UNIVERSITAT JAUME I

SCHOOL OF TECHNOLOGY AND EXPERIMENTAL SCIENCES

MASTER'S DEGREE IN INDUSTRIAL ENGINEERING

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

Master's Thesis

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1. Memory

Memory

1.1. Objective

The main objective of this project is to carry out a comparative study between a district heating and an individual heating installation, 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, it will be also considered the viability of recovering the forestry waste of the surroundings of the municipality for the production of biomass. This biomass will be used as a fuel in the installations of the study and other biomass heating systems of the town. Therefore, it will be known the environmental and social consequences of the energy autonomy in the rural development of Vistabella del Maestrazgo.

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, it is studied the biomass production from the forestry waste. It is analysed the potential quantity of forestry waste in the municipality of Vistabella and the semi-industrial process of pellet production.

Finally, it is analyzed the economical, social and environmental consequences 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 years 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 became to study the incorporation of biomass heating system in different public buildings.

Figure 1. Local government's building

Moreover, in order to profit their own forestry waste, the local government brought a wood chipper, being the first step in the production of local biomass.

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. Whit 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 CO_2 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 CO_2. The main difference between biomass and fossil 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 wide variety of materials for biomass. Nevertheless, only these typologies of biomass with best quality and less cost are alterantives 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 growing 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 it is distributed for residential, commercial or industrial requirements. Normally, heat is transferred underground, being similar to electric or water distribution (Figure 3). 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.

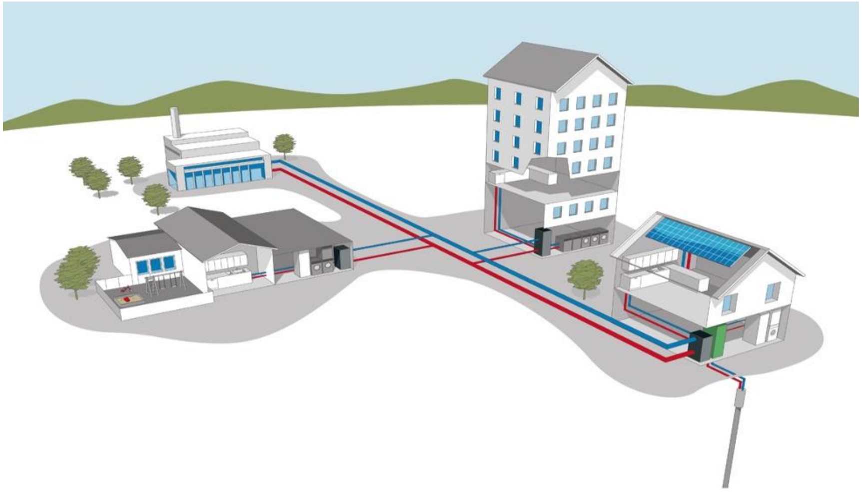

Figure 3. District heating [6]

This application is very 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. Normative and references

1.5.1. Legal provisions and standards applied

Standards and general regulation applied in the present project:

- UNE 157001. Criterios generales para la elaboración formal de los documentos que constituyen un proyecto técnico.
- Reglamento de Instalaciones Térmicas en los Edificios (RITE).
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1.5.3. Software

It has been used the next calculation programs in order to carry out the different steps of design of this project:

– CLIMA V2: software for the calculation of the heat losses in the buildings. It is used in order to compare the values with the theoretical calculations.
– Dinakalc 4.3.0: software for the sizing and design of the pipes for the fume extraction.
– BIORAISE: online GIS tool for Biomass Resources Assessment in Southern Europe. It is used in order to calculate the quantity of potential forestry waste for biomass in Vistabella.

1.6. Design requirements

1.6.1. Client and location

Vistabella del Maestrazgo is a municipality in the province of Castellón (Spain), 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. In the first floor, they are located the kitchen and the canteen, besides the pharmacy and the library (multi-use room), that are separated spaces. In the second floor, they are located three classrooms, an office and the bathrooms. Moreover, the school has a playground, where the gasoil boiler's small house is located.

Furthermore, separated by the entrance of the playground, it is located the residential block for renting, property of the local government. The building hast 4 floor with 3 rooms, bathroom, kitchen, dining room and storage room. Moreover, a 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 main façades facing North and South. Consecutively, it is shown the location of the buildings:

Table 1. Location of the buildings

Location	
School's adress	24, Arrabal Nuestra Señora Loreto Street, 12135, Vistabella del Maestrazgo (Castellón)
Residential block's adress	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, pharmacy and 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. The Saturdays is open from 10:00 to 13:00.

Despite of these are 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 being organizing by a worker.

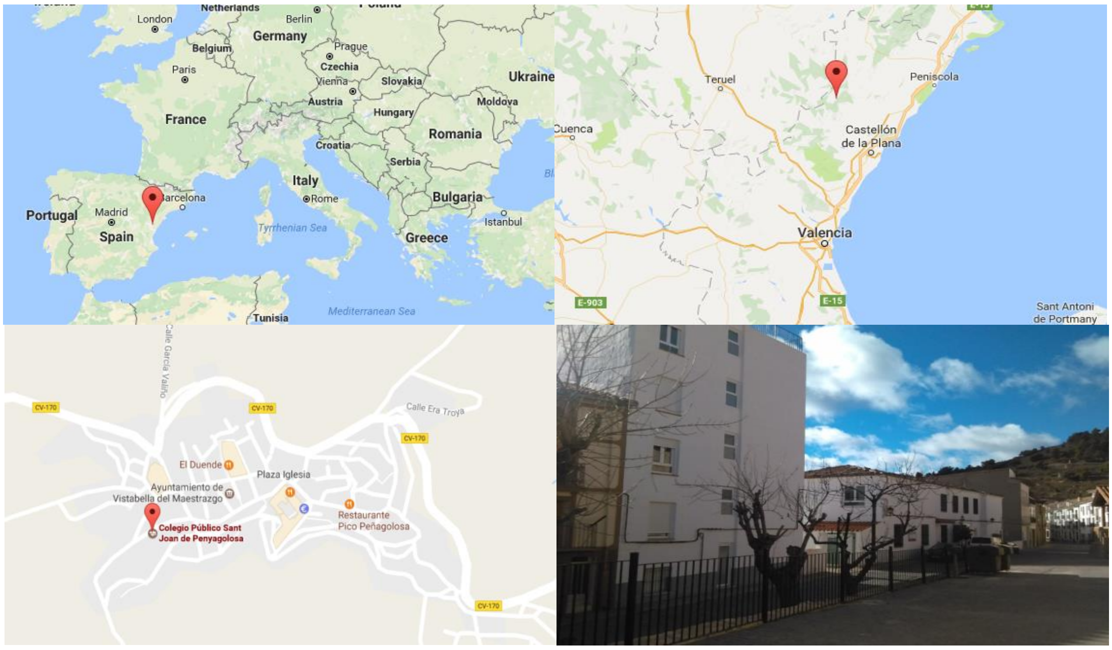


Figure 4. Location of the installation

1.6.2. 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 communicated with the building through copper pipes, whose inner diameters vary between 17 mm and 25,4 mm. It is used iron radiators in order to supply the heat to the school, dividing up between the two floors.

- Library: it shares the installation with the school.
- Pharmacy: although the pipes pass through the pharmacy, this doesn't have a heating system. At best, the pharmacist has a small electric heater that is connected in the coldest days.
- Residential block: there is a chimney for the extraction of fumes that is shared by the 4 floors and the ground floor. The main heating systems installed in the apartments are small stoves of firewood, being located in the dining rooms (Figure 5).

Figure 5. Actual heating systems

1.6.3. 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 1.970 and no information is available. However, there are previous studies that were written by Javier Celades Aparici [7] and Iván Segura Rodríguez [8] where the heating system of the school and the residential block were 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 planes of the apartments and the enclosures, doors and windows were inspected in situ.

1.6.3.1. Enclosures, windows and doors

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

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

Table 3. Characteristics of the enclosures

Enclosure	Material	Thickness (mm)	Conductivity λ (W/mK)	Thermal resistance R (m^2K/W)	Overall heat transfer coefficient U (W/m^2K)
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 (m^2)
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

1.6.3.2. 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 the heating demand of the building and the power requirements of the boilers. The calculations of the thermal power losses are in the annexes (point 2.2.), 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	26.279,41
Windows and doors	11.075,79
Ventilation	19.172,95
TOTAL	**56.528,15**

– Residential block

Table 6. Thermal power losses of the residential block

Losses	Power (W)
Building enclosure	17.708,28
Windows and doors	5.903,69
Ventilation	4.081,14
TOTAL	**27.693,12**

Finally, the total thermal power losses of both buildings are the sum of each one. The total thermal power losses are **84.221,27 W**.

This calculation must be compared with the results obtained with the software CLIMA (table 7). This program does a simulation of the total thermal power losses in the building (point 2.3.).

Table 7. Thermal power losses calculated by the CLIMA

Losses	Power (W)
School's building	43.250,00
Residential block	20.570,00
TOTAL	**64.820,00**

There are important differences between both calculations, given principally by the considerations taken into account. Following those results, it is considered a **boiler of**

more than 50 kW for the school's building, more than 25 kW for the residential block and more than 80 kW for the district heating.

1.6.3.3. Annual energy demand

Following the point 2.2., 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) [9], the Heat Degree Days of each building are:

Table 8. HDD of the buildings

Building	HDD_{15}
School's building	1.326,45
Residential block	2.178,05

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

Table 9. Annual energy demand

Building	Annual energy demand
School's building	20.520,46 kWh
Residential block	39.617,08 kWh
Total	**60.137,54 kWh**

Despite of the 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 the calculus is 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.

The CLIMA software also can calculate the annual energy demand (point 2.3). However, they consider the hours of working in function of the activity, having great differences between the theory and the simulation. The values are shown in the next table:

Table 10. Annual energy demand calculated by CLIMA

Building	Annual energy demand
School's building	11.539,74 kWh
Residential block	16.039,70 kWh
Total	**27.579,44 kWh**

It is taken into account the results obtained in the theoretical calculations because they are less favourable.

1.7. 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 it 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.

1.7.1. Sizing of the boiler

In the boiler's sizing, it is taken into account some considerations 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') establish a technical guide for biomass installations in buildings [10], 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% [11].
- 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 bigger because of the calorific value.

In addition, the local government is in process to obtain grants that allow them to acquire a pelletizer. Therefore, 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 [11].

The project's installation requires a high automatization level because there aren't 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).

Modulating systems adjust to different power levels, depending 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, considering always the technical requirements.

1.7.1.1. Modulating biomass boiler

The use of modulating biomass boilers 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, being 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 is the maximum power is 56,53 kW. Some commercial boilers have a nominal power of 60 kW, so it is considered this option.

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

Table 11. 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 includes 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, it is required a feed auger 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 12. Comparison between KP62 and PelletStar 60

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

In the Table 12, it is possible to see that the only advantage of Biocalora KP62 is the cost (3.788 € less), having the PelletStar 60 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, it is selected the Biocalora KP62 because it has a good performance and less cost.

- **Residential block individual installation**

The maximum thermal power losses in the residential block are 27,69 kW. Considering the distributors that are located near Vistabella, some commercial models are:

Table 13. 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 includes 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 the 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 14. 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, it is selected the Biocalora KP 22 because of the price.

- **District heating**

In this case, it is sized the modulating boiler for the district heating. Therefore, the total power increases, being the sum of the thermal power losses of each building. This maximum power is 84,22 kW.

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

Table 15. 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 the Table 15 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. This 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 (Table 16) has some discounts for this case, being more viable than selecting two independent boilers.

Table 16. 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).

1.7.1.2. Biomass boiler with buffer tank

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

For a demand with a 25% less of the nominal, 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 this 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 this happens only a few hours or days per year.

- **School's building individual installation**

For the school's building, it is selected boilers with a nominal power similar to 50 kW, taking into account the values of thermal power losses calculated previously.

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

Table 17. 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 includes the storage

In this case, there is a really big difference between the 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 the Serie 2000. These boilers are designed for concrete low powers for applications like households, farms, neighbourhood communities… Therefore, 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, it is preferable the Biocalora Seire 2000 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 it is required a buffer tank. 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 being 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 56,53 kW and there are 4,5 h per day of common use, the maximum energy that the buffer tank must store is:

$$Energy = (56{,}53\ kW - 50\ kW) \cdot 4{,}5\ h = 29{,}39\ kWh$$

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, it is established a minimum consign of 60ªC and a maximum of 90ºC 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:

$$Volume\ = 888{,}07\ l$$

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, it is selected a buffer tank of 1000 l. 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 1.000 l. The cost of the unit is 712 €.

- **Residential block individual installation**

In the residential block, the maximum power required is 27,69 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 18. 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 cost: the boiler of Biocalora and the boiler of Met Mann.

However, the boiler Bisolid Mario 25 has a manual cleaning of the burner, being more complicated its integration in the residential block. Therefore, Biocalora Serie 2000 Basic B-Home is the boiler selected because it has a semiautomatic cleaning (only the heat exchanger is manual) and its costs is much lower in comparison with the automatic boilers.

In this case, it is impossible to know the time of the peak power demand, 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, it is selected a stratify buffer tank of Froling with a capacity of 700 l. This volume equate to 25,3 l/kW, being 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, it is used the next equation:

$$Energy\ [kWh] = Volume\ [l] \cdot 0{,}001161 \frac{kWh}{kg \cdot ºC} \cdot 30ºC \cdot 0{,}95$$

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

$$Energy = 23{,}16\ kWh$$

Knowing 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):

$$Time = \frac{23{,}16\ kWh}{(27{,}69\ kW - 25\ kW)} = 8{,}61\ h$$

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

- **District heating**

In this case, the maximum thermal power demand of the two buildings is 84,22 kW. The boilers selected have a lower, but similar, maximum power.

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

Table 19. 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 includes 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, being 792 € and 52 € respectively. Therefore, the total cost of the Biocalora boiler is 14.347 €.

Following the Table 19, 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):

$$Energy = (83{,}17\ kW - 80\ kW) \cdot 4{,}5\ h = 14{,}27\ kWh$$

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

$$Volume\ [l] = \frac{Energy\ [kWh]}{0{,}001161 \frac{kWh}{kg \cdot ºC} \cdot 30ºC \cdot 0{,}95} = \frac{14{,}27}{0{,}001161 \cdot 30 \cdot 0{,}95} = 431{,}12\ l$$

Therefore, with a buffer tank of 500 l it's 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, it is selected a buffer tank 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, it is selected a stratify buffer tank of the company Froling 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:

$$Energy\;= 2.200\;l\;\cdot 0{,}001161\,\frac{kWh}{kg \cdot ºC} \cdot 30ºC \cdot 0{,}95 = 72{,}79\;kWh$$

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

$$Time = \frac{72{,}79\;kWh}{(84{,}22 - 80)kW} = 17{,}25\;h$$

When the demand is lower than the minimum power of the boiler (25 kW approximately) 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 the Table 20 is shown a comparison of costs between the two options, considering a buffer tank of 700 l for the cascade control (in order to supply energy in peak hours):

Table 20. 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 costs is very high so it is preferable to use a Biocalora boiler with a buffer tank of 2.200 l.

1.8. Description of the final solution

1.8.1. Biomass boiler

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

Table 21. 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, models more economic can be selected and the cost decreases considerably.

In addition, buffer tanks have not big prices. 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, increasing considerably 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 in 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 de viability study of each system.

1.8.2. Other equipment

1.8.2.1. 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, it is considered a calorific value of 4,9 kWh/kg and a density of 598 kg/m^3 (average values).

- School's building:

$$Pellets\ mass = 20.520{,}46\ kWh \cdot \frac{1\ kg\ pellet}{4{,}9\ kWh} = 4.187{,}85\ kg\ pellets$$

$$Pellets\ volume = 4.187{,}85\ kg\ pellets \cdot \frac{1\ m^3 pellets}{598\ kg} = 7{,}00\ m^3 pellets$$

- Residential block:

$$Pellets\ mass = 39.617{,}08\ kWh \cdot \frac{1\ kg\ pellet}{4{,}9\ kWh} = 8.085{,}12\ kg\ pellets$$

$$Pellets\ volume = 8.085{,}12\ kg\ pellets \cdot \frac{1\ m^3 pellets}{598\ kg} = 13{,}52\ m^3 pellets$$

- Both buildings:

$$Pellets\ mass = 12.272{,}97\ kg\ pellets$$

$$Pellets\ volume = 20{,}52\ m^3 pellets$$

From this information, it is estimated the storage systems recommended. 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 [12], the storage systems selected are:

- School's building:

Table 22. Characteristics of the school's building silo

Description		**Cost**
Polyester silo 6 m^3 – 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:

$$N = \frac{7\ m^3 pellets}{6\ m^3} = 1{,}16\ loads/year$$

This silo will required the construction of a fence (civil work) in order to restrict the access because of security purposes.

- Residential block:

Table 23. 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 m^3	
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:

$$N = \frac{13{,}52\ m^3 pellets}{5{,}1\ m^3} = 2{,}65\ loads/year$$

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

- Both buildings:

Table 24. 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 m^3	
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:

$$N = \frac{20{,}52\ m^3 pellets}{7{,}1\ m^3} = 2{,}89\ loads/year$$

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

1.8.2.2. Heat exchanger

The heat exchanger is use d 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 produced in 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 produced in 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 produced in 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

1.8.2.3. 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 installation. All the pipes of the school and the library have an inner diameter of 25,4 or 17 mm.

In order to do the hydraulic installation for each case, it is considering the next scenarios:

- In the individual installations case, it is going to consider a new installation for the residential block and an expansion for the school's building. This expansion refers to the pipe conduction for the pharmacy.
- In the district heating case, it is going to re-size the installation of the school's building, considering the current position of the radiators.

For the residential block, it is estimated the creation of four circuits, 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 district heating connects each building underground, crossing the playground of the school. Considering that the boiler is in the ground floor of the residential block, the point of connection is located in the east wall of the school's building, having a longitude for the district heating of 8 meters more or less.

The diameters of the different pipe conductions are shown in the point 2.6. of the calculations part of the project.

1.8.2.4. Expansion vessel

Expansion vessels are tanks whose 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, point 2.4.

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 installations.

1.8.2.5. 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 2.5.

Table 25. Number of radiators

Space	Radiators required
Pharmacy	One radiator of fifteen elements and three radiators of twenty elements
Residential block	Six radiators of ten elements in every apartment

1.8.2.6. 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 the previous study [7] it is selected two Baxi Roca pumps, model PC1025 for pumping water to the heat exchanger and to the tank.

Moreover, in the point 2.7., it is done the calculus of the flow and the pressure losses of the different installations. Considering the information obtained, it is selected the different bombs required for the installations thanks to technical brochures:

- School's building: Distributor Grundfos, model Magna3 25-40. Maximum power of 56W.
- Residential block: Distributor Grundfos, model Magna3 25-60. Maximum power of 91 W.
- District heating: Distributor Grundfos, model Magna 3 50-180. Maximum power of 762 W.

1.8.2.7. Fume extraction

In the current installations, the residential block and the school's building have chimneys for the extraction of fumes. The apartments uses the chimney because of the stoves installed in the dining rooms (Figure 11) and the school's building has the chimney in the small house where the gasoil boiler is located.

Figure 11. Chimney of the residential block

It is going to profit the current spaces for the installation of the new chimneys. It is selected chimneys of the distributor Dinakalc. The chimneys used are T600 N1 D V2 GXX (according to UNE-EN 1856-1), being metal modular chimneys with double isolated wall. The thermal insulator used is rock wool with 30 mm of thickness.

The diameters for each case are calculated in the point 2.8. and the results are shown in the Table 26.

Table 26. Diameters of the fume extraction

Installation	Diameter of the fume extraction
Residential block individual installation	Inner diameter: 125 mm Outer diameter: 185 mm
School's building individual installation	Inner diameter: 150 mm Outer diameter: 210 mm
District heating	Inner diameter: 175 mm Outer diameter: 235 mm

1.9. Production of biomass

1.9.1. Biomass in Vistabella del Maestrazgo

In order to know if the municipality can handle with the energy demand with the biomass that comes from the local forestry waste, it is used the platform BIORAISE. This online application is used for the analysis of the resources and costs of biomass, being developed by the Centro de Desarrollo de Energías Renovables (CEDER, 'Center of Development of Renewable Energies'). This tool works a SIG and can calculate the potential biomass in a determined region of five different countries: Spain, Portugal, Italy, France and Greece.

In this project, BIORAISE is used because it is necessary to estimate a first potential value of the forestry resources in the close area of Vistabella. It is selected the area of a circle with centre in the municipality and a radius of 3 km (Figure 12), being the limit of the municipal term.

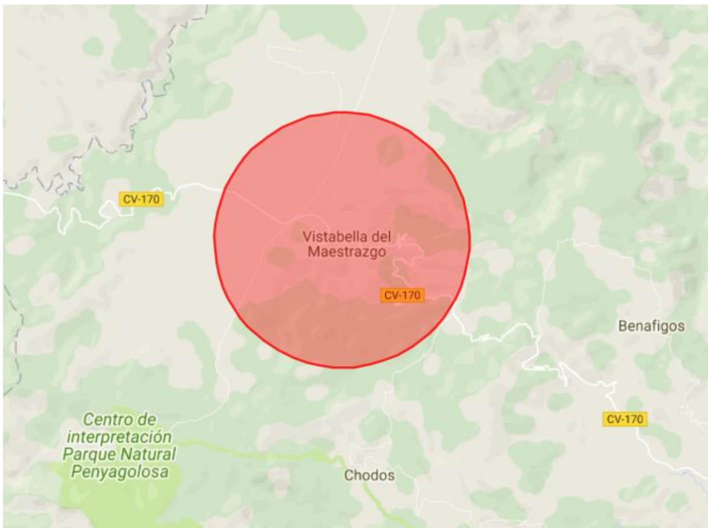


Figure 12. Area of study of the biomass in Vistabella.

It must be taken into account that Vistabella del Maestrazgo has a municipal term of 151 km^2 with a forestry area of the 80 % (Figure 13) [15]. Nevertheless, it is chosen only the previous area because, the closer the biomass is, it is easier and cheaper to obtain it. However, the total potential of Vistabella is much higher than the results obtained.

