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UNLOCKING THE COMMUNITY BIOENERGY POTENTIAL

D4.2. Deployment of the BECoop technical support services

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About

Over the last years, the EU has witnessed some remarkable steps in Renewable Energy (RE) deployment. However, at the same time, we see an increasingly uneven penetration of RE across the different energy sectors, with the heating and cooling sector lagging behind. Community bioenergy schemes can play a catalytic role in the market uptake of bioenergy heating technologies and can strongly support the increase of renewables penetration in the heating and cooling sector, contributing to the EU target for increasing renewable heat within this next decade. However, compared to other RES, bioenergy has a remarkably slower development pace in the decentralised energy production which is a model that is set to play a crucial role in the future of the energy transition in the EU.

The ambition of the EU-funded BECoop project is **to provide the necessary conditions and technical as well as business support tools for unlocking the underlying market potential of community bioenergy.** The project's goal is to make community bioenergy projects more appealing to potential interested actors and to foster new links and partnerships among the international bioenergy community.

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 952930.

Project partners

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Abbreviations

AVG	Vitoria/Gasteiz city council
CAPEX	Capital expenditures
CHP	Combined heat and power
DH	District heating
DHCA	District Heating Company of Amindeo
DHW	Domestic hot water
ESCO	Energy services companies
HHV	Higher heating value
IMF	International Monetary Fund
IRR	Internal Rate of Return
LHV	Lower heating value
OPEX	Operational expenditure
ORC	Organic Rankine Cycle
PBP	Payback Period
PV	Present Value
ROI	Return of Investment
WFOSiGW	Voivodship Fund for Environmental Protection and Water Management
WS	Workshop

Executive Summary

The BECoop project seeks to tap into the potential of bioenergy communities. In order to achieve this goal, different actions are being developed along the project. Task 4.2 provides guidance to the pilot bioenergy cooperatives regarding potential technical considerations towards achieving their bioenergy heating vision. This means that the project partners help RESCoops in developing a technical action plan, as well as guide them through the entire process in order to provide the necessary technical support for the implementation of their bioenergy heating visions. The task leader CERTH, together with the project's developed bioenergy RESCoops, identified the key technical services that they had to include for realising their technical action plans, based on the analysis of their needs, challenges and vision while using the tools developed throughout BECoop project such as the self-assessment tool (T2.1), the BECoop Toolkit (T2.2), the e-market environment (T2.3) and the technical catalogues (T2.4). Then, the technical partners (CERTH, CIRCE, WUELS) provided the necessary technical support for the implementation of the defined bioenergy heating visions.

A set of services has been provided to the project's BECoop RESCoops, as they were defined in T3.1 "Community building and stakeholder mobilisation" and as such, they are described herein:

(i) assistance in the selection of suitable heating equipment/technology (T2.4);
(ii) recommendations regarding the implementation of a reliable supply chain;
(iii) hands-on technical consultancy including the entire spectrum of bioenergy heating technical aspects (e.g. type of resources to be used, quality, quantity, selection of sites for potential plants, cost-benefit analysis studies, assessments of feedstock quality, etc.);
(iv) a full feasibility analysis for each case (using business and financial input from the T4.3 activities).

A core aim of this task was also the identification of relevant local actors interested in cooperation and in forming alliance with the pilot-level BECoop RESCoops in order to empower such community bioenergy projects and initiatives. Furthermore, in the current task, relevant tools developed within the project were used throughout the process. Concluding, the task leader has integrated the outcomes from the activities mentioned in the present Deliverable.

1 Introduction

Energy communities are groups of people, businesses, or organizations that collaborate to develop, operate, and benefit from local renewable energy projects. These communities aim to increase energy efficiency, reduce greenhouse gas emissions, and promote energy independence and security. The concept of energy communities has gained popularity in recent years, especially in Europe, where community-owned renewable energy projects are becoming increasingly common.

Bioenergy is a renewable energy source that is derived from biomass, such as organic waste, agricultural crops, and forestry residues. Bioenergy can be used to produce electricity, heat, and transportation fuels, making it a versatile source of renewable energy that can be used in energy communities.

In energy communities, bioenergy development can take various forms, such as small-scale biogas or biofuel production facilities, community-owned pellet plants that use locally sourced biomass for their operations, or co-generation systems that produce both heat and electricity from biomass.

Advantages of bioenergy in energy communities include:

- **Local economic development:** Bioenergy production can provide opportunities for local economic development, job creation, and income generation.
- **Social benefits for local residents**: The use of local biomass resources led to limitation of energy poverty in the region, increase of social integration and engagement among local stakeholders as well as increase of product responsibility.
- **Energy independence:** Energy communities can reduce their dependence on fossil fuels by using locally available biomass resources.
- **Reduced greenhouse gas emissions:** Bioenergy can help reduce greenhouse gas emissions by replacing fossil fuels in energy production.
- **Waste management:** Bioenergy can be produced from organic waste materials, such as food waste or agricultural residues, helping to reduce landfill waste and associated environmental problems.

However, there are also disadvantages of bioenergy in energy communities such as:

- **Land use conflicts:** Bioenergy production can compete with other land uses, such as food production or nature conservation.
- **Technical challenges:** Bioenergy production technologies can be complex and require specialized knowledge and skills for successful implementation and operation.
- **Cost:** Bioenergy production can be expensive, especially for small-scale projects, and may require significant upfront investment.

Overall, bioenergy development can play an important role in energy communities, but its advantages and disadvantages need to be carefully evaluated to ensure that its benefits outweigh its potential negative impacts.

Aim of the current deliverable is to outweigh the technical challenge and cost/effort needed by an energy community to implement bioenergy projects. This was achieved by providing technical assistance to the four pilots of BECoop project in order for them to be developed in accordance with the roadmaps created in D4.1. The four pilots are different in terms of maturity level as some had already been created before the start of BECoop project while others started “from scratch” during the project. Notwithstanding, deployment of technical support services was crucial in the development of RESCoops regardless of their level of maturity.

In terms of D4.2 structure, posterior to the description of methodology (Chapter 2), the deployment of technical support services is provided for each pilot.

- Therefore, **sections 3, 4, 5 and 6 are dedicated to Spanish, Polish, Italian, and Greek pilots** respectively. The same structure is followed in each section with the following subsections:
    - The first subsection provides a brief **overview of the pilot BECoop RESCoop** and its bioenergy vision.
    - Then, the second subsection develops **the technical support services** regarding the biomass type and quantities to be used by the BECoop RESCoop.
    - Third subsection elaborates on the **logistics of BECoop RESCoop** based on the value chain description and cost of biomass collection.
    - Subsection 4 provides information on the potential **location** of each BECoop RESCoop.
    - Subsection 5 provides brief information of technical support services regarding the **technology and activity** that will be implemented by each BECoop RESCoop (e.g. technology to be used, capacities of the e.g. pellet plant etc.).
    - Subsection 6 provides specific information on the provision of **technical support services regarding the energy demands to be covered** by the BECoop RESCoop (amount of kWh to be covered by the activities of the BECoop RESCoops, how it was estimated etc.).
    - Then, subsection 7 is about the **feasibility study of BECoop RESCoop** with detailed and specific information on feasibility study results, involving two main subsections regarding the boundary conditions considered and the economic indicators calculated for each case.
    - Subsection 8 provides information on the **technical field visits** that have been performed by each pilot team during the duration of T4.2.
    - Subsection 9 provides information on the **potential end-users and/or relevant local actors** that would be willing to join forces with the BECoop RESCoop.
    - Moreover, additional subsections are added in each country section about **independent technical support services** that have been provided for the development of BECoop RESCoop.

Finally, in the Annexes, there is additional information on several technical support activities performed in each BECoop RESCoop that were not included in the main part of the current deliverable.

2 Methodology

Task 4.2 was a crucial phase of the project that aimed to build on the outcomes of Task 4.1 and carry out the technical implementation of the pilot cases. The primary objective of this phase was to identify and perform horizontal technical support activities for each pilot case while ensuring economic feasibility.

The methodology followed in Task 4.2 consisted of several steps. The first step was to carefully review the roadmaps developed in Task 4.1 and use them as a foundation to build upon. After this, bilateral calls were conducted with each pilot team.

During the bilateral calls, CERTH worked closely with each pilot team to develop a technical plan for each pilot case. The technical plan identified the horizontal technical support activities required for each pilot case based on the outcomes of D4.1 and the needs of each pilot.

The pilot teams, consisting of one pilot partner and technical partner, then performed the technical activities required for each pilot case. In brief, the Spanish pilot team consisted of GOI and CIRCE, the Polish team consisted of OBS and WUELS, the Italian consisted of FIPER and supported by PolMil[1] and CERTH, and the Greek pilot team consisted of ESEK and CERTH. CERTH conducted several bilateral calls with the pilot teams during the course of the technical implementation of the pilot cases. These calls helped to keep the project team and the pilot teams aligned on the objectives of the pilot cases and ensured that the tasks of the pilots were appropriately oriented.

It is important to highlight that during Task 4.2, the pilot teams utilized the tools developed under the BECoop project to aid in the successful implementation of the pilot cases. These tools included the BECoop toolkit, technical catalogues, e-market environment, and self-assessment tool. The BECoop toolkit included practical tools and templates that enabled the pilot teams to design and implement their BECoop cases more efficiently and effectively. **The technical catalogues were also an essential tool used by the pilot teams during the implementation phase.** The catalogues contained a comprehensive list of technologies and solutions that were relevant to the pilot cases, enabling the pilot teams to start thinking over the technical aspects of their pilots. Furthermore, the e-market environment provided the pilot teams with a platform where they can ask for support and services or get in contact with potential customers, suppliers, and partners. Finally, the self-assessment tool was an essential tool that allowed the pilot teams to evaluate their progress and assess their performance against predefined criteria. The tool provided a comprehensive overview of the pilot's progress, helping the pilot teams to identify areas that needed improvement and make necessary adjustments.

After the implementation of several technical activities , a **feasibility analysis** was carried out for each BECoop RESCoop. The feasibility analysis aimed to determine the economic feasibility of the new activities. The analysis helped to identify any potential challenges or barriers to the economic feasibility of the pilot cases. Based on the input from T4.3 and the business partners (QPLAN and CBS) and input from the technical activities of the current task, some main economic indicators were calculated for the BECoop RESCoops.

For the feasibility studies, several assumptions were performed and various economic indicators were calculated. More specifically:

- n = 25 years lifetime of each cash flow analysis (year 0= 2025)
- r = fixed inflation rate from 2026 onwards based on IMF data equal with 2%
- Fixed OPEX and revenues, based on the feedback retrieved by each BECoop RESCoop
- Cash Flow = CAPEX + OPEX – Revenues

[1] PolMil, as FIPER's subcontractor

- $Present\ Value\ (PV) = \frac{Cash\ Flow}{(1+r)^n}$
- $Net\ Present\ Value\ (NPV) = \sum_0^n \frac{Cash\ Flow}{(1+r)^n}$
- $Return\ on\ Investment\ (ROI) = \frac{Revenues - OPEX}{CAPEX}$
- $Payback\ Period\ (PBP) = \frac{CAPEX}{Revenues - OPEX}$
- $Internal\ Rate\ of\ Return\ (IRR) = \frac{Cash\ Flow}{(1+r)^n} - CAPEX$

It is worth emphasizing that every BECoop RESCoop is unique in its own way. Each pilot case differs based on their bioenergy vision, capacities, chosen technologies, and level of maturity.

In this light, **the report tries to give a homogeneous presentation of the technical support activities performed in each case**, however it should be noted that in each case, different technical support activities were performed and to a different extent.

3 Spanish BECoop RESCoop

The Spanish BECoop RESCoop is based on the incorporation of bioenergy services into a current RESCoop (as it is GOIENER) with the main core focused on electricity distribution and the promotion of community energy.

In order to carry out this new biomass-based bioenergy services, **Aberasturi case** was selected, and the following points will focus on the accompanying actions that have taken place and the obtained results. Even though Aberasturi is the selected case of the study as it covers the **whole value chain**, in the identification of initiatives to which support could be given that was carried out in task 4.1, **another very interesting case (Murgia) was identified**, which has also been given some technical support. The supporting activities carried out with Murgia are briefly explained in section 3.10.

3.1 Introduction to the BECoop RESCoop

Aberasturi is a small village that belongs to Vitoria-Gasteiz council (Basque Country, Spain), with 133 inhabitants distributed in 56 houses (there are 5 houses more but at this moment are not being occupied). They have an interest in exploiting local biomass resources that currently have no use (herbaceous and forest biomass) in order to cover the energy demands of all the inhabitants through the implementation of a biomass district heating.

Through the workshop that was carried out in Aberasturi village, there was a strong commitment from different stakeholders to take the project forward (more information can be found in D4.1[2]).

3.2 Biomass Assessment

In this section the type of biomass and quantities to be used in Aberasturi are described. As mentioned, Aberasturi has an equal interest in the use of the **two local biomasses, herbaceous and forestry**. Initially in both cases the Bioraise tool (included in the BECoop Toolkit[3]) was used, to get an overall picture, which was then further elaborated as explained in the sections below.

3.2.1 Type of biomass to be used by the BECoop RESCoop

Forestry biomass

The first type of biomass that is of interest for the Spanish BECoop RESCoop is forestry biomass. A demonstration about how to collect the forestry biomass in the forest of Aberasturi was carried out (it will be reported in D4.4), and a sample of this biomass was taken and analysed. The main characteristics can be found in Table 1. It is important to emphasise that the sample was taken after chipping in the forest. The future purpose is to store and carry out a natural drying process in order to feed the woodchips to the biomass boiler with around 25-30 % of moisture.

[2] https://www.becoop-project.eu/wp-content/uploads/D4.1_Co-definition_of_community_bioenergy_heating_roadmaps_v1.0.pdf
[3] https://becoop.fcirce.es/toolkit/

Table 1 Characterization of forest biomass from Aberasturi

Parameter	Unit	Value
Moisture	% a.r.	37.1
Volatile	% d.b.	74.8
Ash	% d.b.	2.5
Fixed carbon	% d.b.	22.8
C	% d.b.	48.10
H	% d.b.	5.80
N	% d.b.	0.42
S	% d.b.	0.02
Cl	% d.b.	0.01
HHV	MJ/kg d.b	18.6
LHV	MJ/kg a.r.	10.0

Herbaceous biomass

Some of the inhabitants of Aberasturi own land where they grow different types of cereals (wheat, barley and oats). Currently, the straw generated is not used, in fact an agricultural services company comes and takes it away (it sells it for energy use to a large biomass plant that produces electricity). Aberasturi was very interested in assessing if this straw could be used to cover their energy demands.

Taking into account that straw can have a quite different composition depending on the crop (3 are considered) and the type of land where it is cultivated (2 areas considered "Rio" and "Monte"), 6 analyses were carried out. Table 2 presents the results obtained from the analyses. As a result, it can be seen that straw from "Wheat (Rio)" "Barley (Rio)" and "Barley (Monte)" have more appropriate characteristics for energy production.

Table 2 Characterization of straw from Aberasturi.

Parameter	Unit	Oat (Rio)	Oat (Monte)	Barley (Rio)	Barley (Monte)	Wheat (Rio)	Wheat (Monte)
Moisture	% a.r.	10.1	9.5	10.0	8.6	8.0	9.0
Volatile	% d.b.	72.1	72.2	75.3	78.4	76.6	73.3
Ash	% d.b.	6.1	8.8	6.9	6.0	5.7	8.7
Fixed carbon	% d.b.	21.8	19.0	17.8	15.6	17.7	18.0
C	% d.b.	43.10	41.40	40.90	41.60	40.40	39.80
H	% d.b.	5.70	5.20	5.50	5.60	5.00	5.60
N	% d.b.	0.43	0.51	0.70	0.54	0.62	0.44
S	% d.b.	0.09	0.14	0.12	0.13	0.07	0.13
Cl	% d.b.	0.65	0.74	0.28	0.36	0.13	0.66
HHV	MJ/kg d.b	17.8	17.6	17.9	17.9	18.3	17.6
LHV	MJ/kg a.r.	14.7	14.6	14.8	15.1	15.6	14.7

3.2.2 Quantities to be used by the BECoop RESCoop

Forestry Biomass

The law in Aberasturi indicates that each house has 9 tonnes per year (dry basis, d.b.) from the local public forest. Currently, 43 households have shown a strong interest in the project, so there is a potential of 387 t/year (d.b.), and if all the houses were involved in the community (the main objective), the potential would be 504 t/year (d.b.), which could even be higher as some houses are currently uninhabited.

Aberasturi is very aware of the sustainability of its forests, which is why it has worked together with the Rural Zona Department from Vitoria City Council in order to carry out a forestry management plan, with the goals of assessing if this quantity can be collected annually from the forest in a sustainable way for forest conservation. According to this plan, the main forestry crops are oak and beech, with an annual volume increase of 3.16 (m^3/ha*year), Table 3 shows the amount of biomass that can be harvested annually from the public forest (493 t/year). This quantity is well aligned with the potential indicated before (504 t/year).

Table 3 Amount of biomass that can be collected each year from Aberasturi according to the forestry management plan carried out.

Annual volume increase with bark	m^3/year	t/year (d.b)
Queijo (type of oak)	577.62	404.34
Oak	24.88	20.87
Beech	88.36	68.22
Total	690.86	493.42

Taking into account that all the energy demand (described in the section 3.5) will be covered with forestry woodchips, the amount of forestry woodchips needed will be around 300 t/year (d.b.), this value is very feasible considering the results obtained in the forestry management plan described in Table 1. Also, this means that around 500 t/year (at 37 % moisture content) should be harvested from the forest.

Herbaceous biomass

The potential of straw that can be collected from these areas was firstly assessed through the BioRaise tool and secondly updated using Residues-to-Surface rations obtained from previous experience in other H2020 projects (AGROinLOG). The results are presented in Table 4. As a result, from all the areas and crops, there is a potential of 618 t/year (d.b.). The potential of the three feedstock mentioned above with the most interest amount to 312 t/year (d.b.).

Table 4 Amount of each different straw that can be collected from each area.

Area	Parameter	Wheat	Barley	Oak
Rio	Surface area (ha)	74	56	37
	Biomass potential (t/year, d.b.)	119	76	48
Monte	Surface area (ha)	115	86	57
	Biomass potential (t/year, d.b.)	185	117	73
Total	**Surface area (ha)**	189	142	94
	Biomass potential (t/year, d.b.)	304	193	121

Similarly, to the forestry biomass, the amount of straw needed to cover all the energy demand of Aberasturi (described in section 3.5) was assessed, and as a result, 320 t/year (d.b.) are needed (“Wheat (Rio)” “Barley (Rio)” and “Barley (Monte)”). This means that around 385 t/year (at 15 % moisture content) should be harvested from the fields.

3.3 Logistics of BECoop RESCoop

3.3.1 Value chain description

Forestry biomass

The Aberasturi Forest is very populated, difficult to access and the operations to be carried out will be based on the thinning of the different trees to improve the sustainability of the forest. Considering this situation, the use of heavy machinery is complicated, for this reason it has been determined that the best way to obtain biomass from this area would be as follows:

- Manual chainsaw cutting of those trees that are considered to improve the sustainability of the forest (normally the ratio is cutting 1 tree out of 3-4 trees).
- Removal of tree cut through a skidder.
- Transportation of the trees to the storage area, where they will be stored for a period of time in order to lower their moisture content.
- Once all the trees are in the storage area, a shredding machine will be rented to carry out this operation at the same time.
- If needed, woodchips will be left for natural drying before being consumed.
- Finally, the biomass will be fed to the biomass boiler.

Figure 1 presents the forest residues value chain of the BECoop RESCoop.

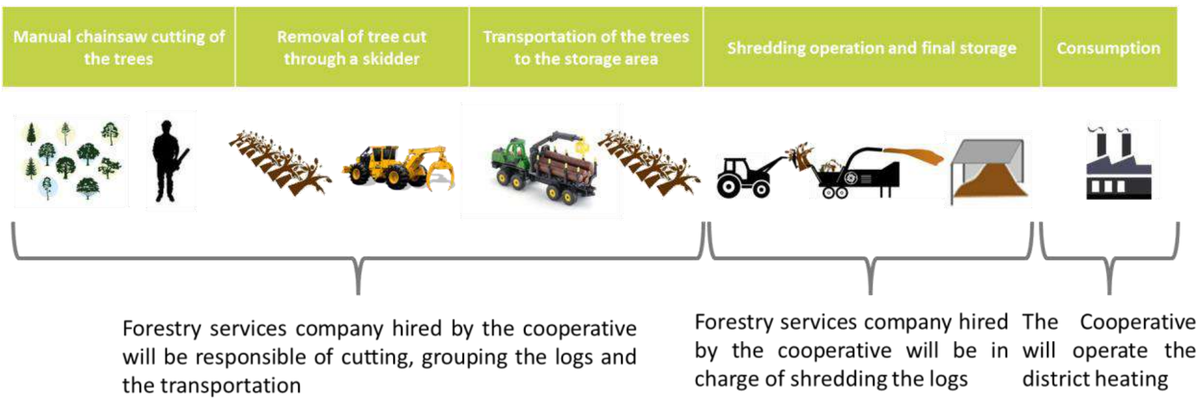


Figure 1 Diagram of value chain operations (forest residues)

Herbaceous biomass

On the other hand, the herbaceous biomass will be collected in a traditional way:

- After harvesting of the crop, the material will remain in the field for approximately one week.
- Windrowing of the material and baling via mechanized means.
- Transportation of the bales to the storage area.
- Finally, the biomass will be fed to the biomass boiler.

Figure 2 presents a diagram for the value chain of herbaceous biomass

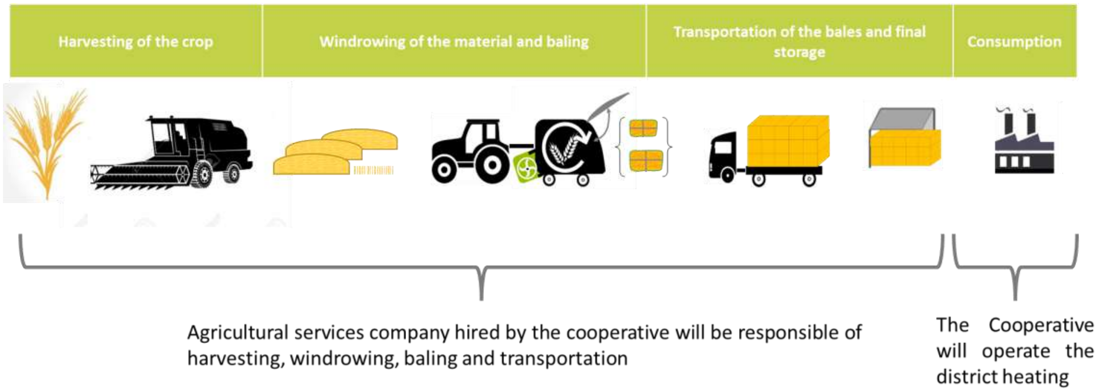


Figure 2 Diagram of value chain operations (herbaceous biomass)

3.3.2 Cost of collection

Forestry biomass

Considering the demonstration of forest biomass (will be reported in D4.4), Table 5 indicates the cost of the different operation previously indicated.

Table 5 Cost of collection of the forestry biomass for Aberasturi.

Operation	Unit	Value
Cutting and removal of the trees	€/t (at 37 % moisture)	70
Transportation of the trees to the storage area	€/t (at 37 % moisture)	10
Shredding	€/t (at 28 % moisture)	25
Final price of the forestry woodchip*	€/t (at 28 % moisture)	124

*In the final price is considered also 5 % of losses of forest biomass in the pretreatment and transportation process

Herbaceous biomass

Table 6 shows the cost considering for the collection of the herbaceous biomass, taking into account the agricultural service companies of the surrounding of Aberasturi.

Table 6 Cost of collection of the herbaceous biomass for Aberasturi.

Operation	Unit	Value
Windrowing of the material and baling	€/t (at 15 % moisture)	31
Transportation of the bales to the storage area	€/t (at 15 % moisture)	10
Final price of the herbaceous bales*	€/t (at 12 % moisture)	45

*In the final price it is considered also 5 % of losses of herbaceous biomass in the pretreatment and transportation process.

3.4 Location of BECoop RESCoop

The Aberasturi BECoop RESCoop will be located in the village of Aberasturi in the northern region of Spain and the southern region of the Basque Country, Figure 3.

Figure 3 Location of Aberasturi in Spain (left) and in the Basque Country (right).

In Aberasturi, the location of the district heating plant was carefully examined to determine the optimal site for both the generation plant and biomass storage area. Public land and buildings in Aberasturi were considered, and the distribution network was also evaluated to ensure efficient delivery of the generated heat.

Regarding the generation plant and the biomass storage area, Figure 4, Figure 5 and Figure 6 represent the most suitable place to be located, taking into account the following considerations:

- Both forest and herbaceous biomass will be used but not mixed, therefore, they should have independent boilers and feed systems.
- The generation plant should be in the south side of the village, in order to avoid noise pollution or emissions (since the prevailing winds come from the north) with the inhabitants.
- The storage area should be located adjacent to the boiler room, in order to avoid higher transport costs.
- There will be an independent room for the control and the management of the installation.

Figure 4 Location of the generation plant and the biomass storage area (red rectangle).

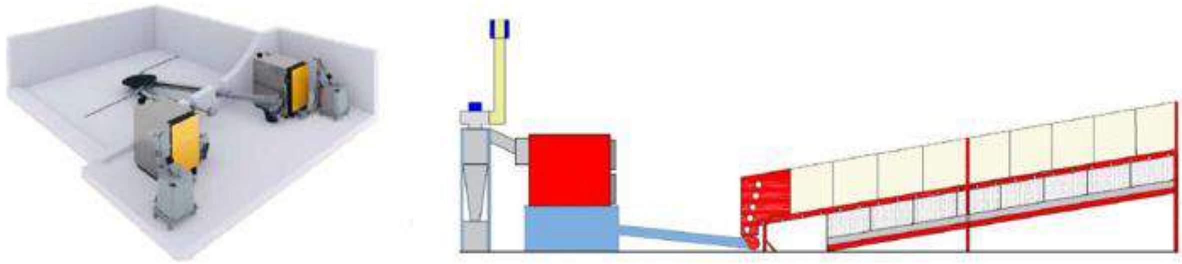


Figure 5 Example of feeding system and biomass boiler for the forestry biomass (left) and herbaceous biomass (right).

Figure 6 Example of storage area of forestry woodchips (left) and herbaceous bales (right).

Regarding the heating network, it was assessed that a main line of 1,500 m will be placed underground in 80 mm deep trenches, along the main streets of Aberasturi, and an extra line of 1,200 m is required for the connection of each house to the main line. As a result, the heating network will have a length of 2,700 m, Figure 7.

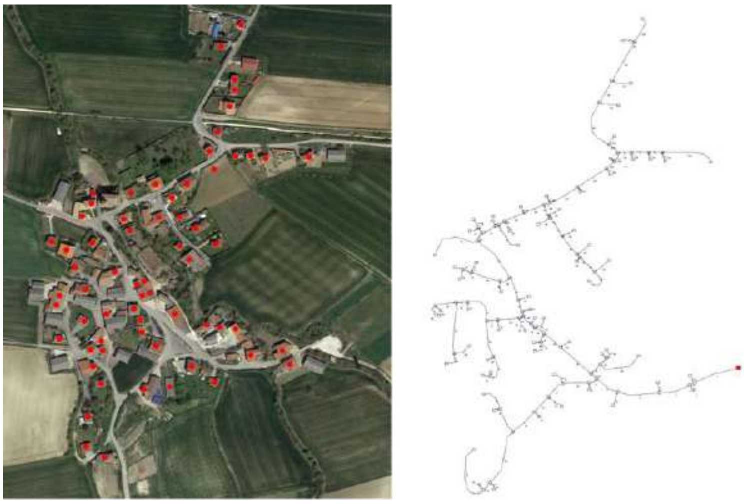


Figure 7 Consumption points (houses, right) and distribution of the network (left) along Aberasturi.

