Pilot 8: Udine (IT)

8.1 Local Context and general objectives

8.1.1 Local context

The Municipality of Udine aims at increasing the use of renewable energy sources (RES) and at reducing the environmental impact and the cost of electricity supply. For this purpose, the objective of the pilot is to take advantage of all the opportunities offered by the national law of February 2020 on renewable energy communities with the related subsequent implementing decrees and regulations.

The pilot includes different types of urban buildings within close proximity of one another as shown in Figure 55:

1. primary School “Lea D'Orlandi” located in via Della Roggia 52
2. kindergarten “Dire, Fare, Giocare” located in via della Roggia 48
3. Friulan Museum of Natural History located in via Cecilia Gradenigo Sabbadini 22/32
4. social housing blocks located in via Cecilia Gradenigo Sabbadini to the house number 52, 54, 56 and 58, with a total of 36 flats.

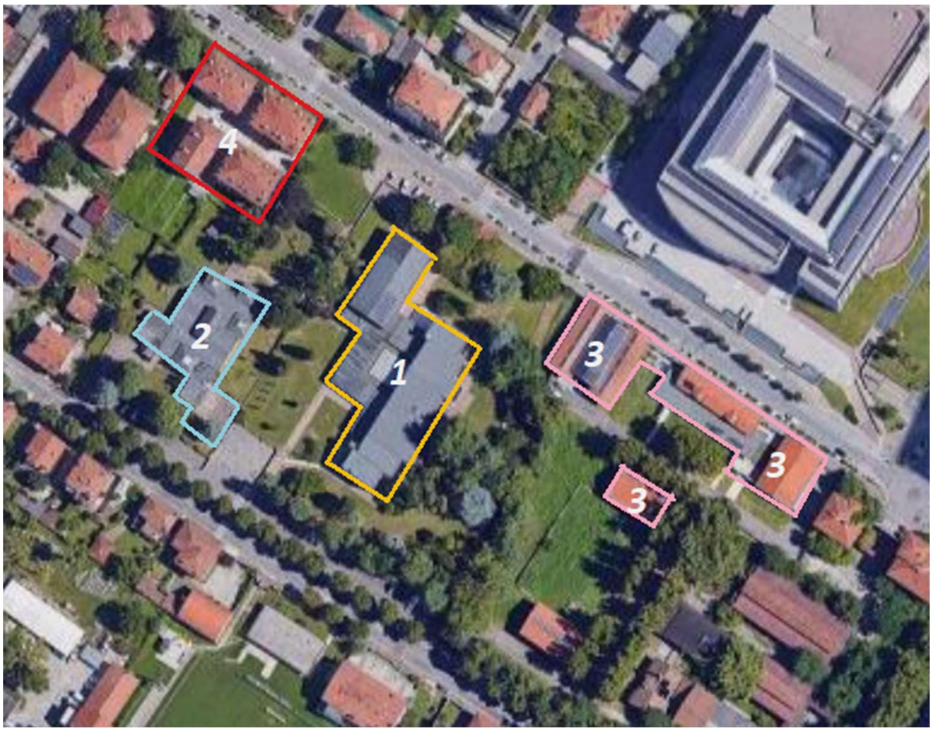

Figure 55 – Aerial photo of buildings involved in the pilot (Udine)

The primary school and the museum are prosumers equipped with PV plants, 6 kWp and 30 kWp respectively. The generated electricity exceeding the local load is fed into the public network in compliance with the rules of ‘Exchange on site’ (‘Scambio sul posto’) which in the current national legislation is the most economically advantageous mode for operating small renewable energy plants.

Heat pumps are installed in the museum and kindergarten for the annual thermal conditioning. The kindergarten also makes use of natural gas-fired boiler for winter thermal load peaks. The primary school and the four social housing blocks use natural gas-fired boilers for winter heating.

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All the energy flows of the pilot were monitored for a full year, from September 2020 to October 2021, in order to have adequately representative data and to take into consideration the seasonal effects (summer-winter thermal conditioning, closing of primary school and kindergarten for some summer months, etc.).

Referring to Figure 56 showing the energy flow scheme of the entire pilot, were monitored:

- the thermal and electrical consumption of primary school and kindergarten,
- the electrical consumption of the museum and 10 apartments located in the same block,

with a rate of 1 sampling per minute.

The measuring system installed in the primary school is sketched in Figure 57.

