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1 Executive Summary

This market analysis examines the potential of a new CHP technology, proposed by the Blaze project and based on gasification and solid oxide fuel cells (SOFC) that can work in the range of 100 – 5000 kWe. This market analysis shows that this technology has significant potential to become a key player in the energy production in the EU.

The main advantage of biomass CHP systems based on gasification and SOFC is their high efficiency and the potential to make the EU not only more independent on energy import, but also fulfilling the goals of both Renewable Energy & Energy Efficiency. These systems can achieve total efficiency levels of up to 90% (from which not less than 50% electricity), significantly higher than conventional systems. The flexibility of this technology is another advantage, as it can work with a wide range of biomass types, making it a viable alternative for much more % of the fossil fuel demand.

The binding targets for Renewable Energy and Energy Efficiency in the European Union are driving the demand for CHP systems that are based not on foreign fossil fuels but on biomass gasification and SOFC. The EU targets are ambitious and reaching them seems impossible if we go on as usual. Therefore, the EU needs a solution that tackles several obstacles simultaneously and opens new markets.

This document explains also that the high cost and complexity of this technology may limit its adoption by smaller organizations and individuals. To overcome these challenges, manufacturers and suppliers of CHP systems based on gasification and SOFC need to focus on improving the efficiency of these systems, simplifying its use and reducing their costs.

As a new technology, we have to find early adopters to create successes that can be easily transposed to other users. Therefore, three types of activities have been identified that may benefit from this technology in a significant way and will set an example for many market players of the same sector. This document gives practical steps to identify these three groups and starting lighthouse projects.

The market analysis concludes that the potential benefits of CHP systems based on gasification and SOFC outweigh the challenges. The increasing demand for decentralized energy solutions, the quest for fuel independence and the need for reliable backup power sources are expected to drive the growth of this market. Manufacturers and suppliers of CHP systems based on gasification and SOFC need to invest in research and development to improve the reliability and durability of these systems to build trust and confidence in the technology.

Overall, the market analysis suggests that the new CHP technology based on biomass gasification and SOFC that can work in the small/medium power range has the potential to become a game-changer in the energy supply, but it will require the support and investment of both the private and public sectors to realize its full potential.

2 Technology

Figure 1. The Blaze plant

The primary objective of the BLAZE plant is to efficiently convert various types of biomass waste, including forest, agricultural, industrial, and municipal waste, into thermal and electrical energy through combined heat and power (CHP). Although the plant is designed to operate at maximum power, it can also be used as a flexible plant for grid balancing by adjusting its power output as needed. The BLAZE plant can quickly ramp up its output from standby mode within 20 minutes. Additionally, the technology used in the BLAZE plant enables it to operate for many more hours per year (up to 6000 hours) than current technologies, which helps to keep the cost per kW and per kWh low, making it a key advantage of this technology.

The technology is designed to cater to a range of CHP capacities, varying from small (25-100 kWe) to medium (100-5000 kWe), which makes it ideal for various sectors such as industry, SME, agriculture, municipal infrastructure, and even residential applications like hotels and apartments. The technology boasts high efficiencies (50% electrical compared to the current 25% of biomass CHP), low investment costs (less than 4 k€/kWe), and operating expenses (approximately 0.05 €/kWh). Moreover, it emits almost zero gaseous and PM and therefore, the cost of electricity production is projected to be below 0.10 €/kWh, which is a very reasonable price considering the recent developments in energy prices.

Biomass gasification is a promising method for generating energy from various agricultural and woody waste materials. However, the technology faces the classic challenge of producing pollutants such as tar and particulate matter during the process. This issue must be resolved to ensure the fuel cell's optimal performance. The Blaze technology also faces this challenge, but it employs a cost-effective solution. Nevertheless, grading biomass types as more or less suitable is necessary for economic operation.

The technology comprises two major units: the gasification unit and the fuel cell. The process scheme is available at https://www.blazeproject.eu/process-2/. See also the following figure.

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The Fuel Cell.

