collectors and that rejected to the ground ranged between 80% and 95% in all the configurations analyzed.

Multi-source Energy Systems for buildings

Cheap GSHPs

GEO 4 CIVHIC

Multi-source Energy Systems for buildings

Solar assisted ground source heat pumps in different climates (Emmi et al, 2020)

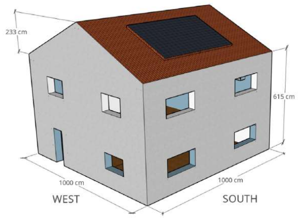
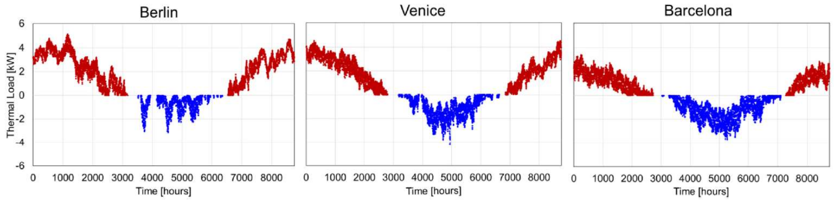


Fig. 2. Sketch of the building envelope.

Table 2
Thermal properties of the building envelope for the case study.

Wall Type	Transmittance [W/(m²K)]
Slab Floor G	0.345
External Wall	0.348
Internal Wall	2.175
Slab Floor G-F	1.043
Slab Floor F-R	0.343
Roof	0.338

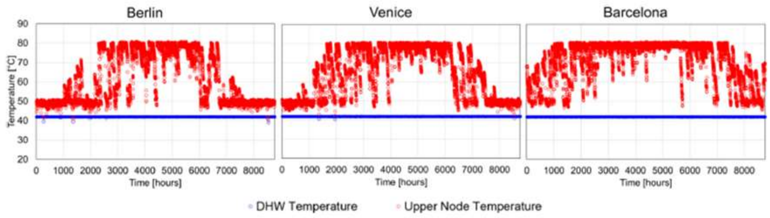


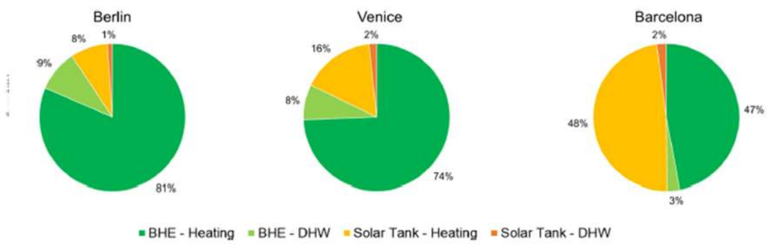
Multi-source Energy Systems for buildings

Solar assisted GSHP in different climates (Emmi et al, 2020)

WITH

SOLAR COLLECTORS

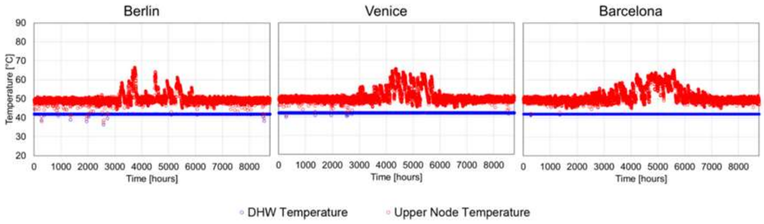


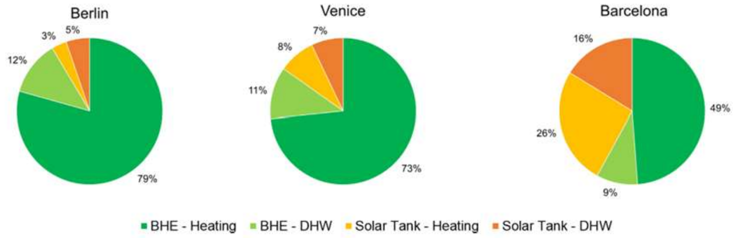


Multi-source Energy Systems for buildings

Solar assisted GSHP in different climates (Emmi et al, 2020)

WITH PVT





Prosumers

What if the renewable production exceeds the needs of the single building?

PROSUMER

It is a player in the energy system that is able both to consume and produce energy.

Example: a building owner with rooftop PV system that supplies electricity to the power distribution grid.

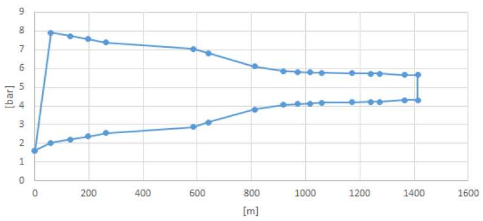
SELF-CONSUMPTION

The use of self-produced electricity aimed at reducing the purchase of electricity from other producers.