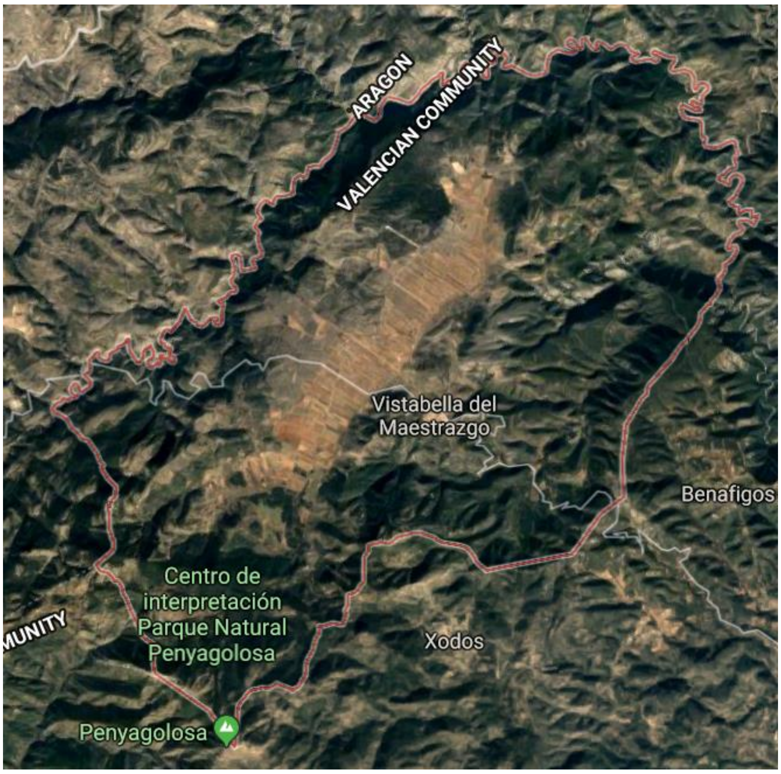


Figure 13. Area of Vistabella.

The main trees that are planted in Vistabella are the pine and, in a lower proportion, the kermes oak. Therefore, it is going to use mainly conifer waste. However, the application gives all the available resources from different plant species (Figure 14).

Recursos en t m.s./año   Costes en €/t m.s.   t m.s. (toneladas de materia seca)

Datos de partida: Lat. : 40,2947022710718   Lng. : -0,294519424438931   Radio : 3 Km

	Recursos potenciales (t m.s./año)	Recursos disponibles (t m.s./año)	Coste medio recolección (€/t m.s.)	Superficie de recursos disponibles (ha)
Secano	1.127,49	308,00	21,73	550,00
Frondosas	28,23	13,21	86,63	12,50
Coníferas	274,49	190,02	48,56	656,25
Mezcla coníferas frondosas	197,20	126,70	59,75	231,25
Matorral	236,25	180,00	45,61	425,00

Figure 14. Information about the biomass available in Vistabella.

Following the results of the BIORAISE (Figure 14) and only considering the conifers available resources, it is have 190,02 tonnes of dry matter per year. Moreover, it is had a recollection cost of 48,56 €/t d.m. The transport cost is calculated by the BIORAISE considering an average fuel price of 1,2 €/l (Figure 15), being for conifers 22,72 €/t d.m.

	Coste medio transporte (€/t m.s.)
Secano	15,25
Frondosas	17,68
Coníferas	22,72
Mezcla coníferas frondosas	17,00
Matorral	17,72

Figure 15. Cost of transport of biomass.

Here, it should be consider that it is possible to use other different plant species, being higher the total available biomass. In addition, as it is said previously, the municipal term of Vistabella is much higher than the area evaluated.

Once the forestry waste has been calculated, it must be contemplated that it is not possible to recollect all those resources. The forest land, following the Plan de Acción Territorial de la Comunitat Valenciana (PATFOR, 'Territorial Action Plan of the Valencian Community'), is classified in ordinary and strategic, being regulated by the article 23 of the Decree 58/2013 [16].

The Strategic Forest Land is the land that is hard to substitute because of its characteristics, location and the environmental service that offers or that can offer. According to the PATFOR, strategic forest lands are the public utility mounts, the mounts of public domain, the priority headwaters, the protector mounts, the wooded masses with a covered square fraction greater than or equal to twenty percent situation in arid an semiarid zones and the zones of high productivity. In the zone of Vistabella, it mainly occurs the two first cases. Moreover, it is prioritized the caring of the Strategic Forest Land, which includes the cleaning of forestry waste. Therefore, for the calculation of the potential forestry waste, that the local government can clean, it is going to calculate the strategic forest land that is inside the area previously considered.

The Generalitat Valenciana (GVA, 'Valencian Government'), provides cartography of the forest land that the PATFOR considers. Observing the map in the area close to Vistabella del Meastrazgo (Figure 16), it can be appreciated that the strategic forest land (dark green) is an important part of the total forest land (light green).

Figure 16. Strategic forest land close to Vistabella.

In order to calculate the resources available in strategic forest lands of the area selected, the GVA says that the 45% of the forest land in the Valencian Community is declared as Strategic Forest Land. Taking this approximation, there are 85,51 t d.m. from conifers in the close area of Vistabella.

Nevertheless, it should be taken into account that it is not considered the forest land that is a private property and, according to the local government of Vistabella del Maestrazgo, there are neighbours that may be interested in the recollection of their forestry waste for biomass use. Therefore, the final value of potential resources might be higher than the calculated.

Moreover, it must be considered that part of the pines (wild pine) are used for carpentry work meanwhile the rest of pines (aleppo pine and maritime pine) are profitable for biomass. Then, the forestry zones selected are the second ones.

1.9.2. Description of the biomass production process

As it is explained in the point 1.3., the project is based on the case of success of Serra (Valencia). The local government of Serra decided to use the pruning and the forestry waste of public areas. Nowadays, Serra has a semi-industrial plant where it is transformed the waste into pellet for biomass. Nevertheless, the local government began with semiautomatic equipment because it is the cheaper and easier way to start for a public administration. Therefore, considering the situation of Vistabella, the best option in order to start the production of pellet is a manual process with semiautomatic equipment.

The process of forestry waste transformation into biomass (Figure 17) has the next steps: forestry waste collection, wood chip, transport to the plant, biodrying, milling and pellet production.

It is designed a pellet production plant with a maximum capacity of 400 kg/h. The plant with model PLT400 is formed by the milling and pellet production, being the keys parts of the process. It is selected this model because it has a medium capacity and its cost is not very expensive, being a semi-industrial process.

However, the final capacity of the plant is just an estimation because the local government has different buildings with biomass. Therefore, it is looked for a pellet plant that can produce more than the required pellet for the buildings of the project.

Regarding the results, it is considered that the collection of pellet is carried out during three weeks and the same workers are in charge to produce and transport pellet during the next seven weeks. Moreover, it must be considered that it must be required to load the silos of the different buildings for time to time.

The collection of the forestry waste and its later production to pellet can be done from the month of September. In this way, it does not interfere with the touristic season and the pellet is prepared just before the cold arrives.

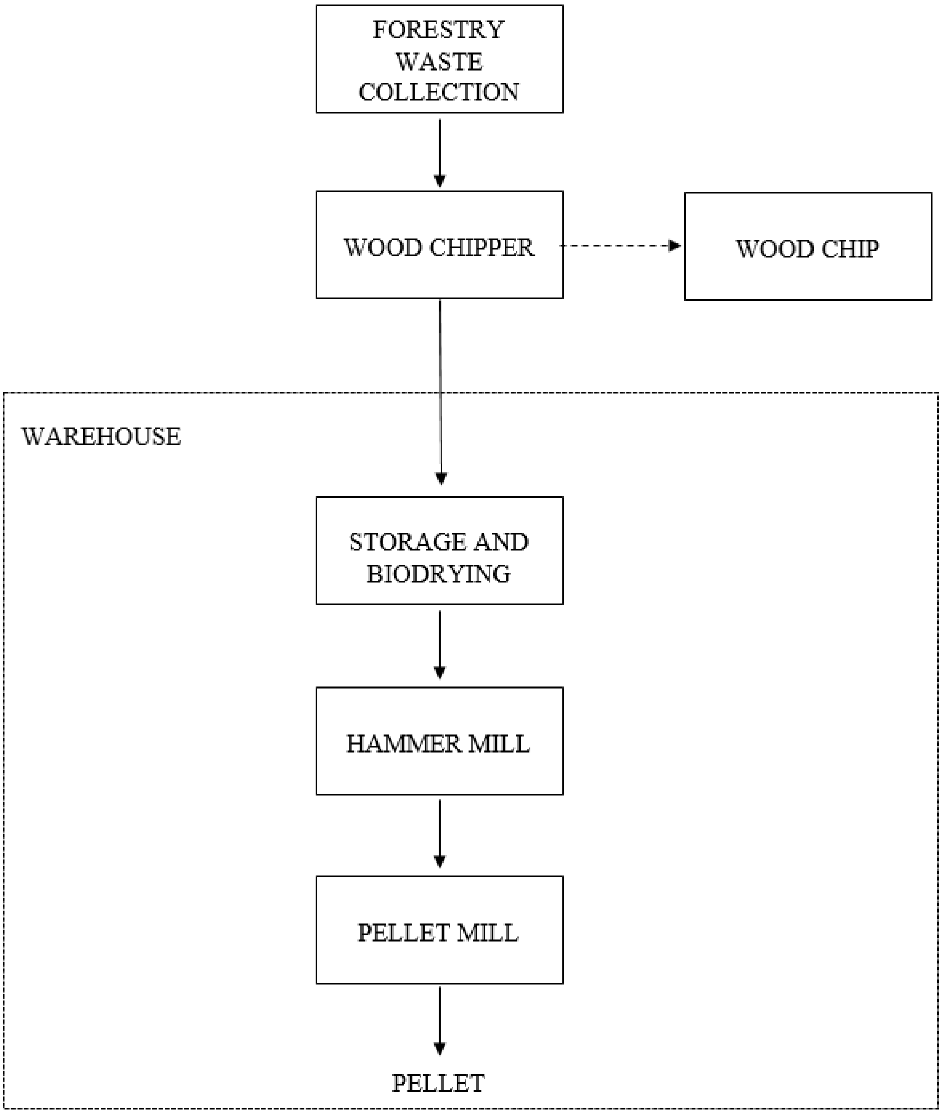


Figure 17. Pellet production process.

1.9.2.1. Forestry waste collection and wood chipping

The process of biomass production starts in the mount with the collection of the forestry waste. The branches and other waste are collected manually. All this waste is chipped in the same forest using a wood chipper. It is used this machine because it reduces the size of the waste so it is possible to load a truck with more wood waste, reducing time and costs.

It must be taken into account that the local government of Vistabella have a warehouse where the process can be placed and they have also acquired a wood chipper. The chipper that is property of the local government of Vistabella is a TW 230DHB of the company Timberwolf [17]. This chipper was designed in order to chip solid wood material up to 160 mm in diameter, with a capacity of 5 tonnes of brushwood per hour.

Following information given by the forest technical engineers of the Conselleria, in zones with high quality of pines, the trunk is used mainly for wood. However, in forests with other type of pines, the technical engineers forest are in charge of the selective cleaning, including the clearing of trees for biomass. In wet zones with a huge growth of the species, the pruning is made every 10-15 years, achieving between 30 and 40 t/ha. Considering that the local government wants to create constant employment, it can be considered that it is going to clear 2 t/ha (maximum 4 t/ha) per year. This allows to have a sustainable forestry management.

Furthermore, from the data obtained in the LIFE ECOCITRIC project [18], it is have that for three workers, the collection of wood chip from waste for biomass requires 2 hours of work per hectare plus the time of chipping. Moreover, it is necessary 30 minutes of load to the truck.

Considering the time of transport of the workers, the loading and the wood chipping, it is have 6 hours per day of work, so it is possible to collect 6.000 kg/day of forestry waste as chip (with four workers). Therefore, the transport can be done with big bags or directly load in a truck. The truck can be property of the local government or subcontracted.

Nevertheless, in order to meet with the objectives, it is not required to work at maximum capacity all the weeks. It is possible to work at half capacity the Fridays or similar.

The wood chipper has a material processing capacity up to 5.000 kg/h, so it is required only about 72 minutes of work. Considering a power of 26 kW, it will consume 31,2 kWh/day of diesel. With a PCI of 9,731 kWh/litre [19], the wood chipper will consume 303,60 l/day, which equals to 780 kg CO_2/day [19] and 344,32 €/day [20].

The average cost of transport is 22,72 €/day, having an average distance of 18,9 km/day according to the Bioraise (Table 15). It is produce also 2,78 kg CO_2/day [21].

1.9.2.2. Storage and biodrying

Once the wood chip arrives to the plant, it is stored manually in a dry closed space in order to carry out the biodrying process. The wood chip collected in the forest have an average humidity of 40% - 50%. In order to have a correct functioning of the pellet plant, it is required an humidity of the 10% more or less.

Considering that the wood chip will be stored in a dry covered place, it is estimated that it will be required a minimum of 20 days for the biodrying. Considering that the collection of pellet is made during three weeks, it is have more than 20 days of biodrying for the first chips collected. The wood chip is stored in pallet boxes. Considering the values obtained in the ECOCITRIC Project [18], it is estimated that it will be required 20 minutes of daily work in the movement of pallet boxes.

In order to speed the process, it can be used an air heater or a biomass boiler in order to reduce the time of drying.

1.9.2.3. Hammer mill

Once the wood chip is dry, it is transported manually to a conveyor belt. This conveyor belt feeds the hammer mill, which mills the wood chip, achieving a homogenous material with small size. The main features of the machine hammer mill are shown in the Table 27.

Table 27. Hammer mill.

TECHNICAL DESCRIPTION	
Model	RC400
Power supply	Three-phase electric power
Power	11 kW
Capacity	300-400 kg/h

The compact hammer mill is located over a loader (Table 28). This loader has a screw conveyor that feeds the pellet mill with the material. This machine is indispensable in order to achieve autonomy in the pellet production process. It has an inverter motor for the regulation of the system and vibrating system.

Table 28. Loader.

TECHNICAL DESCRIPTION	
Model	CRT100
Power supply	One-phase electric power
Power	0,18 kW + 0,22 kW
Capacity	200-400 kg/h
Load volume	0,8 m^3

It is considered that the plant works at maximum capacity (400 kg/h) during 7 hours/day, producing 2.800 kg pellet/day. One hour is dedicated to cleaning and preparation.

It is had two workers for the load of the wood chip to the conveyor belt and the movement of the pallet boxes stored.

It is have a total electricity consumption of 79,8 kWh per day, which equals to 11,97 €/day (considering the cost of the electricity 0,15 €/kWh) and 24,58 g CO_2/day [22].

1.9.2.4. Pellet mill

It is used a pellet mill in order to transform the residue that comes from the loader into pellet. The residue is pushed through rollers to the matrix, where small cylindrical holes compress it, producing pellet. The main features of the pellet machine are shown in the Table 29.

Table 29. Pellet machine.

TECHNICAL DESCRIPTION	
Model	PLT400
Power supply	Three-phase electric power
Power	16 kW
Capacity	150-400 kg/h
Weight	600 kg
Dimensions	1.300 x 1.530 x 700 mm
Diameter of pellet	6 mm
Materials	Matrix: Stainless Steel AISI 420
	Rolls: Tempered 39 NCD3
	Shaft: Galvanized 39 NCD3

The pellet mill includes a vacuum for the removal of the generated dust during the process (Table 30).

Table 30. Vacuum.

TECHNICAL DESCRIPTION	
Model	ASP400
Power supply	Three-phase electric power
Power	2,2 kW
Air flow	3.900 m/h
Pressure	305 mmca
Diameter of the vacuum pipe	100 m (x3)
Dimensions	1.170 x 560 x 570 mm
Weight	90 kg

With a production of 400 kg/h during a working day of seven hours, it is had an electricity consumption of 127,4 kWh, which equals to 19,11 €/day and 39,24 g CO_2/day [22].

1.9.2.5. Storage

The pellet is transported to a textile silo with a screw conveyor. This textile silo has a manual valve in the bottom part for the filling of big bags. Those big bags are storage in the warehouse for their later transport.

For this process, it is used a textile silo of Biocalora with a volume of 5,1 m3 and 3,3 tonnes of capacity, being enough for a production of one day. It is required one worker for the filling of the big bags and the transport to the storage zone.

1.9.2.6. Conclusions of the biomass production process

Each day, it can be produced 2.800 kg of pellets. Therefore, with five days of work, it can be obtained the pellets required for the annual energy demand of the school's building and the residential block. The rest of pellets are used for other public consumptions, for the population of Vistabella or for commercial purpose.

The production of pellet creates three jobs, having a monthly cost of 3.000 € for the local government. This is approximately a cost of 150 €/day. It is considered a contract of three months three months for the three workers.

The collection and transport of the forestry waste from the mount to the warehouse has a total cost of 367,04 €/day and it produces 782,78 kg CO_2/day. The production in the pellet plant has a final cost of 31,08 €/day and it produces 63,82 g CO_2/day.

However, it must be considered that indirect costs like the lightning or water use in the plant are not calculated. From the experience with similar warehouse, it can be considered that the average cost of energy for lighting is about 40 €/month (2 €/day). Furthermore, the average water consumption is 150 l per person and day (considering also the water for cleaning). The cost of water is around 1 €/m^3, so the average cost is 0,45 €/day. Moreover, it is considering a cost of 1.000 € for the renting and use of a truck for a month (during the collection of forestry waste).

Table 31. Costs and emissions of the biomass production process.

	Cost (€)	CO_2 emissions
Forestry waste collection	5.505,60 €	11.741,70 kg CO_2
Pellet production	932,40 €	1,92 kg CO_2
Workers	9.000,00 €	-
Other costs	1.073,50 €	-
TOTAL	16.511,50 €	11.743,62 kg CO_2

In conclusion, for the production of 85,5 t of pellet it is required 15 days of forestry waste collection and 30 days of pellet production in the plant. In the Table 31 are summarized the costs and emissions of the pellet production. The cost of the production of pellet is 16.511,50 €, which equals to 193,12 €/ton of pellet produced.

1.10. Impact of the project for the rural development

1.10.1. Environmental impact

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

1.10.1.1. Natural resources

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

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, being all the systems inside the buildings so they do not affect to the natural space. In the district heating case, civil work affects also to the playground of the school but the effect over the natural environment is practically zero.

Once the installation is working, 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 a 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 the pass of 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, it is considered the fire prevention benefits. Reducing the forestry waste (i.e. dead branches), the probability of fire and propagation decreases.

- **Water and energy demand**

In respect of the water, it is used a closed circuit so it is not required big amounts of water in the installation.

In respect of the energy, the local government bought 7.379 l of gasoil for the school and the library in the year 2016. With the installation of the project, which also includes the pharmacy and the residential block, it is used a renewable energy source (biomass), requiring 12.272,97 kg of pellets per year.

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

1.10.1.2. 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 is located in the playground. However, it is considered a low visual impact.

In the forests the visual impact is clearer because all the dead branches and all the forestry waste would 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 school's building individual installation the noise is not a problem because the small house is separated of the building (Figure 18).

Figure 18. Small house of the school

In 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 to the neighbours. Therefore it is used anti-vibration feet 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 help also with the suggestion of measures.

- **Air pollution and greenhouse gas emissions**

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

Nevertheless, it is used the recommendations and factors provided by the Ministerio de Industria, Energía y Turismo (IDAE, 'Ministry of Industry, Energy and Tourism') [23]:

- 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 is buying 7.379 l of gasoil per year (with a calorific value of 10.250 kcal/kg and a density of 839 kg/m^3 [24]), the total emissions would be 22.690,72 kg CO_2 per year with the current installation.

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 60.137,54 kWh, the emissions with different fuels are:

- Gasoil: 18.703,77 kg CO_2/year
- Biomass (pellets): 1.082,48 kg CO_2/year

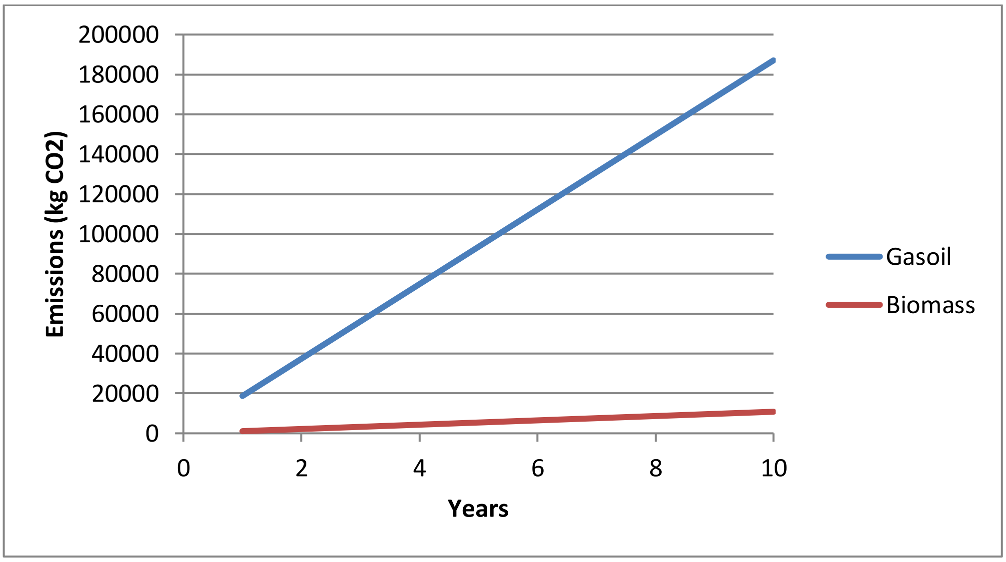


Figure 19. Total emissions of CO_2.

From the graph of the Figure 19, it is shown that pellets emit 94,21 % less of CO_2 than gasoil. Therefore, biomass has a great positive impact in the air. The emissions due to the electric consumption are not considered because they have a low effect over the total pollution.

However, if the emissions of biomass production are considered, the CO_2 produced because of the pellet are higher. For 85,5 t of pellets, it is produced 11.743,62 kg CO_2.

Therefore, for 12.272,97 kg of pellets, the emissions are 1.685,72 kg CO_2. Then the total emissions of CO_2 when the biomass is produced in Vistabella are a 90,99 % less than the emissions produced by the gasoil.

- **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 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.

1.10.2. Social and rural impact

1.10.2.1. 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 in the 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 an absolutely risk 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.

1.10.2.2. 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 in the energy costs of the local government. Moreover, this is considering the average cost of the fuel actually but in a few years, with the management of forestry waste, the energy costs could decrease more.

The analysis of the economic viability of the installation is done in the point 1.13. In this point, it is shown that the installations are viable; being a good option for improving the economical saves of the municipality.

- **New jobs**

The implementation of the project has clear impacts in 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 launching 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, the 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 a 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.

1.10.2.3. 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 is registered in the municipality and 100-150 people lives 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 is shown previously, 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 20) the Mondays and Fridays in the afternoon. The empowerment of spaces like the cultural centre (*edifici Antiga Presó*) or the creation of new alternatives would help in the attraction of families to the municipality.