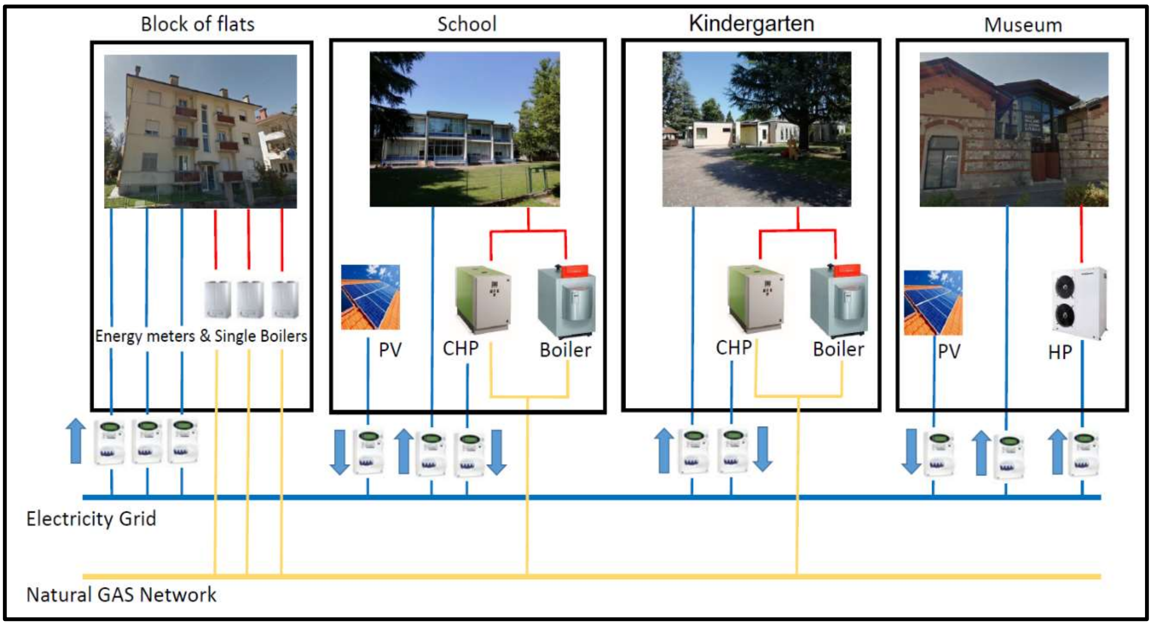

Figure 56 – Energy flow scheme of the pilot (Udine)

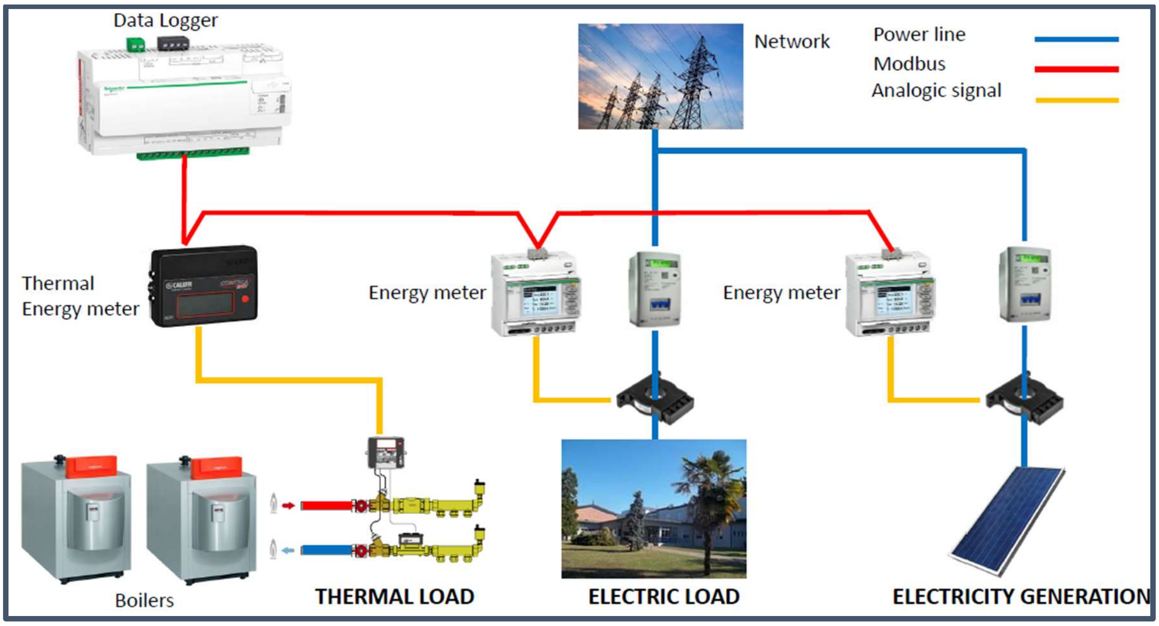

Figure 57 - Measuring system installed at primary school Lea D' Orlandi (Udine)

The annual thermal and electrical consumption values of the pilot are listed in Table 13 while Figure 58 and Figure 59 show the trend of consumption for the different months of the year.