Note: There is not only private local (on-site) self-consumption, where only one actor aims to consume electricity in one place. There are other forms of self-consumption such as collective and virtual self-consumption.

Prosumers

Opportunities and challenges for district heating networks



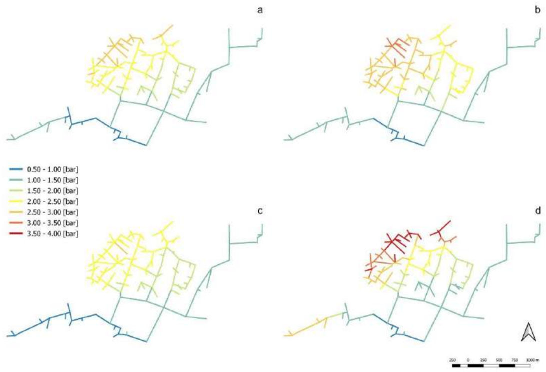


Figura 39. *Gradienti di perdite di perdite di carico per le 4 simulazioni (a=ED, b=RND, c=VIC, d=LON).*

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Prosumers

Opportunities and challenges for district heating networks

[Source:
Ben Hassine & Eicker, 2014]

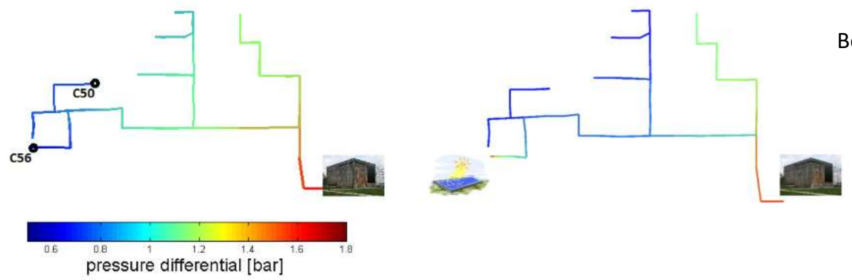

Fig. 5 The calculated pipe differential pressure: (left) without integration, (right) with integration in node 56

Prosumers

Opportunities and challenges for district heating networks

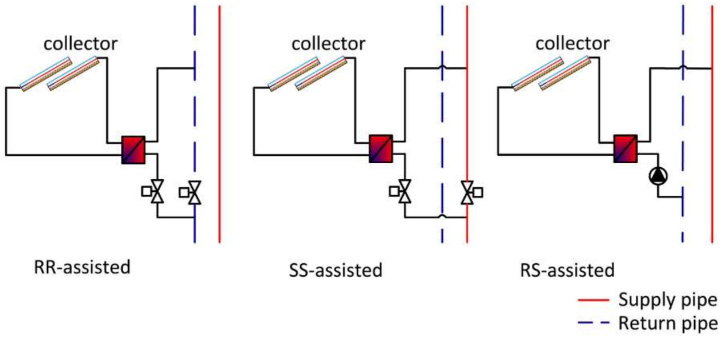

Fig. 10. Solar thermal supply scenarios.

[Source:
Ben Hassine & Eicker, 2013]

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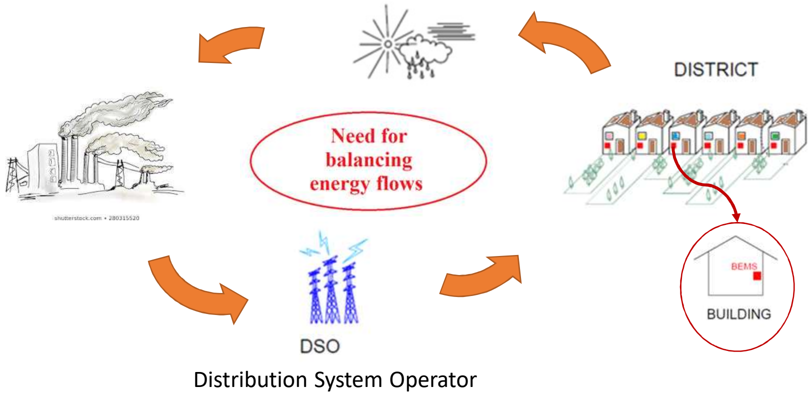
Prosumers

Opportunities and challenges for district heating networks

Opportunities	Problems
Sources of heat in the urban environment (data centers, supermarkets, LT industrial waste heat, waste water etc)	**Contemporaneity** between heat demand and heat availability → need for diurnal or seasonal storage
Development of **low temperature DHC network concepts** (4GDH, 5GDH)	**Technical constraints** (velocities, pressure difference)
Incentives for renewable production in the heating sector (Certificati Bianchi)	**Electrical expenditure** for heat injection (pumping)

Buildings as parts of the energy system



Energy flexibility of buildings

Definition of the energy flexibility of buildings

"…ability to manage its demand and generation according to local climate conditions, user needs and grid requirements" Jensen et al, 2017 (orking group IEA EBC Annex 67)

Definition of the smart readiness of buildings

"…ability in (i) adapting to user needs and energy environment; (ii) operating more efficiently and (iii) interacting with the energy system and with the district infrastructure in the context of demand response programs."