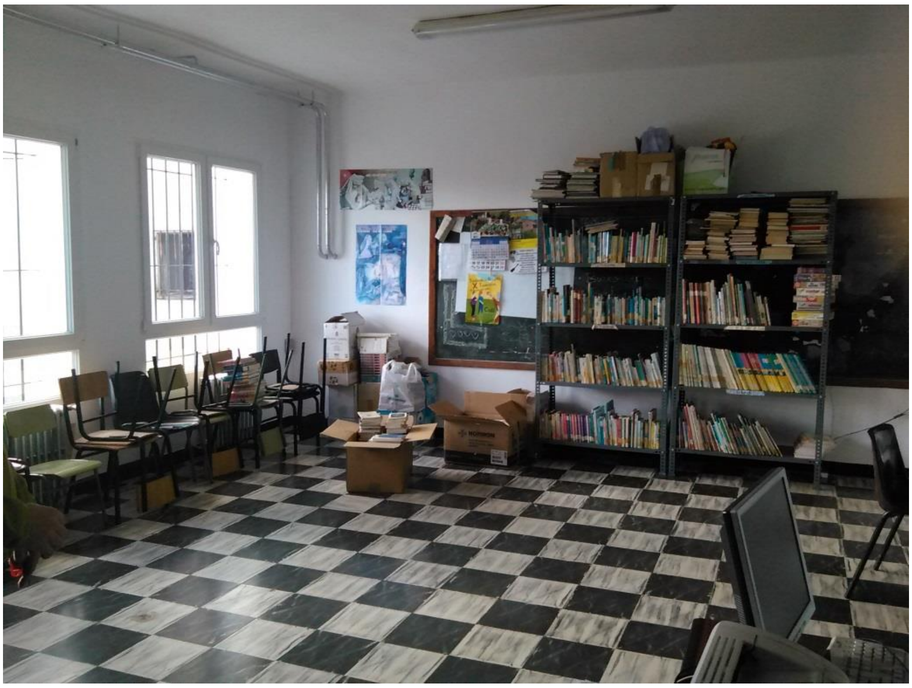


Figure 20. Library of Vistabella del Maestrazgo

Another good example would be the creation of mycological preserves and the management of the forest. The interest in ecotourism is increasing 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 house despite of big distances. Nowadays, this helps the rural towns adapted to new technologies and population needs.

Therefore, the comfort in home, 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.

1.10.2.4. Interviews

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

The interviews are 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 in the project.

1.11. Summary of the budget

1.11.1. Individual installations

Table 32. Individual installations budget.

TOTAL SCHOOL'S INSTALLATION	20.020,22 €
TOTAL RESIDENTIAL BLOCK	22.984,66 €
TOTAL INDIVIDUAL INSTALLATION	**43.004,88 €**
MATERIAL EXECUTION BUDGET	43.004,88 €
13% OF GENERAL EXPENSES	5.590,63 €
6% OF INDUSTRIAL BENEFITS	2.580,29 €
SUBTOTAL	51.175,81 €
21% VAT	10.746,92 €
TOTAL BUDGET	**61.922,73 €**

1.11.2. District heating

Table 33. District heating budget.

TOTAL DISTRICT HEATING	**43.363,05 €**
MATERIAL EXECUTION BUDGET	43.363,05 €
13% OF GENERAL EXPENSES	5.637,20 €
6% OF INDUSTRIAL BENEFITS	2.601,78 €
SUBTOTAL	51.602,02 €
21% VAT	10.836,43 €
TOTAL BUDGET	**62.438,45 €**

1.11.3. Pellet plant

Table 34. Pellet plant budget.

TOTAL PELLET PLANT	**33.920,00 €**
MATERIAL EXECUTION BUDGET	33.920,00 €
13% OF GENERAL EXPENSES	4.409,60 €
6% OF INDUSTRIAL BENEFITS	2.035,20 €
SUBTOTAL	40.364,80 €
21% VAT	8.476,61 €
TOTAL BUDGET	**48.841,41 €**

1.12. Economic feasibility study

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

- It is considered a study for the two biomass installations, using purchased pellet, and a study for these installations and the production of biomass for self-consumption. Moreover, each study can be separated in the case of individual installations and the case of district heating.
- 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 and pellet plants.
- Cost: pellet and gasoil costs are given by information provided by the Ministerio de Energía y Turismo (MINETAD, 'Ministry of Energy and Tourism')[25].
- Fuel annual increase: they are estimated following the average evolution of prices in the last decade.
- Operation and maintenance costs: the value is estimated following the cost of manufacturers [12] for basic maintenance. The cost is the double for individual installations because they have more equipment.
- Self-consumption: in the case of produced pellet, it is considered that only 12,72 t/year of pellet are used in the installation. For the rest of the 85,5 tonnes of pellet produced, it is considered that they are sold or used in other buildings of the municipality. The cost of pellet production is 193,12 €/t, so the economic savings due to the rest of pellet that is not used in the project is the cost of pellet (251,30 €/t) minus the cost of production.

1.12.1. Purchased pellet

1.12.1.1. Individual installations

Table 35. Individual installation with purchased pellet considerations.

Considerations		
Capital cost	61.922,73	€
Estimated energy produced (kWh)	60.137,54	kWh
Annual energy losses	0,50	%
Pellet cost	251,3	€/ton
Pellet cost	0,0502	€/kWh
Gasoil cost (B)	0,0829	€/kWh
Pellet annual increase	0,5	%
Gasoil annual increase	3,5	%
Discount rate	3,5	%
O&M Cost	364	€/year
Investment period	20	years
Grant (IVACE)	45	%

Table 36. Economic feasibility study for the individual installations with purchased pellet.

Year	Energy production (kWh/year)	Pellet cost (€/year)	Gasoil cost (€/year)	Estimated savings (€/year)	O&M costs (€)	Cash-Flow (€)	Cumulative Cash-Flow (€)	Payback (€)	Payback with grant (€)	NPV (€)	NPV with grant (€)
0						61.922,73 €				-61.922,73 €	-34.057,50 €
1	60.137,54	3.016,48 €	4.982,69 €	1.966,21 €	364 €	1.602,21 €	1.602,21 €	-60.320,52 €	-32.455,29 €	-60.374,70 €	-32.509,47 €
2	59.836,85	3.031,56 €	5.169,54 €	2.137,98 €	364 €	1.773,98 €	3.376,19 €	-58.546,53 €	-30.681,31 €	-58.718,67 €	-30.853,44 €
3	59.537,67	3.046,72 €	5.363,40 €	2.316,68 €	364 €	1.952,68 €	5.328,87 €	-56.593,85 €	-28.728,63 €	-56.957,46 €	-29.092,23 €
4	59.239,98	3.061,95 €	5.564,53 €	2.502,57 €	364 €	2.138,57 €	7.467,45 €	-54.455,28 €	-26.590,05 €	-55.093,82 €	-27.228,59 €
5	58.943,78	3.077,26 €	5.773,20 €	2.695,93 €	364 €	2.331,93 €	9.799,38 €	-52.123,34 €	-24.258,12 €	-53.130,39 €	-25.265,16 €
6	58.649,06	3.092,65 €	5.989,69 €	2.897,04 €	364 €	2.533,04 €	12.332,43 €	-49.590,30 €	-21.725,07 €	-51.069,76 €	-23.204,53 €
7	58.355,81	3.108,11 €	6.214,31 €	3.106,19 €	364 €	2.742,19 €	15.074,62 €	-46.848,11 €	-18.982,88 €	-48.914,42 €	-21.049,19 €
8	58.064,04	3.123,65 €	6.447,34 €	3.323,69 €	364 €	2.959,69 €	18.034,31 €	-43.888,42 €	-16.023,19 €	-46.666,79 €	-18.801,57 €
9	57.773,72	3.139,27 €	6.689,12 €	3.549,85 €	364 €	3.185,85 €	21.220,16 €	-40.702,57 €	-12.837,34 €	-44.329,24 €	-16.464,01 €
10	57.484,85	3.154,97 €	6.939,96 €	3.784,99 €	364 €	3.420,99 €	24.641,15 €	-37.281,58 €	-9.416,35 €	-41.904,03 €	-14.038,81 €
11	57.197,42	3.170,74 €	7.200,21 €	4.029,47 €	364 €	3.665,47 €	28.306,62 €	-33.616,11 €	-5.750,88 €	-39.393,39 €	-11.528,16 €
12	56.911,44	3.186,60 €	7.470,22 €	4.283,62 €	364 €	3.919,62 €	32.226,24 €	-29.696,49 €	-1.831,26 €	-36.799,45 €	-8.934,22 €
13	56.626,88	3.202,53 €	7.750,35 €	4.547,82 €	364 €	4.183,82 €	36.410,06 €	-25.512,67 €	2.352,56 €	-34.124,30 €	-6.259,07 €
14	56.343,74	3.218,54 €	8.040,99 €	4.822,45 €	364 €	4.458,45 €	40.868,50 €	-21.054,22 €	6.811,00 €	-31.369,95 €	-3.504,72 €
15	56.062,03	3.234,64 €	8.342,53 €	5.107,89 €	364 €	4.743,89 €	45.612,39 €	-16.310,33 €	11.554,89 €	-28.538,37 €	-673,14 €
16	55.781,72	3.250,81 €	8.655,37 €	5.404,56 €	364 €	5.040,56 €	50.652,96 €	-11.269,77 €	16.595,45 €	-25.631,45 €	2.233,78 €
17	55.502,81	3.267,06 €	8.979,95 €	5.712,88 €	364 €	5.348,88 €	56.001,84 €	-5.920,89 €	21.944,34 €	-22.651,03 €	5.214,20 €
18	55.225,29	3.283,40 €	9.316,69 €	6.033,30 €	364 €	5.669,30 €	61.671,14 €	-251,59 €	27.613,64 €	-19.598,90 €	8.266,33 €
19	54.949,17	3.299,81 €	9.666,07 €	6.366,26 €	364 €	6.002,26 €	67.673,39 €	5.750,66 €	33.615,89 €	-16.476,79 €	11.388,44 €
20	54.674,42	3.316,31 €	10.028,55 €	6.712,23 €	364 €	6.348,23 €	74.021,63 €	12.098,90 €	39.964,13 €	-13.286,38 €	14.578,84 €
TOTAL	1.147.298,20	63.283,08 €	144.584,70 €	81.301,63 €	7.280,00 €	74.021,63 €	74.021,63 €	12.098,90 €	39.964,13 €	-13.286,38 €	14.578,84 €

Table 37. Payback, NPV and IRR for individual installations with purchased pellet.

Payback	19 years
Payback with grant	**13 years**
NPV	-13.286,38 €
NPV with grant	**14.578,84 €**
IRR with grant	**-14%**

1.12.1.2. District heating

Table 38. District heating with purchased pellet considerations.

Considerations		
Capital cost	62.438,45	€
Estimated energy produced (kWh)	60.137,54	kWh
Annual energy losses	0,50	%
Pellet cost	251,3	€/ton
Pellet cost	0,0502	€/kWh
Gasoil cost (B)	0,0829	€/kWh
Pellet annual increase	0,5	%
Gasoil annual increase	3,5	%
Discount rate	3,5	%
O&M Cost	182	€/year
Investment period	20	years
Grant (IVACE)	45	%

Table 39. Economic feasibility study for district heating with purchased pellet.

Year	Energy production (kWh/year)	Pellet cost (€/year)	Gasoil cost (€/year)	Estimated savings (€/year)	O&M costs (€)	Cash-Flow (€)	Cumulative Cash-Flow (€)	Payback (€)	Payback with grant (€)	NPV (€)	NPV with grant (€)
0						62.438,45 €				-62.438,45 €	-34.341,15 €
1	60.137,54	3.016,48 €	4.982,69 €	1.966,21 €	182 €	1.784,21 €	1.784,21 €	-60.654,24 €	-32.789,01 €	-60.714,57 €	-32.617,27 €
2	59.836,85	3.031,56 €	5.169,54 €	2.137,98 €	182 €	1.955,98 €	3.740,19 €	-58.698,26 €	-30.833,03 €	-58.888,64 €	-30.791,34 €
3	59.537,67	3.046,72 €	5.363,40 €	2.316,68 €	182 €	2.134,68 €	5.874,87 €	-56.563,58 €	-28.698,35 €	-56.963,28 €	-28.865,98 €
4	59.239,98	3.061,95 €	5.564,53 €	2.502,57 €	182 €	2.320,57 €	8.195,45 €	-54.243,00 €	-26.377,77 €	-54.941,04 €	-26.843,73 €
5	58.943,78	3.077,26 €	5.773,20 €	2.695,93 €	182 €	2.513,93 €	10.709,38 €	-51.729,07 €	-23.863,84 €	-52.824,37 €	-24.727,07 €
6	58.649,06	3.092,65 €	5.989,69 €	2.897,04 €	182 €	2.715,04 €	13.424,43 €	-49.014,02 €	-21.148,79 €	-50.615,68 €	-22.518,38 €
7	58.355,81	3.108,11 €	6.214,31 €	3.106,19 €	182 €	2.924,19 €	16.348,62 €	-46.089,83 €	-18.224,60 €	-48.317,29 €	-20.219,99 €
8	58.064,04	3.123,65 €	6.447,34 €	3.323,69 €	182 €	3.141,69 €	19.490,31 €	-42.948,14 €	-15.082,91 €	-45.931,46 €	-17.834,15 €
9	57.773,72	3.139,27 €	6.689,12 €	3.549,85 €	182 €	3.367,85 €	22.858,16 €	-39.580,29 €	-11.715,06 €	-43.460,36 €	-15.363,06 €
10	57.484,85	3.154,97 €	6.939,96 €	3.784,99 €	182 €	3.602,99 €	26.461,15 €	-35.977,30 €	-8.112,07 €	-40.906,13 €	-12.808,83 €
11	57.197,42	3.170,74 €	7.200,21 €	4.029,47 €	182 €	3.847,47 €	30.308,62 €	-32.129,83 €	-4.264,60 €	-38.270,83 €	-10.173,53 €
12	56.911,44	3.186,60 €	7.470,22 €	4.283,62 €	182 €	4.101,62 €	34.410,24 €	-28.028,21 €	-162,98 €	-35.556,44 €	-7.459,14 €
13	56.626,88	3.202,53 €	7.750,35 €	4.547,82 €	182 €	4.365,82 €	38.776,06 €	-23.662,39 €	4.202,84 €	-32.764,92 €	-4.667,62 €
14	56.343,74	3.218,54 €	8.040,99 €	4.822,45 €	182 €	4.640,45 €	43.416,50 €	-19.021,95 €	8.843,28 €	-29.898,14 €	-1.800,83 €
15	56.062,03	3.234,64 €	8.342,53 €	5.107,89 €	182 €	4.925,89 €	48.342,39 €	-14.096,06 €	13.769,17 €	-26.957,92 €	1.139,38 €
16	55.781,72	3.250,81 €	8.655,37 €	5.404,56 €	182 €	5.222,56 €	53.564,96 €	-8.873,49 €	18.991,73 €	-23.946,04 €	4.151,27 €
17	55.502,81	3.267,06 €	8.979,95 €	5.712,88 €	182 €	5.530,88 €	59.095,84 €	-3.342,61 €	24.522,62 €	-20.864,21 €	7.233,09 €
18	55.225,29	3.283,40 €	9.316,69 €	6.033,30 €	182 €	5.851,30 €	64.947,14 €	2.508,69 €	30.373,91 €	-17.714,10 €	10.383,21 €
19	54.949,17	3.299,81 €	9.666,07 €	6.366,26 €	182 €	6.184,26 €	71.131,39 €	8.692,94 €	36.558,17 €	-14.497,32 €	13.599,98 €
20	54.674,42	3.316,31 €	10.028,55 €	6.712,23 €	182 €	6.530,23 €	77.661,63 €	15.223,18 €	43.088,41 €	-11.215,45 €	16.881,85 €
TOTAL	1.147.298,20	63.283,08 €	144.584,70 €	81.301,63 €	3.640,00 €	77.661,63 €	77.661,63 €	15.223,18 €	43.088,41 €	-11.215,45 €	16.881,85 €

Table 40. Payback, NPV and IRR for district heating with purchased pellet.

Payback	18 years
Payback with grant	**13 years**
NPV	-11.215,45 €
NPV with grant	**16.881,85 €**
IRR with grant	**-12%**

1.12.2. Produced pellet

1.12.2.1. Individual installations

Table 41. Individual installations with purchased pellet considerations.

Considerations		
Capital cost	110.764,14	€
Estimated energy produced (kWh)	60.137,54	kWh
Annual energy losses	0,50	%
Pellet cost	193,12	€/ton
Pellet cost	0,0385	€/kWh
Gasoil cost (B)	0,0829	€/kWh
Pellet produced and not used	73,23	ton
Pellet sold or used in other inst.	4.260,35	€
Pellet annual increase	0,5	%
Gasoil annual increase	3,5	%
Discount rate	3,5	%
O&M Cost	364	€/year
Investment period	20	years
Grant (IVACE)	45	%

It must be taken into account that the wood chipper cost is not considered in the project because the local government is already the proprietary of this machine. Nevertheless, for replicable projects, it must be considered this cost in the economic feasibility study. A new wood chipper has a cost of 16.973 €. With a grant of the 45%, the final cost of the wood chipper would be 9.335,15 €.

Table 42. Economic feasibility study for individual installations with produced pellet.

Year	Energy production (kWh/year)	Pellet cost (€/year)	Gasoil cost (€/year)	Estimated savings (€/year)	Pellet gains (€)	O&M costs (€)	Cash-Flow (€)	Cumulative Cash-Flow (€)	Payback (€)	Payback with grant (€)	NPV (€)	NPV with grant (€)
0							110.764,14 €				-110.764,14 €	-60.920,27 €
1	60.137,54	2.318,12 €	4.982,69 €	2.664,58 €	4.260,35 €	364 €	6.560,92 €	6.560,92 €	-104.203,21 €	-54.359,35 €	-104.425,08 €	-54.581,22 €
2	59.836,85	2.329,71 €	5.169,54 €	2.839,84 €	4.281,65 €	364 €	6.757,49 €	13.318,41 €	-97.445,73 €	-47.601,87 €	-98.116,90 €	-48.273,03 €
3	59.537,67	2.341,36 €	5.363,40 €	3.022,05 €	4.303,06 €	364 €	6.961,10 €	20.279,51 €	-90.484,63 €	-40.640,76 €	-91.838,38 €	-41.994,52 €
4	59.239,98	2.353,06 €	5.564,53 €	3.211,47 €	4.324,57 €	364 €	7.172,04 €	27.451,55 €	-83.312,59 €	-33.468,73 €	-85.588,36 €	-35.744,50 €
5	58.943,78	2.364,83 €	5.773,20 €	3.408,37 €	4.346,19 €	364 €	7.390,57 €	34.842,12 €	-75.922,02 €	-26.078,16 €	-79.365,70 €	-29.521,84 €
6	58.649,06	2.376,65 €	5.989,69 €	3.613,04 €	4.367,93 €	364 €	7.616,97 €	42.459,08 €	-68.305,05 €	-18.461,19 €	-73.169,30 €	-23.325,43 €
7	58.355,81	2.388,53 €	6.214,31 €	3.825,77 €	4.389,77 €	364 €	7.851,54 €	50.310,62 €	-60.453,52 €	-10.609,65 €	-66.998,06 €	-17.154,20 €
8	58.064,04	2.400,48 €	6.447,34 €	4.046,87 €	4.411,71 €	364 €	8.094,58 €	58.405,20 €	-52.358,94 €	-2.515,07 €	-60.850,94 €	-11.007,08 €
9	57.773,72	2.412,48 €	6.689,12 €	4.276,64 €	4.433,77 €	364 €	8.346,41 €	66.751,61 €	-44.012,52 €	5.831,34 €	-54.726,92 €	-4.883,06 €
10	57.484,85	2.424,54 €	6.939,96 €	4.515,42 €	4.455,94 €	364 €	8.607,36 €	75.358,97 €	-35.405,16 €	14.438,70 €	-48.625,00 €	1.218,86 €
11	57.197,42	2.436,66 €	7.200,21 €	4.763,54 €	4.478,22 €	364 €	8.877,77 €	84.236,74 €	-26.527,40 €	23.316,46 €	-42.544,21 €	7.299,65 €
12	56.911,44	2.448,85 €	7.470,22 €	5.021,37 €	4.500,61 €	364 €	9.157,98 €	93.394,72 €	-17.369,42 €	32.474,45 €	-36.483,61 €	13.360,25 €
13	56.626,88	2.461,09 €	7.750,35 €	5.289,26 €	4.523,12 €	364 €	9.448,37 €	102.843,09 €	-7.921,04 €	41.922,82 €	-30.442,28 €	19.401,58 €
14	56.343,74	2.473,40 €	8.040,99 €	5.567,59 €	4.545,73 €	364 €	9.749,32 €	112.592,42 €	1.828,28 €	51.672,14 €	-24.419,33 €	25.424,53 €
15	56.062,03	2.485,76 €	8.342,53 €	5.856,76 €	4.568,46 €	364 €	10.061,22 €	122.653,64 €	11.889,50 €	61.733,36 €	-18.413,88 €	31.429,98 €
16	55.781,72	2.498,19 €	8.655,37 €	6.157,18 €	4.591,30 €	364 €	10.384,48 €	133.038,11 €	22.273,98 €	72.117,84 €	-12.425,09 €	37.418,77 €
17	55.502,81	2.510,68 €	8.979,95 €	6.469,26 €	4.614,26 €	364 €	10.719,52 €	143.757,63 €	32.993,50 €	82.837,36 €	-6.452,14 €	43.391,73 €
18	55.225,29	2.523,24 €	9.316,69 €	6.793,46 €	4.637,33 €	364 €	11.066,79 €	154.824,42 €	44.060,28 €	93.904,15 €	-494,21 €	49.349,65 €
19	54.949,17	2.535,85 €	9.666,07 €	7.130,22 €	4.660,52 €	364 €	11.426,73 €	166.251,15 €	55.487,02 €	105.330,88 €	5.449,47 €	55.293,33 €
20	54.674,42	2.548,53 €	10.028,55 €	7.480,01 €	4.683,82 €	364 €	11.799,83 €	178.050,99 €	67.286,85 €	117.130,71 €	11.379,67 €	61.223,53 €
TOTAL	1.147.298,20	48.632,03 €	144.584,70 €	95.952,68 €	89.378,31 €	7.280,00 €	178.050,99 €	178.050,99 €	67.286,85 €	117.130,71 €	11.379,67 €	61.223,53 €

Table 43. Payback, NPV and IRR for individual installations with produced pellet.

Payback	14 years
Payback with grant	**9 years**
NPV	11.379,67 €
NPV with grant	**61.223,53 €**
IRR with grant	**2%**

1.12.2.2. District heating

Table 44. District heating with produced pellet considerations.

Considerations		
Capital cost	111.279,86	€
Estimated energy produced (kWh)	60.137,54	kWh
Annual energy losses	0,50	%
Pellet cost	193,12	€/ton
Pellet cost	0,0385	€/kWh
Gasoil cost (B)	0,0829	€/kWh
Pellet produced and not used	73,23	ton
Pellet sold or used in other inst.	4.260,35	€
Pellet annual increase	0,5	%
Gasoil annual increase	3,5	%
Discount rate	3,5	%
O&M Cost	182	€/year
Investment period	20	years
Grant (IVACE)	45	%

It must be taken into account that the wood chipper cost is not considered in the project because the local government is already the proprietary of this machine. Nevertheless, for replicable projects, it must be considered this cost in the economic feasibility study. A new wood chipper has a cost of 16.973 €. With a grant of the 45%, the final cost of the wood chipper would be 9.335,15 €.

Table 45. Economic feasibility study for district heating with produced pellet.

