Ref. Ares(2023)6612432 - 29/09/2023

BECoop
UNLOCKING THE COMMUNITY BIOENERGY POTENTIAL

D4.5 BECoop evaluation results

SEPTEMBER 2023

www.becoop-project.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement no. 952930.

Project Acronym:	BECoop
Programme:	HORIZON2020
Topic:	LC-SC3-RES-28-2018-2019-2020
Type of Action:	Coordination and Support Action
Grant Agreement number:	952930
Start day:	01/11/2020
Duration:	36 months
Contact:	contact@becoop-project.eu

Document information

Document Factsheet	
Full title	D4.5: BECoop evaluation results
Work Package	WP4
Task(s)	T4.5: Monitoring and evaluation of BECoop market uptake support impact
Author Organisation	Michalis Alexandros Kougioumtzis, Dionysis Papaggelis, Anatoli Rontogianni (CERTH)
Reviewers	Sebastian Zapata Habas (CIRCE), Arkadiusz Dyjakon (WUELS), Vanessa Gallo (FIPER), Vasileios Filippou (ESEK), Magdalena Zatońska (OBS), Chris Merveille (GOI), Pablo Castells (GOI), Kostas Dasopoulos (QPLAN), Antonia Kalimeri (WR), Dimitrios Chapizanis (WR).
Date	September 2023

Document dissemination Level

Dissemination Level	
X	PU - Public
	PP - Restricted to other programme participants (including the EC)
	RE - Restricted to a group specified by the consortium (including the EC)
	CO - Confidential, only for members of the consortium (including the EC)

Document history

Version	Date	Main modification	Entity
V0.1	19/09/23	Draft version distributed for quality review	CERTH
V0.2	27/9/23	Internal Quality review	Q-PLAN, WR
V0.3	27/9/23	Review by the project coordinator	WR
V1.0	29/9/23	Final version submitted to the EC	WR

Legal Notice

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

Table of Contents

List of Figures

List of Tables

Abbreviations

CAPEX	Capital expenditure
CHP	Combined heat and power
$CO_{2\ eq}$	Carbon dioxide equivalent emissions
d.b.	Dry basis
DH	District heating
DHW	Domestic hot water
FTE	Full-time equivalent jobs
GDP	Gross domestic product
GHG	Greenhouse gasses emissions
IRR	Internal rate (of) return
KPI	Key performance indicator
LHV	Lower heating value
NPV	Net present value
OPEX	Operational expenses
ORC	Organic Rankine Cycle
PB	Pay-back (period)
RE	Renewable energy
RED II	Renewable Energy Directive II
RESCoop	Renewable energy source co-operative
ROI	Return of investment
t	Metric tons
w.b.	Wet basis
WS	Workshop

Executive Summary

The BECoop project seeks to tap into the potential of bioenergy communities. To that end, a variety of different actions have been developed alongside the project towards the establishment of the BECoop RESCoops through the corresponding tasks of WP4 such as T4.1 (Co-definition of community bioenergy heating roadmaps), T4.2 (Deployment of the BECoop technical support services), T4.3 (Deployment of the BECoop business and financial support services) and T4.4 (Small scale demonstration activities). **Task 4.5, aims to monitor and evaluate the support activities deployed under WP4 and address the socio-economic and environmental impact of the BECoop bioenergy communities.**

Feedback was collected from the various BECoop REScoops support cases, as well as from the project's Task leaders, using dedicated templates developed by CERTH and tools developed during the BECoop project **such as the self-assessment tool (T2.1).** This feedback has been consistently monitored and evaluated to assess whether any reorientation of activities for any BECoop RESCoop would be necessary. A detailed report on the **results of these monitoring activities** can be found in this deliverable. This document also summarizes the highlights of all the support activities provided to the BECoop RESCoops. It presents an **overview of each BECoop RESCoop along with the lessons learned, barriers and risks, that have been recorded throughout the project and after the provision of all the support activities.** Through this discussion it was possible to leverage individual cases and extract valuable knowledge on the social, economic, and environmental impact of the BECoop project.

Through the critical analysis of the various data that was collected, the aim has also been to **identify common needs and barriers, key success factors/ lessons learned and risks, and define good practices to be utilized in community bioenergy heating projects**. Thus, this report also serves as a point of reference for future initiators of community bioenergy heating projects.

Project objectives within Task 4.5, and overall WP4, have been successfully achieved. According to the DoA, all the KPIs were met and even surpassed. In brief, WP4 resulted into **5 community bioenergy roadmaps, one technical services report, one business and financial services report, 2,879 stakeholders that received the project-provided supporting services, 9 Peer-to-peer mentoring events, 13 small-scale demonstration activities** and - with this deliverable - **5 outcome evaluation reports** (**4 for each of the four pilots**, and **one cross regional)**.

1 Introduction

In an era dominated by an ever-pressing need for sustainable energy sources, the embrace of renewable alternatives has become an imperative for societies around the world. Among the myriad of options, bioenergy stands as a beacon of hope, offering the promise of clean, renewable, and locally sourced energy. Europe, in its steadfast commitment to reducing carbon emissions and addressing the challenges of climate change, has emerged as a fertile ground for pioneering community-driven bioenergy projects. These initiatives not only reflect the continent's dedication to greener energy but also underscore the pivotal role of local communities and citizens in shaping the future of energy production. At the core of T4.5 lies the recognition that bioenergy's significance transcends environmental benefits, intertwining with societal, economic, and ecological dynamics. The narrative is based on tangible actions, unwavering dedication, and measurable results, as Task 4.5 strives to unveil.

Through meticulous analysis, this report uncovers the multifaceted impact of the BECoop RESCoops on local communities and the environment and evaluates the support activities that were provided to them throughout the project. The exploration extends to economic landscapes and environmental considerations, where biomass sourcing sustainability and reductions in greenhouse gas emissions are examined.

Each of the **pilot** cases had its **own set of characteristics**, with a complex mix of innovative ideas and practices, all aimed at the goal of a more sustainable and less energy-poor future for rural communities:

- **In the Spanish BECoop RESCoop**, there are two distinct support measures being implemented. Firstly, in **Aberasturi**, the objective is to utilize local forest biomass, to provide thermal energy via a district heating network that serves most of the buildings in the municipality. The other initiative was implemented in **Murgia**, where certain public buildings already use biomass-fuelled boilers, although the biomass is not locally sourced. The purpose of this initiative was to assess whether the locally produced biomass meets the required standards for the biomass boilers in Murgia.
- **The Polish BECoop RESCoop** aims to establish a biomass-based logistical chain in which local farmers and forest management stakeholders provide biomass to a local pellet plant. The produced biomass pellets would then be used into the local market towards community heating purposes.
- **The Italian BECoop RESCoop** focuses on the concept of biomass CHP district heating. The technologies targeted in the Italian BECoop RESCoop are already well-established and matured – the Italian pilot region is known for its successful forest biomass district heating systems, already widespread in the area.
- Finally, **the Greek BECoop RESCoop's** main activity is the management of a biomass plant for the production of solid biofuels to generate energy for heating purposes and operate as a bioenergy ESCO, installing biomass boilers and selling heat to the end-users.

In the following chapters, lessons learned from community bioenergy projects in Spain, Poland, Italy, and Greece are unveiled. Generated insights gleaned from these diverse European experiences serve as guiding beacons for future endeavours, offering a roadmap for harnessing biomass to safeguard the environment, invigorate local economies, and empower communities.

The aim of the current deliverable is to provide a report **summarizing the activities carried out in the previous tasks of WP4**, **evaluating the impact of the market uptake of the BECoop RESCoops** and provide a **critical analysis** at the end. The **evaluation** of these **outcomes** has been conducted on many levels: on a self-assessment (from the BECoop RESCoop perspective) level, a socioeconomic level, and an environmental level. Lastly, this deliverable also outlines the **risks and lessons learned** in the field of **community bioenergy**, intended to serve as guidelines for any stakeholders interested in similar bioenergy community initiatives.

In terms of structure, D4.5 starts with a methodology section (Chapter 2), where a brief explanation is offered on the various tools that were utilized by T4.5.

Continuously, **sections 3, 4, 5 and 6** are dedicated to the **monitoring and evaluation of market uptake support impact in the Spanish, Polish, Italian and Greek pilots** respectively. The same structure is followed in each section with the following subsections:

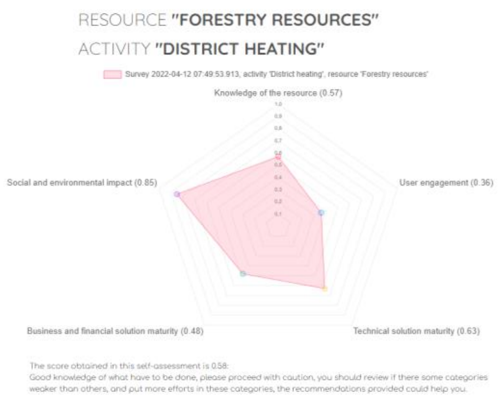
- **Overview of the BECoop RESCoop**
- Overview of the **various technical support services** provided to each pilot.
- Overview of the **small-scale demonstrations** performed in each pilot.
- Evaluation of the BECoop **market uptake support impact** containing:
  - The results of the BECoop Self-assessment Tool*.
  - A projection of the **socioeconomic and environmental impact** of the BECoop RESCoop.
  - The number of **stakeholders** engaged with the various activities performed in WP4.
  - The barriers and challenges identified by each BECoop RESCoop, along with separate sections where challenges, risks, lessons learned, and opportunities identified are discussed.
  - **Next steps** for the BECoop RESCoop.

At the end, in Chapter 7 (Critical Analysis) a **cross region examination** of the various **aspects** and **experiences** of each pilot was conducted. Special effort was given to this section as a means of self-reflection and performance benchmark for the whole WP4 activities, as well as a means of creating a frame of reference for similar future projects in community bioenergy.

*** The self-assessment tool**

The BECoop self-assessment tool provides an evaluation methodology along with a set of indicators, metrics and definitions for preliminarily assessing the current status and future potential of a community endeavour regarding community bioenergy.

The tool consists of **self-evaluation forms that allow to assess an initiative's status and identify the process, technical solution and business model that needs to be followed for initiating and taking part in a community bioenergy heating project**.



The questions asked act as a roadmap, helping the user to check if the most relevant aspects or considerations have been taken into account. The different answers provided suggest the steps needed to achieve a successful implementation of a new business model, as well as links (if applicable) to current tools and reports that may be useful to get beyond that stage. Such outputs offer:

- a clear picture of a user's project status,
- highlighting the strengths and weaknesses through a visual way in a spider-net, and
- providing a series of recommendations for further developing the initiative.

2 Methodology

In accords with the goals of this task, CERTH has deployed various monitoring and data collection mechanisms such as various dedicated templates, questionnaires, and qualitative means. Feedback from these has been constantly monitored, recorded, and evaluated.

This task expanded upon findings of all previous tasks of WP4, aiming to provide more tangible insights in the development of BECoop and summarizing the highlights and lessons learned. T4.5 adopted a comprehensive approach encompassing multiple stages. It initiated by meticulously reviewing the roadmaps crafted in Task 4.1, utilizing them as a fundamental framework to build upon. Concurrently, substantial attention was devoted to Tasks 4.2, 4.3, T 4.4 which delved into intricate technical and business aspects of the BECoop-explored community energy initiatives. Subsequently, individual discussions were conducted with each pilot team through bilateral calls. In these exchanges, CERTH closely collaborated with each team so as to effectively analyse and translate the findings from the regional level project activities into valuable insights on the impact and market uptake of community bioenergy heating projects across Europe.

2.1 Monthly monitoring regarding technical support activities

One of the tools developed is presented in Figure 1. It is an online sheet, where all BECoop RESCoops were tasked with ***continuously reporting their progress during the deployment of the technical support activities (T4.2) in each BECoop RESCoop***. Pilot partners reported their actions, making sure to update their monthly development along the way. This tool was used for supervision and communication, so that all involved pilots can keep a close eye on each other's progress, monitor the activities of each BECoop RESCoop and make it possible to re-orientate the aims of each BECoop RESCoop as needed.

T4.2 Activities						
Name of Activity	Brief description of montlhy BECoop RESCoop progress (what, who, where, when?)					
	before 6/30/22	31/7/2022	31/8/2022	30/9/2022	31/10/2022	30/11/2022
	before M20	M21	M22	M23	M24	M25
Quantification of local biomass (forest residues, coffee residues, urban biomass)	Literature survey on forest biomass productivity. Data from coffee residues collection demo are being used for the quantification of the coffee residues in the area. Urban prunings from city parks and gardens are being transported to ESEK. Data are being recorded regarding the amount of urban biomass that can be exploitted in the area.	Urban prunings being transported to ESEK. Data being recorded regarding the amount of urban biomass that can be exploitted in the area and the logistics.	No progress due to summer period	Physical meeting with the municipality about the collection of municipal pruning and the transportation to ESEK. Meeting with local forest cooperative in order to organize on-site measurements for biomass productivity of local forests	on-going analysis of results from city pruning collection and coffee residues collection.	on-going analysis of results from city pruning collection and coffee residues collection. Literature data used for estimate local forest residues potential
Field Visits	Field visit (CERTH, ESEK) at successful case of Lechovo (Northern Greece) where two schools are heated with biomass (vine pruning chips and sunflower husk pellets), operated by local municipal DH operator	No progress	No progress due to summer period	No progress	No progress	No progress
Identification of potential end users for the installation of biomass boilers	In contact with local hotel owners at Lake Plastira that expressed their interest to the new activities of the BECoop RESCoop	Arranging a meeting with the local hotel owners of Lake Plastira for September	Arranging a meeting with the local hotel owners of Lake Plastira for September, probably together with a Workshop	Meeting with hotel owners postponed for November. In communication with local authorities to provide energy consumptions of municipal schools in the area	Communications with municipal bodies to provide energy demands of municpila buildings	Retrieved data on heating consumptions of local municipal schools

Figure 1. Spreadsheet for the monitoring of monthly activities (snapshot from Greek BECoop RESCoop).

2.2 Monthly monitoring regarding demonstration activities

Similarly, actions related to the monthly monitoring of demonstration-related activities (T4.3) were recorded, as seen bellow in Figure 2. In the same sense, ***each BECoop RESCoop reported its activities related to the organization, preparation and execution of its demonstration activities.*** Again, this provided the opportunity to closely monitor the demonstration activities of each BECoop RESCoop and to re-orientate, if needed, the activities of any BECoop RESCoop.

T4.4 Activities						
Name of Activity	Brief description of montlhy BECoop RESCoop progress (what, who, where, when?)					
	before 6/30/22	31/7/2022	31/8/2022	30/9/2022	31/10/2022	30/11/2022
	before M20	M21	M22	M23	M24	M25
Coffee residues Exploitation	Demonstration of collecting coffee residues from the city of Karditsa. 10 local coffee houses participated, around 100 kg of coffee residues collected.	Completed				
Pellet production	Production of coffee pellets and forest residues pellets (mixed with other biomass sources) at ESEK.	No progress	Completed			
Fuel Characterization	Produced pellets sent to CERTH's laboratories for fuel characterization. On-going fuel analyses	On-going	No progress due to summer period	Fuel characterization of 27 samples of produced pellets completed	On-going analysis	Analysis of results
City pruning Exploitation	Urban prunings from city parks and gardens are be	In contact with equipment manufacturer to provide a chipper to chip the city prunings at ESEK facilities	Organizing the transportation of a stationary chipper to ESEK facilities to treat the urban prunings in September.	Demonstration of shredding the collected urban prunings at ESEK	Analysis of results from urban pruning shredding	Analysis of results from urban pruning shredding

Figure 2. Spreadsheet for the monitoring of monthly activities (snapshot from Greek BECoop RESCoop).

2.3 Assessment exercise using the BECoop self-assessment tool

The BECoop self-assessment tool (developed and thoroughly introduced in T2.1) was also used as means to evaluate BECoop's market uptake support impact at the pilot-level.

The BECoop self-assessment tool provides an evaluation methodology along with a set of indicators, metrics and definitions for preliminarily assessing the current status and future potential of a community endeavour regarding community bioenergy.

The tool consists of **self-evaluation forms that allow to assess an initiative's status and identify the process, technical solution and business model that needs to be followed for initiating and taking part in a community bioenergy heating project**. The questions asked act as a roadmap, helping the user to check if the most relevant aspects or considerations have been taken into account. The different answers provided suggest the steps needed to achieve a successful implementation of a new business model, as well as links (if applicable) to current tools and reports that may be useful to get beyond that stage. Such outputs offer:

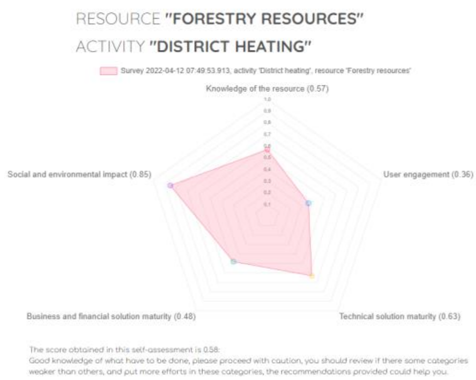


Figure 3. Example of self-assessment outputs visualised as a spider-net diagram

- a clear picture of a user's project status,
- highlighting the strengths and weaknesses through a visual way in a spider-net, and
- providing a series of recommendations for further developing the initiative.

2.4 Measuring the socio-economic impact of the BECoop RESCoops

Other ***tools were also used to quantify the socio-economic and environmental impact of the BECoop RESCoops*** and the influence they have on their areas. *These tools (Figure 4), developed by CERTH*, drew upon resources from previous H2020 projects (Up_running[1] and AgroBioHeat[2]) and available literature. The data utilized for these assessments and general guidelines were drawn from EU Environmental Agency guidebooks[3], from the EU Directive 2018/2001 on the promotion and the use of energy from renewable sources (RED II[4]) and from sustainability reports[5].

[1] https://www.up-running.eu/
[2] https://agrobioheat.eu/
[3] European Environment Agency guidebook-Chapter 1.A.4 (https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-4-small-combustion/view)
[4] RED II, https://joint-research-centre.ec.europa.eu/welcome-jec-website/reference-regulatory-framework/renewable-energy-recast-2030-red-ii_en
[5] Deloitte (2022) Towards an Integrated Energy System: Assessing Bioenergy's Socio-Economic and Environmental Impact. Study commissioned by Bioenergy Europe. Available here: https://bioenergyeurope.org/articles/347-towards-an-integrated-energy-system-assessing-bioenergy-s-socio-economic-and-environmental-impact.html / Tables 3 and 4

To calculate the social impact, the tool requires an input of the biomass mobilized by a bioenergy project, along with the LHV (Lower Heating Value in dry basis). It then uses data drawn from sustainability reports in a function that relates mobilized biomass to economic metrics. More specifically, the tool estimates the amount of new full-time jobs created in several sectors such as equipment manufacturing, construction, feedstock supply, operation and maintenance of the plant and indirect jobs. The tool also calculates the GDP impact of the bioenergy activities on these sectors.

T5.2: Guidelines for a simplified assessement

Employment and GDP impact by agrobiomass mobilization

WP5 - Providing Europe with a strategy and regulations for agrobiomass heat

Task 5.2 - National Strategic Plan

AgroBioHeat

Author: CERTH
Version: 2.5
Date: 18/02/2022

Straw	14.9	LHV, a.r., MJ/kg	9.2	% moisture
Forest	10	LHV, a.r., MJ/kg	37.1	% moisture

Insert Values by user
Results - Automatically calculated

Input Data for calculating employment and GDP impact		
Annual quantity (dry basis)	620	t
NCV (dry basis)	17.0	GJ/t

Straw	320	t/y (d.b.)	16.7	LHV, d.b	51.6% % of fuel mix
Forest	300	t/y (d.b.)	17.3	LHV, d.b	48.4% % of fuel mix
	620				

Results based on biomass DH:	Employment impact		GDP impact	
Equipment manufacturing	1	FTE	0.02	MEUR
Construction	0	FTE	0.01	MEUR
Feedstock supply	0	FTE	0.01	MEUR
Operation and maintenance	1	FTE	0.03	MEUR
Indirect	0	FTE	0.02	MEUR
TOTAL	2	FTE	0.09	MEUR

Results based on biomass individual heating	Employment impact		GDP impact	
Equipment manufacturing	0	FTE	0.01	MEUR
Construction	0	FTE	0.00	MEUR
Feedstock supply	1	FTE	0.03	MEUR
Operation and maintenance	0	FTE	0.00	MEUR
Indirect	0	FTE	0.02	MEUR
TOTAL	1	FTE	0.06	MEUR

Results based on Bioelectricity (CHP):	Employment impact		GDP impact	
Equipment manufacturing	0	FTE	0.01	MEUR
Construction	0	FTE	0.01	MEUR
Feedstock supply	4	FTE	0.09	MEUR
Operation and maintenance	2	FTE	0.17	MEUR
Indirect	2	FTE	0.10	MEUR
TOTAL	8	FTE	0.38	MEUR

Biomass DH	15,371	ktoe		
EU-27 data (Deloitte, 2022):	Employment impact		GDP impact	
Equipment manufacturing	34,880	FTE	1,297	MEUR
Construction	10,088	FTE	715	MEUR
Feedstock supply	16,981	FTE	373	MEUR
Operation and maintenance	47,165	FTE	1,766	MEUR
Indirect	25,434	FTE	1,494	MEUR
Total	134,548	FTE	5,645	MEUR

Biomass individual heating systems	41,527	ktoe		
EU-27 data (Deloitte, 2022):	Employment impact		GDP impact	
Equipment manufacturing	26,390	FTE	1,548	MEUR
Construction	8,390	FTE	434	MEUR
Feedstock supply	210,511	FTE	4,895	MEUR
Operation and maintenance	4,669	FTE	244	MEUR
Indirect	66,387	FTE	3,508	MEUR
Total	316,347	FTE	10,629	MEUR

2019

Biomass CHP	9,935	ktoe (electriity_	10217 ktoe (heat	
EU-27 data (Deloitte, 2022):	Employment impact		GDP impact	
Equipment manufacturing	5,811	FTE	216	MEUR
Construction	4,642	FTE	445	MEUR
Feedstock supply	153,047	FTE	3,668	MEUR
Operation and maintenance	69,544	FTE	6,791	MEUR
Indirect	60,669	FTE	3,889	MEUR
Total	293,713	FTE	15,009	MEUR

Figure 4. Social impact assessment tool developed by CERTH.