3.5 Technology and Activity of the BECoop RESCoop

From the beginning, Aberasturi wanted to assess whether it was technically and economically feasible to implement a district heating network in their village. In order to provide this technical support services about district heating, the BECoop technical catalogue[4] was considered.

[4] https://www.becoop-project.eu/wp-content/uploads/Biomass-District-Heating.pdf

Initially, the team considered the homes that were currently interested in being part of the district heating system, as well as those that might be interested in the future. After identifying these homes, the team assessed their current energy demand. More information on this is provided in the relevant section of the report (3.5).

Secondly, the power of the new installation (generation plant of the district heating) was assessed taking into account the data indicated in Table 7. As a result, the estimated power of the generation plant was 1.2 MW, which will produce around 1,400 MWh/year.

Table 7 Parameters considered for assessing the power of the generation plant.

Parameter	Unit	Value
Efficiency of the heating network	%	92
Efficiency of the power plant	%	85
Nº of hours of operation of the generation plant	h/year	1400
Average working load of the operation	%	80

Taking into account that consumption will be different from month to month, and that they are very different fuels, a modular design will be chosen, consisting of at least two boilers, one fuelled with straw and the other with woodchips.

Thirdly, the amount and the cost of biomass needed was assessed and reported in the section 3.2 and 3.3, respectively. Aberasturi wants to cover (at least initially) 50 % of the demand with straw and 50 % with woodchips. By taking into account this consideration, Table 8 shows the amount of biomass that should be harvested, the amount that should be fed to the biomass boiler and the corresponding costs.

Table 8 Amount and cost of the biomass needed to cover the energy demand.

Parameter	Unit	Value
Forestry		
Amount needed of forest biomass to be collected in the field	t/year (at 37 % moisture)	247
Amount of forest biomass to be consumed in the boiler	t/year (at 28 % moisture)	200
Total cost of the forest biomass to be consumed in the boiler	€/year	24,790
Ratio of the forest biomass to be consumed in the boiler	€/t (at 28 % moisture)	124
Straw		
Amount needed of straw biomass to be collected in the field	t/year (at 15 % moisture)	192
Amount of straw biomass to be consumed in the boiler	t/year (at 12 % moisture)	175
Cost of the harvesting and transportation to the storage area	€/year	7,885
Ratio of the straw biomass to be consumed in the boiler	€/t (at 12 % moisture)	45

Fourthly, some estimations were done for assessing other operational costs, mainly associated with the electricity consumption and the maintenance operations of the DH plant. As a result 44,251 €/year was considered for the other operational costs. From these, 16,463 €/year was the electricity cost, where an electricity cost of 0,25 €/kWh was considered for a consumption of 65,850 kWh/year. The maintenance cost includes: i) 9,600 €/year of staff cost with 800 €/month (one person part-time) and ii) cost of the maintenance associated with equipment at 18,188 €/year (1 % of the total investment).

Finally, regarding the investment needed initially some estimations were done. In order to be more accurate, different meetings were carried out with 3 different ESCOs (with experience in district heating) in order to: i) present the project; ii) to assess if they agree with the results obtained; iii) to see if they would be interested in the construction of the district heating; and iv) how much it would cost. Some of the ESCOs were interested, from which one has prepared a preliminary design of the installation with a total cost of 1,8 M€. Further details are presented in the Feasibility Study section (Section 3.6).

3.6 Energy demands to be covered

One of the first technical activities carried out in the accompaniment was related with the estimation of the energy demands to be covered in each of the houses of Aberasturi. Initially, a first estimation was assessed through an online tool named Hotmaps, that can be found in the BECoop toolkit. Then, to be more precise, a questionnaire was carried out, in which the following topics were addressed:

- Specific address of the house.
- Fuel used in order to cover the thermal energy demand (heating and sanitary hot water).
- Thermal energy demand.
- Price of the fuel consumed.
- Annual hours of use.
- Current use of the house (first house or second house)

The inhabitants of Aberasturi have been closely involved in this process, and **43 houses** responded in detail to the questionnaire. Since Aberasturi wants to cover all the houses of the village with the district heating, an estimation was done for the houses that did not participate in the questionnaires. All these numbers were deeply analysed, and the energy demand to be covered in each house was assessed and grouped in two types of houses: i) first house, which means people who lives there all the time; and ii) second house, mainly they make use of it at weekends). The results are presented in Table 9.

Table 9 Ratio of heating consumptions per type of house assessed in Aberasturi.

Type of house	Number of houses	Heating consumption per house (kWh/year)	Total heating consumption (kWh/year)
First house	41	22,500	922,500
Second house	20	8,750	175,000
Total	61	-	1,097,500

Furthermore, the distribution of the current energy source that they are using in order to cover their thermal energy demand was obtained from the questionnaire presented in Table 10.

Table 10 Distribution of the energy source used to cover the thermal energy demand.

Distribution of the energy source in Aberasturi	Unit	Value
Energy consumed from oil boilers	%	57
Energy consumed from biomass (firewood)	%	32
Energy consumed from propane	%	10
Energy consumed from heat pump	%	1

According to the data provided in Table 9 and Table 10, the efficiency of the installation of these energy sources used and the low heating values of these fuels, the total primary energy to be covered by the Spanish BECoop RESCoop in Aberasturi was calculated at 1,435 MWh/year. Moreover, the current heating costs of the citizens of Aberasturi, based on the energy source that they use, are calculated at 141,231 €/year and the corresponding unit costs are presented in Table 11.

Table 11 Cost of each fuel in Aberasturi region.

Energy source	Unit	Value
Heating oil	€/l	1.2
Biomass (firewood)	€/t	67.5
Propane	€/t	2,550
Electricity (heat pump)	€/kWh	0.35

3.7 Feasibility Study of the BECoop RESCoop

3.7.1 Boundary Conditions for the feasibility study

Although they have already been indicated some of them, the main boundary conditions that have been considered for this study are the following:

- Both local biomass resources should be considered: forestry woodchip and bales of straw.
- Half of the energy demand should be covered with each biomass in this feasibility study.
- The storage area of both biomass should be located near the generation plant in order to reduce the transportation cost.
- The heating network should cover all the houses of Aberasturi (61).
- It is considered that it may be feasible to achieve 50 % of public grant in order to finance the total investment (CAPEX) of the district heating.

For this analysis, the revenues are considered to be the energy savings, because the profitability of this concept will be upon the money saved from the citizens of Aberasturi in making use the heat from the DH plant instead of the current options (natural gas, propane, oil, heat pump etc.). Taking into account these boundary conditions, Table 12 summarises the main data considered in the feasibility study.

Table 12 Main data considered in the feasibility study of Aberasturi.

<table>
<tr><th colspan="2">Parameter</th><th>Unit</th><th>Value</th></tr>
<tr><td colspan="4">Current situation</td></tr>
<tr><td colspan="2">Primary energy consumed in Aberasturi</td><td>kWh/year</td><td>1,435,675</td></tr>
<tr><td colspan="2">Total heating cost (considered as energy savings)</td><td>€/year</td><td>141,231</td></tr>
<tr><td colspan="2">Ratio heating consumption cost</td><td>€/kWh</td><td>0.129</td></tr>
<tr><td colspan="4">Future situation</td></tr>
<tr><td colspan="2">Primary energy to be produced in the biomass plant</td><td>kWh/year</td><td>1,403,453</td></tr>
<tr><td colspan="2">Power of the heating plant</td><td>kW</td><td>1,253</td></tr>
<tr><td colspan="2">Length of the heating network</td><td>m</td><td>2,700</td></tr>
<tr><td rowspan="3">Investment of the district heating</td><td>Generation plant</td><td>€</td><td>751,850</td></tr>
<tr><td>Heating network</td><td>€</td><td>945,000</td></tr>
<tr><td>Substations</td><td>€</td><td>122,000</td></tr>
<tr><td rowspan="2">Operational cost</td><td>Forestry woodchip biomass</td><td>€/year</td><td>24,790</td></tr>
<tr><td>Straw bales biomass</td><td>€/year</td><td>7,885</td></tr>
</table>

Parameter		Unit	Value
	Other operational cost (electricity and maintenance)	€/year	44,251
% of public grant considered to cover the total investment		%	50

3.7.2 Economic Indicators (IRR, NPV, PBP)

Considering the previous data, the internal rate of return, net profit value and the payback period of the new installations were calculated. Table 13 shows the economic indicators that are obtained in the base case. As a result, a payback period of almost 14 years is obtained, which is high but for this type of installation and taking into account that the lifetime of the installation is around 25 years, it is economically feasible to implement.

Table 13 Economic indicators (base case).

Economic indicators	Unit	Value
Internal rate of return (IRR)	%	2.91
Net profit value (NPV)	€	346,047
Payback Period (PBP)	Years	14.14

Further to this base scenario, it was also taken into consideration a carbon tax for the use of fossil fuels. In this case, the payback period can be reduced in 11.9 years as presented in Table 15. To this end, a sensitivity analysis was applied with the implementation of carbon tax in order to better demonstrate the benefits of using bioenergy instead of fossil fuels. Carbon tax is already being implemented and will be established in all the EU countries to meet the EU goals. The consequence of this tax implementation will be the additional increase of fossil fuel prices. The cash flow analysis of this scenario, along with their investment evaluation can be seen in the following table and figure.

Table 14 Cash Flow Analysis

CUMULATIVE CASH FLOWS									
Years	CAPEX €	OPEX €	Inflation Rate	Revenues €	Carbon Tax €	Cash flow €	Cumulative €	PV €	NPV €
0	909,425		2.00%		4,118	-905,307	-905,307	-905,307	-905,307
1		76,926	2.00%	141,231	5,284	69,590	-835,717	68,226	-837,082
2		76,926	2.00%	141,231	6,451	70,757	-764,960	68,009	-769,072
3		76,926	2.00%	141,231	7,618	71,923	-693,037	67,775	-701,297
4		76,926	2.00%	141,231	8,784	73,090	-619,947	67,524	-633,773
5		76,926	2.00%	141,231	9,951	74,257	-545,690	67,257	-566,517
6		76,926	2.00%	141,231	11,118	75,423	-470,266	66,974	-499,543
7		76,926	2.00%	141,231	12,284	76,590	-393,676	66,676	-432,866
8		76,926	2.00%	141,231	13,451	77,757	-315,919	66,365	-366,502
9		76,926	2.00%	141,231	14,618	78,923	-236,996	66,040	-300,462
10		76,926	2.00%	141,231	15,784	80,090	-156,906	65,702	-234,760
11		76,926	2.00%	141,231	16,951	81,257	-75,649	65,352	-169,408

CUMULATIVE CASH FLOWS									
Years	CAPEX €	OPEX €	Inflation Rate	Revenues €	Carbon Tax €	Cash flow €	Cumulative €	PV €	NPV €
12		76,926	2.00%	141,231	18,118	82,423	6,774	64,990	-104,418
13		76,926	2.00%	141,231	19,284	83,590	90,364	64,618	-39,800
14		76,926	2.00%	141,231	20,451	84,757	175,121	64,235	24,435
15		76,926	2.00%	141,231	21,618	85,923	261,045	63,842	88,277
16		76,926	2.00%	141,231	22,784	87,090	348,135	63,440	151,718
17		76,926	2.00%	141,231	23,951	88,257	436,392	63,030	214,747
18		76,926	2.00%	141,231	25,118	89,423	525,815	62,611	277,358
19		76,926	2.00%	141,231	26,284	90,590	616,405	62,184	339,542
20		76,926	2.00%	141,231	27,451	91,757	708,162	61,750	401,291
21		76,926	2.00%	141,231	28,618	92,923	801,085	61,309	462,600
22		76,926	2.00%	141,231	29,784	94,090	895,175	60,861	523,461
23		76,926	2.00%	141,231	30,951	95,257	990,432	60,408	583,869
24		76,926	2.00%	141,231	32,118	96,423	1,086,856	59,949	643,817
25		76,926	2.00%	141,231	32,118	96,423	1,183,279	58,773	702,591

The Investment evaluation & profitability can be also seen in Figure 8.

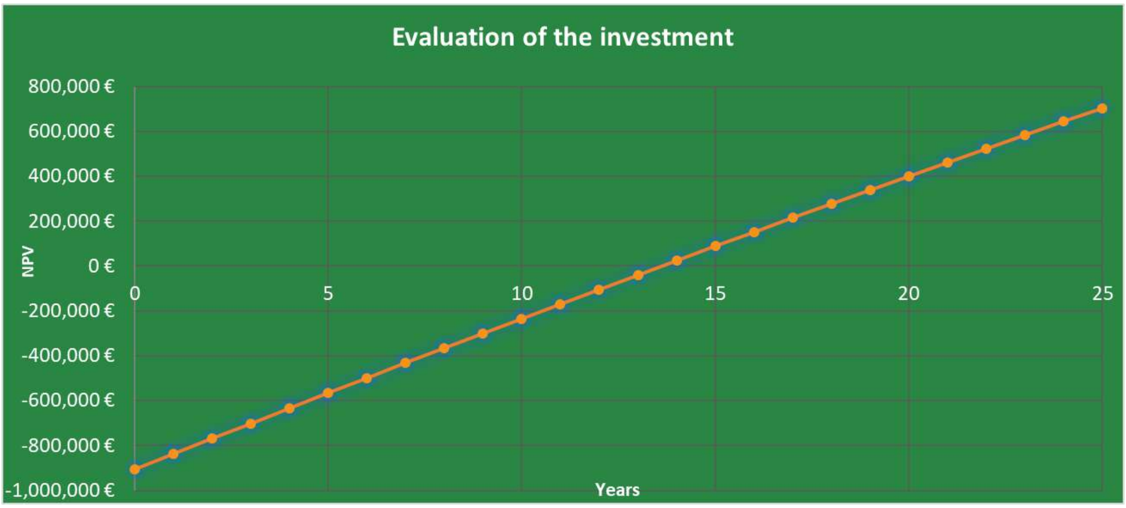


Figure 8 Graph of the investment planning

Table 15 Economic indicators considering a carbon tax for fossil fuels.

Economic indicators	Unit	Value
Internal rate of return (IRR)	%	5.16
Net profit value (NPV)	€	702,591
Payback period (PBP)	Years	11.9

Finally, two sensitivity analyses were carried out on the base case (without carbon tax). Firstly, it was assumed an increase in the price of the fossil fuels compared with the biomass at 5, 10 and 15 % (Table 16), and secondly, it was considered that the public grant to cover the investment could be 30, 60 and 80 % (Table 17).

Table 16 Sensitivity analysis considering an increase of the price of the fossil fuels.

Consideration	IRR (%)	NPV (€)	PBP (years)
5 % of increase of the price of fossil fuels vs the price of the biomass	4.78	597,285	11.78
10 % of increase of the price of fossil fuels vs the price of the biomass	6.53	848,523	10.10
15 % of increase of the price of fossil fuels vs the price of the biomass	8.19	1,099,761	8.84

Table 17 Sensitivity analysis considering the percentage of public grant achieved.

Consideration	IRR (%)	NPV (€)	PBP (years)
30 % of public grant to cover the CAPEX	-0.12	-17,723	19.80
60 % of public grant to cover the CAPEX	5.23	527,932	11.31
80 % of public grant to cover the CAPEX	15.05	891,702	5.66

From the previous data, it can be concluded that there are some parameters such as the carbon tax and the increase of the price of fossil fuels that would affect the final economic indicators. However, the parameter with the most impact is the public grant obtained.

3.8 Technical field visits

During the accompaniment carried out with Aberasturi, the BECoop partners along with the inhabitants visited current district heating plants working with biomass and an installation working with straw bales. For this reason, two field visits were carried out described in Table 18 and Table 19.

Table 18 Field visit to a Biomass District Heating

Field Visit: Biomass district heating lighthouse case	
   	
Brief Description:	Two district heating installations fed with forestry woodchips were visited (Sabando and Roitegi) in order to obtain information about how the district heating was created, how it is operated, how the biomass is collected, etc.
When:	June 2022
Where:	Sabando and Roitegi (Vitoria-Gasteiz), Spain
Why:	The inhabitants of Aberasturi want to know the surface needed for the generation plant, the storage area of the biomass, the main problems that can appear, and mainly the level of satisfaction of the inhabitants of Sabando and Roitegi with the current installation of the biomass district heating.
No of participants:	17
Type of stakeholders:	Citizens/General Public / Biomass Owners / Authorities/Municipalities / Research Centers/Universities / Biomass management companies.

Table 19 Field visit to an installation with a biomass straw boiler.

Field Visit: Biomass straw boiler lighthouse case	
  	
Brief Description:	A hotel was visited, since they supply the heating demand with a biomass boiler fed with wheat straw.
When:	November 2022
Where:	Murillo de Gállego (Zaragoza), Spain
Why:	The residents of Aberasturi were interested in visiting an actual installation that used straw bales to gain technical insights into the feeding system, biomass boiler, and other key aspects required for the successful operation of such an installation.
No of participants:	18
Type of stakeholders:	Citizens/General Public / Biomass Owners / Authorities/Municipalities / Research Centres/Universities / Boiler manufacturers.

3.9 End users/local actors identified for cooperation

3.9.1 Potential End users

The potential end-users of the biomass district heating in Aberasturi will be the village's own inhabitants, who will be able to act as prosumers of the thermal energy generated by the system. All of them were engaged from the beginning through the co-creation workshop that was carried out and reported in deliverable 4.1, and their involvement with the project was very positive.

One example of this implication is that 43 houses out of 56 inhabited (77 %) answered to the questionnaire that was prepared for monitoring the current energy demand of each house and the energy source used. Another positive indication is the high number of inhabitants that came along to the field visits described in Table 18 and Table 19.

Additionally, regular meetings (approximately every two months) have been held with the main stakeholders who were leading the initiative (indicated in Table 20).

3.9.2 Local actors interested in cooperation

The list of stakeholders involved in the case of Aberasturi are indicated in Table 20.

Table 20 List of main stakeholders (Aberasturi RESCoop)

Stakeholder	Role
Goiener	Assistant in the creation of the RESCoop (development team) and possibly heat retailer
CIRCE - Technical support	Assistant in the creation of the RESCoop (development team)
AVG_Energy department - Energy focal point and BECoop focal point	Assistant in the creation of the RESCoop (development team)
AVG_ Rural zone department - biomass resource and local management focal point	Assistant in the creation of the RESCoop (development team)
AVG_ Rural zone department - Forest technician	Assistant in the creation of the RESCoop (development team)
Small Local Entity belonging to AVG (Aberasturi village) - End user and council chairperson - End user and council member	End user (Promoter group)

Furthermore, during the activities of WP4, contact has been made with other actors. One such is the City Council of Vitoria, which through their different departments (energy and rural zone) have been involved at all times in order to make progress in the accompaniment and specially to keep the inhabitants of Aberasturi informed and motivated.

On the other hand, to carry out the forest biomass demonstration (D4.4), as well as to know the cost of production and transportation of straw bales, different agricultural and forestry service companies in the area have been contacted and contracted on certain occasions (for example for the forest biomass demonstration). Some of these stakeholders in the future can be part of the community or being contracted by the community in order to harvest the local biomass (forestry and herbaceous) that belongs to Aberasturi or their inhabitants.

Finally, in order to assess the feasibility of the district heating installation two manufacturers of biomass boilers were contacted (especially in the case of straw boilers, as they are less frequently) and three energy services companies (ESCO) to whom the project has been explained through different meetings. As a result, one of them showed great interest in the project, and has drawn up a preliminary project that it was explained to the inhabitants of Aberasturi. The role of this ESCO will be to carry out the whole installation and to provide technical support for possible problems/maintenance operations that may arise during the operation of the installation (which will be carried out by the community members).

3.10 Additional technical support activities

3.10.1 Overview of support provided to 2nd BECoop RESCoop case of Murgia

Murgia is located in the Gorbeialdea mountain region and is composed of six small rural municipalities. There is a vocational training institute which offers forest management classes and has their own equipment based on a tractor and a wood chipper. Additionally, they have an area where the biomass is stored and naturally dried.

Some public institutions from Murgia have biomass boilers, but the biomass consumed is not local. For this reason, it has been identified that there is a great potential to match the initiative of the institute of Murgia (production of local woodchips) with the current and future needs of biomass supply for Murgia's public buildings.

Table 21 List of stakeholders (Murgia RESCoop)

Stakeholder	Role
Goiener	Assistant in the creation of the RESCoop (development team)
CIRCE - Technical support	Assistant in the creation of the RESCoop (development team)
Gorbeialdeko Ingurumen Teknikaria	Assistant in the creation of the RESCoop (development team)
Institute of Murgia	Biomass supplier and trainings for future biomass suppliers (promoter group)
Murgia council and the six rural municipalities	End user (Promoter group)

During the provision of the technical support services, it was identified that one of the main concerns was to know whether the woodchip produced by the Murgia Institute is suitable for the facilities that the municipality has, which are currently fed with woodchips that are not of local origin. In order to provide support on this aspect, some meetings were carried out. Furthermore, a representative sample of woodchips was analysed and the results obtained were compared to a reference good quality woodchip. The main parameters analysed are indicated in Table 22 and Figure 9.

Table 22 Main characteristic of the forestry woodchip from the Institute vs a good quality woodchip.

Parameter	Unit	Woodchip from the Murgia Institute	Reference woodchip
Moisture	% a.r.	18.3	19.7
Volatile	% d.b.	77.0	85.4
Ash	% d.b.	2.3	1.0
Fixed carbon	% d.b.	20.7	13.6
Density	kg/m^3 d.b.	220	205
C	% d.b.	51.30	49.46
H	% d.b.	5.60	5.86
N	% d.b.	0.47	0.10
S	% d.b.	0.01	0.02
Cl	% d.b.	0.01	0.01
HHV	MJ/kg d.b	19.5	18.7
LHV	MJ/kg a.r.	14.4	13.5

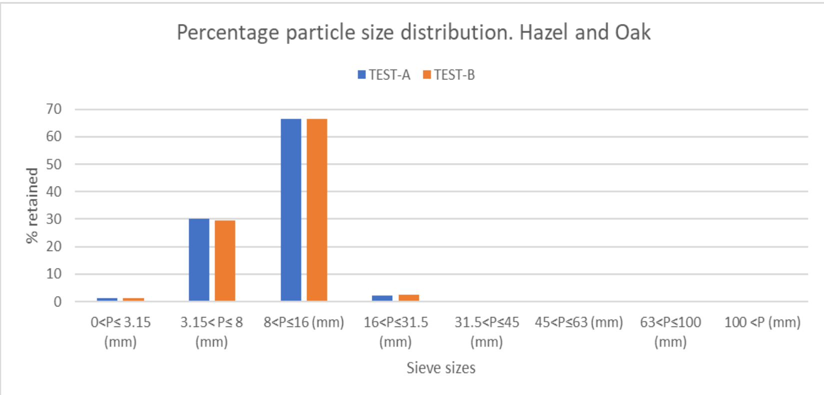


Figure 9 Size distribution of the forestry woodchip from the Institute.

A report describing the analysis was carried out and was explained in a meeting to the Institute and to the council of Murgia. The woodchip produced by the Institute shows a good characterization and theoretically could be suitable for the current biomass boiler that the municipality of Murgia has.

In order not to remain only in a theoretical self-evacuation of the fuel, a real test with about 400 kg of this woodchips was performed in a boiler of the municipality. This demonstration will be further described in detail in deliverable 4.4. The manufacturer of the actual boiler was also involved in the combustion test, along with a total of 23 people that assisted at some point during the test (Figure 10).

Figure 10 Pictures of the combustion test carried out in Murgia.

The results obtained from the test were good, achieving adequate performance and without any operating problems (more info in D4.4) and were presented to both the institute (suppliers of biomass) and the town council of Murgia (consumers of biomass).

Nonetheless, the institute cannot supply all the biomass needed by the different biomass boilers in Murgia and the other neighbouring municipalities. What can be done through the Institute is to train young people so that they are able to develop a local biomass supply business, as it has been proven that the quality of the local biomass is suitable for boilers and can be obtained through the methodology followed by the Institute.

4 Polish BECoop RESCoop

4.1 Introduction to the BECoop RESCoop

The commune of Oborniki Śląskie (OBS), apart from the town itself, is a typical agricultural region with a large dispersion of households, including those engaged in agricultural activity. There is no heating network in the commune. The single houses, multifamily houses and other buildings (schools, cinema, health centres, SMEs, shops, municipal offices, etc.) are heated primarily with individual heating units located directly in the building. In terms of the heating source, more than about 75% of households are heated indirectly or directly with coal, and about 20% with natural gas. Thus, the fossil fuels dominated the OBS area leading to the serious problem of high environmental pollution. Moreover, most of those heating units fired by coal are very old and inefficient.

At the same time, there are resources of forest and agricultural biomass in the OBS region which, after appropriate processing, could be used for heating purposes by local residents/users. Moreover, the anti-smog resolution currently in force in Poland together with the national Clean Air programme create the possibility of replacing old coal-fired boilers with new automatic boilers (for example, powered with biomass pellets), as well as the simple switching of coal itself into solid biomass (without changing the boiler unit).

Taking additionally into account that in the OBS Commune there is a potential for the construction of a technological line producing pellets by a local entrepreneur (e.g. the owner of a sawmill), the idea of creating a dedicated logistics chain was proposed (Figure 11). The ultimate goal is to create conditions for heating houses and other buildings with local biomass.

Figure 11 Bioenergy vision in the Polish OBS Pilot Area

In practice, **local farmers and institutions dealing with forest management could sell biomass** to a local pellet production plant, from which, in turn, the residents of the commune (or other companies and institutions) would buy the produced fuel (biomass pellets) for heating their households, businesses or other facilities public utility. Such a solution should allow to **reduce heating costs**, and thus the phenomenon of energy poverty, but also to stimulate social activity and local cooperation between stakeholders. An added value would also be to increase energy security and to reduce pollutants emission to the environment (due to the significant reduction of coal consumption).

The Oborniki Śląskie commune, as a partner of the BECoop project and a local government unit in the region, became not only the initiator of such an action, but also a potential beneficiary, due to the possession and management of many communal buildings/apartments and other public utility facilities (schools, commune office, cinema, sports facilities, rural community centres, etc.).

4.2 Biomass Assessment

The region of OBS commune is a rural area with biomass potential from forestry and agriculture. Therefore, it is important to provide the data related to biomass resources that will include the type of biomass and available quantities. Moreover, those values should be supported by the ultimate and proximate analysis to assess the energy potential and propose technological solutions leading to the heat production from biomass in the region. The toolkits developed within the BECoop project are the additional supporting tools to be used in Polish case for better understanding of the challenges and opportunities during the technical activities focused on the bioenergy cooperatives/community creation. Regarding the type of biomass and quantities, the data related to the area coverage by forests and field crops provided by OBS commune has been used.

4.2.1 Type of biomass to be used by the BECoop RESCoop

The selection of the type of biomass to be considered within this project was performed taking into account the statistical data, reported data by the farmers in the agricultural agency, reported data by the forestry department, type of agricultural crops in the region, animal husbandry data in the region, etc.. Moreover, the field visits and direct meetings have been performed to select the biomass sources and type of biomass for further analysis.

Based on the provided data and technical analysis of their potential use for energy purposes, it was decided to select:

- forestry biomass (wood logs and wooden residues assigned for energy production),
- agricultural biomass (straw).

Both sources of biomass can be used for pellets and briquettes production.

Nonetheless, it should also be mentioned that within the analysis, the potential use of animal manures and slurries (for biogas production and biogas plant construction) was considered as well. However, the technical reasons (location of the considered biogas plant in Pęgów cottage) and ineffective use of biogas for heating (high level of households scattering, lack of heating network in this area, too high investment costs) caused that the OBS commune excluded this variant from further analysis in this moment. Additionally, the OBS commune also considered the potential utilisation of the municipal green residues for energy purposes and other residues from food-processing. Despite its potential as a source of energy, the complex processes related to the collection, storage, and management of this material led the Polish pilot case to exclude this option. However, the OBS commune did note that this biomass stream could be a promising source of energy in the future. During this process, the results of the physical and chemical analysis performed by WUELS were used, as well as the catalogues and toolkit developed by the BECoop project (Biomass properties catalogue).

