# SMART ENERGY

# Biomass: just district heating, cogeneration or tri-generation? Compared solutions

**Feasibility study for the improved efficiency, scalability and transferability through suitable technological and control adaptations to the wood biomass district heating plant to achieve heat, electricity and cooling energy cogeneration.**

**SUMMARY**

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# ALTERENERGY - FEASIBILITY STUDY

Summary, Version of 26 September 2014

**Why the study and why Polverara**

The context in which the feasibility study originates is the Town of Polverara. The urban and morphological characteristics, as well as site ground use, meet the need to demonstrate that **three systems can be integrated in a town from the energy standpoint**: **the residential areas, the industrial areas near the town and the surrounding rural areas**.

The town was chosen since already equipped with a district heating plant (in operations since 2010), that provides heat for both public and private utility heating and hot water. The plant has significant margins of energy efficiency and, although located on a plain, it is powered by an agro-forestry origin wood biomass boiler with 700 kWt rated power and uses chip wood as fuel. The plant operates from September to May and serviced 6 public and 71 private utilities in 2013.

The current plant accessories are already able to provide heat energy to a larger number of utilities but the feasibility study, before facing the grid extension topic, intends to verify the reasons for which, currently, operations are at such a low load and, especially, with high discontinuity due to the intermittent boiler trend, with the undesirable effect of a drastic drop in yield.

Moreover, poor operations also affect the district heating plant, that would otherwise need to work at almost constant temperatures for the longest time possible. When this does not occur, given the high thermal inertia in the distribution circuit, when the heat energy demand changes, the system is not able to provide the required heat on the short-term since the large quantity of water in the circuit must be fully heated before reaching the temperature required by the active utility.

This mechanism often causes a low temperature situation in the most remote grid utility supply points with the consequent result of not being able to provide the heat required by the utility.

The feasibility study delves further to expand the analysis, in fact, aiming to evaluate whether, in addition to current plant conditions , technological interventions can be beneficial in order to produce electricity and whether it is also possible to add district air conditioning to the current services rendered.  Lastly, this document studies the possibility of creating local chip wood production chains and the opportunity of further developing the proposed plant solution.

**The starting point and various design scenarios**

Given the current problems, this study assumes a “zero solution”, indicating the significant margins of improvement achievable by adopting some simple adjustments, first and foremost, the increase in accumulation capacity in the heat plant. Considering that 20 to 30 litres of heat accumulation are required for each installed thermal kW in standard operating conditions, the accumulation tank capacity should be at least 20 - 25 m3. If, vice versa, actually installed biomass boiler real operations are considered as well as the plant load curve characterised by a high level of partialization during most of the day and high peaks concentrated in short periods during the day, it could be concluded that accumulation tank capacity required review, reaching at least 50 litres per installed kW, according to the number and type of utilities serviced and time in which maximum power is required. This means installing an accumulation tank with at least 30 m3 capacity. This cost of such an improvement would be about 1,000 - 1,500 €/m3, but would undoubtedly be beneficial to the overall system. Accumulation would permit the boiler to continuously operate at maximum power, storing heat in excess to that required by final utilities. Plant yield would be immediately improved, finally matching the rated values foreseen for the specific type of boiler used. At the same time, the district heating plant would be equipped with an accumulation capacity that would return carrier fluid to practically constant temperature values, with a consequent improvement to the low temperature problems for the more remote utilities.

Another element of improvement concerns the interaction methods between the chip wood boiler and methane boiler. At times, in fact, after the main biomass boiler is turned off, the automatic control system is not able to promptly intervene to activate the supplementary methane boiler. Plant yield could thus be further improved by implementing an adequate management and control system for the two generators that would optimise the dialogue between the two devices. The solution could also be provided by a simple control system and data communication network, either wireless or wired.

Lastly, to overcome the inability to produce the hot water required in summer periods, installing a boiler with adequate capacity based on single home needs could be interesting. This way, each user would have a hot water reserve available to use at any time of the day, heated by the night district heating plant or offset to heating demand times. The potential installation of a dedicated boiler would increase benefits in the summer when the district heating plant is only powered for uses tied to hot water.

After analysing the current plant operating conditions, since the type of boiler installed in Polverara can only produce hot water, in the first design scenario, in addition to the "zero option", the installation of a *ORC* plant powered small alternator is hypothesised upstream from the district heating plant keeping the current boiler (700 kW) unaltered. The solution would create a *cogeneration plant* for the combined production of electricity and heat and, in this new context, the feasibility of obtaining cogeneration both during the entire calendar year and only during the summer is evaluated.

Since the project purposes concerned by this feasibility study regard the identification of a sustainable model transferrable to other contexts, the parameters that make the re-proposal of the analysed starting solution and how the development of the model originally used for Polverara could become an energy, economic and environmental advantage are also critically analysed. Thus, based on these considerations, other dimensional and technological hypotheses on which a new, more efficient and thus more sustainable and competitive model can be formulated are analysed: cogeneration with a higher capacity new combined cycle steam boiler, under 1 MW.

The possibility of obtaining tri-generation, meaning the additional production of a third type of energy, cooling, required to air condition some utility types, is assessed in the conclusion to this study. In fact, given the technological problems and after accurately evaluating the cost of installing a district cooling plant, we chose to consider the production of cooling energy only for some special end users and using water absorbers directly powered by the district heating plant. Here too, we considered the installation of a new steam boiler and absorbers in specific user/utility points.

To facilitate the comparison between the different systems, we chose to accompany the description with a summary graph for each analysed solution.

In fact, we believe that the overall system, made up of the power plant and district heating plant, is working with excessively low yield compared to that hypothesised and thus desired.

***Scheme no. 0: current situation with hot water boiler.***

The district heating plant is powered by a biomass boiler with 700 kWt power and/or an auxiliary gas plant with 600 kWt power.

