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Master's degree in
Territorial, Urban, Environmental and Landscape Planning - *Planning for the Global Urban Agenda*

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Master's Degree Thesis

Feasibility study of an energy community in the territory of Scalenghe (TO)

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- **Abstract**

The objective of this research thesis is the identification of a procedure useful for defining the methodologies and design tools for the energy transition and the assessment of the possibility of achieving energy self-sufficiency in the area under analysis in compliance with the limits of the Regional Law 12/2018.
The analysis carried out consists of a small community made up of 6 municipalities. In the first part of the thesis, attention is focused on the political and regulatory context in hich the energy communities are inserted. In the second part, after a detailed analysis of the state of affairs, the consumption, production and producibility profiles of the users are defined, classified into three categories (corporate, municipal, domestic) and divided by type (producer, consumer, prosumer) the data calculated for various categories are determined on an annual, monthly and hourly scale. These calculations were made for photovoltaic, biogas, agricultural biomass, forestry and waste sources. With the result obtained, the data from the various sources were aggregated, obtaining the optimization of energy supply and demand.

- **Abstract (ITA)**

L'obiettivo di questa tesi di ricerca è l'individuazione di una procedura utile alla definizione delle metodologie e degli strumenti progettuali per la transizione energetica e la valutazione della possibilità di raggiungere l'autosufficienza energetica nell'area in esame nel rispetto dei limiti della Legge Regionale 12/2018. L'analisi effettuata consiste in una piccola comunità composta da 6 comuni. Nella prima parte della tesi l'attenzione è focalizzata sul contesto politico e normativo in cui si inseriscono le comunità energetiche. Nella seconda parte, dopo un'analisi dettagliata dello stato di fatto, vengono definiti i profili di consumo, produzione e producibilità degli utenti, classificati in tre categorie (aziendali, municipali, domestici) e suddivisi per tipologia (produttore, consumatore, prosumer) i dati calcolati per le varie categorie sono determinati su scala annuale, mensile e oraria. Questi calcoli sono stati effettuati per il fotovoltaico, il biogas, la biomassa agricola, la silvicoltura e le fonti di rifiuti. Con il risultato ottenuto, sono stati aggregati i dati provenienti dalle varie fonti, ottenendo l'ottimizzazione della domanda e offerta di energia.

- **INTRODUCTION**

The objective of this research thesis is the identification of a procedure useful to define methods and planning tools and their feasibility for the energy transition on a small scale, such as the territory under examination, which represents a union of 6 municipalities, which have expressed their interest in becoming energy self-sufficient and in reducing their environmental impact to zero.

In recent decades, the energy transition has become increasingly necessary. International agreements such as the Paris Agreement and the 2030 Agenda and the climate events of recent years have prompted the European Union to present the Green Deal.

Energy is central to a country's economic and social development. However, today this development has proven to be unsustainable for future generations, so it is crucial to switch to new and more sustainable sources. The energy transition defined by the change in the use of non-renewable to renewable energy sources is part of the broader transition to sustainable economies through the use of renewable energy, the adoption of one of the new energy saving techniques and sustainable development. In this sense, Energy Communities represent an innovative form of distribution, production and consumption of energy produced from renewable energy sources.

The analysis, aimed at verifying the feasibility of the transition towards better energy sources, was carried out starting from the study of the current environmental, social and economic situation in order to analyse and observe the constraints that could hinder the project and the development of energy consumption and production models in the European Union and in Italy. Subsequently, the regulations to be followed in the case of creating an energy community were analysed, paying attention to existing incentives. A chapter was drafted with the methodologies used for the realisation of the different energy and territorial scenarios that can be applied to other municipalities/users interested in the creation of an energy community. After analysing and defining the energy consumption profiles of those involved and the production and producibility profiles based on local resources, the economic part concerning the payback time of the investments and the energy and economic gain obtainable over the years was elaborated.

Finally, a comparison, an aggregation between the scenarios and the resources considered was made that aimed at assessing compliance with legal requirements and defining possible intervention scenarios. As well as providing useful information for project implementation.

1. DEFINITION

- **Le comunità energetiche**

  Energy communities organise collective and citizen-driven energy actions that will help pave the way for a clean energy transition, while moving citizens to the fore. They contribute to increase public acceptance of renewable energy projects and make it easier to attract private investments in the clean energy transition. At the same time, they have the potential to provide direct benefits to citizens by advancing energy efficiency and lowering their electricity bills.

  By supporting citizen participation, energy communities can moreover help in providing flexibility to the electricity system through demand-response and storage.

  Energy communities are made up of individuals, groups of individuals, whole neighbourhoods or communities. They participate as pro-consumers (active consumers, i.e. consumers who equip themselves with the technologies needed to collect energy from renewable sources). They contribute to the reduction of CO2 emissions. By meeting their own energy needs and possibly those of others.

  The EU through the Clean energy for all Europeans package, has introduced the concept of energy communities in its legislation, as a community for renewable energy (REC) which is contained in the recast Renewables Directive, and citizen energy communities which is contained in the provisionally agreed recast Electricity Directive.

  The Energy Community is also defined as a legal entity in which citizens, small and medium-sized enterprises and local authorities, as end users of energy, are part of a network of subjects that participate in the production, distribution, storage and consumption of energy from renewable sources (RES), in order to carry out energy efficiency measures aimed at reducing consumption or in offering management services and optimization of energy demand. "Energy Community", therefore, is defined in different ways and according to different national and regional legislative and regulatory references, within an evolving European regulatory framework.

2. REGULATIONS

2.1 EUROPEAN LEVEL

- **CleanEnergy Package for All European (8 legislative acts**): Proposed by the European Commission in November 2016, consisting of eight legislative acts that entered into force at the end of 2019, but approved at different times, these acts must be incorporated into the national law of all member countries within two years from the date of promulgation. Below are the legislative acts included in the package.
  - Renewable Directive 2001/2018/EU (RED II):
    Entered into force in December 2018, as part of the Clean energy for all Europeans package, the goal is to keep global leader the EU in a renewables by helping the EU to meet its emissions reduction commitments under the Paris Agreement.
    Recognise the role of the prosumer user, as an active subject in the production and consumption of energy from renewable sources, 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; the shareholders or members of which are natural persons, SMEs or local authorities, including municipalities; 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.
    In the same article, reference is made to the Community of producers/consumers of renewable energy which are also authorized as well as the prosumers described above, without being subject to disproportionate procedures and charges that do not take into account costs. Therefore, the objective of the Directive is not only to promote the formation of Energy Communities but invites the Member States to support these

initiatives and to remove any obstacles that exist to their full development.

- Electricity Directive 2019/944/ EU – (Direttiva Mercato n 994/2019) It evidence rules for the distribution, generation, transmission, supply and storage of electricity, together with consumer protection aspects, with the goals to create integrated competitive, consumer-centered, flexible, fair and transparent electricity markets in the EU.
  It also contains rules on retail markets for electricity, whereas Regulation (EU) 2019/943, which was adopted at the same time, mainly contains rules on the wholesale market and network operation.
  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; 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.

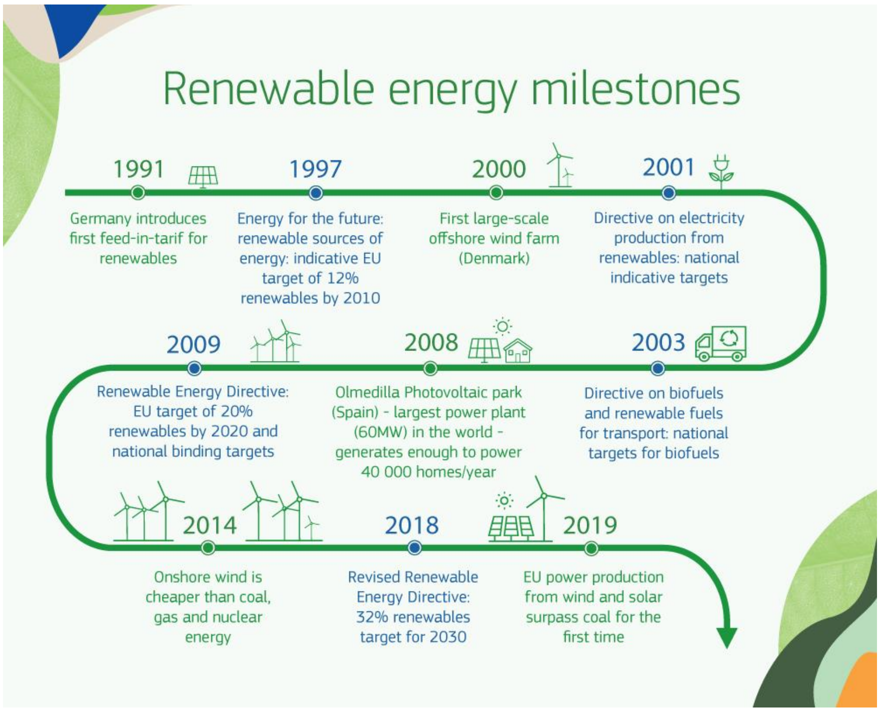


Figure 1Renewable energy milestones. *sources: https://ec.europa.eu/info/news/focus-renewable-energy-europe-2020-mar-18_en*

2.2 NATIONAL LEVEL

- **PNIEC 8/2020: t**he plan outlines the way in which Italy intends to achieve the respective EU objectives in the ten-year period 2021-2030 and in the long-term vision of 2050. Sent to the European Commission at the end of 2018, it received in response some specifications, including those relating to the implementation of the use of FER in the air conditioning sector and the degree of energy efficiency in the building sector, considering the ample room for improvement, as well as the suggestion of a comparison with neighboring countries to highlight the cross-border potential and finally attention to analyzes on air quality and atmospheric emissions.
  The main objectives of the PNIEC by 2030 to achieve a percentage of energy from FER, on the total gross final consumption of energy, equal to 30%, to reduce primary energy consumption by 43% and greenhouse gases in all sectors for a share equal to 33%, compared to 2005. The plan also presents a broad vision inherent to the transformation of the economy in which decarbonisation, the circular economy, energy efficiency and the rational and equitable use of natural resources together represent objectives and tools for creating a national scenario with greater respect for people and the environment.

- **Delibera ARERA 318/2020/R/EEL**: it provides regulation of economic items relating to electricity shared by a group of renewable energy self-consumers who act collectively in buildings and condominiums or shared in a renewable energy community.
  The resolution confirms a virtual regulatory model that allows for the economic recognition of the benefits, where present, deriving from the on-site consumption of locally produced electricity:
  1. avoiding the need to implement technical (such as electricity grids other than grids with third party connection obligations) or corporate solutions (such as those necessary to be classified

among the Simple Production and Consumption Systems - SSPC) to obtain these benefits;

2. keeping separate evidence of the benefits associated with self-consumption (which do not depend on sources, type of networks and / or corporate structures) and explicit incentives (which, as such, can be appropriately calibrated according to the sources and / or technologies).

- **GSE** - "Shared electricity enhancement and incentive service", Technical rules for access to the economic incentive to promote shared energy, 22/12/2020.

  The GSE is responsible for carrying out the following obligations:

  - prepare and transmit, for positive verification by the Director of the Wholesale Energy Markets and Environmental Sustainability Department of ARERA, the application scheme, the contract scheme and the technical rules containing, the precise calculation criteria that may be necessary, the methods of communicating to the Coordinator of the configurations that benefit from the shared electricity enhancement and incentive service and the methods of profiling the metering data and the related methods of use;
  - provide territorial assistance services to Public Administrations;
  - prepare a specific IT portal interoperable with the GAUDÌ system, ai purposes of accessing the electricity enhancement and incentive service shared, as well as for the technical and economic management of the same service

- **D.L. n.162 del 30/12/2019 –Art. 42 bis - Innovation in the field of self-consumption from renewable sources.**

  For the purposes set out in Directive (EU) 2018/2001, this decree redefines the right of final energy customers to associate themselves to collectively self-consume renewable energy. In addition, it establishes that shareholders and members are natural persons, including SMEs, local authorities, local authorities, municipalities, low-income or vulnerable citizens and families, associated with the aim of providing environmental, economic or social benefits at the community level. and for each of them the participation cannot constitute the main commercial and industrial activity. Some limitations of which the participating subjects produce energy for their own consumption with plants powered by renewable sources with a total power not exceeding 200 kW and the entry into operation of the same after the date of entry into force of the decree. The self-produced energy is shared for instant self-consumption, storage systems are allowed using the existing low voltage distribution network, underlying the same MT/BT transformer substation on which the withdrawal and injection points of the participating subjects are located.

2.3 PIEDMONT REGIONAL LEVEL

In Italy, the Piedmont Region was the first region to have deliberated on the subject of Energy Communities.

- **L.R. n.12/2018 – Regione Piemonte: t**he Law promotes the establishment of Energy Communities, in which public and private non-profit entities can participate, established in order to encourage the process of decarbonization of the economic and territorial system, and to facilitate, promote production, exchange and the consumption of energy generated mainly from renewable sources, as well as forms of improving energy efficiency and reducing energy consumption. Municipalities wishing to join the constitution of an energy community, or to an existing energy community, adopt a specific memorandum of understanding. Energy communities acquire and maintain the qualification of energy producers if annually the share of the energy produced destined for self-consumption by the members is not less than 70 percent of the total energy produced, the drafting of two documents is required: an energy balance and a strategic document for actions to reduce consumption and energy efficiency.

- **LR N.12 del 03/08/2018**: Promotion and establishment of energy communities
  It is based on the incentive of self-production and sharing of energy produced from renewable sources. This law will allow communities of people, entities and businesses to exchange energy produced from alternative sources with each other. It favors the creation of small cooperatives for the production and consumption of energy, to obtain electricity and heat from locally available renewable sources and forms of efficiency and reduction of consumption. According to the law, companies, individuals, public administrations can join forces whose purpose is to equip themselves with renewable energy sources to be used within the community.

- **DGR 8 Marzo 2019 n 18-8520**: Criteria for financial support. The Regional Council Resolution n.18-8520 / 2019 defines the implementing provisions organized according to four criteria:
  1. Adoption of the memorandum of understanding of the municipalities adhering to the CE and definition of the minimum requirements of the same;
  2. Drafting of the energy balance of the CE
  3. Drafting of the strategic document for the reduction and efficiency of CE consumption
  4. Regional financial support for the CE constitution phase

1. Point 1 the protocol of Understanding and Minimum Requirements must refer to the deed of constitution of the energy community, based on the legal form chosen for the configuration, indicating the procedures for joining and withdrawing from the same in compliance with the principles of competition, transparency and consumer protection. Furthermore, it defines the role of each subject with reference to the preparation of the energy balance and the obligation for each subscriber to make available the consumption data pertaining to it.

The minimum requirements for the establishment of an CE:

A. annual electricity consumption of at least 0.5 GWh;
B. the share of energy produced annually and destined for self-consumption, through the use of public networks, not less than 70% of total production;
C. energy production from locally available renewable energy sources for at least half of the minimum 70% share of energy produced for self-consumption, understood as the energy balance of the connection points to the public grid;
D. the presence of a plurality of subjects (public and private) producers and consumers of electricity

2. Points 2 and 3 of the DGR concern respectively the "criteria for drawing up the energy balance of energy communities" and the "criteria and characteristics of the strategic document of energy communities".

The regional law indicates that the energy balance must be drawn up within six months of the constitution of the community itself while the strategic document within twelve months therefore we will limit ourselves to identifying the salient points of these criteria as they will be issues to be addressed only after the constitution of the community. energy.

Among the "criteria for preparing the energy balance" we mention:

- "the energy balance of the energy community concerns one year";
- "in addition to the energy balance, the Energy Community prepares the balance of CO2 associated with the production and final consumption of energy, adopting conversion factors recommended by the Intergovernmental Panel on Climate Change (IPCC)."

The drafting of the strategic document, which is valid for three years, is called upon to define the actions and interventions of the

CE for the short term (3 years) and long term (10 years), to achieve the goal of reducing specific consumption of energy in the various sectors of use (buildings, production processes, mobility and network services) for a share of not less than 3% per year. Other objectives are to increase the self-consumption share and the percentage of energy produced from renewable sources through the updating of the energy mix, the installation and renewal of new plants, in compliance with the objectives of air quality and environmental protection, the improvement of the dispatching service within the CE and / or modulation actions of the electrical and thermal load curve and finally, communication and awareness actions of CE members, also with respect to the opportunities for financial support existing at European, national level and regional.

3. Point 4 Financial support. the manifestations of interest of the participating municipalities in creating an energy community sent according to the terms and methods established by the provision (DD n. and 2019.

- **D.D. n. 547 del 8 ottobre 2019**: http://www.regione.piemonte.it/governo/bollettino/abbonati/2019/42/siste/00000258.htm

  In 2019 the Piedmont Region published a public notice for the collection of expressions of interest in a financial contribution in support of the establishment of energy communities.

  Which recognizes the expenses incurred for the documentation related to the establishment of energy communities, and the drafting of projects, such as project documents and reports, technical-economic feasibility analyzes and legal documents. On which a ranking is made based on the following criteria:

  3. number of municipalities and subjects involved and plurality of electricity and thermal energy producers;

4. entities of production and consumption of electricity and heat;
5. share of self-consumption and related self-consumption from FER, with reference to the minimum requirements of the D.G.R.n.18-8520;

Following the investigation, the available resources are divided on the basis of the number of expressions of interest evaluated positively and a sum of not less than 5,000.00 euros is allocated to each applicant.

3. MATERIALS AND METHODS

3.1 TERRITORIAL ENERGY PLANNING

3.1.1 TOOLS FOR TERRITORIAL ANALYSIS

The analysis of territorial classification allows to observe the characteristics of the territory, taking into consideration the connections between them at different scales and identifying critical points and opportunities. In carrying out the analysis, Geographycal Information System (GIS) tools were used through the use of ArchGis software and Qgis.

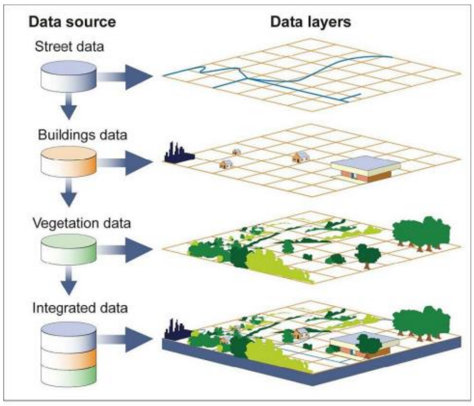


Figure 2 operating diagram for the data processing of the Geographycal Information System (GIS). Source: National Geographic Encyclopedia

Through this software the entire territory is observed according to the characteristics:

- Environmental, geo-morphological and climatic characteristics
- Socio-economic characteristics of the population
- Characteristics of the building stock and built environment

For the various characteristics, the elements that affect the quantity and quality of energy consumption and production have been identified, such as to analyze and describe more precisely the state of affairs and highlight the information useful for defining possible future intervention scenarios.

- **ENVIRONMENTAL, GEO-MORPHOLOGICAL AND CLIMATIC CHARACTERISTICS**
  - **Weather stations and geography of the territory**

For this representation, the Digital Terrain Model (DTM) raster file was used which contains information about the elevation of the terrain referring to areas of 50x50m, and the shape file of the Regional Technical Map (BDTRE, updated to 2019) from which they were derived the municipal administrative limits and the presence of the main water bodies, both available from the Geoportal of the Piedmont Region. The weather stations have been obtained the coordinates of each station from the Portal of the Regional Agency for the Protection of the Environment (ARPA Piemonte), through the meteoweb application.

- **Average altitude [m a.s.l.]**

The average altitude map was calculated using the information contained in the database of the DTM raster file for each municipality with the ArchGis Summarized value: Average tool.

- **Day Degrees and Climatic Zones**

Degree days are defined by the D.P.R. n. 412/1993 as "the sum, extended to all days of a conventional annual heating period, of only the daily positive differences between the ambient temperature, conventionally set at 20 ° C, and the average daily external temperature."

It also provides a consistent degree day value for each Italian municipality, and groups the Italian municipalities into six climatic zones. For each of them there is the duration of the heating season, that is the period of ignition of the systems and the daily time of use allowed (Table 1).

Climatic zones	Degrees Day	Heating season	
	GG	Months	Hours a day
A	<600	1 Dec - 15 Mar	6
B	600-900	1 Dec - 31 Mar	8
C	900-1400	15 Nov - 31 Mar	10
D	1400-2100	1 Nov - 15 Apr	12
E	2100-3000	15 Oct - 14 Apr	14
F	>3000	No limitation	No limitation

Figure 3. Climatic zones, Degrees Day and heating season. Source: D.P.R. n. 412/1993

- **SOCIO-ECONOMIC CHARACTERISTICS OF THE POPULATION**

This point shows the formulas used to describe the various indicators and indices of the main characteristics of the population. All the data used refer to the 2011 ISTAT census.

Indicator	Unit	Formula
Number of inhabitants	[n. ab]	Population tot
Population density	[ab / km²]	Total population / territorial surface
Old age index	[%]	(people aged 65 or over) / (people aged 0 to 14) * 100
Average age	years	For each age: (Σ average age * number of residents with that age) / total residents
Structural dependency in	[%]	[(people aged 65 or over + people aged 0 to 14) / (people aged 14 to 64 y
Foreigners	[%]	Total foreign population / Tot

Figure 4. Socio-economic characteristics of the population. Personal processing.

- **CHARACTERISTICS OF THE BUILDING HERITAGE AND THE BUILT ENVIRONMENT**

The CTR (BDTRE, updated to 2019) of the Geoportal of the Piedmont Region was used to determine the main characteristics regarding the building stock. Through the statistical code of the ISTAT territorial administrative units, with the use of the ArcGIS software, the information about the intended use of the buildings present was selected and geo-referenced. The calculated data refer to the 2011 ISTAT census and have also been geo-referenced by census section.

Indicator	Unit	Formula
Total number of buildings	[n.]	Total number of buildings
Number of residential (used) buildings	[n.]	Occupied residential buildings
Number of buildings (used) for other uses	[n.]	Buildings for productive, commercial, tertiary, tourist / hospitality use, busy services and other
Prevailing construction period	Years	-
State of maintenance of buildingsresidential buildings (very good / good / mediocre / very bad)	[%]	For each state of maintenance: (Number of residential buildings in the state of maintenance / total number of residential buildings) * 100
Residential Buildings Utilization Rate -	[%]	(Occupied Residential Buildings / Total Residential Buildings) * 100
Percentage of second homes	[%]	Homes occupied by non-residents / (Homes occupied by residents+ Dwellings occupied by non-residents) * 100

Figure 5. Characteristics of the building stock. Personal processing. Data source: 2011 ISTAT Census

3.1.2 CHARACTERIZATION OF USERS, ENERGY CONSUMPTIONS AND PRODUCTIONS

For the preparation of the energy balance after the analysis of territorial classification, the users were classified and characterized in order to create a database of energy consumption and production data. The energy data was analyzed considering four aspects: type of energy (electricity), energy direction in the balance sheet (consumption (-), production (+)) and producibility (+)), time duration (annual, monthly, daily, hourly) and environmental sustainability (RES, NON-RES).
In the first phase of compiling the energy balance, a comparison was made between energy needs (energy consumed) and energy supply (locally produced energy). Subsequently, the scenarios were evaluated, adding the energy that can be produced by exploiting local resources not yet used.
The collected data of consumption and production of electricity are expressed with the unit of measurement of the kilowatt hour [kWh]. The electricity models were drawn up according to four levels of temporal detail: annual energy data [kWh / a], monthly [kWh / m], daily and hourly energy data [kWh]. To simplify the data to be analyzed, 12 typical days were identified on the total days of a calendar year, representative of the seasonal variability and work activity of a typical week.

TYPICAL DAYS			
	Weekday		Holiday
	Monday	Wednesday	Sunday
Winter	23/01/2017	25/01/2017	29/01/2017
Spring	17/04/2017	19/04/2017	23/04/2017
Summer	24/07/2017	26/07/2017	30/07/2017
Autumn	23/10/2017	25/10/2017	29/10/2017

Figure 6. shows for example the dates selected for the year 2017

The subjects considered in the analysis were classified by distinguishing three types of energy consuming end users and three categories of subjects, as defined by the European Directives previously described.
Types of utilities:

- companies (including all sectors)
- municipal public utilities (municipalities)
- domestic users (residential)

This classification is related to energy and economic aspects: the use profile that depends on the use of energy (appliances, lighting or industrial machinery), the amount of energy required in the time interval, and the price of energy expressed in euro cents per kilowatt hour [eurocent / kWh], is different for each of the three types of users and is defined by market rules free within the parameters established by ARERA.

Subject categories:

- producers
- consumers
- prosumer

3.1.3 ENERGY PERFORMANCE

- **Energy Consumption**

This indicator corresponds to the energy consumption of the end user, deducting the conversion and distribution loss and of the primary energy conversion coefficient. It is measured in kilowatt-hours [kWh] and can be reduced on different time scales (year, month, day, hour) to distinguish electrical energy from thermal.

