Universidad de Valladolid

ESCUELA DE INGENIERÍAS INDUSTRIALES

UNIVERSIDAD DE VALLADOLID

ESCUELA DE INGENIERIAS INDUSTRIALES

Grado en Ingeniería de Organización Industrial

TECHNO-ECONOMIC ASSESSMENT OF A SMALL-SCALE BIOMASS ORC-CHP FOR DISTRICT HEATING

Autor:

Subrá Morales, Jaime

Izquierdo Millan, Segismundo Samuel

University of Applied Sciences in Nysa

Valladolid, Junio de 2023.

TFG REALIZADO EN PROGRAMA DE INTERCAMBIO

TÍTULO:	TECHNO-ECONOMIC ASSESSMENT OF A SMALL-SCALE BIOMASS ORC-CHP FOR DISTRICT HEATING
ALUMNO:	Subrá Morales, Jaime
FECHA:	22/05/2023
CENTRO:	Universidad de Valladolid
UNIVERSIDAD:	University of Applied Sciences in Nysa
TUTOR:	Dr. Jacek Tomasiak

RESUMEN

El tema de estudio en el siguiente artículo tiene una alta repercusión en cuanto al rumbo que quiere marcar la sociedad. Sabiendo que vivimos en un mundo finito en el cual sus recursos cada día se ven más diezmados por el ser humano.

Por eso, en el siguiente artículo se desarrolla una holgada explicación tecno-económica que engloba todos los ámbitos de los sistemas ORC-CHP, los cuales son capaces de aportar energía eléctrica, calor o incluso frío a partir de un combustible renovable como es la biomasa. Es por esto, que se fomenta su investigación y desarrollo aportando numerosos datos de numerosas investigaciones para promoverlo en mayor medida en los locales y edificios residenciales.

PALABRAS CLAVE

Ciclo orgánico de Rankine, biomasa, calefacción urbana, energía, aspectos tecno-económicos, medio ambiente.

ABSTRACT

The subject of study in the following article has a high impact on the direction society wants to take. Knowing that we live in a finite world in which its resources are increasingly decimated by human beings.

For this reason, the following article develops a comprehensive techno-economic explanation that encompasses all areas of the ORC-CHP systems, which are capable of providing electricity, heat or even cold from a renewable fuel such as biomass. This is why its research and development is encouraged by providing numerous data from numerous investigations to promote it to a greater extent in premises and residential buildings.

KEYWORDS

Organic Rankine cycle, biomass, district heating, energy, techno-economic aspects, environment.

PAŃSTWOWA AKADEMIA NAUK STOSOWANYCH W NYSIE

UNIVERSITY OF APPLIED SCIENCES IN NYSA

DEGREE IN PRODUCTION MANAGEMENT AND ENGINEERING

TITLE:

TECHNO-ECONOMIC ASSESSMENT OF A SMALL-SCALE BIOMASS ORC-CHP FOR DISTRICT HEATING

Promotor:

Dr. Jacek Tomasiak

Autor:

Jaime Subrá Morales

Nysa, May 2023

ACKNOWLEDGEMENTS

I wish to show my appreciation to the University of Valladolid and to the University of Applied Sciences of Nysa, for giving me the opportunity to develop this project in such a positive experience as the Erasmus exchange program.

The assistance provided by Mr. Jacek Tomasiak was greatly appreciated, he always guided me when I needed help and advice, besides helping me in the developing of this article all the way.

INDEX

Content

INTRODUCTION

A district heating system distributes heat and hot water to numerous buildings from a single location. This system is widely used in cities and can be powered by a variety of energy sources, including biomass, coal, or natural gas. However, due to its potential as a renewable and sustainable energy source, the use of biomass as a fuel for district heating systems is growing and getting noticed not only in big companies but in small communities also.

For small-scale district heating applications, biomass Organic Rankine Cycle combined heat and power (ORC-CHP) systems have a big potential in a nearby future. These systems use biomass as a fuel source to produce heat and electricity for nearby communities or apartment buildings. To supply hot water for district heating, the ORC-CHP system consists of a biomass boiler, an ORC unit like the one show non Figure 1, and a heat exchanger which will be seen later on this article [1].

Understanding the practicality and economic viability of putting such a system into place requires a deep understanding of the Techno-Economic Assessment of a Small-Scale Biomass ORC-CHP for District Heating. This evaluation includes a review of the system's expenses and sources of income. The evaluation will show the system's potential advantages in terms of the viability, expenses and society [2].

The main objective of this thesis is to do an analysis of the techno-economic data of a small-scale biomass ORC-CHP for district heating gathered between this investigation and others. Costs, revenue sources and the functioning of this system are some of the topics to be discussed in the thesis a thought of the beneficial facts this can offer to society, they are revealing and can lead the functioning of the heating and power in houses to a new level of self-sustainability along with reducing prices to make them more suitable.

The thesis will be organized as follows: It starts with a Review with some data of previous studies. After that, the objectives and some real cases are explained. Following this, it is explained how the ORC-CHP system works, showing off practical examples, it is also divided several explanations for the ORc cycle and the Biomass boiler as well. Then, it follows some additional information of this kind of systems, and for the end of the article it focuses more on the biomass, including uses or European laws for its use [2].

Figure 1. Climeon ORC-CHP system representation 1

NOMENCLATURE

The nomenclature of this article can be seen in Table 1:

Table 1. Nomenclature

Abbreviations		$\dot{Q}$	thermal power (kW)
AP	air preheater	T	temperature (ºC)
BB	biomass burner	$\dot{V}$	volumetric flow rate (m3/h)
CHP	combined heat and power	$\dot{W}$	electrical power (W)
COND	condenser		
DH	district heating	*Greek symbols*	
DHN	district heating network		
EVAP	evaporator	η	efficiency (-)
EXP	expander	ρ	density (kg/m3)
FCI	fixed capital investment cost	*Subscripts*	
GHG	greenhouse gas		
GWP	global warming potential	exp	expander
HTO	heat transfer oil	i	in
ODP	ozone depletion potential	n	net
OH	oil heater	o	out
ORC	Organic Rankine Cycle	oil	thermal oil
PEC	purchased equipment cost	pp	pump
PUMP	pump	w	water
RCV	liquid receiver		
REC	recuperator	*Acronyms*	
ST	stack	CCHP	Combined Cold Heat and Power
TCI	total capital investment cost	ORC	organic Rankine cycle

REVIEW

By 2030, the EU hopes to reduce greenhouse gas emissions and increase renewable energy sources achieving a better energy efficiency. It is necessary to create and develop efficient energy systems to accomplish the goals set by the EU.

In the discussed topic, biomass is regarded as a renewable energy source and one of its primary applications is burning to produce combined heat and power. The Rankine cycle is one of the most frequently considered alternative for producing a combinations of heat and power from biomass. In this following section there are some of the practical cases scientists and investigators have done with comparisons of energy production or costs between other facts.

The Rankine cycle is not financially viable below 1 MWe. Organic Rankine Cycle (ORC) technology is an alternative if we are looking for producing typically below 2 MWe, and it can also be used to utilize a variety of energy sources including landfill, water treatment plants, solar, waste heat, geothermal, agricultural or gas companies. Typically, biomass ORC-CHP plants run at lower temperatures (300 °C), with lower efficiencies of under 25%. Currently, commercial biomass ORC-CHP plants are primarily used for district heating, pellet production and other wood-related processes. They are usually available at power capacities above 1000 kWe, with the majority appearing at capacities between 500 kWe and 2000 kWe [1].

Notably, 300 plants are currently operational or under construction, primarily in Europe, North America, and Asia, and constitute about 11% of all ORC plants. The economic viability of these plants is a crucial factor, and it strongly relies on the characteristics of the heat demand. Several studies have concentrated on the optimization of the thermodynamic design to increase its efficiency and the techno-economic assessment of biomass ORC-CHP units [1].

According to the authors, the gas value was approximately 87-96.3 £/MWhe, while the ORC-CHP system electricity selling price to cover energy waste was considerably lower at 40.4–49.5 £/MWhe [1].

If we focus on the techno-economic efficiency of wood ORC-CHP systems created for the generation of district heating, a 390 kWe biomass-fired ORC and a 931 kWe biomass gasification system was evaluated. With a payback period of about 7.8 years compared to the ORC's 9.9 years. In an economic study of biomass ORC-CHP plants for district heating, some variables were investigated, including installed power, the heating price, the cost of selling energy and the cost of biomass fuel. According to the authors, the payback time was lowered to under 7.5 years when they were considered. It was also investigated the viability of a biomass ORC-CHP for district heating with electricity capacities ranging from 500 kWe to 4500 kWe with a combination of heat and electricity production, with a result of a range from 3 to 15%. In the profitability of a biomass ORC-CHP facility that alkanes and hydrocarbons, the results showed that the simple payback time for the project was around 5,26 years, noticing a big reduction of the payback time in comparison with the first case [1].

The development of smaller plants, below 500 kWe, for small-scale and micro-domestic scales is currently one of the main study trends. No studies have investigated the economic potential of smaller biomass ORC plants with power capacities in the range of tens of kWe for district heating. The plants are designed to operate with a variety of working fluids with extremely low heating temperatures with low warming potential. Another fact is that it is common to see the use of the component R1233zd, this is a no flammable hydrofluoroolefin which has the main goal of optimizing the net installed power [1].

For all working fluids, the authors found that the operating hours annually equalled to 8000. Additionally, the cost of the plant is estimated using different methodologies, while the estimation of the annual biomass consumption, electrical energy and heat production is done considering loads of buildings in Athens, Berlin, and Helsinki [1].

OBJETIVES OF ORC-CHP SYSTEM

The main objective of an ORC-CHP system is to produce both heat and electricity from a single energy source. The Organic Rankine Cycle and the Combined Heat and Power system are the two technologies that make up the ORC-CHP system. The expected when we talk about ORC-CHP systems are the next qualities [2]:

1. High efficiency: Trying to convert as much of the primary energy source's energy as possible into electricity and heat.

2. Cost-effectiveness: In comparison to other energy generation technologies, ORC-CHP systems should be financially accessible.

3. Environmental friendly: ORC-CHP systems seek to minimize environmental effects with the beneficit of the Earth and have a notorious difference in pollution with other heat and energy producers.

4. Reliability: To guarantee a steady supply of heat and electricity, ORC-CHP systems should have a high level of availability.