In 2013, 873 MWh were rendered from the 500 tonnes of chip wood used and the remaining 321 MWh from methane to meet the connected users' energy demand. Considering that the **wood was purchased at 69 €/t (for a total of 40,000 €)** and **that about 30,000 € was spend for Gas, having evaluated both overhead costs of about 59,000 €** and **heat energy sales revenues for about 91,000 €,** the conclusion is that operations not only fail to produce profits, but the **administration posted a loss of about 40,000 € per year**. In light of these results, the first question that naturally comes to mind is: what is the plant's energy yield?

The analysis indicates that the plant's yield is 58% while the boiler's is 54%, too low for the competitiveness of a service that in bound by contract to remain 16% under methane gas market values. Thus we should consider which solutions could be adopted to make the plant more efficient and actually sustainable.

**"Zero" project hypothesis: existent boiler (700 kW) + thermal plant redevelopment.**

***Scheme no. 1: redeveloped existent hot water boiler***

This solution would allow a suitably dimensioned accumulation tank to be exploited to increase chip wood boiler operating times and improve overall production yield. In addition to this intervention, already described in the previous paragraph, other interventions concerning some improvements to the chip wood accumulation and storage system, methane boiler and chip wood boiler dialogue system and the installation of a sleeve filter system with higher performance than the currently installed one were evaluated.

In this case, the following reference parameters were assumed for the calculations: boiler power: 700 kW; Boiler yield: 85%; District heating plant yield; 70%; Fuel heating power: 3.2 MWh/t; halved methane gas consumption; Heat energy remuneration: 0.077 €/kWh.

**Economic sustainability**

**Installation costs** for the new components can be estimated at **about 95,000 €,** including the heat accumulation tank, existent storage system adjustment, interconnection between the methane boiler and chip wood boiler and installation of a new sleeve filter to reduce air emissions.

In this case, the **annual revenues would substantially equal fuel and plant overhead costs** without leading to further losses. The advantage totals about 40,000 € compared to current conditions, against a 95,000 € expense. Total pay back time can thus be estimated in 2.5 years.

**First project hypothesis: existent boiler (700 kW) + ORC system.**

***Scheme no. 2: cogeneration with existent hot water boiler***

This solution exploits the currently installed boiler equipping it with a low enthalpy co-generator that receives input water at 95°C and outputs water at 85°C. The choice takes into account current operating limits determined by two restricting operating conditions: the reduced chip wood boiler capacity and maximum working temperature that cannot exceed 95° C. Following are the reference data used for calculations: Boiler power: 700 kW; Boiler yield: 88%; District heating plant yield: 90%; Fuel heating power: 3.2 MWh/t; Fuel cost 69 €/t or 52 €/t; Heat energy remuneration: 0.077 €/kWh; Electricity remuneration: 0.229 €/kWh (all-inclusive rate);

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As for the sale of heat energy, the production cost is about 27 €/MWh, sales revenues are 77 €/MWh and thus, for each MWh sold, the provider gains about 50 €/MWh, with which, in addition to paying back the investment, overhead and operating margins would be covered.
As for electricity, considering an average yield of 10 – 11 % typical of a small ORC turbine, the production cost is about 225 €/MWh; sales revenues are 229 €/MWh, that implies a profit margin of about 4 €/MWh, from which overhead and investment depreciation costs are deducted.
To create a electrical-bent cogeneration plant with the addition of the ORC component, the heat improvement the boiler must provide must be increased (10 °C at the ORC evaporator and 5°C at district heating), with the consequent reduction of distributable power to the district heating plant, and thus the number of serviceable users.
Maintaining, on the other hand, the heat-bent, the ORC plant would act as an inertial accumulation guaranteeing constant operations for the system at maximum load. The main result of this choice would be that of increasing generation and distribution yields to finally make the district heating plant convenient. The economic calculations take into account the overhead costs, similar to the actual ones, that can, however, be progressively reduced.

**Economic sustainability**
Since the main system components are already installed in the situation in question (boiler, part of the system, building structures, various connection fittings, etc.), **installation costs** for new components can be estimated at about **270,000 €**.
In this case the **annual profits substantially allow costs to be covered even when chip wood is paid at 69 €/t (1,500 €/year profits), while with chip wood priced at 52 €/t, profits would be 33,000 €/year with an 8-year pay back time.** On the other hand, the results could be further improved if waste heat is recovered as in typically industrial plants where costs are not required for additional fuel and, thus, once the investment is sustained to purchase the cogenerator, electricity production does not required additional costs. It could be added that, should fuel be produced at zero cost, the system would generate about 180,000 €/year (excluding overhead); but this requires provisioning solutions to be investigated (woodland management, use of pruning wood after analysing waste material regulations, etc.)
**Therefore, the resulting idea is not to increase electricity production detrimental to heat energy production since this obviously appears like an unfeasible contradiction, nor able to guarantee heating for already connected heating utilities (78 current utilities against 38 potential utilities). The choice, therefore, is to use the ORC system as a flexible and functional alternative to the traditional initial heat accumulation system.**

**Second project hypothesis: combined cycle ≤ 1MW, news team boiler + cogeneration**

***Scheme no. 3: cogeneration with new steam boiler (combined cycle ≤ 1000 KW)***

This solution uses a boiler that will produce steam at 212 °C and 20 bar in supply and return at 90°C at room pressure. In this case, in order to maintain the size under 1MW, the work flow must be 1,300 kg/h steam, considering a yield of 88% and about 880 kW heat power yield.

**Supply, via the district heating plant, was considered for about 120 homes** with the previously defined characteristics.

Based on the estimates requested of various suppliers, the **installation costs** were estimated at

**1,3600,000 €,** including the supply and installation of the biomass boiler, system connections, steam turbine, ORC plant, steam plant and accessory costs (construction work, tanks, plumbing connections to the district heating plant). The district heating plant part remains, obviously, excluded from the costs.