- **Energy Production**

This indicator corresponds to the final energy production supplied to consumers, minus losses Factory service subsystem (generation, distribution, storage, regulation, emission) and carrier Energy used. It is measured in kilowatt hours [kWh] and can be used in different time scales (year, month, days, hours), to distinguish between electrical energy and thermal energy.

- **Consumption by sector**

This indicator distinguishes the sectors to which end users belong (housing, industry, transportation, services, and agriculture sectors).

- **Per capita consumption**

The indicator is calculated as the ratio between energy consumption (total or by sector) and the number of inhabitants residing in the reference territory considered [kWh / inhabitant].

- **Self-consumption**

The indicator is calculated as the difference between the total self-produced energy (P_{tot}) and the share of self-produced energy fed into the grid (P_{imm}) [kWh]. Self-consumption is expressed in percentage terms.

(1) $$Selfconsumption\ [\%] = \frac{P_{tot} - P_{imm}}{P_{tot}}$$

3.1.4 ECONOMIC PERFORMANCE

- **Energy costs**

The indicator means the cost of energy per unit of consumption and varies according to the type of energy carrier considered and the type of end user, as well as the different use of energy in quantitative and qualitative terms [€ / kWh].

- **Energy Productivity**

The indicator is calculated as the ratio between sales (or total income) and total energy consumption, referring to the same set of consumer subjects and to the same temporal detail scale.

- **Energy price by sector**

The indicator refers to the cost of energy per unit of consumption, according to each sector of energy use in quantitative and qualitative terms [€ / kWh].

3.1.5 ENVIRONMENTAL IMPACT

- **Energy Poverty**

The indicator measures the percentage of the population that is in a state of forced inability to keep the house adequately warm [%]. Its intend those people with an equivalized disposable income below the at-risk-of-poverty threshold, which is set at 60% of the median national equivalized disposable income.

- **Energy Production by RES**

The indicator presents the final production of energy produced starting from renewable energy resources (RES), destined for the consumer user, net of the losses of the plant service subsystems (generation, distribution, accumulation, regulation, emission) and of the energy vector used. It is measured in kilowatt hours [kWh] and can be declined at different time scales (year, month, day, hour), distinguishing between electricity and thermal energy.

- **Consumption rate from RES**

The indicator evaluates the share of renewable energy consumption in gross final energy consumption, equivalent to the energy used by final consumers plus network losses and self-consumption of production plants [%].

- **Self-consumption by RES**

The indicator is calculated on a par with self-consumption [kWh] or [%]. In this case, self-produced energy corresponds only to self-produced energy from RES sources.

3.2. SOURCE OF DATA AND METHODS OF RETRIEVAL

The data used to perform the analysis are accessible databases drawn up at national, regional and municipal level.

3.2.1 EUROPEAN LEVEL:

- **PVGIS photovoltaic (Photovoltaic Geographical Information System)**

It’s an accessible, free open web provides Solar radiation and temperature, as monthly averages or daily profiles; PV potential for different technologies and configurations of grid connected and stand alone systems; full time series of hourly values of both solar radiation and PV performance for any location in Europe.

3.2.2 NATIONAL LEVEL

- **ISTAT The National Statistical Institute (ISTAT)**

It is an Italian public research body with different roles. Established in 1926, it deals with the census of the population, industry, services and agriculture, carries out sample surveys on households and economic surveys at national level. For this study, the last year of the population census, were used that referring to 2011, and the Census Sections were obtained in files (.shp format) useful for geo-referencing the information acquired.

- **ALTAIMPIANTI**

is the geographic information system of the Italian Energy Services Operator dedicated to the collection of the main renewable electricity and thermal energy production plants in Italy. The service consists of a platform accessible online, consists of the interactive map of the plants present on Italian soil and is constantly updated. The data presented in this work are updated to 2019.

3.2.3 REGIONAL LEVEL

- **ARPA Piemonte**

The Regional Agency for Environmental Protection of Piedmont is a public body placed under the supervision of the President of the Regional Council to ensure the implementation of the planning guidelines of the Piedmont Region in the field of forecasting, prevention and environmental protection. From the site, through the accessible databases, it is possible to access the historical data of each meteorological station present on the regional territory and georeferenced, regarding climatic data such as temperature, humidity, rainfall etc.

- **SIFOR**

The Regional Forest Information System has an accessible online portal through which it is possible to download information regarding the regional forest heritage. For this study, was used the 2016 Regional Forest Map.

- **GeoPortale Regione Piemonte**

The Piedmont GeoPortal consists of a catalog of metadata that can be navigated through a search service in different ways: consultation, download with related licenses for use and conversion. For the purpose of this study, the information contained in the Regional Technical Charter (CTR - BDTRE) updated to 2019 was downloaded, in formats useful for processing using GIS software (shape and raster files)

- **Municipal energy consumption**

This database is the only non-freely accessible database used in this study. It consists of the inventory of the annual consumption of electricity and heat of each municipality in the Piedmont Region. The data is expressed in kilowatt hours per year [kWh / year] and is differentiated by types of users and sectors of use. These data are made available to the Piedmont Region by the electricity and thermal energy distributors operating in the area. The data used in this study refer to the year 2017.

3.3 CALCULATIONS OF ANNUAL HOURLY CONSUMPTION, PRODUCTION AND PRODUCIBILITY PROFILES

3.3.1 ENERGY CONSUMPTION MODELS

The definition of the electricity profile was carried out following the subdivision of the three users considered in the study: companies, municipalities and households.

- **Company Users**

In order to determine company consumption profiles, it was considered appropriate to define a forecast model, as each company has a specific, variable consumption profile. Starting from the information obtained on some companies in the area, the model obtained can be applied to other companies, allowing to estimate their consumption profiles at different time scales starting from variables that are accessible and related to energy consumption.

Calculation of Profiles of daily average monthly consumption [kWh/dm]

The average monthly electricity consumption profile [kWh_{el}/dm] was calculated by dividing the total monthly electricity consumption input data [kWh_{el}/dm], by the number of days worked in each month [dd/m], as specified the working hours and the holiday calendar of each company.

The variables chosen as input data are the degree days per hour, the heated area of the building and the heat loss coefficient for the cooling season according to the company sector.

We proceeded with the estimate of the annual consumption for production [kWh_{el}/y], which coincides with the total consumption. The calculation is performed using the generalized linear regression model n, which allows you to estimate the consumption kWh_{el}/y (dependent variable) and is described as follows:

The annual consumption for production was estimated [kWh_{el}/y], which coincides with the total consumption. The calculation is performed using the generalized linear regression model n, which allows to estimate the consumption kWh_{el}/y (dependent variable) and is described as follows:

(2) $$kWh_{el}[\frac{kWh}{y}] = \beta 0 + \beta 1 * Area = +\beta 1 * Area$$

where β0 is the intercept, β1 is the angular coefficient that is multiplied by the Area [m2] (independent variable).

Using the method of least squares, available through the Solver tool of the Excel spreadsheet, the values of β0 and β1 have been optimized in order to minimize the value of the sum of the absolute errors between real consumption data and estimated consumption data.

- **Farm Users**

On the other hand, for the elaboration of consumption profiles for farms it was considered appropriate to determine a forecast model, as each farm has a specific consumption profile that is extremely variable and the available databases that have been provided with data of the farm type updated as of May 31, 2021 and SIATEL consumption data by municipality.

Starting from the information obtained from the analysis, the model can be applied to other farms and makes it possible to estimate their consumption profiles at different time scales starting from variables that are accessible and related to energy consumption.

The input data contains a list of the types of farms subdivided in the type of production if meat or milk. From this information, an aggregation was made between the two files, associating the consumption of the corresponding farm supplied by SIATEL to the municipality with each farm. From this association a *figure 3* linear regression was obtained which determines the association between the number of animals and the corresponding consumption, looking at the *figure 4* the degree of correlation between the two values is indicated by the R indicator which above 0.70 from 1 for milk and 0,9 for meat, this indicates good aggregation between the data and that the two variables vary together.

Finally, to estimate the annual consumption of a farm, having the number of cows present, it is sufficient to substitute the data in the equation of the linear regression mx + q of the line.

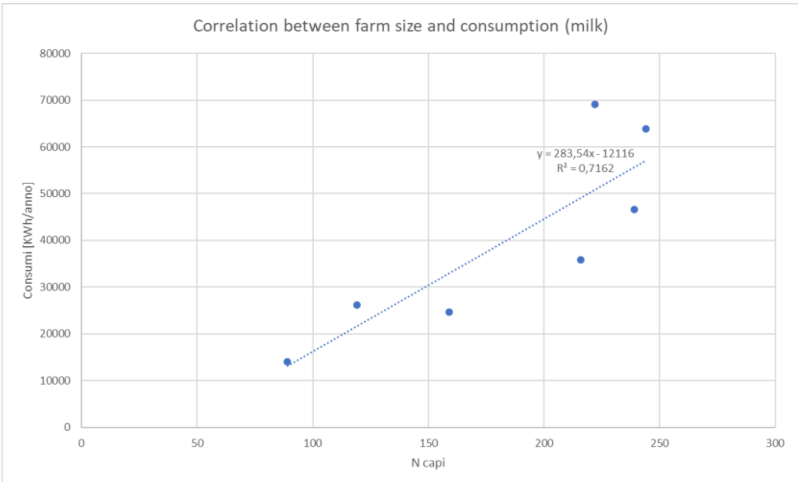


Figure 7. Correlation of livestock population and consumption (milk), personal processing

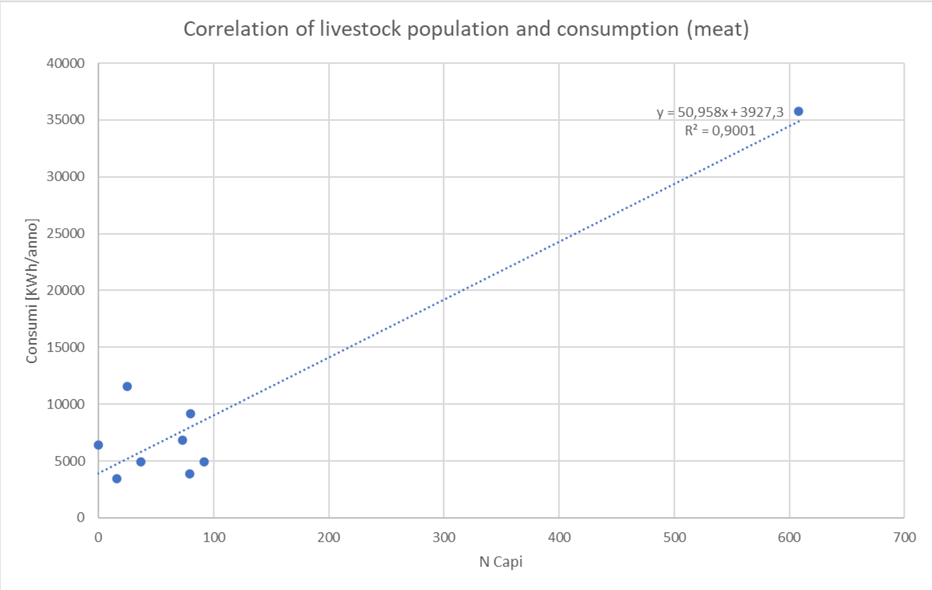


Figure 8. Correlation of livestock population n (meat), personal processing

Calculation of Profiles of daily average monthly consumption [kWh/dm]

For monthly, daily and hourly consumption, the starting data used to determine the consumption model are derived from a monitoring carried out for one week of the Asvisio Melano farm, for the days between 18/05/2021 and 25/05 / 2021.

The data obtained from this measurement is the amount of kilowatt/hour consumed every 5 minutes. From this data an hourly aggregation was made for the 7 days observed, obtaining similar behaviors *figure 6* for the hours between the different days to determine one or more consumption profiles. the average consumption recorded from Monday to Sunday was calculated by evaluating the weight of each day with respect to this average figure as shown in the following *table 4.*

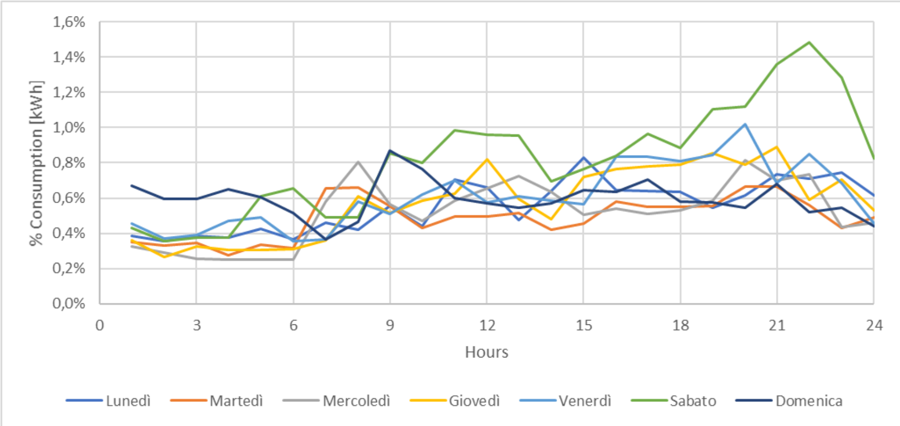


Figure 9. Consumption every 5 minutes of a typical agricultural week

As you can see from the *table 4* the values of the days Monday, Tuesday and Wednesday have very similar values between 0.80 and 0.95, Thursday and Friday are between 0.95 and 1.05, Saturday has a value greater than 1, 05 while for Sunday it is equal to 1 this because the real values coincide with the average value. the reason for this subdivision is given by the fact that the annual consumption includes two households and the energy costs of the company store. On the basis of this data and observations, Monday, Tuesday and Wednesday,

Tipologia di stabulazione	total cattle and buffalo in housing	total cattle and buffalo in housing							
		dairy cows and buffaloes in housing	dairy cows and buffaloes in housing				other cattle and buffalo in housing	other cattle and buffalo in housing	
			dairy cows and buffaloes in fixed housing with use of litter	dairy cows and buffaloes in fixed housing without the use of litter	dairy cows and buffaloes in free housing with use of litter	dairy cows and buffaloes in free housing without the use of litter		other cattle and buffalo in housing with use of litter	other cattle and buffalo in housing without the use of litter
Cantalupa	116	62	6	..	56	..	54	54	..
Frossasco	2935	120	62	..	58	..	2815	2815	..
Roletto	659	534	266	..	155	113	125	125	..
San Pietro Val Lemina	60	30	12	..	..	18	30	30	..
Scalenghe	7066	3546	327	..	1365	1854	3520	3065	455
Vigone	6215	1472	347	..	332	793	4743	3397	1346

Figure 10. number of animals per municipality and type of housing

Thursday and Friday were aggregated, while Saturday and Sunday are separated, obtaining 4 profiles *figure 6*.

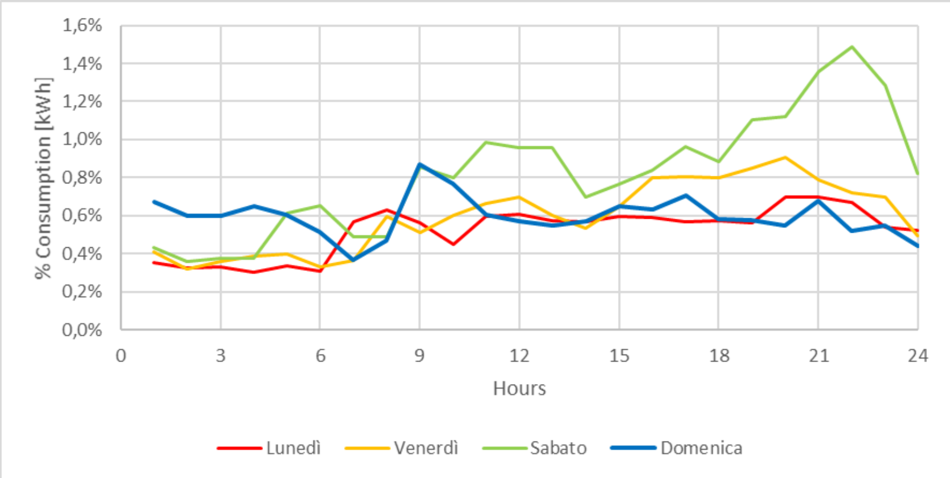


Figure 11. Average daily consumption typical of 4 days of the week

Subsequently, the 4 profiles were spread at the annual hourly / daily level, thus obtaining the monthly consumption for the farm with the sum of each month.

- **Municipal Users**

The input data consists of the amount of electricity consumed in the year by the "Buildings, equipment/tertiary and municipal systems" sector in each of the municipalities of the area under study and coincides with the annual electricity consumption figure [kWh_{el}/y].

Calculation of monthly electricity consumption [kWh_{el}/m]

Monthly electricity consumption was estimated by distributing the annual consumption according to the monthly reference profile, expressed in percentage terms.

Calculation of daily electricity consumption [kWh_{el}/d]

The daily consumption was calculated spreading the monthly data based on the working days of the municipality attributing 2 weights one for the working days which in turn changes according to the working hours and one for the holidays.

- **Domestic Users**

The data used consists of the quantity of electricity consumed during the year by the “Residential building” sector in each municipality and coincides with the annual electricity consumption figure [kWh_{el}/y]. The data was obtained from the database that the Piedmont Region receives from the local electricity distributor (Enel Distribuzione S.p.A.).

Calculation of monthly electricity consumption [kWh_{el}/m]

As regards the monthly consumption of electricity, it was determined by spreading the annual consumption figure based on the percentage of the monthly reference profile. This data was obtained from Acea Pinerolese Energia (APE) S.r.l. based on a sample of 378 households and describes the monthly consumption profile of a typical household user.

Calculation of hourly electricity consumption [kWh_{el}/h]

For the hourly consumption of electricity [kWh_{el}/h] of the typical domestic user, it was obtained through a real data provided by Acea Pinerolese Energia (APE) S.r.l., calculated the average hourly consumption [kWh_{el}/h] on 378 sample domestic users of the territory for each of the 12 standard days selected. From this data, this profile was transformed into a percentage value by calculating the consumption for each hour of the day in relation to the total daily consumption.

Calculation of daily electricity consumption [kWh_{el}/d]

The daily electricity consumption [kWh_{el}/d] was calculated as the sum of the hourly consumption [kWh_{el}/h] of each of the 12 typical days in the 24 h, this data refers to the single domestic user.

3.3.2 PRODUCTION MODELS

- **PV Model: Photovoltaic systems**

The installed power of the system [kWp] refers to the input data used, found from the Atlaimpianti portal. The photovoltaic solar systems have been divided into two groups according to the threshold of the installed power greater than 3 kWp to differentiate between domestic [<3kWp] and non-domestic systems [>3kWp] to which the following calculation model is applied.

As a first step, we proceeded with adding the installed powers to the number of systems present in each of the municipalities. To describe a more precise production model, it was chosen to keep the municipal scale, based on solar irradiation values calculated for each municipality.

Calculation of annual electricity production [kWh_{el}/y]

The annual production [kWh_{el}/y] is obtained by multiplying the sum of the installed powers [kW] by the number of hours of operation of the plant [h/y] y. This variable always refers to the "Number of equivalent hours" indicated by the PEAR for the technological system considered and is equivalent to 1150 h/y.

Calculation of monthly electricity production [kWh_{el}/m]

This calculation consists in the distribution of the annual production data [kWh_{el}/y] according to the monthly operating profile of reference, expressed in percentage terms. This profile was obtained starting from the analysis carried out with the PVGIS software which made it possible to calculate the theoretical annual [kWh_{el}/y] and monthly [kWh_{el}/m] production for each kWp installed by entering the address or the geographical coordinates of each of the municipalities under study. The profile was then transformed and expressed in percentage terms; subsequently multiplied by the annual production figure [kWh_{el}/y] which resulted in the amount of electricity produced monthly [kWh_{el}/m].

Calculation of daily electricity production [kWh_{el}/d]

For the calculation of the daily production [kWh_{el}/d], the total monthly production [kWh_{el}/m] was divided by the total number of days of each month of the year. Subsequently, the average daily production for each month [kWh_{el}/dm] was calculated as the average of the daily production of all the days of each month. Then, the average daily production for all four seasons was calculated [kWh_{el}/dm_stag].

Calculation of hourly electricity production [kWh_{el}/h]

Finally, the hourly production [kWh_{el}/h] was calculated for four typical days in relation to the four seasons. For each season the seasonal average daily production data [kWh_{el}/dm_stag] is distributed according to the reference hourly production profile [%]. This profile was calculated starting from the input data calculated with the PVGIS software of the hourly data of solar irradiance [Wh/m²] in each municipality. This data made it possible to compare the variation in the distribution of solar irradiation at different times of the day according to seasonality.

- **BIOMASS MODEL**

The input data used is the installed power of the system expressed in kiloWatt [kW], found from the Atlaimpianti portal. For this model, constant use of the system is assumed during the hours and days of each month of the year. This model repeats the same process as the one before. However, it is necessary to indicate the different value of the number of equivalent hours indicated by the PEAR [121] which for this technological system foresees 8000 h/y hours of annual operation and the consequent number of annual days of operation equal to 333 [dd/a].

3.3.3 ELECTRICAL PRODUCIBILITY MODELS

- **FOREST BIOMASS**

Calculation of the accessible wooded area

For the calculation of the energy that can be produced in the following point, it was estimated starting from the evaluation of the raw material of forest biomass available in the area under analysis. ArcGis software was used in all phases of the analysis. The main input data is the description of the regional forest heritage contained in the database " I boschi del Piemonte", downloadable in shapefile format from the SIFOR Regional Forest Information System portal and updated in 2016. The documentation contains the various forest categories present and for each of these the relative surface extension expressed in hectares [ha].

Descrizione	Superficie (ha)	%
Abetine	15.221	1,7
Acero-tiglio-frassineti	40.845	4,7
Alneti planiziali e montani	5.200	0,6
Arbusteti planiziali collinari e montani	2.547	0,3
Arbusteti subalpini	31.770	3,6
Boscaglie pioniere e d'invasione	59.932	6,9
Castagneti	204.364	23,4
Cerrete	3.967	0,5
Faggete	135.768	15,5
Lariceti e cembrete	79.537	9,1
Orno-ostrieto	12.897	1,5
Peccete	8.825	1
Pinete di pino marittimo	806	0,1
Pinete di pino montano	2.669	0,3
Pinete di pino silvestre	14.326	1,6
Querceti di rovere	38.579	4,4
Querceti di roverella	42.762	4,9
Querco-carpineti	35.039	4
Rimboschimenti	18.989	2,2
Robinieti	108.136	12,4
Saliceti e pioppeti ripari	12.475	1,4

Figure 12. Forest categories in the territory of the Piedmont Region (SIFOR)

After selecting only the wooded areas present in the various municipalities of the area of analysis, we proceeded by evaluating the accessibility of the resource. This last point is defined according to the existing forest road system and the slope of the land, as both affect the possibility of access for the means necessary for cutting and transporting the wood material. Based on the information found in the file The woods of Piedmont, three slope classes have been defined (Table), which correspond to bands of variable width accessible to vehicles via road and forest roads: terrain slopes with> 75% are excluded. since they are considered inaccessible to motorized vehicles.

Slope (%)	Widths of the bands served by roads
0 – 25	250
26 – 50	100
51 - 75	50

Figure 13. Classes of slope and relative width of the bands accessible to the means served by the roads. Source: I boschi del Piemonte

The information relating to road traffic (main and secondary) was obtained from the CTR-BDTRE of the Geoportal of the Piedmont Region, those relating to forest roads from the SIFOR portal; both in vector format. The slope of the terrain was calculated by filtering the information contained in the Digital Terrain Model (DTM 5x5m) a raster file, obtained from the Ispra portal, in which each cell corresponds to the altitude value above sea level with a detail of 5 meters x 5 meters. After having classified the area according to the three slope classes and having integrated the information relating to the presence of road and forest roads, a buffer was calculated around the latter with the relative width of the band as indicated in the Table. The result obtained consists in the creation of a layer indicating the area of the territory accessible via road and forest roads. By intersecting this information with the database relating to the wooded areas present, a new layer was obtained containing the information of only the wooded areas accessible via road and forest roads.

Calculation of the available wooded area and definition of the constraints

The forest resource available and used is the one without legal constraints imposed to safeguard and protect the environment. At thein order to verify its presence, the regional legislation in force was checked (D.G.R. n.6/2012), from which it is possible to identify two types of constraints

1- Constraint on the withdrawal of the forest resource.
2- Constraint on the installation of biomass plants.

