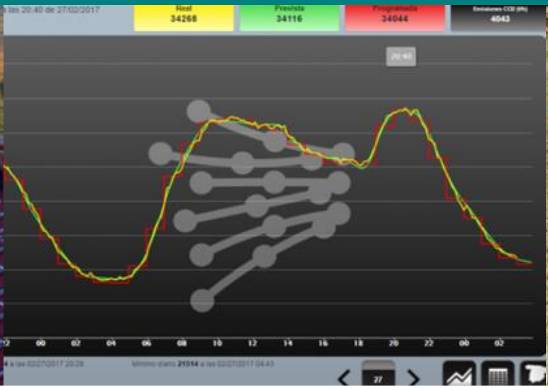
Renewable energy for local development: National case studies

Compilation of case studies of applying renewable energies to local development nationally implemented along IN2RURAL project: Stage 1

Coordinators: Leonor Hernández and Hèctor Beltran


IN2RURAL

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TABLE OF CONTENTS

Compilation of case studies of applying renewable energies to local development nationally implemented

Castelló de la Plana, july 2017

Content:

Case study 1 - Ivan Segura (UJI)	
Case study tutor	Lluis Monjo
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Project/case study title	Comparative study between the use of district heating and individual heating systems, based on biomass, in an inland rural town of the province of Castelló
Project/case study summary	The present Project is focused on carrying out a study where advantages and disadvantages of using district heating and individual heating systems for different municipal buildings of Vistabella del Maestrazgo (Castelló) are compared. The public buildings that will be examined in order to compare these two systems are a block of rental housing, a school, a library and a pharmacy. The project is part of a local government's plan to take advantage of the forest waste, which appears in the surroundings of the town, in order to produce biomass for self-consumption energy. Therefore, the technical, economic, social and environmental factors that encompass the project will be taken into account.

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Project/case study title	Study and design of renewable energy installations in Torre Martinez. Building isolated without connection to electric, potable water and sanitation grid

Project/case study summary	The case study focuses on a house isolated from electric, potable water and sanitation grid in the municipality of Vistabella del Maestrazgo (Castelló). To make a specific project but at the same time replicable to other buildings, the different systems to be implemented have been detected and different solutions have been analyzed. From these solutions we have chosen and calculated the most convenient ones according to a responsible consumption. Always with all comforts and attending to a sustainable model and respectful with the environment and taking advantage of local resources. That is, the electrical installation, installation for heating, potable water and wastewater treatment. The electrical system consists of the generation part. The heating system must guarantee the comfort temperature in the main rooms of the building at the times that the weather so requires. At present they have a water system, but it is insufficient. So be evaluated an alternative system. Finally, the wastewater treatment, trying to reuses as much as water it is possible.

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Project/case study title	Installing a biomass fired boiler and testing its efficiency at the central building of Budapest Forestry Co. Ltd.
Project/case study summary	The aim of the study to analyze the possibility of installing a biomass boiler. Research question: Is one investment enough for the factual realisation of a biomass boiler? The advantages of biomass are the following: • it produces useful warmth, this energy can be utilized with technology tools • Even one boiler is enough to maintain institition • Not only the hot water supply of the building • One-time investment • Lower overhead • More workplaces

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English tutor	Silvia Leonte
SME Supervisor	Valerica Rusu/Laurențiu Măgureanu
Project/case study title	Utilization of biomass in the energy supply of the Plant Diversity Centre in a Hungarian village.
Project/case study summary	The project will analyse the energy needs of two buildings of a pigs farm located in Slatina, a small villages from the neighbourhood county of Bacau. The project will design the photovoltaic installation for these buildings and the possibility to extend the power supply for other two constructions which will be developed in time. An analysis of the advantages of this solution, compared with other renewable sources, will be done. The investment costs also will be made.

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Renewable tutor	Csaba Patkós - GEOLIN
Rural development tutor	Vicent Querol
English tutor	Imre Baják
SME Supervisor	Csaba Patkós
Project/case study title	On-grid photovoltaic installation for a pig farm
Project/case study summary	The aim of the study to analyze the possibility of utilization of biomass energy in the energy supply. Research question: Does it make sense to use biomass energy for heating green houses and buildings in a site of Pland Diversity Centre in Tápiószele (Hungary). It is advantageous to utilize biomass because • it uses agricultural, forest, urban and industrial residues and waste • it produces heat and electricity with less effect on the environment than fossil fuels

Case study 6 - Cosmin Constantin BUCUR (UB)	
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English tutor	Silvia Leonte
SME Supervisor	Valerica Rusu/Laurențiu Măgureanu
Project/case study title	Study concerns the efficiency of wind energy in the area of Pincesti village, Bacau.
Project/case study summary	Pincesti village is located in the central-eastern part of Bacau county, on the left bank of Siret, where it receives the waters of a tributary, the waters of Fulgeriş. From this point of view the wind energy it is a good solution. The study will be concentrated on wind energy potential and will also analyze the possibility to combine wind and solar energy as alternative solution for a higher energy supply safety. The study will include also the investment cost and the impact of local community.

Co-funded by the Erasmus+ Programme of the European Union

REPORT OF THE CASE STUDY ON RENEWABLE ENERGIES TO LOCAL DEVELOPMENT NATIONALLY IMPLEMENTED

COMPARATIVE STUDY BETWEEN THE USE OF DISTRICT HEATING AND INDIVIDUAL HEATING SYSTEMS, BASED ON BIOMASS, IN AN INLAND RURAL TOWN OF THE PROVINCE OF CASTELLÓN

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Castellón, May 2017

INDEX

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Memory of the project

1. Introduction to the project

1.1. Objective

The main objective of this project is to carry out a comparative study between a district heating installation and an individual heating, using biomass, in the municipality of Vistabella del Maestrazgo in the province of Castellón (Spain). The comparison will help the local government to know the advantages and disadvantages of both alternatives, in order to select the best type of installation for their requirements.

Moreover, the viability of recovering the forestry waste of the surroundings of the municipality for the production of biomass will be also considered. This biomass will be used as a fuel in the installations of the study and other biomass heating systems of the town. Therefore, the environmental and social consequences of the energy autonomy in the rural development of Vistabella del Maestrazgo will be known.

Consequently, this study will provide information to the municipality, which can be used for dealing problems like unemployment, youth migration, climate change, etc.

1.2. Scope

The present study is based on waste energy self-sufficiency, focusing on biomass heating installations. The main purpose is to find the best heating system from a technical and economical point of view for different public buildings in Vistabella del Maestrazgo, reinforcing the rural development of the locality.

The study contains a detailed technical description of the optimal heating systems for two public buildings: the school, which includes a pharmacy and a library, and a residential block. The sizing of the heating system takes into account the energy demand of the building and different specific requirements. The main components of the installation are taken into account in the sizing of the installation.

Moreover, the economic, social and environmental consequences are analysed due to the project's execution and the waste forestry management.

1.3. Precedents

The present study arises from the interest of the local government of Vistabella del Maestrazgo in the case of success of Serra. The town of Serra is located in the province of Valencia (Spain), which has a population of 3,070 people. A few years ago, the local government of Serra decided to carry out a project of waste recovery [1]. The case of Serra became popular because they use pruning and forestry waste for the production of biomass, which is used in public heating systems. Moreover, the project was totally successful, having a positive impact in economic savings, jobs creation and rural development.

The municipality of Vistabella had contact with the Serra's project talking with the municipal engineer Juan José Mayans. After this example of successful case, the local government decided to change the gasoil installations of the public buildings for biomass systems. Moreover, Vistabella has a big potential of forestry waste because the forest occupies the major part of municipal hectares. This reason is another pillar in the decision of recycling forestry waste for the production of biomass (replicating again the Serra's case).

The installation of biomass heating systems started in Vistabella during the last year with the incorporation of a biomass boiler in the local government's building (figure 1). Thanks to the good results of this installation, the municipality began to study the incorporation of biomass heating system in different public buildings. For example, the Cultural House will also include a biomass boiler.

Figure 1. Local government's building

In the case of the project, where the school's building and the residential block are in the same street, another case of success is a precedent. The town of Todolella became the first town of Castellón province with a district heating installation [2]. This typology of heating installation can be extrapolated to Vistabella because of the location of the two public buildings. Therefore, the local government is interested in the best option for the integration of biomass system in the school's building and the residential block.

Furthermore, the rural exodus and the depopulation of the town is one of the biggest problems actually. With only 370 people in Vistabella, the local government is looking for measures that can help in the attraction of young families. The creation of new jobs, the improvement of the quality of life or the establishment of social spaces are problems that must be faced for improving the rural and social development of the town.

1.4. State-of-art in the problem domain

1.4.1. Biomass

Although the term biomass has different definitions, it can be understood like an energy source that is based on plants or similar biological materials. All these materials are carbon based because of atmospheric CO2 during the life of the plants (photosynthesis).

When biomass is burned, it produces heat which can be used for different energy applications. Moreover, the carbon stored in the plant is returned to the atmosphere as CO2. The main difference between biomass and fossils fuels is the management and time scale. It is considered that new plants are planting and growing up, taking up CO_2 from the atmosphere, at the same time biomass is released by combustion. Therefore, biomass is considered as a renewable energy and emission-neutral.

There are a wide variety of materials for biomass. Nevertheless, only these typologies of biomass with best quality and less cost are alternatives in the market. The main categories of material for biomass are [3]:

- Virgin wood from forestry
- Energy crops grown up for energy applications
- Agricultural residues
- Food waste
- Industrial waste

For heating installations solid biomass is normally used that can come from virgin wood, energy crops or agricultural and forestry waste. The principal fuels used in biomass boilers are:

- Firewood: biomass cylinders with 10-15 cm of diameter and 50 cm of large approximately. They must have less than 20% of humidity.
- Pellets: they are fabricated from wood waste, compressing in small cylinders. They are the most popular, having a high calorific value (4.7 kWh/kg more or less [4]).
- Wood chips: cheap fuel with small dimensions. They must have less than 30% of humidity. They have a lower calorific value than pellets (about 3.7 kWh/kg [4]).
- Other fuels: there are a wide range of materials for biomass heating applications. Some examples are straw, olive stone or almond shell.

Figure 2. Biomass fuels [5]

The selection of the solid fuel in biomass heating installations depends on different factors like final application, energy demand, the economic resources or the type of boiler installed.

1.4.2. Biomass heating systems

Basically, biomass heating systems are the installations that use biomass for the generation of heat. Although there are different technologies or categories of the systems (gasification, combined heat and power, anaerobic and aerobic digestion…), the principal system used is direct combustion.

Direct combustion consists in burning fuels for the production of heat that can be used in different applications. Considering a wide range of applications, it is common to separate between domestic applications and industrial applications, which englobes different aims.

Nevertheless, if different heat installations are close, there are two options for the provision of energy: individual installations and district heating.

Individual installations are the basic and normal cases, which consider only one application or building. For example, the installation of a biomass boiler for the heating of an isolated house is a typical one.

Nowadays, people are more connected and technology is being developed faster. District heating refers to the connection of different heating systems that are installed for different applications. Basically, the heat is generated in a centralized location and the heat is distributed for residential, commercial or industrial requirements. Normally, heat is transferred underground, being similar to electric or water distribution (figure 6). The main benefits of district heating are the reduction of emissions, higher efficiencies and less maintenance. Moreover, in the application site is required less space.

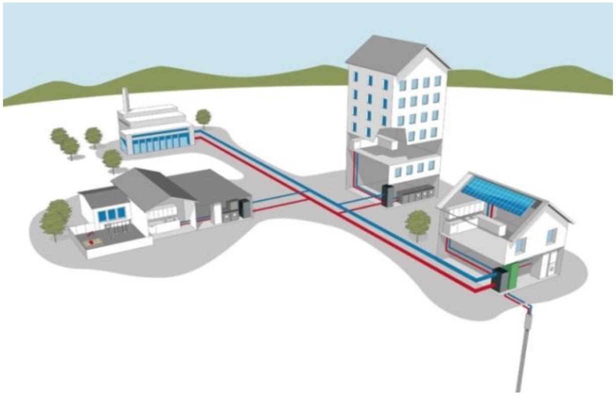

Figure 3. District heating [6]

This application is really extended in European cold countries like Iceland, Denmark or Poland, as it is one of the technologies with a big perspective of future.

1.5. Design requirements

1.5.1. Client and location

Vistabella del Maestrazgo is a municipality in the province of Castellón (España), situated in an elevation of 1,249 m. The study is carried out for a residential block and the school CEIP Sant Joan de Penyagolosa (figure 4), a building of two floors. On the first floor, the kitchen and the canteen are located, besides the pharmacy and the library (multi-use room), that are separated spaces. On the second floor, three classrooms, an office and the bathroom are located. Moreover, the school has a playground, where the gasoil boiler's small house is placed.

Furthermore, separated by the entrance of the playground, the residential block for renting, is located, which is the property of the local government. The building has 4 floors with 3 rooms, a bathroom, kitchen, dining room and storage room. Moreover, the ground floor is not used with windows facing the playground.

Both buildings are located in the same street, in a zone with moderate slopes and with the front of the building facing North and South.

Consecutively, the location of the buildings is the following:

Table 1. Location of the buildings

Location	
School's adress	24, Arrabal Nuestra Señora Loreto Street, 12135, Vistabella del Maestrazgo (Castellón)
Residential block's address	26, Arrabal Nuestra Señora Loreto Street, 12135, Vistabella del Maestrazgo (Castellón)
Coordinates	40º17'34.87" N, 0º17'39.113" W

Respect to the use of the buildings, the school, the pharmacy and the library have defined schedules:

- School: from 9:30 to 16:30; from Mondays to Fridays.
- Pharmacy: from 9:00 to 14:00 and from 17:00 to 19:00; from Mondays to Saturdays.
- Library: from 18:00 to 20:30; Mondays and Fridays. On Saturdays it is open from 10:00 to 13:00.

Despite of these the public schedules, the different spaces of the school's building could be used in extra hours by the local government's employees. For example, when the visit to Vistabella was carried out, the library was organized by a worker.

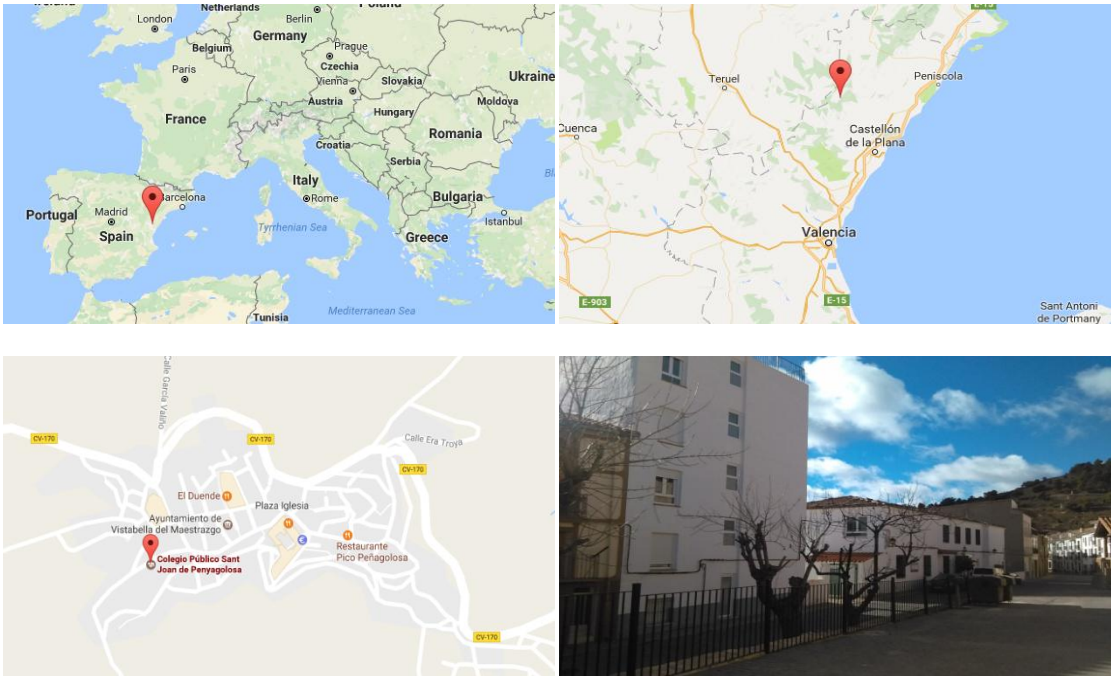

Figure 4. Location of the installation

1.5.2. Previous installations

Nowadays, the buildings of the study have the next heating systems:

- School: it has a boiler of gasoil. The boiler is a ROCA NGO-50 of 45.3 kW of nominal power (figure 5), which is located in a small house in the playground. The main characteristics of the boiler are:
-

Table 2. Characteristics of the gasoil boiler

Boiler ROCA NGO-50	
Nominal power (kW)	45.3
Voltage/Frequency	230 V/50 Hz
Gasoil flow (kg/h)	3.2 – 4.4

The boiler is connected with the building through copper pipes, whose inner diameters vary between 17 mm and 25.4 mm. It uses iron radiators in order to supply the heat to the school, divided up between the two floors.

- Library: it shares the installation with the school.
- Pharmacy: although the pipes pass through the pharmacy, there is no heating system there. At best, the pharmacist has a small electric heater.
- Residential block: there is a chimney for the extraction of fumes that is shared among the 4 floors and the ground floor. The main heating systems installed in the apartments are small stoves of firewood, located in the dining room (figure 5).

Figure 5. Actual heating systems

1.5.3. Heating demand

The calculation of the heating demand is carried out for both buildings separately. Then, one of them is the school's building, which includes the pharmacy and the library, and the other is the residential block.

It should be taken into account that the project of the school is previous to 1970 and no information is available. However, there is a previous study that was written by Javier Celades Aparici [7] where the heating system of the school was analysed. Therefore, some of the parameters about walls or windows come from this study and its data collection.

In respect of the residential block, the local government provided the plans of the apartments and the enclosures, doors and windows were inspected in situ.

1.5.3.1 Enclosures, windows and doors

In order to know the thermal power losses and the energy demand required in the buildings, the main characteristics of the enclosures, windows and doors are needed.

All the different enclosures that appear in the two buildings, with their materials and characteristics, are in the table 3.

Table 3. Characteristics of the enclosures

Enclosure	Material	Thickness (mm)	Conductivity λ (W/mK)	Thermal resistance R (m²K/W)	Overall heat transfer coefficient U (W/m²K)
External wall (N,E,W)	Mortar of cement for masonry	50	1,8	0,028	1,22
	Partition of double air brick (60 mm<E<90 mm)	240	0,432	0,556	
	Skim coat	20	0,3	0,067	
External South wall	Mortar of cement for masonry	70	1,8	0,039	0,98
	Partition of double air brick (60 mm<E<90 mm)	320	0,432	0,741	
	Skim coat	20	0,3	0,067	
Floor against ground	Generic surface + mortar	50	1,8	0,028	2,06
	Slab of reinforced concrete	150	2,5	0,060	
	Bed of stones	150	2,3	0,065	
Floor against local without conditioning	Generic surface + mortar	50	1,8	0,028	1,44
	Ceramic flooring blocks 20 c.c. Norm.	230	0,67	0,343	
	Air gap	30		0,160	
	Skim coat	20	0,25	0,080	
Roof	Roofing tile of baked clay	10	1	0,010	1,61
	Generic surface + mortar	50	1,8	0,028	
	Ceramic flooring block 20 c.c. Norm.	230	0,67	0,343	
	Air gap	30		0,160	
	Skim coat	20	0,25	0,080	
Party wall	Skim coat	150	0,3	0,500	2,21
	Hollow bricks	650	0,445	1,461	
	Stone coat	150	0,3	0,500	
Wall against local without conditioning	Skim coat	20	0,3	0,067	3,14
	Hollow bricks	80	0,432	0,185	
	Skim coat	20	0,3	0,067	

Moreover, windows and doors are considered also in the generation of thermal power losses. The main characteristics are shown in the next table:

Table 4. Characteristics of the windows and doors

Windows and doors	Material	Thickness (mm)	Area (m²)
Window 80	Double crystal Climalit	4-6-4	1,44
	Metallic carpentry without RPT		
Window 100	Double crystal Climalit	4-6-4	1,8
	Metallic carpentry without RPT		
Window 120	Double crystal Climalit	4-6-4	2,16
	Metallic carpentry without RPT		
Window 150	Double crystal Climalit	4-6-4	2,7
	Metallic carpentry without RPT		
Window 180	Double crystal Climalit	4-6-4	3,24
	Metallic carpentry without RPT		
Internal door			5
External door			5

1.5.3.2 Thermal power losses

The thermal power losses are caused by the difference of temperature between the room with heating and other non-conditioning spaces or abroad. In the calculus of the thermal power losses, there are different considerations that must be taken into account. The area of the enclosures, windows and doors, the thermal resistance, the thickness or the difference of temperature are parameters that can provide information about the power dissipated.

The calculus of the thermal power losses is used to know for the heating demand of the buildings and the power requirements of the boilers. The calculations of the thermal power losses are in point 2.1., and the main results are shown in the next tables:

- School's building:

Table 5. Thermal power losses of the school's building

Thermal power loss	Power (W)
Building enclosure	28,534.19
Windows and doors	10,456.50
Ventilation	18,259.96
TOTAL	**57,250.64**

- Residential block:

Table 6. Thermal power losses of the residential block

Thermal power loss	Power (W)
Building enclosure	12,992.97
Windows and doors	9,040.77
Ventilation	3,886.80
TOTAL	**25,920.54**

Finally, the total thermal power losses of both buildings are the sum of the individual totals. The total thermal power losses are **83,171.18 W**.

1.5.3.3 Annual energy demand

Following point 2.1., the annual energy demand is calculated with the Heat Degrees Days (HDD) method, which considers a base temperature of comfort, an average temperature for each month and the time that the buildings are used.

Using a base temperature of 15ºC (a normal value in Spain) [8], the Heat Degree Days of each building are:

Table 7. HDD of the buildings

Building	HDD_{15}
School's building	1326.45
Residential block	2178.05

As the thermal power losses are known, the annual energy demand is calculated. The results are shown in the next table:

Table 8. Annual energy demand

Building	Annual energy demand
School's building	34,914.99 kWh
Residential block	38,935.33 kWh
Total	**73,850.22 kWh**

Despite of the fact that thermal power losses of the school's building are bigger, the residential block has more annual energy demand. The reason of this is the considerations assumed. It is impossible to estimate the use of the residential block so a calculation was made for the most unfavourable case. Therefore, the number of hours of heat demand is much bigger in the residential block than in the school's building.

1.6. Design alternatives to be considered

Basically, the design of alternatives is focused in the study and sizing of the boiler, the main equipment of the heat system installation. In order to select the best option, the alternatives are based on two considerations.

On the one hand, the comparison is carried out for the cases of district heating and individual heating systems. The first case considers the sum of the two building's demands and thermal power losses for the calculus. Moreover, the district heating has an extra section of conduction that connects the two installations and must be considered in the sizing of the installation. In contrast, the individual installations act independently, requiring more equipment.

On the other hand, in the sizing of the boiler is considered another two options. The first option is the sizing of a modulating biomass boiler without buffer tank, regulating the energy with the same boiler. The second option is the sizing of a biomass boiler with a buffer tank that can provide energy in the peak hours of demand, allowing the installation of a boiler with less power.

1.6.1. Sizing of the boiler

In the boiler's sizing, some considerations were taken into account depending on the demands of the local government and the conditions of the buildings. The apartments only have small firewood stoves in the dining rooms, so the biomass installation would be new. Furthermore, the school and the library have a heating system based on gasoil, but the local government wants to change it for a biomass system.

Moreover, the Instituto para la Diversificación y Ahorro de la Energía (IDAE, 'Institute of Energy Diversification and Savings') established a technical guide for biomass installations in buildings [9], where they give some important factors for the sizing of the boiler:

- Typology and quality of the fuel.
- High efficiency (>90%) and low emissions. It must be taken into account that the RITE establishes a minimum efficiency for biomass boilers of 75% [10].
- High automatization level.
- It is recommendable to use a modulating system that allows the variation of power.
- Availability of distributors and installation companies.
- The cost of the system and the availability of public grants.

In order to select the typology of fuel, it must be taken into account that the local government pretends to use their own forestry waste, located in the surroundings of the municipality, in a long term. Nowadays, they have a shredder machine that can produce wood chips. However, the quality of the pellets is better because of the calorific value. In addition, the local government is in process to obtain grants that allow them to acquire a pelletizer. Therefore, it is preferable to use pellet or multi-fuel boilers.

Due to the requirements of the RITE, all the commercial biomass boilers have high efficiency. Normally, standard biomass boilers have an efficiency of the 92%, approximately.

The project's installation requires a high automatization level because there are not maintenance workers for the specific maintenance of the boiler. It is considered that the ash extraction would be carried out by the *alguacil* (local government staff).

To adjust modulating systems to different power levels, depends on the energy demand. It is preferable to use a modular boiler with a big range of work, in order to avoid a boiler that works only in on/off.

Finally, there are regional grants for the implementation of biomass installations. In respect to the cost, one of the main approaches is the minimum cost, always considering the technical requirements. The boilers of the study are selected from local distributors [11][12][13].

1.6.1.1 Modulating biomass boiler

The use of modulating biomass boiler is one of the simplest alternatives in the actuality because the same machine allows the adaption of the production to the different levels of energy demand, depending on the hour of the day.

Principally, these boilers are used with pellets as a fuel, which is stored in a hopper, and transported to the combustion chamber thanks to a feed auger. The supply of fuel is controlled in order to modulate the power, using an oxygen sensor (Lambda probe). The heat produced is transmitted through a heat exchanger.

In order to select the boiler more suitable, it is required that the maximum power of the installation could be supplied. Considering the high costs of the boilers, it is compared different models for each case study, looking for the best price and features.

- **School's building individual installation**

For the school's building, it must be taken into account that the maximum power is 57.25 kW, which is the thermal power loss of the building.

Considering the distributors that are located near Vistabella, some commercial models are:

Table 9. Modulating boilers for the school's building

Producer/Model	Max Power [kW]	Min Power [kW]	Efficiency [%]	Fuel	Cleaning	Cost [€]
Biocalora/KP61	61	18.3	91.2	Pellet – Olive Stone	Semiautomatic	7,850 €*
Biocalora/KP62	61	18.3	91.2	Pellet – Olive Stone	Automatic	9,890 €*
Froling/P4 Pellet 60	58.5	17.3	92.1	Pellet	Automatic	16,093 €
Herz/PelletStar 60	60	13	93.7	Pellet	Automatic	14,841 €

* It does not include the storage

There is a big difference of cost between Biocalora boilers and Froling or Herz. The main reason is that Biocalora boilers do not include a small hopper for the storage of pellets.

Moreover, considering that the difference of cost is not very large, the boiler of Biocalora model KP61 is dismissed because the cleaning is semiautomatic (only the heat exchanger is manual).

In respect of the boiler Biocalora KP62, a small hopper should be installed, too. From the same distributor, it is obtained that a hopper of 100 l, adapted for level sensor, has a cost of 319 €. Moreover, a feed auger is also required that connects the hopper with the combustion chamber. The manufacturer's cost is 792 €. Other components of connection like elbows or wall plates have a cost of 52 €. Therefore, the minimum cost of the boiler is 11,053 €.

In this case, Froling boiler is dismissed because of the cost, having the next comparison between the two options:

Table 10. Comparison between KP62 and PelletStar 60

	KP 62	PelletStar 60
Less cost	✓	X
Higher efficiency	X	✓
Less dimensions	X	✓
More power range	X	✓

In table 9 it is possible to see that the only advantage of Biocalora KP62 is the cost (3,788 € less), PelletStar 60 has better characteristics. In respect of the efficiency, the difference is insignificant (only 2.5 %). In respect of the size, the two boilers have enough space in the small house. Finally, in respect of the power range, KP 62 can supply from 18.3 kW to 60 kW and PelletStar 60 can supply from 13 kW to 60 kW. Considering that the maximum demand is lower than the maximum powers and the minimum power is very low in both cases, the differences are negligible.

Therefore, despite of PelletStar 60 has better properties, Biocalora KP62 has been selected, because it has a good performance and less cost.

- **Residential block individual installation**

The maximum thermal power losses in the residential block are 25.92 kW. Considering the distributors that are located near Vistabella, some commercial models are:

Table 11. Modulating boilers for the residential block

Producer/Model	Max Power [kW]	Min Power [kW]	Efficiency [%]	Fuel	Cleaning	Cost [€]
Biocalora/KP21	28.5	8.55	90.2	Pellet – Olive Stone	Semiautomatic	5,313 €*
Biocalora/KP22	28.5	8.55	90.9	Pellet – Olive Stone	Automatic	7,900 €*
Froling/P4 Pellet 32	32	8.9	93.5	Pellet	Automatic	12,600 €
Herz/PelletStar 30	30	6.1	92.6	Pellet	Automatic	10,940 €

* It does not include the storage

Considering that the difference of cost is not very large, the boiler of Biocalora model KP21 is dismissed because the cleaning is semiautomatic (only the heat exchanger is manual).

Moreover, considering the same hopper and feed auger of the previous case, the final total cost of Biocalora KP 22 is 9,063 €.

In this case, the boiler of Froling is dismissed because of the high cost. Then, the main characteristics of the two other boilers are analysed:

Table 12. Comparison between P4 Pellet 32 and PelletStar 30

	P4 Pellet 32	PelletStar 30
Less cost	✓	X
Higher efficiency	X	✓
Less dimensions	X	✓
More power range	X	✓

The result is very similar to the school's case with a difference of 1,877 € in the final cost. Considering that the technical characteristics are similar, Biocalora KP 22 has been selected because of the price.

- **District heating**

In this case, the modulating boiler is sized for the district heating. Therefore, the total power is increased, it is the sum of the thermal power losses of each building. This maximum power is 83.17 kW.

Considering the distributors that are located near Vistabella, some commercial models are:

Table 13. Modulating boilers for district heating

Producer/Model	Max Power [kW]	Min Power [kW]	Efficiency [%]	Fuel	Cleaning	Cost [€]
Froling/P4 100	100	24	94.3	Pellet	Automatic	22,719 €
Froling/T4 90	90	27	>90	Pellet – Wood Chip	Automatic	22,663 €
Herz/Firematic 100	99	23.2	92.5	Pellet – Wood Chip	Automatic	21,052 €
Met Mann /Pelletherm 100	100	35	93	Pellet	Automatic	12,275 €

It is possible to see in table 13 that all the boilers can work in the maximum power, having a big difference of cost between one model and the others. However, the range of power of the boilers cause that they are incompatible with the installation, because the minimum power is in the order of 25 kW or more. It is a problem, considering that many times the demand comes only from the residential block (for example, in the nights). In this case, the boiler would supply more energy and it would work all time switching on and off.

Then, one alternative is to use pellet boilers with cascade control. This control allows a bigger range of appliance (the minimum power is the minimum of one boiler and the maximum is the sum of two boilers). The company Froling has some discounts for this case, it is more viable than selecting two independent boilers.

Table 14. Characteristics of the Froling P4 48

Producer/Model	Max Power [kW]	Min Power [kW]	Efficiency [%]	Fuel	Cleaning	Cost [€]
2 x Froling/P4 48	96	14.4	85.4	Pellet	Automatic	30,433 €

As can be seen, the cost of the installation increases a lot but it is possible to do the modulation of the power in the night (without the consideration of buffer tanks).

1.6.1.2 Biomass boiler with buffer tank

In the previous case, the boilers that are taken into account do not require buffer tanks, in order to have a quicker start. However, the buffer tanks have more purposes.

For a demand with a 25% less of the nominal (approximation), modulating boilers cannot regulate the supply of power. In this case, it is preferable to use a buffer tank, avoiding a continuous switching on and off. Furthermore, the boilers require time to stop because some fuel is still burning. Buffer tanks can profit all the energy of the boiler when it is shutting down.

Finally, in order to reduce the investment costs, the buffer tanks can provide energy in the peak hours. Therefore, the nominal power of the boiler and the consumption of fuel can be reduced. In conclusion, for the sizing of the boiler, modulating boilers with less power than the maximum are considered. At the same time, the sizing of the buffer tanks is also done. This consideration is reasonable because the maximum thermal power losses occur in the most unfavourable scenario and it only happens a few hours or days per year.

- **School's building individual installation**

For the school's building, it must be taken into account that the maximum power is 57.25 kW, which is the thermal power loss of the building. Therefore, the boilers selected have a lower, but similar, maximum power.

Considering the distributors that are located near Vistabella, some commercial models are:

Table 15. Boilers with buffer tanks for the school's building

Producer/Model	Max Power [kW]	Min Power [kW]	Efficiency [%]	Fuel	Cleaning	Cost [€]
Biocalora/S2000 Basic B-Essential 50 kW	50	25	90.1	Pellet	Semiautomatic	5,289 €
Biocalora/KP51	49.2	14.7	90.2	Pellet – Olive Stone	Semiautomatic	6,405 €*
Froling/P4 48	48	14.4	92.4	Pellet	Automatic	15,774 €
Herz/PelletStar 45	45	13	94.4	Pellet	Automatic	13.732 €

* It does not include the storage

In this case, there is a really big difference between Biocalora Serie 2000 and the other models. Moreover, this model includes a hopper of 300 l and a feed auger. However, the disadvantage is that the cleaning is semiautomatic. Nevertheless, only the heat exchanger requires manual cleaning.

This enormous difference of cost is due to the design of Serie 2000. These boilers are designed for concrete low powers for applications like households, farms, neighbourhood communities. Therefore, it is well adapted to the requirements of the school. Moreover, the buffer tank required is smaller than the other alternatives because the maximum power is more similar to the maximum thermal power losses.

With this in mind, despite of the cleaning is semiautomatic, Biocalora Seire 2000 is preferable for the school. The main reason of this selection is the great difference of cost between the different models. Moreover, the local government has staff members (the *alguacil*) that can do simple maintenance tasks periodically, such as cleaning.

Selecting this boiler, the maximum power that can be supplied is 50 kW, so a buffer tank is required. Therefore, it is considered that the most unfavourable case is when the activity of the school and the activity of the pharmacy coincide (it is also considered that the library is used for the personal of the local government). The rest of the day, the boiler can act individually because the demand is lower.

If the maximum thermal power losses are 57.25 and there are 4.5 hours per day of common use, the maximum energy that the buffer tank must store is:

$$Energy = (57.25\ kW - 50\ kW) \cdot 4.5\ h = 32.625\ kWh$$

In order to select a buffer tank, the volume of the unit is required by the manufacturers. The volume can be calculated using the next equation:

$$Energy = m \cdot Cp_{water} \cdot \Delta T$$

where *m* is the mass of water, Cp_{water} is the specific weight of the water and *ΔT* is the differences of temperature between the minimum and maximum in the buffer tank (the difference establishes when works the buffer tank or the boiler).

Following the recommendations of the manufacturer, a minimum consign of 60ªC and a maximum of 90ºC is established for the buffer tank. Therefore, the temperature gradient is 30ºC.

Furthermore, the specific weight of the water is 4,180 J/kg·ºC and it can be expressed in kWh dividing between 3,600,000. The result is 0.001161 kWh/kg·ºC.

Considering that the density of the water is 1 kg/l, the mass can be replaced by the volume in the expression. Finally, with an estimated efficiency of the 95 %, it is obtained the next expression:

$$Volume\ [l] = \frac{Energy\ [kWh]}{0.001161\,\frac{kWh}{kg\cdot ºC}\cdot 30ºC\cdot 0.95}$$

The required volume of the buffer tank for the school's building is:

$$Volume\ = 985.99\ l$$

This value is inside the recommendations of the manufacturers, who recommend a buffer tank with a volume of 15-30 l/kWh of the boiler.

Following different product brochures, a buffer tank of 1000 l is selected. One economic option is the proposal of the company Froling, who provides stratifies buffer tanks with low cost. The height of the buffer tank selected is 2,170 mm, with a volume of 1000 l. The cost of the unit is 712 €.

- **Residential block individual installation**

In the residential block, the maximum power required is 25.92 kW so the boilers selected have a lower, but similar, maximum power.

Considering the distributors that are located near Vistabella, some commercial models are:

Table 16. Biomass boilers with buffer tank for the residential block

Producer/Model	Max Power [kW]	Min Power [kW]	Efficiency [%]	Fuel	Cleaning	Cost [€]
Biocalora/S2000 Basic B-Home 25 kW	25	12	90	Pellet	Semiautomatic	4,313 €
Froling/P4 25	25	7.5	93.6	Pellet	Automatic	11,125 €
Herz/PelletStar 20	20	6.1	92.9	Pellet	Automatic	9,831 €
Met Mann/Bisolid Mario 25	25	7.5	91	Pellet	Manual	3,145 €

In this case, there are two models that stand out for their costs: the boiler of Biocalora and the boiler of Met Mann.

However, the boiler Bisolid Mario 25 has a manual cleaning of the burner, its integration is more complicated in the residential block. Therefore, Biocalora Serie 200 Basic B-Home is the boiler, which is selected, because it has a semiautomatic cleaning (only the heat exchanger is manual) and its cost is much lower in comparison with the automatic boilers.

In this case, the time of the peak power demand is impossible to know, because it depends on the external temperature and the use of the buildings. Therefore, manufacturer recommendations are used, establishing a buffer tank volume between 15 and 30 l/kWh of the boiler. Moreover, if the demand is not stable, it is preferable to use more volume.

Consequently, following commercial brochures, a stratify buffer tank of Froling is selected with a capacity of 700 l. This volume equates to 28 l/kW, it is in the range of recommended values. The cost of the buffer tank is 695 €.

To calculate the total energy that the buffer tank can store, the next equation is used:

$$Energy\,[kWh] = Volume\,[l] \cdot 0.001161 \frac{kWh}{kg \cdot ºC} \cdot 30ºC \cdot 0.95$$

For a volume of 700 l, the energy in kWh is:

$$Energy = 23.16\,kWh$$

As we know the difference between the peak power and the maximum power of the boiler, it is possible to calculate the time that the buffer tank can supply energy (considering the most unfavourable case):

$$Time = \frac{23.16\,kWh}{(25.92\,kW - 25\,kW)} = 25.17\,h$$

The autonomy of the buffer tank is sufficiently high for operating in the most unfavourable case.

- **District heating**

In this case, the maximum thermal power demand of the two buildings is 83.17 kW. The boilers selected have a lower, but similar, maximum power.

Considering the distributors that are located near Vistabella, some commercial models are:

Table 17. Biomass boiler without buffer tank for district heating

Producer/Model	Max Power [kW]	Min Power [kW]	Efficiency [%]	Fuel	Cleaning	Cost [€]
Biocalora/KP 82	80	24	90.1	Pellet – Olive Stone	Automatic	12,990 €*
Froling/P4 80	80	24	94.3	Pellet	Automatic	22,361 €
Herz/Firematic 80	80	23.2	92.4	Pellet – Wood Chip	Automatic	19,895 €
2 x Froling/P4 38	76	8.9	85.7	Pellet	Automatic	26,472 €

* It does not include the storage

Considering that the installation has more capacity with the two buildings, the hopper selected has more volume. With a hopper of 700 l, the cost is 513 €. The feed auger and the other materials (elbows and wall plates) have the same cost that previous cases, they were 792 € and 52 €, respectively. Therefore, the total cost of Biocalora boiler is 14,347 €.

Following the table 17, Froling and Herz boilers are dismissed because of costs in comparison with Biocalora. Moreover, cascade control is not required in this installation because a good sizing of the buffer tank can avoid the on/off mode. Therefore, Biocalora KP 82 is the alternative selected, achieving important economic savings.

In the sizing of the buffer tank, it must be taken into account the case of peak demand and the case of low demand. The maximum demand can be only required during 4.5 h per day (when school and pharmacy is open):

$$Energy = (83.17\ kW - 80\ kW) \cdot 4.5\ h = 14.265\ kWh$$

This is the most unfavourable case, which is improbable. With this energy, the volume of the buffer tank is:

$$Volume\ [l] = \frac{Energy\ [kWh]}{0.001161 \frac{kWh}{kg \cdot ºC} \cdot 30ºC \cdot 0.95} = \frac{14.265}{0.001161 \cdot 30 \cdot 0.95} = 431.12\ l$$

Therefore, with a buffer tank of 500 l it is enough to supply power for peak hours.

On the other hand, it is necessary to determine how the heat is regulated when the demand is lower than the minimum power of the boiler. This scenario could occur during holidays or the nights, when the school's building is closed.

It should be understood that using a thermostat, the boiler can be switched on and off according to the heat requirements of the buildings. However, it is preferable to use a buffer tank that stores energy and avoids the commutation of the boiler.

Following the recommendations of the manufacturers, a buffer tank is selected between 15 and 30 l/kW of the boiler. Considering that the demand is variable, it is preferable to use a buffer tank with more capacity:

$$Volume = 30 \frac{l}{kW} \cdot 80\ kW = 2{,}400\ l$$

Considering commercial brochures, a stratify buffer tank of the company Froling is selected with a volume of 2,200 l, which corresponds to 27.5 l/kW. The cost of the buffer tank is 1,415 €.

The quantity of energy that can be stored in the buffer tank is:

$$Energy\ = 2200\ l\ \cdot 0.001161 \frac{kWh}{kg \cdot ºC} \cdot 30ºC \cdot 0.95 = 72.79\ kWh$$

It should be taken into account that the maximum demand occurs only for the most unfavourable case, which only affects a few hours per day. The autonomy for the peak hours is:

$$Time = \frac{72.79\ kWh}{(83.17 - 80)kW} = 22.96\ h$$

When the demand is lower than the minimum power of the boiler (25 kW) the buffer tank has autonomy for the worst case of:

$$Time = \frac{72.79\ kWh}{25\ kW} = 2.91\ h$$

The buffer tank cannot provide enough energy for the 14 hours of difference among the pharmacy is open and close. Nevertheless, in this case the boiler supplies energy to the buffer tank and it switches off when the tank arrives to the maximum temperature. Considering that the autonomy is high, there are no problems of commutation.

Technically, using two boilers with cascade control and a boiler with buffer tank are good options. However, in table 18 a comparison of costs between the two options can be seen, considering a buffer tank of 700 l for the cascade control (in order to supply energy in peak hours):

Table 18. Comparison between one boiler and two boilers

	Boiler's cost	Buffer tank's cost	Total cost
One boiler with 2200 l	14,347 €	1,415 €	15,762 €
Two boilers	26,472 €	695 €	27,167 €

In conclusion, the difference of the costs is very high, so it is preferable to use a Biocalora boiler with a buffer tank of 2,200 l.

1.7. Description of the final solution

1.7.1. Biomass boiler

Once the different installations are analysed, it is known that all the alternatives are technically viable. In the next table, a cost comparison between the different the best selected options are shown:

Table 19. Cost of the different alternatives

Alternatives	School's building	Residential block	Individual installation	Centralized installation
Modular boiler	11,053 €	9,063 €	20,116 €	30,433 €
Boiler with buffer tank	6,001 €	5,008 €	11,009 €	15,762 €

The first conclusion drawn from the table is that **is preferable to use buffer tanks** in order to reduce the cost of the installation. The main reason is the reduction of the boiler's power. Thanks to the reduction of power, more economic models can be selected and the cost decreases considerably.

In addition, buffer tanks are not so expensive. Therefore, the use of cascade control increases the final cost more.

On the other hand, inside the heating systems with buffer tanks there are two alternatives. Installing two boilers requires less investment than district heating because the boilers have a semiautomatic cleaning. Moreover, the boiler of district heating has a better performance and more power, considerably increasing the cost. Another disadvantage of the district heating is the civil work required. In the case of Vistabella, the connection between the two buildings would be in the buried in the common street, increasing the final cost of the investment.

However, the district heating installation has some advantages in a technical way. First, the cleaning is totally automatic, requiring less operation and maintenance. Therefore, the annual cost of the district heating installation is lower.

Furthermore, district heating requires less space because it has only one boiler, one storage system, one buffer tank, etc. With district heating, it is possible to install all the equipment on the ground floor of the residential block, improving the supply of pellets and the operation.

In conclusion, the difference of investment is not very large between district heating and an individual installation. Moreover, there are different advantages and disadvantages for each technology. Therefore, the comparison must be done considering all the equipment required and considering the final cost and the feasibility study of each system.

1.7.2. Other equipment

In this point, the main components of biomass systems for district heating and individual installations with biomass boilers and buffer tanks are examined.

1.7.2.1 Storage

The sizing of the storage systems takes into account the available space and the energy demand of the buildings. The calculation of the quantity of pellets required, a calorific value of 4.9 kWh/kg and a density of 598 kg/m^3 (average values) are considered.

- School's building:

$$Pellets\ mass = \ 34{,}914.99\ kWh \cdot \frac{1\ kg\ pellet}{4.9\ kWh} = 7{,}125.51\ kg\ pellets$$

$$Pellets\ volume = 7{,}125.51\ kg\ pellets \cdot \frac{1\ m^3 pellets}{598\ kg} = 11.92\ m^3 pellets$$

- Residential block:

$$Pellets\ mass = \ 38{,}935.33\ kWh \cdot \frac{1\ kg\ pellet}{4.9\ kWh} = 7{,}945.99\ kg\ pellets$$

$$Pellets\ volume = 7{,}945.99\ kg\ pellets \cdot \frac{1\ m^3 pellets}{598\ kg} = 13.29\ m^3 pellets$$

- Both buildings:

$$Pellets\ mass = \ 15{,}071.50\ kg\ pellets$$

$$Pellets\ volume = 25.21\ m^3 pellets$$

From this information, the recommended storage systems are estimated. Furthermore, it is important to consider the trucks and the number of load per year, trying to reduce this number. Following the brochure of the distributor Grupo Nova Energía [11], the storage systems selected are:

- School's building:

Table 20. Characteristics of the school's building silo

Description		**Cost**
Polyester silo 6 m³ - 3,500 kg		**2,241 €**
Height	4,350 mm	
Load mouth	500 mm	
Diameter	2,060 mm	
Unload mouth	580 mm	
Width of the base	2,500 mm	

Figure 6. Polyester silo

In this case, the silo is too big, so its location would be the playground of the school. The number of loads per year is:

$$N = \frac{11.92\ m^3 pellets}{6\ \ m^3} = 1.99\ loads/year$$

- Residential block:

Table 21. Characteristics of the residential block silo

Description		**Cost**
Textile silo of Biocalora		**2,123 €**
Width x Large x Height	250 x 250 x 200 cm	
Volume	5.1 m³	
Tonnes	3.3 t	

Figure 7. Textile silo of the residential block

It is possible to install the silo inside the ground floor of the building, inside the dining room. The number of loads per year is:

$$N = \frac{13.29\ \ m^3 pellets}{5.1\ \ m^3} = 2.6\ loads/year$$

However, the annual energy demand is for the most unfavorable case, which is improbable, so the local government must do the management and control of the loads.

- Both buildings:

Table 22. Characteristics of the district heating silo

Description		**Cost**
Textile silo of Biocalora		**2,726 €**
Width x Large x Height	300 x 300 x 200 cm	
Volume	7.1 m³	
Tonnes	4.6 t	

Figure 8. Textile silo of the district heating

It is possible to install the silo inside the ground floor of the building, inside the dining room. The number of loads per year is:

$$N = \frac{25.31\ m^3 pellets}{7.1\ m^3} = 3.56\, loads/year$$

Then, it is more economic to use one silo than two. Moreover, other equipment must be taken into account (feed auger, adapter, etc.), which increase the cost of the individual installations.

1.7.2.2 Heat exchanger

The heat exchanger is used in the transmission of heat from the buffer tank to the installation. The sizing is carried out in function of the boiler's power, selecting a heat exchanger with a similar power.

- School's building: heat exchanger of the company IDROGAS model DS14-30H. It is made of stainless steel, with a power of 60 kW, a maximum temperature of work of 225 ºC and a maximum pressure of 30 bars.
- Residential block: heat exchanger of the company IDROGAS model DS14-20H. It is made of stainless steel, with a power of 30 kW, a maximum temperature of work of 225 ºC and a maximum pressure of 30 bars.
- District heating: heat exchanger of the company IDROGAS model DS14-40H. It is made of stainless steel, with a power of 80 kW, a maximum temperature of work of 225 ºC and a maximum pressure of 30 bars.

Figure 9. Heat exchanger of IDROGAS

1.7.2.3 Pipe conduction

Actually, the school and the library have an installation of copper pipes because of the heating system. Nevertheless, the pharmacy and the residential block do not have any installations. All the pipes of the school and the library have an inner diameter of 25.4 or 17 mm.

For the pharmacy installation, part of the circuit would be used, installing pipes for the specific part of the space. Following the previous study of Javier Celades [7], an inner diameter of 17 mm for the flow and return is selected.

For the residential block, the creation of four circuits is estimated, one for each apartment. All the circuits would have 6 terminal points (3 for the rooms, 1 for the bathroom and 2 for the dining room). The inner diameters of the circuits are 17 mm, in order to have low pressure losses and similar values with the actual conductions. The size of the conductions are shown in the annexes (Annex I), are estimated from the plans. In addition, there is a pipe which connects all the 4 circuits, and it has an inner diameter of 25.4 mm, because of the longitude.

The district heating connects each building underground, crossing the Arrabal Nuestra Señora Loreto Street. Considering that the boiler is on the ground floor of the residential block, the point of connection is in the same place where the gasoil installation is located now. The copper pipe has an inner diameter of 33 mm and the longitude is more or less 50 m, following the distance between the two points.

1.7.2.4 Expansion vessel

Expansion vessels are tanks which main purpose is the absorption of the overpressures in the fluid installations. The sizing of the expansion vessels is shown in the calculus part of the project, in point 2.3.

Following the results obtained, the commercial models of the company Industrias Ibaiondo S.A. selected are:

- School's Building: 150 AMR-PLUS of 150 litres of capacity and vertical. The cost is 277.75 €.
- Residential block: 80 AMR-PLUS of 80 litres of capacity and vertical. The cost is 195.30 €.
- District heating: 220 AMR-PLUS of 200 litres of capacity and vertical. The cost is 329.70 €.

Figure 10. Vertical expansion vessel

Once again, it is cheaper to have one big installation than two smaller individual ones.

1.7.2.5 Radiators

They are the terminal elements of the installation. In the school and the library they are conserved, in order to reduce the final investment. The number of radiators required in the pharmacy and apartments is calculated in the point 2.4.

Table 23. Number of radiators

Space	Radiators required
Pharmacy	One radiator of five elements and two radiators of fifteen elements
Residential block	Five radiators of ten elements and one radiator of five elements in every apartment

1.7.2.6 Pumping system

The movement of the hot water through the installation is due to different pumps located in some points of the conductions.

Considering that the requirements of losses are low and in the previous study [7] two Baxi Roca pumps were selected, model PC1025 for pumping water to the heat exchanger and to the tank.

Moreover, in point 2.4., the calculus of the flow and the pressure losses of the different installations are done. Considering the information obtained, the different bombs required for the installations were selected thanks to technical brochures (figure 12):

- School's building: Distributor Baxi Roca, model PC 1045. Maximum power of 205 W.
- Residential block: Distributor Baxi Roca, model PC 1025. Maximum power of 88 W.
- District heating: Distributor Baxi Roca, model Quantum ECO 32 H. Maximum power of 305 W.

Figure 11. Pump of the series PC

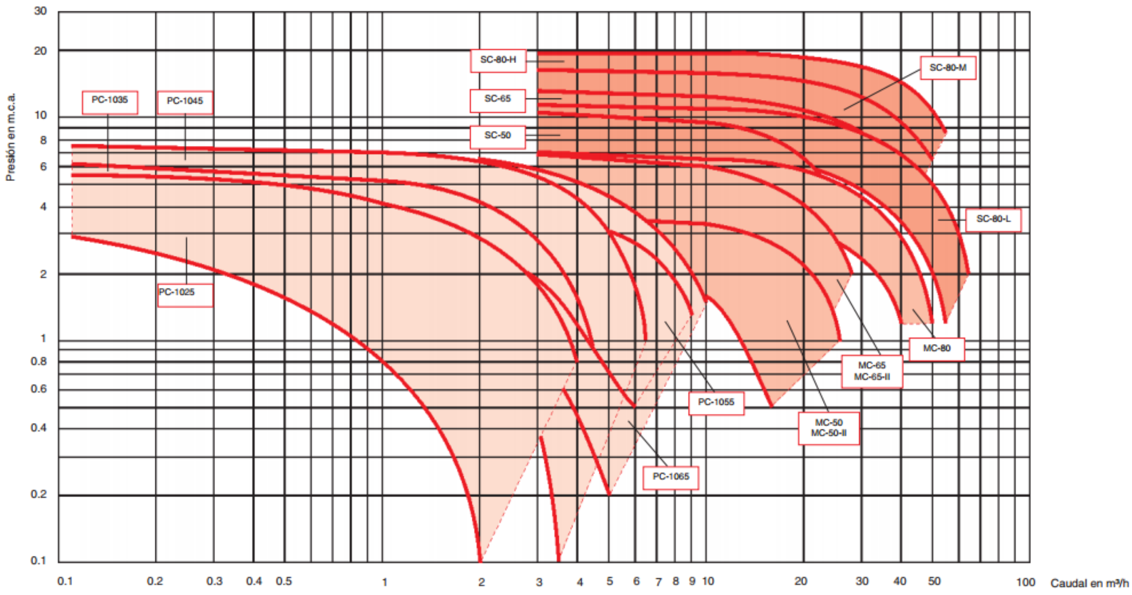

Figure 12. Curves of Baxi Roca's pumps; models PC, SC and MC

1.7.2.7 Fume extraction

The residential block and the school's building have chimneys for the extraction of fumes. The apartments use the chimney because of the stoves installed in the dining rooms (figure 13) and the school's building has the chimney in the small house where the gasoil boiler is located.

Figure 13. Chimney of the residential block

The biomass boilers can use the actual installations or the bore created for the chimneys, in order to reduce the final investment. Nevertheless, it should be required to do an exhaust study of the fumes emitted due to the biomass boilers and a sizing of the chimneys for the new installations. This part is considered for future projects.

1.8. Impact of the project for the rural development

1.8.1. Environmental impact

The environmental impact is studied from two points of view. On the one hand, the influence of the execution of the project to the natural resources of Vistabella del Maestrazgo and the surroundings is considered. On the other hand, the emissions of greenhouses gases avoided are studied thanks to the installations of biomass.

1.8.1.1 Natural resources

In respect of the natural resources, the consequences of the project for the natural space, the water demand and the energy demand must be considered.

The installation of biomass heating systems forms part of the local government's plan, which pretends to profit the forestry waste of the surrounding of Vistabella del Maestrazgo for the production of biomass (pellets and/or wood chips). This plan is based on a previous experience in the municipality of Serra (Valencia), where their local government uses the pruning waste.

- **Space, landscape and soil demand**

The installation of biomass is placed in the municipality of Vistabella, all the systems are inside the buildings, so they do not affect to the natural space. In the district heating case, civil work affects also to Arrabal Nuestra Señora Loreto Street but the effect over the natural environment is practically zero.

Once the installation starts to work, there are some different effects over the landscape and the natural resources of Vistabella. These effects are related with the use of forestry waste for self-consumption in the heating systems of public buildings.

First of all, there are few trees and plants inside the town, so the pruning waste is negligible. Therefore, the main interest of the local government is the management of the forestry waste, which appears in public and private forests.

Nowadays, the surrounding mounts are widely neglected, affecting traditional ecosystem of the zone. The lack of management has caused the apparition of dead branches that do not let pass the sunlight. For example, due to this lack of management, a large mycological variety has been lost. With the cleaning of the dead branches and the control of the forest, mushrooms and other species could grow up again. Furthermore, a mycological preserve could be created because of the plan's development. The control and cleaning of the forest should be done in a professional way, considering all the environmental aspects (protection of different species, reduction of emissions, etc.).

Finally, the fire prevention benefits are considered. Reducing the forestry waste (i.e. dead branches), the probability of fire and propagation decreases.

- **Water and energy demand**

In respect of the water, a closed circuit is used, so the installation does not require much water.

In respect of energy, the local government bought 7,379 l of gasoil for the school and the library in the year of 2016. With the installation of the project, which also includes the pharmacy and the residential block, a renewable energy source (biomass) was used, requiring 15,071.5 kg of pellets per year.

The electric demand is very low, in the most unfavourable case it is 1 kW (the sum of boiler's power and the pumps). This consumption is similar to the actual, which includes the gasoil boiler, the pumps and a small electric heater.

1.8.1.2 Environmental strains and emissions

- **Visual impact**

The installation is inside a building and the district heating is buried, so the visual impact is considered almost zero. Only the polyester silo of the individual installation has a visual impact because it is located on the playground. However, it can be considered as a low visual impact.

In the forests the visual impact is clearer because all the dead branches and all the forestry waste should be removed. The management of the forest has a big effect in the mount, improving the growth of grass or mushrooms.

- **Noise impact**

In the case of the individual installation in the school's building, noise is not a problem because the small house is separated well from the building (figure 14).

Figure 14. Small house of the school

In the case of the installation of the residential block, noise can be a critic problem. The movement of pellets and the boiler itself produce important levels of noise that can molest the neighbours. Therefore anti-vibration feet are used in the boiler in order to reduce the noise produced. Furthermore, an acoustic audit must be done for the validation of the noise and insulation level. The acoustic audit can also help with the suggestion of measures.

- **Air pollution and greenhouse gas emissions**

Gasoil and other fossil fuels emit large amounts of greenhouse gases, placing a big focus on air pollution. In contrast, biomass is considered a neutral fuel in emissions. This means that biomass does not unbalance the concentration of greenhouses gases in the atmosphere.

Nevertheless, the recommendations and factors are used provided by the Ministerio de Industria, Energía y Turismo (IDAE, 'Ministry of Industry, Energy and Tourism') [14]:

- Gasoil for heating: 0.311 kg CO_2/kWh of energy
- Biomass (pellets): 0.018 kg CO_2/kWh of energy

Therefore, considering that the local government buys 7,379 l of gasoil per year (with a calorific value of 10,250 kcal/kg and a density of 839 kg/m^3 [15]), the total emissions would be 22,690.72 kg CO_2 per year.

However, not all the fuel is consumed. Moreover, in the installations of the project different considerations are taken into account. With an annual energy demand of 73,850.32 kWh, the emissions with different fuels are:

- Gasoil: 22,967.45 kg CO_2/year
- Biomass (pellets): 1,329.31 kg CO_2/year

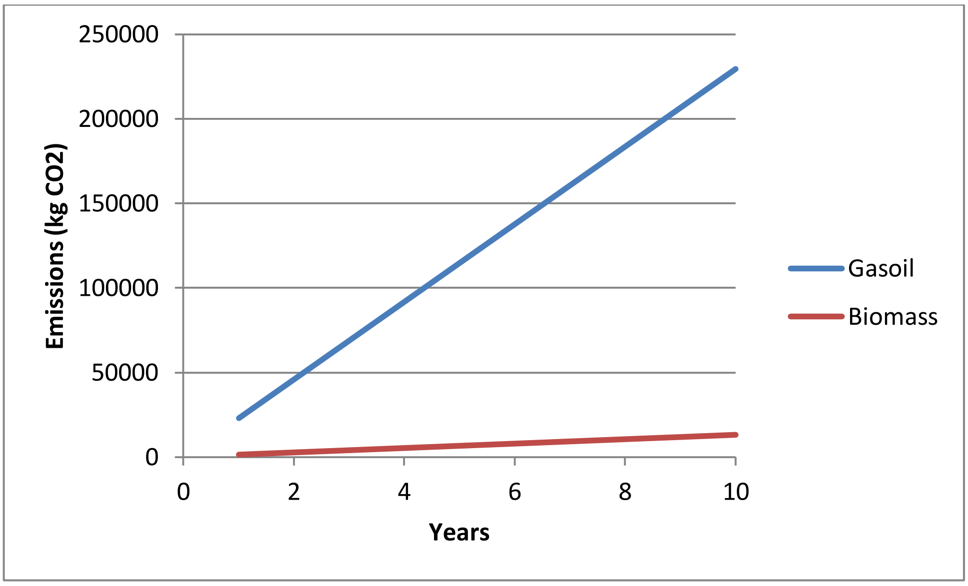

Figure 15. Emissions in ten years with different fuels

From the graph of figure 15, it is shown that pellets emit 94.21 % less of CO_2 than gasoil. Therefore, biomass has a great positive impact on the air. The emissions due to the electric consumption are not considered because they have a low effect over the total pollution.

- **Water and soil pollution**

The installation has a closed circuit, so the pollution of water is considered zero. In addition, the consideration of the soil is also considered practically zero.

- **Waste production and management**

The biomass boilers produce ashes that must be extracted for the correct functioning of the system. The worker who could be the person in charge is the *alguacil* (staff). The treatment of the ash should be done as following manufacturer recommendations with a timetable derived from the use of the boiler.

Furthermore, all the components or equipment replaced should be treated adequately by the personal approved in the residual management.

1.8.2. Social and rural impact

1.8.2.1 Energy security

Nowadays, energy is a basic human need around the world, arriving step by step to the population. In the places where the winter is very cold, heating systems become an essential part for the development of the area and the municipalities. Vistabella del Maestrazgo arrives to sub-zero temperatures a lot of days per year. Therefore, the energy security focuses on two main points related with the installation of biomass heating systems:

On the one hand, one of the objectives of local government is the self-consumption of municipality forestry waste, producing useful biomass. The use of their own fuel, totally or partially, in the heating systems of the public buildings gives a certain energy independence and autonomy to the local government.

On the other hand, the actual occupied apartment does not have a heating system in all the rooms, according to the tenant. Considering the extreme temperatures of winter in Vistabella del Maestrazgo, the energy poverty is absolutely risky for the human health. Therefore, the installation of biomass heating system helps in the improvement of the quality of life of the neighbours, assuring the supply from the local government. Moreover, this is one of the indisputable qualities that the apartments should have if the municipality wants to attract new families.

1.8.2.2 Economic development

- **Economical saves**

The cost of the pellets is lower than the cost of the gasoil, so the biomass installation has a direct impact on the energy costs of the local government. Moreover, the average cost of the fuel is considered actually, but in a few years, with the management of forestry waste, the energy costs could decrease more.

The analysis of the viability of the installation is done in point 3 of budget and economic analysis. In this point, it is shown that the installations are viable; it is a good option for improving the economical saves of the municipality.

- **New jobs**

The implementation of the project has clear impacts on the creation of new jobs. There are two types of jobs created with the project: direct and indirect jobs.

The direct jobs created because of the project are the related with the design and development of the installation and the launch of all the system. However, the operation and the maintenance are minimum and periodic, because of the level of automatization. In this sense, the cleaning of different parts of the boiler or the extraction of ashes could be done by actual workers of the local government.

The creation of indirect jobs caused by the installation affects mainly to biomass companies, distributors and carriers. However, one important indirect result of the project that affects to the creation of new jobs is the management of forestry waste.

At first, local government wants to create a local job workshop dedicated to the cleaning and management of the forests. This workshop can help in the development of professionals that are conscious about environment protection. Moreover, in the near future, the plan of the municipality is the implementation of a "clean-up squad". This squad of professional would help in the creation of new jobs related with the management of the waste forestry.

1.8.2.3 Reversing rural exodus

One of the most important problems that affects to Vistabella del Maestrazgo is the rural exodus or rural depopulation. Actually, about 370 people are registered in the municipality and 100-150 people live there in winter. Therefore, one of the main preoccupations of the local government is to attract 2 or 3 families with kids for the school.

One fundamental pillar is the creation of new jobs. As it was previously shown, the "clean-up squad" is an important point in this panorama because it can attract unemployed people to the town. Moreover, the installation of biomass heating systems ensures minimums of welfare and quality of life, being another two basic points in the reversing of rural exodus.

However, new jobs and adapted building are not the only things that are required for the establishment of new families. It is very important that the municipality and the community establish different social spaces. One example related with the project is the tales workshop (*rondalles*) that is carried out in the library (figure 16) on Mondays and Fridays in the afternoon. The empowerment of spaces like the Cultural House (*edifici Antiga Presó*) or the creation of new alternatives would help in the attraction of families to the municipality.

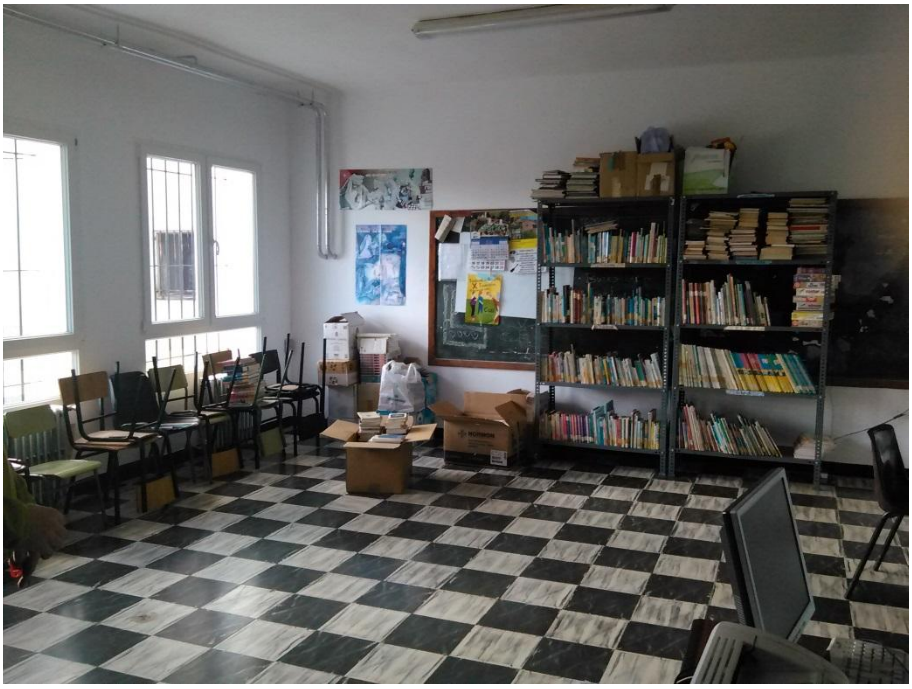

Figure 16. Library of Vistabella del Maestrazgo

Another good example would be the creation of mycological preserves and the management of the forest. The interest in ecotourism increases every day and the connection between Vistabella del Maestrazgo and the natural environment is another positive point that the project and the municipality offer.

Finally, thanks to internet connection, it is possible to work from home despite of big distances. Nowadays, this helps the rural towns to adapt to new technologies and population needs.

Therefore, the comfort at homes, cultural and social spaces and the possibility of personal development are some of the most important keys for reversing rural exodus in Vistabella del Maestrazgo and other rural areas.

1.8.2.4 Interviews

During the visit to Vistabella del Maestrazgo, qualitative samples have been done, trying to pick up the opinions of different subjects related with the project. The questions of the interviews are characterized to be open, clear and associated with the project, renewable energies and forestry waste management.

The interview is an important tool to understand the perception of different actors affected by the project. Therefore, there are two dissemination purposes: one is to explain to the people the study and the other is to bring to the local government the opinion of the neighbours concerned.

The interviewees are two members of the local government, a teacher of the school and the pharmacist, which is the only tenant in the residential block, actually. A small presentation of the interviewees and the interviews are annexed at the end of the study.

1.9. Summary of the budgets

Table 24. Summary budget of the school's building

BUDGET OF THE SCHOOL'S BUILDING	
TOTAL SCHOOL'S BUILDING INSTALLATION	12.108,05 €
TOTAL RESIDENTIAL BLOCK	14.429,68 €
TOTAL INDIVIDUAL INSTALLATION	26.537,73 €
MATERIAL EXECUTION BUDGET	26.537,73 €
13% OF GENERAL EXPENSES	3.449,90 €
6% OF INDUSTRIAL BENEFITS	1.592,26 €
SUBTOTAL	31.579,90 €
21% IVA	6.631,78 €
TOTAL BUDGET	**38.211,68 €**

Table 25. Summary budget of the residential block

BUDGET OF THE RESIDENTIAL BLOCK	
TOTAL DISTRICT HEATING	32.295,74 €
MATERIAL EXECUTION BUDGET	32.295,74 €
13% OF GENERAL EXPENSES	4.198,45 €
6% OF INDUSTRIAL BENEFITS	1.937,74 €
SUBTOTAL	38.431,92 €
21% IVA	8.070,70 €
TOTAL BUDGET	**46.502,63 €**

1.10. Conclusions

There are different conclusions that can be extracted from the study. First of all, the environmental, rural and social benefits that the project could bring to the municipality must be highlighted.

On the one hand, the change of gasoil installations for biomass has a great impact in the reduction of greenhouse gas emissions, improving the quality of the air. Moreover, the management of the forestry waste could help in the recovery of natural spaces. On the other hand, the execution of the study could be associated with positive rural development aspects like new jobs, a better quality of life or energy security. Therefore, it is shown that the project can be an important key in the attraction of new families to Vistabella del Maestrazgo.