4.2.2 Quantities to be used by the BECoop RESCoop

In the assessment of the available quantities of biomass, the following data were used: the forest area, timber harvesting index (logging rate), the crops area, straw harvesting index, selected biomass properties. The report presents the findings of the analysis conducted to determine the potential of the OBS commune for the selected types of biomass as shown in Table 23.

Forestry biomass

Table 23 Biomass potential of forestry biomass in OBS commune

Resource availability (local potential)	
Typology of biomass	Forest residues
Supply basin (local name and hectares)	5,400 ha
Monthly/Seasonal/Annual quantity available (estimation)	Rather monthly availability
Average distance from transformation/treatment facility	From 5-30 km
Location/Coordinates	51°17′55″N 16°54′06″E
Owners/management	Oborniki Śląskie forestry management

In Poland it is assumed that current volume increment in forests is 9.2 $m^3/(ha{\cdot}yr)$[5]. The wood harvesting rate for energy purposes in Poland is 25%. Wood density is around 650-750 kg/m^3. Moisture content in harvested wood is above 55%. The LHV of the wet biomass is 8.0 MJ/kg.

Technical energy potential: 64,584 GJ/yr or 17,940 MWht/yr or 8,073 tonnes (wet basis)/ 3,633 tonnes (dry basis)

Agricultural residues: Straw

Table 24 Biomass potential of straw in OBS commune

Resource availability (local potential)	
Typology of biomass	Agricultural residues
Supply basin (local name and hectares)	8,500 ha
Monthly/Seasonal/Annual quantity available (estimation)	Seasonal (mainly in August/September)
Average distance from transformation/treatment facility	From 5-30 km
Location/Coordinates	51°17′55″N 16°54′06″E
Owners/management	Private farmers
Comments	The average straw yield is 3.5-4.0 t/ha. In Poland it is assumed that 50% of the straw can be used for energy purposes. The LHV for straw is 16.0 MJ/kg Technical energy potential: 238,000 GJ/yr or 66,110 MWht/yr or 14,875 tonnes (dry basis).

It should be marked that the assumed capacity of technological line for the production of biomass pellets is 0.5-1.0 t/hr. Furthermore, it is planned to use 50% of straw and 50% of wood for pellets production. Taking into account that the pellets production line will operate for 12 hr/day and 5 days per week (initial estimation), the required amount of biomass that should be secured from local resources is around 3,120 tons. As a result, the demand for straw is around 1,560 tonnes, and for wood around 1,560 tonnes, respectively. These values correspond to around 10% of the straw potential in the region, and around 40% of wooden biomass potential in the region.

[5] https://www.lasy.gov.pl/pl/informacje/publikacje/informacje-statystyczne-i-raporty/raport-o-stanie-lasow/raport-o-lasach-2020.pdf/view

4.3 Logistics of BECoop RESCoop

The logistics chain of the heat production from local resources in the OBS commune is focused on following main elements:

- Biomass harvesting,
- Biomass transportation to the processing plant,
- Biomass delivery to the final users,
- Biomass storage issues,
- Selection of the biomass boilers for heat production.

4.3.1 Value chain description

As the biomass for heating purposes comes from two different sources, the two logistics chains have been proposed/defined by WUELS (Figure 12, Figure 13):

Forestry wood biomass logistics chain:

The local forestry cooperative will cut and collect forest residues with a harvester. The collected biomass will then be transported by trucks (by a local transport company or sawmill owner) to the pellet plant where the biomass is properly processed and stored. The final product (pellets) is delivered to the end user by truck (belonging to the company). In the case of lower demand the pellets can be taken directly by the end user.

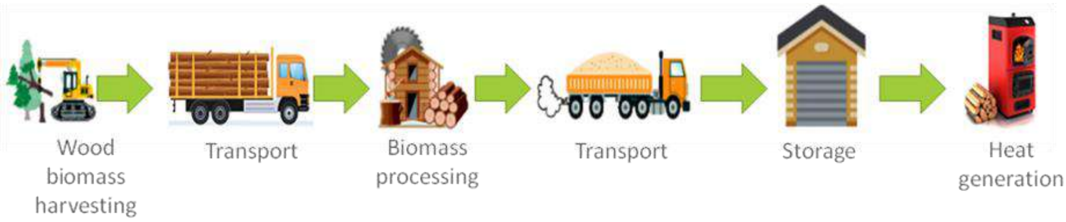


Figure 12 Diagram of value chain operations (forestry biomass)

Agricultural straw biomass logistics chain:

After crops are harvested, the straw is collected in the field and processed directly into bales (with a round baler) or squares (with a square baler). The compressed straw is then loaded onto a trailer and transported to the pellet production plant. Operations can be carried out directly by the farmer or by a local third party. The produced pellets are properly stored in the warehouse, from where the final product (pellets) is delivered to the final user by trucks (owned by the company). In case of lower demand, pellets can be taken directly by the end user.

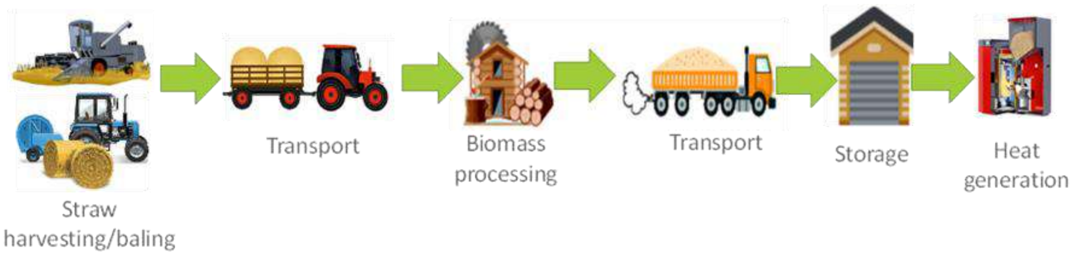


Figure 13 Diagram of value chain operations (agricultural straw biomass)

It is worth noting that the production of wood/straw blend pellets is a viable option, subject to market demand. Based on current trends, where fully automatic heating systems are preferred by end-users, WUELS suggested **a logistics chain that includes a pellets production line and biomass boilers specifically designed for pellets combustion.** The proposed system also includes suitable storage systems for pellets and addresses issues related to pellets quality and testing. These aspects were presented and discussed in the report.

The technical catalogues developed within the BECoop project have been used as supporting materials.

4.3.2 Cost of collection

The logistic chain of biomass utilisation for heating purposes is associated with different unit costs including: biomass purchase, biomass harvesting (in the forest, in the field), material transportation (wood, wood chips, logs, straw bales, pellets, briquettes etc.), biomass conversion and processing (pellets, briquettes, logs, bales), fuel storage (open-air, under roof, silos etc.). Typical costs related to BECoop/RESCoop activities are shown in Table 25. Of course, final costs depend on the location, topography of the terrain, forest density, type of wood/ straw, total area to be managed etc.

Table 25 Selected costs of the logistics chain in Polish OBS Pilot Area

Activity/Stage	Unit	Cost	Comments
Wood biomass harvesting[6,7]	€/ha	110 - 175	Adopted: 9.2 m^3 of wood/ha/yr
	€/m^3	12 - 19	
Wood biomass transportation[8]	€/km	1.7 - 2.1	
Wood biomass (cost of fuel)[9]	€/m^3	26 - 36	Based on the price list of the Oborniki Śląskie Forestry Inspectorate from 2023. Loco price (place of the wood biomass harvesting)
	€/t	33 - 38	Density of freshly cut wood: 690-1,080 kg/m^3. Loco price (place of the wood biomass harvesting)
Straw harvesting[10]	€/ha	43 - 67	Adopted: 3,500-4,000 kg of straw/ha/yr; density of straw bale with diameter 120 cm: 81-136 kg/m^3
	€/m^3	0.9 - 2.6	
Straw transportation[11]	€/km	1.7 - 2.1	
Straw bales (cost of fuel)[12,13]	€/m^3	7.5 - 13.6	Adopted volume of straw bale: 1.47 m^3. Loco price (place of the straw harvesting)
	€/t	55 - 167[14]	Adopted: straw bale price: 11-20 €; the mass of straw bale: 120-200 kg. Loco price (place of the straw harvesting)
Open-air biomass storage[15,16]	€/m^3/month	0.11 - 0.36	Assumed material's maximum storage height: 4m. Adopted: rent of storage square near Oborniki Śląskiecommune
Under-roof biomass storage[17,18]	€/m^3/month	0.44 - 0.80	Adopted: installation of a rented warehouse tent was assumed to be installed on a rented storage square
Warehouse biomass storage[19]	€/m^3/month	0.89 - 2.11	Adopted: rent of warehouse near Oborniki Śląskie commune

6 https://zlotow.pila.lasy.gov.pl/sprzedaz-drewna#.Y9Yp_a2ZO3A
7 https://www.gov.pl/web/nadlesnictwo-swidnik/wystapienia-komunikaty-i-ogloszenia
8 https://edu.trans.eu/kursy/transport-drogowy/ceny-w-transporcie/3
9 https://www.instalacjebudowlane.pl/152-33-68-wartosc-energetyczna-drewna-opalowego--tabela.html
10 https://www.farmer.pl/technika-rolnicza/maszyny-rolnicze/zniwa-2022-stawki-za-prasowanie-slomy,121535.html;
11 https://edu.trans.eu/kursy/transport-drogowy/ceny-w-transporcie/3
12 http://www.amazonepolska.pl/pdf/RB344R.pdf
13 https://strefaagro.pl/cena-suchej-slomy-ile-kosztuje-bela-na-poczatku-2023-roku-czasem-stara-slome-ktos-oddaje-za-darmo-lub-za-obornik/ar/c8-15106150
14 http://www.amazonepolska.pl/pdf/RB344R.pdf
15 https://www.prawo.pl/kadry/na-jaka-wysokosc-mozna-ukladac-na-palecie-zmanipulowane-drewno,192996.html
16 https://www.olx.pl/d/nieruchomosci/dzialki/wynajem/dolnoslaskie/q-plac-sk%C5%82adowy/
17 https://neodynamik.pl/?gclid=CjwKCAiA3KefBhByEiwAi2LDHHIpnqt3kREpWDuq0ze7JqvxmCixA3hCryEV5C5S2D9XUC8CCPYavBoCTIkQAvD_BwE
18 https://www.halenamioty.com.pl/wynajem/
19 https://www.olx.pl/d/nieruchomosci/hale-magazyny/wynajem/oborniki-slaskie/?search%5Bdist%5D=10

Activity/Stage	Unit	Cost	Comments
Pellets production[20] [21]	€/t	40 - 70	Cost of pellets production depends on the capacity of the installation, type o material (straw, wood, etc.)
Straw pellets (cost of fuel)[22]	€/t	222 - 622	Loco price (producer). Cost depends on the packing method (big-bag, small bag, loose form)
Wood pellets (cost of fuel)[23]	€/t	356 - 706	
Pellets storage at the producer[24] [25]	€/m^3/month	0.58 - 2.81	Adopted: pellet's maximum storage height: 3m; storage at rented warehouse tent/warehouse (under the roof in relatively dry conditions)
	€/t/month	0.77 - 4.69	Assumed pellet's bulk density: 600-750 kg/m^3
Pellets transportation to final user	€/km	0.4 - 1.1	Based on consultation with local shipping companies

4.4 Location of BECoop RESCoop

The proposed logistic chain is intended to operate within the area of the Oborniki Śląskie commune, which is known for its dispersed residential buildings (Figure 14). Similarly, the biomass material (straw and wood) should come from the local area, and the pellets production line should also be located in this region. Therefore, for a Polish OBS Pilot Area it was assumed that the radius for the Polish case is around 30 km. The potential sources of wood biomass and straw are shown in Figure 13, respectively. As part of the BECoop project and as a result of discussions with stakeholders, it was assumed that the pellet production line could be located in a local sawmill or in/at a wood processing plant (e.g. production of transport pallets, production of wooden furniture, etc.). The possible locations of the pellets production line are indicated in Figure 14. Finally, the scattering of larger pellets consumers are presented in Figure 15.

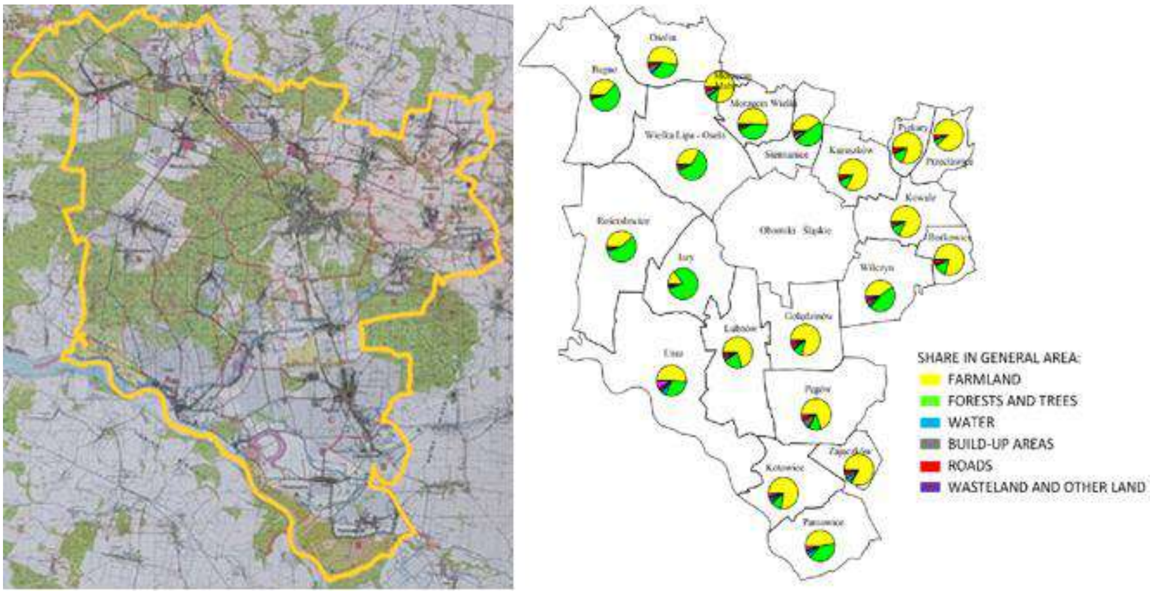


Figure 14 Left: The map with scattered build-up areas (potential final users) in Oborniki Śląskie commune;
Right: Share of crops fields (straw potential) and forest (wood biomass potential) in Oborniki Śląskie commune

[20] https://wilczynscy-ogrody.pl/produkcja-pelletu-ze-slomy-krok-po-kroku-na-wlasne-potrzeby-koszty-i-oplacalnosc/
[21] https://technomaszbud.pl/oplacalnosc-produkcji-pelletu-z-trocin
[22] https://www.olx.pl/d/oferty/q-pellet-ze-s%C5%82omy/?search%5Border%5D=filter_float_price:asc&search%5Bfilter_float_price:from%5D=1000&search%5Bfilter_float_price:to%5D=3000
[23] https://www.olx.pl/d/oferty/q-pellet-drzewny/?search%5Border%5D=filter_float_price:asc&search%5Bfilter_float_price:from%5D=1000&search%5Bfilter_float_price:to%5D=5000
[24] https://www.olx.pl/d/nieruchomosci/hale-magazyny/wynajem/oborniki-slaskie/?search%5Bdist%5D=10
[25] https://pellet4you.pl/abc-pelletu/magazynowanie-pelletu/

Figure 15 Potential locations of pellets production line commune and identified major consumers of biomass pellets in Oborniki Śląskie commune

4.5 Technology and Activity of the BECoop RESCoop

In terms of acquiring biomass for energy purposes in the region, agricultural and forest biomass are the main sources. However, in the near future, other types of biomass residues are also being considered, as OBS Commune is responsible for the proper management of bio-residues collected from the region. The key element of the short logistic chain is the pellet production line. Taking into account the potential market competition and ensuring the continuity of operation, it was assumed that the capacity of the installation should range from 0.5 to 1.0 t/h. The other boundary conditions related to the pellets production line are, as follow: the plant operates only on working days (about 260-310 days per year), the daily operation time of the production line is about 8-12 hours. As a result, the production line should produce about 1,040-3,720 tons of pellets annually. The pellet will be distributed among local residents (and other final users) that heat the households by automated biomass pellets boilers. The boilers will be provided by the households owners itself. Only larger capacity boilers, in the case of small district heating creation, could be installed within the RESCoop. Within the technical services, the representatives of OBS Commune and local entrepreneurs have visited the company that is specialized in biomass boilers design, production and installation.

4.6 Energy demands to be covered

The OBS Commune area is around 154 km^2. There are no local heating networks in the Oborniki Śląskie commune. Residential buildings, public utility buildings, SMEs and production companies are supplied with heat by means of local heating stoves or their own boiler rooms. The heat consumers in the commune, besides the city of Oborniki Śląskie, are very dispersed. In OBS Commune there are 5,478 households and the population density is around 131 prs/km^2. Residential buildings are heated mainly with eco-pea coal, coal, electricity, natural gas. Other heating sources, like fuel oil, LPG, wood, heat pumps are a minority of heating systems.

For the calculation of the indicative heat demand for the commune, the average energy consumption index 198.0 kWh$_t$/(m^2·year) has been applied. The usable floor area of apartments in the OBS commune amounted to 659,452 m^2 (data from year 2015). Hence, the heat demand in the OBS commune is 130,571.5 MWh$_t$/year[26].

Based on the average thermal insulation standard of households in the OBS commune it has been assumed that one household fired by coal (main source of heat in the commune) consumes around 6 t/year (for coal

[26] Założenia Do Planu Zaopatrzenia W Ciepło, Energię Elektryczną I Paliwa Gazowe Dla Gminy Oborniki Śląskie Na Lata 2016 - 2030

LCV=24 MJ/kg). As a result, if we assume that 50% of households are directly or indirectly fired by coal then the heat demand for those households in OBS commune amounts to 109,560 MWh_t/year.

Taking into account that the technical energy potential from local biomass resources analysed in this Polish OBS Pilot Area is 17,940 MWh_t/yr, it can be assumed that **around 15-20% of the heat demand by the households could be covered**.

In terms of pellets production line with a capacity of 0.5 – 1.0 t/hr (initially proposed in the OBS Pilot Area) it is possible to provide 3,120 tons of pellets. Taking into account the average energy demand by the household (6 tons of coal) it is feasible to provide the fuel in the form of biomass pellets for around 350 households.

4.7 Feasibility Study of the BECoop RESCoop

4.7.1 Boundary Conditions for the feasibility study

This analysis was based on the initial concept of OBS as outlined in their roadmap (T4.1), and was conducted to determine its feasibility. The aim is to construct a pellet production plant in the local area and install approximately 830 domestic boilers (average value of 16 kW) in the local residential and municipal buildings. The total production capacity of the plant has been estimated as 3,170 t pellet/year with a total investment of 2.9 million Euros. To that end, QPLAN/CBS gathered the necessary information from the technical partners and conducted the analysis. The breakdown of the capital and operational expenses as well as the revenues can be seen below. For the investment evaluation, critical financial indicators were calculated to demonstrate the profitability of the case.

Before diving into the cost benefit analysis and the cumulative cash flow table, it is needed to state the assumptions and the formulas upon which the feasibility study was based to conduct. These assumptions were received after careful considerations among the technical and pilot partners in order to reflect the most appropriate conditions for the analysis and align the profitability with the reality. The most important ones are:

CAPEX breakdown: (2,878,790 €)

- One pellet production plant with a capacity of 3,170 t/year
- Transportation cars and machinery/equipment
- 830 biomass boilers (thermal power in the range of 8-24 kW)
- R&D, permits and taxes
- No use of subsidy or national grant

OPEX breakdown for the required pellet for the 830 boilers ~ 3,170 tonnes produced **(869,461 €)**

- Pellet production plant operational costs **(40 €/t)**
    - Thermal demands
    - Electrical demands
    - Dryness
    - Pelletizing
    - Packaging
- Machinery and vehicles maintenance and depreciation **(20 €/t)**
- Biomass logistics (pruning, wood waste, forest residues) **(46 €/t)**
    - Collection
    - Transportation
    - Storage
- Labour costs **(60 €/t)**

- Other costs **(89,525 €)** annual fees and yearly service of the equipment which includes pellet production plant machinery and cars as well boilers and they are assumed at the level of 3% of the initial value of all used equipment.

Revenues breakdown:

The revenues have not been calculated with the current price due to the energy crisis but with a lower value (400 Euros/t) which is more realistic for the near future.

- Selling pellets to public buildings at around 400 €/t
- Installation and maintenance costs are included in the prices above.

4.7.2 Economic Indicators (IRR, NPV, PBP)

For the calculation of economic indicators that assess the viability of an investment, it is necessary to conduct a cash flow analysis. The results of the analysis can be seen in Table 26.

Table 26 Cash Flow Analysis

CUMULATIVE CASH FLOWS								
Years	CAPEX €	OPEX €	Inflation Rate	Revenues €	Cash flow €	Cumulative	PV €	NPV €
0	2.878.790	0	2,00%	0	-2.878.790	-2.878.790	-2.878.790	-2.878.790
1		869.461	2,00%	1.248.000	378.539	-2.500.251	371.117	-2.507.673
2		869.461	2,00%	1.248.000	378.539	-2.121.711	363.840	-2.143.833
3		869.461	2,00%	1.248.000	378.539	-1.743.172	356.706	-1.787.127
4		869.461	2,00%	1.248.000	378.539	-1.364.633	349.712	-1.437.415
5		869.461	2,00%	1.248.000	378.539	-986.094	342.855	-1.094.560
6		869.461	2,00%	1.248.000	378.539	-607.554	336.132	-758.428
7		869.461	2,00%	1.248.000	378.539	-229.015	329.541	-428.887
8		869.461	2,00%	1.248.000	378.539	149.524	323.080	-105.807
9		869.461	2,00%	1.248.000	378.539	528.064	316.745	210.937
10		869.461	2,00%	1.248.000	378.539	906.603	310.534	521.471
11		869.461	2,00%	1.248.000	378.539	1.285.142	304.445	825.916
12		869.461	2,00%	1.248.000	378.539	1.663.681	298.476	1.124.392
13		869.461	2,00%	1.248.000	378.539	2.042.221	292.623	1.417.015
14		869.461	2,00%	1.248.000	378.539	2.420.760	286.885	1.703.901
15		869.461	2,00%	1.248.000	378.539	2.799.299	281.260	1.985.161
16		869.461	2,00%	1.248.000	378.539	3.177.839	275.745	2.260.906
17		869.461	2,00%	1.248.000	378.539	3.556.378	270.339	2.531.245
18		869.461	2,00%	1.248.000	378.539	3.934.917	265.038	2.796.283
19		869.461	2,00%	1.248.000	378.539	4.313.456	259.841	3.056.124
20		869.461	2,00%	1.248.000	378.539	4.691.996	254.746	3.310.870
21		869.461	2,00%	1.248.000	378.539	5.070.535	249.751	3.560.621
22		869.461	2,00%	1.248.000	378.539	5.449.074	244.854	3.805.475
23		869.461	2,00%	1.248.000	378.539	5.827.614	240.053	4.045.528
24		869.461	2,00%	1.248.000	378.539	6.206.153	235.346	4.280.874
25		869.461	2,00%	1.248.000	378.539	6.584.692	230.731	4.511.605

As it can be seen from the graph (Figure 16) and the results of the investment planning (Table 27), it appears that the concept is profitable and offers a payback period of 7.6 years. To the best of the results, safety factors and conservative scenarios were integrated due to the current energy crisis and the huge fluctuations in energy prices. The projection of the concept's profitability is highly related to the revenues which have been calculated as 400 €/t including installation and maintenance costs, whereas nowadays this cost meets the price of 570 €/t and above. This concept as can be seen from the section below is about to be implemented from 2025 onwards when decrease in all energy prices is expected.

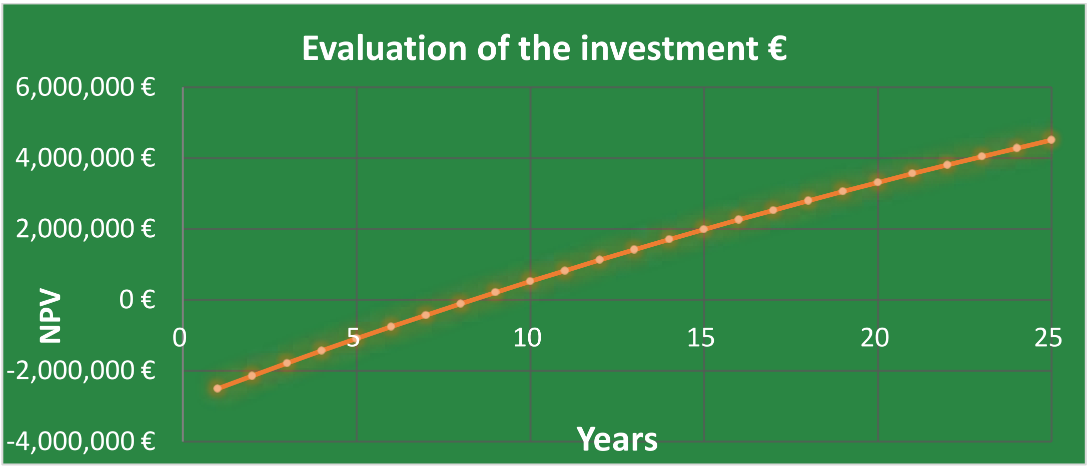


Figure 16 Graph of the investment planning

Table 27 Results of the investment planning

Net Present Value	4,511,605
Return On Investment	13.15%
Pay-pack period	7.60 years
Internal Rate of Return	6.98%

On the other hand, as we can see from the graph below (Figure 17), the current energy costs in the OBS commune are highly dependent on the consumption of fossil fuels. There is also a contribution of biomass with firewood where it has massive potential in the area. As it can be seen from the graph, pellets seem to be the cheapest energy solution for heating in the local area. The construction of the pellet production plant and the installation of the domestic boilers will offer significant relief to the citizens and will face local energy poverty by reducing their energy bills to the minimum. It is realised that the pellet plant will offer a lot of benefits to the local community across economic, environmental and social dimensions. Therefore, it should be considered a viable project both for the current period and the short-term future, which offers a cheap, and at the same time sustainable solution.