EPBD 2018/844

Energy flexibility of buildings

Demand Side Management (DSM)

"…the planning and implementation of those electric utility activities designed to influence customer uses of electricity in ways that will produce desired changes in the utility's load shape." (Gellings, 1985)

Demand Response

Among the possible DSM activity, active demand response (ADR) programs are defined as "*the changes in electric energy use implemented directly or indirectly by end users from their normal consumption patterns as function of certain signals*" (Arteconi et al., 2016).

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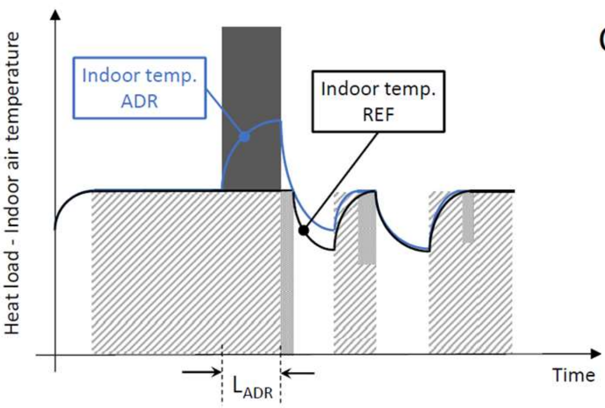
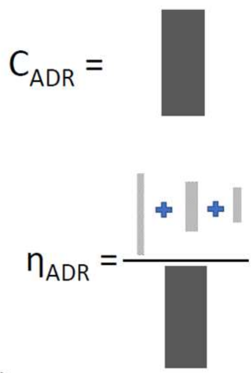
Energy flexibility of buildings

Energy flexibility indicators





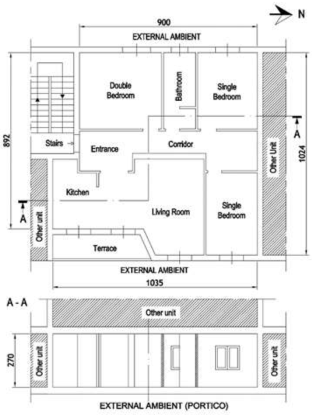
Surplus/deficit of energy during Active Demand Response (ADR) event

Amount of **energy effectively shifted in time** compared to the surplus/deficit

Energy flexibility of buildings

Evaluating ADR indicators on a case study building

General data	
V: Air-conditioned volume [m³]	202.5
S: Thermal loss area [m²]	151.1
Ratio S/V [m⁻¹]	0.746
Main dimensions of the building [m²]	
External walls	20.6 (West) 19.6 (East)
Floor & ceiling	94.4
Windows	4.5 (West) 12.4 (East)
Internal Walls	106.2
Dividing walls	57.9



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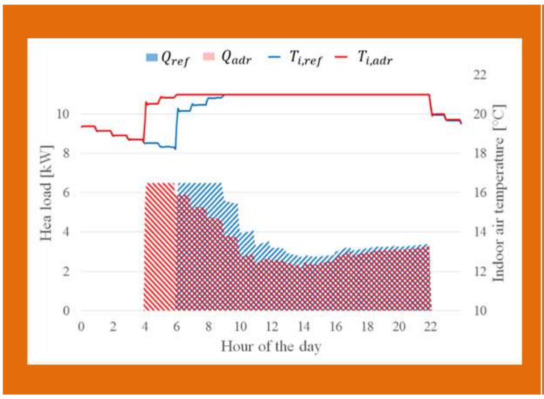
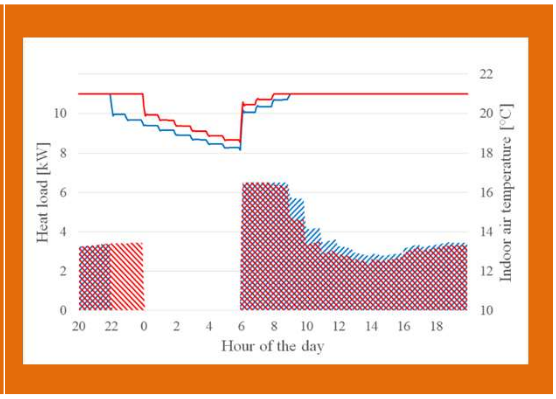
Energy flexibility of buildings