In this sense, in the interviews, it is reflected the high interest in the project by the actors involved. They see positively the inclusion of renewable energies in their daily life.

In addition, the viability study shows that both projects are profitable, there is an economical alternative in the installation of the systems in comparison with gasoil. Moreover, thanks to the grants that reduce the initial investment, it is easier to carry out the project.

About the comparison between individual installations and district heating, there are some advantages and disadvantages for each technology.

District heating requires less operation, maintenance and space. All the installations would be done on the ground floor of the residential block, so a polyester silo on the playground is not required. Moreover, the installation would tend to have less technical problems because the level of the automatization is higher. Nevertheless, the inversion is lower in the individual installations, having a better financial viability in the next years. However, if the evolution of the payback is considered through the years (figure 17), it can be demonstrated that the difference is very small and the district heating would be more rentable with time.

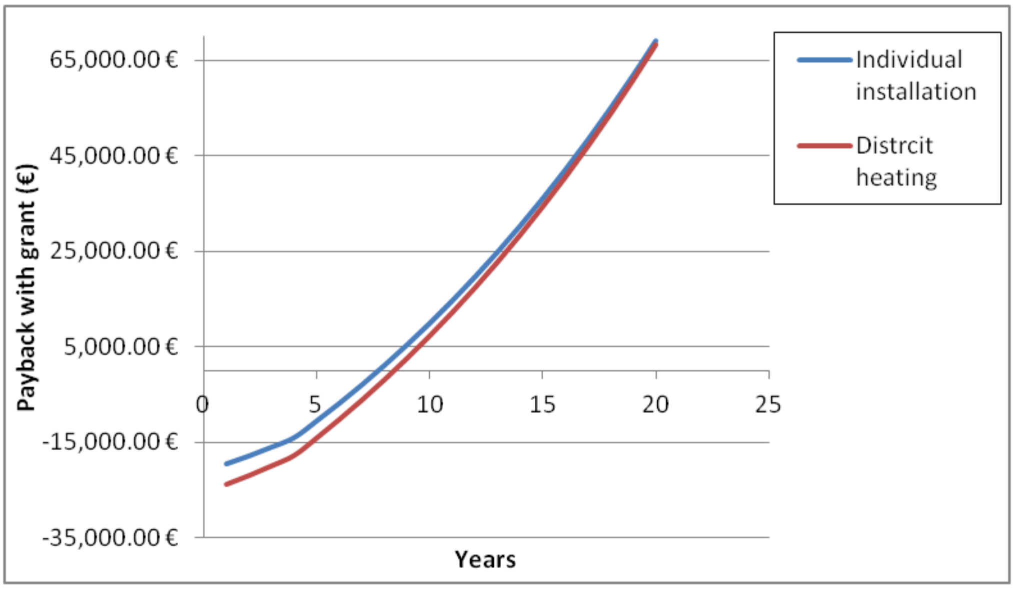

Figure 17. Evolution of the payback

In conclusion, the installation of biomass heating systems in the school's building and the residential block has a large number of positive benefits for the municipality of Vistabella del Maestrazgo. However, it is the local government's decision to select the best alternative, considering the advantages and disadvantages of each option and the available resources of the town.

1.11. Future developments

Owing to the length of the study, some parts of the project are not totally defined. Therefore, if the local government decides to do the installation, it is required to carry out some important calculations.

First, the chimney for the exhaust fumes must be sized correctly, considering the available space, the characteristics of the boiler and all the appropriate considerations. Furthermore, the profitability of creating a new connection point in the school's building installation would be studied. In the study the actual point is considered, where the gasoil boiler is installed. However, this alternative supposes the use of a large district heating pipe.

Finally, it would be necessary to do a study of the forestry waste capacity of Vistabella del Maestrazgo. This study could help in the estimation of the economic savings due to the use of the biomass produced in the municipality.

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Calculations

2. Calculations and design

2.1. History of temperatures in Vistabella del Maestrazgo

From the data obtained on the Associació Valenciana de Meteorologia Josep Peinado (AVAMET, 'Valencian Meteorologist Association Josep Peinado') [16], there is the history of temperatures in Vistabella del Maestrazgo during 2016 and the first coldest month of 2017 (table 26).

Table 26. History of temperatures in Vistabella del Maestrazgo

Month	Min. Temp. (ºC)	Avg. Temp. (ºC)	Max. Temp. (ºC)
01/2016	-5,1	4,9	14,3
02/2016	-9,6	4,0	15,2
03/2016	-7,2	4,4	17,9
04/2106	-3,6	6,7	16,6
05/2016	-4,6	10,2	21,4
06/2016	2,4	15,5	27,7
07/2016	1,7	18,7	30,0
08/2016	6,2	17,8	29,2
09/2016	2,5	14,9	31,7
10/2016	2,2	11,2	22,3
11/2016	-5,2	5,4	19,1
12/2016	-6,2	3,1	16,3
01/2017	-13,8	1,4	15,2
02/2017	-4,3	4,1	14,6

2.1. Calculation of heating demand

To calculate the demand or load of heating from the buildings, the losses are going to be taken account caused by enclosures as well as the losses caused by holes and windows in the buildings.

The calculation of the power that is dissipated is obtained with the following expression:

$$Q = U \cdot A \cdot \Delta T \; [W]$$

Where *U* is the global coefficient of heat transfer, *A* is the surface area in which the heat dissipation is made, and *ΔT* is the difference between the desired temperature inside and the minimum temperature outside.

The surface area is obtained from the plan and the measurements made in each enclosure, empty or window. Regarding the temperature difference, it will depend on the outside, it is different in each enclosure.

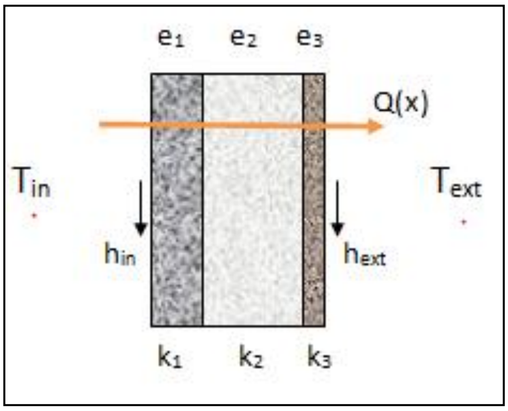


Figure 18. Heat transfer through a wall

To calculate the global coefficient of heat transfer, the thermal resistance of the enclosure must be obtained first, hole or window. For that, the calculation will be the sum of the thermal resistance of conduction (the wall) and the one of convection.

The thermal resistance of the walls and windows is calculated as the thickness among the conductivity of material:

$$R = \frac{e}{k} \left[\frac{m^2 K}{W}\right]$$

The thermal resistance linked with the convection is the opposite of h_{in} or h_{ext}, depending on the side of the wall:

$$R = \frac{1}{h} \left[\frac{m^2 K}{W}\right]$$

To calculate the total thermal resistance R_{tot}, all the thermal resistance equivalent to the conduction and the convection will be added. Finally, the overall heat transfer coefficient will be the inverse of this total thermal resistance:

$$U = \frac{1}{R_{tot}} \left[\frac{W}{m^2 K}\right]$$

To calculate the resistances, the thickness will be a figure from the installation, and the thermal conductivity will directly depend on the used material. The conductivity data will be obtained easily through different internet bibliographies [7].

To calculate the convection coefficients, it must have been considered that it is a natural convection, with a similar case of flat plates. Moreover, the air speed inside has been estimated of 1m/s and outside of 26 m/s, since Vistabella is in a windy zone, according to the CTE (Código Técnico de Edificación, 'Technical Building Code').

Likewise, as it is considered a flat plate, the characteristic lengths must be estimated. In this case, the critic case is estimated: the maximum width of each building. For the ensemble of the School, the length will be 28.63 m and for the block of buildings 9.41 m.

After making the previous considerations, the first step is to calculate the number of Reynolds (*Re*) which will establish if the flow is laminated or eddy. In this case, the Reynolds number is calculated as follows:

$$Re = \frac{v \cdot \rho \cdot L}{\mu}$$

where *v* is the fluid speed [m/s], ρ is its density [kg/m^3], μ is its dynamic viscosity [Pa·s] and L is the characteristic length of the plate (in this case the wall) [m].

Another parameter needed is the Prandtl number (*Pr*), which links the conduction with the convection. It is calculated as follows:

$$\mathrm{Pr} = \frac{\mu \cdot Cp}{K}$$

where μ is the fluid dynamic viscosity [Pa s], *Cp* is the heating capacity of the fluid [J/kg K] and *K* is the thermal conductivity of the fluid [W/m K].

With both values, the number of Nusselt (*Nu*)can be calculated, which measures the growth of the heat transmission from a surface where a fluid runs, compared with the heat transmission if it would happen only by conduction.

There are different correlations for the calculation of *Nu*. Due to its degree of difficulty for determining this number, which depends on several experimental results, the Colburn expression is used in this particular case. The following equation is used for turbulent eddy flows on flat plates:

$$Nu = 0.037 \cdot Re^{0,8} \cdot Pr^{1/3}$$

Once the Nusselt number is known, the convection coefficient can be directly obtained

$$h = \frac{Nu \cdot K}{L} \left[\frac{W}{m^2 K}\right]$$

For the project's case, the following preliminary data have been considered for the air:

Table 27. Preliminary data for the air

v_i (m/s)	1
v_e (m/s)	26
ρ (kg/m3)	1.2
μ (Pa·s)	0.0000195
Cp (J/kg K)	1000
K (W/mK)	0.024

Therefore, the coefficients of convection in the school are:

Table 28. Coefficients of convection in the school

	Re	Pr	Nu	h (W/m²K)
Inside	1,761,846.15	0.81	3,427.02	2.87
Outside	45,808,000	0.81	46,440.40	38.93

Whereas the convection coefficients in the residential block are:

Table 29. Coefficients of convection in the residential block

	Re	Pr	Nu	h (W/m²K)
Inside	1,761,846.15	0.81	3,427.02	2.87
Outside	45,808,000	0.81	46,440.40	38.93

Knowing the convection coefficients, the overall heat transfer coefficients (*U*) can be calculated and, consequently, the power which is dissipated through walls, windows and/or doors.

On the other hand, ventilation is one of the major points in which a great quantity of money is lost. For the residential block, as well as for the school building, the ventilation is natural, carried out by opening the windows. In order to work out the calculation, the recommended steps on the UNE-EN 12831-2003 for natural ventilation have been followed.

This guide is based on the hygiene conditions required for natural air circulation. Nonetheless, as it is carried out manually, it may not be guaranteed that proper ventilation is made.

Following the rule, to calculate the ventilation is required to know the volume of the ventilated room, the indoor and outdoor temperature (choosing the most unfavourable), and the index of minimum renovation. This index varies depending on the type of room and it is provided by the regulation.

Table 30. Index of minimum renovation

Enclosure	n_{min} (1/h)
Living space (default)	0.5
Kitchen or bathroom	1.5
Office	1
Meeting room, classroom	2

From the input data, the minimum flow of air renovation can be calculated as follows:

$$V'i = Vi \cdot n_{min}\,[\frac{m^3}{h}]$$

where *Vi* is the room's volume. Once this value is known, the coefficient of thermal loss may be calculated from this equation:

$$H_{v,i} = 0.34 \cdot Vi \cdot n_{min}\,[\frac{W}{K}]$$

Once this coefficient is known, the thermal loss in the room is equal to the coefficient due to the difference between temperatures indoor and outdoor.

2.1.1. Initial considerations

Before the calculations, some previous considerations must be taken into account. Firstly, it has been estimated that the comfort temperature indoor during winter is 21ºC, whereas the lowest possible temperature, according to AVAMET (table 26), is -13.8ºC.

To calculate the floor temperature pattern, a specific study is required carried out in Vistabella del Maestrazgo. Therefore, it has been estimated by extrapolating data from previous studies and considering a winter month as the most unfavourable case with an ambient temperature around 0ºC. For the floor, considering 2 m of depth, the temperature is 7 ºC.

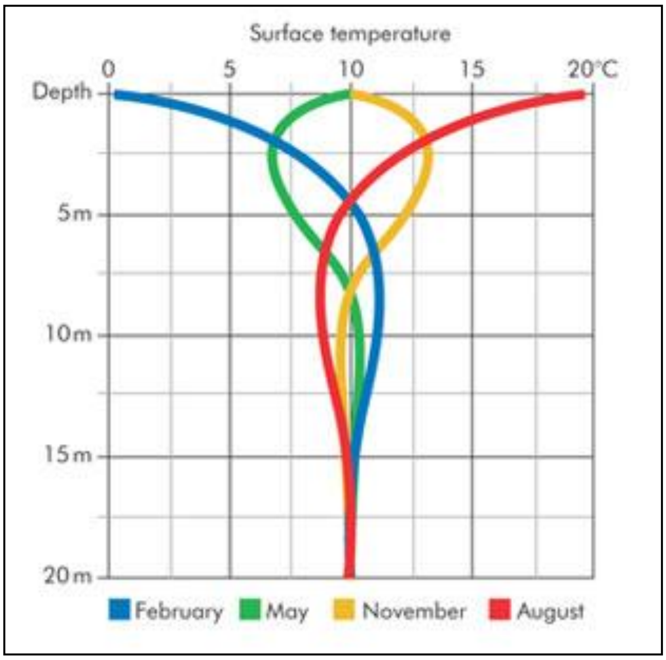


Figure 19. Floor temperature pattern. [17]

For the temperatures of the non-climate controlled room and the party walls, they are estimated based on the Javier Celades' study [7], and a temperature of 3ºC is obtained as the most unfavourable case.

Moreover, the global coefficient of transfer from Windows and doors has been estimated as 3.3 W/m2K from previous data.

Co-funded by the Erasmus+ Programme of the European Union

Another important factor that must be carried out is the comparison between the option of a boiler for both the block building and the school's building, and the option of having each building its own boiler. As "School's building" is understood the library, the chemist's and the school. Likewise, the block building will be calculated as one whole, not independent apartments, thus the most unfavourable case will be considered, as if the building would be completely full.

Regarding the block building, the first floor does not have access to the ground, but to a local non-conditioned, where the biomass boiler would be installed. Moreover, as it can be appreciated in figure 20, the first two dwellings have another building next to the party wall, whereas the last two do nott have this situation. This will vary the reference temperatures in the calculation of the demand.

Figure 20. Residential block

2.1.2. Thermal power losses in the school's building

Firstly, the overall heat transfer coefficient (*U*) for all the enclosures is calculated:

Table 31. Properties of the school's building's enclosure

Building enclosure	R conv. out	R cond.	R conv. in	R total	U total
	(m²K/W)				(W/m²K)
External wall (N, E, W)	0.026	0.650	0.348	1.024	0.977
External South wall	0.026	0.846	0.348	1.220	0.820
Floor against ground	0.026	0.153	0.348	0.527	1.898
Floor against local witohut conditioning	0.026	0.611	0.348	0.985	1.015
Roof	0.026	0.621	0.348	0.995	1.005
Party wall	0.026	2.461	0.348	2.834	0.353

From the considerations of temperature and areas of each enclosure, according to building's plans, the power dissipated through the enclosures can be calculated:

Table 32. Power dissipated through the enclosures of the school's building

Building enclosure	U (W/m²K)	ΔT (K)	Area (m²)	Power (W)
External wall (N, E, W)	0.977	34.8	269.38	9,156.70
External South wall	0.820	34.8	147.51	4,207.41
Floor against ground	1.898	14	113.48	3,015.95
Floor against local without conditioning	1.015	18	140.21	2,562.63
Roof	1.005	34.8	269.61	9,431.10
Party wall	0.353	18	25.26	160.41
			TOTAL	28,534.19

Furthermore, knowing the *U* of walls and windows and their quantity, the thermal power losses are:

Table 33. Thermal power losses through school's windows and doors

Windows and doors	U (W/m²K)	ΔT (K)	Area (m²)	Units	Power (W)
Window 100	3.3	34.8	1	1	114.84
Window 120	3.3	34.8	2.16	10	2,480.544
Window 150	3.3	34.8	2.7	20	6,201.36
Window 180	3.3	34.8	3.24	2	744.1632
External Door	1.754	34.8	5	3	915.588
				TOTAL	10,456.50

Calculations about the natural ventilation of the school's building are shown in the next table:

Table 34. Natural ventilation of the school's building.

Name of the enclosure	Canteen	Kitchen	Preschool classroom	Primary classroom	Computer lab	Bathroom	Office	Library	Pharmacy
Interior volume Vi (m³)	210.57	47.18	145.39	142.37	142.37	49.98	42.83	168.39	104.79
External temperature Te (ºC)	-13.8	-13.8	-13.8	-13.8	-13.8	-13.8	-13.8	-13.8	-13.8
Internal temperature Ti (ºC)	21	21	21	21	21	21	21	21	21
Minimum index of air renovation nmin (1/h)	0.5	1.5	2	2	2	1.5	1	2	0.5
Minimum air flow V'min (m³/h)	105.28	70.76	290.77	284.74	284.74	74.96	42.83	336.78	52.40
Thermal loss coefficient Hvi (W/K)	35.80	24.06	98.86	96.81	96.81	25.49	14.56	114.51	17.81
Thermal power loss due to ventilation (W)	1,245.71	837.26	3,440.41	3,369.07	3369.07	886.97	506.74	3,984.78	619.94

The total value of the thermal power losses due to ventilation is the sum of the last row, it is 18,259.96 W.

From the data obtained in the previous tables, the total thermal power losses of the schools' building are:

Table 35. Thermal power losses of the school's building

Thermal power loss	Power (W)
Building enclosure	28,534.19
Windows and doors	10,456.50
Ventilation	18,259.96
TOTAL	**57,250.64**

2.1.3. Thermal power losses in the residential block

Firstly, the overall heat transfer coefficient (*U*) for all the enclosures is calculated:

Table 36. Properties of the residential block's enclosure

Building enclosure	R conv. out	R cond.	R conv. in	R total	U total (W/m²K)
	(m²K/W)				
External wall (N, W)	0.021	0.650	0.279	0.949	1.054
External wall E (Party Wall)	0.021	2.461	0.279	2.760	0.362
External South wall	0.021	0.846	0.279	1.146	0.873
Wall against local without conditioning	0.021	0.319	0.279	0.618	1.619
Floor against local without conditioning	0.021	0.611	0.279	0.910	1.099
Roof	0.021	0.621	0.279	0.920	1.087

From the considerations of temperature and areas of each enclosure, according to building's plans, the power dissipated through the enclosures can be calculated:

Table 37. Power dissipated through the enclosures of the residential block

Building enclosure	U (W/m²K)	ΔT (K)	Area (m²)	Power (W)
External wall (N, W)	1.054	34.8	120.41	4,414.61
External wall E	0.362	34.8	32.77	413.18
External wall E (Party Wall)	0.362	18	32.77	213.71
External South wall	0.873	34.8	55.09	1,673.56
Wall against local without conditioning	1.619	18	111.25	3,241.78
Floor against local without conditioning	1.099	18	52.72	1,042.51
Roof	1.087	34.8	52.72	1,993.62
			TOTAL	12,992.97

Furthermore, knowing the *U* of walls and windows and their quantity, the thermal power losses are:

Table 38. Thermal power losses through school's windows and doors

Windows and doors	U (W/m²K)	ΔT (K)	Area (m²)	Units	Power (W)
Window 80	3.3	34.8	1.44	4	661.48
Window 100	3.3	34.8	1.8	12	2,480.54
Window 150	3.3	34.8	2.7	8	2,480.54
Internal Door	1.899	18	5	20	3,418.20
				TOTAL	9,040.77

Calculations about the natural ventilation of the residential block are shown in the next table:

Table 39. Natural ventilation of the residential block

Name of the enclosure	Dining-Room	Room 1	Room 2	Room 3	Bathroom
Interior volume V_i (m³)	189.44	98.30	95.74	97.79	58.57
External temperature Te (ºC)	-13.8	-13.8	-13.8	-13.8	-13.8
Internal temperature Ti (ºC)	21	21	21	21	21
Minimum index of air renovation n_{min} (1/h)	0.5	0.5	0.5	0.5	1.5
Minimum air flow V'_{min} (m³/h)	94.72	49.15	47.87	48.90	87.86
Thermal loss coefficient H_{vi} (W/K)	32.20	16.71	16.28	16.62	29.87
Thermal power loss due to ventilation (W)	1,120.73	581.57	566.42	578.54	1,039.55

The total value of the thermal power losses due to ventilation is the sum of the last row, it is 3,886.80 W.

From the data obtained in the previous tables, the total thermal power losses of the schools' building are:

Table 40. Thermal power losses of the residential block

Thermal power loss	Power (W)
Building enclosure	12,992.97
Windows and doors	9,040.77
Ventilation	3,886.80
TOTAL	**25,920.54**

2.1.4. Annual energy demand

Once the thermal power losses of each building are calculated, the last step is the calculus of the heat energy demand during all the year.

The calculus of the demand comes from heating degree days, in Spain it is common to use a base temperature of 15 ºC. This way of demand estimation uses an indicator connecting the average temperature with a certain comfort temperature. The degree days (HDD) of a month are calculated as:

$$HDD_{15} = (15 - T_{avg}) \cdot Number\ of\ days$$

where T_{avg} is the average temperature of a month. The number of days depends on the use of the building, so the value refers to a certain period.

The lack of heat demand in the months of June, July and August must be taken into account, when the average temperature is bigger than the comfort temperature.

Knowing the HDD_{15} and the thermal power losses, the annual energy demand is obtained with the next equation:

$$E = \frac{HDD_{15} \cdot P(kW) \cdot Hours/day}{T_{comfort} - T_{outside}}\ [kWh]$$

In the school's building calculation, the useful days of the school are considered in order to obtain the HDD. This estimation can be done because the school is the biggest cause of the power losses. In the next table, heating degree days are shown:

Table 41. HDD of the school's building

Months	Useful days	T_{avg} (ºC)	HDD_{15}
January	19	3.15	225.15
February	20	4.05	219
March	19	4.4	201.4
April	15	6.7	124.5
May	21	10.2	100.8
June	-	15.5	-
July	-	18.7	-
August	-	17.8	-
September	15	14.9	1.5
October	22	11.2	83.6
November	20	5.4	192
December	15	3.1	178.5
		TOTAL	**1,326.45**

Considering a use of 16 h/day, the annual energy demand is:

$$E = \frac{1{,}326.45 \cdot 57.25 \cdot 16}{21 - (-13.8)} = 34{,}914.99\ kWh$$

The residential block follows the same process, considering a total use of the apartments, because it is impossible to estimate the occupation. In the same way, it is considered a 24 hours of use every day. Predictably, considering this worst case scenario, the residential block will be oversized.

Table 42. HDD of the residential block

Months	Useful days	Tavg (ºC)	HDD15
January	31	3.15	367.35
February	28	4.05	306.6
March	31	4.4	328.6
April	30	6.7	249
May	31	10.2	148.8
June	-	15.5	-
July	-	18.7	-
August	-	17.8	-
September	30	14.9	3
October	31	11.2	117.8
November	30	5.4	288
December	31	3.1	368.9
		TOTAL	**2,178.05**

The annual energy demand is:

$$E = \frac{2{,}178.05 \cdot 25.92 \cdot 24}{21 - (-13.8)} = 38{,}935.33\ kWh$$

2.2. Sizing of expansion vessels

From the data obtained on the Reglamento de Instalaciones Térmicas en los Edificios (RITE, 'Regulations of Heating Systems in Buildings') [10], the volume of the expansion vessel can be calculated with the next equation:

$$V_t = V \cdot C_e \cdot C_p \ [l]$$

where V_t is the total volume of the expansion vessel, *V* is the volume of water inside the installation, C_e is the coefficient of expansion of the liquid and C_p is the coefficient of pressure of the gas.

The volume *V* can be calculated with all the consumptions of the heating installation or with an estimation given by the RITE. This estimation is:

$$V = \frac{P \cdot 15}{1000} \ [l]$$

where *Q* is the power of the boiler in kcal/h. For the installations of the project, the volumes are:

Table 43. Volumes of the installations

Installation	P (kW)	P (kcal/h)	V (l)
School's building	50	42,992.26	644.88
Residential block	25	21,496.13	322.44
District heating	80	68,787.62	1,031.81

The calculus of the expansion coefficient is carried out with the next equation:

$$C_e = (3.24 \cdot T^2 + 102.13 \cdot T - 2{,}708.3) \cdot 10^{-6}$$

where *T* is the temperature of the fluid. In this case, a temperature of 75 ºC is selected, because it is the average between 60 ºC and 80 ºC, the two stated values of the buffer tanks. The value of the coefficient C_e is 0.02318.

The value of C_p is normally tarred the vessel with 3 atm (*Pt*), meanwhile the minimum pressure depends on the height (it is considered the middle of the last floor as a worst scenario):

$$Pmin = 1.5 + 0.1 * 10.24 = 2.524 \ atm$$

Considering the previous information, the pressure coefficient is calculated with the next equation:

$$C_p = \frac{Pt - Patm}{Pt - Pmin}$$

If the atmospheric pressure is 1 atm, the pressure coefficient is:

$$C_p = \frac{3 - 1}{3 - 2.524} = 8.4$$

Finally, with the total volume and the coefficients calculated, it is possible to obtain the volume required for each expansion vessel:

Table 44. Volume required for each expansion vessel

Installation	Vt (liters)
School's building	125.57
Residential block	62.78
District heating	200.91

2.3. Number of radiators and flow

Following the normative IT 1.3.4.4.1 of the RITE [10], the temperature of the radiators is limited to 80 ºC. Moreover, manufacturer specifications [11] establish as a reference a power of 87.5 kcal/h for an increase of 50 ºC, with a coefficient of n = 1.3 for the characteristic curve.

If the average temperature of the fluid is 75 ºC and the temperature of comfort is 21 ºC, the difference of temperature is:

$$\Delta T = \frac{(80+75)}{2} - 21 = 56.5\ ºC$$

Using the characteristic curve and the reference of the manufacturer, the power of the radiators can be calculated:

$$P_r = 87.5 \cdot \left(\frac{56.5}{50}\right)^{1.3} = 102.57 \frac{kcal}{h \cdot element} = 119.21 \frac{W}{element}$$

The number of elements required in each room is the division between the thermal power losses of the room (calculated with the method of the 2.1) and the power of an element. It must take into account that the school and library have radiators, so they are not taken into account. The pharmacy's thermal power losses are given in a previous project [7] and the apartment's thermal power losses are the result of the division of the total residential block losses between 4.

Table 45. Number of elements in one apartment and pharmacy

Installation	Thermal power losses (W)	Number of elements
Pharmacy	3.914	32.83
Apartment	6.480,14	54.36

The element distribution is done in function of the space and necessities. In the pharmacy, it is decided to use two radiators of 15 elements and one of 5 elements. In the apartments, the distribution is done in proportion with the area of each room. It is decided to use one radiator of 10 elements in each room, two radiators of 10 elements in the dining room and one radiator of 5 elements in the bathroom. It is required to install 255 elements and 27 radiators in the pharmacy and residential block.

Finally, the flow of the different radiators is calculated with the next equation:

$$P_r \cdot Number\ of\ elements = \dot{m} \cdot c_p \cdot \Delta T$$

where P_r is the power per element, $\dot{m}$ is the mass flow of water, c_p is the specific heat and has a value of 4.184 J/gºC and ΔT is the difference of temperature of the water. It must be considered that the density of the water is 1 kg/l so the value of the flow can be directly calculated.

Table 46. Flow in each radiator

Radiator	Flow (l/s)
15 elements	0.0285
10 elements	0.019
5 elements	0.0095

For the worst case (maximum flow of 0.0285 l and a diameter of 17 mm), the velocity of the water is calculated as flow between area, which is less than 1 m/s. This means that the installation will not have problems of noise.

$$v = \frac{Q}{A} = \frac{0.0285/1000}{\pi \cdot \frac{0.017^2}{4}} = 0.13\ m/s$$

2.4. Flow and pressure losses

- **Flow**

In order to select the pumps required for the installations, the pressure losses and the flows must be known. The flow can be calculated from all the radiators of the installation. In the school's building, the maximum flow is 3.03 m^3/h [7]. In the residential block, the maximum flow available is 4.535 m^3/h.

- **Pressures losses due to conduction**

The total pressure losses due to conduction in the school, library and pharmacy are 2.833 mca [7] as the previous study shows it. In the residential block, these losses are calculated according to the longitudes, using Darcy's equation:

$$h = \frac{8 \cdot f \cdot L}{g \cdot \pi \cdot D^5} \cdot Q^2$$

For the case of the residential block and district heating installations, a friction coefficient f of 0.015 is considered. Knowing all the longitudes, flows and diameters, the pressure losses due to conduction are:

Table 47. Pressure losses due to conduction

Conduction	Pressure losses due to conduction (mca)
Bathroom	0.0004
Dining Room 1	0.0008
Dining Room 2	0.0006
Room 1	0.003
Room 2	0.001
Room 3	0.003
Total of the 4 apartments (flow and return)	0.07
Ground floor – floor 1	0.06
Floors 1-2	0.03
Floors 2-3	0.015
Floors 3-4	0.004
Total of common conduction (flow and return)	0.22
Total residential block	**0.292**
District heating	**1.16**

The main reason of the low pressure losses are the diameters selected and the small flow of the terminal points. Nevertheless, low pressure losses means less requirements in the sizing of the pumping system.

- **Pressure losses due to radiators**

The pressures losses of the radiators are calculated with the graph of the figure 21 [7]. This graph connects the flow of the radiators with the losses so it is considered the worst case.

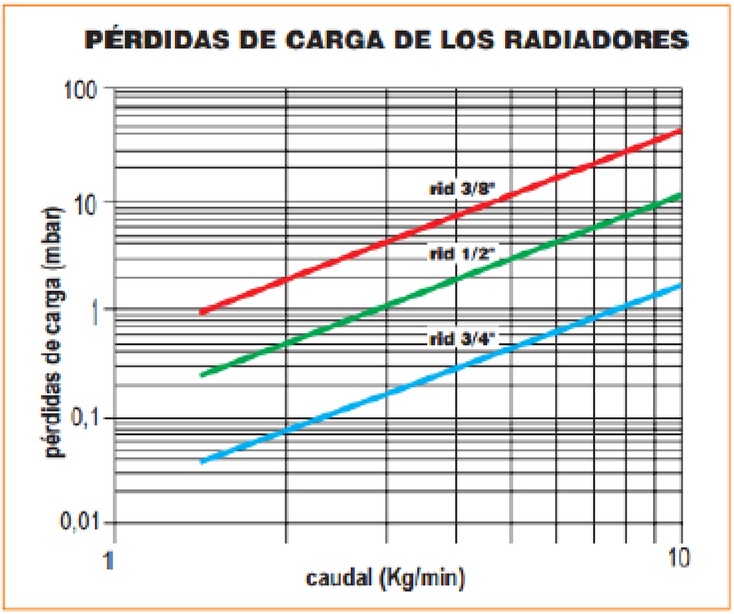


Figure 21. Pressure losses of the radiators

The pressure losses due to radiators are:

Table 48. Pressure losses due to radiators

Installation	Pressure losses due to radiators (mca)
School's building	0.69
Residential block	0.18
Total	0.87

- **Locating pressure losses**

They are the losses due to valves, elbows or other small parts of the installation. Normally, they suppose between a 5% and a 20% of the total pressure losses due to conduction. In this case, it is considered 15%:

Table 49. Locating pressure losses

Installation	Locating pressure losses (mca)
School's building	0.425
Residential block	0.05
Total	0.643

- **Pressure losses in the heat exchanger**

The estimation of the pressure losses due to the heat exchanger is done considering recommendations [7] where it is considered a value of 1.5 mca. Therefore, this component is one of the biggest causes of pressure losses.

- **Total pressure losses**

The total pressure losses in all the installations can be calculated as the sum of all the pressure losses analysed before. In the next table, the total values are shown:

Table 50. Total pressure losses

Installation	Total pressure losses (mca)
School's building	5.448
Residential block	2.022
Total	8.708

Budget and economic analysis

3. Economical aspects of the project

3.1. Budget of the installation

Table 51. Budget of individual installations

Denomination	Units	Cost (€)	Total cost (€)
School's installation			
Biomass boiler Biocalora Serie 2000 Basic B-Essential	1	5.289,00 €	5.289,00 €
Froling's buffer tank	1	712,00 €	712,00 €
Polyester silo	1	2.241,00 €	2.241,00 €
Heat exchanger of IDROGAS	1	140,00 €	140,00 €
Pipe of rigid copper with an inner diameter of 17 mm	48	10,35 €	496,80 €
Brass check valve of 1/2"	4	9,86 €	39,44 €
Expansion vessel of 150 l	1	277,75 €	277,75 €
Radiator of cast iron with 5 elements	1	335,54 €	335,54 €
Radiator of cast iron with 15 elements	2	242,65 €	485,30 €
Pump PC 1025	2	366,04 €	732,08 €
Pump PC 1045	1	371,14 €	371,14 €
Anti-vibration feet	1	41,20 €	41,20 €
Transport of the boiler	1	350,00 €	350,00 €
Installation and activation	1	250,00 €	250,00 €
Basic maintenance	1	182,00 €	182,00 €
Connection to the chimney	1	164,80 €	164,80 €
Residential block			
Biomass boiler Biocalora Serie 2000 Basic B-Home	1	4.313,00 €	4.313,00 €
Froling's buffer tank	1	695,00 €	695,00 €
Textile silo of Biocalora	1	2.123,00 €	2.123,00 €
Heat exchanger of IDROGAS	1	110,00 €	110,00 €
Pipe of rigid copper with an inner diameter of 17 mm	62	10,35 €	641,70 €
Pipe of rigid copper with an inner diameter of 25.4 mm	23	14,24 €	327,52 €
Brass check valve of 1/2"	4	9,86 €	39,44 €
Expansion vessel of 80 l	1	195,30 €	195,30 €
Radiator of cast iron with 10 elements	20	173,90 €	3.478,00 €
Radiator of cast iron with 5 elements	4	105,15 €	420,60 €
Pump PC 1025	3	366,04 €	1.098,12 €
Antivibration feet	1	41,20 €	41,20 €
Transport of the boiler	1	350,00 €	350,00 €
Installation and activation	1	250,00 €	250,00 €
Basic maintenance	1	182,00 €	182,00 €
Connection to the chimney	1	164,80 €	164,80 €
		TOTAL SCHOOL'S INSTALLATION	12.108,05 €
		TOTAL RESIDENTIAL BLOCK	14.429,68 €
		TOTAL INDIVIDUAL INSTALLATION	26.537,73 €
		MATERIAL EXECUTION BUDGET	26.537,73 €
		13% OF GENERAL EXPENSES	3.449,90 €
		6% OF INDUSTRIAL BENEFITS	1.592,26 €
		SUBTOTAL	31.579,90 €
		21% IVA	6.631,78 €
		TOTAL BUDGET	**38.211,68 €**

Table 52. Budget of district heating

Denomination	Units	Cost (€)	Total cost (€)
District heating			
Biomass boiler Biocalora KP 82	1	12.990,00 €	12.990,00 €
Hopper of 700 l	1	700,00 €	700,00 €
Feeding auger	1	792,00 €	792,00 €
Other materials (elbows, metal sheets...)	1	52,00 €	52,00 €
Froling's buffer tank	1	1.415,00 €	1.415,00 €
Textile silo of Biocalora	1	2.726,00 €	2.726,00 €
Heat exchanger of IDROGAS	1	170,00 €	170,00 €
Pipe of rigid copper with an inner diameter of 17 mm	110	10,35 €	1.138,50 €
Pipe of rigid copper with an inner diameter of 25.4 mm	23	14,42 €	331,66 €
Pipe of rigid copper with an inner diameter of 33 mm	51	22,29 €	1.136,79 €
Brass check valve of 1/2"	4	9,86 €	39,44 €
Expansion vessel of 200 l	1	329,70 €	329,70 €
Radiator of cast iron with 5 elements	5	105,15 €	525,75 €
Radiator of cast iron with 15 elements	2	242,65 €	485,30 €
Radiator of cast iron with 10 elements	20	173,90 €	3.478,00 €
Pump PC 1025	2	366,04 €	732,08 €
Pump Quantum ECO 32 H	1	990,00 €	990,00 €
Anti-vibration feet	1	41,20 €	41,20 €
Transport of the boiler	1	400,00 €	400,00 €
Installation and activation	1	300,00 €	300,00 €
Basic maintenance	1	182,00 €	182,00 €
Connection to the chimney	1	164,80 €	164,80 €
Cutting of the pavement	102	1,18 €	120,36 €
Mechanical excavation	25,5	28,42 €	724,71 €
Sand for pipe protection	25,5	24,33 €	620,42 €
Replacement of the pavement	25,5	67,06 €	1.710,03 €
		TOTAL DISTRICT HEATING	32.295,74 €
		MATERIAL EXECUTION BUDGET	32.295,74 €
		13% OF GENERAL EXPENSES	4.198,45 €
		6% OF INDUSTRIAL BENEFITS	1.937,74 €
		SUBTOTAL	38.431,92 €
		21% IVA	8.070,70 €
		TOTAL BUDGET	**46.502,63 €**

3.2. Payback, IRR and NPV

To carry out the viability study of the two installations, the following considerations are taken into account:

- Investment: there are two options in the consideration of the investment. One is the total budget of each installation and the other option considers a grant of the 45%. The grant is provided by the Instituto Valenciano de Competitividad Empresarial (IVACE, 'Valencian Institute of Business Competitiveness') for new biomass installations.
- Costs: pellet and gasoil costs are given by the information provided by the Ministerio de Energía y Turismo (MINETAD, 'Ministry of Energy and Tourism') [18].
- Fuel annual increase: they are estimated following the average evolution of prices in the last decade [18].
- Operation and maintenance cost: the value is estimated following the cost of manufacturers [11] for basic maintenance. This cost is the double for individual installations because they have more equipment.
- Self-consumption: the local government pretends to use their own forestry waste for pellet production First of all, the cost of a pellet machine is very high, so it would be difficult to establish in the next months or year the measure. Furthermore, a good planning and management is required, and this needs some time. On the other hand, it is difficult to estimate the total quantity of forestry waste in the surroundings of Vistabella. Moreover, the management of forestry waste has costs like the salaries of the workers, equipment, etc. Therefore, regarding the problems of pellet cost estimation, a reduction of the 50% of the price is considered in the fifth year. It is assumed that this consideration is conservative.

- **Individual installations**

Table 53. Economic considerations for the individual installations

CONSIDERATIONS		
Capital cost	38211.68	€
Estimated energy production	73850.32	kWh/year
Annual energy losses	0.50	%
Pellet cost	0.0350	€/kWh
Gasoil cost	0.0605	€/kWh
Pellet annual increase	0.50	%
Gasoil annual increase	3.75	%
Discount rate	3.50	%
O&M Cost	364	€
Investment period	20	years
Grant	45	%

Table 54. Viability study of the individual installations

Year	Energy production (kWh/year)	Pellet cost (€/year)	Gasoil cost (€/year)	Estimated savings (€/year)	O&M costs (€)	Cash-Flow (€)	Cash-Flow (€)	Cumulative Cash-Flow (€)	Payback (€)	Payback with grant (€)	NPV (€)	NPV with grant (€)
0						-21016.42	-38211.68					
1	73850.32	2,584.76 €	4,467.94 €	1,883.18 €	364 €	1,519.18 €	1,519.18 €	1,519.18 €	-36,692.49 €	-19,497.24 €	-36,743.87 €	-19,548.61 €
2	73481.07	2,597.69 €	4,635.49 €	2,037.81 €	364 €	1,673.81 €	1,673.81 €	3,192.99 €	-35,018.69 €	-17,823.43 €	-35,181.35 €	-17,986.10 €
3	73113.66	2,610.67 €	4,809.32 €	2,198.65 €	364 €	1,834.65 €	1,834.65 €	5,027.64 €	-33,184.04 €	-15,988.78 €	-33,526.60 €	-16,331.35 €
4	72748.10	2,623.73 €	4,989.67 €	2,365.95 €	364 €	2,001.95 €	2,001.95 €	7,029.59 €	-31,182.09 €	-13,986.84 €	-31,782.02 €	-14,586.77 €
5	72384.36	1,318.42 €	5,176.79 €	3,858.36 €	364 €	3,494.36 €	3,494.36 €	10,523.95 €	-27,687.73 €	-10,492.47 €	-28,839.86 €	-11,644.61 €
6	72022.43	1,325.01 €	5,370.92 €	4,045.90 €	364 €	3,681.90 €	3,681.90 €	14,205.85 €	-24,005.83 €	-6,810.57 €	-25,844.63 €	-8,649.38 €
7	71662.32	1,331.64 €	5,572.32 €	4,240.68 €	364 €	3,876.68 €	3,876.68 €	18,082.53 €	-20,129.14 €	-2,933.89 €	-22,797.59 €	-5,602.34 €
8	71304.01	1,338.30 €	5,781.29 €	4,442.99 €	364 €	4,078.99 €	4,078.99 €	22,161.52 €	-16,050.15 €	1,145.10 €	-19,699.96 €	-2,504.71 €
9	70947.49	1,344.99 €	5,998.08 €	4,653.10 €	364 €	4,289.10 €	4,289.10 €	26,450.62 €	-11,761.06 €	5,434.20 €	-16,552.92 €	642.33 €
10	70592.75	1,351.71 €	6,223.01 €	4,871.30 €	364 €	4,507.30 €	4,507.30 €	30,957.92 €	-7,253.76 €	9,941.49 €	-13,357.61 €	3,837.64 €
11	70239.79	1,358.47 €	6,456.38 €	5,097.90 €	364 €	4,733.90 €	4,733.90 €	35,691.82 €	-2,519.86 €	14,675.40 €	-10,115.15 €	7,080.11 €
12	69888.59	1,365.27 €	6,698.49 €	5,333.22 €	364 €	4,969.22 €	4,969.22 €	40,661.04 €	2,449.37 €	19,644.62 €	-6,826.60 €	10,368.66 €
13	69539.15	1,372.09 €	6,949.68 €	5,577.59 €	364 €	5,213.59 €	5,213.59 €	45,874.64 €	7,662.96 €	24,858.21 €	-3,493.00 €	13,702.25 €
14	69191.45	1,378.95 €	7,210.30 €	5,831.34 €	364 €	5,467.34 €	5,467.34 €	51,341.98 €	13,130.30 €	30,325.56 €	-115.38 €	17,079.88 €
15	68845.49	1,385.85 €	7,480.68 €	6,094.84 €	364 €	5,730.84 €	5,730.84 €	57,072.82 €	18,861.14 €	36,056.39 €	3,305.30 €	20,500.56 €
16	68501.27	1,392.78 €	7,761.21 €	6,368.43 €	364 €	6,004.43 €	6,004.43 €	63,077.25 €	24,865.57 €	42,060.83 €	6,768.10 €	23,963.35 €
17	68158.76	1,399.74 €	8,052.25 €	6,652.51 €	364 €	6,288.51 €	6,288.51 €	69,365.76 €	31,154.08 €	48,349.34 €	10,272.08 €	27,467.33 €
18	67817.97	1,406.74 €	8,354.21 €	6,947.47 €	364 €	6,583.47 €	6,583.47 €	75,949.24 €	37,737.56 €	54,932.81 €	13,816.37 €	31,011.62 €
19	67478.88	1,413.77 €	8,667.50 €	7,253.72 €	364 €	6,889.72 €	6,889.72 €	82,838.96 €	44,627.28 €	61,822.54 €	17,400.10 €	34,595.35 €
20	67141.48	1,420.84 €	8,992.53 €	7,571.69 €	364 €	7,207.69 €	7,207.69 €	90,046.65 €	51,834.97 €	69,030.22 €	21,022.43 €	38,217.69 €
TOTAL	1408909.34	1,616.07 €	6,482.40 €	4,866.33 €	364.00 €	90,046.65 €	90,046.65 €	90,046.65 €	51,834.97 €	69,030.22 €	21,022.43 €	38,217.69 €

Table 55. Payback, NPV and IRR of the study

Payback	11 years
Payback with grant	**7 years**
NPV	21,022.43 €
NPV with grant	**38,217.69 €**
IRR	7.7%
IRR with grant	**14.6%**

- **District heating**

Table 56. Economic considerations for district heating

CONSIDERATIONS		
Capital cost	46502.6288	€
Estimated energy production	73850.3215	kWh/year
Annual energy losses	0.5	%
Pellet cost	0.035	€/kWh
Gasoil cost	0.0605	€/kWh
Pellet annual increase	0.5	%
Gasoil annual increase	3.75	%
Discount rate	3.5	%
O&M Cost	182	€
Investment period	20	years
Grant	45	%

Table 57. Viability study of district heating

Year	Energy production (kWh/year)	Pellet cost (€/year)	Gasoil cost (€/year)	Estimated savings (€/year)	O&M costs (€)	Cash-Flow (€)	Cash-Flow (€)	Cumulative Cash-Flow (€)	Payback (€)	Payback with grant (€)	NPV (€)	NPV with grant (€)
0						-25576.45	-46502.63				-46502.63	-46502.63
1	73850.32	2,584.76 €	4,467.94 €	1,883.18 €	182 €	1,701.18 €	1,701.18 €	1,701.18 €	-44,801.45 €	-23,875.26 €	-44,858.97 €	-23,932.79 €
2	73481.07	2,597.69 €	4,635.49 €	2,037.81 €	182 €	1,855.81 €	1,855.81 €	3,556.99 €	-42,945.64 €	-22,019.46 €	-43,126.56 €	-22,200.37 €
3	73113.66	2,610.67 €	4,809.32 €	2,198.65 €	182 €	2,016.65 €	2,016.65 €	5,573.64 €	-40,928.99 €	-20,002.81 €	-41,307.65 €	-20,381.47 €
4	72748.10	2,623.73 €	4,989.67 €	2,365.95 €	182 €	2,183.95 €	2,183.95 €	7,757.59 €	-38,745.04 €	-17,818.86 €	-39,404.47 €	-18,478.29 €
5	72384.36	1,318.42 €	5,176.79 €	3,858.36 €	182 €	3,676.36 €	3,676.36 €	11,433.95 €	-35,068.68 €	-14,142.50 €	-36,309.07 €	-15,382.89 €
6	72022.43	1,325.01 €	5,370.92 €	4,045.90 €	182 €	3,863.90 €	3,863.90 €	15,297.85 €	-31,204.78 €	-10,278.60 €	-33,165.79 €	-12,239.60 €
7	71662.32	1,331.64 €	5,572.32 €	4,240.68 €	182 €	4,058.68 €	4,058.68 €	19,356.53 €	-27,146.09 €	-6,219.91 €	-29,975.70 €	-9,049.52 €
8	71304.01	1,338.30 €	5,781.29 €	4,442.99 €	182 €	4,260.99 €	4,260.99 €	23,617.52 €	-22,885.11 €	-1,958.92 €	-26,739.85 €	-5,813.67 €
9	70947.49	1,344.99 €	5,998.08 €	4,653.10 €	182 €	4,471.10 €	4,471.10 €	28,088.62 €	-18,414.01 €	2,512.17 €	-23,459.27 €	-2,533.09 €
10	70592.75	1,351.71 €	6,223.01 €	4,871.30 €	182 €	4,689.30 €	4,689.30 €	32,777.92 €	-13,724.71 €	7,201.47 €	-20,134.94 €	791.24 €
11	70239.79	1,358.47 €	6,456.38 €	5,097.90 €	182 €	4,915.90 €	4,915.90 €	37,693.82 €	-8,808.81 €	12,117.37 €	-16,767.81 €	4,158.37 €
12	69888.59	1,365.27 €	6,698.49 €	5,333.22 €	182 €	5,151.22 €	5,151.22 €	42,845.04 €	-3,657.58 €	17,268.60 €	-13,358.82 €	7,567.36 €
13	69539.15	1,372.09 €	6,949.68 €	5,577.59 €	182 €	5,395.59 €	5,395.59 €	48,240.64 €	1,738.01 €	22,664.19 €	-9,908.86 €	11,017.33 €
14	69191.45	1,378.95 €	7,210.30 €	5,831.34 €	182 €	5,649.34 €	5,649.34 €	53,889.98 €	7,387.35 €	28,313.53 €	-6,418.79 €	14,507.39 €
15	68845.49	1,385.85 €	7,480.68 €	6,094.84 €	182 €	5,912.84 €	5,912.84 €	59,802.82 €	13,300.19 €	34,226.37 €	-2,889.48 €	18,036.70 €
16	68501.27	1,392.78 €	7,761.21 €	6,368.43 €	182 €	6,186.43 €	6,186.43 €	65,989.25 €	19,486.62 €	40,412.80 €	678.27 €	21,604.46 €
17	68158.76	1,399.74 €	8,052.25 €	6,652.51 €	182 €	6,470.51 €	6,470.51 €	72,459.76 €	25,957.13 €	46,883.32 €	4,283.67 €	25,209.85 €
18	67817.97	1,406.74 €	8,354.21 €	6,947.47 €	182 €	6,765.47 €	6,765.47 €	79,225.24 €	32,722.61 €	53,648.79 €	7,925.94 €	28,852.12 €
19	67478.88	1,413.77 €	8,667.50 €	7,253.72 €	182 €	7,071.72 €	7,071.72 €	86,296.96 €	39,794.33 €	60,720.51 €	11,604.33 €	32,530.52 €
20	67141.48	1,420.84 €	8,992.53 €	7,571.69 €	182 €	7,389.69 €	7,389.69 €	93,686.65 €	47,184.02 €	68,110.20 €	15,318.14 €	36,244.32 €
TOTAL	1408909.34	1,616.07 €	6,482.40 €	4,866.33 €	182.00 €	93,686.65 €	93,686.65 €	93,686.65 €	47,184.02 €	68,110.20 €	15,318.14 €	36,244.32 €

Table 58. Payback, NPV and IRR of district heating

Payback	12years
Payback with grant	**8 years**
NPV	15,318.14 €
NPV with grant	**36,244.32 €**
IRR	6.16%
IRR with grant	**12.74%**

Project plans

Co-funded by the Erasmus+ Programme of the European Union

4. Project Plans

In the execution of the study, the plans of the school's building and the residential block were provided by the University Jaume I and the local government of Vistabella del Maestrazgo. The school's building plan was made by Javier Celades Aparici [7] while the residential block plans were made by the architect Emilio Segarra Sancho. The plans are included in the annexes of the study.

Moreover, the location of the installations is shown in figure 4 of the memory. However, the cadastral cartography of each building according to the Dirección General del Catastro ('Cadastre General Direction') of the Ministerio de Hacienda y Función Pública ('Ministry of the Treasury and Public Function') is annexed.

Annexes

Co-funded by the Erasmus+ Programme of the European Union

ANNEX I. PIPE CONDUCTION

Table 59. School's building conduction

Circuit	Radiator	Longitude flow and return(m)	Pressure losses (mca)	Inner diameter (mm)
Circuit 1	prim-1	18,01	0,123	25,4
	prim-2	4,68	0,021	25,4
	prim-3	4,64	0,016	25,4
	sec-1	8,16	0,137	17
	sec-2	4,68	0,113	17
	sec-3	4,64	0,076	17
	pc - 1	7,18	0,092	17
	pc - 2	4,68	0,153	17
	pc - 3	4,64	0,102	17
	return	36,06	0,386	25,4
Circuit 2	Bathroom	8,45	0,140	17
	cor-1	9,59	0,048	17
	cor-2	4,02	0,017	17
	cor-3	5,13	0,023	17
	office	30,94	0,180	17
	return	32,98	0,546	17
Circuit 3	ent	25,87	0,272	25,4
	cant-1	14,50	0,042	25,4
	cant-2	4,69	0,093	25,4
	cant-3	4,65	0,049	17
	return	33,53	0,352	17
Circuit 4	pharm-1	13,30	0,043	17
	pharm-2	4,00	0,004	17
	pharm-3	1,50	0,000	17
	return	10,80	0,037	17
Circuit 5	libr-1	8,50	0,005	17
	libr-2	4,00	0,007	17
	libr-3	1,50	0,001	17
	return	8,00	0,064	17

Table 60. Residential block conduction

Circuit	Radiator	Longitude flow and return(m)	Pressure losses (mca)	Inner diameter (mm)
Apartment 1	din-1	2,410	0,0008	17
	din-2	1,985	0,0006	17
	room-1	9,850	0,003	17
	room-2	3,230	0,001	17
	room-3	8,685	0,003	17
	bathroom	5,095	0,0004	17
Apartment 2	din-1	2,410	0,0008	17
	din-2	1,985	0,0006	17
	room-1	9,850	0,003	17
	room-2	3,230	0,001	17
	room-3	8,685	0,003	17
	bathroom	5,095	0,0004	17
Apartment 3	din-1	2,410	0,0008	17
	din-2	1,985	0,0006	17
	room-1	9,850	0,003	17
	room-2	3,230	0,001	17
	room-3	8,685	0,003	17
	bathroom	5,095	0,0004	17
Apartment 4	din-1	2,410	0,0008	17
	din-2	1,985	0,0006	17
	room-1	9,850	0,003	17
	room-2	3,230	0,001	17
	room-3	8,685	0,003	17
	bathroom	5,095	0,0004	17
Common circuit	P0-1	2,900	0,06	25,4
	P1-2	2,900	0,03	25,4
	P2-3	2,900	0,015	25,4
	P3-4	2,900	0,004	25,4

Table 61. District heating conduction

Circuit	Radiator	Longitude flow and return(m)	Pressure losses (mca)	Inner diameter (mm)
District heating	-	51	1,16	33

ANNEX II. INTERVIEWS

Interviewees: Priscila Pauner Meseguer and Cristóbal Martínez Herrera

Position: Administrative assistant (area of innovation, occupation and economic promotion) and *alguacil* (staff).

Interview:
Question: How does the local government decide to be energy self-sufficient?
Answer: They idea emerged because of the contact with Juan Mayans, the engineer who is in charge of Serra's project. In Vistabella we have a suitable forest mass that can be used for self-consumption. Moreover, there are some subsidies that are provided by the autonomic government for projects like this.

Q: What kind of waste is treated? Who are the responsible workers for the recollection and management? How does the conversion of waste work into biomass?
A: First of all, the pruning waste is not remarkable. Nowadays the public mount is widely abandoned, so the treatment of forestry waste can help, replanting the zone. Moreover, there are also forestry owners, they are private areas.

About the responsibility, the first idea is to create a job workshop, but this is not clear for the future. One option that is considered is the creation of clean-up squads depending on the time of the year.

The conversion of waste into biomass is carried out with a trailer chipper. Thanks to this, warehouse is not necessary, the biomass is produced in the recollecting place and is transported to the boilers' location. Nevertheless, in the future the idea is to use pellets but it is more complicated and expensive.

Q: What are the economic, social and environmental benefits expected due to the waste management?
A: The creation of new jobs can help in the attraction of 2 or 3 new families with kids for the school. Actually, the town has a population of 370 inhabitants with 100 or 150 people in winter.

Furthermore, the cleaning of the mounts will increase the mycological richness. Nowadays, branches do not let pass the sunlight, thus the growth of grass is damaged. With the increase of mushroom's population it is possible to create a preserve, which has economic benefits for the local government.

Moreover, there are contacts with environmental engineers and some LIFE projects because another benefit of the waste management would be the fire prevention.

Q: Is there any awareness between the inhabitants towards the environment, climate change or renewable energies? Does it foster their use?
People are aware of those issues. For example, it is explained to old people that the maintenance of biomass boiler is easier than firewood stoves. At school, topics like climate change, renewable energies or sustainability are explained.

Q: What are the installations that predominate in the municipality?
A: People usually have firewood stoves in the houses. The rural houses have gasoil but the price fluctuation is a problem for them. Probably, they are interested in biomass boilers.

About public buildings, the local government has a biomass boiler. Moreover, the Cultural House will also have a biomass boiler in the near future. School's building and the Health Center have gasoil systems. The retirees' building has an electric heating system.

Q: Do you observe economical savings because of the use of biomass boilers?
A: There is no economic information about it yet.

Q: Do you know similar cases of success?
A: Yes, mainly the Serra's project. Moreover, other cases in process are the production of pellets in Villahermosa and the district heating of Todolella.

Interviewee: Vicent Eixeres Cherta

Position: Pharmacist and tenant in the residential block of the study

Interview:
Question: What do you think about the proposal of the local government over energy self-consumption based on forestry waste?
Answer: I think that it is a perfect idea

Q: What kind of heating installation do you have? Do you consume a lot of energy? Is the maintenance difficult?
A: Actually, I do not have a heating system in my house and I only have a small electric heater in the pharmacy. It causes a lot of problems in the cold days.

Q: What do you think about renewable energies? And about the biomass heating? Would you change your actual heating system for a biomass system?
A: I think that renewable energies are the future and absolutely the same for biomass heating. Yes, I would prefer a biomass system.

Q: Would you prefer a district heating with the boiler in a different building, a system similar to water or electric installations?
A: Yes, I think district heating is more comfortable.

Q: Do you know any neighbour, who uses biomass? What kind of problem do they find?
A: No, I do not know any neighbour with a biomass installation.

Q: Do you have any comments about the topic?
No

Interviewee: Mar
Position: Professor of the school
Interview: **Question: What do you think about the proposal of the local government over energy self-consumption based on forestry waste?** Answer: I think it is good if it is only waste. I am against cutting down trees. **Q: What kind of heating installation do you have? Do you consume a lot of energy? Is the maintenance difficult?** A: I have a firewood stove. I do not consume so much energy but living in Vistabella is expensive in energy terms. More or less, the cost of a firewood pack is 75 € and I pay about 90 € for the electricity bill for 2 months. Probably, in winter it is more. **Q: What do you think about renewable energies? And about biomass heating? Would you change your actual heating system for a biomass system?** A: Renewable energies are necessary, they are the future. I do not know a lot about biomass so before changing my actual heating system I should investigate more about it. However, in principle I would not change the actual heating system because I like firewood. **Q: Would you prefer a district heating with the boiler in a different building, a system similar to water or electric installations?** A: I think heating should be public so I like district heating. **Q: Do you know any neighbour who uses biomass? What kind of problem do they find?** A: Only the local government. **Q: Do you have any comments about the topic?** A: I am going to investigate more about pellets and biomass.

ANNEX III. PLANS

- **PLAN 1. CADASTRAL CARTOGRAPHY OF THE SCHOOL'S BUILDING.**
- **PLAN 2. CADASTRAL CARTOGRAPHY OF THE RESIDENTIAL BLOCK.**
- **PLAN 3. PLAN OF THE SCHOOL'S BUILDING.**
- **PLAN 4. PLAN OF THE APARTMENTS.**

GOBIERNO DE ESPAÑA

MINISTERIO DE HACIENDA, Y FUNCIÓN PÚBLICA

SECRETARÍA DE ESTADO DE HACIENDA

DIRECCIÓN GENERAL DEL CATASTRO

Sede Electrónica del Catastro

Provincia de CASTELLÓN

Municipio de VISTABELLA DEL MAESTRAZGO

Coordenadas U.T.M. Huso: 30 ETRS89

ESCALA 1:500

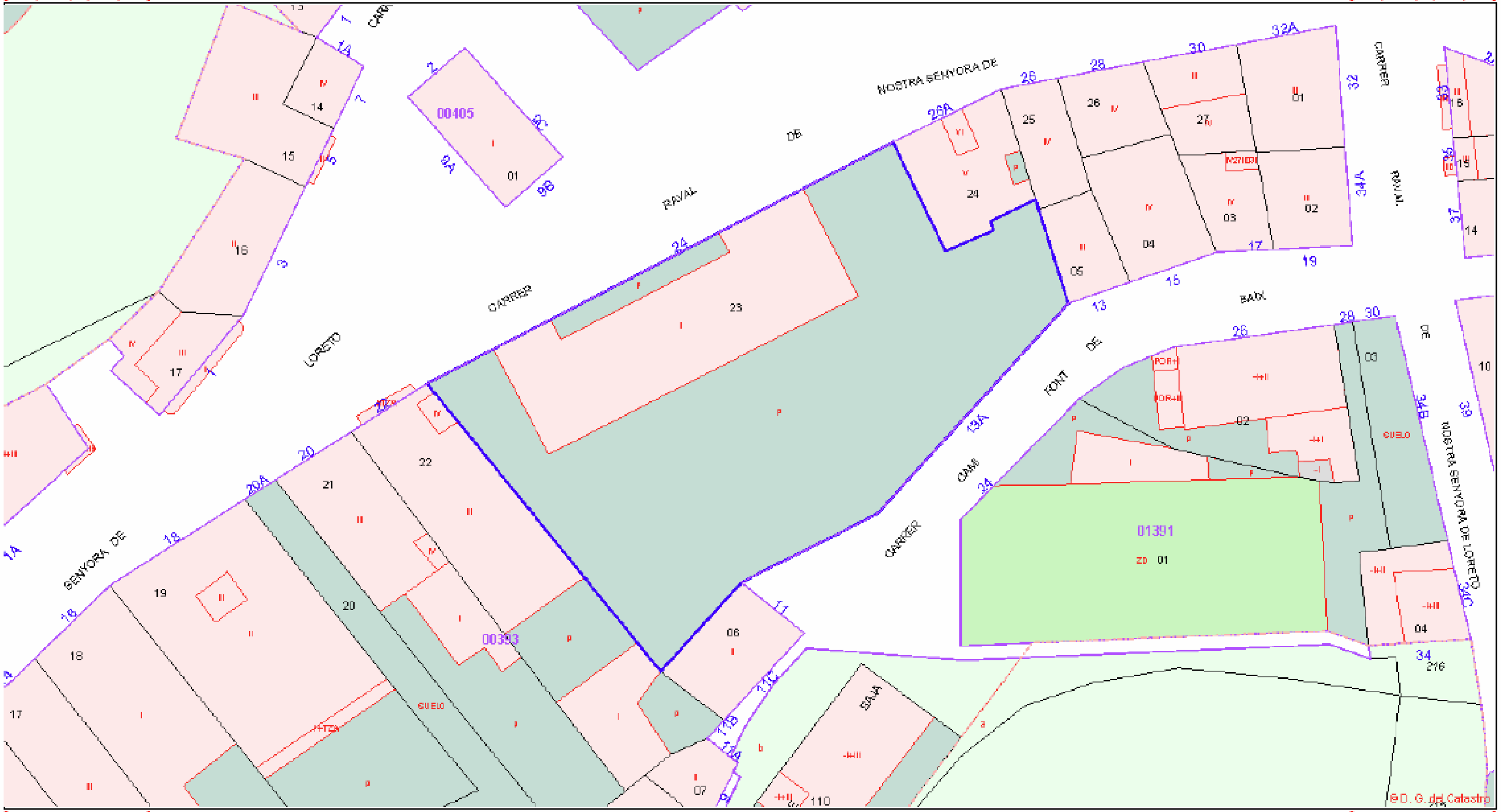
10m 0 10 20m

N

CARTOGRAFÍA CATASTRAL

Parcela Catastral: 0039323YK3604S

[729,943 ; 4,463,812] [730,063 ; 4,463,812]



[729,943 ; 4,463,746] [730,063 ; 4,463,746]

Coordenadas del centro: X = 730,003 Y = 4,463,770

Este documento no es una certificación catastral

GOBIERNO DE ESPAÑA

MINISTERIO DE HACIENDA, Y FUNCIÓN PÚBLICA

SECRETARÍA DE ESTADO DE HACIENDA

DIRECCIÓN GENERAL DEL CATASTRO

Sede Electrónica del Catastro

Provincia de CASTELLÓN

Municipio de VISTABELLA DEL MAESTRAZGO

Coordenadas U.T.M. Huso: 30 ETRS89

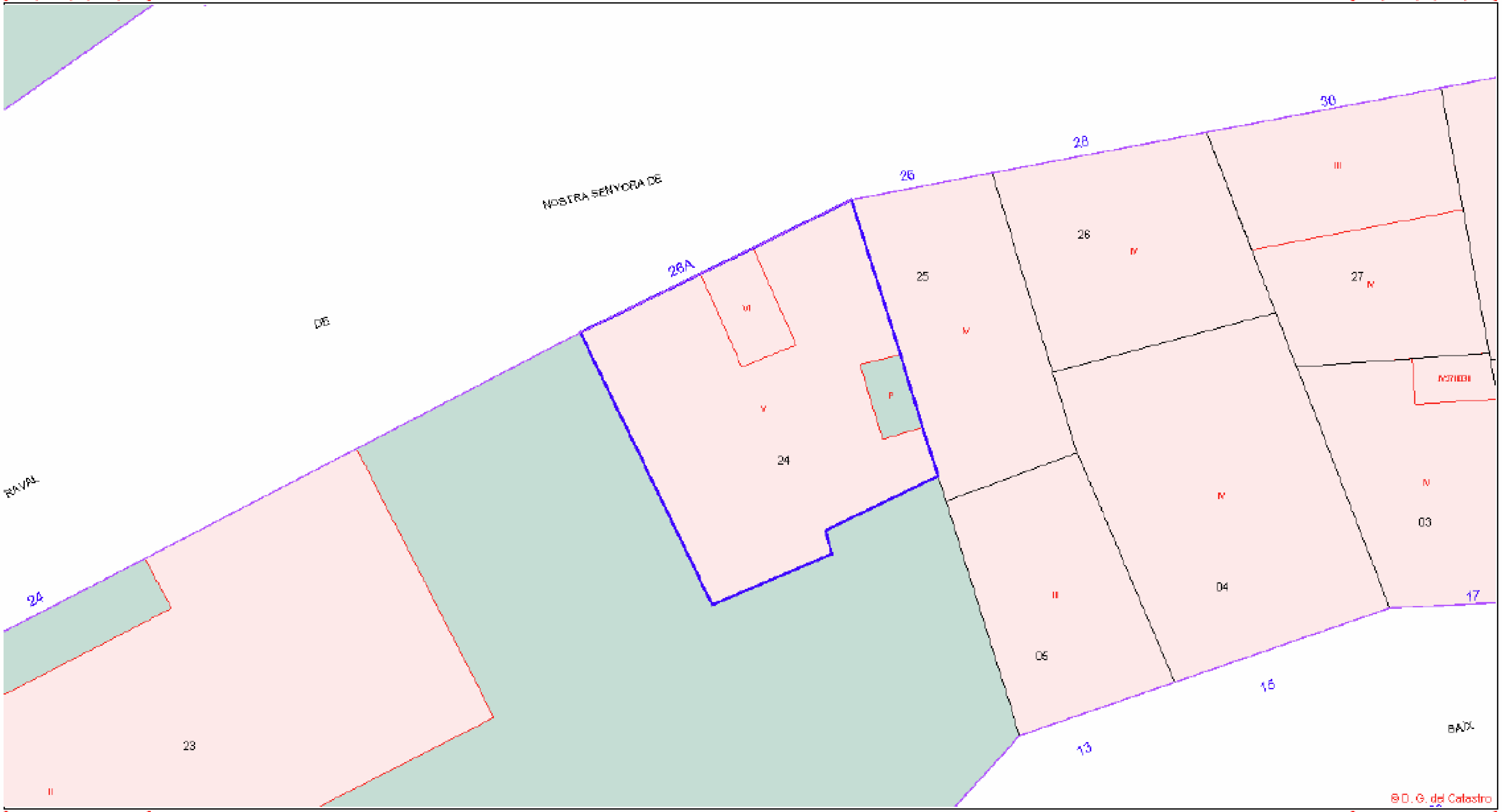
ESCALA 1:200

5m 0 5 10m

CARTOGRAFÍA CATASTRAL

Parcela Catastral: 0039324YK3604S

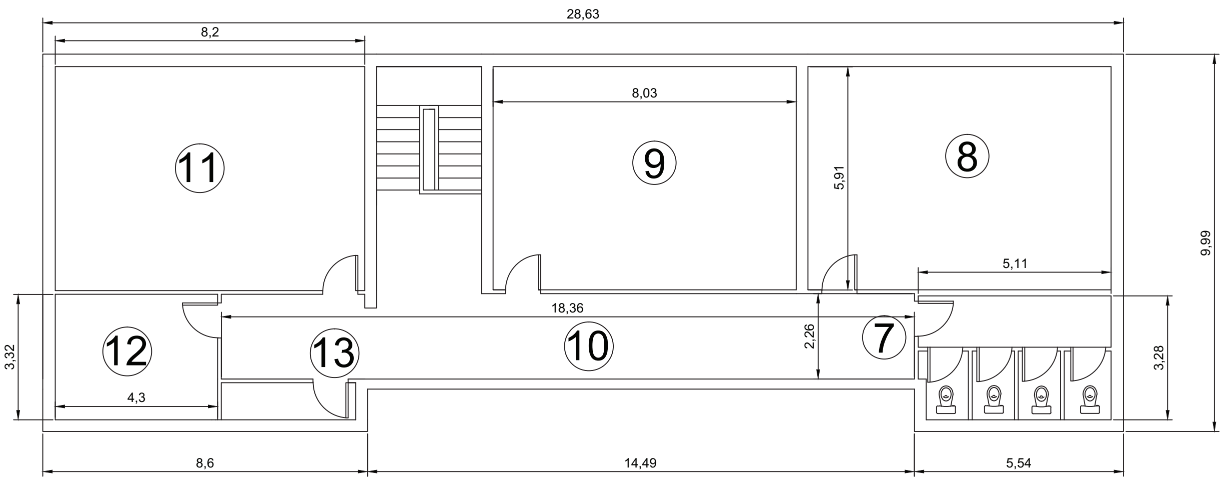
[729,996 ; 4,463,811] [730,044 ; 4,463,811]