Year	Energy production (kWh/year)	Pellet cost (€/year)	Gasoil cost (€/year)	Estimated savings (€/year)	Pellet gains (€)	O&M costs (€)	Cash-Flow (€)	Cumulative Cash-Flow (€)	Payback (€)	Payback with grant (€)	NPV (€)	NPV with grant (€)
0							111.279,86 €				-111.279,86 €	-61.203,92 €
1	60.137,54	2.318,12 €	4.982,69 €	2.664,58 €	4.260,35 €	182 €	6.742,92 €	6.742,92 €	-104.536,93 €	-54.461,00 €	-104.764,96 €	-54.689,02 €
2	59.836,85	2.329,71 €	5.169,54 €	2.839,84 €	4.281,65 €	182 €	6.939,49 €	13.682,41 €	-97.597,45 €	-47.521,51 €	-98.286,87 €	-48.210,94 €
3	59.537,67	2.341,36 €	5.363,40 €	3.022,05 €	4.303,06 €	182 €	7.143,10 €	20.825,51 €	-90.454,35 €	-40.378,41 €	-91.844,20 €	-41.768,27 €
4	59.239,98	2.353,06 €	5.564,53 €	3.211,47 €	4.324,57 €	182 €	7.354,04 €	28.179,55 €	-83.100,31 €	-33.024,37 €	-85.435,58 €	-35.359,65 €
5	58.943,78	2.364,83 €	5.773,20 €	3.408,37 €	4.346,19 €	182 €	7.572,57 €	35.752,12 €	-75.527,74 €	-25.451,81 €	-79.059,69 €	-28.983,75 €
6	58.649,06	2.376,65 €	5.989,69 €	3.613,04 €	4.367,93 €	182 €	7.798,97 €	43.551,08 €	-67.728,77 €	-17.652,84 €	-72.715,22 €	-22.639,28 €
7	58.355,81	2.388,53 €	6.214,31 €	3.825,77 €	4.389,77 €	182 €	8.033,54 €	51.584,62 €	-59.695,24 €	-9.619,30 €	-66.400,93 €	-16.325,00 €
8	58.064,04	2.400,48 €	6.447,34 €	4.046,87 €	4.411,71 €	182 €	8.276,58 €	59.861,20 €	-51.418,66 €	-1.342,72 €	-60.115,60 €	-10.039,67 €
9	57.773,72	2.412,48 €	6.689,12 €	4.276,64 €	4.433,77 €	182 €	8.528,41 €	68.389,61 €	-42.890,24 €	7.185,69 €	-53.858,04 €	-3.782,11 €
10	57.484,85	2.424,54 €	6.939,96 €	4.515,42 €	4.455,94 €	182 €	8.789,36 €	77.178,97 €	-34.100,88 €	15.975,05 €	-47.627,10 €	2.448,84 €
11	57.197,42	2.436,66 €	7.200,21 €	4.763,54 €	4.478,22 €	182 €	9.059,77 €	86.238,74 €	-25.041,12 €	25.034,82 €	-41.421,65 €	8.654,28 €
12	56.911,44	2.448,85 €	7.470,22 €	5.021,37 €	4.500,61 €	182 €	9.339,98 €	95.578,72 €	-15.701,14 €	34.374,80 €	-35.240,61 €	14.835,33 €
13	56.626,88	2.461,09 €	7.750,35 €	5.289,26 €	4.523,12 €	182 €	9.630,37 €	105.209,09 €	-6.070,76 €	44.005,17 €	-29.082,91 €	20.993,03 €
14	56.343,74	2.473,40 €	8.040,99 €	5.567,59 €	4.545,73 €	182 €	9.931,32 €	115.140,42 €	3.860,56 €	53.936,49 €	-22.947,52 €	27.128,42 €
15	56.062,03	2.485,76 €	8.342,53 €	5.856,76 €	4.568,46 €	182 €	10.243,22 €	125.383,64 €	14.103,78 €	64.179,71 €	-16.833,44 €	33.242,50 €
16	55.781,72	2.498,19 €	8.655,37 €	6.157,18 €	4.591,30 €	182 €	10.566,48 €	135.950,11 €	24.670,26 €	74.746,19 €	-10.739,68 €	39.336,25 €
17	55.502,81	2.510,68 €	8.979,95 €	6.469,26 €	4.614,26 €	182 €	10.901,52 €	146.851,63 €	35.571,78 €	85.647,71 €	-4.665,32 €	45.410,62 €
18	55.225,29	2.523,24 €	9.316,69 €	6.793,46 €	4.637,33 €	182 €	11.248,79 €	158.100,42 €	46.820,56 €	96.896,50 €	1.390,59 €	51.466,53 €
19	54.949,17	2.535,85 €	9.666,07 €	7.130,22 €	4.660,52 €	182 €	11.608,73 €	169.709,15 €	58.429,30 €	108.505,23 €	7.428,94 €	57.504,88 €
20	54.674,42	2.548,53 €	10.028,55 €	7.480,01 €	4.683,82 €	182 €	11.981,83 €	181.690,99 €	70.411,13 €	120.487,07 €	13.450,60 €	63.526,54 €
TOTAL	1.147.298,20	48.632,03 €	144.584,70 €	95.952,68 €	89.378,31 €	3.640,00 €	181.690,99 €	181.690,99 €	70.411,13 €	120.487,07 €	13.450,60 €	63.526,54 €

Table 46. Payback NPV and IRR for district heating with produced pellet.

Payback	14 years
Payback with grant	**9 years**
NPV	13.450,60 €
NPV with grant	**63.526,54 €**
IRR with grant	**3%**

1.13. 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 are reflected the high interest in the project by the actors involved. They see positively the inclusion of renewable energies in the daily life.

In addition, the viability study shows that both projects are profitable, being an economical alternative in comparison with gasoil. Moreover, thanks to the public grants offered, it is reduced the initial investment, being easier to carry out the project. In this sense, it is more feasible to produce pellet for self-consumption.

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 automation is higher. Nevertheless, the investment is a bit lower in the individual installations, although it requires most maintenance costs.

In conclusion, the installation of biomass heating systems and the production of pellet 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.

1.14. Order of priority

The order of priority established for the documents of the project is the same that the given by the standard UNE-EN 157001:

1. Project plans.
2. Specifications document.
3. Budget.
4. Memory

2. Calculations and annexes

Calculations and annexes

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') [26], there is the history of temperatures in Vistabella del Maestrazgo during 2016 and until October of 2017 (Table 47).

Table 47. 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
03/2017	-5,1	6,9	22,9
04/2017	-5,2	7,5	21,8
05/2017	-1,2	12,4	23,9
06/2017	5,1	18	29,7
07/2017	3,6	19,1	31,3
08/2017	4,9	18,7	29,8
09/2017	2,8	13,8	24,7
10/2017	-0,3	12,0	24,2

2.2. Calculation of heating demand

To calculate the demand or load of heating from the buildings, it is going to be taken into account the losses 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 it is made the heat dissipation, 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, being different in each enclosure.

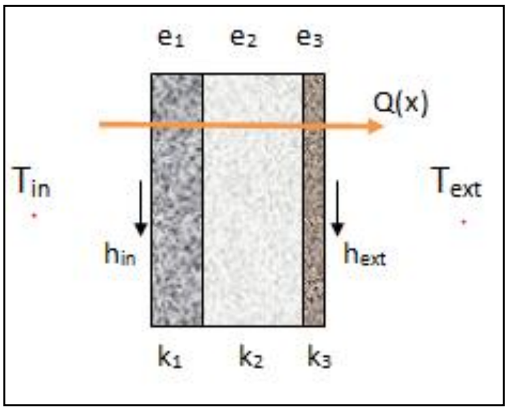


Figure 21. Heat transfer through a wall

To calculate the global coefficient of heat transfer, it must be obtained first the thermal resistance of the enclosure, 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:

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

To calculate the resistances, the thickness will be a figure from the installation, and the thermal conductivity will depend directly on the used material.

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 estimate of 1m/s and outside of 26 m/s, since Vistabella is in an A wind 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, it can be calculated the number of Nusselt (*Nu*), 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, is used the Colburn expression 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

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

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

Table 48. 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 49. Coefficients of convection in the school.

	Re	Pr	Nu	h (W/m²K)
Inside	1.761.846	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 50. Coefficients of convection in the residential block.

	Re	Pr	Nu	h (W/m²K)
Inside	1.761.846	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.

Furthermore, 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 51. 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.

2.2.1. 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 [11], whereas the lowest possible temperature, according to AVAMET (Table 47), is -13,8ºC.

To calculate the floor temperature pattern, it is required a specific study 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.

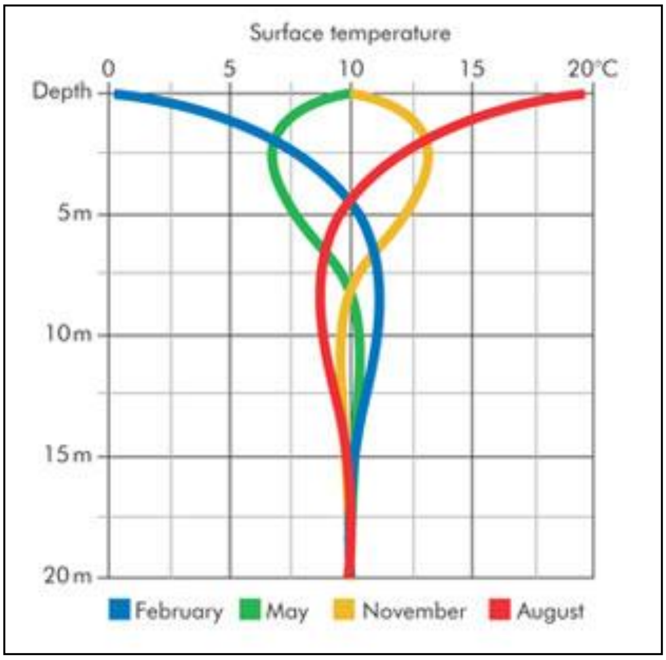


Figure 22. Floor temperatura pattern.

For the temperatures of the non-climate controlled room and the party walls, they are estimated based on the next equation:

$$\Delta T_{eq} = \frac{1}{2}(T_e - T_i)$$

Where T_e is the minimum external temperature and T_i is the inner temperature desired. Moreover, the global coefficient of transfer from windows and doors has been estimated as 3,3 W/m2K from previous data [7].

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 23, the first two dwellings have another building next to the party wall, whereas the last two do not have this situation. This will vary the reference temperatures in the calculation of the demand.

Figure 23. Residential block.

2.2.2. Thermal power losses in the school's building

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

Table 52. Enclosures of the school's building.

Building enclosure	R conv. out (m²K/W)	R cond. (m²K/W)	R conv. in (m²K/W)	R total (m²K/W)	U total (W/m²K)
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
Internal door					1,899

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

Table 53. Thermal power losses of the school's building due to enclosures.

Floor	Local	Enclosure	U (W/m²K)	ΔT (K)	Area (m²)	Power (W)
First floor	Canteen	External wall N	0,977	34,8	8,6	292,33
		External wall E	0,977	34,8	23,49	798,47
		External wall S	0,820	34,8	17,16	489,45
		Floor against ground	1,444	14	85,91	1.737,32
	Hall	External wall N	0,977	34,8	3,34	113,53
		External wall S	0,820	34,8	3,34	95,27
		Floor against ground	1,444	14	27,8	562,19

	Pharmacy	External wall N	0,977	34,8	13,84	470,45
		External wall S	0,820	34,8	12,9	367,94
		Floor against ground	1,444	14	55,23	1.116,89
	Library	External wall N	0,977	34,8	7,03	238,96
		External wall W	0,977	34,8	7,8	265,14
		External wall S	0,820	34,8	16,38	467,20
		Wall against local without conditioning	1,444	17,4	26,26	660,01
		Party wall W	0,977	17,4	0,3	5,10
		Internal door	1,899	17,4	4	132,17
		Floor against ground	1,444	14	56,13	1.135,09
Second floor	Office	External wall N	0,977	34,8	9,96	338,56
		External wall E	0,977	34,8	10,2	346,72
		Wall against local without conditioning	1,444	17,4	1,12	28,15
		Roof	1,005	34,8	42,84	1.498,57
	Childhood Classroom	External wall E	0,977	34,8	17,73	602,67
		External wall S	0,820	34,8	13,8	393,62
		Roof	1,005	34,8	48,46	1.695,16
	Primary Classroom	External wall S	0,820	34,8	14,99	427,56
		Roof	1,005	34,8	47,46	1.660,18
	Computer Lab	External wall W	0,977	34,8	17,73	602,67
		External wall S	0,820	34,8	15,2	433,55
		Roof	1,005	34,8	54,49	1.906,09
	Corridor	External wall N	0,977	34,8	34,83	1.183,93
		Wall against local without conditioning	1,444	17,4	8,91	223,94
		Internal door	1,899	17,4	2,7	89,22
		Roof	1,005	34,8	56,4	1.972,90
	Bathroom	External wall N	0,977	34,8	16,62	564,94
		External wall W	0,977	34,8	9,04	307,29
		Roof	1,005	34,8	18,17	635,60
	Stairs	Externall wall S	0,820	34,8	8,28	236,17
		Roof	1,005	34,8	26,67	933,05
					TOTAL	**25.028,01**

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

Table 54. Thermal power losses of the school's building due to 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	2.480,54
Window 150	3,3	34,8	2,7	20	6.201,36
Window 180	3,3	34,8	3,24	2	744,16
External Door	1,754	34,8	5	3	915,59
				TOTAL	**10.456,50**

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

Table 55. Thermal power losses in the school's building due to natural ventilation.

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)	-13,80	-13,80	-13,80	-13,80	-13,80	-13,80	-13,80	-13,80	-13,80
Internal temperature Ti (ºC)	21,00	21,00	21,00	21,00	21,00	21,00	21,00	21,00	21,00
Minimum index of air renovation nmin (1/h)	0,50	1,50	2,00	2,00	2,00	1,50	1,00	2,00	0,50
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	3.369,07	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, being 18.259,96 W.

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

Table 56. Thermal power losses in the school's building.

Thermal power loss	Power (W)
Building enclosure	25.028,01
Windows and doors	10.456,50
Ventilation	18.259,96
TOTAL	**53.836,33**

Moreover, it is increased the final values with a coefficient of 5 % as safety coefficient:

Table 57. Thermal power losses in the school's building II.

Thermal power loss	Power (W)
Building enclosure	26.279,41
Windows and doors	11.075,79
Ventilation	19.172,95
TOTAL	**56.528,15**

2.2.3. Thermal power losses in the residential block

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

Table 58. Enclosures of the residential block.

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
Internal door					1,899

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

Table 59. Thermal power losses in the residential block due to the enclosures.

Floor	Local	Enclosure	U (W/m²K)	ΔT (K)	Area (m²)	Power (W)
First floor	Dining Room	Wall against local without conditioning	1,619	17,4	8,14	229,16
		External wall S	0,873	34,8	7,82	237,58
		External wall W	1,054	34,8	10,07	369,30
		External wall E	1,054	34,8	2,41	88,41
		Floor against local without conditioning	1,099	17,4	18,50	353,63
		Door	1,899	17,4	2,39	78,81
	Bathroom	Wall against local without conditioning	1,619	17,4	2,36	66,44
		External wall S	0,873	34,8	1,85	56,08
		Party wall E	0,362	17,4	10,46	65,98
		Floor against local without conditioning	1,099	17,4	5,75	109,95
		Door	1,899	17,4	2,39	78,81
	Room 1	Wall against local without conditioning	1,619	17,4	13,38	376,99
		External wall N	1,054	34,8	6,07	222,66
		Party wall E	0,362	17,4	9,47	59,68
		Floor against local without conditioning	1,099	17,4	9,60	183,58
		Door	1,899	17,4	2,39	78,81
	Room 2	Wall against local without conditioning	1,619	17,4	4,21	118,70
		External wall S	0,873	34,8	4,80	145,78
		Floor against local without conditioning	1,099	17,4	9,35	178,80
		Door	1,899	17,4	2,39	78,81
	Room 3	Wall against local without conditioning	1,619	17,4	14,65	412,83
		External wall N	1,054	34,8	10,60	388,80
		External wall W	1,054	34,8	4,64	170,17
		Floor against local	1,099	17,4	9,55	182,62

		without conditioning				
		Door	1,899	17,4	2,39	78,81
Second floor	Dining Room	Wall against local without conditioning	1,619	17,4	8,14	229,16
		External wall S	0,873	34,8	7,82	237,58
		External wall W	1,054	34,8	10,07	369,30
		External wall E	1,054	34,8	2,41	88,41
		Door	1,899	17,4	2,39	78,81
	Bathroom	Wall against local without conditioning	1,619	17,4	2,36	66,44
		External wall S	0,873	34,8	1,85	56,08
		Party wall E	0,362	17,4	10,46	65,98
		Door	1,899	17,4	2,39	78,81
	Room 1	Wall against local without conditioning	1,619	17,4	13,38	376,99
		External wall N	1,054	34,8	6,07	222,66
		Party wall E	0,362	17,4	9,47	59,68
		Door	1,899	17,4	2,39	78,81
	Room 2	Wall against local without conditioning	1,619	17,4	4,21	118,70
		External wall S	0,873	34,8	4,80	145,78
		Door	1,899	17,4	2,39	78,81
	Room 3	Wall against local without conditioning	1,619	17,4	14,65	412,83
		External wall N	1,054	34,8	10,60	388,80
		External wall W	1,054	34,8	4,64	170,17
		Door	1,899	17,4	2,39	78,81
Third floor	Dining Room	Wall against local without conditioning	1,619	17,4	8,14	229,16
		External wall S	0,873	34,8	7,82	237,58
		External wall W	1,054	34,8	10,07	369,30
		External wall E	1,054	34,8	2,41	88,41
		Door	1,899	17,4	2,39	78,81
	Bathroom	Wall against local without conditioning	1,619	17,4	2,36	66,44
		External wall S	0,873	34,8	1,85	56,08
		External wall E	0,362	34,8	10,46	131,95
		Door	1,899	17,4	2,39	78,81
	Room 1	Wall against local without conditioning	1,619	17,4	13,38	376,99
		External wall N	1,054	34,8	6,07	222,66
		External wall E	0,362	34,8	9,47	119,36
		Door	1,899	17,4	2,39	78,81
	Room 2	Wall against local without conditioning	1,619	17,4	4,21	118,70
		External wall S	0,873	34,8	4,80	145,78
		Door	1,899	17,4	2,39	78,81
	Room 3	Wall against local without conditioning	1,619	17,4	14,65	412,83

		External wall N	1,054	34,8	10,60	388,80
		External wall W	1,054	34,8	4,64	170,17
		Door	1,899	17,4	2,39	78,81
Fourth floor	Dining Room	Wall against local without conditioning	1,619	17,4	8,14	229,16
		External wall S	0,873	34,8	7,82	237,58
		External wall W	1,054	34,8	10,07	369,30
		External wall E	1,054	34,8	2,41	88,41
		Roof	1,087	34,8	18,50	699,58
		Door	1,899	17,4	2,39	78,81
	Bathroom	Wall against local without conditioning	1,619	17,4	2,36	66,44
		External wall S	0,873	34,8	1,85	56,08
		External wall E	0,362	34,8	10,46	131,95
		Roof	1,087	34,8	5,75	217,44
		Door	1,899	17,4	2,39	78,81
	Room 1	Wall against local without conditioning	1,619	17,4	13,38	376,99
		External wall N	1,054	34,8	6,07	222,66
		External wall E	0,362	34,8	9,47	119,36
		Roof	1,087	34,8	9,60	363,03
		Door	1,899	17,4	2,39	78,81
	Room 2	Wall against local without conditioning	1,619	17,4	4,21	118,70
		External wall S	0,873	34,8	4,80	145,78
		Roof	1,087	34,8	9,35	353,57
		Door	1,899	17,4	2,39	78,81
	Room 3	Wall against local without conditioning	1,619	17,4	14,65	412,83
		External wall N	1,054	34,8	10,60	388,80
		External wall W	1,054	34,8	4,64	170,17
		Roof	1,087	34,8	9,55	361,13
		Door	1,899	17,4	2,39	78,81
					TOTAL	**16.865,03**

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

Table 60. Thermal power losses din the residential block due to windows.

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
				TOTAL	**5.622,57**

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

Table 61. Thermal power losses in the residential block due to natural ventilation.

Name of the enclosure	Dining-Room	Room 1	Room 2	Room 3	Bathroom
Interior volume Vi (m³)	189,44	98,30	95,74	97,79	58,57
External temperature Te (ºC)	-13,80	-13,80	-13,80	-13,80	-13,80
Internal temperature Ti (ºC)	21,00	21,00	21,00	21,00	21,00
Minimum index of air renovation nmin (1/h)	0,50	0,50	0,50	0,50	1,50
Minimum air flow V'min (m³/h)	94,72	49,15	47,87	48,90	87,86
Thermal loss coefficient Hvi (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, being 3.886,80 W.

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

Table 62. Thermal power losses in the residential block.

Losses	Power (W)
Building enclosure	16.865,03
Windows and doors	5.622,56
Ventilation	3.886,80
TOTAL	**26.374,40**

Moreover, it is increased the final values with a coefficient of 5 % as safety coefficient:

Table 63. Thermal power losses in the residential block II.

Losses	Power (W)
Building enclosure	17.708,28
Windows and doors	5.903,69
Ventilation	4.081,14
TOTAL	**27.693,12**

2.2.4. 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, which in Spain 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:

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

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.

It must be taken into account the lacking of heat demand in the months of June, July and August, when the average temperature is higher 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 64. HDD in the school's building.

Months	Useful days	T_{avg} (ºC)	HDD_{15}
January	19	3,15	225,15
February	20	4,05	219,00
March	19	4,4	201,40
April	15	6,7	124,50
May	21	10,2	100,80
June	-	15,5	-
July	-	18,7	-
August	-	17,8	-
September	15	14,9	1,50
October	22	11,2	83,60
November	20	5,4	192,00
December	15	3,1	178,50
		TOTAL	**1.326,45**

Considering a use of 10 h/day approximately, the annual energy demand is:

$$E = \frac{1.326{,}45 \cdot 53{,}84 \cdot 10}{21 - (-13{,}8)} = 20.520{,}46\ kWh$$

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 65. HDD in the residential block.

Months	Useful days	T_{avg} (ºC)	HDD_{15}
January	31	3,15	367,35
February	28	4,05	306,60
March	31	4,4	328,60
April	30	6,7	249,00
May	31	10,2	148,80
June	-	15,5	-
July	-	18,7	-
August	-	17,8	-
September	30	14,9	3,00
October	31	11,2	117,80
November	30	5,4	288,00
December	31	3,1	368,90
		TOTAL	**2.178,05**

The annual energy demand is:

$$E = \frac{2.178,05 \cdot 27,69 \cdot 24}{21 - (-13,8)} = 39.617,08\ kWh$$

2.3. CLIMA calculations

It is used the software CLIMA in order to have a different alternative for calculating the thermal power losses in both buildings. Moreover, this is a method to corroborate the theoretical calculations.