5. Scalability: Depending on the amount of energy required, ORC-CHP systems can be made to be both small and large.

6. Flexibility: ORC-CHP systems should be capable of running with a variety of energy sources and under various environmental conditions [2].

PROJECT "ORC-STIA-ADMONT"

The project proposed mainly focuses on the implementation of a biomass-fired CHP plant based on an Organic Rankine Cycle as a first demonstration within the European Community. An ecological and cost-effective operation of the process is only possible, if not only the electricity but also the heat produced by the ORC process can be used. An optimal improvement in the overall process efficiency is achieved by properly integrating the ORC process into the heat supply system. This plant will provide heat to STIA-Holzindustrie GmbH and the Benedictine Monastery of Admont [3].

This ORC process covers almost half of the electricity demand of STIA-Holzindustrie GmbH, more exactly around the 45 %. Only untreated wood residuals will be fired at the plant, with the main consequence of replacing fossil fuels, including heavy heating oil used at the Benedictine Monastery of Admont, represented in Figure 2, and light heating oil used at STIA-Holzindustrie GmbH. The project also aims to reduce dust emissions by installing a rotational particle separator which precipitates solid and liquid particles >0.1 m and achieves almost the same precipitation efficiencies as electrostatic precipitators [3].

Figure 2. Monastery of Admont

A biomass CHP plant based on an ORC process is the process' key innovative element. In the cycle or a thermal oil boiler, silicon oil is used as the organic working fluid. The thermal oil will vaporize the working fluid, which will then be expanded in a turbine to power the generator. Along that, condensation of the working fluid takes place at a temperature level which allows the heat recovered to be utilized. After that, a pump will be used to raise the pressure in the liquid working medium to the proper level. This allows for the use of both the heat generated by the condenser and the electricity generated by the generator [3].

The biomass CHP plant proposed is a new environmentally friendly. The first demonstration of an ORC plant to a biomass-fired oven using a thermal oil cycle is another innovative fact. The rotational particle separator and the injection of glue water are two additional elements of the plant. This waste stream can be used as a NOx-reducing agent. Due to the lack of prior experience with this technique, it can be regarded as an innovative technology. A new technology for effectively precipitating solid and liquid particles >0.1 m from gas streams is the rotational particle separator. Since this is the first time that it will be used in a large-scale plant like the one on Figure 3 [3].

Figure 3. STIA Biomass CHP plant based on an ORC process

AKITA PREFECTURE CASE

Due to costs and efficiency issues of long-distance transportation of renewable energy. Decarbonisation is more effective in regions using renewable energy available and then delivered to urban areas. Therefore, it is necessary design decarbonized district energy systems for rural areas and analysis of the supply potential of renewable energy resources for urban areas.

However, it also turns out energy costs will be relatively high because they have large required battery capacity. The aim of this study is to reduce this required battery power and energy supply costs using biomass, which were not considered in previous studies because it has very little potential [7].

100% renewable energy system configurations are shown. Using only renewable resources, all demand sectors, electricity, heat and transport fuels are taken into account. Batteries and water electrolysers are considered energy storage tools. When renewable energy production exceeds electricity demand, it is stored in batteries. While the electricity required for demand forecasting is stored in batteries, the remaining excess electricity is used for hydrogen production. It is assumed that excess electricity beyond the hydrogen production capacity will be supplied outside the region [7].

Current renewable energy and potential for additional wind energy are considered renewable energy. The additional solar and biomass energy that is not considered as potential is much smaller than the potential of wind.

The aim of this study is to reduce the capacity and energy supply costs of energy storage units by considering biomass energy, which was not considered in previous studies.

Adding the use of biomass for power generation, the equation for electricity supply and demand expressed in Equation1 [7]:

$$P_{\text{surplus},t} = P_{\text{wind},t} + P_{\text{biomass},t} + P_{\text{renewable},t} + P_{\text{discharge},t} + P_{\text{import},t} - P_{\text{demand},t} - P_{\text{charge},t}$$

Equation 1

The supply cost of electricity Costelectricity (JPY/kWh) and hydrogen Costhydrogen (JPY/MJhydrogen) are calculated with Equation 2 and 3 [7]:

$$Cost_{\text{electricity}} = \left(Cost_{\text{wind}} \times \frac{P_{\text{wind,elect}}}{P_{\text{wind,total}}} + Cost_{\text{biomass}} + Cost_{\text{battery}} \times \frac{P_{\text{battery,elect}}}{P_{\text{battery,total}}} \right) \times \frac{1}{P_{\text{elect}}}$$

Equation 2

$$Cost_{\text{hydrogen}} = \left(Cost_{\text{wind}} \times \frac{P_{\text{wind,H}_2}}{P_{\text{wind,total}}} + Cost_{\text{WE}} + Cost_{\text{battery}} \times \frac{P_{\text{battery,H}_2}}{P_{\text{battery,total}}} \right) \times \frac{1}{Q_{\text{hydrogen}}}$$

Equation 3

The relationship between each variable is expressed in Equation 4 [7]:

$$P_{\text{wind,total}} = \sum_{t}^{8760} P_{\text{wind},t} = P_{\text{wind,elect}} + P_{\text{wind,charge}} + P_{\text{wind,H}_2}$$

Equation 4

Scenario settings:

"no biomass" scenario: the biomass power was not installed, represented in Figure 4; "supply shortage" scenario: the biomass power supplied to shortage when other renewable energy cannot meet electricity demand, represented in Figure 5; "baseload" scenario: the biomass power operated as baseload, represented in Figure 5.

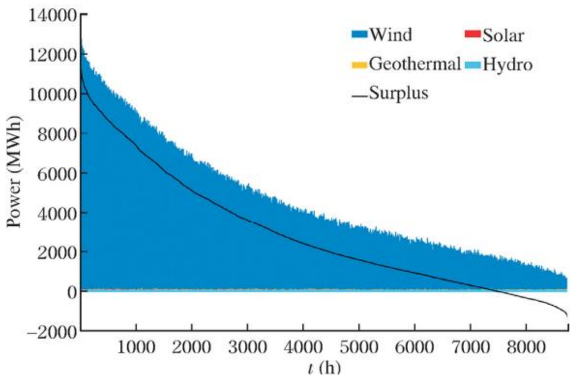

Figure 4. "no biomass"

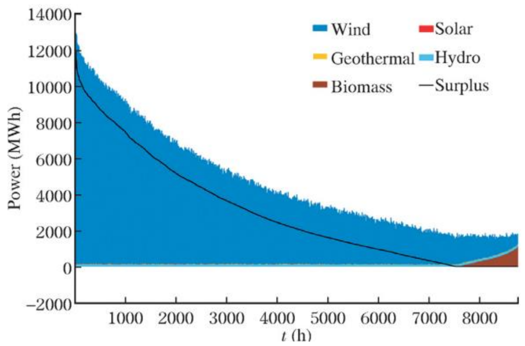

Figure 5. "supply shortage"

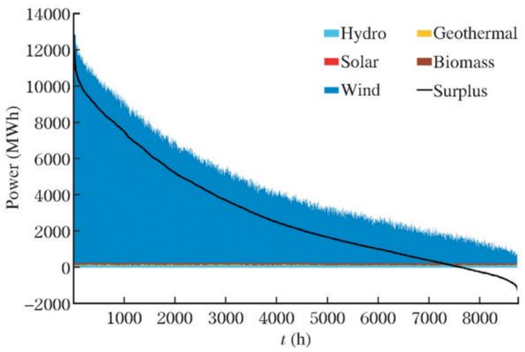

Figure 6. "baseload"

Shows the load curve of the surplus electricity and the cumulative renewable energy generation in each scenario. In scenario, the renewable energy could not meet the electricity demand for more than 1000 h, and the battery 48,407 MWh was needed to supply the shortage. In "supply shortage" scenario, 1,403 MW biomass power was installed. There was no shortage time because the biomass power supplied the shortage [7].

Small generation capacity had such a large impact because the maximum capacity of storage batteries is needed not for large demands of short duration, but for small demands that are continuous for a long time [7].

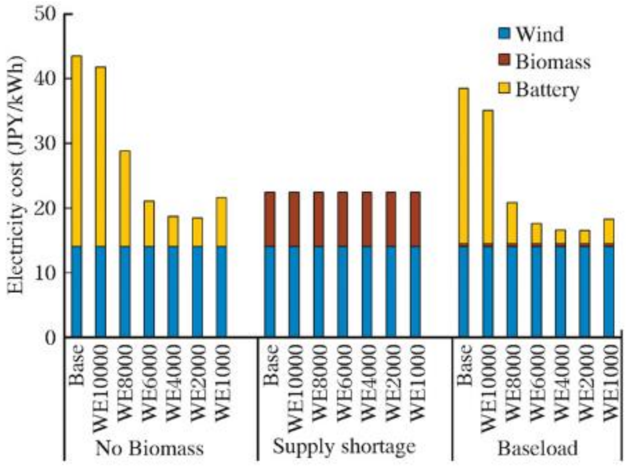

Figure 7. Electrecity cost in each scenario

Figure 7 shows the electricity cost in each scenario and case. In the base case, the smallest cost was obtained in “supply shortage” scenario because the battery costs in the other two scenarios were expensive. With the capacity of water electrolysis, the battery cost was decreased because the battery was utilized not only to supply electricity demand but also to hydrogen production and the availability of battery was increased. The electricity cost in “supply shortage” scenario was the most expensive [7].

Since most of the electricity demand can be met by baseload biomass production, storage capacity is also small compared to generation capacity.

On the other hand, in Akita Prefecture, which is the subject of this study, solar power generation and wood biomass power generation are smaller compared to wind power generation and power demand, and most of the power demand must be met by variable wind power. Consequently, battery capacity increases to compensate for the lack of renewable energy, and costs rise [7].

Energy production from biomass not only reduces the required battery capacity, but also increases the availability of both devices by using the system as a base load. The results show that although the use of biomass resources is much lower than other renewable energy sources, it still has a significant impact on the system as a whole. . Base load operation is best if the main final energy demand is electricity [7].

FUNCTIONING OF ORC-CHP SYSTEM

In the Figure 8 it is found an scheme of an ORC-CHP system, which from the combustion of biomass it is possible to generate power and heat for deliver to either district heating or to the electrical network.