Example of ADR events in the heating season



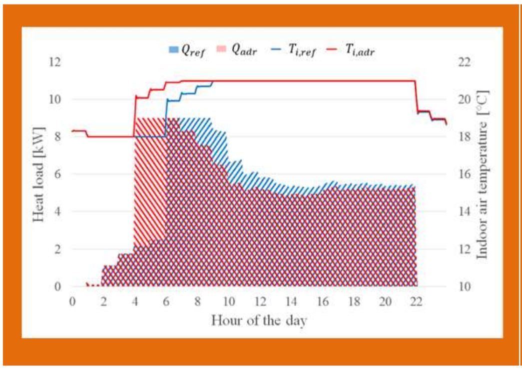


Additional heating from 4 to 6 in the morning

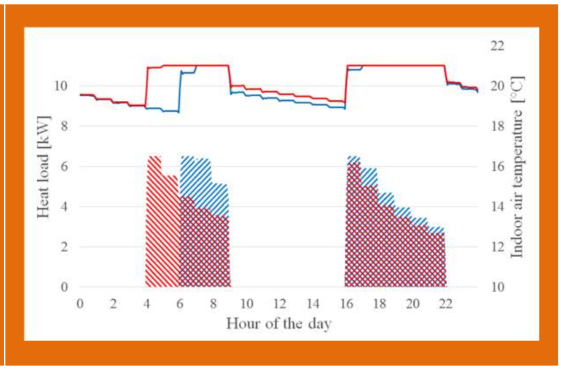
Additional heating from 10 to 12 in the evening

Energy flexibility of buildings

Example of ADR events in the heating season



Old family behaviour



Young family behaviour

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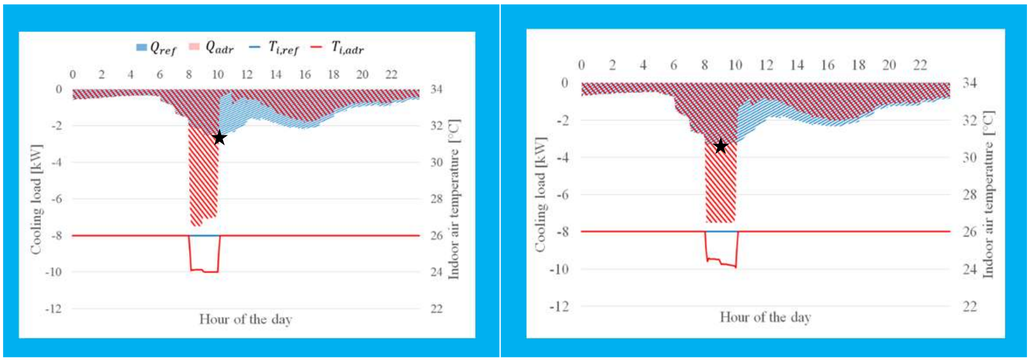
Energy flexibility of buildings

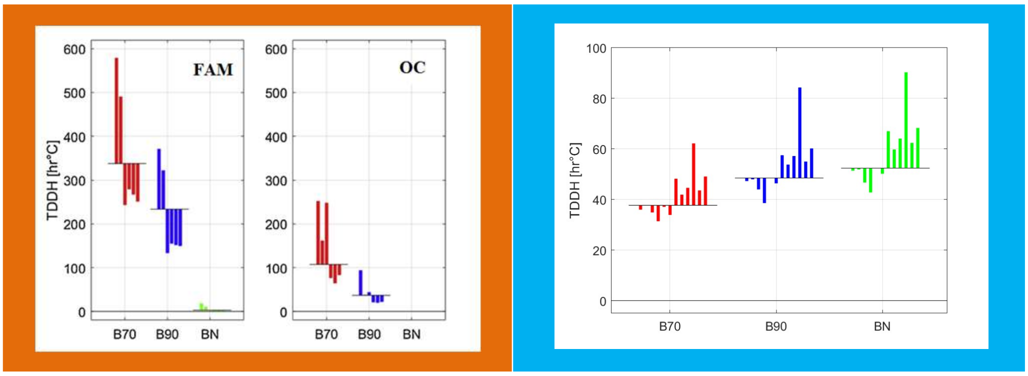
Example of ADR events in the cooling season