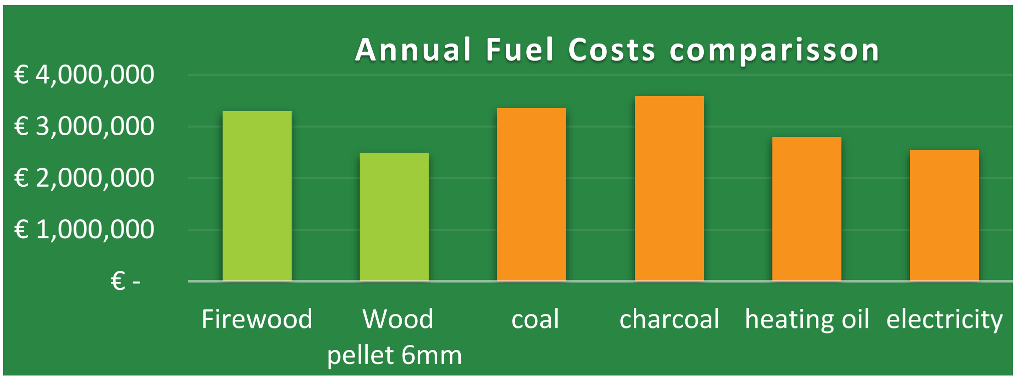


Figure 17 Graph of the fuels costs comparison

1.1 Technical field visits

Field Visit: Biomass fuels production local company

Brief Description:	A technical field visit took place in a neighbouring commune at a local entrepreneur (SME) operating in a rural area, which deals with the processing of various types of biomass waste (e.g. wood pellets and crates, branches from pruning roadside trees and shrubs) and forest biomass into usable fuel in the form of wood chips, logs and briquettes. There are also plans to launch a small pellet production line. The meeting concerned the discussion of logistics processes, sources of biomass, the sale market and problems related to production costs and electricity prices.
When:	18 January 2023
Where:	Strzeszów, Poland
Why:	To observe the collection/production/storage stages of the different types of biomass (logs, wood chips, briquettes) realized by small local company located at rural area.
No of participants:	5
Type of stakeholders:	Farmer, Entrepreneur-activist

Field Visit: Biomass boiler production company

Brief Description:	As part of the technical visit, a meeting was organized at the MetalErg company (Oława, Lower Silesia), which specializes in the production of medium-capacity boilers for burning biomass (especially straw). During the meeting, the production line and technical solutions of boilers that could function as a local heating plant were presented. The technical requirements, service needs, and fuel requirements, as well as the potential and possibilities of project support, were discussed in the context of creating an energy cooperative. Energy aspects were also considered. The company expressed its willingness to cooperate in the utilisation of biomass for energy purposes by providing their technical solutions.
When:	7 April 2023
Where:	Oława, Poland
Why:	Become familiar with the technical capabilities of boilers designed for burning local biomass, particularly straw. This is especially important in the event of a possible decision to construct a medium-sized local heating plant, where we can utilize these boilers.
No of participants:	5
Type of stakeholders:	Commune representative, Entrepreneur-activist, Entrepreneur – biomass producer

Field Visit: Biomass pellets production company	
        	
Brief Description:	The visit to the medium-capacity pellet production plant (capacity: 1.5 t/hour) was aimed at getting acquainted with the actual process conditions, biomass requirements and key elements of the installation. In addition, the topic of storage space was discussed for both the substrate and the final product (pellet). Potential threats related to the investment and production process were discussed.
When:	13 April 2023
Where:	Ciepłowody, Poland
Why:	Getting acquainted with the real conditions, requirements and possibilities of pellet production from agricultural and forest biomass using a medium-capacity production line.
No of participants:	4
Type of stakeholders:	Commune representative, Farmer, Entrepreneur

Field Visit: Straw bales transportation in the region

Brief Description:	The technical visit for the transportation of straw bales from local fields was organized to gain knowledge about the logistics data involved in the process, such as the yield of straw harvesting, loading times, bale sizes, transportation options and capacities, and other relevant information. It was observed that farmers are well prepared for such activities. They are equipped with the machinery required. There are no technical barriers in this logistic process.
When:	20 July 2022
Where:	Paniowice, Poland
Why:	To get some practical knowledge in terms of logistic process of straw bales collection and transportation in the OBS area. Within RESCoop the straw bales must be transported to the company dealing with pellets production.
No of participants:	4
Type of stakeholders:	Commune representative, Saw mill entrepreneur, farmer

4.8 End users/local actors identified for cooperation

As part of the BECoop project's activity in the local OBS Pilot Area related to the proposed logistics chain, various stakeholders have been identified and contacted (with the support of the BECoop e-market environment). These local actors have been assigned to one or more steps of the logistics chain based on their role and intention. Taking into account the strategy adopted by OBS Pilot Area, the effort have been directed to the following actors:

- Farmers (agricultural biomass providers),
- National Forest Department (forest biomass provider),

- Forest management company (biomass harvesting from forests),
- Sawmill owner (potential pellets producer),
- Entrepreneurs (potential pellets producers, biomass boiler providers/installers, etc.),
- Final users (biomass pellets consumers).

4.8.1 Potential End users

In the Polish OBS Pilot Area there is a large group of different potential local end users (residents, institutions, organizations, companies) that are interested to be a part of the proposed concept (heating generation from biomass), including:

- residents and households owners,
- schools,
- church,
- social welfare home,
- farmers,
- SMEs.

To engage/convince the final users to the proposed concept focused on local biomass utilisation for energy purposes, technical support has been provided. Technical services and consultations took place during different events and direct meetings with stakeholders. The list of the consulted issues and topics related to the technical support can be found in the Annex II.

4.8.2 Local actors interested in cooperation

During the warm-up events and other meetings performed at the OBS Pilot Area, some stakeholders with a very positive attitude have been detected (Table 28).

Table 28 List of main stakeholders

Stakeholder	Role
OBS commune	Partner of BECoop project and main initiator intended to develop the short logistic biomass value chain to be used for heating purposes.
Local resident (activist)	There is a local resident of the cottage that is very active in the area of environmental protection. The resident owns a new biomass boiler fired by pellet and is against coal combustion. He is definitely positive for the creation of the bioenergy cooperative in the region, and is very conscious of the economic, environmental, and social benefits. Unfortunately, because of the current energy and economic crisis, he is not able to engage other people to be active and more open for a co-operation.
Local entrepreneur	In the commune adjacent to the commune of Oborniki Śląskie, an entrepreneur was identified who conducts commercial and service activities related to the processing of all types of waste biomass. The entrepreneur buys or takes waste biomass from road maintenance, cleaning of forest areas, as well as forest biomass. Depending on the form and properties of the biomass, it produces wood logs, wood chips or briquettes. The produced biomass fuels are sold for heating purposes to residents or other entrepreneurs. Larger quantities of wood chips are sold to a large CHP plant located approximately 40 km away. The owner is very interested in further development of the company and increasing the potential of using biomass for heating purposes on the local market. He believes that an energy cooperative could be a solution that would help him achieve his goal. He is very open for co-operation in this field.
Farmers	In the OBS commune there are two farmers with large-area cereal crops and, as a result, produce significant amounts of post-harvest straw. Farmers are willing to cooperate in the supply of agricultural biomass for energy purposes. In the current situation, however, the

	problem is the high price of gas, and thus fertilizers, which made it necessary to change the strategy and leave straw on the field as a source of mineral compounds and nitrogen. Nevertheless, they maintain that in the event of positive changes, they will return to the possibility of selling straw for energy purposes.
Local engineering office	Expert of the buildings and heating plants features and performance, promoter of other local projects for biomass to heat mainly by boilers.
Local forestry company	Promoter of the management activities for organizing the exploitation of local forest biomass.
Municipal energy advisor	A commune energy advisor working in the Voivodship Fund for Environmental Protection and Water Management (WFOSiGW) is assigned to the commune. A meeting was held with an employee who showed great interest in the strategy of creating an energy cooperative. He offered his help in presenting the possibilities of financial support from the funds and programs offered by WFOSiGW.
Local industries and commercial activities	In the three municipalities involved in the BECoop RESCoop there are several companies and industries involved in the food transformation and production market. Such companies can represent an interesting constant energy consumption.

4.9 Additional technical support activities

4.9.1 Tests on mechanical durability of pellets

Within technical support actions in OBS Pilot Area, the tests of biomass pellets (Figure 18) have been organized (3 November 2022). The standards procedures during the tests were applied. The potential stakeholders (i.e. biomass pellets final users) could obtain information about the properties of the biomass pellet as a fuel for heating purposes.

Figure 18 Mechanical durability of pellets tests

Main attention was focused on the importance of the adequate mechanical durability of pellets and its influence on storage, transportation and combustion in the boiler. The rules and advices related to storage conditions of pellets in the households were discussed, as well. More details related to this topic can be found in Deliverable 4.4.

4.9.2 Moisture absorption by different forms/types of biomass

Another activity related to technical support actions in OBS Pilot Area was focused on the impact of moisture on the quality of biomass fuels (Figure 19). The presentation together with the measurement of the physical propensities (water absorption ability) has been performed (11 February 2023). This technical service was organized as many residents were asking about the conditions and requirements for biomass storage. As the storage procedures depend on the form and type of biomass, the visual tests have been prepared to facilitate understanding and importance of that issue.

Figure 19 The Influence of moisture on biomass fuels quality

This technical activity increased the attention to the methods of storing various solid biomass fuels.

4.9.3 Bulk density for different forms/types of biomass

In terms of biomass storage and transportation, the bulk density of biomass is another important factor as it is influential to the required storage space, truck volume and costs. As a result, an active presentation was performed during the measurement of the bulk density of various forms and types of biomass as part of the technical support service, with stakeholder engagement (Figure 20). This practical exercise was organized as many households are not prepared to store the whole amount of biomass in the dry and well-ventilated storage room, especially in the case of replacement of peat coal by biomass pellets or briquettes (coal can be stored also in open-air). As the storage space can be limited it is crucial to know how much biomass in the given form/type the final users are able to store at once. The visual tests facilitate understanding the importance of that factor.

Figure 20 The Influence of bulk density on storage and transportation space

This technical activity provided knowledge in terms of space required for storage and transportation of different types/forms of biomass.

4.9.4 Physical-chemical analysis of selected biomass

The typical biomass fuels are forestry wood and agricultural straw, although OBS commune is responsible for selective collection of other bio-residues too. Moreover, in the region there are also various fruit orchards that can also provide some wooden biomass. Finally, some other biomass potential can be obtained from the food processing sector and bio-residues collection from households. As a result, it is important to know the main physical and chemical properties of those fuels as they can play significant role in the road map to increase the utilisation of local biomass residues for heating purposes in the near future. The analysis of various feedstocks' fuel performance is presented in the Annex.

4.9.5 Local technical workshops

Three local technical workshops were organised with the aim to provide practical knowledge regarding the creation/development of bioenergy cooperatives, the local potential of biomass in the Polish OBS Pilot Area and the technical support tools developed by the BECoop project. The workshops were addressed to all stakeholders that are a part of the logistic chain, from biomass producers to final consumers, also including the local government representatives and other institutions that could steer the process of energy cooperative creation, or help in founding acquisition to support these initiatives. Moreover, the workshops were also opened to external audience (from other regions) that would like to gain some knowledge in this issue and initiate such activities in their own area. More details on the workshops can be found in the Annex.

a) b) c)

Figure 21 Local technical workshops in OBS Pilot Area

5 Italian BECoop RESCoop

5.1 Introduction to the BECoop RESCoop

The pilot case of the three municipalities of Mortirolo (Figure 22) is framed in the context of **Valtellina** (Province of Sondrio, northern Italy), where **successful experiences of forest biomass DH systems** can be found (e.g., TCVVV of Tirano) and **uses of wood biomass in domestic boilers and stoves** are available. The intention to develop a biomass DH system has been confirmed by the three municipalities, which are sensitive to sustainability issues at the community level.

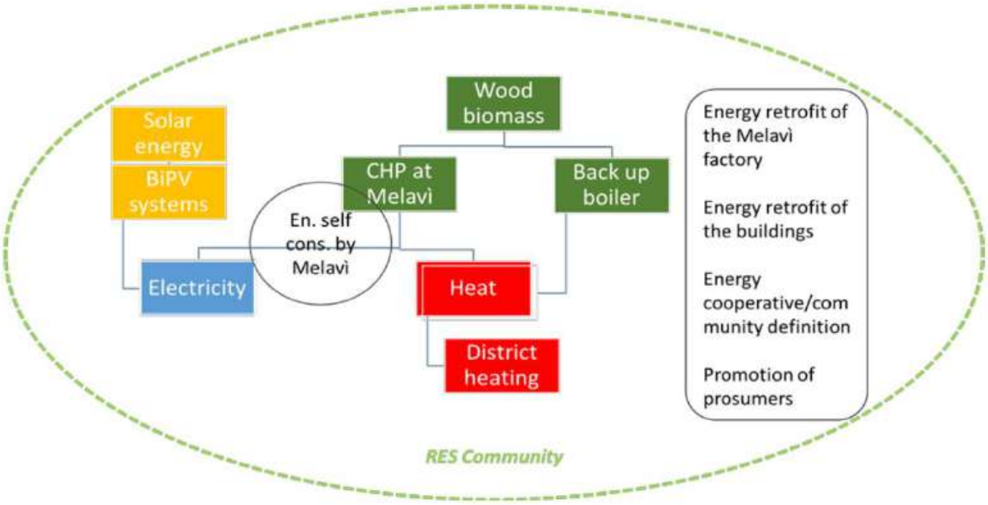


Figure 22 The original scheme of the Italian pilot, involving, firstly, the municipality of Tovo.

Throughout the development of the BECoop project, the **most suitable scenarios for the uptake of the bioenergy community were assessed and defined**. In addition, some objectives, and characteristics of the bioenergy vision in the pilot are changed slightly. Many users have shown interest in the project, but the involvement of the Melavì cooperative has not yet been defined.

The three municipalities, in collaboration with FIPER and local stakeholders, have decided to establish a benefit company (a 'Società Benefit') as the optimal governance model for developing the bioenergy community.

5.2 Biomass Assessment

Based on the characteristics of the pilot, it has been decided that the BECoop and RESCoop will focus on **developing a complete forest-wood chain**. Indeed, a consistent share of the woodlands surrounding the municipalities of Tovo Sant'Agata, Lovero e Mazzo di Valtellina are private and in some cases owned by citizens of the same municipalities, target users of the foreseen bioenergy community. Moreover, based on the results of the activities accomplished during the BECoop project, the local companies active in the field of forest management and wood industry could be involved in the BECoop RESCoop development and uptake.

For the assessment of the available quality and quantity of biomass to be used in the RESCoop, different considerations and methods have been adopted, mixing:

- interviews of wood industry and forest management stakeholders,
- scientific and technical literature references,
- and the use of web tools, available in the BECoop Toolkit.

5.2.1 Type of biomass to be used by the BECoop RESCoop

The biomass to be used is expected to consist mainly of woodchips from surrounding woodlands, in addition to pruning by-products. The quantity of wood chips has to be compatible with the size of the system and the thermophysical characteristics of woodchips need to be suitable for combustion. To achieve this, local wood industry stakeholders will be invited to negotiate agreements and contracts that ensure the appropriate characteristics of the wood biomass used in the plant, including details on quantities, quality, and prices.

For estimating the energy content of the available biomass in the early stage of the RESCoop development process, an average LHV of the woodchips, based on the experience of the local stakeholders involved, was assumed around 9-10 MJ/kg. A further rough estimation of the woodchips energy characteristics and the type of local forest biomass are presented in Table 29 and Figure 23. **Through the tools "Bioraise", available in the BECoop Toolkit**, the energy potential has been estimated in a short radius of 7 km (including the territory till Tirano facility) from the Melavì facility, along with the surrounding trees' typology and surface and are presented in the following table and figure, with the most surface belonging to forest areas:

Table 29 Biomass potential according to Bioraise tool

Type of biomass	Energy content (GJ/year)	Surface of potential resources (ha)
Rainfed crops	3,525	53
Vineyard	11,061	344
Conifers	18,104	2,409
Broadleaved species	5,051	943
Mixed	1,920	293
Shrub	5,416	910
Total	45,077	4953

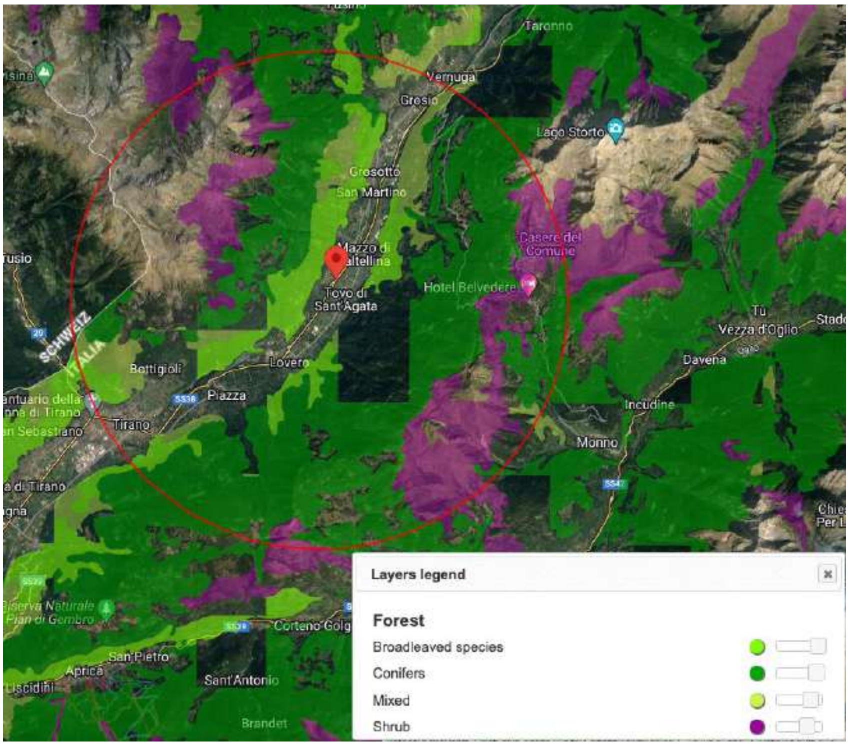


Figure 23 Type of forest biomass in 7 km radius, by Bioraise tool

5.2.2 Quantities to be used by the BECoop RESCoop

The quantity of biomass that will be available is strongly affected by several parameters, such as the adhesion of citizens that own a consistent share of the surrounding woodlands, the surface available and the capacity of the involved companies. An estimation of the possible adhesion has been carried out by submitting a questionnaire to citizens (see also next sections). In the questionnaire, information about citizens that own a private wood area and are interested in making it available for the project have been collected. In particular, on a sample of 161 citizens, the 57% declared to be owner of a private wood area, of which the 88% declared to be interested in selling wood or making the wood area available for the BECoop RESCoop wood chain.

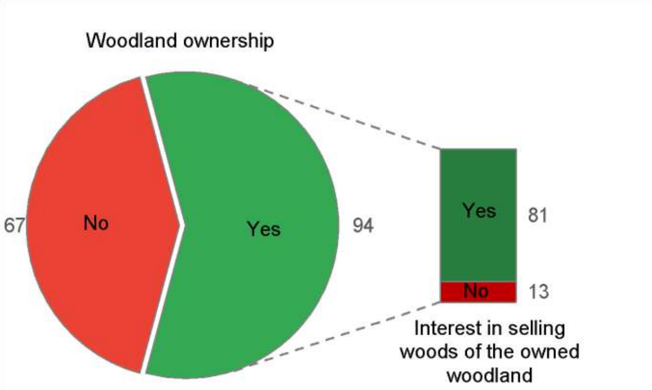


Figure 24 Citizens owners of woodlands and interested in providing wood chips for the Italian pilot

While the results suggest the possibility of utilizing a large area of the surrounding woodland, this information must be further verified through additional investigations involving stakeholders.

In addition to this, a further rough estimation of the possible quantities of available biomass are presented in Table 30 and Figure 25. These estimations have been carried out through the tool “Bioraise”, by assuming a radius of 7 km from the possible location of the DH plant. The quantities estimated by Bioraise are almost the double of those estimated based on the local expertise. In both cases, according to the estimations on the possible size and production by the DH system to be realized, these quantities are not sufficient, so woodchips produced in other area should be integrated.

Table 30 Estimation of the biomass potential according to the tool Bioraise

Type of biomass	Surface of available resources (ha)	Available resources (dry tonnes/year)
All categories	4,944	2,656

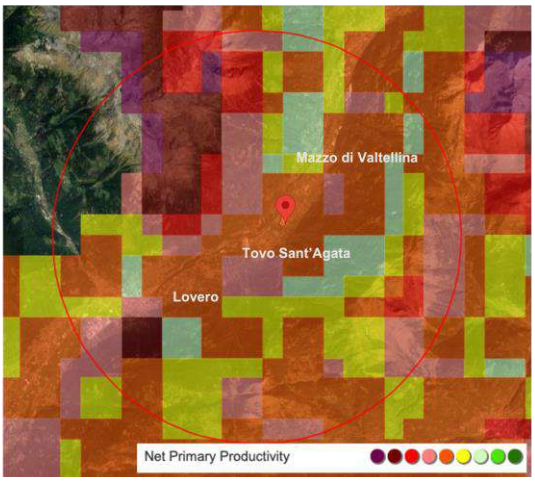


Figure 25 Net productivity of wood biomass according to Bioraise for the area under investigation.
The legend qualitatively shows a range from high values in green, 0,5 ton/ha, to lower values in red, 0,05 ton/ha

To obtain a more accurate estimate of the availability of wooden biomass from the woodlands surrounding the three municipalities, local companies were interviewed as part of local initiatives promoted by FIPER. Table 31 presents the information concerning wood availability from the local forest.

Table 31 Information about wood availability from the local forest

Municipality	Total woodland surface (ha)	Private woodland surface (ha)	Public woodland surface (ha)	Productive woodland (ha)	Protected woodland (ha)	Woodland aboveground volume (m^3)	Yearly volume increase in productive woodlands(m^3)	Yearly volume increase in protected woodlands (m^3)	Total yearly volume increase (m^3)
Mazzo di Valtellina	999.4	697.7	301.7	559.4	440	188,368.5	2,121	1,300	3,421
Lovero	969.3	757.4	211.8	513.3	456	178,619.2	1,912.5	1,119.2	3,031.7
Tovo S.A.	710.5	553.9	156.6	407.9	302.6	125,925.6	1,584.4	731	2,315.4
Total	2,679	2,008.1	670.1	1,480.6	1,198.6	492,913.3	5,617.9	3,150.2	8,768.1

source: Panizza, forest engineering –Ambiente Valtellina ETS - personal communication

Assuming to exploit the yearly increase of the productive woodlands, and an average density of 0.7 t/m^3, the available biomass amounts to: 5,618 m3 * 0.7 t/m3= 3,933 tonnes (wet basis), quite similar to the value obtained by the Bioraise tool. Although the estimated value may not seem sufficient to feed the biomass DH system, the great availability of privately owned woods in the neighbouring territories of Medio-Alta Valtellina should be underlined. In a further radius of e.g. 20- 30 km, there is a huge potential of forest biomass in the nearby area. The local woodlands and forests are currently underutilized; therefore, the owners may be in favour of economically exploiting these resources thanks to the operation of the biomass DH system and becoming prosumers.

5.3 Logistics of BECoop RESCoop

5.3.1 Value chain description

The mechanization of forestry operations is essential to optimize the collection of wood for different uses. The final value of the wood used is strongly influenced by the costs of forestry operations. For this reason, estimating these costs is one of the objectives of the pre-feasibility study, taking into account the specific conditions of the forestry sites and the local context, such as the type of use and whether the area is public or private [27]. The biomass for the BECoop and RESCoop will be collected through the following forest management operations:

Renovation cut:

To promote the establishment of new growth or to encourage existing growth in the coniferous woodlands within the territory of the three municipalities, a renewal cut is performed. The renewal cuts produce from 150 to 300 m^3/ha of roundwood and 30 to 90 tons of fresh biomass, from the recovery of branches and tops. In general, the recovery of scraps allow to obtain approximately 300 kg of additional biomass for each m^3 of roundwood used. When only the tops are recovered, this quantity drops to about 100 kg/m^3 of log. The separate recovery of logs and tops is rarely worthwhile. Vice versa, the extraction of the whole plant is much

[27] Raffaele Spinelli- CRN- Woody biomass: green oil for district heating

more effective and allows an additional gain variable between 10% and 30% compared to what can be obtained with the traditional short wood system. The more these activities are mechanised the greater is the benefit: the introduction of the processor allows a reduction in the processing cost of between 10 and 25%, depending on the type of machine. In this scenario, biomass recovery offers an additional income, which improves the situation but does not change it substantially. With regards specifically to biomass management, direct chipping of branches at the forestry site and transportation of wood chips is always the simplest, and generally, the most cost-effective option.

Thinning:

The thinning actions involve secondary formations of firs and pines (aged between 30 and 70 years), placed on fertile soils and accessible to mechanical means. The results demonstrate the economic convenience of this operation. From these interventions it is possible to recover from 50 to 100 tons of fresh biomass per hectare, depending on the degree of development of the stand and the intensity of thinning. If the plants are sufficiently developed, the mixed production of roundwood and wood chips can be considered, which is preferable when the price of wood chips is modest. This strategy is worthwhile only if it is possible to mechanize the collection by means of harvesters. On the other hand, chipping the entire plant remains the simplest and fastest option. In any case, thinning can become self-sustainable at a wood chip price of around 60-70 € per fresh ton, ex works.

Interventions in newly formed forests:

The interventions carried out on newly formed woods can pursue two distinct management approaches, depending on the quality of the population and the surrounding area. In high density woods, it is possible to opt for the restoration of grazing through clear cutting on small surfaces. Conversely, in the more open territories and with the most promising populations, one can think of a silvicultural valorisation of the evolving forest, to be implemented with selective thinning. Currently, the use of newly formed woods involves losses ranging between 500 and 2,000 €/ha: the application of conventional technologies does not seem to guarantee good results, because the diameter of the trees is too small to allow effective processing.

In brief, a general diagram of value chain operations that would be implemented by the Italian BECoop RESCoop can be found in Figure 26.

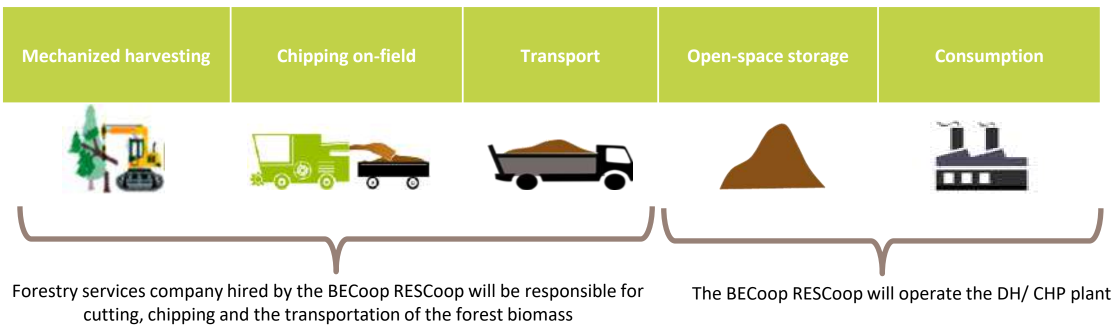


Figure 26 Diagram of value chain operations (forestry wood biomass)

5.3.2 Cost of collection

Some details of the logistics related to the supply of biomass for district heating and cogeneration plants with the related cost analysis are reported in Table 32.

Table 32 Costs of the biomass supply

Type of biomass used	Collection cost (€/t)	Chipping cost (€/t)
Virgin wood from the processing of logs (Diam. 15-50) resinous without branches	60-80	6.02
Debarked virgin wood chips of resinous or beech produced from the first sawmill processing	60-80	6.02
Chips with bark up to 7% of virgin wood resinous product from the first sawmill processing	60-80	6.02
Chips of virgin wood from processing of trunks (Diam. 15-50) resinous species with branches	50-70	6.02
Chips of virgin wood coming from processing in forest of tops and resinous twigs	40-50	10.08
Transport cost in short chain (70 km)	17-18	

5.4 Location of BECoop RESCoop

The area of the BECoop RESCoop includes the surface area of the three municipalities where users are located, as well as the local woodlands surrounding them, which serve as a biomass resource basin. Therefore, the central unit of the DHS will be located at the barycenter of the users' positions. To achieve this, the possibility of utilizing an industrial area on the Melavì site was preliminarily considered, resulting in a proposed location for the central thermal station and primary distribution network (Figure 27).

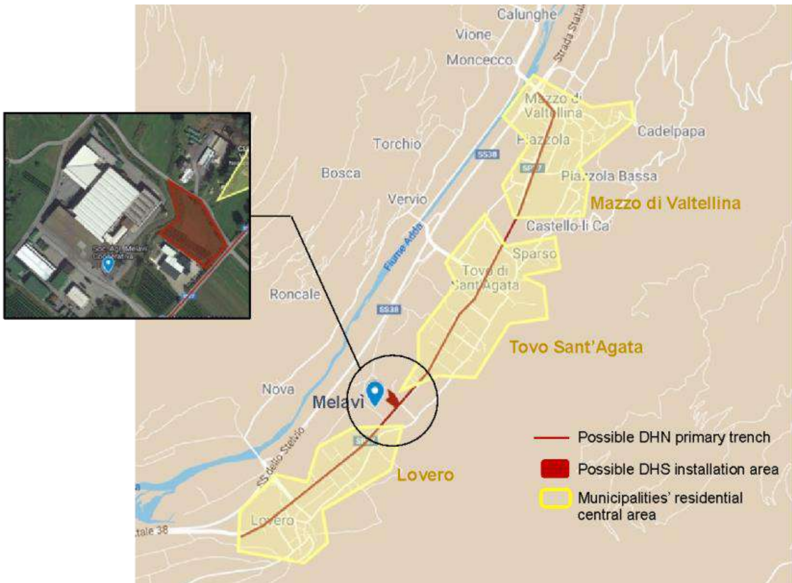


Figure 27 Hypothesis for the DHS location

The area individuated (in red, in Figure 27) is around 5,000-6,000 m^2, in line with the indication from analogous biomass DHS cases (e.g. Sluderno about 6,000 m^2, Cesano Boscone about 10,000 m^2, Villa Guardia 15,000 m^2).