Table 13 – Annual electrical and thermal consumption of the pilot (Udine)

building	electricity		thermal consumption [MWh$_t$/y]
	installed power [kW]	current from grid [MWh$_e$/y]	
primary school	30	29.0	300.0
kindergarten	35	28.5	119.8
museum	90	114.4	Not detected
social housing blocks	114	43.2	Not detected

For electricity, the above list shows the electricity drawn from the grid. In case of the kindergarten and the social housing blocks, this equals the electricity consumption. In case of the two prosumers, the primary school and the museum, this equals the electricity consumption minus the generation from the existing photovoltaic installations. The thermal energy consumed by the kindergarten is for the most part supplied by heat pumps: in the year the consumption of natural gas was equal to 11,800 smc. The primary school is equipped with a 480 kW$_t$ boiler which consumed 40,800 smc in the considered period.

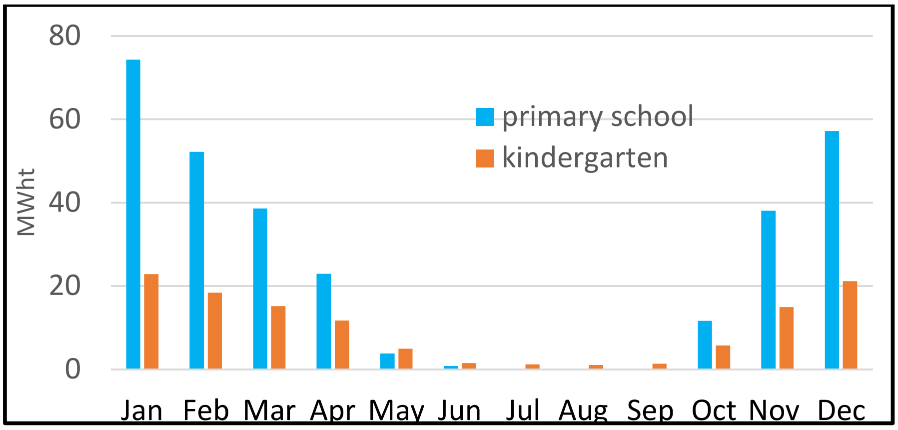

Figure 58 – Monthly thermal consumption of the pilot (Udine)

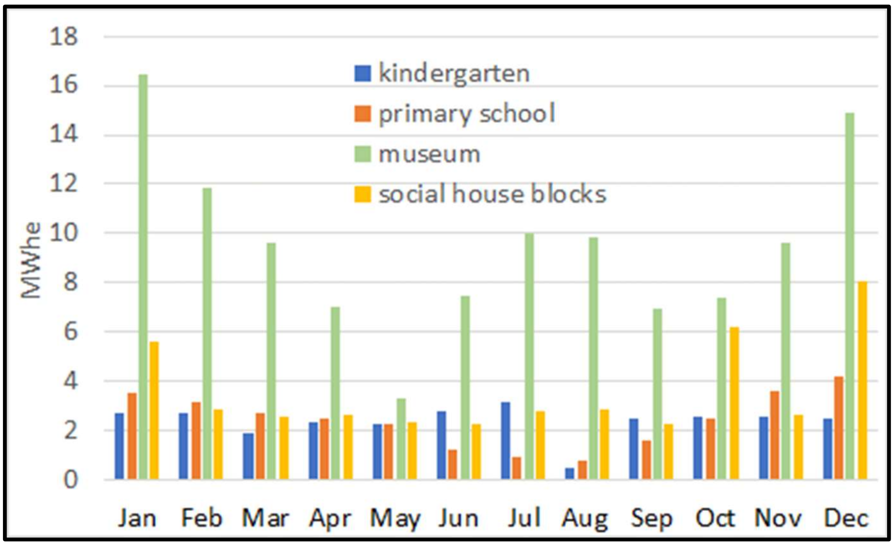

Figure 59 – Monthly electrical consumption of the pilot (Udine)

8.1.2 Objectives

The initial objective was the technical and economic feasibility of local energy community for the whole pilot according to the current national legislative and regulatory framework.