For the first constraint, the areas indicated as unsuitable in the calculation of the forest resource are listed below:

a. Areas subject to the protection of the landscape and of the historical, artistic and cultural heritage, such as UNESCO sites, cultural, landscape, environmental and estates of the Mauritian Order, as indicated in Table 2 of the PPR with reference to Legislative Decree n. 42/2004;

b. Areas for around 50m from the peaks and mountain and foothills ridges, as indicated in Table 4 of the PPR with reference to Legislative Decree n. 42/2004.
c. Alpine woods at altitudes greater than 1,600 m a.s.l. and at distances of less than 300m from the shores of lakes and 150m from the shores of waterways, as indicated by the Galasso Law.
d. Forest areas and protected parks, such as national (Law n.394 / 1991) and regional (LR 19/2009) protected areas, seed woods (DGR n.36-8195/2008), Natura 2000 Network woods, Protection Areas special (SPA) and Sites of Community Interest (SIC) as indicated by the European Habitat Directive.
e. Areas in hydrogeological instability such as areas included within the river belt A and B, areas subject to active and dormant landslides, fans and avalanches, areas characterized by highly dangerous flooding and areas with very high hydrogeological risk, as indicated by the cartography of the Regional Hydrogeological Planning Plan in force [120]. And by the Provincial Territorial Coordination Plan (PTC2, Table 5.1).

For the second type of constraint, the areas indicated as unsuitable for the installation of biomass systems are the following. An exception is made for the installation of very small plants and in compliance with minimum requirements in terms of exploitation of cogeneration.

a. Agricultural areas and specifically the land falling into the first and second class of land use capacity, as indicated in the regional land use charter.
b. Municipalities falling within the Plan Area or in the Maintenance Area as indicated by the Regional Plan for the Protection and Restoration of Air Quality, provided for by the D.G.R. n. 41-855/2014 [95] and subsequent updates after the transposition of the Padano Basin Agreement (D.G.R. n. 42-5805 / 2017).

By intersecting the geographical areas of the constraints of the first type with that relating to the accessible wooded areas, identified previously, the result is the layer with only the accessible and available wooded areas. Furthermore, for each forest category contained in the resulting layer, the available accessible wooded area [ha] was calculated. Type II constraints have been geographically referred to in order to evaluate the areas suitable for the installation of medium or large-scale systems on a supra-municipal scale.

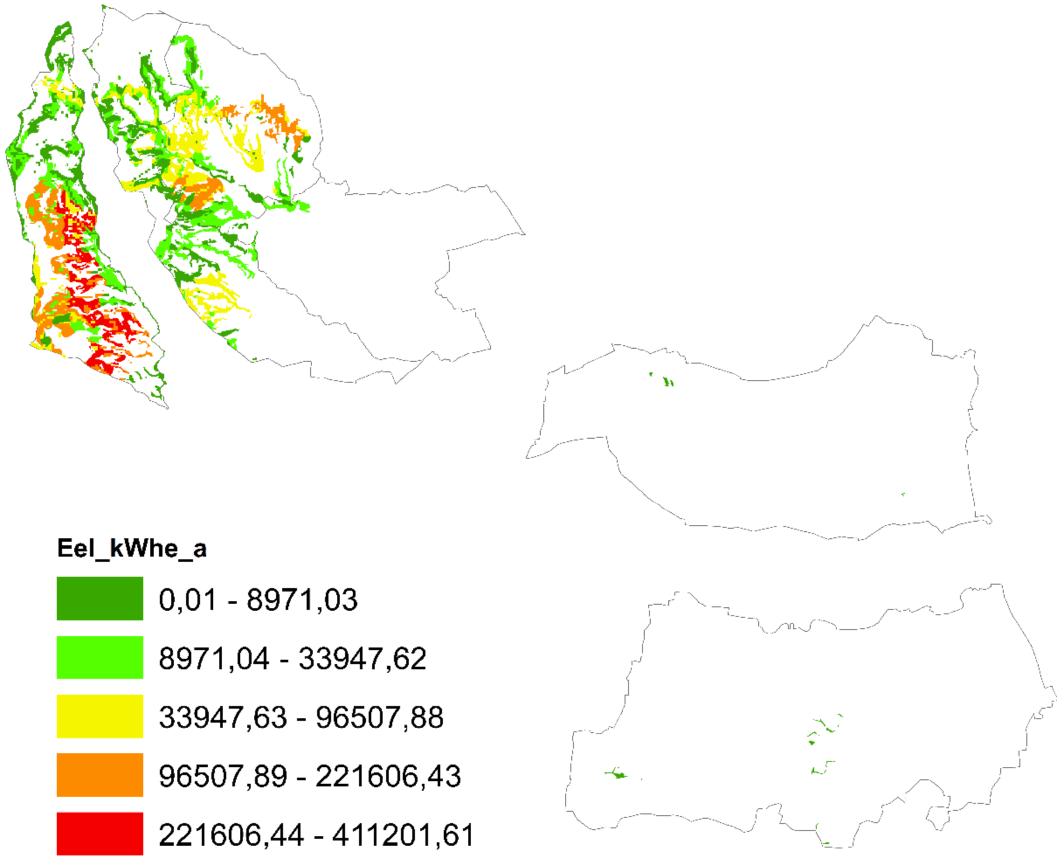


Figure 14. Electricity Producible from forest biomass

Calculation of the annual electrical producibility [kWhel / a]

For each forest category, the characteristic information of gross annual specific productivity (p) [ton / ha] and net calorific value of dry matter (H) [kWh/kg] was obtained. It is calculated by defining the quantity of mass of dry matter (mc), expressed in kilos of dry matter [kgss/y] obtainable annually from each forest category. For the calculation the inverse *(5.)* of the same *(4)* was used.

$$(3) \qquad A[ha] = \frac{m_c}{p*10^4}$$

$$(4) \qquad m_c\left[\frac{kWh}{a}\right] = A * p * 10^3$$

The wooded area (A) [ha] coincides with the accessible and available area [ha] calculated with ArcGis.

The data a obtained allow to calculate the thermal energy (E) [kWh / a] that can be produced annually from obtainable biomass (mc) [kgss / a] in relation with H that is the lower calorific value of the dry matter [kWh / kgss] characteristic of each forest category.

$$(5) \qquad E\left[\frac{kWh}{a}\right] = m_c * H$$

Below is the calculation of the thermal energy (Et) [kWh / a], the electrical energy that can be produced annually (Eel) [kWhel / y] depends on ηel [%] electrical conversion efficiency of the plant considered constant and equal to 0, 25 or 25%.

$$(6) \qquad Eel\left[\frac{kWh_{el}}{a}\right] = E * \boldsymbol{\eta_{el}}$$

Calculation of monthly [kWh_{el}/m], daily [kWh_{el}/d] and hourly [kWh_{el}/h] electrical producibility

With the result obtained with the production of electricity from biomass, it is assumed that the system is used constant in the hours and days of each month of the year. Therefore, the calculation of the electricity that can be produced monthly, daily and hourly starting from the annual data [kWhel/y], is carried out using the Biomass Model procedure for the calculation.

- **AGRICULTURAL BIOMASS**

The data necessary for the calculation of energy from agricultural biomass were obtained from the file "Land Cover Piedmont: Classification of land use 2010" (vectorial) available from GeoPortal.

The data relating to land use are indicated "LCP", which divide the regional area in sectors; not all will be useful, because only some understand the municipalities being analyzed.
In order to calculate the agricultural biomass, some fields have been grouped, according to the distinction of the agricultural areas of the PFT, as indicated.

Desc_4	Tipo
Risaie	
Vigneti	
Arboricoltura da legno indifferenziata	**Altra arboricoltura da legno**
Seminativi semplici in aree non irrigue	**Seminativi in asciutta**
Pioppeti	
Frutteti e frutti minori indifferenziati	**Frutteti**
Castagneti da frutto	
Noccioleti	
Actinidieti	
Pescheti	
Meleti	
Oliveti	

Figure 15. Distinction of agricultural areas within the PFT

Calculation of the electricity that can be produced from agricultural biomass

The calculation of agricultural waste biomass is very similar to the calculation of forest biomass. Once the area used has been determined, it must be multiplied by the unit yield, but also by a factor of "useful fraction" which considers that not all biomasses can be used energetically, because part of the waste is already reused for other purposes.

Paddies – "Risaie"

The waste that I considered are straw and husk. Straw is an inevitable by-product of cultivation, whose yield is 2.87 t / ha and the useful fraction is 60%; while the husk comes from processing in the rice industry, it is therefore important to know its producibility of raw rice, which is equal to 6.54 t / ha. Its refining produces various waste including husk, chaff and others. the waste used is the husk which is about 20% by mass of the raw rice; from which only 50-60% is actually burned, the useful fraction remains is 12% of the raw rice. For these two by-products the power lower calorific is different.

Risaie	Resa [t/ha]	Frazione utile	PCI [kWh/kg]
➢ Paglia di riso	2,87	60%	2,36
➢ Lolla di riso	6,54	12%	4,00

Figure 16. Values for rice fields - Yield and useful fraction (Ente Nazionale Risi), PCI (IPLA)

Arable land in dry conditions "Seminativi in asciutta"

The dry arable land is obtained from land cultivated with cereals, wheat, barley, oats, etc. The waste used is straw which has an average yield of 2.18 t/ha, and a useful fraction of 40%.

Seminativi in asciutta	Resa [t/ha]	Frazione utile	PCI [kWh/kg]
➢ Paglia di cereali	2,18	40%	2,36

Figure 17. Dry arable land values - Yield and useful fraction (Ente Nazionale Risi), PCI (IPLA)

Vineyards "Vigneti"

During the autumn pruning, the shoots are produced which are the thin and fragile branches of the vine. Pruning is a necessary operation for all fruit trees in order to give the plant an adequate shape; compared to forest biomass, the vineyards and orchards, although present in hilly areas even very sloping and often far from easily accessible roads, were not considered as served bands, because pruning is carried out on all trees anyway, so the whole area is " served ".

The waste from the wine industry can also be considered: the virgin stalks and pomace are recovered after pressing the grapes, and the exhausted pomace after distillation.

Vigneti	Resa [t/ha]	Frazione utile	PCI [kWh/kg]
➢ Tralcio di vite	1,45	30%	2,20
➢ Vinacce e raspi	7,05	8,2%	2,20

Figure 18. Vineyard values - Yield and useful fraction (Ente Nazionale Risi), PCI (IPLA)

Orchards "Frutteti"

As with vineyards, pruning is a necessary operation that does not involve additional operations compared to ordinary ones. The values used are the result of an average made on the main types of fruit trees.

Frutteti	Resa [t/ha]	Frazione utile	PCI [kWh/kg]
➢ Potature dei frutteti	2,20	90%	3,40

Figure 19. Orchard values - Yield and useful fraction (Ente Nazionale Risi), PCI (IPLA)

Poplar groves and wood arboriculture "Pioppeti e arboricoltura da legno"

As regards tree crops, the data are evaluated on a multi-year scale as the growth process is long compared to that of other agricultural waste and are based on the average of the various species considered.

Arboricolture da legno	Resa [t/ha]	Frazione utile	PCI [kWh/kg]
➢ Pioppeti	12	15%	2,20
➢ Arboricoltura indifferenziata	17,6	50%	2,20

Figure 20. Wood arboriculture values - Yield and useful fraction (Ente Nazionale Risi), PCI (IPLA)

Considering all these data, the following formulas were used to calculate the biomass produced:

(7) Biomass produced [t] = surface [ha] * yield [t/ha]

(8) Usable biomass [t] = biomass produced [t] * useful fraction [%]

(9) Thermal energy [MWh] = usable biomass [t] * PCI [kWh / kg]

Finally, for the calculation of the electricity that can be produced (Eel) it was only more necessary to multiply the thermal energy obtained by the efficiency of the system, assuming it was equal to 0.25 (25%), as for forest biomass.

(10) Electricity [KWh] = Thermal energy [MWh] * Efficiency of the system [0,25]

- **ENERGY FROM WASTE**

Scraps are waste as they have lost their main utility. Although they are composed of materials that can be recycled or used to produce energy, as they are combustible elements.

Through waste-to-energy plants, thermal energy can be extrapolated from waste through combustion that generates heat, from which thermal energy and in turn electricity can be obtained. Waste-to-energy is a technological innovation capable of exploiting the energy of waste, overcoming incineration. But not all waste can be used for waste-to-energy.

The results expected from this evaluation provide a general view of the situation of the territory under analysis.

Calculation of the electricity that can be produced from waste: performance and analysis of the results

The data used for this analysis were found by the Piedmont Region, which through the Regional Waste Observatory the values of "Total Production of Urban Waste per capita by Municipality" were obtained for 2017, 2018 and 2019.

the data were aggregated to the resident population data for the area under analysis to determine the tons of waste produced per year by municipality:

(11) Waste [t/year] = (Production per capita [kg/inhabitant/year] * Resident population)/1000

Calculation of the electricity that can be produced from waste

The calculation of waste biomass is very similar to that seen for forest and agricultural biomass. Calculated the quantities of waste that are produced and determined by type of waste, then the value by type multiplied by the "Renewable fraction" and finally attributed to a lower calorific value.

The percentage relating to the "renewable fraction" considers that not all waste can be used for energy, because part of it is already reused for other purposes such as recycling. The first two indicators table 14 are taken from the Urban Waste Report, whose data is managed by the ISPRA Waste Service, in implementation of an institutional task provided for by art. 189 of Legislative Decree no. 152/2006.

Componente	Contenuto (%)	Rinnovabilità (%)	Frazione Rinnovabile (%)
Organico	34.4	100.0	34.4
Carta	22.8	100.0	22.8
Plastica	11.6	0.0	0.0
Metalli	4.3	0.0	0.0
Vetro	7.6	0.0	0.0
Legno	3.8	100.0	3.8
RAEE	2.4	0.0	0.0
Tessili	5.1	50.0	2.5
Inerti	2.4	0.0	0.0
Altro	5.5	10.0	0.5
Totale	100.0	-	**64.0**

Figure 21. Average characteristics of Urban Solid Waste produced in Italy estimated by ISPRA

Average characteristics of Urban Solid Waste produced in Italy estimated by ISPRA

For the lower calorific value, the values reported in the study by the Technical University of Denmark in April 2000 are considered.

Frazione	Potere calorifico inferiore [MJ/Kg]
Carta	15.2
Plastica	40.7
Scarti di cibo	6.6
Tessuti	13.5
Legno	16.7
Pannolini	7.2
Scarti di giardinaggio	6.1
Componenti elettronici	2.4
Altre (valore medio)	6
Pericolosi	6

Figure 22.Lower Calorific Value (H. L. Erichsen, M. Z. Hauschild: Department of Manufacturing Engineering, Technical University of Denmark, April 2000.)

(12) Waste category [t] = Waste [t] * Renewable fraction [%]

(13) Thermal energy [MWh] = (Waste category [t] * PCI [Mj / Kg]) * 0.27778

Finally, to obtain the electricity that can be produced, the thermal energy obtained is multiplied by the efficiency of the system, assuming it was equal to 25%.

- **SOLAR PHOTOVOLTAIC**

For the calculation from PV we start with:

Calculation of solar radiation

The energy that can be produced with solar photovoltaics was calculated starting from the evaluation of solar irradiation in the area under analysis with the "Area solar radiation" tool of the ArcGis software.

The analysis provides for the calculation of the total irradiation incident on the horizontal surface as the sum of the direct and diffused radiation and does not consider the reflected component, but the morphology of the territory. The model can calculate some parameters related to the solar geometry.

The latter describes the apparent position of the sun as a function of the chosen temporal configuration and the value of the Azimuth and Zenith angles, relative to the geographic coordinates of the analyzed location. In this phase, the evaluation is set for each month of the year considering the hour as a unit of time. The input data necessary for the model are:

- Data of the three-dimensional elevation of the land and buildings. For this analysis the Digital Surface Model (DSM 5x5m) was used, a raster file in which each cell corresponds to the altitude value above sea level and has a detail of 5 meters x 5 meters. Information available from the Ispra portal.
- % of diffuse solar irradiation and transmissivity of the atmosphere, calculated for each month of the year.

The percentage of diffuse solar irradiation [-] is equivalent to the ratio between diffuse irradiation and global irradiation. This information can be found on the PVGIS website: by entering the coordinates or the address of the area of interest, you can access the history of the information contained in the PVGIS-CMSAF database (2007-2016) from which the global irradiation data on a surface is obtained. horizontal H (h) monthly [Wh/m²] and the ratio between diffuse and global radiation (Kd).

From these it is possible to calculate the ratio between direct and global irradiation (1-Kd) and the direct irradiation on a horizontal surface Hb (h) monthly [Wh/m²] calculated as product of H (h) monthly and the direct ratio / global.

Transmissivity (T) is the percentage of extra-terrestrial radiation that reaches the Earth's surface. Equal to the ratio between the measured global radiation (Gb, h) and the theoretical global radiation or solar constant (1367 W/m²), it is calculated with the following formulas:

(14)

$$G_{b,h} = \frac{Hb(h)}{Ore\ di\ luce}; \qquad T^{FDL} = \frac{G_{b,h}}{Costante\ solare}; \qquad T = \left(\frac{G_{b,h}}{Costante\ solare}\right)^{\frac{1}{FDL}};$$

The daily average direct irradiation Hb (h) daily [Wh/m²] is calculated by dividing the monthly Hb (h) by the number of days of the month. The hours of daily light [h] can be obtained from the Italian atlas of the solar radiation of Enea.

From the following table you can see the monthly data for the percentage of diffuse irradiation and transmissivity calculated. The months with similar results values were grouped as representative of the season and averaged these values and finally entered the ArcGis software, for a total of four simulations.

For each of them, the generated output consists of twelve raster files in which each cell is assigned the monthly value of solar irradiation incident on the horizontal surface expressed in Wh/m². To reconstruct the entire calendar year, it is necessary to extrapolate from each seasonal simulation only the raster files of the months relating to that season.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Diffuse irradiation [%]	0,53	0,46	0,42	0,42	0,43	0,38	0,33	0,34	0,39	0,50	0,53	0,53
Transmissivity[%]	0,35	0,46	0,54	0,62	0,65	0,72	0,74	0,71	0,64	0,52	0,42	0,31

	Winter	Spring	Summer	Autumn
Diffuse irradiation [%	0,53	0,46	0,41	0,35
Transmissivity[%]	0,36	0,51	0,63	0,72

Figure 23. Table 16: Diffuse irradiation [%] and transmissivity [%] values used in the study for the solar analysis of with ArcGis. Personal processing

From the data transformed from raster shapefile to point, the points relative to the buildings present in the area have been selected. These buildings were in turn divided into 3 categories based on the main intended use: Residential Area, Production Area, Agricultural Area.

The annual irradiation [Wh/m²/y] was calculated for all points as the sum of the monthly irradiation data [Wh/m²/m] excluding those that have a value lower than 1,200,000 Wh/ m²/year. We proceeded by dividing the monthly irradiation value [Wh/m²/m] by the number of days of the month, obtaining the monthly average daily irradiation [Wh/m²/dm].

Finally, to aggregate all the points falling on the surface relating to a single building, the average value of the incident solar radiation was determined, which is equivalent to the average of the values of the different points, transforming all units of measurement into kWh/m².

Constraints definition

To verify the suitability of the surfaces for the installation of PV systems, the PPR Regional Landscape Plan and the PEAR Continents Regional Environmental Energy Plan were consulted with current legislation on the subject.

The two legislative references indicate that the preference in the use of systems that do not involve soil consumption, favoring the installation of panels integrated into the roofs of buildings and indicate the suitable sites for the installation of the system on the ground, referring to what is described by the D.G.R. 5-3314/2012. In some cases, the installation necessarily requires the authorization of the Superintendency, otherwise a declaration start of activity (DIA) these cases are:

1- in the case of integrated photovoltaic systems with powers greater than 20kWp
2- in case they are localized in centers historians.

This analysis was carried out considering only the solar irradiation incident on the surfaces of the buildings, determining the amount of energy that can be produced by photovoltaic systems that can only be integrated into the roofs of the buildings. After determining the constraints, we proceeded by excluding from the total of buildings those in which there was already a photovoltaic system, previously identified on Atlaimpianti and considering 30% of the total area of each remaining building as useful for installing a panel.

Calculation of the annual electrical producibility [kWh_{el}/y]

The type of photovoltaic panel chosen for the analysis is "monocrystalline silicon" with an average yield of 18% (η) and a system performance index of 0.75 (PR). The electricity (E_{el}) produced annually by each panel was calculated with the following formula *(15.)*:

$$(15)\quad E_{el}\left[\frac{kWh_{el}}{y}\right] = PR * \eta * S * H_s$$

with S = useful surface of the panel [m²] and H_s = annual cumulative solar irradiation [kWh/m²/y].

Calcolo della producibilità elettrica mensile [kWh_{el}/m] e giornaliera [kWh_{el}/dm]

For the monthly calculation of electricity produced [kWh_{el}/m] and that produced on the average monthly day [kWh_{el}/dm] the following formula was used, replacing the previously calculated solar irradiation value (H_s). Finally, the production on the average seasonal day is calculated [kWh_{el}/m_stag] represents the average of the daily production [kWh_{el}/dm] in the months that make up each season.

Calculation of hourly electrical producibility [kWh_{el}/h]

To calculate the hourly production [kWh_{el}/h] for the 12 typical days described previously, it was necessary to define for each of the four seasons the different reference profiles, which were calculated as the ratio between the production at each hour of the day on the total daily production, expressed in percentage terms and can be obtained from the portal of the Italian atlas of the solar radiation of Enea. Since the data obtained did not distinguish between weekdays and holidays, we proceeded to calculate the hourly production [kWh_{el}/h] for each of the four seasons by distributing the seasonal average daily production [kWh_{el}/dm_stag] according to the relative profile of reference.

- **BIOGAS MODEL**

For the calculation of the biogas producibility, the data of the publications "Dairy cattle and Biogas (CRPA, 2012)" and "Biomass and energy (ENAMA, 2011)" were taken into consideration. First, it was assessed whether the possibility of exploiting cattle effluents to produce biogas is to quantify the biomass produced.

The amount of waste produced depends on 3 factors mainly:

1. number of animals on the farm
2. the effluent removal efficiency
3. the amount of straw used

For this analysis, only the 2 categories of animals with bedding for beef cows and without bedding for dairy cows were considered, as it is the most widespread housing in the area under analysis.

By determining the quantity of meat heads housed in the litter and producing manure while the dairy ones are housed without litter and produce slurry, one has the productive orientation of the farm and the number of animals present, it is possible to determine the total quantities of effluents produced daily, using the average coefficients shown in the following table.

Typology	Manure (kg / 100kg bw * day)	Average manure (kg s.s./100kg pv * day)
Dairy cows	4-12	1,1
Beef cows	3-16	9,5

Figure 24. Average per capita production coefficients of manure produced by cattle breeding

On the basis of the data in the table, 600 kg was taken as a reference for cattle in production and the weight set for this category, ie aged> 2 years. The following choice is because about 70% of the total money comes from productive garments.

For the calculation of the annual production to be spread for the 24 hours, the annual calculation model of the Biogas consumption was performed. Furthermore, for how much phase was the calculation simpler as the animals produce wastewater during the day it would be enough to divide the total produced daily by 24.

This method was also performed to determine the colatile solid component (SV) or the quantity of organic substance contained in the biomass potentially transformable into biogas taking into consideration the following table.

	Sewage [%]	Manure [%]
Dry matter (ST)	8,2	21
Organic substance (SV)	73	79

Figure 25. % organic substance contained in the biomass potentially

Once the result has been obtained, it is possible to determine the volume of extractable biogas based on the conversion coefficient shown in the following table.

Specific biogas production [m^3/t SV]	
Cattle effluents	300-450

Figure 26. specific Biogasproduction [m3/SV]

To determine the maximum biogas production, it is decided to use the highest value of the indicated range as a multiplication factor, i.e. 450 m^3 of biogas per ton of volatile solids produced.

Knowing that biogas is an energy carrier that can be used mainly in three ways:

- as a fuel in a boiler for thermal energy production
- as a fuel in an engine driving generator for the production of electricity only
- and finally it is also possible to produce in a combined way thermal and electric energy through systems of con generation.

To estimate these possibilities, fixed parameters taken from the literature and data from the technical data sheet of an engine (Jenbacher J316 with 1.119kW of power) were adopted as references TABLE:

Parameter	Value	Unit of measure
Lower specific heat Biogas	5,57	kWh/m^3
Lower specific heat Methane	9,59	kWh/m^3
Methane content in biogas	55	%
Motor electric efficiency	37,5	%
System operating hours	7200	h
KW plant cost <100	7000	€/kW
Plant cost 100 <kW <1000	4000	€/kW

Figure 27. fixed parameters taken from the literature and data from the technical data sheet of an engine (Jenbacher J316 with 1.119kW of power)

The yield of the plant is the product between the electrical efficiency of the motor and the lower calorific value of the biogas expressed in kWh/m^3; from the product of the cubic meters, more is the electrical yield, the electrical energy that can be produced is obtained, estimated in kW. By dividing the result by the number of operating hours of the plant, the power of the plant is obtained in kw.

4. CASE STUDY

4.1 TERRITORIAL FRAMEWORK

4.1.1 GENERAL OVERVIEW

The territory under analysis is located in the Piedmont Region in the V homogeneous zone of the Metropolitan City of Turin (here "Area V") as shown in the following *figure28* and coincides with the six municipalities (Cantalupa, Frossasco, Roletto, San Pietro Val Lemina, Scalenghe and Vigone).