5.5 Technology and Activity of the BECoop RESCoop

The technological set foreseen consists of a biomass-based CHP DH system for which different feasibility scenarios have been evaluated. At first, a brief technology review was carried out for individuating details on available technologies and market trends suitable for the Italian BECoop RESCoop case.

The Organic Rankine Cycle (ORC) technology was selected after examining best practices for CHP systems close to the characteristics of this particular case and consulting with experts in the CHP and the biomass fields. Furthermore, this technology is mostly used in the National context for similar plants. The configuration foreseen is similar to many cases in the Italian context, with a co-generative biomass energy system (thermal oil boiler + water boiler + backup + ORC unit), supplying heat to a high temperature (3GDH) DHN (90°C-60°C), as the one shown in Figure 28.

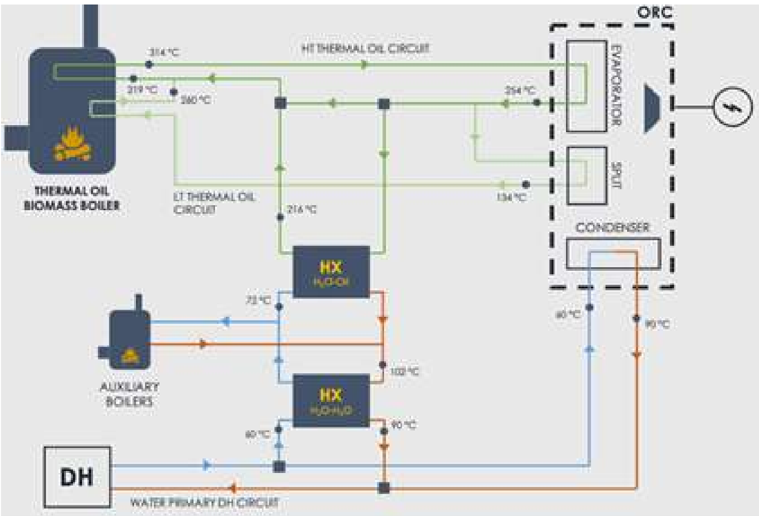


Figure 28 Scheme of the biomass CHP system

For the implementation of this study, questionnaire data retrieved by FIPER along with data retrieved by CERTH from equipment manufacturers, technology experts, ESCOs and from scientific literature were used. Based on these data and with frequent communication and collaboration between the two organisations, eleven different scenarios (with different configurations of CHP/DH) were evaluated techno-economically by CERTH, whereas the most realistic and best performing one are reported in the main body of the current deliverable, while the rest scenarios are briefly presented in the Annex. Based on the prevailing scenario, the following assumptions were formulated:

- The yearly heating demands of the three villages are set at 12,000,000kWh/year
- The demand will be met by the installation of a 3 MWth + 0.7 MWe Organic Rankine Cycle plant utilizing biomass, with an additional back-up biomass boiler of 3 MWth capacity that will help meet peak-demand and act as a back-up boiler
- The number of consumers are 753
- The number of substations serving these consumers are 300 substations
- The fuel for the biomass boilers are woodchips, sourced locally
- Maintenance set to 3 weeks per year, scheduled almost entirely during for summer months
- Finally, the operational mode that was selected was a mixed production model. For the seven months that heating is commonly used in the Lombardia region, the plant works on a production model based on meeting consumer heat demands. For the remaining five months of the year, the plant works as a dedicated electricity production plant, discarding waste heat and selling electricity to the grid.

Table 33 shows the working assumptions based on which the rest of the study was built on.

Table 33 Parameters considered for assessing the power of the generation plant.

Parameter	3 MW Back-up Boiler	ORC – 5 months only electricity production	ORC – 7 months CHP
Efficiency of the heating network	87.50%	87.50%	87.50%
Efficiency of the biomass power plant (net thermal)	85%	0%	68.86%
Efficiency of the biomass power plant (net electric)	0%	16.82%	12.73%
Nº of hours of operations (per year)	2520	3120	5000
Average Working load of the operation	60%	100%	61%
Thermal boiler efficiency	85%	85%	85%

Table 34 contains the assumptions considered for estimating the required amount of forest biomass to cover the feedstock demands of the BECoop RESCoop.

Table 34 Amount of the biomass needed to cover the energy demand.

Amount of forest biomass	3 MW Back-up Boiler	3 MW + 0.7 MWe ORC – yearly operations
Moisture of the forest biomass harvested (initial moisture)	37%	37%
Moisture of the biomass to be consumed in the boiler (final moisture)	28%	28%
Losses of forest biomass in the pretreatment and transportation process	5%	5%
Amount needed of forest biomass to be collected in the field (37% moisture)	1,881 tonnes	9,571 tonnes
Total biomass from forest (37% moisture)	**11,452 tonnes**	
Total biomass before boiler (28% moisture)	9,257 tonnes	

Furthermore, Table 35 contains the cost estimations, based on data both from official sources as well as from local stakeholders.

Table 35 Per tonne cost of the biomass needed to cover the energy demand.

Cost of the forest biomass	
Harvesting operations	70 (€/tonne)
Cost of the shredding operations	7 (€/tonne)
Transportation of forest biomass to the storage area	10 (€/tonne)
Total cost of the forest biomass to be harvested (37% moisture content)	87 (€/tonne)

The plant components are thereafter sized according to actual and forecasted thermal/electric demand according to the above assumptions, from which the techno-economic assessment of the Italian BECoop RESCoop was performed and is described in section 5.7.

5.6 Energy demands to be covered

The following methodologies were used to define the energy demands that are needed to be covered by the BECoop RESCoop. Based on estimates made on the results of the aforementioned questionnaire and on the dataset available for Regione Lombardia (CURIT, i.e. the cadastre of the heating systems, CENED, i.e. the database of the energy efficiency certifications of the buildings) and by the BECoop tools, the following elaborations were made.

Hotmaps (BECoop toolkit)

A preliminary analysis on the energy demands to be covered has been carried out through the **web app "HotMaps", available in the BECoop toolkit.** Such tool is useful for rough preliminary estimation of several indicators, among which heat demand density, visualized in a web GIS platform. The calculation of total heat demand carried out by HotMaps seems overestimated in comparison to the following results. This could be caused not only by the fact that also DHW demand is taken into account by HotMaps but also considering the approximation of the tools for a small area as that considered. For the calculation and spatial representation through HotMaps, the areas involved (surface of the three municipalities) has been selected with the selection tool and the hectare resolution has been chosen to match the desired level of detail. Results (Figure 29) indicate the selection of an area of 136 cells (=136 ha) which heat total demand amount to 29.24 GWh/y, with a heat density ranging from 0.5 MWh/ha*y to 817.2 MWh/ha*y.

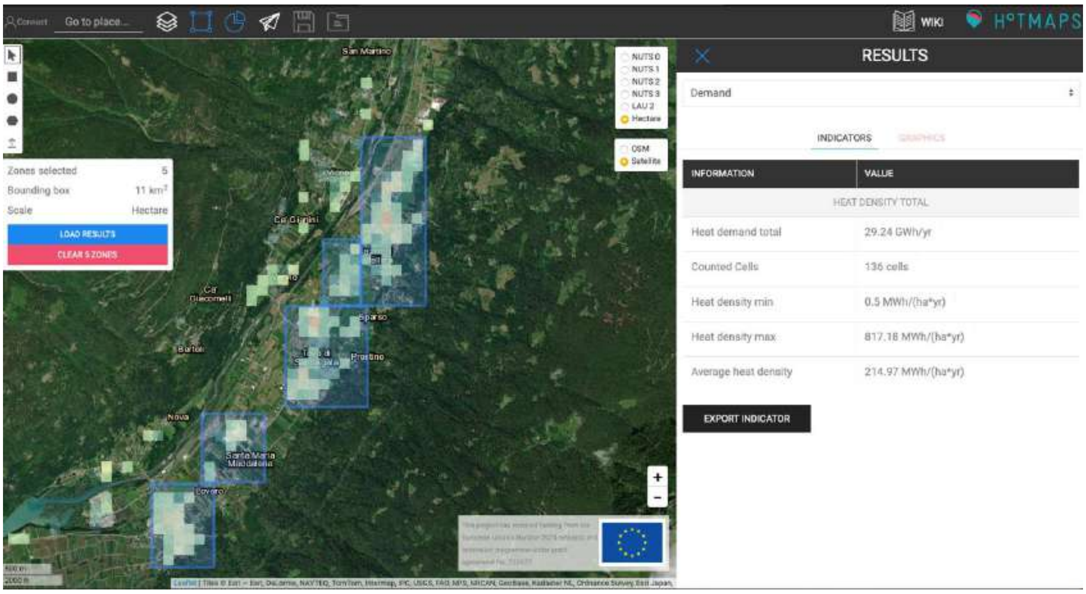


Figure 29 Results of the elaboration by HotMaps

CURIT, open data by Regione Lombardia

The CURIT database contains detailed information about the technical system of each registered house in Lombardy Region. Even if the data available are not complete, uniform and verified, the CURIT cadastre can be adopted for carrying out rough estimations of the average thermal power of the heating systems in the three municipalities. In Table 36, an estimation of the total power to be installed in substations and in the central plant of the DH is provided. The estimation has been carried out both for the whole sample of dwellings available for the three municipalities and for a smaller share of dwellings that are currently fuelled with fossil fuels, that are more likely interested in joining a DH network.

*Table 36 Estimation of the size of the biomass DH system**

	Total Power to be installed in users' substation (MW)	Total Power to be installed in the central thermal station (MW)	Total Power to be installed in users' substation (based only on dwellings with fossil systems) (MW)	Total Power to be installed in the central thermal station (based only on dwellings with fossil systems) (MW)
Total of the three municipalities (CURIT data)	7	3-4	5	2-3
Total of the three municipalities (preliminary estimations for all the buildings)	About 25	About 10	About 20	About 6

* to be realised according to the elaborations performed on the data available in the CURIT cadastre (referred to 254 heating systems for the three municipalities)

CENED, open data by Regione Lombardia

The CENED database contains detailed information about the energy performance of the units or buildings certified in Lombardy Region. Even if the data available are not complete, uniform and verified, the CENED cadastre can be adopted for carrying out rough estimations of the average thermal power and yearly thermal need of the heating systems. In particular, in the CENED 2.0, 342 energy certifications are available for the three municipalities involved, with an average heated surface of 160 m^2 for each unit/building certified, corresponding roughly to the 55% of the total heated surface. Based on the available information, the following draft indicators can be considered for the pre-feasibility study of the pilot plant:

- Average thermal need: 170,2 kWh/m^2y
- Biomass thermal power to be installed: 6-7 MW
- Maximum thermal power to be provided to the final users: 22 MW
- Maximum heat to be delivered to the final users for space heating: 11 GWh/y.

More details on the results of the CENED cadastre can be found in the Annex.

Questionnaires

Further to the abovementioned methodologies, the energy demands of the local area were also assessed through the distribution of questionnaires. In 2022 (July-October), 161 questionnaires were collected from Comune di Tovo S.A, Comune di Mazzo di V. and Comune di Lovero. 43 answers were received in electronic format and 118 in paper format. These were digitized and entered in the same spreadsheet. More details on the results of the questionnaires can be found in the Annex.

The estimation of the most appropriate thermal power for the biomass DH in question may lead to very different values, depending on the boundary conditions and assumptions made. As anticipated, in the estimation it was first decided to consider the thermal energy consumption depending on the type of the user and the willingness to connect to the new DH network. Therefore, the results were extended to the entire sample and to the total population of the three municipalities under study. Specifically:

- the estimation was based considering the percentage of users who answered "Yes" and "It depends" and extending it to all the users in the three municipalities (Table 37);

- the value of energy consumed found in the survey was converted to thermal energy actually delivered to the users (column 2 of Table 37) assuming a thermal efficiency of 85% for all boilers and a COP of 3 for the heat pumps described in the survey;
- the power to be installed at substations was estimated based on the data in Table , extending the results to the entire sample (161 users) and the municipalities indicated (column 3 of Table 37);
- since, on the basis of previous studies conducted for FIPER, it has been verified that the ratio of heat sold to the utilities to the biomass power installed in boilers in contexts similar in terms of climate, morphology, and type of built environment can be assumed to be about 1,700 hours, the power to be installed at the substations was preliminarily estimated as the ratio of the energy delivered to the utilities to the 1,700-hour figure (column 4 of Table 37).

Table 37 Extension of energy and installed power data to the three municipalities

	Energy delivered to users, MWh/year	Estimation of power to be installed in substations, MW	Estimation of power to be installed in the central plant of the DHS, MW*
Sample of 161 users	2,001.4	3.3	1
Comune di Mazzo di V.	5,506.9	9.2	2.8
Comune di Tovo S.A.	3,392.6	5.6	1.7
Comune di Lovero	3,629.8	6.0	1.8
Total of the three municipalities	**12,530.4**	20.9	**6.3**

* power based on 1700 equivalent hours.

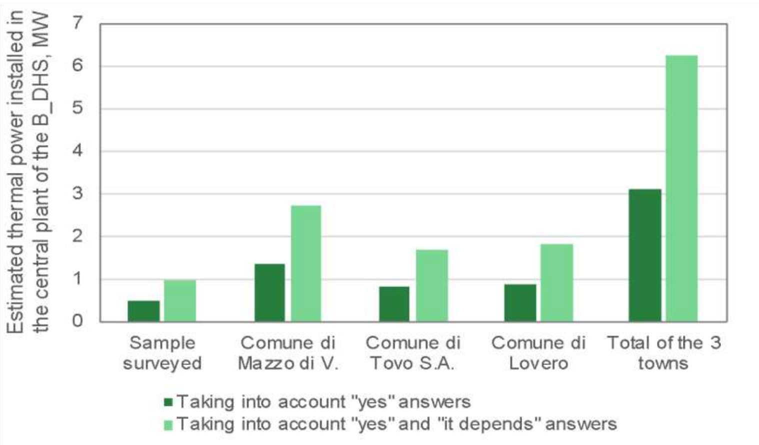


Figure 30 Final results of the questionnaires, power supply side

Considering the uncertainty that characterizes the whole estimation process described and the lack of complete energy consumption data for the sample, it was decided to identify a minimum and maximum threshold for pre-sizing while also taking into account an error factor of ± 20%.

By applying this value and considering the combinations described in the tables above, it was possible to derive a plausible range of biomass power to be installed in the **power** plant betwee**n 2.5 MW and 7.5 MW** and a corresponding plausible range of **heat sold** to the utility between **5 GWh and 15 GWh**. This range of size is also quite compatible with the estimations according to CURIT and CENED.

For verification purposes, the results obtained were compared with some parameters characterizing the nearby DH plant of Tirano. In that case, the estimated number of equivalent hours is about 1700; the connected users are about 2,500 and correspond to about 7,000 citizens, or about 78% of the municipal population. The total power installed at the end-users (sum of the power installed in all the user-side heat exchangers) is about

60 MW, compared with a biomass power installed at the thermal power plant of 20 MW (to this power is then added that of the auxiliary systems).

For the purpose of pre-feasibility verification, the plant type will have to be chosen according to a more in-depth technical-economic analysis, verifying all boundary conditions and the most sensitive parameters characterizing the case under consideration. In such an analysis, the conditions of the current energy market, which has seen an uncontrolled increase in energy sale prices to the end user, will also have to be considered. In this regard, the adoption of a cogeneration-type system could allow further optimization of the return on investment, given the possibility of avoiding buying electricity from the grid at very high prices. In the very first analysis, one could think of a configuration with two 2-3 MW biomass boilers, one of which is connected to a co-generator (example of https://seg.bz.it/fernwaerme/fernheizwerk-schluderns/).

The above estimations/ calculations were used to define the amount of energy to be covered by the BECoop RESCoop. Based on the above methodologies, it was concluded that the Italian BECoop RESCoop would need to cover around 12,000 MWh/year of heating demands in the three municipalities. This was used for the feasibility study that follows.

5.7 Feasibility Study of the BECoop RESCoop

5.7.1 Boundary Conditions for the feasibility study

This analysis is a first feasibility study for a District Heating (DH) project for the municipalities of Tovo di Sant'Agata, Lovero and Mazzo di Valtelina. The general concept is to construct a CHP plant that will cover the heating demands of the three municipalities. To that end, a 3 MWth CHP plant with an integrated 0.7 MWe ORC system and a back-up boiler with a capacity of 3MWth have been chosen. Both systems will utilize local chipped forest biomass as their fuel source.

For the following analysis, some base assumptions have been made:

- Costs are estimates, based on valid sources (recent studies, reports and communications with suppliers), the questionnaire data and best practices.
- The economic part of the study does not include taxes or investment depreciation.
- The inflation rates are adjusted based on the IMF predictions.

Table 38 CAPEX breakdown

Investment cost	3 MW Back-up Boiler	3 MWth + 0.7 MWe ORC
Investment of the generation plant (€)	1,800,000	6,800,000
Length of the heating network (metres)	4,500	
Investment of the heating network (€)	4,500,000	
Number of substations	300	
Cost of the substations (€)	795,000	
Total investment (€)	12,095,000	

The total investment is calculated to be almost 12.1 million Euros. For this feasibility study, a 50% public grant is considered, thus a net total investment of 6,047,500 € was estimated.

Furthermore, the operating expenses that were considered are presented in the table below. For the calculation of the yearly maintenance costs, 3% of the total CAPEX was considered.

Table 39 Operational costs of the plant

Operational cost of the generation plant (electricity and maintenance)	Value
Total cost of the forest biomass to be consumed in the boiler (€)	999,487
Total operational cost of the generation plant (electricity and maintenance) (€)	362,850
Total OPEX (€)	1,362,337

The sources of revenue have been thoroughly researched and are concluded to be:

- Heat sold to end customers at a price of 0.12 €/kWh
- Electricity sold through the network at a price of 0.15 €/kWh

5.7.2 Economic Indicators (IRR, NPV, PBP)

For the calculation of the economic indicators, a lifespan of the investment with a 25 year horizon was determined and the following table that shows the investment's potential was constructed.

Table 40 Cash Flow Analysis

CUMULATIVE CASH FLOWS							
Years	CAPEX (€)	OPEX (€)	Inflation Rate	Cash flow (€)	Cumulative Cash Flow (€)	PV(€)	NPV* (€)
0	6,047,500		2.00%	-6,047,500	-6,047,500	-6,047,500	-6,047,500
1		1,362,337	2.00%	578,323	-5,469,177	566,983	-5,480,517
2		1,362,337	2.00%	578,323	-4,890,855	555,866	-4,924,651
3		1,362,337	2.00%	578,323	-4,312,532	544,966	-4,379,685
4		1,362,337	2.00%	578,323	-3,734,210	534,281	-3,845,404
5		1,362,337	2.00%	578,323	-3,155,887	523,805	-3,321,600
6		1,362,337	2.00%	578,323	-2,577,564	513,534	-2,808,066
7		1,362,337	2.00%	578,323	-1,999,242	503,465	-2,304,601
8		1,362,337	2.00%	578,323	-1,420,919	493,593	-1,811,009
9		1,362,337	2.00%	578,323	-842,597	483,914	-1,327,094
10		1,362,337	2.00%	578,323	-264,274	474,426	-852,668
11		1,362,337	2.00%	578,323	314,049	465,123	-387,545
12		1,362,337	2.00%	578,323	892,371	456,003	68,459
13		1,362,337	2.00%	578,323	1,470,694	447,062	515,521
14		1,362,337	2.00%	578,323	2,049,016	438,296	953,817
15		1,362,337	2.00%	578,323	2,627,339	429,702	1,383,519
16		1,362,337	2.00%	578,323	3,205,662	421,277	1,804,796
17		1,362,337	2.00%	578,323	3,783,984	413,016	2,217,813
18		1,362,337	2.00%	578,323	4,362,307	404,918	2,622,731
19		1,362,337	2.00%	578,323	4,940,629	396,978	3,019,709
20		1,362,337	2.00%	578,323	5,518,952	389,195	3,408,903

CUMULATIVE CASH FLOWS							
Years	CAPEX (€)	OPEX (€)	Inflation Rate	Cash flow (€)	Cumulative Cash Flow (€)	PV(€)	NPV* (€)
21		1,362,337	2.00%	578,323	6,097,275	381,563	3,790,467
22		1,362,337	2.00%	578,323	6,675,597	374,082	4,164,548
23		1,362,337	2.00%	578,323	7,253,920	366,747	4,531,295
24		1,362,337	2.00%	578,323	7,832,242	359,556	4,890,851
25		1,362,337	2.00%	578,323	8,410,565	352,505	5,243,356

* the NPV in the above table is calculated using the inflation rates shown here.

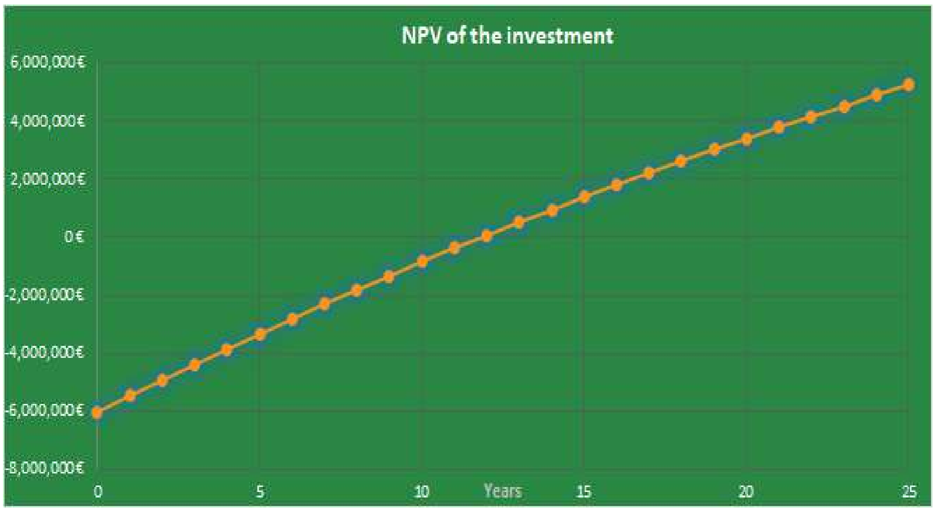


Figure 31 Graph of the investment planning

As can be seen from the cash flow analysis and Table 41, by taking into consideration a funding rate of 50% of the total investment of the plant, the economic indicators result to a feasible investment with a payback period of 10.46 years, an IRR of 8.24 and a ROI of 10.96%. However, in case that no funding at all (no grant) is considered, the feasibility of the investment is questionable with the payback period around 20.9 years and an IRR of 1.42% and a ROI of 5.48%. Thus, the funding of the investment will have an important impact on the economic feasibility of the DH/ CHP plant of the Italian BECoop RESCoop.

Table 41 Results of the investment planning

Grant percentage	50%	0%
Net Present Value	5,243,356 €	-804,144 €
Return On Investment	10.96 %	5.48 %
Pay-pack period	10.4 years	20.9 years
Internal Rate of Return	8.24 %	1.42 %

5.2 Technical field visits

Field Visit: Ferrari forest site	
 	
Brief Description:	Visit and explanation of the different stages of the forest site according to sustainable forest management. Demonstration of three different harvesting methods of forest biomass: via harvesting arm, via helicopter and via cable car. More information to be reported in D4.4.
When:	29th March 2023
Where:	Cavalese, Italy
Why:	To see various forest harvesting methods in practice that could take place in the italian BECoop RESCoop
No of participants:	15
Type of stakeholders:	Citizens/General Public / Biomass Owners / Authorities/Municipalities / Research Centres/ Universities / Biomass management companies/ RESCoops

Field Visit: The sawmill of the Magnificent Community of Fiemme	
 	
Brief Description:	Visit to the sawmill of the Magnificent Community of Fiemme. Lumber processing chain analysis from log to processing residue management (trimmings, wood chips, etc). All forest enterprises send their wood here. The sawmill manages 15,000 ha of public forest (50 km sourcing radius).
When:	29th March 2023
Where:	Cavalese, Italy
Why:	Explanation of chain of custody and forest and wood product certification system.
No of participants:	15
Type of stakeholders:	Citizens/General Public / Biomass Owners / Authorities/Municipalities / Research Centers/ Universities / Biomass management companies/ RESCoops

Field Visit: The heating plant of Bioenergia Fiemme	
 	
Brief Description:	Visit the local biomass district heating plant (two 4 MWth boilers) together with a cogeneration plant (4.5 MWth + 1 MWe) to cover the heating demands of 4,000 inhabitants. Apart from the CHP/ DH plant, there is also a pellet production line and an essential oil production line from forest needles. A presentation of Fiemme energy community was also performed.
When:	29th March 2023
Where:	Cavalese, Italy
Why:	This case is a good example of the activities that the Italian BECoop RESCoop wants to replicate (a biomass district heating with cogeneration).
No of participants:	15
Type of stakeholders:	Citizens/General Public / Biomass Owners / Authorities/Municipalities / Research Centres/ Universities / Biomass management companies/ RESCoops

Field Visit: Biomethane plant Bioenergia Trentino in Cadino	
 	
Brief Description:	Visit to a biomethane plant that produces and sells electricity (700 kWel), biomethane (360 Nm^3/h) and compost (14,000 tons). Supply chain analysis of organic waste collection, management and processing.
When:	29th March 2023
Where:	Cadino, Italy
Why:	A field visit to a success case that implements a technology not investigated thoroughly by the BECoop RESCoops (biogas and biomethane production), that could be an additional technological solution for bioenergy communities.
No of participants:	15
Type of stakeholders:	Associations / Research Centers/ Universities/ RESCoop

Field Visit: E-Werk Prad	
  	
Brief Description:	Visit to a success case of RESCoop with 1,443 members. Activities of RESCoop such as production, supply and distribution of electricity and heat along with distribution of fast internet (fiber to the home). Visit to hydropump plant (3 MW), district heating plants, biogas plant
When:	30th March 2023
Where:	Prato allo Stelvio, Italy
Why:	To visit a successful example of RESCoop that combines and exploits different renewable energy sources such as solar, hydro, biomass.
No of participants:	15
Type of stakeholders:	Associations / Research Centres/ Universities/ RESCoop

Field Visit: Fernheizwerk Toblach-Innichen (Teleriscaldamento Termo-Elettrico Dobbiaco)	
  	
Brief Description:	Visit to a successful case of RESCoop with 1,000 members and a biomass District heating plant with cogeneration (16 MWth, 1.5 MWel total) that implements also ORC technology and provides fiber-optic internet to all its members.
When:	31st March 2023
Where:	Dobbiaco, Italy
Why:	One successful RESCoop that could be an example for replication for the Italian BECoop RESCoop activities: Biomass district heating along with ORC cogeneration.
No of participants:	18
Type of stakeholders:	Associations / Research Centres/ Universities/ RESCoop

5.8 End users/local actors identified for cooperation

The main potential users and actors involved identified in the Italian pilot can be divided in three group:

- a group of citizens and energy consumer industries and companies, end user and prosumer/provider of wood or woodland areas
- the public administration of the three municipalities involved and other possible interested investors among the local energy providers in charge of the development of the DHS
- An association of the interested local actors involved in the management and maintenance of woodlands.

5.8.1 Potential End users

Potential users identified throughout the BECoop project development are:

- the citizens and the public buildings of the three municipalities involved, main users of the heat produced in the biomass energy system and distributed through the DHN
- Local industries and commercial activities
- Local engineering offices

The main types of buildings to be connected to the DHN for thermal energy users, mainly citizens and public buildings, have been assessed through a questionnaire and are reported in Figure 32.