Solar radiation dependency for the cooling load

Energy flexibility of buildings

Thermal discomfort by ADR actions



Energy flexibility of buildings

Thermal inertia of buildings as a source of flexibility

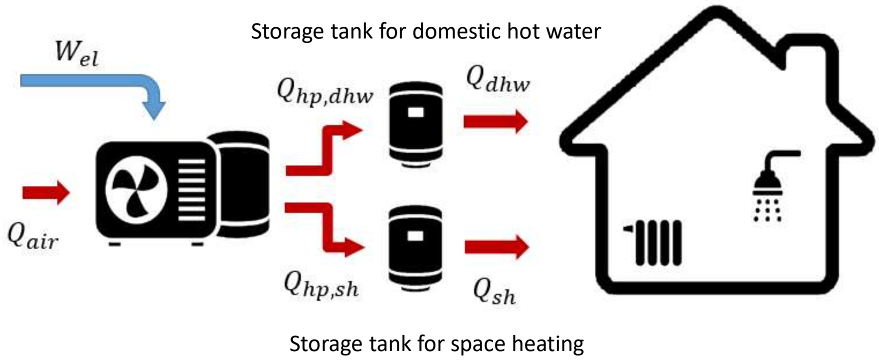
In the heating season, old buildings with low insulation have higher flexibility potential compared to new buildings but with a significant cost in terms of **increased energy consumption** and **reduced thermal comfort**.

In the cooling season, the influence of the thermal insulation level on the energy flexibility of buildings is lower, but the **time of the event** is very important because solar radiation has an immediate impact on the cooling loads.

The energy flexibility is also related to the **user behaviour**. In particular, intermittent operation due to variable setpoint schedules may result in higher heat losses.

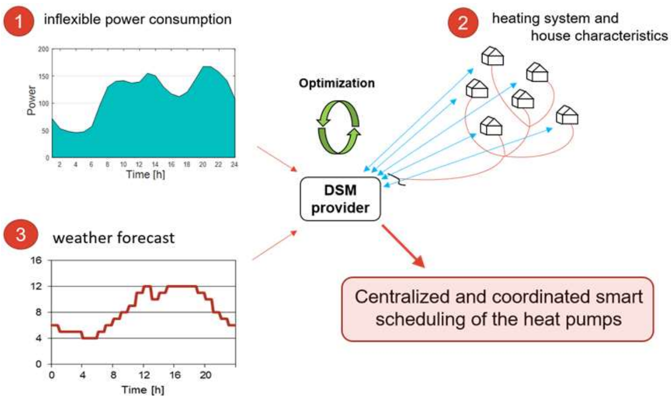
Energy flexibility of buildings

Example of DSM with hot water tanks



Energy flexibility of buildings

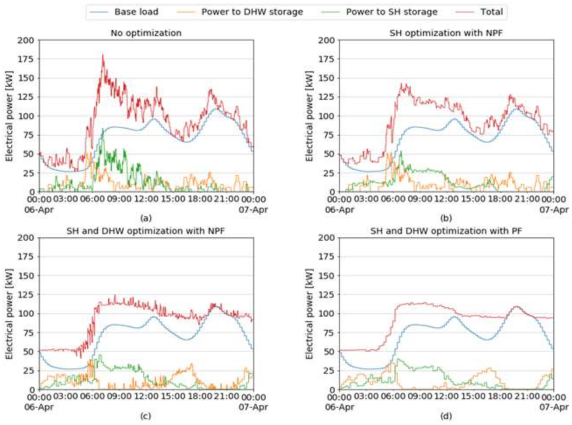
A case-study district of 100 houses and 35 heat pumps



Energy flexibility of buildings

Example of DSM with hot water tanks

Baseline (uncontrolled)



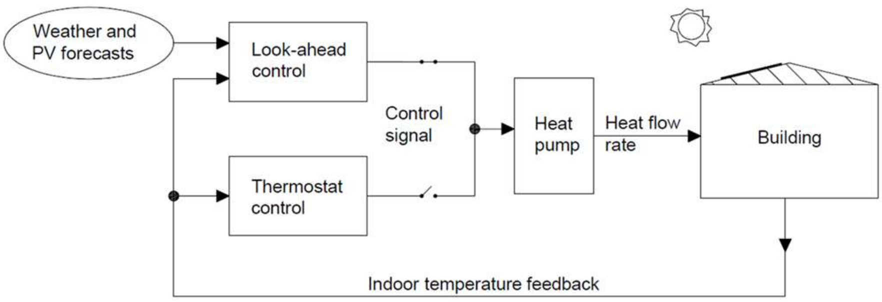
Operating condition playing on the storage heating tanks

Operating condition playing on the storage heating tanks and on DHW storage tanks

Operating condition uif we could predict the DHW consumption (ideal case)