During the course of the project, as monitoring data were acquired and processed, a different approach was adopted, also on the basis the reference regulatory framework. In fact the national legislation providing a collective self-consumption scheme of renewable energy generated defines two possible ways:
a) the first concerns the electricity end users located in the same building or organized in a cluster of self-consumers (condominium); this solution is specifically addressed to households classified as '<u>self-consumers of renewable energy acting collectively</u>';
b) the second one provides for the possibility of a plurality of end users (including public bodies, private, small industries, shops) supplied by the same substation to establish a '<u>renewable energy community'</u> with its own operating rules defined through a private writing.

In addition to addressing different types of end users, these two forms of collective self-consumption enjoy different economic benefits.

With the aim of verifying in practice all the opportunities offered by the current regulatory frame, the pilot was therefore oriented to the feasibility assessment of two energy communities:

- <u>The first one is related to the four social house buildings</u>, fully conforming to the above scheme a), in the full conviction that positive results pay the way for a remarkable replicability on the territory.
- <u>The second one consists of the primary school, the kindergarten and the museum</u>, which in this case are all public buildings but they configure the possibility for public and private entities to establish themselves in the local energy community with the specific objective of a self-consumption of renewable energy.
- This approach on the pilot has been shared and adopted by the decision makers of the Municipality of Udine.
- The general objective was to verify the technical and economic feasibility of the two types of the regulated collective self-consumption schemes, namely the concrete possibility of people and entities intending make use of renewable energy with the related environmental and social benefits for themselves and the local area to invest in renewable sources with acceptable returns of the investment made.

- Among the objectives pursued are also the verification of any organizational and regulatory barriers preventing an effective establishment of local energy community according the current regulating frame and the emerged results are accounted in section 8.5.3.

8.2 Technical description

This section describes the results of the evaluations carried out for two local energy communities considered for the pilot of Udine.

8.2.1 The social house building organized as self-consumers of renewable energy

The access to the benefits related to the self-consumers of renewable energy for the four blocks of social house requires the installation of a plant making use of renewable sources. To this purpose it has been considered the installation of a PV plant on the roof of the four buildings (see Figure 60). In order to optimize the collection of solar radiation, roof layers S-E and S-O oriented have been considered, allowing to install a maximum nominal power of the PV plant of 50 kWp.

For an optimal dimensioning of such plant reference was made to the achievable benefits according to the current regulatory framework. This provides that all the generated electricity which is fed into the public grid receives a compensation related to the 'shared energy' ('energia condivisa'). The shared energy is defined for each time slot as the total electric energy consumed jointly by all self-consumers or the electric energy generated by all renewable energy plants, whichever is less. The recognized benefit amounts to 165.676 Euro for each MWh of shared energy, over a period of 20 years.

Since the greater the shared energy the greater is the achievable benefit, the economical optimization requires to maximize the shared energy in comparison with the electricity generated by the PV plant.

Figure 60 – On-roof PV plant on the social house blocks

The PV system generation for the different months of the year has been evaluated through PVGIS (Photovoltaic Geographical Information System) simulator and therefore the hourly production in the average day of each month (see Figure 61).

Different sizes of the PV plant were considered and for each of them the generated electricity has been compared, hour by hour over the whole year, with the recorded energy consumption of the 36 end users in order to assess the corresponding shared energy.

hour	January	February	March	April	May	June	July	August	September	October	November	December
1	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
3	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
4	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
5	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
6	0,00	0,00	0,00	0,13	1,15	1,75	1,55	0,45	0,00	0,00	0,00	0,00
7	0,00	0,00	0,38	1,99	2,75	3,07	3,07	2,39	0,91	0,00	0,00	0,00
8	0,00	0,85	2,47	3,39	3,90	4,13	4,32	3,80	2,91	1,30	0,07	0,00
9	1,46	2,70	3,65	4,28	4,63	4,82	5,14	4,72	4,04	2,90	1,66	1,11
10	2,45	3,42	4,23	4,79	5,14	5,32	5,74	5,32	4,65	3,57	2,43	2,40
11	2,72	3,72	4,55	5,12	5,46	5,63	6,11	5,70	5,02	3,91	2,67	2,72
12	2,81	3,82	4,67	5,23	5,57	5,74	6,24	5,83	5,14	4,02	2,75	2,81
13	2,72	3,72	4,56	5,12	5,46	5,63	6,11	5,70	5,02	3,91	2,67	2,72
14	2,47	3,42	4,23	4,80	5,14	5,32	5,74	5,32	4,65	3,58	2,44	2,45
15	2,08	2,93	3,71	4,28	4,64	4,82	5,15	4,73	4,06	3,05	2,07	2,03
16	1,55	2,30	3,03	3,61	3,97	4,17	4,37	3,94	3,30	2,35	1,58	1,44
17	0,73	1,45	2,21	2,82	3,20	3,42	3,48	3,04	2,40	1,48	0,85	0,51
18	0,00	0,42	1,26	1,87	2,34	2,58	2,49	1,99	1,36	0,55	0,03	0,00
19	0,00	0,00	0,23	1,14	1,48	1,69	1,49	1,16	0,47	0,00	0,00	0,00
20	0,00	0,00	0,00	0,09	0,78	1,17	0,96	0,28	0,00	0,00	0,00	0,00
21	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
22	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
23	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
24	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
KWh/day	18,98	28,76	39,16	48,64	55,63	59,28	61,96	54,39	43,90	30,62	19,23	18,20
KWh/month	588,42	805,38	1214,08	1459,33	1724,54	1778,43	1920,64	1686,14	1317,12	949,12	576,77	564,22