The investment requires a **pay back time of about 9** years, since **general costs (fuel and overhead) are estimated at 175,000 € and revenues for 320,000 €**, (of which 90,000 € for heat energy sales and 230,00 € for electricity sales), with **profits of about 144.000 €/year.**

**Third project hypothesis: tri-generation with new combined cycle**

***Scheme no. 4: tri-generation with new steam boiler (combined cycle ≤ 1 MW)***

The most frequent solution with reference to the mix that advances is the one with lithium bromide machines. Considering, instead, the generator operating mode, a technological hot-water powered generator is foreseen that can exploit the heat available in a heat carrier fluid for remote cooling energy production.

Given the complexity of the thermo dynamics applied in this type of the machine, the market currently does not offer solutions that can be applied to domestic utilities where cooling energy demand is limited to a few kW. Consequently, to add an absorption machine, the utilities that can connect to the hot water distribution grid will be more or less medium-sized, such as, for example, hotels, retirement homes, industrial utilities or offices.

**Economic sustainability**

The results obtained from the analysis conducted to identify tri-generation economic sustainability are illustrated below.

It should be noted that from the district heating plant users' standpoint, should an absorption system be used to air condition buildings, the end user would pay about 60 €/MWh for each 1,000 kWh of required cooling power if produced with a traditional electric cooling unit (1,000 kWh, produced with a cooling machine with hypothetical ESEER equal to 3.3 and electricity cost equal to 0.20 €/kWh, from which 1,000*0.20/3.3 = 60 €/MWh); about 110 €/MWh if produced with an absorption system, considering that the heat energy purchase price is the one previously indicated, meaning 77 €/MWh

(1,000 kWh, produced with an absorption cooling machine with hypothetical ESEER equal to 0.7, from which 1,000*77/0,7 = 110 €/MWh).
A hypothesis to be checked is the one in which in order to encourage the application of these technologies, **during the summer season** the district heating plant service provider and **apply discounts to sell heat energy at 40 €/MWh**. In doing this, the price for air conditioning paid by the end user would be competitive with the traditional system. In fact, according to the previous reasoning, cooling energy would cost the end user about 57 €/MWh.
Another aspect concerns the purchase cost. As already indicated, on average, an absorption cooling unit costs about 55,000 €, which is double the cost of a classic electric chiller. Therefore, still attempting to make the use of the district heating plant convenient in the summer, the investment could be made directly by the plant manager.
Investment costs would therefore be about 1,635,000 including the biomass cogeneration plant (1,360,000 €) and the costs of the 5 absorbers for the grid provider according to that previously explained.
Compared to the hypothesis of not servicing users in the summer, please note that based on that considered, the investment is convenient in the event of heat energy demand over 2,500 hours, albeit without significant benefits.
The indicated trends verify how, with a few connected users, the heat energy deducted from the ORC plant is not able to lower plant yield. As energy required by the absorbers increases, the ORC turbine yield decreases since the supply heat power decreases, until the number of absorbers is such for which the lost profits due to electricity sales are compensated by the revenues obtained from heat energy sales in the summer.
This solution also requires the use of a 212° steam boiler and **supplying the same 120 previously defined homes** was considered.
**Installation costs** estimated at 1,360,000 € in the previous hypothesis are thus increased to **1,635,000 due to the purchase of the absorbers while overhead (fuel and overhead) remain at 175,000 €**. **Revenues thus become 377,000 €** (of which 197,000 € for heat energy sales and 180,000 € for electricity sales), with **profits of about 202,000 €/year**.
**Pay back time** is thus **8 years**.

**Conclusions**

*The discussions in this feasibility study for the improved efficiency, scalability and transferability through suitable technological and control adaptations to the Polverara wood biomass district heating plant*, indicated that the **town's initiative mainly suffers from the failed completion of the grid originally calibrated on 120 heat utilities**.

**The implemented solutions is, however, characterised as an original solution in the local energy policy context aimed to plan, design and manage energy production from renewable sourced tied to the territory, highlighting the concrete possibility of connecting the rural production potential, the energy demand from the urban context – with special regard to public buildings - and, in the future, even special industrial or tertiary utility consumptions.**

Naturally, the boiler power and number of connectable users were originally identified based on a building potential identified by the town that included the construction of new buildings and increase in the resident population. Instead, in Polverara, the world economic crisis slowed investment in new constructions and, consequently, district heating plant connections, that are still limited to 72 private utilities and 6 public utilities, with the direct consequence of having an over-dimensioned plant system whose generation yield (58%) and distribution (54%) are too low to guarantee adequate economic sustainability.

To resolve and improve the described conditions, **the study identified some of the possible adoptable technologies** to increase overall yield to values suitable to those originally foreseen, so as to not jeopardise the intentions of the initiated experience. They are ***technologically suited solutions, hopefully shared through a participative process that involves the current and future users and, more in general, all citizens, that could outline new development scenarios and promote the extension of the district heating plant to reach the initially foreseen number of users or exceed it thanks to the connection of new users, for example, buildings to be renovated, additional public utilities*** and so on.

**The identified road cannot, however, neglect the pursuit of a high level of environmental sustainability and must, therefore, on the one hand, invent wood biomass production paths on the local scale, driven by suitably targeted regional agricultural policies and, on the other, direct administration towards the continuous improvement of smoke reduction systems.**

**Heat accumulation**

Delving into the solutions identified by the feasibility study, the addition of a heat accumulation tank that acts as an inertial flywheel for the demand from the grid should be the first thing to consider. Accumulation would allow the boiler to continuously operate at maximum power, storing heat in excess to that required by final utilities. Plant yield would be immediately improved, finally near the rated values foreseen for the specific type of boiler used. At the same time, the district heating plant would be equipped with an accumulation capacity that would return carrier fluid to practically constant temperature values, with a consequent improvement to the low temperature problems for the more remote utilities.

**The smart heat grid**

In addition to that described, another element of improvement concerns the interaction methods between the chip wood boiler and methane boiler. At times, in fact, after the main biomass boiler is turned off, the automatic control system is not able to promptly intervene to start the supplementary methane boiler. Plant yield could thus be further improved by implementing an adequate management and control system for the two generators that would optimise the dialogue between the two devices. The solution could also be provided by a simple control system and data communication network, whether wireless or wired.