The simulation of the thermal power losses and the heating demand is done for each building separately. In both cases, the external conditions and the operations conditions will be the same. The operative temperature and the relative humidity are defined in the RITE [11], as it is shown in the Table 66.

Table 66. Operative temperatures (Table 1.4.1.1 RITE).

Season	Operative Temperature ºC	Relative Humidity %
Summer	23…25	45…60
Spring	21…23	40…50

According to the information provided by the RITE, it is selected an operative temperature of 21 ºC and a relative humidity of the 40 %.

Furthermore, it is necessary to define the external conditions of the buildings (Figure 24). Vistabella is not defined in the programme so it is created a new page with information about the town. Vistabella is located in the Spanish Climate Zone B3, with an altitude of 1.246 m and a latitude of 40,29 º. Following the Figure 22, the temperature of the ground is 7 ºC. Moreover, the most important part in the heating system sizing is the determinations of the external temperatures in winter. It is shown in the Table 47 that the minimum temperature (*T,s,ext,min*) in Vistabella is -13,80 ºC. Moreover, it is selected an average humidity of 58 % and an average daily oscillation (OMD) of 5 ºC (standard value of the software).

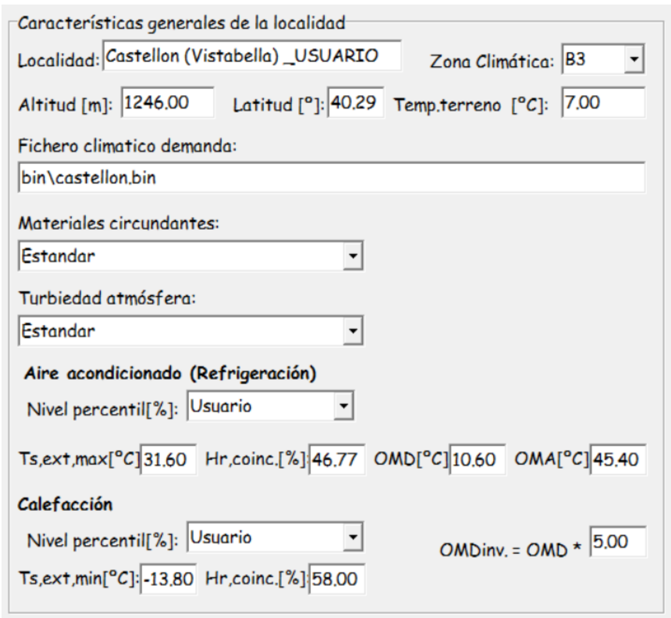


Figure 24. Considerations of Vistabella in CLIMA.

2.3.1. School's building

Once the external conditions are defined, the next step is the determination of the use of the building. In this part of the programme, the hours of work are the input for the posterior calculus of the demand (Figure 25). For the school's building, it must be taken into account that the simulation is done in three parts because of the different activities that are placed in the building: the school, the pharmacy and the library. The schedule of each activity is described in the Table 1, matching the hours with the biomass boiler activity (it is required to switch on before the activity starts and it can be switched off ends).

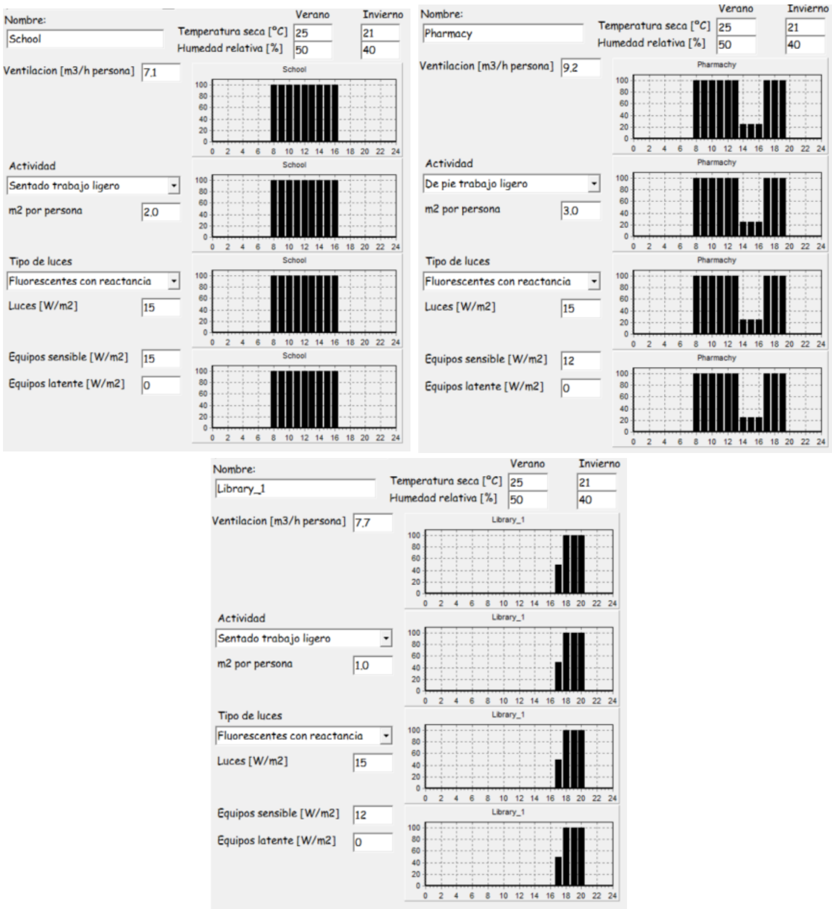


Figure 25. Hours of work of the school's building.

Moreover, the programme can calculate the thermal power losses due to ventilation. In both buildings, the ventilation is natural but this option is not possible in the software. For this reason, the value of ventilation flow selected corresponds to the required value to obtain the same thermal power losses of natural ventilation.

Once the activities are defined, the locals are created. The locals are divided in floors and, in the case of the school, it is had two floors. In both floors, it is defined the different locals, establishing the locals that are not conditioned (archive, small house and small storage room). Moreover, for each local, it must be defined the activity of the room (school, pharmacy or library), the geometry and the enclosures with their properties, windows and doors. In the Figure 26, it is shown an example of the canteen:

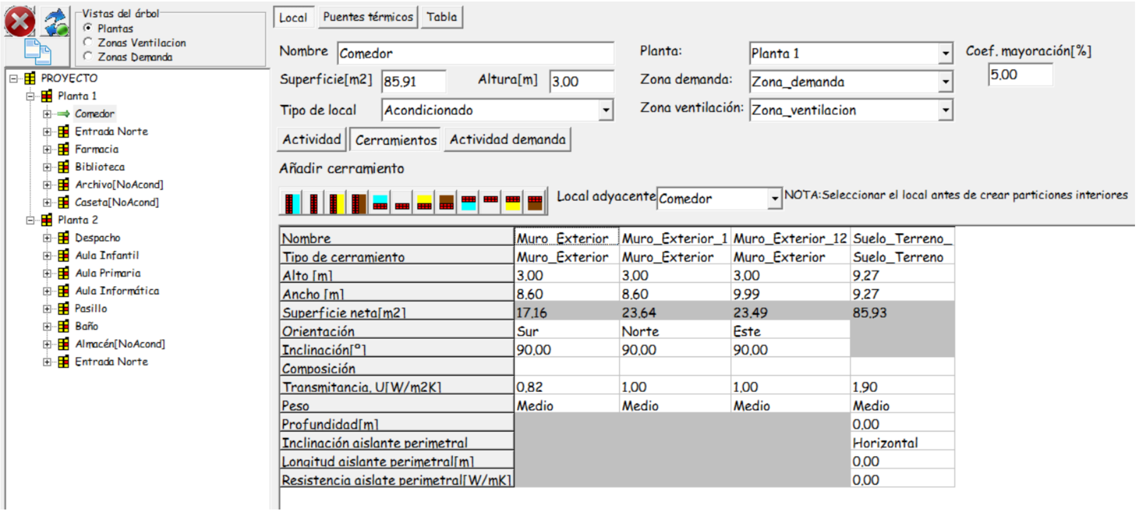


Figure 26. Enclosures of the schools' bulding.

The properties of the enclosures, windows and doors are the same that were selected for the theoretical calculations. There are four different types of the enclosures in the school's building:

- External wall: walls of the building that are influenced directly by environment (external temperature, irradiation of the sun, etc.).
- Internal wall: walls against local without conditioning. It is consider that the other locals are not habitable.
- Roof: top of the building, it is influenced by the sun and the external temperature.
- Floor against ground: bottom of the building. It is consider that the building is at ground level and the temperature of the ground is 7 ºC (Figure 22).

Furthermore, the software allows selecting "hollows" (doors and windows) in the external walls. The number of windows and doors, and their properties, are described in the theoretical calculations (Table 54).

Once all the locals are determined with their enclosures, activities, hollows and properties, the programme calculates the total thermal power losses (Figure 27) with minus sign because they are heating loads.

CARGAS EDIFICIO	Total	Sensible
Total[kW]	-43,25	-35,94
Ratio[W/m2]	-95,15	-79,07
Ocupantes [kW]	0,00	0,00
Luces [kW]	0,00	0,00
Equipos [kW]	0,00	0,00
Ventilación [kW]	-18,25	-11,29
Cerramientos [kW]	-18,58	-18,58
Huecos [kW]	-7,45	-7,45
Puentes térmicos [kW]	0,00	0,00
Mayoracion [kW]	-2,06	-1,71
LOCALES		
Local:Comedor[42e308e0] [kW]	-8,17	-6,57
Local:Entrada Norte[8e9c44fb] [kW]	-2,33	-1,81
Local:Farmacia[2dccd932] [kW]	-4,65	-3,76
Local:Biblioteca[acdbdba2] [kW]	0,00	0,00
Local:Despacho[1c2f397e] [kW]	-2,15	-1,88
Local:Aula Infantil[f1cf8b8e] [kW]	-5,86	-4,96
Local:Aula Primaria[a3883e3c] [kW]	-5,09	-4,20
Local:Aula Informática[d08df7ec] [kW]	-6,30	-5,28
Local:Pasillo[8377d177] [kW]	-3,72	-3,37
Local:Baño[b1f14964] [kW]	-2,46	-2,12
Local:Archivo[6a0e4f35] [kW]	0,00	0,00
Local:Caseta[adac8cc2] [kW]	0,00	0,00
Local:Almacén[c5a74255] [kW]	0,00	0,00
Local:Entrada Norte[80a80a20] [kW]	-2,51	-1,99

Figure 27. Results of the simulations of the school's building.

The total thermal power losses of the building are 43,25 kW. The ventilation has a value of 18,25 kW because it was defined in order to have the same value as the theoretical natural ventilation. The hollows (windows and doors) have a value of 7,45 kW. This value is lower than the value obtained in the theoretical calculation because the maximum power losses due to this item is given when the schools is close (Figure 28). Finally, the maximum thermal power losses due to enclosures is 18,58 kW, which is far below its theoretical calculus. For this reason, a good approximation is to define a thermal power loss of 50 kW for the school's building.

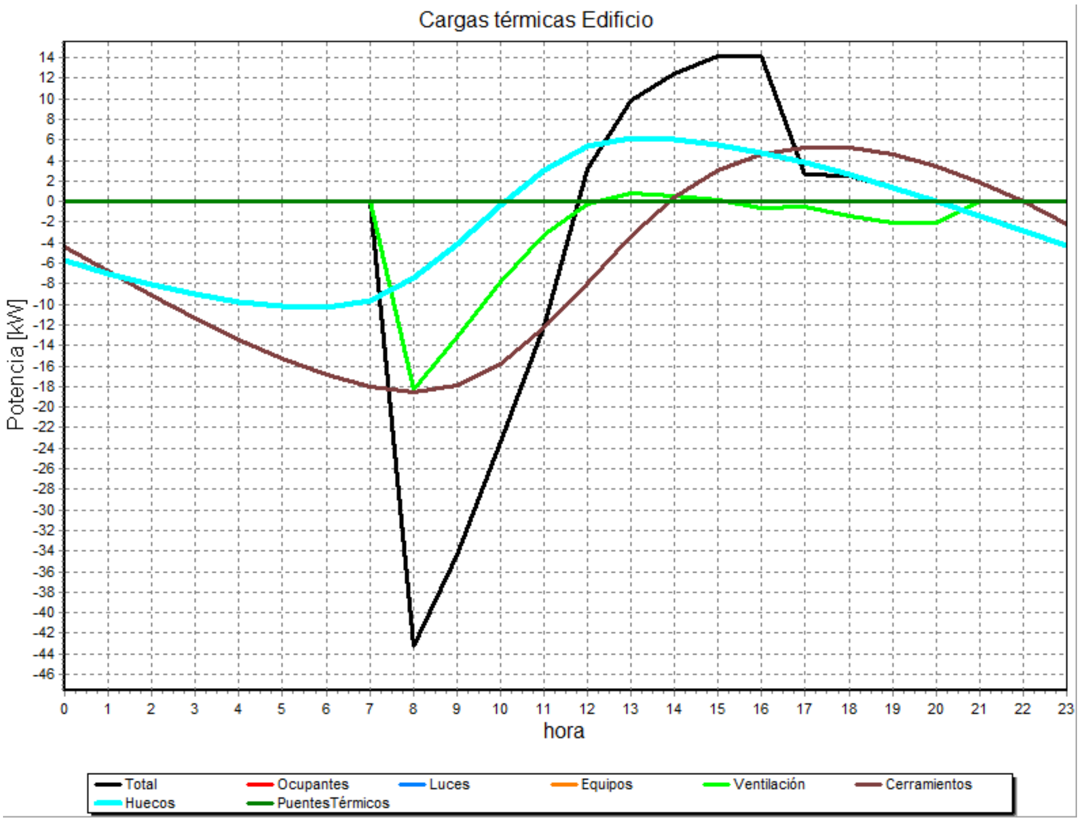


Figure 28. Graphic with the heat power losses in the school's buliding.

In the Figure 28, it is show the evolution of the thermal power losses due to the enclosures (brown), ventilation (green), hollows (blue) and the total (black). The maximum total value is give at 8 a.m., right after the school opens.

Although the value is not the same that the theoretical calculation, it is shown that they have a similar order of magnitude. The difference is that the theoretical calculation considers the most unfavourable case, when all the loads have their maximum value at the same time.

Moreover, it is calculated the energy demand of the building according to the different thermal power losses and the hours of activity. The total annual energy demand is 11.539,74 kWh.

2.3.2. Residential block

The procedure in the case of the residential block is the same that the case of the school's building. First, it is defined the activity of the building. The software has predefined the residential activity, which includes all the hours of the day (Figure 29). Moreover, the value of ventilation flow selected corresponds to the required value to obtain the same thermal power losses of natural ventilation.

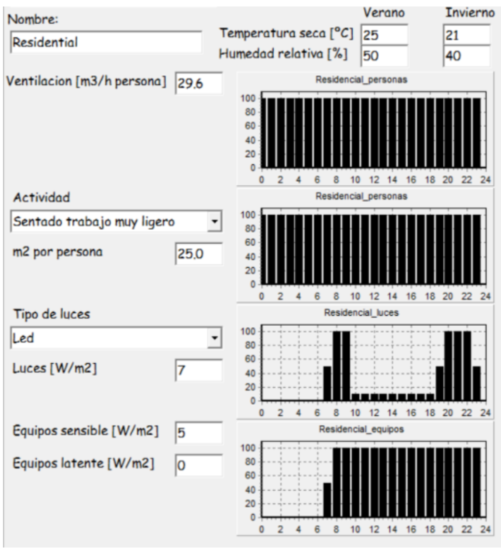


Figure 29. Work hours of the residential block.

Once the activities are defined, the locals are created. The locals are divided in floors and, in the case of the residential block, it is had four floors. Each floor has five conditioned rooms: a dining room, a bathroom and three rooms. Moreover, for each room, it must be defined the geometry and the enclosures with their properties, windows and doors. In the Figure 30, it is shown an example of the bathroom:

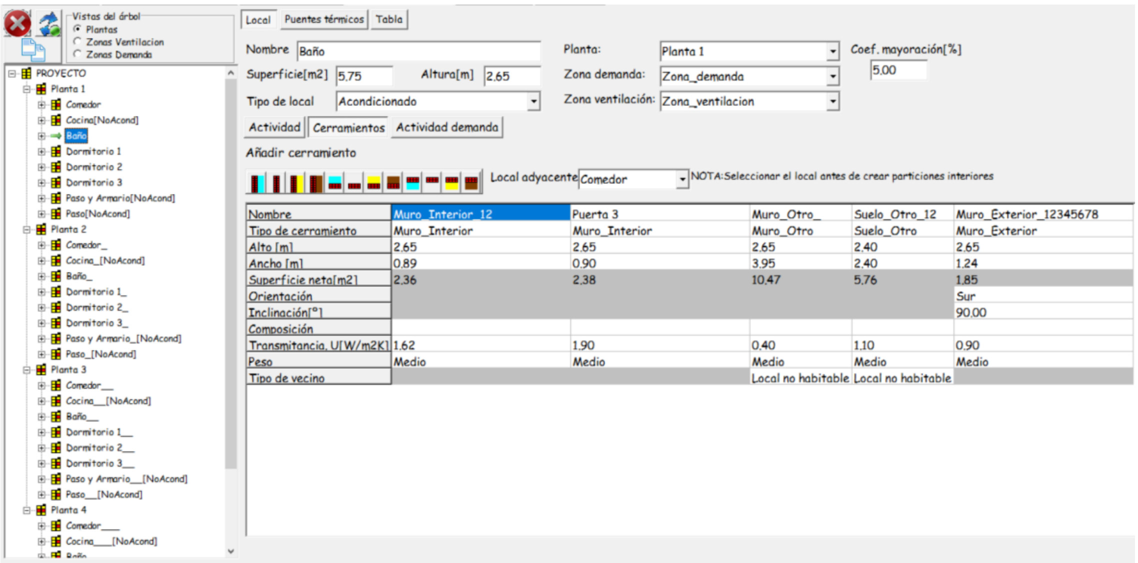


Figure 30. Enclosures of the residential block.

The properties of the enclosures, windows and doors are the same that were selected for the theoretical calculations. The types of enclosures are the same that in the case of the school except:

- The first floor has a floor against a local without conditioning, which is the local where the boiler is installed.
- The first and the second floor has a party wall against another building in the East. It is consider that the building is not habitable.

Furthermore, the software allows selecting "hollows" (doors and windows) in the external walls. The number of windows, and their properties, are described in the theoretical calculations (Table 60).

Once all the locals are determined with their enclosures, activities, hollows and properties, the programme calculates the total thermal power losses (Figure 31) with minus sign because they are heating loads.

Cargas de calefacción

Fecha máxima carga:	Febrero	Hora: 6
CARGAS EDIFICIO	Total	Sensible
Total[kW]	-20.57	-19.23
Ratio[W/m2]	-97.48	-91.14
Ocupantes [kW]	0.00	0.00
Luces [kW]	0.00	0.00
Equipos [kW]	0.00	0.00
Ventilación [kW]	-4.08	-2.80
Cerramientos [kW]	-10.00	-10.00
Huecos [kW]	-5.51	-5.51
Puentes térmicos [kW]	0.00	0.00
Mayoracion [kW]	-0.98	-0.92

Figure 31. Results of the simulation of the residential block.

The total thermal power losses of the building are 20,57 kW. The ventilation has a value of 4,08 kW because it was defined in order to have the same value as the theoretical natural ventilation. The hollows (windows and doors) have a value of 5,51 kW. This value is lower than the value obtained in the theoretical calculation because the maximum power losses due to this item is given when the schools is close (Figure 32). Finally, the maximum thermal power losses due to enclosures is 10 kW, which is far below its theoretical calculus. For this reason, a good approximation is to define a thermal power loss of 25 kW for the residential block, following the commercial boilers.

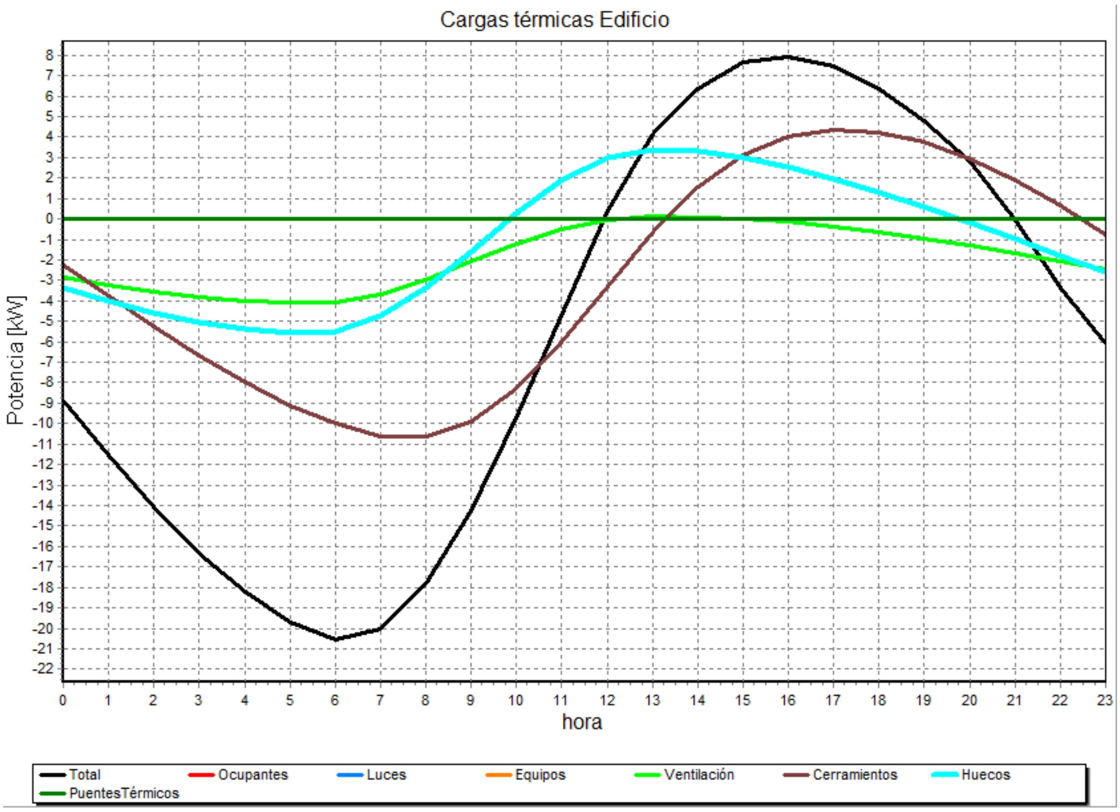


Figure 32. Graphic with the heat power losses in the residential block.

In the Figure 32, it is show the evolution of the thermal power losses due to the enclosures (brown), ventilation (green), hollows (blue) and the total (black). The maximum occurs at 6 a.m., right before the sun rises.

Although the value is not the same that the theoretical calculation, it is shown that they have a similar order of magnitude. The main difference comes from the enclosures because the software does not consider the same conditions for the unfavourable case as the theoretical calculus does.