Figure 61 – Producibility of 10 kwp on-roof PV system installed on social house blocks

The best return on investment occurs for a 13 kWp PV plant. Table 14 lists the generated electricity by PV plant in close comparison with the electrical of the 36 end users and the shared energy for the 12 months of the year. The annual shared energy amounts to 13.1 MWh, equal to 92.5 % of the electricity generated and fed into the network.

For more powerful PV system this ratio is lower, resulting in a lower economic return on investment. For instance, the annual shared energy in case of 26 kWp PV, requiring an investment about double the optimal one, would increase to 18.1 MWh in so determining an increase of the benefits only by 38 %.

Table 14 – Shared electricity for a 13 kWp PV plant for the self-consumers community

	Total Consumption [kWh]	Generated electricity [kWh]	Shared Energy [kWh]	Shared Energy vs Generated electricity
January	7,016	588	588	100,0%
February	3,599	805	800	99,4%
March	3,235	1,214	1,171	96,5%
April	3,265	1,459	1,350	92,5%
May	2,938	1,726	1,389	80,5%
June	2,845	1,778	1,431	80,5%
July	3,516	1,921	1,667	86,8%
August	3,587	1,686	1,496	88,7%
September	2,812	1,317	1,126	85,5%
October	7,743	949	945	99,5%
November	3,313	577	577	100,0%
December	10,100	564	564	100,0%
Total	**53,969**	**14,584**	**13,104**	**92,5%**

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The energy and environmental benefits related to the establishment of the community of self-consumption are related to 14.6 MWh/year of renewable energy generated, equal to 24 % of the pilot's total electric consumption, and, taking into account average grid losses of 2.7 % in the distribution grid, about 0.4 MWh/year of avoided losses in the distribution network. Taking into account further, that there is potential for at least 1 million of clusters of self-consumers (condominia) in Italy similar to the pilot in Udine, of which at least a quarter of them reside in regions pertaining to the Alpine Space, there is a potential of avoiding 0.4 TWh/year of losses in the distribution grid at national scale and 0.1 TWh/year in the Alpine Space.

The financial-economic framework for the adopted solution can be summarized as follows:

- Total required investment: 15,240 Euro (including 1,410 Euro for inverter replacement after 10 years),
- Operating cost: 510 Euro/year,
- Total achievable benefits: 43,000 Euro (evaluated over a period of 20 years),
- Net Present Value: 9,730 Euro (evaluate over a period of 20 years, 3 % annual discount rate),
- IRR = 10 %.

8.2.2 The renewable energy community including the primary school, the kindergarten and the museum.

Renewable energy communities are also required by the current regulations to install a renewable source and fed all the generated electricity into the public grid with a related compensation of 174.22 Euro/MWh of shared energy.

Assuming that a PV plant has to be installed, the same assessments described in the previous paragraph have been carried out. The resulting data are summarized in Table 15 showing the generated electricity, the total consumption of the three buildings and the corresponding shared energy for a PV plant with a peak power of 43 kWp and an annual production of 47.8 MWh.

The renewable energy community including primary school, kindergarten and museum, is able to locally generate 27.8 % of its electricity consumption, a result not much different from that of the of the self-consumers community.