The final result would simply be a SMART HEAT GRID.

**Cogeneration with hot water boiler**

An alternative or, in any case, complementary solution to heat accumulation is offered by the possibility of installing a cogeneration plant combined with the existent boiler. Typically, cogeneration plants work on much higher powers than the one set for Polverara, since the increase in plant size also causes significant increases in electricity production yield.

The intervention identified aims to produce work according to thermo dynamic cycles completed by organic fluids able to evaporate at temperatures lower than the water boiling temperature. This way, the cogeneration plant dimensions are reduced and functional even with the powers in play similar to those found in the Polverara town power plant.

The analysis results indicate that should an ORC system with turbine be added to the current system, the investment would be convenient since, considering overhead costs equal to 50,000 €/year (that appear high), profits would be 33,000 €/year and simple pay back, without considering any financial charges, would be 8 years.

The ORC cycle becomes interesting for application when suitable heating supply is believed to guarantee grid demands. In this case, the ORC system would act as inertial accumulation to guarantee constant operations at maximum load for the entire system. Generation and distribution yields could increase to values near 88% for the first and 90% for the second. The ORC system represents, in this sense, a flexible and modern alternative to the simple installation of inertial accumulation tanks.

**Cogeneration with steam boiler**

If the decision is made to operate the system with a steam boiler, whether converting the existent one with suitable changes and adjustments, or installing a new one, still at a power under 1 MW, the amount of electricity products could be increased by exploiting the combined steam and ORC turbine cycles or, according to the alternative proposed by Triogen, exploiting the steam to increase the organic fluid temperature in the ORC circuit.

In this case, considering the overall costs, that would be reduced in the event of changes without replacing the existent boiler, the cost could be recovered in about 9 years with profits near 145,000 €/year. Here too, any produced electricity sales would be secondary to the possibility of increasing overall grid-power plant system yield.

**Tri-generation with absorption cycles**

Aimed to have the heat plant run for the highest number of hours possible, and since electricity remuneration is secondary to that obtained from heat energy sales, the possibility of installing absorption cycles that generate cooling energy from input heat energy was also analysed (instead of electricity that normally powers a traditional air conditioning or climate control system). This tri-generation would surely benefit the grid provider, reducing the returns on investment to 5 years. From the user's standpoint, on the other hand, the economic benefit would be reduced since electric cooling machines have reached costs and efficiencies that make the exploitation of an absorption cycle poorly competitive. This applies when the grid provider no longer intends to reduce the sales price of produced heat or invests to install the project absorbers at his own expense. In this case, although the investment cost is borne by the provider, the investment would be feasible, albeit with pay back time near to 10 years. All this with reference to the installation of only 5 cooling units, with potential near 100 kW/each, characteristic of office, industrial plants or tied to specific destinations such as retirement homes, hotels or pools.

Thus, this is not actual district cooling but a solution that maintains a sole heat distribution grid to be used in both winter and summer.

**Solar cooling**

Solar cooling, meaning the production of cooling energy through solar power, was analysed with the same energy and distributed generation performance goals. The proposed assessment does not currently seem worthy of disclosure, since there are still obvious price and technology limits that would hinder development.

**Final considerations**

Lastly, the analysed system leads to the conclusion that prompt intervention is required on the existent district heating plant to increase overall system generation and distribution yield, to make the local administration's initiative, extremely interesting from the energy and environmental conduct standpoints sustainable, even economically, in-sync with the most advanced European "smart energy" policies and climate-changing emission reduction actions in addition to, naturally, the reduction of our dependence on fossil fuels.

**The identified solutions, whether the installation of an accumulation tank or the construction of cogeneration and/or tri-generation plants combined with the existent plant, denote the feasibility of the operation since they promote the increase of the set thermal goals**.

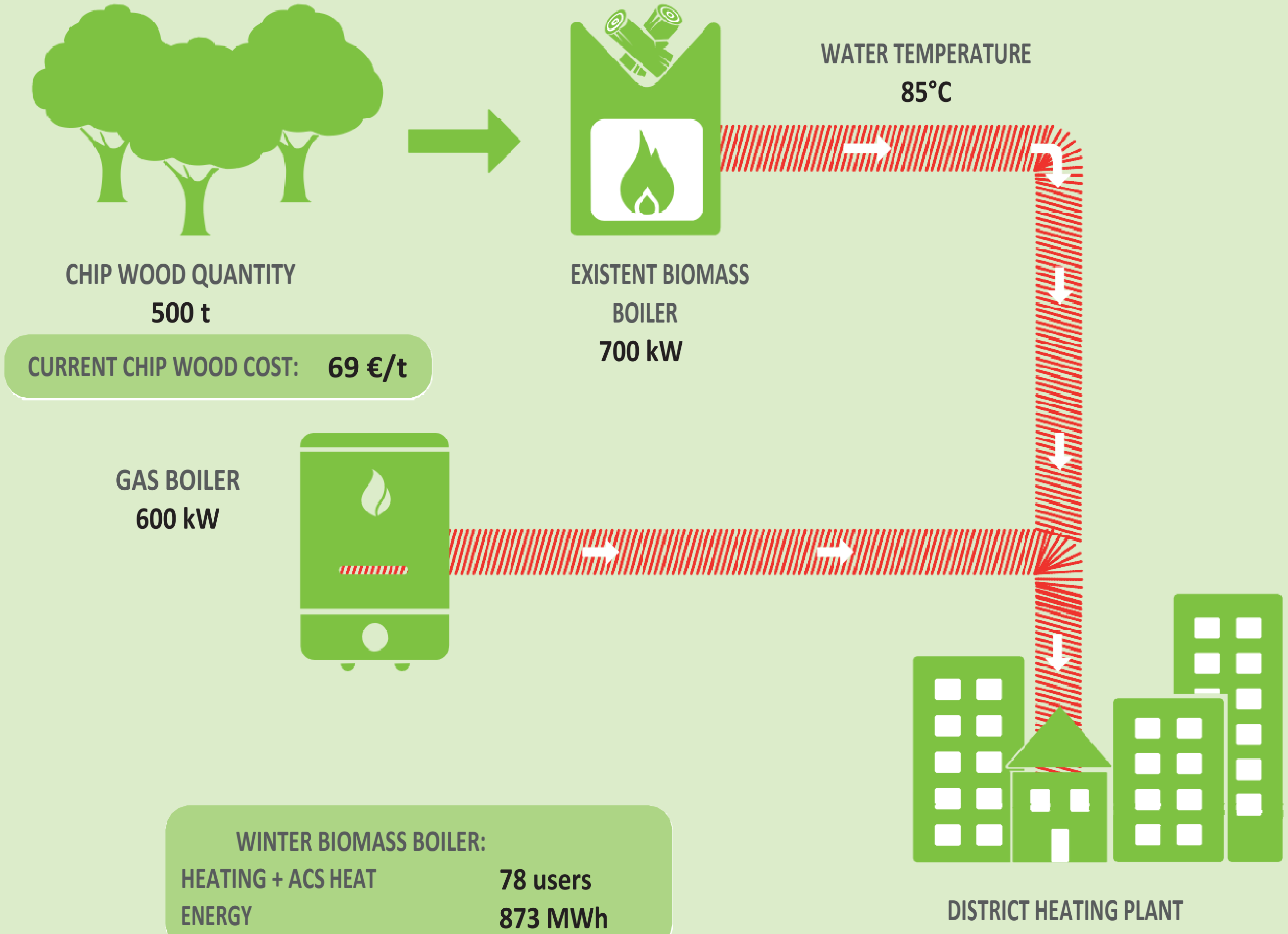
The production and corresponding sale of electricity, on the other hand, is only a way to improve heat yield, resulting, on the economic level, poorly profitable if alone.