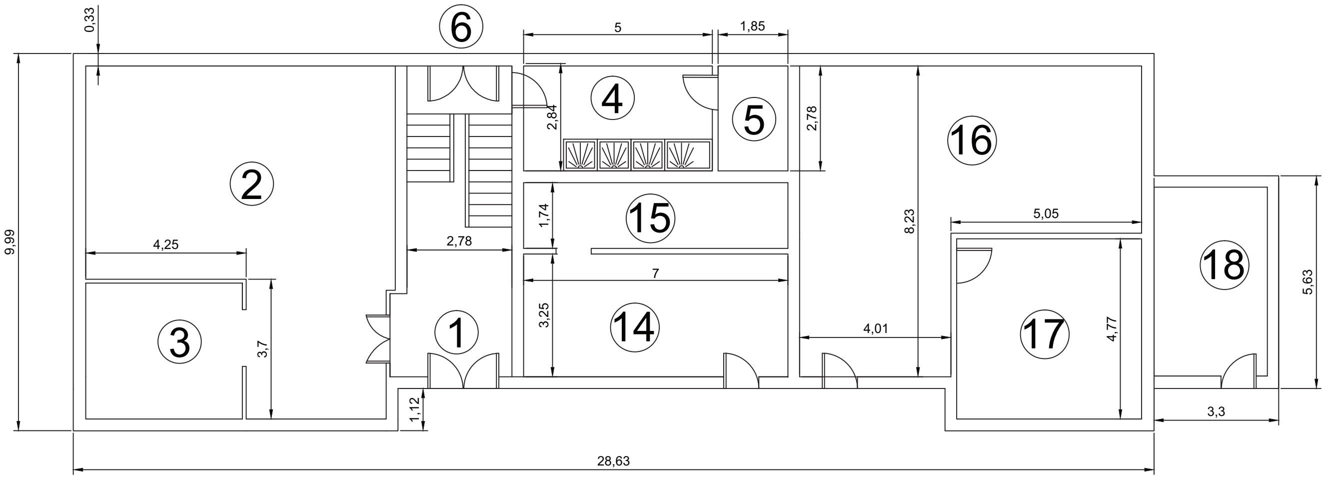
[729,996 ; 4,463,785] [730,044 ; 4,463,785]

Coordenadas del centro: X = 730,020 Y = 4,463,798

Este documento no es una certificación catastral



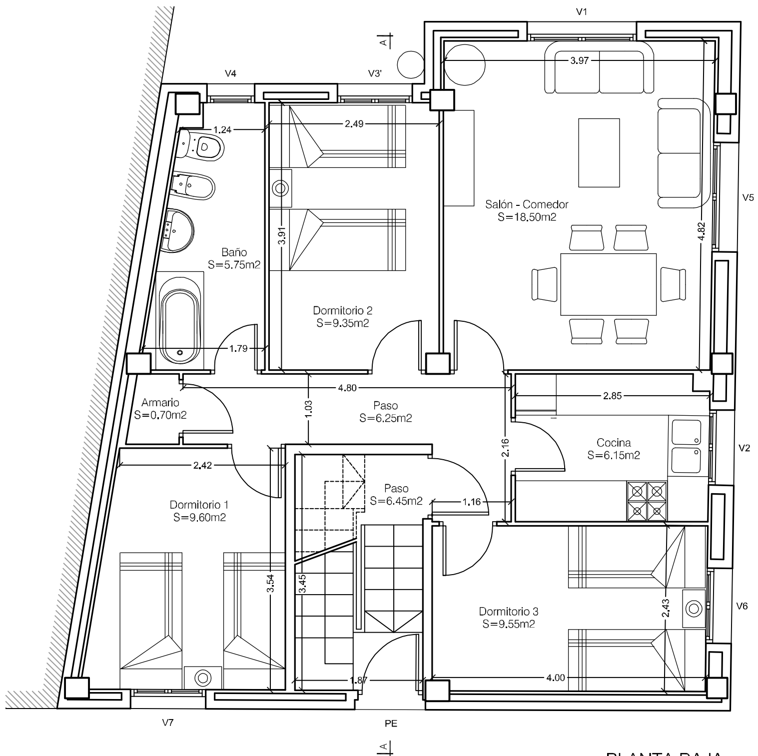
Planta 2



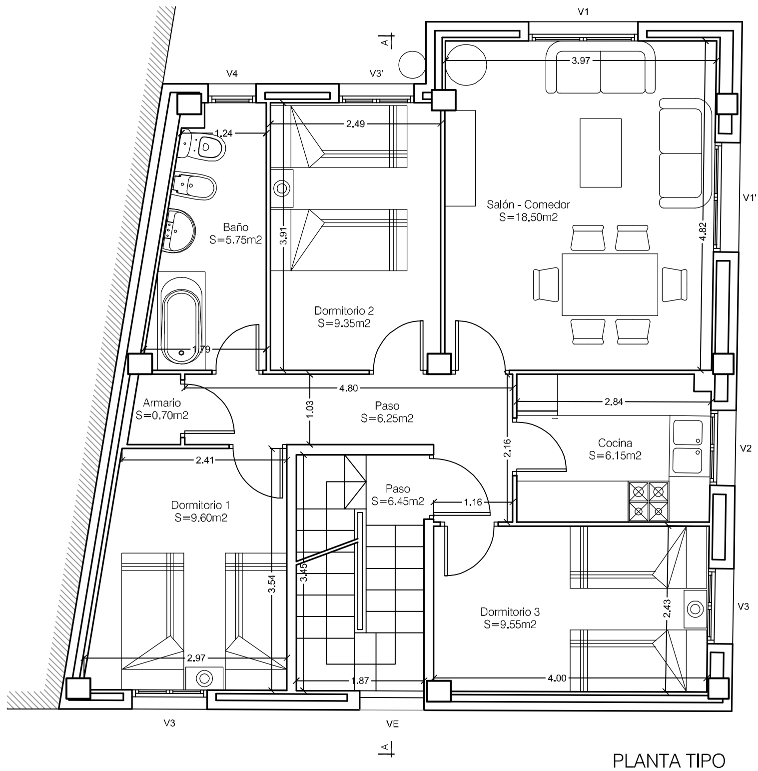
Planta 1

Zonas del Edificio	
1	Entrada Norte
2	Comedor
3	Cocina
4	Vestuarios
5	Almacén vestuarios
6	Entrada Sur
7	Baños
8	Aula de informática
9	Aula de primaria
10	Pasillo
11	Aula de infantil
12	Despacho
13	Almacén
14	Farmacia
15	Almacén de la Farmacia
16	Sala de Música
17	Almacén de la Sala de Música
18	Sala de la Caldera

	NOMBRE	FECHA	PROYECTO
DIBUJADO	Javier Celades	04/09/2014	Proyecto de instalaciones de ventilación, calefacción y ACS para la escuela de Vistabella del Maestrazgo
COMBROBADO	Leonor Hernández	09/09/2014	
ESCALA	NOMBRE DE PLANO		Nº PLANO
1:100	Distribución en planta del C.E.I.P. Sant Joan de Penyagolosa		2



PLANTA BAJA



PLANTA TIPO

SUPERFICIES CONSTRUIDAS (m^2)

PLANTA BAJA	VIVIENDA	80.05m2
	ELEMENTOS COMUNES	7.65m2
PLANTA PRIMERA	VIVIENDA	80.05m2
	ELEMENTOS COMUNES	7.65m2
PLANTA SEGUNDA	VIVIENDA	80.05m2
	ELEMENTOS COMUNES	7.65m2
PLANTA TERCERA	VIVIENDA	80.05m2
	ELEMENTOS COMUNES	7.65m2
PLANTA CUARTA	VIVIENDA	80.05m2
	ELEMENTOS COMUNES	7.65m2
TOTAL		438.50m2

PROYECTO BÁSICO Y DE EJECUCIÓN DE MEJORA DE LA EFICIENCIA ENERGÉTICA Y REPARACIONES EN UN EDIFICIO DE VIVIENDAS MUNICIPALES

El arquitecto: Emilio Segarra Sancho	ESTADO ACTUAL IGUAL AL ESTADO PROYECTADO PLANTAS DE DISTRIBUCIÓN, COTAS Y SUPERFICIES	PLANO: 3
Situación:	C/ Rabal de Nuestra Señora de Loreto nº26-A. Vistabella del Maestrat.	Escala: 1/50
Promotor:	AJUNTAMENT DE VISTABELLA DEL MAESTRAT	Fecha: II-2016

SESAN ARQUITECTURA Y URBANISMO S.L.P.
Avda. del Mar Nº27, Bajo Izquierda. 12003 Castellón. Tfno.964 23 81 51 Fax.964 22 06 20 e-mail: sesan@sesan.es

REPORT OF THE CASE STUDY ON RENEWABLE ENERGIES TO LOCAL DEVELOPMENT NATIONALLY IMPLEMENTED

Study and design of renewable energy installations in Torre Martínez at a building isolated without connection to electric, potable water and sanitation grids

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Universitat Jaume I

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Study case: Lluis Monjo Mur

Renewable energies tutor: Jose Segarra Murria

Rural development tutor: Vicente Alberto Querol Vicente

English tutor: Noémi Fiser

Professional supervisor: Zsuzsanna Kray

UMANS URBANISME I MEDI AMBIENT NEBOT I SEGARRA

Paraje Grutas de Sant Josep s/n

12600 La Vall d'Uixó (Spain)

January to February 2017

Contents of the project

Memory of the project

1. Introduction to the project

1.1 Aim of the project

The aim of the project is the dimensioning of the facilities of electricity, water, sanitation and heating in an isolated house. Moreover, it pretends that the design becomes a model for other homes in the area with similar characteristics.

1.2 Project scope

This document have dimensioned installations of electricity, water, sanitation and heating using renewable energy following the guidelines and regulations in Spain. [1]-[6]

The different parts composing the installations have been taken into account. The electricity has dimensioned the production, storage, distribution and consumption. The water has dimensioned collection, storage, purification, distribution and final treatment. Finally, heating has dimensioned heat production and distribution.

The project takes into account the perception of the local residents in the renewable energies and the solutions they have in their homes. This perception is taken by seven interviews in different profiles in the area.

1.3Location

The study focuses on Torre Martínez house located 4.5 kilometers north of Vistabella del Maestrat. Vistabella is a municipality of the interior of Castellópertaining to the region of Alcalatén. It is located in Penyagolosa region and is the highest town of Comunitat Valenciana with 1249 m. The average temperature in summer is 19.5 °C and 2.8 °C in winter.

Length: 40.333292

Latitude: -0.273667

Figure 1. Province of Castelló.

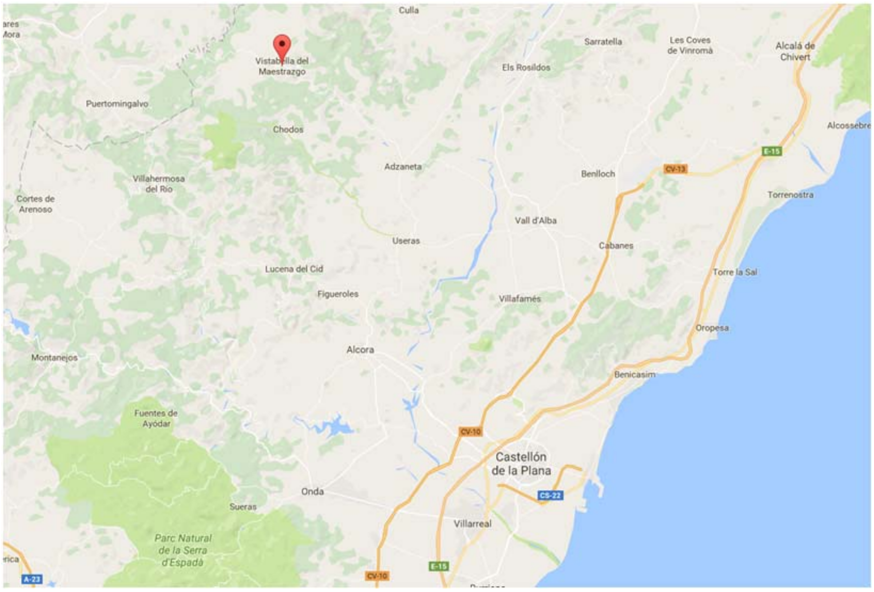

Figure 2.Location of Vistabella.

Figure 3. Locationof Torre Martínez.

Figure 4. Torre Martínez.

1.4 State-of-art in the problem domain

The current population of Vistabella is 369 inhabitants. 78%of them is registered in the town and 22% in different villages around the territory. This information was obtained from the municipality of Vistabella in February, 2017. Moreover, most of the people living in the village also own anisolated house and other people who live far away from Vistabella use the isolated houses as a second residence. Only in Vistabella, the number of isolated houses registered is nearlya hundred. Only 5% of them have a connection to the electricity distribution network. The other houses have self-sufficient system or do not have electricity.

1.4.1 Electricity

Torre Martínez had earlier a system which generated electricity by using photovoltaics. The installation is 1.2 kW and a DC voltage of 12V. Moreover, has two batteries with 1050A each. This installation is insufficient to cover the consumption of the house. The tower also has internal wiring, but this does not comply with the regulations.

Figure 5. Photovoltaic installation.

Figure 6. Batteries.

Figure7. State of the installation.

1.4.2 Water

The house has a rainwater utilization system. This system does not comply with the regulations because there is no process of purifying the water before its use. In addition, the water deposit is insufficient. In addition, the pressure isnot enough, too. Moreover, the house does not have hot water. Finally, the drains of the house are thrown directly into the land, which is banned by regulations.

Figure 8. Drain pipe.

Figure9. Point evacuation of wastewater.

Figure 10.Water Deposit.

1.4.3 Heating

Torre Martínez is heated by a stove-oven on the ground floor. The other rooms are warmed by the tube of the chimney. This stove uses wood from the owner's land. This system is insufficient to warm the whole house because of the climate.

Figure11. Stove-oven.

Figure12. Tube of the chimney.

1.4 Design alternativesto be considered

The installation has calculated using the experiences of other homes around, the material provided in in2rural web about energy photovoltaic and biomass [12] and the regulations.

1.5.1 Electricity

A photovoltaic system is common to use in the electricity of an isolated house. This can also be designed with a combination of photovoltaic and eolic systems. The only difference between the two facilities is in the generation part, where the solar system has only photovoltaics panels and a combined system has solar panels and a wind generator. In both cases, the rest of the installation presents no differences.

This installation has three parts:

- The first part is the generation. It is the part of the installation, where the electricity is produced. The voltage and intensity depend on the configuration of the components in this part of the installation. In photovoltaic systemit depends on the open circuit voltage (V_{oc}) and short circuit current (I_{sc}). The solar technology can be monocrystalline, polycrystalline or thin layer. [9] Wind turbines are horizontal axis, three horizontal axis blades, multiblades horizontal axis or vertical axis. [11]
- The next part of the installation is the storage. When electricity production is higher than electricity consumption in the installation, the batteries load up. In the market, there are different technologies for storage. Technology AGM, Monoblock, and stationary batteries. [14] The sizing must consider the stress and time and rate of discharge of the batteries.
- The third part of the installation is the distribution and consumption. This part is the same as in the case of any other traditional house connected to the traditional network. [5] The distribution is composed by protections against overvoltage and short circuit, wiring, floor protection and switches. Consumption points are sockets and lights.

These three parts of the electric installation need a monitoring and a control system that is composed of regulatory and investor. The regulator is responsible for loading the batteries safely from the electricity generation part. The investor is responsible for converting the DC voltage from the batteries to AC 230V / 50Hz for distribution in the building. These are also provided by protection between the different parts.

1.5.2 Water

In regions such as Vistabella, where it is not easy to find water, the most common solution is to build a water tank to store water from the rain. This deposit should be enough for months with less rainfall. This water cannot be consumed directly and must to be purified. [6]

There are several water purification systems [13] here we mention three of these options:

- Chlorine is an inexpensive and effective method. You must put the required amount of chlorine in the water, but you have to check that there isnot an excess or deficiency of concentration. A problem is that you must wait for 30 minutes before using the

water. In a system for collecting water directly, you cannot control when the water enters. For this reason, it requires constant monitoring.
- Activated carbon is very effective, but can overwhelm and pollute the water with microorganisms. It needsto change the filter after five months. Moreover, it needs second ultraviolet rays filtering or ionic silver to makethe water safe for consumption.
- Inverse osmosis can remove up to 95% of dissolved solids and 99% of bacteria. The problem is that half of the water that enters in the purification process is rejected. Osmosis incorporates a sediment filter, an activated carbon, membrane, an ultraviolet lamp and two more filters. It cleans itself. It can operate with a good maintenance up to 10 years.

Another point to take care of is hydraulic pressure. One option is to use a pump that provides the necessary pressure in the circuit all the time. The problem is that the pump needs electricity for its operation all the time. Another option is a system with auxiliary tank. It is in height for gravity to make sufficient pressure. It has the disadvantage of requiring a pump to raise water and an auxiliary tank high. But it has the advantage of having pressurized water if there was a power cut if the auxiliary tank had water.

Hot water is essential in a home. A solution to these types of requirements with renewable energy systems would use a solar thermal panel. The disadvantage of this system is that if there is no sun, there will be no hot water. Another option is to obtain hot water with a biomass boiler. An electric heater can also be considered, but these consume much energy making the electrical system oversized.

The most common solution for wastewater is the use of a cesspool. Another option is the installation of a sewage treatment plant.

1.5.3 Heating

The owner has free wood in his land, the options described for heating are based on wood biomass.

An option is to heat the house installing a wood stove on each floor, as some of the houses nearby have.

Another option would be to use a wood boiler to heat water and distribute heat through radiators in rooms that need to be acclimated.

1.5 Description of the final solution

1.6.1 Electricity

The guide used for dimensioning of the generation and accumulation is provided by the “Instituto para la diversificación y ahorro de la energía (IDAE) Pliego condiciones Instalaciones Técnicas Aisladas Red”. [1]

The inner installation is regulated by “el reglamento eléctrico de baja tensión (REBT)”. [5]

The electrification of the house has chosen a system of solar power generation. The wind option is discarded because the wind is not constant and in some areas would not be sufficient. The wind system requires a previous study.

The consumption of the house is in Table 1. I am looking for the most efficiency appliances in the market.

Table 1. Consumptions.

Component	Units	Power(W)	Time(h)	Daily energy (Wh)
LightsLED	15	8	4	480
Fridge	1	160	8	1,280
Extractor	1	172	1	172
Microwave	1	800	0.5	400
TV	1	30	4	120
Computer	1	45	4	180
Modem	1	5	4	22
Washingmachine	11	190	1	190
Osmosis	1	108	1.5	162
Water pump	1	736	1.5	1,104
Treatment system	1	60	24	1,440
Biomass boiler	1	140	8	1,120
			Total	**6,670**

The required daily energy is estimated at 6.67 kWh/day.

The selected components can be seenin Table 2.

Table 2. Components of the electric installation.

Components	Model	Nº of components	Comments
Solar panel	A-300P	10	2series and 5 parallel
Regulator	Outback FM80	1	80 A 48V
Batteries	Hoppecke 6 packs 2V 8 OPZS 800	4	4 series
Inverter	VFX 3048E	1	48V 3000VA

Solar panels are designed to be installed on the roof of the house. They are connected with five sets of two parallel plates in each set series. The inclination is 45 degrees, as the inclination of the roof. The other components of the installation have stayed in the room where the former system was previously installed. The storage was calculated at a voltage of 48V, making losses effect Joule is less. In plan 01 you can see the complete installation and in Figure 10 the simplified installation of generation.

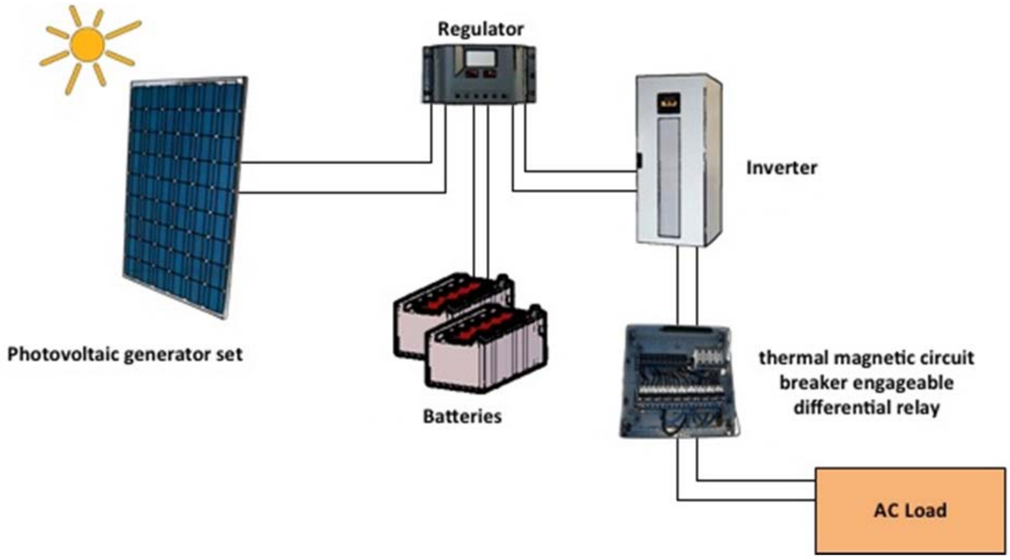

Figure 13. Pictureof photovoltaic installation. Picture from [Reference 15]

The part of the installation of distribution and consumption can be seen in plan 02. This facility has the elements of Table 3.

Table 3. Inner electrical installation.

Components	Number/Quantity
Lights	15 units
Switches	24 units
Plugs	15 units
Tubes	112 meters
Electrical boxes	26 units
Wires (phase, neutral and earth wire)	375 meters

1.6.2 Water

The legislation has been used for sizing is the “codigo técnico de la edificación (CTE)”[3]. and “Guía técnica de aprovechamiento de aguas pluviales en edificios” [6]

The solution chosen is an auxiliary tank and a purification inverse osmosis. The sanitation of hot water has been chosen by biomass boiler.

We have calculated with a new tank of 20,000 litres. It is located in the western part of the building, where the land is lower than the roof of the entire building, reusing all the available roof area. Moreover, new pipes were calculated by rainwater catchment with PVC material that does not alter the chemical properties of the water utilised.

The water rises inside the top floor of the house to avoid frostbite due to weather conditions in the area. The elevation is made by a pump with protection against overpressures to protect the inverse osmosis machine, which is directly connected to it. Both the pump, as the machine osmosis should work for an hour and a half a day. Both potable water and waste water coming from the osmosis machine, stored in an auxiliary tank of 200 litres,one for each type of water. The legislation allows non-potable water use for downloads toilet, washing machine and for cleaning the floor. Potable water is used for other purposes. Tanks have their corresponding distribution pipes avoiding the mixing of the two waters.

The average water consumption per person is 130 litres / day. It is distributed at the various consumption points as is shown in Figure 11.

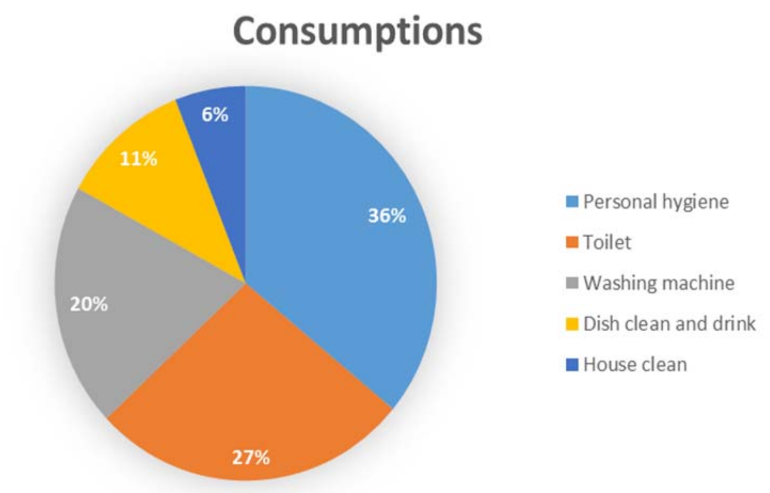

Figure 14. Water consumptions

Because this type of installation has limited water resources, Ihave implemented some components that save water. Table 4. [references]

Table 4. Saving in the consumption points.

Component	Normal consumption (Litres/day per person)	Savings rate (%)	Final consumption (Litres/day per person)
Toilet	34.1	40	21.06
Water tap	46.8	50	23.4

Applying the savings in different parts, will achieve a consumption of 93.1 l / day per person.

The sanitation of hot water required is 28 l / day per person. This is obtained by the biomass boiler. [Look at section 1.6.3]

For wastewater treatment plant Bioviana ATC-P 6 has been selected, with an auxiliary tank that can use the depurated water for irrigation in compliance with current legislation on reclaimed water.

The installation can be seen in plans 03, 04 and 05.

The hydraulic components of the installation are shown in Table 5

Table 5. Hydraulic installation components.

Component	Capacity / Power /Number	Comments
Main tank	20.000 litres	Located in the lower part of the roof to maximize it
Auxiliary tank	200 litres	2 tanks located in the highest room of the house.
Pump and protection	1 cv	Protection against pressures on the input filter
Professional Filter 800 GPD	2.2 l/min	waste 50%
Transparent filter holder 20 "	2 units	
Sediment Filter 20 "20 microns polyps.	1 unit	
Sediment Filter 20 "Polyester 5 microns	1 unit	
Water taps	6 units	Toilet, sinks, washing machine, shower
Tubes	30 meters	0.02 m diameter
Gutter	Gutter 32 meters Tube 46 meters	Gutter 0.127 meters width Tube diameter 0.1 meters

1.6.3 Heating

The regulation used to estimate energy demand in the house is based on the "Reglamento de instalaciones térmicas en los edificios (RITE)". [2]

The heating of the house has been designed using a wood-fired boiler. It heats hot water which circulates through radiators and the sanitation of hot water. During those months, when heating is not needed, the boiler can operate only for a fraction of the day for the sanitation of hot water.

The thermal load of the house can be seen In Table 6.

Table 6. Surfaces.

Place	a (m)	b (m)	minus	Surface (m^2)
East wall	6.5	7	1.64	43.85
West wall	6.5	7	0	45.5
North wall	5.3	5.7	0	30.21
South wall	5.3	6	1.82	29.98
Warehouse wall	5.3	2,2	0	11.66
Floor	5.5	4	0	22
Roof	5.3	7	0	37.1
Door	0.78	2.11	0	1.65
2nd floor windows	0.7	0.7	0	0.49
1st floor windows	0.7	0.9	0	0.63
Ground floor Windows	0.7	1	0	0.7

Table 7. Thermal load.

Place	Transmission ($w/m^2 \cdot k$)	Thermal (ºC)	Transmission losses	Orientation	Losses + orientation
East wall	1.53	19	1274.84	1.05	1338.58
West wall	1.53	19	1322.68	1.05	1388.82
North wall	1.53	19	878.20	1.1	966.03
South wall	1.53	19	871.52	1	871.52
Warehouse wall	1.75	14	285.67	1.1	314.24
Floor	2.17	14	668.36	1	668.36
Roof	2.63	19	1853.89	1	1853.89
Door	5.7	19	178.24	1.05	187.15
2nd floor windows	5	19	46.55	1	46.55
1st floor windows	5	19	59.85	1	59.85
Ground floor Windows	5	19	66.5	1	66.5
		Total	7506.30	Total	7761.48
				Exterior walls +10%	8537.63
Total loses	9321.6374	Wh	141.23693	$W/h \cdot m^2$	

The thermal load obtained follows the guidance of the RITE, was 141.23 W/hm^2

The distribution of the heating installation can be seen in plan 06. In Table 7 are the components of the installation. Figure 12 is the picture of hydraulic installation.

Table 8. Heating installation components.

Component	Comments
Boiler VIGAS 25 S - Gasification boiler of 25 kW of gasification.	
3/4 "Honeywell Thermal Valve, Boiler Lift Feet, Ashtray and Ashtray	
Return temperature rise unit with electronic pump	
Depth sounder KYT	
Safety group VIGAS	
Tank EO Tank 800, 8 nozzles and insulation 100 mm. With instant production of hot water.	
Radiators	9 Units
Tubes 0.02 m diameter	60 meters

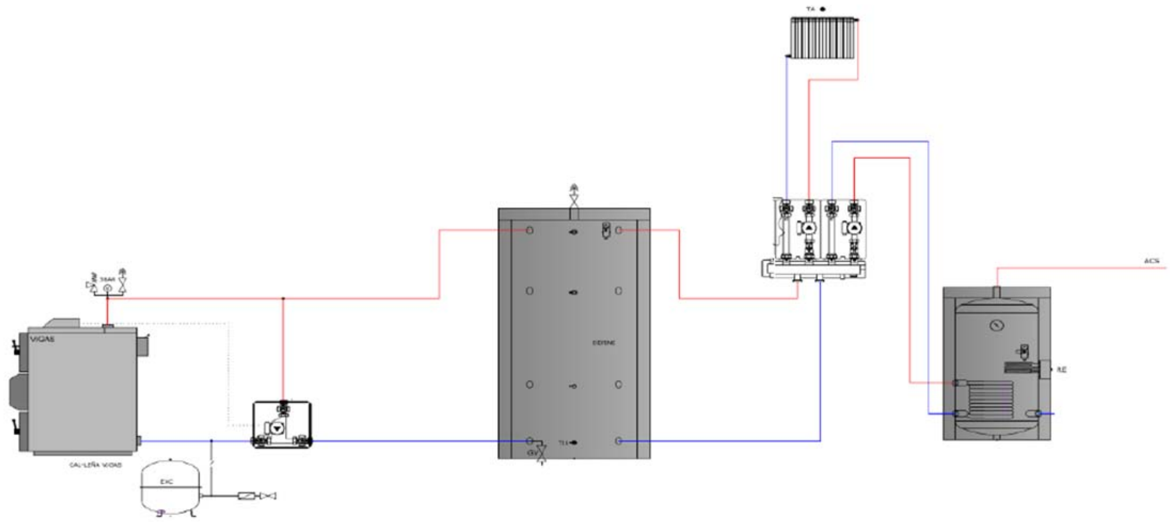

Figure 15. Picture of hydraulic installation. Provided from the seller [J].

1.6 Impact of the project for the rural development

Electricity is essential today. These renewable systems are more economic than the connection to the traditional network of electricity. Light allows farmers to have more daylight hours and they do not depend on the sun. It also allows you to work or study in the evenings. Moreover, to have comforts of today want people to stay where they were born and not to move to other towns. These systems bring you an economic freedom, but with an initial amount of money. An important inconvenience is that depends on weather conditions.

The potable water in homes is essential today. If there is no possibility of connecting to the network of potable water, a self consumption system is a good option. But it also depends on the rain and are limited to the amount you have. The inverse osmosis system is easy and comfortable for potabilize the water. The wastewater treatment plant is a perfect option to reuse the water.

Heating is essential in colder months. In towns like Vistabella it is essential. The use of the resource in the area and the distribution of heat through radiators is the most efficient and cheaper option than buy other combustibles.

1.7 Environmental impact

The electricity obtained from renewable energy is undoubtedly cleaner. In renewable energy, the emission of CO_2 in the atmosphere is negligible, with the exception of biomass. The CO_2 emissions into the atmosphere from biomass is a fact, because it burns. But the cycle of this renewable energy is neutral, since the CO_2 released during combustion is fed by different plants to grow, making the final balance neutral. The emission of CO_2 in the atmosphere cannot be completely considered a void in a renewable system. Because in the manufacture of components and transportation and installation of these systems make CO_2 emissions. These emissions of CO_2 are the same as in non-renewable energy. Non-renewable systems also emit CO_2 in the production.

The following figure shows the curve of electricity consumption of traditional network in Spain taken from the official website of the Spanish electric gridd [10]

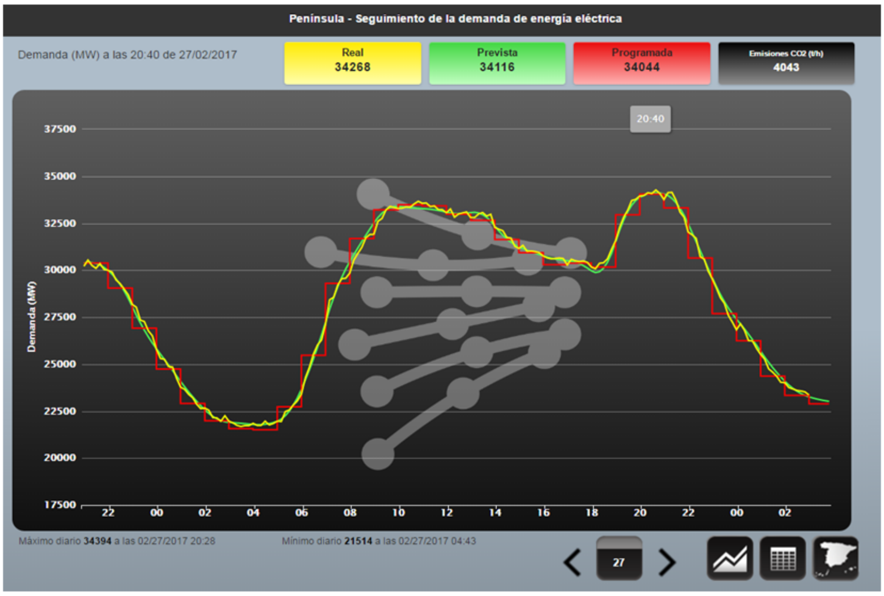

Figure 16. Electricity consumption. Spain 27th of February 2017.

The following Figure shows, at the point of maximum demand on 27 February 2017 at 20:40 pm. from where the electricity comes. Figure from Spanish electric grid [10]

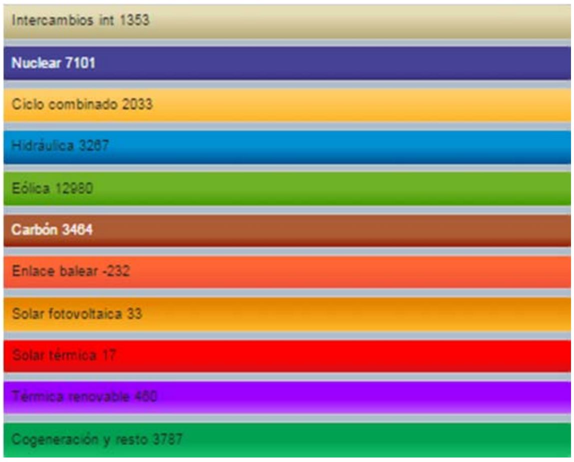

Figure 17. Provenance of the electricity. Spain 27th of February 2017 20:40 pm.

You can see that the first production of renewable energy is in third place. Nuclear and the combined cycle are the top sources of production in Spain.

At the time of maximum consumption the CO_2 production was 4043 tons / hour. With a demand of 34,268 MW is obtained a production of 1.18 · 10-4 Tones / (kWh)

The installation designed by 6.67 kWh / day · 365 days = 2,434.55 kWh in a year.

The emissions savings of CO $_2$ in the case study is 0.287 tons per year in electricity.

On heating, the total emissions savings is all.Because the wood is used by the owner's land.There isno emission of CO $_2$ for transport.

1.8 Social and rural impact

It is a fact that the rural world has affected by a progressive depopulation since the industrial revolution. People have gone to the cities where there are new ways to work and earn money. In Vistabella, the town where the project is developed, is an example of what the countryside has suffered. The local cadastre reached its maximum of people living in the village with 2775 inhabitants in 1910 [7] and nowadays 369 people live there. [8]

The depopulation of a region has an effect on people. If schools do not have enough students they are forced to close. This requires students to move to other locations or families move to other locations where schoolsare still open. The shops are also affected because there are not people to consume. They are forced to close lack of customers with the consequent destruction of jobs and the displacement of active people to other locations.

The land is also affected. Because of less people, crop fields are abandoned. Here are someplaces for the growth of vegetables and wild animals. Fire is more difficult to control because the accumulation of wood. Moreover, the population of animals destroys crop fields that are still working to make losses to the agriculture.

1.9 Questionnaries

There have been questionnaries for the local population to meet their needs and the perception of renewable energies. This questionnaire was done qualitatively sample in order to obtain inhabitants perceptions on renewable energies, choosing different profiles in the area. This sample is not representative, in order to draw a more precise conclusion a study for all the isolated houses should be done, and in the surrounding municipalities also have a large population living in villages.

The sample consists of young couples without children, couples with small children, pensioners, workers and local businesses in the area. They are between 30 and 62 years with children from 5 to 7 years. I made seven questionnaries.More detailsare in Annex I.

The main conclusions are:

- Survey respondents have or live in a house without connections to traditional networks. Connection to the network assumes a high cost. And all of them possess a system of electricity through a photovoltaic system.
- The perception of survey respondents on renewable energies in all cases is good. But the high initial cost of the installation is a problem, too.
- All agree that electricity is essential both for life and for work. The fact of having electricity, allowed a local farmer not only depending on the sun while taking care of the animals.
- Some survey respondents have enough knowledge in the field of renewable energy and other basic skills. All who were asked think that maintenance is easy.
- Some of the installations are complemented by a traditional diesel generator.

- They also agree that this installation needs a knowledge about what you have and make rational use of energy.

1.10 Conclusions

After the study, it is proved that there are totally viable renewable energy installations in isolated houses. These have their inconveniences as it is dependent on environmental factors and the responsible use for the inhabitants of the house. But they also have their advantages as the independence of the external problems or a cheaper alternative.

The reproducibility of this project in the buildings around the study case building, is an incentive for people to come and live in these areas. The fact that it is sustainable with the environment can encourage young couples to come to live there. These young couples will have children and the population of the municipality increases. There is a huge part of the population worried about the planet and its problems. And this type of installation, where you have the same as the traditional resources, but more clean, is an easy step for a more sustainable society.

These types of facilities must have a period to check that all components are correct and consumption estimates are correct, because the limitation, depending on the use, must be obtained systems success or shortcomings.

1.11 References

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Calculations

Co-funded by the Erasmus+ Programme of the European Union

2. Calculations and design

2.1 Electricity

The guide used for dimensioning of the generation and accumulation is provided by the Institute for Diversification and Saving of Energy "(IDAE) Pliego condiciones Instalaciones Técnicas Aisladas Red". [1]
The design takes into account the real useful radiation depending on the location and inclination. With the consumption in the house and this useful radiation, I selected the power of the photovoltaic panels. With an autonomy of three days minimum, I have chosen the batteries. The regulator and inverter are selected with the characteristics of the photovoltaic panels, DC voltage and batteries.
The inner installation is regulated by "el reglamento eléctrico de baja tensión (REBT)". [5]The wires sections and protections are calculated with the load.

2.1.1 Consumptions

Table 9. Consumption.

Component	Units	Power(W)	Time(h)	Daily energy (Wh)
Lights LED	15	8	4	480
Fridge	1	160	8	1,280
Extractor	1	172	1	172
Microwave	1	800	0.5	400
TV	1	30	4	120
Computer	1	45	4	180
Modem	1	5	4	22
Washingmachine	1	190	1	190
Osmosis	1	108	1.5	162
Water pump	1	736	1.5	1,104
Treatment system	1	60	24	1,440
Biomass boiler	1	140	8	1,120
			Total	**6,670**

2.1.2Radiation

Table 10. Horizontal radiation in Vistabelladel Maestrat (Castelló) - PVGIS © EuropeanCommission.

	Daily Radiation (Wh/m²/day)	**Days**	**Month radiation (kW/m²)**
January	2,170	31	67.27
February	3,120	28	87.36
March	4,580	31	141.98
April	5,190	30	155.70
May	6,060	31	187.86
June	6,920	30	207.60
July	6,980	31	216.38
August	5,950	31	184.45
September	4,630	30	138.90
October	3,420	31	106.02
November	2,440	30	73.20
December	1,910	31	59.21
ANNUAL	4,447	365	1.625.93

Table 11. Radiation at 45º in Vistabella del Maestrat (Castelló).

	K inclination 45º	**Daily radiation (Wh/m²/day)**	**Days**	**Month radiation (kW/m²)**
January	1.83	3,970	31	123.07
February	1.58	4,930	28	138.04
March	1.28	5,860	31	181.66
April	1.05	5,460	30	163.80
May	0.92	5,550	31	172.05
June	0.86	5,960	30	178.80
July	0.89	6,180	31	191.58
August	1.00	5,950	31	184.45
September	1.19	5,510	30	165.30
October	1.43	4,890	31	151.59
November	1.75	4,270	30	128.10
December	1.93	3,680	31	114.08
ANNUAL	15.70	5,184.17	365	1,892.52

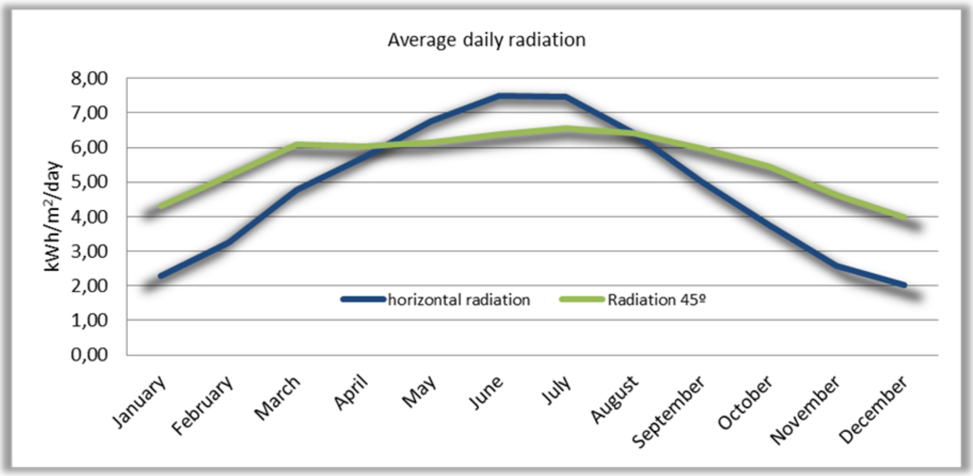

Figure 18. Monthly average daily radiation.

2.1.3 Generation and accumulation

Table 12. Gide IDAE isolated installations.

Parameter	Units	Value	Comment
Town		Vistabella del Maestrat	
Latitude		40.33º	
ED	kWh/day	6.67	Consumption of the installation
Period design		December	Month worst radiation and constant consumption (K= 1.93) [Table 15. Table III IDAE]
$(\alpha_{opt}, \beta_{opt})$		(0º, 50º)	α_{opt} south direction, β_{opt} Latitude + 10
(α, β)		(0º, 45º)	Orientation and inclination of the roof
$G_{dm}(0)_{december}$	$kWh/(m^2 \cdot day)$	1.91	PVGIS © European commission
FI		0.99	$FI=1-[1.2\cdot10^{-4}(\beta-\beta_{opt})^2+3.5\cdot10^{-5}\cdot\alpha^2]$
FS		1	Shadows placement
$PR_{december}$		0.6	Overall system efficiency inverter + Battery
$G_{dm}(\alpha, \beta)_{december}$	$kWh/(m^2 \cdot day)$	3.66	$G_{dm}(\alpha, \beta)_{december} = G_{dm}(0)_{december} \cdot K \cdot FI \cdot FS$ Daily radiation on the PV panels.
$P_{mp,\ min}$	kWp	3	$P_{mp,min} = \frac{E_D \cdot G_{CEM}{}^{**}}{G_{dm}(\alpha,\beta) \cdot PR}$

$^{**}G_{CEM}=1$

Parameters of the photovoltaic module:

- Maximum power = 300Wp
- Current short= 8.89A
- Current in the maximum power point= 8.21A
- Open circuit voltage= 44.97V
- Voltage at maximum power point = 16.52V

A generator of 3,000 Wp was selected. Distributed two modules in series and in parallel five. All together 10 modules.

Also four accumulator nominal capacity of 915Ah. Distributed these four in series.

The continuous voltage installation is 48 V to minimize losses by Joule effect.

The voltage regulator adjusts the maximum discharge at 50%.

The efficiency of the inverter is 93%. The storage and regulator efficiency is 98%.

Table 13. Continuation Table 11.

Parameter	Units	Value	Comment
P_{mp}	Wp	3000	$P_{mp}<1.2\cdot P_{mp,\,min}$ (mandatory requirement for the general case) Maximum power.
C_{10}	Ah	915	Nominal capacity of an accumulator
PD_{max}		0.5	Discharge maximum allowed by the regulator
η_{inv}		0.93	Inverter efficiency
η_{rb}		0.98	Regulator and storage efficiency
V_{NOM}	V	48	Nominal voltage installation
L_D	Ah	139	Daily consumption of discharge(LD=ED/VNOM)
A	Days	3.17	Autonomy: $A = \frac{C_{20}PD_{max}}{L_D}\eta_{inv}\eta_{rb}$
C_{10}/I_{SC}	h	20.58	$C_{10}/I_{sc}<25$ (mandatory requirement for the general case) I_{sc}(generator,CEM)=26.67

Table 14. Components.

Components	Model	Numberof components	Comments
Solar panel	A-300P	10	2 series, 5 parallel
Regulator	Outback FM80	1	80 A 48V
Batteries	Hoppecke 6 2V 8 OPZS 800	4	4 series
Inverter	VFX 3048E	1	48V 3000VA

Table 15. Table III IDAE translated.

Design period	β_{opt}	$K = \frac{G_{dm}(\alpha = 0, \beta_{opt})}{G_{dm}(0)}$
December	Φ + 10	1.7
July	Φ - 20	1
Annual	Φ - 10	1.15

Φ=Latitude placement

2.1.4 Distribution and consumption installation

Table 16. Components of inner installation.

Component	Characteristics	Comments
Lights	LED	15 units
Switches		24 units
Plugs		15 units
Corrugated tube	16 mm diameter	112 meters
Electrical boxes	0.8 x 0.8 meters	26 units
Wires (phase, neutral and earth wire)	Diameter 1.5 mm 215 meters Diameter 2.5 mm 160 meters	375 meters

2.1.5 Protections

Table 17. Protections.

Component	Characteristics	Location
Magnetothermal	2 x 25 A	One between Regulator and batteries and other between batteries and inverter
Magnetothermal	1 x 10A 2 x 16A	10 A for lights 16 A one for plugs and the other for the water pump
Differential	40 A	For inner installation

2.2 Water

The legislation has been used for sizing is the “codigo técnico de la edificación (CTE)” [3]. and “Guía técnica de aprovechamiento de aguas pluviales en edificios” [6]
I took the precipitation in the area and the surface of the roof to calculate the volume of water collected. This volume has been compared with consumption of the house with water savers. It has been enough. The tanks are oversized for some extra requirements. The inner installation has done not to mix the two types of water duet to the water purification system. In wastewater system I chose a sewage enough to clean the water generated in a day.

2.2.1 Precipitation

Table 18.Rain water.

Average rainfall area	50 mm/m^{2}month
Roof surface	250 m^2
Volume of water collected monthly	12.5m^3
Gutter	Gutter 32 meters 0.127 meters width Tube diameter 0.1 meters 46 meters

2.2.2 Purification

Table 19. Characteristics inverse osmosis.

Dissolved solids elimination	Bacteria elimination	Rejected water	Production of purification water
95%	99%	50%	2.2 Litres/min

2.2.3 Hydraulic pressure

Table 20. Hydraulic pressure.

Minimum height between deposits and consumption points	Minimum flow of water by gravity at the worst point of consumption	Caudal needed in the worst point of consumption according to cte regulations.	Minimum pressure water by gravity to the point of worst consumption
4.4 meters	31.5 dm^3/s	0.2 dm^3/s	44 kPa

Equation 1: Flow water

$$Q = v \cdot A$$

Where Q=flow, v=velocity and A=area

Equation 2: Pressure

$$P = g \cdot h \cdot \rho$$

Where P=pressure, g=gravity, h=height and ρ=density.

2.2.4 Consumption

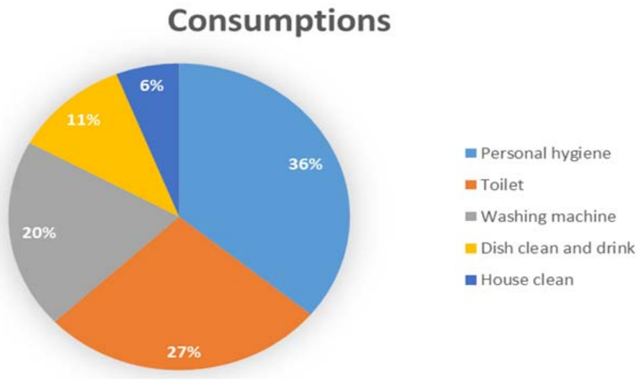

Figure 19.Water uses.

Table 21.Water savings.

Component	Normal consumption (Litres/day per person)	Savings rate (%)	Final consumption (Litres/day per person)
Toilet	34.1	40	21.06
Water tap	46.8	50	23.4

Table 22House consumptions.

Person consumption in a day without savers	Person consumption in a day with savers	Number of people living in the house	Daily Water consumption in the house	Monthly consumption (31 days)
130 Litres	93.1 Litres	4	372.4 Litres	11.6 m^3

Table 23. Water destination.

Water type	Uses	Percentage daily water	Daily litres	Tank
No potable	Toilet, Washing machine, floor	53%	197.372 litres	200 litres
Potable	Other uses	47%	175.028 litres	200 litres

2.2.5 Inner installation

Table 24. Components inner hydraulic installation.

Component	Characteristics	Comments
Tube	Diameter 20 mm	30 meters
Water tap	6 units	Toilet, sinks, washing machine, shower

2.2.6 Sewage

Table 25. Sewage.

Amount of wastewater generated daily in the house.	Sewage capacity Bioviana AC-P 6	Treated waterobtained
372.4 Litres	600 Dailylitres	372.4 Litres

2.3 Heating

The reglament used to estimate energy demand in the house is the "Reglamento de instalaciones térmicas en los edificios (RITE)". [2]

I took the building characteristics for calculating the required energy demand. For the demand and the surface, I estimated the power of the boiler. I chose one boiler from the market with the charasteristics I needed. I also looked for a tank with hot sanitation water generation. The radiators size depends on the size of the room.

Table 26. Ventilation.

Admission	People	Flow per person(m^3/h)	Total (m^3/h)
1st floor	4	18	72
2nd floor	2	18	36
		Total	108

Table 27. Extraction.

Extraction	Surface (m^2)	Flow per person(m^3/h)	Total(m^3/h)
Ground floor	17	7.2	122.4

Table 28.Equilibrated flow.

Extraction (m^3/h)	Admission (m^3/h)	Difference (m^3/h)	For each room (m^3/h)
122.4	108	14.4	7.2

Table 29. Volume.

Surface (m^2)	Height (m)	Volume (m^3)
66	2.2	145.2

Table 30. Horary renovation.

Flow (m^3/h)	Volume (m^3)	Renovation
122.4	145.2	0.84297521

Table 31. Renovation admission.

Place	Surface(m^2)	Volume(m^3/h)	Air flow(m^3/h)	Renovation/h
1st floor	22	48.4	79.2	1.636363636
2nd floor	22	48.4	43.2	0.892561983

Equation 3: Ventilation losses

$$\text{Ventilation losses} = A \cdot V \cdot C \cdot D \cdot \Delta T$$

Where A=Renovation/hour,V=Volume, C=$P_{specific}$Air, D=$C_{specific}$Air, ΔT =Thermal difference= 22ºC – 3ºC (January).

Table 32. Losses.

Place	Renovation/h	Volume (m^3)	$E_{specific}$ (kg/m^3)	$E_{specific}$ (Wh/Kg·ºC)	Thermal difference (ºC)	Losses (W)
1st floor	1.63636364	48.4	1.204	0.28	19	507.298176
2nd floor	0.89256198	48.4	1.204	0.28	19	276.708096
					Total	784.006272

Equation 4: Transmission

$$T_{ransmission} = S \cdot T \cdot \Delta T$$

Where S=Surface, T=Transmission, ΔT =Thermal difference.

Table 33. Surfaces.

Surface	a (m)	b (m)	minus	Surface (m^2)
East wall	6.5	7	1.64	43.85
West wall	6.5	7	0	45.5
North wall	5.3	5.7	0	30.21
South wall	5.3	6	1.82	29.98
Warehouse wall	5.3	2,2	0	11.66
Floor	5.5	4	0	22
Roof	5.3	7	0	37.1
Door	0.78	2.11	0	1.65
2nd floorwindows	0.7	0.7	0	0.49
1st floorwindows	0.7	0.9	0	0.63
Ground floor Windows	0.7	1	0	0.7

Table 34. Thermal load.

Surface	Transmission ($w/m^2 \cdot k$)	Thermal (°C)	Transmission losses	Orientation	Losses + orientation
East wall	1.53	19	1274.84	1.05	1338.58
West wall	1.53	19	1322.68	1.05	1388.82
North wall	1.53	19	878.20	1.1	966.03
South wall	1.53	19	871.52	1	871.52
Warehouse wall	1.75	14	285.67	1.1	314.24
Floor	2.17	14	668.36	1	668.36
Roof	2.63	19	1853.89	1	1853.89
Door	5.7	19	178.24	1.05	187.15
2nd floorwindows	5	19	46.55	1	46.55
1st floorwindows	5	19	59.85	1	59.85
Ground floorWindows	5	19	66.5	1	66.5
		Total	7506.30	Total	7761.48
				Exteriorwalls +10%	8537.63
Total losses	9321.6374	Wh	141.23693	$W/h \cdot m^2$	

Table 35. Necessary power.

Necessary power	Surface(m^2)	Total power(W/h)
141.23693 $W/h \cdot m^2$	66	9,321.64

Table 36. Components

Component	Comments
Boiler VIGAS 25 S - Gasification boiler of 25 kW of gasification.	
3/4 "Honeywell Thermal Valve, Boiler Lift Feet, Ashtray and Ashtray	
Return temperature rise unit with electronic pump	
Depth sounder KYT	
Safety group VIGAS	
Tank EO Tank 800, 8 nozzles and insulation 100 mm. With instant production of hot water.	
Radiators Orion HP 600 cointra. 2 x 5 elements, 1 x 8 elements, 6 x 10 elements	9 Units
Tubes 0.02 m diameters	60 meters

Budget and economic analysis

3. Economical aspects of the project

3.1. Budget of the installation

3.1.1 Electricity

Table 37. Electric installation cost.

Component	Price Ref.	Characteristics	Price (€)	IVA	Price with IVA (€)
Solar panel	A	A-300P	2,915.10	21%	3,690.00
Regulator	B	Outback FM80	523.26	21%	633.14
Batteries	C	Hoppecke 6 packs 2V 8 OPZS 800	7,062.60	21%	8,940.00
Inverter	D	VFX 3048E	1,307.45	21%	1,655.00
Solar panel structure	E	2 horizontal rails fixed to the roof by roof tile saver claws. The panels are attached to the rail using special staples	434.50	21%	550.00
Protections	F	Magnetothermal Schneider electric 2 x 25A, 1 x 10A, 2 x 16A Differential Schneider electric 40 A	58.82	21%	74.45
Corrugated tubes	F	PVC 16 mm diameter 112 meters	13.43	21%	17.00
Wires	F	Diameter 1.5 mm 215 meters Diameter 2.5 mm 160 meters	79.00	21%	100.00
Lights	F	LED 15 units	132.72	21%	168.00
Switches	F	24 units FONTINI BF 18	121.35	21%	153.60
Plugs	F	15 units FONTINI BF 18	86.50	21%	109.50
Electrical boxes	F	0.8 x 0.8 meters 26 units	18.49	21%	23.40
Installation	G	Labour	1,593.16	21%	2,016.66
		TOTAL	14,323.30	21%	18,130.75

3.1.2 Water

Table 38. Water installation cost.

Component	Price Ref.	Characteristics	Price(€)	IVA	Price with IVA (€)
Tank	G	20.000 litres	5,450.90	21%	6,899.86
Tank	G	2 x 200 litres	235.92	21%	285.47
Water pump	G	1 cv	83.57	21%	105.78
Osmosis machine	H	Professional filter 800 GPD 2 x Transparent filter holder 20 " Sediment Filter 20 "20 microns polyps. Sediment Filter 20 "Polyester 5 microns	422.39	21%	511.09
Tubes	G	Diameter 20 mm 30 meters	251.1	21%	303.84
Water tap	F	6 units Toilet, sinks, washing machine, shower	90.85	21%	115.00
Gutter	G	Gutter 32 meters 0.127 meters width Tube diameter 0.1 meters 46 meters	340	21%	411.4
Sewage	I	Bioviana AC-P 6	1,817.00	21%	2,300.00
Installation	G	labour	443.79	21%	536.98
		TOTAL	9,060.84	21%	11,469.42

3.1.3 Heating

Table 39. Heating installation cost.

Component	Price Ref.	Characteristics	Price (€)	IVA	Price with IVA (€)
Biomass boiler pack	J	Boiler VIGAS 25 S - Gasification boiler of 25 kW of gasification. 3/4 "Honeywell Thermal Valve, Boiler Lift Feet, Ashtray and Ashtray Return temperature rise unit with electronic pump Depth sounder KYT Safety group VIGAS Tank EO Tank 800, 8 nozzles and insulation 100 mm. With instant production of hot water.	5,461.00	21%	6,607.81
Radiators	F	Radiators Orion HP 600 cointra. 2 x 5 elements, 1 x 8 elements, 6 x 10 elements	474.316	21%	600.40
Tubes	G	Tubes 0.02 m diameters 60 meters	502.2	21%	607.68
Installation	G	labour	332.83	21%	421.30
		TOTAL	6,507.38	21%	8,237.19

3.1.4 Price References.

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3.2 Payback, IRR and NPV

We did not have incomes and expenses for each of the facilities.

3.2.1 Electricity

The cost to connect to traditional grid in the area is around 65,000€ plus the bills at the end of the month. The cost of the photovoltaic installation is around 17,500 €. The cost of the electricity in Spain for 4 people with 6.7 kWh/day is around 87.5€/month and an increment of 5% per year.

Table 40. Electricity.

Year	Photovoltaic installation	Price for traditional electric grid (without the connection)
1	17,500€	1,050€
2	17,500€	2,152.5€
3	17,500€	3,307.5€
4	17,500€	4,515€
5	17,500€	5,775€
6	17,500€	7,087.5€
7	17,500€	8,452.5€
8	17,500€	9,870€
9	17,500€	11,340€
10	17,500€	12,915€
11	17,500€	14,542.5€
12	17,500€	16,222.5€
13	17,500€	17,955€

The payback for the electric installation comes at 12.9 years.

3.2.2 Water

The cost of the rain water profit and sewage is around 11,000€. I have compared the water cost with the cost of the traditional water 40€/month with an increment of 1% per year.

Table 41. Water Payback.

Year	Water installation	Traditional grid
1	11,000€	480€
2	11,000€	964.8€
3	11,000€	1,454.4€
4	11,000€	1,948.8€
5	11,000€	2448€
6	11,000€	2,952€
7	11,000€	3,460.8€
8	11,000€	3,974.4€
9	11,000€	4,492.8€
10	11,000€	5,016€
11	11,000€	5,544€
12	11,000€	6,076.8€
13	11,000€	6,614.4€
14	11,000€	7,156.8€
15	11,000€	7,704€
16	11,000€	8,256€
17	11,000€	8,812.8€
18	11,000€	9,374.4€
19	11,000€	9,940.8€
20	11,000€	10,512€
21	11,000€	11,088€

The payback for the water installation comes at 20.11 years

3.2.3 Heating

The heating cost about the biomass Boiler is around 6,300 €. The wood is free. The cost of a fuel boiler is around 1,500 €. The cost of the fuel is around 0.838 €/litre. The consumption in a house of 70 m^2 is around 200 litres. The boiler is not used for central heating for three months in the whole year.

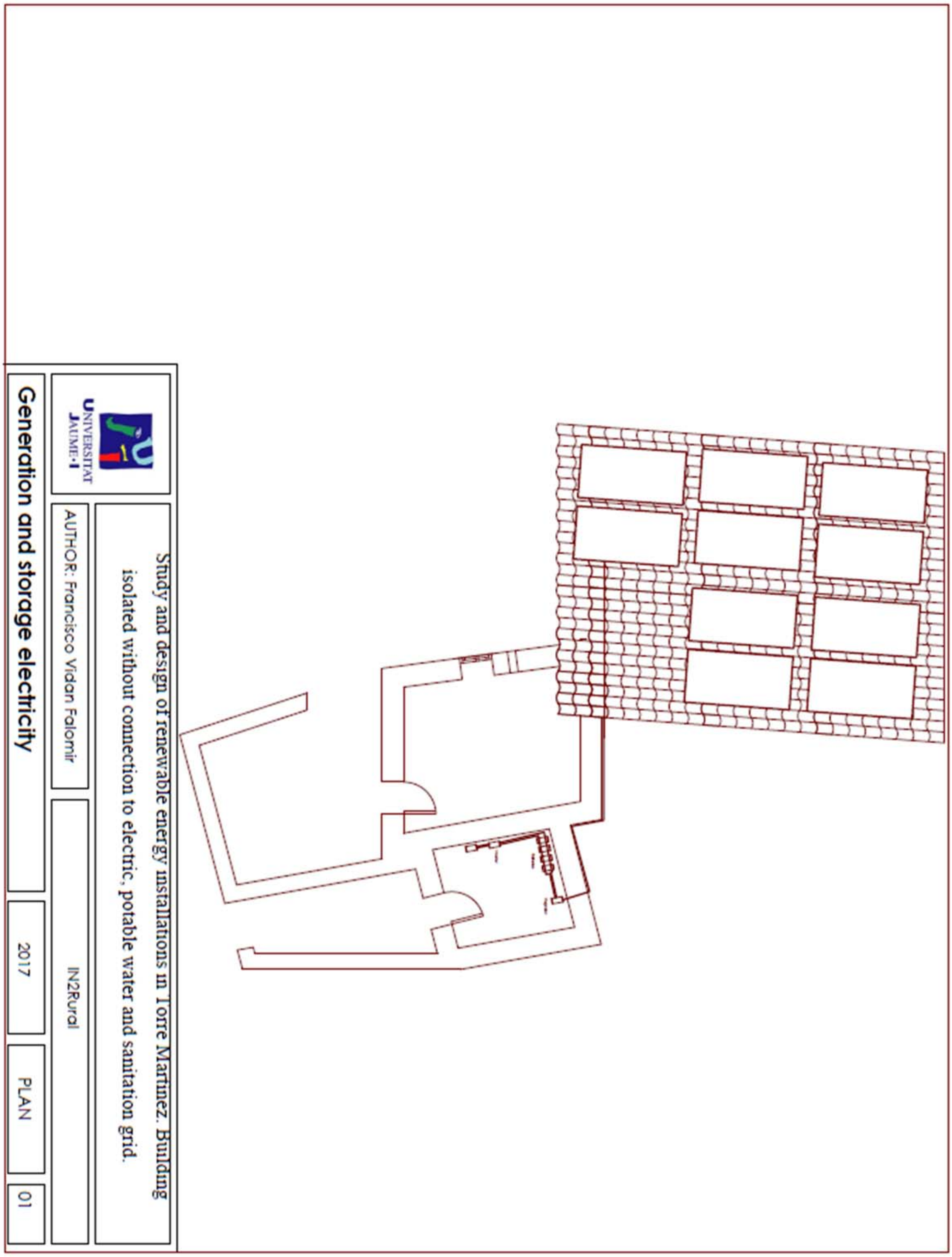
Table 42. Heating.

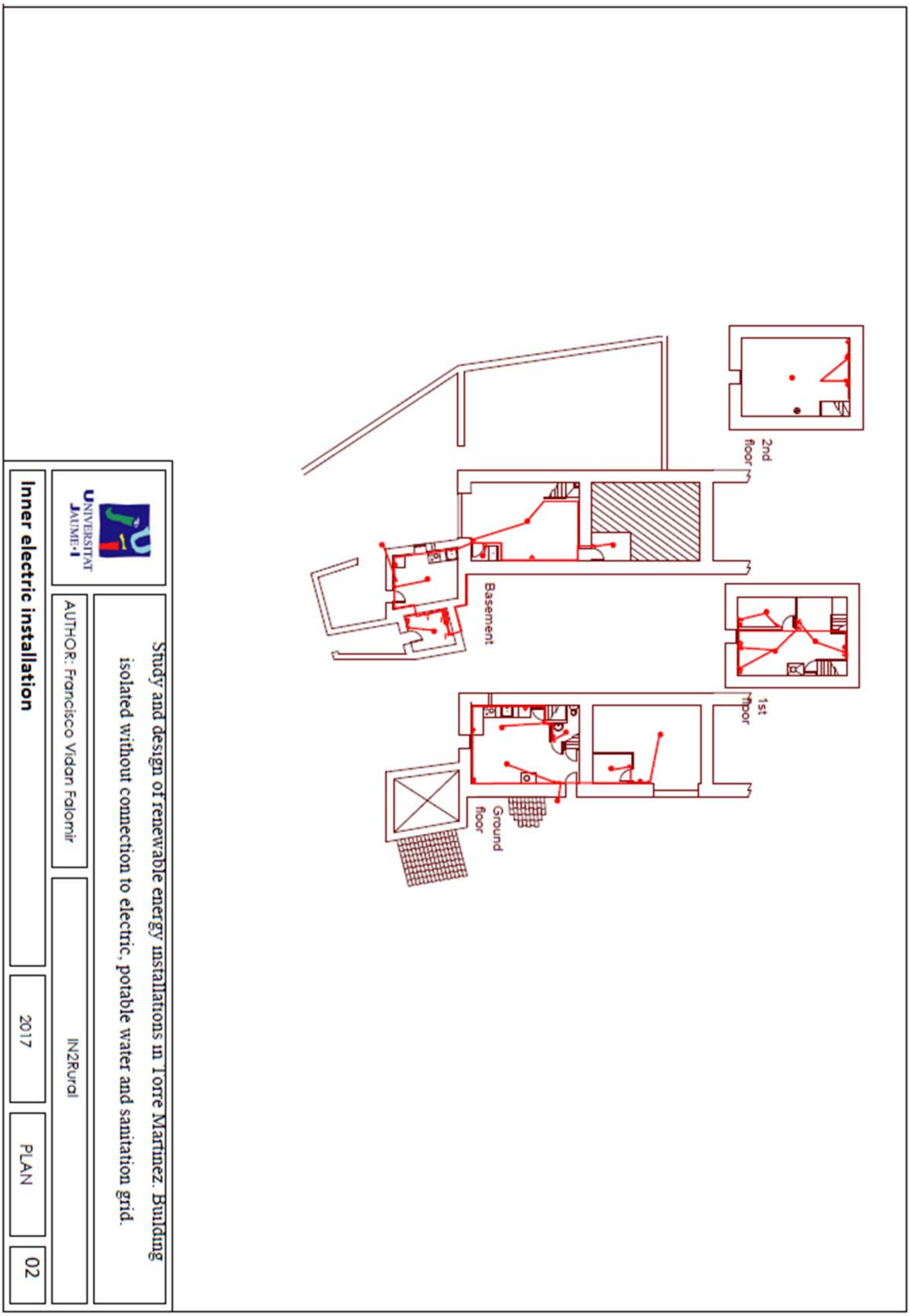
Year	Biomass installation	Fuel cost
1	6,300€	3,008.4€
2	6,300€	4,516.8€
3	6,300€	6,025.2€
4	6,300€	8,036.4€

The payback for the heating installation comes at 3.2 years.