The area of ambit V has an area of 1,348 km^2 of which the six municipalities coincide with an area of approximately (see surface 6 municipalities GIS), includes 47 municipalities and a total population of about 150,000 inhabitants of which 17,400 are from the EC (Istat data updated to 2011).

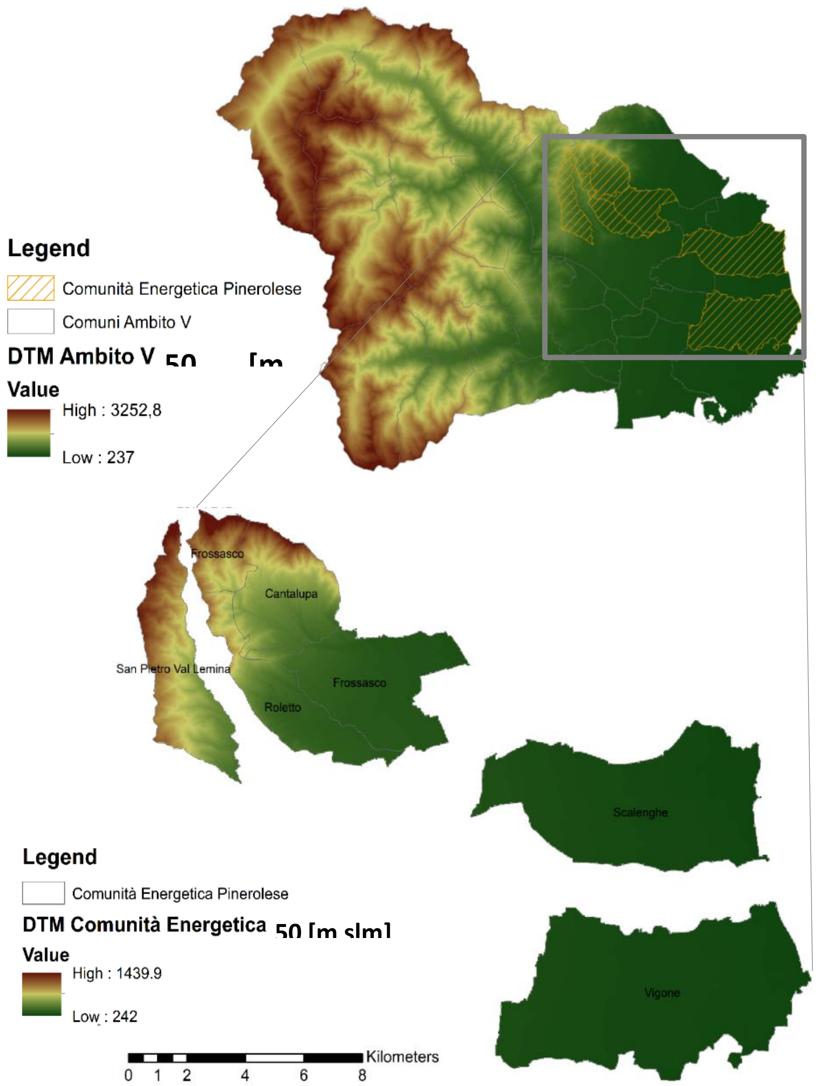


Figure 28. territorial framework area 5 and the six municipalities of the EC6

As can be seen from the previous fi*gure 28*, the energy community presents a semi-homogenous morphology, mainly including flat areas in the South, South-East and North, North-West are the mountain and foothills that touch 3 municipalities.

4.1.2 ENVIRONMENTAL, GEOMORPHOLOGICAL AND CLIMATIC CHARACTERISTICS

- **ALTIMETRIC AREAS [M.S.L.M.]**

The average height of the energy municipalities is equal to 350 m above sea level, as can be seen in the following Figure.

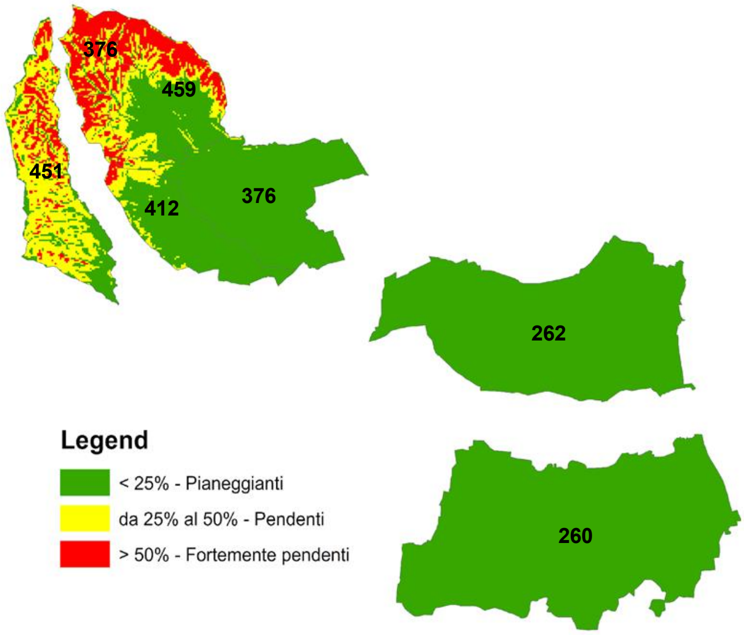


Figure 29. •ALTIMETRIC AREAS [M.S.L.M.]

- **DEGREES DAY AND CLIMATIC ZONES**

From the calculation of the Day Degrees (GG), each municipality has been assigned the corresponding climatic zone. As can be seen from Figure 48, the municipalities under analysis are part of a climatic zone which is in turn subdivided into 2 climatic zones: the climatic zone E2 and the climatic zone E3. In both cases, the heating season lasts from 15 October to 14 April, it is assumed that the system will be used for 14 hours a day and for a total of 183 days a year.

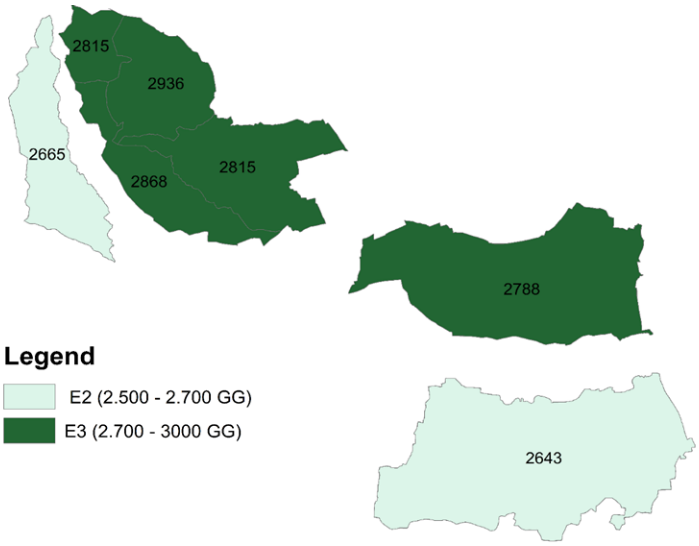


Figure 30. DEGREES DAY AND CLIMATIC ZONES

The annual Degree Days and the climatic zones to which they belong are reported for each municipality in Area V. Personal processing. Source: D.P.R. n. 412/1993 [Ref DPR412]

Zona Climatica	Gradi Giorno	Stagione di riscaldamento	
	GG	Mesi	Ore al giorno
A	<600	1 Dic - 15 Mar	6
B	600-900	1 Dic - 31 Mar	8
C	900-1400	15 Nov - 31 Mar	10
D	1400-2100	1 Nov - 15 Apr	12
E	2100-3000	15 Ott - 14 Apr	14
F	>3000	No limitazione	No limitazione

Table 27. climatic zones, degree days and heating season. source: d.p.r. n. 412/1993 [rifdpr412

- **METEOROLOGICAL STATION**

About three quarters of the Pinerolo area is characterized by mountain areas. Within the area there are 14 weather stations of the ARPA Regional Agency for the survey of climate data, most of which are located in mountain areas.

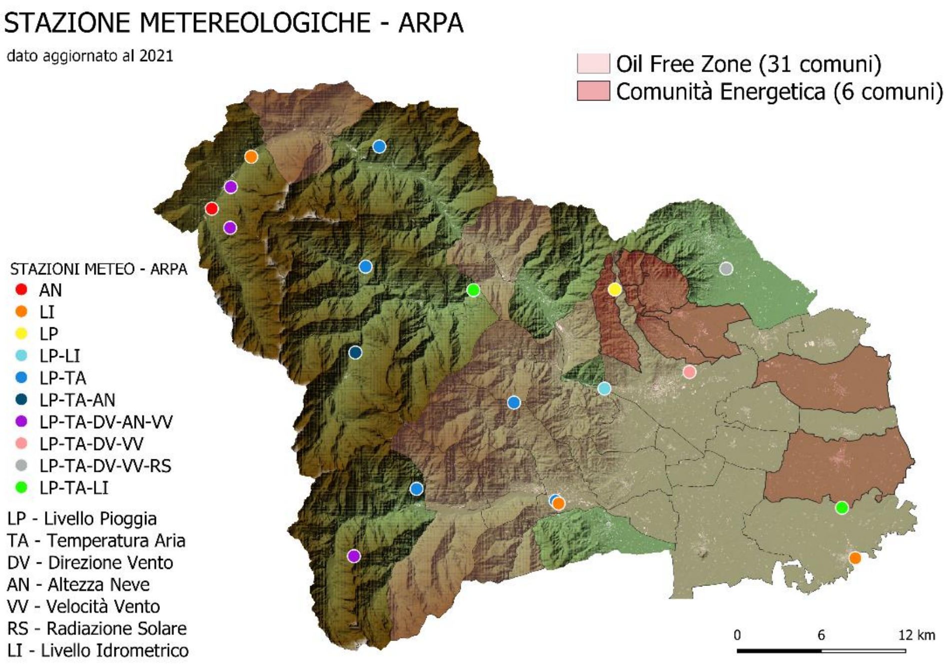


Figure 31. Morphography of the territory and meteorological stations. Data source: Piedmont Geoportal and Piedmont ARPA Portal

4.1.3 SOCIO-ECONOMIC CHARACTERISTICS OF THE POPULATION

The following table 28 shows the main socio-economic indicators. The average population density of the EC is slightly lower than the regional average and higher than the average density of area V.

Indicatori	Piemonte	Ambito V	CE Pinerolese
Numero Abitanti (ISTAT 2011)	4.363.916	149.249	17.306
Densità Abitativa [ab/km2]	172	111	137
Indice di vecchiaia	231%	219%	190%
Età media	48 anni	48 anni	46 anni
Indice di dipendenza strutturale	65%	66%	59%
Stranieri	6,9%	3,9%	3,6%

Table 28. Socio-economic characteristics of the population (ISTAT 2011 data)

As can be seen from the *figure 32* that the areas with a high rate of population density correspond mainly to the foothills in relation to the consistency of the buildings.

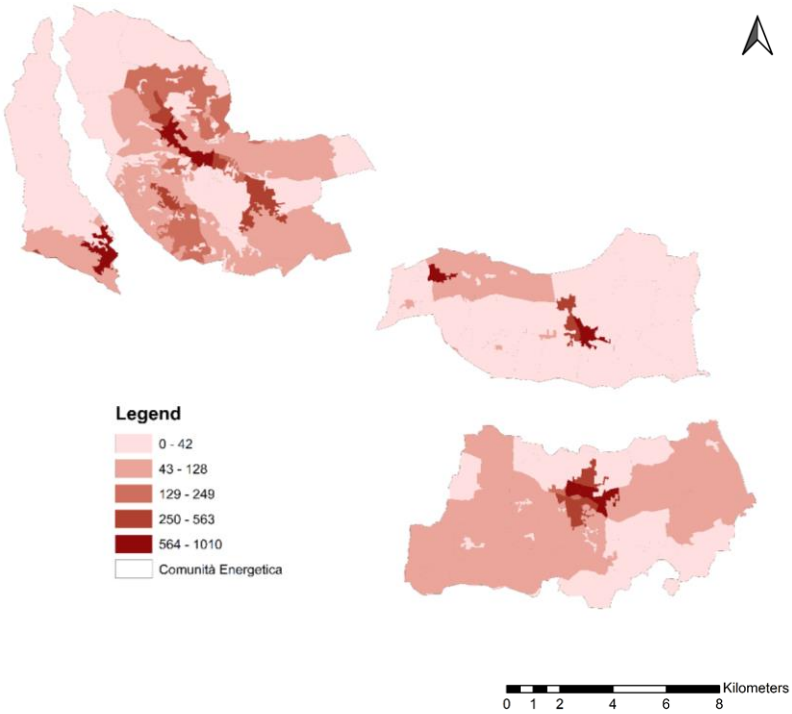


Figure 32. Population density. Data source: ISTAT [Ref ISTAT 2011

4.1.4 INTENDED USE OF THE BUILDING

The following table highlights the main characteristics of the building and there maintenance status of the area under analysis compared with the data relating to the area under study (Area V) and the regional ones.

		Piemonte	Ambito V	CE Pinerolese
Numero di edifici totali		1135209	47.395	5.874
Stato di manutenzione degli edifici residenziali	ottimo	34,1%.	39,3%	36,9%
	buono	50,5%	46,5%	51,5%
	mediocre	13,8%	12,7%	10,6%
	pessimo	1,6%	1,4%	1,0%
Tasso di utilizzo degli edifici residenziali		78,6%	73,9 %	88,9%
Percentuali di seconde case		21,4%	26,1%	11,1%

Table 19. Characteristics of the buildings (ISTAT data updated to 2011)

The calculation of these data is useful to deduce the materials used, the construction type of the buildings, to establish the consumption profile as can be seen from the following maps Construction period and intended use of the buildings.

Features such as the prevailing construction period allow you to make very general assessments about the technological systems and the use of building construction materials, also about the current legislation of the time and the mandatory energy performance standards.

The state of maintenance of the buildings, on the other hand, indicates the consistency of the building stock that requires redevelopment interventions, to which evaluations from an energy point of view can be added.

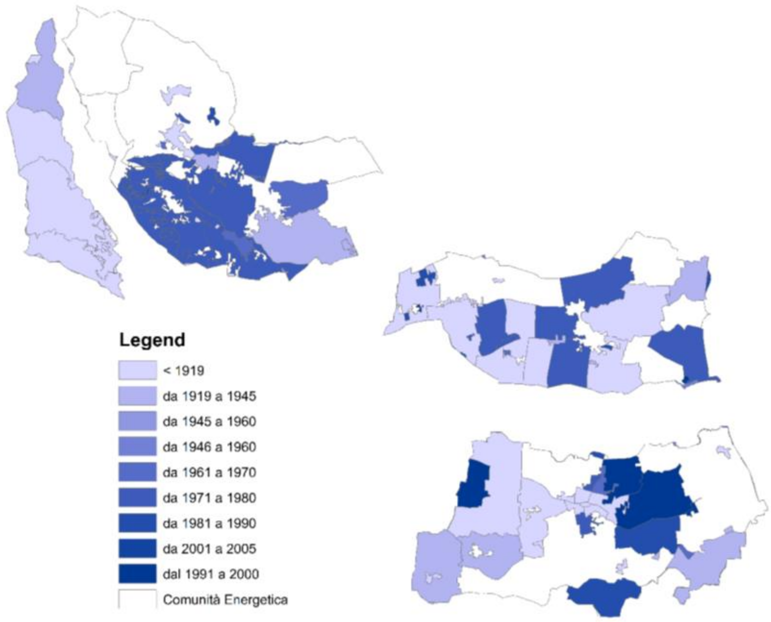


Figure 33. Prevailing construction period of residential buildings. Personal processing. Source: BDTRE 2019 and ISTAT 2011.

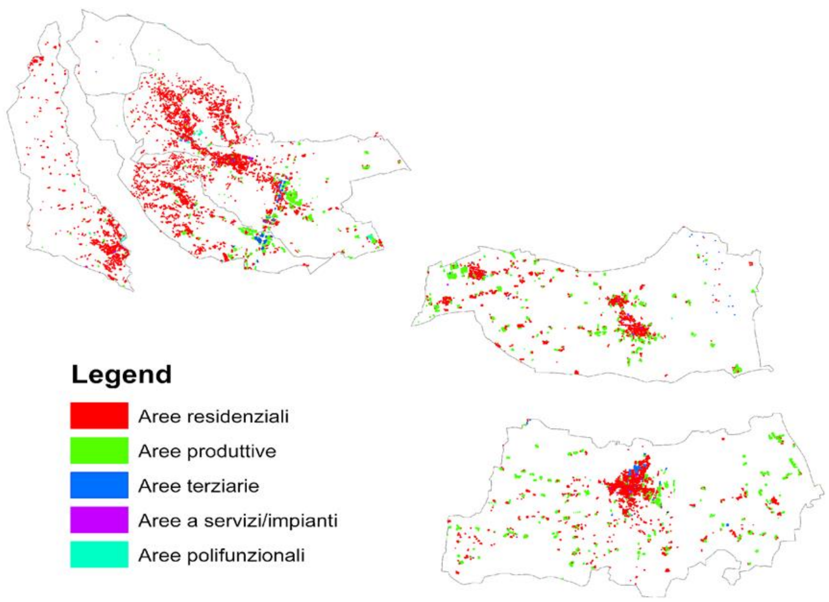


Figure 34. Main intended use of the building stock. Personal processing. Source: BDTRE 2019

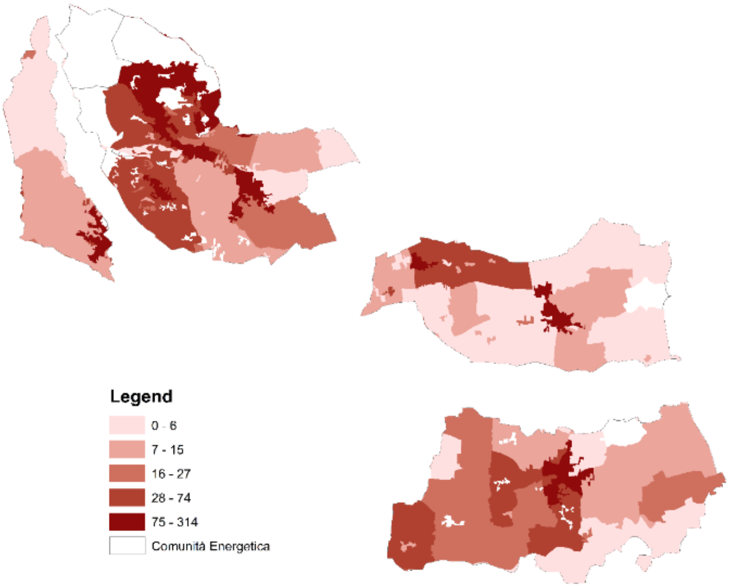


Figure 35. Number of housing units by census section. Personal processing. Source: BDTRE 2019

4.2 ENERGY FRAMEWORK

4.2.1 ENERGY BALANCE

The following paragraph shows the municipal consumption belonging to the area under study (EC). The graphs shown have analyzed the annual consumption data available from SIATEL for the types of users for the years 2017, 2018 and 2019 which are divided into:

- Domestic non-residential
- Household Residential
- Not Maid

Only for the municipality of San Pietro Val Lemina the consumption data for the years 2017, 2018 and 2019 were not provided as for the other municipalities, and for Vigone only the consumption was given without specifying the subdivision by type, while for the four other municipalities detailed data were obtained.

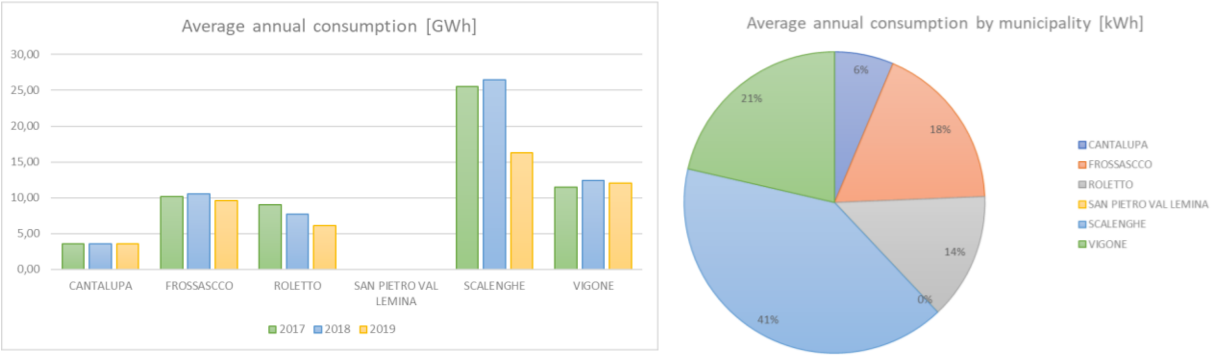


Figure 36. Average annual consumption [GWh]

As can be seen from the *figure 36* that the municipality of Scalenghe consumes 41% of the EC total, followed by Vigone and Frossasco. This data is justifiable by the presence of the Smat company which is part of non-domestic users and consumes a large amount of electricity annually figure 37.

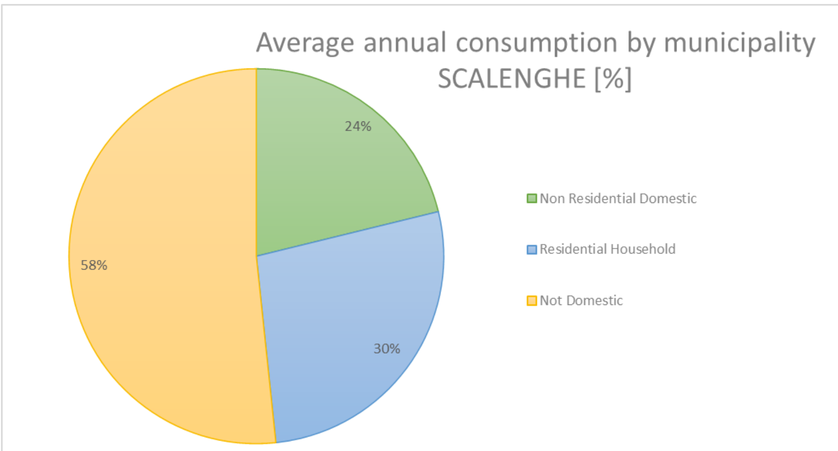


Figure 37. Average annual consumption by muncipality Scalenghe [%]

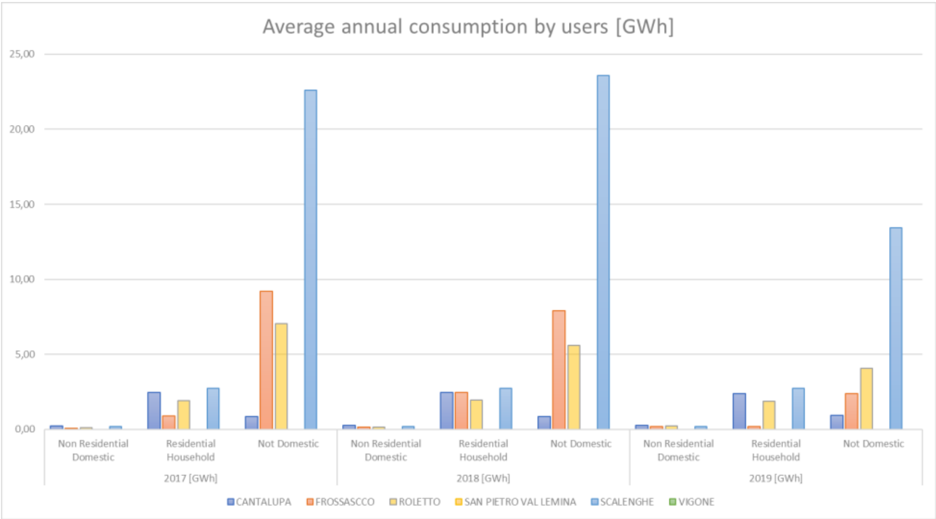


Figure 38. . Average annual consumption by users [GWh]

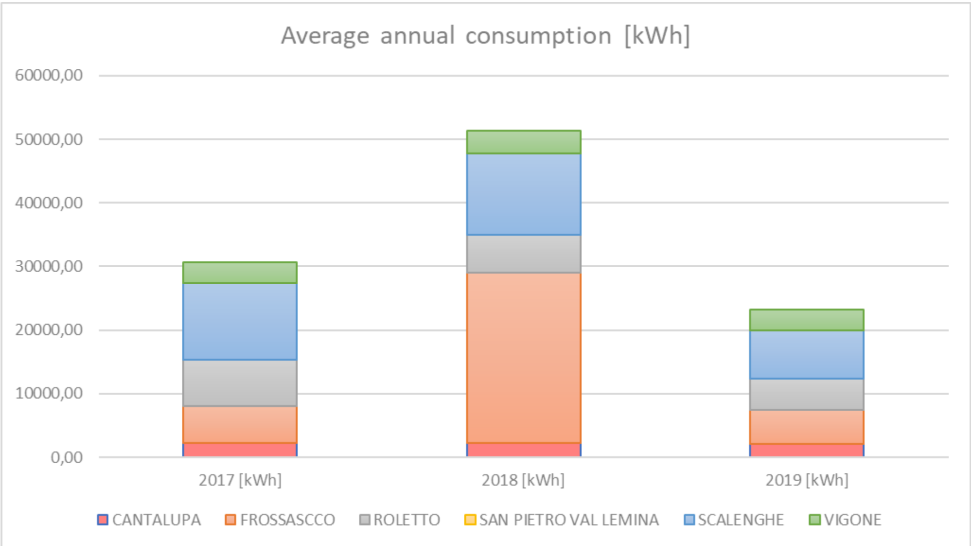


Figure 39. . Average annual consumption [kWh]

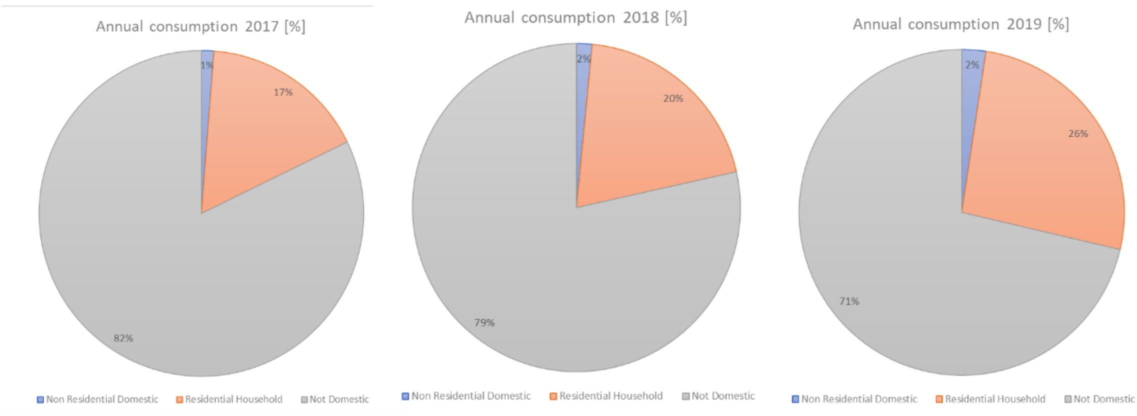


Figure 40 AVERAGE CONSUMPTION PER YEAR

4.2.2 FRAMEWORK OF THE ELECTRICITY NETWORK

For the assessment of membership and compliance with the requirements of the EC in reference to the L.R. 12/2018, it was analyzed whether the belonging of the users involved in the context of the EC6 to the same area of the electricity network.