**In any case, the number of operating hours at full boiler load need to be increased, increasing the number of connected users operating in the territory, through training, information and participation policies that can help citizens and users to fully understand the proposed solution and any additional developments that must be based on ethical and sustainable principles**.

To this regard, the reduction in chip wood production price, obtainable by developing local cultivations aimed at wood biomass production, combined with improved harvesting of similar resources in the territory, would further help the popularity of the initiative to the full benefit of end users and the grid provider. It is for this reason that, using AIEL (Italian Agro-Forestry Energy Association) as a source of chip wood cost data, were referred to the value of 52 €/t referable to local productions within 20 k of the point of use. The choice may seem to be forced in the specific case of Polverara, but may not be so in other contexts similar to those of the target communities defined in the Alterenergy project. As for the 69 €/t price used in study calculations, economic assessments made in the last year regarding potential contracts between the provider and local suppliers were used. To this regard, the indicated amount represents a goal to be pursued and monitored to obtain the greatest advantage for district heating plant users. All good calculations, like this study, take other fundamental variables into account in addition to the purchase price of chip wood: heat and electric plant yield, operating hours, the number of connected users, working temperature.

As each of these change, the analysis and overall results significantly change. This is why a calculation file was created to govern and verify every possible change caused by change one or more variables in play. In the general report, only for brevity, the results of the most representative situations are provided. Substantially, we can simplify by saying that the summary tables found in the general study are the results of some initial hypotheses, varying the hypotheses vary the results and the study user can, based on need, identify the calculation references and adapt the model to specific project needs.

# 0/CURRENT SITUATION WITH HOT WATER BOILER




CURRENT CHIP WOOD COST: 69 €/t

**WINTER BIOMASS BOILER:**

| | |
|---|---|
| HEATING + ACS HEAT | 78 users |
| ENERGY | 873 MWh |

**SUMMER GAS BOILER (+ WINTER BIOMASS BLOCKS):**

| | |
|---|---|
| ACS GAS BOILER | 78 users |
| HEAT ENERGY | 321 MWh |

| | |
|---|---|
| PLANT YIELD: | 58% |
| BOILER YIELD: | 54% |

**COSTS**

| | |
|---|---|
| OVERHEAD COSTS: CHIP | about 59,000 €/year |
| WOOD COST: | 40,000 €/year |
| METHANE COST: | about 30,000 €/year |
| TOTAL: | about 129,000 €/year |