Project plans

4. Project Plans




2nd floor
Basement
1st floor
Ground floor
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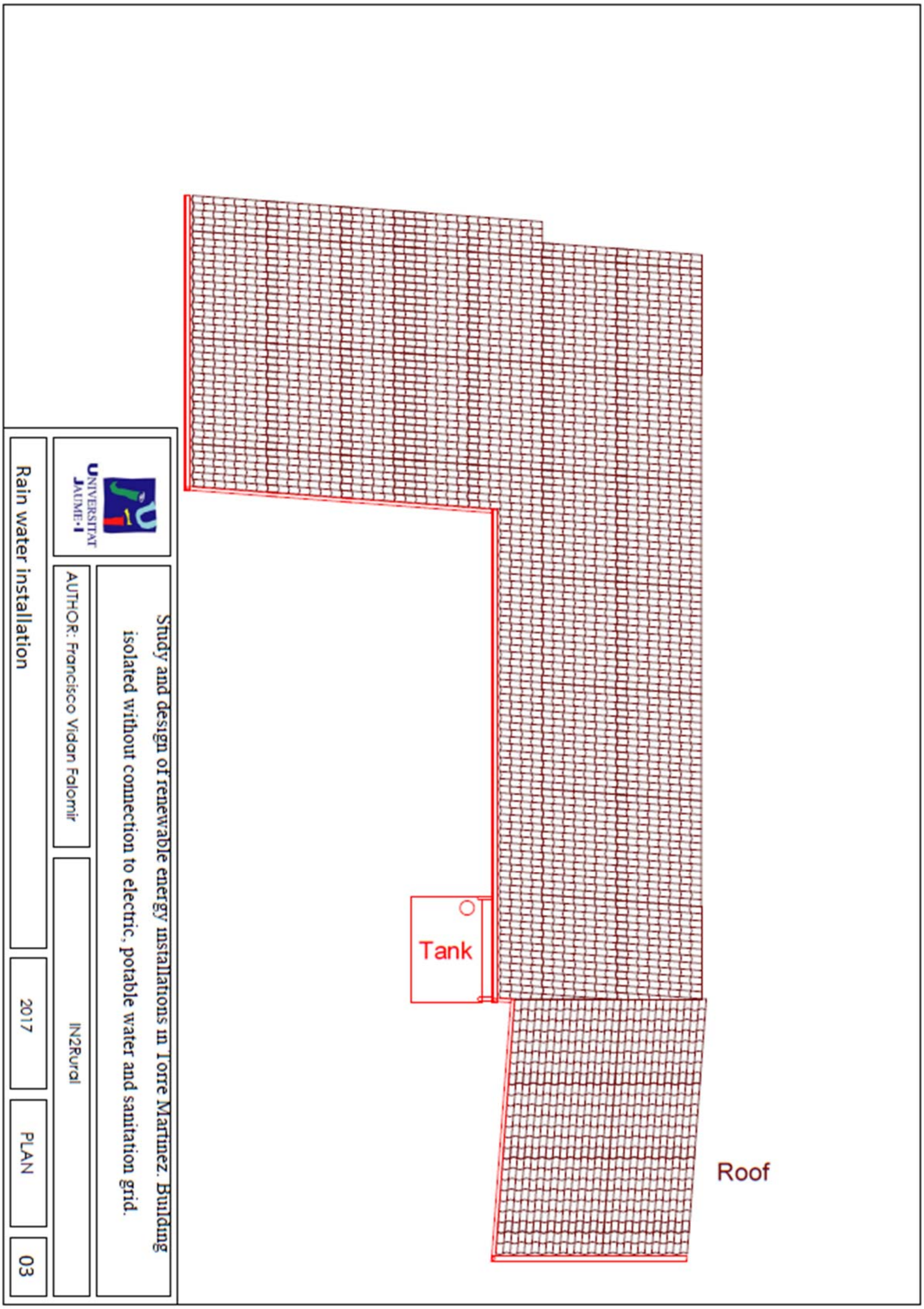
IN2Rural
Inner electric installation
2017
PLAN
02


Roof
Tank
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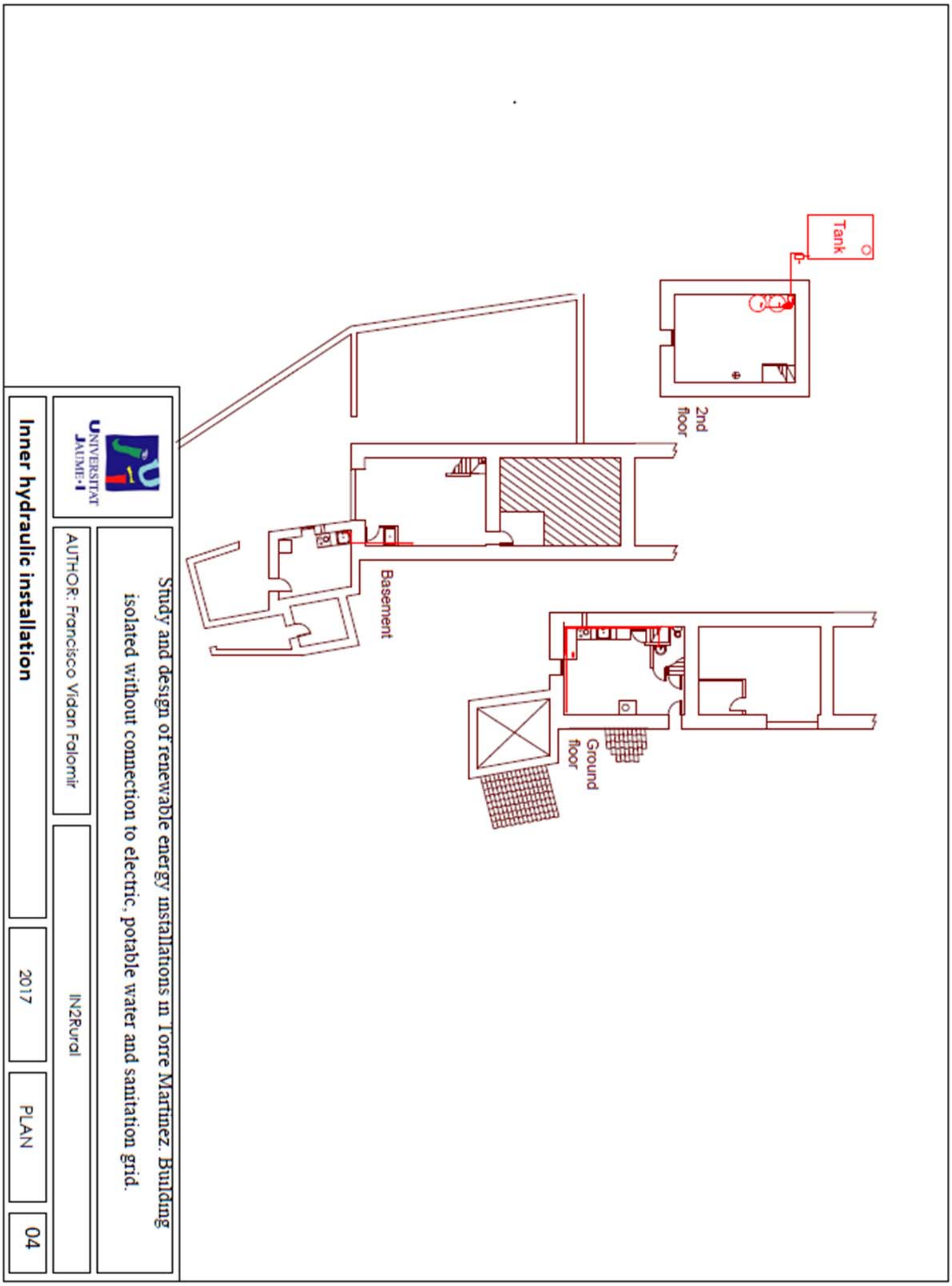
03



Tank
2nd floor
Basement
Ground floor
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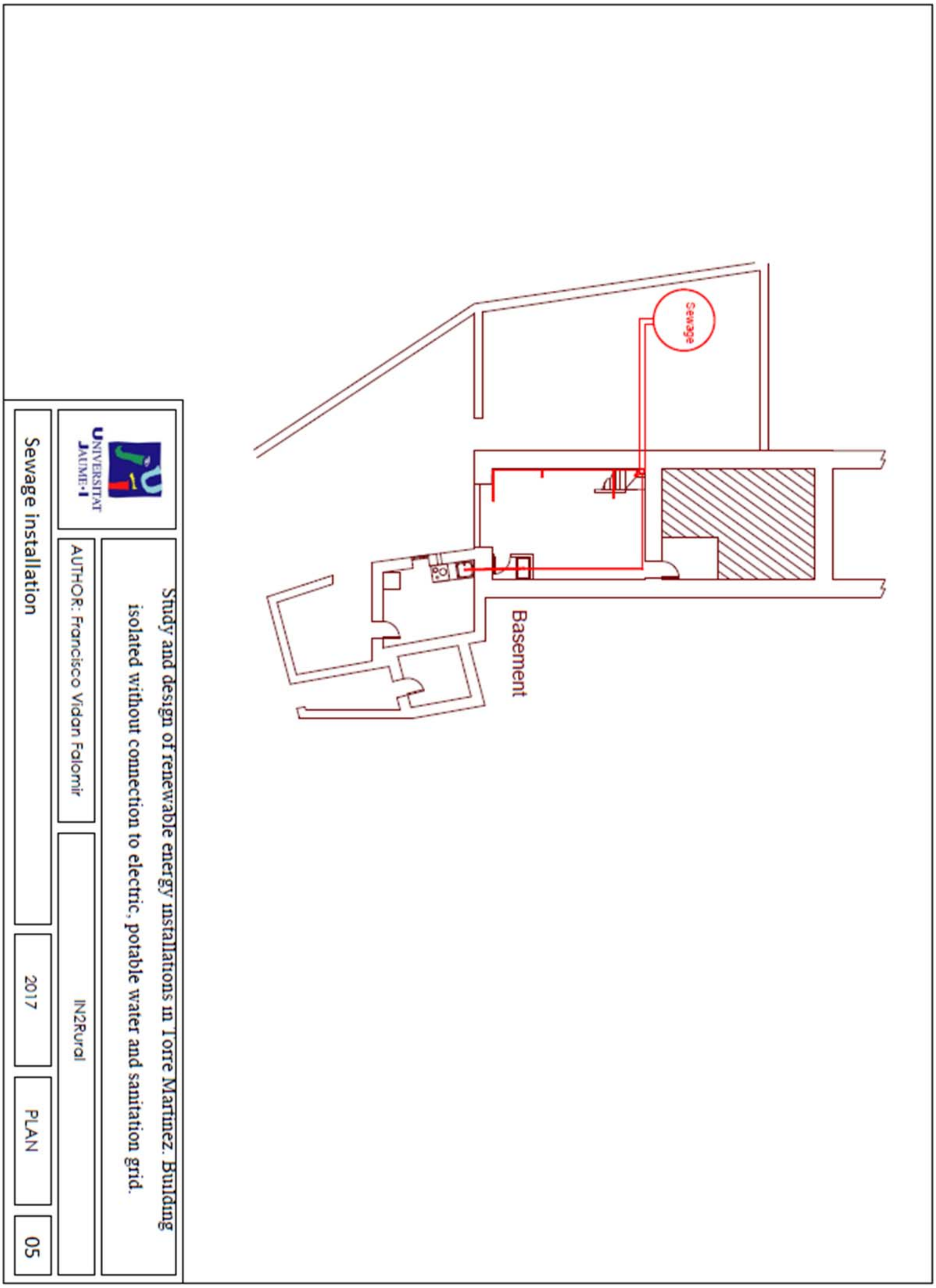
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Sewage installation
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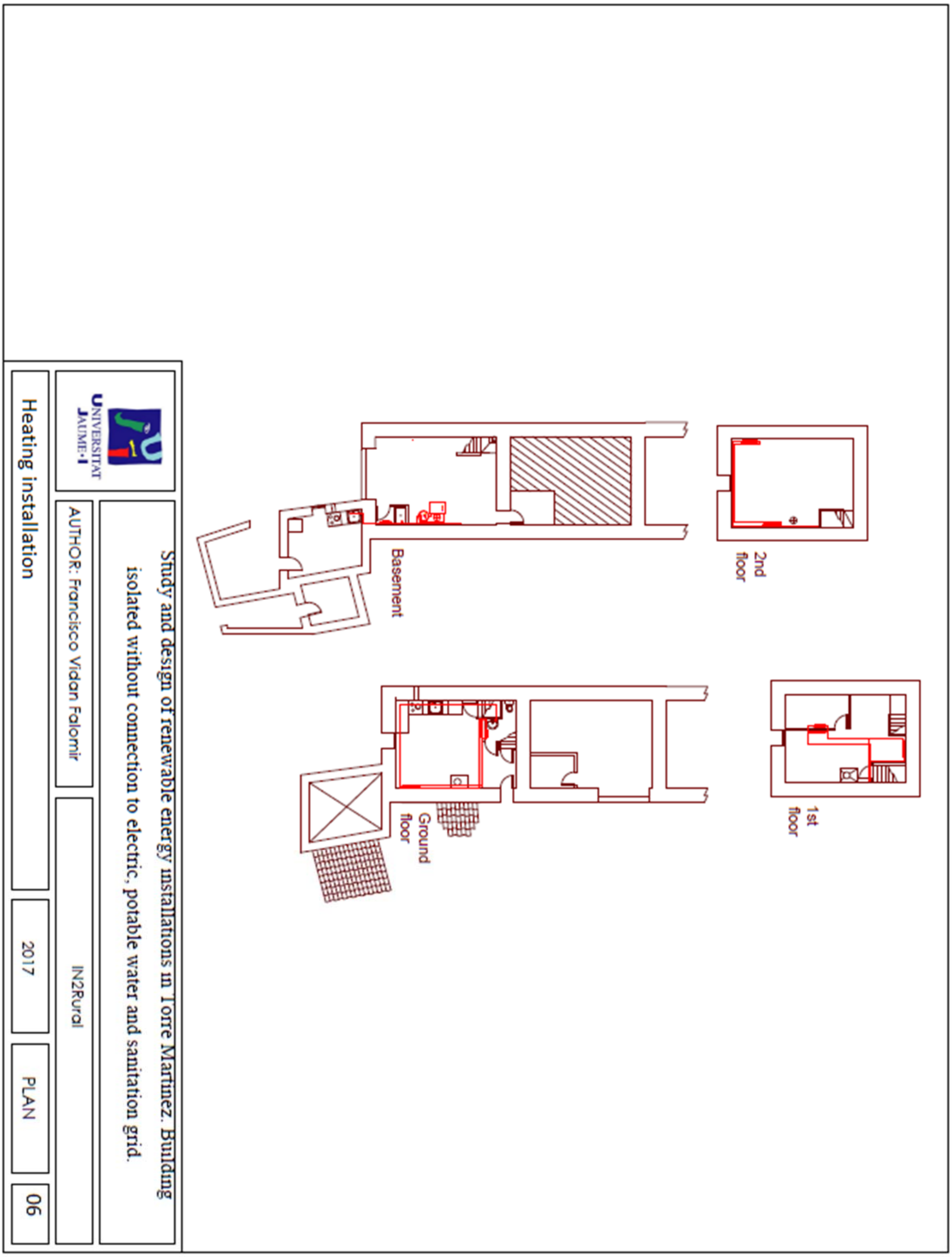
PLAN
05


Basement
2nd floor
Ground floor
1st floor
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IN2Rural
Heating installation
2017
PLAN
06

Annexes

5. Annexes.

Annex I. Interviews

Table 43. Interview 1: Young couple without children.

Question	Answer
Interviewee	31 years old, woman
Profession	Public sector
Renewable energies knowledge?	Medium
House utilization	Daily
How many people do live there?	2
Is it connected to the electric grid?	No
Do you have any systems to have electricity? Advantages and disadvantages.	A photovoltaic system with solar panels, 12 batteries, regulator and 1500 W Inverter. Advantages: No bills. Disadvantages: 4-5 days without sun, no electricity
Is electricity important? Why?	Yes, for daily use.
How much does it cost to have electricity?	I don't remember. 2 Batteries, 2 solar panels and an inverter cost 3.000€ last time.
Maintenance	Easy, monitor of the distilled water.
Did you try to connect to the electric grid? How much didit cost?	No, it is too much money. Around 42.000 €
What is the perception of renewable energies?	Good perception.A lot of money.
Are you afraid of thefts?	Yes.
What kind of heating system do you have?	Oven for each floor.
Do you have a water system? What kind?	Yes, rain water system 10.000 litres.
Do you make the water potable?	No. We do not drink and cook with this water.
How do you obtain hot water?	Gas heater.
Hydraulic pressure	Water pump 12W
Wastewater?	Decanting system with some different tanks.
Comments	Gas fridge. It is important to know what you have.

Table 44. Interview 2: Young couple without children.

Question	Answer
Interviewee	30 years old, woman
Profession	Public sector
Renewable energies knowledge?	Low
House utilization	Hardly ever
How many people do live there?	0
Is it connected to the electric grid?	No
Do you have any systems to have electricity? Advantages and disadvantages.	No. We want to install a photovoltaic system.
Is electricity important? Why?	Yes. It is necessary to live there.
How much does it cost to have electricity?	I do not have electricity system yet.
Maintenance	None
Did you try to connect to the electric grid? How much did it cost?	No.
What is the perception of renewable energies?	Renewable energies are a way for rural development.
Are you afraid of thefts?	Little bit.
What kind of heating system do you have?	Chimney
Do you have a water system? What kind?	Rain water system.
Do you make the water potable?	No.
How do you obtain hot water?	No.
Hydraulic pressure	We take the water with a water vessel from the tank
Wastewater?	No.
Comments	At present we are repairing the building to use.

Table 45. Interview 3: Young couple with children.

Question	Answer
Interviewee	40 years old, man
Profession	Education
Renewable energies knowledge?	High
House utilization	Daily
How many people do live there?	3
Is it connected to the electric grid?	No
Do you have any systems to have electricity? Advantages and disadvantages.	A photovoltaic system with 8 solar panels, 800W Aero generator, batteries, regulator, inverter and a 5000 W fuel generator. Advantages: Nobody controls us. Disadvantages: Initial inversion, financial solvency, Administration difficulties, 3 days without sun, no electricity.
Is electricity important? Why?	Yes, rationalise.
How much does it cost to have electricity?	12.000€ first investment + 4.000€ grant. In case of the 2nd investment I do not remember.
Maintenance	Batteries monitor the distilled water. Monitor voltage batteries. For the heating system there is no low batteries voltage.
Did you try to connect to the electric grid? How much did it cost?	If I was a distance of 0.5 Km from the grid I tried, but 11 Km is a fortune.
What is the perception of renewable energies?	It is a solution for isolated building. It is very useful. It is blocked by the government.
Are you afraid of thefts?	It usually happens when nobody lives there.
What kind of heating system do you have?	Wood biomass boiler. With radiators.
Do you have a water system? What kind?	Yes, rain water systemof 65.000 litres.
Do you make the water potable?	No.
How do you obtain hot water?	Auxiliary tank is used in the biomass boiler tank. It is 150 litres.
Hydraulic pressure	Water pump 3-4 bar
Wastewater?	Sewage.
Comments	Bioclimatic building. Building isolation is important.

Table 46. Interview 4: Young couple with children.

Question	Answer
Interviewee	43 years old, man
Profession	Environment worker
Renewable energies knowledge?	High
House utilization	Daily.
How many people do live there?	5
Is it connected to the electric grid?	No
Do you have any systems to have electricity? Advantages and disadvantages.	A photovoltaic system with 5 solar panels 180W each,12 stationary batteriesof 500mA, solar tracker, regulator, and inverter.Advantages: No bills. Disadvantages: limited system
Is electricity important? Why?	Yes, itessential with 3 children.
How much does it cost to have electricity?	It was 9.000€ seven years ago.
Maintenance	Batteries monitor the distilled water only once in 7 years. Calibrate solar tracker.
Did you try to connect to the electric grid? How much did it cost?	Yes, 73.000€
What is the perception of renewable energies?	It must be the present. Where there is no other option, it is a good solution. The autonomic level cannot be viable.
Are you afraid of thefts?	I have an anti-theft device system.
What kind of heating system do you have?	Stove
Do you have a water system? What kind?	Yes, rain water system.
Do you make the water potable?	No.
How do you obtain hot water?	Gas heater.
Hydraulic pressure	500W water pump to auxiliary tank with isolated room out of the house. 2.5 meters high from the consumption points. We have never had pressure problems.
Wastewater?	Dry toilet.
Comments	In 7 years, we have a current cut only 3 times, 2 in summer because of too much consumption and 1 in winter for many days without sun. Gas fridge.I have a gasoil generator but it was never plugged on.

Table 47. Interview 5: Worker.

Question	Answer
Interviewee	48 years old, woman
Profession	Farmer
Renewable energies knowledge?	Low
House utilization	Daily farm, building hardly ever.
How many people do live there?	0
Is it connected to the electric grid?	No
Do you have any systems to have electricity? Advantages and disadvantages.	A gasoil system. Advantages: It does not depend on weather conditions. Disadvantages: high price and filling the gasoil tank daily.
Is electricity important? Why?	Yes, for all. For animals.
How much does it cost to have electricity?	4.000€ for the gasoil generator and 20€ gasoil every day.
Maintenance	The generator is reviewed every two years.
Did you try to connect to the electric grid? How much did it cost?	Yes, 3 Km far away, it was more than 36.000€
What is the perception of renewable energies?	Good perception.
Are you afraid of thefts?	Yes.
What kind of heating system do you have?	Chimney
Do you have a water system? What kind?	Yes, fountain nearby.
Do you make the water potable?	No.
How do you obtain hot water?	We have no hot water.
Hydraulic pressure	No.
Wastewater?	No.
Comments	We do not try to change to a renewable energy system because of the high initial investment.

Table 48. Interview 7: Pensioner.

Question	Answer
Interviewee	62 years old, man
Profession	Farmer pensioner
Renewable energies knowledge?	Low
House utilization	Before this daily, now occasionally.
How many people do live there?	Before this up to 9, now 0.
Is it connected to the electric grid?	No
Do you have any systems to have electricity? Advantages and disadvantages.	A photovoltaic system with 1 solar panel, 6 batteries, regulator, inverter. Advantages: I have cheap electricity in the house and on the farm. Disadvantages: Almost nothing.
Is electricity important? Why?	Yes, It helps me to look for the animals at night.
How much does it cost to have electricity?	It was 400.000 pesetas(2.404€) twenty five years ago. 60% grant
Maintenance	Batteries monitor the distilled water.
Did you try to connect to the electric grid? How much did it cost?	No.
What is the perception of renewable energies?	Good. It helps a lot.
Are you afraid of thefts?	I have never had a problem but some are afraid of them.
What kind of heating system do you have?	Chimney
Do you have a water system? What kind?	Fountain nearby.
Do you make the water potable?	No.
How do you obtain hot water?	I do not have hot water.
Hydraulic pressure	No.
Wastewater?	Mountain.
Comments	I have had the photovoltaic installation for 25 years. “If there were electricity and water, more people and me would live there”

Table 49. Interview 6: Worker in the area.

Question	Answer
Interviewee	39 years old, man
Profession	Electrician
Renewable energies knowledge?	High
Is it connected to the electric grid?	Most of the isolated buildings in the area have not got any electric connection to electric grid.
Advantages and disadvantages of a self-system electricity.	Advantages: Independence, some opportunities of work. Disadvantages: Limited system, high cost of the installation, thieves.
Is electricity important? Why?	Today it is essential for our commodities.
How much does it cost to have an electricity self-system?	It depends on, all the consumptions in the building must be considered and make a rational use.
Maintenance	Easy.
What is the perception of renewable energies?	It is a good alternative comparing to the costly traditional connection to the electric grid.
Do you have a water utilization system? What kind?	Most of the people have a rain water profit tank.
Hydraulic pressure	With pressure groups.
Comments	Legislation is a problem. I have not got an isolated building.

IN2RURAL

Compilation of case studies of applying renewable energies to local development nationally implemented

Co-funded by the Erasmus+ Programme of the European Union

REPORT OF THE CASE STUDY ON RENEWABLE ENERGIES TO LOCAL DEVELOPMENT NATIONALLY IMPLEMENTED

Installing a biomass fired boiler and testing its efficiency at the central building of Budapest Forestry Co. Ltd.

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Budapesti Erdészet

Budapest, 04.2017,

Contents of the project:

Memory of the project

1.Introduction to project

The next case study is the In2rural project, which is a framework for co-operation between schools about the use of renewable energy sources.

Purpose: the utilization and use of renewable energy sources, and the impact on the environment and our lives, as well as the examination of the attitudes towards the economic situation

In this project, among the many green energy sources, the biomass is presented. My job is to examine the possible installation of a biomass boiler in a building in Budapest Forestry from several aspects.

Figure 1. Logo of in2rural

In the course of the study, I was looking at the concept of the biomass boiler of the above company, which is currently operating at the Szentendre Army Military Academy

Since observation is a larger volume project that is why this is only a primitive method, therefore, that I have been presented representative of the biomass heating plant I have spent 27 working days. Throughout the time I got to know the full construction and performance of the boiler, and the Budapest Forestry Co. Ltd gave me credible information to create a real project. Therefore, the examination of later data will be the measured calculations received during my practical period, which were run by the operation of the above boiler. During the 27-day practice, I could gain insight into every stage of the boiler, so I will be able to understand the structure of the boiler.

1.1 .About Szentendre

Szentendre is located in Hungary, in Pest county, 10 km from the capital city, Budapest.

Population: 25 542 inhabitanst

Inhabitant: 43,82 km^2

The city is still a tourist attraction in the immediate periphery of Budapest, which is well-known for its museums, skanzen and the relaxing effect of the Danube.

Figure2. Szentendre's logo

In this area is also one of the institutes of the Hungarian Defense Forces, the Szentendre Military Academy. This facility is home to a biomass-operated boiler owned by forestry. Boiler operation from complex functions is fully automated.

1.2. Operation of the biomass boiler

First of all, the site has freshly shredded biomass. Dried material from biomass plant chips. It is utilized by incineration, whereby the resulting heat is used for heating and other purposes. Due to the maximum flammability of the biomass raw material, hard wood, walnut, acacia, oak is the best. However, because of the price and growth they use, they use softer but cheaper wood than, for example, linden, poplar, birch, but the most obvious is the combination of mixed chips, soft or hardwoods.

	Cost (Ft/m^3)	Evolution (year)	Produced heat (kWh/m^3)	Density (kg/m^3)
Walnut	14 000	35	2700	600-700
Linden	5 000	15	1700	380-580
Mixed	10 000	25	2200	570

Table 1.

As the table illustrates, the low price does not carry good quality in itself, so it is necessary to use mixed chips. The chips are a chopped vegetable derivative, which is illustrated in the picture below.

Figure 3 Wood pellet

Once they arrive at the boiler site, they leave it dry regardless of the state of the biomass. The essence of this is that it is possible to completely dry out when boiling in the boiler, since dry chips lighter and produce more heat than water.

In addition, it is important to note that, for example, in the drying process, such as a sponge, which contains a resin, is completely dry, as more moisture in the boiler adds more resin to the boiler, melting into the interior chamber where it can cause a large amount of damage .

In the drying, you have to imagine a large concrete-walled courtyard with chisels in the mountains. Do this with a machine underneath a worker's top so that no rain is soaked (see Figure 4).

But you only have to cover the area you need to ensure continuous combustion, and let the others dry. When the wood is covered in an overdrinking condition, it is constantly replaced, so the boiler always receives fresh and dry refills.

Figure 4. Biomass power plant

Thereafter, an automated and timer-driven metal sheet folds the biomass on it into a compactor. The curved sheet is shown in Figure 5, which the shredder uses with the grabber. After this process, the biomass goes into a concrete ditch where a compacted iron sheet begins to combine the loose material and pushes it into the boiler's forehead.

Figure 5. metal sheet

In order to prevent the rope sheet from pushing into the ditch ditch more than the specified amount, a laser measuring device is located at the top of the trench. This meter detects if I have little or no need for more chips in the packer and automatically control the inflow of the wood. The sensory part of the structure means a palm surface, but the equipment responsible for the corresponding measurements is much larger and it is responsible for the operation of automated technology. The laser measuring sensor is shown in Figure 6. Visible behind it, and the chips that are delivered by the sheet, which are in the ditch ditch. The left side of the image shows a red border inlet. This opening enters the boiler room through a passageway. The compaction sheet compresses the crusher in the ditch, pushes it slowly and smoothly into the interior of the boiler with slow, even movement.

Figure 6. Sensor

Biomass has now been in the boiler room. The inside of the boiler consists of a staircase with a top-down slope, the top of which is sloping from the top to the stairs. He continues to burn and produce heat during his progress. In the downhill path, there are small gaps between the stairs, so the combustion product of the burned biomass falls off and does not prevent further progression of the unbleached chips. The combustion product is nothing but ash that falls beneath the stairs of the boiler. In order to avoid the pavement under the boiler, a small container moving on a rails has been placed, which, if it is full, needs to be emptied through human interference.

Figure 7. Inside the boiler

This is how a concrete space is located beneath a flap door located in front of a boiler, where the containers are. This concrete shaft is designed to pull the maneuver on the rails to the trap door opening after the trailing door is opened by a winch, and then lift the ash container with a special lifting mechanism located above an opening. After lifting, ashes are transported and used elsewhere later.

Figure 8. Trap

Returning to the inside of the boiler, where a staircase moves the biomass down to the sky as the sky produces heat. This heat will be used later. In the boiler's interior, the incinerator down the slope can reach nearly 1000 C0. Because it is well known that hot air is easier than cold, so it rises upwards. As for the boiler, if this were the case, the hot air would gather in one of the top corners of the boiler and would slowly melt the wall of the boiler plate. To avoid this, the engineers created a bucket inside the boiler. This arch is located above the steep slope and divides the combustion heat into two parts. Thus, not only one corner is centered on all the heat, but with the help of the arc bottom and top.

Figure 9. Arch

As shown in Figure 9, the arch is visible beneath which the stairs are located downstream and the biomass is ashes to the air, but the warm air flows over the arc.

Of course, under and above the arch, the air would stop, and a melting phase would lead to the accumulated temperature if there was no airflow regulator 3 located on the side of the boiler. These fans are primary, secondary and tertiary fans responsible for mixing the temperature in the combustion chamber of the boiler and not in a single space.

Due to the location of the fans, the hot air flows out of the boiler through an insulated pipe.

Figure 10 illustrates the location of the primary, secondary and tertiary fan (in the order shown).

Figure 10. Primer ventilator

The heat or the flue gas circulated by the fans is utilized so that the flue gas fan is vacuumed through an insulated pipework. As biomass boilers do not emit harmful substances during their operation, so there are several fine filters in the pipeline to prevent the release of pollutants.

Figure 11. Burning pellet

After the filters, the flue gas passes through several units where the pressure is regulated, cooled and cleaned. Finally, the temperature warms the water circulated by the circulating pump in the connected water system.

1.3. Purpose

Installing a biomass fired boiler has become necessary due to high energy consumption and expensive invoices. The head office of forestry is an institution in Budapest, whose heating system I would like to modernize with my project, and to regulate the building's heating center in such a way that we can get less energy and loss and more energy.

As a solution, I would place the boiler in the empty real estate area next to the central office, which would result in material shortage due to proximity, so that less waste would be generated. From the boiler to the central office, hot water would come in, which would connect the building to the internal water system with hot water, and the heating would be solved by the hot water radiators.

1.4. Opportunities, alternatives

If we use other renewable energy sources as the applicable technology, we quickly realize that only two of them will be built up. The first is solar energy. Relatively effective, however, is too costly energy that is bound to space. Being a Hungarian relative, it is the most common institution in a capital city that the solar collector occupies the institution's stake. So its territory is completely limited, which may not produce the necessary energy, so investment is not very good. The other energy is the biomass already mentioned.

For the sake of completeness, I would mention the wind power, but in this case it would not lead to results, mainly because of the space saving aspect.

1.5. Decision support

The energy sources listed above are not easy except for the biomass boiler installation. The biomass fired boiler does not require a large area for installation, it is not connected to weather elements (eg sunshine, wind or water) with the modern operation of modern equipment, there is no need for constant monitoring. It is the most effective in terms of price and value, since it is possible to use high energy by low cost production. Thus, the final solution is the biomass heating plant. The cost of installing, though long-term, will be reimbursed.

1.6. Impacts

Of course, besides the countless positive effects of biomass, we must also mention the negative effects. Although these factors are not measurable, they can not be ignored.

When operating a biomass heating plant, it operates several loudspeakers such as the primary fans. Sound pollution is more than a solar solution, but the collector really does not have any disadvantages for the environment.

In addition to noise pollution, as it is a boiler plant where ash produced from burned final products, which I knew was dusty. Thus, although there are several alternative solutions, the boiler area would be very dusty, but these can be controlled by filters.

Figure 12.

1.6.1. Environmental impact

Its environmental impacts are not so much reported as described above. As the case study is based on the characterization of the effects, so district III. of Budapest installed a smaller boiler which does not destroy its surroundings even as much as a construction or a pollution caused by a multitude of motor vehicles typical of the capital. Because a natural living environment (trees, birds, wild animals, river, lake) is not found in the neighborhood, so for a living there, a boiler would be a completely normal phenomenon.

Various filtering equipment that can not be controlled or even eliminated beyond the installation of the boiler is the air pollution of the plant. The vapor released into the air is clear and free from harmful substances. Which, before entering the air, is cooled and cleaned through the pipe in the figure above. This is important to clear the exhaust air from the remaining harmful material. Its cooling is accompanied by a huge fan-like device located next to the boiler building.

Figure 13.

1.6.2. Economical and socal impact

As I wrote to the noise and the dust provided by the boiler (these are the disadvantages for the rest of my study, how can I control it) because of the contamination of the capital? Its social impact in this area is insignificant. However, economically, the effect is much more significant, as the heating can reduce the number of bills and the re-circulation of the hot water network could make the institution self-sufficient. Although in the first 10 years, this investment would still push the budget in a negative direction, but afterwards, self-sufficiency would bring the energy and capital back to it. However, it should be mentioned as a positive effect that approx. 12 new jobs will be created that could be filled after a fast qualification.

1.7. Conclusions

Man has been using fire since ancient times. Fire was the foundation of our modern society and socialization, as it did not only heat us away, but also changed our lifestyles by our habits. This fund is utilized to this day in man only in more precise and sophisticated forms than it used to be. This is how the biomass fired boiler could be created that produces a high temperature with a dry crop crust so that it can be utilized. Not only as hot water, but high temperatures can also be profitable from an energetic point of view, even if they invest in instruments that are able to produce electricity from this energy.

Besides the many positive effects of the boiler, there are, of course, negative effects, which can be remedied with little care and low capital expenditures. The biomass boiler is a newbie among renewable energy sources, but there is still a big future waiting for it.

1.8. Resources

Figure 1. In2rural projekt

Figure 2. www.wikipedia.org

Figure 3. Own source

Figure 4. Own source

Figure 5. Own source

Figure 6. Own source

Figure 7. Own source

Figure 8. Own source

Figure 9. Own source

Figure 10. Own source

Figure 11. Own source

Figure 12. Own source

Figure 13 Own source

Figure 14. Own source

Figure 15. www.gepesztherm.hu

Figure 16. www.italianvibes.com

Figure 17. Own source

Figure 18. Own source

Figure 19. Own source

Figure 20. Own source

Figure 21. Own source

Figure 22. Own source

Figure 23. Own source

Figure 24. Own source

Figure 25. Own source

Figure 26.1 www.azaramara.hu

Figure 26.2 www.energiaoldal.hu

Figure 27. Own editing by Google maps

Figure 28. Own source

Figure 29. Own source

Figure 30. Own source

Figure 31. Own source

Figure 32. Own source

Figure 33. Own source

Figure 34. Own editing by Google maps

Figure 35. Own source

Figure 36. Own source

Figure 37. Own source

Figure 38. Own source

Figure 39. Own source

Figure 40. Own source

Figure 41. Own source

Figure 42. Own source

Figure 43. Own source

Table 1. Own editing

Table 2. Own editing

Table 3. Own editing

Table 4. Own editing

The data presented and used by me were submitted by the employees of the Szentendre biomass heating plant with the permission of the Budapest Forestry Zrt.

Calculations

2.1. Calculations and design

As I have already mentioned, I have made a case study on the establishment of a biomass plant in one of the buildings of Budapest Forestry Ltd. The most obvious building was the central office building as it is the largest area of forestry. The rest of the property would not be able to heat such a boiler because of its inoperability. So the choice went to the central office building.

Budapest Forestry Ltd. has been operating under the control of Budapest District of III. number 4-6 numbering center for years. Its task is for uniting and co-ordinating the central management of smaller forestry units under the hierarchical structure of the forestry organization. All forestry reports to the central management reporting on the number of animals, plant varieties, possible changes in their territory and possible changes in the problems that may arise.

The central office is also responsible for the diversification of hundreds of hectares of land related to public forestry. Since the surface of their territory is constantly changing (due to the built roads, urbanization processes), they can not always rely on nature to shape the surface. Therefore, deforestation becomes necessary to increase the required area.

In addition, in order to regenerate nature, it is often necessary to reduce the forested areas. So this process is not always destructive. However, there are wooded areas where only fast-growing saplings are to be found, which, after enlargement, are immediately harvested. These areas may also be referred to as productive areas. Their purpose is like wood cutting in the field, and the use of the more valuable trees (the rarer), or cutting through a cutter after cutting. During the harvest, the last branch of the tree is also shipped as a shredder on a truck platform.

This is very important because forestry does not have to pay for herbicide crops (as her own). From this it can be concluded that there is no additional charge for the raw material of the briquette boiler.

Here I would like to emphasize the above-mentioned chip prices, which I have already shown. Let's take it again, but we can leave the development year because we do not have to count on it:

	Cost (Ft/m^3)	Evolution(year)	Produced heat (kWh/m^3)	Density (kg/m^3)
Walnut	14 000	35	2700	600-700
Linden	5 000	15	1700	380-580
Mixed	10 000	25	2200	570

Table 2.

As stated in the previous chapter, the fact that mixed chips is the most convenient (this information has been confirmed to me by the forestry industry). So, with this price, I'll show the calculations hereafter.

It is worth mentioning the fact that the forests owned by forestry, which are cultivated only for chopping wood for grubbing and firing, have a financial implication for its extraction and transportation. This is where my case study can be divided into two parts. Both parts will be outlined in detail for complete understanding. Both alternatives are right and true.

2.2 Alternative fiction

In the first part, I would like to look at the above mentioned fact as to how costly and cost-effective forestry forestry is extracted. In this case, since soft trees planted for rapid development in the area, for example, linden, so in order to get mixed chips in the boiler, forestry has to produce an area of another existing forest where there is a walnut tree.

The table above is a guideline, which depends on the economic situation so I can represent an average price for this section of the budget.

So there is a lime (softwood) and a walnut tree (hardwood) area in the same amount. The quantity here will be a lorry amount of approximately 50 m^3.

However, this price does not have to be taken into account because forestry is not obliged to pay for its own wood production because it goes to its own budget. However, they are obliged to pay for the extraction fee, which is again negligible in this case, as the shredding of the chips from the production area to the boiler. The answer is simple, as people doing the job just like suppliers and suppliers of both the forestry staff and thus their monthly salary for doing this job (which is included in their job descriptions) does not mean any revenue for them.

In addition to this cost, other boiler heating tariffs will not be charged. Incidental costs include the monthly remuneration of the boiler operator, which can not be considered as a separate cost, except for the fixed monthly income paid by the forestry as an employer to the employee.

So forestry by processing trees grown on its own territory and delivering it to the boiler does not entail extra costs. In this respect it can be stated that the calculation part of my study is irrelevant in this case as forestry can maintain the boiler's self-sufficiency.

2.3 Real solution

The second assumption is based on the fact that, due to the conservation of biodiversity, forestry does not utilize the woody woody area owned by it as fuel or as a shredder, but preserves it in its natural state.

In this case, the total price will change as all the extra costs are borne by the forestry. The price will change in the following picture.

In all kinds of images we have to count the cutting, production, shipping costs and the material price of the chips. Thus, this will change in a way that is calculated with the shipping cost mentioned above.

The fuel costs incurred in transport can not be calculated as an average as the fuel costs are directly proportional to the changes in the world economy. Thus, it is to be assumed that for one month the transport of the above-described chips to a truck amounts to a payload of 500 ft / km.

The cut-off area closest to the central office, from which wood chips can reach 20 km, while the most remote forested area for forestry is approx. 80 km. Since all areas are running out of wood, they are forced to cut away distances, so I took the average distance, which is 50 km. As a result, km x by ft / km based on the remuneration is a single tgk. We get the consumption of a road. This amount has to be doubled, as the forestry site starts to run. And arrives there, so he does the same trip twice.

Of course, a lorry (50 cubic meters of chips) is not enough, since the same amount of wood is needed, which means another way. Thus, for the 2 additional (100 m^3) chips the lorry 4 times make the trip a single day.

Calculation formula (without data):

(km X ft/km) X 4.

Calculated:

(50 km X 500 ft/km) X 4 = 100 000 Ft.

Figure 14.

In addition to this cost, the price of wood chips should be calculated, in which case not only the HUF 10 000 price in the table but also the amount of 50 m^3 softwood and 50 m^3 of hardwood purchased half the share.

That is:

(50 m3 X 5 000 Ft) + (50 m3 X 14 000 Ft) = 950 000 Ft.

The wood chip and the shipping fee together: **1 050 000 Ft.**

This amount should be counted if forestry does not use its own forests and work machines. But this is not the case according to forestry, because, according to their accounts, they provide for the replacement of trees in every forest area.

2.4 Calculation of heat supply

With reference to the Szentendre biomass boiler and its data, I came to the conclusion that a boiler of similar power would be suitable for the central building of the forestry. Based on the information used, the entire building would be supplied with hot water and the associated turbine with electricity.

The boiler of Szentendre generates 2 MW of energy supplying the building there with energy.

When calculating the properties of wood chips, it is possible to get about 20 ft / kg of chips. Depending on the quality, an average of 12 MJ / kg of energy. The efficiency of the combustion technology is almost 90-96% of wood chips, which shows excellent combustion.

So, if we calculate the heat production, we have to write the formula that the price of the chips per kilogram will be divided by the energy production and the combustion product. Since combustion data is expressed in percentages, so the percentage value of the combustion will be 90% → 0.9.

Available datas:

~ 20Ft/kg
12MJ/kg
η= 90…96%

Calculation formula (without datas):

(Ft/kg) / (MJ/Kg X %)= Ft/MJ

Calculated:

(20) / (12 X 0,9)= <u>1.85.Ft/MJ</u>.

This value will be the unit cost of producing heat energy.

2.5 Comparison of heat production costs

During this study, I compared the cost of producing heat energy with other wood raw materials with the wood chip, using all the above formulas to obtain a convincing result. In the list of raw materials I examined, I included the heating with electricity.

The result is energetic compared to the comparison of other biomass feedstocks. As an illustrative example, consider the listed ingredients, ie wood chips, pellets, well-known wood chips and electricity.

Figure 15

The production of the logs does not require a specific description, since it is known that after cutting the cut wood to logs, the wood blocks are cleaved. From the volume point of view this is the second place.

he first place is the pellet material. The pellet is nothing but a mixture of finely ground wood composite briquettes.

Figure 16.

The well-presented wood chip covers the least of the biofuel boiler fuels. It is important to note that the data of the electricity shown in the first table can not be measured in many cases, since there is no electricity at our facility or in our home.

With its unique 100% calorific value, it is legitimate to use other materials if their utilization is 100%. This will be examined in the table below.

	Tree logs	Pellet	Wood chips	Electric heating
Moisture content (air dry)	25%	10%<	25%	0%
Heating value	12%	18%	13%	100%
Ash	2-5%	1%<	2-5%	0%
Volume density	450 kg/m^3	650 kg/m^3	150 kg/m^3	0

Table 3.

As Table 3 illustrates, wood chips are almost the same as those of a tree comuln, which, if we consider the fact that the same two raw material is minced only to one of the smaller pieces. While pellets are better in moisture, ash content, and calorific value than their predecessors. But if the electricity is 100% utilized, and the pellet is also of better quality than the other two wood derivatives, then why not utilize them?

In order to obtain the answer, consider the second table, which lists the same fuel, only by examining other aspects. The calorific value and the energy bands have been investigated, as this is the base for heating.

The examination of the ash content is negligible since in this first chapter I have explained that the ash produced in a biomass-heated boiler will contain ash in a container, which is later utilized. Ashes should not be regarded as waste.

However, the prices of the materials and the cost of heat production have also come to the fore. After all, when installing a biomass boiler, one of the most important factors is that it is worth heating the boiler. The answer is yes, and the table shows that heating with wood chip is the cheapest of all.

	Tree logs	Pellet	Wood chips	Electric heating
Price	27 ft/m3	50 ft/m3	20 ft/m3	44 ft/kWh
Energy	12 MJ/kg	18MJ/kg	12 MJ/kg	12 Ft/MJ
Heathing value	90 %	90%	90%	100%
Price of the heathing value making	2,57 Ft/MJ	3,08 Ft/MJ	1,85 Ft/MJ	12,22 Ft/MJ

Table 4.

2.6 Current using

Based on the information available to me on the part of the forestry, I use natural gas for the heating of the office building and for the supply of hot water.

Main gas is a distant heat service operating in Hungary, which is the gas service provider responsible for the central heating and gas-based heat supply of the major institutions, buildings, panel houses.

If we calculate the m^3 data in the above tables and data and burn 50-50 m3 of wood chips into the prospective boiler, then calculate the same volume unit from the gas supplier. That is, 100 m^3 of mixed quality chips arrive for heating purposes to indicate that the installed boiler operates 1 050 000 Ft. (This data was previously calculated based on the above formulas, which also includes shipping costs).

By contrast, the price of 100 m^3 gas provided by the gas supplier is different. In case of heating, the service provider charges 50 HUF / m^2 fee. Since forestry did not bring it to my knowledge, the exact dimensions of the central office building, so they are only approximate data. The base area is approximately 300 m^2 and needs to be tripled for 3 floors. Thus, the total area to be heated is approx. 900 m^2. Approximately based on the gas data

50 Ft X 900 m2 = 45 000 Ft

But this cost only takes into account the room space and an average price. Since m^2 is just a floor area, so we only get about how much the 900 m^2 floor would be heated. The heating is determined on the basis of an aero-meter. In this case, an approximate m^2 area is multiplied by an average height of 250 cm. So we get it

300 m2 X 25 dm = <u>7 500 m^3</u>

But with this result, we only get airtight data for a single level. Therefore, the resulting result is multiplied by three times to get the predicted amount of anthropometers of the whole property to be heated

7 500 m3 X 3 (emelet) = <u>22 500 m^3</u>

The monthly breakdown prices indicated by Főtáv are:

- Warm-warming fee
- heating base fee
- gas supply

They can be calculated for a total of 70 Ft / m3. With this data, the air volume we get multiplied by 70 Ft, then we get the amount of cost per month:

22 500 m3 X 70 Ft = 1 575 000 Ft

It would be just gas service.

Thus, if we compare the heating cost of a biomass heating plant:

1 050 000 FT

As well as the costs now received:

1 575 000 Ft

Then there is not much to think about which one is worth the better. Thus, it was found that it is really necessary to install a biomass boiler, one of the disadvantages of having a high installation cost. But installation costs will be reimbursed within 2 decades.

2.7. Crusher placement

Of course, there must always be more chips on the spot than they need, since after they have dried them, they are forced out of the boiler, but they have to keep up the supply. To this extent, it is necessary to calculate the amount of space needed to store chips.

To calculate this, from Szentendre to me, a formula was given which looks like this:
VSP = 15 x TB x QN (1-0,3 x (QH/Qmin))

BOS: volume of buffer storage in liters

QN: rated thermal output in kW

TB: burning period in hours

QH: the heating load of the building in kW

Qmin: minimum heat output in kW

However, to calculate this, the actual data of the boiler is required but they are constantly changing due to the heat produced by the combustion product.

On average, it would be possible to calculate the buffer space of the required buffer, but I was told that unnecessary and incorrect data were generated, since it is not the best way to measure the size of the dryer at 100% of the boiler's performance. Rather, the proportions of available space should be considered and based on the area.

2.8 The boiler's energy

The boiler of Szentendre can produce 2 MW of energy, previously powered by a generator and then powered by electricity. Thus, at the same time, the boiler simultaneously provided the building of the Military Substitute Academy with heat, hot water and electric power a few years ago. During the 27 working days spent there, I was admitted to the locked generator house where I was shown to the generator there and the turbine connected to it. Which is illustrated in the following illustrations

Figure 17.

Figure 18.

The equipment can still be put into operation until today, but it is not feasible to attach it to the boiler for other reasons.

Not only did the boiler look structurally, but the connected computer system was also shown, which includes thermometers, sensors in the boiler and sensors of the logs responsible for chip insertion, sending both electrical impulses and signals to the computer.

The data given by the sensors are compared with the specified limit data, and if the limit value is not reached, the device works correctly. If the limit value is close to the signal and indicates any sensor, the boiler is working correctly, just high or too low.

For example, the sensor responsible for inserting the chips (it was already mentioned in the first chapter) indicates if too little or too many chips have been added to the shaft, leaving an automated system to either give or chop it or ignore it.

These features can be tracked in the computer program.

In addition, the thermometer sensors inside the boiler indicate the actual temperature in the boiler and control the primary secondary and tertiary fans operating speed.

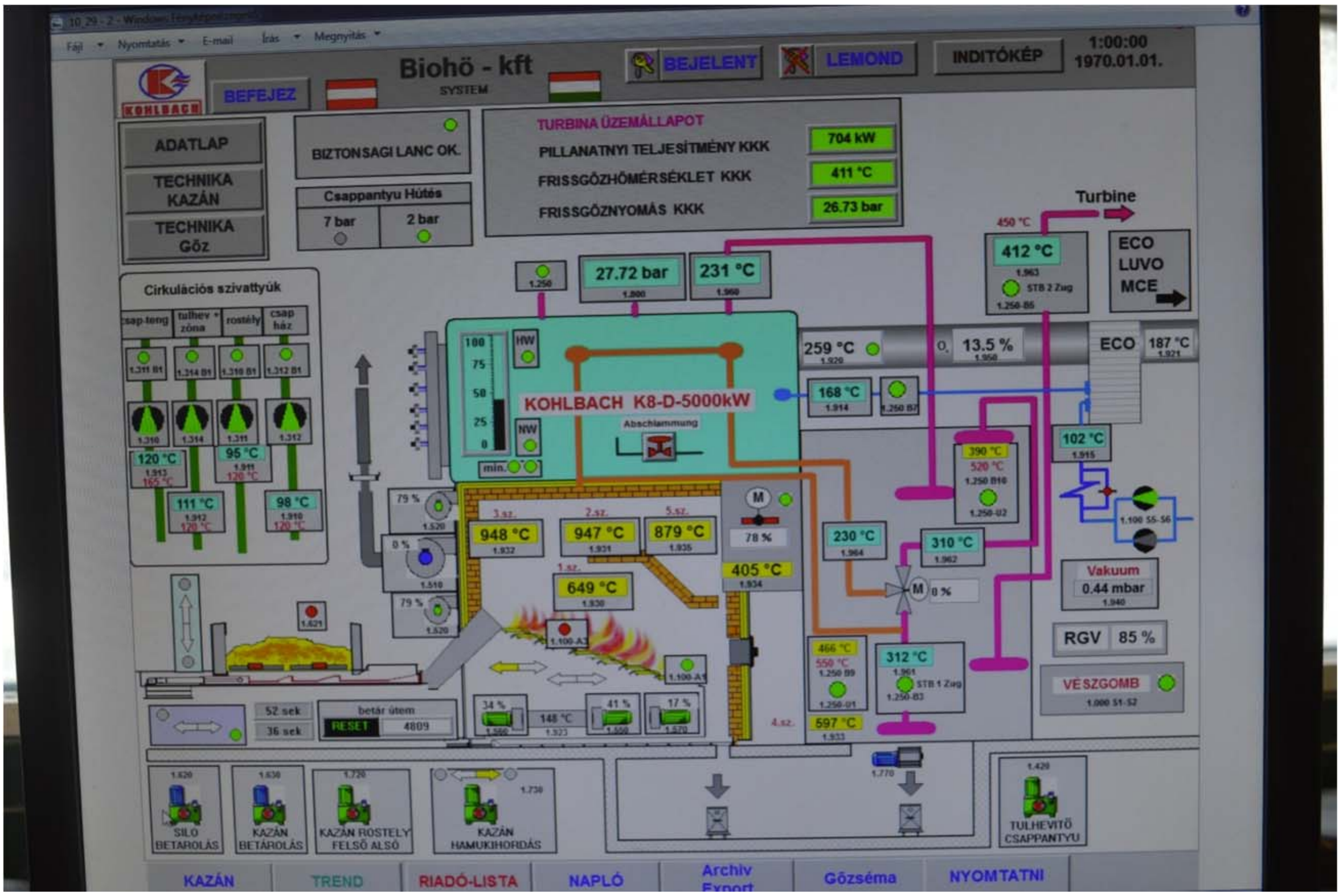

Figure 19.

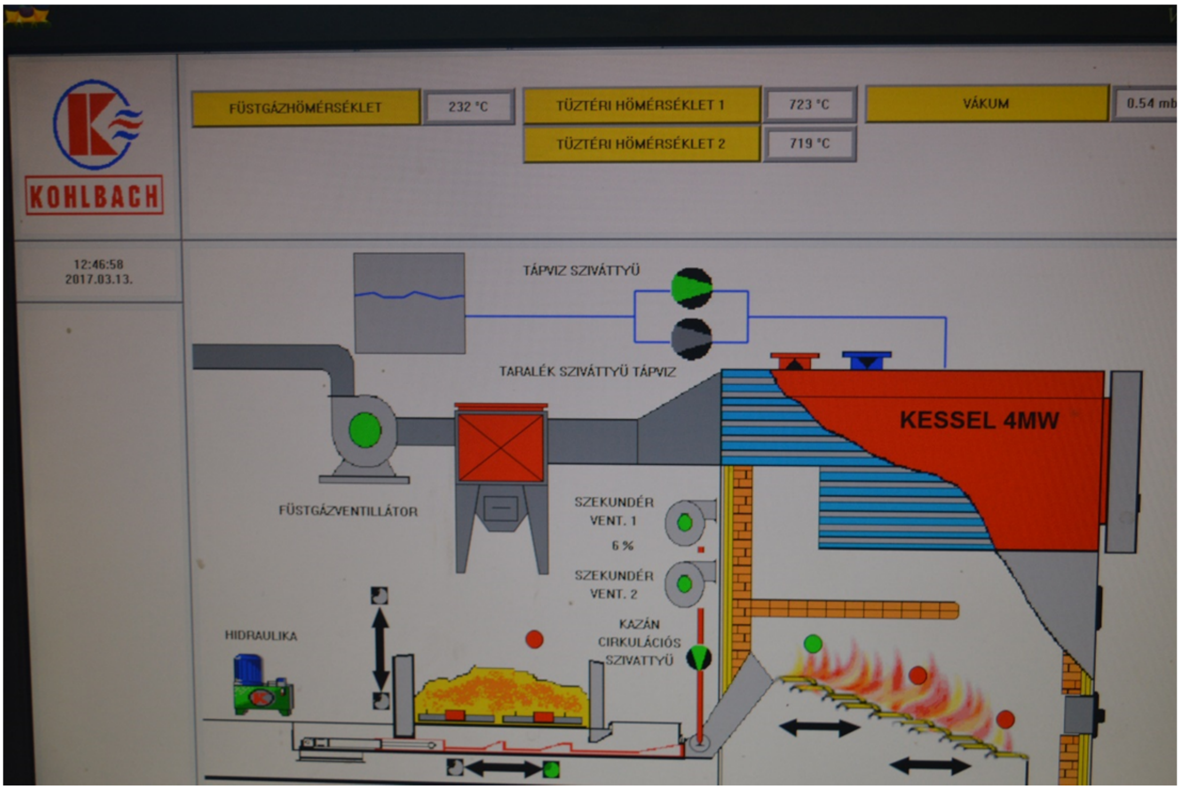

Figure 20.

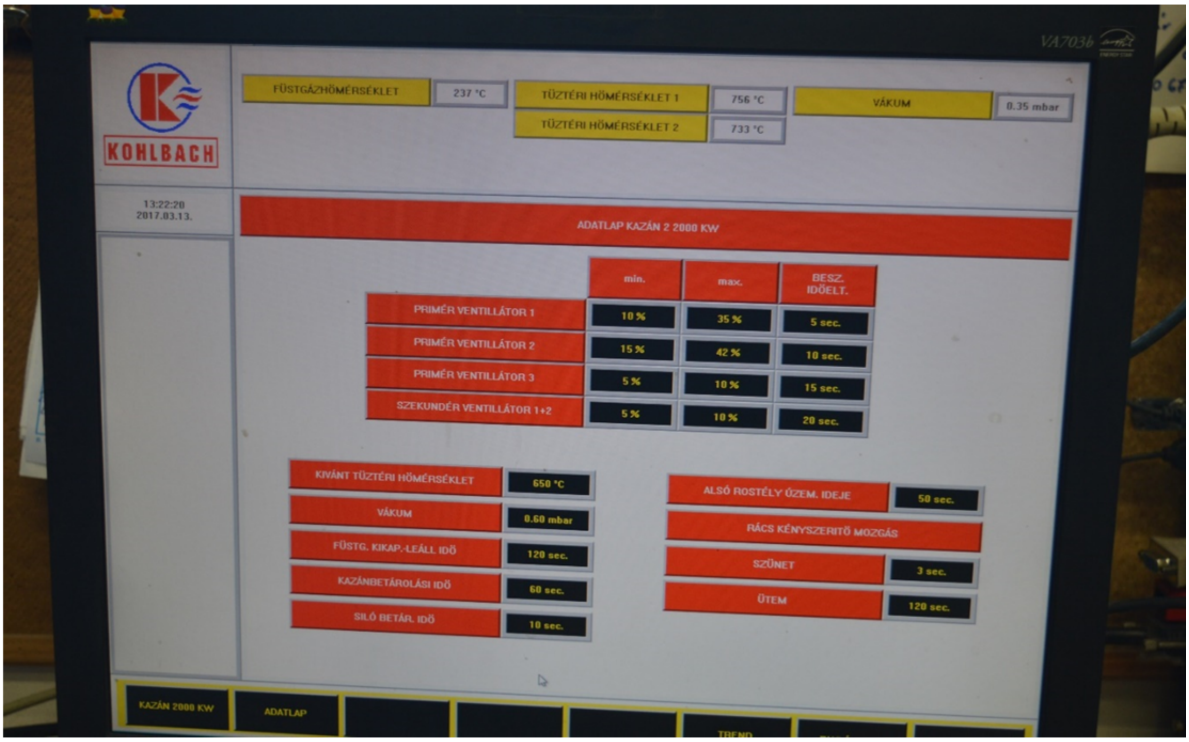

Figure 21.

The above figure perfectly illustrates what has been said so far, including the first chapter, as outlined by the processes I have described, but showing real-time data.

This figure illustrates the fan% s performance and indicates that it is just 756 degrees Celsius in the boiler's boiler.

The boiler's data are realistic and regulation plays an important role in their operation, since almost every plant is under pressure or vacuum system, and high temperatures can be dangerous.

In the illustration shown, the figure shown here shows a pressure gauge mounted on a pressurized pipe. The pressure gauge is 2160.1 m3 / hr. This means that the tube on which the clock is mounted supplies 2160.1 liters of water per hour over the pipe cross section.

Just to restore it to our imagination, a much larger natural form of it is Danube Waterfall of 2350 m3 / s. Of course, the Danube 1/60 is part of this data, but the

60 X 2350 = <u>141 000 m3/hr</u>

It may seem small, but do not forget that one is a 350-meter-wide 2860 km long river, while the illustrated pipe is only 20 cm in diameter, and yet it has to handle the pressure to work perfectly.

Figure 22.

The first boiler activation required great attention, since all the pressure pipes, piping networks and the boiler itself were fully tested. There was not enough equipment to function properly, it was necessary to have all the functional consistency between the machines so that each machine would work well.

From the heating of the boiler in the plant I could get an insight into a diagram that was shown on a curve

This figure shows the cooling and re-commissioning curves for wood-fired plants.

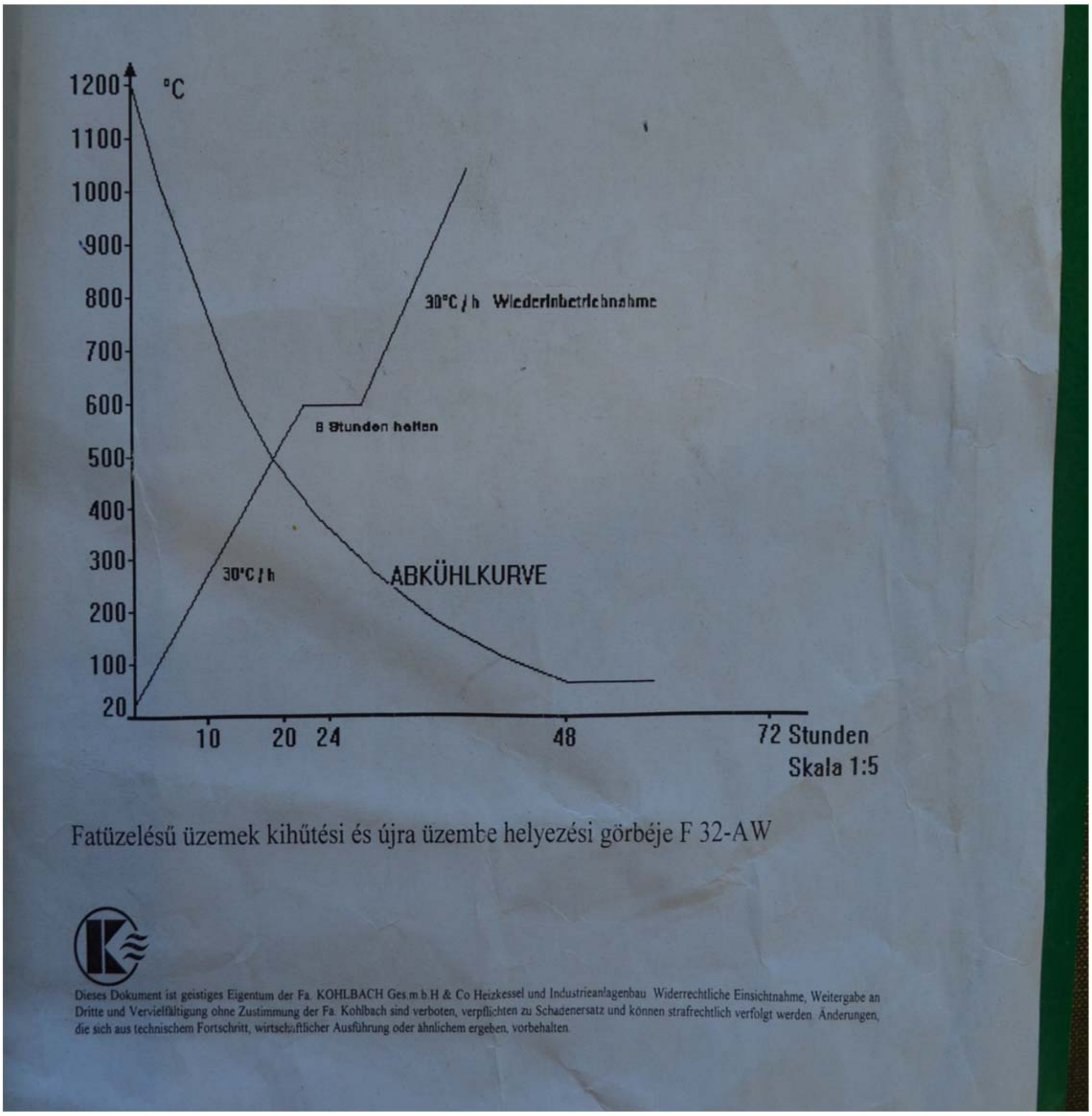

Figure 23.

However, in the lower picture, only the heating curve is shown int he temperature/minute unit.

Co-funded by the Erasmus+ Programme of the European Union

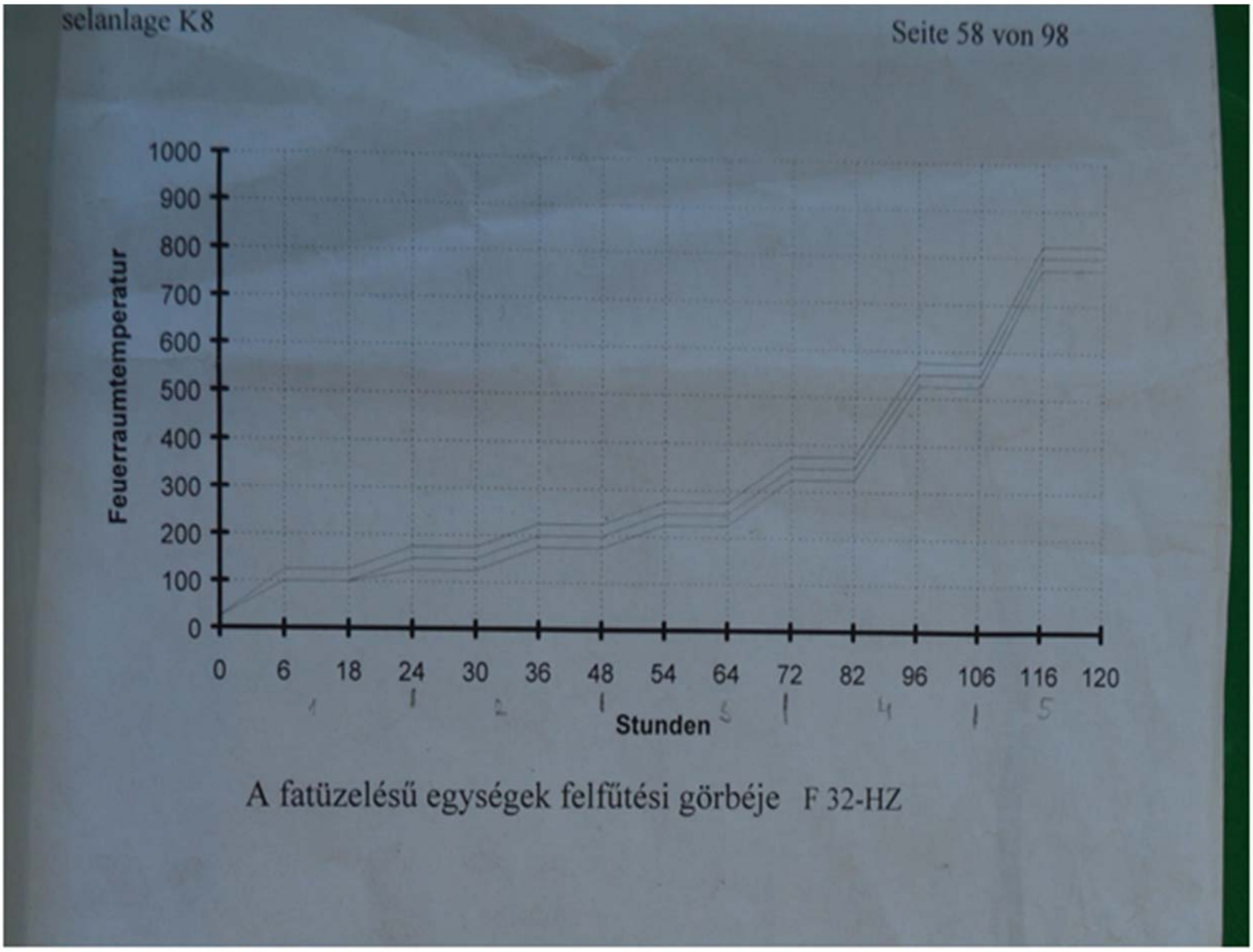

Figure 24.

Budget

3.1 Installation

Based on the above described and detailed plans, I believe it would be possible to install a biomass fired boiler that would supply the Budapest Forestry Zrt building with warm water and heat.

Installation, as the data illustrates, is not just a plan but a concrete implementation idea. In the first place, environmental consciousness and nature conservation are guided, but when general data is illustrated, one faces the fact that a biomass boiler is more profitable both economically and socially than any other alternative or green solution.