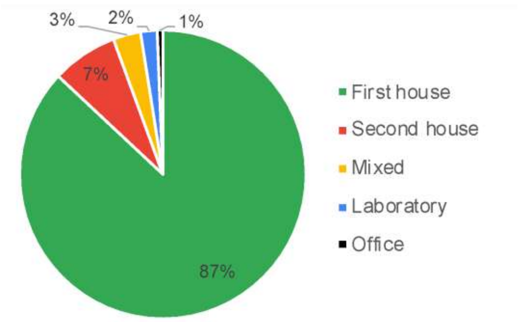


Figure 32 Types of buildings to be connected to the DHN of the Italian BECoop RESCoop (survey results)

5.8.2 Local actors interested in cooperation

Table 42. List of main stakeholders

Stakeholder	Role
FIPER	Partner of BECoop project and expert for development of biomass DH and biomass CHP systems.
Local engineering office	The expert has experience in assessing the features and performance of buildings and heating plants, and has also promoted other local projects that use biomass primarily for heating via boilers
Local forestry companies	Promoter of the management activities for organizing the exploitation of local forest biomass, including contracts.
Local industries and commercial activities	In the three municipalities involved in the BECoop RESCoop there are several companies and industries involved in the food transformation and production market. Such companies can represent an interesting constant energy consumption.
Municipalities involved	Local environmentally conscious municipality, promoter of a biomass DH system and other initiatives for enhancing the energy self-sufficiency also reducing energy poverty; promoters of biomass uses and other initiatives for energy sustainability.
Ambiente Valtellina Onlus	Operating in biomass collection from local forest and vineyards pruning.

6 Greek BECoop RESCoop

The Greek BECoop RESCoop targets the expansion of the biomass supply chain of ESEK (energy community of Karditsa, Thessaly) and extension of its activities to bioenergy production. **ESEK already owns and operates a pellet plant**, thus, through T4.2 it has been investigated how this plant can be used **to expand the RESCoop activities and combine them with the uptake of a local bioenergy heating community**. The technical support services provided are explained in detail through the present section except from demonstration activities which will be provided via D4.4.

6.1 Introduction to the BECoop RESCoop

The Greek BECoop RESCoop is in Karditsa, a city in western Thessaly, in mainland Greece. Currently, the resources used for thermal purposes are oil (53%), electricity (22%) and natural gas (18%) while biomass represents a small percentage (6%) considering its great potential. Notwithstanding, the continuous expansion of the local fossil fuel network hinders the uptake of RE heating solutions such as biomass boilers. At the same time, the region has a great biomass supply chain potential through agricultural, forestry and wood processing industries that can easily support the uptake of bioenergy technologies.

The main activity of the energy community is the **management of a biomass plant for the production of solid biofuels to generate energy for heating (and cooling) purposes.** The raw material consists of industrial residuals (sawmills) such as sawdust woodchips, logging residues such as branches, tops and stumps, coming from Forest Cooperatives. Partnerships with local authorities allow the Energy Community to expand the supply chain with plant biomass coming from municipal residues (branches and tops of city trees).

To complete the plant, a manufacturing unit processes and standardizes local biomass and converts it into a commercial form, such as pellets. A main element of Greek BECoop RESCoop is the expansion of products and services of the already existing ESEK's pellet production facility. In particular, the main targets are the processing and production of new mixtures of alternative and cheaper biofuels focusing on the exploitation of spent coffee grounds from local coffee houses, along with urban and forest residues. Apart from the investigation of new feedstock, T4.2 targeted the expansion of activities of ESEK to operate as an ESCO by installing and operating biomass boilers in municipal buildings and selling heat to end-users. By this way, ESEK will provide the end-user with solid biofuels, operate the installed biomass boilers and get revenues by selling heat (per kWh or per tonne biofuel), whereas end-users will only have to pay for their heat consumptions and not bother with the maintenance of the boilers and their fuel supply. Figure 33 provides an overview of existing ESEK's activities as well as the new BECoop activities proposed:

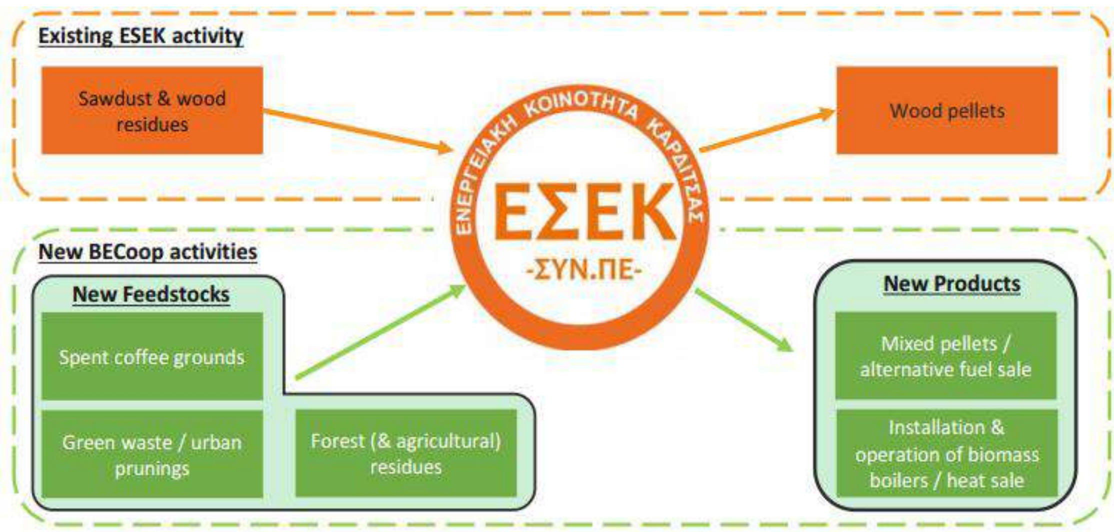


Figure 33 Overview of the Greek RESCoop

6.2 Biomass Assessment

One of the main goals of BECoop activities in T4.2 was to expand the current sources of biomass that are used by ESEK, by using new local feedstocks that remain unexploited. Therefore, the feedstocks investigated in the Greek BECoop RESCoop were residual urban biomass from city pruning, wood residues from maintenance of local forests and residual coffee from the local coffee houses.

6.2.1 Type of biomass to be used by the BECoop RESCoop

Coffee Residues

Coffee residues are produced through the brewing process of coffee in coffee houses, hotel complexes, municipal buildings or at local citizens' houses. However, they are treated as a residue and are disposed of with the rest organic residues. Currently, coffee residues are disposed of in landfills and burden the municipalities with waste disposal costs. More specifically, the current disposal cost of wastes in landfills amounts to 50 euros/t. This cost increases every year by 5 euros/ ton, until 2027 when these costs would be 70 euros/t. Through BECoop and WP4 activities, such biomass source was investigated for exploitation by the BECoop RESCoop. Fuel properties and high availability due to high consumption are reasons that could make residual coffee a "perfect candidate" for bioenergy production. Furthermore, coffee houses that dispose of the residues for bioenergy or other alternative uses could have a benefit/ incentive in exchange, such as reduced municipal taxes etc., as they contribute to the reduction of the waste disposal costs for the municipality. Table 43 provides typical fuel analyses of coffee residues that have been collected in Kilkis (Northern Greece) and examined in CERTH's lab.

Table 43 Main properties of coffee residues (CERTH)

Parameter	Unit	Value
Moisture	% a.r.	61.7
Volatile	% d.b.	81
Ash	% d.b.	1.6
C	% d.b.	53.34
H	% d.b.	6.79
N	% d.b.	1.53
S	% d.b.	0.13
Cl	% d.b.	0.06
HHV	MJ/kg d.b	22.83
LHV	MJ/kg a.r.	6.68

Urban prunings

Annually, trees from city parks and roads are pruned for maintenance and plant health reasons. From such activity, an adequate amount of biomass is produced. This feedstock remains unexploited, as in most cases it is disposed of in illegal landfills or burned on-field, although it is a prohibited practice, producing emissions harmful to human health and environment. Through WP4 activities, such feedstock was further investigated for bioenergy applications, as raw material for pellet production. Table 44 presents the main characteristics of urban prunings.

Table 44 Main properties of urban prunings (Phyllis database[28])

Parameter	Unit	Value
Moisture	% a.r.	30.78
Volatile	% d.b.	75.93

[28] https://phyllis.nl/Browse/Standard/ECN-Phyllis

Parameter	Unit	Value
Ash	% d.b.	5.89
Fixed carbon	% d.b.	18.18
C	% d.b.	47.99
H	% d.b.	5.55
N	% d.b.	1.44
S	% d.b.	0.10
HHV	MJ/kg d.b	19.45
LHV	MJ/kg a.r.	11.87

Forest residues

Forest residues may derive from the maintenance of local forests, along with fallen trees from extreme weather phenomena (e.g. medicane "Ianos"). The mountainous area of Lake Plastira, around 20 km from the city of Karditsa has an untapped source of biomass that remains unexploited. Examination of forest residues has proved their suitability for use as biofuels. In the following table (Table 45), the main characteristics of the two main types of trees found in those forests (fir, oak), obtained through Phyllis database, are presented. Additionally, their deposition in the forests often causes fires especially during the summer months. Despite the high potential of this source and support of municipality of lake Plastira and willingness in participating in a pilot project for harvesting forest residues for bioenergy production, the current legal framework hinders the exploitation of forest residues, and thus only the theoretical biomass potential of such source was investigated within BECoop project.

Table 45 Main characteristics of fir and oak (Phyllis database[29])

Parameter	Unit	Fir	Oak
Moisture	% a.r.	37	38
Ash	% d.b.	0.28	0.32
C	% d.b.	50.36	49.42
H	% d.b.	5.92	5.54
N	% d.b.	0.05	0.81
S	% d.b.	-	0.08
HHV	MJ/kg db	21.10	18.16
LHV	MJ/kg ar	11.58	9.58

6.2.2 Quantities to be used by the BECoop RESCoop

The estimation of biomass theoretical potential along with the estimation of biomass technical potential for residual coffee and city prunings have been realized through demonstration activities (D4.4). Therefore, the quantities are mentioned in the present deliverable while the detailed methodology will be provided through D4.4. Regarding the forest residue quantities to be used by Greek RESCoop, a different approach was used. In particular, the estimation of forest residues was based on literature surveys as the current legal framework hinders the exploitation of forest residues.

Coffee Residues

Through WP4 activities (mainly T4.4), demonstration activities of collecting local coffee residues were performed, along with the help of InCommOn[30] (Greek civil non-profit company) and their product Kafsimo[31].

[29] https://phyllis.nl/Browse/Standard/ECN-Phyllis
[30] https://incommon.gr/
[31] https://incommon.gr/kafsimo/

Several local coffees participated in the demonstration activity, where bins were installed in a close distance with coffee houses located in the city of Karditsa. Employees or/and owners of coffee houses disposed of their residual coffee into these bins and an employee of ESEK collected the content of all bins and transported it to ESEK's plant for further processing. Based on the results of the demonstration, estimations on the quantities of residual coffee have been performed, in which the total quantity of coffee residues in the city of Karditsa was estimated as 600 t/y (wet basis) or 300 dry t/y of residual coffee that could be exploited by the BECoop RESCoop.

Urban prunings

In the same logic with the coffee residues, demonstration activities of urban prunings collection were performed under T4.4. City pruning collection was performed throughout the year with the use of two trucks with crane and crab. Urban prunings were collected by the local municipality and transported to ESEK's plant for processing. The estimations of harvested quantities were made during the demo activities based on the trucks' capacities and the number of transportations of prunings to ESEK's plant. Details of those activities regarding specific distances and times of loading, unloading and transportation will be given via D4.4. Nonetheless, it was estimated that the annual obtained quantity that ESEK can treat is at 4,000 tonnes (wet basis), whereas the theoretical potential of urban prunings is estimated at 14,000 tons (wet basis)[32].

Forest residues

Due to bureaucracy and legislation reasons, on-field measurements of forest residue production could not be performed during the project's duration as initially planned. For this reason, to have a preliminary idea of the forest residues potential of the forest area near ESEK, data from literature were used. There are several forests in the local area, nonetheless, the woodland of Karditsa municipality, which is of higher interest for the BECoop RESCoop, includes the following forests (Table 46):

Table 46 Woodland of Karditsa municipality [33]

Municipality	Forest (Ha)	%
Karditsa	15,063	22%
Limni Plastira	7,282	11%
Sofades	11,934	17%
Mouzaki	11,283	17%
Argithea	22,776	33%
Total	68,337	100%

According to a study on the distribution of organic matter and nutrients in the soil in spruce and beech ecosystems in Northern Greece [2], with the aim of estimating the nutrient stocks and forest residues in order to use them for energy production, it was pointed out that the highest quantity of nutrients is involved in the trunk. The results show that thin twigs (<2 cm) together with leaves have higher amounts of Nitrogen while twigs of higher diameter (>2 cm) were found to have limited quantity of nutrients. Therefore, part of the branches with diameter >2 cm could be harvested along with trunk extraction provided that the particularities of forest ecosystems of the country are considered. The considered forest area in the study mentioned has similar characteristics with our area of study and thus, we assume that we would harvest branches of diameter >2 cm.

[32] INTENSSS- PA. H2020 Project, Integrated Sustainable Energy Plan RLL of Karditsa (2018)
[33] GEOTECHNICAL CHAMBER OF GREECE VOL: 28 - ISSUE VI - No 1/2019

The following table presents the Residue-to-Surface Ratio (RSR), as calculated for the Northern Greek forests and for several site qualities, similar to the case of the BECoop RESCoop. Therefore, the quantities that could be obtained from the forest areas by causing no harm to the soil are mentioned in Table 47:

Table 47 RSR ratios of forest residues applied to the BECoop RESCoop

Diameter of branches (cm)	Fir (soft wood) (site quality II) (t/ha, a.r.)	Conifers (site quality IV) (t/ha, a.r.)	Beech (hard wood) site quality II (t/ha, a.r.)	Beech (hard wood) site quality III (t/ha, a.r.)
>5	1.79 (0.895)	0.43 (0.215)	1.46 (0.73)	0.77 (0.385)
>2 – 5	0.73	0.41	0.30	0.3
TOTAL	2.52 (1.625)	0.84 (0.625)	1.76 (1.03)	1.07 (0.685)

Taking into account that the 50% of residues with diameter >5 cm are collected and used as firewood, the total forest residue quantity produced in the prefecture of Karditsa can be estimated at 0.99 t/ha (average of branches residues >2cm - 5 cm and 50% of branches residues >5 cm, a.r.). Considering a forest area of 68,337 ha, the theoretical potential of forest residues can be estimated at 67,653 wet tonnes, thus a huge potential of forest residues exist in the area.

6.3 Logistics of BECoop RESCoop

6.3.1 Value chain description

Logistics steps of the BECoop RESCoop value chain have some small differences depending on the feedstock examined. In particular:

Urban prunings

In case of residual urban biomass, the municipality of Karditsa performs city tree cuts for maintaining the good-health of the plants in the urban parks, gardens, roads etc. The municipal workers collect manually or with a front loader the urban prunings and load them to a truck. Through the demonstrations performed under T4.4, the municipal staff have been trained for the collection of prunings as not to collect plastics and other residues, together with the urban prunings, but to sort only the woody biomass. After the loading of the branches, the trucks move to other points in the city where urban prunings are available. After being fully loaded, the trucks (owned and handled by the municipality of Karditsa) are sent to ESEK's plant. There, they are stored in open space. After a period of one-two months, the urban prunings are chipped through a static chipper of ESEK and then further processed for pellet production. It should be mentioned at this point that the municipality examines the possibility to procure a wood-chipper and process the produced pruning on-site in order for the transportation costs to be reduced along with transportation emissions reduction.

Value chain operations of urban prunings are depicted in Figure 34:

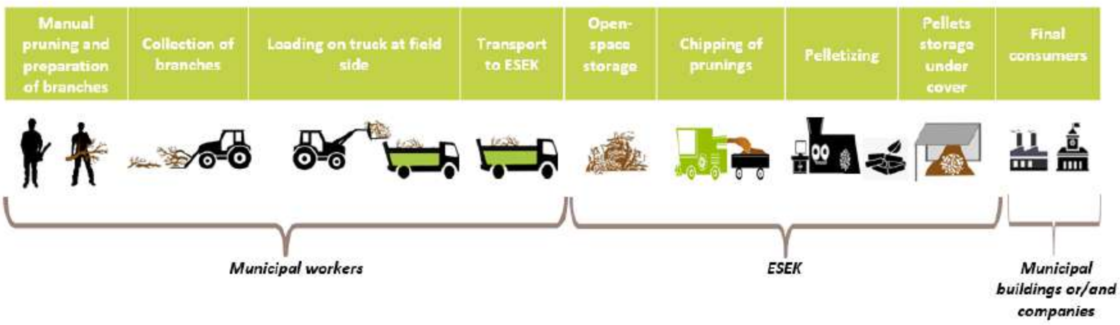


Figure 34 Diagram of value chain operations (urban prunings)

Coffee Residues

Coffee residues from each coffee house are disposed of in dedicated bins, located at central points. Based on extensive discussions with the managers of coffee houses to determine and point out the most effective way of residual coffee collection, as well as the timeline for the collection of residues in order to avoid problems with storage and biodegradation, it was decided that the most suitable collection frequency was once per 15 days. Thus, every 15 days, coffee residues are collected by ESEK and transported to ESEK's biomass plant for storage and treatment. Coffee residues are stored in the open and spread (not in high piles) in order to lower its moisture (> 60% initial moisture content). After two-three weeks, the coffee residues are treated for pellet production (Figure 35).

Figure 35 Diagram of value chain operations (coffee residues)

Forest residues

Forest residues from the mountainous area of Lake Plastira, around 20 km from the city of Karditsa, are an untapped source of biomass that remain unexploited. For this value chain (Figure 36), the idea would be that forest cooperatives are responsible for collecting and transporting forest residues at ESEK's plant. Forest cooperatives and agencies that are responsible for the management of the forest biomass would collect the forest residues and load them on a truck on site. Then the truck is sent to ESEK's plant to discharge the forest residues. Forest residues are stored in open space and then treated via ESEK's static chipper. After that, the forest residues are further processed into pellets and roof-stored before they are sent to the end-users.

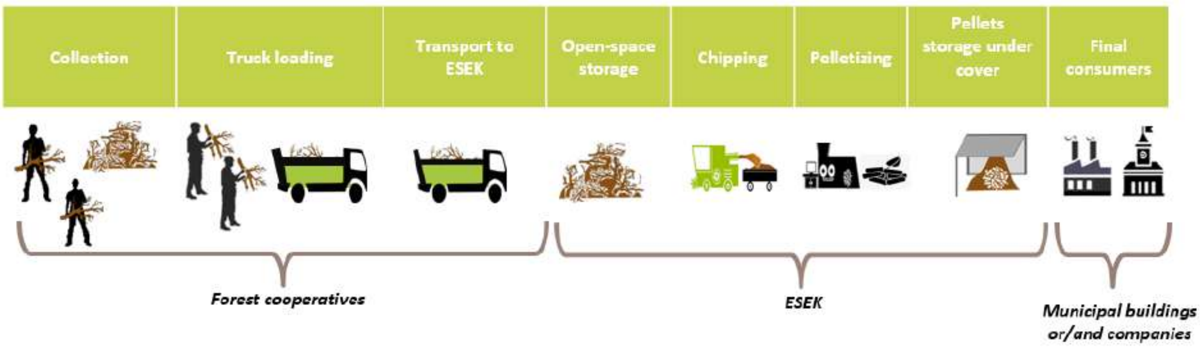


Figure 36 Diagram of value chain operations (forest residues)

6.3.2 Cost of collection

Harvesting, transportation and storage costs of the examined feedstocks vary due to different distances to storage facilities, the quantities of residues removed, road conditions, terrain, the fuel cost and salary of employees working on these stages. You can see below the corresponding costs of each feedstock where data from the demonstrations performed under T4.4 were also used:

Urban prunings

The salary of each municipal worker of Karditsa responsible for transportation is 1,000 € PM. Two persons are required for this work, thus, the total salary cost for transportation will be 2,000 €. Regarding the quantity of harvested residues, it is up to 5 t for 1 shift/month. Considering that each month the days of operation are 22, the total quantity of residues transported to ESEK will be 110 t. Regarding the cost of fuel for transportation of the total distance (truck depot - collection sites - ESEK- truck depot), it is considered 100 km/shift. Furthermore, an assumption for the fuel cost to be 1.70 €/lt was considered. Taking into account the category of vehicle having been used for the transportation, the fuel consumption of it is up to 32 €/100km. The cost attributed to each stage of the collection process can be seen in Table 48. However, it should be highlighted that in the current situation and as it is planned, this collection cost will not be attributed to ESEK (BECoop RESCoop) but to the municipality, as the latter is responsible for the transportation of urban prunings to ESEK. Finally, there is no storage cost of biomass for BECoop RESCoop activities as the prunings are stored in ESEK's facilities.

Table 48 Cost attributed to harvesting, transportation and storage of urban prunings

Cost	unit	value
Salary* attributed to transportation of residues	€/t	18.2
Fuel for the transportation of residues	€/t	10.88
Sum	€/t	**29.08**

Coffee Residues

The distance from ESEK's plant to the city of Karditsa is approximately 7 km thus, the total distance of transporting the residues to ESEK and going back to Karditsa is up to 14 km. Transportation to ESEK is realized by car with fuel cost set at 0.15 €/km, thus the total cost for transport of the feedstock to ESEK and going back to the town of Karditsa is 2.1 €. The employees of the coffee houses dispose of the coffee residues to the bins, which have been provided close to the shops for this reason. For transportation, we take into consideration only the fuel cost as a person from ESEK is responsible for this. The quantity of coffee residues collected twice per month is approximately 100 kg each time, thus 200 kg/month. Here, there is no storage cost since they are stored in ESEK's facilities. The cost attributed to each stage can be seen in Table 49:

Table 49 Cost attributed to harvesting, transportation and storage of coffee residues

cost	unit	value
Salary of employee responsible for the transportation of residues	€/t	Assumed 0 as a person from ESEK will be responsible for the transportation just twice/month
Fuel for the transportation of residues	€/t	21
Sum	€/t	21

Forest residues

Karditsa community's forests are located at a distance of approximately 15-35 km from the centre of Karditsa. The tilting truck which transports the branches consumes 8 €/t while the price set by forest cooperatives for the transportation of residues from the forest to ESEK facilities is 25 €/t. The collection cost attributed to each stage can be seen in Table 50:

Table 50 Cost attributed to harvesting, transportation and storage of forest residues

cost	unit	value
Price set by cooperatives regarding the harvesting of residues	€/t	25
Fuel for the transportation of residues	€/t	8
Sum	€/t	33

6.4 Location of BECoop RESCoop

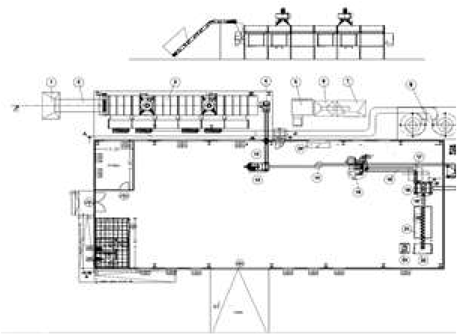
As the RESCoop concept for ESEK with the examination of new feedstocks and activities have been reported in the previous subsections, the following figures provide an overview of the ESEK's pellet plant, its location and the sourcing distances of the new feedstocks from the plant as well as the distance to the potential end-users (Figure 37, Figure 38).

Figure 37 ESEK's plant location

Figure 38 ESEK's pellet plant

6.5 Technology and Activity of the BECoop RESCoop

The main activity of ESEK (BECoop RESCoop) is related to the management of a biomass plant for the production of solid biofuels to generate energy for heating (or cooling) purposes, which can set up the value chain for the local community. A manufacturing unit for processing and standardizing local biomass and converting it into a commercial form, such as pellets, has been created. The raw material for pellet production consists of industrial residuals (sawmills) such as sawdust woodchips and logging residues such as branches, tops and stumps, coming from forest Cooperatives. The existing pellet plant of ESEK (Figure 39) has a capacity of producing 0.5 t/h pellets and consists of several components such as feeding system, drying system (belt dryer), hammer mill (capacity up to 5 t/h), biomass boiler (0.6 MW) that burn pellets, pellet mill and a cooler and siever (capacity up to 2 t/h).



a

b

c

Figure 39 a) ESEK's plant layout b) ESEK's plant c) ESEK's open storage area

Based on BECoop activities, the new concept for this BECoop RESCoop is to treat new feedstocks such as coffee residues from the local coffee houses, city prunings and forestry residues from the maintenance of the local forests.

Further to the new feedstocks, the BECoop RESCoop will have two main activities. Firstly, the production of "alternative" biomass fuels such as pellets from the new feedstocks. Based on the new feedstocks and the existing pellet plant, the BECoop RESCoop will be able to expand its supply chain and produce new mixtures of alternative solid biofuels.

The second activity regards the promotion of a new turnkey service for space heating, including biomass supply, pellet production, boiler installation and operation and sale of thermal energy. In this frame, ESEK could install biomass boilers to public buildings, local industries etc. and sell heat to the customers. Thus, the end-users will only have to pay for their heat consumptions and not bother with the maintenance of the boilers and their fuel supply.

For the needs of the BECoop project and based on the bioenergy vision and roadmap developed through WP4 tasks, it was assumed that in the next 2-3 years (up to 2026), the Greek BECoop RESCoop will have installed 20 biomass boilers (average 45 kW) in 20 municipal buildings. This would translate, apart from the currently on-going activities of ESEK, the production of additional around 200 tonnes of pellets to cover the heating demands. Such pellets are considered to be produced from the mixing of the new feedstocks.

Furthermore, during WP4 activities, the identification and contact of suitable equipment manufacturers that could support the new activities of ESEK was performed. One boiler manufacturer that was visited was Camino Design[34], where conversations were held over the new activities of the BECoop RESCoop, the identification of suitable biomass boilers was performed and the willingness of the equipment manufacturer to support such activities was expressed. Furthermore, communication with Energon Heating Systems was also performed in order to investigate biomass heating solutions available and suitable for the new activities of the BECoop RESCoop. Finally, through WP4 tasks, the Greek BECoop RESCoop made contact with two equipment providers of shredding machines (Aegean Biomass[35] and Cultura Verde[36]) that would be suitable for shredding the new feedstocks such as urban prunings and forest residues. The equipment provider showed interest in collaborating with ESEK for its new activities and identified shredders that could support them.

[34] https://www.caminodesign.gr/
[35] https://www.aegean-biomass.gr/
[36] https://culturaverde.gr/

6.6 Energy demands to be covered

Firstly, the open-source GIS tool "HOT Maps" from the BECoop Toolkit was used in order to estimate the total heating demands of the local area. Based on the tool, in a radius of 25 km from ESEK plant (Figure 40), the total amount of heating demands are around 632 GWh/ year that breakdown into 131.3 GWh/year heat demands for the residential sector and 500.6 GWh/year heat demands in the residential sector. Of course, the BECoop RESCoop is not going to cover all the thermal demands of the area, however the calculations were made in order to highlight the needs for heating.

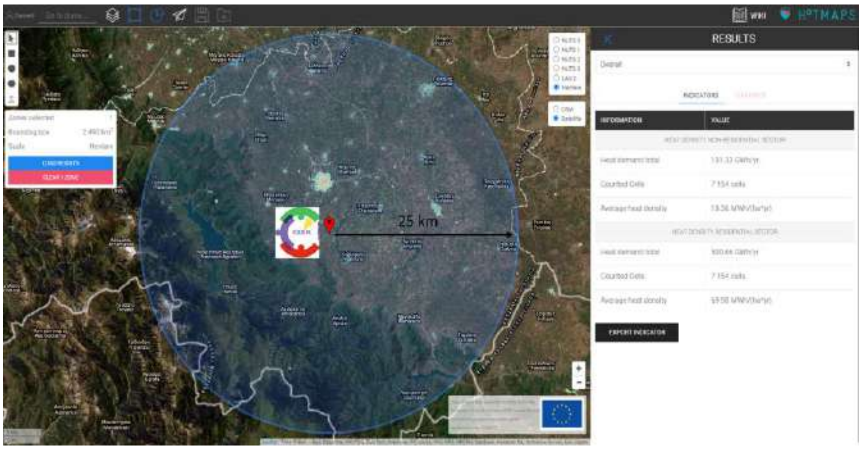


Figure 40 Total heat demands in a 25 km radius from ESEK (Hot Maps tool)

To further narrow down the heating demands of the local area, the heating demands of municipal buildings were retrieved. Municipal buildings (e.g. schools) could be potentially end-users of the BECoop RESCoop activities. This has been also demonstrated in T4.4, where the heating of a municipal school is performed with a biomass boiler and fuel from ESEK.