Table 15 – Shared electricity for a 43 kWp PV plant for the renewable energy community

	Total Consumption [kWh]	Generated electricity [kWh]	Shared Energy [kWh]	Shared Energy vs Generated electricity
January	22,654	1,931	1,931	100,0%
February	17,704	2,643	2,582	97,7%
March	14,271	3,984	3,563	89,4%
April	11,898	4,788	4,030	84,2%
May	7,856	5,659	4,280	75,6%
June	11,416	5,835	3,769	64,6%
July	14,077	6,302	5,789	91,9%
August	11,144	5,533	4,898	88,5%
September	11,000	4,322	3,962	91,7%
October	12,505	3,114	2,862	91,9%
November	15,757	1,893	1,868	98,7%
December	21,616	1,851	1,851	100,0%
Total	**171,898**	**47,854**	**41,835**	**86,5%**

The resulting economic and financial framework:

- Total required investment: 50,000 Euro (including 5,860 Euro for inverter replacement after 10 years)
- Operating cost: 1,650 Euro/year
- Total achievable benefits: 137,700 Euro (evaluated over a period of 20 years)
- Net Present Value: 28,890 Euro (evaluate over a period of 20 years, 3 % annual discount rate)
- IRR = 9.7 %

shows that the current regulatory rules allow an acceptable return of investments related to new renewable energy plants.

Considering the thermal consumption of the primary school, 300 MWh/year and the electrical consumption of the primary school, kindergarten and museum, it has been investigated the installation of a Combined Heat and Power system (CHP) in partial replacement of the existing two natural gas fuelled boilers. In fact, the use of a CHP system shall in principle to primary energy saving compared to separate generation of heat and electricity. A heat driven CHP operation at its maximum power in presence of thermal demand. The heat generated by CHP exceeding the thermal demand is stored. When the thermal demand exceeds the maximum thermal power from CHP, at first is used the stored thermal energy and subsequently the existing boilers begin to work according to a master-slave logic.

A suitable sizing of the CHP and of the associated thermal storage allows almost a continuous operation of CHP. Figure 62 shows this situation: a 38 kW_t CHP, equipped with 15 kWh of thermal storage, works always at its maximum power for all the time thus providing about 35 % of the required thermal energy and reducing the peak load of the boiler of over 80 kW_t.

The optimal CHP size from energy point of view has been assessed on the basis of the thermal consumption of the primary school over a whole year and considering the systems available on the market.

The best performances were obtained with a CHP system, with 38 kW_t of thermal power and 16 kW_e of electric power, equipped with a thermal storage of 15 kWh_t (obtained through 500 litres of water operating in the temperature range between 45°C and 70°C).

Table 16 lists the thermal energy supplied by CHP and boilers to satisfy the primary school's thermal demand during the 12 months of the year together with the electricity generated by CHP.

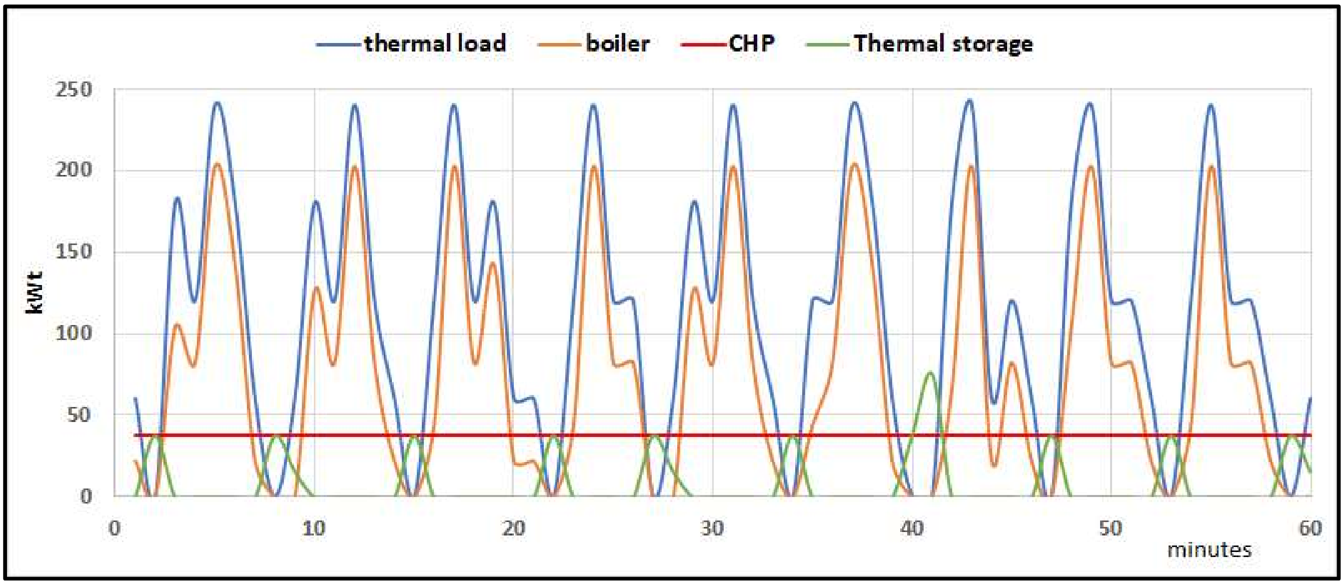

Figure 62 – Primary school: thermal load, supply by boiler and CHP, and level of thermal storage (from 6 am to 7 am on 2/11/2020)