More details on the methodology of the tool can be found in the Annex section.

2.5 Measuring the environmental impact of the BECoop RESCoops

Regarding the environmental assessment tool (Figure 5), ***GHG emissions are calculated*** via a simple methodology mainly based on: i) GHG accounting methodology presented in the Report of the European Commission COM (2010) 11[6] plus additions in the European Commission Staff Working Document SWD (2014) 259[7]; ii) JRC report EUR 27215 EN[8] and iii) European Project BIOGRACE II "Harmonised Greenhouse Gas Calculations for Electricity, Heating and Cooling from Biomass"[9]. Through the tool, GHG emissions in each BECoop RESCoop are calculated as ***CO_2 equivalent emissions***. Aim of the tool is to calculate the GHG emissions savings in each pilot area based on the new activities of each BECoop RESCoop. ***More details on the methodology can be found in the Annex section***.

CO_{2eq} emissions from usage of biomass fuels	Details	Value	Unit
APPR biomass/fuel input to energy conversion process		620	t (dry basis)
Moisture content of product		0%	dry basis
LHV of biomass/ fuel		17.0	MJ/kg (dry basis)
Energy content of fuel		10,540,000	MJ, dry
Total CO_{2eq} emissions from production of fuel before energy conversion		0.47	gCO_{2eq}/MJ (dry basis)
Electrical efficiency	η_{el}	0.00%	
Heat efficiency	$\eta_{h\&c}$	92%	
Cooling efficiency- seasonal coefficient of performance (SCOP)	η_c	80%	
Temperature of useful heat at point of delivery	T_h	120	°C
Carnot efficiency in heat	C_h	0.35	
Total CO_{2eq} emissions from electricity production	**EC_{el}**	**-**	**gCO_{2eq}/MJ**
Total CO_{2eq} emissions from heat production	**EC_h**	**0.52**	**gCO_{2eq}/MJ**
Total CO_{2eq} emissions from cooling production	**EC_c**	**0.64**	**gCO_{2eq}/MJ**

Savings of CO_{2eq} emissions		Min. requirements - RED II
Savings, electricity	**-**	80%
Savings, heating	**99.36%**	80%
Savings, cooling	**99.19%**	80%

Figure 5. Environmental impact assessment tool developed by CERTH.

[6] COM/2010/11, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:0011:FIN:EN:PDF
[7] http://ec.europa.eu/energy/sites/ener/files/2014_biomass_state_of_play_.pdf
[8] https://ec.europa.eu/energy/sites/ener/files/documents/Solid%20and%20gaseous%20bioenergy%20pathways.pdf
[9] http://www.biograce.net/biograce2/

3 Monitoring and evaluation- Spanish BECoop RESCoop

3.1 Overview of the BECoop RESCoop (ES)

In the Spanish initiative, there are two distinct endeavours being supported. To start with, in **Aberasturi, the objective revolves around harnessing local biomass, encompassed of straw and wood chips, to power a district heating network that will deliver thermal energy to all residential and commercial structures within the municipality**. While the procedure of gathering herbaceous biomass is widely understood, the main aim concerning forestry lies in the preservation of local forests, which are currently overlooked. Consequently, the extraction of biomass was a priority for the project, with a vital need to evaluate the associated expenses and the fuel quality to ascertain its feasibility.

On the other hand, in **Murgia**, certain public buildings are equipped with boilers currently fuelled by biomass, though not procured locally. Moreover, the local high school is educating students in forest biomass harvesting techniques. **The purpose of this endeavour is to validate whether the quality of the locally produced biomass from the high school is suitable and appropriate for the biomass boilers utilized in Murgia and its neighbouring vicinity**.

3.1.1 Roadmap of BECoop RESCoop

Aberasturi is a small village of 133 inhabitants located in the Basque country. The goal of supporting the Spanish BECoop RESCoop is to gain knowledge and experience on BE community heating in order to deploy a renewable thermal assessment service among its members, and to assist other REScoops in Spain and Europe to replicate. The roadmap to the end of BeCoop project and to 2030 is presented in **Error! Reference source not found.**. The secondary Spanish case of Murgia had already in place a biomass heating system in certain public buildings, using non-local forest biomass**. The vision in this case was the construction of a new swimming pool and recreation center, that utilize a biomass technology heating system.** The local vocational-training institute at Murgia offers forest management classes and already owned some basing forestry equipment that will support the harvesting and treating of local forest residues.

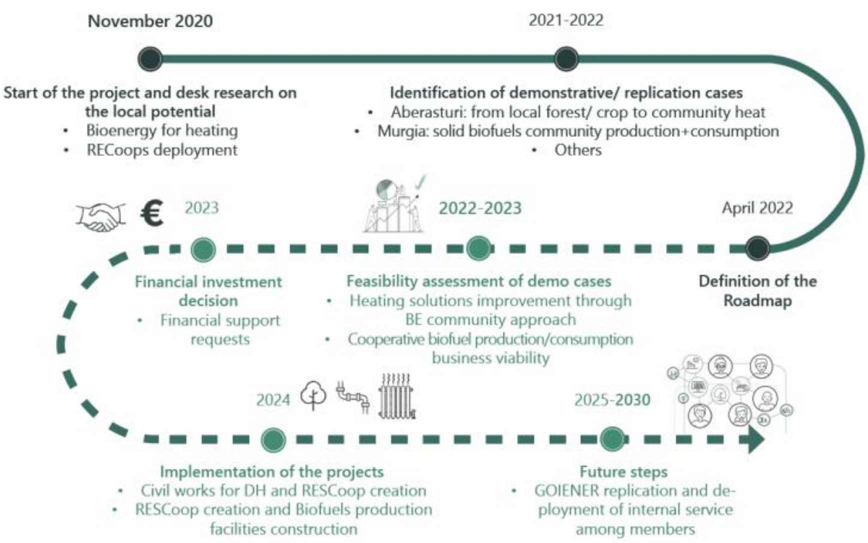


Figure 6. Scheme of the roadmap (Spanish pilot).

For more details on the roadmap of the Spanish BECoop case, please refer to DLV 4.1 "Co-definition of community bioenergy heating roadmaps".

3.1.2 Overview of technical support services provided

In this section can be found a brief overview of the various technical support services provided to the Spanish BECoop RESCoop. For more details, please refer to DLV 4.2 "Deployment of the BECoop technical support services".

Biomass assessment

Starting off with the Aberasturi case, the initial interest was centred around **two local biomass sources**, **forestry and herbaceous (straw)**. Concerning the forestry biomass, the technical support services provided related to analysing the characteristics of the biofuel and assessing its availability. Based on the existing forestry management plant and current practises, around 500 t/year (d.b.) of forest biomass can be potentially harvested, with a typical moisture content of 37%. In terms of the herbaceous biomass, straw was the primary candidate that was assessed. The potential of straw that can be collected from the local areas of interest (Rio, Monte) amount to around 620 t/year (d.b), with a typical moisture content of 15%.

Logistics of the BECoop RESCoop

The primary issue with the Aberasturi forest is it's dense plant population, making the biomass hard to access and the forest's sustainability endangered. To address this issue, thinning of the different trees was suggested. The use of heavy machinery was also suggested to be avoided, preferring manual chainsaws, the removal of the cut trees with a skidder, and their transportation in a long term storage area to lower their moisture content (Figure 7). The renting of a chipping machine was also proposed, along with natural drying for the woodchips if need be, before they are fed to the boilers. Concerning the herbaceous biomass, a more traditional value chain was recommended. After the crop's harvest, the material would remain in the field for one week, then be winnowed and balled with mechanized means. The bales would be transported to the storage area then fed to the biomass boilers (Figure 8).

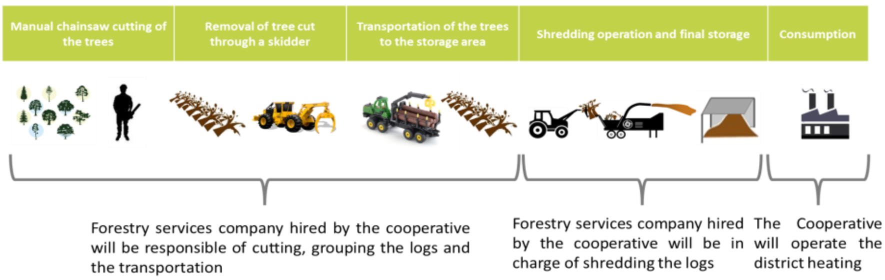


Figure 7. Forest biomass value chain for Aberasturi.

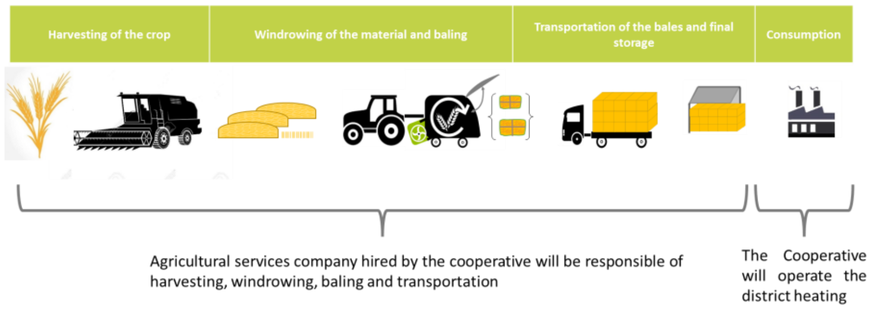


Figure 8. Herbaceous biomass value chain for Aberasturi.

Cost of collection

Assessments on the cost of collection (harvesting and transportation) were provided, for both types of biofuels. For forestry biomass the final price of the woodchips, validated through a demonstration in T4.4, was estimated around 70 €/t (at 37% moisture). For the herbaceous biomass, the collection cost was estimated at 45 €/t (at 12% moisture).

Location of the BECoop RESCoop

The BECoop RESCoop was suggested to be situated inside the village of Aberasturi. An assessment of the potential district heating and how it could be implemented was studied including the potential length and topology of the main line of the underground piping system to cover all of the residences needs (Figure 9). Regarding the generation plant and the biomass storage area, its placement took several considerations, including avoiding the mixing of potential fuels, avoidance of noise pollution and emissions and facilitating of its operation by placing the storage area close to the boiler, as well as ensuring adequate space for a control room.

Figure 9 Location of the generation plant and the biomass storage area (red rectangle).

Technology and activity of the BECoop RESCoop

The activity for the Spanish BECoop RESCoop was considered a **District Heating plant, fueled by locally sourced forest residues and straw**. To provide a technically and economically feasible implementation of district heating in the village of Aberasturi, the BECoop technical catalogue[10] was considered. Considerations included present and future resident interest in district heating as well as energy demands. The power of the plant was assessed at **1.2 MW, which will produce 1,400 MWh/year**, taking into account parameters like the efficiency of the heating network (92%), the efficiency of the power plant (85%), the number of hours of its potential operation (1400 h) and its average working load (80%). Monthly variation in consumption was also considered. Furthermore, the amount of fuel needed for the operation of the Spanish BECoop RESCoop was assessed. Aberasturi intended to cover it with a 50-50 split of forestry and straw biomass, resulting to 247 t/y forest biomass and 192 t/y straw. Finally, an estimate on the investment costs was provided (1.8 M€), with help from meetings with 3 different ESCOs with relative DH experience.

Energy demands to be covered

An estimation of the energy demands of Aberasturi was performed. The energy demands were calculated to be 1,435 MWh/year based on a questionnaire that was distributed. Resident participation was of particular note, with all 43 households responding in detail to the questionnaire.

Feasibility study of the BECoop RESCoop

For the purposes of this analysis, the revenues were considered to be energy savings, as the profitability of the concept (1.2 MW DH plant) rested on the finances saved by the residents in using DH options instead of fossil fuel ones. The feasibility study considered factors like the energy consumption, heating costs, the

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

amount of energy to be produced by the biomass plant, its power, the length of the heating network, the investment and operational costs. Other factors like carbon tax for fossil fuels were also considered to further strengthen this hypothesis. Considering the data provided by this analysis, economic indicators (IRR, NPV, PB[11]) were calculated and it was determined that the operation was economically feasible. In brief, a**n IRR of 5.16, a NPV of 702,591€ and a payback period of 11.9 years** were calculated.

Overview of technical support activities provided to second Spanish BECoop RESCoop case of Murgia

Murgia is located in the Gorbeialdea mountain region and is composed of six small rural municipalities. During the provision of the technical support services, the key issue was determining whether the woodchips produced locally would be suitable for the boilers already installed. To that end, meetings were caried out, and a sample of the woodchips was analysed and compared to a suitable sample. The report compiled at the conclusion of these activities concluded that the biofuels would indeed be suitable. To back this result, a combustion test was performed in the boiler of the municipality, and its results were reported in T4.4. The results of the pilot were very positive, achieving adequate performance without any operating issues.

3.1.3 Overview of small-scale demonstration activities performed

In this section can be found a brief overview of the various small-scale demonstration activities performed in the Spanish BECoop case. For more details, please refer to DLV 4.4 “BECoop small-scale demonstration activities”.

Mechanized harvesting of forest residues and fuel analysis

Based in Aberasturi, this demonstration had the purpose of addressing the issues rising from the non-utilization of local biomass. With the support of the BECoop project and the Vitoria City Council, it designed a forest management plan to determine the amounts of biomass that could be obtained from the adjacent Aberasturi woodland, with the aim of improving its sustainability (Figure 10).

Given the dense tree population, the harvesting method that was decided was manual tree felling with chainsaws and a skidder for the extraction of the trees out of the forest and into a storage area. The selection and felling are performed meticulously, both because of the difficulty of the operation and to ensure a high-quality end product and the forest’s preservation. The demonstration was carried out on a 4.3 ha area of public forest, utilizing two different methods, with different distribution of workers between the forestry tasks (felling, limbing, stacking etc). Through both methods a total of 196,2 t of wood (37% moisture). Out of the two methods, the second, involving cutting trees before removing them from the forest was found to be more profitable and bear a bigger yield.

Samples were taken from the biomass and analysed to determine their physical and chemical properties. To address the high moisture content of cut trees, a storing period was suggested to lower their moisture content to 20-30%. Overall, the biomass was found to be of high quality and suitable for energy valorisation.

[11] IRR: Internal rate of return; NPV: Net profit value; PB: Payback.

Figure 10. Images from the forest biomass harvesting demonstration

Combustion tests with the local biomass and fuel analysis

In Murgia, biomass boilers were already available, but the biomass fuels were not being sourced locally (Figure 11). The small-scale demonstration involved the local high school, where students were being trained in forest biomass harvesting methods. With their aid, the initiative aimed to harness the area's potential for locally sourced biomass as an energy source for heating purposes. The demonstration focused on the assessment of the biomass quality and a combustion test in a biomass installation in the city council building. The laboratory analysis performed on the woodchip samples found them to be of good quality. Their moisture content was comparable to literature woodchips, their bulk density was adequate and homogenous, accompanied by small fines and low ash content. To corroborate these results, the combustion tests were also performed. The combustion tests verified the good quality of the biofuel and that it could in-fact be used in the installations.

Figure 11. Images of the silo loading with the new fuel.*

*Silo empty (left); people from the institute helping by weighing and helping to put the material into the silo (centre); staircase where the material was fed through (right).

3.2 Evaluation of BECoop market uptake support impact (ES)

3.2.1 Self-assessment results

In the Spanish case study in Aberasturi, an initial self-assessment was conducted to evaluate the feasibility of district heating utilizing forestry resources. Figure 12 presents a 5-point spider chart comparison conducted at the outset and after receiving support through WP4 activities. **Significant progress** has been made across all facets of the initiative (**0.48 to 0.87** global score improvement), with notable improvements in areas such as resource knowledge, technical proficiency, and business and financial aspects. Moreover, there is evidence of improved awareness regarding social and environmental considerations, as well as enhanced engagement with users, resulting in a commendable overall level of knowledge and understanding of the community bioenergy initiative within the BECoop RESCoop.

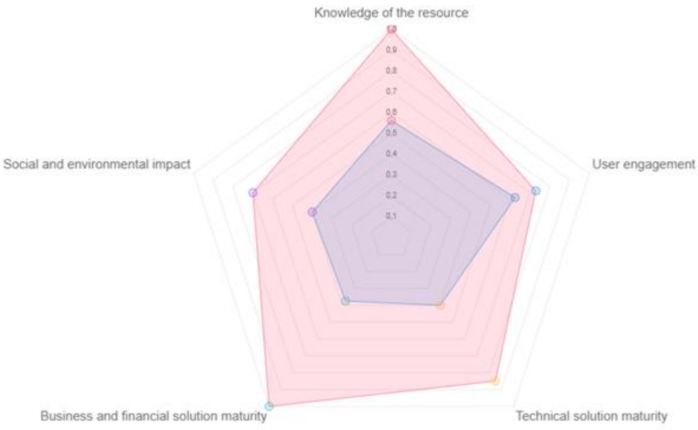


Figure 12. Final self-assessment (pink) compared with the initial one (blue) carried out for the Spanish case in Aberasturi concerning forestry resources related with "district heating" category.

Similar to Aberasturi, a self-assessment was conducted for the BECoop RESCoop in Murgia, specifically focusing on logistics operations involving forestry resources. Figure 13 below illustrates significant advancements across all dimensions of the initiative, resulting in an **overall increase** in the global score from **0.59 to 0.87**. Noteworthy improvements have been observed in resource knowledge and technical and economic aspects. While areas related to social, environmental, and engagement aspects may benefit from additional support, the overall evaluation of the BECoop RESCoop demonstrates promise and positive development.

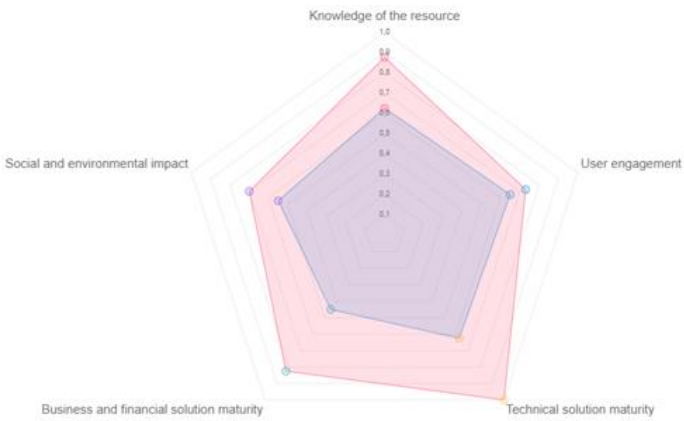


Figure 13. Final self-assessment (pink) compared with the initial one (blue) carried out for the Spanish case in Murgia concerning forestry resources related with "logistics" category.

A more detailed presentation of the results and breakdown of scores of the self-assessments are presented in Table 1

Table 1. Self-assessment results for the Spanish BECoop RESCoop.

	Aberasturi		Murgia	
	Initial Assessment	Final Assessment	Initial Assessment	Final Assessment
Knowledge of resources	0.57	1	0.63	0.88
User engagement	0.63	0.74	0.66	0.74
Technical solution maturity	0.41	0.86	0.63	1
Business and financial solution maturity	0.38	1	0.46	0.83
Social and environmental impact	0.41	0.7	0.56	0.7
Global score	**0.48**	**0.87**	**0.59**	**0.84**

3.2.2 Socio-economic and environmental impact of the BECoop RESCoop

To assess the **socio-economic impact** of the Spanish BECoop RESCoop, as mentioned in section **Error! Reference source not found.**, CERTH developed specific tools for the task. The results from the application of these tools, for the Spanish BECoop RESCoop, and its district heating activity, are as follows (Table 2).

Table 2. Spanish pilot socio-economic impact.

Results based on biomass DH:	Employment impact (FTE[12])	GDP impact (M€)
Equipment manufacturing	0.3	0.01
Construction	0.1	0.01
Feedstock supply	0.1	0.00
Operation and maintenance	0.5	0.02
Indirect	0.2	0.01
TOTAL	**1.3**	**0.05**

The estimated biomass utilized annually by the pilot project was 319 tonnes (dry basis), with an LHV of 17.6 GJ/t (calculated as average for straw and forest biomass). The employment impact, calculated for a biomass district heating station of the appropriate size for the project, gave an estimated **1.3 employment opportunities** created at its current scope. This translates to a **GDP impact of 50,000€**.

The GDP impact for a project of this scale, is expectedly low, but the Spanish BECoop RESCoop was created mostly as a test, to evaluate the potential of community bioenergy and replicate in similar cases in the country. So, it can be assumed that the project's scope is expected to change and expand. This can be also demonstrated by the roadmap of the project, highlighted in section 3.1.1.

Similarly, using the developed tools it can be assessed that the **environmental impact** of the Spanish pilot is as demonstrated on Table 3.

Table 3. Spanish pilot environmental impact.

	Value	Units	
CO_{2eq} emissions from transport and distribution (e_{td})	3.1	gCO_{2eq}/MJ_{Fuel}	Minimum GHG emissions savings based on RED II for new biomass installations
CO_{2eq} emissions from processing (e_p)	1.1	gCO_{2eq}/MJ_{Fuel}	
CO_{2eq} emissions from fuel in use (e_u)	0.3	gCO_{2eq}/MJ_{Fuel}	
Total CO_{2eq} emissions from production of fuel before energy conversion (E)	4.5	gCO_{2eq}/MJ_{Fuel}	
Total CO_{2eq} emissions produced	25.2	tCO_{2eq}	
Total CO_{2eq} emissions from heat production	5.3	gCO_{2eq}/MJ	
GHG emissions savings**,** heating	93.4%	%	80%

The environmental impact of the project reveals great potential. The total CO_{2eq} emissions for heat production for the activity of the Spanish RESCoop was estimated at **5.3 gCO_{2eq}/MJ or a total of 25.2 tCO_{2eq}**. In brief, due to the small amount of biomass mobilized and the small sourcing/ transportation radius, the environmental impact of the BECoop RESCoop is positive.

This can be translated into **93.4% CO_{2eq} savings**, compared to fossil fuel comparators for heating production. This is in line with the minimum requirements (80%) set by RED II guidelines for GHG emissions savings for

[12] Full time equivalent.

electricity, heating and cooling production from biomass fuels used in installations starting operation after 1 January 2021.