Energy flexibility of buildings

Building Energy Management Systems (BEMS)



Energy flexibility of buildings

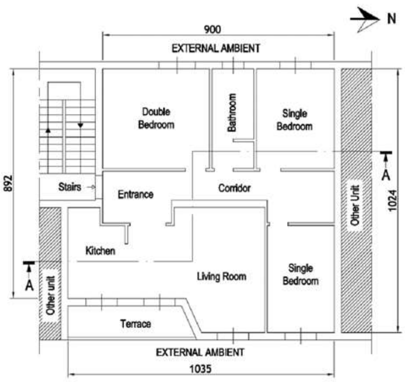
Building Energy Management Systems (BEMS)

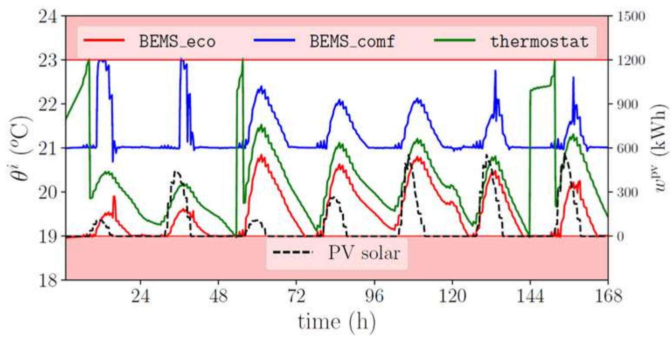
BEMS

Controllers

Energy flexibility of buildings

Building Energy Management Systems (BEMS)





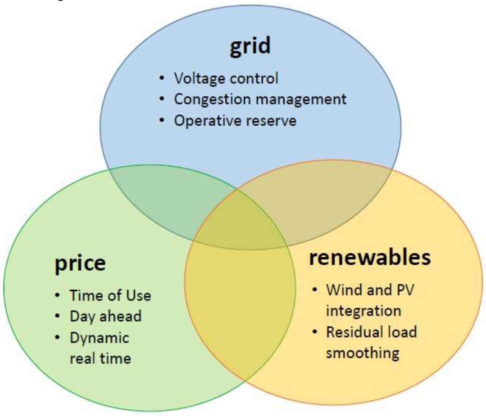
Energy flexibility of buildings

Building Energy Management Systems (BEMS)

Figura 4 – Foto/rendering del laboratorio

Energy flexibility of buildings

The role of heat pumps



[Source:
Fischer & Madani, 2017]

Energy Communities

General definition and characteristics

Table 1 Types of energy communities

	Place-based communities	Non-place based communities
Energy-only communities	Localized communities formed for the sole purpose of producing/ distributing energy according to shared rules	Non-localized communities formed for the sole purpose of producing/ distributing energy according to shared rules
Multi-issue communities	Localized communities formed in order to share the management/ consumption of various goods and services, including those related to energy	Non-localized communities formed in order to share the management/ consumption of various goods and services, including those related to energy

[Source: Moroni et al, 2018]

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Energy Communities

Definitions according to EU Regulation

Article 2(16) Renewables Directive – 'Renewable Energy Community'	**Article 2(11) Electricity Directive – 'Citizen Energy Community'**
A legal entity: (a) which, in accordance with the applicable national law, is based on **open and voluntary participation**, is **autonomous**, and is **effectively controlled by shareholders or members that are located in the proximity** of the renewable energy projects that are owned and developed by that legal entity; (b) the shareholders or members of which are **natural persons, SMEs or local authorities**, including municipalities; (c) the **primary purpose** of which **is to provide environmental, economic or social community benefits** for its shareholders or members or for the local areas where it operates, **rather than financial profits**.	A legal entity that: (a) is based on **voluntary and open participation** and is **effectively controlled by** members or shareholders that are **natural persons, local authorities, including municipalities, or small enterprises**; (b) has for its **primary purpose to provide environmental, economic or social community benefits** to its members or shareholders or to the local areas where it operates **rather than to generate financial profits**; and (c) **may engage in** generation, including from renewable sources, distribution, supply, consumption, aggregation, energy storage, energy efficiency services or charging services for electric vehicles or provide other energy services to its members or shareholders;
*While not part of the definition, RECS are entitled to **produce, consume, store and sell** renewable energy, including through renewables power purchase agreements, to share renewable energy within the community, and to access all suitable markets*	

Energy Communities

Definitions according to EU Regulation

	Renewable EC	Citizen EC
Energy sources	Renewables only	Any
Place	Place-based	Non place-based
Ownership	Owned by (property of) members	Not necessarily owned by members

Energy Communities

The initiatives analysed by JRC show that EC might engage in some or all of the following activities:

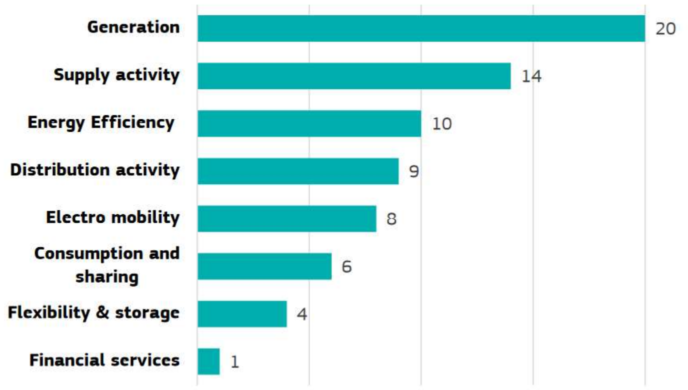
- **Generation**: community energy projects collectively using or owning generation assets (mostly solar, wind, hydro) where members do not self-consume the energy produced but feed it into the network and sell it to a supplier
- **Supply**: the sale (and resale) of electricity and gas to customers (electricity, wood pellets, biogas and others). Large communities can have a large number of retail customers in their vicinity, and may also engage in aggregation activities combining customer loads and flexibility or generate electricity for sale, purchase or auction in electricity markets
- **Consumption and sharing**: the energy produced by the energy community is used and shared inside the community. This includes both consumption (individual and collective self-consumption) and local sharing of energy amongst members that is produced by the generating installations within a community.

Energy Communities

- **Distribution:** ownership and/or management of community-run distribution networks, such as local electricity grids or small-scale district heating and (bio)gas networks; often cooperatives can do both energy generation and distribution, but the network infrastructure is central to their business
- **Energy services**: energy efficiency or energy savings (e.g. renovation of buildings, energy auditing, consumption monitoring, heating and air quality assessments); flexibility, energy storage and smart grid integration; energy monitoring and energy management for network operations; financial services
- **Electro-mobility**: car sharing, car-pooling and/or charging stations operation and management, or provision of e-cards for members and cooperatives
- **Other activities**: consultation services to develop community ownership initiatives or to establish local cooperatives, information and awareness raising campaigns, or fuel poverty measures

Energy Communities

Figure 2 Overview of activities corresponding to the 24 case studies



Source: JRC based on the case studies, 2019

Energy Communities

PV Sharing

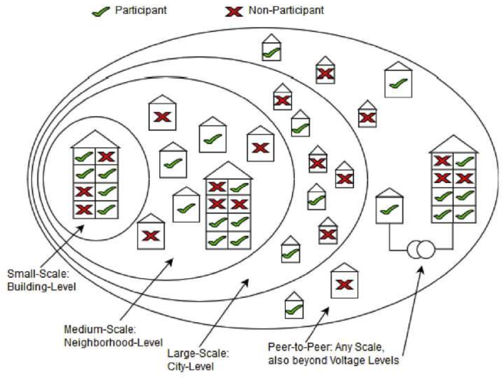
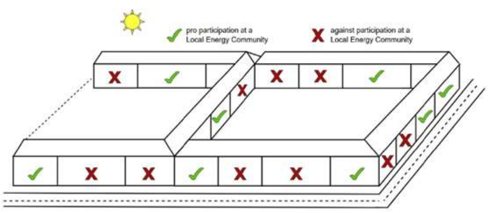


Fig. 1. Scales of EC implementation.

[Source: Fina et al, 2019]

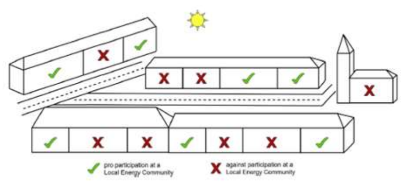
Energy Communities

PV Sharing

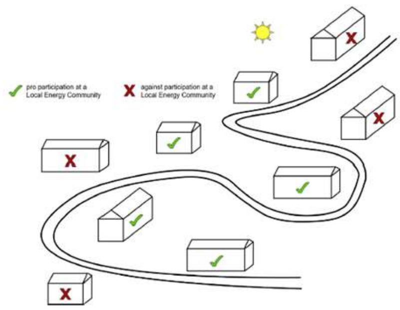


Multi-apartment building area

[Source: Fina et al, 2019]