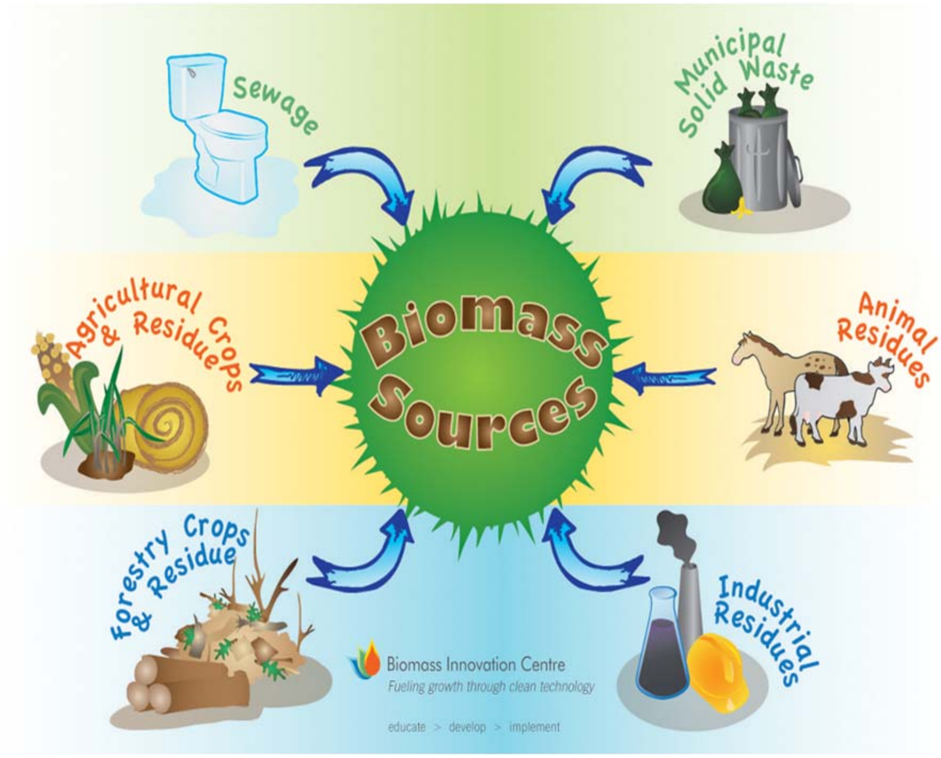

Figure 25.

Man is a source of original knowledge and, as a result of his pursuit of excellence, he has the opportunity to keep up with our technical know-how in order to preserve our own environment and to be one step closer to saving our earth.

In this context, the establishment of such a boiler would be advantageous and economically viable for the headquarters of the Budapest Forestry Zrt. Although we may list negative impacts for the approx. 500 m2 boiler, which also includes the covered part of the crushed storage.

As a negative effect, only the size of the site and its installation costs could be mentioned.

Figure 26.1

The visual plan illustrated in the above figure would be a sufficient site for a larger investment in several buildings. The cost of investing is very high but in our case there is no need for such an installation. The plan illustrates only the location of the boiler site, which shows how logically and how a plant is built.

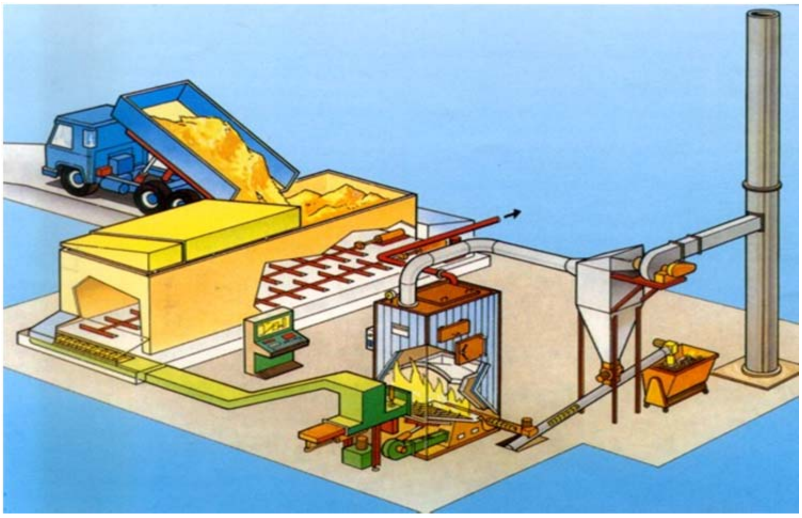

Figure. 26.2

However, to illustrate my case study, the picture can be completely folded.

In this figure, we see a much smaller plant that would supply enough energy to the forestry building. Furthermore, the cost of the installation investment is much lower than shown in the other diagram.

For the installation, the forestry office is available on the adjacent empty site for the required area. The property owned by the abandoned local government is waiting for it to be demolished.

One of the shame of the neighborhood is also referred to as the empty collapsing building. For a small amount of forestry, the local government can conclude a contract for rent, or fully purchase the above property.

If rented, as a compromise solution with the local government, forestry will renovate the building, which also favors the local government. For this reason, it would be the aim of the local government to transfer the real estate property or its wage rights at preferential rates.

Since the real estate area is under the supervision of the local government under forestry, they can begin the transformation of the area. You can also start installing the boiler.

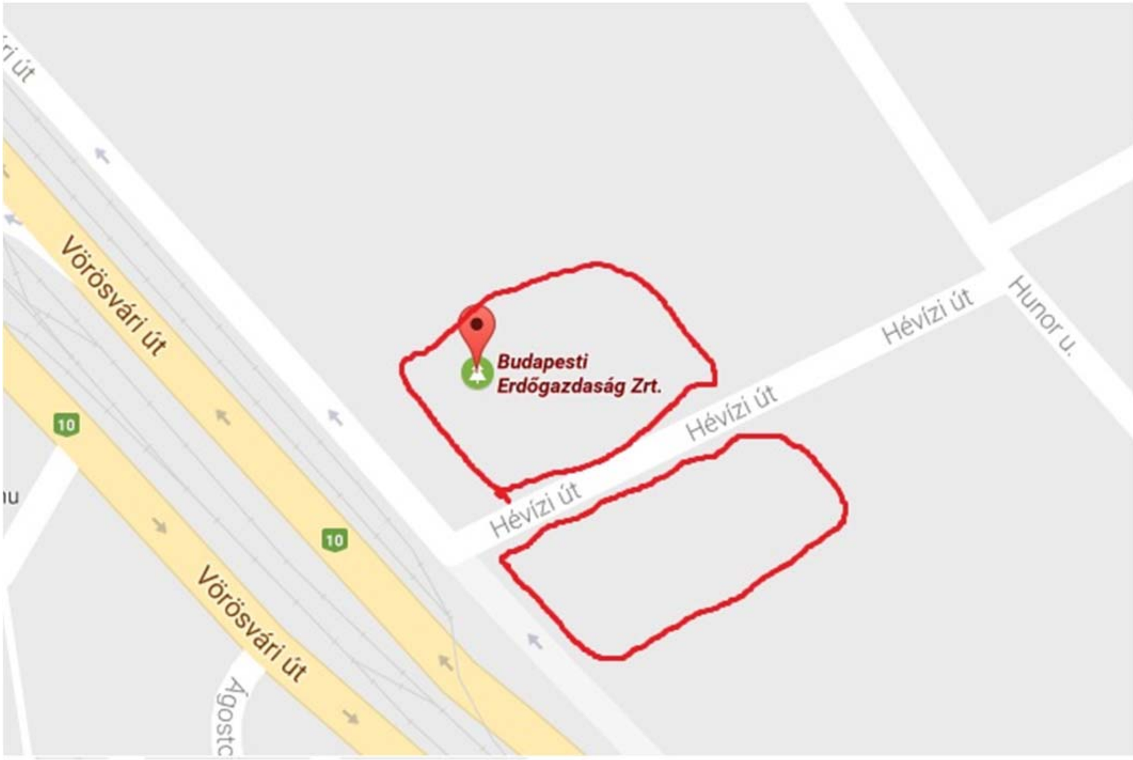

Figure 27.

Firstly, I would like to illustrate the map sketch above which the head office of Budapest Forestry Zrt. Can be seen, indicated by the GPS location. The office building is located in the red marked area, and opposite the Hévíz road is the empty ruined building mentioned earlier. As the map illustrates, the building is almost the same size as the office, but it is empty because of its inoperability.

By installing a boiler according to my plans, excluding planting costs would only have positive effects. With regard to the economic part, it is not necessary to build such a long pipeline network as if it were to be built somewhere else.

It is advisable to measure the size of the trucks with easy maneuvers and deliveries. Since there is a large turnover in this area therefore the most logical is if the drier area is close to the entrance. They can park the shipped timber easily from the truck.

3.2 Smart solution during the installation

It is important to build up the dryer when it comes to sunlight. In view of its position on the map, the outdoor dryer is also best placed. This is important because even though there is an enclosed part of the dryer, there are only those shredders that will be placed in the boiler within a short, foreseeable time, as they must be completely dry.

The chopper on the outside without cover is subject to weather conditions. Although they are constantly trying to solve the full and even drying of the chips, but sometimes it still suffers. It is therefore advisable to place on a side where little sunlight is exposed. Even if it reaches more sunlight for only a few hours, it also means much, as it dries faster.

The complete and even drying of the chips can be solved, but sometimes it is still precipitated. It is therefore advisable to place on a side where little sunlight is exposed. Even if it reaches more sunlight for only a few hours, it also means much, as it dries faster.

During the installation process, it is necessary to clarify the correct use of the site in such a way that the logical structure is the same as the operating structure. This is the next generous picture.

Figure 28.

As illustrated, the drying area is located directly behind the boiler.

The first chapter provides a detailed description of the boiler operation step-by-step. Accordingly, the boiler supplies the fuel from behind, so it must be behind the plant. At this point it should be considered that, although the back of the plant requires a larger space for the shredding of the chips, but how much space is required for the first entrance of the boiler.

Returning to one of the comments in the first chapter, so let's not look at the ash as garbage. This was not a coincidence, as ash has a very large area of use. In winter, the roads are sprinkled with wood trees in many places, hindering the slip of the road, but the most common use is in the garden. Since the ash is not rubbish, the ash collected from the boiler is stored in containers and then removed from the plant via the entrance.

Figure 29.

This figure clearly shows that a small container does not require such a large space, so the entrance can save you a lot. However, my plans would not require a first entry. If we only consider the transport of ash on and off, we will place a strong winch running on a ceiling on the entire area of the plant, which highlights the ashes and removes it from the building via a remote control or even using an automated system. Similar technology also operates on the plant of the biomass heating plant of Szentendre, but it is only a single-actuated picking winch.

Figure 30.

A steel rail has been fixed to the roof on which a roller motor is fixed, with a load capacity of nearly 2 tonnes. A strong chain is attached to the motor, which hangs over and at the end there is a hook. This hook is reinforced on a rigid u-shaped iron that highlights the ash-filled containers at the bottom of the boiler. If the containers have wheels, they can be removed at the front entrance but if they are not equipped to roll, the winch can be run on the rails up to the entrance. Then you either emptied it into a larger container or storage and transported by a truck over time.

Figure 31.

Hereinafter, the boiler area is given, so no separate calculation is required in the area of booking and estimation. However, there is another important part of the boiler, which is also located outside the plant. These fans, located directly at the boiler wall, are responsible for cleaning and cooling processes.

Due to their size and priority, they can not occupy the walls. Because of their functionality, pipes connect the boiler's building so they can not be far from the boiler.

Figure 32.

So it could be best placed from the boiler to the right, compared to the drier. The space between the two would be sufficient to accommodate maneuvering trucks, and from the fanhouse, a parking lot or other storage area, for example, where the ash can be stored.

Of course, these are only plans for the time being, which are difficult to imagine, so I would like to outline the numbering on the map already mentioned.

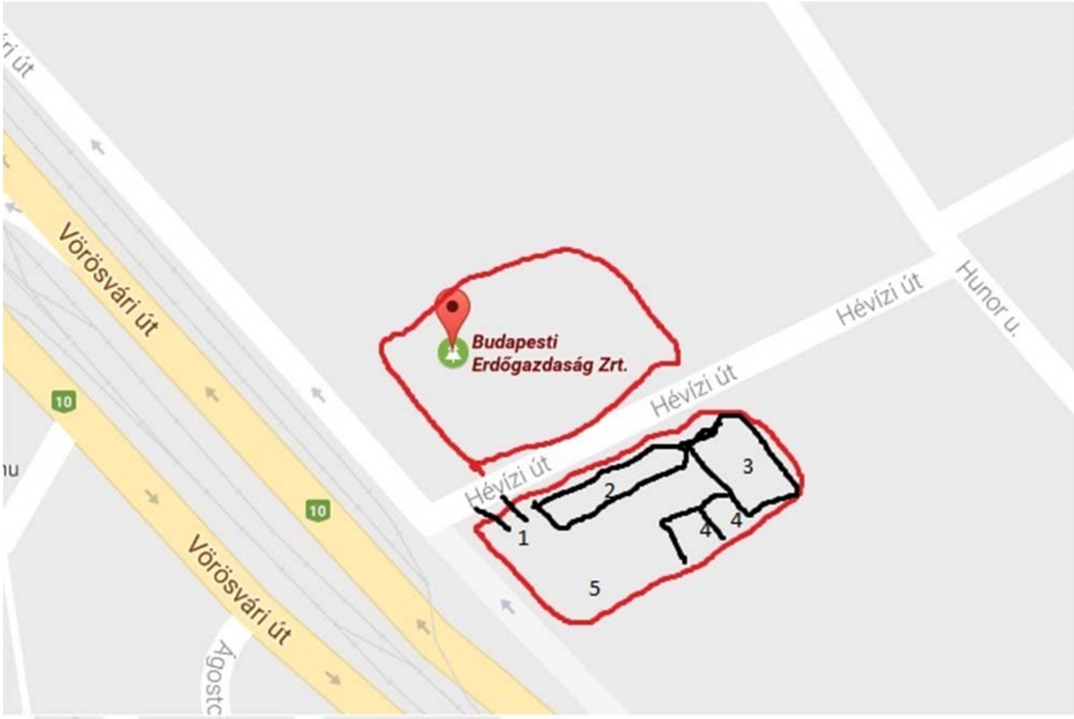

Figure 34.

First of all, the two parallel black lines would signal the entry of the battery, so it could go directly from the beginning of the Hévíz Road so that the traffic could go smoothly and not necessarily create congestion because a truck is trying to enter a narrow space.

Then, on the left, the cover and the lidless drying section would come where the truck arrived to lay the apron.

To do this, the boiler would be connected directly to the farthest point of the floor area.

He is followed in sequence by the fan housing, which includes two fans in case of a larger plant. In our case, it is enough to install a single unit.

Then it will remain behind the empty area as a parking lot or as a storage facility.

So, in this order of the map and its description, it looks like this:

1. Entrance

2. Dryer

3. Boiler plant area

4. Fan housing

5. Parking area of storage space

The layout would be the most conservative in this layout. The functional function of the boiler would not be affected by its geographical location, since it would be arranged on the basis of every logical structure, which is otherwise subject to stringent regulations.

One thing was not mentioned in the layout, which also supports the correctness of the layout. This factor is the link between the site and the forestry office, since the generated heat energy has to be transferred to the forestry building, so it is advisable to place the pipe system of about 15-20 m in length between the two places.

This figure is an insulated pipeline, similar to the above, which is discharged from the biomass boiler building to the ground. This method is more complicated in that if there is a potential problem in the pipeline running underground, there is no built-in repair shaft or service tunnel, so it is necessary to break the area, causing material damage and traffic congestion as finding a fault In the meantime, road traffic must also be limited.

Figure 35.

Since these tubes operate under enormous pressure, their approach may be dangerous to a non-professional in case of problems. In the event of overpressure, pipes may be opened which can easily damage the buildings or car parks in the vicinity or lead to personal injury.

The other solution can be an airborne solution between the two real estate areas.

In this formation, the pipe coming out of the boiler does not go downhill, ie its direction towards the ground, but moves horizontally to the building of the opposing forestry. Which is advantageous compared to the other version, is the fact that if any complication in the pressurized tube so a lifting car is needed and the equipment can be repaired. You do not have to put on the road. But the further dangers of this solution exist. In addition, it must be indicated at the beginning of the street, an altitude restraining table, because it is not necessary to build the pipe too high and thus the vehicles with higher loads may be signaled too.

Figure 36.

Plans of the project

4.1 Maintenance

My case study described above is a possible alternative and long-term plan for Budapest Forestry. In order to create this project, the observation of the Szentendre biomass heating plant contributed to the fact that it is indeed possible to realize the plan described above. Of course, the cost of the investment is very high, but since this is a long-term investment, it will pay off. The cost analysis did not include the repair of equipment essential for the operation of a boiler that soon disappeared. Given the fact that I have previously demonstrated how much heat, pressure and vacuum there is in such a boiler, so the mechanical devices there are forced to repair or clean over time.

Such as a flue gas filter in the boiler through which fine-grained smoke passes through the filter, but it needs to be cleaned.

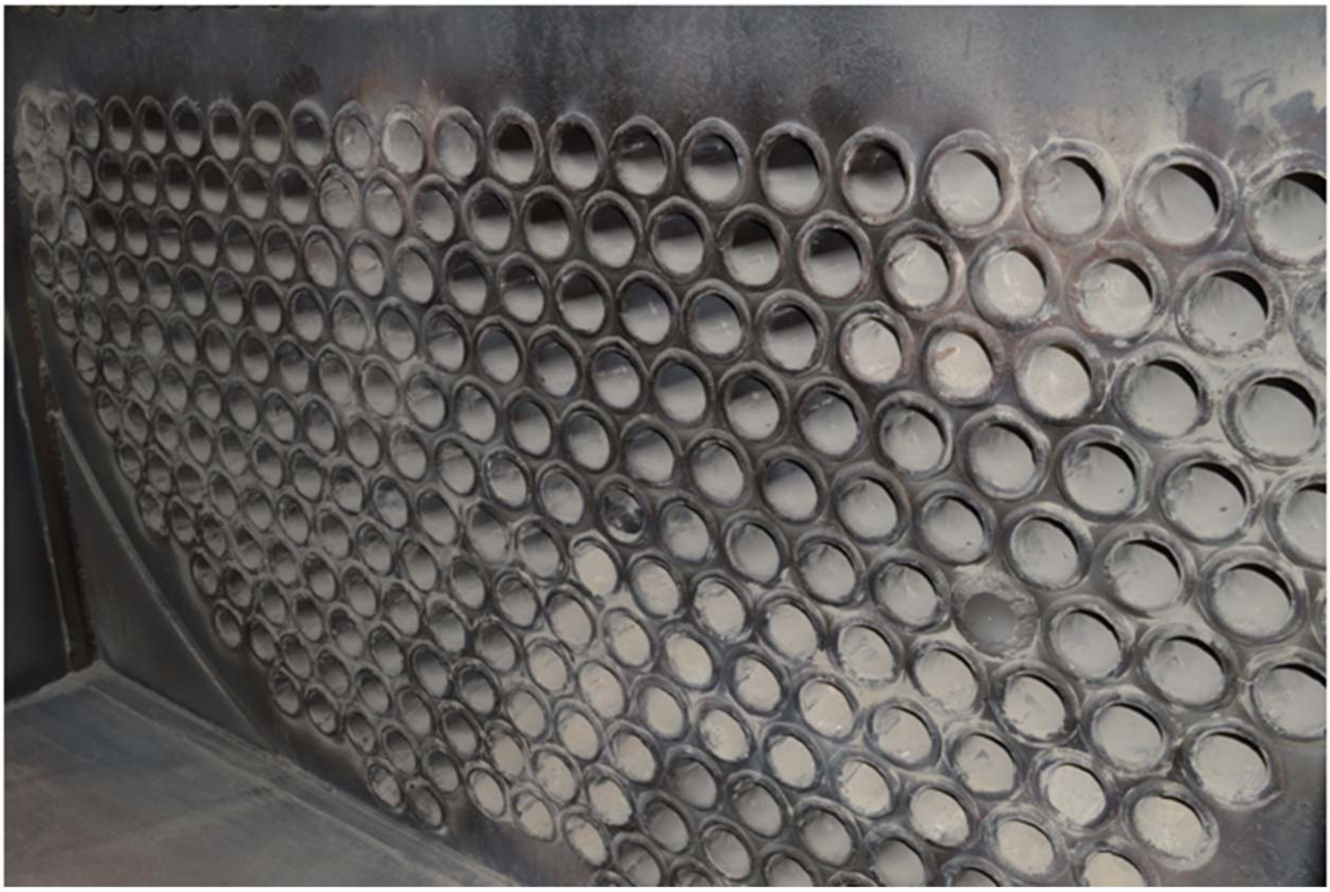

Figure 37.

The two figures represent a device that fits perfectly.

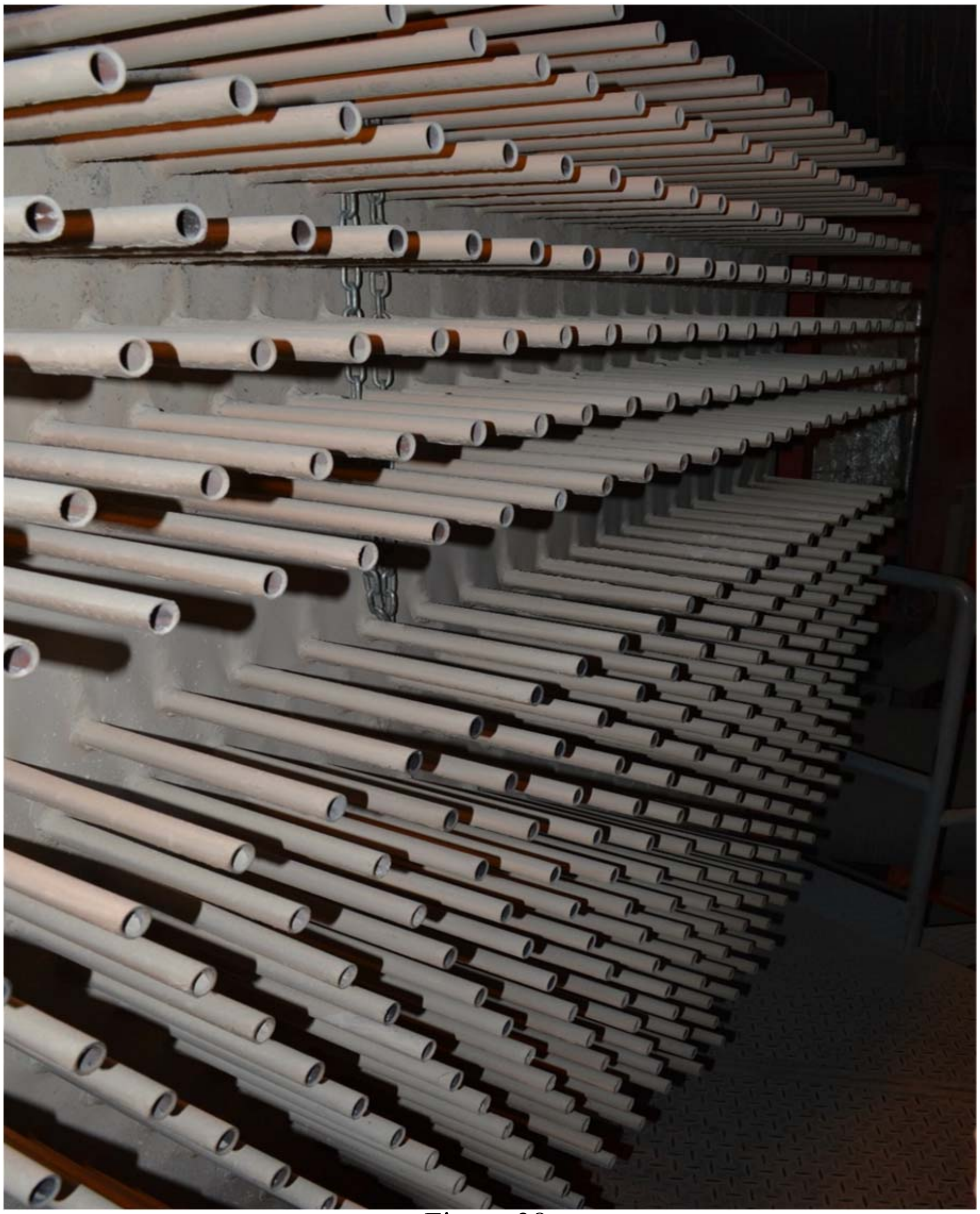

Figure 38.

Through the visible small holes the flue gas flowing from the tubes in the lower picture that it is waiting for is filtered.

Despite the planned electronics and automated systems, there is always a need for specialists. Therefore, the fact that the biomass plant creates additional jobs is a positive social impact. The constant maintenance and supervision of the equipment requires a presence of 0-24 h. Even in primitive technology, there are so many simple problems that a chopper will get jammed, it needs to be remedied and removed from it to keep the appliance running smoothly.

The picture below has a similar problem.

Figure 39.

Or, as outlined above, the exhaust gas filter shown in its closed state often needs to be cleanedbecause it is filled with small dust, which can cause more damage in case of non-cleaning

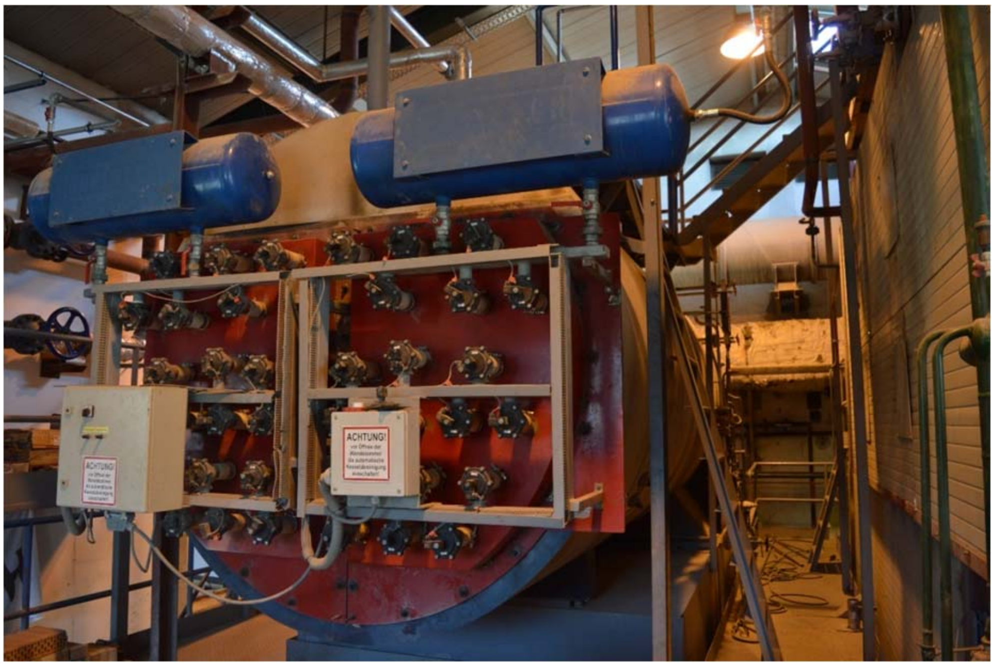

Figure 40.

4.2 Summary

With the study I wanted to demonstrate that by calculations it has been proven that it is worthwhile to use biomass firing in a larger office building, but even at home in a residential or family home. Although they operated with an automated system, it was still apparent that human surveillance and sometimes interference were indispensable.

Figure 41.

In addition, we could gain insight into what kind of data is needed to install a biomass boiler for the production of an office in a given area.

The turbine and generator housing documented on the production of the electricity described above, due to the local infrastructure, can not be solved, it would be good to include in the project,

Figure 42.

That there is no need for extra output but the boiler can produce electricity itself.

This fact is correct and real, the Hungarian conditions have not yet enabled the drafting of the project to make the electricity produced by the biomass boiler legally payable, but I hope that this problem will soon be resolved and fully self-sustaining in the office building or private buildings With this great renewable energy source boiler.

Figure 44.

Co-funded by the Erasmus+ Programme of the European Union

REPORT OF THE CASE STUDY ON RENEWABLE ENERGIES TO LOCAL DEVELOPMENT NATIONALLY IMPLEMENTED

Utilization of biomass in the energy supply of the Plant Diversity Centre in a Hungarian village

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E-mail: doralenart17@gmail

Renewable energies tutor: Csaba Patkós

Rural development tutor: Vicent Querol

English tutor: Imre Baják

Professional supervisor: Csaba Patkós

Center for Plant Diversity

Tápiószele, February 2017

Contents of the project

Memory of the project

1. Introduction to the project

Precedents

Over the last decades, it has become increasingly clear that the environmentally polluting and energy-saving soul of humankind can lead to the depletion of natural resources and the ecological disaster in the long run. The most threatening global problems, overpopulation, high atmospheric carbon dioxide levels, and the thinning of the ozone layer are expected to be treated, which can only be solved by international agreements. Several international conventions, such as the Rio de Janeiro Convention signed in 1992, set out general principles on the principles of resource utilization, environmental protection, sustainable development and cooperation between individual countries.

The use of renewable energy sources, including biomass, is increasingly widespread in terms of energy. The increased energy needs of the planet and the constant fall in the stock of the fossil fuels lead to the fact that alternatives are gaining ground.

My choice of topic was justified to find out what the possibilities of using biomass at the Plant Diversity Center are. In other words, it is a curiosity about the possibilities of using alternative uses of alternative energy sources.

Choosing a place was not a question to me because I have a personal connection at Plant Diversity Center. I have been working as a student worker since the summer of 2013 in the Field Plants Department. This year I spent one semester of my internship at the Development Information and Coordination Department. In recent years I feel that I have gained significant new knowledge and good professional relationships. Here, I decide what to do to learn later and why I want to deal with it. I am most glad that from my point of view, from a different point of view, I can look into the operation of Plant Diversity Center.

Objectives

In my paper I will examine the possibilities of utilizing the biomass and other alternative energy use of institutions and analyze the level of familiarity of renewable energy technologies based on a questionnaire. As a result I will be able to formulate suggestions and provide decision making criteria for introducing alternative fueling for the heating system in place. Moreover the results of my questionnaire survey will lead to formulating communication and/or education needs for better awareness of available renewable energy technologies.

1.1. Fossil fuels

"Fossil fuels are a primary source of energy in their natural form and can be extracted, which are a primary energy source, including coal, crude oil, natural gas and uranium." [SOURCE: SIMON T., 2010]

Most of the energy consumption is still fossil fuels such as crude oil, natural gas and coal. The economic and political role of natural gas and oil is particularly high.

There are limited quantities of fossil fuels, so their utilization is not capable of building up a sustainable energy economy. The solution is switching to the utilization of renewable energy sources, which requires a temporary energy source. We have large quantities of natural gas available because it is available in larger quantities than crude oil, occurs in many different locations and is less polluting.

1.2. Renewable energy sources

"Renewable energy sources are common names of energy sources that are re-produced during a typical time cycle or can be used without the risk of exhaustion."[SOURCE: LUKÁCS G. S., 2010]

Renewal of fossil fuels with renewable energy sources can have significant economic and social benefits. One of the most important and beneficial properties of the renewable energy sources is that they have a considerably lower environmental impact than fossil fuels. In addition to the environmental aspects, renewable energy sources are also emerging as a result of the continuous growth of fossil fuel prices.

Using renewable energy sources will not solve all our environmental pollution problems, but it will greatly help to create an environmentally friendly and sustainable energy economy.

Renewables include:

• direct solar collectors, photoelectric converters, solar power plants,

• indirect solar energy - wind, water, green (biomass), tidal, geothermal energy, and heat energy of the ocean's heat and waves.

The use of wind and sun as an energy carrier is "limited" because the sun is not always shining and the wind is not always blowing; They can only be used intermittently. Biomass and geothermal energy are also limited; they are otherwise limited: they can occupy farmland. You have to find the ideal balance.

The most widely used and largest source of renewable energy sources in the world is firewood, followed by hydropower by a great lag and then comes geothermal energy.

1.3. Concept and types of biomass

"Biomass is the indirect energy utilization of solar energy by the conscious use of biological phenomena. Agricultural and forestry production is in fact the transformation of solar energy: transforming solar energy into the surface of the Earth into plant chlorophyll chemical energy, which is nutrition, food, raw material, energy. "[TÓTH L., 2016]

Under the term biomass we mean

• the mass of all living and recently dead organisms (micro-organisms, plants, animals) on land and in water;

• the products of microbiological industries;

• man, animal and manufacturing industries are all products of biological origin, waste.

Based on the origin of biomass we can distinguish:

• primary biomass: natural vegetation (agricultural crops, forests, meadows, pastures, horticultural plants, aquatic plants);

• Secondary biomass: animal and animal husbandry main and ancillary products, wastes;

• tertiary biomass: byproducts of processing industries, by-products of human life. Products made from biomass in everyday usage: food, feed, industrial raw material, energy carrier, organic fertilizer, vegetable nutrition.

1.4. Energy use of biomass

The utilization of biomass for energy purposes has been known and used since ancient times. It was the evolution of technology and at the same time it made it possible to apply high energy resources in all areas of everyday life. As a result, the biomass energy utilization is undercut.

Biomass can be used as an energy carrier, it is energy source material. This advantageous feature makes it a top priority for renewable energies to be the most important. Its disadvantage is that its energy density is low, so it is best to use as a local source of energy

Biomass occurs in nature, field and forestry in many forms, and this circumstance and the wide range of uses have led to the development of a wide variety of technologies. Among the various technological solutions, the most distinctive is the disaggregation of the biomass used.

The most important uses of biomass are the following:
• biomass as a solid fuel for heat generation;
• for alternative liquid fuel propellants;
• biogas, fuels and propellants.

Benefits of using biomass could bet he aspects mentioned below:
• promote the rational use of land,
• contribute to a secure energy supply to a country,
• facilitates the diversification of energy supply,
• provide alternative sources of income in the countryside,
• creates a local workplace,
• results in regional development,

- improve field and forest management,
- affect the infrastructure,
- has an impact on the landscape
- means new technical development opportunities,
- a new industry can develop

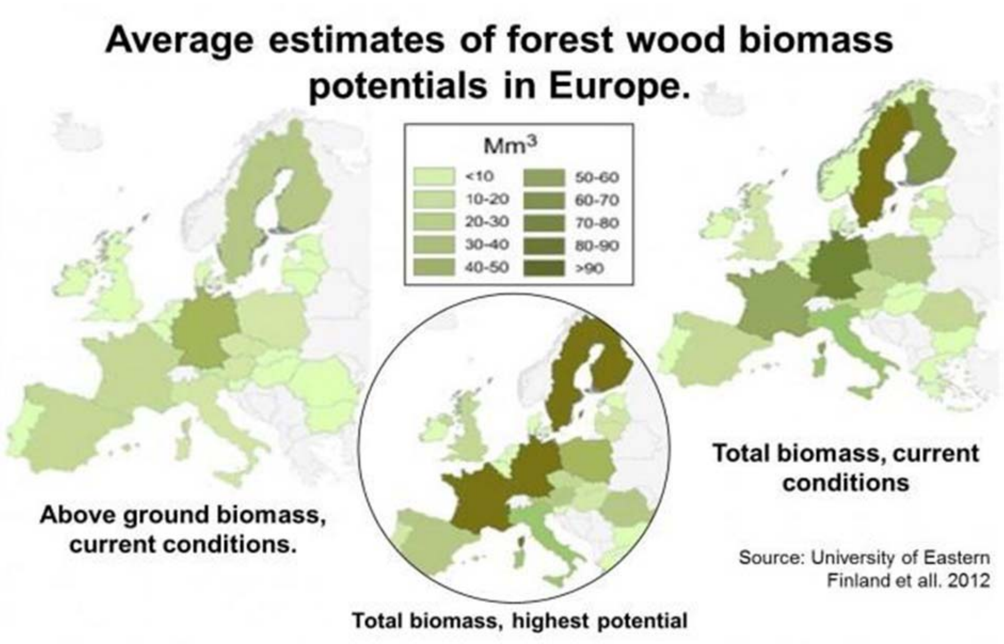
There are some disatvantages to using biomass as well:
- In some applications, the implementation of systems is more costly,
- the utilization on the basis of direct costs is more expensive,
- biomass burners can ruin the landscape,
- some technologies have a higher emission of harmful substances,

1.5. Biomass potential in the European Union

The graph shows that there is a high proportion of renewable energy sources (69%), compared to other energy sources.

Sustainable development is one of the bases for using renewable energy sources. If we were to move on to a large extent to the use of renewable energy sources, and thus to the energy efficient way of life, the volume of greenhouse gas emissions and the consumption of fossil fuels could also be significantly reduced.

This would amount to between 200 and 300 million tonnes per year for non-renewable fuels and 600-900 million tonnes per year for carbon dioxide emissions.



1. Figure: Biomass potentials in Europe

1.6. Center for Plant Diversity:

2. Figure: Location

yellow: The area of the institution
red: Bird protection area
Village: Tápiószele
Coordinates: 47°21'19.9"N 19°53'23.6"E
Address: 15. Külsőmező, 2766, Tápiószele
The institute was reorganized as the Center for Plant Diversity on November 1 in 2010.

And its tasks also covers the conservation of wild plant species too due to Pannon Seed Bank EU LIFE+ project as well. Currently the Center for Plant Diversity is a national base gene conservation institute for wild and cultivated plant genetic resources, furthermore it is responsible for the professional coordination of national gene preservation activities, the operation for the National Base Storage Chamber, the creation of the National Database of genetic reserves, as well as the harmonization of the national and international co-operations connected with the domestic gene conservation activities, which are under the supervision of the Ministry of Agriculture and the Plant Genebank Council.

Andor Jánossy, founder and director of the Institute for Agrobotany in Tápiószele until his death (1975) recognized in time that collecting the traditional and local varieties should be done urgently, as a consequence of the spreading intensive farming these varieties will easily disappear from cultivation in a short time. Together with his colleagues he organized collecting expeditions and trips, especially for searching and rescuing the Hungarian corn, red clover and alfalfa landraces. He paid special attention on the development of the international relations of the institute as well. He launched and published the scientific journal of the institute entitled 'Agrobotany' (1959) and the catalogue of seeds (the "Index Seminum") for serving genetic material transfer with partner institutes.[3]

The Convention on Biological Diversity adopted in 1992 at the United Nations Conference on Environment and Development in Rio drew attention again on the importance of biodiveristy, and provided opportunity for continuation of activities related to genetic resources conservation, evaluation and exploitation. On January 1 in1993, the Institute for Agrobotany as an independent institution was re-established under the supervision of the Agricultural Department of the Ministry of Agriculture. In 2006 the institute lost its independence again, and carried out its basic tasks with radically reduced headcount at first as the Agrobotanical Center of the National Institute For Agricultural Quality Control, and then as a unit of the Central Agricultural Office (CAO).

1.6.1. **Enablers,** ***Climate and surface conditions***

The institution is situated on an area of nearly 300 acres. Hydrological conditions are predominantly defined by the drainage work of the nineteenth century and the second half of the 1970s, and two natural surface water (lake), four drainage channels and drainage ditches can be found on the area of the institute. The landscape is essentially flat, its microrelief is quite varied. Except for acidic sandy soil and acidic forest soils each major type of soil can be found here. The reason of the installation reason of the predecessor, the Institute for Agrobotany in this place was the great diversity of the soil types, which allows successful plantation and piling plant species and varieties different soil needs.[4]

1.6.2. Watery habitats

Two lakes can be found here, with their own natural vegetation. Wetland include ditches and the drains, as well as particularly strongly fled woody areas, for example, the low lands and the waterfilter area. Typical vegetations are reeds (Phragmitetum communis), typha beds (Typhateum latifoliae), glyceria beds (Glycerietum maximae).

3. Figure: Waterly habits

1.6.3. Woods

Many of them can be found in the territory of the institute, most of them are also under forestry cultivation. The most important character species are scotch pine (Pinus sylvestris), acacia (Robinia pseudo-acacia), noble poplars, but we can also see endemic species, for example english oak (Quercus robur), white poplar (Populus alba), hedge maple (Acer campestre) here. Broad-leaved Helleborine (Epipactis helleborine) as a protected pioneer plant species is an important element of the herbaceous flora of the forests. [3.]

1.6.4. Alleys and balks

Fields are mainly lined by lines of trees and bushes, the most characteristic species of these is european ash (Fraxinus excelsior), which is far spreading here. The preservation of these habitats is very important, because creating a “green corridor” allows the spreading of different species. Herbaceous species of these habitats consist of mainly species of grasslands (groundnut pea vine (Lathyrus tuberosus)), woodies (cathfly (Silene vulgaris)) and ruderal species (common chicory (Cichorium intybus)). [3]

4. Figure: Woods

1.6.5. Fauna

Many different protected and strictly protected animals can be found here. The characteristic nested birds of the reeds are great reed warbler (Acrocephalus arundinaceus), which nests only here in Tápió region, sedge warbler (A. schoenobaenus) and common reed bunting (Emberiza schoeniclus). The lake serves as a feeding place for many birds, mainly for cranes (e.g. Egretta alba). Also many birds visit us through marching time (great bittern, (Botaurus stellaris), black stork (Ciconia nigra), and mallard (Anas platyrhynchos)). Wild ducks stay here for the whole winter many times, they only leave in extremely cold for the south. The typical nesting birds of the grassland are Eurasian skylark (Alauda arvensis), blue headed wagtail (Motacilla flava) and whinchat (Saxicola rubetra). Rare, strictly protected european roller (Coracias garrulous) and grey shrike and red-backed shrike (Lanius minor, L. collurio) with decreasing stand in Europe are typical species of woody habitats. Also black woodpecker (Dryocopus martius), european green woodpecker (Picus viridis), great spotted woodpecker (Dendrocopos major) and hoopoe (Upupa epops) breed here. European bee-eater (Merops apiaster), which is often seen to haunt in the institute bred in the neighbouring sandpit. Regular winter guest is bullfinch (Pyrrhula pyrrhula). Fieldfare (Turdus pilaris), misletrush (T. viscivorus) and bohemian waxwing (Bombycilla garrulous) are also apparent frequently, as well as goldfinch (Carduelis carduelis) and chaffinch (Fringilla coelebs). Out of carnivorous birds the boarding birch renter common buzzard (Buteo buteo) and common kestrel (Falco tinnunculus) are worth mentioning, like the newly roosting brown owl (Strix aluco) in one of our industrial buildings. Winter feeding and settling and servicing rots are important activities of bird protection. Squirrel (Sciurus vulgaris) and different bats (Ordo Chrioptera) are also frequent visitors and residents, sometimes also otter (Lutra lutra) could be found here earlier. Many raptors and amphibians live in the lake such as marsh frog (Pelophylax rudibuntus), water-snake (Natrix natrix) and pond turtle (Emys orbicularis), but tree frog (Hyla arborea) and great crested newt (Triturus cristatus) are also common here. Several unique arthropods can be found here, like fen raft spider (Dolomedes plantarius), rhinoceros beetle (Oryctes nasicornis) and stag-beetle (Lucanus cervus) in parkland also have habitats around the lake. Lycosa singoriensis (the biggest protected kind of wolf-spiders) is also apparent on the quickly upheating ground. [4]

1.6.6. The Tápió-Hajta Rural Landscape

The Protection Area covers an area of 4516 hectares, of which 182 hectares are heavily protected. The Protected Landscape Area belongs to the Directorate of the Danube-Ipoly National Park. The Tápió countryside, less than 40 km from Budapest, is one of the most exciting, but least discovered, areas of the Central Hungarian Region. The landscape conservation area, consisting of 21 independent units, lies in the valley of the Tápió River, in the county of Pest and Szolnok.

The Tápió region is situated at the junctions of three great peaks, between the Danube-Tisza River, the Tisza and the Northern Mountains, which allowed for the development of a diverse wildlife rich in rarities. In the protection of this diversity, in July 1998 the Tápió-Hajta Rural Landscape Protection Area was established.

5. Figure: Tápio- Region

The Research Centre for Agrobiodiversity is situated in the Tápió-Region. The whole area of the institute is about 300 acres. The annual average temperature (by the data of our own meteorological measuring station) moves around 10,5 °C, and the annual precipitation is nearly 540 mm here. The rate of the annual global radiance is about 145 W/m². Hydrological conditions were mainly defined by the water regulation works of the XIXth century and the second half of the 70's. Two natural lakes, four drainage channels and gutters can be found here. The area is mainly flat, the altitude is about 100 m. The relief is rather varied. Also every main soil type except for the sour sandsoil and the sour woodsoil can be found here. Partially the diversity of the soil types caused the settling of the ancient of the NöDiK, the Institute for Agrobotanic here – that allows the successful piling of different species and types with different soil demands.

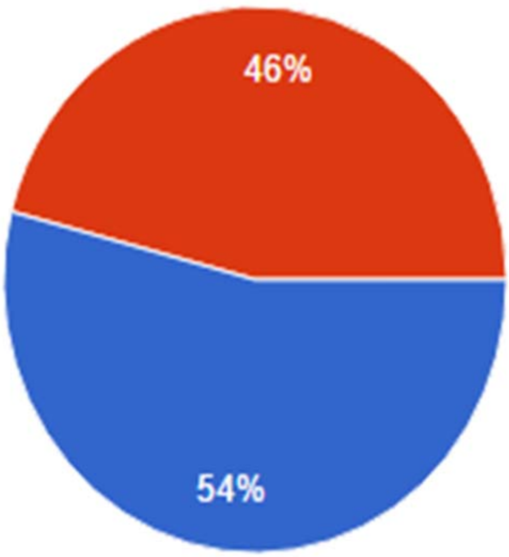
The area of the inner parks is 5.5 acres altogether. The oldest pedunculate oaks were settled in the second half of the 19th century. Nearly 200 tree- and bush species can be found in the expanding arboreus park. Probably this is the only place in Hungary for three copies of Quercus lobata to find, which is an oak endemic in the dry valleys of California. Cupressus bakeri and Pinus uncinata are also unique dendrological value. The garden itself was estbalished after the settling of the Institute in 1960 by Gabriella Székács, Béla Koch and László Lún with the help of the workers.

Salt-tolerant, natural association builder, ornamentical trees and bushes were planted to the partially wet, salt-like sand soil, wich are endemic in the Tápió Region. Both areas are part of the Agrobotanical Garden of Tápiószele, which can be found in the registration of Hungarian Arboretums and Botanical Gardens.

1.7. Questionnaire based survey about renewable energy sources

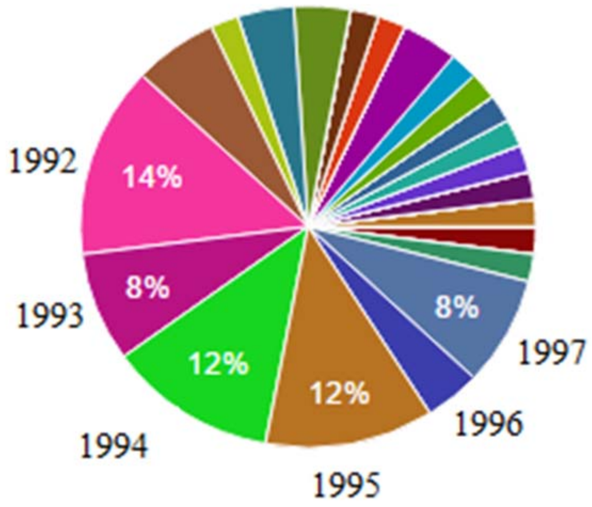
Method:
The institution's data is accessible to anyone on its own internal interface. In addition, I learned more information from personal instructors during personal interviews. The details of the boiler types can be read from the label on the boiler side. Further information on boilers can be found on the distributor's web site.
Method of calculation: the calculation of the total fuel consumption of boilers in the heating season was done by means of an excel table as they did not require too complicated calculations.

Question Q10 (Figure 20) of the questionnaire was processed by cross-analysis in the excel table to answer my question.
The content of the questionnaire was produced with the knowledge of renewable energy sources. I was wondering what people heard of renewable energy sources and about biomass as a concept. And I was generally interested in whether people know whether or not they are using renewable energy in their environment at all.
The demographic questions in the questionnaire are designed to help to find answers for the above mentioned questions broken down to a composition based on age, place of residence and the school qualification of the applicants.
My questionnaire was made on-line. I shared it on the largest internet community site. I have edited my questionnaire with Google.
Before I shared the questionnaire on the Internet, I had a trial question from 3 independent individuals beforehand, showing that the questions were not clear at all times. I had to fix, add or clarify some of the items (questions or answers to be given).
In a relatively short time (two weeks), 50 people filled out my questionnaire; I consider this to be a very good result and I think the results can be well appreciated. It is important to say that the sample can not be considered representative due to the sampling method.



6. Figure: Distribution of respondents

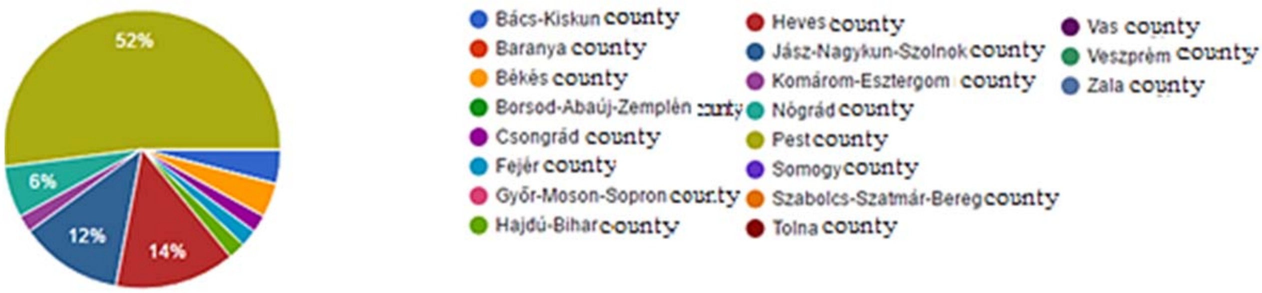
The questionnaire was filled in 54% by men and 46% by women.



7. Figure: Age distribution

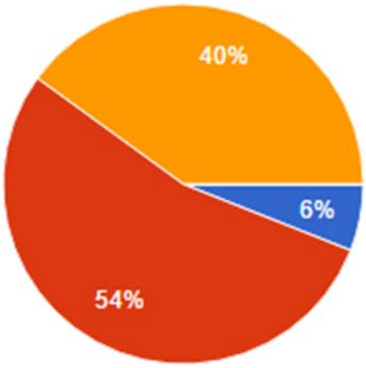
The youngest respondent was born in 2000 and the oldest was born in 1964. Most of them were born between 1992 and 1997. This can be explained by the typical age of users using the community site.

- Under 18 - 1 person
- 18-25 – 29 people
- 26-40 – 14 people
- 41-60 – 5 people
- 60+ - 1 person



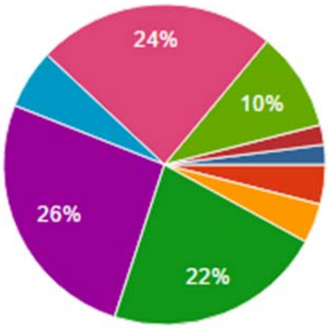
8. Figure: County Divisions

The questionnaire was filled out from 10 different counties, most of them from Pest county (52%), Heves county (14%), Jász-Nagykun-Szolnok county (12%). These values also result from the possible distorting effects due to the typical feature of the community site.



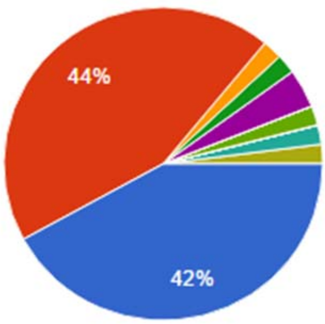
9. Figure: Resettlement breakdown

Most of the respondents live in a city (54%), 40% in a village and 6% in the capital.



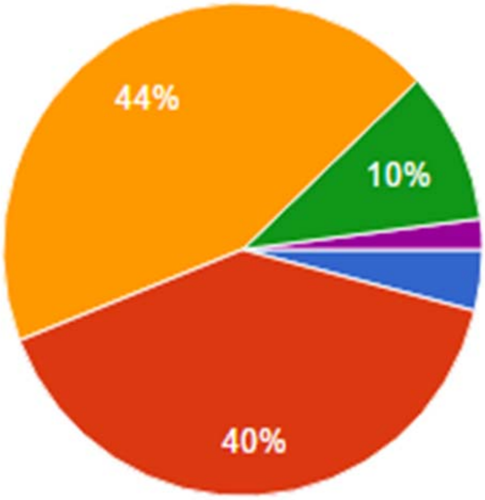
10. Figure: Educational distribution

Considering the educational level, the scale is very wide. Most of the respondents have high school qualification(26%), followed by college (24%), followed by vocational secondary school (22%) and university (10%) qualifications.



11. Figure: Occupational distribution

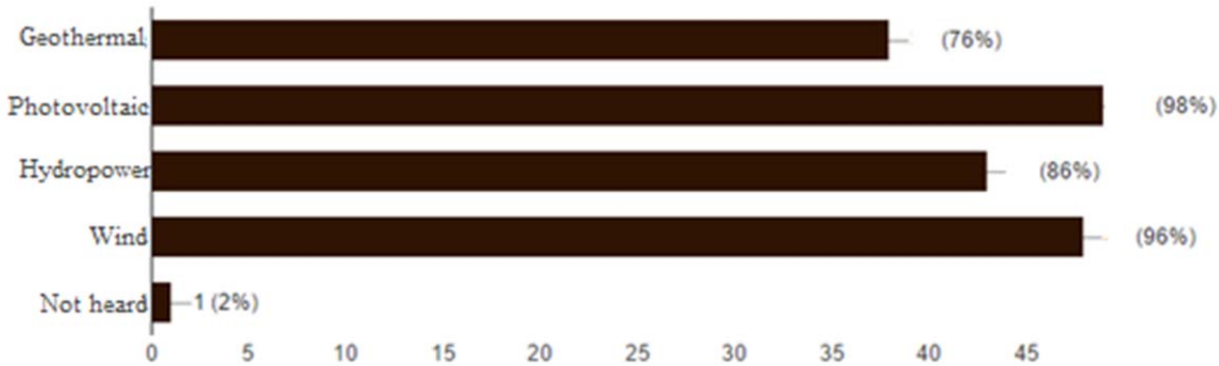
In terms of occupation, the two most marked answers were employment in full-time or part-time (44%) or the student (42%). These values can also be explained by the features of the community site.



12. Figure: Distribution by Existential Situation

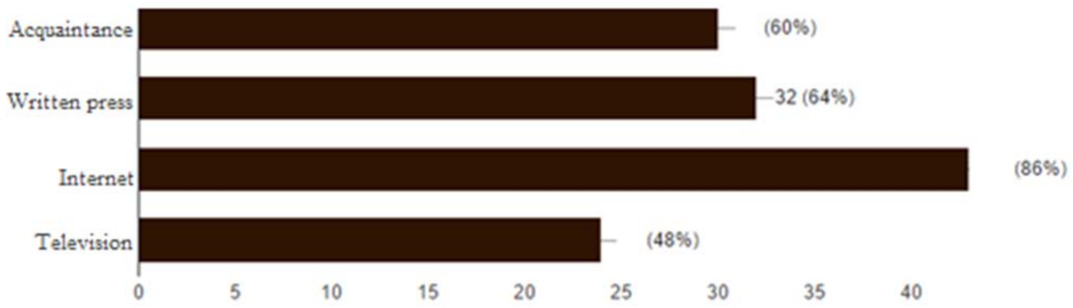
44% said they need financial discipline to be existentially okay 40% surprisingly stated that they have no financial problems (40%) and only (10%) indicated that they have to pay extra attention to make ends meet.

Next I asked about renewable energy technologies



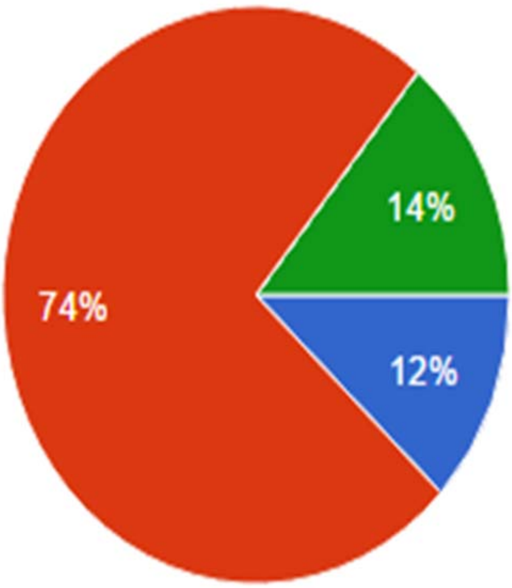
13. Figure: Knowing Renewable Energies

Most of them heard about solar energy (98%), followed closely by wind (96%), hydropower (86%) and geothermal energy (76%). Most respondents have heard about almost every renewable energy source. There was a person who said that he had not heard any of them. I think that these numbers, that so many renewable energies have been heard of by the respondents, are very positive.



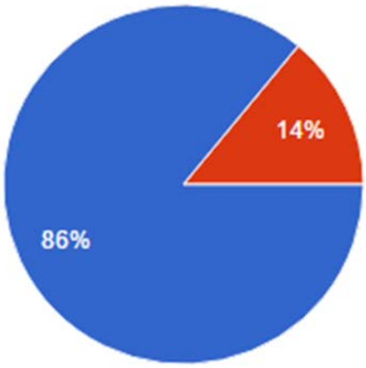
14. Figure: Location of information

Most of these resources have been heard of on the Internet (86%). This was followed by the written press and then the acquaintances, the families, the relatives and at the last place the television was mentioned.



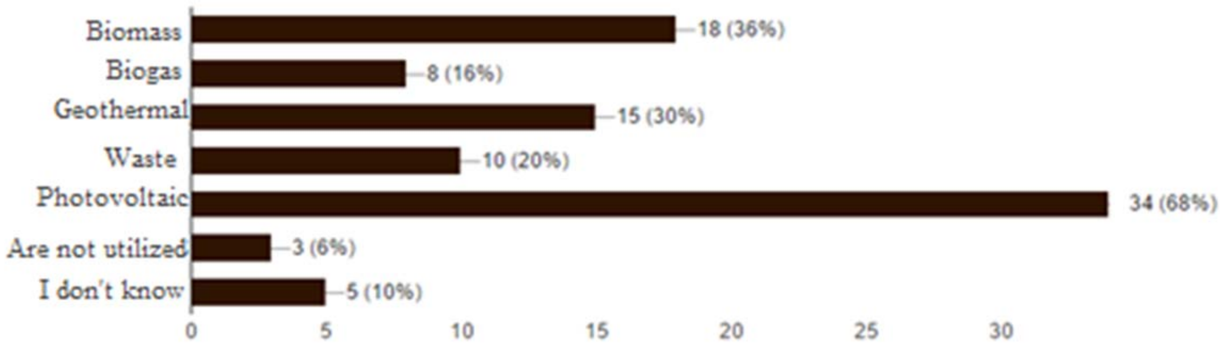
15. Figure: The first thought when hearing of a renewable energy source

Most people will associate the use of renewable energies to environmental protection (74%), followed by tying it to high investment costs (14%) and residual energy (12%).



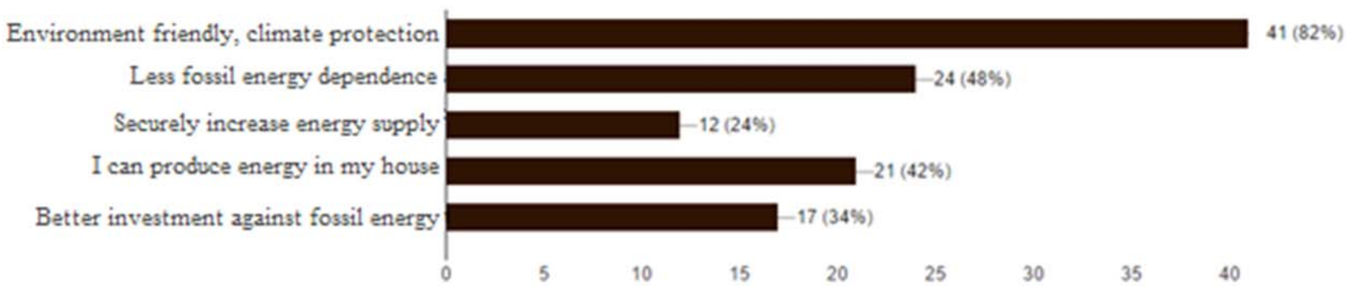
16. Figure: Knowledge of your own area

86% of respondents answered that they knew that they use renewable energy in their environment / small area. This is also a very positive feedback that people are aware of their environment.



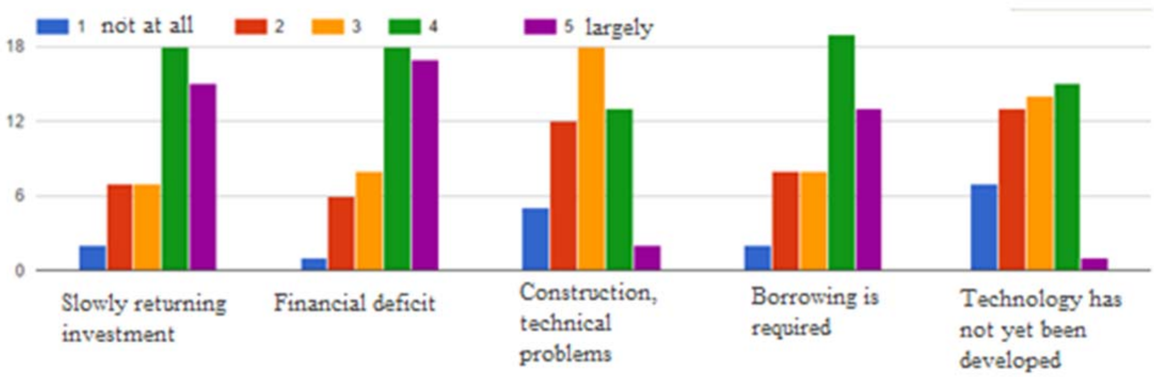
17. Figure: Knowledge of your own area II.

The next question is whether they know which renewable energy sources are utilized in their environment / micro-region. The answer was that they utilize most of the solar energy (68%). This is followed by biomass, geothermal energy, municipal waste and biogas. 6% said they were not utilized and 10% could not answer. If we observe, respondents in their place of residence can conclude that they do not know each renewable energy source, they only heard about it.



18. Figure: There are arguments in favor of renewable energy

As for the arguments in favor of the use of renewable energy, most of them opted for an environmentally-friendly climate protection option (82%). This is followed by a smaller fossil energy dependency (48%), I can produce energy in my house (42%), a good investment (34%) due to the increase in fossil energy, and an increase in security of energy supply (24%). These results are also very positive, respondents often hear and therefore realize that the primary purpose of using renewable energy is environmental protection.



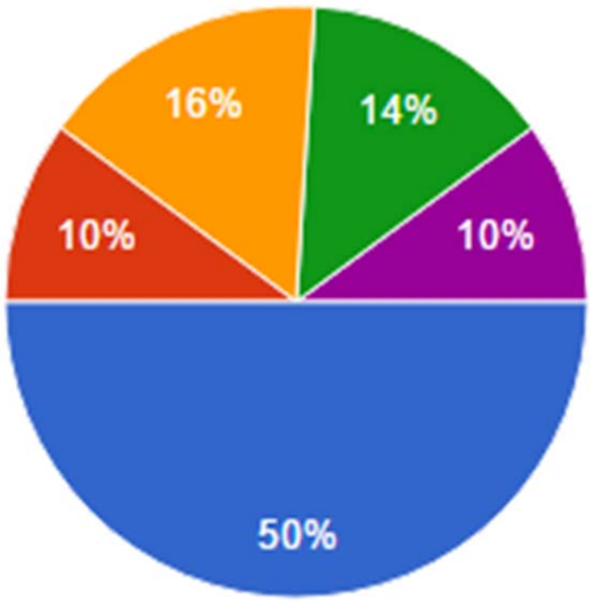
19. Figure: Investigating factors

In the following, I asked the respondents to say whether they think the investments into these renewable energy technologies are making the following factors more difficult. They had to vote on a scale of 1 to 5. 1 is not at all, 5 influences greatly.

The slow-return investment does not have a large and significant impact on the investment. The lack of financial resources is also a very influential factor. Construction, technological problems are so-so, this question is considered mostly neutral by respondents. The need for financing is a sufficiently influential factor among respondents. The technology is not yet well-developed, according to the respondents this is also a factor.

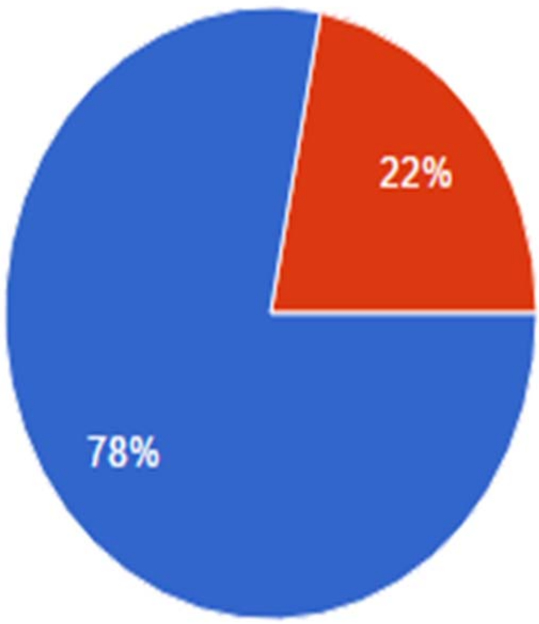
Responses show that, even among those who are in a good income situation, such an investment would not be supported without additional financing.

In my opinion, the technology is not sufficiently mature is a false statement. This also suggests that respondents do not have enough information on renewable energy technologies.



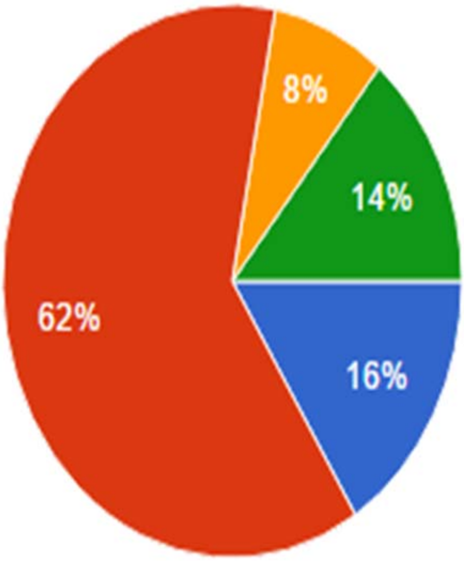
20. Figure: Hungary's share of renewable energy according to respondents

In the question of which is the most widely used renewable energy in Hungary most respondents voted for solar energy (50%). This was followed by hydropower (16%), biomass (14%) and geothermal and wind energy equivalents (10-10%). The results here also show a lack of information.



21. Figure: Knowledge of biomass

78% of respondents responded that they have a knowledge of biomass. The previous answers do not justify this, and neither do the following ones.



22. Figure: Calorific value of biomass

Next, I asked the respondents to mark the truthful statement. The most, 62% of them chose "The calorific value of biomass is similar to the calorific value of coal, but it is a renewable energy source and therefore its use is more advantageous" 16% thought the calorific value of biomass is lower than the one of carbon. 14% replied that the calorific value of biomass is twice the calorific value of carbon. The remaining 8% replied that the calorific value of the biomass is slightly better than the calorific value of the coal.

Most have indicated the second possibility that the calorific value of the biomass is similar to the calorific value of the coal, but this is a renewable energy source therefore its use is more advantageous. This option is not a good answer, because of the second term, many have been "trapped". The correct answer is that it is twice the calorific value of the carbon. This option was chosen by 7 people, 3 men and 4 women. Six of the 7 people have a university degree.

1.8. Design alternatives to be considered

In such a place, the energy use of biomass can be very diverse. The local conditions of the institution would be appropriate for energy plantations. But the purpose of the institute is not to serve this purpose. Its main target is gene conservation, it only produces propagation material, so the residues of the crops grown are unnecessary by-products. It is thus possible to utilize these by-products as energy sources. Due to the grain, all cultivated plants are originally delivered to the sheltered storage, except for cereals grown with the purpose of crop rotation. There are special machines for picking up the plant wastes that have been produced, which are delivered to a composting site. Based on my plans, it is possible to burn these wastes in the biomass boiler. On a yearly basis, a significant amount of such by-product is produced. These by-products equate to the energy value of other pellets. There are three biomass sources within the institution: primary, for example: enhancing the yield of trees; secondary, for example: plant residues resulting from seeding; tertiary, for example: stored seed lost in germination. At present, pellet boilers have been operating for heating the center's service homes since 2014. At present, two boilers provide heating for five apartments, heating up to 1200 m^3 of air. The heating system of these homes, the replacement of the pellet boiler, would be a boiler capable of utilizing a wide range of fuels.