There is also the potential to upscale the BECoop RESCoop's activities to cover the needs of other communities. If this example can be replicated in other areas, the results could potentially be invaluable from an environmental perspective

3.2.3 Stakeholders engaged through BECoop activities in the pilot area

In total, **155 stakeholders were engaged** in the various activities performed in the framework of WP4. The activities included visits to various sites or businesses related to the project, physical and digital meetings, workshops demonstrations etc. The stakeholders involved were research institutions, both public and private, other RESCoops, SMEs, public authorities, citizens, owners of various scales etc.

3.2.4 Barriers, challenges, and risks identified by the BECoop REScoop

Bioenergy communities can offer significant environmental and energy efficiency benefits. However any bioenergy project will have to face various challenges in today's market. Whether it be public acceptance, legislative issues, or internal struggles, it is vital to identify those and use the feedback to create a stronger base not only for current, but also future bioenergy projects.

Throughout the project, several barriers, challenges and risks have been addressed while also identifying potential future ones. Here are some of the primary obstacles and challenges identified from the Spanish case:

- **The Location of BECoop RESCoop:** One of the most crucial factors in establishing any RESCoop is identifying a suitable location with motivated residents who are committed to environmental protection, renewable energy initiatives, and a collaborative approach to problem-solving. Aberasturi is an example of a location that meets these criteria. Aberasturi benefits from a unique administrative structure known as the 'concejo,' which is connected to the municipality of Vitoria Gasteiz while also maintaining a degree of autonomy in certain areas. Additionally, Aberasturi's countryside location, surrounded by nature, has made its residents very aware of environmental issues.
- **Availability of local biomass sustainably and economically obtained:** Having locally sourced biomass at hand is crucial. Both Spanish pilot projects were successful in this aspect. In Aberasturi, the resources were plentiful, of high quality, and cost-effective to collect. Similarly, in Murgia, where the challenge was ensuring boiler compatibility, it also proved to be successful.
- **Insecurity in Biomass Supply:** Biomass availability can be affected by weather conditions, seasonal changes, and other factors. For example, there is an ongoing initiative from the livestock sector to forbid the usage of straw for energy purposes because there is a lack of straw for feeding the animals due to the persistent drought.
- **Local authorities' engagement:** The involvement of local authorities can sometimes be challenging, but it is essential for the successful implementation and promotion of heating projects like Aberasturi and Murgia. Their support can streamline regulatory processes, secure funding, engage the community, and align projects with broader environmental and energy goals, ensuring a more sustainable and integrated approach to heating solutions. That was achieved for both cases and was essential for the successful, implementation of the BECoop RESCoops.
- **High Initial Investment Costs:** Establishing a district heating system based on biomass like the project in Aberasturi, requires significant upfront investment in infrastructure, such as biomass boilers, storage facilities, and a network of pipes to distribute the heat. These initial costs, especially the

network of pipes, are directly related to the density of heat demand. It is generally accepted that heat demand over 3 MWh/m*year is needed for being economically feasible, (Aberasturi has 0.6 MWh/m*year) but in rural areas where biomass is available, such ratios are uncommon. On the other hand, in city centers and municipalities where there are sport facilities, swimming pools, schools, hospitals etc., density ratios are higher, but biomass resources are often not local.

- **Governance model/ Ownership Issues:** The governance model of an energy community poses significant challenges. It impacts not only the community's decision-making processes but also determines ownership of the installation, responsibility for investments, accessibility to financing programs, the allocation of energy bills and cost distribution, and various financial aspects.
- **Regulatory and Permitting Hurdles:** Community energy projects are facing regulatory and permitting hurdles at the local, regional, or national level. There is not a stable regulatory framework for this type of projects and the way the local authorities can be involved promoting this kind of actuations (what, as has been said, is extremely recommended). Environmental assessments, land-use approvals, and compliance with emissions standards are some of the common challenges that can delay or complicate project implementation.
- **Competition with Fossil Fuels:** Biomass for thermal use faces competition from existing fossil fuel-based heating systems, especially natural gas in Spain, which is already well-established and cheap and typically is perceived as more convenient/comfortable or cost-effective by citizens. Natural gas wasn't a concern in our demonstration sites since there was no access to a natural gas grid in those areas. However, it remains a general issue;
- **Locating specialized companies to cover specific needs:** There are specific categories of companies that may not be readily available in all areas, such as those involved in biomass collection, boiler maintenance, or other activities related to complex technological projects. It's essential to address these needs sustainably, considering factors like responsible harvesting practices;
- **Lack of Community/ citizen Engagement:** Without active participation and buy-in from community members, a bioenergy community may struggle to gain traction and support. Lack of interest or awareness can lead to insufficient investment and commitment from the community. Information sessions and facilitation of co-creation activities are necessary to overcome inertia and drive community activity. Citizens showed lack of knowledge on biomass-based district heating systems. These systems can be complex to design, install, and operate, particularly in comparison to traditional heating systems. The absence of this knowledge may have led to a lack of citizen engagement and even opposition. Convincing the public of the benefits of biomass district heating is essential. Some people may have misconceptions about biomass energy, associating it with deforestation or air pollution. Raising awareness and addressing concerns can be a significant challenge. Engaging citizens is a relevant challenge because a high level of participation in district heating (over 70% as in the case of Aberasturi) is essential to make investments & operations economically viable.
- **Financial Viability**: Sustainable energy projects often require substantial upfront investments, especially biomass projects which are much more technologically complex projects than PV ones. If an energy community cannot secure adequate funding or fails to generate revenue through energy sales or savings, it may become economically unsustainable. Besides public institutions involvement should assure a certain amount of public grants that make the projects feasible.
- **Technical Challenges**: Implementing and maintaining energy infrastructure within a community requires technical expertise. Lack of access to qualified professionals or technical support can hinder the successful operation of energy projects.
- **Mismatched Energy Demand and Supply**: Energy communities rely on a balance between energy demand and supply. If the energy generation capacity exceeds demand or is insufficient to meet

community needs, it can lead to inefficiencies and financial challenges. Besides, Biomass supply should be locally harvested for assuring supply chain and avoiding transportation.

- **Social and Cultural Factors**: Social dynamics, cultural norms, and conflicts within the community can impact the successful collaboration and functioning of an energy community.
- **Resilience and Reliability Concerns**: Energy communities need to demonstrate resilience and reliability, if the thermal system is not reliable, community members may lose trust in the system.
- **Perception and Awareness**: Misconceptions or negative perceptions about energy community concepts may deter potential participants and investors.

To address these barriers and challenges, the BECoop project has been designed using a bottom-up approach. This involves organizing co-creation workshops that bring together various stakeholders, including policymakers, industry experts, and citizens. Through these collaborative efforts, the aim is to develop supportive policies, secure funding, enhance biomass supply chains, and promote citizen acceptance of biomass-based district heating as a sustainable and customized energy solution

3.2.5 Lessons learned and opportunities identified by the BECoop RESCoop

Throughout the various tasks undertaken by BECoop RESCoop thus far, a multitude of valuable lessons learned, and opportunities have come to light. These insights encompass aspects such as job creation, rural development, sustainability, and the harnessing of underutilized local resources. In the following section, we outline some of these key takeaways, highlighting best practices from our experience with the Spanish BECoop RESCoop.

The lessons learned and opportunities identified during the project development in Aberasturi and Murgia are:

- **Exploitation of underutilized resources**: local residues (straw) and woody biomass from a forest management plan for avoiding forest fires and improving wood quality for future forestry operations will be an opportunity for substitution of fossil fuels for thermal purposes. It reduces the need of transport of the straw surplus for remote valorisation.
- **Locally sourced fuel:** having locally collected fuel makes the communities independent from the fluctuations of the energy markets. Local biomass is also a cheap fuel compared to propane or diesel in the areas where the natural gas grid is not available. One other point to consider is that multi-fuel usage reduces the risk of biomass availability shortage.
- **Local society benefits**: biomass usage also promotes the local economy and generates jobs that will help the rural areas to develop. Community-driven solutions promote social cohesion and serve as breeding ground for other projects such as collective self-consumption, energy efficiency, home renovation, sustainable mobility, food sovereignty. The promotion of rural economies also **reduces internal migration** to big city centres. **Having a school on forest management** and local biomass additionally gives the opportunity to students to become entrepreneurs and promote local biomass economy, in the Murgia case.
- **Government model benefits**: The existence of an organisational structure (“Concejo”) in Aberasturi, with an elected community representative and established communication channel, is of great benefit.
- **Dealing with energy poverty:** community solutions take into consideration measures for the alleviation of energy poverty.
- **Forest maintenance and sustainability**: The exploitation of local biomass helps maintain the forests reducing the risk of forest fires.

- **Reduction of fossil fuels and electricity reliance**: With community bioenergy heating the **decarbonisation** of the thermal needs can be achieved. Furthermore, solutions based on biomass exploitation helps the reduction of electricity reliance, as the other options for decarbonization are heat pumps and the electrical grid is not prepared for absorbing the thermal consumption plus e-mobility consumption.
- **Strengthening of rural economies:** a local value chain can generate benefits to local employment and to the local economy as it increases energy independence and thus reduces the leakage of wealth out of the community. The practice of firewood allotments assigned to local residents and harvested from public land (e.g. "suertes" in Alava, "lotes" in Navarre), is generally an underexploited local resource.
- **Active participation of local authorities**: it is of utmost importance, as for instance they hold the responsibility of granting permission for the harvesting activities or the installation of the heating network in the rural area, their engagement can facilitate the search for public funding, etc. Also, including non-residential buildings (administrative buildings, schools, sports facilities, but also small businesses) may kick-start the initiative and make the business plans economically viable. It can be helpful to find non-residential consumers with consumption profiles that are complementary to the typical residential profiles. Where possible, taking advantage of scheduled public works for other services (transport, water, electricity, telecommunications); if the streets need to be dug up anyway, why not use the opportunity to install a biomass-fueled heat network.
- **Supportive external structures and alliances**: having the support of entities that can advise and guide the study of a project's feasibility (technically and economically), or the caveats of energy-community formation and which model to follow, can be very important, especially for new ventures that lack know-how. Setting up collaborations with local industry (agro-industry) as they may have biomass residues, surplus heat, complementary consumption requirements etc. The collaboration should benefit both partners.

3.2.6 Next steps of the BECoop RESCoop

The BECoop project has helped pilot case GoiEner with various exploitation activities that will be developed in the short to medium term. On one hand, the demo case of Aberasturi has a clear path in the coming months. The public administration of the "concejo" has **presented the DH project to a public funding program** during April 2023. The resolution of this program is expected by December 2023. If the project receives approval, the **next steps will involve establishing an energy cooperative**, which is the recommended legal entity for the energy community.

The process of constitution is: i) constituent assembly; ii) notarial act; iii) registration in the Cooperatives register; iv) admission of new members. The district heating network and biomass plant will be public property and the Bioenergy community will oversee the O&M. During 2024 the tender for works would follow and by winter 2024 the DH plant would be in operation.

The Murgia case also exhibits significant potential for development, but it requires increased engagement from local stakeholders. During the BECoop project it has been demonstrated that there is a potential market for local Biomass to be used in the public institution's buildings both in the actual biomass boilers and in the future ones, as it is mandatory for the public institutions to substitute fossil fuel boilers for renewable sources. Now it is time for citizens (students from the forest management school that were engaged during the project activities under T4.4) to establish a company which could fill in the opportunity that has been highlighted during the project.

Furthermore, **GoiEner is on the lookout for opportunities related to biogas and biomethane installations**. Legislative changes are expected which will permit the trading of certificates of origin for biomethane injected into the natural gas distribution grid. In addition, in the future plants of GoiEner and the Spanish BECoop RESCoop is to provide consultancy and engineering support to homeowner associations of multi-dwelling building blocks to decarbonise their collective heating installations in the coming years. Anticipated legislation will prohibit collective heating systems powered by fossil fuels starting in 2030 and beyond.

Finally, **GoiEner will continue developing consultancy & support services for Energy Communities where biomass is available**. As part of its diversification strategy, GoiEner is firmly dedicated to involving energy communities in utilizing all the locally available sustainable energy alternatives. Biomass holds significant potential, especially in rural areas of the region. In fact, one region in the northern part of Navarre has already contracted GoiEner for an energy demand assessment and to explore potential biomass projects for thermal purposes.

4 Monitoring and evaluation- Polish BECoop RESCoop

4.1 Overview of the BECoop RESCoop (PL)

The purpose of the Polish BECoop RESCoop, or commune of Oborniki Śląskie (OBS), was to **set up a biomass-based logistic chain** (forest and agricultural residues) where local farmers and institutions dealing with forest management could **sell biomass to a local pellet production plant**, from which the residents of the commune, or other interested parties, **could buy biofuel for household, business or other facilities heating purposes.** The commune also hoped to address the issue of fossil fuel usage in the area and encourage local people in retrofitting their coal boilers into biomass ones. At the same time, the nearby forest and agricultural region could be used to cover the heating needs of the community.

Through this initiative, it would be possible to **reduce heating costs**, and **address the existing energy poverty** in the area, but also **stimulate social activity** and **local cooperation** between stakeholders. Additionally, it helps towards energy security, reducing pollutant emission due to coal consumption reduction.

4.1.1 Roadmap of BECoop RESCoop

The focus of the Polish BECoop RESCoop was to disseminate the message of fossil-free bioenergy to the local community, and to attract investors and stakeholders. To that end, more effort was put on the education of the local community and the promotional campaign of bioenergy, thus several activities were performed, ranging from workshops to visits to related industries and related demonstrations. The timeline of the RESCoop's future activities (**Error! Reference source not found.**) mainly focuses on forming partnerships with potential stakeholders and establishing itself with many different types of them – residents, entrepreneurs, government actors, scientific institutions, specialists in the industry etc. with **aim to enable the creation of a local short supply chain, which in the future could lay the foundation for the establishment of an energy cooperative in the region**.

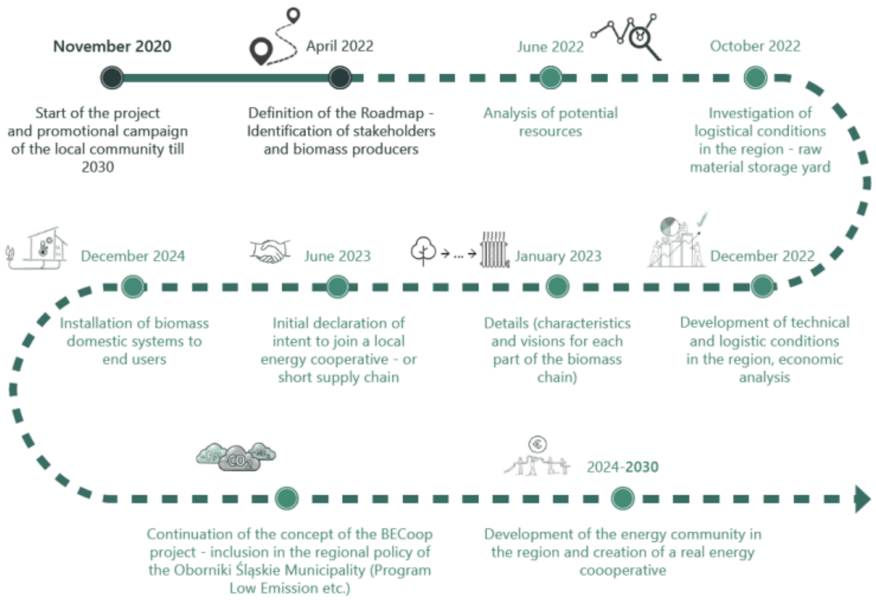


Figure 14. Scheme of the roadmap (Polish pilot).

For more details on the roadmap of the Polish BECoop case, please refer to DLV 4.1 "Co-definition of community bioenergy heating roadmaps".

4.1.2 Overview of technical support services provided

In this section can be found a brief overview of the various technical support services provided to the Polish BECoop RESCoop. For more details, please refer to DLV 4.2 "Deployment of the BECoop technical support services".

Biomass assessment

As a starting point for the whole project, information related to the type and quantities of available biomass was provided. The values were supported by the ultimate and proximate analysis, to assess the energy potential. Two types were decided upon: for**estry biomass and agricultural biomass from straw**. Animal manures were also considered for future application. Finally, an assessment was made on the available quantities of biomass, resulting to a technical potential of around 3,600 tons (d.b.) of forest biomass and 14,900 tons (d.b.) of straw in the local area.

Logistics of the BECoop RESCoop

Two different logistics chains were proposed, one for each type of available biomass. The forestry (wood) biomass logistics chain starts with the felling and collection of forest residues with a harvester. The biomass is then transported by trucks to the pellet plant (by a local transport company or sawmill owner) where it will be processed and stored. The pellets thus produced will be then delivered to the end users by truck belonging to the company. In case of lower demand, the pellets can be taken directly by the end users (Figure 15). The agricultural logistics chain starts with the collection of straw after the harvest from the field. The straw is then pressed into either round or square bales. The compressed straw is then loaded on a trailer and transported to the pellet production plant. These operations can be carried out either by the farmers themselves or a third party. Again, the pellets are stored in the warehouse, from where the final product can be delivered to the end users by trucks owned by the company, or in case of lower demand directly picked up by the end users (Figure 16).

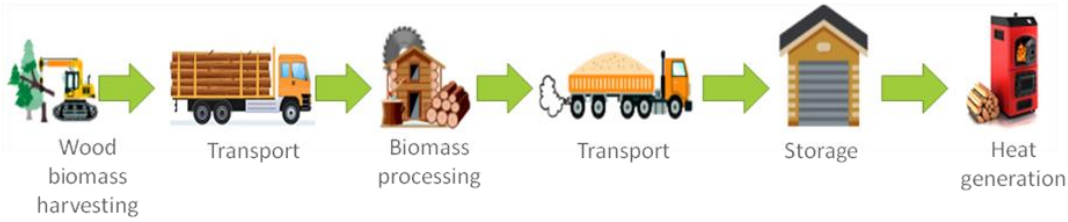


Figure 15. Diagram of value chain operations (forestry biomass)

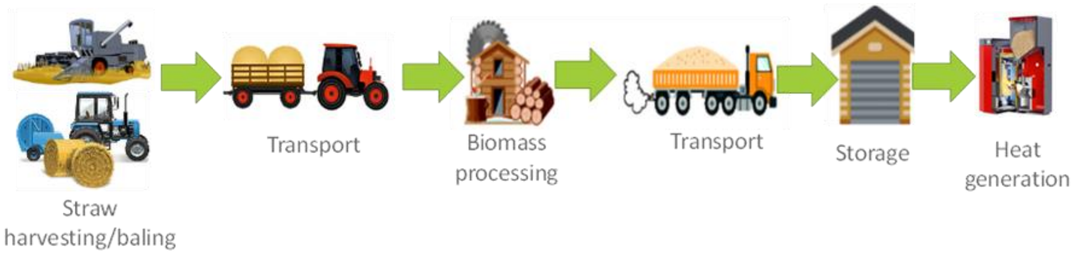


Figure 16. Diagram of value chain operations (agricultural straw biomass)

Cost of collection

The logistics chain for utilizing biomass for heating entails a range of unit expenses, encompassing various aspects like procuring biomass, collecting biomass (from forests and fields), transporting materials (wood, wood chips, logs, straw bales, pellets, briquettes, etc.), converting and processing biomass (creating pellets, briquettes, logs, bales), as well as storing fuel (outdoors, under cover, within silos, etc.). Costs of collection ranged from 55-167 €/t for straw and 33-38 €/t for wood. This information was compiled and offered to the stakeholders in the OBS pilot area.

Location of the BECoop RESCoop

The proposed logistic chain was aimed to be operated within the area of the Oborniki Śląskie commune. The biomass materials should be locally sourced as should be the pellet production line. Therefore, the assumed radius for the Polish OBS pilot was 30 km. 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. Maps detailing the potential location of the pellet line, including a scattering of the larger pellet consumers, were made (Figure 17).

Figure 17. Potential locations of pellets production line commune and identified major consumers of biomass pellets in Oborniki Śląskie commune.

Technology and activity of the BECoop RESCoop

A **pellet production line** was suggested with **agricultural and forest biomass** to be the main sources, to cover present energy needs and possible future biomass residue management needs for the OBS commune. However, in the near future, other types of biomass residues are also being considered. Considering 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 residents that heat the households by automated biomass pellets boilers. The boilers will be provided by the household's 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.

Energy demands to be covered

To determine the energy demands of the commune, several factors were considered. The total area, the lack of local heating networks, the sparseness of the residencies, along with the consumption rates for each household, using data from previous years. Considering the technical energy potential from local biomass resources analysed in this Polish OBS Pilot Area, this is 17,940 MWht/yr. 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 around **3,170 tons of pellets**.

Feasibility study of the BECoop RESCoop

The analysis was based on the OBS initial concept through their roadmap. The base concept was to construct a pellet production plant locally (3,170 t) and install approximately 830 domestic boilers (16 kW) in the municipality's residential and municipal buildings. All corresponding costs/ revenues were taken into consideration such as the investment cost (for pellet boilers and pellet plant 2.9 M€), operational costs (869,461 €), revenues (400 €/t pellet) etc. A cumulative cash flow analysis was then performed resulting to profitable investment with **a payback period of 7.6 years, a NPV if 4,511,600 € and an IRR of 13.15%**.

4.1.3 Overview of small-scale demonstration activities performed

In this section can be found a brief overview of the various small-scale demonstration activities performed in the Polish BECoop case. For more details, please refer to DLV 4.4 "BECoop small-scale demonstration activities".

Mechanized forest biomass harvesting

This small-scale demonstration involved the mechanized harvesting of forest biomass using light industrial machinery – a biomass harvester and a forwarder. Its prime goal was to present the stakeholders the steps for such an operation (Figure 18). A point was also made on the sustainability of the forest through a presentation of the processes of new tree planting after harvest. Another goal of the demonstration was to highlight the viability of the project and help attract potential stakeholders and investors.

Figure 18. Forest biomass harvesting demonstration.

Sustainable forest management

In order to dispel the negative cloud that biomass use for energy purposes has gathered as of the latest years, this small-scale demonstration organized a workshop, inviting various forest experts to help disseminate its message. These experts explained the various steps needed to ensure a productive yet sustainable forest management, with no negative impact on the environment, that can serve as an adequate replacement for fossil fuels – coal in particular. The demonstration included an on-site visit, where the experts went in detail on tree selection for felling, areas that need to be completely cleared to make room for less invasive species of trees, disease prevention, the use of otherwise useless wood for industrial purposes, and general sustainable forest management techniques that would complement a short logistic chain related to local biomass harvesting. These processes would significantly increase the energy effectiveness of the system and improve its energy balance.