**REVENUES:**

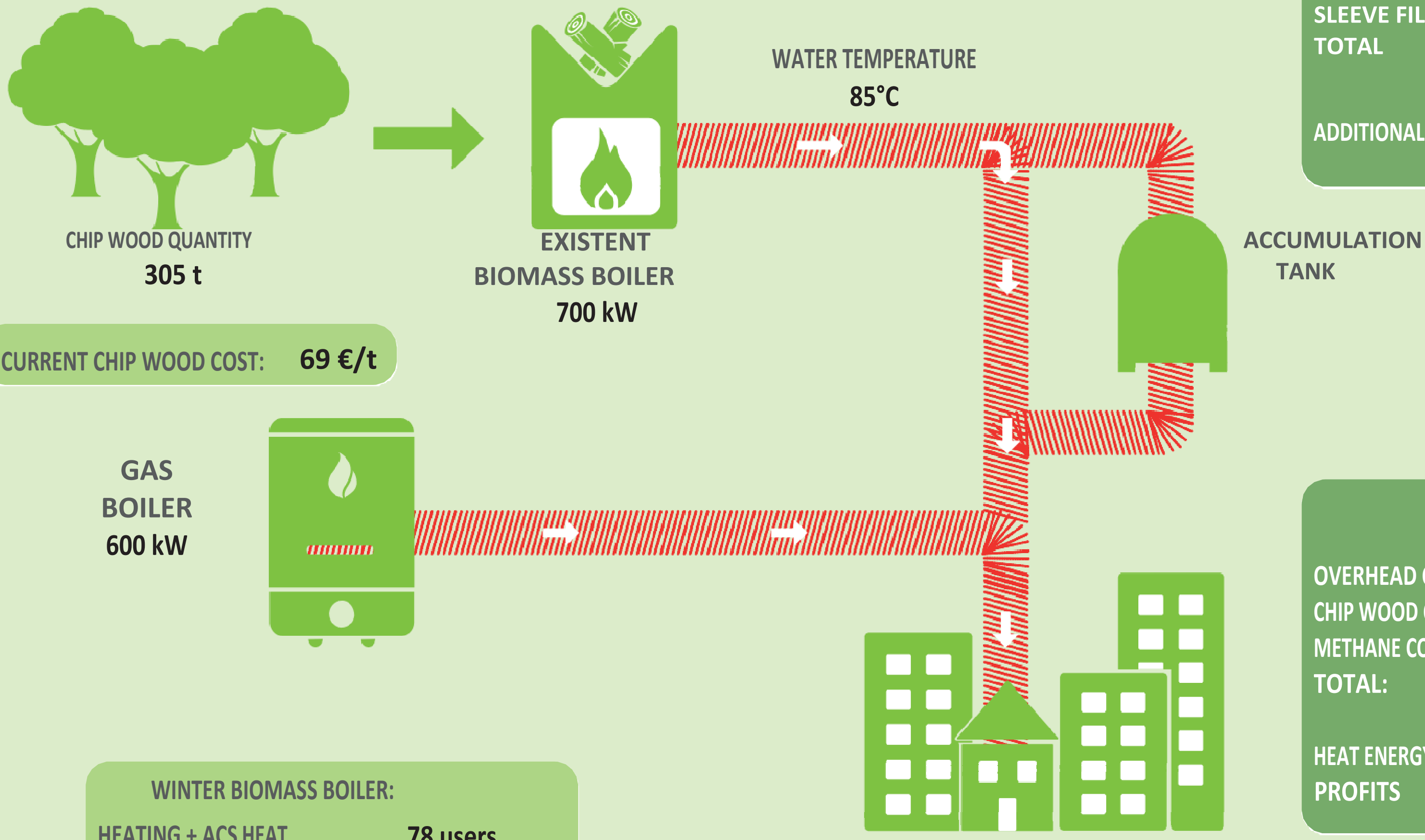
| | |
|---|---|
| HEAT ENERGY: | about 91,000 €/year |
| PROFITS | about -40,000 €/year |

# 1/REDEVELOPED HOT WATER BOILER

INTERVENTION COST: 95.000 €
PAY BACK: 2,5

CONVENIENT

| OBJECT | ESTIMATED COSTS |
|---|---|
| ELECTRONIC UNIT HEAT | 50.000 € |
| ACCUMULATION OBJECT AND COMMUNICATION SYSTEM | 5.000 € |
| IMPROVEMENT STORAGE SILOS | 10.000 € |
| SLEEVE FILTER | 30.000 € |
| TOTAL | 95.000 € |
| ADDITIONAL ANNUAL OVERHEAD COSTS | 2,000 €/y |
| SINGLE USER BOILER | 1,000 €/each |




CURRENT CHIP WOOD COST: 69 €/t

| COSTS | |
|---|---|
| OVERHEAD COSTS: | about 50,000 €/year |
| CHIP WOOD COST: | 24,000 €/year |
| METHANE COST: | about 15,000 €/year |
| TOTAL: | about 89,000 €/year |
| REVENUES: | |
| HEAT ENERGY: | about 91,000 €/year |
| PROFITS | 2,000 €/year |

WINTER BIOMASS BOILER:

| | |
|---|---|
| HEATING + ACS HEAT | 78 users |
| ENERGY | 873 MWh |

SUMMER GAS BOILER
(+ WINTER BIOMASS BLOCKS):