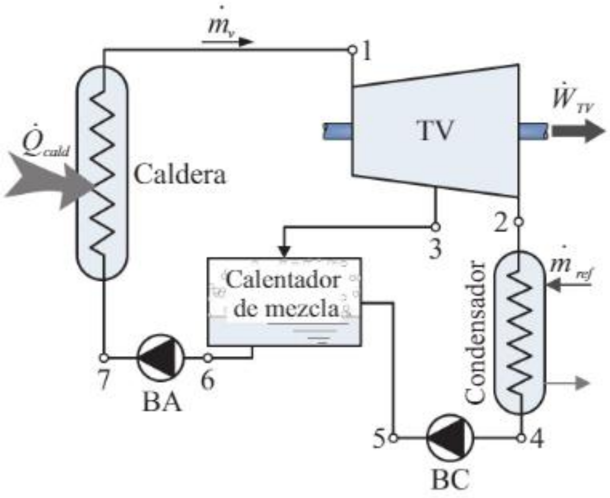

Figure 8. Representation o fan ORC-CHP system

A thermodynamic process called the Rankine Cycle uses water as the working fluid to transform thermal heat into mechanical work, which is then converted into electricity. In order to take advantage of low-temperature heat sources, ORC, or Organic Rankine Cycle, technology, uses an organic working fluid rather than water [11].

The working fluid is pumped to the evaporator at the pump, which initiates the ORC thermodynamic cycle. The heat source there transfers heat to the working fluid. The gas is sent to the expander from the evaporator's outlet, where it expands and is used to generate mechanical work first, and then electricity later using a generator. By using a regenerator heat exchanger to pre-heat the liquid entering the evaporator, the expanded working fluid helps the system operate more efficiently. The cycle is completed by the condensation of the vapor, which releases low-temperature heat which is at the right temperature for the distribution in close by areas and giving a second function to the system [11]. This procedure is better represented in Figure 9.

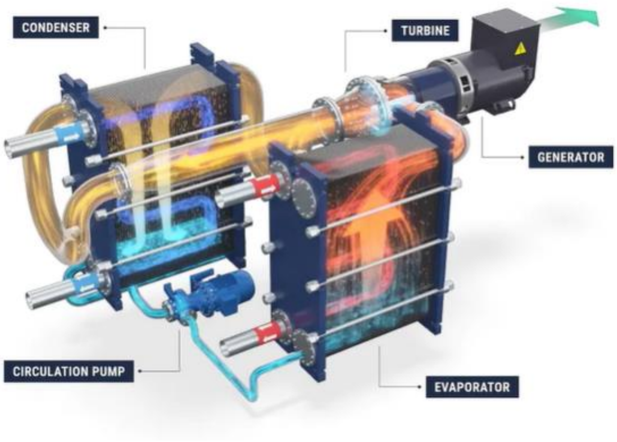

Figure 9. ORC system

COMPONENTS OF AN ORC-CHP SYSTEM

In the next practice case, it is shown how the different values of the data in a Rankine cycle are obtain in a general way, always relating in and out equations between pipes and doing energy balances around the main pieces of the system. The first balance in Figure 10 is around the turbine.

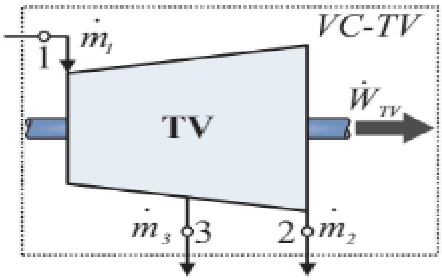

Figure 10. Balance around turbine

$$\begin{aligned} \sum_i \dot{H}_{entrante-i} &= \sum_i \dot{H}_{saliente-j} + \dot{W}_{TV} \\ \dot{m}_1 h_1 &= \dot{m}_2 h_2 + \dot{m}_3 h_3 + \dot{W}_{TV} \end{aligned}$$

Equation 5

By solving the Equation 10 it is possible to know the value of h1 and h2, for the value of h3 it is meant to follow the Equation 11 [11]:

$$h_3 = \frac{\dot{m}_1 h_1 - \left(\dot{m}_2 h_2 + \dot{W}_{TV}\right)}{\dot{m}_3}$$

Equation 6

As it is a stationary process, it also states the Equation 12 [11]:

$$\dot{m}_1 = \dot{m}_2 + \dot{m}_3$$

Equation 7

To calculate the Enthalpy in the state 4, it is by the tables of saturated liquid which is the one which comes from the Condenser, after that the h5 is obtained comparing the difference between 4 and 5, as a result of the work of the pump after the condenser solved in Equation 13 [11]:

$$|w_{BC}| = h_5 - h_4 \rightarrow h_5 = h_4 + |w_{BC}|$$

Equation 8

For the wBC it is necessary to follow the next Equation 14 [11]:

$$|w_{BC}| = \int_4^5 vdp \approx \frac{v_4 \Delta p}{\eta_{s-BC}} = \frac{v_4 \left(p_5 - p_4\right)}{\eta_{s-BC}}$$

Equation 9

Fort he obtention of h6 It is necessary to calculate an energy balance in the mixture exchanger of the Figure 11 [11]:

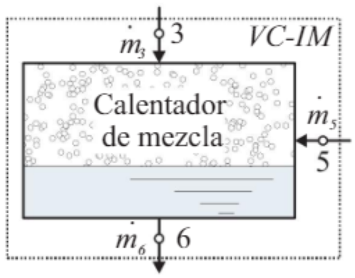

Figure 11. Balance around mixture exchanger

Once the balance is made, the next Equation 15 is stablished [11]:

$$\left[\begin{array}{ccc} \sum_i \dot{H}_{entrante-i} & = & \sum_i \dot{H}_{saliente-j} \\ \dot{m}_3 h_3 + \dot{m}_5 h_5 & = & \dot{m}_6 h_6 \\ \dot{m}_3 + \dot{m}_5 & = & \dot{m}_6 \end{array}\right]$$

Equation 10

With the following result in the Equation 16 [11]:

$$h_6 = \frac{\dot{m}_3 h_3 + \dot{m}_5 h_5}{\dot{m}_6}$$

Equation 11

The work done in the pump BA is obtained by the difference of the enthalpies between the conditions 6 and 7, with this Equation 17 [11]:

$$|w_{BA}| = |h_7 - h_6| = \int_6^7 v dp \approx \frac{v_6\,(p_7 - p_6)}{\eta_{s-BA}}$$

Equation 12

Once it is known the specific enthalpy for all the states in this Rankine Cycle, it proceeds to the calculation of the efficiency of the system through the heat of the boiler first. Then, another energetic balance is made around the boiler represented in Figure 12:

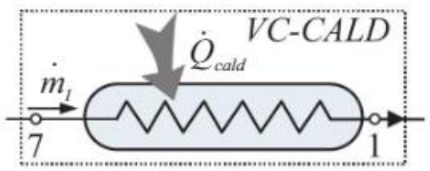

Figure 12. Balance around boiler

With this results in the Equation 18 [11]:

$$\dot{m}_1 h_7 + \dot{Q}_{cald} = \dot{m}_1 h_1 \rightarrow \dot{Q}_{cald} = \dot{m}_1 (h_1 - h_7)$$

Equation 13

The performance is calculated by the Equation 19 [11]:

$$\eta_{ciclo} = \frac{\dot{W}_{neta}}{\dot{Q}_{cald}}$$

Equation 14

The Wneta, represents the total electric power of this system. It is obtained by the power of the Turbine, deducting the power of the two pumps in the cycle like in Equation 20 [11]:

$$\dot{W}_{neta} = \dot{W}_{TV} - \left|\dot{W}_{BC}\right| - \left|\dot{W}_{BA}\right|$$

Equation 15

While WBC and WBA, the power of the pumps, can be represented by Equation 21 [11]:

$$|\dot{W}_{BC}| = \dot{m}_2 |w_{BC}|$$
$$|\dot{W}_{BA}| = \dot{m}_6 |w_{BA}|$$

Equation 16

If it was also required to obtain the efficiency of only the turbine and not the whole system, it would be this way, knowing that in this case, with a isentropic turbine, which represents a relation between an ideal and a real functioning of the turbine with constant pressure before and after, the formula would be this Equation 22 [11]:

$$\eta_{s-TV} = \frac{h_1 - h_2}{h_1 - h_{2s}}$$

Equation 17

After calculating the isentropic efficiency value, the real value of the electric power of this turbine will be lower than the ideal value, because here other aspects interfere. We obtain the real value by using the isentropic value and this Equation 23 [11]:

$$\eta_{s-TV} = \frac{h_1 - h_2}{h_1 - h_{2s}} \equiv \frac{\dot{W}_{TV}}{\dot{W}_{s-TV}}$$

Equation 18

This Figure 13 is a graphic demonstration by a Mollier Diagram which shows a representation of the Rankine Cycle for an ideal case in the turbine with 100% efficiency.

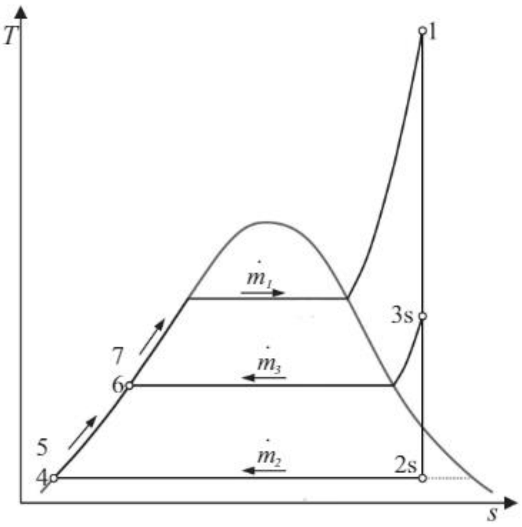

Figure 13. Diagram T – s resolved by the isentropic process

f

The other Figure 14 is the result of a Diagram T – s not resolved by the isentropic process in the turbine, which means with no constant pressure.