Biomass pellets production

The most promising and feasible logistic chain for the OBS Pilot project was centred around the pellet. Such pellets could be produced using either forest residues, agricultural residues or a mix of both. A key advantage of pellets is their capacity to be produced on various scales, either industrial or local. Also, they offer the capability for automatic feeding instead of the coal boiler's traditional manual feeding. Practical demonstrations were organized to demonstrate a potential biofuel production line, and the pellet machine itself. Such demonstrations were carried out in various locations (Strzeszów, Paniowice, Pęgów) to reach a wide group of stakeholders (Figure 19). Through these activities the OBS commune aimed to attract potential stakeholders. During the demonstration the quality of the product was also discussed with the attendees (its properties like bulk density, size, lower heating value etc.) and they were also informed on its potential to replace coal for heat generation.

Figure 19. Mobile pellet production demonstration.

Biomass pellets distribution to households

Within the Oborniki Śląskie Commune (as well as across all of Poland), over half of households rely on coal for heating. The objective was to demonstrate to these users that transitioning to a more sustainable fuel source, like biomass, is achievable without requiring complex alterations to their boilers or heating systems. To motivate these coal users to switch to an environmentally friendlier option, a pellet distribution initiative was arranged. This initiative was aimed at households using automated coal-fired boilers (including peat coal) for residential heating. Each resident was provided with four complimentary bags of high-quality pellets, amounting to approximately 60 kg. Consequently, an opportunity was presented for residents to evaluate the performance of these pellets in their typical coal-fired boilers. This allowed them to witness the boiler's operation with the new fuel source (biomass pellets) and ascertain if any additional adjustments were needed due to the fuel transition. This demonstration held significant importance for the Polish BECoop, as it enabled end users to personally test the pellets in their own boilers and assess their performance. To obtain some valuable feedback after the tests, the residents have been asked to fulfil the elaborated satisfaction survey.

4.2 Evaluation of BECoop market uptake support impact (PL)

4.2.1 Self-assessment results

A self-assessment was conducted to evaluate the logistical supply of agricultural resources in the Polish case study. The 5-point spider chart in Figure 20 illustrates the comparison between the initial assessment (blue chart) and the assessment after receiving support from WP4 BECoop RESCoop (pink chart). Significantly, substantial progress has been made in various aspects of the activity, particularly in the maturity of technical solutions and resource knowledge. However, areas such as social and environmental impact, as well as business and financial aspects, may require further support. Despite these areas for improvement, there has been notable **overall progress**, with the initial score of **0.37 increasing to an impressive 0.79 score**.

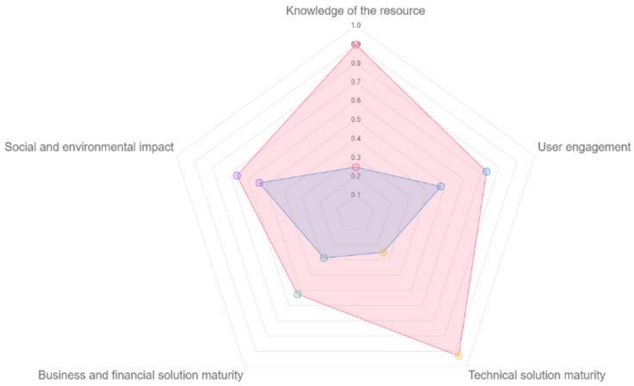


Figure 20. Final self-assessment (pink) compared with the initial one (blue) carried out for the Polish case concerning logistic supply of agricultural resources activity.

Another self-assessment was conducted to evaluate the implementation of forestry resources for pellet or woodchip generation activity in the Polish BECoop RESCoop. Figure 21 presents a comparison of the BECoop RESCoop's status before and after the support activities provided by WP4. Notably, there has been significant improvement in all aspects. Further support could be provided in social and environmental aspects of this biomass-based activity. Nevertheless, there has been **significant progress**, with the initial overall score of **0.45 increasing to 0.81**.

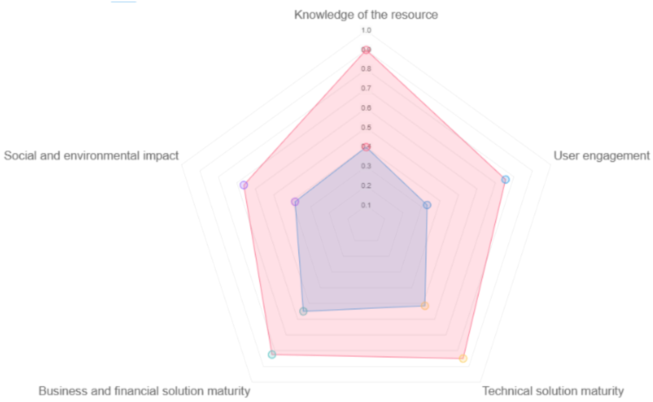


Figure 21. Final self-assessment (pink) compared with the initial one (blue) carried out for the Polish case. Pellets/woodchips generation of forestry resources.

Finally, a detailed presentation of the results and breakdown of scores of the self-assessments are presented in Table 4.

Table 4. Self-assessment results for the Polish BECoop RESCoop.

	Logistic supply of agricultural resources		Pellets/woodchips generation of forestry resources	
	Initial assessment	Final assessment	Initial assessment	Final assessment
Knowledge of resources	0.25	0.9	0.41	0.91
User engagement	0.48	0.74	0.33	0.76
Technical solution maturity	0.25	0.93	0.52	0.86
Business and financial solution maturity	0.29	0.53	0.56	0.83
Social and environmental impact	0.54	0.67	0.39	0.67
Global score	**0.37**	**0.79**	**0.45**	**0.81**

4.2.2 Socio-economic and environmental impact of the BECoop RESCoop

To assess the **socio-economic impact** of the Polish BECoop RESCoop, as mentioned in section **Error! Reference source not found.**, CERTH developed specific tools for the task. The results from the application of these tools, for the Polish BECoop RESCoop are as follows (Table 5).

Table 5. Polish pilot socio-economic impact.

Results based on biomass individual heating:	Employment impact (FTE[13])	GDP impact (M€)
Equipment manufacturing	0.88	0.05
Construction	0.28	0.01
Feedstock supply	7.03	0.16
Operation and maintenance	8.0	0.17
Indirect	2.22	0.12
TOTAL	**18.4**	**0.51**

The estimated biomass utilized annually by the pilot project was 3,170 tonnes (dry basis), with an LHV of 18.3 GJ/tonne. The employment impact, calculated for biomass individual heating systems, gave an estimated **18.40 employment opportunities** created at its current scope. This translates to a **GDP impact of 510,000€**.

The social impact of the Polish pilot project was the creation of a variety of employment opportunities. It was in the project's scope to create openings in the local municipality for economic activity in forestry and agriculture operations, mainly producing and selling biomass for pellet production by the BECoop RESCoop. The project also expected the replacement of older coal-heating boilers with newer biomass systems, resulting several employment opportunities relating to these activities, mainly the manufacture and installation of such systems.

Similarly, using CERTH's tools it can be assessed that the **environmental impact** of the Spanish pilot is as demonstrated on Table 6.

Table 6. Polish pilot environmental impact.

	Value	Units	
CO_{2eq} emissions from transport and distribution (e_{td})	3.6	gCO_{2eq}/MJ_{Fuel}	Minimum GHG emissions savings based on RED II for new biomass installations
CO_{2eq} emissions from processing (e_p)	15	gCO_{2eq}/MJ_{Fuel}	
CO_{2eq} emissions from fuel in use (e_u)	0.3	gCO_{2eq}/MJ_{Fuel}	
Total CO_{2eq} emissions from production of fuel before energy conversion (E)	18.9	gCO_{2eq}/MJ_{Fuel}	
Total CO_{2eq} emissions produced	1097.5	tCO_{2eq}	
Total CO_{2eq} emissions from heat production	21	gCO_{2eq}/MJ	
GHG emissions savings**,** heating	83.1%	%	80%

The total CO_{2eq} emissions for heat production for the activity of the Polish BECoop RESCoop was estimated at **18.9 gCO_{2eq}/MJ or a total of 1097.5 tCO_{2eq}**. Due to the medium amount of biomass mobilized and the small sourcing/ transportation radius, the environmental impact of the BECoop RESCoop is positive.

Adjusted for individual heating biomass boilers, it can be translated into **83.1% CO_{2eq} savings** compared to fossil fuel comparators for heating production. This is in line with the minimum requirements (80%) set by RED II guidelines for GHG emissions savings for electricity, heating and cooling production from biomass fuels used in installations starting operation after 1 January 2021. The use of modern, state-of-the-art biomass boilers will also be of great benefit to the Polish case. Modern biomass boilers guarantee optimal combustion

[13] Full time equivalent.

conditions, along with filtration systems that minimize the emission of harmful particles from biofuel combustion. This is particularly important to Oborniki Śląskie, where most of the municipality's heating needs are being covered through traditional coal stoves. In Poland there is an ongoing effort to limit particle emission in the atmosphere, and this will be greatly aided through the gradual adoption of the systems the project aims towards.

4.2.3 Stakeholders engaged through BECoop activities in the pilot area

In total, **963 stakeholders** actively participated in the diverse activities conducted within the scope of WP4. These activities were categorized based on their associated tasks and the types of services they provided, such as technical support, workshops, demonstrations, business-related events, or mentoring events. The engagement initiatives encompassed site visits to various project-related businesses, physical and virtual meetings, workshops, and live demonstrations. The stakeholders involved represented a wide spectrum, including research institutions (both public and private), other RESCoops, SME's, public authorities, citizens, and owners of various scales, among others.

4.2.4 Barriers, challenges, and risks identified by the BECoop RESCoop

Several barriers, challenges and risks have been addressed during the project. The most important ones are the following:

- **Strict legal requirements on community energy:** In Poland, there are strict legal requirements for community energy, i.e., the number of cooperative members may not exceed 1000 participants, the total installed capacity is limited to 10 MW in the case of electricity, 30 MW in the case of heat, 40 million m^3 in the case of biogas production. It must be adjacent to no more than three rural or urban-rural communes directly adjacent to each other, in the area of one distribution system operator electricity or gas distribution network or heating (limitations in terms of energy communities' location). Therefore, it significantly reduces the potential of RESCoop development in Poland. This also disincentivises potential cooperative founders. Another issue is due to the Polish regulations in force that forbid the cooperatives not to sell the energy. The cooperatives are only able to transfer their surplus to the joint distribution grid. Finally, the requirement to guarantee 70% of energy demand coverage by RES for cooperative members is a very challenging threshold. This makes it difficult to create an energy cooperative because it requires careful and thoughtful selection of its members and precise calculation/determination of their energy needs (to meet the condition of the minimum level of coverage of energy needs).
- **Increase of fertilizers' price:** Another new problem that has emerged from the unforeseen increase in gas prices is the drastic increase in the price of fertilizers for agriculture. This resulted in a significant reduction in the possibility of selling e.g., straw for energy purposes due to the need to leave it in the fields to compensate for the deficiency of nutrients in the soil, which until now were provided by artificial/mineral fertilizers produced by the chemical industry.
- **Limitation on the amount of forest biomass for energy use:** The National Forest (the state forest management unit) can sell wood harvested from local forests for energy purposes to the local community in the amount of only 10%. The remaining wood resources are listed on the national stock exchange (in accordance with the provisions of the Timber Trade Act). This is a significant limitation in the development of local energy cooperatives based on biomass fuel.
- **Limited bioenergy RESCoop experience:** There are no bioenergy cooperatives in Poland, creating an entirely new research space. The lack of experience in this field in Poland is also an obstacle in convincing the local community to engage more deeply because nobody wants to be a battlefield,

especially in times of energy crisis and unstable political situation - no examples in Poland related to the bioenergy community creation, operation, and maintenance, heat costs, etc..

- **Disbelief in community/ cooperative schemes due to historical complexities:** The negative experience of rural residents related to the concept of cooperative, due to historical reasons is still relative in today's social climate, making the potential stakeholders sometimes skeptical towards community bioenergy concepts.
- **Limited knowledge on biomass exploitation:** A low level of environmental education characterizes the rural region's inhabitants. They have minimal knowledge of solid fuel properties and how to burn them properly in the heating boiler. Little is known about the emission of pollutants into the atmosphere from coal-fired boilers, incredibly poisonous and hazardous compounds. The lack of sufficient ecological awareness or knowledge by final biomass users regarding its proper processing and utilization leads to the combustion of wet biomass and significant pollutants emissions to the atmosphere. This is due to the unappropriated processing and storage of biomass caused by a lack of appropriate knowledge in this field.
- **Resistance to changes:** Residents of rural areas have been used to burning coal in their households for generations and do not consider this fuel is harmful to the environment. In addition, they do not like changes and are skeptical about novelties in an area they do not know. Therefore, convincing rural residents to use a different fuel is a difficult task. This situation is worsened by the still-existing **subsidies for coal use**, making the switch to bioenergy less lucrative to consumers.
- **Lack of national success cases:** The potential local stakeholders want to see the Polish success cases (achieved in Polish conditions). International examples do not work convincingly and do not build trust;
- **Local authorities' involvement:** The involvement of local authorities (e.g. municipalities) and its partnership is highly recommended and helpful. The presence of the commune as a member of an energy cooperative is a kind of guarantor of the project (also in the financial context), which can increase trust and involvement of others willing to work in this area and facilitate obtaining external funds for potential investments.
- **Costly and time-consuming process for RESCoop creation:** The registration process of the RESCoop requires expenses (lawyer services, accounts services, registration costs, technical analysis etc.) which hinder the initiation of this process. People don't want to spend money on something that doesn't guarantee success. Creating an energy cooperative is a rather long-term process, requiring a lot of patience and gradual action. Good grounds for cooperation with stakeholders should be created through all relative means (education, access to information provided an accessible way, dissemination of basic knowledge about energy cooperatives and its benefits for the local community etc.).
- **Risk of inability to satisfy all energy cooperative members**: During the implementation of the investment, there may be a conflict of interest between individual stakeholders, i.e., eco-activists, sponsors, issues of democracy etc. which may cause delays or failure of the project. Moreover, the RESCoop establishment in Poland time-consuming (up to 1 year) which is also discouraging for their members.
- **Communication between members**: Conversations with people from various social groups show that cooperation in the region between people with different professional profiles (non-agricultural), social status, time of residence in the region (people living for generations, people coming from e.g., the city), and way of thinking is difficult, which complicates the work of developing the energy community, which requires understanding and joint activity in this area (building mutual social trust and a sense of joint responsibility for the region).

- **Disbelief in crowdfunding schemes:** As part of creating a bioenergy cooperative in the Polish pilot area, it was proposed to raise money for this purpose through crowdfunding among local people. Unfortunately, this form of financing does not suit the region's inhabitants. They think that if money is collected for a common benefit, it will not actually belong to anyone individually which increases reluctance to invest.
- **Lack of funding/ Skeptical to invest in community projects**: In 2017, five municipalities near Wrocław: Prusice, Oborniki Śląskie, Wisznia Mała, Wołów, and Żmigród created the Renewable Energy Cluster of Trzebnickie Hills. Photovoltaic and bio-power plants were to be built as part of their activity. However, it collapsed due to a failure to obtain external funds for its development. Too many partner entities could be harmful here, resulting in a conflict of interest or abandonment of duties by individual partners resulting from the lack of assigned responsibility. Another issue is also the **lack of subsidy support for community heating,** which are a staple in similar cases. No financial support for the construction of district heating under RESCoop. This is a costly operation, and so far, Poland has not launched subsidy support for this type of initiative. Only direct heating installations are eligible for co-financing through a non-repayable grant or loan, i.e., “Energy for the countryside program”

4.2.5 Lessons learned and opportunities identified by the BECoop REScoop

Some opportunities and lessons learned identified by the Polish BECoop RESCoop can be found below:

- **Decarbonization of the heating system:** Poland relies on hard coal as a heating source, especially in rural areas (more than 50% of households are heated with coal directly or indirectly). This is a very large space for action and change, because the use of coal should be limited for environmental reasons and the requirements of EU directives. Only biomass allows for a relatively simple, quick and, above all, cheap way to replace coal. In the simplest solution, it is the selection of biomass of the appropriate form (wood chips, briquettes, pellets, chips, bales, cubes) adapted to combustion in each coal boiler. There is therefore much to be done in this area and biomass can make a significant contribution to this.
- **Mitigation of energy poverty:** Parts of the population suffering from energy poverty live in villages, and energy cooperatives may be established in rural and urban-rural communes. Regarding energy poverty, the problem lies not only in financial matters because statistics show that only 20% of poverty is caused by low income. Insufficient infrastructure is responsible for the remaining 80%. Building installations using local biomass resources can increase the region's energy security, thus making it independent of fuel and electricity supplies.
- **Biomass availability:** OBS has a large area of forests (approx. 5,400 ha) and cultivated fields (approx. 8,500 ha). The total amount of energy is estimated at approx. 85,000 MWh/year. After appropriate processing, residents/users could use it for heating purposes, reducing dependence on fuel supplies.
- **Anti-smog law:** The anti-smog resolution currently in force in Poland, together with the national Clean Air program creates 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). Furthermore, in connection with the above resolution, from July 1, 2018, the use of sludge and coal flotation concentrates and mixtures produced with their use, lignite and solid fuels produced with the use of this coal, loose hard coal with a grain size of less than 3 mm, solid biomass with humidity in the working condition above 20% is forbidden.

- **National policy on energy communities:** The “National Plan for Energy and Climate for 2021-2030” provides for the development of distributed energy. It is estimated that in 2030 there will be approximately 300 energy-sustainable areas at the country's local level. This task was included in the “Strategy for Responsible Development until 2020 (with a perspective until 2030) as one of the priorities in the energy field and was also included in the Energy Policy of Poland until 2040. Such an assumption may mean a broader development of energy community support programs.
- **Local economic benefits:** for the local society, energy cooperatives are also an important element of the economy, as the involvement of entrepreneurs, farmers, and craftsmen from a given region stimulates the economic activity of the region, which in turn translates into financial benefits for individual members of the cooperative and the entire local community.
- **The lack of active energy communities:** this means that there is space to be covered by the BECoop pilot project in this field, making it an up-and-coming, dynamic project.
- **Financial incentives:** Financial incentives mainly convince stakeholders to invest their money in bioenergy solutions.
- **Firsthand contact**: Stakeholders prefer a direct contact with technical specialist combined with the possibility to see solutions or machineries in reality (demonstrations), knowledge and "live" presentations have a much better and faster impact on the stakeholder, including the understanding of the issue and the involvement of the listener.
- **Local stakeholder engagement/rising awareness campaigns**: constructing a plan of action to ensure the increase of local stakeholders is very important. Information campaigns to dispel misconceptions or transfer knowledge on biomass use for heating purposes were also deemed important. E.g. conveying information that the use of local forest biomass does not lead to deforestation of the area in any way, and it is even recommended to ensure proper development and growth of the forest in the commune or making stakeholders aware of the risks of straw burning, which is a common practice in Poland.
- **Local authorities engagement:** The involvement of local authorities was also found to be a great incentive to some stakeholders. Furthermore, investment is better perceived by the general community if a local government unit, e.g. a commune, is involved in the project;
- **Lightweight projects:** It is better to try to create an energy cooperative based on only a few members and with a similar financial contribution. This makes it easier to pre-talk as the risk is spread evenly among the members (do not build the large RESCoop if the initiator/members do not have a proper experience in this field).

4.2.6 Next steps of the BECoop RESCoop

The next crucial step that requires further development and expansion is the ongoing education of residents in the areas of energy cooperatives and the utilization of bioenergy. Despite the low level of knowledge about these initiatives in the pilot area (and in general in Poland), there is a clear upward trend in interest in RESCoop. It is therefore necessary to continue **raising awareness among the residents about the socio-economic advantages of this solution** to increase the potential number of interested stakeholders and the project's profitability. For this purpose, **it may be helpful to build specially dedicated training programs and information points that will provide advice on the creation, operation, and development of energy cooperatives**. At the same time, these points could gather residents who want to take part in the initiative, but who have the will/strength to independently take action to gather a larger group of people.

At the local level, building trust between local authorities and potential stakeholders is also necessary. Strengthening the bonds between individual units (especially at the commune-citizen level) will significantly help to overcome social barriers, which are one of the main factors hindering the development of energy cooperatives. It is recommended to continue regular meetings at the local level, where it will be possible to exchange ideas, submit comments and observations between all stakeholder groups. **Creating a forum for increased social integration between various groups of stakeholders can help shorten the distance and bring closer the idea of partnership**, on which the functioning of an energy cooperative is based.

An extremely important step is to promote good practices and exchange of national experience in the field of energy cooperatives. Most people in the pilot area and in Poland were not aware of the idea and principles of operation of energy cooperatives before, due to the lack of similar initiatives in the region, despite the existence of such projects in other European countries for several decades. Building a long-term, well-thought-out and properly prepared information and marketing campaign can be a milestone in the creation of future projects based on energy cooperatives. It may be essential to **promote national/local financial support programs that help such initiatives**. Based on the previous successes of government support programs dedicated, among others, to photovoltaic installations (the "My Electricity" program), it is assumed that increasing national funds to help small bioenergy cooperatives may cause a snowball effect, thanks to which many new people will be able to familiarize themselves with these types of projects. However, to achieve this, legal consultations are recommended at the national level to facilitate the regulations and procedures related to the establishment of energy cooperatives in Poland, which are currently extremely restrictive. In addition, it is recommended to shorten the steps in the registration of energy cooperatives, due to the lengthy bureaucratic process.

From a technical point of view, developing short, biomass logistic chains on a local scale is recommended, which can be treated as precursors of bioenergy cooperatives in Poland. Due to the safety of such projects, lower financial entry threshold, ease of resignation and lack of national, local good practices for larger initiatives, the creation of short logistics chains (such as farmer - biomass processing company -end users) may be a good starting point for the development of larger initiatives. It is important since such solutions already exist in the pilot area (Strzeszów area) and they are positively associated and perceived by the residents. It is therefore, essential to continue and expand this strategy.