| | |
|---|---|
| ACS GAS BOILER HEAT | 78 users |
| ENERGY | 321 MWh |

DISTRICT HEATING PLANT

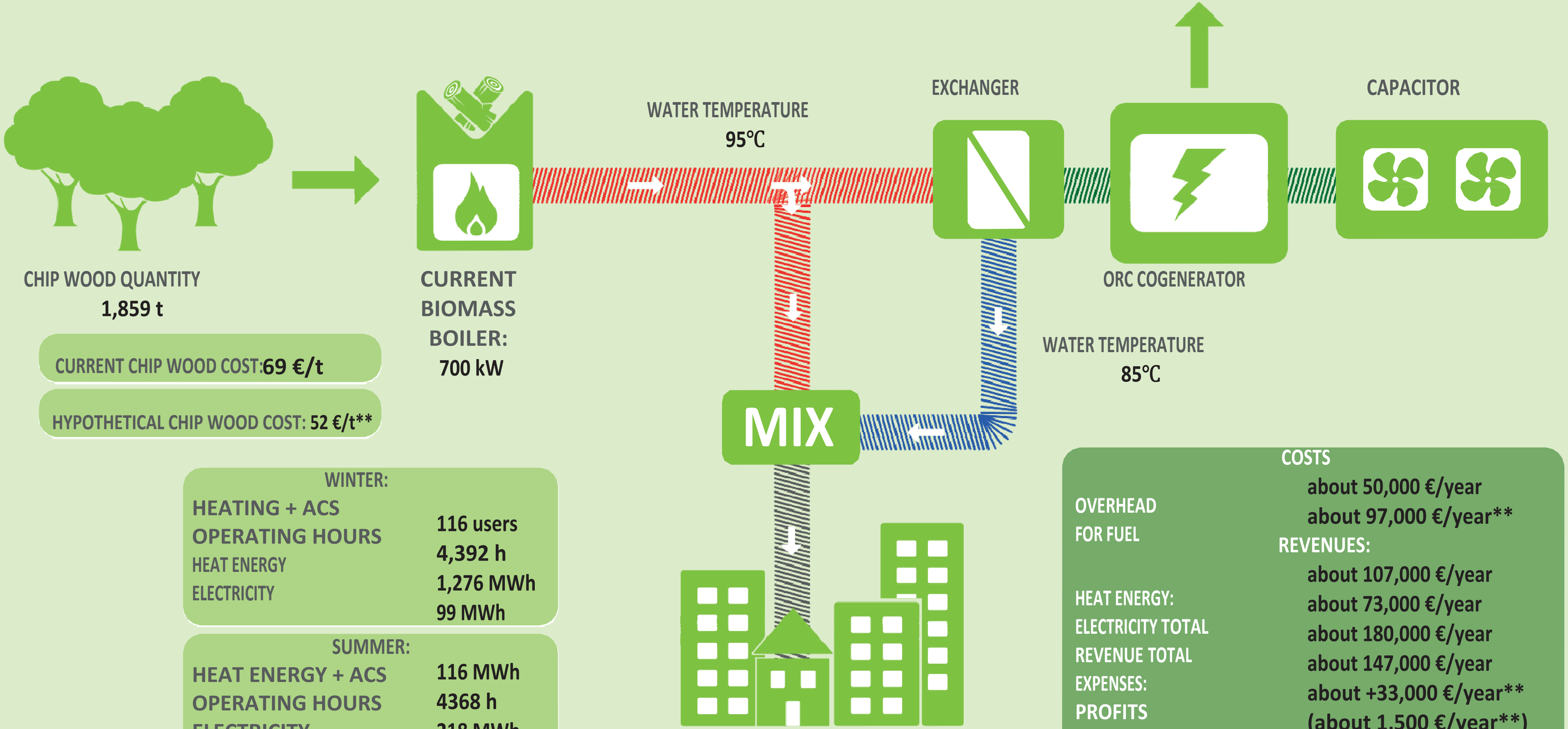
PLANT YIELD: 70%

BOILER YIELD: 85%

# 2/COGENERATION WITH HOT WATER BOILER

INTERVENTION COST: **270.000 €**
PAYBACK: 8 YEARS**

CONVENIENT




CURRENT CHIP WOOD COST: **69 €/t**

HYPOTHETICAL CHIP WOOD COST: 52 €/t**

**WINTER:**

| | |
|---|---|
| HEATING + ACS | 116 users |
| OPERATING HOURS | 4,392 h |
| HEAT ENERGY | 1,276 MWh |
| ELECTRICITY | 99 MWh |

**SUMMER:**

| | |
|---|---|
| HEAT ENERGY + ACS | 116 MWh |
| OPERATING HOURS | 4368 h |
| ELECTRICITY | 218 MWh |

**COSTS**

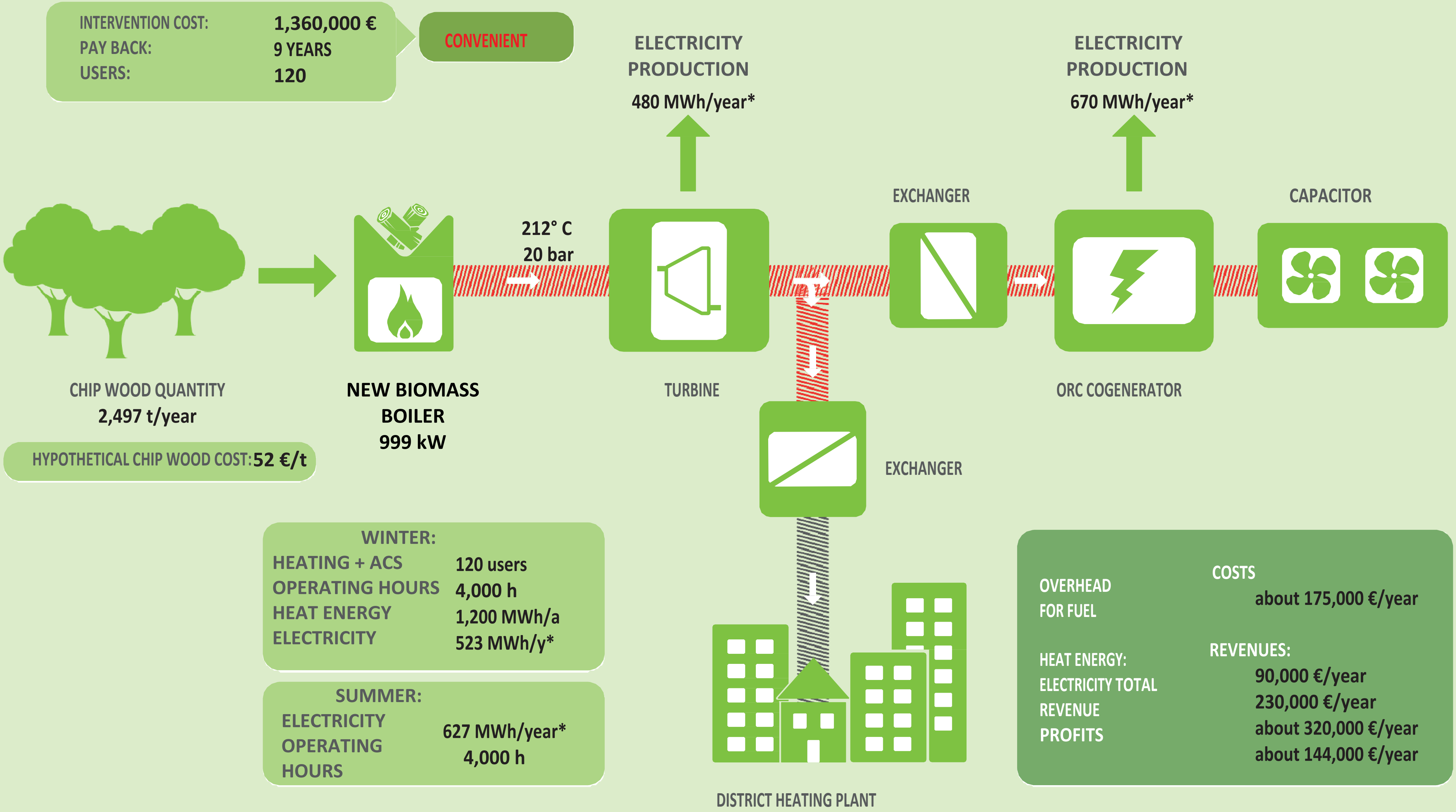
| | |
|---|---|
| OVERHEAD | about 50,000 €/year |
| FOR FUEL | about 97,000 €/year** |