The establishment has 300 hectares of land, 10 hectares of permanent grassland. The latter is cut three times on a yearly basis with the lawn mover of the institution. After mowing the institution wighs and sells biomass to workers at a discount price. The maintenance of permanent grassland is an integral part of the current agricultural policy, and therefore the institution takes great care of maintaining and professionally managing these grasslands. If you extracted these areas from production for any other purpose it would be against regulations. There are no livestock in the area of the institution because the institution serves the conservation of genes as a priority. The biomass produced on the grasslands is 700q on the basis of sales deposits, the amount received from the sale only amounts to the harvest. Based on my primary calculations, it would be useful to utilize the above-produced quantity in a complex wood-fired boiler that would heat all the rooms in the central building during the full heating season. It is advisable to calculate the amount of heat available with an energy expert and then consider the air m^3 of the main building, and then a common boiler room would be worthwhile.

23. Figure: Wood chips

24. Figure: Sunflower pellet

In addition to heating, hot water could be produced using a buffer tank. The institute has 40-50 ha of woods in which sick, aged trees and shrubs can be found, so they can produce the chips themselves. Every five years the maintenance of forests is common. So far the wood has been distributed among workers . However, these could be utilized as wood chips and might be used to heat other sites when converting a lot of available biomass into heating energy. It would be possible to replace seasonal heating in changing rooms, dining rooms, laboratories, and workshops. It is desirable to select the locations in a targeted manner from the point of view of installation and operation.

The boiler would be suitable for combusting the following fuels:

• wood chips of a given size

• pellets

• seeds of truncated fruits

• walnut, almond oil

• cleaning by-products

• crop by-products (stems)

• seeds with lost germinantion potential

Sand straw could also be used to run boilers, such as wheat, barley, circus and oat. From the area baling residues are collected and sold to workers. The bale would be given, and the residues of the areas will always be removed, so no extra cost would be generated. The disadvantage is that not enough such byproduct is produced in the cultivation of the aforementioned plants, so that it would be worthwhile to buy a straw boiler. However, the straw mixed with chips can be fueling a high-performance chopping boiler.

When combusting biomass in a boiler, biological and chemical oxygen demand is no more than the rate of oxygen demanded during the decay or fermentation. It means that it does not pollute the environment more. The ash which is generated in the pellet boiler is currently not being usedand is cut to the outside taken care of by an external company in Jobbágyi. At present, the destruction of 6 m3 of ash waste costs 127,000 HUF (transported to Jobbágyi).

The benefits of the woodcutter and straw boiler are also supported by the park's machinery (8 tractors, 2 combines, 1 parcel combine harvester, 7 trailers, 2 balers, 1 loader, 1 wood splitter, 4 chain saw, 2 tractor-gripper mowers, 2 shredder trunks).

There is an old mill building in the institution, 3 closed grain containers, 9 open containers. However, these containers are empty. They would be suitable for storing biomass at the site.

Figure: Plant Diversity Centre

Source: https://www.google.hu/maps/place/N%C3%B6v%C3%A9nyi+Diverzit%C3%A1s+K%C3%B6zpont/@47.3571567,19.8883906,565m/data=!3m2!1e3!4b1!4m5!3m4!1s0x47410c11e3b17d95:0xe06a45f1cf6393e6!8m2!3d47.3571531!4d19.8905793?hl=hu

1. Taxonomic laboratory
2. Three big greenhouses
3. Special greenhouses
4. Warehouse
5. Greenhouse
6. Gene Bank
7. Main Building
8. Shop
9. Company apartments
10. New laboratory
11. Special greenhouses

Wood chips fired boiler

Heating with pellet is a very well automated heating mode (Figure 25), which makes the gas combustion comfort almost accessible, in today's accelerating world. Accurate mechanical design plus the dispensing system and the control of the electronics make pellet heating excellent andfully automatic.

25. Figure: boiler

The pellet is nothing more than pressed wood chip, sawdust. The pelletization is a widespread applied compression technology for dusting materials. The pelletized wood waste has been used for about 20 years for heating. Tree barking is not a simple process: a little dose is good at igniting. We burn the wood with flammable material to ignite. . To have this water removed from the wood, it has to be heated and this process lasts until the water evaporates. This process brakes the combustion, so it's harmful to us. Then the pellet starts to burn. The drier the wood, the easier it will ignite and burn. The fuel should be dried for several years before it is fired. The pellet is doing this against very little moisture for the simple reason that humidity is removed from the material when compressed. The pellet easily ignited, can be easily dispensed. Its moisture content is around 8%. The overall moisture content of the firewood is about 15-20%, because the wood stored in the open air absorbs the moisture content of the air, in dry weather.

Freshly cut wood stores 50-70% water, the calorific value is half of the similar amount of dry material. Thus twice as much is needed to produce the same amount of heat.

IRSA-THERM "B" 35 kW boiler with automatic ignition

For the heating solution of the service homes of the center, I suggest using the pellet-fired boiler offered with a chisel-fired boiler which can utilize a wide range of fuels. The boiler can ultimately be connected to the existing fuel storage and forwarding system. The transformation affects the drive, the conveyor screw and the electric motor, and its cost can be determined by an accurate survey, which of course is done according to the investor's decision. However, given that the manufacturer's fuel supply system can safely solve the crushing of substantially sharper chips at present, and it also offers anti-jamming protection, we recommend that it be applied in this place.

26. Figure: boiler irsa-therm

The Main features of the boiler:

- Three-way protection against backfireing
- Manual chimney cleaning - this is a few minutes a week.
- Independent burner with PLC control
- Built-in automated ignition system
- Flue gas fan
- Fireplace temperature monitoring
- Automatic ignition-controlled, unattended, intermittent operation

Fuel supply:

- necessary conversion of the product - not included in our quotation, a separate evaluation is needed
- installing a factory conveyor into the existing storage area (spring roller, motherboard, screw)

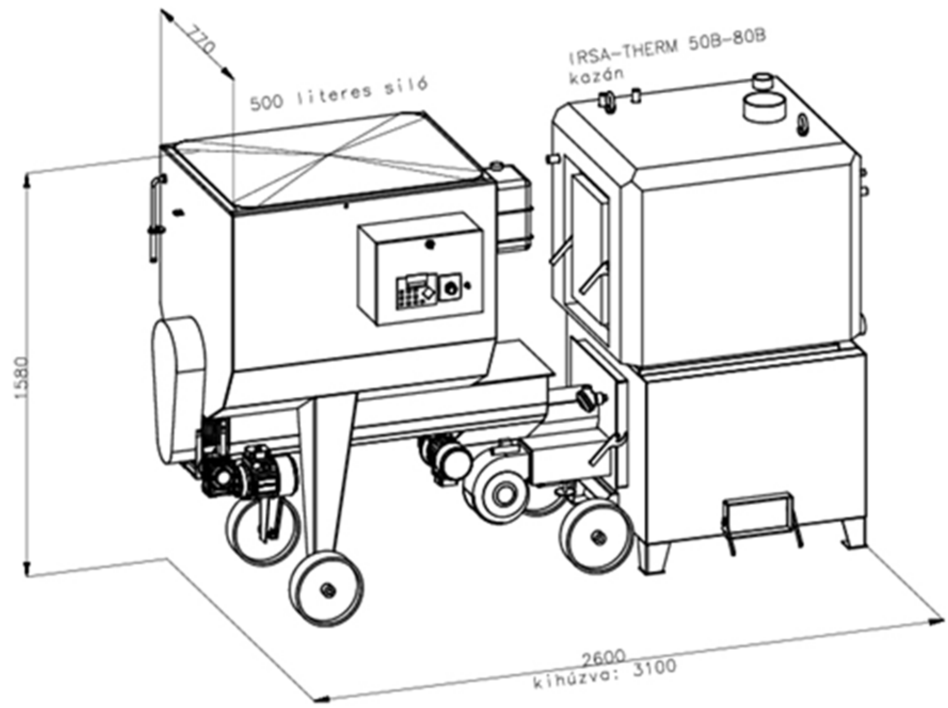
The boiler is suitable for the combustion of the following fuels:

- G 30-50 wood chips
- wood pellets
- seeds of nuts and nuts
- walnuts and almonds
- cleaning by-products (other)

1. Table: Boiler's data

Source: http://www.dolinakft.hu/termekek/btipusu-faapritek-kazanok-76

Type	**IRSA-THERM**
	50B
Heat output kW	35-50
Heating surface m^2	4,8
Water content liter	142
Water pressure max. bar	2
Water temperature max. °C	90
Boiler weight kg	508
Silo weight with burner kg	192
Efficiency%	85-90
Flue diameter in mm	150
Total length of boiler and silo (B) mm	2350
Boiler height (D) mm	1480
Boiler width (A) mm	830
Sewer height (C) mm	1680
Average flue gas temperature: ° C	140-170



27. Figure: Biomass boil

a. Flow water connection (1 ")
b. Return water connection (1")
c. Burner unit
d. Ashless door
e. Cleaning door
f. Chimney (smoke pipe)
g. Thermometer
h. Thermostat
i. Lift eyes
j. Sharpener silo
k. Cover plate
l. Control Box (PLC)
m. Water tank (5 liters)

Other renewable energy sources that could also be used in the case of the Center for Plant Diversity

- Geothermal energy

It is not unimportant that there are old-fashioned buildings in the area of the Center for Plant Diversity, for the heating of which it is necessary to build a complex heating system (underfloor heating), floor-level insulation and masonry insulation for heating with geothermal energy. Without state support, the upgrading of the existing old buildings' heating is not feasible due to the enormous cost of investment.

- Solar energy

In the Center for Plant Diversity there are two modes of operation: either in island mode or photovoltaic power generation connected to a high power network. The island mode is expensive and it has expensive storage capacity even though the TESLA batteries are cheaper. If the contract is concluded with a power supplier, the power generation and re-utilization takes place over and over again. This gives you the opportunity to use the energy you generate later, so you can get energy from the sunshine. If you contract with a power supplier, you can save the battery charge. It is advisable to set up an electrical heating system by specific buildings.

- Wind Energy

Firstly, data on annual wind measurements should be obtained, after which it is worth planning wind energy. The Center for Plant Diversity is classified as an area of unfavorable wind conditions. An additional obstacle to the installation is the direct vecinity of the NATURA 2000 sites, an area of protection for birds, which is a exclusion for wind energy utilization.

- Hydropower

There is no river in the vicinity of a 30 km radius that would have sufficient water flow to operate the turbine, so it is not possible to design such an energy generating plant in the region of the Center for Plant Diversity.

1.9. Description of the final solution.

The geographical location and the terrain, the hydrographic features of institution, the proximity to NATURA 2000 area significantly determines what alternative energy can be used to change or supplement fossil energy use. For the foregoing reasons, wind power and hydropower are not feasible.

As the institute has horticultural, arable and wild plant genetic preservation tasks, its aim is not mass production but the production of quality propagating material . Only a limited amount of hereditary material is collected and stored. In addition, the plants produced are unnecessary for the institution, some of them are actually destroyed or sold to workers at production cost. The utilization of biomass that was unnecessary during technological production for energy production could lead to significant savings in operating costs. I find the energy of the bio-mass more economical with the introduction of wood-scavenging boilers. It depends on the financial situation of the institution how much investment can be planned. An amount of biomass is available for the institution annually, so that all the heating of its heated rooms can be replaced by biomass firing. Beside the main building, the building of the financial department can directly be attached. Building a heating system would be solved with a heating plant, only the financial constraints of the institution will restrain the implementation. It would be desirable to build an entirely new heating system based on biomass on a tendering system. A significant advantage is the existence of mechanization, the carrying of biomass produced for processing purposes. For easy storage, bales that are considered as by-products can be baled with the baler, stored in existing containers until utilization without any deterioration. This existing equipment would mean significant savings. If it were to be carried out, it would also serve as a demonstration facility for regional farms and family farms. Families who deal with agriculture and have the opportunity to collect biomass as a by-product will find a copyable example for replacing fossil energy production with biomass energy. They already sell straw boilers in commerce at affordable prices, without any major conversion to the mixed-fired boiler system.

1.10. Impact of the project for the rural development

Rural Development Effects of Biomass

Biomass production has a significant rural development effect, this effect is through the production and utilization that can lead to increasing regional competitiveness. Its role is supported by European Union's tenders and financial resources.

1. The production and use of the biomass energy creates new jobs. *Boiler operators are needed,* the *Center for Plant Diversity employs 3 people for this position.*
2. In the most disadvantaged micro-regions, it is possible to earn a lasting income. The *incineration of agricultural by-products and cutting waste means extra income for several farmers in the area.*
3. It can have a lasting role in retaining the population. *See points 1 and 2. and it improves the quality of the environment.*
4. Increases local employment. *See points 1 and 2.*
5. Increases the competitiveness of regions and micro-regions. *Quite obvious. In addition to the cost of maintaining local governments and institutions is reduced by improving energy efficiency.*

There are some other things to be considered which are generally true and related to the area in question as well:

6. It has a lasting positive impact on regional development.
7. It is best suited to the requirements of sustainable development, since they do not limit future opportunities because of the rapid redesign.
8. It increases the country's security of supply as a domestic source of energy.
9. As a domestic source of energy, it reduces import dependency.
10. The demand for the close co-operation and co-operation between landowners, landlords, heating owners, municipalities, micro-regions contributes to the development of a new, more efficient, more rational mentality.

Creating targeted co-operation with the Plant Diversity Center mutually reinforces each other's reputation. Professional and tourism programs within the institute is possible, and the city can provide a broader, more informal setting for the Center for its activities and values.

In addition to the local government and the Plant Diversity Center, local residents, businesses and schools can be involvedThe program would increase social responsibility, strengthen urban identity, create community spaces.

1.11. Summary

The institution depends significantly on the use of fossil energy, the use of electricity is significant. There is no infrastructure for the renewable energy source yet.

Because of its environmental condition wind and water energy can not come to mind. It would be best to switch to geothermal energy, but it is costly, so it is not economically feasible without state aid. It is a goal to switch to solar energy. The institution has submitted a tender for the use of energy sources, which is expected to be evaluated, with the advantage of low cost maintenance and low need for serviceing.

The annual production of biomass in the Institution area is so large that fossil fuels can be significantly replaced with them. Especially since the biomass produced comes from secondary sources. Shipping and storage costs are not significant. In a very short time, the amount spent will be reimbursed. The use of professional staff for the technology is desirable, so it is advantageous taking into account the workflows that can be carried out in the agricultural sector in winter.

The environment is not burdened by this alternative energy supply and is sustainable in the long term. Making technology available for public visitors would have a positive impact on the environment, or even the example could be copied by other (public) institutions.

The survey data show that people have little knowledge of alternative energy use. They are not forced to learn these technologies. Fossil fuels have also just returned from fat burning because they are cheaper. The investment costs of alternative energy production tools would have to be considerably cheaper.

Back in time houses were heated up by a fireplace; today this can be considered an efficient biomass burner. The furnaces also operated with the primary and secondary biomass of the farms. The ash produced was used for soap production due to its strong alkalizing effect.

I hope that in the coming decades energy use will be more environmentally conscious .

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Calculations

2. Calculations

Calculations and design

For getting data that support decision making in the field of using heating systems based on renewable energy sources I did some calculations for justification and project feasibility. I did not design a completely new heating system. My suggestion in the project is to switch from fossil fueling of the heaters/boilers to biomass (woodchips and pellets).

The monthly average temperature data along with the list of lowest temperatures measured for the period in question (table 2.) show that installing heating systems in different facilities of the PDC is a must in the classical heating period typical of Hungary generally and the region more specifically.

2. Table: Temperature data

Temperature data 01.09.2015 - 31.04.2016								
Description	**September**	**October**	**November**	**December**	**January**	**February**	**March**	**April**
Monthly average temperature	15,8	13,2	8,2	1,6	2,7	5	9,6	13,4
Lowest temperature	5,5	-1,6	-3,4	-7,6	-10,4	-8,4	-2,9	2,7

Source: www.metnet.hu

The heating system in place at the moment is fossil fuel based and the fuel consumption is shown in table 3. One can see the consumption levels are in line with the dynamics of the temperature shown in the previous table, thus the need for heating is double justified. In my calculations I did not focus on technical specifications and special requirements of the different investigated buildings ; it is quite obvious that the fine-tuning of the heating of a laboratory may be completely different from that of a shop or a gene bank.

3. Table: Fossile oil

Place	**Fuel oil consumption 01.09.2015 - 31.04.2016**									Energy MJ/ kWh	Boiler power-kW*
Gene Bank	200	600	700	900	1650	1000	650	600	6300	264 600 / 73 500	2 x 50
New Laboratory	1500	1800	2000	2100	2128	2354	2073	2919	16874	708 708 / 196 863	2 x 130
Main Building	2100	2500	2800	3100	3400	3200	2700	2300	22100	928 200 / 257 833	2 x 170
Shop	200	500	1100	1000	1000	1000	1100	300	6200	260 400 / 72 333	1 x 96
All	**4000**	**5400**	**6600**	**7100**	**7178**	**7554**	**6523**	**6119**	**50474**		

Source: January 1, 2015 - March 31, 2016 data available from the company, others are approximations, estimates.

* In 83% of the year, the actual heat demand is lower than half the maximum demand. This means that for these periods boilers can be run on renewable energy sources, biomass in our case.

Budget and economic analysis

3. Budget

In table 4. I am demonstrating the financial justification of switching to renewable energy sources. The numbers shown talk for themselves, the calculation methodology followed is the one below:

* Wood chips cost = 4000 Ft/m^3 - 1 m^3 wood chips weight 300 kg, energy 12 MJ / kg

Cost with oil = Use energy(MJ) * 7,4 Ft/MJ-oil

Cost with wood chips = Use energy(Mj) * 1,33 Ft/MJ-wood chips

Savings = Cost with oil - Cost with wood chips

4. Table: Savings

Place	Use energy / MJ /	Ft/ MJ - oil	Ft/ Mj -wood schips*	Cost with oil	Cost with wood chips	Savings
Gene Bank	264600	7,4	1,33	1 958 040 Ft	351 918 Ft	1 606 122 Ft
New Laboratory	708708	7,4	1,33	5 244 439 Ft	942 582 Ft	4 301 857 Ft
Main Building	928200	7,4	1,33	6 868 680 Ft	1 234 506 Ft	5 634 174 Ft
Shop	260400	7,4	1,33	1 926 960 Ft	346 332 Ft	1 580 628 Ft
All	**2161908**			**15 998 119 Ft**	**2 875 338 Ft**	**13 122 781 Ft**

Project plans

4. Project plans

For the strategic and scientific importance of the analysed company the plans of the buildings investigated for alternative heating solutions were only available for viewing in person. A permit was not granted for including them in the paper.

Figure list

Table list

Annexes

ANNEX I. Questionnaire

Dear Responder!

As a student of Environmental engineer of agricultural engineering - in my thesis I will examine the level of familiarity of renewable energy technologies. Answering the questions is voluntary and anonymous. I, the undersigned, undertake to use the responses in aggregate and solely for the purposes of this research. Please help me by filling out the questionnaire here. If you want to know the results of the survey, please enter your email address at the end of the questionnaire.

Thank you for your cooperation! Dóra Lénárt

Introductory questions

Q1. Which of the following energy sources did you hear about?
(Please tick the appropriate answers!)

- Geothermal energy
- Solar Energy
- Hydropower
- Wind Energy
- None of them

Q2. How did you hear about these energy sources?
(Please tick the appropriate answers!)

- About friends, friends, relatives
- Written press
- Internet
- the television

Q3. What comes to your mind first about the use of renewable energies?
(Please tick the correct answer as you like)

- Environment
- Access to more work by agricultural entrepreneurs
- On-site energy
- High investment cost

Q4. Do you know which renewable energy sources you are using in your environment / micro-region?
(Please tick the appropriate answers!)

- Biomass
- Biogas
- Geothermal energy
- Municipal waste
- Solar Energy
- Do not use it
- I do not know

Q6. What do you think are the main arguments for using renewable energy?
(Please tick the appropriate answers!)

- Environmentally friendliness, climate protection
- Less fossil energy dependence
- Increasing security of energy supply
- I can produce energy in my own house
- It is a good investment due to the increase in the price of fossil energy
- I do not know

Q7. How much are the following factors influence investments ?
1. Not at all - 5 To a great extent

- Slow return on investment -1- 2- 3- 4- 5-
- Lack of financial opportunities 1- 2- 3- 4- 5-
- Construction, technical problems 1- 2- 3- 4- 5-
- Need to Recruit Credentials -1- 2- 3- 4- 5-
- The technology is not sufficiently mature -1- 2- 3- 4- 5-

Q8. Which energy source is the most widespread use of renewable energy in your country?
(Please tick the correct answer!)

- Solar Energy
- Wind Energy
- Hydropower
- Biomass
- Geothermal

Q9. Do you know what biomass means?
(Please tick the correct answer!)

- yes
- no

Q10. Please tick the true statement. (Please tick the correct answer!)

- The calorific value of biomass is lower than the calorific value of carbon
- The calorific value of the biomass is similar to the calorific value of the coal, but it is a renewable energy source therefore its use is more advantageous
- The calorific value of biomass is slightly better than the calorific value of coal
- The calorific value of biomass is twice the carbon calorific value

Responder data

Q11. Your gender?
(Please tick the correct answer!)

- man
- woman

Q12. Your age?
(Please tick the correct answer!)

- 18 to 25 years
- 26 to 34 years
- 35-44 years

- 45-54 years
- 55-64 years
- over 65 years of age

Q13. In which county is the settlement where you live?
(Please tick the correct answer!)

- Baranya County
- Bács-Kiskun County
- Békés county
- Borsod-Abaúj-Zemplén county
- Csongrád county
- Fejér county
- Győr-Moson-Sopron County
- Hajdú-Bihar county
- Heves county
- Jász-Nagykun-Szolnok County
- Komárom-Esztergom county
- Nógrád county
- Pest county
- Budapest
- Somogy county
- Szabolcs-Szatmár-Bereg county
- Tolna County
- County of Vas
- Veszprém county
- Zala County

Q14. What is the type of settlement where they live?
(Please tick the correct answer!)

- Capital
- Other city
- Village

Q15.Your highest educational level?
(Please tick the correct answer!)

- I have not completed primary school education
- Completed primary school
- Vocational school,
- Secondary Grammar School
- High School
- Higher vocational training
- College
- University
- Accredited vocational training
- Technical School

Q16. What is your occupation?

(Please tick the correct answer!)

- Student
- Employed (full or part time)
- Child care (has a job)
- Child care (no workplace)
- Work in own business
- Housewife
- I live from casual jobs and orders
- Unemployed
- I am a public worker
- Living with social assistance
- I am retired
- Disability Retirement
- Never worked

Q17.Your existential status?
(Please tick the correct answer!)

- Wealthy
- No financial problems
- I have a comfortable financial situation
- I need strict control ove my money matter to make ends meet
- Poor

REPORT OF THE CASE STUDY ON RENEWABLE ENERGIES TO LOCAL DEVELOPMENT NATIONALLY IMPLEMENTED

On-grid photovoltaic installation for a pig farm

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Bacău, 2017

Contents of the project

Memory of the project

1. Introduction to the Project

1.1. Objective

The main objective of the project is to provide the necessary information in order to design and apply a photovoltaic system that is able to accommodate a pig farm, located in the North-Eastern part of Romania. The energy must suffice the use of electricity for 7 days a week.

The North-Eastern part of Romania lacks renewable energies and this photovoltaic system may also be an example to other industries, helping them to make a move towards green energy, towards a type of energy that doesn't harm the environment.

In a similar time, all energy sources have some effect on our condition. This project makes sure to take them all into consideration, in order to have the slightest negative impact over the soil, air, generally the rural area in which the photovoltaic system will be installed.

The project also takes into consideration the rate of unemployment in Romania, as well as the way in which the education system works now and how it may be improved in the near future.

1.2. Scope

The present study case is based on a self-sustained photovoltaic system, able to provide a pig farm in the area of Slatina, Suceava county, with green energy. The case study takes into consideration every aspect: the best choice for solar panels, considering the needs but also the economic situation, the inverters needed, system losses, but also has an economical point of view, considering materials used, costs or payback.

Social and environmental issues are also discussed in the case study, as it is an important matter to each and every one of the projects of this kind.

1.3. Precedents

The case study emerges from the fact that Romania is more and more interested in renewable energies. Not only this, but the business-owners realized that going for renewable energies seems to be the future. Not only that it helps the environment, but also the payback is fair and the systems are profitable after a few years. The government also motivates the business-owners by giving them green certificates, an additional gain for the “clean energy” that they deliver into the main network.

Green energy in Slatina village is still at the beginning, not many owners having the funds to adopt this type of energy. Even so, there are many farms in Transylvania, for example, that had a lot of success over green energy. This study case is also a source of motivation to the other farms in the region and in the country itself, as it is a sustainable project that is running for two years already.

Romania itself has been very active in the renewable energies sector. In the past few years, Romania registered a “boom” in renewable energies, capable in 2013 of generating 1794 MW, from only 13.1 MW four years earlier.

Wind energy, solar energy and hydroelectric producers have to buy green certificates for every MW/h which they can sell. Having installed more than 2000 MW from renewable energies and about the same being built today, Romania is close to the target of providing 24% of the energy it needs from renewable sources, until 2020.

1.4. State-of-art in the problem domain

1.4.1. Greenhouse impact

For 2.5 million years, the Earth's atmosphere has varied, cycling from ice-ages to hotter periods. However, in the most recent century, the planet's temperature has risen strangely quick: around 1.2-1.4 degrees Fahrenheit. Researchers trust it's human movement that is driving the temperature up; a procedure known as "global warming".

The greenhouse impact starts with the sun and the energy it emanates to the Earth. The Earth and the climate assimilate some of this energy, while the rest is emanated once more into space. Greenhouse gasses in the air trap some of this energy and reflect it back, warming the Earth.

Researchers now trust that the greenhouse effect is being intensified by the additional greenhouse gasses that people have discharged. Evidence from an unnatural weather change incorporates both a long haul warming pattern and a few late years that have broken the record for the hottest year in the current history. In the meantime, readings taken from ice caps demonstrate that the greenhouse gasses carbon dioxide and methane have hit their most abnormal amounts. Cold ocean ice is additionally contracting. As indicated by NASA's reviews, the degree of ice ocean ice has declined around 10% over the most recent 30 years.

What's less sure is the thing that rising temperatures mean for the planet *(Figure 1)*. Some atmosphere models foresee unpretentious changes, others gauge rising ocean levels, which could surge waterfront zones far and wide. Climate examples could change, making tropical storms more regular. Serious dry seasons could turn out to be more typical in warm ranges and species not able to adjust to the changing conditions could confront eradication.

Even if there is still much to be learnt about a dangerous atmospheric deviation, numerous associations support cutting the ozone with harming substance discharges to lessen the effect of a worldwide temperature alteration. Consumers can help by sparing energy around the house, changing to fluorescent lights and driving less miles in the auto every week. These basic changes may help keep the Earth cooler later on.[1]

Based on a 2016 report, renewable energies contributed 19.2% to human's global energy consumption.

The wind, the sun, and Earth are wellsprings of sustainable power source. These energy sources actually reestablish, or renew themselves. Wind, daylight, and the Earth have energy that changes in ways we can see and feel. We can see and feel confirmation of the exchange of energy from the sun to the Earth in the daylight sparkling on the ground and the glow we feel when daylight sparkles on our skin. We can see and feel confirmation of the move of energy in wind's capacity to maneuver kites higher into the sky and shake the leaves on trees. We can see and feel proof of the move of energy in the geothermal energy of steam vents and geysers. Individuals have made diverse approaches to catch the energy from these inexhaustible sources:[2]

- Solar energy;
- Wind energy;
- Geothermal energy;
- Biomass energy;
- Hydroelectric energy;
- Tidal energy;
- Wave energy.

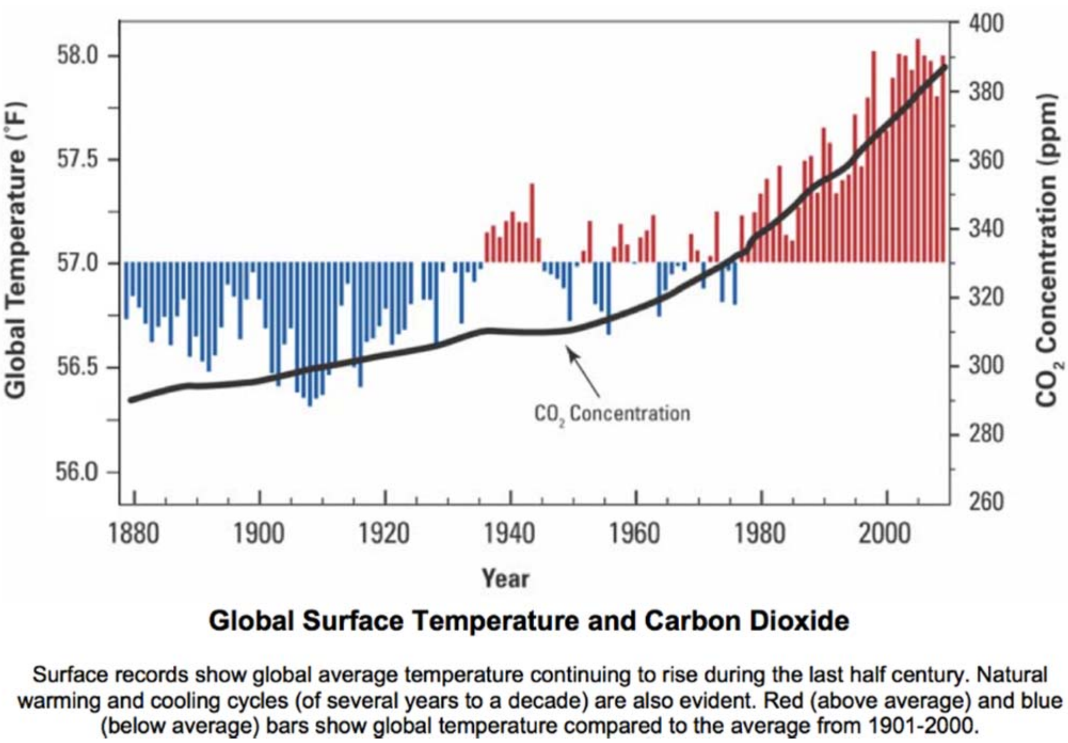

Figure 1. Global Surface Temperature and Carbon Dioxide

(Source: http://www.ucsusa.org/global_warming/science_and_impacts/science/global-thermometer-still-climbing.html)

Romania itself has been very active in the renewable energies sector. In the past few years, Romania registered a “boom” in renewable energies, capable in 2013 of generating 1794 MW, from only 13.1 MW four years earlier.

Wind energy, solar energy and hydroelectric producers have to buy green certificates for every MW/h which they can sell. Having installed more than 2000 MW from renewable energies and about the same being built today, Romania is close to the target of providing 24% of the energy it needs from renewable sources, until 2020.

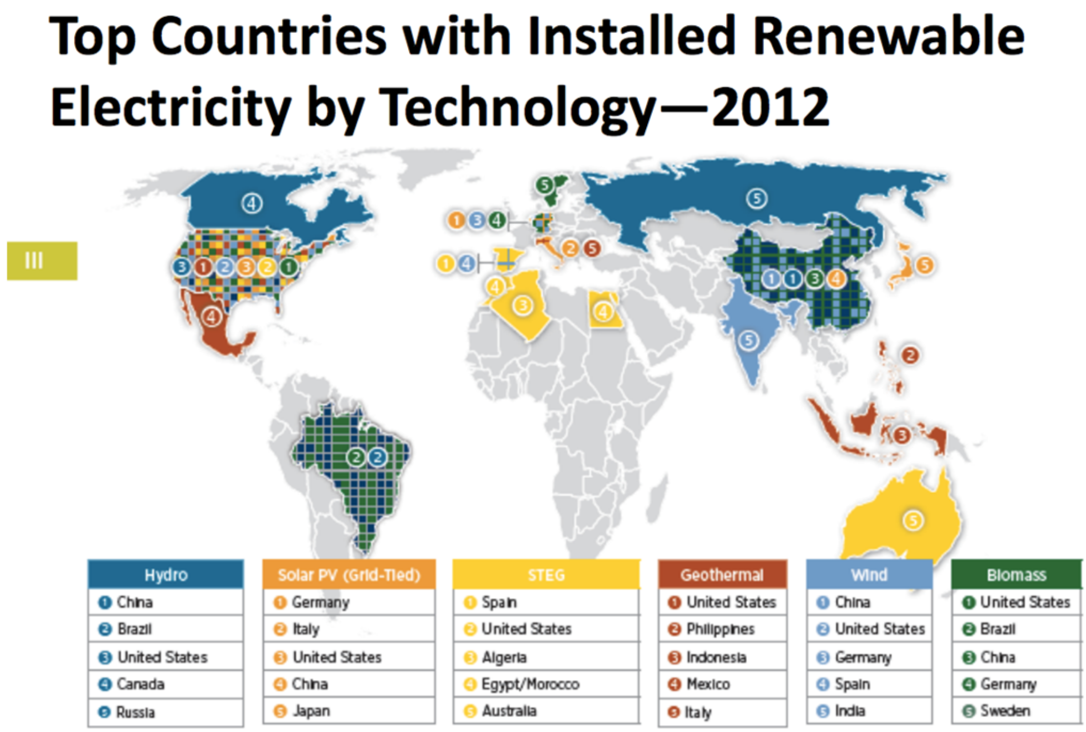

Figure 2. Clean Energy World Ranking

(Source: https://cleantechnica.com/2014/01/03/nrel-23-global-electricity-generation-supplied-renewable-sources/)

The graph above *(Figure 2)* shows the renewable energies used by the countries who embrace these technologies the most. Depending on the geographical position of each country, they tend to use one or more types of renewable energies. For example, Russia only uses hydro energy, while the United States of America use all of them: hydro energy, solar panels, STEG (he main activities of *STEG* are the design, construction, operation and maintenance of installations of renewable energy and cogeneration), geothermal energy, wind energy and biomass.

Not only that the usage of renewable energies helps the planet, but it’s also beneficial in an economical way, as it provides jobs *(Figure 3).* We can see in the figure above that in 2012, nearly 6 million people had jobs in this sector. Also, we can see that solar energy and biofuels provide the most jobs (more than a million each) – *Figure 4*.

ESTIMATED DIRECT AND INDIRECT JOBS IN RENEWABLE ENERGY WORLDWIDE, BY INDUSTRY

Technologies	Global	China	EU-27	Brazil	United States	India	Germany	Spain
	Thousand Jobs							
Biomass[a]	753	266	274		152[f]	58	57	39
Biofuels	1,379	24	109	804[e]	217[g]	35	23	4
Biogas	266	90	71			85	50	1
Geothermal[a]	180		51		35		14	0.3
Hydropower (Small)[b]	109		24		8	12	7	2
Solar PV	1,360	300[d]	312		90	112	88	12
CSP	53		36		17		2	34[i]
Solar Heating/ Cooling	892	800	32		12	41	11	1
Wind Power	753	267	270	29	81	48	118	28
Total[c]	**5,745**	**1,747**	**1,179**	**833**	**611**	**391**	**378[h]**	**120**

Figure 3. Global Renewable Energies Jobs

(Source: https://hub.globalccsinstitute.com/publications/renewables-2013-global-status-report/wind-power)

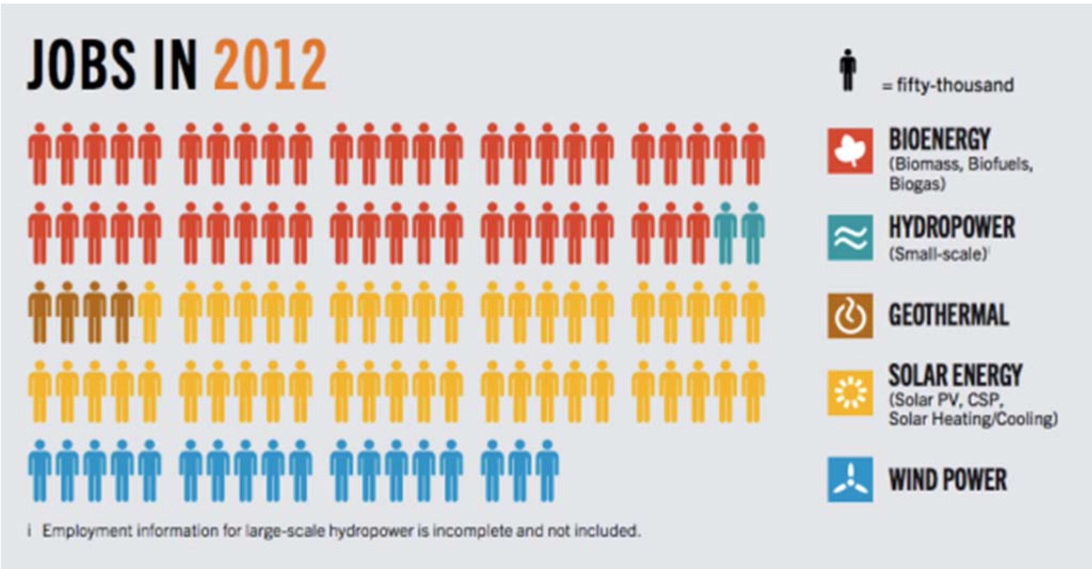

Figure 4. Jobs in 2012 (Renewable Energies)

(Source: https://hub.globalccsinstitute.com/publications/renewables-2013-global-status-report/wind-power)

1.4.2. Solar Energy

Consistently, the sun pillars onto Earth all that could possibly be needed energy to fulfill worldwide energy requirements for a whole year. Sunlight based energy is the introduction used to deal with the sun's energy and make it useable. Today, sadly, the innovation creates short of what 0.10% of worldwide energy request.

We as a whole know about photovoltaic cells or sun powered boards *(Figure 5)*, found on things like space crafts, housetops, handheld calculators, recently outlined autos or big fields. The cells are made of semiconductor materials like these found in PC chips. At the point when the sunlight hits the cells, it thumps electrons free from their molecules. As the electrons course through the cell, they produce power.

Another system utilizes moveable mirrors to concentrate the sun's beams on an authority tower, where a collector sits. Liquid salt moving through the collector is heated to run a generator.

Other sunlight based advancements are aloof. For instance, huge windows set on the sunny side of a building permit daylight to warmth spongy materials on the floor and walls. These surfaces then discharge the warmth during the evening to keep the building warm. Likewise, permeable plates on a rooftop can warm fluid in tubes that supply a house with heated water.

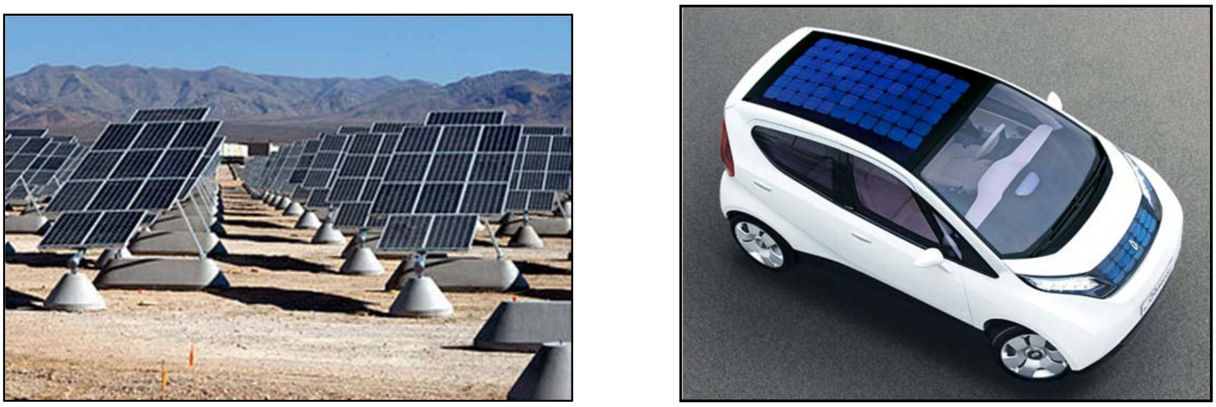

Figure 5. Uses of Solar Panels

(Source: https://en.wikipedia.org/wiki/Solar_power_by_country)

Sun based energy is commended as a limitless fuel source that is contamination and frequently noise free. The innovation is additionally flexible. For instance, sun oriented cells create energy for far-out spots like satellites in Earth circle and lodges somewhere down in the mountains as effortlessly as they can control downtown building and modern autos.

Sunlight based energy doesn't work around night time without a capacity gadget, for example, a battery, and shady climate can make the innovation questionable amid the day. Sun oriented advances are likewise exceptionally costly.

In spite of the disadvantages, sun powered energy utilize has surged at around 20 percent a year in the course of recent years, because of quickly falling costs and pick up in productivity. The United States, Germany and Japan are significant markets for sun oriented cells. If used properly, solar power can frequently pay for itself in five to ten years.[3]

The cost of acquiring a photovoltaic system was extremely big two-three decades ago *(Figure 6)*. That is not the case nowadays since newer and newer technologies are being discovered. This makes solar energy a worthy adversary to the power plants. Indeed, the power plants are still cheaper on short-term and many people still use the system that harms our planet, but in a long-term view solar energy is much cheaper.

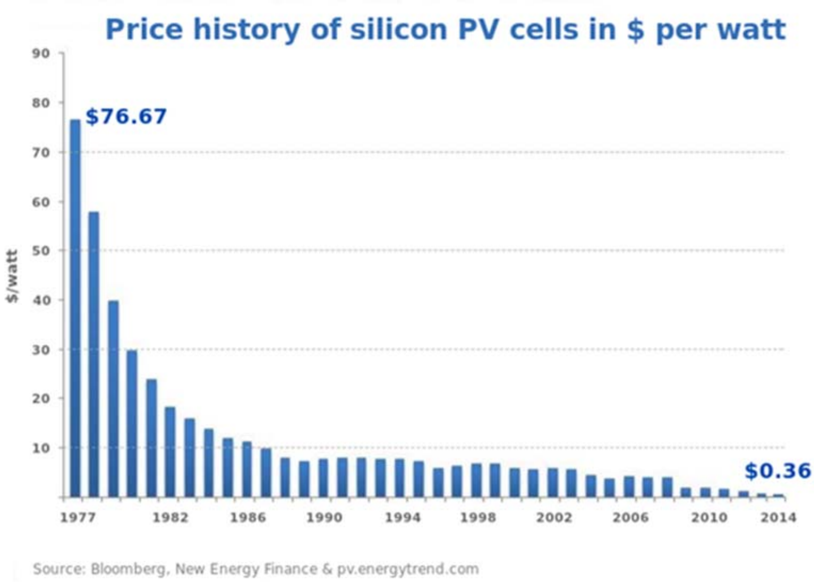

Figure 6. Price history of silicon PV cells

(Source: https://www.forbes.com/sites/peterdiamandis/2014/09/02/solar-energy-revolution-a-massive-opportunity/#66a224a76c90)

The governments are encouraging people to go for solar energy. If the users have too much energy, they can send it to the system and the government company pays the users per kW, making this a very profitable option for them.

While the innovation behind sun powered energy may appear to be highly complicated, when broken down, how sun based power works is straightforward – especially in a grid connect situation as it just requires a couple of parts introduced in a home or business *(Figure 7)*.

- The sun shines on the solar panels, creating DC electricity;
- The DC electricity is nourished into a solar inverter that converts it to 240V 50Hz AC electricity.
- The 240V AC electricity is used to power appliances in the home.
- Surplus electricity is nourished again into the main grid.

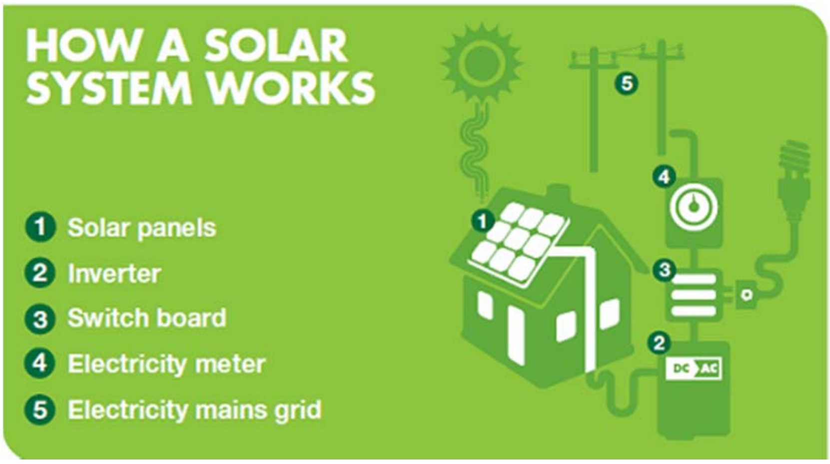

Figure 7. How a solar system works

(Source: http://www.energymatters.com.au/residential-solar/how-solar-power-works/)

At whatever point the sun sparkles (and even in cloudy climate), the sun based cells produce electricity. The grid connect inverter changes the DC power created by the sun based panels into 240V AC power, which can then be utilized by the property/family.

In the event that a system is delivering more power than is being consumed, the surplus is fed into the mains power grid. Some power organizations will meter the power fed into the system by your system and give a credit on your bill. This measure taken by the electricity companies encourages people to have their own photovoltaic system. Providing a credit on the bills means that the payback time is reduced considerably.

When the solar cells are not producing power, for example at night, your power is supplied by the mains power grid as usual. The energy retailer charges the usual rate for the power used.

1.4.3. Photovoltaic panels

The history of photovoltaic panels starts in the 19th century when it is observed that the presence of daylight is capable of creating usable electrical energy. Solar cells have gone ahead to be utilized as a part of numerous applications *(Figure 8)*. They have historically been utilized in situations where electrical power from the grid was inaccessible.

Figure 8. Roof - photovoltaic system

(Source: http://www.rfidwizards.com/)

In the 1860s, an electrician called Willoughby Smith was trying submerged transmit lines for issues utilizing a material called selenium. By luck, he found that power went through selenium extremely well when it was in light, yet it didn't if the selenium was in darkness.

In the late 1870s, two American researchers, William Adams and Richard Day, ended up noticeably intrigued by this. They soon found that the sun's energy makes a stream of power in selenium.

All through the accompanying ten years, analysts strived to see more about selenium. By then in the mid-1880s, Charles Fritts envisioned the main PV cell by putting a layer of selenium on a metal plate and covering it with a gold leaf *(Figure 9)*. Put in the sunlight, this cell made fundamentally more noteworthy power yet inadequate to be useful. A couple of specialists ended up being incredibly energized for this creation, in any case, however most analysts gave watchful thought to it. Some idea it was just a pointless gimmick. In light of what they thought about dim materials getting the sun's glow energy, they couldn't see how a cell that wasn't dim could use the sunshine to create power.

It didn't help that PV advancement was fighting with other better made developments that were making power. Steam-driven power generators (or "dynamos" as they were called at the time) had been around since Michael Faraday imagined the principle electromagnetic generator in 1831.

Prior to the finish of the nineteenth Century, this advancement had upgraded an impressive measure. In 1882, Thomas Edison opened his first electric power station in New York. It used coal to make steam.[4]

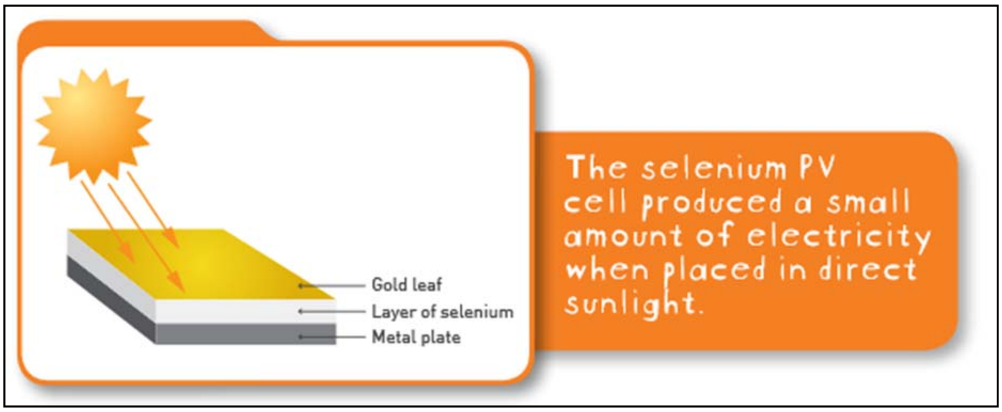

Figure 9. Selenium PV cell

(Source: http://www.schoolgen.co.nz/pdf/D2%20solar%20factsheet.pdf)

❖ *Types of Solar Panels*

The rising interest for solar power is fueling progresses in research work of solar based PV innovation. Nonetheless, from multiple points of view, major solar energy producing innovation hasn't changed much since the presentation of the monocrystalline sun powered panel in the nineteen-fifties. It's just shown signs of improvement, as changes in proficiency, quality and flexibility keep on developing.

Monocrystalline Silicon Solar Cells

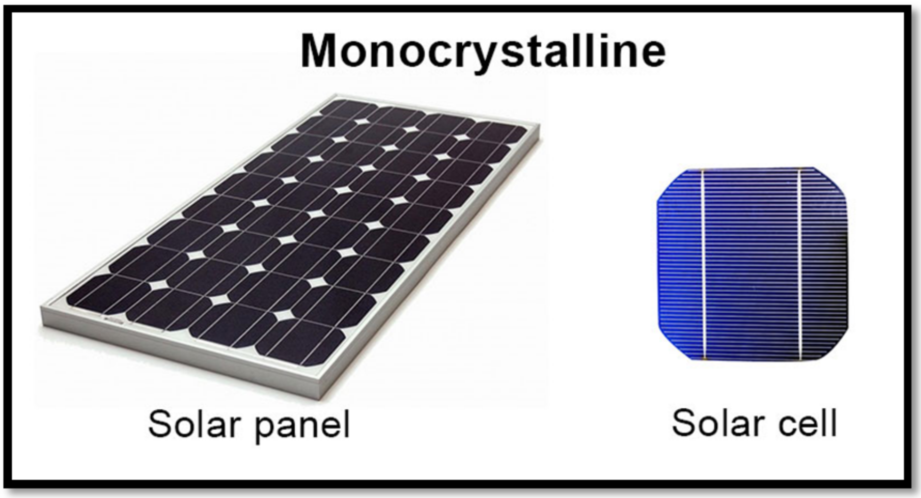

Figure 10. Monocrystalline Silicon Solar Cell

(Source: http://www.ledwatcher.com/solar-panel-basics-and-types-of-solar-panels-used-in-flood-lights/)

Generally, monocrystalline silicon solar PV *(Figure 10)* is the best innovation to convey productivity, as calculated by wattage output identified with the panel's size. In any case, this efficiency can accompany costs. The best value is solar PV innovation is polycrystalline silicon, offering proficiency levels close to monocrystalline panels, but at half the costs in some cases.

Monocrystalline solar is made by growing a solitary crystal. Since these precious stones are generally an oval shape, monocrystalline boards are cut into the particular patterns that give them their unmistakable appearance: the cut silicon cells uncover the missing corners in the framework like structure. The precious stone system in a monocrystalline is even, delivering an unfaltering blue shading and no grain marks, giving it the best virtue and most astounding efficiency levels.

Advantages:

- Monocrystalline sunlight based panels have the most astounding productivity rates since they are made out of the higher-grade silicon. The productivity rates of monocrystalline sun oriented panels are regularly 25%;
- Monocrystalline silicon solar panels are space-productive. Since these sun oriented panels yield the most noteworthy power outputs, they likewise require minimal measure of space contrasted with some other sorts. Monocrystalline sun powered panels create up to four times the measure of power as thin-film sun based boards;
- Monocrystalline sun based panels last the longest. Most sun oriented panel producers put a 25-year guarantee on their monocrystalline sun based panels;
- Have a tendency to perform superior to anything comparably evaluated polycrystalline sunlight based panels at low-light conditions.

Flaws:

- Monocrystalline solar panels are the costliest. From a monetary angle, a sun powered panel that is made of polycrystalline silicon (and sometimes thin-film) can be a superior decision for a few property holders;
- On the off chance that the sun oriented panel is somewhat secured with shade, dirt or snow, the whole circuit can separate. Consider getting smaller scale inverters rather than focal string inverters on the off chance that you think coverage will be an issue. Small scale inverters will ensure that not the whole sunlight based cluster is influenced by shading issues with just a single solar panel;
- The Czochralski procedure is utilized to deliver monocrystalline silicon. A lot of the first silicon winds up as waste;
- Monocrystalline sun powered panels have a tendency to be more proficient in warm climate. Execution suffers as temperature goes up, however less so than polycrystalline sun based panels. For most property owners, temperature is not a worry.

Polycrystalline Silicon Solar Cells

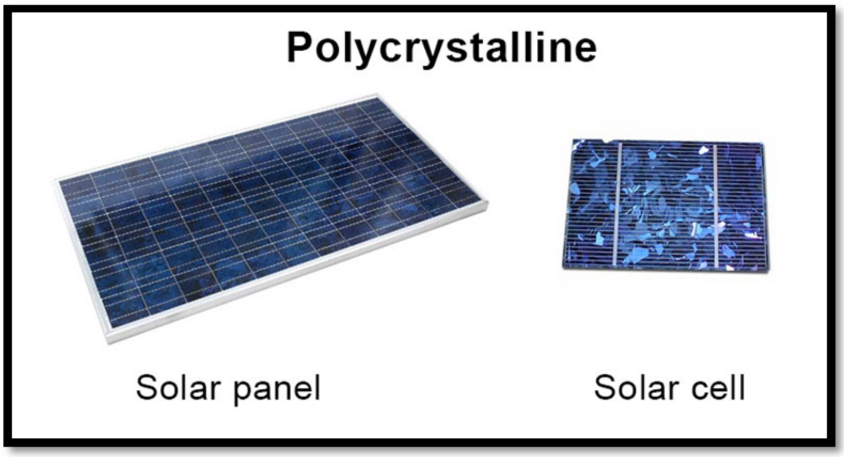

Fig 11. Polycrystalline Silicon Solar Cell

(Source: http://www.ledwatcher.com/solar-panel-basics-and-types-of-solar-panels-used-in-flood-lights/)

Polycrystalline silicon, also known as polysilicon or poly-Si, is a high purity polycrystalline form of silicon, used as a raw material by the solar photovoltaic and electronics industry.

Polycrystalline silicon is the key feedstock in the crystalline silicon based photovoltaic industry and used for the production of conventional solar cells. For the first time, in 2006, over half of the world's supply of polysilicon was being used by PV manufacturers. The solar industry was severely hindered by a shortage in supply of polysilicon feedstock and was forced to idle about a quarter of its cell and module manufacturing capacity in 2007. Only twelve factories were known to produce solar-grade polysilicon in 2008. However, by 2013 the number increased to over 100 manufacturers. Monocrystalline silicon is higher priced and a more efficient semiconductor than polycrystalline.

The first sun powered panels based on polycrystalline silicon, which likewise is known as polysilicon (p-Si) and multi-crystalline silicon (mc-Si), were acquainted with the market in 1981. Not at all like monocrystalline-based sunlight based panels, polycrystalline sun powered panels don't require the Czochralski procedure. Crude silicon is liquefied and filled a square form, which is cooled and cut into flawlessly square wafers.

Advantages:

- The procedure used to make polycrystalline silicon is more straightforward and costs less. The amount of waste silicon is less contrasted with monocrystalline;
- Polycrystalline sun oriented panels have a tendency to have somewhat lower warmth resistance than monocrystalline solar panels. This actually implies they perform worse than monocrystalline sun based boards in high temperatures. Warmth can influence the execution of sunlight based panels and abbreviate their life expectancy. Be that as it may, this impact is minor, and most mortgage holders don't have to consider.

Flaws:

- The efficiency of polycrystalline-based solar panels is ordinarily 17-18%. In light of lower silicon purity, polycrystalline solar panels are not exactly as productive as monocrystalline sun based panels;
- Low space-efficiency. You, for the most part, need to cover a bigger surface to yield an indistinguishable electrical power from you would with a sunlight based board made of monocrystalline silicon. Be that as it may, this does not mean each monocrystalline sun based panel performs superior to those in view of polycrystalline silicon.;
- Monocrystalline and thin-film solar panels have a tendency to be all the more aesthetically satisfying since they have a more uniform look contrasted with the spotted blue shade of polycrystalline silicon.[5]

Thin Film Solar Cells

Thin film panels are a totally different technology to Mono and Poly crystalline panels. They are a new technology compared to Mono and Polycrystalline cells and would not be considered a mature technology as vast improvements in this technology are expected in the next 10 years.

A thin film panel can be identified as having a solid black appearance. They may or may not have a frame, if the panel has no frame it is a thin film panel.

Figure 12. Thin film solar cells

(Source: https://www.solarmarket.com.au/buying-tips/choosing-the-right-system/solar-panel-technologies/)

Construction

Thin film panels are made by depositing a photovoltaic substance onto a solid surface like glass. The photovoltaic substance that is used varies and multiple combinations of substances have successfully and commercially been used. Examples of the most common photovoltaic substances used are:

- Amorphous Silicon;
- Cadmium Telluride (CdTe);
- Copper indium gallium selenide (CGIS);
- Dye-sensitized solar cell (DSC);

Each of the above are known as different panel 'types' but all fall under the umbrella of being a Thin Film panel.

Performance

Thin film cells have got a reputation as being the 'worst' of the solar panel technologies because they have the lowest efficiency. However, this is only because they have a lower power efficiency which only means they require the most space for the same amount of power. Since they are becoming the cheapest panels to produce because of the low material costs for thin film they are quickly becoming the more economically efficient panel types.

Advantages:

- Typically, commercial panels sit at 20% efficiency;
- Far less affected by shading than Mono or Polycrystalline panels;
- More efficient in low light conditions;
- Performance and cost improving the most rapidly;
- Likely to become the dominant technology in the next 10 years.[6]

1.4.4. Power Inverters

Unless you anticipate utilizing battery power for everything, you will require a Power Inverter. Since the greater part of present day accommodations all keep running on 120 volts AC, the Power Inverter will be the heart of your Solar Energy System. It not just changes over the low voltage DC to the 120 volts AC that runs most appliances, but can additionally charge the batteries if associated with the utility grid or an AC Generator as on account of an absolutely autonomous stand-alone sun oriented power systems.

Inverter Stacking: Using multiple inverters

Two inverters can be introduced in an arrangement known as stacking that can give more power or higher voltage *(Figure 13)*. In the event that two good inverters are stacked in arrangement you can provide the yield voltage. This would be the procedure to use to give 120/240 volts AC. Then again, on the off chance that you arrange them in parallel, you can double your energy. Two 4000 watt inverters in parallel would give you 8000 watts (8KW) of power.[7]

Figure 13. Inverter Stacking

(Source: http://www.cebusolar.com/photo-voltaic/hybrid-solar-inverters-on-and-off-grid/hybrid-inverters-stacking)

String Inverters

Solar panels are introduced in rows, each on a "string." For instance, in the event that you have 25 panels you may have 5 lines of 5 panels. Different strings are associated with one string inverter. Each string conveys the DC control the sun oriented panels create to the string inverter where it's changed over into usable AC control consumed as electricity. Contingent upon the measure of the establishment, you may have a few string inverters each getting DC control from a couple of strings *(Figure 14)*.

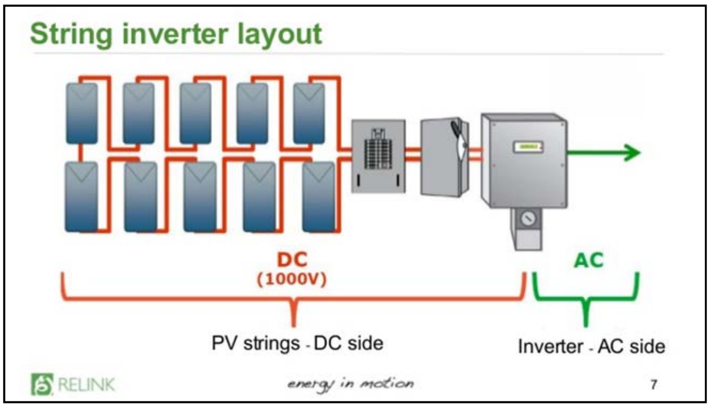

Figure 14. String Inverter

(Source: https://www.slideshare.net/MarcoAchilli1/relink-benefit-of-micro-inverters)

String inverters have been around for quite a while and are useful for establishments without shading issues and in which panels are situated on a solitary plane so that they don't confront distinctive bearings. In the event that an establishment utilizes string inverters and even one panel is shaded for a part of the day lessening its execution, the yield of each panel on the string is diminished to the battling boards' level. In spite of the fact that string inverters aren't ready to manage shading issues, the innovation is trusted and demonstrated and they are more affordable than systems with small scale inverters. String inverters are ordinarily utilized as a part of private and business applications. Additionally, as innovation enhances permitting string inverters to have more prominent power thickness in smaller sizes, string inverters are turning into a famous option over focal inverters in little utility establishments smaller than 1 MW.

String inverters can likewise be combined with power optimizers, an alternative that is picking up prevalence. Control optimizers are module-level power gadgets meaning they are introduced at the module level, so each sunlight based panel has one. Some panel manufacturers coordinate their items with power optimizing agents and offer them as one arrangement known as a *Smart Module*. This can make installation less demanding. Power optimizers can relieve impacts of shading that string inverters alone can't. They condition the DC power before sending it to the inverter, which brings about a higher general effectiveness than utilizing a string inverter alone. Power optimizers offer comparative advantages as smaller scale inverters, however have a tendency to be more affordable thus can be a decent choice between utilizing entirely string inverters or miniaturized scale inverters.

Microinverters

Microinverters *(Figure 15)* are additionally turning into a prominent decision for private and business establishments. Like power optimizers, microinverters are module-level gadgets so one is introduced on each panel. Be that as it may, unlike power optimizers which do no conversion, microinverters change over DC energy to AC right at the panel, thus they don't require a string inverter.

Additionally, due to the panel-level conversion, on the off chance that at least one board is shaded or is performing on a lower level than the others, the performance of the rest of the panels won't be imperiled. Microinverters are additionally monitor the execution of every individual panel, while string inverters demonstrate the execution of each string. This makes microinverters useful for establishments with shading issues or with panels on numerous planes confronting different bearings. Frameworks with microinverters can be more proficient, however these regularly cost more than string inverters.

Figure 15. Micro Inverter

(Source: http://www.remonsolar.com/en/89-wvc-295-grid-tie-micro-inverter.html)

Microinverters can likewise be sold through panels producers effectively coordinated into the board, like Smart Modules however rather known as an AC Module. This makes installation simpler and less expensive.

Central inverters

Central inverters *(Figure 16)* are like string inverters, however they are significantly bigger and can bolster more series of panels. Rather than strings running straightforwardly to the inverter, as with string models, the strings are associated together in a typical combiner box that runs the DC energy to the focal inverter where it is changed over to AC power. Central inverters require less part associations, however require a pad and combiner box. They are most appropriate for huge establishments with reliable generation over the array.[8]

Figure 16. Central inverter

(Source: http://www.solarpowerworldonline.com/2016/05/different-types-solar-inverters/)

Solar Pumping Inverters

Advanced solar pumping inverters convert DC voltage from the solar array into AC voltage to drive submersible pumps directly without the need for batteries or other energy storage devices. By utilizing MPPT (maximum power point tracking), solar pumping inverters regulate output frequency to control the speed of the pumps in order to save the pump motor from damage.

Solar pumping inverters usually have multiple ports to allow the input of DC current generated by PV arrays, one port to allow the output of AC voltage, and a further port for input from a water-level sensor.

1.5. Making or Saving Money with Solar Panels

Figure 17. Saving Money

(Source: https://loanatlast.com/how-to-start-saving-money/)

Switching to solar panels is definitely a good measure to save money *(Figure 17)*. Of course, it depends on the electric bill, the cost of installation, size of the system and several others. Below you can see 10 ways of saving money with solar panels:

1. The government offers motivators that help balance the cost of installation, so that a consumer can understand energy reserve funds all the more rapidly. This implies bringing down energy cost in a shorter time period.
2. Solar panels can be utilized to create a part of your home's energy keeping in mind the end goal to lessen your dependency on customary power sources. For example, you can introduce panels to give power just to machines or lighting, to decrease your reliance on the utility company, and in addition bring down your bill.
3. With solar panels as another power source, you can arrange a better rate with your nearby electric organization in many cases. Since your utilization will be lower, and your house is more energy effective, you may meet all requirements for lower rates.
4. Feed-in tariffs, which are government-prompted motivations for energy suppliers to change to alternative, renewable energy sources. This can incorporate homeowners, which implies you can offer surplus energy created by your solar panels back to the electric grid.

5. Power Purchase Agreements (PPA's) permit homeowners to rent equipment from a privately-owned business for use in producing power, and the organization then offers surplus power to its client at a lower cost than the nearby utility. This likewise gives the property holder an alternative that reduces the cost of introducing his own equipment.
6. Net Metering is another strategy that attempts to the upside of property holders utilizing sun based power. Electric meters will quantify your power generation and additionally your utilization, and ascertain the difference. So, as you produce power with your solar panels, you are generally keeping money credit with your neighborhood electric organization.
7. While not an immediate investment funds on your electric bill, there is another budgetary advantage from sunlight based powering your home. The resale estimation of your home will increment by as much as 20% with the establishment of solar panels.
8. Heating bills can be diminished by utilizing your solar panels to provide the power to your home heating system. Your reserve funds on warming expenses as opposed to utilizing routine power can receive your significant money related benefits.
9. Another choice is to connect your water heater to the solar panel array you've introduced. You'll have the additional advantage of realizing that you can in any case wash up, in your comfortably warm home in case of a winter power blackout.
10. There are various DIY kits accessible to purchasers which will direct you in building your own particular sun panels with shockingly little exertion or cost. This can enormously lessen your initial cost, which in turn conveys you to benefit that much sooner.

1.6. Client and location

Now that we have all the basic information about pollution, renewable energies and solar panels, we can move forward to phase two of the introduction. We will implement a solar panel system in a rural area from Romania.

First of all, we will present the location, including some geographical information so that we can choose the most efficient option. This chapter will also include the environmental impact of the solar system, but also the social and rural impact.

The project refers to a pig farm *(Figure 24)* in the rural area of Slatina, Suceava county (47°26′46″N 25°59′50″E) – *Figure 19*. At the moment, the pig farm takes electricity from the grid. The owners want to implement two solar arrays on top of two of their farms (the black rectangles shown in figure 18).

Figure 19. Romanian Map

Figure 18. Pig Farm

(Source: Provided by SC ELECTROPREST SRL Bacau)

Slatina county is located in the north-eastern part of Romania, in the region of Moldavia. The census made in 2011 shows that the population in Slatina county was about 4800 inhabitants, declining from 5200 inhabitants registered in 2002. The decline is mostly due to the bad economic situation in the region. The inhabitants tend to leave the county in favor of bigger cities close to it or even abroad, in search for better jobs and a better life.

The altitude in the county is not that high, at 467m above the sea level. Even though it's not a plain, implementing a solar array would still be a good idea.

1.7. Design alternatives to be considered

Considering the economic aspects of the region, we have to choose a cheaper alternative, as we will demonstrate.

Choosing the PV cells

We can choose between monocrystalline solar cells, polycrystalline cells or thin-film cells. Choosing the right one will mainly determine the costs of the installment, but also the IRR, payback time and NPV.

1st choice: Monocrystalline solar cells

The efficiency rates of monocrystalline solar panels are at the highest level (25%). We also have to keep in mind that those solar panels are space-efficient, as they yield the higher power outputs.

Another advantage of these solar cells is that they live the longest, most of the manufacturers putting a 25-year warranty on them.

All seems in order and this might be the best choice already, but they do have some drawbacks, and among them the biggest one of them all: price. Monocrystalline solar panels are the most expensive.

It is needless to say that the weather in Romania varies from very hot (30+ degrees Celsius during the summer) to very cold (-10-15 degrees Celsius during the winter). It is a well-known fact that if these solar panels are partially covered with shade, dirt or snow, the entire circuit can break down. Considering that the financial status of the owners doesn't afford breakdowns, it is safe to avoid this option as it is not reliable, even with the 25-year warranty.

2nd option: Polycrystalline solar cells

The process used to make polycrystalline silicon is simpler and costs less than the monocrystalline silicon. Even so, heat can affect the performance of these solar panels and shorten their lifespan.

In comparison with the monocrystalline solar cells, the polycrystalline ones need more space, so they aren't that space-efficient. Although this fact is a reason for some not to go for them, space is not the issue with our pig farms, as the roofs provide sufficient space for placing the solar panels.

If we also had to look at the panels from an aesthetic point of view, monocrystalline and thin-film solar panels tend to be more aesthetically pleasing, since they have a more uniform look.

3rd option: Thin-film solar cells

It is a well-known fact that thin-film solar cells have the reputation of being the less-efficient cells, with an efficiency of 20%.

Even if we start off with a disadvantage, there are some interesting things we can say about the thin-film solar cells. Those cells are far less affected by shade than the mono and polycrystalline panels, they are more efficient in low-light conditions. Being more efficient in low-light conditions automatically means that they are more efficient during the winter, when the peak-solar hours are less than during the summer.