An intriguing solution appears to be the establishment of new logistics chains for biomass residues, as burning such residues is still a common practice in Poland (straw, grass, post-harvest residues). This solution can be especially helpful for people struggling with energy poverty.

Lastly, there should still be an effort directed towards building trust, both between local authorities and residents and among the residents themselves. Fostering a collective belief within the local community, where they perceive their actions as serving not only their own interests but also the greater good, is pivotal. This belief is what can effectively lead to the establishment of robust cooperation and, subsequently, the creation of an energy community, followed by the formation of an energy cooperative in the next phase.

5 Monitoring and evaluation- Italian BECoop RESCoop

5.1 Overview of the BECoop RESCoop (IT)

The Italian BECoop RESCoop takes place in the three municipalities of Mortirolo (Mazzo di Valtelina, Lovero, Tovo S.A.), in the Valtelina region of northern Italy, Providence of Sondrio. The area is known for its successful forest biomass district heating systems, namely the TCVVV (Teleriscaldamento Cogenerazione Valtellina Valchiavenna Valcamonica) system of Tirano. Domestic biomass boilers are also very prevalent in the region, making the are a prime candidate for the formation of a BECoop RESCoop. The three communities have expressed their intention to develop a biomass CHP district heating system, demonstrating a high awareness of sustainability issues on a communal level.

To aid in that direction, various scenarios were evaluated to identify the most suiting for this case, with the goal of building **a biomass CHP district heating system in sight**. Through collaboration with FIPER and local stakeholders, the **three municipalities** have collectively opted to establish **"Società Benefit," a type of benefit company, as the preferred organizational structure for driving the development of the bioenergy community**. This decision aligns with the project's objectives and ensures efficient management and operation of the bioenergy initiatives.

5.1.1 Roadmap of BECoop RESCoop

The vision towards 2030 implies the different stages of the design activities, the development of the overall project, the implementation of the biomass CHP system and of the DH network involving one or more municipalities next to the plant (**Error! Reference source not found.**). These actions could include also the energy retrofit of Melavì plant and moving and setting of new activities in Tovo Sant'Agata. An integral aspect of this vision entails the collaborative formation of a local RESCoop, capable of engaging citizens as active participants (e.g., some individuals can supply wood to the plant and receive heat for their needs). In alignment with this vision, the objective is to evolve the region into a communal or consortium entity that is highly independent from fossil fuels and energy self-sufficient.

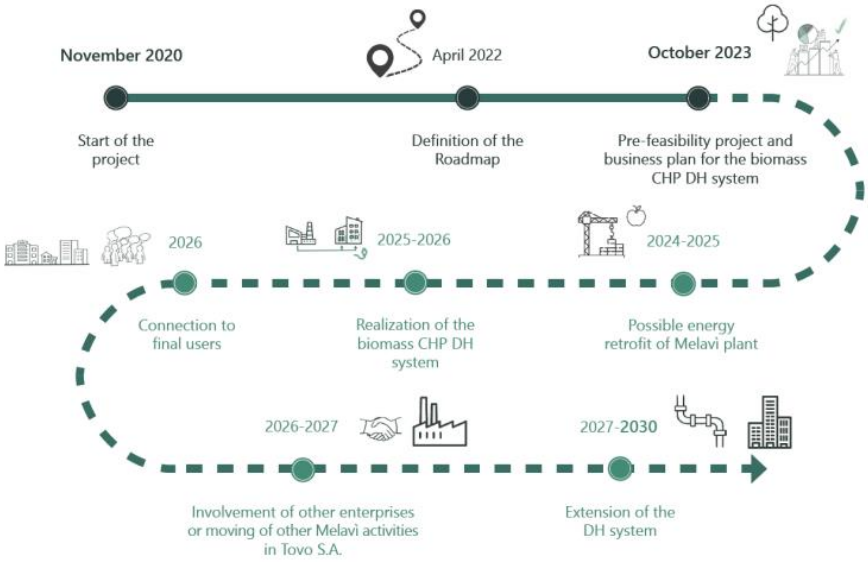


Figure 22. Scheme of the roadmap (Italian pilot).

For more details on the roadmap of the Italian BECoop case, please refer to DLV 4.1 "Co-definition of community bioenergy heating roadmaps".

5.1.2 Overview of technical support services provided

In this section can be found a brief overview of the various technical support services provided to the Italian BECoop RESCoop. For more details, please refer to DLV 4.2 “Deployment of the BECoop technical support services”.

Biomass assessment

The most suitable type of biomass for this case was determined to be woodchips provided from local forests, supplemented by pruning by-products (e.g., apple pruning byproducts). To determine the available quantities from the woodlands surrounding the three municipalities, interviews were performed with the local companies, resulting to around 4,000 tonnes (wet basis). 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 a biomass DH system and becoming prosumers.

Logistics of the BECoop RESCoop

The value chain was defined, with special care given to the preservation of the forest, meaning that plans were made to ensure the longevity of the forest. The biomass for the BECoop and RESCoop will be collected through the following forest management operation: i) renovation cut; ii) thinning; and iii) interventions in newly formed forests. In brief, a general diagram of value chain operations that would be implemented by the Italian BECoop RESCoop can be found in Figure 23.

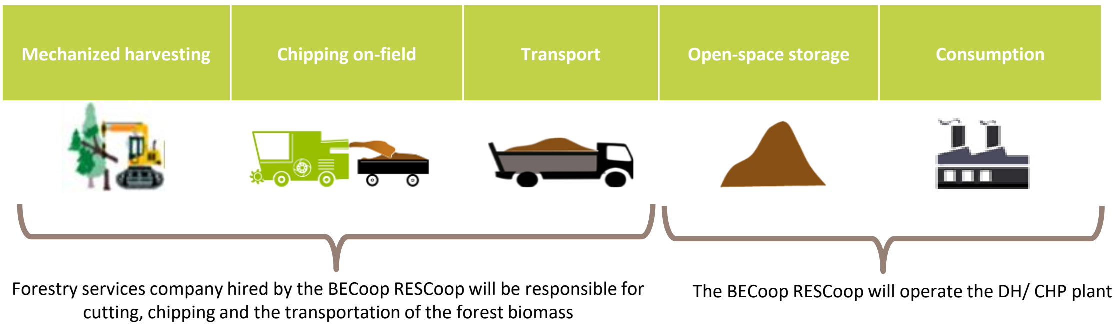


Figure 23. Diagram of value chain operations (forestry wood biomass).

Costs of collection

Several costs of the logistics regarding the harvesting, chipping and transportation of forest biomass were estimated. In brief, a range of 50-80 €/t were estimated as collection cost for different type of forest biomass (e.g., virgin wood from processing of logs, debarked virgin wood chips, woodchips from processing of trunks etc.). A chipping cost was estimated at around 6 €/t and a transportation cost in short radius (70 km) at 17-18 €/t.

Location of the 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 DH system (around 5,000-6,000 m^2) will be located at the barycentre of the users' positions. To achieve this, the possibility of utilizing an industrial area on the Melavì site was preliminarily considered (Figure 24).

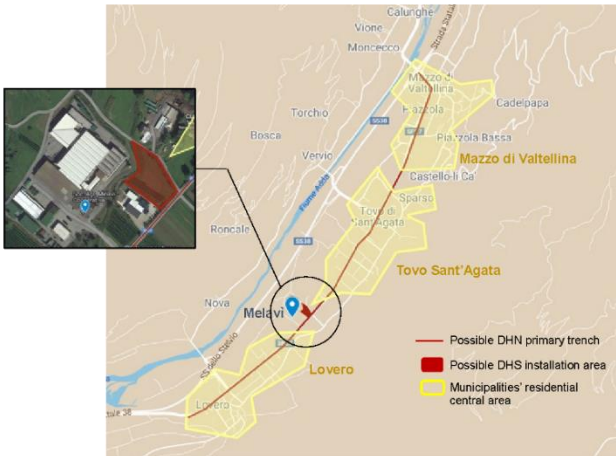


Figure 24 Potential location of the DHS location.

Technology and Activity of the BECoop RESCoop

The technological set foreseen consists of **a biomass-based CHP DH system, fueled mainly by forest biomass**. The Organic Rankine Cycle technology was selected after close examination of the best practices related to CHP systems, and similar cases. 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 DHN (90°C-60°C). The yearly heating demands were found to be 12,000 MWh/year, which can be covered by the installation of **a 3MWth + 0.7MWe Organic Rankine Cycle biomass plant, with an additional backup 3MWth biomass boiler** that will operate in peak season. The CHP will be working for 7 months producing both heat (68.86% efficiency) and electricity (12.73% efficiency) and the remaining 5 months it will be working only for producing electricity with 16.82% efficiency. To cover the peak demands for heating, during winter months, a 3 MWth back-up boiler was also considered (85% efficiency) for supplying the heating network of the BECoop RESCoop. For the operation of the CHP DH system, it was estimated that around 11,452 tonnes (37% moisture) will be needed.

Energy demands to be covered

A variety of methodologies were utilized to define the energy demands to be covered by the BECoop RESCoop, including questionnaires, software, datasets available etc. In brief, it was calculated that the energy demands to be covered by the BECoop RESCoop were around **12,000 MWh/year** in all three municipalities. The results were used in the feasibility study, mentioned in the section below.

Feasibility study of the BECoop RESCoop

A first feasibility study for a CHP DH project for the municipalities of Tovo di Sant'Agata, Lovero and Mazzo di Valtelina was performed. 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 evaluated. Both systems will utilize local chipped forest biomass as their fuel source. A total CAPEX of 12,095,000 € was assumed, with a 50% of that sum being covered by public grant, and a 3% of the total CAPEX to be the expected maintenance costs. The total OPEX calculated was estimated at 1,362,337 €, whereas it was assumed that heat would be sold at 0.12 €/kWh and electricity at 0.15 €/kWh. Based on a cash-flow analysis for 25 years, **a payback period of 10.4 years, a NPV of 5,2433,356 € and with an IRR of 8.24 %** were calculated, making it a feasible investment.

5.1.3 Overview of small-scale demonstration activities performed

In this section can be found a brief overview of the various small-scale demonstration activities performed in the Italian BECoop case. For more details, please refer to DLV 4.4 "BECoop small-scale demonstration activities".

Small-Scale Demonstration: Visit to wood biomass CHP district heating plant of Tirano

TCVVV stands as one of the pioneering ventures in Italy in terms of establishing a biomass-energy chain through the initiation of a district heating facility. TCVVV holds a position as a founding member of FIPER. The objective of the visit to the Tirano power plant was to illustrate the viability of a bioenergy community engaged in the investment and operation of a biomass CHP DH system (20 MWth, 1.1 MWe) and to learn from its logistic management and woody biomass supply chain and its operation (Figure 25).

Figure 25. Visit to TCVVV biomass CHP DH plant.

Small-Scale Demonstration: Three harvesting methods of forest residues by the Ferrari company

The objective of this demonstration was twofold; To provide a range of possibilities in forestry techniques, and to illustrate the cost-opportunity relation of the technologies available on the market. The three forestry methods demonstrated using various mechanical tools (harvester, helicopter, or ropeway/cable car) depending on the accessibility of the area in question (Figure 26). All the demos were performed by the Ferrari company, a leader in forest innovation technologies in Italy.

Figure 26. Forest biomass harvesting demonstration with processor with harvesting arm and helicopter.

Small-Scale Demonstration: Visit to Bioenergia Fiemme – Biomass district heating and essential oil production

Bioenergia Fiemme operates a biomass CHP DH plant with a pellet production line. The plant uses the recovered heat to cover the thermal demands required for producing pellets. All this is made possible by exploiting processing waste and through the production of pellets derived from sawdust. Over time, the company has developed other activities regarding the valorization and recovery of food waste by exploiting its intrinsic energy capacity by producing biogas and biomethane within a circular economy perspective. The company continuously seeks to expand its area of activities, spanning to pellet production and even essential oils production, effectively utilizing all available resources to the end of a circular economic pattern.

The visit's purpose was to showcase how biomass CHP DH plant operates as Bioenergia Fiemme is one of the most significant examples in the Alpine area of the diversification of activities that can be achieved by having a woody biomass district heating plant. To that end, a multitude of activities taken by the company were highlighted, as a point of comparison and example for the Italian BECoop RESCoop (Figure 27).

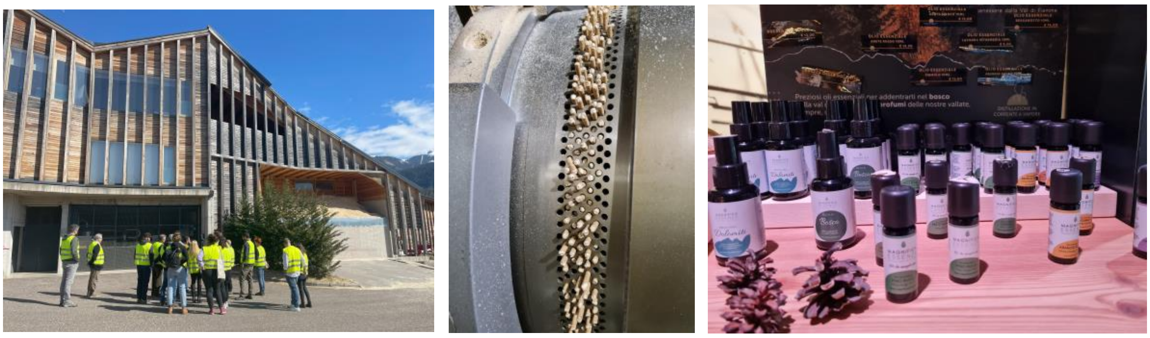


Figure 27. Visit to Bioenergia Fiemme.

5.2 Evaluation of BECoop market uptake support impact (IT)

5.2.1 Self-assessment results

A self-assessment was conducted to assess various aspects related to the utilization of forestry resources in the Italian case study. This self-assessment covered three distinct activity types:, logistics of forestry resources (Figure 28), district heating (Figure 29) and co-generation (Figure 30). The comparison of these activities before and after the support activities provided by WP4 reveals noteworthy progress.

In the logistic supply of forestry resources, as illustrated in Figure 28, there has been a significant increase in the social and environmental impact, technical solution maturity, and user engagement. However, there is still room for improvement in terms of knowledge about the resource and the maturity of business and financial solutions. This activity has demonstrated notable progress attributable to the actions of the BECoop RESCoop, with the overall score **increasing** from an initial **0.50 to an impressive final global score of 0.88**.

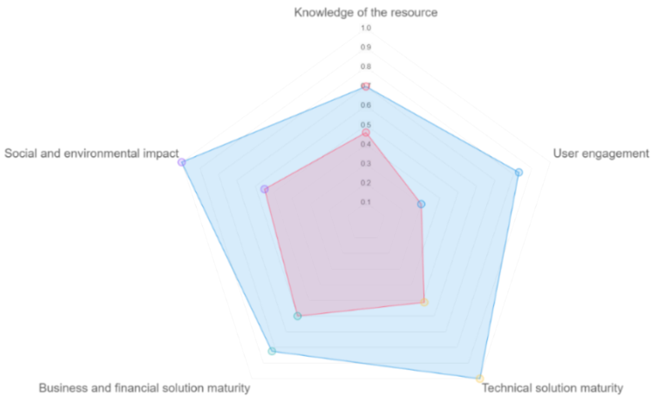


Figure 28. Final self-assessment (blue) compared with the initial one (pink) carried out for the Italian case of the "logistic supply of forestry resources" activity.

The self-assessment results for the implementation of district heating, as depicted in Figure 29, showcase significant advancements compared to the initial assessment conducted at the beginning of the support activities. While there is still room for improvement in terms of user engagement and knowledge about the resources, positive developments are evident in the areas of social and environmental impact, as well as technical solution maturity. Moreover, there has been excellent progress in achieving business and financial solutions maturity. In summary, this case study reflects substantial progress resulting from the actions of the

BECoop RESCoop, with the overall score **increasing** from an initial **0.50 to a commendable final global score of 0.83**.

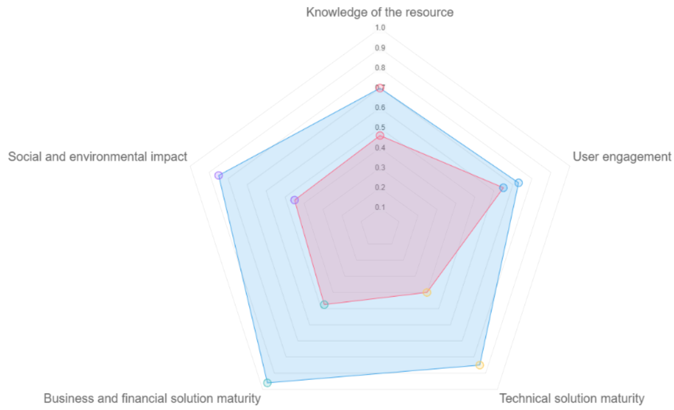


Figure 29. Final self-assessment (blue) compared with the initial one (pink) carried out for the Italian case concerning district heating activity .

In the case of co-generation activity, as depicted in Figure 30, there has been significant improvement across all aspects of the initiative, with a particular focus on the maturity of technical solutions. Notably, this case study has made substantial progress, with an initial overall score of **0.49 increasing to 0.79.**

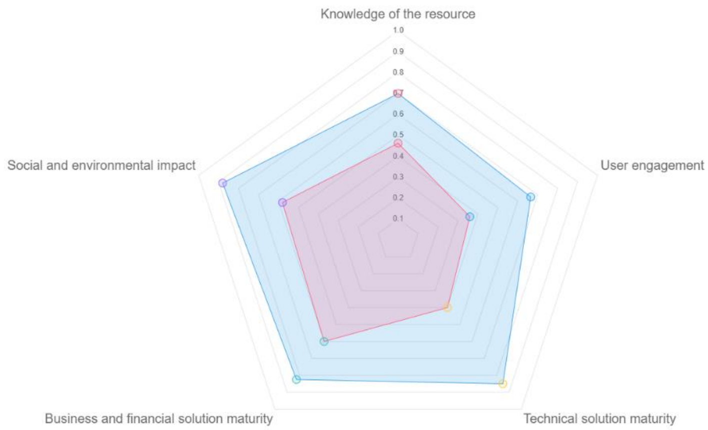


Figure 30. Final self-assessment (blue) compared with the initial one (pink) carried out for the Italian case concerning co-generation activity.

Finally, a detailed presentation of the results and breakdown of scores of the self-assessments are presented in Table 7.

Table 7. Self-assessment results for the Italian BECoop RESCoop.

	Logistics of forestry resources		District heating		Co-generation	
	Initial assessment	Initial assessment	Initial assessment	Initial assessment	Initial assessment	Final assessment
Knowledge of resources	0.47	0.47	0.47	0.47	0.47	0.7
User engagement	0.31	0.66	0.37	0.37	0.37	0.67
Technical solution maturity	0.52	0.41	0.41	0.41	0.41	0.86
Business and financial solution maturity	0.61	0.48	0.61	0.61	0.61	0.83
Social and environmental impact	0.57	0.46	0.58	0.58	0.58	0.88
Global score	**0.5**	**0.5**	**0.49**	**0.49**	**0.49**	**0.79**

5.2.2 Socio-economic and environmental impact of the BECoop RESCoop

To assess the **socio-economic impact** of the Italian BECoop RESCoop, as mentioned in section **Error! Reference source not found.**, CERTH developed specific tools for the task. The results from the application of these tools, for the Italian BECoop RESCoop are as follows Table 8.

Table 8. Italian pilot socio-economic impact.

Results based on biomass DH/CHP:	Employment impact (FTE[14])	GDP impact (M€)
Equipment manufacturing	2	0.03
Construction	1	0.06
Feedstock supply	21	0.48
Operation and maintenance	11	0.90
Indirect	9	0.51
TOTAL	**44**	**1.98**

The estimated biomass utilized annually by the pilot project was 7,215 tonnes (dry basis) with an LHV of 18.5 GJ/tonne. The employment impact, calculated for a biomass district heating station of the appropriate size for the project, gave an estimated **44 employment opportunities** created at its current scope. This translates to a GDP impact of **1,980,000€**. Most FTE are allocated to the feedstock supply and the operation and maintenance of the plant.

As expected, the estimated GDP and employment impact of the Italian BECoop RESCoop was significant. It is a project of large size, resulting in more than 40 employment opportunities created in the municipalities involved.

Similarly, using CERTH's tools it can be assessed that the **environmental impact** of the Spanish pilot is as demonstrated on Table 9.

Table 9. Italian pilot environmental impact.

	Value	Units	
CO_{2eq} emissions from transport and distribution (e_{td})	3.6	gCO_{2eq}/MJ_{Fuel}	Minimum GHG emissions savings based on RED II for new biomass installations
CO_{2eq} emissions from processing (e_p)	1.9	gCO_{2eq}/MJ_{Fuel}	
CO_{2eq} emissions from fuel in use (e_u)	0.5	gCO_{2eq}/MJ_{Fuel}	
Total CO_{2eq} emissions from production of fuel before energy conversion (E)	6.0	gCO_{2eq}/MJ_{Fuel}	
Total CO_{2eq} emissions produced	800.8	tCO_{2eq}	
Total CO_{2eq} emissions from heat production	8.9	gCO_{2eq}/MJ	
GHG emissions savings, heating	88.9%	%	
Total CO_{2eq} emissions from electricity production	25	gCO_{2eq}/MJ	
GHG emissions savings**,** electricity	86.4%	%	80%

The total CO_{2eq} emissions for CHP production for the activity of the Italian RESCoop was estimated at **8.9 gCO_{2eq}/MJ** for heat production, and **25 gCO_{2eq}/MJ** for electricity or **800.8 tCO_{2eq}** in total annually. In brief, due to the medium amounts of biomass mobilized, the minimal processing of the biofuels after collection and the small sourcing/ transportation radius, the environmental impact of the BECoop RESCoop is positive.

[14] Full time equivalent.

The GHG emissions calculated can be translated into **88.9% CO_{2eq} savings** for heat production and **86.4% CO_{2eq} savings** for electricity production. This is in line with the minimum requirements (80%) set by RED II guidelines for GHG emissions savings for electricity, heating and cooling production from biomass fuels used in installations starting operation after 1 January 2021. The plant's carbon savings were calculated to be well within the community guidelines for its category, making it a successful project from an environmental perspective, with the added benefit of job creation for its local society. This result stems from the utilization of woodchips, which is a minimally processed biofuel, requiring a very few steps to produce the end fuel. Also, transportation emissions are very low since the biomass is considered to be sourced from a location very close to the CHP plant (less than 50-70 km). Of note should be the projected reduction in airborne particles emissions, that is guaranteed by the use of modern biomass boilers and novel filtration techniques. As was seen in one of the demonstrations of the Italian BECoop RESCoop, the DH plant of TCVVV with state-of-the-art antipollution systems and filters has a minimal environmental impact in terms of emissions.