After communicating with the municipality of Karditsa, information was provided about the thermal costs in schools of primary and secondary education during 2021. Based on that and by knowing the average cost of natural gas and oil in Greece for the same period, the energy consumption of the schools was estimated. It has to be mentioned that the value used for the cost of natural gas and oil includes tax and boiler efficiency of 98% and 87% respectively. In Table 51 you can see the cost for the local schools that used natural gas and for those that used oil and the estimated values for energy consumption of these buildings. This was realized with the aim of figuring out the potential amount of kWh, currently covered by fossil fuels, that could be (part of it) covered by the activities of BECoop RESCoop in the near future. Thus, the total heating demands (potential) of the municipal schools in the municipality of Karditsa amount to around 934 MWh yearly, that could partially be covered by the BECoop RESCoop.

Table 51 Energy consumption of schools in municipality of Karditsa

Cost of natural gas (€)		Number of schools	Thermal energy cost (€/kWh)[37]	Energy consumption (kWh)
Primary education	70,526	19	0.16	440,790
Secondary education	55,540	12	0.16	347,123
Cost of oil (€)				
Primary education	12,000	4	0.13	92,308
Secondary education	7,000	1	0.13	53,846
Sum	1,45066	36		934,067

Based on the assumptions performed in WP4 and the roadmap and bioenergy vision developed for the BECoop

[37] http://www.lsbtp.mech.ntua.gr/system/files/2021-12/NTUA%20Study%20December%202021.pdf

case, the new activities of ESEK assumed to cover the heating demands of 20 municipal buildings in the near future, where ESEK would install the biomass boilers and sell the heat to the end-users. Based on these assumptions, to address the heating demands of the new biomass installations, ESEK would need to cover additional 730 MWh of heating demands with its new activities (new alternative pellets).

6.7 Feasibility Study of the BECoop RESCoop

6.7.1 Boundary Conditions for the feasibility study

The feasibility of the ESEK initial concept, as outlined in its roadmap (T4.1), was assessed through this analysis. The concept is to install 20 biomass boilers (45 kW) in the local municipal buildings with a total capacity of 1 MW. The breakdown of the capital and operational expenses as well as the revenues can be seen below. For the evaluation of the investment, crucial financial indicators are calculated in order to demonstrate the profitability of the BECoop RESCoop.

Before diving into the cost benefit analysis and the cumulative cash flow table, the assumptions and the formulas upon which the feasibility study was based are presented. These assumptions were received after careful considerations among the technical and pilot partners in order to reflect the most appropriate conditions for our analysis and align the profitability with the reality. The most important ones are:

CAPEX breakdown: 105,800 €

- 20 biomass boilers approximately with total thermal capacity 1 MW
- Transportation, connection and configuration
- R&D, permits and taxes
- No use of subsidy or national grant

OPEX breakdown (annual) for the required pellet for the 20 boilers 185 t: **30,614 €**

- Pellet production plant operational costs (40 €/t)
  - Thermal demands
  - Electrical demands
  - Dryness
  - Pelletizing
  - Packaging
- Machinery and vehicles maintenance and depreciation (20 €/t)
- Biomass logistics (pruning, wood waste, forest residues and coffee residues) (46 €/t)
  - Collection
  - Transportation
  - Storage
- Labour costs (60 €/t)
- Other costs

Revenues breakdown:

- Sell pellets to the public buildings at around 350 €/t or
  - Pricing the thermal kWh at approximately 0.10 €/kWh
- Installation and maintenance costs are included in the above pricings

6.7.2 Economic Indicators (IRR, NPV, PBP)

To calculate the economic indicators that assess the viability of an investment, it is necessary to conduct a cost-benefit and cash flow analysis. The breakdown of each cost is given below (Table 52) and the results of the analysis can be seen in the following cumulative cash flow table.

Table 52 Cash Flow Analysis

CUMULATIVE CASH FLOWS								
Years (n)	CAPEX €	OPEX €	Inflation Rate (r)	Revenues €	Cash flow €	Cumulative €	PV €	NPV €
0	105,800	30,614	2.00%	0	-136,414	-136,414	-136,414	-136,414
1		30,614	2.00%	64,693	34,079	-102,334	33,411	-103,003
2		30,614	2.00%	64,693	34,079	-68,255	32,756	-70,246
3		30,614	2.00%	64,693	34,079	-34,175	32,114	-38,133
4		30,614	2.00%	64,693	34,079	-96	31,484	-6,648
5		30,614	2.00%	64,693	34,079	33,984	30,867	24,218
6		30,614	2.00%	64,693	34,079	68,063	30,262	54,480
7		30,614	2.00%	64,693	34,079	102,142	29,668	84,148
8		30,614	2.00%	64,693	34,079	136,222	29,086	113,235
9		30,614	2.00%	64,693	34,079	170,301	28,516	141,751
10		30,614	2.00%	64,693	34,079	204,381	27,957	169,708
11		30,614	2.00%	64,693	34,079	238,460	27,409	197,117
12		30,614	2.00%	64,693	34,079	272,540	26,871	223,988
13		30,614	2.00%	64,693	34,079	306,619	26,345	250,333
14		30,614	2.00%	64,693	34,079	340,699	25,828	276,161
15		30,614	2.00%	64,693	34,079	374,778	25,322	301,482
16		30,614	2.00%	64,693	34,079	408,858	24,825	326,307
17		30,614	2.00%	64,693	34,079	442,937	24,338	350,645
18		30,614	2.00%	64,693	34,079	477,016	23,861	374,507
19		30,614	2.00%	64,693	34,079	511,096	23,393	397,900
20		30,614	2.00%	64,693	34,079	545,175	22,934	420,834
21		30,614	2.00%	64,693	34,079	579,255	22,485	443,319
22		30,614	2.00%	64,693	34,079	613,334	22,044	465,363
23		30,614	2.00%	64,693	34,079	647,414	21,612	486,975
24		30,614	2.00%	64,693	34,079	681,493	21,188	508,163
25		30,614	2.00%	64,693	34,079	715,573	20,772	528,935

The Investment evaluation & profitability can be also seen in Figure 41.

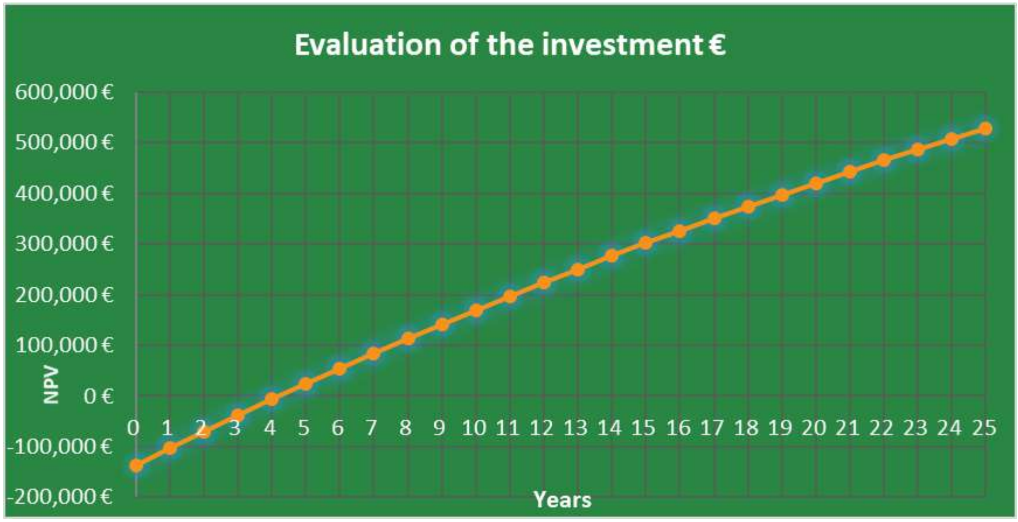


Figure 41 Graph of the investment planning

As it can be seen from the graph (Figure 41) and the results of the investment planning, it appears that the concept is very profitable and offers a payback period of only 4 years. For more realistic results, safety factors and conservative scenarios were integrated due to the current energy crisis and the huge fluctuations of energy prices. The projection of the concept's profitability is highly related with the revenues which have been calculated as 350 €/t including installation and maintenance costs whereas nowadays this cost meets the price of 600 €/t and above. This concept as can be seen from the section below is about to be implemented from 2025 onwards where we expect a decrease in all the energy prices. The results of the other financial indicators can be seen in the Table 53 along with the formulas.

Table 53 Results of the investment planning

Net Present Value	528.935
Return On Investment	24,98%
Pay-pack period	4,00 years
Internal Rate of Return	22,23%

On the other hand, by comparing the current prices of the existing heating solutions for the area of Karditsa, it can be seen that the pellet option is the most advantageous one from an economic point of view. These values (Figure 42) represent the costs needed to be covered from the various heating sources for the thermal energy demand of the 20 boilers installation- 1 MW. It can be seen that solid biofuels like ESEK's pellet offer many benefits to the local community across economic, environmental and social dimensions. Therefore should be considered both for the current period and in the short-term future as a solid biofuel which is at the same time a cheap and sustainable solution.

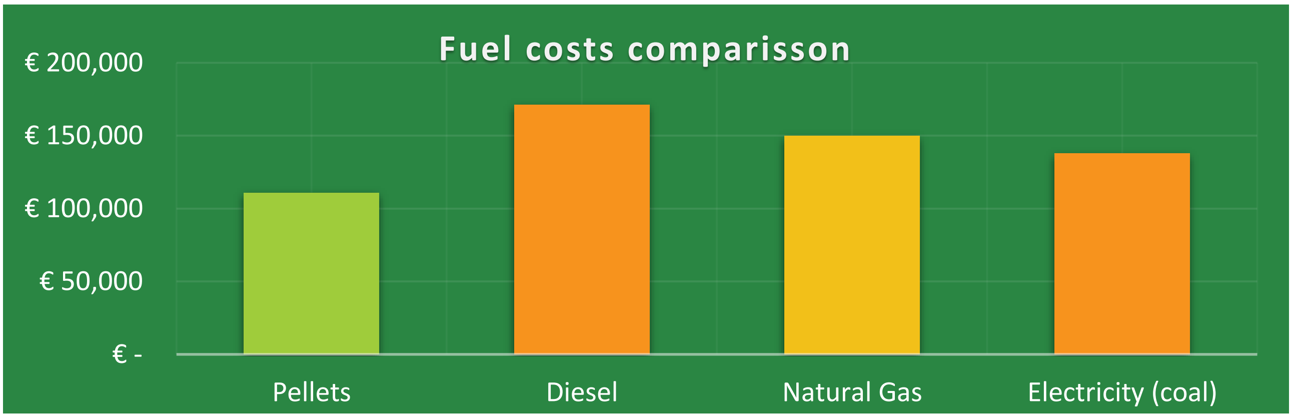


Figure 42 Fuel costs comparison

6.1 Technical field visits

Field Visit: LEHOVO	
    	
Brief Description:	Visit school in Northern Greece that is heated with biomass (vine pruning chips, sunflower husk pellets). Organised in collaboration with AgroBioHeat Project. Heating municipal buildings (two schools) with biomass. Fuels used: vine pruning chips, sunflower husk pellets. It is operated by local municipal DH operator (District Heating Company of Amindeo (D.H.C.A.))
When:	21/02/2022
Where:	Lechovo, Greece
Why:	Potentially replicable to the new activities of the BECoop RESCoop
No of participants:	7
Type of stakeholders:	RESCoop, ESCO and installers

Technical Visit: Kozani (Camino Design)	
	
Brief Description:	Visit at Camino Design (biomass boiler manufacturer) to bring in contact the Greek BECoop RESCoop with an equipment manufacturer needed for implementing its new activities.
When:	22/02/2022
Where:	Kozani, Greece
Why:	Bring in contact the BECoop RESCoop with an important stakeholder for implementing its new activities
No of participants:	2
Type of stakeholders:	Equipment Manufacturer

Technical Visit: D.H.C.A. (District heating plant)

Brief Description:	Visit the municipal DH plant Amyntaio that is heated with biomass (vine pruning chips, sunflower husk pellets, agricultural residues, lignite). Organised in collaboration with AgroBioHeat Project.
When:	21/02/2022
Where:	Amyntaio, Greece
Why:	Potentially replicable to the new activities of the BECoop RESCoop
No of participants:	7
Type of stakeholders:	RESCoop, ESCO and installers

Field Visit: Biomass boiler at Monastery in the region of Karditsa

Brief Description:	Field visit at a monastery in Karditsa that covers its heating demands with biomass (wood chips/on-site produced from local forestry residues and pellets)
When:	24/06/2022
Where:	Karditsa, Greece
Why:	To showcase good examples of biomass heating in larger buildings
No of participants:	10
Type of stakeholders:	RESCoop, Municipalities, Agricultural Organization

6.8 End users/local actors identified for cooperation

In order to form alliances between a range of local stakeholders and contribute to the formation of RESCoops, the project conducted a search and identification of potential end users and other relevant local actors.

6.8.1 Potential End-users

Potential end-users of the new activities of the BECoop RESCoop could be any municipal building such as administrative buildings, schools, swimming pools etc. or even industries or hotel complexes. For the needs of the project, we considered that in the immediate future, a potential number of end-users as 20 municipal buildings or/and companies in Municipality of Karditsa could be a realistic goal. **The installation of a biomass boiler has already been performed in a school of Karditsa** (Kalifoni), thus, similar procedures will be followed for the other buildings in the future. Other potential end-users could be local greenhouses, industries or even hotel complexes in the mountainous area of Karditsa.

Furthermore, another potential end user could be a recently funded biogas plant that is located near to the facilities of ESEK. ESEK has already made the first meeting and is investigating potential collaboration regarding the residual coffee. The coffee grounds are considered ideal material for the production of biogas, thus ESEK has sent coffee residue samples at the labs of the biogas plant, in order to measure the properties and estimate the quantities that may be needed for the biogas production. This may be another interesting activity regarding the circular economy and bioeconomy.

6.8.2 Local actors interested in cooperation

The identification of local partners has been realized by taking into consideration that there are partners that can benefit from the alliance with BECoop project while they also have the ability to reinforce our message. Table 54 presents a list of potential partners:

Table 54 Potential partners

ESEK	(BECoop partner) Energy cooperative – biomass facility operator, responsible for storage and treatment of collected biomass.
Municipality of Karditsa	Provides the urban pruning, potential end-user of biomass fuels (e.g., public buildings, swimming pools, schools etc.).
Municipality of Plastiras lake	Contribution at the exploitation of the forest residues (municipal forest), potential end user of biomass fuels (e.g., public buildings, schools etc.).
CERTH	(BECoop partner) Technical consultancy on new biomass-based activities.
University of Thessaly - Department of forestry wood sciences and design	Provide academic support for the production of biofuels and the exploitation of forest residues.
Oksigono Agrafon (NGO)	Possible contribution at the exploitation of the forest residues.
InCommOn (NGO)	Contribution at the exploitation of the coffee residues.
Agency development of Karditsa AN.KA	Networking and consultancy.
Biomass boiler manufacturers	Provide support in the installation and operation of biomass boilers in the local area.
Citizens, farmers, forest cooperatives, coffee shops	Provide feedstock, end-users, general role in the community.
Local hotels and industries	Potential end users of biomass fuels.

6.9 Additional technical support activities

6.9.1 Production of alternative pellets and solid fuel analyses

The RESCoop produced "alternative" biofuels such as pellets in mixtures of the feedstocks mentioned beforehand. Thus, the supply chain of the BECoop RESCoop was expanded as new mixtures of alternative and cheaper solid biofuels have been produced. ESEK produced several mixtures of pellets by mixing coffee residues in different percentages (0%, 10%, 30%, 50%, 70%, 100%) with various feedstocks such as urban prunings, forest residues, industrial residues, agricultural residues etc. Then, the produced pellets were sent to CERTH's lab for solid fuels analysis and characterization. CERTH analyzed more than 30 solid fuel samples. Details regarding the analyses will be provided in D4.4.

6.9.2 Combustion of produced alternative pellets and emissions monitoring

The installation of biomass boiler at the municipal building (school) of Karditsa was realized after the municipality of Karditsa was contacted. First, it was clarified that ESEK would be responsible for the installation of the biomass boiler and the provision of the solid biofuel, as a replication of the new activity of the BECoop RESCoop. Three types of pellets produced from ESEK were tested: i) wood pellets from ESEK; ii) mix of coffee residues with urban prunings; iii) mix pellets of coffee residues with industrial waste wood. Afterwards, those pellets were analyzed at CERTH's laboratories and tested at the biomass boiler, while fuel emissions were monitored. Both the pellet characteristics and ash analysis were conducted. Results of such demonstration will be reported in D4.4.

7 Conclusions

Task 4.2 provided technical support services to all BECoop RESCoops so they can start developing their bioenergy visions as described in Task 4.1 and their respective roadmaps. The technical support services differed based on the maturity, technology readiness and specific peculiarities of each BECoop RESCoop case.

Aim of the technical support services was to guide the BECoop RESCoops hand-by-hand and accelerate the development of their bioenergy visions.

In general, the timing and effort required for a community bioenergy project can vary depending on several factors, including the project's size, complexity, and location. The technical support services provided via T4.2, significantly reduced the community bioenergy project development times and efforts. According to available literature[38], the development process can take up to 3 years from the initial concept to project completion, from which up to 22 months (~60% of the development time of the project) can be required for the feasibility studies, option appraisals and specifications. Within the current task (and Task 4.3 with a duration of M16-M30), feasibility studies for the BECoop cases, along with additional technical activities (e.g. type of biomass, biomass availability, stakeholders engagement, contact with equipment manufacturers etc.) were provided to each BECoop RESCoop, **thus reducing the community bioenergy project development timings and efforts by more than 25%** (KPI-10, KPI-11) as described in the DoA.

An overview of the technical support activities provided in each BECoop RESCoop can be found in Table 55.

Table 55 Overview of technical support activities provided

<table>
<tr><th>Spanish BECoop</th><th>Polish BECoop</th><th>Italian BECoop</th><th>Greek BECoop</th></tr>
<tr><td colspan="4">• Biomass availability and assessment of BECoop RESCoops’ feedstock
• Definition of logistics and location of BECoop RESCoop
• Energy demands to be covered by the BECoop RESCoops
• Estimation of CAPEX/ OPEX and feasibility study of each BECoop RESCoop
• Stakeholders engagement and identification that can provide support and collaborate with each BECoop RESCoop
• Field visits that provided motivation and knowledge to the BECoop RESCoops</td></tr>
<tr><td>• Solid fuel analyses of feedstocks
• Distribution of questionnaires to inhabitants of Aberasturi for energy demands assessment
• Preliminary design of biomass DH plant
• Additional technical support services to Murgia case</td><td>• Solid fuel analyses of feedstocks
• Tests related to water absorption by pellets, mechanical durability of pellets, solid fuels bulk density
• Preliminary design of pellets production line capacity
• Selected logistics costs of the value chain</td><td>• Evaluation of different configuration scenarios of biomass CHP/ DH
• Distribution of questionnaires to local citizens for energy demands assessment</td><td>• Solid fuel analyses of produced mixed pellets, at different mixing ratios
• Combustion of “alternative” pellets on biomass boiler and monitoring emissions</td></tr>
</table>

[38] Community Power Agency, https://cpagency.org.au/wp-content/uploads/2019/07/Community-Energy-How-To-Guide.pdf

For the completion of T4.2, several tools developed during BECoop project were used. An overview of the tools used at each BECoop case can be seen in Table 56.

Table 56 Overview of BECoop Tools used in WP4 tasks

BECoop Case	BECoop Toolkit	Technical Catalogues	Self-Assessment Tool	E-market
Spain	• Hot Maps • BioRaise • Phillys2	• District heating • Direct heating	✓	✓
Poland	• Phillys2 • BioRaise	• Direct heating • Biogas • Factsheet of solid biofuels production • Factsheet of solid biomass for small-scale heating applications	✓	✓
Italy	• Hot Maps • BioRaise • GenLess • Thermos	• Small co-generation • District heating	✓	✓
Greece	• Hot Maps • BioRaise • Phillys2	• Direct heating • Factsheet of solid biofuels production • Factsheet of solid biomass for small-scale heating applications	✓	✓

Outcomes of Task 4.2 were provided for the development of business models and investment planning of Task 4.3 and highlighted crucial points for each pilot case that needed to be demonstrated under Task 4.4. Moreover, Task 4.2 provided important information on the BECoop concepts and set their boundary conditions under which they will be evaluated under Task 4.5, along with their socio-environmental impact. Furthermore, the results of T4.2 provided input to the BECoop Replication Handbook (Task 5.2) providing a stepwise approach to initiate a bioenergy community heating project. Finally, the information and knowledge collected through Task 4.2 will also serve as a basis for BECoop technical experts, to provide high-level support to eight more follower cases across Europe via Task 5.2.

In a nutshell, the activities of the current task, along with its outcomes, informed, transferred knowledge, and guided the local communities to set up the basis and develop their bioenergy projects. Four different local communities were supported to develop their technical action plan and received thorough technical consultation for the implementation of their bioenergy heating visions. Since services and resources were elaborated to varying EU settings and studies were made for initiatives of different framework conditions, we firmly believe that T4.2 and its outcomes can be used as **a stepping-stone for the acceleration of the development of the European bioenergy community vision.**

Annexes

Annex I: Spanish BECoop RESCoop

Throughout the entire period of accompaniment with Aberasturi, the following milestones have been achieved:

- To engage the inhabitants of the Aberasturi and the public institutions.
- To know the availability of forest and herbaceous local biomass potential. And in the case of the forestry biomass to support the implementation of a forestry management plant in order to know from which areas should be collected the biomass in a sustainable way.
- To know the composition of both biomass, and in the case of the straw which is more interesting to use for energy use.
- To assess the current energy demands to be cover, and the current price that the inhabitant pay for that.
- To carry out a preliminary design of the biomass district heating, assessing the power of the heating plant and the length of the heating network.
- To estimate the CAPEX and OPEX of the new installation.
- To carry out a feasibility assessment with Sensitivity analysis in order to see the feasibility of the initiative.
- To identify the stakeholders that can provide support, either for the collection of biomass or for the installation of the heat network, and their role in the RESCoop.
- To visit some installation in order to obtain feedback from people with experience in the use of forestry and herbaceous biomass and the district heating installations.
- To keep the inhabitants of Aberasturi informed at any time of the progress of the project.

As a result, the inhabitants of Aberasturi have improved their knowledge about the RESCoop they want to implement, proof of this, for example, is the final result obtained by carrying out a self-assessment about the implementation of the district heating and comparing it with the one that took place at the beginning of the accompaniment. This increase of the knowledge of the BECoop RESCoop through the tasks of WP4, will be reported in DLV4.5.

At the moment, the initiative has been well received, and all the documentation obtained during the accompaniment is being prepared for submission to a subsidy programme with the aim of reducing the cost of CAPEX (which, as it was seen, is one of the main technical risks for the initiative to be economically viable). In parallel, discussions on how to create the RESCoop and the statutes should be carried out (although more information on the business side will be given in deliverable 4.3).

Finally, as with Aberasturi, a final self-assessment has been carried out to monitor the accompaniment provided in the case of Murgia. The reason was to compare the readiness level of the BECoop case in the beginning of WP4 activities and in the end of the accompaniment. As a result of the WP4 tasks, the inhabitants of Murgia have improved their knowledge about the RESCoop they want to implement. The results of the self-assessment tool will be reported as well in DLV 4.5.

Annex II: Polish BECoop RESCoop

Further Data on the transportation costs in Polish case

It should be marked that transportation cost depends on factors such as: transportation distance, the amount of the biomass to be transported, access to the loading place, loading time, type of truck etc.. Therefore, in **Error! Reference source not found.** more detailed costs related to the biomass transportation are presented.

Table A1. Biomass transportation costs in Polish OBS Pilot Area

Position	Unit	Low-tonnage transport (loading mass: up to 3.5 tons, loading volume: 15-27 m³)	Medium-tonnage transport (loading mass: 3.5-12 tons, loading volume: V=35-60 m³)	High-tonnage transport (loading mass: up to 24 tons, loading volume: V= 78-100 m³)
Kilometres rate with freight	€/km	0.4 - 0.5	0.5 - 0.9	0.9 - 1.1
Kilometres rate - access to pick up freight	€/km			0.8 - 1.0
Hourly parking fee for the driver (loading and unloading time)	€/h	10.0 - 20.0	10.0 - 20.0	10.0 - 20.0
Average loading time	h	0.5 - 1.0	1.0 - 1.5	1.5 - 2.0
Average unloading time	h	0.25 - 0.5	0.5 - 1.0	1.0 - 1.5

Potential End users

In the Polish OBS Pilot Area there is a large group of different potential local end users (residents, institutions, organizations, companies) that are interested to be a part of the proposed concept (heating generation from biomass), including:

- residents and households owners,
- schools,
- church,
- social welfare home,
- farmers,
- SMEs.

To engage/convince the final users to the proposed concept focused on local biomass utilisation for energy purposes, technical support has been provided. Technical services and consultations took place during different events and direct meetings with stakeholders. The list of the consulted issues and topics related to the technical support are summarized in **Error! Reference source not found.**.