1.8. Description of the final solution

After taking into consideration all the advantages and disadvantages of the three options, we decided to go for the thin-film solar panels. We took this decision because of two deciding factors:

- Lower cost than mono and polycrystalline solar cells;
- Less affected by shade.

Information regarding the *photovoltaic panels (Table 1)* that compose the photoelectric central:

- Technology used: CDTE Thin Film
- Manufacturer: RECOM ITALIA
- Type of solar panel: 80Wp
- Surface area of the solar panel (m^2): 0.72

Table 1. Photovoltaic panels specifications

Electrical Characteristics of the solar panel			
Installed Power	P	Wp	80Wp
Technology	-	-	Thin Film
Installed power on the surface of the PV	-	Wp/m^2	111 Wp/m^2
Efficiency		%	15.03%
Number of Cells	n	cells	300 cells
Rated Current	In	A	2,5A
Nominal Voltage	Un	V	30.8V
Shortcircuit Current	Isc	A	3A
Voltage Idling	U0	V	37.5V
Maximum Operating Voltage	Uccmax	V	1000V
Mechanical Characteristics			
Lenght x Width x Thickness		mm	1200 x 600 x 21 mm
Metallic Frame		Yes/No	Yes
Panel Weight		kg	12kg

Co-funded by the Erasmus+ Programme of the European Union

Information regarding the *inverters (Table 2)*:

The conversion installation will consist of inverters. The inverters will make the conversion between the DC produced by the photovoltaic panels to the alternative current which can be delivered into the installation. The inverters will have a digital display which will allow direct reading of the electrical values, also being able to be monitored remotely, with the help of their accessories.

Table 2. Inverter specifications

Technical characteristics of the inverter		
Entry (DC)		
Maximum power cc	kW	17.41kW
Maximum voltage cc	V	1000V
Maximum current admissible (entry A / B)	A	33A / 11A
Nominal voltage	V	580V
Voltage range it works	V	150 ... 800V
Minimum starting voltage	V	180V
Number of strings	Strings	2
Exit (AC)		
Maximum power 400V, 50Hz, cos φ = 1	kVA	17kVA
Nominal voltage	V	257,6
Frequency	Hz	50Hz ± 5Hz
Maximum exit voltage	A	24.6A
Power factor cosφ		Adjustable 0.8 Capacitive – 0.8 Inductive
Maximum efficiency	%	97.6%
Active cooling system		Yes
Noise level	dB	<50dB
General data		
Lenght x Width x Thickness	mm	470 x 730 x 240 mm
Weight	kg	37kg
Running temperature	°C	-25°C ...+60°C
Night-time consumption	W	1W
DC and AC connectors		Yes
Digital Display		Yes
Remote monitoring possibility		Yes

Co-funded by the Erasmus+ Programme of the European Union

After reviewing the advantages and disadvantages of the system being connected with the grid or off-grid, the beneficiary decided to make the photovoltaic system connected to the grid, therefore not needing batteries.

The extra energy produced will be sent back into the system. Also, if and when the farm needs more power than the panels are supplying, it can draw power from the electric network.

Therefore, the farm owners decided to go with the procedure known as "net metering". This means that the farm gets a credit on the service charge for the power that is sent back into the network. If and when the farm is using more power than the panels produce, it can utilize the credits as opposed to paying to the utility.

Information regarding the combiner box:

We will be using a MidNite Solar MidNite MNPV8HV-DISCO 4X Disconnecting Combiner Box

The MNPVHV series of combiners are manufactured for indoor / outdoor use and designed for combining high voltage strings using 10mm x 38mm fuses. The use of touch-safe din rail mount fuse holders and fuses allow operation up to 600 Volts. The micro switch is available to run the Midnite Birdhouse directly from the combiner. Rated for 600VDC. The MNPVHV combiners are rated for outdoor use. Designed for combining high voltage strings using 10mm x 38mm fuses. The use of touch safe din rail mount fuses and fuse holders allows operation up to 600 Volts. The MNPV red handle is lockable in the off position.

Features and attributes:

- Weight: 18.16kg;
- Convertible configuration;
- 4 + 4 positive strings, separate PV+ and PV- for use with 2 inverters;
- Load Break compatible;
- Type 4X aluminum enclosure;
- 15A/600V fuses installed.

Figure 20. Combiner box

(Source: https://www.wholesalesolar.com/cms/midnite-solar-midnite-mnpv8hv-disco-4x-disconnecting-combiner-box-3247829244.jpg)

Ground-fault protection information

Ground-fault circuit interrupters are very useful in the protection of personnel from the hazard of an electric shock. Other kinds of leakage current and ground fault protective devices have been introduced for various applications.

We will be using the Morningstar Ground Fault Protection Device 600V.

Figure 21. Ground-fault protection

Co-funded by the Erasmus+ Programme of the European Union

1.9. Impact of the project for the rural development (environmental, social and rural impact)

Environmental impact

All energy sources have some effect on our environment. Fossil fuels — coal, oil, and natural gas — do generously more harm than renewable energy sources by most measures, including air and water contamination, harm to public well-being, wildlife and habitat loss, water use, land use, and unnatural weather change emissions.

It is still essential, in any case, to understand the environmental effects related with producing power from renewable sources such as wind, solar, geothermal, biomass, and hydropower.

The exact type and intensity of environmental impacts fluctuates relying upon the specific technology used, the geographic area, and a number of other variables. By understanding the current and potential environmental issues associated with each renewable energy source, we can take steps to effectively avoid or minimize these impacts as they become a bigger segment of our electric supply.

The sun provides a tremendous resource for generating clean and sustainable electricity. The ecological effects related with solar power can include land use and habitat loss, water use, and the use of hazardous materials in manufacturing, though the types of impacts vary greatly depending on the scale of the system and the technology used — photovoltaic (PV) solar cells or concentrating solar thermal plants (CSP). The environmental impact of solar energy depends on the scale of the solar project and what the energy is eventually used for.

Large scale solar energy projects will have a larger effect on the environment, both positively and negatively.

Unlike fossil fuels, solar power emits no carbon dioxide into the atmosphere, therefore using solar energy results in a lower amount of greenhouse gasses being emitted into the atmosphere. One energy technology company estimates that converting the entire US electric grid to solar power would reduce greenhouse gasses in the atmosphere by 40%.

Solar energy systems are also silent, and usually have no loud moving parts so they do not release any sort of disturbing noise pollutions.

Unfortunately, solar energy panels can only absorb light when the sun is shining, so solar systems are often times needed to be very large in order to be efficient. These large systems can use a large amount of space and land, which may have negative impact on the surrounding environment and animal life. Clearing land to build large scale solar power systems can negatively impact the environment by disturbing ecosystems and removing plant life.

Also, the manufacturing of solar panels can have a negative impact on the environment. Solar panel manufacturers release greenhouse gases and other pollutants into the atmosphere during the manufacturing and doping process of solar panels. Transportation of solar panels will also have a negative impact on the environment if fossil fuels are used during transportation.

Every solar panel that is built and successfully used as a substitute for fossil fuels is reducing the amount of pollutants released into the atmosphere. Overall, using solar energy as a substitute for fossil fuels will have a positive impact on the environment.

Social impact

When cities or companies decide to build and operate solar energy facilities, the projects often help to create numerous jobs. For instance, workers are needed to plan the project, develop and implement the project, build the solar energy plant, manage the equipment and operate the facility. Thus, many new jobs can be fulfilled by workers as a result of a city or state using solar energy facilities to generate electricity for the area, and this would in turn help decrease the unemployment rate of the given area.

With more people able to find employment as a result of the increased number of jobs created by the development and operation of solar energy panels, more people would have money to contribute the nation's economy. Also, manufacturing solar energy is less expensive than burning fossil fuels, which is the traditional method of generating electricity. Thus, if businesses or households decide to use solar energy to power electricity in their homes or buildings, their electric bills can be substantially less than if they use energy generated from fossil fuels. Over an extended period of time the financial difference of cheaper electric bills can become quite significant, enabling families and businesses to inject more of their money into the economy.

Rural impact

Rural areas attract a large part of investment related to renewable energy deployment, tending to be sparsely populated but with abundant sources of RE. The case studies have found that RE deployment can provide hosting communities with some benefits, including:

- ✓ New revenue sources. Renewable energy increases the tax base for improving service provision in rural communities. It can also help generating extra income for land owners and land-based activities. For example, farmers and forest owners who integrate renewable energy production into their activities have diversified, increased, and stabilized their income sources;

- ✓ New job and business opportunities. Although renewable energy tends to have a limited impact on local labor markets, it can create some valuable job opportunities for people in regions where there are otherwise limited employment opportunities. Renewable energy can create direct jobs, such as in operating and maintaining equipment. However, most long-term jobs are indirect, arising along the renewable energy supply-chain (manufacturing, specialized services), and by adapting existing expertise to the needs of renewable energy;

- ✓ Innovations in products, practices and policies in rural areas. In hosting renewable energies, rural areas are the places where new technologies are tested, challenges first appear, and new policy approaches are verified. Some form of innovation related to renewable energy has been observed in all the case studies. The presence of a large number of actors in the renewable energy industry enriches the “learning fabric” of the region. Small and medium-sized enterprises are active in finding business niches as well as clients and valuable suppliers. Even when the basic technology is imported from outside the region, local actors often adapt it to local needs and potentials;

- ✓ Capacity building and community empowerment. As actors become more specialized and accumulate skills in the new industry, their capacity to learn and innovate is enhanced. Several rural regions have developed specific institutions, organisms, and authorities to deal with renewable energy deployment in reaction to large investment and top-down national policies. This dynamic has been observed both in regions where local communities fully support renewable energies and in regions where the population is against potentially harmful developments;

- ✓ Affordable energy. Renewable energy provides remote rural regions with the opportunity to produce their own energy (electricity and heat in particular), rather than importing conventional energy from outside. Being able to generate reliable and cheap energy can trigger economic development.[9]

As explained before, Slatina is a small county that experiences declining population due to various reasons, including the lack of job opportunities. At the same time, Slatina is the county that is very well developed in farming. Nowadays, about half a dozen pig farms are running in the county. European funds have been earmarked for setting up farms, especially for pig breeding, providing both job opportunities and food for the community.

There are many Faculties of Agronomic Sciences throughout Romania, including in the city of Iaşi, which is only 140km away from Suceava or Slatina itself. This can be a great opportunity for the owners of the pig farms to attract students:

- Helping them do practical work during their studies;
- Providing jobs when they graduate.

This way, not only will the pig farms have trained and motivated workers, but they'll bring back some of the population and increase the economy in the area.

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1.10. Conclusion

After all of the above-mentioned aspects have been taken into account, we can come with a conclusion.

Due to the advantages that the thin-film solar panels offer (Lower cost than mono and polycrystalline solar cells; less affected by shade), but also taken into account the budget of the client, the panels that will be installed are from RECOM ITALIA. 300 panels will be installed on the roof. The technology used to make the panels is CDTE Thin-film, as mentioned above.

In order to cope with the panels, two inverters will also be installed and connected with them. Both of the inverters are of 12.5kW.

We will also use the following combiner box: a MidNite Solar MidNite MNPV8HV-DISCO 4X Disconnecting Combiner Box.

In order to avoid the risk of an electric shock, the system will also have a ground-fault protection: Morningstar Ground Fault Protection Device 600V

Calculations

1. Method of execution

The photovoltaic panels will be fitted on the top of the building, considering the following parameters:

- The panels installment will be done towards south;
- The angle of the panels will be 20°;
- We will choose the optimum position, which on east – south – west direction doesn't present obstacles higher than the location of the photovoltaic panels;
- The photovoltaic panels will be installed on a metalic fixation system, using galvanized bolts and nuts;
- The location of the panels will have easy access from the outside so as to allow access for maintenance and periodic cleaning of the panels;
- Installing in areas in which the accumulation of snow/ice may damage the system is not allowed.

The total number of photovoltaic panels will be:

$$300 \text{ panels} \times 80W = 24.000W = 24kW$$

The connections between panels will be made using **special cables** for photovoltaic applications with high resistance from UV. The cables will be monopolar with cable polarity markings and indications about the connection. Inside the building, cables will be marked with visual warning signs.

The inverter power will be installed in the basement of the beneficiary's building, as close as possible to the control panel. The room of the inverter will be equipped with a ventilation grille with an area of at least $100cm^2$. The inverter is mounted on special bracket on the wall, as indicated by the supplier.

The way the connection is made is schematically indicated below:

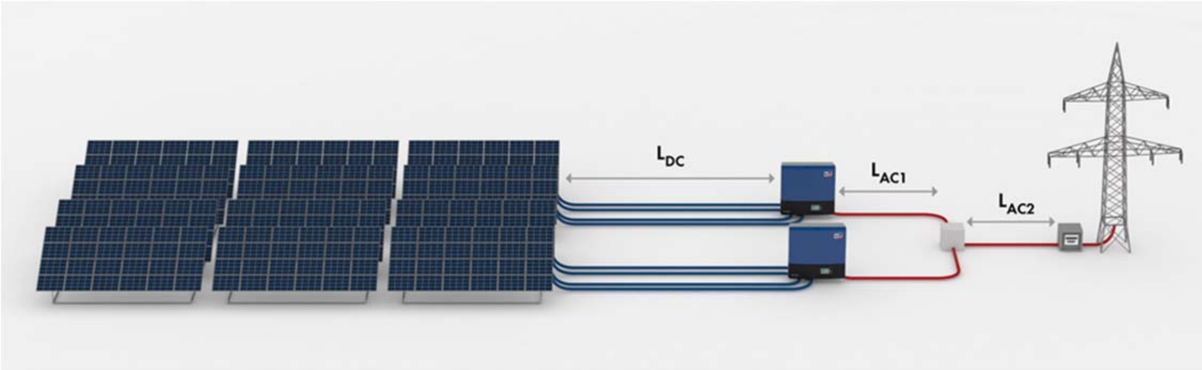

Figure 22. PV installation connection

(Source: Provided by SC ELECTROPREST SRL Bacau)

The array will be made of photovoltaic panels with dimensions of 1200mm x 600mm (useful area). The total number of panels is 300 panels mounted lengthwise. The panels will be installed on 20 groups each with three rows of five panels. The type of photovoltaic panel is one with the power of 80 Wp, CdTe Thin Film. The total output of CEF SC NEO-COREL COMEXIM will be 24 kW.

The holder/support is designed so that it can be adapted to a number of different photovoltaic panels and is removable. Photovoltaic panels will be fixed by screws and special frames are connected by special cables supplied by the manufacturer *(Fig. 27)*.

Figure 23. Installing the PV panels

(Source: Photos taken from the visit to the site)

Figure 24. Panels installed

(Source: Photos taken from the visit to the site)

The 24kW powered photovoltaic panels produce DC. In order to transform it to AC, we need inverters. The installation will use:

2x SUNNY TRIPOWER STP 12000TL-10 *(Figure 30, 31)*

In order to keep the system efficient and not to overwhelm it, each inverter will receive 150 panels, as followed:

3 rows x 5 panels x 10 groups = 150 panels

15 panels in series * 10 groups in parallel

150 panels x 80 Wp = 12000Wp = 12 kWp per inverter

Figure 25. Installed inverters

(Source: Photos taken from the visit to the site)

Figure 26. Inverter technical information

(Source: Photos taken from the visit to the site)

In order to find out if the inverters are able to cope with the solar panels, we need to take into consideration the following:

- PV panels' short-circuit current;
- PV panels' voltage idling;
- PV panels' operating voltage;
- Inverter's voltage
- Inverter's maximum admissible current;
- Voltage range the inverters work.

So far, we know that we have 150 panels connected to each inverter. 15 panels connected in series times 10 in parallel. We need to calculate weather if the inverter can cope with 15 panels connected in series *(Tables 3 and 4)*.

Table 3. PV information

PV information	
Short-circuit current	3A
Voltage idling	37.5V
Maximum operating voltage	1000V

Table 4. Inverter information

Inverter information	
Maximum current admissible	33A
Voltage range it works	150-800V
Maximum voltage	1000V

- ✓ *37,5V * 15 panels = 562,5V*
- ✓ *150V < 562,5V < 800V*
- ✓ *3A * 10 groups = 30A*

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2. System losses

To get the ideal figuring and aftereffect of a photovoltaic establishment different standards must be thought about on the grounds that they will influence the execution of the establishment. Some of these variables are:

* Orientation loss: As the PV installation will be placed on a south-facing roof with the horizontal angle of 0º, we shall have no orientation loss;

* Shade loss: Baring in mind that the PV installation will be placed on the roof of the farm, we don't seem to have any nearby objects/buildings that are in the way of the connection between the sun and our PV installation;

* Losses by dirt: Dirt and dust accumulate on the panels as a result of their outside location. In normal environments, like ours, the dirt losses are 5%;

* Losses by wiring: Performance losses through wiring reach 2%;

* Inverter performance: The inverter performance is 97.6%;

In this manner, the Performance Ratio of the system would be:

$$PR = 1 - (Loss_{orient} + Loss_{shade} + Loss_{dirt} + Loss_{cable} + (1 - Perf_{inv}) + (1 - Perf_{reg}))$$

Where:

$Loss_{orient}$: losses due to orientation;

$Loss_{shade}$: losses by shadows;

$Loss_{dirt}$: losses by dirt;

$Loss_{cable}$: losses by wiring;

$Loss_{inv}$: performance of the inverter;

$Perf_{reg}$: performance of the Regulator/Maximiser (usually 98%);

$Perf_{bat}$: performance of the batteries (not the case);

Los_{deter}: loss due to deterioration of the panels (normally, the panels lose 20% of the production in 20 years).

$$PR = 1 – (0.05 + 0.03 + (1 – 0.976) + (1 – 0.98)$$

$$PR = 100\% - (5\% - 3\% - 2.4\% - 2\%) = 87.6\%$$

Performance Ratio of the system is 87.6%.

3. Energetic evaluation of the project

Romania is situation in the B European area of sunlight, which offers the locals real advantages to save thermal energy, which means money if they use solar energy. The irradiation level is very good, in comparison with other countries with temperate climate, and the differences, depending on the geographical area, are minor. Romania is divided into three zones of sunlight *(Figure 32)*:

- ✓ Red zone (>1450kWh/m^2/year), includes the south area;
- ✓ Yellow zone (1300 - 1450kWh/m^2/year;
- ✓ Blue zone (1150 - 1300kWh/m^2/an), includes mountain areas.

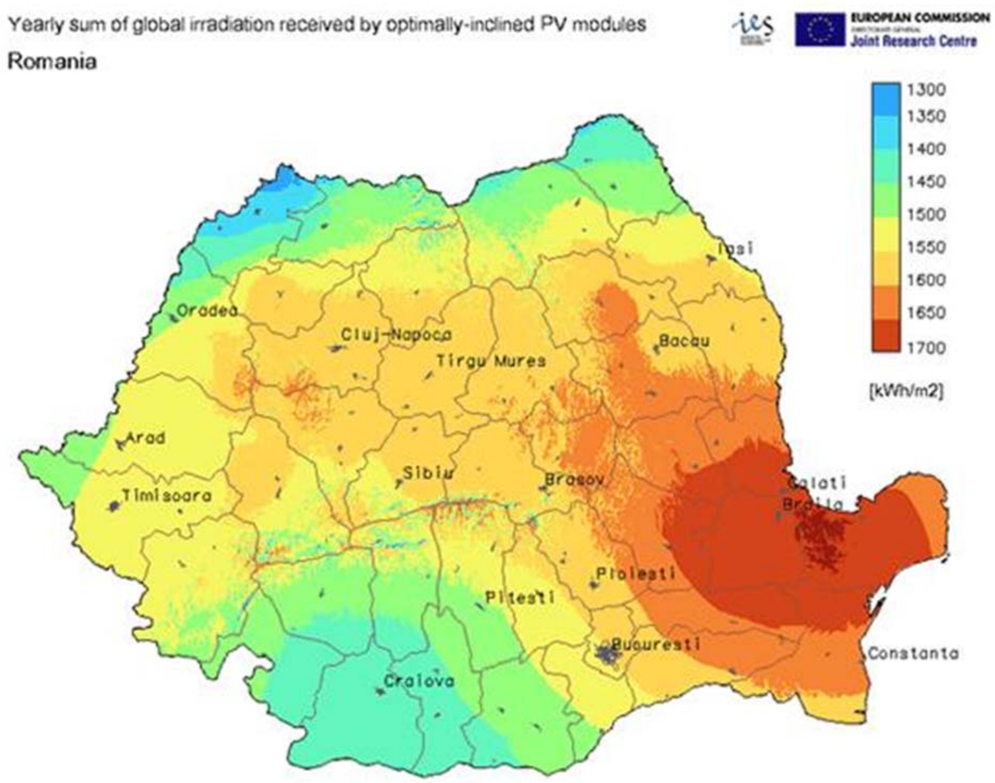


Figure 27. Sum of global irradiation

(Source: https://europe-versus-energy.wikispaces.com/Romanian+Energy+Economy)

Performance of Grid-connected PV

PVGIS estimates of solar electricity generation

Location: 47°15'35" North, 25°35'23" East, Elevation: 1002 m a.s.l.,
Solar radiation database used: PVGIS-CMSAF

Nominal power of the PV system: 24.0 kW (CdTe)
Estimated losses due to temperature and low irradiance: 2.8% (using local ambient temperature)
Estimated loss due to angular reflectance effects: 3.0%
Other losses (cables, inverter etc.): 6.0%
Combined PV system losses: 11.4%

	Fixed system: inclination=20 deg., orientation=0 deg.			
Month	**Ed**	**Em**	**Hd**	**Hm**
Jan	27.30	846	1.16	36.0
Feb	44.50	1250	1.96	54.8
Mar	71.80	2230	3.28	102
Apr	85.80	2580	4.08	122
May	99.90	3100	4.83	150
Jun	98.70	2960	4.83	145
Jul	104.00	3210	5.05	156
Aug	95.70	2970	4.64	144
Sep	76.70	2300	3.58	107
Oct	58.70	1820	2.68	83.1
Nov	35.30	1060	1.56	46.8
Dec	21.60	670	0.92	28.4
Year	68.40	2080	3.22	98.0
Total for year		25000		1180

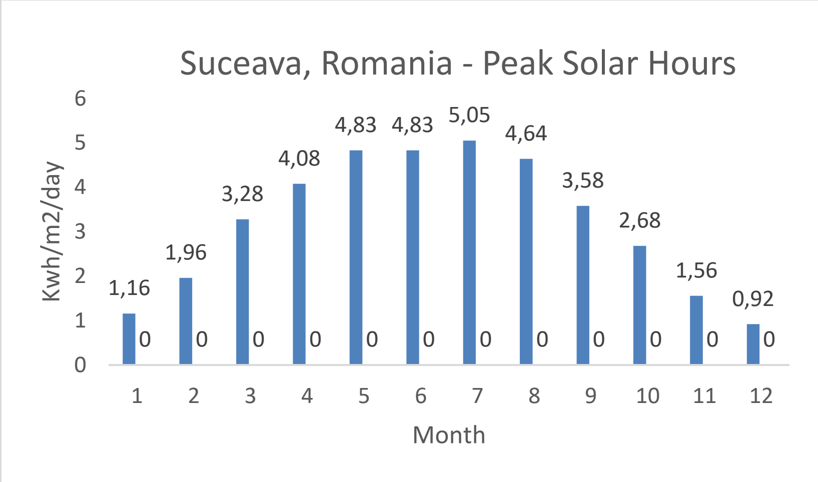
Ed: Average daily electricity production from the given system (kWh)
Em: Average monthly electricity production from the given system (kWh)
Hd: Average daily sum of global irradiation per square meter received by the modules of the given system (kWh/m2)
Hm: Average sum of global irradiation per square meter received by the modules of the given system (kWh/m2)

Figure 28. Performance of Grid-Connected PV

Source: http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php?lang=es&map=europe)

Using the values of Hd (Average daily sum of global irradiation per square meter received by modules of the given system) – calculated using the inclination of 20 degrees, we can calculate the daily and monthly PV generation.

Graph 1. Peak Solar Hours



The photovoltaic system is one of 24kWh/day (DC). Considering the graph above *(Fig. 34)*, the average PSH in the region is 3.22 hours/day.

Even though the system is one of 24kW, that is the power of direct current (DC). The inverter indeed converts the DC into alternative current (AC) so that the energy can be used, but that only happens in a proportion of 85%. In order to calculate the daily production, monthly production and annual production, we need to see how much AC current the system produces per hour and per day.

Solar panels production/h (DC) = 24 kWh

*Solar panels production/h (AC) = 85% * 24 = 20.4 kWh*

Once calculated the AC solar panels production per hour, we can now calculate how much energy they produce per day, month and year. Even though the average PSH is 3.22 in the region, the PSH depend on the month, as we shall demonstrate in the table below.

Table 5. Daily, monthly and annual energy production

Month	Solar panels production [kW]	PSH	Daily production [kW]	Monthly Production [kW]
Jan	20.4	1.16	23.66	733.46
Feb	20.4	1.96	39.98	1119.44
Mar	20.4	3.28	66.91	2074.21
Apr	20.4	4.08	83.23	2496.90
May	20.4	4.83	98.53	3054.43
Jun	20.4	4.83	98.53	2955.90
Jul	20.4	5.05	103.02	3193.62
Aug	20.4	4.64	94.66	2934.46
Sep	20.4	3.58	73.03	2190.90
Oct	20.4	2.68	54.67	1694.77
Nov	20.4	1.56	31.82	954.60
Dec	20.4	0.92	18.77	581.87
ANNUAL ENERGY PRODUCED				23,985 kW

The table above *(Table 5)* shows us that the photovoltaic system produces almost 24 MWh of alternative current (AC).

Budget and economic analysis

1. Budget of the installation

Budgeting is the way toward making an arrangement to spend your cash. This spending arrangement is known as a financial plan. Making this spending arrangement permits you to decide ahead of time whether you will have enough cash to do the things you have to do or might want to do. Planning is essentially adjusting your costs with your wage.

The payback time frame is the time span required to recuperate the cost of an investment. The payback time of a given venture or project is an essential determinant of whether to attempt the position or project, as longer payback periods are commonly not attractive for investment positions.

Internal rate of return (IRR) is a metric utilized as a part of capital planning measuring the productivity of potential investments. Internal rate of return is a discount rate that makes the net present value(NPV) of all cash flows from a specific project equivalent to zero.

In financing, the net present value(NPV) or net present worth (NPW) is an estimation of the productivity of an endeavor that is figured by subtracting the present values(PV) of cash outflows (counting starting expense) from the present estimations of money inflows over a timeframe.

This section provides a survey of the most important economic aspects of the project. In order to calculate the payback, IRR and NPV, we must first find out how much the whole system costs. The table below *(Table 6)* shows us exactly that:

Table 6. System costs

Nr. Crt.	Chapters and subchapters	Value (euro)
1	2	3
	CHAPTER 1: Expenses for obtaining and improving the land	
1.1.	Obtaining the land	0.00
1.2.	Improving the land - dismantling	0.00
1.3.	Improvements for environment protection	0.00
	TOTAL CHAPTER 1	**0.00**
	CHAPTER 2: Expenses for utilities necessary for the objective	0.00
	TOTAL CHAPTER 2	**0.00**
	CHAPTER 3: Expenses for design and technical assistance	
3.1.	Field studies: topography, hydrography, geography	0.00
3.2.	Taxes for obtaining: notices, authorizations, deals	74.00
3.2.1.	Environment notice	0.00
3.2.2.	Urbanism certificate	0.00
3.2.3.	Other notices and deals	0.00
3.2.4.	Authorization of construction	74.00
3.3.	Design and engineering	134.00
	TOTAL CHAPTER 3	**208.00**
	CHAPTER 4: Expenses for the basic investment	
4.1.	Building and installation	7431.00
4.1.1.	Photovoltaic panels equipment	7431.00
4.2.	Equipment installation and technological equipment	2182.00
4.2.1.	Photovoltaic panels montage	2182.00
4.3.	Equipment and technological equipment and functional mounting	26433.00
4.3.1.	Photovoltaic panels and inverters	26433.00
	TOTAL CHAPTER 4	**36045.00**
	CHAPTER 5: Other expenses	
5.1.	Site organization	0.00
5.2.	Commissions, taxes, legal shares, financing costs	95.00
5.2.1.	Commissions, taxes and legal shares	95.00
5.2.1.1.	Fee for quality control of construction	48.00
5.2.1.2.	The fee for inspection of building and planning	10.00
5.2.1.3.	Contribution to Social House of Builders	37.00
	TOTAL CHAPTER 5	**95.00**
	TOTAL SYSTEM COST	**36348.00**

2. Payback, IRR and NPV

a. Payback

For us to be able to calculate the payback time, we have to calculate the annual income generated by the photovoltaic energy production. In order to calculate that, we have to take into consideration the price/kWh paid to the electricity supplier, which is **0.106EUR/kW**.

The table below *(Table 7)* shows the estimate monthly energy production and the monthly income. This way, we can then calculate the annual income that we need in order to find out the payback time.

Table 7. Monthly income

Estimate monthly energy production	Electricity production (%)	kW	Monthly income
January (31 days)	3.06	733.46	77.75
February (28 days)	4.66	1119.44	118.66
March (31 days)	8.65	2074.21	219.87
April (30 days)	10.41	2496.9	264.67
May (31 days)	12.74	3054.43	323.77
June (30 days)	12.33	2955.9	313.33
July (31 days)	13.32	3193.62	338.52
August (31 days)	12.24	2934.46	311.05
September (30 days)	9.12	2190.9	232.23
October (31 days)	7.07	1694.77	179.65
November (30 days)	3.97	954.6	101.19
December (31 days)	2.43	581.87	61.68
TOTAL	**100**	**23985.00**	**2542.41**

$$Cashflow = Energy\ production \times Price\ of\ energy$$

$$Cashflow = 23985\ x\ 0.106 = 2542.41\ €$$

Once calculated the annual income generated by the photovoltaic energy production, we can continue and calculate the payback time.

Table 8. Payback time

Power of the PV system	KWp	24.00
Cost of the PV system	€ (EUR)	36695.00
Loses of PV system *	%	12.40
Solar radiation, annual average **	KWh/m2	1180.00
Price/ KW paid to the electric supplier	€ (EUR)	0.106
Annual production of PV electricity	KW	23985.00
Annual income generated by the PV electricity production	€ (EUR)	2542.41
The investment of the PV system will pay off in	Years	**14.43**

* *On-grid PV system losses up to 15% (inverter, cable, temperature-performance ratio)*

*** In Central Europe and Northern Europe between 1200-850 W/m^2 and in Southern Europe up to 2000 W/m^2*

$$Payback = \frac{Real\ Investment}{Cash - flow}$$

$$Payback = \frac{36695\ €}{2542.41\ €} = 14.43\ years$$

The payback time is better explained in the table below:

Table 9. Payback per year

YEAR	Energy Production (kWh/year)	CASH-FLOW	Cumulated Cash-Flow	Payback
0		-36695		
1	23985.00	2542.41	2542.41	-34152.6
2	23985.00	2542.41	5084.82	-31610.2
3	23985.00	2542.41	7627.23	-29067.8
4	23985.00	2542.41	10169.64	-26525.4
5	23985.00	2542.41	12712.05	-23983
6	23985.00	2542.41	15254.46	-21440.5
7	23985.00	2542.41	17796.87	-18898.1
8	23985.00	2542.41	20339.28	-16355.7
9	23985.00	2542.41	22881.69	-13813.3
10	23985.00	2542.41	25424.1	-11270.9
11	23985.00	2542.41	27966.51	-8728.49
12	23985.00	2542.41	30508.92	-6186.08
13	23985.00	2542.41	33051.33	-3643.67
14	23985.00	2542.41	35593.74	-1101.26
15	23985.00	2542.41	38136.15	1441.15
TOTAL	359775	38136.15	38136.15	1441.15

3. Net Present Value (NPV) and Internal Rate of Return (IRR)

Net Present Value (NPV) is the difference between the present value of cash inflows and the present value of cash outflows. NPV is used in capital budgeting to analyze the profitability of a projected investment or project.

In order to calculate the net present value, we will use the following formula:

$$\sum_{t=1}^{T} \frac{Ct}{(1+r)^{\wedge}t} - C_0, \text{ while:}$$

C_t = net cash inflow during the period t

C_o = total initial investment costs

r = discount rate

t = number of time periods

One essential issue with gauging a venture's productivity with NPV is that NPV depends intensely upon different suppositions and appraisals, so there can be considerable space for blunder. Assessed elements incorporate venture costs, markdown rate and anticipated returns. A venture may regularly require unanticipated expenditures to get off the ground or may require extra expenditure at the project's end.

As such, these components may need to be changed in accordance with record for unexpected expenses or misfortunes or for excessively hopeful money inflow projections.

It is conceivable that the venture's rate of return could hence encounter a sharp drop, a sharp increment or anything in the middle. Examinations of speculations' payback periods, then, won't really yield a precise portrayal of the profitability of those ventures.

Table 10. Profitability

YEAR	PROFITABILITY			
	CASH-FLOW [€]	CUMULATIVE CASH-FLOW [€]	PAYBACK [€]	NET PRESENT VALUE - NPV [€]
0	**-36695.00**		**-36695.00**	
1	2524.41	2524.41	-34170.59	-34207.90
2	2524.41	5048.82	-31646.18	-31794.30
3	2524.41	7573.23	-29121.77	-29452.59
4	2524.41	10097.64	-26597.36	-27181.16
5	2524.41	12622.05	-24072.95	-24978.45
6	2524.41	15146.46	-21548.54	-22842.92
7	2524.41	17670.87	-19024.13	-20773.07
8	2524.41	20195.28	-16499.72	-18767.43
9	2524.41	22719.69	-13975.31	-16824.54
10	2524.41	25244.10	-11450.90	-14942.99
11	2524.41	27768.51	-8926.49	-13121.39
12	2524.41	30292.92	-6402.08	-11358.38
13	2524.41	32817.33	-3877.67	-9652.63
14	2524.41	35341.74	-1353.26	-8002.83
15	2524.41	37866.15	1171.15	-6407.70
16	2524.41	40390.56	3695.56	-4865.99
17	2524.41	42914.97	6219.97	-3376.45
18	2524.41	45439.38	8744.38	-1937.89
19	2524.41	47963.79	11268.79	-549.13
20	2524.41	50488.20	13793.20	790.99
TOTAL	**50488.20**	**50488.20**	**13793.20**	**790.99**

Table 11. Summary

PAYBACK	**14.43 YEARS**
NET PRESENT VALUE (NPV)	**790.99 €**
INTERNAL RATE OF RETURN (IRR)	**1.6%**

Project plans

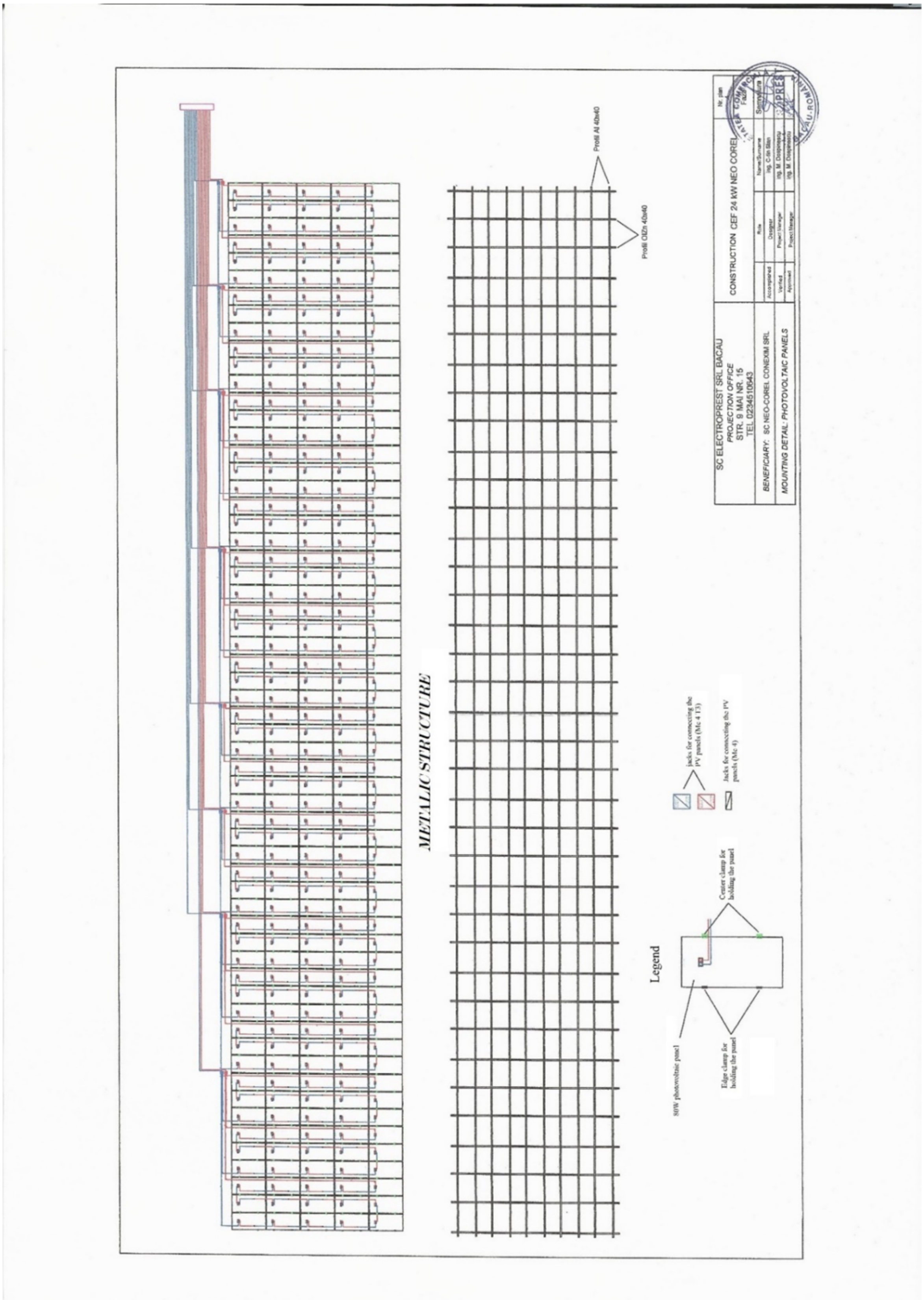


Figure 29. Metallic Structure

(Source: Provided by SC ELECTROPREST SRL Bacau)

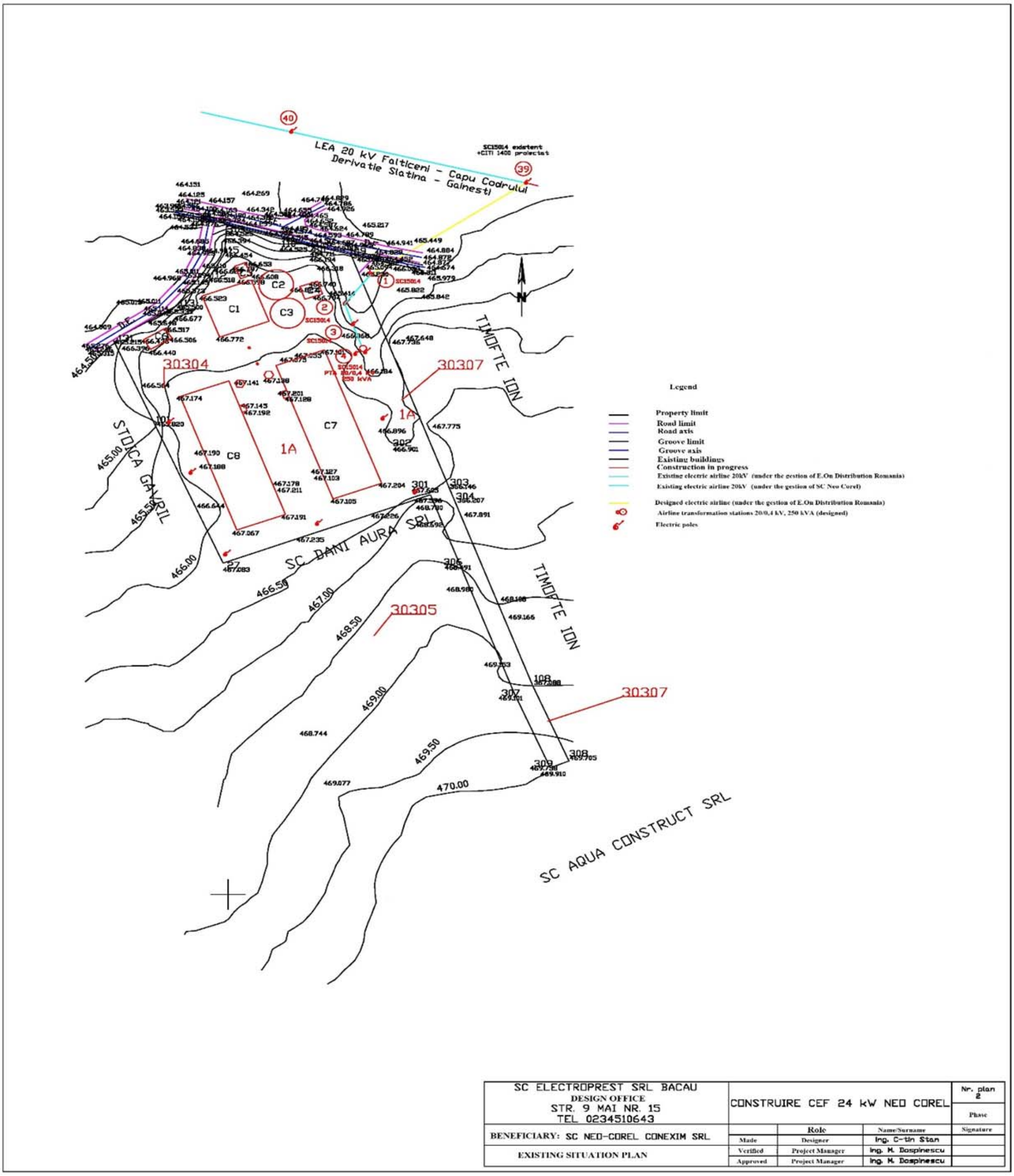
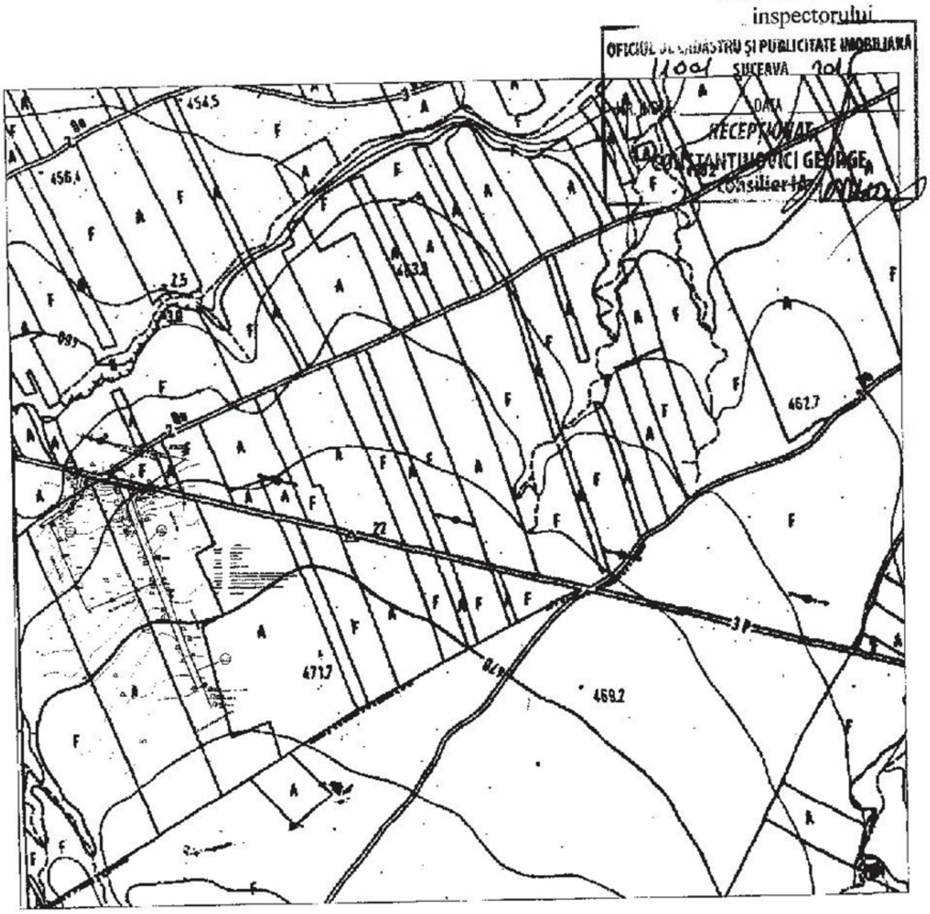


Figure 30. Situation plan

(Source: Provided by SC ELECTROPREST SRL Bacau)

FITTING PLAN IN THE AREA
SCALE: 1:5000
Trapez: L-35-17-C-a-3-II
Beneficiary: S.C. SC NEOCOREL COMEXIM SRL
Property: 30304, 30307

OCPI
(receptie)
Semnatura si parafa
inspectorului



DATA: 27.05.2015

ÎNTOCMIT:
Ing. SCUTAR V. Vasile

Figure 31. Fitting plan in the area

(Source: Provided by SC ELECTROPREST SRL Bacau)

Co-funded by the Erasmus+ Programme of the European Union

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Co-funded by the Erasmus+ Programme of the European Union

REPORT OF THE CASE STUDY ON RENEWABLE ENERGIES TO LOCAL DEVELOPMENT NATIONALLY IMPLEMENTED

Study Concerns the Efficiency of Wind Energy in the Area of Pincesti Village, Bacău

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Bacău, 2017

Contents of the Project

Memory of the Project

1.1. Introduction to the Project

Being an European country, Romania is trying to reduce the carbon footprint which affects the environment by increasing the amount of energy produced through renewable systems.

Renewable energy is energy collected from renewable resources such as sunlight, wind, tides, waves, biomass, biogas and geothermal heat. Renewable energy often provides energy in four important areas: electricity generation, air and water heating/cooling, transportation and rural (off-grid) energy services [1].

Renewables are an important source for producing energy, mainly because they exist in wide geographical areas, in contrast with traditional energy sources which are limited to certain regions of the world's countries. The development of renewable technologies can provide us with energy security and economic benefits.

Prior to the development of coal in the 19th century, nearly all energy used was renewable. Almost without a doubt, the oldest known renewable energy is the use of biomass for fire. Probably the second oldest use of renewables is harnessing the wind in order to sail ships over water. Other forms of renewable energy have also been historically used in grain crushing mills (hydro and wind energy) or in agriculture. Even solar power has been traditionally used for cooking, drying things and industrial applications such as salt production.

The publication of the Peak Oil theory in 1956 (announcing for the first time the limitation of the global oil resources and forecasting a future increment of the oil prices due to its scarcity), together with some environmental movements in the 1970s, promoted a certain renaissance of the renewables. It was intended both as a replacement for the eventual depletion of oil, as well as an escape from the big dependence on oil in the OECD (Organization for Economic Cooperation and Development) countries. [2]

Nowadays, renewable energy (also known as "green energy") is widely used for generating electricity. It can be particularly suitable for developing countries. In rural and remote areas, the transmission and distribution of energy generated from fossil fuels can be difficult and expensive. Producing renewable energy locally can offer a viable alternative.

Among the natural resources that can be classified as renewable sources of energy, the following can be highlighted:

- ✓ Sunlight, which can provide photovoltaic power;
- ✓ Air movements around the planet, which can produce energy using wind turbines;
- ✓ Water from rivers, which give rise to technologies such as large hydropower and mini-hydraulic installations;
- ✓ Biomass, such as plants and animal waste;
- ✓ Heat from the Earth, used to produce geothermal energy.

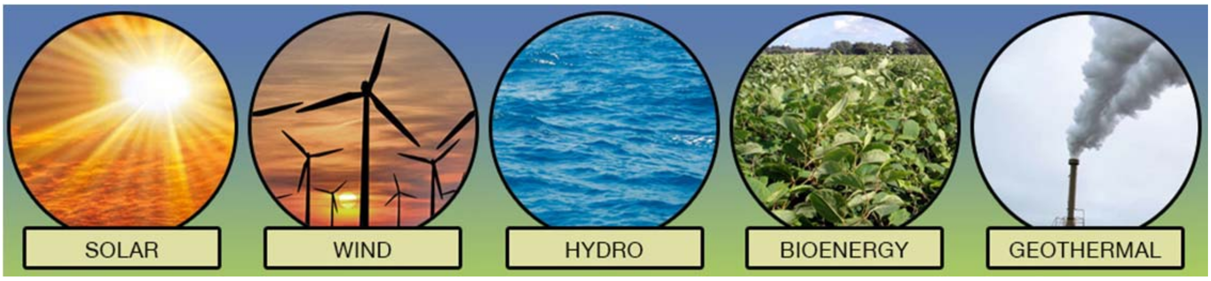


Figure 1. Renewable energies [Source:http://www.azureeducation.org/wp-content/uploads/2015/07/header-renewable.jpg]

The production of renewable energies around Europe keeps increasing year after year. This is stated in all the reports completed by official and international agencies such as the European Environmental Agency (EEA) or the Renewable Energy Policy Network for the 21st Century (REN21).

Renewables are tending to become a mainstream source of energy. Their rapid growth is driven by the improving cost-competitiveness of renewable technologies, supportive policy initiatives, easy access to funding, energy independence and environmental concerns, the growing demand for energy in developing and emerging economies, and the need for access to modern energy. Consequently, new markets for both centralized and distributed renewable energy are emerging in all regions.

Based on REN21's 2016 report, renewables contributed 23.7% to the global generation of electricity in 2015 (figure 2). [3]

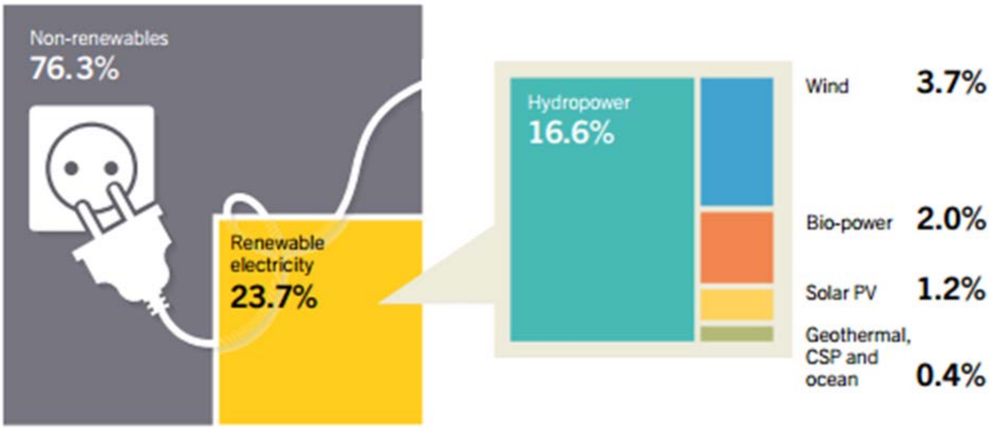


Figure 2. Estimated Renewable Energy Share of Global Energy Production, End-2015 [Source: REN21, Global status report 2016]

The same report estimated that renewable energies were used to supply 19.2% of the world energy consumption in 2014. This energy consumption was divided as 8.9% coming from traditional biomass, 4.2% as heat energy (modern biomass, geothermal and solar heat), 3.9% as hydro electricity and 2.2% as electricity coming from wind, solar, geothermal and biomass sources (figure3).

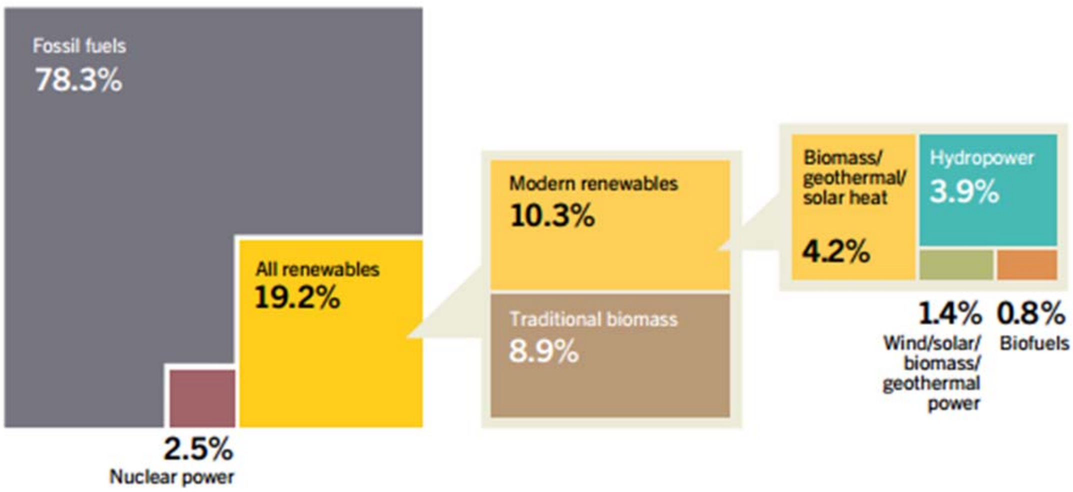


Figure 3. Estimated Renewable Energy Share of Global Final Energy Consumption, 2014 [Source: REN21, Global status report 2016]

Wind power is an important source of renewable energy and has a growing role in meeting energy demand. It was the leading source of the new power generating capacity in Europe and the United States in 2015, and the second largest in China. Globally, a record of 63 GW was added for a total of about 433 GW (figure4). Corporations and other private entities continued turning to wind energy for reliable and low-cost power, while many large investors were drawn by its stable returns.

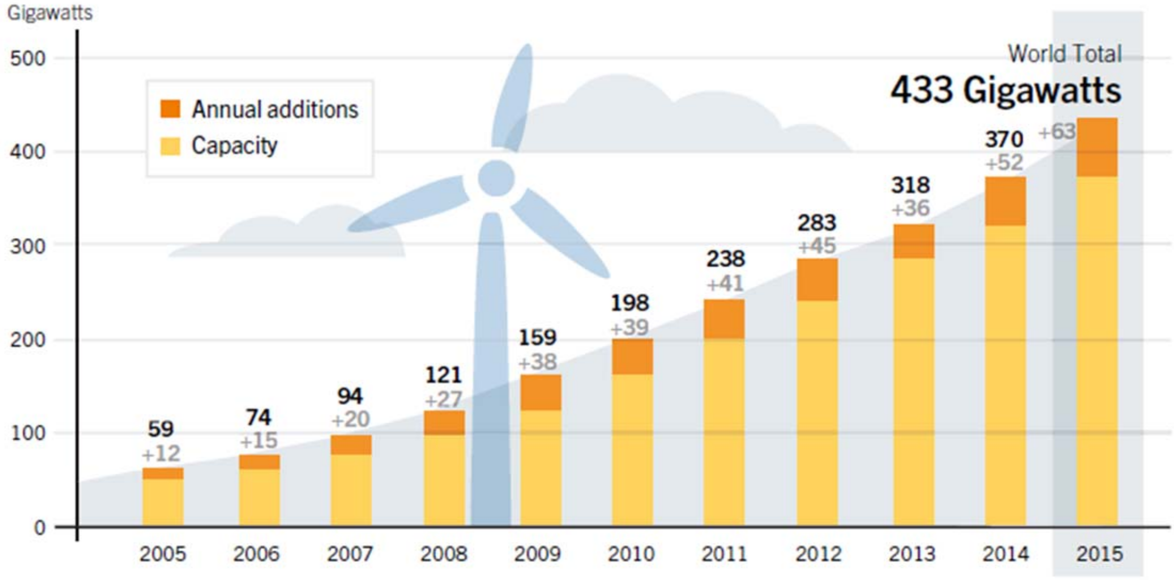


Figure 4. Wind Power Global Capacity and Annual Additions, 2005-2015
[Source: REN21, Global status report 2016]

The industry is growing and most top turbine manufacturers are breaking their own annual installation records. To meet the rising demand, new factories have been opened or under construction around the world.

Wind power is the use of air flow through wind turbines to mechanically power generators for electric power. Wind energy is an alternative to burning fossil fuels. It is renewable, widely distributed, clean and produces no greenhouse gas emissions during operation [4].

The emergency of new concepts in the field of materials and modern technologies have resulted in a spectacular development of the wind turbine size, from heights of 15 m in 1980 to heights of 140 m in 2014. Also, rotor diameters have evolved depending on the installed power, from 15 m for a power of 50 kW up to 126 m for an installed capacity of 8.000 kW. In 2012, in France, Haliade 150 wind turbine, the largest wind turbine in the world, with a power of 6 MW, was built. In 2013, in Scotland, a Samsung Heavy Industries S7.0-171 turbine with a power of 7 MW was build. In 2014, Vestas announced that it had produced the largest wind turbine on the planet generating electricity, with the installation of its V164-8.0MW prototype at the Danish National Test Center for Large Wind Turbines in Østerild, Denmark. [5]

The goal of this project is building a renewable energy system composed of a wind turbine for providing electricity in the rural area of Pincesti, which is located in the central-eastern part of Bacău County, in the eastern part of Romania (figure 5). According to a study from 2011, Pincesti has a population of 3919 inhabitants, declining from 4311 inhabitants registered in 2002. The main reason of this decline is that the rural people tend to move to urban areas in order to find a better job and a better lifestyle [6].

Figure 5. The location of Pincesti on the map of Romania
[Source: https://ro.wikipedia.org/wiki/Comuna_Pâncești,_Bacău]

The renewable energy system will provide electricity for a guest house and for a water pump used for irrigation. The wind turbine has to be designed so that it can supply electricity for the 10 room guest house and for the water pump used in agriculture, fish farming, fishing and different recreational activities.

Implementing a renewable energy system in this rural area is a benefit for the local people because new jobs will be available, it will reduce the cost of their electricity bills and the energy production can attract new investors in the future.

1.2. State-of-art in the Problem Domain

The population of the world has been using the wind's energy for hundreds of years. From old Holland to farms in the United States, windmills have been used for pumping water or grinding grain. Today, the windmill's modern equivalent – a wind turbine – can use the wind's energy to generate electricity. [7]

The continuous development in the field of materials and modern technologies has resulted in a great improvement of the wind turbine size, from 15 meters (over 30 years ago) to more than 100 meters.

The small wind industry has demonstrated remarkable growth in the past decade, as consumer interest has been increasing and many new companies have entered the sector. In the past, small wind turbines in rural areas were common for residential and farming needs and for water-pumping stations. Today, common applications of small wind turbines include:

- Residential uses;
- Commercial and industrial uses;
- Fishery and recreational boats;
- Hybrid systems;
- Pastures, farms and remote villages;
- Portable systems for leisure;
- Pumping;
- Desalination and purification;
- Remote monitoring;
- Research and education;
- Telecom base stations.

The future of the small wind industry depends on the cost of technology, fossil-fuel prices, investor interest, consumer awareness, certification and quality assurance, permitting processes and regulations, and wind evaluation tools.

In the attempt to meet the European Union's goals for promoting "green" energy, Romania is supporting renewable energy production (wind energy, solar energy, biomass and others) by providing the local producers of environment-friendly energy with green certificates. The Romanian state supports the production of solar / PV energy by offering three (3) green certificates and two (2) green certificates for wind energy production for each MWh produced and injected into the grid. One green certificate will be traded on a regulated market (i.e. OPCOM) with a price that varies between EUR 29 to EUR 60 per green certificate [8].

The rural area of Romania is starting to become more attractive for companies and people willing to invest into renewable energy. For Pincesti, the best example of investing in "green" energy is the 1 MW solar power plant. A local company decided to invest into a solar plant and send the energy into the grid. According to Romanian legislation, they will receive green certificates for being producers of energy that will be sold in order to make the investment profitable.

Romania has one of the highest wind potential in continental Europe. A study of Erste Bank places Romania and especially the Dobrogea Region, with its Constanta and Tulcea counties, as the second best place in Europe (after Scotland) to construct wind farms, due to its large wind potential. Another study made by the Romanian Energy Institute (REI) says that wind farms could contribute 13GW to the national power generation capacity by 2020 [9].

Wind turbines, like windmills, are mounted on a tower to capture the most energy. At 30 meters or more aboveground, they can take advantage of faster and less turbulent wind. Turbines catch the wind energy with their propeller-like blades. Usually, two or three blades are mounted on a shaft to form a rotor [10].

Figure 6. Types of wind turbines
[Source: http://www.robotshop.com/media/files/images/horizon-fct-windpitch-wind-turbine-education-kit-large.jpg]

A blade acts like an airplane wing. When the wind blows, a pocket of low-pressure air forms on the downwind side of the blade (figure 7). The low-pressure air pocket then pulls the blade toward it, causing the rotor to turn. This is called lift. The force of the lift is actually much stronger than the wind's force against the front side of the blade, which is called drag. The combination of lift and drag causes the rotor to spin like a propeller, and the turning shaft spins a generator to make electricity.

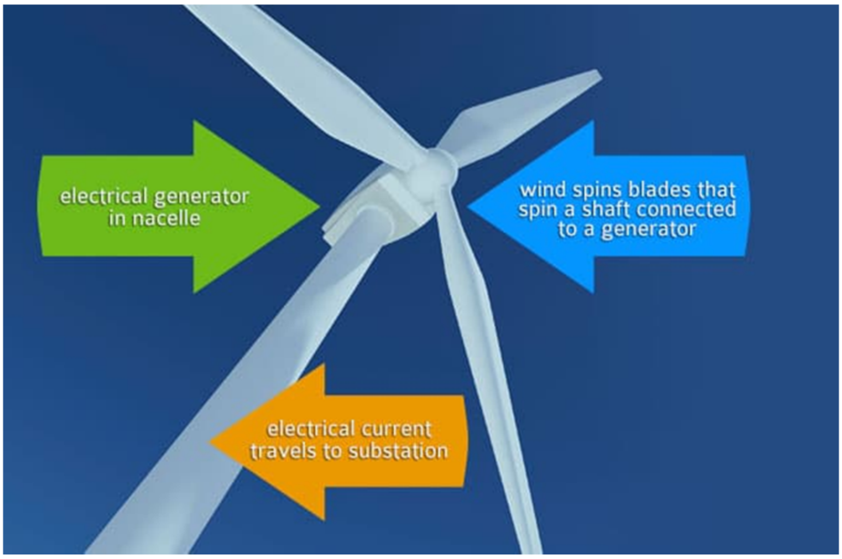


Figure 7. Wind turbine [Source: http://qmgzqy7265-flywheel.netdna-ssl.com/wp-content/uploads/2016/09/windfacts-how-wind-works-1.jpeg]

Based on the location of the wind turbine, two types of wind farms can be presented:

- Onshore wind farms (or on-land turbines);
- Offshore wind farms.

The most substantial environmental cost in terms of both onshore and offshore wind power comes with the manufacturing and later recycling of materials used for wind turbines. During the operation, wind turbines are very environmentally efficient and greenhouse gas emissions are not a big concern.

The onshore wind energy is the most cost-effective and mature of all the renewable technologies. The onshore wind power has an impact on the environment chiefly in form of noise pollution, visual pollution and harm to birds.

Onshore wind often has the benefit of being close to existing electrical grids, reducing the environmental impacts associated with building new electrical grids. Building and installing an onshore wind turbine is the part of the process that is the most harmful to the environment.

Figure 8. Onshore wind turbines

[Source: https://bvgassociates.com/wp-content/uploads/2016/11/onshore.jpg]

Although offshore wind is another great source of clean energy, it is not the best investment because of its high costs, immature technologies and development constrains. Offshore wind energy sources are currently one of the most expensive energy technologies. Offshore wind farms are 90% more expensive than fossil fuel generators and 50% more expensive than nuclear generators. This high expense is a result of the technical difficulties of offshore turbine contruction and connection to the national grid.

Offshore wind power exists both right off the coast, with wind turbines placed on concrete platforms that extend to the bottom of the sea, and further out in the sea through the use of floating platforms, increasing environmental cost through additional materials. As offshore wind turbines move further out, the effect they have on humans is lowered, as is the effect on many living sea organisms. The additional materials needed to build platforms for floating wind turbines that can withstand conditions at deep sea levels are eventually cancelled out through the added efficiency that comes with placing wind turbines further offshore.

Figure 9. Offshore wind turbines [Source: http://assets.inhabitat.com/wp-content/blogs.dir/1/files/2016/07/offshore-wind-farm.jpg]

Electricity produced by offshore wind turbines travels back to land through a series of cable systems that are buried in the sea floor. This electricity is channeled through coastal load centers that prioritize where the electricity should go and distributes it into the electrical grid to power homes, schools and businesses.

Offshore winds are typically stronger during the day, allowing for a more stable and efficient production of energy when consumer demand is at its peak. Most land-based wind resources are stronger at night, when electricity demands are lower.

Regarding the design, there are two basic configurations of wind turbines (figure 10):

- With a vertical axis, the axis of rotation being perpendicular on the direction of the wind;
- With a horizontal axis, the axis of rotation being parallel to the wind direction.

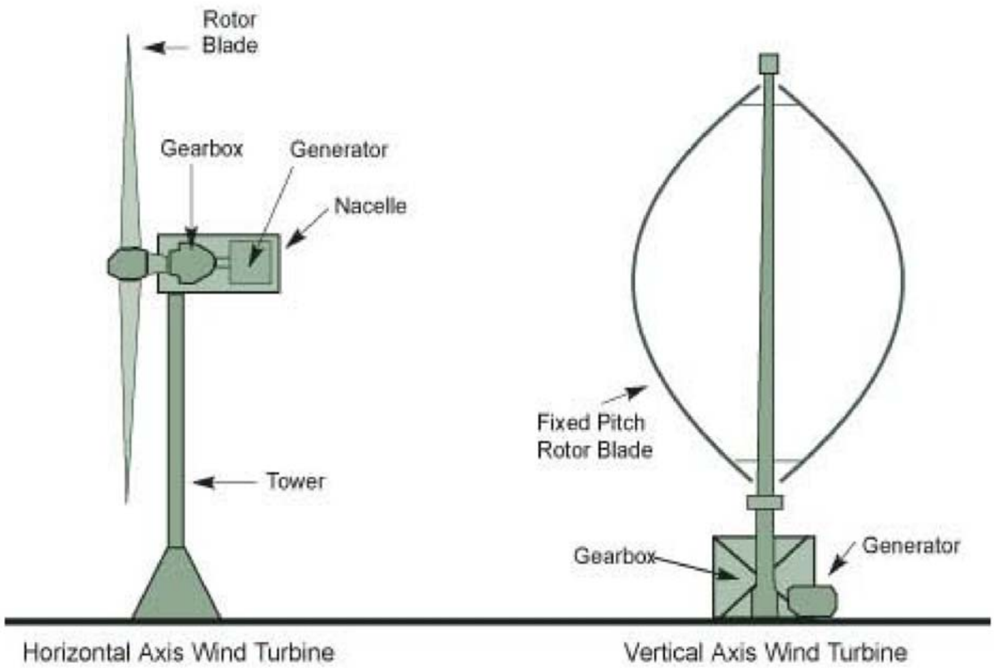


Figure 10. Basic configuration of wind turbines [Source:https://s-media-cache-ak0.pinimg.com/originals/8d/7a/73/8d7a734e43729b71276a59c633f6c66f.jpg]

Regardless of the constructive configuration of the turbine, its function is to generate the necessary torque to drive the electric generator in the conversion of wind energy into electricity.