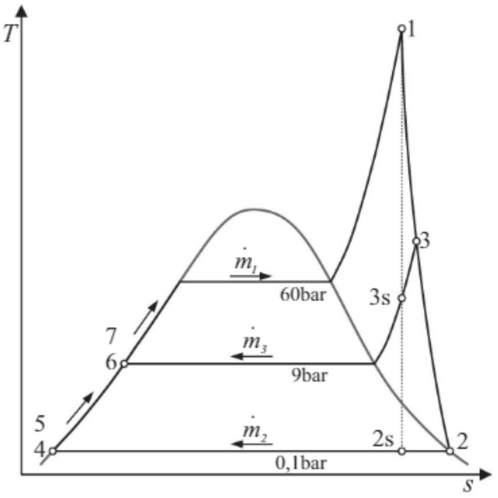

Figure 14. Diagram T – s not resolved by the isentropic process

BIOMASS BOILER and TECHNO-ECONOMIC FACTORS

Once seen how the ORC-CHP system works, it is also an important factor how this heat which arrives to the ORC system is produced. For its explanation it is followed the image below.

The biomass boiler in Figure 15 includes the biomass burner (BB), oil heater (OH), air preheater (AP) and stack (ST). The ORC includes the pump (PUMP), recuperator (REC), evaporator (EVAP), expander (EXP), condenser (COND) and liquid receiver (RCV). The two subsystems are connected through the heat transfer oil (HTO) circuit [16].

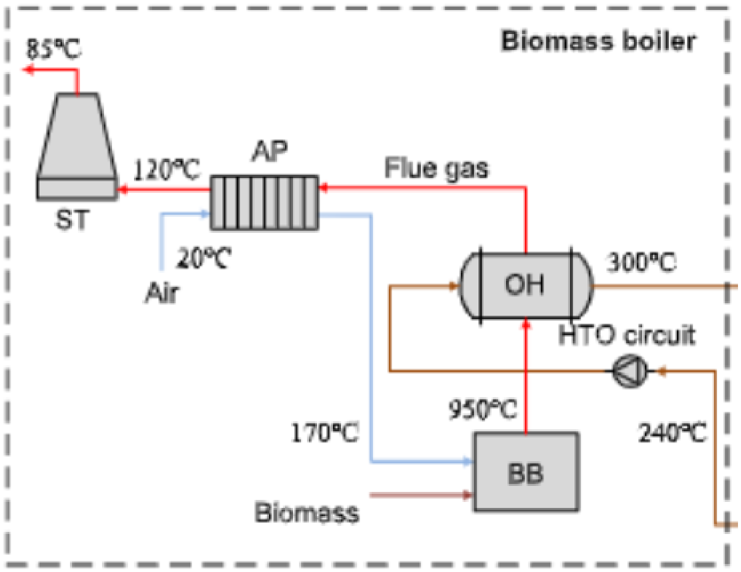

Figure 15. Biomas boiler and its components representation

The source used in this article to heat the organic fluid from the ORC system is biomass, which is a vegetal fuel which usually comes from natural waste, this could be from forests, or some field or industrial processes. With this fuel it is possible to produce power and heat.

Another way to represent it is the following case, which shows a real Project in which a supermarket is involved. In the scheme it is appreciated that as the examples explained in the article it mixes power generation with heat distribution, but in this case the is a cooling system for a supermarket in addition, showing that this kind of cycles could have more tasks tan the ones in study.

It can be seen in Figure 16 that the heat energy is supplied by the biomass boiler (1). The ORC system (2) recovers this thermal energy to produce electricity and useful heat at two different temperature levels. In particular, the heat generated by ORC condensation, if available, can be used for heating (5), while some of the heat generated by the expander can be used to power the absorption system (3). In particular, the absorption system is used to increase the degree of subcooling of the condenser of the high temperature stage of the R450A/CO2 cascade refrigeration system (4), thus reducing the energy consumption of the compressor [5].

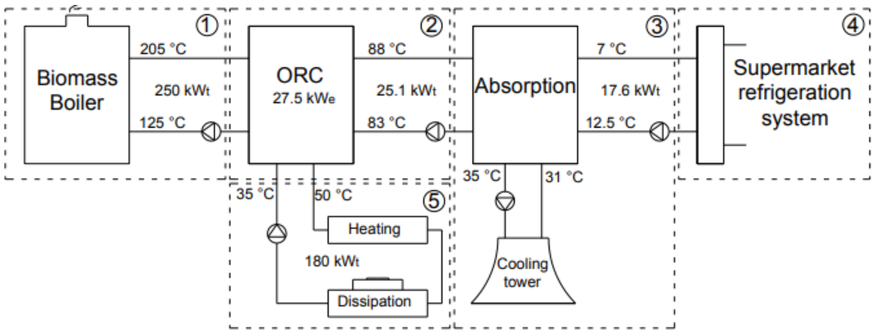

Figure 16. Biomass ORC-CCHP system for a supermarket study in Vitoria

The representation of the previous case in a Temperature-entropy diagram in Figure 17:

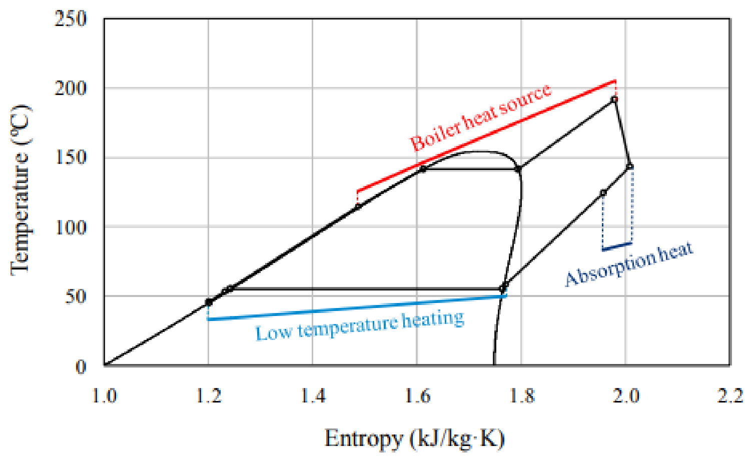

Figure 17. Thermodynamic cycle in temperature-entropy diagram: heat source from the boiler, heating from the condenser and absorption heat from the expander exhaust.

In this case, a natural gas plant is used to provide the necessary heat and temperature for the ORC. Thus, the same heat source conditions can be achieved. The thermal energy consumption of the absorption and heating system is simulated with two dissipative systems that control temperature and current damping. The organic working fluid used is HFC-245fa, a non-flammable and low-toxicity fluid that allows operation up to 240 ºC [5]. The rest of the information from this ORC cycle is available in the following Table 2:

Table 2. Cycle information for system developing.

Rated electrical power (kW)	30
Cycle architecture	Regenerative
Organic working fluid	HFC-245fa
Expansion technology	Volumetric
Heat exchangers technology	Brazed plate
Thermal oil inlet temperature range (ºC)	180-205

The heat capacity provided by the heat transfer oil is obtained by Equation 24 Use of thermal oil volume flow, evaporator inlet and outlet temperatures, and thermal oil characteristics under operating conditions. Similarly, the thermal effect is obtained by removing water with Equation 25. Use the equation to calculate the net electrical efficiency of the system in Equation 26 From the measured electric power produced by the expander, the measured electric power consumed by the pump and the heat input [5].

$$\dot{Q}_{oil} = \dot{V}_{oil} \rho c_p \left(T_{oil,i} - T_{oil,o} \right)$$

Equation 19

$$\dot{Q}_w = \dot{V}_w \rho c_p \left(T_{w,o} - T_{w,i} \right)$$

Equation 20

$$\eta_n = \frac{\dot{W}_{exp} - \dot{W}_{pp}}{\dot{Q}_{oil}}$$

Equation 21

The next Table 3 presents the input parameters and the results of the energy, economic and environmental analysis [5].

Table 3. Techno-economic aspects of the Project.

Electricity power (kWe)	25
Heat source thermal power (kWt)	250
Heat sink (heating) thermal power (kWt)	180
Heat sink (absorption) thermal power (kWt)	26
Absorption COP (-)	0.75
Absorption cooling capacity (kWt)	19.5
Operating time (with heating usage) (h)	4000
Operating time (without heating usage) (h)	4000
Electricity generation (kWh)	200000
Biomass consumption (kWh)	2000000
Cooling energy (kWh)	156000
Heating energy (kWh)	720000
Electricity price (€/kWh)	0.115
Cooling price (€/kWh)	0.055
Heating price (€/kWh)	0.065
Biomass cost (€/kWh)	0.025
Net cash flow (€)	28380
Biomass consumption emission rate (kgCO_2/kWh)	0.018
Electricity production emission rate (kgCO_2/kWh)	0.339
Cooling energy emission rate (kgCO_2/kWh)	0.192
Heating energy emission rate (kgCO_2/kWh)	0.311
Emission reduction (kgCO_2)	285610

Since the thermal energy demand of the supermarket is greater than the heat capacity of the CCHP system, it is considered a constant consumption of all produced energy during the considered operation period. The energy analysis shows that the amount of electricity produced per year is 200,000 kWh, of which 720,000 kWh is saved for heating and 156,000 kWh is saved for cooling. Based on the current energy purchase price, the annual net cash flow is 28,380 euros. Although the net cash flow value is lower, the biggest benefit comes from the results of the environmental analysis [5].

FLUIDS COMPARISON TO USE

Six ultra-low GWP working fluids were examined, which are the ones on Table 4:

Table 4. Ultra-low GWP working fluids

Working fluid	P_{crit} (bar)	T_{crit} (°C)	ODP	GWP
cyclopentane	45.1	238.6	0	11
n-pentane	33.7	196.6	0	4
isopentane	33.8	187.3	0	4
R1233zd	35.7	165.5	0	1
butane	38	152	0	4
isobutane	36.5	134.7	0	3

Five compounds that fully comply with the most recent environmental rules and have no potential to deplete the ozone layer. These comprise one hydrofluoroolefin (R1233zd) and five natural hydrocarbons (cyclopentane, n-pentane, isopentane, butane, and isobutane). The hydro-carbons are combustible, but R1233zd is not, although it has a far greater buying price, as will be demonstrated later. These working fluids are chosen in addition to having desirable environmental characteristics because they have essential temperature and pressure values that, under the application's operating conditions, allow them to make highly effective ORCs [1].

Working fluid's price is determined by its quantity. Knowing the precise dimensions of heat exchangers and their heat transfer zones, as well as piping dimensions like diameters and lengths, is necessary for the proper calculation of the working fluid quantity. In the current work, a streamlined calculation is performed under the assumption that the quantity of the working fluid and the system size are linearly related [1].