**REVENUES:**

| | |
|---|---|
| HEAT ENERGY: | about 107,000 €/year |
| ELECTRICITY TOTAL | about 73,000 €/year |
| REVENUE TOTAL | about 180,000 €/year |
| EXPENSES: | about 147,000 €/year |
| PROFITS | about +33,000 €/year** (about 1,500 €/year**) |

* gross of auxiliary consumption
** with chip wood cost 52€/t
*** with chip wood cost 69€/t

# 3/COGENERATION WITH NEW STEAM BOILER (COMBINED CYCLE 999 kW)

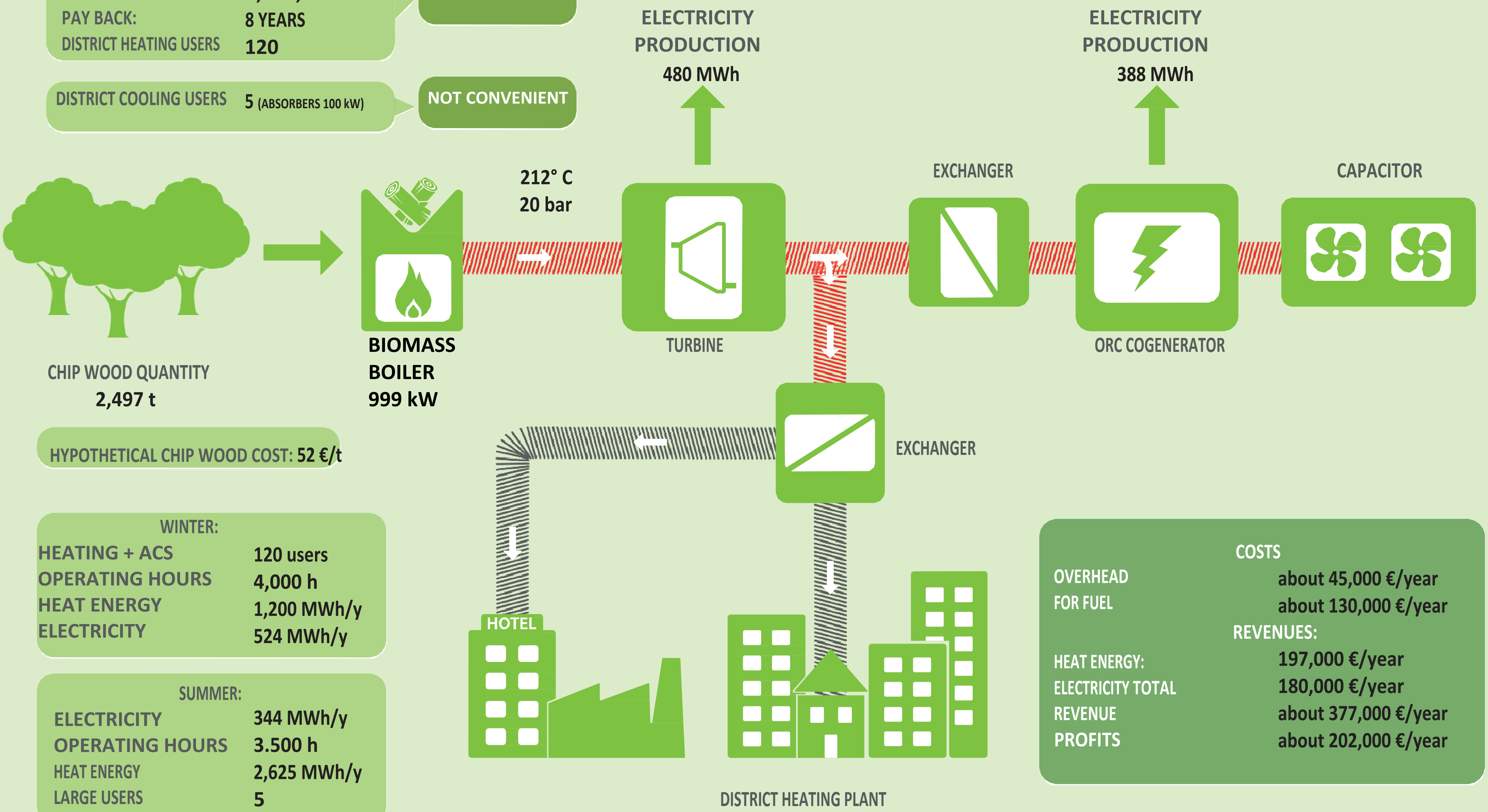



* gross of self-consumed energy for auxiliaries

# 4/TRI-GENERATION WITH STEAM BOILER

| | | |
|---|---|---|
| INTERVENTION COST: | 1,635,000 € | CONVENIENT |
| PAY BACK: | 8 YEARS | |
| DISTRICT HEATING USERS | 120 | |

| | | |
|---|---|---|
| DISTRICT COOLING USERS | 5 (ABSORBERS 100 kW) | NOT CONVENIENT |




HYPOTHETICAL CHIP WOOD COST: 52 €/t

| WINTER: | |
|---|---|
| HEATING + ACS | 120 users |
| OPERATING HOURS | 4,000 h |
| HEAT ENERGY | 1,200 MWh/y |
| ELECTRICITY | 524 MWh/y |

| SUMMER: | |
|---|---|
| ELECTRICITY | 344 MWh/y |
| OPERATING HOURS | 3.500 h |
| HEAT ENERGY | 2,625 MWh/y |
| LARGE USERS | 5 |

| COSTS | |
|---|---|
| OVERHEAD | about 45,000 €/year |
| FOR FUEL | about 130,000 €/year |
| **REVENUES:** | |
| HEAT ENERGY: | 197,000 €/year |
| ELECTRICITY TOTAL | 180,000 €/year |
| REVENUE | about 377,000 €/year |
| PROFITS | about 202,000 €/year |