Moreover, it is calculated the energy demand of the building according to the different thermal power losses and the hours of activity. The total annual energy demand is 16.039,70 kWh, considering that the software has a standardization of the residential activity that differs from the unfavourable case of the HDD calculation.

2.4. Sizing of expansión vessels

From the data obtained on the Reglamento de Instalaciones Térmicas en los Edificios (RITE, 'Regulations of Heating Systems in Buildings') [11], 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:

$$V = \frac{P \cdot 15}{1.000} \; [l]$$

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

Table 67. Volume for 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, it is selected a temperature of 75 ºC, because 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 68. Volume of expansion vessels.

Installation	Vt (liters)
School's building	125,57
Residential block	62,78
District heating	200,91

2.5. Sizing of radiators

Following the normative IT 1.3.4.4.1 [11], the temperature of the radiators is limited to 80 ºC. Moreover, manufacturer specifications 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 are the division between the thermal power losses of the room (calculated with the method of the point 2.2.) and the power of an element.

Table 69. Elements required for installation.

Installation	Thermal power losses (W)	Number of elements
School's building	56.528,15	474,19
Residential block	27.693,12	232,31

The element distribution is done in function of the space and necessities. It must take into account that the school and library have radiators so their spaces can be reused.

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 10 elements in the bathroom. This is 240 elements and 24 radiators.

The selection of the radiators in the school is carried out in order to use the radiators that are right now installed in the building. Therefore, in the individual installations only is considered the expansion of hydraulic system with the pharmacy's radiators and in the case of the district heating it is going to profit the radiators that are already installed. It is going to use one radiator of 15 elements in the hall, three radiators of 20 elements in the canteen, three radiators of 20 elements in the library, one radiator of 15 elements in the office, three radiators of 20 elements in the childhood classroom, three radiators of 20 elements in the primary classroom, three radiators of 20 elements in the primary classroom, three radiators of 20 elements in the corridor, one radiator of 15 elements in the bathroom and one radiator of 15 elements and three of 20 for the pharmacy and its storage area.

Finally, it is calculated the flow of the different radiators 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 at the entrance and the exit of the radiator (15 ºC). It must be considered that the density of the water is 1 kg/l so it can be calculated the value of the flow directly.

Table 70. Flow of radiators.

Radiator	**Flow (l/s)**
20 elements	0,038
15 elements	0,0285
10 elements	0,019
5 elements	0,0095

2.6. Sizing of the conduction system

In order to do the sizing of the heating conduction system, it is going to consider two possible scenarios: one for the district heating and another for the individual installations.

2.6.1. Individual installations

In this case, it is had two different boilers installed in two different points of each building. The conduction system of the residential block is sized totally, because it is a new installation. However, the installation of the school's building is considered as an expansion of the previous installation. Therefore, for the school it is only required to size the conduction for the pharmacy.

In the residential block, it is used the following nomenclature:

Table 71. Nomenclature conductions.

Character	Meaning
0	Boiler's exit
1.x	First floor
2.x	Second floor
3.x	Third floor
4.x	Fourth floor
x.0	First radiator of the dining room
x.1	Second radiator of the dining room
x.2	Radiator of the room 2
x.3	Radiator of the bathroom
x.4	Radiator of the room 3
x.5	Radiator of the room 1

The first step is to calculate the flows in all the sections and to measure the distance of all these sections (Table 72).

Once all the sections are defined, it is going to calculate the uniform hydraulic slope and the critical path. This method establish that it is required to maintain the same hydraulic slope in all the pipes. The hydraulic slope is:

$$j_h = \frac{h_f}{L}$$

The hydraulic slope that will be selected for the sizing of the pipes is the one that gives the critical path, which is the route with the minimum pressure of service. Because in this installation it is going to have a pump that gives the pressure in the entrance, it is assumed a value of j_h for all the possible paths, which is between 0,05-0,1 mca/m. This value will give us the value of the P_{pump} required (Table 73).

Table 72. Residential block conductions.

	Pipe	Flow (l/s)	Flow (m^3/s)	Longitude (m)
Floor 1	0 – 1.0	0,38	0,00038	4,225
	1.0 – 1.1	0,019	0,000019	4,395
	1.0 – 1.2	0,038	0,000038	5,215
	1.2 – 1.3	0,019	0,000019	1,245
	1.0 – 1.4	0,038	0,000038	9
	1.4 – 1.5	0,019	0,000019	5,355
Floor 2	1.0 – 2.0	0,285	0,000285	2,9
	2.0 – 2.1	0,019	0,000019	4,395
	2.0 – 2.2	0,038	0,000038	5,215
	2.2 – 2.3	0,019	0,000019	1,245
	2.0 – 2.4	0,038	0,000038	9
	2.4 – 2.5	0,019	0,000019	5,355
Floor 3	2.0 – 3.0	0,19	0,00019	2,9
	3.0 – 3.1	0,019	0,000019	4,395
	3.0 – 3.2	0,038	0,000038	5,215
	3.2 – 3.3	0,019	0,000019	1,245
	3.0 – 3.4	0,038	0,000038	9
	3.4 – 3.5	0,019	0,000019	5,355
Floo 4	3.0 – 4.0	0,095	0,000095	2,9
	4.0 – 4.1	0,019	0,000019	4,395
	4.0 – 4.2	0,038	0,000038	5,215
	4.2 – 4.3	0,019	0,000019	1,245
	4.0 – 4.4	0,038	0,000038	9
	4.4 – 4.5	0,019	0,000019	5,355

Table 73. Critical path residential block conductions.

Node	Li (m)	Zi (m)	Zj (m)	P_{pump}	ΔH	j_h (mca/m)
41	17,32	0	12,925	14,925	2	0,115
43	19,385	0	12,925	14,925	2	0,103
45	27,28	0	12,925	14,925	2	0,073

Once the uniform hydraulic slope is calculated, it can be obtained the minimum diameter required for each pipe with the next equation:

$$D = \sqrt[5]{\frac{8 \cdot f \cdot Q^2}{\pi^2 \cdot g \cdot j_h}} \ [m]$$

Where f is the friction coefficient, Q is the flow in m^3/s, j_h is the hydraulic slope in mca/m and g is the acceleration due to gravity force (9,81 m/s^2).

The friction coefficient is calculated with the previous equation and the equation of Colebrook in an iterative method:

$$\frac{1}{\sqrt{f}} = -2 \cdot log_{10}\left(\frac{\varepsilon}{3,7 \cdot D} + \frac{2.51}{Re \cdot \sqrt{f}}\right)$$

The value of the friction coefficient f is calculated for the first pipe, being 0,1826.

With the previous equation of the diameter and the values of the Table 73, it is obtained the diameter required for the uniform hydraulic slope estimated (Table 74). The diameters in m are converted into mm in order to select commercial diameters.

Table 74. Residential block pipes.

	Pipe	D (m)	D (mm)	Commercial pipe (mm)
Floor 1	0 – 1.0	0,0197	19,70	32x4,4
	1.0 – 1.1	0,0059	5,94	20x2,8
	1.0 – 1.2	0,0078	7,84	20x2,8
	1.2 – 1.3	0,0059	5,94	20x2,8
	1.0 – 1.4	0,0078	7,84	20x2,8
	1.4 – 1.5	0,0059	5,94	20x2,8
Floor 2	1.0 – 2.0	0,0176	17,56	32x4,4
	2.0 – 2.1	0,0059	5,94	20x2,8
	2.0 – 2.2	0,0078	7,84	20x2,8
	2.2 – 2.3	0,0059	5,94	20x2,8
	2.0 – 2.4	0,0078	7,84	20x2,8
	2.4 – 2.5	0,0059	5,94	20x2,8
Floor 3	2.0 – 3.0	0,0149	14,93	32x4,4
	3.0 – 3.1	0,0059	5,94	20x2,8
	3.0 – 3.2	0,0078	7,84	20x2,8
	3.2 – 3.3	0,0059	5,94	20x2,8
	3.0 – 3.4	0,0078	7,84	20x2,8
	3.4 – 3.5	0,0059	5,94	20x2,8
Floor 4	3.0 – 4.0	0,0113	11,32	32x4,4
	4.0 – 4.1	0,0059	5,94	20x2,8
	4.0 – 4.2	0,0078	7,84	20x2,8
	4.2 – 4.3	0,0059	5,94	20x2,8
	4.0 – 4.4	0,0078	7,84	20x2,8
	4.4 – 4.5	0,0059	5,94	20x2,8

The commercial pipes selected are PP-R multiplayer pipe with fiber from Salvador Escoda S.A. This pipe of green colour has an intermediate layer of grey fiber with orange stripes in the surface. This pipe is specially selected for heating. Moreover, all the pipes have a flexible tubular insulator with M1 class and a thermal conductivity of 0,039 W(m.k).

The return conduction is seized using the unfavourable case for each path (Table 75). In the case of the residential block, it will be used a diameter of 20x2,8 for each floor and a diameter of 32x4,4 for the pipes that goes from the ground floor to the top floor.

Table 75. Return conduction for the residential block.

	Pipe	**Return conduction (mm)**
Floor 1	0 – 1.0	32x4,4
	1.0 – 1.1	20x2,8
	1.0 – 1.2	
	1.2 – 1.3	
	1.0 – 1.4	
	1.4 – 1.5	
Floor 2	1.0 – 2.0	32x4,4
	2.0 – 2.1	20x2,8
	2.0 – 2.2	
	2.2 – 2.3	
	2.0 – 2.4	
	2.4 – 2.5	
Floor 3	2.0 – 3.0	32x4,4
	3.0 – 3.1	20x2,8
	3.0 – 3.2	
	3.2 – 3.3	
	3.0 – 3.4	
	3.4 – 3.5	
Floor 4	3.0 – 4.0	32x4,4
	4.0 – 4.1	20x2,8
	4.0 – 4.2	
	4.2 – 4.3	
	4.0 – 4.4	
	4.4 – 4.5	

For the school’s building, it is used the previous installation (Table 76) [7] in order to reduce the final investment cost. It is only required to expand the pharmacy sector with the installation of four radiators, one of 15 elements (ph1) and 3 of 20 elements (ph2, ph3 and ph4).

Table 76. School's building individual installation conduction.

	Radiator	Flow (l/s)	Flow previous conduction (l/s)	L (m)	Diameter (mm)
Circuit 1	child1	0,028	0,282	10,8	25,4
	child2	0,028	0,254	2,3	25,4
	child3	0,028	0,226	2,3	25,4
	prim1	0,028	0,198	4,1	25,4
	prim2	0,028	0,170	2,3	17
	prim3	0,028	0,142	2,3	17
	comp1	0,038	0,114	7,2	17
	comp2	0,038	0,076	2,3	17
	comp3	0,038	0,038	2,3	17
Circuit 2	bathroom	0,033	0,130	8,5	17
	corr1	0,020	0,097	4,7	17
	corr2	0,028	0,077	2,2	17
	corr3	0,022	0,049	2,5	17
	office	0,027	0,027	14,7	17
Circuit 3	hall	0,041	0,281	25,9	25,4
	cant1	0,080	0,240	3,0	25,4
	cant2	0,080	0,160	2,3	17
	cant3	0,080	0,080	2,3	17
Circuit 4	lib1	0,030	0,090	7,0	17
	lib2	0,030	0,060	2,0	17
	lib3	0,030	0,030	1,5	17

In this case it is have only two possible paths, one to ph1 and another to ph4, which is the critical. It is estimated an uniform hydraulic slope of 0,1 mca/m (this value will serve to size the pump after) and a friction coefficient of 0,018. In the Table 77 is shown the value of the diameters in each pipe.

Table 77. School's building expansion.

Pipe	Flow (l/s)	Flow (m^3/s)	Longitude (m)	D (m)	D (mm)	Commercial pipe (mm)
0'-0	0,1425	0,000143	10,91	0,0198	19,77	25,4
0-ph1	0,0285	0,000029	6,75	0,0104	10,39	17
0-ph2	0,114	0,000114	4,62	0,0181	18,08	25,4
ph2-ph3	0,076	0,000076	2,3	0,0154	15,37	17
ph3-ph4	0,038	0,000038	2,3	0,0117	11,65	17

The pipes selected are made of cooper, being the same material as the previous installation.

Table 78. School's building expansion return conduction.

Pipe	Return conduction (mm)
0'-0	25,4
0-ph1	
0-ph2	
ph2-ph3	
ph3-ph4	

The conduction of return is seized using the greatest commercial pipe for all the expansion (Table 78).

2.6.2. District heating

In the district heating case, the boiler is located in the ground floor of the residential block so the conduction system of this building will be the same as the previous one calculated (it will differ in the pumping system).

For the school's building, the connection point will be different in respect of the individual installation. In order to achieve the less buried pipe across the street, it is going to resize the conduction system considering that the connection point is in the canteen. With this system, the radiators can be maintained but the conduction system will be modernised, changing the cooper pipes for PP-R multiplayer with fiber. In the Table 79 is shown all the nodes of the system and their previous pipes.

Table 79. School's building conduction for district heating.

Node	Flow (l/s)	Previous conduction flow (l/s)	P. Flow (m^3/s)	L (m)
0	-	0,926	0,00093	8,00
cant1	0,080	0,514	0,00051	5,00
cant2	0,080	0,434	0,00043	2,30
cant3	0,080	0,354	0,00035	2,30
hall	0,041	0,274	0,00027	9,08
ph1	0,029	0,029	0,00003	5,75
ph2	0,038	0,204	0,00020	7,88
ph3	0,038	0,166	0,00017	2,30
ph4	0,038	0,128	0,00013	2,30
lib1	0,030	0,090	0,00009	3,00
lib2	0,030	0,060	0,00006	2,30
lib3	0,030	0,030	0,00003	2,30
1	-	0,412	0,00041	3,00
child1	0,028	0,282	0,00028	5,30
child2	0,028	0,254	0,00025	2,30
child3	0,028	0,226	0,00023	2,30
pri1	0,028	0,198	0,00020	6,08
pri2	0,028	0,170	0,00017	2,30
pri3	0,028	0,142	0,00014	2,30
comp1	0,038	0,114	0,00011	3,30
comp2	0,038	0,076	0,00008	2,30
comp3	0,038	0,038	0,00004	2,30
2	-	0,130	0,00013	3,00
office	0,027	0,027	0,00003	1,66
corr1	0,020	0,103	0,00010	13,28
corr2	0,028	0,083	0,00008	2,30
corr3	0,022	0,055	0,00006	2,30
bathroom	0,033	0,033	0,00003	4,70

Once all the sections are defined, it is going to calculate the uniform hydraulic slope and the critical path. This method establish that it is required to maintain the same hydraulic slope in all the pipes.

The hydraulic slope that will be selected for the sizing of the pipes is the one that gives the critical path, which is the route with the minimum pressure of service. Because in this installation it is going to have a pump that gives the pressure in the entrance, it is assumed a value of j_h for all the possible paths, which is between 0,05-0,1 mca/m. This value will give us the value of the P_{pump} required (Table 80).

Table 80. Critical path school's building for district heating.

Node	Li (m)	Zi (m)	Zj (m)	P_{pump}	ΔH	j_h (mca/m)
lib3	46,76	0	1,5	8	6,5	0,139
ph1	32,43	0	1,5	8	6,5	0,200
comp3	39,48	0	4,5	8	3,5	0,089
bathroom	36,58	0	4,5	8	3,5	0,096
office	15,66	0	4,5	8	3,5	0,223

Once the uniform hydraulic slope is calculated, it can be obtained the minimum diameter required for each pipe (Table 81), using the same method that was used in the individual residential block system.

Table 81. School's building pipes for district heating.

Node	D (m)	D (mm)	Commercial pipe
0	0,0270	27,01	DUO 32 + 32/150
cant1	0,0213	21,34	32x4,4
cant2	0,0199	19,94	32x4,4
cant3	0,0183	18,38	32x4,4
hall	0,0165	16,59	25x3,5
ph1	0,0067	6,71	20x2,8
ph2	0,0147	14,75	25x3,5
ph3	0,0135	13,58	20x2,8
ph4	0,0122	12,24	20x2,8
lib1	0,0106	10,63	20x2,8
lib2	0,0090	9,04	20x2,8
lib3	0,0069	6,85	20x2,8
1	0,0195	19,54	32x4,4
child1	0,0168	16,79	25x3,5
child2	0,0161	16,10	25x3,5
child3	0,0154	15,37	25x3,5
pri1	0,0146	14,57	25x3,5
pri2	0,0137	13,71	25x3,5
pri3	0,0128	12,76	25x3,5
comp1	0,0117	11,69	20x2,8
comp2	0,0099	9,94	20x2,8
comp3	0,0075	7,53	20x2,8
2	0,0123	12,32	20x2,8
office	0,0066	6,57	20x2,8
corr1	0,0112	11,22	20x2,8
corr2	0,0103	10,29	20x2,8
corr3	0,0087	8,73	20x2,8
bathroom	0,0071	7,12	20x2,8

For the district heating conduction (between the nodes 0' and 0), it is selected a special tube for this application, which has two pipes: one for the normal conduction and the other for the return. The pipes are made of PE-X and they are pre-isolated. It is chosen a RAUVITHERM DUO 32+32/150 of the company Rehau.

For the conduction system of the building is selected PP-R multiplayer pipe with fiber from Salvador Escoda S.A. This pipe of green colour has an intermediate layer of grey fiber with orange stripes in the surface. This pipe is specially selected for heating. Moreover, all the pipes have a flexible tubular insulator with M1 class and a thermal conductivity of 0,039 W(m.k).

The return conduction is seized using the unfavourable case for each path (Table 82).

Table 82. Return conduction for the school's building in the district heating.

Node	L (m)	Return conduction
0	8,00	DUO 32 + 32/150
cant1	5,00	32x4,4
cant2	2,30	
cant3	2,30	
hall	9,08	
ph1	5,75	20x2,8
ph2	7,88	25x3,5
ph3	2,30	
ph4	2,30	
lib1	3,00	
lib2	2,30	
lib3	2,30	
1	3,00	32x4,4
child1	5,30	25x3,5
child2	2,30	
child3	2,30	
pri1	6,08	
pri2	2,30	
pri3	2,30	
comp1	3,30	
comp2	2,30	
comp3	2,30	
2	3,00	20x2,8
office	1,66	
corr1	13,28	
corr2	2,30	
corr3	2,30	
bathroom	4,70	

2.7. Flow and pressure losses

2.7.1. 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 (Table 70).

Table 83. Flow in installations.

Installation	Flow (m^3/s)
Residential Block	0,00038
School's building	0,00093
Total	**0,00131**

2.7.2. Pressure losses due to conduction

The pressure losses due to conduction can be calculated using Darcy's equation:

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

The friction coefficient f considered for the installations are 0,01826 for the residential block and 0,018 for the school's building. Knowing all the longitudes, flows and diameters, the pressure losses can be calculated for each installation considering the critical path (Tables 84, 85 and 86).

Table 84. Pressure losses in the residential block.

Pipe	L (m)	D (m)	Q (m3/s)	hf (mca)
0 – 1.0	4,225	0,0232	0,00038	0,430
1.0 – 2.0	2,9	0,0232	0,000285	0,166
2.0 – 3.0	2,9	0,0232	0,00019	0,074
3.0 – 4.0	2,9	0,0232	0,000095	0,019
4.0 – 4.4	9	0,0144	0,000038	0,099
4.4 – 4.5	5,355	0,0144	0,000019	0,015
			TOTAL	0,80

Table 85.Pressure losses in the school's building expansion.

	Radiator	Flow (m^3/s)	L (m)	Diameter (m)	hf (mca)
Circuit 1	child1	0,000282	10,83	0,0254	0,381
	child2	0,000254	2,34	0,0254	0,067
	child3	0,000226	2,32	0,0254	0,052
	prim1	0,000198	4,08	0,0254	0,071
	prim2	0,00017	2,34	0,017	0,223
	prim3	0,000142	2,32	0,017	0,154
	comp1	0,000114	7,18	0,017	0,307
	comp2	0,000076	2,34	0,017	0,045
	comp3	0,000038	2,32	0,017	0,011
				TOTAL	1,31

Table 86. Pressure losses in the district heating.

Node	Flow (m^3/s)	L (m)	D (m)	hf (mca)
0	0,0009255	8	0,0262	2,594
1	0,000412	3	0,0232	0,354
child1	0,000282	5,3	0,0180	1,042
child2	0,000254	2,3	0,0180	0,367
child3	0,000226	2,3	0,0180	0,291
pri1	0,000198	6,08	0,0180	0,589
pri2	0,00017	2,3	0,0180	0,164
pri3	0,000142	2,3	0,0180	0,115
comp1	0,000114	3,3	0,0144	0,324
comp2	0,000076	2,3	0,0144	0,100
comp3	0,000038	2,3	0,0144	0,025
			TOTAL	5,96

2.7.3. Pressure losses due to radiators

The pressure losses of the radiators are calculated with the graph of the Figure 33 [7]. This graph connects the flow of the radiators with the losses so it is considered the worst case.

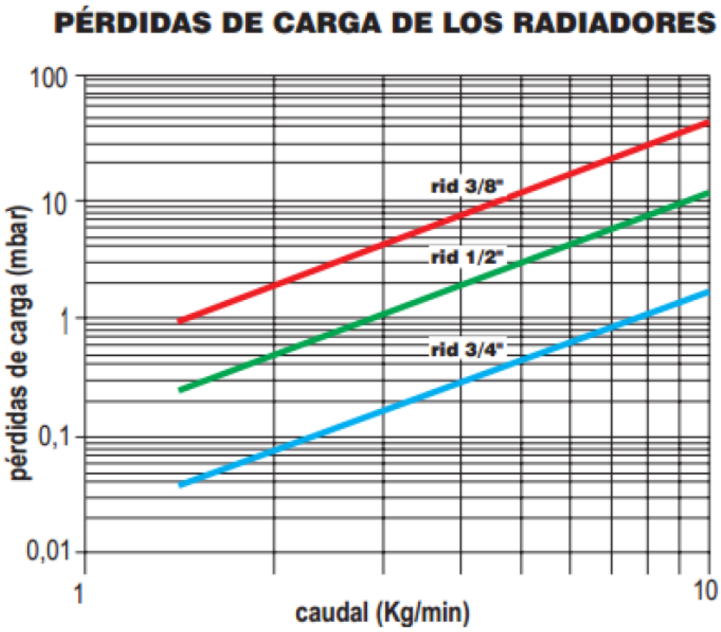


Figure 33. Pressure losses in radiators.

The pressure losses due to radiators are shown in the Table 87.

Table 87. Pressure losses due to radiators in the installations.

Installation		Pressure losses (mca)
Individual installations	Residential block	0,25
	School's building	0,77
District heating		1,02

2.7.4. Locating pressure losses

There are 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 a 15%:

Table 88. Locating pressure losses.

Installation		Locating pressure losses (mca)
Individual installations	Residential block	0,92
	School's building	1,51
District heating	Residential block	0,92
	School's building	6,86

2.7.5. Pressure losses due to the heat exchanger

The pressure losses due to the heat exchanger are given directly by the producer (Table 89). [27]

Table 89. Locating pressure losses.