Table A2. List of technical support provided by WUELS within OBS Pilot Area

Issues/topics	Comments/Details	Type of final user	Supporting materials
The possibility of replacing the old coal-fired boiler with a new fully automatic biomass boiler fed by pellets	The issue has been clarified. Some consequences were discussed (exemplary pros → higher boiler's efficiency, lower heating costs, lower pollutants emission, limited serviceability of the boiler resulting from the built-in and programmed control system, less ash produced; exemplary cons → new chimney building or stainless pipe installation)	Residents and households owners, farmers	Technical catalogues, BECoop movie
The possibility of replacing the light oil fired boiler with a new	The issue has been clarified. Some consequences were discussed (exemplary pros → lower pollutants emission, exemplary cons → lower	Residents and households owners, SMEs	Technical catalogues

Issues/topics	Comments/Details	Type of final user	Supporting materials
fully automatic biomass boiler fed by pellets.	efficiency, new chimney building or stainless pipe installation, the need to periodically empty the ash container). There is also an option to change the burner itself and add the appropriate pellets feeding system		(“Biomass direct heating”)
The possibility of replacement of hard coal by biomass pellets	The issue has been clarified. In the case of peat coal the fuel change is possible and very easy without the necessity of heating unit replacement. Some consequences were discussed (exemplary pros → lower ash content, lower pollutants emission, less dustiness; exemplary cons → lower calorific value, the possibility of high-temperature corrosion issues (i.e., chlorine corrosion) which may lead to degradation of the boiler fittings).	Residents and households owners, farmers	Technical catalogues (“Biomass direct heating”)
The possibility of the replacement of the coal by biomass in the manually fed boiler	The issue has been clarified. In this case the biomass briquettes are recommended to be used. Some consequences were discussed (exemplary pros à lower pollutant emission, less ash produced, ash can be used as fertilizer; exemplary cons à more frequent fuel loading resulting from lower calorific value, the need for larger storage space.	Residents and households owners, farmers	Technical catalogues (“Biomass direct heating”)
How much biomass pellets is required in comparison to coal for heating in winter	The issue has been clarified. It was explained that as a result of lower calorific value, it is required to use c.a. 1.5 times more pellets than hard coal to maintain the same thermal comfort. This value depends among others on the physical-chemical properties of the processed material.	Residents and households owners, farmers, SMEs	BECoop T 1.2. Report
What is pellets	The issue has been clarified. It was explained that pellets are biofuels made of fragmented biomass (e.g., agricultural residues, forest raw materials, or other organic products) due to pressure agglomeration. The product obtained in this way is a light, smooth, glassy, and homogeneous granulate[39]. They are generally 5 to 30 mm long, and the diameter usually does not exceed 25 mm[40]. The stages of the material pelletization process were also presented and the standards that should be met by pellets used as biofuel were briefly discussed.	Residents and households owners, farmers, SMEs	Technical catalogues (“Biomass direct heating”)
What kind of biomass can I use for pellets production	The issue has been clarified. The types of raw materials intended for the production of pellets were discussed, which include: agricultural biomass: (residues that are generated after the harvesting of the main product e.g. straw or from regular prunings of permanent crops e.g. vineyards, orchards), forestry biomass (from the wood processing sector i.e., sawdust, wood shavings, etc.), agro-industrial biomass (residues that are generated after processing a main agricultural crop in an agroindustry i.e., sunflower husks), biomass from urban parks and	Farmers	Factsheets (“Solid biomass for small-scale applications”)

[39] https://strefainstalatora.pl/poradnik-instalatora/jakosc-pelletu-czy-warto-kupowac-pellet-z-certyfikatem/
[40] http://polskaradapelletu.org/o-pellecie/

Issues/topics	Comments/Details	Type of final user	Supporting materials
	gardens (tree prunings and other cuttings that are generated in an urban setting)		
How can I manage the ash after burning biomass fuels?	The issue has been clarified. Some of the ashes can be used agriculturally. However, the chemical composition of the biofuel must be controlled so as not to cause an increase in soil acidification or to increase the concentration of heavy metals in the soil.	Residents and households owners, farmers	BECoop T1.2 Report
How to store properly biomass fuels?	The issue has been clarified. There are many solutions for the storage of solid biofuels, depending on the size, construction and form of biomass. The storage area should be large enough to be filled max. 3-4 times per year, and also to maintain the good quality of fuel, the storage method should prevent ingress of moisture and be free from any contaminants (stones, animal carcasses, metals, coatings or preservatives)[41]. The storage room requires proper ventilation to avoid rooting, decomposition and insure air access for maintenance of the proper hygienic/climatic conditions. It is recommended to clean a storage room once a year (after the heating season)[42]. In contrast to coal, the access of rodents, which may reduce the quality of biomass fuel, should be additionally limited.	Residents and households owners, farmers, SMEs	Technical catalogues ("Biomass direct heating")
Will the prices of biomass fuels produced by a bioenergy cooperative be lower than those currently available on the market?	The issue has been clarified. The cooperative has a strictly defined area of operation from which biomass is obtained. This limits the length of the logistic chain, which, considering today's prices of fuels and energy, can significantly affect the cost of purchasing biofuels.	Residents and households owners, farmers, SMEs	Factsheets ("Biomass logistic supply chain")
What can negatively affect the operation of a biomass boiler?	The issue has been clarified. <u>Among the reasons stand out:</u> • Boiler is too large for the heat demand it is supplying Biomass boilers are designed to run for extended periods. When a biomass boiler is too large it only needs to fire for a very short time to satisfy the heat demand placed upon it. This leads to many short periods of firing during operation known as cycling. If a boiler cycles regularly it goes through multiple start up and shutdown phases which are known to reduce efficiency, increase emissions, increase component wear and increase auxiliary electricity consumption for components such as fans running at a higher speed than during steady operation. In the case of automatically fed boilers, excessive cycling means the boiler fails to reach its most	Residents and households owners, farmers, SMEs	BECoop T1.2 Report

[41] https://www.treco.co.uk/news/article/what-is-biomass-heating
[42] EPC Storage Guidelines. Recommendations on the design, installation and operation of fuel stores for heating appliances

Issues/topics	Comments/Details	Type of final user	Supporting materials
	efficient state of operation and temperatures never reach those required for optimal combustion and heat transfer. This results in increased emissions. • Poor quality fuel Biomass combustion is heavily influenced by the type and quality of fuel burned within the boiler. Your biomass boiler should be designed to burn a particular type and grade of fuel cleanly and efficiently. This is specified by the manufacturer. The use of poor quality fuel causes increased emissions, low efficiency, component failure, increased repair costs, high running costs and poor performance of the system. Fuels with a high moisture content can lead to difficulties maintaining operating temperatures, leading to an increase in particulate emissions, incomplete combustion, loss of efficiency and even damage to the boiler or flue. • Poor adjustment of boiler and system controls Well-adjusted controls ensure the safe, efficient and optimum operation of the biomass boiler whilst satisfying the heat demand of the site. When controls are unavailable, set incorrectly, or not regularly reviewed the performance of the biomass system can suffer. Poor control can result in the boiler operating when there is little demand for heat. This leads to multiple start up and shutdown phases, known as cycling. This leads to an increase in electricity consumption.		
Can I blend biomass pellets with peat coal?	The issue has been clarified. Yes, pellets can be burned together with coal. However, special care must be taken to maintain the necessary operating parameters of the boiler for the combustion process to run smoothly and efficiently. As a rule, some boilers that burn pellets can also be combined with eco-pea coal. However, in particular, follow the instructions provided by the boiler manufacturer to eliminate the risk of damage or inefficient combustion.	End-users of biomass, RESCoops members.	Technical catalogues (“Biomass direct heating”) Technical Workshops
What is the different between pellet and briquette?	The issue has been clarified. Mainly, the differences are due to these biofuels' shape and other production processes. Pellets are generally 5 to 30 mm long, and the diameter usually does not exceed 25 mm[43]. Briquettes are characterized by the shape of a cylinder, cuboid, or block[44]. Most often, cuboidal	Residents, Owners, Farmers, ESCOs, RESCoops members	Technical catalogues (“Biomass direct heating”) Factsheets (“Solid biofuel production”)

[43] http://polskaradapelletu.org/o-pellecie/
[44] https://muratordom.pl/aktualnosci/brykiet-zamiast-wegla-brykiet-drzewny-alternatywa-dla-ogrzewania-weglem-aa-Qbs9-ekU8-mYdY.html

Issues/topics	Comments/Details	Type of final user	Supporting materials
	briquettes have 15 x 10 x 7 cm dimensions, while cylindrical briquettes are up to 30 cm long and do not exceed 8 cm in diameter[45]. The basic physicochemical properties of fuels also differ, such as moisture content, ash content, lower heating value, and bulk density.		
How to recognize a good quality of pellets?	This has been clarified in the technical workshops and the technical catalogue. First, the product should have a bright, smooth, glassy, homogeneous structure[46]. Wood pellets should meet the requirements of the EN Plus A1 or A2 standard in terms of humidity (10%), specific density (from 1.12 kg/dm3), and ash content[47].	Residents, Owners, Farmers, RESCoops members	Technical catalogues ("Biomass direct heating")
How can I store the biomass pellets?	The issue has been clarified There are many options for storing pellets, and they depend primarily on the technical capabilities of the end user. This was explained in detail at meetings with residents and described in the technical catalogue. In general, there are 4 basic options for storing pellets[48]: a) Storage in a dry room (on the ground) b) Storage in room with sloping floor c) Storage in separate tanks/big bags d) Mixed options	Residents, Owners, Farmers, RESCoops members	Technical catalogues ("Biomass direct heating")
Difference between wood pellets and straw pellets	The issue has been clarified The differences result primarily in the physical and chemical characteristics of fuels and the possibilities of their use. Above all[49]: - Straw pellets contain more nitrogen, sulfur, chlorine, ash - Straw pellets are easier to access and cheaper, - To burn straw pellets, more effort is needed to remove the ash As a rule, wood pellets are more desirable because they have better properties, but their price is also higher.	Residents, Owners, Farmers, RESCoops members	Technical catalogues ("Biomass direct heating") Technical Workshops Factsheets
Why the new boiler fired by pellets can have lower thermal power than old coal fired boiler?	The issue has been clarified This is due to the efficiency of the boilers. The higher the boiler's efficiency, the lower the heat output required by the end user. Old coal-fired boilers had an efficiency of up to 88%[50] (often much less). Therefore, replacing a coal-fired boiler with a pellet one, the efficiency of which reaches even 95%[51], results in lower boiler output due to a more optimal and efficient combustion process.	Boiler's owners, ESCOs, Members of RESCoop	Technical catalogues ("Biomass direct heating") Technical Workshops Factsheets
How to calculate the capacity of the pellets production line?	The issue has been clarified. Calculating the capacity of a pellet production line can be complex and difficult to estimate. First of all, we should start	Farmers, Biomass owners,	Technical Workshops Factsheets

[45]https://muratordom.pl/aktualnosci/brykiet-zamiast-wegla-brykiet-drzewny-alternatywa-dla-ogrzewania-weglem-aa-Qbs9-ekU8-mYdY.html
[46] https://strefainstalatora.pl/poradnik-instalatora/jakosc-pelletu-czy-warto-kupowac-pellet-z-certyfikatem/
[47] http://arbuz-adopcje.pl/pellet/
[48] https://www.kwb.net/en/products/storage-room-technique/pellet-storage-options-overview/
[49] https://edepot.wur.nl/192415
[50] https://ikotly.com.pl/blog/co-decyduje-o-sprawnosci-kotla-na-pellet/
[51] https://ikotly.com.pl/blog/co-decyduje-o-sprawnosci-kotla-na-pellet/

Issues/topics	Comments/Details	Type of final user	Supporting materials
	with estimating the biomass potential that we will have at our disposal or that can be purchased on the local market. Then, this amount should be reduced by the losses related to the decrease in biomass mass resulting from drying (you should also calculate what mass loss should be expected - how moist biomass we will get from the supplier). In addition, depending on the specifications of the selected production line devices (chipper, shredder, grinder), losses may occur, e.g. due to the deposition of part of the material on the sieves, walls, etc. (usually a small percentage). Based on the total amount of losses, selected equipment and the initial amount of biomass, we can estimate the efficiency of pellet production (usually in kg/h).	Biomass processing companies, Investors	

Physical-chemical analysis of selected biomass

The typical biomass fuels are forestry wood and agricultural straw. However, as the OBS commune is responsible for selective collection of other bio-residues. Moreover, in the region there are also various fruit orchards that can also provide some wooden biomass. Finally, some other biomass potential can be obtained from food processing sector. As a result, it is important to know the main physical and chemical properties of those fuels (**Error! Reference source not found.**) as they can play significant role in the coming future in the r oad map to increase the utilisation of local biomass residues for heating purposes.

Table A3. Selected physical-chemical properties of various biomass types

Type of biomass	Lower Heating Value (MJ/kg)	Ash content, (%)	Moisture content, (%)	Volatile matter content, (%)	Carbon, (%)	Hydrogen, (%)	Nitrogen, (%)	Sulphur, (%)
Forest wood	17.89	0.66	3	77.8	47	6.7	0.11	0.021
Straw	15.99	7.27	10.3	72.8	40	6.1	0.69	0.089
Grass	18.63	6.76	1.16	76.91	46	7	1.7	0.206
Pine tree	20.09	1.06	0.81	81.98	49	7.3	0.1	0.021
Sunflower husk	18.25	2.99	13.8	71.8	44	6.4	0.8	0.131
Apple pruning	15.86	3.65	12.12	80.66	51	8.5	0.2	0.015
Cherry pruning	17.02	3.48	9.39	74.8	52	8.5	0.78	0.032
Pear prunning	17.03	4.19	8.77	80.22	49	8.8	1.2	0.058
Digestate	17.22	7.1	16.4	67.3	40	6.5	1.5	0.47* [52]
Peach Seeds	20.51	0.79	0.236	76.97	49	6.9	0.54	0.025
Beetroot Pomace	17.55	5.87	1.03	77.96	50	8.7	1.3	0.186

[52] (PDF) Effects of Organic Energy Crop Rotations and Fertilisation with the Liquid Digestate Phase on Organic Carbon in the Topsoil (researchgate.net)

Type of biomass	Lower Heating Value (MJ/kg)	Ash content, (%)	Moisture content, (%)	Volatile matter content, (%)	Carbon, (%)	Hydrogen, (%)	Nitrogen, (%)	Sulphur, (%)
Walnut shells	18.73	1.1	4.32	81.4	48	8	3.1	0.015
Hazelnut shells	17.08	1	9.56	78	49	7.8	0.4	0.021
Peanut shells	18.45	2.2	6.32	78.8	49	7.9	1.2	0.074
Orange peels	17.97	3.25	4.5	90.6	48	7.9	0.68	0.051
Lemon peels	16.11	4.9	4.22	80.77	45	8.6	1.1	0.074
Mandarin peels	16.07	3.9	4.57	82.16	47	8.7	1	0.072
*value obtained from literature								

Further information on local technical workshop.

The aim of the local technical workshops is to provide practical knowledge in terms of bioenergy cooperative creation/development in the Polish OBS Pilot Area. The workshops were addressed to all stakeholders that are a part of the logistic chain, from biomass producers to final consumers, including also the local government representatives and other institutions that could steer the process of energy cooperative creation, or help in founding acquisition to support these initiatives. Moreover, the workshops were also opened to external audience (from other regions) that would like to gain some knowledge in this issue and initiate the activity in their own area.

The agenda of the local technical workshop (**Error! Reference source not found.**, Figure , Figure) included the f ollowing issues:

a) Introduction - the concept of an energy cooperative operating in the field of renewable energy and the role of biomass in heat production in rural areas.
b) General characteristics of the commune of Oborniki Śląskie and the potential of biomass for energy purposes.
c) Module description - issues related to the development of a bioenergy cooperative in the Polish pilot area:
   module 1 - technical aspects,
   module 2 - political aspects,
   module 3 - economic aspects,
   module 4 - stakeholder involvement,
   module 5 - bioenergy community,
   module 6 - market study.
d) Support materials - technical support tools developed by the BECoop project.
e) Open discussion and conclusions.

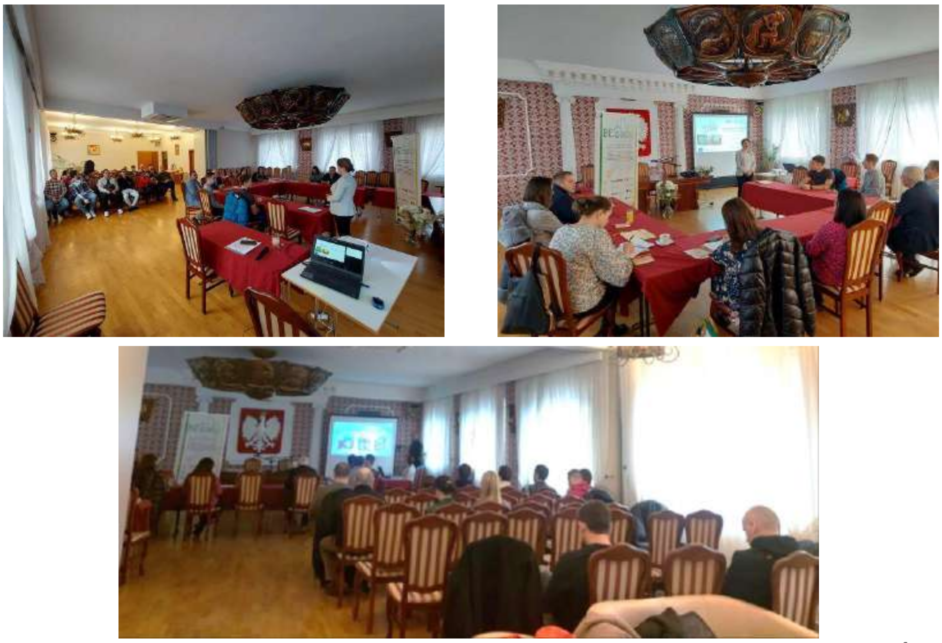


Figure A1. Local technical workshops in OBS Pilot Area (29 November 2022, Oborniki Śląskie)

Figure A2. Local technical workshops in OBS Pilot Area (11 February 2023, Bagno)

Figure A3. Local technical workshops in OBS Pilot Area (28 February 2023, Oborniki Śląskie)

Annex III: Italian BECoop RESCoop

Results from Bioraise tool regarding the biomass potential and the logistic costs

A rough estimation of the biomass collection cost has been also assessed by the adoption of the tool "Bioraise" in function of the typology of biomass withdrawn. A circular range of 7 km radius and a transport fuel cost of 1,86 €/t has been considered. Results are provided in the following table.

Table A4. Estimation of the biomass potential and costs according to the tool Bioraise

Type of biomass	Surface of potential resources	Surface of available resources	Potential resources	Available resources	Average cost of collection	Average transport cost
	(ha)	(ha)	(tDM/year)	(tDM/year)	(€/tDM)	(€/tDM)
Rainfed crops	53	53	447	224	23	5.3
Vineyard	344	344	960	672	47	6.1
Conifers	2,409	2409	2052	1026	65	6.9
Broadleaved species	943	934	628	309	56	5.9
Mixed	293	293	248	113	58	6.5
Shrub	910	910	624	312	50	7.7
tot	4,953	4,944	4,960	2,656	54 (*)	7 (*)

(*) average value based on available resource quantity

Further information on Energy demands estimation

Results from CENED regarding the energy demands assessment of the Italian BECoop RESCoop

The CENED database contain detailed information about the energy performance of the units or buildings certified in Lombardy Region. Even if the data available are not complete, uniform and verified, the CENED cadastre can be adopted for carrying out rough estimations of the average thermal power and yearly thermal need of the heating systems. In particular, 195 energy certifications are available for the three municipalities involved, with an average heated surface of 218 m^2 for each unit/building certified, corresponding roughly to the 40% of the total heated surface. Based on the available information, the following draft indicators can be considered for the prefeasibility study of the pilot plant:

- Average thermal need: 143 kWh/m^2y
- Biomass thermal power to be installed: 7 MW
- Maximum thermal power to be provided to the final users: 22 MW
- Maximum heat to be delivered to the final users for space heating: 11 GWh/y.

A new version of the CENED cadastre (2.0) has been released. In the new cadastre, a different calculation approach is considered and applied to obtain the energy performance certificate in Lombardy. Results on the CENED 2.0 are provided separately from the 1.2 due to the non-complementarity of the two samples in the dataset.

In particular, in the CENED 2.0, 342 energy certifications are available for the three municipalities involved, with an average heated surface of 160 m^2 for each unit/building certified, corresponding roughly to the 55% of the total heated surface. Based on the available information, the following draft indicators can be considered for the prefeasibility study of the pilot plant:

- Average thermal need: 170,2 kWh/m^2y
- Biomass thermal power to be installed: 6-7 MW
- Maximum thermal power to be provided to the final users: 22 MW
- Maximum heat to be delivered to the final users for space heating: 11 GWh/y.

Results from questionnaires regarding the energy demands assessment of the Italian BECoop RESCoop

The breakdown of questionnaires received for each of the three municipalities and the sample definition for some key information is shown in the next tables (Table , Table , Table).

Table A5. Results of the on site survey, part 1

		% on the total sample			% of the sample on the total users in the three municipalities
Sample (num. of users covered)	161	100%	Population (num. of total users)	1008	16%
Comune di Tovo S.A.	61	38%	Comune di Tovo S.A.	273	22%
Comune di Mazzo di V.	55	34%	Comune di Mazzo di V.	443	12%
Comune di Lovero	45	28%	Comune di Lovero	292	15%

Table A6. Results of the on site survey, part 2

			Number of data collected	% on the sample
Sample (num. of users covered)	-	446.5	151	94%
Heated surface	m^2	19071	121	75%
Tot. Power installed	kW	3196.5	103	64%
Energy consumption for heating and DHW	MWh	779	43	28%

Despite the small number of responses, the sample is still representative. Specifically, 87% of users are primary residences, 7% secondary residences, 5% refer to mixed types, followed by 2% as laboratories and 1% as offices.

The feasibility of connecting users depends on many factors, mainly technical and economic. The following estimates are basically based on the data collected on the installed power at the users, the type of fuel used, the type of user (e.g. primary residence, secondary residence, offices, etc.), and the declared interest in the initiative. For the purpose of verifying the concrete feasibility of the biomass DHS, other aspects, such as, for example, the presence of a technical room, its distance from the access road, etc., should be further investigated.

Table A7. Results of the on site survey, part 3

		Indicators calculated on the full sample	Indicators calculated on primary houses
Average heated surface	m^2/user	157.6	117.3
Average installed power	kW/user	28.9	29.2
Average specific installed power	kW/m^2	0.23	0.2
Average energy consumption	MWh/user	18.1	16.2
Average specific energy consumption	kWh/m^2	121.5	130.9

The m^2/user figure is calculated for users who declared m^2 heated (121). The average specific energy consumption figure is calculated for users who declared the consumption figure (43).

Table A8. Extension of energy and installed power data to the three municipalities, connection with "Yes" answer

	Energy delivered to users (MWh/year)	Estimation of power to be installed in substations (MW)	Estimation of power to be installed in the central plant of the DHS (MW)*
Sample of 161 users	995,7	1,7	0,5
Comune di Mazzo di V.	2739,7	4,6	1,4
Comune di Tovo S.A.	1688,4	2,8	0,8
Comune di Lovero	1805,9	3,0	0,9
Total of the three municipalities	6252,1	10,4	3,1

*power based on 1700 equivalent hours

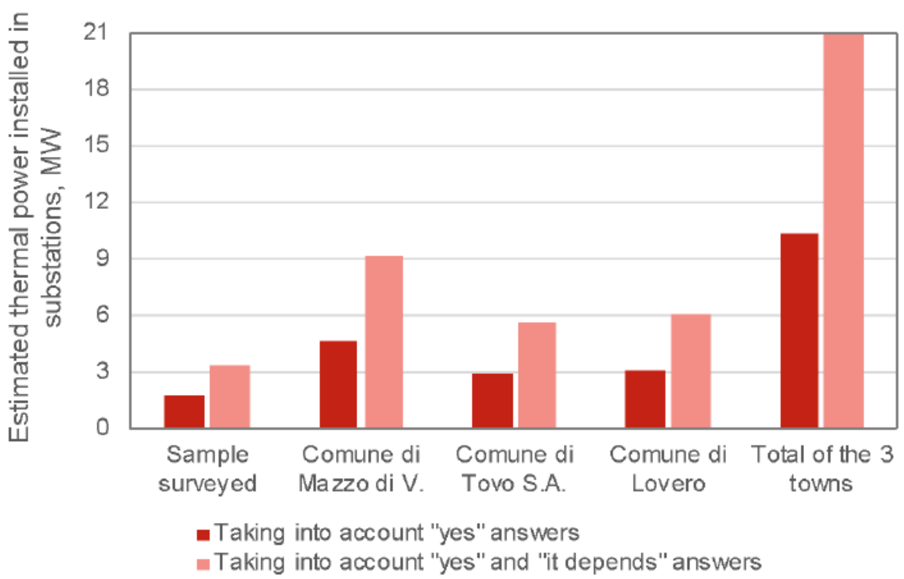


Figure 43 Final results of the questionnaires, power users side

Brief presentation of examined scenarios and their techno-economic evaluation

During the analysis phase of the feasibility study, a number of scenarios were procured and examined. That was in order to find the better performing ones, so that they could be improved upon, until a scenario that was both practical, economical and fulfilled the needs of all involved municipalities and organisations could be successfully identified. The scenarios that led to the one that was chosen will be briefly presented in the following section and following that, a table will be presented, showcasing some of their economic indicators.

Scenarios 1 and 2 worked more as guidelines for the scenarios that came after them and as such they will not be presented here.

Unless otherwise specified, all scenarios were developed under the following assumptions:

- Thermal needs to be covered are considered 12,000,000 kWh/year
- Number connections is 753
- Number of substations is 753

The scenarios examined are described in brief:

- **Scenario 3** examined the option of a 3 MW thermal DH plant that would provide heat and hot water to the municipalities during the 7 months when there is demand for heating.
- **Scenario 4.1** examined the option of a 5 MW thermal CHP plant with an electrical capacity of 1.2 MWe that would provide heat and hot water to the municipalities during the 7 months when there is demand for heating, selling excess electricity produced during that time to the grid. During the remaining 5 months of the year it would operate as a dedicated electricity production plant, selling electricity to the grid.
- **Scenario 4.2** examined the option of a 5 MW thermal CHP plant with an electrical capacity of 1.2 MWe that would provide heat and hot water to the municipalities during the 7 months when there is demand for heating, selling excess electricity produced during that time to the grid.
- **Scenario 5.1** examined the option of a 3 MW thermal CHP plant with an electrical capacity of 0.7 MWe that would provide heat and hot water to the municipalities during the 7 months when there is demand for heating, selling excess electricity produced during that time to the grid. During the remaining 5 months of the year it would operate as a dedicated electricity production plant, selling electricity to the grid.
- **Scenario 5.2** examined the option of a 3 MW thermal CHP plant with an electrical capacity of 0.7 MWe that would provide heat and hot water to the municipalities during the 7 months when there is demand for heating, selling excess electricity produced during that time to the grid.
- **Scenario 5.3** examined the option of a 3 MW thermal CHP plant with an electrical capacity of 0.7 MWe, with a backup generator of 1 MW thermal capacity in order to meet peak demand, that would provide heat and hot water to the municipalities during the 7 months when there is demand for heating, selling excess electricity produced during that time to the grid. During the remaining 5 months of the year it would operate as a dedicated electricity production plant, selling electricity to the grid.
- **Scenario 5.4** examined the option of a 3 MW thermal CHP plant with an electrical capacity of 0.7 MWe, with a backup generator of 1 MW thermal capacity in order to meet peak demand, that would provide heat and hot water to the municipalities during the 7 months when there is demand for heating, selling excess electricity produced during that time to the grid.
- **Scenario 6** examined the option of a 3 MW thermal CHP plant with an electrical capacity of 0.7 MWe that would provide heat and hot water to the municipalities during the 7 months when there is demand for heating, selling excess electricity produced during that time to the grid. For this scenario, the number of substations was considered to be 500.

- **Scenario 7** examined the option of a 3 MW thermal CHP plant with an electrical capacity of 0.7 MWe that would provide heat and hot water to the municipalities during the 7 months when there is demand for heating, selling excess electricity produced during that time to the grid. For this scenario, the number of substations was considered to be 300.

The main results of the abovementioned scenarios are presented in the following table.

Table A9. Main results of alternative scenarios examined during the feasibility study of the Italian BECoop RESCoop

	Final heat provided to consumers (kWhth)	Net electricity production (kWhe)	Total investment (CAPEX, €)	Amount of public grant (€)	Net total investment (CAPEX, €)	OPEX (€)	NPV (€)	Payback Period (years)	IRR	Forest Biomass harvested (tonnes, 37% moisture)
Scenario 3	12,075,000	0	8,295,450	4,147,725	4,147,725	820,843	3,401,147	10.73	7.94%	5724
Scenario 4.1	12,031,250	5,744,625	12,995,450	6,497,725	6,497,725	1,717,871	-3,401,692	>25	-5.91%	15217
Scenario 4.2	12,031,250	2,000,625	12,995,450	6,497,725	6,497,725	1,012,014	1,771,142	14.9	4.32%	7129
Scenario 5.1	12,063,188	4,133,009	11,495,450	5,747,725	5,747,725	1,383,227	295,106	18	2.51%	11898
Scenario 5.2	12,063,188	1,824,209	11,495,450	5,747,725	5,747,725	960,842	3,236,439	11.95	6.52%	7058
Scenario 5.3	12,063,188	4,133,009	12,095,450	6,047,725	6,047,725	1,401,227	-356,316	20.76	1.39%	11898
Scenario 5.4	12,063,188	1,824,209	12,095,450	6,047,725	6,047,725	978,842	2,585,017	13.19	5.51%	7058
Scenario 6	12,063,188	1,824,209	10,825,000	5,412,500	5,412,500	940,728	3,964,350	10.67	7.73%	7058
Scenario 7	12,063,188	1,824,209	10,295,000	5,147,500	5,147,500	924,828	4,539,772	9.74	8.76%	7058