A relatable fluid cost study taking care of different facts could be the following in Table 5:

Table 5. Working fluid costs

Working fluid	Cost (€/kg)
cyclopentane	2.05
n-pentane	0.94
isopentane	1.64
R1233zd	24.6
butane	1.80
isobutane	2.46

CALCULATION WORKSHEET FOR HEAT LOAD FOR A BUILDING

Table 6. Calculation worksheet for heat load for a building

HVAC QUICK LOAD PROGRAM

COMPANY:			DATE:	Oct 28, 2016
PROJECT:			PROJ. NO.:	

AHU #	MONTH (1-12)	TIME (7am-6pm)	OUTDOOR AIR TEMPERATURES			INDOOR AIR TEMP	
			SUMMER		WINTER	RH =	50.0% RH
AHU-1	8	5	94.0°F db	74.0°F wb	12.0°F	72.0°F db	60.1°F wb
AHU TYPE BLOWTHRU = BT DRAWTHRU = DT		HOURS OF OPERATION (12, 16, 24)	"U" VALUES			GLASS SAFETY FACTORS	
			WALL	ROOF	GLASS	BARE	SHADED
DT		24	0.10	0.08	1.13	0.80	0.65

GLASS SOLAR HEAT GAIN

INT SHADE ? (Y/N)	EXPOSURE	AREA (SQ.FT.)	PEAK SOLAR HEAT GAIN	24 HR STORAGE	SHADE FACTOR	SAFETY FACTOR	BTU/HR
N	N	100	37	0.80	0.80	1.10	2,605
N	S	100	111	0.45	0.80	1.10	4,396
N	E	100	219	0.20	0.80	1.10	3,854
N	W	100	219	0.48	0.80	1.10	9,251
N	NE	100	141	0.17	0.80	1.10	2,109
N	NW	100	141	0.40	0.80	1.10	4,963
SKYLIGHT	HORIZ.	100	225	1.00	1.00	1.10	24,750
						SUB-TOTAL =	51,928

TRANSMISSION HEAT GAIN

	EXPOSURE	AREA (SQ.FT.)	EQUIVALENT TEMP. DIFF.	TEMP. CORRECTION	"U" VALUE	SAFETY FACTOR	BTU/HR
WALL:	N	100	11	10	0.10	1.10	231
WALL:	S	100	23	10	0.10	1.10	363
WALL:	E	100	13	10	0.10	1.10	253
WALL:	W	100	34	10	0.10	1.10	484
ROOF:	HORIZ.	100	43	10	0.04	1.10	233
GLASS:		700	22		1.13	1.10	19,142
PARTITION:		100	10		0.20	1.10	220
						SUB-TOTAL =	20,926

INTERNAL HEAT GAIN

	QUANTITY OR SQ.FT.	WATTS PER SQ.FT.	CONVERT FACTOR	MULTIPLIER FACTOR	SAFETY FACTOR	BTU/HR
FLUOR. LIGHTS (SF):	1000 SF	2.00	3.413	80%	1.10	6,007
INCAN. LIGHTS (SF):	1000 SF	0.25	3.413	100%	1.10	939
POWER (SF):	1000 SF	2.00	3.413	100%	1.10	7,509
EQUIPMENT (SF):	1000 SF	2.00	3.413	100%	1.10	7,509
INFILTRATION SENSIBLE:	100 CFM	22.0°F		1.08	1.10	2,624
					SUB-TOTAL =	27,337

ROOM SENSIBLE HEAT GAIN

TOTAL STATIC = 2.00 in. wg		ROOM SENSIBLE HEAT (BTU/HR)=	100,191
AIRFLOW @ 20.0°F TEMP. DIFF. =	4619 CFM		
MOTOR SIZE = 2.4 BRAKE HORSEPOWER			
MOTOR HEAT RISE = 1.2°F		HEAT GAIN FROM MOTOR (BTH/HR) =	6,165
		SUB-TOTAL =	106,357

RETURN AIR HEAT GAIN

	EXPOSURE	AREA (SQ.FT.)	EQUIVALENT TEMP. DIFF.	TEMP. CORRECTION	"U" VALUE	SAFETY FACTOR	BTU/HR
WALL:	N	10 SF	11	10	0.10	1.10	23
WALL:	S	10 SF	23	10	0.10	1.10	36
WALL:	E	10 SF	13	10	0.10	1.10	25
WALL:	W	10 SF	34	10	0.10	1.10	48
ROOF:	HORIZ.	100 SF	43	10	0.04	1.10	233
LIGHTS:	(FLUOR.)	1000 SF	2.0 W/SF	3.413	20%	1.10	1,502
MOTOR BHP:		2.4 BHP			HEAT GAIN FROM MOTOR =		
						SUB-TOTAL =	1,868

OUTSIDE AIR HEAT GAIN

	CFM PER PERSON	CFM	TEMP. DIFFERENCE	MULTIPLIER FACTOR	SAFETY FACTOR	BTU/HR
O/A SENSIBLE:	375	3750	22.0°F	1.08	1.10	98,418
				GRAND TOTAL SENSIBLE HEAT (BTU/HR) =		206,643

LATENT HEAT GAIN

	CFM OUTSIDE AIR	DELTA GRAINS	MULTIPLIER FACTOR	SAFETY FACTOR	BTU/HR
INFILTRATION LATENT:	100	36	0.68	1.10	2,676
PEOPLE LATENT:	10 PEOPLE @ 200 BTH PER PERSON			1.10	2,200
				SUB-TOTAL =	105,213

		GRAND TOTAL LATENT HEAT (BTH/HR) =	105,213
ROOM SENSIBLE HEAT RATIO =	0.98	GRAND TOTAL HEAT (BTU/HR) =	311,856
TOTAL SENSIBLE HEAT RATIO =	0.66	TONNAGE =	26.0
ENTERING ENTHALPY =	35.4 BTU/LB	ENTERING AIR TEMPERATURE =	89.9°F
LEAVING ENTHALPY =	20.4 BTU/LB	LEAVING AIR TEMPERATURE =	50.8°F

The worksheet just seen in Table 6 is an example on how the different data to obtain the heating wanted in the building is measured, and how this facts are placed in this table depending on the biggest temperature difference during the day, glass solar heat gain, transmission heat gain in each wall, internal heat gain, room sensible heat gain, return air heat gain, outside air heat gain and latent heat gain considering sq. meters or the amount of people between others.

The HVAC Load Calculations Worksheet allows choosing a system and making initial design selections. The design engineer may enter, modify, and manipulate various HVAC load changes on the spot to the simplicity and distinctive compactness, and the output is immediately visible for the user. The final product is a one-page form that contains all the necessary information and design specifications for choosing the right heating equipment to meet the space circumstances [14].

On the market, there are a lot of HVAC Load Calculations Worksheets but they precise a lot of data input and they generate a lot of output, with the benefits of being very precise in terms of HVAC loads, and the big disadvantage of being typically pretty expensive. It is essential to design the building's HVAC systems using the most precise and realistic computer model possible. This will establish how the structure will operate in varied heating and cooling conditions as well as throughout the day, week, month, or year.

Owners, architects, and engineers choose the type of system at this stage of the design process based on factors such the total load, the desired system control, the necessary space setpoints, etc [14].

USAGE OF BIOMASS

Biomass is a non-fossil resource of biological origin that is renewable, sustainable, clean, and regularly available. Biomass is also called the waste of living organisms. Yadav describes biomass materials as organic materials that can store energy from the sun as carbon, hydrogen, hydrogen, oxygen, nitrogen, and small amounts of sulphur [9].

The goal is to have a fuel that can provide all the energy needed for any building without worrying about things like choosing the right fuel, the overuse of fossil fuels, their prices and his exhaustion. In addition, there are new rules. Energy, with an ecological and economic conscience. One of the biggest advantages of using this fuel is that we can get energy without polluting the environment.

Research has shown that when these materials are compressed, they can be very useful for many household and industrial processes. Biomass waste is considered a renewable alternative energy source that will reduce dependence on fossil fuels.

One of the advantages of biomass as a reliable energy source is that its production can be localized and is not affected by wholesale price fluctuations in the international market. Agricultural biomass also proved to be an economically viable source to produce graphite and the use of agricultural wastes such as peanut husks, coconut husks and rice husks as reinforcing materials for strengthening aluminium. Biomass-based industries contribute to job creation, business development and income generation in rural areas [9].

ENERGY PRODUCTION

Different countries continue to take proactive measures to curb the adverse effect of global warming and climate change due to the use of fossil fuel. Thus, renewables energy source will be the most demanded by 2050 [9].

The Figure 18 is a representation of biomass route to different sources of energy:

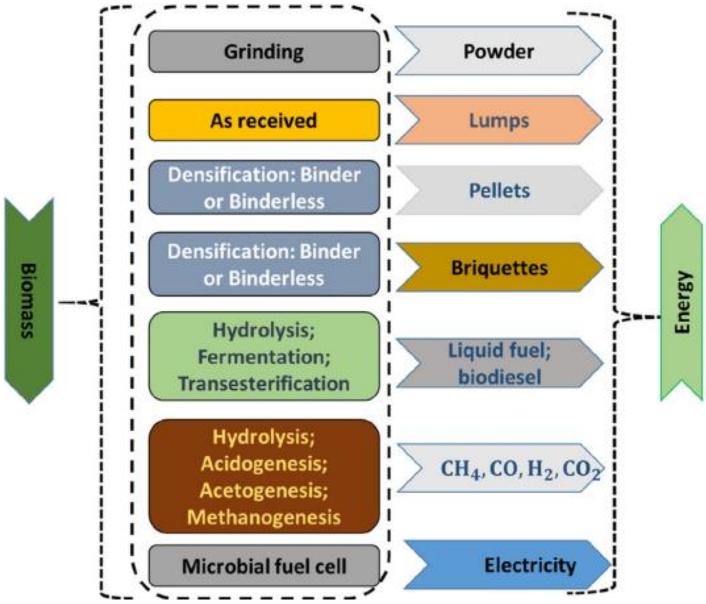

Figure 18. Representation of biomass route to different sources of energy.

Figure 19 shows the sources of biomass energy supply for domestic use across the different continents. The figure shows that Asia is the world largest producer of biomass energy. Asia is also the world largest producer of biogas and solid biofuels. Africa majorly produce biogases and solid biofuels, while America, Asia and Europe derive bioenergy from liquid biofuels [9].