Installation		Locating pressure losses (mca)
Individual installations	Residential block	1,45
	School's building	0,77
District heating		1,01

2.7.6. 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 90. Total pressure losses.

Installation		Locating pressure losses (mca)
Individual installations	Residential block	3,42
	School's building	4,36
District heating		16,58

2.8. Sizing of the fume extraction

In order to calculate the diameter of the chimney for the extraction of the fumes, it is going to use the UNE-EN 123001 and the UNE-EN 13384-1. It is used the software Dinakalc 4.3, created by the company Dinak, in order to calculate the inner and outer diameter of the chimneys.

It is designed the chimneys for the individual installations and the district heating installation. In order to do the calculation, it must be considered that the boiler is centralized, being pressurized. The altitude of Vistabella is 1.249 m, being the maximum and minimum temperatures those given by the Table 47. It is have an external mounting. The datasheets and the software gives the features of the boilers. In order to know the longitude of the conduction, it is followed the standards. In the case of the residential block, the chimney's exit will be 1 m above the roof. In the case of the school's building, the chimney's exit will be 1 m above the roof of the school although the boiler is placed in a separated small house.

The conductions of the study are the model DP (Figure 34), which is specifically design for similar applications.

Figure 34. Type of pipe for fume extraction.

2.8.1. Individual installation of the residential block

First, it is calculated the pipe diameter for the fume extraction system of the residential block. The pipe will be located in the same place as the previous one, used by the stoves. The horizontal longitude of the chimney will be 1 meter and the vertical longitude will be 15,25 m. The inputs are shown in the Figure 35.

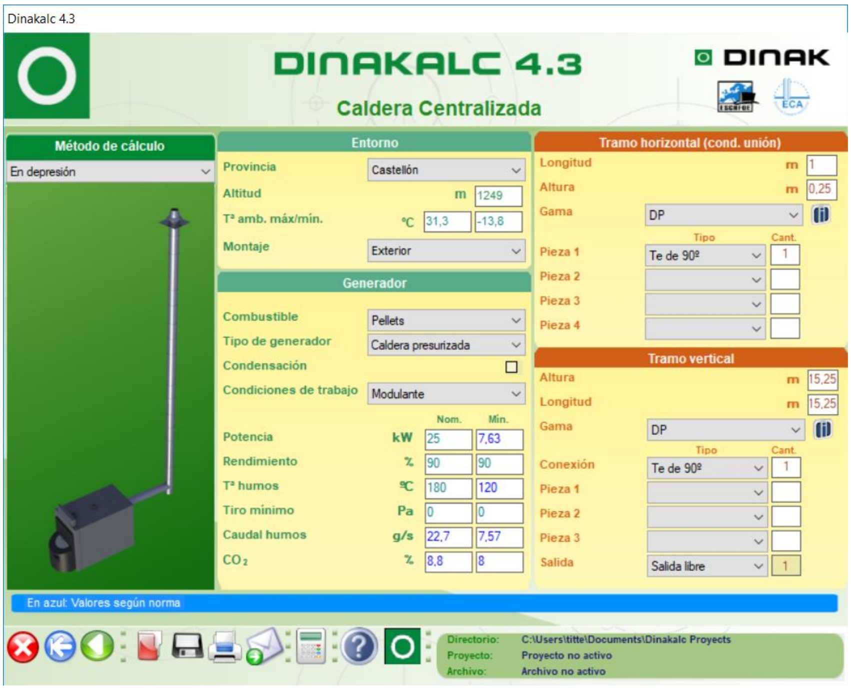


Figure 35. Inputs for fume extraction in the residential block.

The results show that it is required a pipe with an inner diameter of 125 mm for all the conduction (Figure 36).

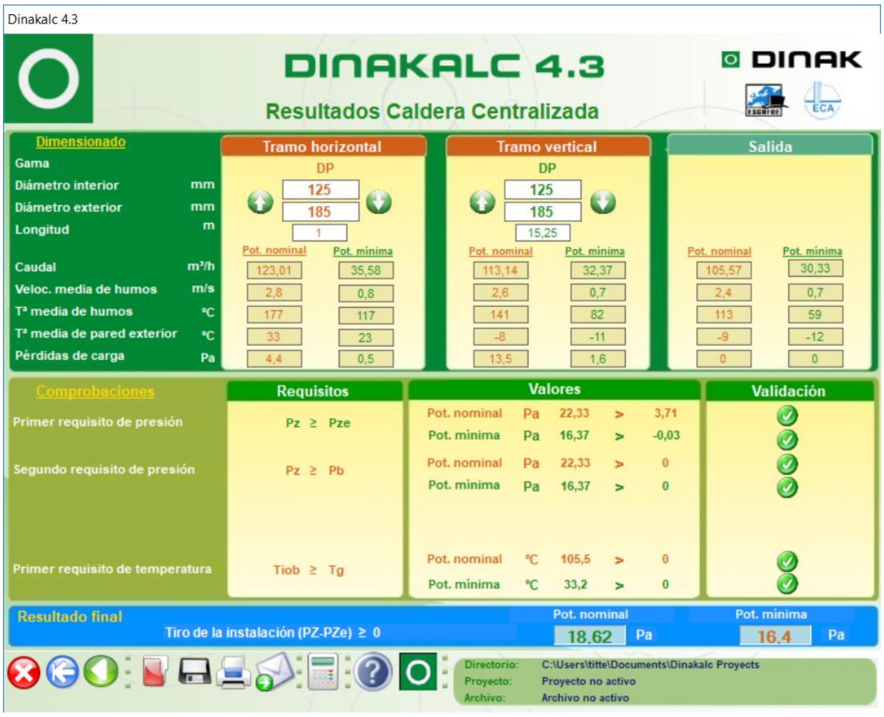


Figure 36.Pipe for the fume extraction in the residential block.

2.8.2. Individual insallation of the school's building

It is calculated the pipe diameter for the fume extraction system of the school's building. The pipe will be located in the same place as the previous one, used by the gasoil boiler. The horizontal longitude of the chimney will be 0,5 meter and the vertical longitude will be 7 m. The inputs are shown in the Figure 37.

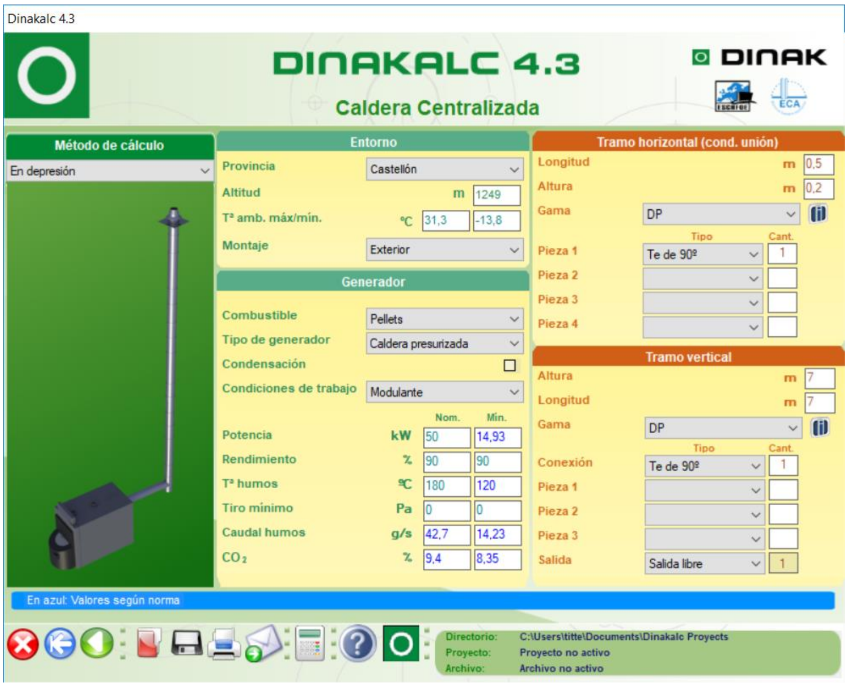


Figure 37. Inputs for the fume extraction for the school's building.

The results show that it is required a pipe with an inner diameter of 150 mm for all the conduction (Figure 38).

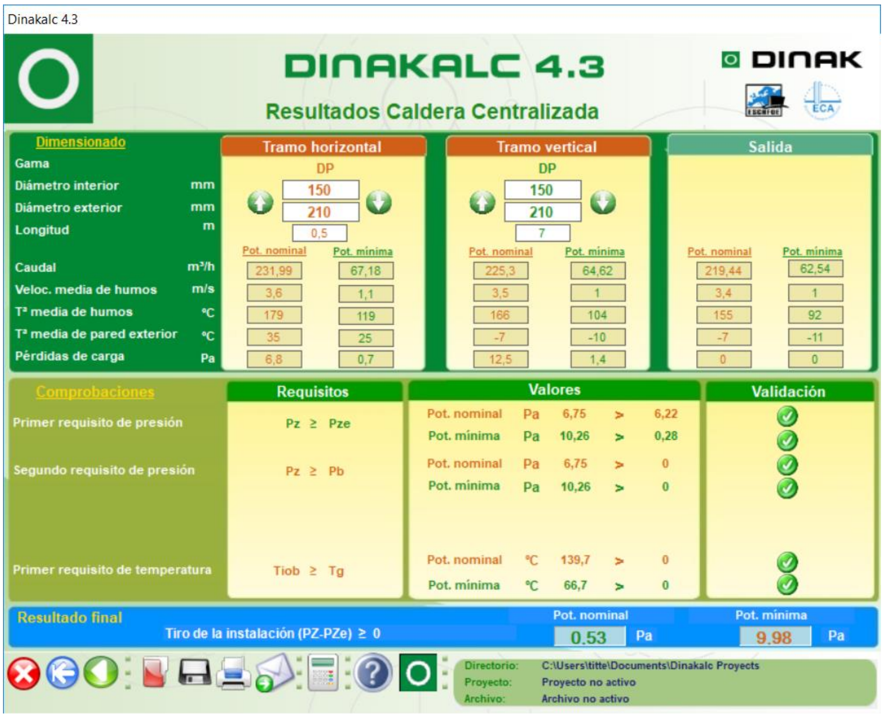


Figure 38. Fume extraction for the school's building.

2.8.3. District heating

For the district heating installation, the fume extraction system will be the same for both buildings, being located in the residential block. The pipe will be located in the same place as the previous one, used by the stoves. The horizontal longitude of the chimney will be 1 meter and the vertical longitude will be 15,25 m. The inputs are shown in the Figure 39.

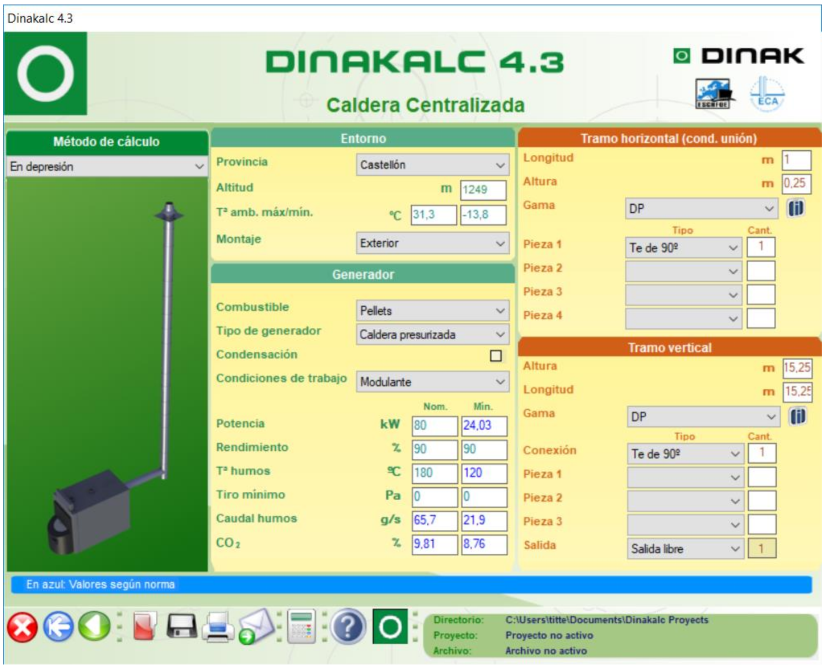


Figure 39. Inputs for the fume extraction of the district heating.

The results show that it is required a pipe with an inner diameter of 175 mm for all the conduction (Figure 40).

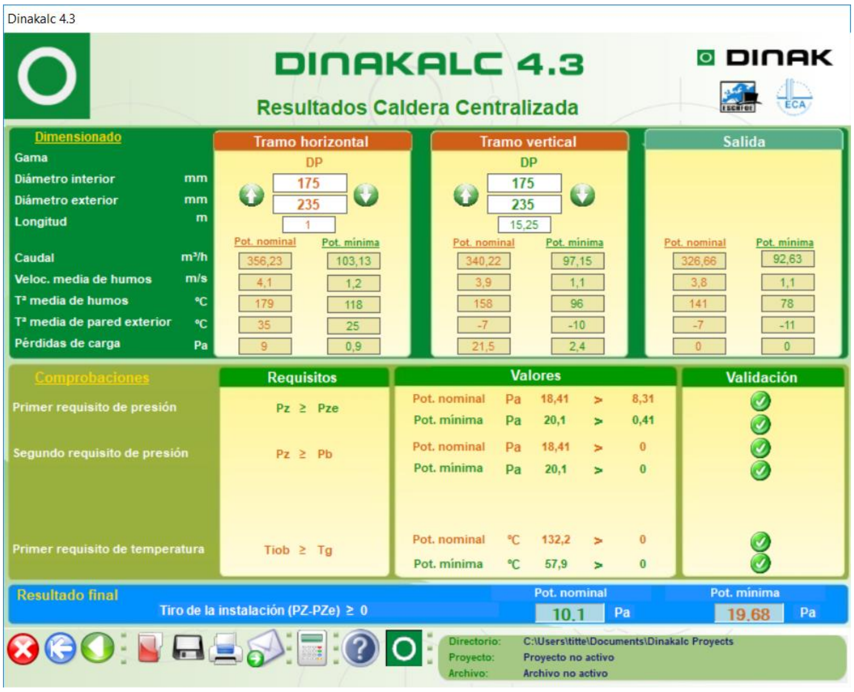


Figure 40. Fume extraction for the district heating.

2.9. Datasheets

2.9.1. Biomass boilers for the individual heating system

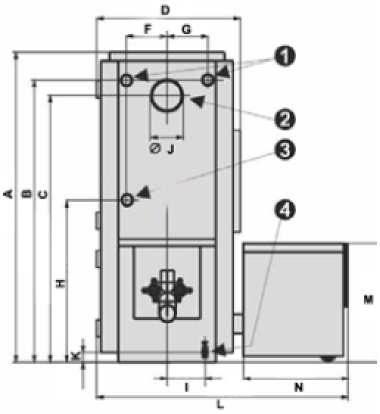
I BIOCALORA **SERIE 2000**

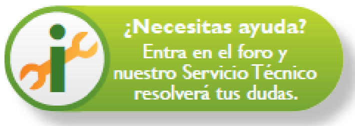
Datos técnicos		Pellet 25	Pellet 50	Pellet 100	Pellet 200	Pellet 300
Potencia máxima	kW	25	50	100	200	300
Volumen aire calefactable	m³	200-350	600-900	1200-1800	2200-2800	3300-4800
Tipo combustible		Pellet DIN Ø 6 mm ÷ l = 5 - 30 mm				
Eficiencia	%	90	90,1	95,8	95,1	92,5
Conexión impulsión	"	1"1/2	2	2	2	2
Conexión retorno	"	1"1/2	2	2	2	2
Acceso contenedor ceniza	mm	235x225	235x225	350x300	415x400	415x400
Ø conexión salida humos	mm	132	150	200	250	300
Altura caldera	mm	1180	1170	1390	1680	1700
Anchura caldera	mm	400	480	720	840	1085
Profundidad caldera	mm	500	640	870	1240	1680
Volumen agua	litros	40	68	156	411	650
Peso	kg	142	242	463	837	1500
Presión máxima de trabajo	bar	2	2	2	2	2
Temperatura máxima de trabajo	°C	90	90	90	90	90
Presión prueba	bar	4	4	4	4	4
Tiro mínimo chimenea	Pa	20	20	20	20	20
Dimensiones cámara combustión	mm	600x235x330	520x355x455	730x560x700	820x640x1000	800x890x1400
Voltaje		230V-50 HZ				
Intercambiadores	nº	4	5	5	5	5
Eficiencia	%	89,2	90,1	95,8	95,1	92,5
Emisiones partículas	mg/m³	5,19	10,4	24,9	27,0	21,4
Emisiones CO	mg/m³	219,8	481	404,4	469,3	229,6
Emisiones NOx	mg/m³	139,2	114,7	128,5	122,9	127,2

* Potencias nominales calculadas en base a uso de pellet.

2.9.2. Biomass boiler for the district heating

Dimensiones		KP 12.1	KP12	KP 22	KP 52.1	KP 52	KP 62	KP 82
A	mm	1440	1440	1440	1595	1595	1744	1744
B	mm	1310	1310	1310	1460	1460	1610	1460
C	mm	1240	1240	1240	1396	1396	1545	1396
D	mm	539	483	618	816	816	760	816
F	mm	121	121	190	255	255	255	255
G	mm	121	121	190	255	255	255	255
H	mm	750	750	750	907	907	907	907
I	mm	-	-	-	255	255	255	255
K	mm	46	46	46	46	46	46	46
L	mm	815	815	950	1106	1106	1185	1106
M	mm	512	512	512	612	612	612	612
N	mm	283	283	283	383	383	383	383
1	mm	G 1 1/2"						
J - 2	mm	130 Ø	130 Ø	150 Ø	160 Ø	160 Ø	160 Ø	160 Ø
3	mm	G 1 1/2"						
4	mm	G 1/2"		-	G 1/2"			
5	mm	-	-	Semiautomatico	-	-	-	-



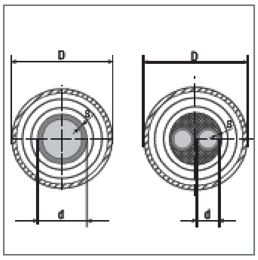


Datos técnicos		KP 12.1	KP12	KP 22	KP 52.1	KP 52	KP 62	KP 82
Potencia nominal	kW	14,9	19	28,5	44,9	49,2	61	80
Rango de potencia	kW	4,5-14,9	5,7-19	8,55-28,5	13,5-44,9	14,7-49,2	18,3-61	24-80
Consumo de combustible (pellets)	kg/h	0,98-3,35	1,14-4,55	1,9-6,6	3,1-10,3	3,44-10,91	4,39-13,1	5,58-18,18
Eficiencia a máx. potencia	%	90,8	90,5	90,9	91,2	91,2	91,2	90,1
Eficiencia a mín. potencia	%	90,6	88,9	88,5	89,7	89,8	89,6	89,7
Temperatura gases de combustión	°C	126	127	134	140,6	141	140	147
Tiro natural necesario chimenea	mbar	0,1-0,2	0,1-0,2	0,1-0,2	0,1-0,3	0,1-0,3	0,3-0,4	0,3-0,4
Temperatura de impulsión	°C	55-80						
Peso	kg	255	310	370	520	520	590	700
Consumo eléctrico	W	173	173	210	210	210	340	400
Voltaje de conexión	230V AC±10% / 50 Hz±2Hz							
Emisiones partículas	mg/m³	28	27	32	34	34	31	14
CO	mg/m³	68	49	167	9	9	137	180
NOx	mg/m³	162	166	171	188	188	173	190

2.9.3. District heating pipe

1 RAUVITHERM CALEFACCIÓN, SDR 11

RAUVITHERM para la calefacción a distancia, SDR11
(Cubierta exterior en negro).
Apto para hasta máx. 95° C (temperatura flotante) y 6 bar, compuesto por:
- Tubo interior en polietileno reticulado (PE-Xa) según DIN 16892/93 con capa barrera contra la difusión del oxígeno (EVOH) según DIN 4726.
- El aislamiento de los tubos RAUVITHERM de SDR11 se compone de capas de espuma de PE reticulado y, en el caso de los tubos DUO, adicionalmente de una pieza espumada en el centro.
- Cubierta exterior de polietileno (PE-HD) negro corrugado, sobreextrusionada sin costuras.
- Se suministra en rollos.



RAUVITHERM UNO

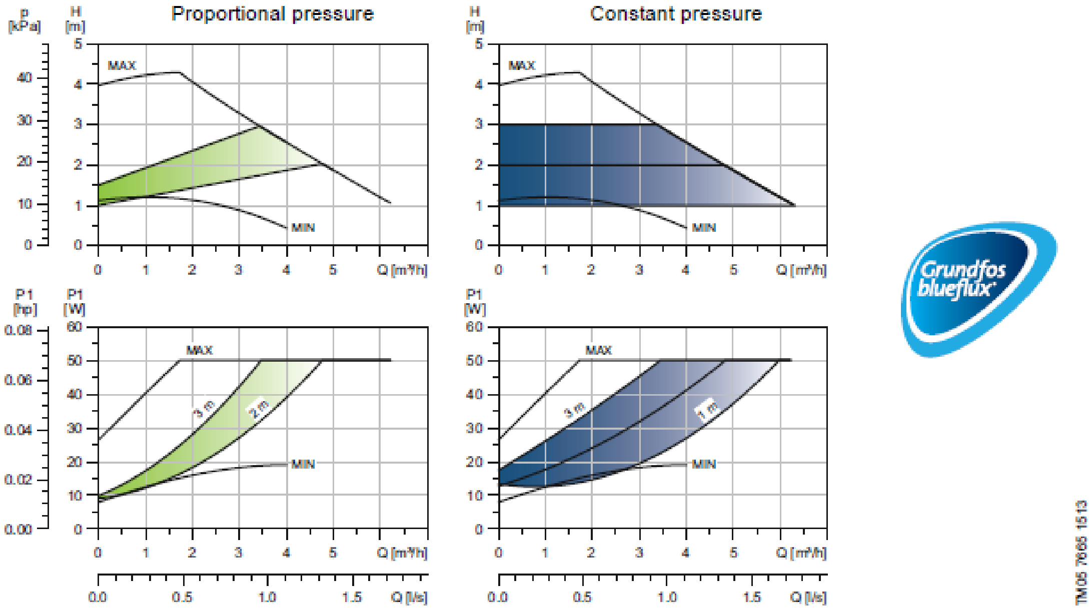
Artículo	Tipo	d	s	D	aprox. [kg/m]	Longitud máxima de bobina [m]
1 132053 1 001	25/120	25	2,3	113	0,98	290
1 132063 1 001	32/120	32	2,9	114	1,07	290
1 132073 1 001	40/120	40	3,7	116	1,22	290
1 132083 1 001	50/150	50	4,6	144	1,75	230
1 132093 1 001	63/150	63	5,8	145	2,08	230
1 132103 1 001	75/175	75	6,8	170	2,99	130
1 132113 1 001	90/175	90	8,2	175	3,64	130
1 132123 1 001	110/190*	110	10,0	187	4,60	100
1 132133 1 001	125/210*	125	11,4	209	6,10	80

RAUVITHERM DUO

Artículo	Tipo	d	s	D	aprox. [kg/m]	Longitud máxima de bobina [m]
1 132003 1 001	25 + 25/150	25	2,3	144	1,66	230
1 132013 1 001	32 + 32/150	32	2,9	146	1,87	230
1 132023 1 001	40 + 40/150	40	3,7	148	2,24	175
1 132033 1 001	50 + 50/175	50	4,6	177	3,31	130
1 132043 1 001	63 + 63/210	63	5,8	208	4,77	90

2.9.4. Pumping system

MAGNA3 25-40 (N) **1 x 230 V, 50/60 Hz**

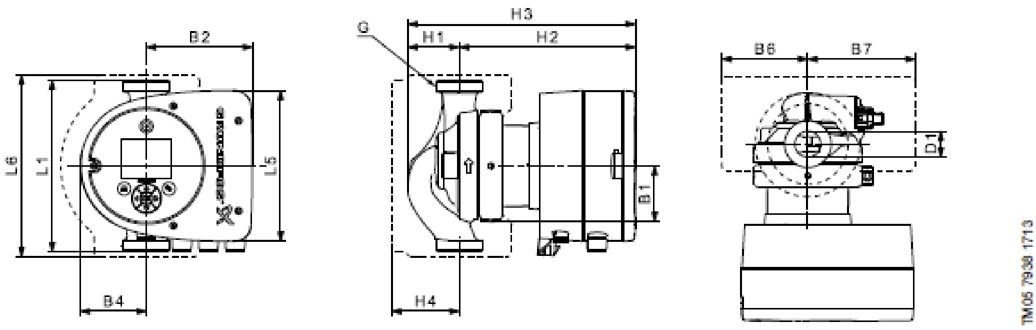


Speed	P1 [W]	$I_{1/1}$ [A]
Min.	9	0.09
Max.	56	0.46

The pump incorporates overload protection.