Table 16 – Breakdown of the thermal energy to be supplied to the primary school

	Primary school thermal consumption [MWh_t]	Heat supplied by boilers [MWh_t]	Heat supplied by CHP [MWh_t]	Electricity generated by CHP [MWh_e]
January	74,9	49,7	25,2	10,4
February	52,2	35,1	17,1	7,2
March	38,6	23,9	14,7	6,2
April	22,9	13,1	9,8	4,2
May	3,8	1,5	2,3	0,98
June	0,77	0,01	0,76	0,32
July	0	0	0	0
August	0	0	0	0
September	0	0	0	0
October	11,6	4,8	6,8	2,9
November	38,0	21,0	17,0	7,2
December	57,3	33,5	23,8	10,0
Total	**300,0**	**182,6**	**117,4**	**49,44**

The CHP system is able to supply 39 % of the thermal demand of the primary school and 29 % of electrical self-sufficiency of the whole complex consisting of primary school, kindergarten and museum. The use of CHP instead of the existing boilers allows a primary energy saving of 55 MWh/year compared to the separate generation of heat and electricity at the national average efficiency. Moreover, about losses of about 1.3 MWh/year are avoided in the distribution network.

The relevant economic and financial indices result as follows:

- Total required investment: 44,000 Euro,
- Operating cost: 800 Euro/year,
- Total achievable benefits: 154,850 Euro (evaluated over a period of 20 years and considering the existing national rules for 'high efficiency cogeneration'),
- Net Present Value: 61,875 Euro (evaluate over a period of 20 years, 3 % annual discount rate),
- IRR: 16.6 %.

A close comparison of the above results with those obtained for the renewable energy community using a 43 kWp PV plant leads to the following conclusions:

- ✓ considering the energy assessment, the use of a PV system allows a similar energy self-sufficiency, but the primary energy saved is definitely greater,
- ✓ in financial terms the CHP system results in a better return on investment.

It has to be also outlined that the solution based on PV plant is currently regulated in Italy, while the use of natural gas fueled CHP only downstream of the full transposition of the EU directive concerning the 'citizen energy community' may be considered for a local energy.

8.3 Legislative framework

The pilot activities made reference to the national current legislative context, namely the Art. 42 bis of the Law n. 8 dated 28/2/2020, partially transposing the Directive on common rules for the internal market for electricity (EU) 2019/944[6] (Electricity Market Directive, EMD) that allows for collective self-consumption of electricity generated from renewable sources.

According to this law the electrical end users can join to become a collective prosumer in two possible ways:

a) the end-users located in the same building or organized in a condominium may become 'self-consumers of renewable energy acting collectively'; this solution is specifically addressed to households;

b) citizens, small and medium-sized enterprises, local authorities or municipalities may establish a 'renewable energy community' under the following conditions:

- for each member of the community the electricity generation and the energy exchange with the public network does not constitute the principal commercial or professional activity,
- all members of the community are supplied by the same electrical substation.

For both the above defined possibilities of clustering the following shall apply:

- each end user maintains his electricity supplier and pays the same bill for the consumed electricity and committed power (all levies, charges and taxes) as before,
- a renewable plant with no more than 200 kW in power has to be installed, at a time following the law issuance, in areas owned by the members of the community,
- all the generated electricity from renewable sources has to be fed into the existing distribution network and acquired by GSE ('Gestore dei servizi energetici'), the national company appointed to promote the sustainable development,
- GSE provides the renewable energy community or the cluster of self-consumers a refund related to the 'shared energy' ('energia condivisa') defined for each hourly period as the energy jointly consumed by renewable energy community or the energy generated by the renewable sources, whichever is less; this refund consists in:
  - an incentive equal to 110 Euro for each MWh of shared energy in the case of renewable energy community and 100 Euro for each MWh of shared energy in the case of self-consumers clustering,
  - a return of the variable components of electricity transmission and distribution rate, equal for 2020 year to 8.22 Euro per each MWh of shared energy,
  - 2.6 % of the 'zonal price' ('prezzo medio locale dell'energia elettrica') for each MWh of shared energy for the self-consumers clustering only, as a compensation for the avoided loss in the transmission and distribution network,
  - the 'zonal price' for each MWh of the electricity by the renewable plant and fed into the public network.
- the members of the renewable energy community and of the self-consumers clustering have to draw up a private agreement regulating at least the allocation of the investment for the renewable sources and of the refund received by GSE, the rules according to which any member may withdraw from the collective consumption.