To assess this requirement, reference was made to available, accessible information of the regional technical map BDTRE 2019 (Layers of the Basic Cartography-Network of subservices-Node of the Electricity Network) it was possible through this information to reproduce figure 40.

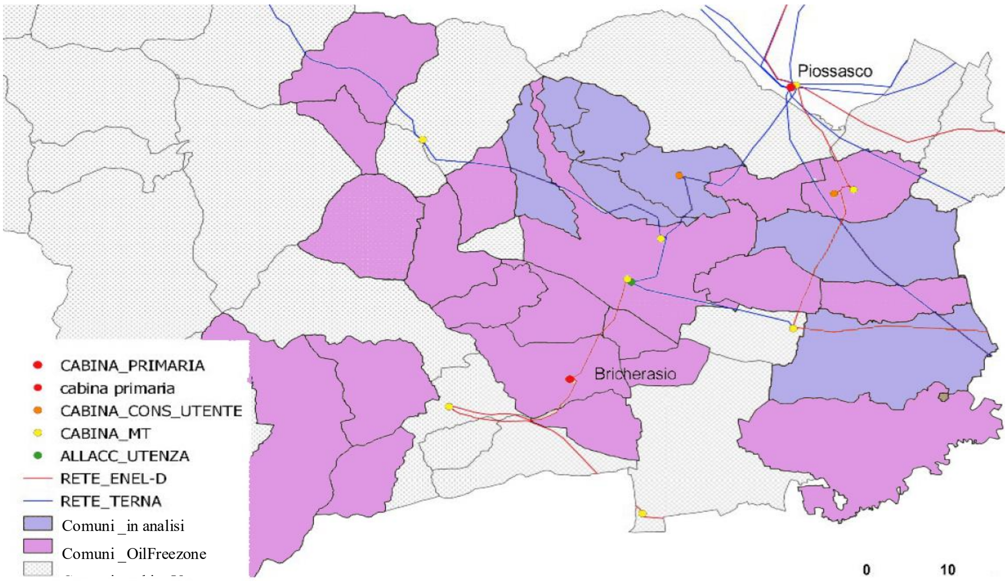


Figure 41. Extract from BDTRE, Nodes of the electricity network, Piedmont Region Geoportal. Represents the high voltage grid divided according to the ownership of the supplier, Enel E-Distribuzione (in red) and Terna (in blue) and the substations (transformation

The grid corresponds to the portion of the high voltage (HV) electricity grid, falling within the territory under analysis and managed in part by the distribution service provider (E-DisIntribuzione S.p.A.) and in part by the transmission service provider (Terna S.p.A.). The various nodes present correspond to the HV/MV energy transformation cabins defined as Units of branch/transformation-primary cabin (red dot).

4.3 CONSUMER PROFILES

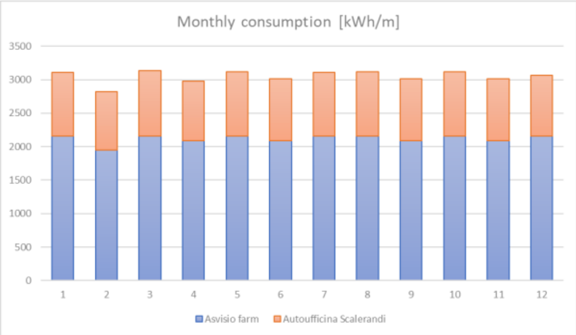
This paragraph presents the results of the models for calculating the electricity consumption profiles described above in materials and methods, assessed for each type of user and for each of the scenarios identified. The following data refer to the evaluation carried out for a selection of subjects including CE6; as they vary according to the resources used due to the scarcity of some files provided and as different data useful for the following analysis have been provided only annually and not for each single building in the area.
In the following paragraphs we proceed to the description of the various profiles for the resources used and in some cases we analyze in more detail one municipality compared to another on the basis of the material obtained from the municipality and the various bodies involved.

4.3.1 COMPANY USERS

The company users involved in the different scenarios (PV and Biogas) are mainly the ASVISIO company located in the municipality of Scalenghe and Autoufficina Scalerandi located in the same municipality. Their consumptions have been processed according to their function for the self-workshop the method described above was applied for general business users, while for the Asvisio company what indicated in the paragraph of the calculation methodology for agricultural users was always carried out, as consumption was processed based on one week of monitoring.

- **CAMPANY USERS**

Thanks to the model developed that can be applied to various other business users, the average consumption profile *figure 41* and the average daily consumption per month *figure 41* were obtained.



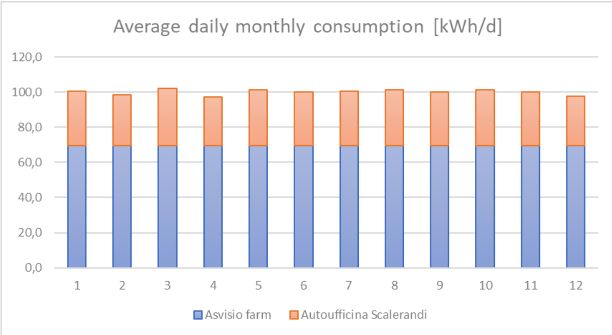
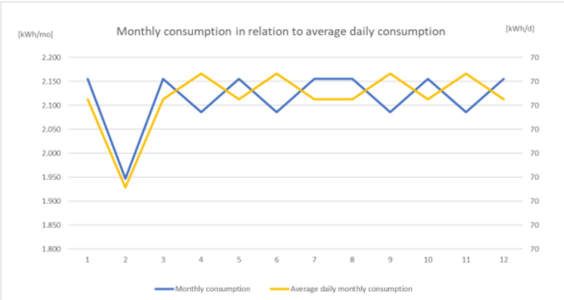


Figure 42. Total monthly consumption of the 2 companies (left) and average monthly daily consumption (right)



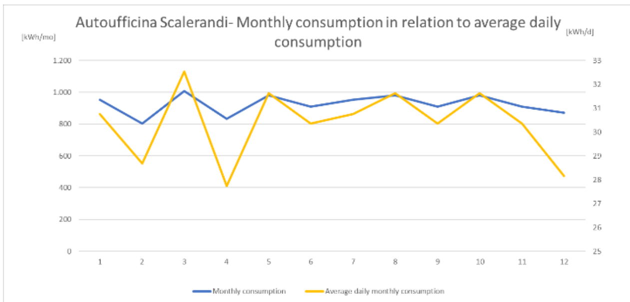


Figure 43. Asvisio farm - Monthly consumption in relation to average daily consumption (left) and Autoufficina Scalerandi - Monthly consumption in relation to average daily consumption (right)

- **FARM USERS**

For the calculation of consumption, as previously mentioned, the input data that were used are those referred to a week of monitoring of the Asvisio farm and the data of the type of farming by municipality, obtaining a reliable standard profile for farms due to the lack of other data.

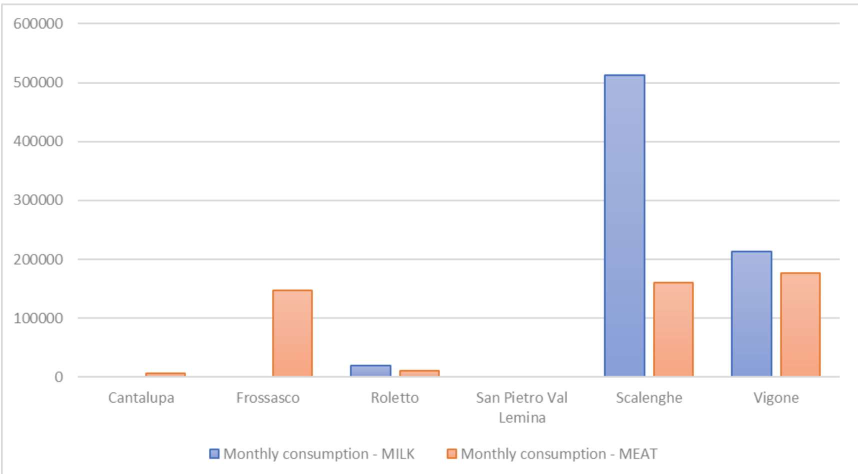


Figure 44. Farm type annual consumption by municipality [kWh]

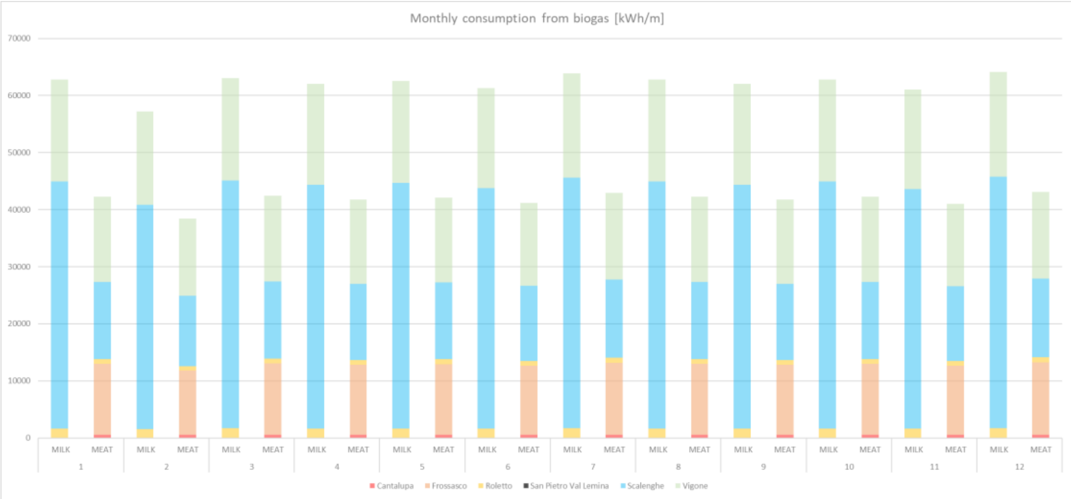


Figure 45. Monthly consumption from biogas

DAILY AND HOURLY CONSUMPTION FOR COMPANY USERS

The daily and hourly electricity consumption of the company refers to the typical seasonal days for each municipality highlighted by the calculation of the annual daily consumption Figures 85-90.

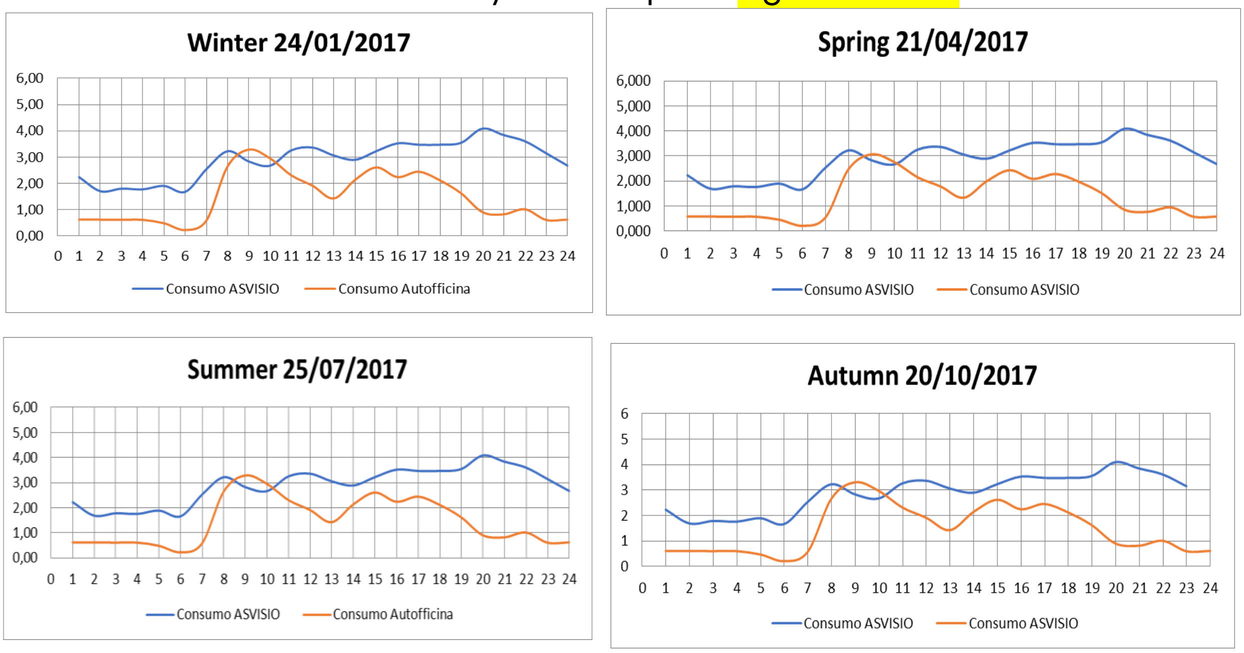
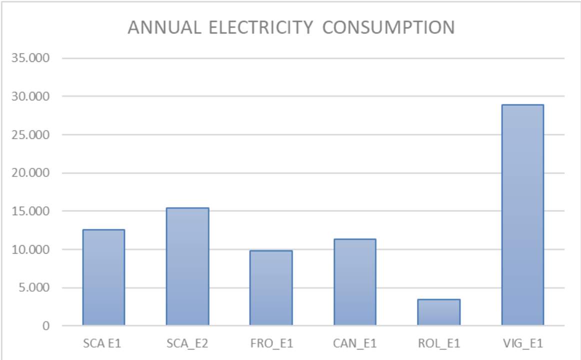


Figure 46. The daily and hourly electricity consumption of the company refers to the typical seasonal days

- **MUNICIPAL USERS**

The following graph shows the annual consumption of the various municipal buildings considered in the different scenarios. The data calculated in reference to the year 2017 are the following



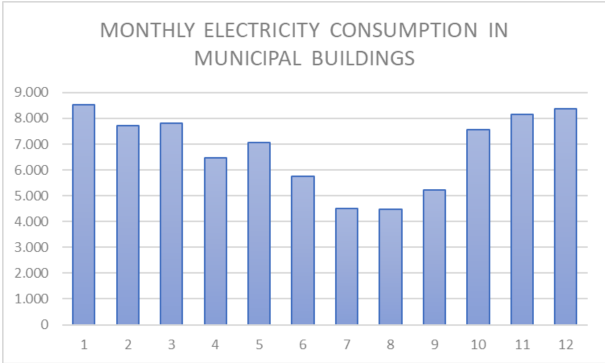
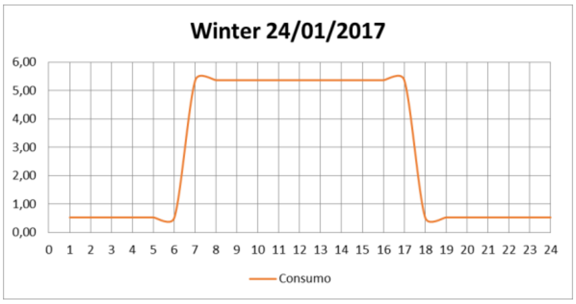
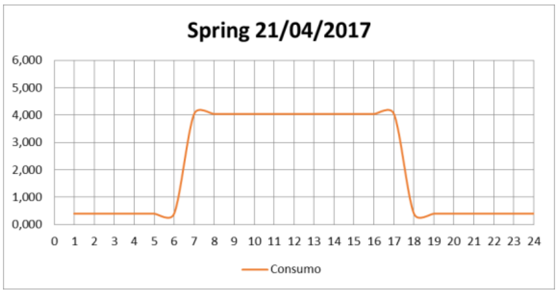
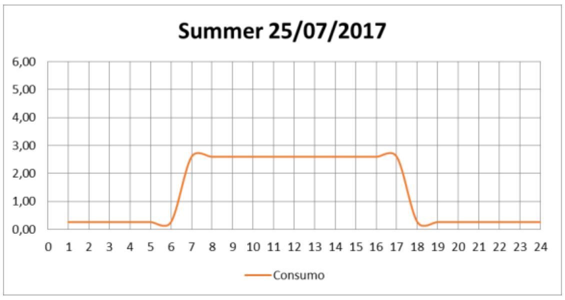


Figure 47. the annual consumption of the various municipal buildings







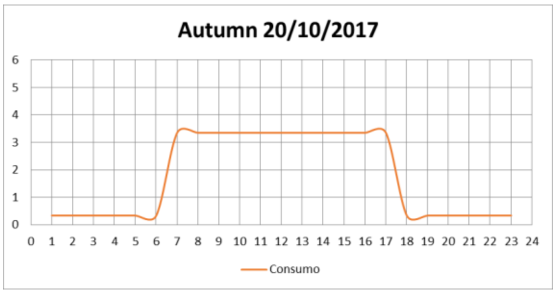


Figure 48. A typical day of consumption for municipal buildings

- **HOUSEHOLD UTILITIES**

Annual and monthly consumption

The annual electricity consumption of households in the EC6 is equal to 17,279 MWh/y calculated with reference to the year 2017. The calculation method indicated above has been used. The following figure represents the annual and monthly consumption of residential users considered in the scenarios present in the municipality of Scalenghe.

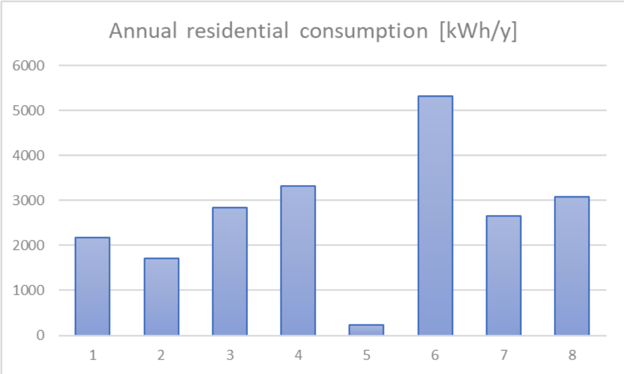


Figure 49. monthly consumption of residential users

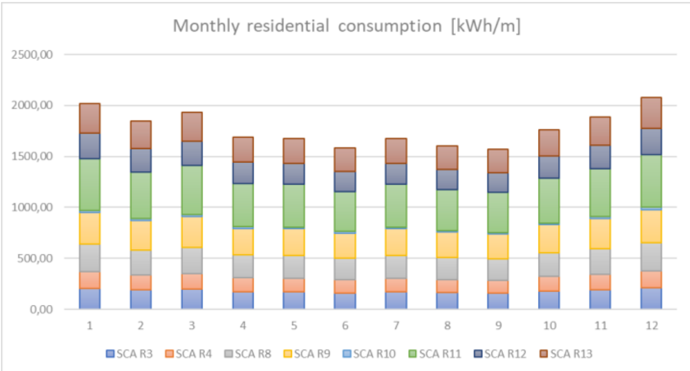


Figure 50. Annual residential consumption [kWh/y] (left), Monthly residential consumption [kWh/m] (right)

DAILY AND HOURLY CONSUMPTION

For domestic users in the municipalities of the study area, the daily electricity consumption and the electricity consumption per hour are defined, with reference to each weekday (Mon and Wed) and public holiday (Sun) of the four seasons of the year. The figures below show the hourly consumption of domestic users in the municipalities.

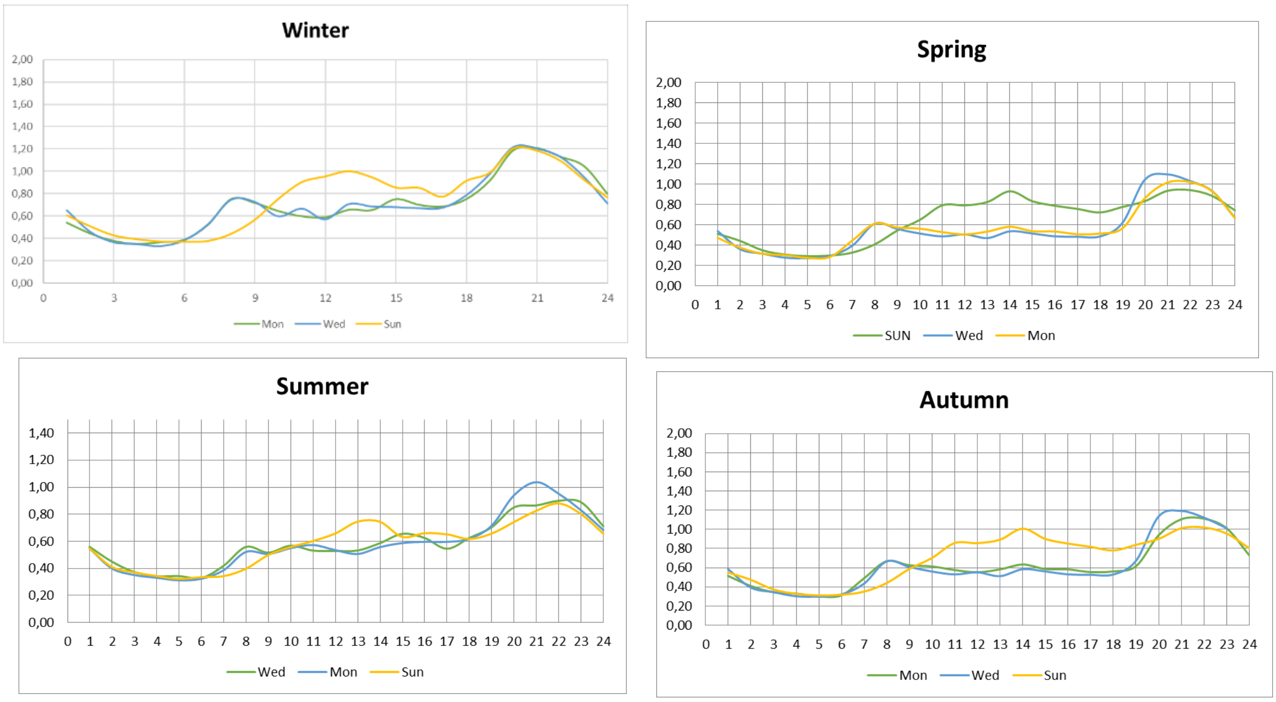


Figure 51. the daily electricity consumption and the electricity consumption per hour are defined, with reference to each weekday (Mon and Wed) and public holiday (Sun) of the four seasons of the year.