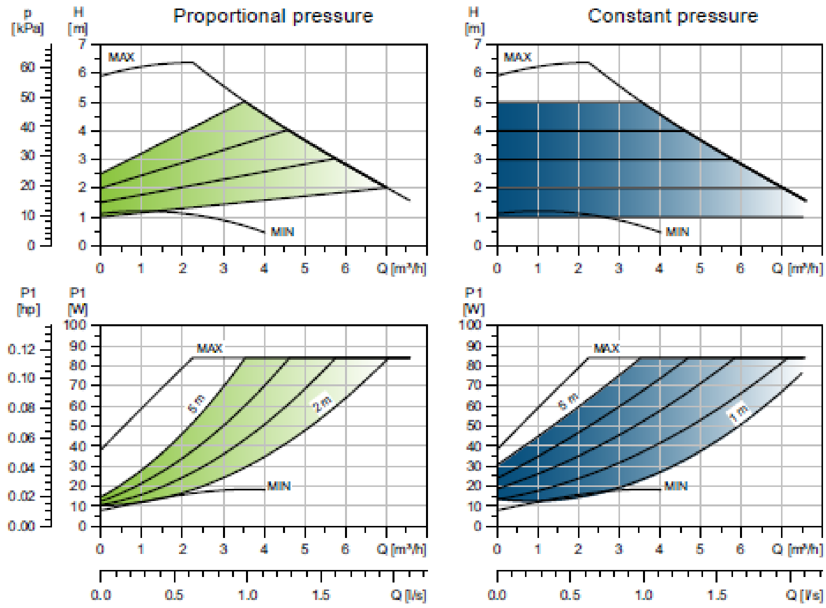
Net weights [kg]	Gross weights [kg]	Ship. vol. [m³]
4.8	5.3	0.01

Connections:	See *Pipe connections*, page 134.
System pressure:	Max. 1.0 MPa (10 bar). Also available as max. 1.6 MPa (16 bar).
Liquid temperature:	-10 to 110 °C (TF 110).
Also available with:	Stainless-steel pump housing, type N.
Specific EEI:	0.19.



Pump type	Dimensions [mm]													[inch]
	L1	L5	L6	B1	B2	B4	B6	B7	H1	H2	H3	H4	D1	G
MAGNA3 25-40 (N)	180	158	190	58	111	69	90	113	54	185	239	71	25	1 1/2

MAGNA3 25-60 (N) 1 x 230 V, 50/60 Hz

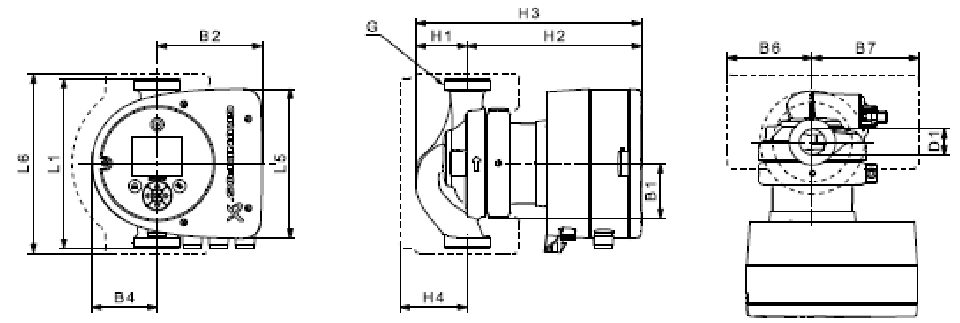


Speed	P1 [W]	$I_{1/1}$ [A]
Min.	9	0.09
Max.	91	0.75

The pump incorporates overload protection.

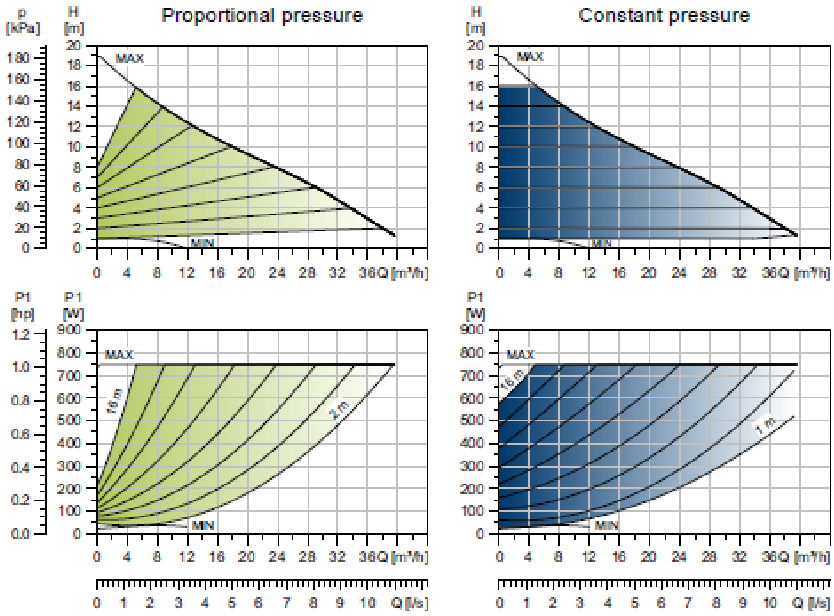
Net weights [kg]	Gross weights [kg]	Ship. vol. [m³]
4.8	5.3	0.01

Connections:	See *Pipe connections*, page 134.
System pressure:	Max. 1.0 MPa (10 bar). Also available as max. 1.6 MPa (16 bar).
Liquid temperature:	-10 to 110 °C (TF 110).
Also available with:	Stainless-steel pump housing, type N.
Specific EEI:	0.19.



Pump type	Dimensions [mm]												[inch]
	L1	L5	L6	B1	B2	B4	B6	B7	H1	H2	H3	H4	D1	G
MAGNA3 25-60 (N)	180	158	190	58	111	69	90	113	54	185	239	71	25	1 1/2

MAGNA3 50-180 F (N) **1 x 230 V, 50/60 Hz**

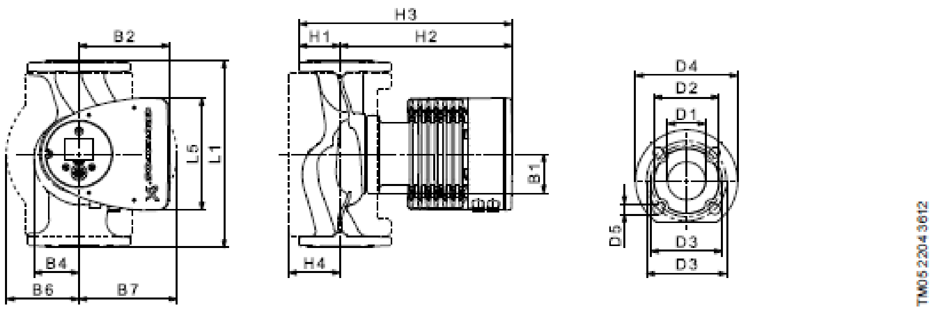


Speed	P1 [W]	$I_{1/1}$ [A]
Min.	23	0.24
Max.	762	3.35

The pump incorporates overload protection.

Net weights [kg]	Gross weights [kg]	Ship. vol. [m³]
18.3	21.9	0.05

Connections:	See *Pipe connections*, page 134.
System pressure:	Max. 1.0 MPa (10 bar). Also available as max. 1.6 MPa (16 bar).
Liquid temperature:	-10 to 110 °C (TF 110).
Also available with:	Stainless-steel pump housing, type N.
Specific EEI:	0.17.



Pump type	Dimensions [mm]														
	L1	L5	B1	B2	B4	B6	B7	H1	H2	H3	H4	D1	D2	D3	D4	D5
MAGNA3 50-180 F (N)	280	204	84	164	73	127	127	72	304	376	97	50	102	110/125	165	14/19

2.9.5. Wood Chipper

TIMBERWOLF TW 230DH(a) (ADJUSTABLE TOWHEAD) SPECIFICATION

Engine type:	*Kubota 4-cylinder diesel*	**Maximum diameter material:**	*160mm (6 ⅓ ")*
Maximum power:	*26kW (35hp)*	**Fuel capacity:**	*18 litres*
Cooling method:	*Water cooled*	**Hydraulic oil capacity:**	*15 litres*
Overall weight:	*749kg*	**Material processing capacity:**	*up to 5 tonnes/hr*
Starting method:	*Electric*	**Fuel type:**	*Diesel*
Roller feed:	*Twin hydraulic motors*		

2.9.6. Pellet plant

PLT400 / PLT 800 / PLT1000:

Las peletizadoras industriales Smartec son el corazón de la planta de peletizado. Se trata de equipos robustos diseñados con los mejores materiales de ORIGEN EUROPEO para garantizar un funcionamiento y una durabilidad prolongada.
El residuo es empujado A TRAVÉS DE LOS RODILLOS HACIA LA MATRIZ, donde gracias a sus aberturas cilíndricas, se comprime y produce el pélet.

DESCRIPCIÓN TÉCNICA

	PLT400	PLT800	PLT1000
Accionamiento	Motor trifásico 22kW	Motor trifásico 37kW	Motor trifásico 45kW
Producción horaria	150-400 kg/h	200/500 kg/h	400-700 kg/h
Consumo de energía	16kW	32kW	40kW
Peso aprox.	600 kg	650 kg	950 kg
Dimensiones mm. (Al x An x Prof)	1300 x 1530 x 700	1550 x 1600 x 900	1550 x 1750 x 900
Seguridad sobrecalentamiento	No necesario	Sistema de enfriamiento con aceite	
Diámetro pélet	6 mm. (otras medidas posibles con matrices sustituibles)		
Composición de los principales componentes	Matriz: Acero Inoxidable templado AISI 420		
	Rodillos: 39 NCD3 templado		
	Eje central: 39 NCD3 galvanizado		
	Cuerpo de peletización		

PELETIZADORA PLT400

ASPIRADOR ASP400-1500

Este aspirador sirve para ELIMINAR EL POLVO GENERADO en los equipos domésticos o en una moderada producción tanto de la PLT400 como de la PLT800. Especialmente indicado PARA COMPLEMENTAR LA PLANTA MÍNIMA.

DESCRIPCIÓN TÉCNICA	
POTENCIA	Motor trifásico 2'2 kW
CAUDAL AIRE	3900 m/h
PRESIÓN	305 mmca.
DIAMETRO TUBO ASPIRACIÓN	100 mm. (x3)
DIMENSIONES	1170x560x570 (mm.)
PESO	90 kg.

CARGADOR CRT100

CARGADOR MEDIANTE SINFÍN, indispensable para el funcionamiento autónomo de la serie PLT. Dispone de un motor inverter para la regulación de la carga del material, removedor antivóbedas y sistema vibratorio.

DESCRIPCIÓN TÉCNICA	
Alimentación	Eléctrica monofásica
Potencia	0'18 kW + 0'22 kW
Producción horaria	200-400 kg/h
Volumen de carga	0'8 m3

REFINADOR RC400

El refinador RC400 es un molino de MENOR PRODUCCION y COMPACTO. Su posición sobre el cargador CRT100 facilita la alimentación y posibilita una reducción de espacio. Forma parte, junto con la peletizadora PLT400, de la Planta Media.

DESCRIPCIÓN TÉCNICA	
Alimentación	Eléctrica trifásica
Potencia	11 kW
Producción horaria	300-400 kg/h.

2.10. 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.

3. Plans

Plans

P.1. Hydraulic installation of an apartment.

P.2. Hydraulic installation of the school's building (individual case).

P.3. Hydraulic installation of the school's building (district heating).

4. Specifications document

Specifications document

4.1. Technical conditions

4.1.1. Biomass boilers

The biomass boilers produce heat from the direct combustion of pellet. Depending on the installation, it is have a boiler of 25 kW, 50 kW or 80 kW.

Installation conditions

- The placement of the installation (the ground floor for the residential block and the small warehouse for the school's building) must be conditioning for the installation of the biomass boiler and the auxiliary equipment.
- The biomass boiler must include anti-vibration feet.
- It must be verified that the situation of the biomass boiler corresponds with the situation of the Project.
- The contractor must coordinate the installation of the boiler with other installations that can affect.

Installation process

- Setting-out on site. Presentation of the elements. Installation of the boiler and accessories. Connection with hydraulic and electric system. Connection with fume extraction system. Start-up.
- The boiler must be fixed to a bench with enough space for cleaning and maintenance operations.

Operation and maintenance

- All the elements must be protected against bumps, aggressive materials, humidity or dirt.

4.1.2. Buffer tank

Deposit that is used for the accumulation of heat water. It improves the efficiency of heating systems.

Installation conditions

- The placement of the installation (the ground floor for the residential block and the small warehouse for the school's building) must be conditioning for the installation of the buffer tank and the auxiliary equipment.
- It must be verified that the situation of the buffer tank corresponds with the situation of the Project.
- The contractor must coordinate the installation of the buffer tank with other installations that can affect.

Operation and maintenance

- The buffer tank must be protected against bumps, aggressive materials, humidity or dirt.

Material specifications

- It must be used mild steel with inner lining or stainless steel.

4.1.3. Storage system

Textile silo in the case of the residential block and district heating and polyester silo in the case of the school's building.

Installation conditions

- The placement of the installation (the ground floor for the residential block and district heating and the playground for the school's building) must be conditioning for the installation of the silos and the auxiliary equipment.
- The polyester silo that is placed in the playground of the school must be enclosed with fences in order to not allow the pass to kids or anyone who is not authorized. The fences must allow the maintenance of the silo and its load.

Installation process

- Setting-out on site. Collocation of the silo. Connection to the extraction system.

Material specifications

- It is used polyester for the silo that is in the playground and textile for the silo that is in the ground floor of the building.

4.1.4. Hydraulic installation

The hydraulic installation of the heating system is formed by the pipes, the expansion vessels, the pumping systems and small elements.

Applicable regulation

- Installation: CTE DB-HS Salubridad

Installation conditions

- It must be verified that the situation and conduction correspond to those of Project, and that there is sufficient space for their installation.
- The district heating installation must be placed buried in the playground of the school.

- The pipe conduction must have mechanical resistance. All the installation must be watertight.

Operation and maintenance

- All the elements of the installation must be protected against bumps and splashes.

Testing service

Tests of mechanical resistance and watertight. Regulation:

- CTE DB-HS Salubridad.
- UNE-ENV 12108. In the case of the residential building and district heating.

4.1.5. Fume extraction

Set of elements for the extraction of the fumes that are generated in the biomass boiler.

Installation conditions

- It must be verified that the situation and conduction correspond to those of Project, and that there is sufficient space for their installation.

Installation process

- Setting-out on conduction path. Marking and anchoring of the conduction supports. Installation and fixation of the conduction. Connexion between the conduction and the biomass boiler. Testing the service.
- The conduction and the mouthpieces must be watertight.

Operation and maintenance

- The fume extraction must not host other installations.

Testing service

Tests of mechanical resistance and watertight. Regulation:

- UNE-EN 1507.

4.1.6. Pellet plant

The pellet plant is the part of the project that produces the pellet from the forestry waste collected.

Materials that can be used in the pellet plant

- Wood chip < 4 mm

- Humidity: 12 – 15%
- If the pellet is produced from different woods, it must be mixed before the materials in order to have an homogeneous feedstock.

Previous conditions to the installation of the pellet plant

- Total surface of ground and warehouse: 30 m^2 just ground and a minimum of 400 m^2 of warehouse for feedstock, production and plant.
- Supply of water: it is required a water intake of ½".
- Supply of air: it is required an air compressor with a flow of 1.000 l in order to use the lubricant devices PMP800 and the machine refrigeration.
- Supply of electricity: it is required 36 kW or a electric generator of 50KVA (PLT400), 50 Hz and 380-400 V.
- Required loads and foundation details: Base floor with polished concrete. It is not required to have a special zone for overload.

Installation process information

For the installation of the pellet plant, it is required:

- 1-3 qualified workers. It is recommended that these worker would be the same that the worker who produce the pellet.
- Stepladder of 3 meters.
- Forklift truck.
- Slings or supporting chains.

5. Budget

Budget

5.1. Individual installations budget

Table 91. Individual installations budget.

Denomination	Units	Cost (€)	Total cost (€)
School's installation			
Biocalora Serie 2000 Basic B-Essential 50 kW	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 a inner diameter of 17 mm	11,35	10,35 €	117,47 €
Pipe of rigid copper with a inner diameter of 25,4 mm	42,41	19,46 €	825,30 €
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 15 elements	1	279,48 €	279,48 €
Radiator of cast iron with 20 elements	3	358,35 €	1.075,05 €
Pump PC 1025	2	366,04 €	732,08 €
Pump Grundfos Magna3 25-40	1	568,00 €	568,00 €
Antivibration feets	1	41,20 €	41,20 €
Transport of the boiler	1	350,00 €	350,00 €
Installation and activation	1	6.000,00 €	6.000,00 €
Basic maintenance	1	182,00 €	182,00 €
Chimney of 210 mm	1	557,15 €	557,15 €
Fence and civil work	10	59,33 €	593,30 €
Residential block			
Biocalora Serie 2000 Basic B-Home 25 kW	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 €
PP-R multiplayer pipe of 20 mm	202	6,14 €	1.240,28 €
PP-R multiplayer pipe of 32 mm	25,85	16,40 €	423,94 €
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	24	173,90 €	4.173,60 €
Pump PC 1025	2	366,04 €	732,08 €
Pump Grundfos Magna3 25-60	1	675,00 €	675,00 €
Antivibration feets	1	41,20 €	41,20 €
Transport of the boiler	1	350,00 €	350,00 €
Installation and activation	1	6.000,00 €	6.000,00 €
Basic maintenance	1	182,00 €	182,00 €
Chimney of 185 mm	1	490,82 €	490,82 €
Civil work and conditioning	1	1.200,00 €	1.200,00 €
		TOTAL SCHOOL'S INSTALLATION	20.020,22 €
		TOTAL RESIDENTIAL BLOCK	22.984,66 €
		TOTAL INDIVIDUAL INSTALLATION	**43.004,88 €**
		MATERIAL EXECUTION BUDGET	43.004,88 €
		13% OF GENERAL EXPENSES	5.590,63 €
		6% OF INDUSTRIAL BENEFITS	2.580,29 €
		SUBTOTAL	51.175,81 €
		21% VAT	10.746,92 €
		TOTAL BUDGET	**61.922,73 €**

5.2. District heating budget

Denomination	Units	Cost (€)	Total cost (€)
District heating			
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 €
PP-R multiplayer pipe of 20 mm	280,18	6,14 €	1.720,31 €
PP-R multiplayer pipe of 25 mm	77,02	14,42 €	1.110,63 €
PP-R multiplayer pipe of 32 mm	60,13	16,40 €	986,13 €
DUO 32 + 32/150 - District heating pipe	8	57,86 €	462,88 €
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 10 elements	24	173,90 €	4.173,60 €
Radiator of cast iron with 15 elements	1	279,48 €	279,48 €
Radiator of cast iron with 20 elements	3	358,35 €	1.075,05 €
Pump PC 1025	2	366,04 €	732,08 €
Pump Grundfos Magna3 50-180	1	2.680,00 €	2.680,00 €
Antivibration feets	1	41,20 €	41,20 €
Transport of the boiler	1	400,00 €	400,00 €
Installation and activation	1	7.500,00 €	7.500,00 €
Basic maintenance	1	182,00 €	182,00 €
Chimney of 235 mm	1	623,47 €	623,47 €
Cutting of the pavement	20	1,18 €	23,60 €
Mechanical excavation	8	28,42 €	227,36 €
Sand for pipe protection	8	24,33 €	194,64 €
Replacement of the pavement	8	67,06 €	536,48 €
Civil work and conditioning	1	1.200,00 €	1.200,00 €
		TOTAL DISTRICT HEATING	**43.363,05 €**
		MATERIAL EXECUTION BUDGET	43.363,05 €
		13% OF GENERAL EXPENSES	5.637,20 €
		6% OF INDUSTRIAL BENEFITS	2.601,78 €
		SUBTOTAL	51.602,02 €
		21% VAT	10.836,43 €
		TOTAL BUDGET	**62.438,45 €**

5.3. Pellet plant budget

Denomination	Units	Cost (€)	Total cost (€)
Pellet plant			
Pellet plant PLT400. Includes pellet machine, loader CRT100, hammer mill RC400, vacuum ASP355 PLUS, transport and installation.	1	28.805,00 €	28.805,00 €
Screw conveyor	1	792,00 €	792,00 €
Conveyor belt	1	2.200,00 €	2.200,00 €
Textile silo of Biocalora	1	2.123,00 €	2.123,00 €
		TOTAL PELLET PLANT	**33.920,00 €**
		MATERIAL EXECUTION BUDGET	33.920,00 €
		13% OF GENERAL EXPENSES	4.409,60 €
		6% OF INDUSTRIAL BENEFITS	2.035,20 €
		SUBTOTAL	40.364,80 €
		21% VAT	8.476,61 €
		TOTAL BUDGET	**48.841,41 €**