The most used wind turbines are those with a horizontal axis. Their main components (figure 11) are:

- blades
- turbine rotor (hub)
- nacelle
- low-speed shaft
- gearbox
- high-speed shaft
- cooling system provided for the gearbox and for the generator
- electric generator
- measurement and control systems (wind vane and anemometer)
- supporting tower

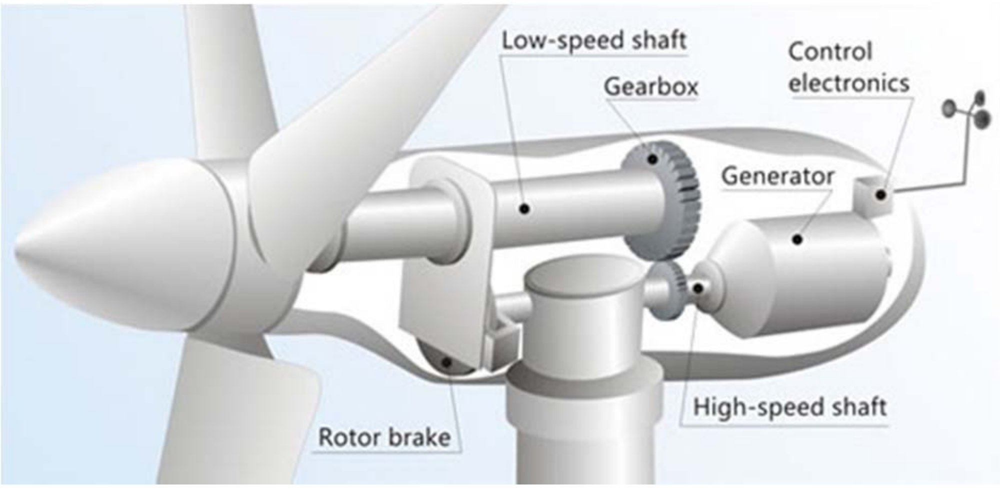


Figure 11. Wind turbine components [http://www.daviddarling.info/images2/wind_turbine_nacelle.jpg]

The turbine blades are designed to transmit the kinetic energy of the wind to the rotor. The wind passes over the blades creating the lift (just like an aircraft wing) which causes the rotor to turn. The most used wind turbine is the one with three blades, which provides:

- limiting vibrations, noise and reduce rotor fatigue;
- increasing power factor by approximately 13% as compared to the one-blade turbine and 3% as compared to the two-blade turbine;
- a low investment cost, taking into account the rotational speed of the wind sensor.

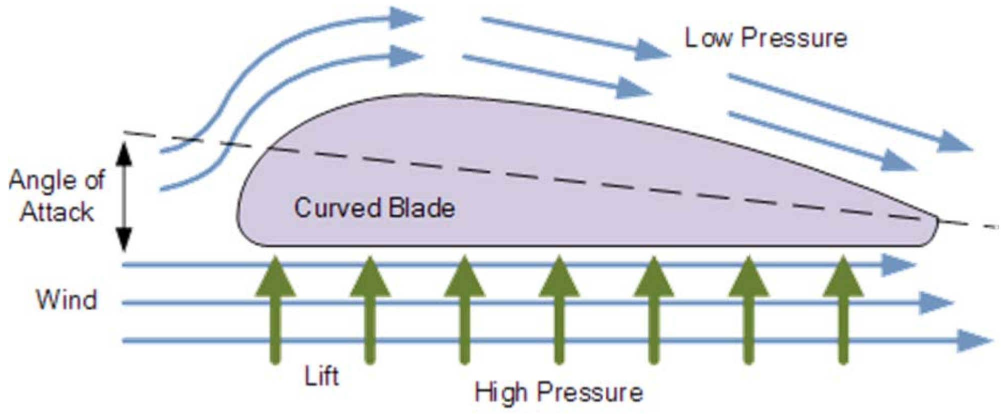


Figure 12. Wind turbine blade [Source:http://www.alternative-energy-tutorials.com/images/stories/wind/alt110.gif]

The hub is the mounting bracket of the turbine blades and it is fitted with their guidance system that allows controlling the rotation speed of the wind turbine.

The nacelle houses the low-speed shaft, the gearbox (or alternatively a slow rotating generator and no gearbox), the high-speed shaft, the electric generator, the cooling system and the control systems.

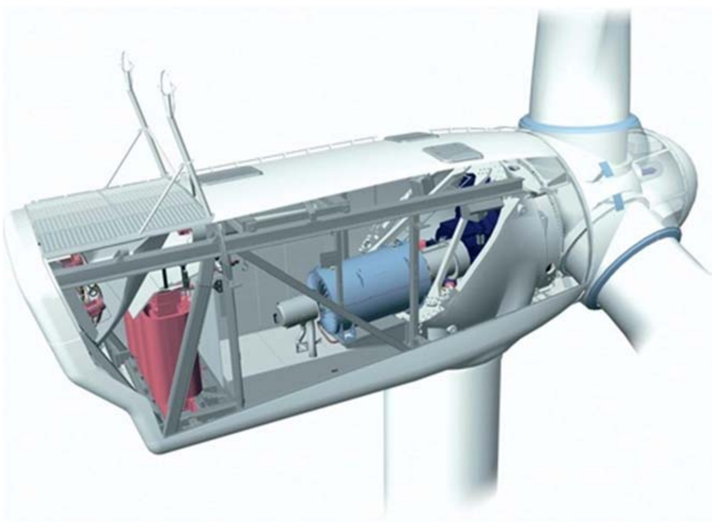


Figure 13. The inside view of a nacelle [Source: https://www.wind-energy-the-facts.org/images/3-8.jpg]

The low-speed shaft is also being called the main shaft or the rotor shaft; the turning blades spin this shaft 20-40 times per minute.

The gearbox – the gear in this box connects the low-speed shaft to the high-speed shaft. They boost the rotation speed of the high-speed shaft to 1000 – 1800 rotation per minute.

The high-speed shaft (the generator shaft) aims to train the electric generator and it is equipped with a safety device (a mechanical disc brake) for limiting the rotation speed when the wind speed becomes critical.

The generator – the electricity goes to a transformer that converts it to the right voltage for the larger electricity grid. The generator can provide direct current (DC) or alternating current (AC).

Control systems are used to overview the turbine and help to:

- adjust the angle of the rotating blades;
- stop the rotor when the wind speed is above the normal values;
- facilitate nacelle orientation to the wind.

The supporting tower is usually made of metal used to support the wind turbine and to pass the connecting cables for the electricity supply. The height of the tower has a major importance because the wind intensity and the turbine efficiency increases with height.

Figure 14. Wind turbine towers [Source: https://www.kenresearch.com/blog/wp-content/uploads/2017/04/Wind-Turbine-Towers.jpg]

Wind turbines can be used as stand-alone applications, or they can be connected to a utility power grid or even combined with a photovoltaic system. For utility-scale sources of wind energy, a large number of wind turbines are usually built close together to form a wind plant. Several electricity providers today use wind plants to supply power to their customers.

Stand-alone wind turbines are typically used for water pumping or communications. However, homeowners, farmers and ranchers in windy areas can also use wind turbines as a way to cut down their electricity bills.

Small wind systems also have potential as distributed energy resources. Distributed energy resources refer to a variety of small, modular power-generating technologies that can be combined to improve the operation of the electricity delivery system.

1.3. Design Alternatives to be Considered

1.3.1. Wind Turbine Sizing

Based on the information provided by ANM Romania, the annual average wind speed for Pincesti, Bacau is 7 m/s. Starting from this, the following wind turbines will be taken into account to be used for providing electricity:

- Bergey Excel 10 kW wind turbine;
- Polaris 20 kW wind turbine;
- Aeolos-H 30 kW wind turbine.

a) The **Bergey Excel 10** is ideal for homes, farms and small businesses. It is designed for high reliability, low maintenance and automatic operation in adverse conditions.

Rated Power	10 kW
Peak Power	12.6 kW
Cut-In Speed	3 m/s
Nominal Rotor Speed	0-400 rpm
Rotor Diameter	7 m
Weight	545 kg
Temperature Range	-40 / 60˚C

Table 1. Bergey Excel 10 specifications

[Source: http://bergey.com/products/wind-turbines/10kw-bergey-excel]

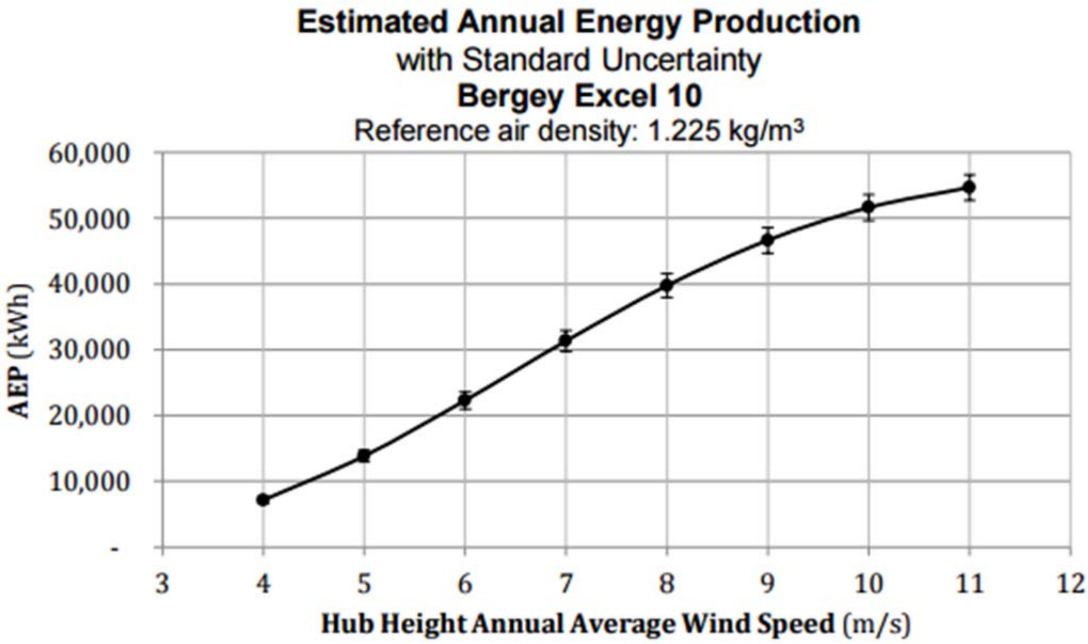


Figure 15. Annual energy production

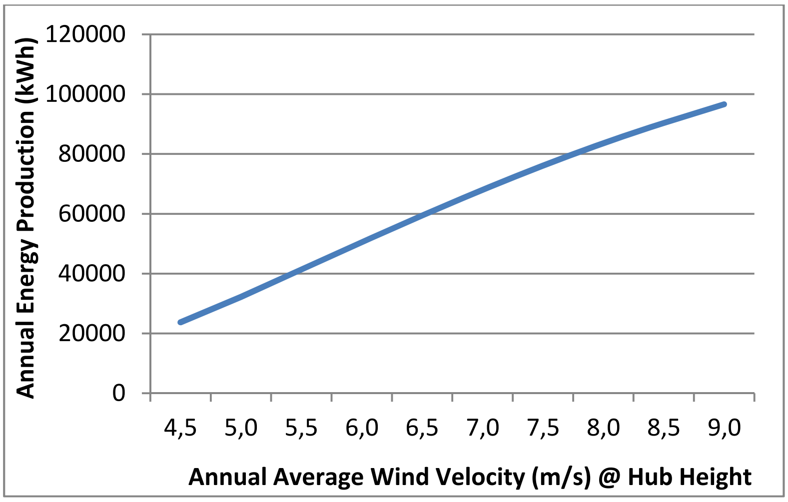
[Source: http://bergey.com/products/wind-turbines/10kw-bergey-excel]

Based on the annual energy production chart, one Bergey Excel 10 wind turbine can produce around 30 kWh per year at an average wind speed of 7 m/s.

b) The **Polaris 20 kW wind turbine** is a residential turbine but is also used as community sized wind turbine that produces the right amount of power for residential development, farms and small businesses. Predominantly, however, 20 kW units are often used in agricultural and light industrial applications. It has also been used for years in remote village applications, where diesel power systems supply electricity for a small grid.

Rated Power	20 kW
Cut-In Speed	3 m/s
Voltage Output	230 VAC / 460 VAC
Operation RPM	100 rpm
Rotor Diameter	10 m
Weight	1,800 kg
Temperature Range	-25 / 50˚C

Table 2. Polaris 20 kW wind turbine specifications [Source: http://www.polarisamerica.com/turbines/20kw-wind-turbines/]



Annual Average Wind Velocity (m/s)	Annual Energy Production (kWh)
4.0	16061
4.5	23699
5.0	32233
5.5	41300
6.0	50473
6.5	59448
7.0	68022
7.5	76069
8.0	83527
8.5	90370
9.0	96601

Figure 16. Annual energy production
[Source: http://www.polarisamerica.com/turbines/20kw-wind-turbines/]

As presented in the chart and in the table above, one Polaris 20 kW wind turbine can produce around 68 kWh per year at an average wind speed of 7 m/s.

c) The **Aeolos-H 30 kW wind turbine** uses a directly driven generator without a gearbox or booster device. The generator is directly driven by the blade rotor. It has 30% more power output than induction generators at the same wind speed.

Rated Power	**30 kW**
Peak Power	40 kW
Cut-In Speed	3 m/s
Voltage Output	360 VDC
Rotor Speed	90 rpm
Rotor Diameter	12.5 m
Weight	980 kg
Temperature Range	-20 / 50˚C

Table 3. Wind turbine specifications

[http://www.windturbinestar.com/30kwh-aeolos-wind-turbine.html]

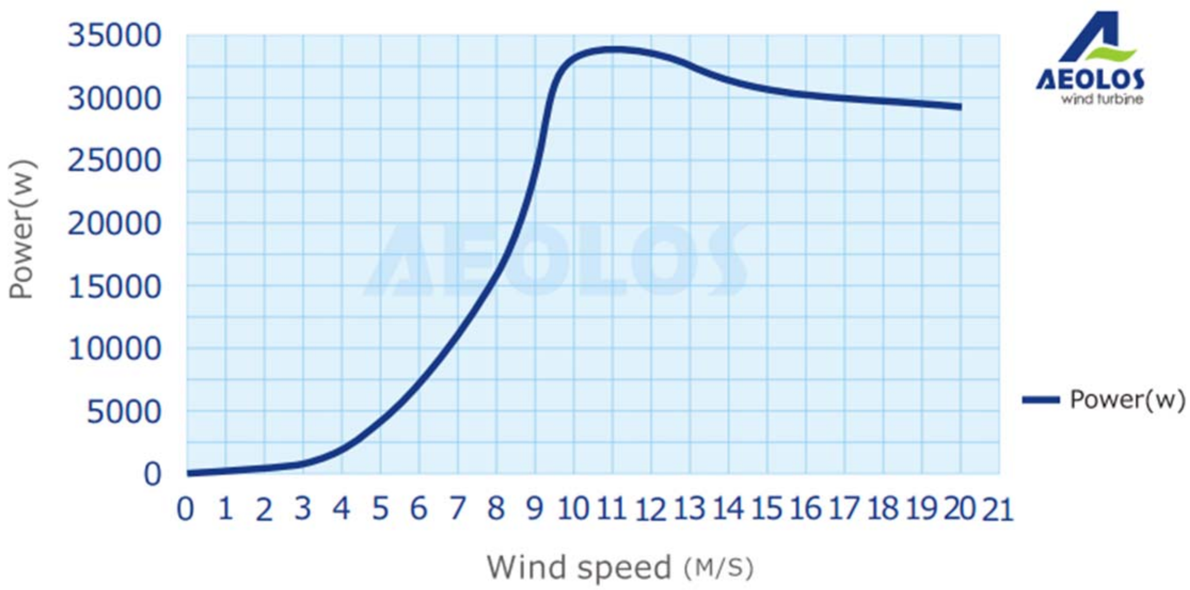


Figure 17. Wind speed / Power Curve

[https://www.windturbinestar.com/uploads/pdf/aeolos-output.pdf]

	Bergey Excel 10	Polaris turbine	Aelos-H turbine
Rated Power	10 kW	20 kW	30 kW
Cut-In Speed	3 m/s	3 m/s	3 m/s
Annual Energy Production at 7 m/s	30 kWh	68 kWh	85 kWh
Price	25,000 €	50,000 €	67,700 €

Table 4. Short comparison between the wind turbines

1.3.2. The Inverter

Inverters convert DC (typically low voltage) into AC as required for conventional appliances. There are generally two types of inverters available: off-grid and grid-connect.

The objective of this project is designing an off-grid wind installation and the used components have to be suited for an isolated system. The following inverters are analysed:

- SMA Sunny Island 8.0H
- Studer Xtender XTH 6000-48

	SMA Sunny Island 8.0H	Studer Xtender XTH 6000-48
Rated Power	6,000 W	5,000 W
Rated Frequency	50 Hz	45-65 Hz
AC Output	230V	230V / 120 V
Battery DC Input	48V	48V
Efficiency	95%	96%
Price	3,300 €	4,500 €

Table 5. Inverter specifications

1.3.3. Batteries

Deep-cycle flooded lead-acid batteries are the most common type in use today for renewable energy systems.

The advantages of using lead-acid batteries are:

- Long deep cycle life;
- High discharge rate capability;
- Easy maintenance;
- Tolerant to overcharging;
- Long, proven history of use.

	Rolls Solar 4000 Series	Trojan L16G
Voltage	6 V	6 V
Storage Capacity (C100)	600 Ah	433 Ah
Cells	3	3
Reserve Capacity @25A	979 minutes	789 minutes
Batteries Needed	240	328
Price	300 €	330 €

Table 6. Rolls batteries and Trojan batteries

1.4. Description of the Final Solution

1.4.1. The Wind Turbine

Aeolos Wind Turbine is a small wind turbine manufacturer founded in Denmark in 1986. The Aeolos-H 30kW (figure 18) is used for both on-grid and off-grid applications and can supply power for farms, schools or small enterprises. The turbine uses a no gearbox configuration which reduces the overall weight in the nacelle. This design requires less maintenance that conventional gearbox equipped turbines, which means less non-producing time offline [11].

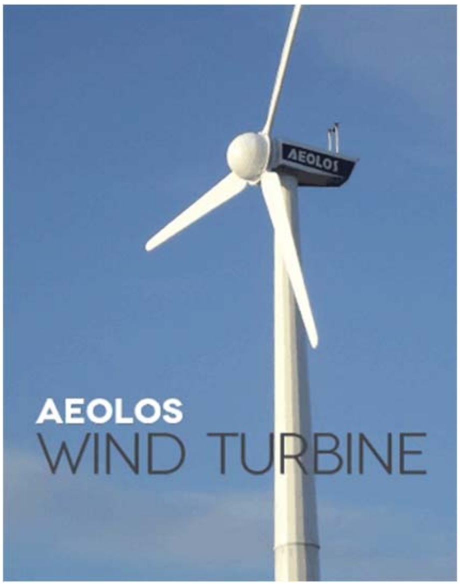


Figure 18. Aeolos-H 30kw wind turbine

[Source: http://www.windturbinestar.com/uploads/images/30kw.gif]

The Aeolos-H 30kW generator has a greater efficiency when wind speeds are not at full rating as compared to the conventional designs. It can be installed as a single unit or combined as multi-units when building a wind farm.

Rated Power	30 kW
Maximum Output Power	35 kW
Generator	Direct-Drive Permanent Magnet Generator
Generator Voltage	360 VDC
Blade Quality	3 Glass Fiber Blades
Rotor Blade Diameter	12.5 m
Swept Area	122.7 m^2
Start-up Wind Speed	3 m/s
Rated Wind Speed	10 m/s
Controller	PLC with Touch Screen
Safety System	Yaw Control, Electrical Brake & Hydraulic Brake
Turbine Weight	1380 kg
Noise	55 db(A) @ 7 m/s
Design Lifetime	20 years

Table 7. Aeolos-H 30 kW wind turbine specifications

[http://www.windturbinestar.com/30kwh-aeolos-wind-turbine.html]

With a cut in wind speed of 3 m/s, the direct drive technology enables the turbine to make efficient use of the low wind conditions. The wind speed is an important factor in electricity generation. This is shown in the table below:

Wind speed (m/s)	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Power (kW)	0.76	2.16	4.26	7.37	11.65	16.36	23.31	33.02	34.03	33.52	32.52	31.57

Table 8. Aeolos-H 30 kW Wind Turbine Output
[https://www.windturbinestar.com/uploads/pdf/aeolos-output.pdf]

1.4.2. The Grounding System

A wind turbine is generally the highest point in the landscape and is, therefore, at particular risk of being struck by lightning. Lightning and overvoltages can cause significant damage and may even result in the complete loss of the wind turbine. An earthing (grounding) system is one of the most important components required for an appropriate protection of a wind turbine.

The main characteristics of a grounding system are:

- Good electrical conductivity;
- Conductors capable of withstanding high fault currents;
- Low ground resistance and impedance;
- Equipotential bonding;
- Good corrosion resistance;
- Electrical and mechanical robustness and reliability.

A typical grounding system of an individual wind turbine consists of a ring electrode installed around the foundation and bound to the metal tower through the concrete foundation, as can be seen in Figure 19.

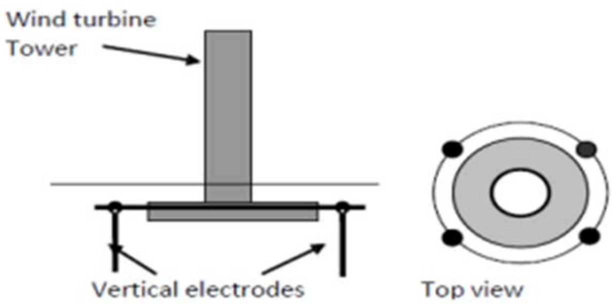


Figure 19. Typical wind turbine grounding layout

Vertical rods and additional horizontal electrodes are often used in conjunction with the ring electrode to achieve earth resistance. Some alternative earthing arrangements are shown in Figure 20.

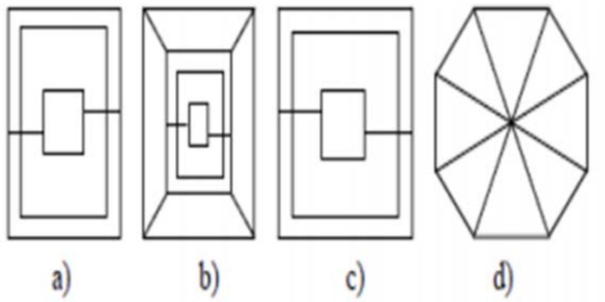


Figure 20. Alternative grounding arrangements

1.4.3. The Inverter

The Sunny Island 8.0H (figure 21) supports a wide range of on-grid and off-grid applications. It is a good choice when combined with other equipment and the system can be configured to meet the power requirements. The Sunny Island is compatible to most lithium-ion batteries and all lead-acid batteries.

The home screen gives access to the energy flow between the loads, battery and external energy sources. It also controls the most important charging and discharging processes fully automatically, increasing the electrical endurance of the batteries.

The intelligent load and energy management system of Sunny Island 8.0H ensures that off-grid systems remain operational even in critical situations. If there is a shortage of renewable energy, the Sunny Island automatically starts the diesel generator. When wind energy is available again, the inverters start charging the batteries and connect the loads again [12].

Figure 21. Sunny Island 80.H Inverter [http://danishgreentech.com/images/stories/virtuemart/product/SMA_Sunny_Island_5048_500x500.png]

Technical data

Producer	SMA Solar Technology AG
Model	Sunny Island 8.0H
AC output voltage	230 VAC
Rated frequency	50 Hz
Rated power	6,000 W
DC input voltage	48 V
Efficiency	95%
Dimensions	467 mm x 612 mm x 242 mm

Table 9. Technical data of Sunny Island 8.0H inverter [http://www.sma.de/en/products/battery-inverters/sunny-island-60h-80h.html]

1.4.4. Batteries

Rolls premium deep cycle batteries have earned a reputation of reliability and dependability in the renewable energy markets. Dual container construction, high-density polyethylene materials and unique "resistox" plate design provide a life expectancy that is the longest in the battery industry [13].

Some of the pros for Rolls 4000 Series batteries are:

- 1280 cycles of 50% DOD (depth of discharge);
- 800 cycles of 80% DOD;
- 7 year warranty.

Make and model	Rolls Solar 4000 Series RB-S605
Voltage	6 V
Depth of Discharge (DOD)	50%
Storage Capacity @5hr	328 Ah
Storage Capacity @10hr	398 Ah
Storage Capacity @20hr	468 Ah
Storage Capacity @100hr	605 Ah
Dimensions (mm)	318x181x425

Table 10. Technical data about Rolls batteries

[http://www.windandsun.co.uk/products/Batteries/Rolls-Batteries#.WQC_36i0nIU]

1.4.5. The Diesel Generator

It is however, important to note the limitations of the wind energy system. In order to ensure a continuous electricity flow, the installation has to be equipped with a backup generator for the days when the wind turbine is not producing energy.

The Zyraxes 3029-SA three phase diesel generator is used with the wind installation. The 32 kW generator, equipped with a John Deere motor, is a good solution for this project.

Make and model	Zyraxes 3029-SA
Nominal Power	32 kW / 40 kVA
Peak Power	35.2 kW / 44 kVA
Rated Frequency	50 Hz
Rated Speed	1500 rpm
Power Factor	0.8
Fuel	Diesel
Fuel Consumption	7.5 litres/hour
Fuel Tank Capacity	50 litres

Table 11. Diesel generator specifications

[Source: http://www.generatoaredecurent.info/generator-curent-zyraxes-3029-sa-32-kw/]

1.5. Impact of the Project on the Rural Development

1.5.1. Environmental Impact

Environmental impacts are an inherent part of electricity production and energy use. Electricity generated from renewable energy sources has a smaller environmental footprint than power from fossil-fuel sources, which is arguably the major impetus for moving away from fossil fuels to renewables. However, although the types and magnitude of environmental effects differ substantially from fossil-fuel sources and from one renewable source to another, using renewables does not avoid impacts entirely.

The electricity generation is fully produced by converting the wind power. During the production of a wind turbine auxiliary materials are also used which help to increase the efficiency of the mechanism. A wind turbine includes equipment for transmitting and transforming the energy (gearbox, generator), which requires lubrication and cooling. During these processes different chemical substances are used: oil (for lubrication and cooling the gearbox) and water (for cooling the generator). These substances are used in closed circuits for preventing subsequent spilling into the environment.

Concerns about climate change and greenhouse gas (GHG) emissions are a major driver in the push for use of renewable energy sources. The figure below illustrates the range of estimates of CO_2e emissions for various sources of electricity. The equivalent carbon dioxide emissions (CO_2e) are the amount of greenhouse gas emissions expressed as carbon dioxide [14].

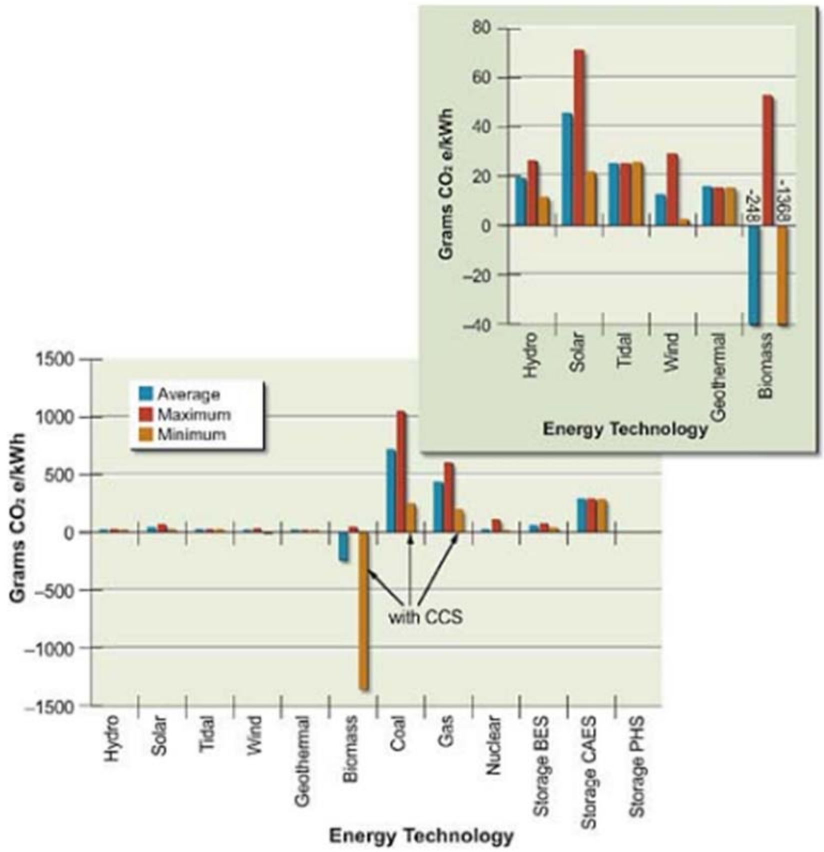


Figure 22. Estimated emissions of greenhouse gases

[Source: https://www.nap.edu/openbook/12619/xhtml/images/p2001a9a5g203001.jpg]

Not surprisingly, renewables are estimated to have significantly less CO_2e emissions than coaland gas; most estimates of emissions from nuclear power use are similar in magnitude to those from the use of renewables. Adding carbon capture and storage (CCS) to coal and gas systems, however, significantly reduces the relative advantage renewables have in terms of carbon and energy savings. The relative advantage is also modestly reduced by adding energy storage to a renewable technology.

Of the renewable technologies included in the figure above, solar PV technologies have the highest CO_2e emissions. Emissions from PV are sensitive to innovations in conversion efficiencies and to the energy mix used to generate electricity during manufacturing.

The wind is estimated to be among the lowest life-cycle emitters of greenhouse gasesof all the renewable energy technologies. In spite of producing very low life-cycle carbon emissions, the wind is often discounted as a viable source of electricity because of its intermittent availability.

Land use may be a limiting factor for the use of renewable energy technologies and also an environmental factor. The power plan size and the quantity of electricity generated need to be taken into consideration.

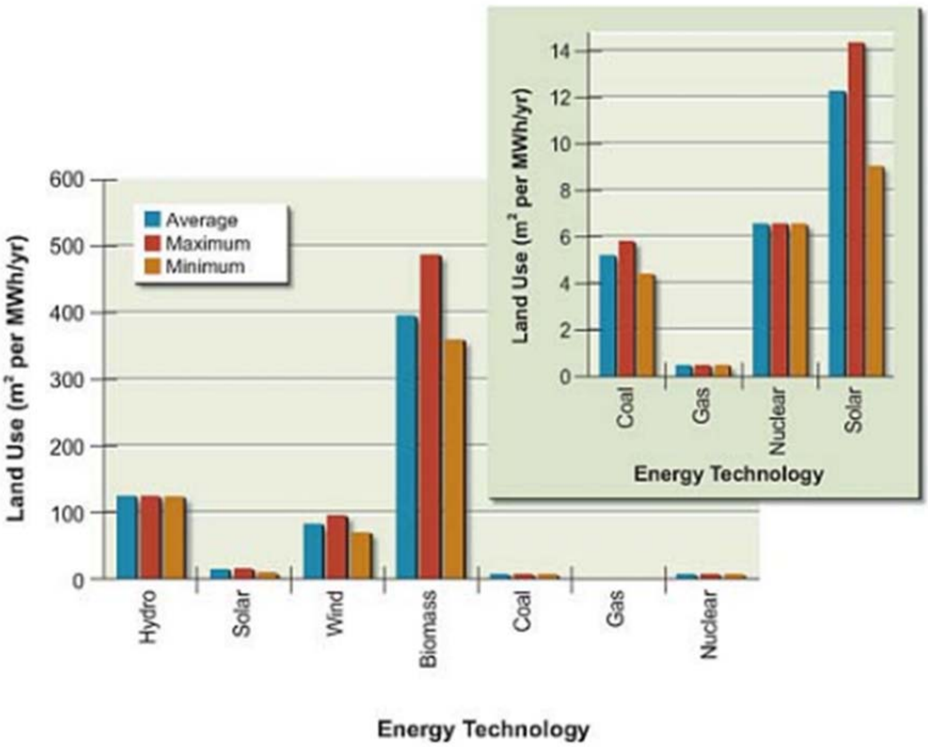


Figure 22. Land use for various energy technologies (m^2 per MWh/year)
[Source: https://www.nap.edu/openbook/12619/xhtml/images/p2001a9a5g213001.jpg]

A key factor affecting land use is the generating efficiency of the technology per unit area. By design, technologies using high energy density power sources use less land to produce more electricity at the point of generation than do the more diffuse renewable technologies. Based on this, renewables have relatively large land-use requirements [15]. Moreover, the land used by some diffuse renewable electricity technologies usually allows for multiple uses, or the technology makes use of sites that also serve an alternative purpose (e.g., PV installations on roofs of buildings, wind turbines on farms). Another thing that has to be pointed out is that the remainder of the land can be used for other purposes, like livestock grazing, agriculture and also the wind facilities can be placed on abandoned or underused land [16].

An important environmental impact is linked with noise and vibrations. During the operation of the wind turbine, the noise is produced by the generator and by the blades. Most of the noise is caused by the movement of the blades through the air. There is also a mechanical sound generated by the turbine itself. The level of the sound depends on the turbine and on the wind speed. Wind turbines don't produce vibrations during operation.

Another impact of the wind turbines concerns the wildlife, and mainly birds. Spinning turbines can cause changes in the air pressure that will cause bird deaths because of the collision with the blades. This impact is relatively low and does not pose a threat to species populations.

1.5.2. Social and Rural Impact

The way in which energy is generated and used is in a continuous transformation: increasing the proportion of home-developed low-carbon generation, while using less through an energy efficiency revolution. Much of this is driven by large organizations, but individuals and local communities can also make an important commitment to maintaining energy security, tackling climate change and keeping costs down for consumers.

In electricity generation, community involvement at any scale can bring benefits in fortifying communities and sharing financial returns, including alternatives for lower energy bills.

Over the coming decades, we need a continued supply of reliable and affordable energy as we move our economy onto a low carbon basis to meet our climate responsibilities. Over time, this will mean a major shift in the way we generate and use energy nationally and in rural communities.

Meeting the challenge of affordable energy security in a low carbon economy, rural communities have to involve themselves in generating energy (electricity or heat), reducing energy use (saving energy through energy efficiency and behavior change) and managing energy (balancing supply and demand).

Addressing climate change or reducing carbon emissions, as well as saving money on energy bills are the main motivating factors for rural communities to start energy projects. However, this goes beyond energy security, climate change and energy bills, and can also bring further benefits as:

- Developing new skills. Members of the community of all ages can benefit from opportunities to learn new skills through involvement in energy activities, young people can gain work experience or energy and climate change education.
- Financial benefits. Rural energy generation presents opportunities for an increased income through green certificates for the generation of renewable energy, selling the energy produced or even collecting rent for a power plant location by the landowners.
- New jobs. An energy production system will provide jobs for the local people, in a wide range of domains, such as finance and accounting, project management, business planning, electrical engineering, legal expertise, monitoring, evaluation of impact on the environment.
- Improvement of local infrastructure. Building a new road or improving an existing one is a positive impact on the rural area. It can lead to the modernization of the area.

Tourism can be greatly increased based on wind projects, and thus it will have a good impact on local communities. Investors and local authorities can help tourism by organizing trips to wind power plants, allowing people to observe the construction of a wind turbine. Usually, the idea of “green energy” is appreciated by people. Based on this, different activities can be introduced for both educational and relaxation purposes.

The visual impact is an important concern associated with operating wind turbines. The location of the wind turbine can affect the landscape. Being a vertical structure with rotating blades, a wind turbine has the potential of attracting people's attention. Wind farms with several wind turbines spread around the territory may become dominant points in the landscape.

1.6. Conclusions

Based on the information provided in this first chapter and the calculations from the second one, it can be concluded that the best renewable energy system for this location is an off-grid wind system. For this, the Aeolos-H 30kW wind turbine equipped with Sunny Island inverters is being used.

The decision of using an off-grid system has been made by analyzing the calculations of energy production and the cost-effectiveness of this installation. By comparing the energy produced by the turbine and the alternative of using a diesel generator, the best decision is to use the renewable system.

In the third chapter the calculation of payback time for the installation is presented. It was determined that the system is going to be profitable starting with the 9^{th} year of its utilization, which makes it a good investment.

Despite the high amount of energy produced by the turbine, there are also gaps during the production of electricity. It is, however, important to note the limitations of wind energy generation. In this case, the Zyraxes 3029-SA diesel generator is used to ensure a continuous supply of electricity.

To conclude, choosing this renewable energy installation is a good way to meet electricity needs by not being connected to the utility grid and it also helps you to be in control of your carbon footprint on the environment.

1.7. References

[1] [2] https://en.wikipedia.org/wiki/Renewable_energy

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[11] http://www.windturbinestar.com/30kwh-aeolos-wind-turbine.html

[12] http://www.sma.de/en/products/battery-inverters/sunny-island-60h-80h.html

[13] http://www.windandsun.co.uk/products/Batteries/Rolls-Batteries#.WQC_36i0nIU

[14] https://www.nap.edu/read/12619/chapter/7

[15] https://www.nap.edu/read/12619/chapter/7#213

[16] http://www.ucsusa.org/clean-energy/renewable-energy/environmental-impacts-wind-power#.WPjs9qi0nIV

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Calculations

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2.1. Energy Requirements

To start designing the wind energy system it is necessary to know the daily consumption of energy required. To do so, a list of energy consuming equipment and the daily number of operating hours is needed. The performance data is estimated for the main consumers of the guest house and the water pump used for irrigation.

Consumption	Units	Power (W)	Hours/Day	Energy (kWh/day)
Fridge	2	200	10	4.00
Illumination	40	10	4	1.60
TV	15	50	3	2.25
Computer	3	300	10	9.00
Mini-fridge	10	50	10	5.00
Washing machine	3	1,500	0.5	2.25
Air conditioner	1	900	5	4.50
Water pump	1	45,000	4	180.00
Others				3.00
TOTAL				**211.60**

Table 12. Power consumption of different equipment

The daily energy required in Wh/day is obtained by multiplying the rated power by the operating hours of the equipment.

$$Ed\ (Wh) = P(W) \cdot h_{func}$$

The result of the equation is divided by 1000 to obtain the energy in kWh/day and, in the end, it is multiplied by the number of units.

For example, to calculate the energy required for a TV, the equation is:

$$Ed\ (Wh) = P(W) \cdot h_{func} = 50 \cdot 3 = 150\ Wh/day$$

$$Ed(kWh) = \frac{Ed(Wh)}{1000} = 0.15\ kWh/day$$

In this case, there are 15 TVs, and the final result is:

$$Ed_t(kWh) = 15 \cdot Ed(kWh) = 15 \cdot 0.15 = 2.25\ kWh/day$$

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The water pump supplied by the installation is a Grundfos SP 30-46 submersible borehole pump. All steel components are made of stainless steel, that ensure high corrosive resistance. The motor is fitted with the Grundfos Tempcon sensor that, by use of powerline communication together with a MP204 control panel, enables temperature monitoring.

Product Name	SP 30-46
Speed for Pump Data	2900 rpm
Rated Flow	30 m^3/h
Pump Type	SP30
Stages	46
Motor Diameter	8 inch
Rated Power	45 kW
Mains Frequency	50 Hz
Net Weight	326 kg

Figure 24. Grunfos SP 30-46 water pump

[Source: http://product-selection.grundfos.com]

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2.2. Wind Energy Potential

To carry out the calculus and sizing of the wind installation, the wind energy potential has to be known. For this, the next wind speed map and wind rose diagram are used:

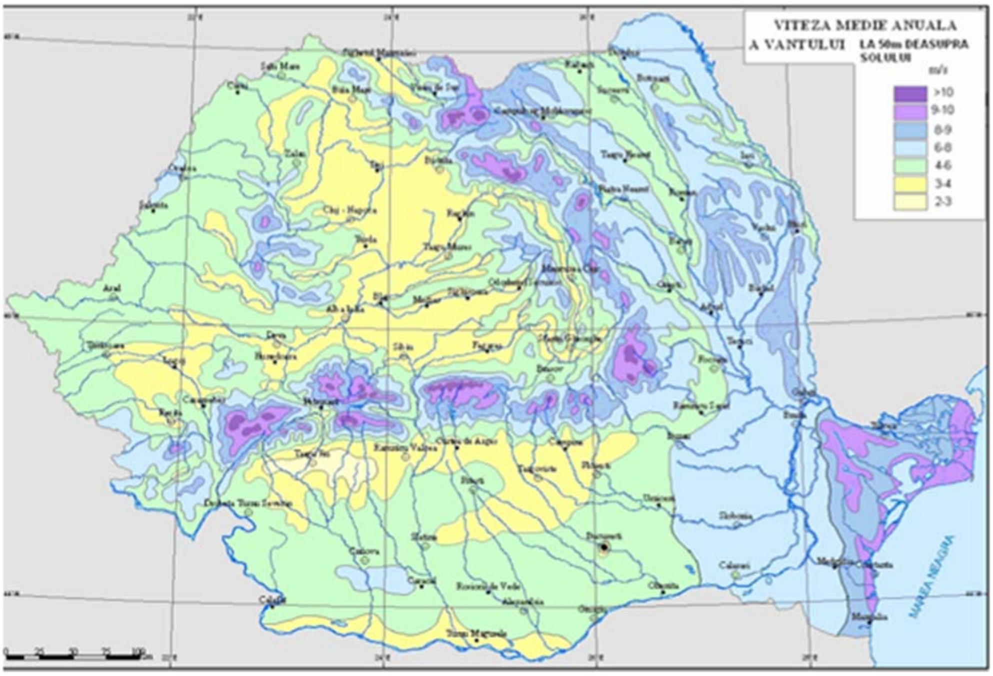


Figure 25. Wind speed map for Romania [ANM, 2006, http://www.meteoromania.ro/]

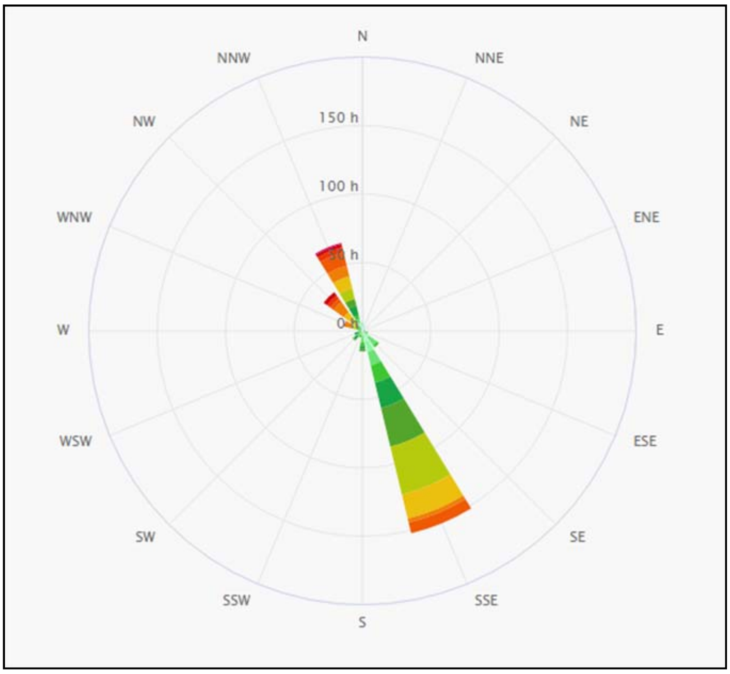


Figure 26. Wind rose diagram [Source: https://www.meteoblue.com/ro/vreme/archive/windrose/bacău_românia_685948]

Based on the information above, the following values for wind speed and yearly hours were obtained:

Wind speed (m/s)	Yearly hours (h/year)
3	1400
4	1300
5	900
6	700
7	650
8	800
9	750
10	500
11	360
12	100
13	50
14	50
15	0
16	0

Table 13. Wind speed and yearly hours for selected location (own elaboration)

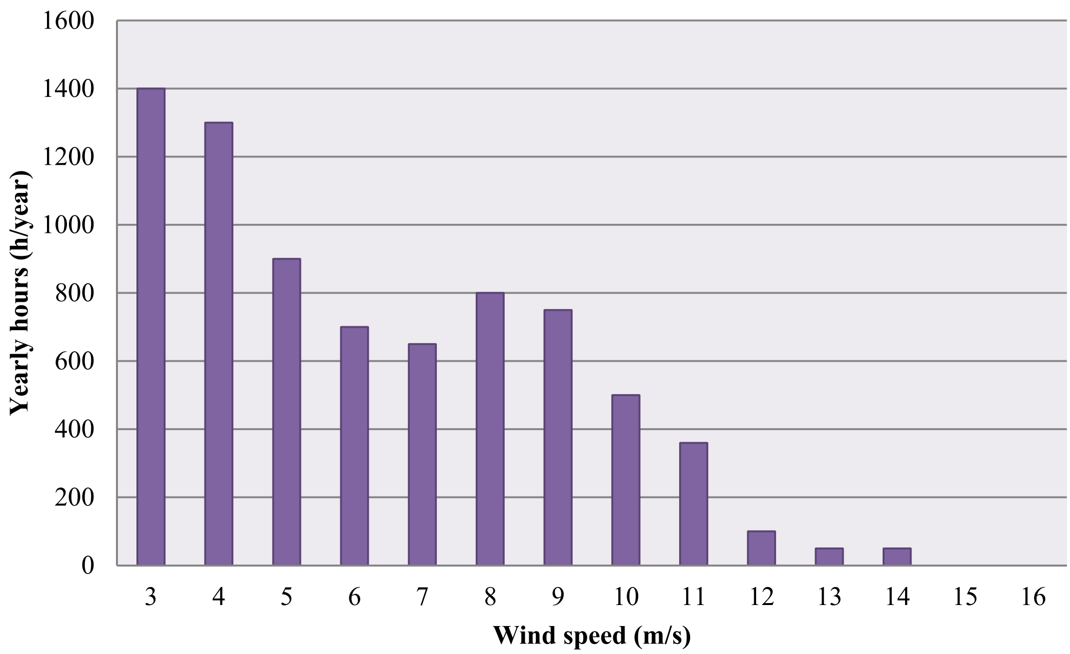


Figure 27. Wind speeds histogram (own elaboration)

2.3. Wind Power Generation

The power supplied by the wind turbine directly depends on the power coefficient. The area swept by the rotor, cubic wind speed and air density also affects the power as can be seen in the following equation:

$$P_t(W) = \frac{1}{2} \cdot C_p \cdot \rho \cdot A \cdot v^3$$

Where: C_p : the power coefficient

ρ : air density (1.225 kg/m^3)

A : the area swept by the rotor in square meters (531 m^2)

v : wind speed in m/s

Having the technical information of the wind turbine, we can proceed to the power generated based on the wind speed:

Wind speed (m/s)	Power (kW)
3	0.76
4	2.16
5	4.26
6	7.37
7	11.65
8	16.36
9	23.31
10	33.02
11	34.03
12	33.52
13	32.52
14	31.57

Table 14. Power generation of the wind turbine

If we combine the power curve of the Aeolos-H 30 kW wind turbine (presented in the first chapter) with the speed and yearly hours of wind information, we obtain the following production of annual energy:

Wind speed (m/s)	Power (kW)	Yearly hours (h/year)	Energy (kWh/year)
3	0.76	1,400	1,064.0
4	2.16	1,300	2,808.0
5	4.26	900	3,834.0
6	7.37	700	5,159.0
7	11.65	650	7,572.5
8	16.36	800	13,088.0
9	23.31	750	17,482.5
10	33.02	500	16,510.0
11	34.03	360	12,250.8
12	33.52	100	3,352.0
13	32.52	50	1,626.0
14	31.57	50	1,578.5
ANNUAL ENERGY			**85,261.3**

Table 15. Calculated energy production of the installation

The daily energy produced by the Aeolos-H 30 kW in this location is:

Daily energy = 233.6 kWh/day

Having the annual production of electricity and the power consumption of the equipment, we can point out that the wind installation can provide enough energy:

$$Annual\ energy\ production = 85{,}261.3\ kWh/year$$

$$Annual\ power\ consumption = 365\ days \cdot 211.60\ kWh/day = 77{,}234\ kWh/year$$

2.4. Selecting the Batteries

In order to calculate and select the batteries needed, the following parameters are considered:

Energy Requirements (E_g)	211,600 Wh/day
Battery Bank Voltage (V_{bat})	48 V
Depth of Discharge (DOD)	50%
Number of days without wind production (D)	2

Table 16. Battery requirements and parameters

The required capacity for the batteries is determined with the following formula:

$$C_{bat}(Ah) = \frac{E_g \cdot D}{V_{bat} \cdot DOD} = \frac{211{,}600 \ \cdot 2}{48 \cdot 0{,}5} = 17{,}633 \ Ah$$

Based on the batteries capacity, the next battery bank is chosen:

Batteries	
Make and model	Rolls Solar 4000 Series
Voltage	6 V
Capacity C100	600 Ah
Depth of Discharge (DOD)	50%
Battery Bank	
Total no. of units	240 units
Units in series	8 units
Parallel series	30
Battery bank voltage	48 V
Total capacity	18,000 Ah

Table 17. Battery bank configuration
[http://www.windandsun.co.uk/products/Batteries/Rolls-Batteries#.WQC_36i0nIU]

Figure 28. Rolls Solar 4000 Series
[http://www.windandsun.co.uk/media/20579/prod2.jpg?width=800]

2.5. Selecting the Inverter

Based on the data provided above, the energy demand of the consumers is around 54 kW and the power needed from the inverter is calculated below:

$$P_{inv}[kW] = \left(\sum P_{eq}\right) \cdot 1.25 = 54 \cdot 1.25 = 67.5\ kW$$

The following inverters were decided to be installed:

Inverter

Producer	SMA Solar Technology AG
Model	Sunny Island 8.0H
Continuous Output Power	6,000 W
DC Input Voltage	48V
AC Output Voltage	230 VAC
Inverter Group	
Total Units	12
Total Power	72 kW

Table 18. Inverter Configuration

[http://www.sma.de/en/products/battery-inverters/sunny-island-60h-80h.html]

2.6. The Generator

In order to support the designed wind system, a diesel generator is used to supply electricity. The generator selected has the following specification:

Diesel Generator

Producer	Zyraxes
Model	3029-SA
Continuous Power	32 kW / 40 kVA
Dimensions (mm)	2200 x 900 x 1400
Fuel Consumption	7.5 l/h

Table 19. Diesel Generator

[http://www.generatoaredecurent.info/generator-curent-zyraxes-3029-sa-32-kw/]

Budget and Economic Analysis of the Project

3.1. Budget of the Installation

In order to begin the economic analysis of the project, the total budget of the wind installation has to be known. This is shown in the table below:

DESCRIPTION	UNITS	UNIT COST	TOTAL COST
Wind Turbine Aeolos-H 30 kW and 18 m Tower	1	67,700 €	67,700 €
Inverter SMA Sunny Island 8.0H	12	3,300 €	39,600 €
Batteries Rolls Solar 4000 Series	240	300 €	72,000 €
Generator Zyraxes 3029-SA	1	12,500 €	12,500 €
Site Preparation and System Installation	1	5,000 €	5,000 €
Design, Management and Administrative Cost	1	1,500 €	1,500 €
TOTAL COSTS			198,300 €

Table 20. Wind turbine installation cost

Knowing all the costs needed for the installation, a comparative analysis is needed to determine the economic viability of the installation.

First of all, operation and maintenance costs are estimated at 0.7% of the investment, totalling an estimated cost of 1,388.10 €/year.

For the diesel generator, the minimum annual production of electricity for supplying the consumers during low wind conditions is estimated to be around 10% of the total energy consumption. This means about 7,723 kWh annually. The following parameters are considered:

Diesel generator operation costs with wind turbine	
Diesel generation needed (E_r)	7,723 kWh/year
Generator consumption (F_c)	0.26 L/kWh
Diesel density (ρ_{diesel})	0.83 kg/L
Diesel unit cost (C_{diesel})	1.00 €/L

Table 21. Diesel generator operation data with wind turbine

The unit price of the energy produced by the generator is calculated as follows:

$$Generator\ unit\ energy\ cost\ (E_{cost}) = \frac{F_c}{\rho_{diesel}} \cdot C_{diesel} = \frac{0.26}{0.83} \cdot 1.00 = 0.31€/\mathrm{kWh}$$

$$Generator\ fuel\ expenditures = E_r \cdot E_{cost} = 7{,}723 \cdot 0.31 = 2{,}394.13\ €/\mathrm{year}$$

As a result, the following operational costs are obtained:

Operation costs with wind turbine	
Operation & Maintenance (0.7% of the investment)	1,388.10 €/year
Fuel expenditures	2,394.13 €/year

Table 22. Operating costs with wind turbine

Next, the comparative costs without the wind installation must be determined. Considering the parameters and calculations above, the following values can be shown:

Operation costs without wind turbine	
Diesel generation needed	85,261.3 kWh/year
Fuel consumption	0.26 L/kWh
Diesel density	0.83 kg/L
Diesel unit cost	1.00 €/L
Generator energy cost	0.31 €/kWh
Generator fuel expenditures without wind turbines	26,431 €/year

Table 23. Diesel generator operating costs without wind turbine

3.2. Net Present Value (NPV) and Payback

The profitability of the investment is evaluated based on the NPV criterion given by:

$$NPV = -I_0 + \sum_{t=1}^{n} \frac{CF_t}{(1+i)^t}$$

Where:

- I_0 is the investment costs at t=0
- CF_t is the cash flow at time t
- i is the interest rate, which is assumed to be 4%

The time span for the NPV is 20 years.

For the calculation of Cash Flow, the operating expenses of the wind installation are taken into account against the saving obtained by it in comparison to the use of the generator.

$$CF_t = (Fuel\ expenditures)_{without\ wind\ turbines} - (O\&M + Fuel\ expenditures)_{with\ wind\ turbines}$$

$$CF_t = 26{,}431 - 3{,}782.23 = 22{,}648.77\ €$$

The following results can be obtained:

- the payback time is 9 years;
- NPV = 8,432.60 €;
- a profit of 254,675.40 € after 20 years.

YEAR	ENERGY PROD. [kWh/year]	ESTIMATED SAVINGS [€/year]	TOTAL COST [€/year]	CUMU-LATED CASH FLOW	PAYBACK	NET PRESENT VALUE [NPV]
1	85,261.30	26,431	3,782.23	22,648.77	-175,651.23	-176,522.34
2	85,261.30	26,431	3,782.23	45,297.54	-153,002.46	-156,419.88
3	85,261.30	26,431	3,782.23	67,946.31	-130,353.69	-137,895.98
4	85,261.30	26,431	3,782.23	90,595.08	-107,704.92	-120,858.95
5	85,261.30	26,431	3,782.23	113,243.85	-85,056.15	-105,221.81
6	85,261.30	26,431	3,782.23	135,892.62	-62,407.38	-90,902.09
7	85,261.30	26,431	3,782.23	158,541.39	-39,758.61	-77,821.57
8	85,261.30	26,431	3,782.23	181,190.16	-17,109.84	-65,906.12
9	85,261.30	26,431	3,782.23	203,838.93	5,538.93	-55,085.47
10	85,261.30	26,431	3,782.23	226,487.70	28,187.70	-45,293.03
11	85,261.30	26,431	3,782.23	249,136.47	50,836.47	-36,465.70
12	85,261.30	26,431	3,782.23	271,785.24	73,485.24	-28,543.74
13	85,261.30	26,431	3,782.23	294,434.01	96,134.01	-21,470.56
14	85,261.30	26,431	3,782.23	317,082.78	118,782.78	-15,192.60
15	85,261.30	26,431	3,782.23	339,731.55	141,431.55	-9,659.13
16	85,261.30	26,431	3,782.23	362,380.32	164,080.32	-4,822.18
17	85,261.30	26,431	3,782.23	385,029.09	186,729.09	-636.37
18	85,261.30	26,431	3,782.23	407,677.86	209,377.86	2,941.26
19	85,261.30	26,431	3,782.23	430,326.63	232,026.63	5,951.27
20	85,261.30	26,431	3,782.23	452,975.40	254,675.40	8,432.06
TOTAL	1,705,226.00	528,620	75,644.60	452,975.40	254,675.40	8,432.06

Table 24. Profitability results of the investment

Based on the profitability calculus, the next graph is obtained (figure 27). It presents the evolution of the costs of the wind installation compared with the diesel generation cost for the production of the energy needed.

Even if the wind installation has a high initial investment cost (198,300 €), the yearly operation and maintenance cost (1,388.10 €/year) and the fuel expenditure (2,394.13 €/year) combined are lower than the yearly fuel expenses for operating only a diesel generator in order to meet the energy requirements (26,431 €/year).

As we can see in the graph, the payback of the wind installation investment will be covered in a period of9 years and will generate a saving of 256,675 € after 20 years of operation.

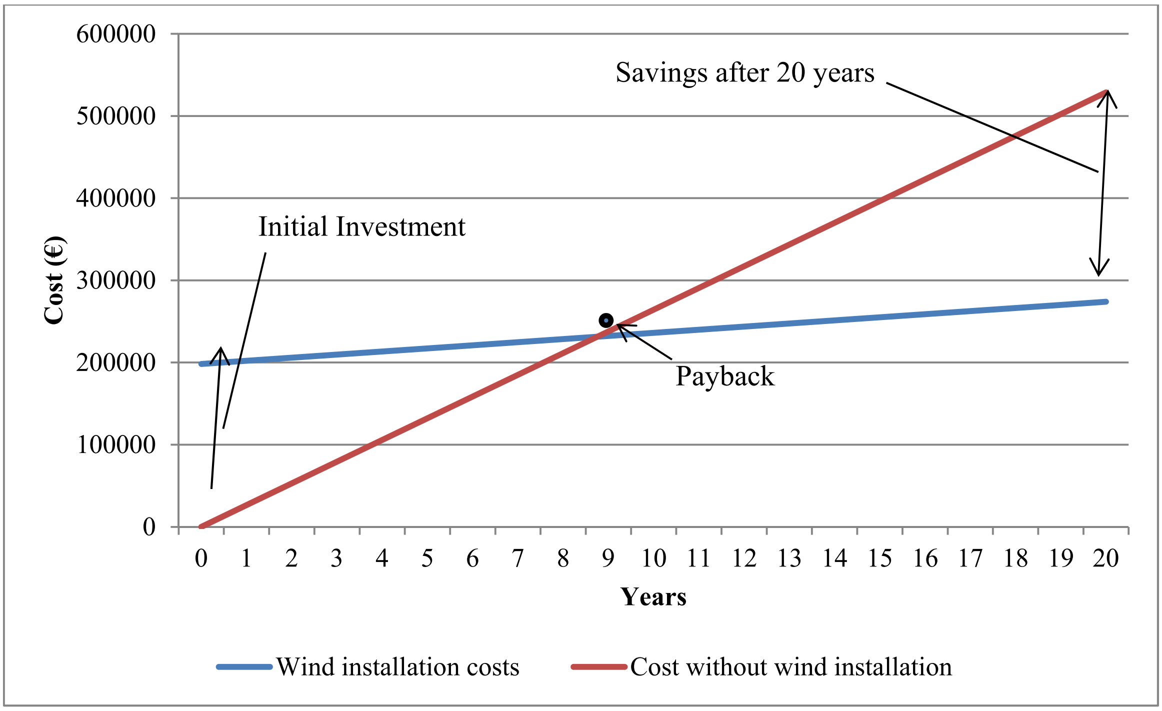
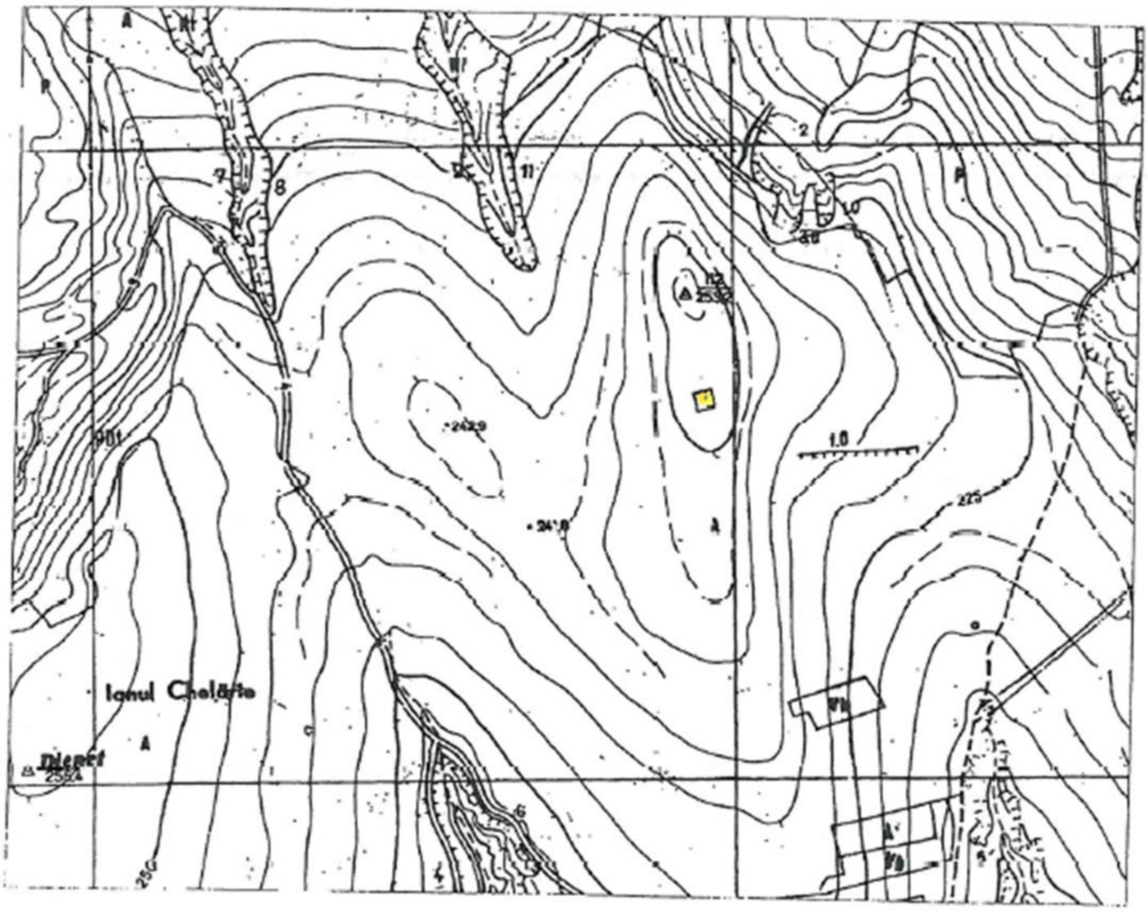


Figure 29. Comparative costs between wind energy and diesel energy production

Project Plans

Development Site Plan



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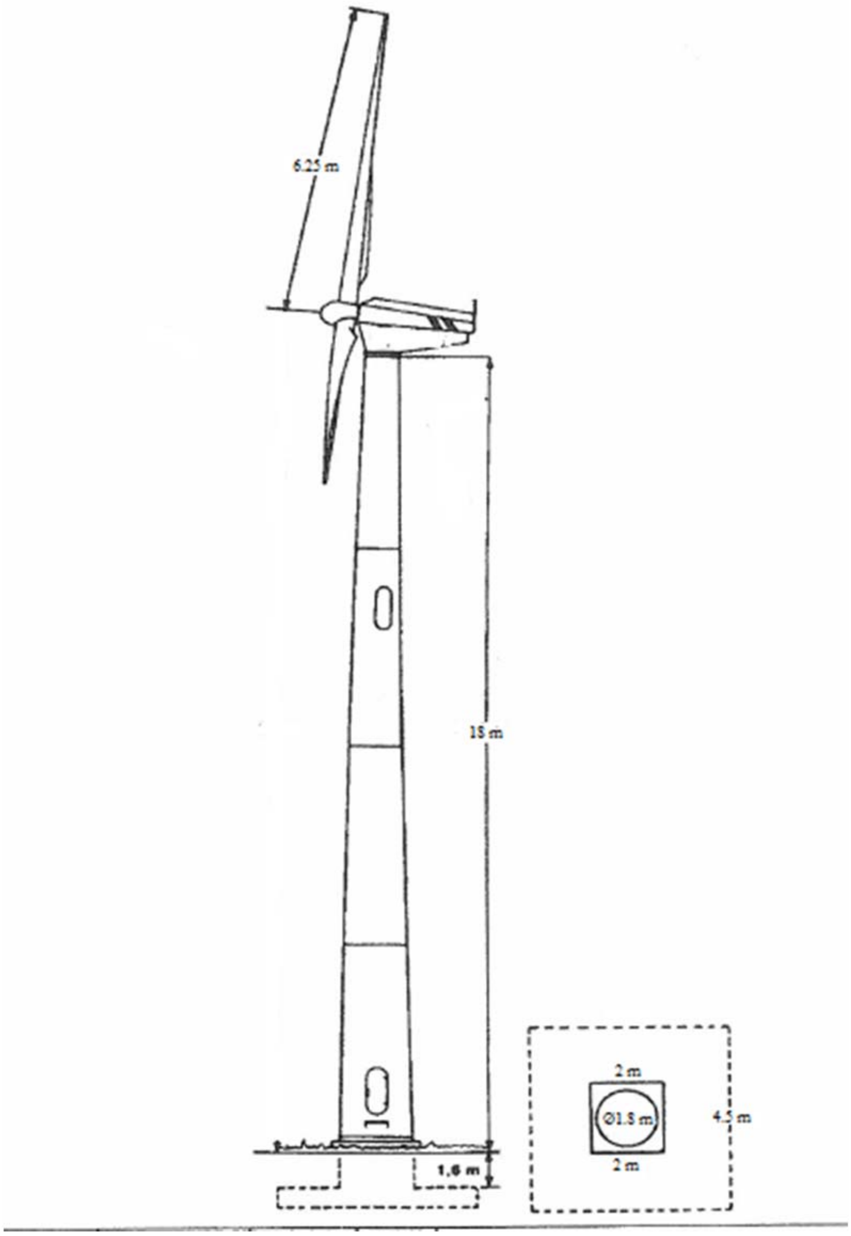
Schematic Side View of the Wind Turbine



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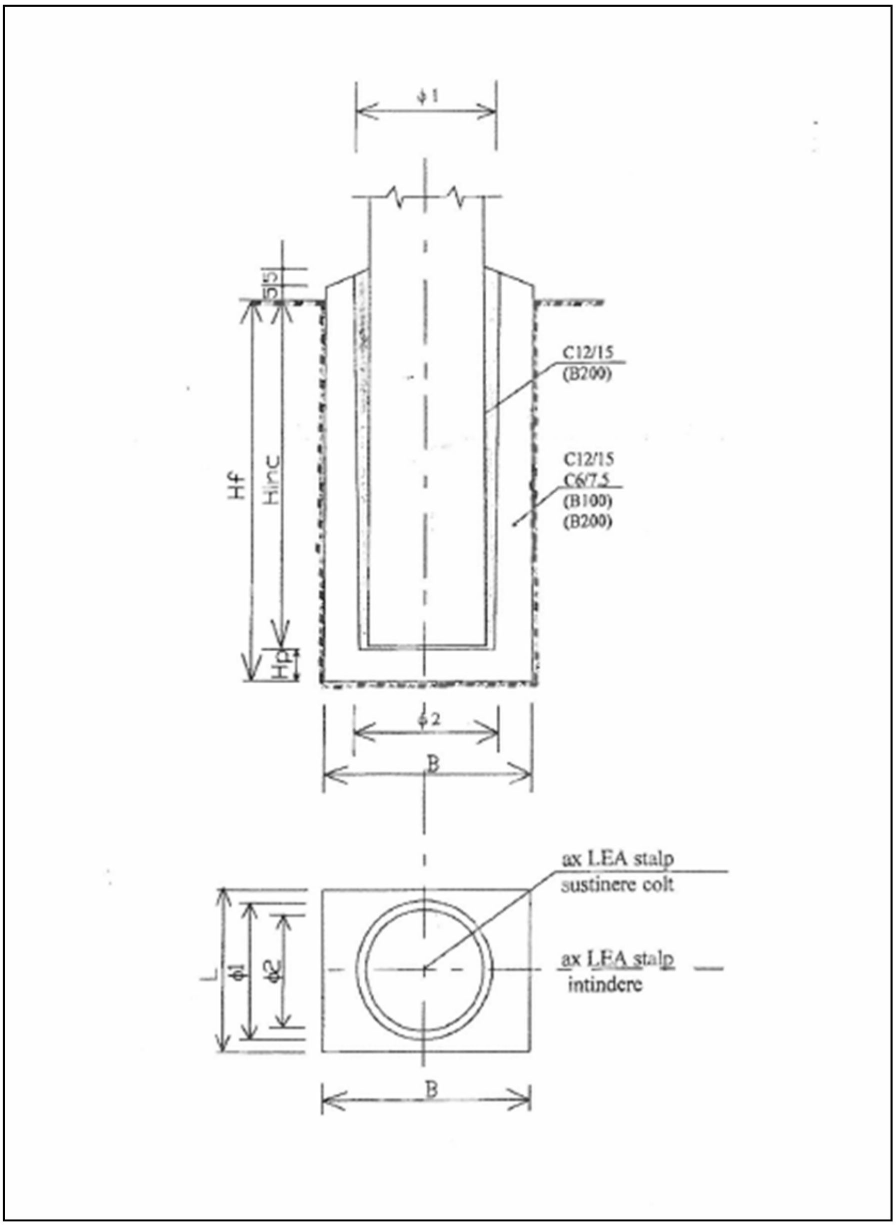

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