Historical area



Rural area

Energy Communities

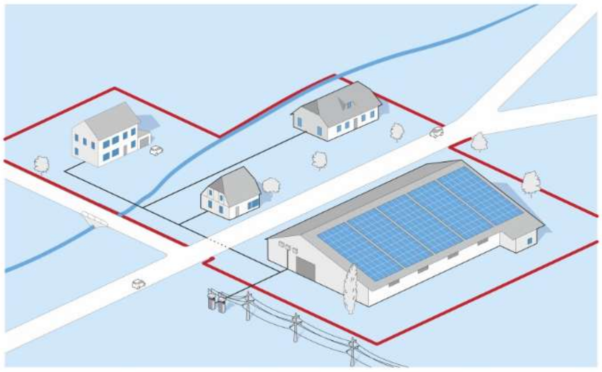
PV Sharing

The article from Fina et al. (2019) found that:

- PV sharing is most convenient in areas with multifamily buildings and in general when buildings have diverse consumption patterns
- Participants providing large roof/facade areas can significantly contribute to increasing the cost saving potential for the whole community.
- A cost-optimal PV system implementation does not require every building in a community to install PV.

Energy Communities

PV Sharing



[Source: www.svizzeraenergia.ch]

From single prosumers to Energy Communities

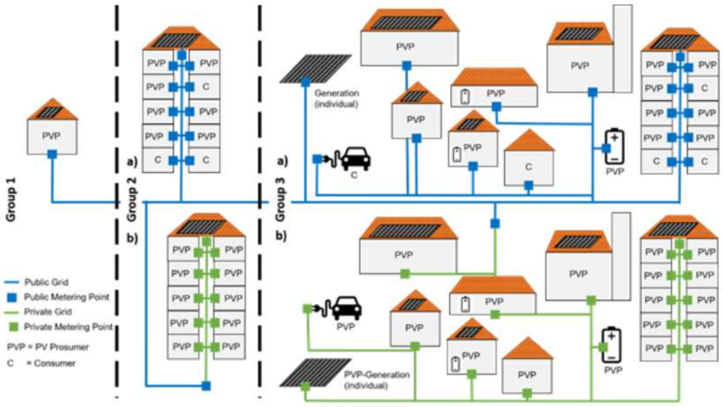


Figure 2. Classification of possible PVP concepts according to their system boundaries (Source: own elaboration)

Urban scale analysis of buildings

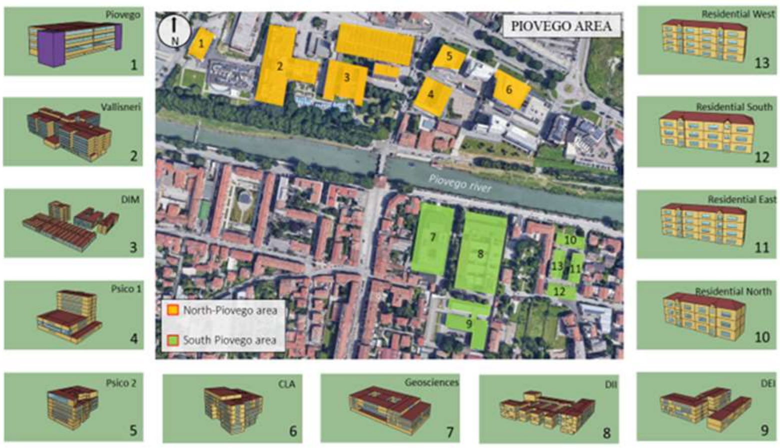
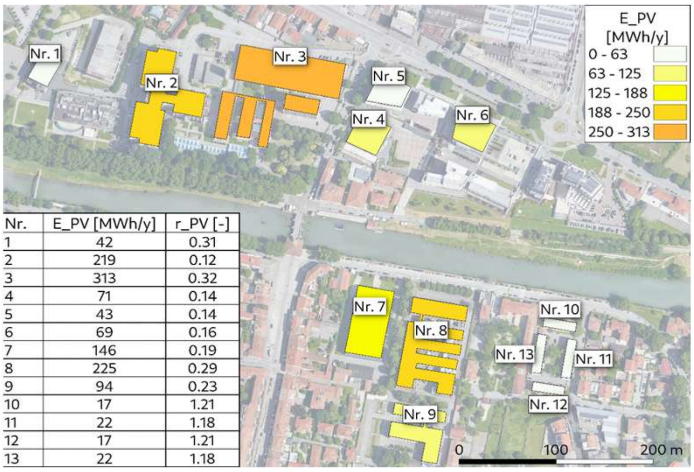


Figure 4 - Satellite image of the area surrounding the Piovego river and building models

Urban scale analysis of buildings



Nr.	E_PV [MWh/y]	r_PV [-]
1	42	0.31
2	219	0.12
3	313	0.32
4	71	0.14
5	43	0.14
6	69	0.16
7	146	0.19
8	225	0.29
9	94	0.23
10	17	1.21
11	22	1.18
12	17	1.21
13	22	1.18

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