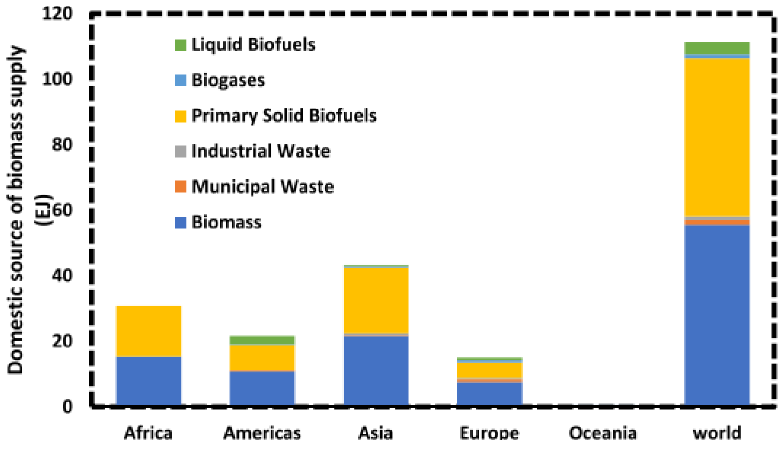

Figure 19. Biomass energy supply for domestic use

BIOCHEMICAL PRODUCTION

Environmental sustainability efforts have led many researchers to explore alternative methods of producing raw materials for the biochemical industry. Through various processes, biomass can be converted into three main products; electricity/heat, transport fuel and chemical raw materials. Other materials that can be derived from biomass include bioplastics and biocomposites for use in the textile, electronics, and healthcare industries.

Production of polyhydroxyalkanoates (PHAs) has been recognized as a good alternative to polypropylene and petroleum-derived polystyrene. It has been found that PHA can be obtained from cellulosic biomass and used in the biochemical industry [9].

The various methods identified are biochemical, microwave and thermochemical transformation methods. Biochemical conversion involves breaking down the biomass structure by enzymatic hydrolysis, which converts polysaccharides into mono- and disaccharides. Thermochemical conversion methods use pyrolysis to break down lignocellulosic biomass into useful chemical products for industrial applications. Microwave processing requires the use of microwave radiation to ensure efficient distribution of heat into molecules through ion conduction. The study highlights the importance of microwave processing compared to the other two methods.

CONSTRUCTION

The construction industry is a very large industry with high demand for diverse materials including granite, cement, tiles, wood, steel, sand, water, and bricks [9]. This Figure 20 is a clear example of how biomass is used in this industrial sector and what it is capable of.

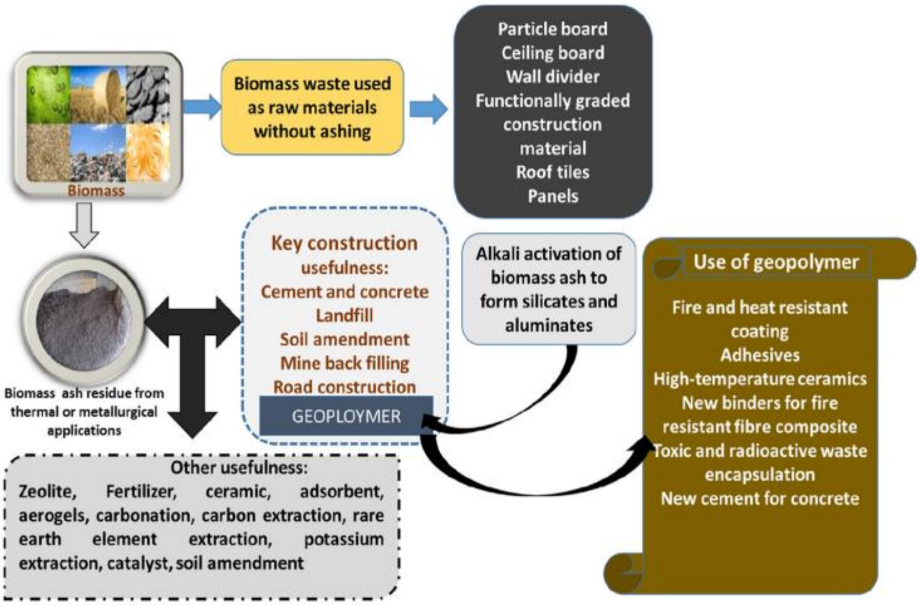

Figure 20. Biomass for construction scheme

REINFORCEMENT IN METAL MATRIX COMPOSITE

Biomass has also been widely used in the production of metal matrix composites (MMC) in recent years because the ash contains some useful oxides of elements. Combustion of biomass produces very rich residual ash. The concentrate contains silicon dioxide (SiO2) as the main ingredient, which acts as a strengthening agent for MMC. Biomaterials are good and cheap sources of silica and carbon and other strength-providing oxides. Biomaterials and their derivatives can provide unique structures that cannot be obtained using traditional ceramic processing methods [9].

Some of the materials used for this function in this área are the following ones:

1. rice husk and its derivatives
2. groundnut shell and its derivatives
3. coconut shell and its derivatives as reinforcement
4. bamboo leaf and its derivatives as reinforcement
5. bean pod and its derivatives as reinforcement
6. palm kernel shell and its derivatives as reinforcement

BIOMASS IN TRADITIONAL MEDICINE

Wood shavings, agricultural residues and herbs (herbs) are ancient raw materials and natural ingredients in traditional medicine. Biomass contains cellulose, hemicellulose, lignin and some natural or extractable compounds. One of the many examples where biomass can be used in this field is the extracts of bamboo parts such as stems, branches and leaves, which have been shown to be effective in said medicinal functions. Research is still largely focused on using bamboo vitality to treat skin conditions [9].

Maximizing the use of biomass should be encouraged to achieve sustainable and verifiable reductions in greenhouse gas emissions. This will level the playing field between different uses of biomass materials. Therefore, sustainable land use and forest management are included. It will also contribute to climate change mitigation, avoid direct and indirect land-use changes, reduce impacts on biodiversity, ensure greater use of biomass and remove barriers to biomass trade worldwide [9].

AGRICULTURE BIOMASS AS FUEL

As a **direct fue**l, more than 30% of global household energy comes from agricultural biomass for heating, cooking and lighting [8].

As a **gaseous fuel**, biogas is produced from agricultural biomass, stored, and transported for domestic use to meet energy needs for heating, cooking and lighting. According to the report published by the European Commission, there is a desire to increase the proportion of agricultural biomass, fertilizer and manure as raw materials and to increase the efficiency of biogas and biomethane production plants [8].

As a **liquid fuel**, agricultural biomass can be used to produce ethanol. However, there are various other methods that need to be explored and evaluated to utilize agricultural biomass. The main components of agricultural biomass are cellulose and hemicellulose, which can be converted into bioetanol [8].

As **Pellets** will be explained later. Finally, for **Energy Production** as this generation of electricity from biomass is a viable option in developing countries. In the European Union, there are various power plants that produce electricity from agricultural biomass. A 38-megawatt power plant under construction in Cambridgeshire, UK, uses straw as fuel. In a study conducted in Poland by economy (2010) [8].

It is indicated that the structure of biomass use will change within 20-25 years, as can be seen in the Table 7.

Table 7. Structure of biomass along years

Options for biomass utilization	2006	2010	2020	2030
Electricity	3.8	6.3	14.9	16.1
Heat	94.0	83.3	71.4	72.3
Biofuels	2.2	10.4	15.7	11.6

Among the different types of biomass available to us, this paper examines particles, an evolutionary application of biomass that is clean and easy to handle as they can be handled like a liquid. These are small cylinders made of crushed, dried and pressed wood.

The next Figure 21 shows how pellets compare to other fuels such as petrol, diesel or propane gas and it can be seen that our fuel is by far the cheapest.

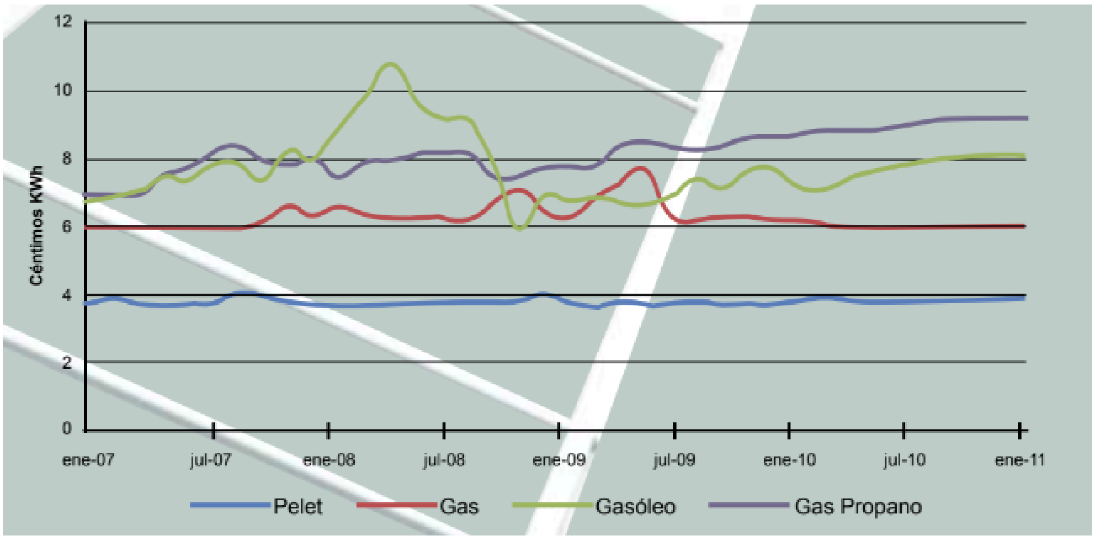

Figure 21. Price of pellets compare to other fuels

See the difference between the price of pellets in cents per 2 kg and the price of diesel fuel in cents per liter in the Figure 22:

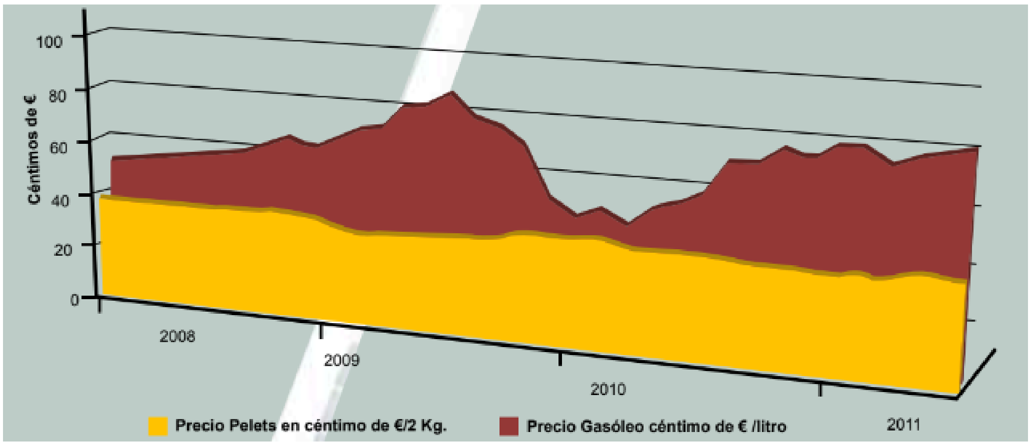

Figure 22. Difference between the price of tablets in cents per 2 kg and the price of diesel fuel in cents per liter

Biomass costs less than fossil fuels, the calorific value of 2 kg of pellets is the same as 1 liter of diesel fuel or 1 m3 of natural gas, and the price is very competitive with these fuels. To strengthen the local economy, promote employment in rural areas, stabilize the population and promote comprehensive development of rural areas.

It has great price stability and creates prosperity in our country, which is not affected by energy crises or conflicts in third countries, nor at the expense of formulas that refer to BREND DE PETROL prices [15].

Burning biomass is thought to release twice less carbon dioxide into the atmosphere tan trees take in as they grow. Therefore, all the carbon dioxide released when burning biomass is neutral like shown in Figure 23, which is the second reason why biomass is considered a renewable energy source. Some of the main advantages of using pellets are [15]:

1. Deforestation residues are used for the production of pellets and wood chips which helps reducing the risk of fire.

2. Combustion of pellets is very effective, which promotes the benefit of energy.

3. Ash can be used as fertilizer for gardening as they contain important signs of nitrogen, phosphorus and plants and thereby improve the ecosystem.

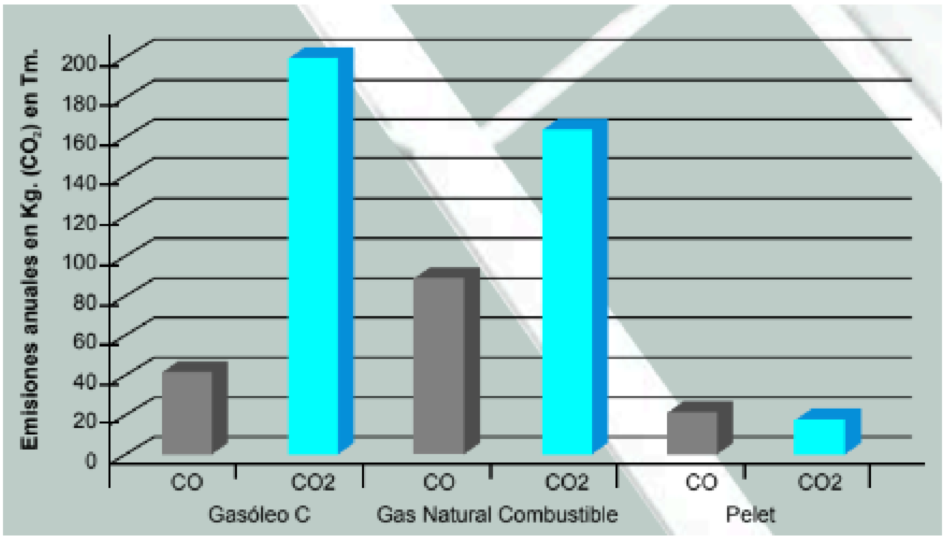

Figure 23. Annual emissions in Kg(CO2) in Tm

Other benefits of using pellets include [15]:

1. No risk of explosion.
2. No Volatile.
3. Odorless and leak free.
4. Non-toxic and harmful to health.

BIOMASS ISSUES

The number of issues need to be addressed before agricultural biomass can be used as energy, including:

CHALLENGES RELATED TO THE PRODUCTION OF BIOFUELS

Energy production through the gasification process is an ecologically and economically sound solution that can ensure sustainable global development. The environmental impact of the gasification process can be made more sustainable if decarbonisation technologies are used. However, there are still concerns about the use of agricultural biomass for energy production due to the existence of a subsidized fossil fuel market. Some of these issues are security of energy supply, cheaper energy imports or greenhouse gas (GHG) emissions [8].

RISKS AND CONTROLS

1. Problems with food and fuel

At the moment, first-generation biofuels do not seem too good because they could put imminent pressure on food. However, second-generation biofuels are produced only from non-food biomass, including agricultural biomass, which may alleviate food safety concerns [8].

2. Reduced soil quality

Biomass, like crop residues, helps retain moisture in the soil by reducing evaporation losses, which in turn improves soil quality. The consumption of biomass for fuel production can hinder this and negatively affect soil quality. Farmers can avoid this by leaving some of the biomass on the farmland. However, crops for biofuel production can be grown on marginal land with minimal impact on soil quality [8].

3. Economic sustainability

The most important obstacle to start using agricultural biomass fuel is the lack of financial support [64]. However, countries are implementing policies to encourage the use of biomass-based fuels [8].

4. Need for technical improvements

Biomass growth, yield and collection can be improved with the latest technology, equipment and effective farm management. In addition, the efficiency of biomass production can be improved by reducing agricultural inputs such as water, fertilizers and agrochemicals [8].

ENVIRONMENTAL PROBLEMS DUE TO INEFFICIENT USE OF BIOMASS

Burning agricultural biomass in fields is a traditional practice to improve soil fertility and reduce pest infestation after planting. Burning agricultural biomass is harmful to the environment and contributes to the accumulation of methane in the atmosphere, which absorbs and reflects infrared radiation about 60 times more efficiently than carbon dioxide. Methane from agricultural biomass currently accounts for about 10% of total methane emissions from fossil fuel combustion [8].

Directive (EU) 2018/2001 ON THE PROMOTION OF THE USE OF RENEWABLE ENERGY RESOURCES

To have in consideration:

Article 1

(21) When developing support schemes for renewable energy sources, Member States should consider the biomass available for sustainable supply and take due account of the principles of the circular economy and the waste hierarchy set out in Directive 2008/98/EC of the European Parliament and of the Council (1), in order to avoid unnecessary distortions of the raw material markets. Waste prevention and recycling should be the first choice. Member States should avoid setting up support schemes which are incompatible with the objectives of waste treatment or which may result in an inefficient use of recyclable waste [13].

(64) Provision should be made for a limited local impact derogation allowing Member States to adopt specific criteria in order to ensure eligibility for financial support for the consumption of certain biomass fuels. Member States should have the possibility to adopt such specific criteria for installations using biomass fuels and located in an outermost region as defined in Article 349 TFEU, as well as for biomass used as fuel in such installations which does not comply with the harmonised criteria for sustainability, energy efficiency and greenhouse gas emission reduction set out in this Directive [13].

(81) Directive (EU) 2015/1513 of the European Parliament and of the Council recognizes that the magnitude of greenhouse gas emissions linked to indirect land use change is capable of fully or partially cancelling out the greenhouse gas emission reductions linked to different biofuels, bioliquids or biomass fuels [13].

(94) Biofuels, bioliquids and biomass fuels should always be produced in a sustainable manner. Biofuels, bioliquids and biomass fuels used to meet the Union targets set out[1] in this Directive and those benefiting from support schemes should therefore be

required to comply with the sustainability and greenhouse gas emission reduction criteria of the Union's energy policy set out in Article 194 TFEU [13].

(101) Union-wide sustainability and greenhouse gas emission reduction criteria should be introduced for biomass fuels used in the electricity sector and the heating and cooling sector in order to continue to ensure a high reduction of greenhouse gas emissions compared to fossil fuel alternatives, to avoid undesired sustainability effects and to promote the internal market [13].

(114) If land with large carbon stocks, in soil or vegetation, is converted to grow feedstocks for biofuels, bioliquids and biomass fuels, some of the stored carbon will normally be released into the atmosphere as carbon dioxide (CO2). The resulting negative impact, in terms of greenhouse gases, can offset, in some cases by a large margin, the positive impact of using biofuels, bioliquids and biomass fuels [13].

Article 2

Definitions

24) biomass' means the biodegradable fraction of products, residues and waste of biological origin from agricultural activities, including substances of plant and animal origin, from forestry and related industries, including fishing and aquaculture, as well as the biodegradable fraction of waste, including industrial and municipal waste of biological origin [13].

32) "bioliquids" means liquid fuels intended for energy uses other than transport, including the production of electricity and heating and cooling from biomass [13].

(33) 'biofuels' means liquid fuels intended for transport and produced from biomass [13].

(36) "renewable liquid and gaseous fuels of non-biological origin" means liquid or gaseous fuels used in the transport sector other than biofuels and biogas, the energy content of which comes from renewable sources other than biomass [13].

Article 4

Support systems for electricity from renewable energy sources

5. Member States may limit the tendering procedures to certain technologies where the opening of support schemes to all producers of electricity from renewable sources would lead to sub-optimal results, taking into account: (e) in the case of biomass, the need to prevent distortions in the markets for feedstock [13].

Article 20

Access to and operation of networks

3. Annex I to Regulation (EU) 2018/1999. a, Member States shall, where appropriate, take the necessary measures to develop infrastructure for district heating and cooling systems to enable the development of heating and cooling from large biomass, solar, ambient and geothermal energy installations as well as waste heat and cooling [13].

Article 26

Specific standards for biofuels, bioliquids and biomass fuels produced from food and feed crops

For the calculation of the gross final consumption of energy from renewable sources, , the share of biofuels and bioliquids as well as biomass fuels consumed in transport, where produced from food and feed crops, shall not be more than 1 percentage point higher than the share of such fuels in the final energy consumption in the rail and road transport sectors in 2020 in that Member State, with a maximum of 7% of the final energy consumption in the rail and road transport sectors in that Member State [13].