5.2.3 Stakeholders engaged through BECoop activities in the pilot area

In total, **1766** stakeholders actively participated in a diverse range of activities conducted within the scope of WP4. These activities were categorized based on their associated tasks and the types of services they provided, including technical support, workshops, demonstrations, business-related events, mentoring events, brokerage events, conferences, and more. They encompassed site visits to various project-related locations and businesses, as well as both in-person and virtual meetings, alongside scientific evaluations. The stakeholders involved in these endeavours represented a wide array of entities, including public and private research institutions, other RESCoops, SMEs, public authorities, citizens, and owners of various enterprises.

5.2.4 Barriers, challenges, and risks identified by the BECoop REScoop

The following barriers, challenges and risks have been identified by the Italian BECoop RESCoop:

- **Fragmentation/ ownership of land and supply chain development:** On the structuring of the upstream chain, a highly critical element is the fragmentation of land ownership. This aspect conditions the supply chain and requires the creation of a network of companies for the coordination of picking, storage, and logistics activities. The mayors of the three municipalities also highlighted the difficulty of identifying forestry companies in the area capable of meeting the demands of forest management at competitive costs.
- **Lack of funding in technological means:** another barrier to the development of the upstream supply chain is the absence of specific measures in the Rural Development Plan to finance machinery and technology for the forestry supply chain.
- **Legislative framework:** a critical aspect is related to the legislative framework that currently does not provide incentives for collectively produced and self-consumed thermal energy.
- **Collaboration issues:** various forms of collaboration will be assessed for both the supply chain and the implementation and operation of the new energy system. The potential source of funding that municipalities may access to initiate the initial segment of the district heating network is at the regional level within Lombardy, specifically through the FEARS program. Based on the discussions initiated with the Region, the Call for Proposals is expected to be released in the first quarter of 2024.
- **Reticence of local people and the instability of the energy market**: The possible reticence of local people and the instability of the energy market should be faced to that end, also considering the effect of the recent Russia-Ukraine crisis, still in progress, and the consequences on the Italian energy market.
- **High initial investment cost:** The overall investment costs, about 4-5 M€ of which 1.5-2 for the DH network (very draft estimation, to be verified in the next steps by further deep investigations) are

relevant for small municipalities and for medium enterprises. The possibility to have public funding for the investment and/or incentives during the operation must be explored further. A modular implementation of the new energy system can be considered, to defer the investment costs.

- **Melavì case challenges:** an official agreement should be submitted as soon as possible to ensure its involvement in the proposal, even if other local companies can be integrated in the proposal instead. This opportunity has become even more important in the current energy market due to the evident increase of the energy prices in Italy, a condition that, after the two pandemic years for Covid-19, can lead enterprises to bankruptcy and families to energy poverty.
- **Inadequate allocation of National Financing Support** for Efficient District Heating Development in the National Recovery Plan (NRP) Relative to the Sector's Potential. On several occasions within the table set up between the MASE and the trade associations, FIPER has reiterated the need to invest more resources in the promotion of district heating from renewable sources, a position in line with other European countries, including the German government, which has allocated EUR 2.9 billion, and the Swiss government around CHF 1 billion.
- **Emissions deriving from biomass use**: In Italy, domestic heating fueled by woody biomass contributes 54% of primary PM10 emissions, the concentration of which is particularly critical in some areas, such as the Po Valley basin. In the winter period, these emissions are mainly generated by domestic combustion of biomass, primarily firewood and pellets. The bulk of PM10 emissions come from obsolete stoves and fireplaces that are no longer compatible with current air quality improvement processes. These still account for 70% of the installed stock and are responsible for almost 90% of the particulate matter from wood biomass heating. Thus proper combustion systems and anti-pollution systems must be used. Although air quality is continuously improving thanks to the progressive replacement of obsolete appliances, the use of biomass to produce thermal energy remains a central issue in the policies of the region and especially in the Po Valley basin. In the Po Valley basin, woody biomass district heating plants are currently only allowed in Alpine areas, while it is forbidden in lowland areas. This greatly limits the development of new bioenergy communities in these areas.
- **Economic insecurities:** The instability of the energy market, coupled with the insufficient public backing of bioenergy in the current legislative framework and the high investment costs are all potentially detrimental to the well-being of any community bioenergy project.

5.2.5 Lessons learned and opportunities identified by the BECoop REScoop

- **Increased interest on DH projects and funding opportunities:** On 23 December 2022, the Ministry of the Environment and Energy Security published the rankings of the approved projects for measure M2C3 - Investment 3.1 - Promotion of efficient district heating systems of the NRP. The Call for Proposals met with strong interest from operators: 118 projects were submitted for the start-up and extension of efficient district heating systems, testifying to a growing, capital intensive and low-risk sector. Of the 118 projects submitted, 29 were accepted for funding. The measure provides for an allocation of EUR 200 million against a request for assistance of about EUR 556 million. The 60 positively evaluated projects that were excluded due to lack of financial resources amounted to EUR 233 million. It should be noted that the value of the projects submitted corresponds to about 2 times the value of the requested funding; therefore, the total value of the 79 approved projects is about EUR 1.1 billion. Through measure M2C3 - Investment 3.1, resources amounting to approximately EUR 0.4 billion will be mobilized.

- **An interesting opportunity emerged considering the conditions of the buildings in the area.** Apart for some exceptions, most have low energy performances (high surface to volume ratio, not well insulated walls, and roofs) and the heating density seems quite compatible with a DH network (2-3 floors above ground, low distance among the buildings, location along the same main road). The "linear power density", i.e., the ratio of the connected power needs to the total length of the network, should be verified by accurate investigations since a minimum value of 1 kW/m has to be guaranteed for the energy and economic feasibility of the district heating network.
- **Stakeholder engagement:** due to the active presence of the key stakeholders, the workshops succeeded in meeting the planned objective and a network of collaboration has been created, even if FIPER will be strongly engaged in developing an actual relationship in the framework of the BECoop. Participants were satisfied with the workshop and interested in the further developments of BECoop, thinking also of synergies with other planned projects.
- **Decarbonization Policies**: Policies to achieve the goals of increasing bioenergy communities must be based on an overall strategy to decarbonize the economy, in line with EU and national climate, environmental, circular economy and bioeconomy guidelines, through economically and socially sustainable solutions. In this direction, greater integration of the national energy policy with forestry, climate and environmental policies will enable the country to fulfil its commitments, while providing new investment and development opportunities for local communities, particularly in inland areas
- **Responsible and sustainable forest management:** It is necessary to adopt an approach to the use of forest resources that falls in line with the inspiring principles of the National Forestry Strategy and the recently issued European Forestry Strategy, i.e., based on sustainable and responsible practices that aim at the best valorization of the resources available in each specific context. This is particularly true for Italy, where the forestry sector needs to be relaunched through a structural, systemic, and integrated approach, to promote and support the development of all the national production chains, stimulating silviculture based on sustainable and responsible management and combating the abandonment of cultivation, to make better and more efficient use of its forest heritage. It is essential to ensure that society's demands do not compromise forest resources, given their strategic role in carbon absorption and storage. It offers an integrated approach to ensure that silvicultural activities provide social, environmental, and economic benefits, balance competing demands and maintain and enhance forest functions today and in the future. The role of sustainable forest management therefore aims to balance and enhance multiple functions: i) productive; sustainable production of quality products and renewable raw materials, supply of non-wood by-products, supply of biomass for land-integrated energy systems, etc. ii) protective and environmental; hydro-geological management, air purification, oxygen emission, absorption of carbon dioxide, purification and regulation of water resources, soil and slope consolidation, containment of desertification phenomena, fire prevention, conservation of animal and plant biodiversity, landscape definition, mitigation of the effects of climate change, etc. iii) socio-cultural and recreational: historical-cultural, tourist-recreational and sanitation services.
- **Emissions reduction and environmental benefits**: Best practices have shown that the use of woody biomass in a district heating plant, with centralized generators equipped with bag or filter abatement systems, generates both primary fossil energy savings of between 60% and 80%, and overall environmental benefits in view of the fossil fuels replaced (essentially diesel) and the technologies for using alternative renewable sources (domestic wood-fired systems, pellets). A novel nitrogen oxide abatement technique developed by Ricerca Sistemi Energetici - RSE that can be easily integrated into existing district heating plants, to be used on medium-sized woody biomass combustion plants. The technique consists in integrating, in a single plant unit, two of the most effective flue gas purification technologies: dedusting through fabric sleeve filtration and

denitrification ($DeNO_x$) through a Selective Catalytic Reduction (SCR) reaction that reduces NO_x to nitrogen and water with high efficiency using ammonia or urea as a reducing agent in a catalytic reactor. The catalyst has shown high NO_x abatement efficiency within the same temperature range, between 140 and 200 °C, at which the bag filters used downstream of wood biomass-fired boilers operate, and therefore the technology developed by RSE allows the NO_x emission limits set by the NEC (National Emission Ceiling) to be reached. Specifically, it stipulated that for NO_x from 01/01/2020 the emission level must be reduced by at least 40% compared to the national limits imposed by Legislative Decree 171/2004 and in force until 31/12/2019.

5.2.6 Next steps of the BECoop RESCoop

The tools and actions put in place to ensure the effectiveness and adequacy of policy actions must be coherent, robust and detailed at national, regional and local levels. To this end, Italy first adopted the Unic text for forest and Forest Chain (TUFF) with the aim of standardising forestry policies at the national level, and then the National Forestry Strategy (SFN). The National Forest Strategy represents an innovative planning and regulatory tool adopted for the benefit of Italy's forestry heritage, in the collective interest.

In particular, access to credit is a critical factor for initiating bioenergy projects in Mortirolo. In light of this, discussions with the Lombardy Region were initiated within the project to advocate for the BECoop model as a strategic initiative for the establishment of renewable energy communities. It is anticipated that the call for proposals related to this initiative will be issued in the first quarter of 2024.

6 Monitoring and evaluation- Greek BECoop RESCoop

6.1 Overview of the BECoop RESCoop (GR)

The Greek BECoop RESCoop is ESEK, the Energy Community of Karditsa, a citizen energy cooperative located in Thessaly, central Greece. Its main activity (as-is) is the management of a biomass plant for the production of solid biofuels, to generate energy for heating and cooling purposes. The raw materials utilized consist of industrial residues, such as sawdust, woodchips, and logging residues, including branches, tree-tops and stumps coming from local forest cooperatives.

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**, WP4 tasks targeted the **expansion of activities of ESEK to operate as an bioenergy 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.

6.1.1 Roadmap of BECoop RESCoop

The community's roadmap focuses mainly on end-user identification for its services, identification of new feedstock sources, seeking out potential collaborations and partners and expansion of existing activities. It implies the development of the overall project, including the possible increase of the ESEK plant capacity and expansion of its activities. Based on the accumulating experience of the BECoop community in handling the new feedstocks and through its new business activities, the community would continuously develop by collecting more unexploited local sources, installing more biomass boilers in municipal buildings and in the end by investing on a biomass power plant of 1 MWe. The roadmap of the Greek BECoop RESCoop is depicted **Error! Reference source not found.**.

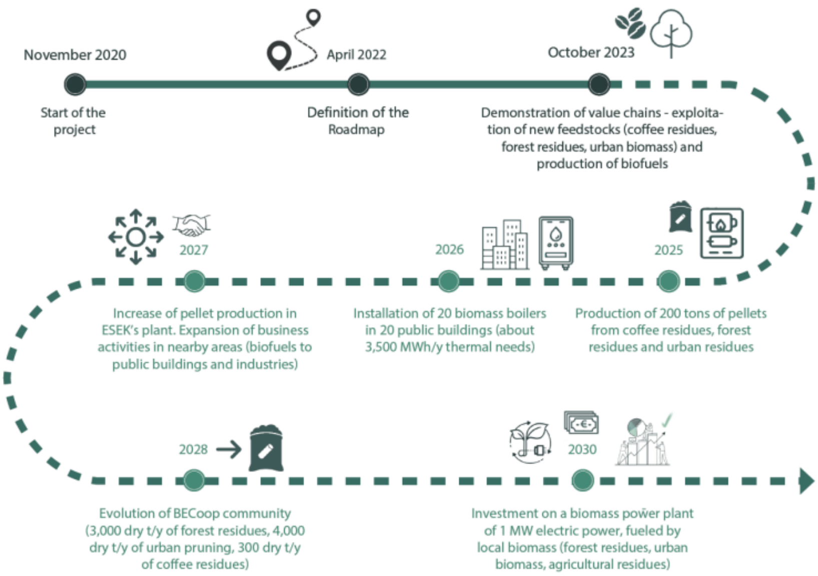


Figure 31. Scheme of the roadmap (Greek pilot).

For more details on the roadmap of the Greek BECoop case, please refer to DLV 4.1 "Co-definition of community bioenergy heating roadmaps".

6.1.2 Overview of technical support services provided

In this section can be found a brief overview of the various technical support services provided to the Greek BECoop RESCoop. For more details, please refer to DLV 4.2 “Deployment of the BECoop technical support services”.

Biomass assessment

In accord with the community’s main goals and purposes, a biomass assessment was the first support service provided to the stakeholders. Various types of potential feedstocks of interest were investigated such as **urban biomass from city pruning, wood residues from local forestry activities and residual wastes from local coffee houses**. Each type of biomass was assessed individually. Its chemical and mechanical properties were examined, to ensure its compatibility with biomass boilers, and usability for the production of pellets. An estimate on the quantities available to be used by the BECoop RESCoop was also performed. In brief, coffee residues in the city of Karditsa were estimated at 600 t/y (wet basis or 300 dry t/y), the urban prunings were estimated around 14,000 t/y (w.b.), where the Greek BECoop RESCoop with the existing facilities can treat up to 4,000 t/y (w.b.) and lastly, the forest residues have a theoretical potential of 67,650 t/y (w.b.) in the area, still unexploited.

Logistics of the BECoop RESCoop

The steps of the logistics chains of the BECoop RESCoop demonstrate different needs for each individual case, so proper training and organization was ensured to attain the operation’s high standards. In Figure 32, Figure 33, and Figure 34 are demonstrated the steps of each logistics chain. 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. 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. In the case of coffee residues, they are disposed from each coffee house in dedicated bins, located at central points. 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) to lower its moisture (> 60% initial moisture content). After two-three weeks, the coffee residues are treated for pellet production. Regarding the forest residues from the mountainous area of Lake Plastira, around 20 km from the city of Karditsa, 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.

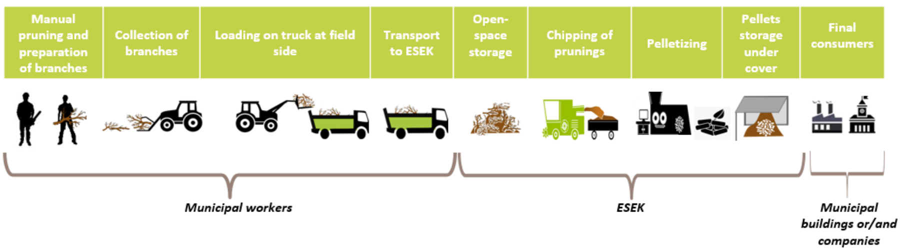


Figure 32. Diagram of value chain operations (urban pruning residues).

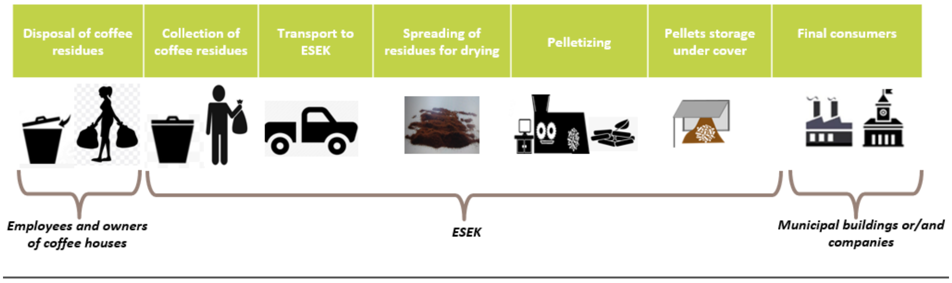


Figure 33. Diagram of value chain operations (coffee residues).

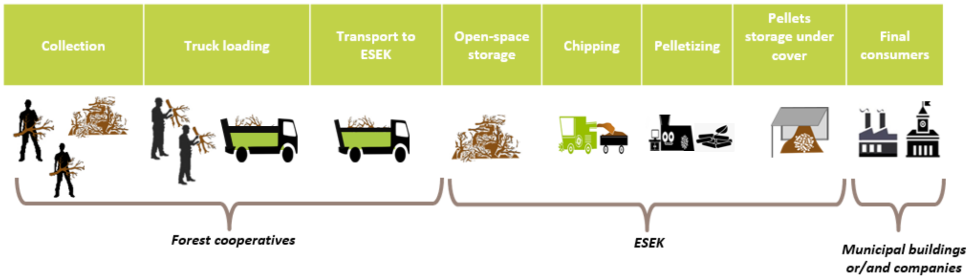


Figure 34. Diagram of value chain operations (forest residues).

Costs of collection

Several costs of the logistics regarding the collection of the three feedstocks of interest for the Greek BECoop RESCoop were estimated. The costs associated with their collection were calculated at 29.1 €/t for the urban prunings, 21 €/t for the coffee residues and 33 €/t for the forest residues.

Location of the BECoop RESCoop

The location of the BECoop RESCoop is that of where the ESEK's pellet plant is located. Figure 35 gicves and overview of the sourcing distance for new feedstocks, distance to potential end-users and facilities already in place.

Figure 35. ESEK's plant location.

Technology and activity of the BECoop RESCoop

ESEK's main field of activity 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 the processing and standardizing local biomass and converting it into a commercial form, such as pellets, is already in place. The raw materials for the plant's operation consist of various biological waste materials, as mentioned in previous sections. The plant has a production capacity of 0.5 t/h for pellets. 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.

Energy demands to be covered

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 200 tonnes of pellets to cover the heating demands. Such pellets are considered to be produced from the mixing of the new feedstocks. This would mean that the new activities of the BECoop RESCoop would cover 730 MWh.

Feasibility study of the BECoop RESCoop

The concept for the feasibility study of the Greek BECoop RESCoop is the installation of 20 biomass boilers (45 kW) in local municipal buildings. Calculations were performed to estimate the CAPEX (~105k € for 20 boilers etc.) and OPEX (~30k€ for the production of around 200 tonnes of pellets). By considering revenues with a selling price of 350 €/t pellet, a cash flow analysis was performed for 25 years resulting to a **NPV of 528.935 €, a payback period of 4.00 years, and an IRR of 22.23%.**

6.1.3 Overview of small-scale demonstration activities performed

In this section can be found a brief overview of the various small-scale demonstration activities performed in the Greek BECoop case. For more details, please refer to DLV 4.4 "BECoop small-scale demonstration activities".

Small-scale demonstration: Collection and chipping of urban pruning residues

City pruning residues collection was performed with the use of two trucks with a crane and crab. Urban pruning residues (tree branches with leaves) were collected by the local municipality. Afterwards, chipping of the residues was also demonstrated in a biomass management company with the use of one truck with a crane and crab and a woodchipper. The wood residues were chipped and transported to ESEK's plant for further processing and pellet production. The collection, transportation and chipping were monitored for recording operational data of such activities and costs, required for the Greek BECoop RESCoop (Figure 36). In total 120 tonnes of urban prunings were collected.

Figure 36. Urban pruning collection and chipping demonstration.

Small-scale demonstration: Collection of coffee residues

As part of the BECoop project, a new feedstock that was explored was coffee residues. Within this context, a demonstration was conducted in collaboration with InCommOn[15] and their project: "Kafsimo[16], to showcase the collection of coffee residues from local coffee houses (Figure 37). The collected coffee residues were subsequently utilized in the production of mixed pellets. Trucks would then collect them and transport them to the pellet plant for processing. In total, around 7 tonnes of coffee residues were collected.

Figure 37. Coffee residue collection receptacles.

Small-scale demonstration: Mixed coffee pellet production and fuel characterization

A pilot pellet production process was carried out in ESEK's pellet plant by mixing coffee residues at different percentages with other biomass residues such as sawmill residues, forest residues, urban pruning residues, maize residues, miscanthus, peach prunings etc. (Figure 38). Subsequently, the mixed pellets were sent to the laboratories of CERTH/CPERI for fuel characterization. This initiative aimed to explore the feasibility and potential of using coffee residues along with other biomass materials to create a diversified and sustainable source of pellets for energy generation. The demonstration revealed that the various mixtures that were tried out had, as expected, different properties between them, but most of them were actually viable as a competitive alternative biofuel source for residential or industrial use.

[15] https://incommon.gr/
[16] https://incommon.gr/kafsimo/

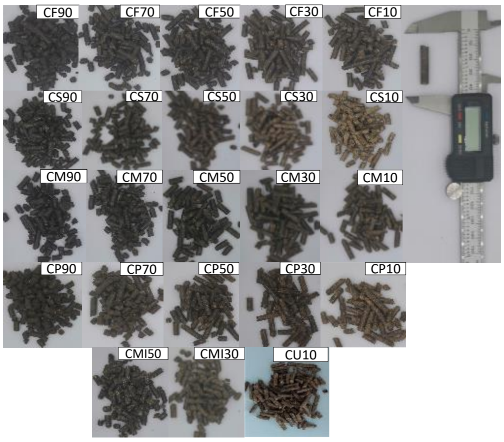


Figure 38. Mixed coffee pellets produced at ESEK's plant.

Small-scale demonstration: Pellet boiler installation and emissions monitoring

This demonstration involved the installation of a 35 KW pellet boiler in a kindergarten, and subsequent combustion test using three different fuels: i) A1 wood pellets produced by ESEK; ii) coffee pellets (10% coffee residues) mixed with urban prunings; iii) coffee pellets (10% coffee residues) mixed with sawmill residues (Figure 39). The test served as a validation test for the new alternative pellets, and as a replication case for the new activities of the Greek RESCoop. During the combustion tests, fuel samples before their use were retrieved for fuel analyses and flue gas emissions were monitored on site. The small-scale demonstration effectively showcased the practical implementation of the upcoming activities envisioned by the BECoop RESCoop and satisfying the end-users of the kindergarten.