4.4 PRODUCTION PROFILES

4.4.1 ELECTRICITY PRODUCTION PROFILES

The following analysis consists in the evaluation of different scenarios in the current state of the CE6 Area, in order to observe the collective hourly self-consumption between the various participants and quantify the energy exchange, the withdrawal necessary from the electricity grid to cover the missed demand. and the production surpluses placed on the network. Furthermore, the hourly data allows some preliminary economic assessments. For the creation of the budget, the hourly consumption and production profiles calculated according to the methodology were used, from which hourly profiles were created that include a typical user for each of the three categories of consumer (corporate, municipal and domestic) and a production profile for the different available energy resources considered.

- **Creation of typical time profiles**

Typical domestic users
The data used are obtained from SIATEL data, from APE s.r.l. and data from the 2011 ISTAT census.
The hourly consumption of a family in a house with an area equivalent to 43.46m2 per occupant, consisting of 2.15 people per household.

Municipal user type
The main uses of electricity shared by all municipal utilities in the area were considered, relating to the public services offered; moreover, consumption refers to the headquarters of the municipal offices and the elementary, middle school and kindergartens.

- Per capita hourly consumption of the municipal building [kWh / total inhabitants]
- Per capita hourly consumption of the primary school building [kWh / total inhabitants]

Typical business users
The user data refer mainly to the data of the two companies located in the municipality of Scalenghe.

- Azienda agricola Asvisio

- Autofficina Scalerandi.

- **Electricity production**

The plants for the production of energy from renewable sources located in the territory of analysis were extracted from the portal of the GSE Atlaimpianti in.
The calculation of the annual, monthly and daily production values was performed using the application of different models depending on the type of system.

	PV Kw	BIOENERGIE kW	TOTAL RES [MWh]	Total CONSUMPTIONS	Self sufficiency
CANTALUPA	475,82		20,497	31,444	65%
FROSSASCO	4071,44		15,383	7,64	201%
ROLETTO	1577,47		23,717	24,654	96%
SAN PIETRO VAL LEMINA	300,06		23,99	13,02	184%
SCALENGHE	2841,08	200	16.836	19,128	88%
VIGONE	2503,63	526	11,413	4,544	251%

Table 30 Energy production for each source present in the area

- **Impianti solare fotovoltaico**

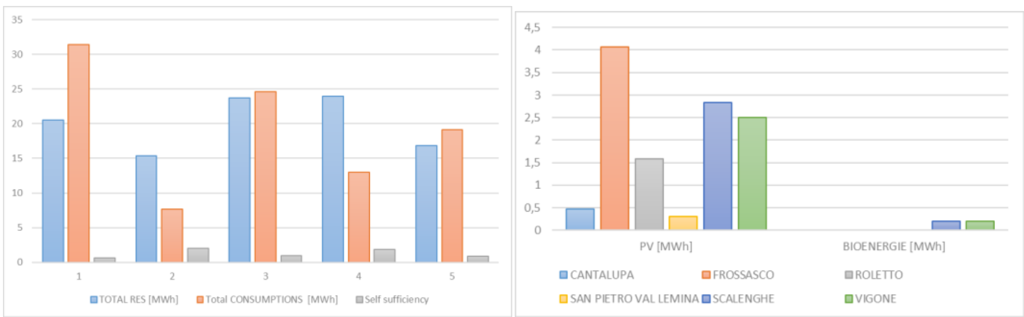


Figure 52. Consumption and production for consumption

4.5 PRODUCIBILITY PROFILES FROM REC

- **BIOGAS**

By applying the calculation method described above, it was possible to calculate the consumption and energy that can be produced for the farms in the area under analysis.
For this calculation, farms with a number of heads greater than 50 were considered, because it is disadvantageous to create a small / medium-sized plant given their high investment cost compared to medium-large ones.

		TOT_CAPI	KWHe
Cantalupa	**Milk**	0	0,00
	Meat	54	6678,9937
Frossasco	**Milk**	0	0
	Meat	2815	147372,95
Roletto	**Milk**	113	19923,84
	Meat	125	10296,98
San Pietro Val Lemina	**Milk**	18	0
	Meat	30	0
Scalenghe	**Milk**	1852	513003,753
	Meat	3065	160112,354
Vigone	**Milk**	793	212732,544
	Meat	3397	177030,28

Table 31. Energy consumption, number of garments and type of production for each municipality

Calculated the consumption and production data (table) divided between heads of milk and meat for an hourly daily annual detail.

		TOT_CAPI	C_KWHe	P_kWh	Extraproduzione kWh	Uncovered demande dkWh	SC self-consumption	Mancato acquisto energia €	Energia immessa in rete €	Spese di prelievo €	RICAVI €	SPESE €	Indice SCI	Indice SSI
Cantalupa	**Milk**	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Meat	54	6678,99	63211,66	56532,66	0,00	6678,99	1001,85	2888,64	0,00	3890,49	0,00	0,11	1,00
Frossasco	**Milk**	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Meat	2815	147372,95	3295200,22	3147827,27	0,00	147372,95	22105,94	160886,31	0,00	182992,25	0,00	0,04	1,00
Roletto	**Milk**	113	19923,83584	111390,52	91466,68	0,00	19923,84	2988,58	4671,95	0,00	7660,52	0,00	0,18	1,00
	Meat	125	10296,98	146323,28	136026,29	0,00	10296,98	1544,55	6951,60	0,00	8496,15	0,00	0,07	1,00
San Pietro Val Lemina	**Milk**	18	0	17743,62	17743,62	0,00	0,00	0,00	907,04	0,00		907,04	0,00	0,00
	Meat	30	0	35113,58	35113,58	0,00	0,00	0,00	1794,93	0,00	1794,93	0,00	0,00	0,00
Scalenghe	**Milk**	1852	513003,7532	1825621,63	1312617,88	0,00	513003,75	76950,56	67003,36	0,00	143953,93	0,00	0,28	1,00
	Meat	3065	160112,3536	3587437,21	3427336,09	11,23	160101,12	24015,17	175167,78	1,69	199182,95	1,69	0,04	1,00
Vigone	**Milk**	793	212732,5442	781705,16	568972,62	0,00	212732,54	31909,88	29045,36	0,00	60955,24	0,00	0,27	1,00
	Meat	3397	177030,2797	3976027,47	3799009,61	12,42	177017,86	26552,68	194163,73	1,86	220716,41	1,86	0,04	1,00

Table31 Tabella of consumption and producibility data for farms present in the ce6

Having determined the starting data, a REC with two prosumer users was hypothesized and subsequently another scenario was defined which envisages the inclusion of 137 residential users to whom the excess energy produced will go.

SCENARIO REC	1	2	3	4	5	6	7	8	9	10	11	12	tot_anno	
Consumi	105069	95672	105492	103787	104648	102500	106779	105070	103787	105069	102078	107200	**1247152**	kWh
Produzione	1174639	1061748	1175507	1137587	1175507	1137587	1175507	1175507	1137587	1175507	1137587	1175507	**13839774**	kWh
Extraproduzione	1069593	966076	1070015	1033800	1070858	1035087	1068728	1070436	1033800	1070437	1035509	1068306	**12592646**	kWh
Uncovered demanded	24	0	0	0	0	0	0	0	0	0	0	0	**24**	kWh
SC self-consumption	105046	95672	105492	103787	104648	102500	106779	105070	103787	105069	102078	107200	**1247128**	kWh
Mancato acquisto energia	15757	14351	15824	15568	15697	15375	16017	15761	15568	15760	15312	16080	**187069**	€
Energia immessa in rete	80362	52320	45472	40384	42260	33467	50339	55604	47930	56149	68640	70553	**643481**	€
Spese di prelievo	4	0	0	0	0	0	0	0	0	0	0	0	**4**	€
Energia scambiata tra membri	0	0	0	0	0	0	0	0	0	0	0	0	**0**	kWh
Collective self-consumption	96119	66671	61296	55952	57958	48842	66356	71364	63498	71909	83952	86633	**830550**	€
RICAVI	192237	133342	122592	111905	115915	97684	132712	142729	126997	143818	167903	173265	**1661100**	€
SPESE	4	0	0	0	0	0	0	0	0	0	0	0	**4**	€
Indice SCI	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	**0,09**	
Indice SSI	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	**1,00**	

Table 32. REC 1 summary for dairy farms

As can be seen from the previous table, that the self-sufficiency index is equal to 1, since self-produced energy is always greater than total consumption. While for the self-consumption index the values are clearly low.

The following graph represents the correlation between self-consumption and self-sufficiency of the different scenarios.

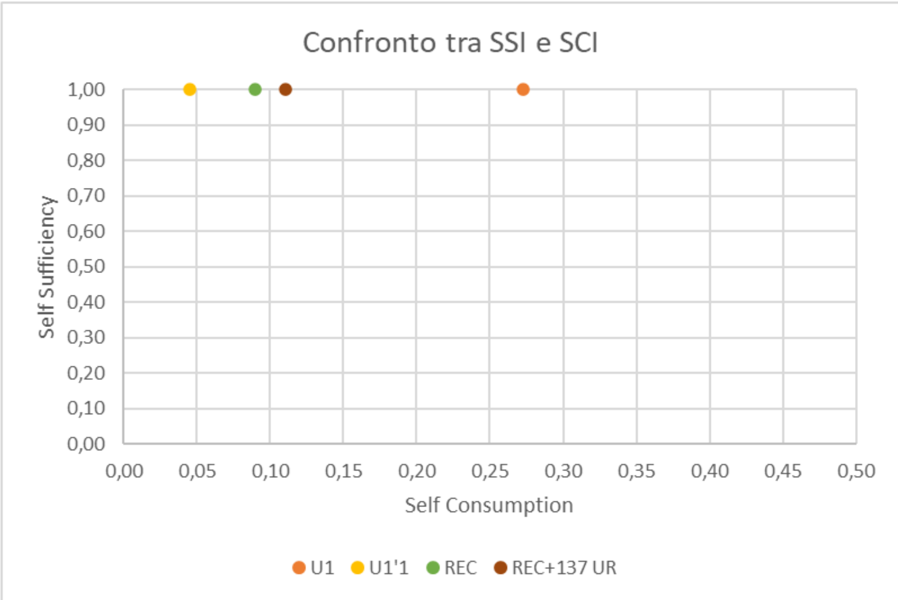


Figure 53. correlation between self-consumption and self-sufficiency

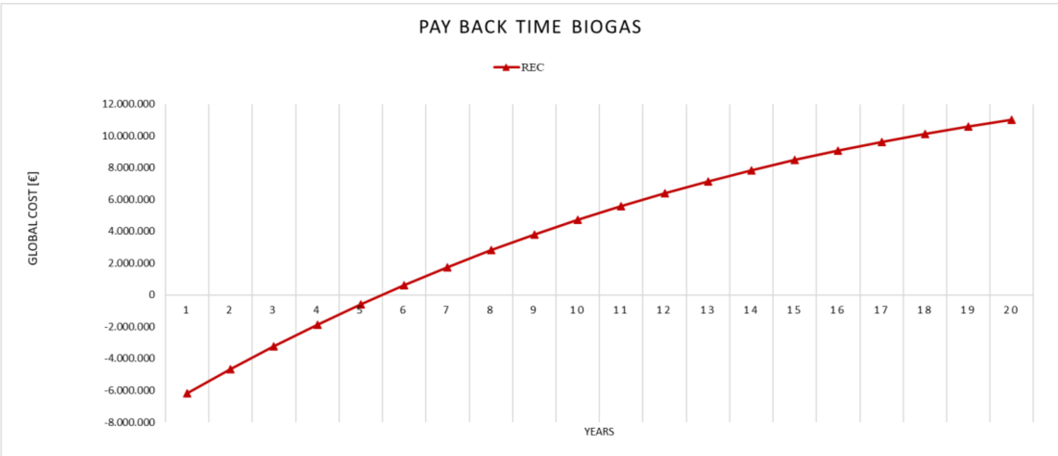
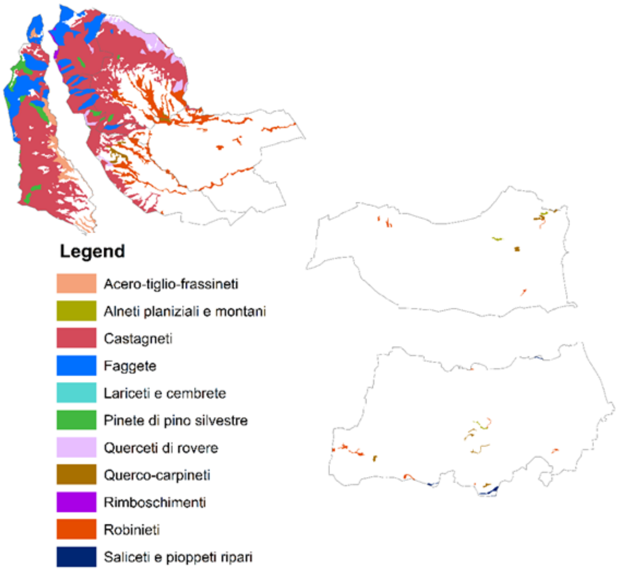


Figure 54. payback time of BIOGAS

The payback time for the installation of the BIOGAS system for the REC without aggregation of residential users there is a return on the costs invested after 6 years while for the REC + 137 residential users the flows are negative and a return is expected beyond 20 years, in the two cases a high self-sufficiency is covered but correlated with the costs it would be better to carry out the REC without the users.

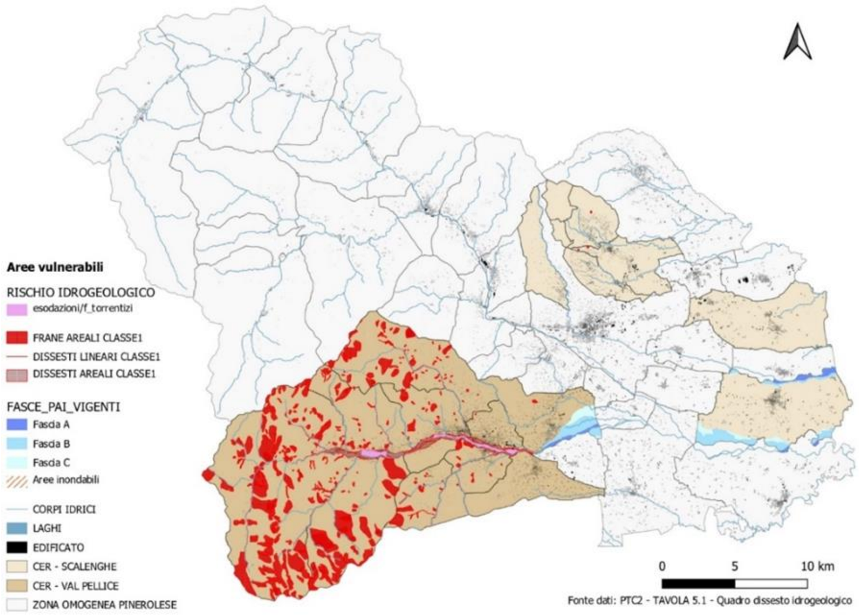
- **FOREST BIOMASS**

For the calculation of the producibility from forest biomass it is necessary to start by defining the existing accessible forest areas.



GRAPHIC accessible forest areas present in the CE6

To determine accessibility, the various constraints present in the area under examination were analyzed. From the analysis of the constraints, it can be seen that within the 6 municipalities there are various constraints as can be seen from the following maps.



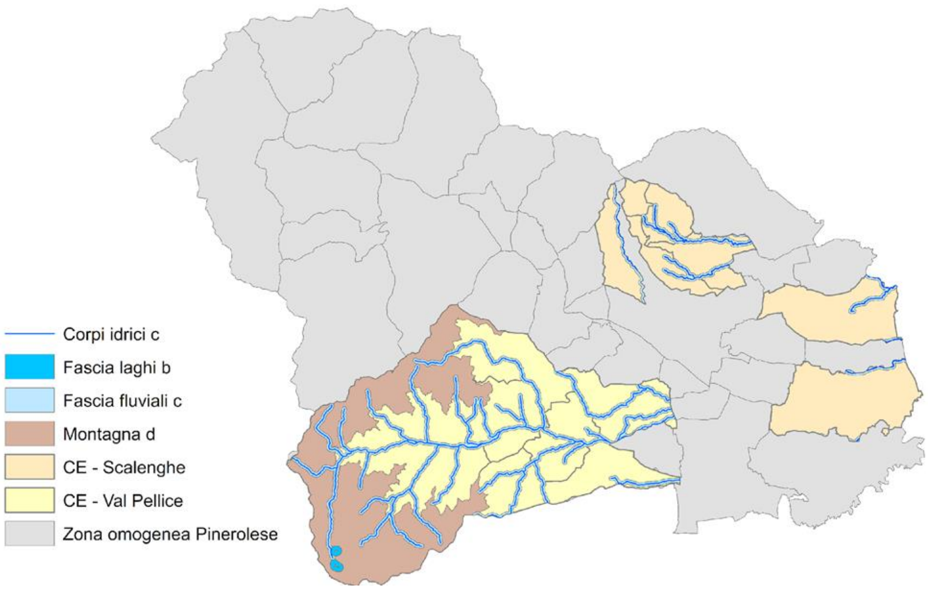


Figure 55analysis of the constraints

By analyzing the constraints and determining accessibility, they made it possible to determine the electricity that can be produced.

The maximum electricity that can be produced is approximately 3598.2 MWh, the 4 pre-mountain municipalities have a high number of producibility compared to Scalenghe and Vigone

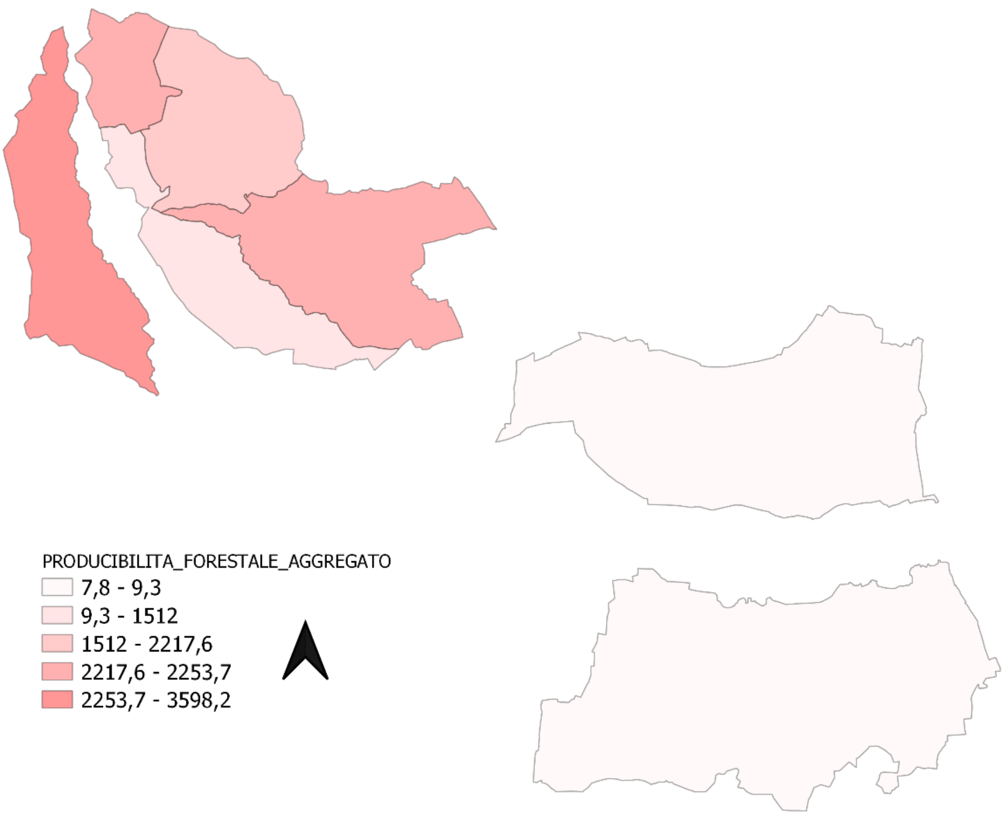


Figure 56result producibility from forest biomass

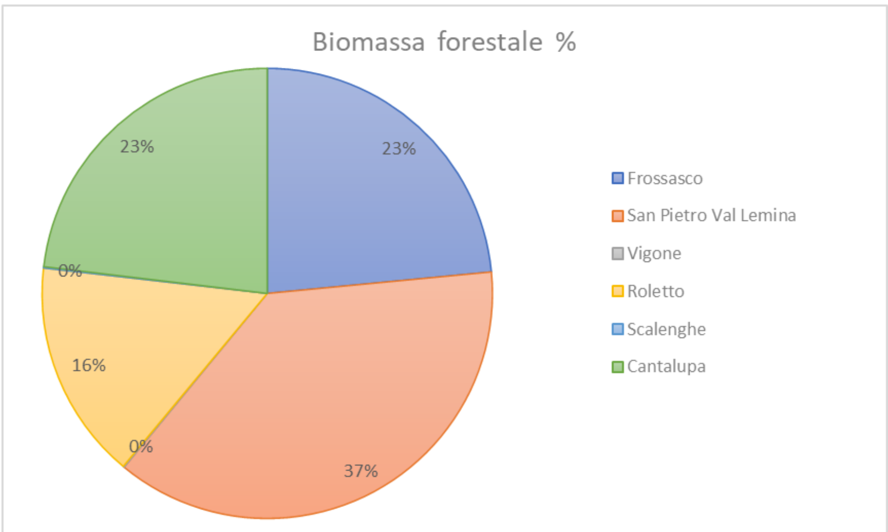


Figure 57 % forest biomass

- **AGRICULTURAL BIOMASS**

As anticipated in the methodologies, agricultural biomasses are made up of different materials that can be used for energy purposes: crop residues, products of dedicated crops, wood residues from pruning, waste from agri-food industries.

By carrying out the various analyzes and calculations indicated, the electrical energy that can be produced (Eel) was determined by multiplying the thermal energy obtained by the efficiency of the plant, assuming it was equal to 0.25 (25%), as for the forest biomass obtaining as result.

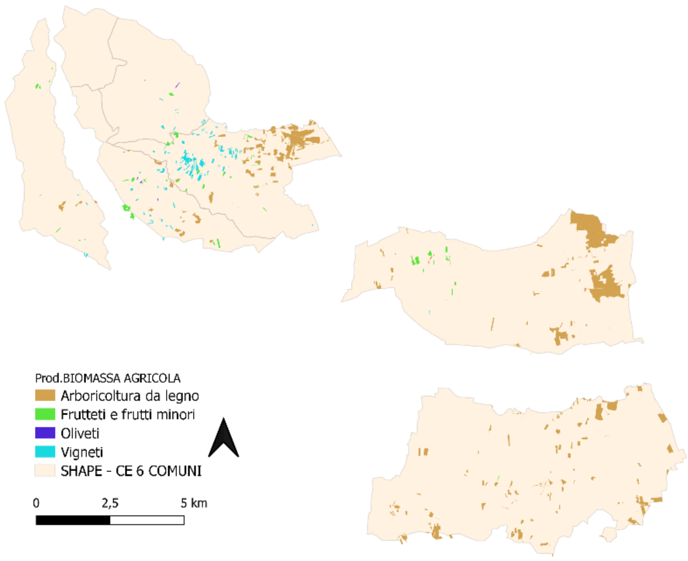


Figure 58Type of agricultural biomass present

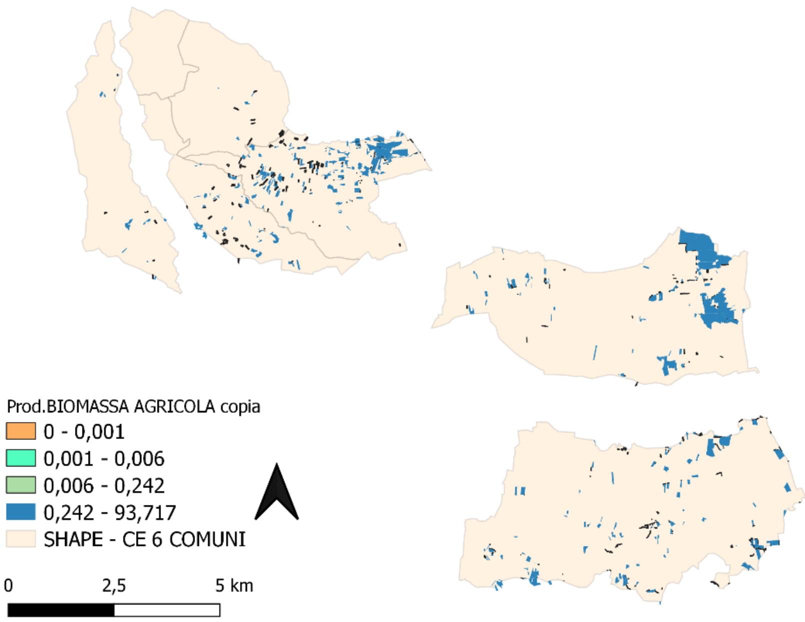


Figure 59 Electricity produced from agricultural biomass

- **BIOMASS FROM WASTE**

To calculate the electricity that can be produced from waste, as done for forest and agricultural biomass, it is sufficient to multiply the thermal energy obtained by the efficiency of the system, assuming it was equal to 25%.