Article 29

Sustainability and greenhouse gas emissions reduction criteria for biofuels, bioliquids and biomass fuels

Energy from biofuels, bioliquids and biomass fuels shall be taken into account for the purposes expressed in points (a), (b) and (c) of this paragraph only if they fulfil the sustainability criteria and greenhouse gas emission reduction criteria [13]:

(a) to contribute to the Union target set out in Article 3(1) and to the renewable energy share of Member States; 21.12.2018 EN Official Journal of the European Union L 328/129.

(b) to assess compliance with renewable energy obligations, in particular the obligation laid down in Article 25;

(c) to qualify for financial support for the consumption of biofuels, bioliquids and biomass fuels.

Biomass fuels shall meet the criteria of sustainability and reduction of greenhouse gas emissions when used in installations producing electricity, heating and cooling or fuels with a total rated thermal input equal to or greater than 20 MW in the case of solid fuels derived from biomass, and with a total rated thermal input equal to or greater than 2 MW in the case of gaseous fuels derived from biomass.

Alon with the points 2, 3, 4, 5, 6 and 7 of Article 29.

9. No later than 31 December 2026, the Commission shall assess, on the basis of available data, whether the criteria established effectively minimize the risk of using forest biomass derived from unsustainable production and meet the LULUCF criteria [13].

The Commission shall, if appropriate, submit a proposal to amend the criteria established for the period after 2030[2].

Article 30

Verification of compliance with sustainability and greenhouse gas emission reduction criteria

Article 31

Calculating the effect of biofuels, bioliquids and biomass fuels on greenhouse gas emissions

Article 33

Follow-up by the Commission

1. The Commission shall monitor the origin of biofuels, bioliquids and biomass fuels consumed in the Union and the effects of their production, in particular displacement effects, on land use in the Union and the main third country suppliers. This monitoring shall be based on the national integrated energy and climate plans and related progress reports of the Member States provided for in Articles 3, 17 and 20 of Regulation[3] (EU) 2018/1999 and on reports from affected third countries, intergovernmental organizations, scientific studies and other relevant information [13].

2. The Commission shall maintain a dialogue and exchange of information with third countries and with producers of biofuels, bioliquids and biomass fuels, consumer organisations and civil society on the overall implementation of the measures of this Directive relating to biofuels, bioliquids and biomass fuels [13].

3. In 2026, the Commission shall, if appropriate, present a legislative proposal on the regulatory framework for the promotion of energy from renewable sources for the period after 2030 [13].

[2] Directiva UE (2018)
[3] Directiva UE (2018)

Article 34

Procedure

1. The Commission shall be assisted by the Energy Union Committee established by Regulation (EU) 2018/1999 [13].

2. For matters relating to the sustainability of biofuels, bioliquids and biomass fuels, the Commission shall be assisted by the Committee on the Sustainability of Biofuels, Bioliquids and Biomass Fuels. That committee shall be a committee within the meaning of Regulation (EU) No 182/2011 [13].

STUDY CASE

This is a techno-economic study of a small-scale biomass Organic Rankine Cycle Combined Heat and Power for district heating. The main goal is to evaluate the viability of such a system providing techno-economic information to see the viability of the project. It focuses on the benefits and potential solutions associated with creating a biomass ORC-CHP system for district heating in a specific place.

District heating is a sustainable solution for supplying heat to residential and commercial areas. Biomass CHP systems are being taken into consideration as a renewable and environmentally friendly alternative to fossil fuel systems.

For this case, I am selecting the region of Scandinavia, whose countries are Sweden, Norway, and Finland. These countries are known for their constantly work moving towards renewable energy and district heating systems. These countries have a lot of forests which means they have plenty of biomass resources base and a good district heating infrastructure, making them ideal for installing small-scale biomass ORC-CHP system for district heating. Additionally, these regions have cold climates, which result that they consume a lot of heating.

Scandinavia has a lot of forests, and utilizing woody biomass from sustainably managed forests can be a viable option. Woody biomass can include various types of wood, such as wood chips, sawdust, and wood pellets. This biomass can be provided locally from forest residues and the availability of biomass in the region makes it a low-cost option for the biomass ORC-CHP system.

One specific city to install this system could be Stockholm, in Sweden. Stockholm is the capital and largest city of Sweden, with a population of over 1 million people. It has a good and modern district heating network. During the winters is a very cold places so like it was mentioned before there is a high demand for heating. By integrating a small-scale biomass ORC-CHP system into Stockholm's district heating network, it could contribute to cover the heating needs of a big number of customers. The city has set goals to become fossil fuel-free city, making it an ideal place to show the European community the environmental and economic benefits of a biomass ORC-CHP system.

Some of the factors we have to consider for a techno analysis are the following:

Biomass Supply, ORC-CHP System Design, energy production, heat generation and environmental Impact.

Some of the factors to consider in and economic analysis are:

Capital Costs, operational costs, financial Indicators, risk assessment and mitigation and comparison with other systems.

An example of a techno-economic analysis for a small-scale biomass ORC-CHP system in Stockholm could be:

1. Biomass Supply:

   Woody biomass feedstock necessary: 20,000 tons/year

   Biomass fuel price: $50/ton

2. ORC-CHP System Design:

   Heat-to-power ratio: 2:1

   ORC efficiency: 15%

   Investment cost: $2,000,000

3. Energy and heat Generation:

Biomass consumption rate: 4 tons/hour

Heat generated: 8 MW

Power generated: 4 MW

Overall system efficiency: 80%

4. Environmental Impact:

   Biomass combustion emissions: CO_2 - 0.1 tons/MWh, compared to fossil fuel systems, the biomass ORC-CHP system reduces CO_2 emissions by 90%.

5. System Control and Operation:

   Maintenance and repair costs: $50,000/year

   Operational hours per year: 7,000 hours

6. Performance Evaluation:

   Annual heat production: 56,000 MWh

   Annual power production: 28,000 MWh

CONCLUSION

In conclusion, the biomass ORC-CHP system is a promising solution for sustainable energy generation from biomass resources. The system has the potential to significantly reduce greenhouse gas emissions and contribute to the transition towards a low-carbon energy future.

The ORC-CHP system can efficiently convert the waste heat generated from the biomass combustion process into electricity, improving the overall energy efficiency of the biomass plant. The use of an organic Rankine cycle allows for the generation of electricity at low temperatures, making it possible to use biomass fuels that are not suitable for traditional steam-based power plants.

Optimizing the biomass ORC-CHP system is crucial to achieving maximum efficiency and economic feasibility. It requires careful selection of the working fluid, appropriate heat exchanger design, and sizing of the components based on the specific operating conditions of the application. Additionally, the integration of the ORC-CHP system into existing energy systems must be considered to ensure that it operates optimally and delivers maximum benefits.

The biomass ORC-CHP system has the potential to provide a reliable and sustainable source of electricity, heat, and cooling, making it an attractive solution for a wide range of applications, including industrial processes, district heating, and rural electrification. However, further research and development are necessary to optimize the system's performance and accelerate its adoption in various industries. Overall, the biomass ORC-CHP system represents an important step towards achieving a more sustainable and environmentally friendly energy system.

BIBLIOGRAPHY

TEXT REFERENCES

[1] Konstantinos Braimakis, Antonios Charalampidis and Sotirios Karellas (2021). Techno-economic assessment of a small-scale biomass ORC-CHP for district heating. Energy Conversion and Management, Volume 247.

[2] Bob Gemmer (2019). Organic Rankine cycle integration and optimization for high-efficiency CHP genset. U.S. Department of Energy.

[3] CORDIS (1998). BM.-00120-98: BIOMASS FIRED CHP PLANT BASED ON AN ORC CYCLE - PROJECT "ORC-STIA-ADMONT". European Commission.

[4] Morales-Contreras, J., Hernández-Sotelo, D., Serrano-Bravo, A., & Núñez-Carrera, A. (2022). Optimization of an Organic Rankine Cycle coupled with a biomass boiler for small-scale applications. Journal of Energy Storage, 44.

[5] Joaquín Navarro-Esbrí , Francisco Molés , Bernardo Peris , Adrián Mota-Babiloni, José Pascual Martí , Roberto Collado , Manuel González (2017). Combined cold, heat and power system, based on an organic Rankine cycle, using biomass as renewable heat source for energy saving and emissions reduction in a supermarket. Science Direct.

[6] Ciclo de Rankine. Química.es.

[7] Takaaki Furubayashi (2022). The role of biomass energy in a 100% renewable energy system for Akita prefecture, Japan. Energy Storage and Saving.

[8] Muhammad Saleem (2022). Possibility of utilizing agriculture biomass as a renewable and sustainable future energy source.Heliyon.

[9] A.A. Adeleke , P.P. Ikubanni, T.A. Orhadahwe, C.T. Christopher , J.M. Akano , O.O. Agboola, S.O. Adegoke, A.O. Balogun, R.A. Ibikunle (2021). Sustainability of multifaceted usage of biomass: A review. Heliyon.

[10] Climeon. CREATING A SUSTAINABLE FUTURE WITH WASTE HEAT RECOVERY.

[11] Santiago Ruiz Rosales, Ricardo Novella Rosa, Carlos Micó Reche and Javier Montsalve Serrano(2016). Cuestiones y problemas resueltos de Termodinámica técnica. Universidad Politécnica de Valencia.

[12] Lisa Branchini, Andrea De Pascale, Francesco Melino and Noemi Torricelli (2020). Optimum Organic Rankine Cycle Design for the Application in a CHP Unit Feeding a District Heating Network. Energies, 13(6), 1314.

[13] Directiva UE (2018). Diario Oficial de la Unión Europea: Directivas. L 328/82.

[14] (2023). HVAC Load Calculations Worksheet. Engineering Design Resources.

[15] Tumpa R. Sarker, Castaneda S. German, Venu Babu Borugadda, Venkatesh Meda, Ajay K. Dalai (2023). Techno-economic analysis of torrefied fuel pellet production from agricultural residue via integrated torrefaction and pelletization process. Heliyon.

[16] Maria Anna Chatzopoulou and Christos N. Markides (2018). Thermodynamic optimisation of a high-electrical efficiency integrated internal combustion engine – Organic Rankine cycle combined heat and power system. Applied Energy.

FIGURE REFERENCES

EQUATION REFERENCES

Table references