Figure 39. Boiler installation and flue gas emissions monitoring.

6.2 Evaluation of BECoop market uptake support impact (GR)

6.2.1 Self-assessment results

In the Greek case study, an initial self-assessment was conducted for the production of pellets/ woodchips from various feedstock such as forestry resources (Figure 40), biomass from urban parks and gardens resources (Figure 41), and agricultural resources (Figure 42). The figures below illustrate the 5-point spider chart comparisons that occurred at the outset of the support activities and after the BECoop RESCoop interventions.

Figure 40 displays the chart outlining the preliminary results for forestry resources in contrast to the final results achieved after WP4 activities. Notable progress is evident in the categories of "Knowledge of the resources," "business and financial solution maturity," and technical aspects. However, there is room for improvement in terms of user engagement for this activity. It is worth noting that the assessment reveals a static situation regarding social and environmental impact, where little optimization opportunities exist. Overall, this case study reflects a positive impact from the BECoop actions, resulting in an **increase** from an initial score of **0.65 to a final score of 0.96**.

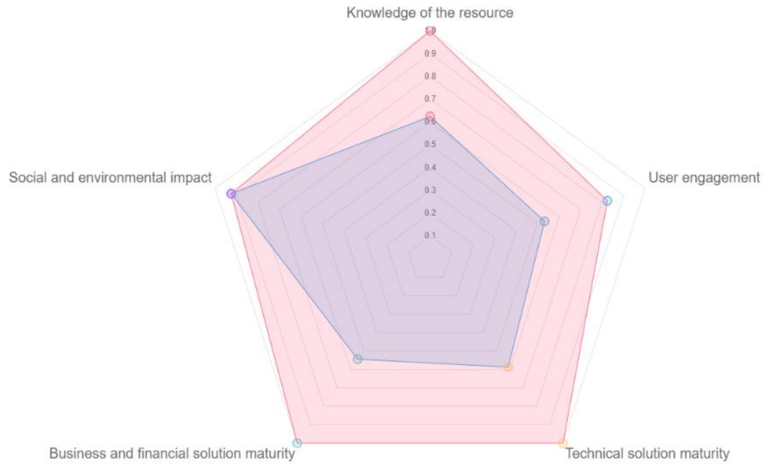


Figure 40. Final self-assessment (pink) compared with the initial one (blue) carried out for the Greek case concerning forestry resources related with "pellets/woodchips production" category.

Figure 41 illustrates the chart displaying the preliminary results for the pellet production from biomass from urban parks and gardens resources activity, along with the final assessment outcomes. Notably, there is substantial progress and optimization in several key areas, including "Knowledge of the resources," "business and financial solution maturity," "social and environmental impact," and technical aspects. However, there remains room for slight improvement in terms of user engagement. Overall, this case study demonstrates significant progress in the imprint of BECoop RESCoop actions, resulting in an **increase** from an initial score of 0**.37 to a final score of 0.97**.

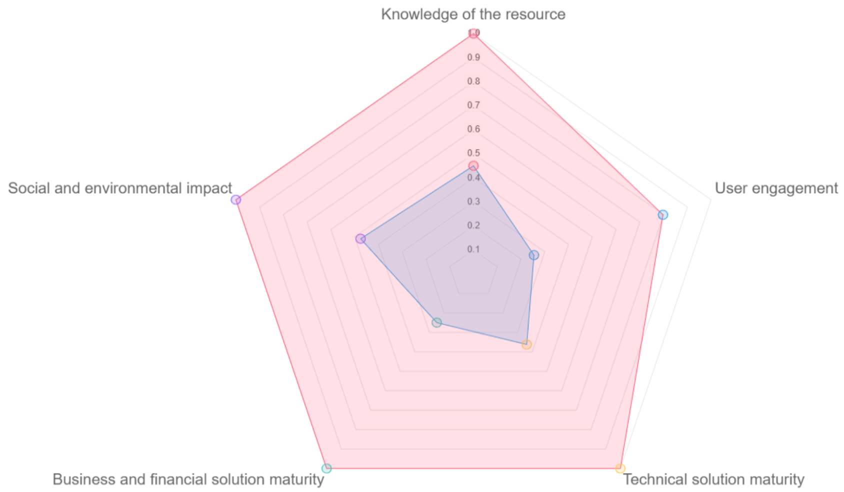


Figure 41. Final self-assessment (pink) compared with the initial one (blue) carried out for the Greek case concerning biomass from urban parks and gardens resources related with "pellets/woodchips production" category.

Figure 42 presents the preliminary results for the production of pellets from agricultural resources activity, in comparison to the final assessment outcomes. While there is considerable optimization across four out of the five studied factors, with minor areas for improvement, it is noteworthy that "user engagement" requires further action where there is still little room for improvement. Overall, this case study reflects less progress in the impact of BECoop RESCoop actions compared to the two previous cases. Nonetheless, a significant increase is observed in the final global score, rising from an initial score of **0.59 to a final score of 0.89**.

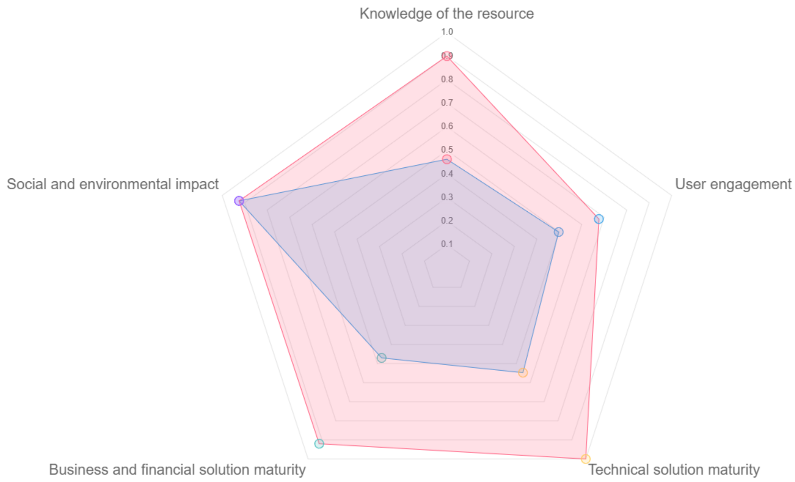


Figure 42. Final self-assessment (pink) compared with the initial one (blue) carried out for the Greek case concerning agricultural resources related with "pellets/woodchips production" category.

Finally, a detailed presentation of the results and breakdown of scores of the self-assessments are presented in Table 10.

Table 10. Self-assessment results for the Greek BECoop RESCoop activity regarding pellet production from different feedstock.

	Forestry resources		Biomass from urban parks and gardens resources		Agricultural resources	
	Initial assessment	Final assessment	Initial assessment	Final assessment	Initial assessment	Final assessment
Knowledge of resources	0.63	1	0.46	1	0.47	0.9
User engagement	0.54	0.83	0.26	0.8	0.5	0.68
Technical solution maturity	0.59	1	0.37	1	0.55	1
Business and financial solution maturity	0.55	1	0.25	1	0.48	0.93
Social and environmental impact	0.93	0.93	0.48	1	0.93	0.93
Global score	**0.65**	**0.96**	**0.37**	**0.97**	**0.59**	**0.89**

6.2.2 Socio-economic and environmental impact of the BECoop RESCoop

To assess the **socio-economic impact** of the Greek BECoop RESCoop, as mentioned in section **Error! Reference source not found.**, CERTH developed specific tools for the task. The results from the application of these tools, for the Greek BECoop RESCoop are as follows in Table 11.

For the Greek case, two scenarios were examined: a) the pellet production scenario of 1,200 tonnes pellets, which is the existing case of ESEK and b) the 1 MWe biomass power plant scenario which is the end-game scenario of the Greek RESCoop in its developed roadmap. The estimated biomass utilized annually for the pellet production scenario was 1,200 tonnes (dry basis) for heating purposes exclusively, and for the power plant scenario it was estimated that 5,700 dry tonnes of local biomass would be sourced.

Table 11. Greek pilot socio-economic impact.

	Pellet production		1 MWe plant	
	Employment impact (FTE[17])	GDP impact (M€)	Employment impact (FTE)	GDP impact (M€)
Equipment manufacturing	0.30	0.02	1	0.03
Construction	0.10	0.00	1	0.06
Feedstock supply	2.40	0.06	19	0.45
Operation and maintenance	4.0	0.07	9	0.84
Indirect	0.76	0.04	8	0.48
TOTAL	**7.55**	**0.19**	**38**	**1.86**

The estimated employment impact of the Greek pilot project can be separated in two cases: the initial case for the installation of 20 biomass boilers in municipal buildings will result in the opening of **7.55 new employment opportunities** for the local community and potential partners from outside it. The actions taken by the project will translate to a **GDP impact of 190,000€**; the secondary case for the 1MW biomass power plant will result in the opening of **38 new employment opportunities** for the local community and potential partners from outside it. The actions taken by the project will translate to a **GDP impact of 1,860,000€**.

As demonstrated, there are great potential economic gains in a project such as the Greek BECoop RESCoop. In a small community such as Karditsa, where ESEK is located, the potential opening for more than 60 new jobs can have an impact on many families, revealing the project's economic potential if it is upscaled or applied to other prospective areas in Greece.

Similarly, using CERTH's tools it can be assessed that the **environmental impact** (in termos of GHG savings compared to fossil fuel use) of the Greek pilot is as demonstrated on Table 12.

Table 12. Greek pilot environmental impact.

	Pellet plant case	1 MWe biomass plant	Units	
CO_{2eq} emissions from transport and distribution	3.4	3.1	gCO_{2eq}/MJ_{Fuel}	Minimum GHG emissions savings based on RED II for new biomass installations
CO_{2eq} emissions from processing	0.3	1.1	gCO_{2eq}/MJ_{Fuel}	
CO_{2eq} emissions from fuel in use	0.3	0.3	gCO_{2eq}/MJ_{Fuel}	
Total CO_{2eq} emissions from production of fuel before energy conversion	4.00	4.50	gCO_{2eq}/MJ_{Fuel}	
Total CO_{2eq} emissions produced	79.2	469.4	tCO_{2eq}	
Total CO_{2eq} emissions from energy production	4.4	26.8	gCO_{2eq}/MJ	
GHG emissions savings	94.4%	85.4%	%	80%

The environmental impact of the project reveals great potential. The total CO_{2eq} emissions for heat production for the activity of the Greek RESCoop was estimated at **4.4 gCO_{2eq}/MJ** or a total **of 79.2 tCO_{2eq}**. Respectively, CO_{2eq} emissions for electricity production were at **26.8 gCO_{2eq}/MJ** or a total of **469.4 tCO_{2eq}**.

[17] Full time equivalent.

Due to the medium amount of biomass mobilized and the small sourcing/ transportation radius, the environmental impact of the BECoop RESCoop is positive. For the case of ESEK, regarding the pellet production process, it was considered that the head demands in the pelletization processes (e.g., drying) are covered by the combustion of biomass (either in chips form or pellets) and the electricity demands are covered by RES-deriving electricity only, coming from the grid, thus having greater GHG savings.

In the case of biomass boilers used for heating purposes, an estimated **94.4% CO_{2eq} savings** was calculated. For the case of the 1MW biomass electricity production plant, **85.4% CO_{2eq} savings** from electricity production compared to fossil fuel comparators. The minimum requirement, according to RED II guidelines for both heating and electricity GHG savings for new biomass installations is at 80%.

ESEK has taken a great deal of care to develop a biomass pellet production method that is very environmentally friendly. It utilizes electricity from the grid that derives only from RES and heat that derives only from biomass combustion. This results in minimal carbon emissions, aided by the proximity of the biomass supply to the pellet plant (less than 100km). Regarding the emissions of new mixed pellets with coffee residues that would be produced, through the combustion tests performed in T4.4, it was seen that the mixed pellets (10% coffee residues and 90% sawmill residues) were below the CO limit of 3,000 mg/Nm^3 for nominal capacity of boilers with less than 50 kW and below the limit of 340 mg/Nm^3 for the NO_x emissions, that is required for the new biomass boiler emissions to accord to Greek legislation and comply with the requirements of Class 3/EN303-5 and its related limits. It should be also noted that the measurements were performed with simple equipment and in a simple/non-sophisticated biomass burner and that during the change of fuels, the combustion parameters were not altered/ optimized. Thus, the performance of the three fuels at a state-of-the art biomass boiler, with state-of-the-art anti-pollution systems and filters and with optimized combustion parameters/ boiler settings, based on the fuel that is combusted, would further increase the combustion performance and emissions.

6.2.3 Stakeholders engaged through BECoop activities in the BECoop pilot area

In total, **349 stakeholders** were engaged in the various activities such as technical support meetings, workshops, demonstrations, business-related events, mentoring events, brokerage event and field visits. The stakeholders involved were research institutions, both public and private, other RESCoops, SMEs, public authorities, citizens etc.

6.2.4 Barriers, challenges, and risks identified by the BECoop RESCoop

The following barriers and challenges have been identified by the Greek BECoop RESCoop:

- **Lack of sufficient logistics:** a greater optimization of the route system for the collection of local biomass would lead to better overall efficiency. For example, revamping (municipal) transportation and upgrading the fleet for improved efficiency and reliability. The operation of collecting urban pruning residues (performed by the municipality) would greatly benefit from a new fleet of transportation vehicles of the municipality. The vehicles currently used were of older technology and frequently needed repair, as well as they were prone to frequent breakdowns that disrupted the gathering and distribution of materials. An expansion of the fleet would also allow for a wider area of operations, covering potentially the whole municipality of Karditsa.
- **Optimizing combustion for novel biofuel mixtures:** the lack of experience with the new fuels coupled with the absence of sophisticated boiler control systems have also played their role. The combustion

of the new fuels at a state-of-the-art biomass boiler and with optimized combustion parameters/ boiler settings, based on the fuels that are combusted, would further increase the combustion performance and results.

- **Misconceptions and lack of awareness about biomass valorisation:** relates to misinformation or lack of awareness about benefits and risks of bioenergy, on sustainable and responsible biomass exploitation which can lead to deforestation, habitat destruction, on smog problems, concerns about emissions such as particulate matter particularly in densely populated areas and other environmental problems.
- **Lack of technical knowledge:** a shortage of skilled personnel and technical expertise in bioenergy can hinder project development and operation.
- **Unsupportive/Complex legislation**: not supportive enough legislations/ incentives for biomass solutions compared to fossil fuels. For example, in Greece, VAT for biofuels is at 24%, compared to natural gas or electricity that is at 6%. This, coupled with the existing **complex regulatory framework,** which makes potential bioenergy communities go through lengthy bureaucratic permitting processes and regulatory requirements, can significantly delay project development. **Constantly changing policies** can also create instability for bioenergy projects.
- **Financial barriers**: high initial costs that bioenergy projects often require, can be challenging for communities to secure, making it a potential failure factor.
- **Lack of similar success cases** of bioenergy projects in the area.
- **Community opposition**: resistance from local community who are skeptical or opposed to bio-energy projects due to concerns about environmental impacts, health risks and other misconceptions.
- **Mistrust on co-operative schemes**: due to the unsuccessful experience with most co-operative schemes in agriculture (e.g., agricultural cooperatives), the local people are reluctant to invest/ join an energy community. To address these risks and barriers, relating to the local community's relation to the BECoop RESCoop, it's crucial for any community bioenergy project to engage with the local stakeholders, conduct thorough environmental and health impact assessments, ensure compliance with regulations, provide transparent and fair benefit-sharing mechanisms, and invest in sustainable and efficient technology.

6.2.5 Lessons learned and opportunities identified by the BECoop RESCoop

The opportunities and lessons learned identified by the Greek BECoop RESCoop are the following:

- **High potential of residual biomass in the area**: the region has a great biomass potential in agricultural and forestry biomass, yet unexploited, that can easily support the uptake of bioenergy technologies. Coffee residues are discharged in landfills, agricultural residues are mostly burned, forestry residues are mostly left inside the forests, while urban pruning residues are left in open spaces, being a risk for fire hazards. Their exploitation not only reduces waste volume and waste management costs, but also provides a useful new resource to the local community.
- **Energy poverty mitigation:** The exploitation of local biomass sources also aids in the fight against energy poverty; using solid biofuels coming from local residual biomass reduces the heating related cost by 20%.
- **Coffee residues exploitation opportunities**: The implementation of an improved system for the sorting of coffee grounds would benefit the collection of such unexploited residue in the area and promote circular economy solutions. Moreover, municipalities can increase the network of coffee

houses by giving them motivation (i.e., through the reduction of municipal taxes, municipal tax incentives), benefiting both SMEs and the public, to provide various benefits to the local SMEs and general economy. Another potential opportunity lies in **harnessing electric vehicles for sustainable coffee residue management**; electrical vehicles (e-bikes, e-cars etc.) can be used for the collection of coffee residues, further improving the sustainability and the environmental impact of the coffee residues exploitation value chain on the local area. Coffee residues were found to be a "Trojan horse" with which terms like circular economy and bioenergy were communicated and adopted by local society.

- **Community bioenergy production has significant potential for Europe**: It is empirically shown that energy communities are important enablers of the energy transition while also leading to a wide spectrum of social impact. This can include an increased acceptance of renewable energy developments (in contrast with commercially led projects which are often faced with public opposition), faster uptake of low carbon technologies, more sustainable practices, and lower risk of energy poverty. In its updated Renewable Energy Directive II (RED II), the EU clearly considers community energy as a key factor for future RE market uptake and mandates Member States to implement regulatory frameworks for enabling and facilitating this process.
- **Participation of local authorities in bio energy projects through Energy Communities:** Creates local investments and add value to the community. A significant part of the return remains and is distributed into the local economy. In this way Energy Communities promote local growth and sustainability.
- **Ownership and involvement of residents in bioenergy projects through Energy Communities**: strengthen social cohesion, as it enhances the dialogue between the members that share the benefits of RES, which is key to their long-term viability. When local communities and citizens have a sense of ownership and are actively involved in the decision-making process, project planning and implementation, it often leads to project success.
- **Activation and raising awareness of society**: It is done both through informing and through invitation to participate in decision-making on the development of bioenergy projects, as well as the benefits of participating in them. In this way energy democracy is taking place and more effective control is possible by the citizens. **Raising citizen awareness around the message of circular economy** (as it was showcased through the coffee residues collection in Karditsa) and how it can be integrated in their daily life is also an issue to be addressed by any potential bioenergy community, especially in the cadre of modern societal needs and how they will develop in the upcoming environmental crisis.
- **Economic Benefits**: Bioenergy communities' projects generate employment opportunities within the community, thus more job opportunities. Financial benefits, such as revenue – sharing mechanisms and access to affordable energy.
- **Environmental sustainability**: Sustainable sourcing and management of residual biomass resources creates a long – term viability of bioenergy projects, prioritize environmental sustainability and reduce greenhouse gas emissions.
- **Policy and regulatory framework**: Government incentives, subsidies and favorable regulatory frameworks can significantly boost the feasibility and attractiveness of bioenergy projects.
- **Knowledge transfer, training, and education**: Bioenergy communities educate and training their members, general public, transferring technical knowledge, skills and abilities that go beyond what it acquires a traditional investor (who usually focuses only on stock profitability), build support and trust within the communities.
- **Increase of energy independence**: Bioenergy communities offering reliable, affordable and "local" energy to local communities, thus reducing the dependence on fossil fuels.

- **Adaptation to local conditions**: Bioenergy projects are tailored to local biomass availability, climate conditions and community needs.

In summary, the **success** of bioenergy projects in local communities and citizen communities depends on a **combination** of **economic**, **environmental**, **social**, and **regulatory factors**. Building **trust**, engaging the community, and addressing their **specific needs** and concerns are critical elements for success. Additionally, aligning the project with **broader sustainability goals** and seeking policy support can further enhance the prospects of success.

6.2.6 Next steps of the BECoop RESCoop

The BECoop RESCoop project has demonstrated significant potential for sustainable bioenergy development within the local community. By analysing the drivers and barriers mentioned previously, we can outline a vision for the project's future, including plans for expansion, diversification, and long-term sustainability.

To expand the bioenergy initiatives, ESEK needs to scale up, to build on the success of the BECoop project including the expansion of bioenergy activities within the community and potentially branching out to nearby regions. New partnerships should be made by collaborating with neighbouring municipalities and communities to create a network and strengthen the collective impact.

Raise the public awareness by expanding the community outreach efforts to inform the local community about the benefits of bioenergy, dispel misconceptions and invest in education and training programs to develop expertise in bioenergy technologies and sustainable biomass management.

Collaborate with local and national governments to advocate supportive policies, tax incentives and regulatory frameworks as well as exploring financing options such as grants, loans and investments to ensure financial stability and reinvesting profits into the community for infrastructure improvements, community development and expansion.

Beyond the BECoop project the Greek pilot can be a replicative case, sharing knowledge, experiences and best practices with other communities, nationally and internationally in order to encourage the establishment of similar bioenergy communities.

In conclusion, the BECoop RESCoop project envisions a future where bioenergy plays a central role in sustainable community development. By addressing barriers, leveraging drivers, and following a comprehensive roadmap, the project aims to not only thrive but also serve as a beacon of inspiration for others looking to embark on similar ventures in the pursuit of a greener and more sustainable future.

7 Critical analysis and discussion

As the world faces the pressing need for **transition towards sustainable energy sources and reduced carbon emissions**, community-based bioenergy projects have emerged as promising solutions. Such types initiatives not only empower local communities but also promote a fair economic growth, and contribute to environmental sustainability. Drawing insights from the successful bioenergy initiatives of BECoop across different European regions, this chapter **identifies risks** that could jeopardize projects of such nature, along with **success factors/ lessons learned** that underpin their achievements.

As discussed in previous deliverables, **each BECoop pilot case represents a unique and heterogeneous case of a community bioenergy heating project**. Pilots have different bioenergy goals, technological choices, maturity levels, and the socio-political context in which they operate may also vary. Some pilots correspond to already established RESCoops, while others explore the initiation of a community bioenergy from scratch. Thus, instead of performing a strict comparative analysis, we **rather conducted a more in-depth examination of all BECoop RESCoop characteristics, aiming to identify common opportunities and challenges** among the BECoop pilots. By critically **analysing success and failure factors** related to these project-initiated community bioenergy initiatives, **valuable insights and conclusions** can be drawn for the wider European landscape of community bioenergy heating.