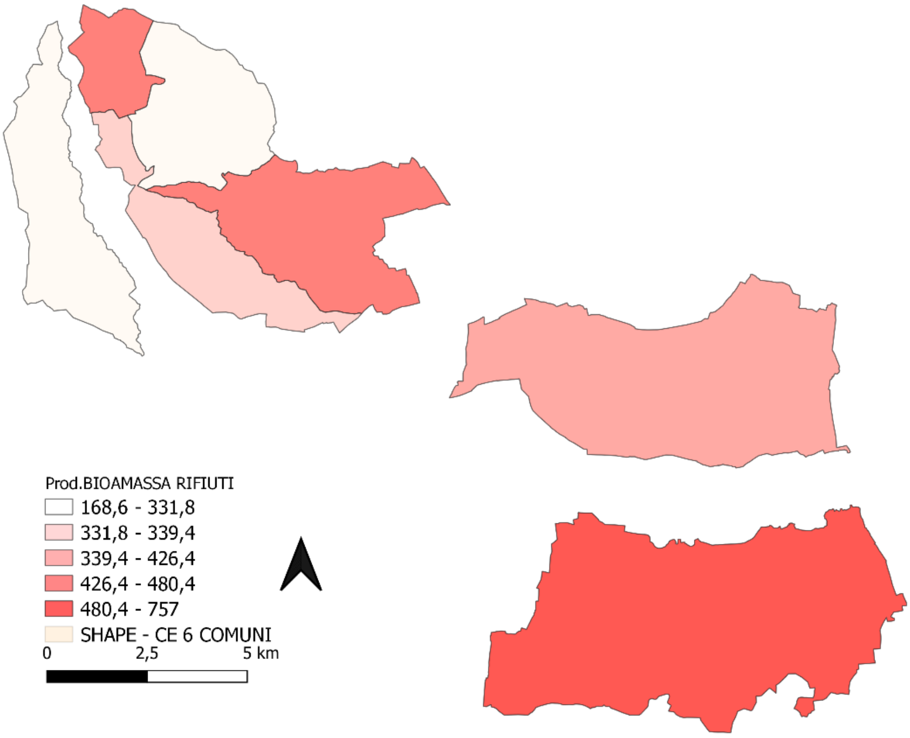


Figure 60. electricity that can be produced from waste

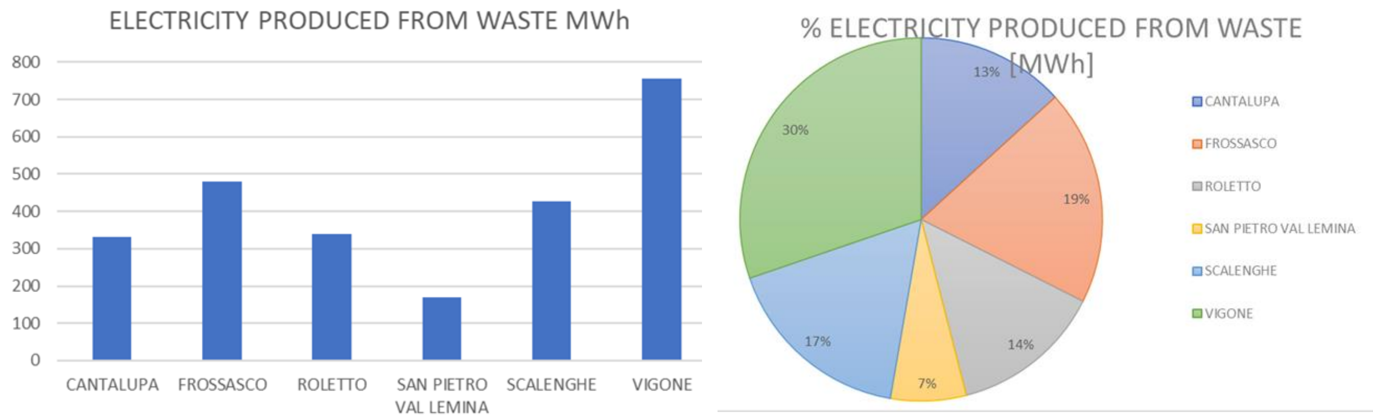


Figure 61electricity produced from waste

- **PRODUCTION FROM SOLAR PHOTOVOLTAICS**

From the following map the percentage of electricity produced by waste comes from vigone followed by scalenghe and frosassco while the other municipalities have a given low.
The data used refers to the hourly production for each kilowatt hour of installed power (1 kWp), evaluated on each seasonal day, at the local environmental and climatic conditions. The results obtained from the following profile vary according to the type of user all the REC have different participating users and the REC they belong to and are as follows:

SCENARIO 1:
For this scenario, the various RECs positioned in the 6 municipalities belonging to the EC6 with different types of users were considered the photovoltaic production envisaged by positioning the panels in the most south-facing pitch given the inclination of the buildings, the best exposures that allowed a better exposure. The table below contains the monthly consumption and production profiles for the different RECs included in the scenario, while the graphs represent the individual RECs.

	SCENARIO 1 FALDA EXPOSED TO SOUTH														
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**tot_anno**	
REC1 SCALENGHE	**Consumption**	4488	3907	3969	3118	3529	2626	1871	1837	2627	3382	4248	4283	**39885,00**	kWh
	Production	791	1404	2501	3717	4969	4665	5778	5941	4126	2876	970	1629	**38575,33**	kWh
REC2 SCALENGHE	**Consumption**	2934	2326	3427	2359	2763	2371	2393	2364	2599	2614	3096	3136	**32383,00**	kWh
	Production	882	754	1375	2029	2698	2584	3174	3219	2244	1554	520	877	**21907,75**	kWh
REC3 SCALENGHE	**Consumption**	3109	2750	3164	2919	3136	2997	3109	3136	2997	3136	2997	3029	**36480,55**	kWh
	Production	259	451	804	1183	1570	1477	1829	1890	1332	932	314	537	**12578,68**	kWh
REC4 CANTALUPA	**Consumption**	1109	942	988	858	965	785	773	729	840	1294	1025	1068	**11376,00**	kWh
	Production	73	117	252	364	490	472	599	592	410	261	97	148	**3875,77**	kWh
REC5 FROSSASCO	**Consumption**	2481	2242	1889	1357	1159	746	505	511	784	1383	1717	1513	**16287,00**	kWh
	Production	509	943	1605	2232	2822	2642	3401	3653	2683	1966	716	1511	**24172,43**	kWh
REC6 ROLETTO	**Consumption**	247	200	169	176	141	113	282	323	371	431	506	512	**3471,00**	kWh
	Production	357	835	1311	2071	2621	2549	3184	3263	2191	1532	564	952	**21431,81**	kWh
REC7 VIGONE	**Consumption**	2481	2242	1889	1357	1159	746	505	511	784	1383	1717	1513	**16287,00**	kWh
	Production	532	1296	2965	4281	5826	5991	7171	7128	4891	3161	956	1460	**45126,60**	kWh

Table 33 first scenario of CE6

The following graph represents the monthly consumption and production of the first scenario. The monthly trend of electricity production is much higher in the spring/summer months and low in the winter. Considering that in the summer months the use of electricity decreases with this scenario if it is applied, it can be said that municipalities can cover the lack of energy in the winter months.

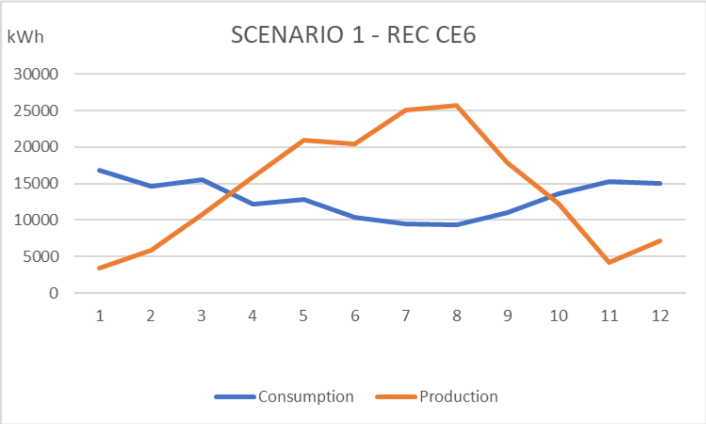
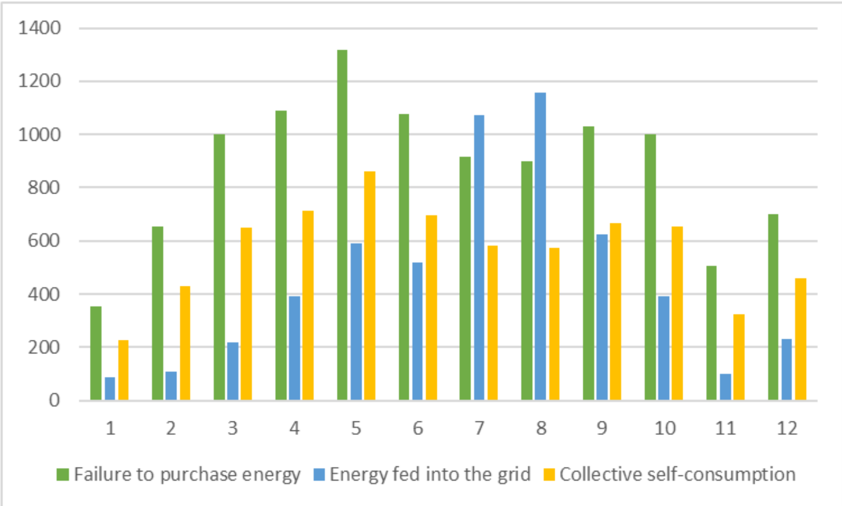


Figure 62 first scenario of CE6

From this scenario we obtain a good trend of collective self-consumption, energy fed into the grid high in the months of July and August, while the Failure to purchase energy has a high trend in the various months except in January and November.



From the various results obtained for scenario 1 we have a self-Sufficiency index equal to 0.41 per year and self-consumption 0.43.

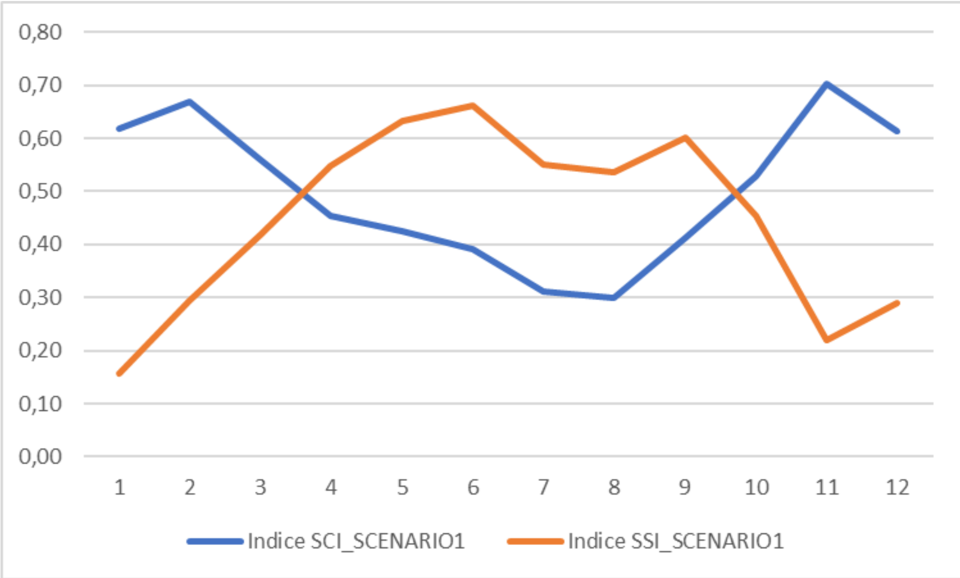


Figure 63. self-sufficiency index and self-consumption of scenario 1

SCENARIO 2:

This scenario involves the total use of the roof pitches of the building to make the most of the hours of daily irradiation; this scenario was analyzed only for two RECs in the Scalenghe area in order to evaluate the final installation costs in order not to exceed a payback time of 20 years (this point will be analyzed later).

	SCENARIO 2 Total flap														
		1	2	3	4	5	6	7	8	9	10	11	12	tot_anno	
REC1 SCALENGHE	Consumption	4488	3907	3969	3118	3529	2626	1871	1837	2627	3382	4248	4283	**39885,00**	kWh
	Production	1354	2379	4279	6298	8397	7921	9805	10042	7029	4876	1650	2776	**65451,43**	kWh
REC3 SCALENGHE	Consumption	3109	2750	3164	2919	3136	2997	3109	3136	2997	3136	2997	3029	**36480,55**	kWh
	Production	307	561	1011	1530	2064	1959	2410	2430	1667	1129	384	620	**16073,00**	kWh
TOT_REC CE6	Consumption	7597	6657	7133	6037	6665	5623	4980	4973	5624	6518	7245	7312	76366	kWh
	Production	1661	2940	5290	7828	10461	9881	12215	12472	8696	6005	2033	3396	81524	kWh

Figure 64. Scenario 2 consider the whole roof of the buildings

From this scenario, a self-sufficient index and self-consumption index of 0.51 and 0.41 respectively were obtained.

SCENARIO 3:

This scenario provides for several users to exchange energy for each REC. From the analysis carried out and comparing with scenario 1, an

			1	2	3	4	5	6	7	8	9	10	11	12	YEAR
REC3 SCALENGHE	REC (BAU) - SCENARIO 1	Self-Consumption Index	0,89	0,94	0,87	0,80	0,78	0,81	0,74	0,73	0,79	0,87	0,91	0,93	**0,80**
		Self-Sufficiency Index	0,07	0,15	0,22	0,33	0,39	0,40	0,43	0,44	0,35	0,26	0,09	0,17	**0,28**
	REC+1RES	Self-Consumption Index	1,00	1,00	1,00	1,00	0,99	1,00	0,91	0,90	1,00	1,00	1,00	1,00	**0,97**
		Self-Sufficiency Index	0,08	0,15	0,23	0,37	0,45	0,45	0,49	0,49	0,40	0,27	0,10	0,16	**0,30**
REC4 CANTALUPA	REC (BAU) - SCENARIO 1		0,82	0,85	0,72	0,73	0,69	0,71	0,68	0,64	0,74	0,83	0,86	0,81	**0,72**
		Self-Sufficiency Index	0,05	0,11	0,18	0,31	0,35	0,43	0,53	0,52	0,36	0,17	0,08	0,11	**0,25**
	REC+4RES	Self-Consumption Index	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	**1,00**
		Self-Sufficiency Index	0,04	0,08	0,15	0,25	0,30	0,33	0,42	0,43	0,28	0,13	0,06	0,09	**0,20**
REC5 FROSSASCO	REC (BAU) - SCENARIO 1	Self-Consumption Index	0,12	0,28	0,46	0,64	0,79	0,85	0,57	0,54	0,79	0,58	0,25	0,40	**0,44**
		Self-Sufficiency Index	0,59	0,66	0,54	0,39	0,32	0,24	0,09	0,08	0,23	0,41	0,60	0,40	**0,30**
	Rec+3RES	Self-Consumption Index	0,17	0,34	0,58	0,74	0,86	0,91	0,80	0,78	0,87	0,70	0,32	0,56	**0,57**
		Self-Sufficiency Index	1,00	1,00	0,89	0,62	0,52	0,44	0,25	0,23	0,43	0,69	1,00	0,76	**0,54**
REC6 ROLETTO	REC (BAU) - SCENARIO 1	Self-Consumption Index	0,47	0,68	0,81	0,83	0,89	0,90	0,58	0,56	0,83	0,69	0,50	0,48	**0,64**
		Self-Sufficiency Index	0,32	0,16	0,10	0,07	0,05	0,04	0,05	0,05	0,14	0,20	0,45	0,26	**0,10**
	REC+3RES	Self-Consumption Index	0,27	0,69	0,97	0,98	0,99	0,99	0,91	0,90	0,96	0,91	0,36	0,61	**0,79**
		Self-Sufficiency Index	1,00	1,00	0,96	0,56	0,47	0,46	0,39	0,39	0,63	0,92	1,00	1,00	**0,60**
REC7 VIGONE	REC (BAU) - SCENARIO 1	Self-Consumption Index	0,12	0,32	0,58	0,75	0,87	0,89	0,58	0,56	0,85	0,66	0,30	0,38	**0,50**
		Self-Sufficiency Index	0,58	0,56	0,37	0,24	0,17	0,11	0,04	0,04	0,14	0,29	0,55	0,39	**0,18**
	REC+1RES	Self-Consumption Index	0,15	0,39	0,74	0,86	0,93	0,95	0,87	0,87	0,94	0,82	0,34	0,56	**0,65**
		Self-Sufficiency Index	1,00	1,00	0,77	0,49	0,37	0,30	0,20	0,20	0,37	0,66	1,00	1,00	**0,43**

increase the result o an increase in the self-sufficiency and self-consumption index is shown.

Figure 65Comparing with scenario 1 with scenario 3

SCENARIO 4

The last scenario analyzed to evaluate the possibility of conserving the energy produced in the maximum months to be able to exploit them in the colder months is the REC + storage scenario. This evaluation shows that the REC CE6 + storage slightly exceeds 50% of self-sufficiency and self-consumption for the 12 months of the year and there is a new self-consumption due to energy storage.

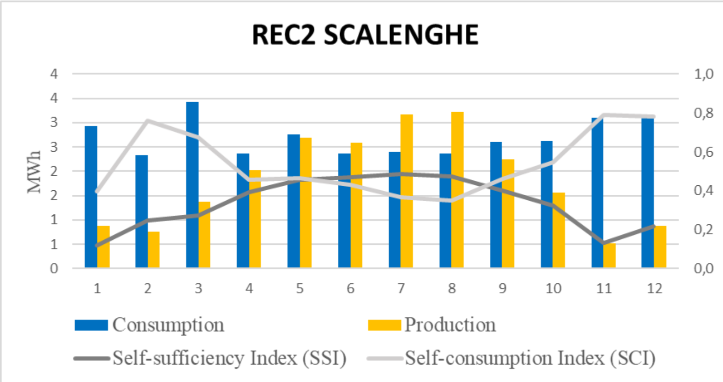
New Self-consumption	422	687	1096	1222	1431	1151	1112	1116	1182	1165	514	813	11911
Indice SCI	0,90	0,85	0,75	0,63	0,58	0,52	0,46	0,45	0,58	0,74	0,90	0,84	0,60
Indice SSI	0,28	0,41	0,57	0,75	0,82	0,83	0,88	0,88	0,81	0,67	0,31	0,48	0,59

Table35 Result obtained for scenario 4 REC + storage

CORRELATION BETWEEN THE RESULTS FOR EACH REC

This paragraph will show the different correlation graphs made for the various RECs that explain the usefulness of this PV installation intervention.

Figure 66REC1 shows the correlation between consumption, production and self-consumption and self-sufficient (left), the aggregation between over production, Uncovered demand and self-consumption and self-sufficient (right



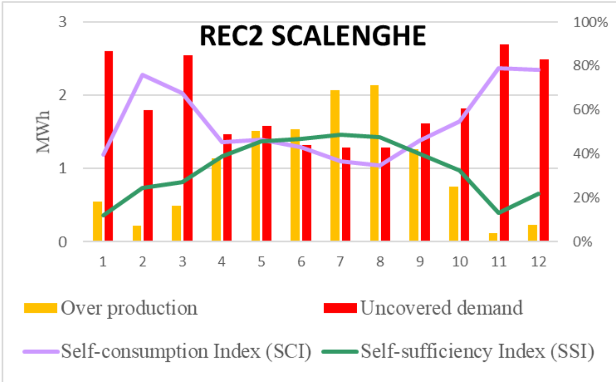
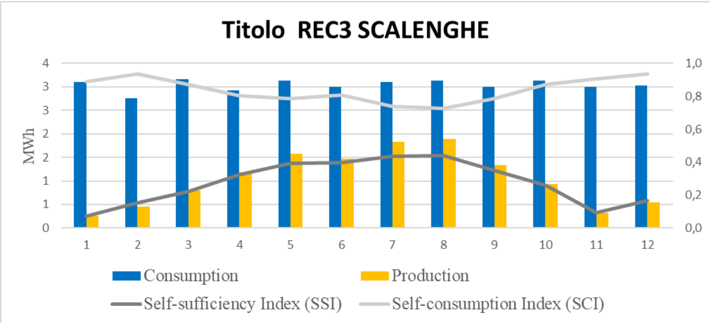


Figure 67. REC2 shows the correlation between consumption, production and self-consumption and self-sufficient (left), the aggregation between over production, Uncovered demand and self-consumption and self-sufficient (right)



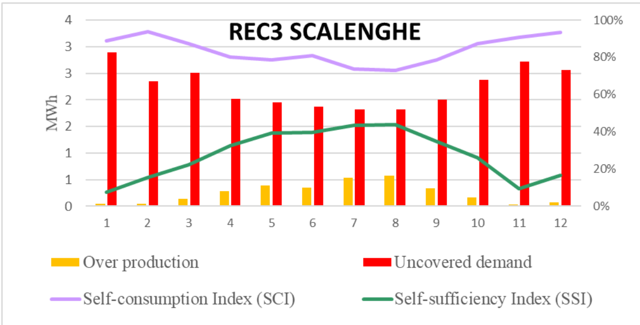


Figure 68REC3 shows the correlation between consumption, production and self-consumption and self-sufficient (left), the aggregation between over production, Uncovered demand and self-consumption and self-sufficient (right)

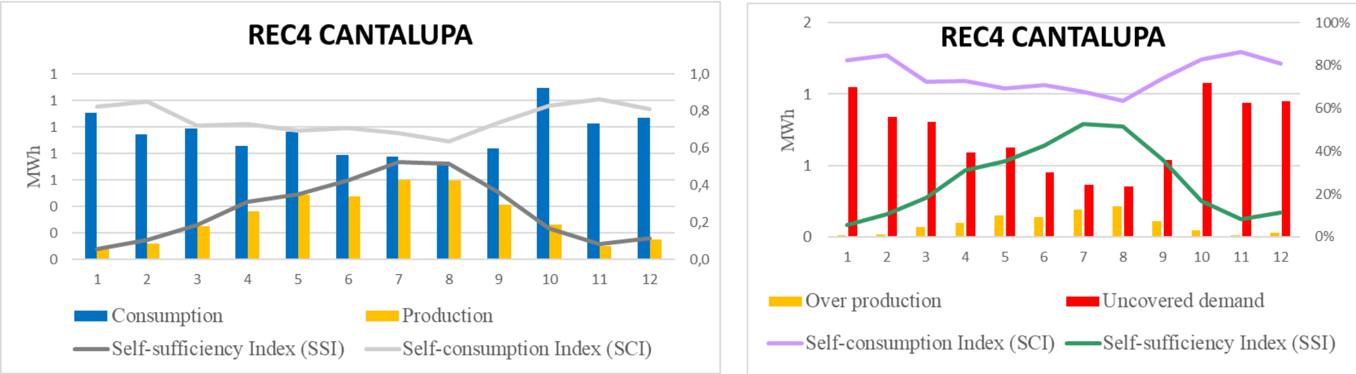


Figure 69REC4 shows the correlation between consumption, production and self-consumption and self-sufficient (left), the aggregation between over production, Uncovered demand and self-consumption and self-sufficient (right)

Figure 70REC5 shows the correlation between consumption, production and self-consumption and self-sufficient (left), the aggregation between over production, Uncovered demand and self-consumption and self-sufficient (right)

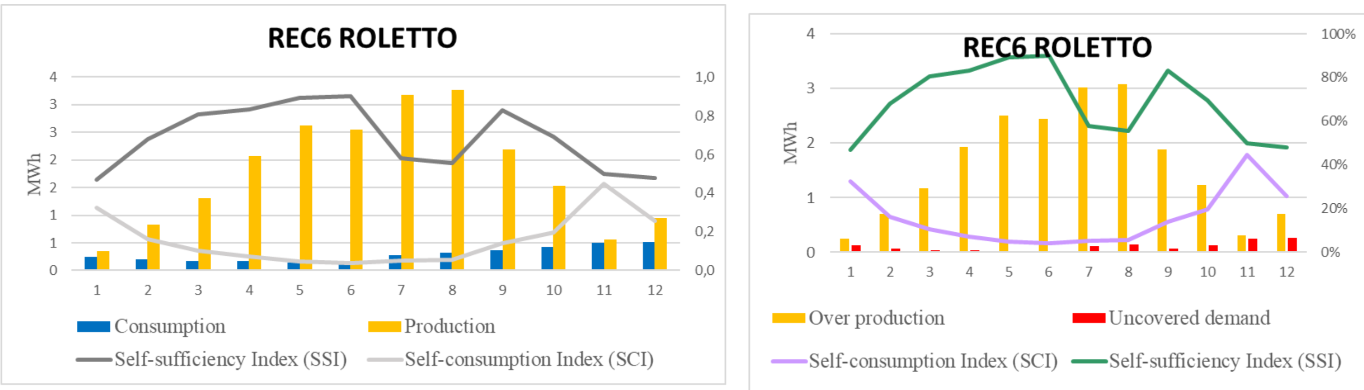
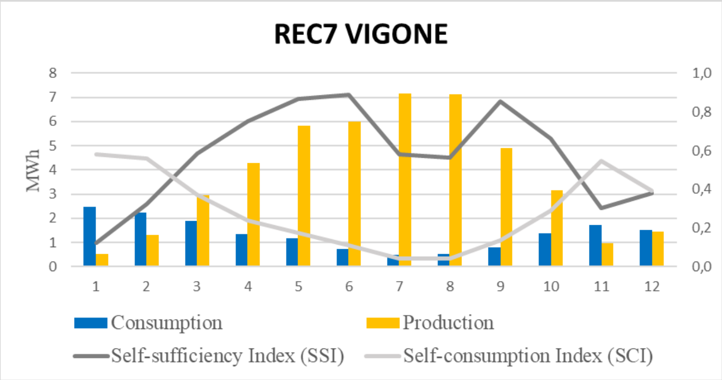


Figure 71REC6 shows the correlation between consumption, production and self-consumption and self-sufficient (left), the aggregation between over production, Uncovered demand and self-consumption and self-sufficient (right)



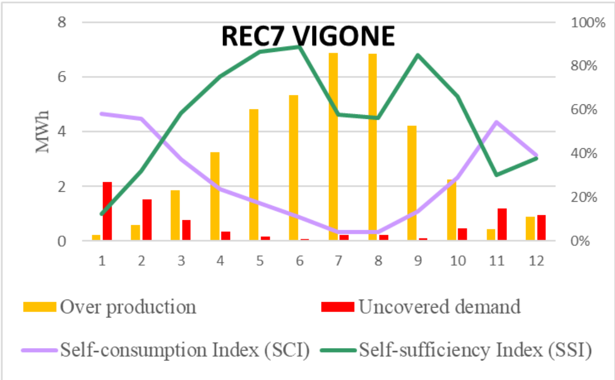


Figure 72REC7 shows the correlation between consumption, production and self-consumption and self-sufficient (left), the aggregation between over production, Uncovered demand and self-consumption and self-sufficient (right)

➔ ENERGY AND ECONOMIC EVALUATION

The economic evaluation related to energy production was based on the attribution of a price (in euro cents per kilowatt hour) with reference to whether the input (withdrawal) or output (injection) between the internal grid of the EC6 and the national electricity grid . Always bearing in mind that the cost of energy changes according to the type of final user considered (table 35), a single price was assumed for the energy expenditure of the EC, equivalent to that of business users (0.15 € / kWh) and a single price for the remuneration of the energy produced and not self-consumed by the EC (0.06 € / kWh).