8.4 The energy community

8.4.1 Players involved, their roles and contractual relationships

As stated at section 8.1.2 the considered energy communities are compliant with the existing national regulatory framework:

[6] https://ec.europa.eu/energy/topics/markets-and-consumers/market-legislation/electricity-market-design_en; text of the directive: https://eur-lex.europa.eu/legal- https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2019.158.01.0125.01.ENG&toc=OJ:L:2019:158:TOC

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- the 36 end users of the four social house blocks are to clustered as ‘self-consumers of renewable energy acting collectively’,
- the primary school, the kindergarten and the museum are configured as a ‘renewable energy community’.

It hast to be outlined that all the involved end users belong to the Municipality of Udine and all the electrical invoicing are paid by the Municipality. This implies some critical issues:

- at least two different end users are required to perform a cluster of self-consumers,
- it has to be clarified, in the light of the current regulation for public bodies, how the refund by GSE are allowed or not and how they are to be considered (subsidies, grant).

These issues lead to a slowdown in the implementation of the two considered collective self-consumption forms.

Whatever the solutions that will be adopted, certainly the predominant part of the investment will be the responsibility of the Municipality and consequently will be addressed the private agreement that must be defined in order to access the collective self-consumption solutions provided for by current legislation.

8.4.2 Classification of energy community

At present, the two considered energy communities may be included in Class 6 - Municipal Utilities.

8.5 Results

8.5.1 Scenario chosen for pilot design implemented

Reference has been made to the existing legislative framework which, although with various limitations, currently provides for a procedure (not completely exhaustive and facilitating) for the establishment of energy communities capable to foster the use of renewables and in view to overcoming the current constraints of the electrical system still structured according to top-down schemes.

With the aim to make available to the Municipality of Udine solutions that can be implemented on the territory the pilot project has been kept strictly in line with legislative requirements, leaving aside perhaps more energy effective technical solutions.

8.5.2 Obstacles encountered

No specific obstacles were found in the design of the pilot. On the other hand, administrative and/or regulatory real obstacles emerged in the preliminary phase for the establishment of the two considered energy communities, as described above.

8.5.3 Proposals for modifications of legislative framework

Considering the current legislative framework, it is essential for the potential members of an energy community the availability of appropriate formats, or at least detailed guidelines, supporting the draw-up of the private agreement regulating the operation of the community, from the allocation of the investment in renewable sources until the allocation of the refund paid by GSE. The adopted approach based on the development over time of a practice in this regard, without any available reference, is problematic for an effective result of the law itself.

A further neglected item in the current regulating framework concerns the possibility for end users who intend to set up an energy community to know the amount of the achievable benefits in order to size the renewable source of the community. GSE for the evaluation of the refund takes into consideration the hourly consumption of all members of the community and the hourly generation of electricity from renewable sources so to define for each time slot the shared energy to which such benefits are related. Such a process cannot be carried out by the members of the constituent community because they only know the monthly consumption. Without a clear definition of the return of the investment related to the required new renewable source of the community it’s very unlikely that potential members will join it. A possible solution is that GSE, in response to a request for the establishment of a community, should acquire for some time the hourly consumption data of the members of the community (anticipating the operation to be carried out later for the assessment of the refunds) and communicate them to the community.

The current legislation explicitly provides for arrangements encouraging the “direct participation of municipalities and public administrations in renewable energy communities”. From what described in paragraph 8.3.1 this aspect of the law is still disregarded, while it would be of extreme interest for municipalities to develop effective demonstrative solutions to be replicated in the territory.

8.5.4 Elements proposed to be included in a Alpine Microgrid Model

The Alpine Microgrid model in promoting the development of microgrids and energy communities, has to take great account of driving role of municipalities. These have public buildings distributed throughout the territory (schools, kindergartens, sports centres, cultural and meeting centres) that can constitute the aggregation point for innovative initiatives (which in fact are still both the microgrids and the energy community) involving the citizens but also commercial shops and small/medium enterprises. The concrete demonstration of the advantages acquired in social terms, energy and environment would be a sure reference for private investors who would find convenient to support similar solutions on the territory.