This analysis was founded on the **feedback obtained from the BECoop RESCoops**, drawing on **their experiences** accumulated throughout the project's activities. It also builds upon insights gained from previous tasks, such as T1.1 (State-of-play of community bioenergy across Europe: market size, applications, and best practices) , T1.2 (Mapping the regional and EU framework and value chain conditions affecting community bioenergy uptake) and T1.3 (Identification of stakeholders' perceptions and needs). **These tasks have equipped us with the knowledge to interpret the outcomes of the pilot's unique experiences and to create a coherent narrative**.

To assess the relevance of each partner to the various points, a color system was used. Each color represents the pilot's relationship to the point; green means it is directly referenced by the partner in the relative section of the document and is of strong relevance, yellow means that it is referenced at another section or implied and is of medium relevance, and red means that there could be an association, but it was not reported by the pilot in this instance and is of low relevance.

7.1 Risks, barriers and challenges in community bioenergy heating

The following table (Table 13) gives an overview of several risks, barriers and challenges encountered by the four BECoop RESCoops during WP4 tasks or could be encountered in the direct future.

Table 13. Risks, barriers and challenges critical analysis. Green: strong relevance; Yellow: medium relevance; Red: low relevance.

Risks, barriers and challenges		ES	PL	IT	GR
Regulatory, legislative and policy issues	Complex or unstable regulatory framework that can impede the development of energy communities	Green	Green	Green	Green
	Bureaucratic barriers, over-complicating and time-consuming procedures and requirements in creating an energy community.	Green	Green	Red	Yellow
	Limits in biomass exploitation in rural areas. Lack of legislations forbidding e.g. open field burning of agricultural residues etc..	Red	Green	Red	Yellow

Risks, barriers and challenges		ES	PL	IT	GR
	Insufficient public support or incentives towards adoption of bioenergy.				
Technical issues	Logistics problems related to the whole supply of materials (proximity and ease of access to raw materials, storage areas, infrastructure, processing stations etc.).				
	Biomass availability.				
	Choosing right technological solutions to case's needs & capabilities (e.g. district heating based on heating densities, individual boilers, choosing fuel types etc.).				
	Lack of successful (bioenergy) cases in the area.				
	Lack of access to qualified professionals or technical support or local SMEs.				
	Lack of energy demand/ competition with NG grid or other RES.				
Economic issues	Economic sustainability concerns.				
	Lack of access to external funding sources.				
	High initial costs for sustainable energy projects.				
	Energy crisis impact on market.				
	Insufficient government subsidy support.				
	Crowdfunding attempts unsuccessful at some cases.				
Community engagement, opposition and governance issues	Community opposition due to concerns about environmental impacts and health risks.				
	Lack of community engagement and buy-in.				
	Negative perceptions (experience from cooperatives etc.) or misconceptions or lack of knowledge about energy community concepts and their benefits.				
	Need for careful structuring of governance model to avoid internal struggles (economic, partitioning of responsibilities, ownership, land fragmentation etc).				
	Locals resistant to communal governance models due to localized factors.				

All of the pilots highlighted the **importance of selecting an appropriate location for a BECoop RESCoop**. This encompasses factors such as ensuring access to an adequate biomass supply to meet the community's needs, addressing logistical challenges, identifying potential local partners in close proximity, and considering more abstract issues like community readiness for a communal project or any reservations about biomass utilization. Optimal site selection lies at the heart of establishing a robust RESCoop and can greatly benefit from the insights gathered from the pilots.

Special attention must also be devoted to the careful structuring of a governance model tailored to the unique needs of each BECoop RESCoop. An unexpected factor that emerged was the resistance to such projects in Poland, given the country's trust issues towards communitarian forms of organization due to historical factor. On the other hand, the Greek case revealed that conventional marketing of renewable energy sources faced resistance from the community. However, the involvement of the BECoop project helped residents overcome their preconceptions and become more receptive to the idea of adopting bioenergy.

All four BECoop RESCoops identified regulatory issues as potential risk factors. Though not outright prohibitive initially, regulatory issues can cause delays and hinderances that may disincentivize stakeholders and make the project 'fizzle out' or kill it in its initial stages. This demonstrates the need for a more thought-out and comprehensive, but also flexible, national plan for all related EU countries towards the adoption of biomass as a fossil fuel alternative.

Financial and funding challenges were also found to be a commonly reported failure factor. The high initial investment costs, especially for biomass district heating and CHP projects, can be prohibitive for aspiring communes to get off the ground. Coupled with a reported, in some cases, **lack of external funding** (either through subsidies or investors), can create a framework that allows access only to investors with high-budget availability. Some also voiced concerns about the sustainability of their pilots, i.e., through access to high quality feedstock or other disruptions that can cause significant economic damage and harm or terminate an energy community. Furthermore, the ongoing political/energy crisis created by the latest developments in Europe was also reported as a potential hazard to developing projects, whether it was through raising gas prices or other goods or in general energy instability.

Another reported category was the lack of community engagement or outright opposition to biomass RE. Many misconceptions exist around the use of biomass for energy purposes, and having to combat these at a local level may cause lack of interest in the project or outright hostility towards it. This may lead to a lack of end-users or even individuals, worrying about the sustainability of biomass that oppose it.

Lastly, issues related to ownership, land fragmentation, and governance problems emerged as common themes across the BECoop RESCoops. In the Italian case for example, there is ambiguity around ownership of forest land, adding an extra hurdle in its exploitation as a RE source. The Polish BECoop RESCoop on the other hand dealt with suspicion towards the communal nature of governing a RE cooperative. These factors can be very important as they may hinder securing of resources or cause internal conflict that may result in failure for a project.

7.2 Lessons learned and opportunities in community bioenergy heating

The following table (Table 14) summarizes common lessons learned/success factors and opportunities as they were derived from the experience of the BECoop RESCoops throughout WP4 activities.

Table 14. Lessons learned and opportunities critical analysis. Green: strong relevance; Yellow: medium relevance; Red: low relevance.

Lessons learned and opportunities		SP	PL	IT	GR
Community Engagement aspects	Community engagement (SMEs, civilians, municipal authorities) is important for an energy community to be successful.	Green	Green	Green	Green
	Stakeholders respond more positively to project if personally involved. Active stakeholder participation creates sense of ownership and leads to overall success.	Green	Green	Red	Green
	Community education in bioenergy is important to address misconceptions.	Green	Green	Yellow	Green
	Active participation in RESCoop promotes social cohesion, serves as breeding ground for other projects.	Green	Yellow	Yellow	Green
	Various community outreach events (workshops, meetings, picnics etc.) helped develop bonds between community and stakeholders.	Yellow	Green	Green	Green
	Job creation for rural areas.	Green	Green	Yellow	Green

Lessons learned and opportunities		SP	PL	IT	GR
Economic opportunities	Energy poverty mitigation.				
	Stimulation of rural economic activity on multiple layers. Business opportunities for SMEs and local communities				
	Increased interest in investments in bio-heating and bio-based district heating.				
	Heating expenses reduction for biomass-heating adapters/ cheap alternative to coal & fossil fuels.				
	Requirement for incentives/ motivation to attract stakeholders – economic, government involvement, education on sustainable bioenergy etc.				
Environmental Sustainability aspects	Proper forest management can increase sustainability, ensure preservation and supply of raw material, reduces risk of forest fires.				
	Utilization of waste/residues (forestry, agricultural etc.) as an energy source promotes circular economy and have positive environmental impact.				
	Bioenergy communities aid in fossil fuel independence.				
	Novel anti-pollution systems (e.g. filters) and modern boilers decrease emissions.				
Technical aspects	Have in place an elaborated plan of action for the technical, logistical, and business aspects of the community.				
	Take advantage/upgrade pre-existing infrastructure or mechanisms (e.g., logistics chains) already in place.				
	Utilization of multiple feedstock sources (e.g., coffee beans, industrial wastes, municipal wastes etc.) can secure feedstock supply chain.				
	High potential of residual biomass in the area, yet unexploited, is important for a successful bioenergy community.				
Supportive Regulatory aspects	Developing symbiotic relationship with municipal authorities/local SMEs.				
	Project's inclusion in national RE management plans is greatly beneficial.				
	Government subsidy support is important.				

Lessons learned and opportunities		SP	PL	IT	GR
BECoop Metrics	New jobs creation from BECoop RESCoop activity (FTE).	1.3	18.4	44	a) Pellet: 7.55 b) 1MWe: 38
	Total CO_{2eq} emissions from energy production (gCO_{2eq}/MJ).	5.3	21	25 electr./ 8.9 heat.	a) Pellet: 4.4, pellet b) 1MWe: 26.8
	GHG emissions savings (%).	93.4%	83.1%	86.4% electr./ 88.9% heat.	a) Pellet 94.4% b) 1MWe: 85.4%

Overall, in terms of community engagement, **the involvement of local communities and citizens through RESCoops enhances social cohesion, promotes dialogue, and fosters a sense of ownership and involvement in renewable energy projects.** Local authority and community participation in bioenergy projects contribute to local growth, create job opportunities, and generate economic benefits within the community. Providing reliable and affordable energy to local communities reduces energy poverty and enhances energy independence.

To achieve environmental sustainability, which is a pivotal aspect of modern bio-heating initiatives, **prioritizing sustainable sourcing and management of biomass resources is essential**. This approach guarantees the long-term viability of bioenergy projects, reduces greenhouse gas emissions, and contributes to overall environmental sustainability. **Proper forest management is vital** in this area; utilizing forest science and current forestry techniques can not only support the trees habitat and provide better growing conditions but also help in forest preservation against wildfires etc.

Furthermore, government support was reported by all partners as an important success factor. **Favourable regulatory frameworks, government incentives, and subsidies play a significant role in boosting the feasibility and attractiveness of bioenergy project**. The EU's recognition of community energy and the implementation of regulatory frameworks that enable community participation also provide a supportive environment for bioenergy project success.

Community education helps combat preconceptions around RE and guides potential stakeholders towards adopting them. **Educating and training community members, promoting technical knowledge transfer, and building support and trust contribute to the success of bioenergy projects.** To that end, tailored projects can also assist. Adapting bioenergy projects to local conditions, biomass availability, climate, and community needs enhances project relevance and viability. **Another point to consider relates to energy democracy**: engaging citizens in the decision-making processes of a bioenergy commune and allowing them to participate in project development promotes energy democracy and project success.

All BECoop RESCoops identified some form of economic opportunity associated with their respective cases. Most commonly, **these opportunities were linked to the stimulation of rural economies, which included aspects such as job creation, investment opportunities, and engagement with local SMEs in the project.** This is also demonstrated by the socio-economic metrics included in this deliverable, that highlight the **employment opportunity creation potential of the BECoop project – some of it already taking place in some cases**. Additionally, the potential GDP impact was emphasized, and it was noted that, depending on the scale of each project, this impact could be substantial. The projects were found to have the potential for profitability, and with proper nurturing, they could expand, providing a significant boost to rural economies.

The technical aspects also were recognized as a common opportunity. **By utilizing novel technologies, like state-of-the-art boilers or filtration systems for flue gasses and anti-pollution systems, better combustion conditions are guaranteed, along with minimized emissions** – a crucial point as most EU countries strive to minimize carbon and particle emissions in the immediate future.

The community benefits of the BECoop project are also very notable. **The pilots reported that locals showed interest in engagement with the project, either through active participation** with the community aspect of community bioenergy, **or indirectly as customers**. The various workshops that involved hundreds of participants verify these claims, as demonstrated by the shareholders engaged sections of this deliverable. The benefits for rural communities can encompass a range of advantages, including **enhanced social cohesion through engagement in a democratic decision-making process**, **increased awareness** of green energy and its economic benefits, and investment opportunities for SMEs or individual actors. For example, a farmer could benefit by selling agricultural by-products as feedstock for bioenergy projects.

8 Conclusions

Through the lens of real-world experiences and valuable insights gathered from the BECoop RESCoops, this study paints a vivid picture of the **transformative potential** and **inherent challenges** of community-driven renewable energy initiatives. This task aimed to **measure and quantify the progress** and the milestones reached through the execution of the various WP4 activities. Task 4.5 expanded on the foundations set by the previous tasks, Task 4.1 (cases roadmaps), Task 4.2 (technical support services) Task 4.3 (business and financial support services) and T4.4 (small- scale demonstrations), with its main goal being to evaluate the results of the whole WP4 activities.

Task 4.5 served as a **conclusion** and **wrap-up** for the **WP activities** as well as a **benchmark for their results**. Through the various activities performed in its framework, T4.5 strived to **quantify the economic, social, environmental, and general market uptake of the previous activities** employed by WP4. It also serves as a **potential frame of reference for any future bioenergy community** that seeks to be informed by the practices and experience accumulated by the BECoop project.

This deliverable successfully completed an impact assessment for the BECoop project's activities and outcomes for all the different pilot cases and areas, and offered a critical analysis that helps identify common needs, barriers, risks and lessons learned. Table 15 presents some Key Performance Indicators (KPIs) that were set by the DoA and were accomplished within WP4 tasks.

Table 15. Key Performance Indicators.

KPI	Related Task	Target Value	Current Status
Community Bioenergy Roadmaps defined	T4.1	4 (1 per case)	5, D4.1
Deployment of the BECoop Technical Services report	T4.2	1	1, D4.2
Deployment of the business and financial services report	T4.3	1	1, D4.3
Stakeholders receiving services	T4.1, T4.2, T4.3, T4.4	> 400 (100 per case)	2,879 Spain:155 Poland: 609 Italy: 1766 Greece: 394
Peer-to-peer mentoring events	T4.3	8 (2 per pilot)	9, D4.3
Small-scale demonstration activities	T4.4	4 (1 per pilot)	13, D4.4
Outcomes evaluation reports	T4.5	5 (4 local and 1 cross regional)	5, D4.5

The experience gained from the BECoop RESCoops provided valuable lessons and insights for sustainable energy development. **By examining these insights, several crucial practical recommendations have been derived for similar future interventions in biomass or other community bioenergy projects:**

Recommendations for future interventions:

- **Community Engagement and Ownership:** Foster active involvement of local communities and residents through RESCoops to promote ownership and enhance social cohesion. Create platforms for open dialogue and information sharing to ensure community members understand and support the project's goals.
- **Economic and Social Benefits:** Collaborate with local authorities and community stakeholders to ensure that the economic benefits of the project remain within the local economy. Highlight the potential for job creation, revenue-sharing mechanisms, and affordable energy access to increase community support and project viability.
- **Environmental Sustainability:** Prioritize sustainable biomass sourcing and management to ensure the long-term environmental viability of the project. Exploit local biomass resources that remain untapped. Implement emission reduction technologies and strategies to mitigate environmental impacts and contribute to overall sustainability goals.
- **Planning in advance:** Schedule in detail beforehand the logistics, biomass supply, feasibility study, technology to be implemented, collaborators and end-users of the community bioenergy activity.
- **Policy and Regulatory Framework:** Advocate for supportive regulatory frameworks and government incentives that enhance the feasibility and attractiveness of bioenergy projects. Collaborate with policymakers to ensure alignment with national and EU-level energy and environmental objectives.
- **Knowledge Transfer and Education:** Establish educational initiatives to build technical knowledge and skills within the community, fostering a deeper understanding of the project's benefits and operation. Provide resources and workshops to inform and engage community members about bioenergy technologies and practices.
- **Local Adaptation:** Customize projects to fit local conditions, biomass availability, and community needs to ensure the project's relevance and long-term success. Conduct thorough feasibility studies and assessments to determine the suitability of the project within the specific context.
- **Strengthened Social Cohesion:** Promote energy democracy by involving community members in project decision-making and planning processes and tackling energy poverty. Establish transparent communication channels to address concerns and ensure that the community's voice is heard.
- **Collaborative Partnerships:** Forge partnerships with local authorities, educational institutions, and technical experts to leverage expertise, funding opportunities, and knowledge sharing.
- **Alignment with Broader Goals:** Ensure that the project aligns with broader sustainability, climate, and environmental goals to attract support from both local communities and policymakers. Highlight the project's contribution to reducing greenhouse gas emissions and advancing regional energy independence.

By considering these recommendations, **future bioenergy community projects can enhance their chances of success**, contribute to local development, and promote sustainable energy solutions within their communities.

9 References

References of the various sources utilized throughout the document are cited as hyperlinks and footnotes. Further references are reported in detail in the previous deliverables.

Annex

Annex I Methodology on GDP calculation

The tool utilized data provided by Deloitte's reports on the economic and social impact of bioenergy in Europe. Deloitte employed three equivalent approaches, acknowledged by the European System of National and Regional Accounts (ESNRA), to calculate the Bioenergy sector's contribution to EU27 GDP: the added value approach, the income approach, and the expenditure approach.

The added value approach defines value added as the value of all newly created goods and services minus the value of all goods and services consumed in their production, excluding the depreciation of fixed assets. This calculation yields GDP at market prices.

The Income approach encompasses salaries and other forms of compensation for employees, net taxes on production and imports, gross operating surplus, and mixed income. This approach reveals how GDP is distributed among various participants in the production process.

Both the value added and income approaches were utilized to assess the sector's impact on GDP, utilizing data disclosed in the financial statements of companies. Supplementary data were collected through surveys of participants in the Bioenergy industry. The calculation using the expenditure approach necessitates an estimation of the sector's exports and imports, which was conducted based on the available information in financial statements.

The assessment of job creation (Full time jobs) within various subsectors of the Bioenergy industry, as well as related economic sectors, relied on employment data disclosed by companies within the industry and complementary industries, as found in their financial statements and annual reports. Direct employment was determined by summing the reported number of jobs in each Bioenergy company's financial statement or annual report. Indirect employment has been estimated utilizing the economic activity of bioenergy in other sectors, using indices of productivity per employment calculated in the Input-Output tables.

The indirect effects of the industry on the other areas of the economy were quantified using a matrix of technical coefficients and the Leontief inverse matrix. For this calculation of the indirect GDP impact, the following information was required: i) the latest EU Input-Output tables (2020) from Eurostat, containing the table 'Symmetric Input-Output for domestic output at basic prices'; ii) questionnaires developed to incorporate the breakdown of the bioenergy industry key stakeholders. This information was introduced to a matrix, technical coefficients were drawn to measure the relative importance of each industry in the total production of another subsector. Then a Leontief inverse matrix was drawn, to measure the indirect impact of the sector's economic activity. Income multipliers were calculated to measure the relation between gross added value and total production. Finally, the indirect impact of bioenergy sector was estimated by multiplying the expenses in goods and services by the multipliers of each economic activity.

Annex II Methodology on calculating the GHG savings

Through each process of the value chain, some factors are estimated to calculate the total emissions before energy conversion as can be seen in the following equation:

$E = e_{ec} + e_{l} + e_{p} + e_{td} + e_{u} - es_{ca} - e_{ccs} - e_{ccr}$,

Where,

E = total emissions from the production of the fuel before energy conversion.

e_{ec} = emissions from the extraction or cultivation of raw materials.

e_l = annualised emissions from carbon stock changes caused by land use change; (not considered in the tool).
e_p = emissions from processing.
e_{td} = emissions from transport and distribution.
e_u = emissions from the fuel in use, that is greenhouse gases emitted during combustion.
e_{sca} = emission savings from improved agricultural management; (not considered in the tool).
e_{ccs} = emission savings from carbon capture and geological storage; (not considered in the tool) and
e_{ccr} = emission savings from carbon capture and replacement (not considered in the tool).
Emissions from the manufacture of machinery and equipment shall not be considered.

Because the BECoop RESCoops that are investigated in this deliverable mobilizes small amounts of biomass, the emissions related to the harvesting, transportation processing and use (e_{ec}, e_p, e_{td}, e_u) are drafted from the default values for such emissions factors that are proposed in the RED II for such bioenergy projects.

Continuously, GHG gas emissions from the use of solid and gaseous biomass in producing electricity, heating or cooling, including the energy conversion to electricity and/ or heat or cooling produced are calculated as follows:

- For the electricity or mechanical energy coming from energy installations delivering useful heat together with electricity and/or mechanical energy:

$$EC_{el} = \frac{E}{\eta_{el}} \cdot \left(\frac{C_{el} \cdot \eta_{el}}{C_{el} \cdot \eta_{el} + C_h \cdot \eta_h} \right)$$

- For the useful heat coming from energy installations delivering heat together with electricity and/or mechanical energy:

$$EC_h = \frac{E}{\eta_h} \cdot \left(\frac{C_h \cdot \eta_h}{C_{el} \cdot \eta_{el} + C_h \cdot \eta_h} \right)$$

Where:
$EC_{h,el}$ = Total GHG gas emissions from the final energy commodity.
E = Total GHG gas emissions before end-conversion.
η_{el} = The electrical efficiency, defined as the annual electricity produced divided by the annual fuel input.
η_h = The heat efficiency, defined as the annual useful heat output divided by the annual fuel input.
C_{el} = Fraction of exergy in the electricity, and/or mechanical energy, set to 100 % (C_{el} = 1).
C_h = Carnot efficiency (fraction of exergy in the useful heat).
Carnot efficiency, C_h, for useful heat at different temperatures:
Where:
T_h = Temperature, measured in absolute temperature (kelvin) of the useful heat at point of delivery.
T_0 = Temperature of surroundings, set at 273 kelvin (equal to 0 °C)
For T_h, < 150 °C (423 kelvin), C_h can alternatively be defined as follows:
C_h = Carnot efficiency in heat at 150 °C (423 kelvin), which is 0.35

At the end, the tool calculates the GHG gas emission savings from implementing the biomass-based value chain (production of heat/cooling/ electricity from biomass) compared to the emissions produced from the generation of heat/cooling/ electricity from fossil fuels. GHG emission savings from heating, cooling, electricity generation from biomass shall be calculated as:

SAVING = ($EC_{F(h\&c,el)}$ – $EC_{B(h\&c,el)}$)/$EC_{F\ (h\&c,el)}$, where
$EC_{B\ (h\&c,el)}$ = total emissions from the production of heat, cooling, electricity from biomass;
$EC_{F\ (h\&c,el)}$ = total emissions from the fossil fuel comparator for heating and cooling, electricity.