User	Withdrawal from the grid [€ / kWh]	Feed into the grid [€ / kWh]
Corporate	0,15	0,06
Municipal	0,18	0,06
Housekeeper	0,22	0,06

Table 35 Price of energy in force in the Pinerolo area

➔ INVESTMENT COST AND RETURN TIME

From the different scenarios created the cost and return time of the investment was evaluated, this calculation to evaluate the economic aspects for the different users.

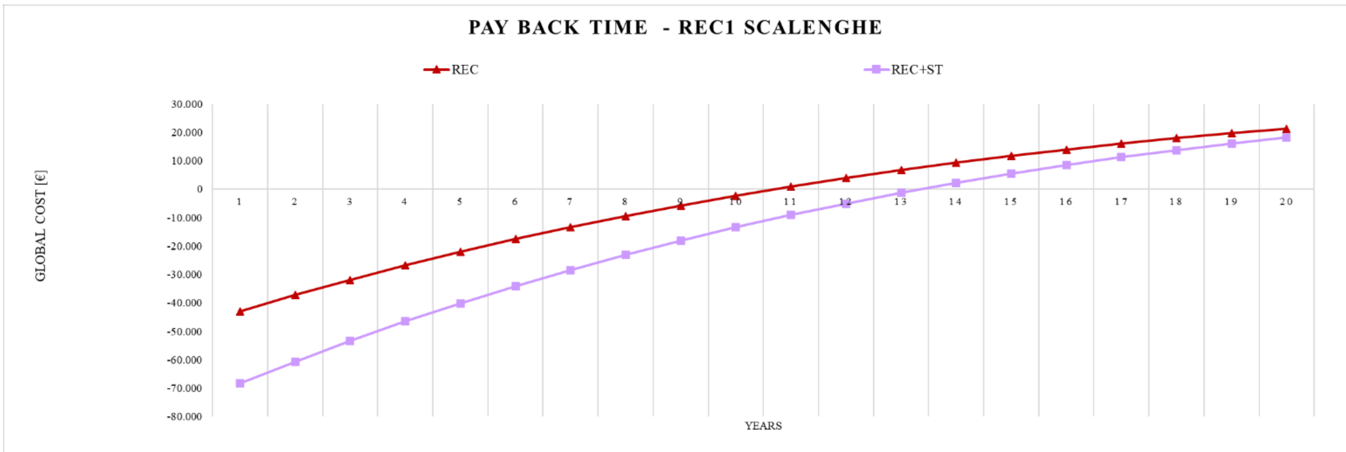


Figure 73 REC1 shows the payback time of REC and REC with storage in 20 years

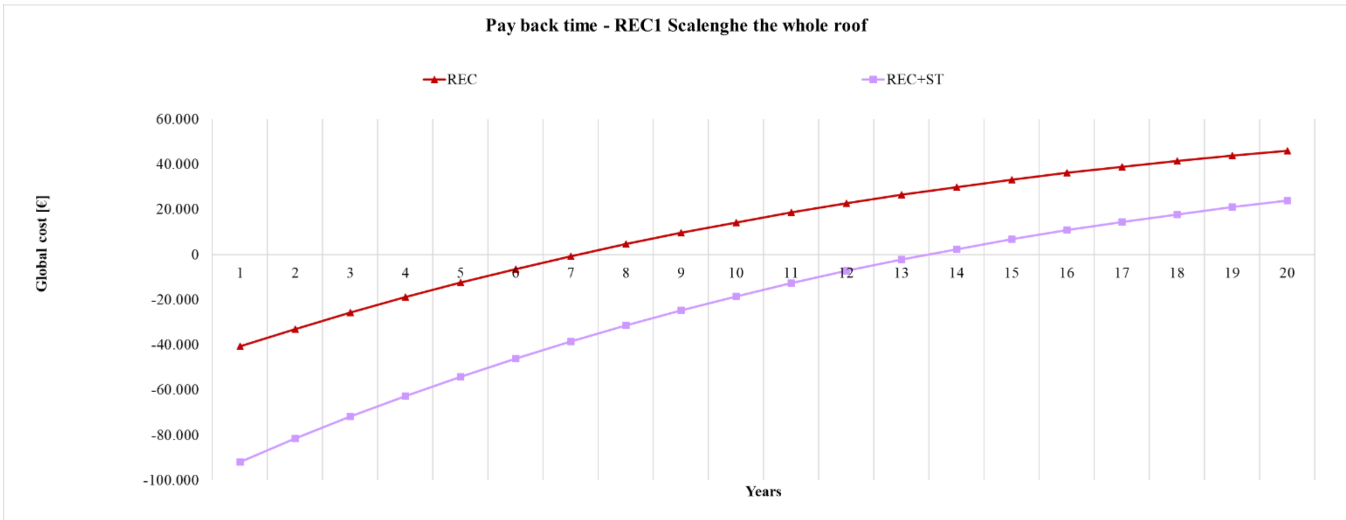


Figure 74 REC1 shows the payback time of REC and REC with storage in 20 years of the whole roof

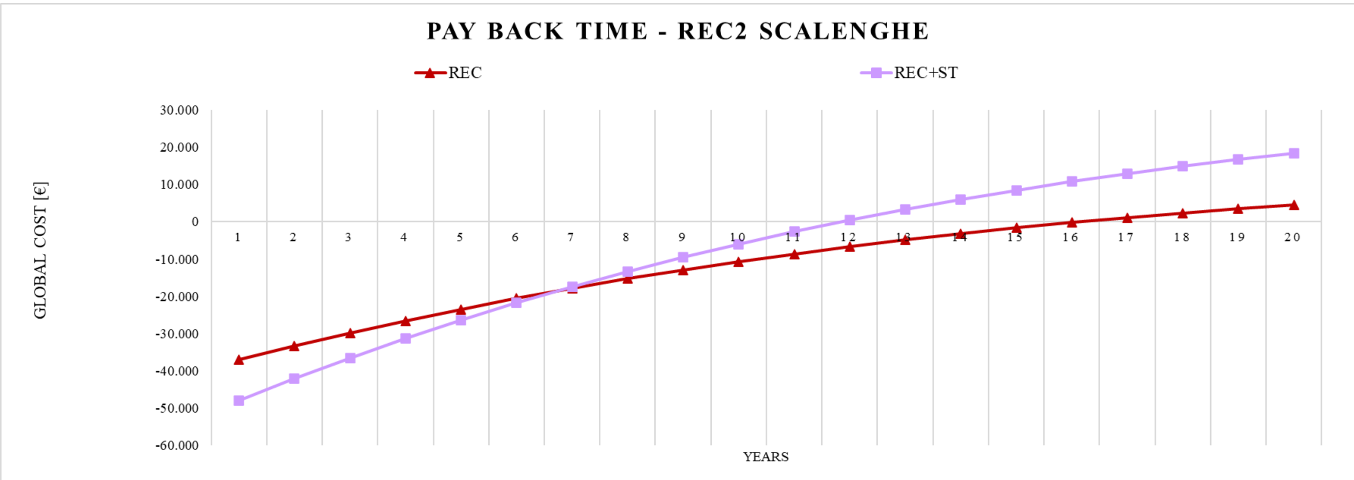


Figure 75 REC2 shows the payback time of REC and REC with storage in 20 years

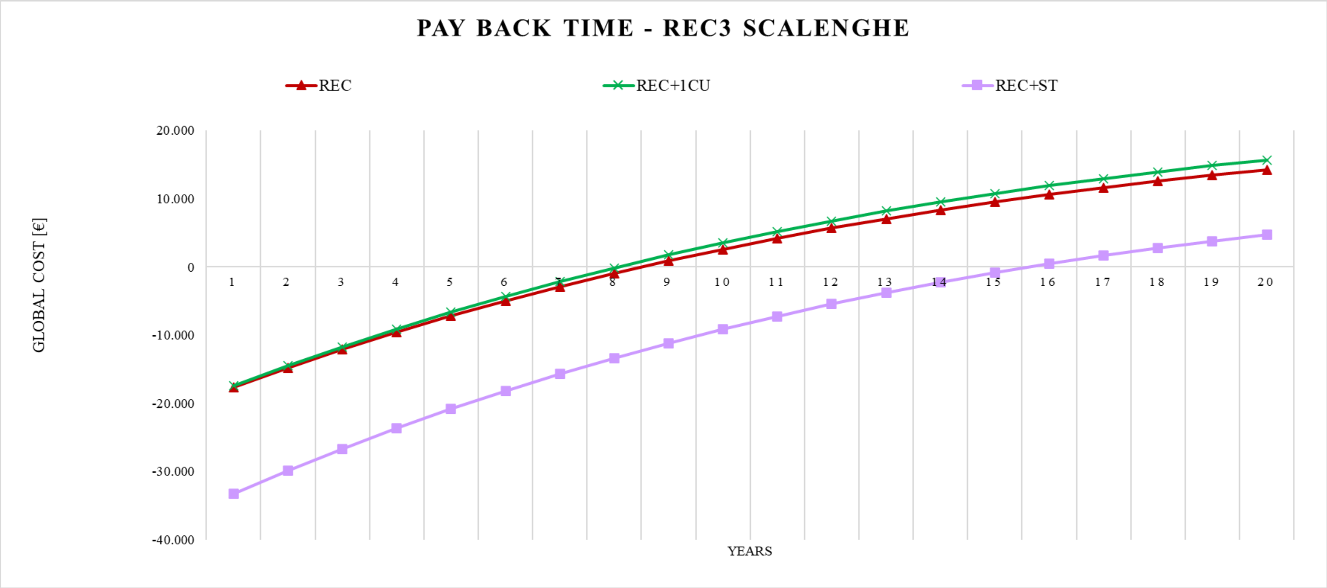


Figure 76 REC3 shows the payback time of REC, REC+1CU and REC with storage in 20 years

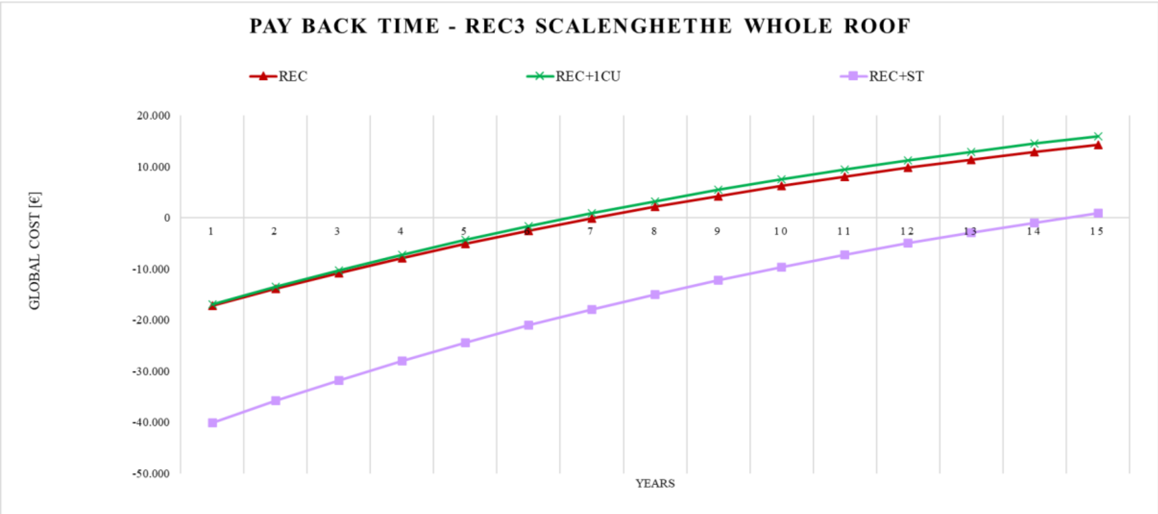


Figure 77 REC3 shows the payback time of REC, REC+1CU and REC with storage in 20 years

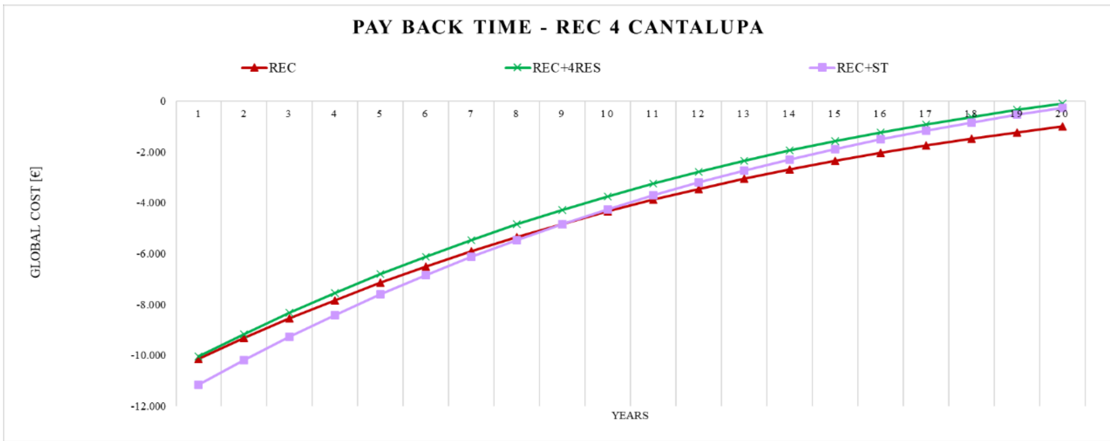


Figure 78REC4 shows the payback time of REC, REC+1CU and REC with storage in 20 year

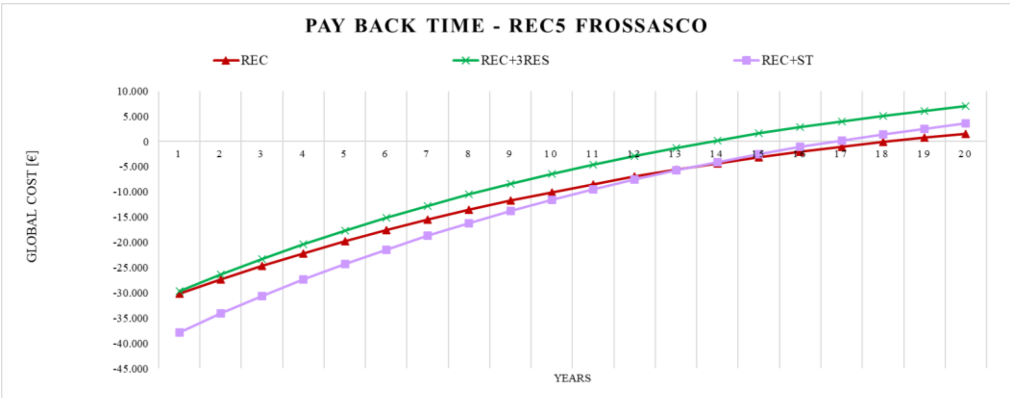


Figure 79REC5 shows the payback time of REC, REC+1CU and REC with storage in 20 year

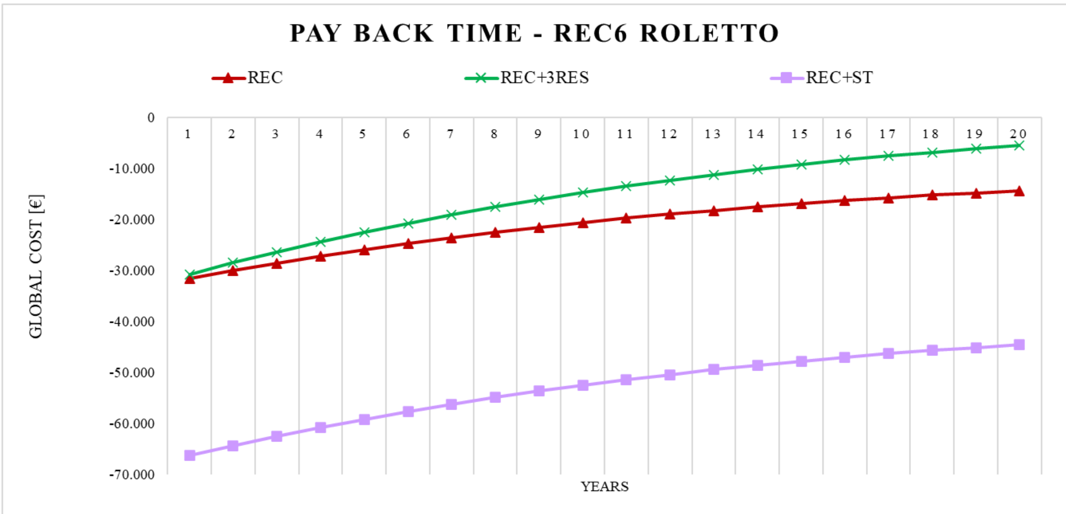


Figure 80 REC6 shows the payback time of REC, REC+1CU and REC with storage in 20 year.

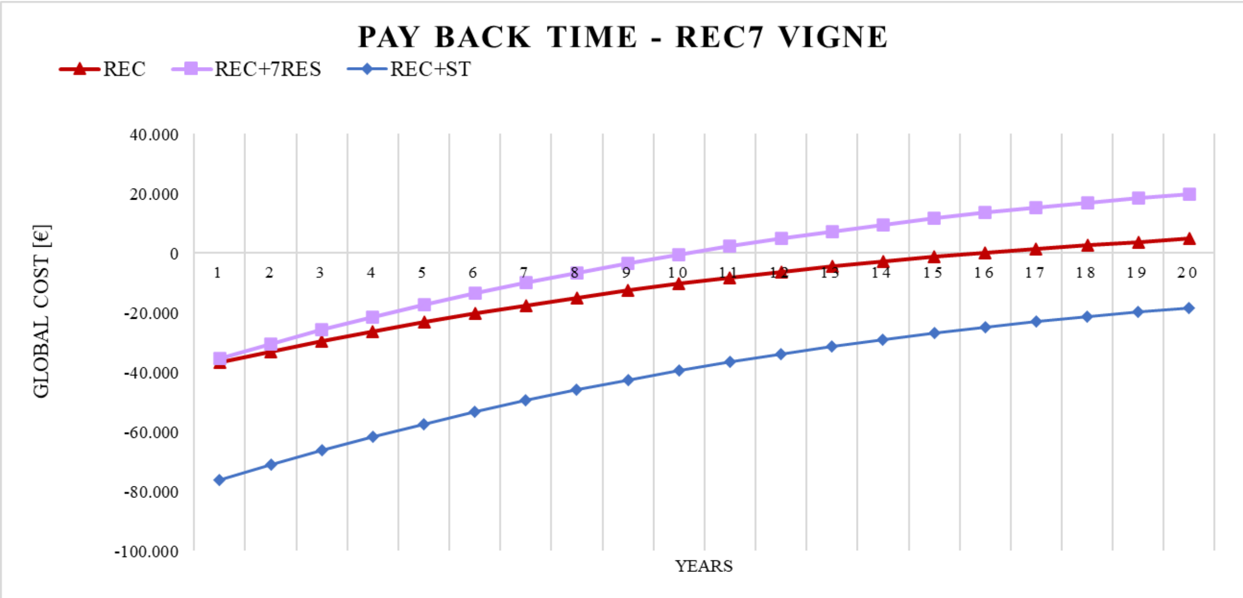


Figure 81 REC7 shows the payback time of REC, REC+1CU and REC with storage in 20 yeaR

The following graphs show that the payback time of the costs incurred for several RECs is very high compared to the other RECs that the payback time exceeds 15 years.

5. Conclusions

The results of the analysis show that urban and energy planning are connected through the study of the territory in all its complexity and potential, and in its size.
This analysis shows that the possible limitation to the constitution of an energy community is the vastness of the territory, which does not concern the CE6 that meets the minimum requirements of the law.
The actors involved differ in terms of the type of users and the scenarios described which present a diversification of renewable resources. As far as electricity is concerned, business users account for the largest share of consumption.
The total annual demand significantly exceeds the minimum limit set by law and has an almost constant monthly trend, since it is mostly determined by industrial production demands. Electricity production, mainly based on ACEA's biogas production, allows the demand to be covered in all months, except winter, achieving a high share of self-consumption.
Following the evaluation of the locally available resources, it is possible to state that the availability of forest resources is present only in the municipalities of San Pietro Val Lemina, Cantalupa and Roletto and the fraction useful for energy production is about 80% of the accessible one. This is because both municipalities are located in the piedmont area, which is easily reachable by means of hydrogeological risk. It should be considered that in this area there are strong limitations to the realization of biomass power plants since all municipalities, except Cantalupa, are subject to type B constraints. Productivity from solar radiation was assessed by selecting the buildings of business, municipal and residential users that were without plants, therefore, the main contribution is from municipal buildings, as they are present in greater numbers. The first intervention scenario assumed, concerning the implementation of electrical production, sees an increase in production compared to the state of affairs and the possibility of covering energy needs in all months of the year.

PRODUCIBILTY			
MWh	PV	BIOGAS	BIOMASSA
CANTALUPA	156,19	63,21	2596,96
FROSSASCO	10,51	3295,20	4966,49
ROLETTO	24,96	257,71	531,46
SAN PIETRO VAL LEMINA	0,00	52,86	3672,10
SCALENGHE	22,95	5413,06	1116,40
VIGONE	47,42	4757,73	3967,13

Ultimately, the objective of the energy community is to maximize internal exchange and instantaneous collective self-consumption, limiting the withdrawal and injection of energy into the external national grid, and also to maximize existing resources, limiting the use and intervention of further investment or financing for the creation of new production plants or the installation of storage systems, which are not only economically wasteful but also environmentally damaging. storage systems, which are not only economically expensive but also have an environmental impact.

MWh/y	TOTAL CONSUMPTION	Total PRODUCTION	Total PRODUCIBILITY	SELF-SUFFICIENCY SC = (P+PP)/C	UNDERCOVERD DEMAND (UD = C – P – PP)
CANTALUPA	3935,6	547,4	4483	1,28	-1094,8
FROSSASCO	13142,6	4681,65	17824,25	1,71	-9363,3
ROLETTO	88899,2	1813,55	90712,75	1,04	-3627,1
SAN PIETRO VAL LEMINA	3000,00	345	3724,96	1,36	-1069,96
SCALENGHE	27999,8	4467,15	32466,95	1,32	-8934,3
VIGONE	15905,8	6034,45	21940,25	1,76	-12068,9

In conclusion, it is stated that the study carried out and the results obtained show a reduction if not a cancellation of uncovered applications for electricity and an increase in the self-sufficiency of the 6 municipalities..

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