The CHP technology depicted in the picture is predominantly built upon the Solid Oxide Fuel Cell (SOFC) fuel cell, which is the core element of the system. The SOFC fuel cell is known for its high electrical efficiency and modularity in different scales. In addition to generating heat within the fuel cell, the rest of the system also contributes to heat production, making it a CHP system with more than one heat source (at different temperatures).

The gasifier.

The gasifier is a crucial part of the system, responsible for converting feedstock into gas that can be used by the fuel cell. The gasifier used in this system is a dual bubbling fluidised bed gasifier (DBFB) that is designed for small to medium scale use. Compared to micro and small-scale fixed bed updraft gasifiers, the DBFB system is more cost-effective, compact, and efficient with better fuel flexibility, stable operation and lower emissions, especially when hot gas cleaning and conditioning measures are applied. By implementing these measures, Blaze technology can handle a wider range of biomass, overcoming the common obstacle of limited feedstock in traditional biomass power plants. This allows more biomass types to be applied, making biomass-based CHP more competitive with fossil fuel-based CHP.

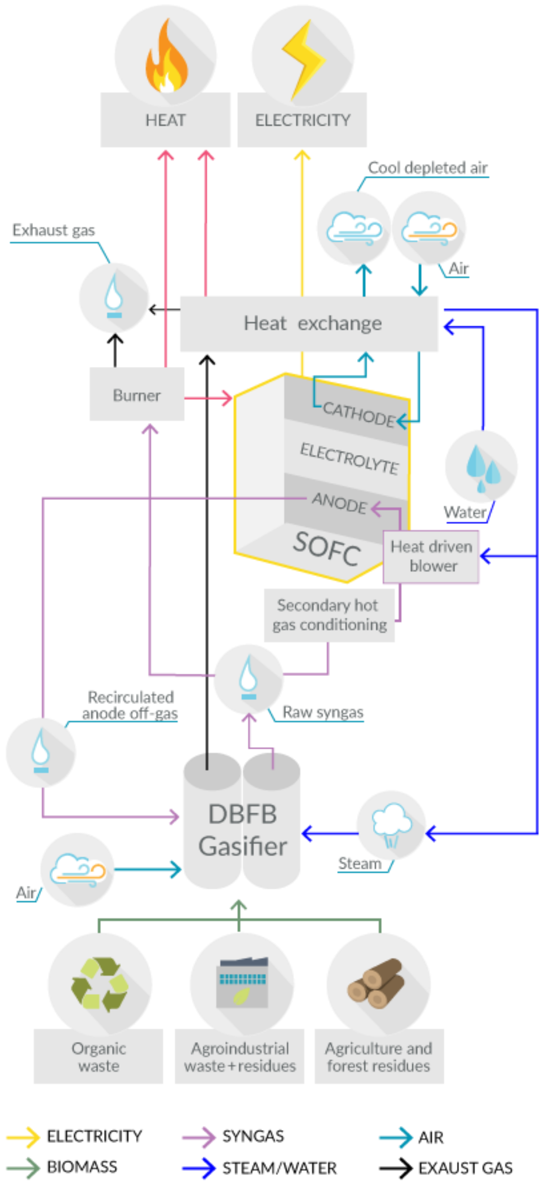


Figure 2. Blaze flow diagram

Gasifier process steps.

The plant's biomass is initially gasified in the DBFB, converting it into raw syngas. The DBFB's cleaning mechanism, which is based on sorbents and catalysts in the fluidised bed, results in syngas of a certain quality. The syngas is then processed in the Secondary Conditioner to prepare it for the fuel cell, where it enters under a specific pressure, using a Heat Driven Blower. The fuel cell converts some of the gas into water, while the remainder is reused in the gasifier. The thermal hub for many of the processes is the heat exchanger located above the fuel cell symbol. For instance, steam is produced from water in the heat exchanger, which combines with the CO fraction of the syngas in the gasifier to create CO_2 and H_2. The pictures below show how the plant is set up in a standard container.

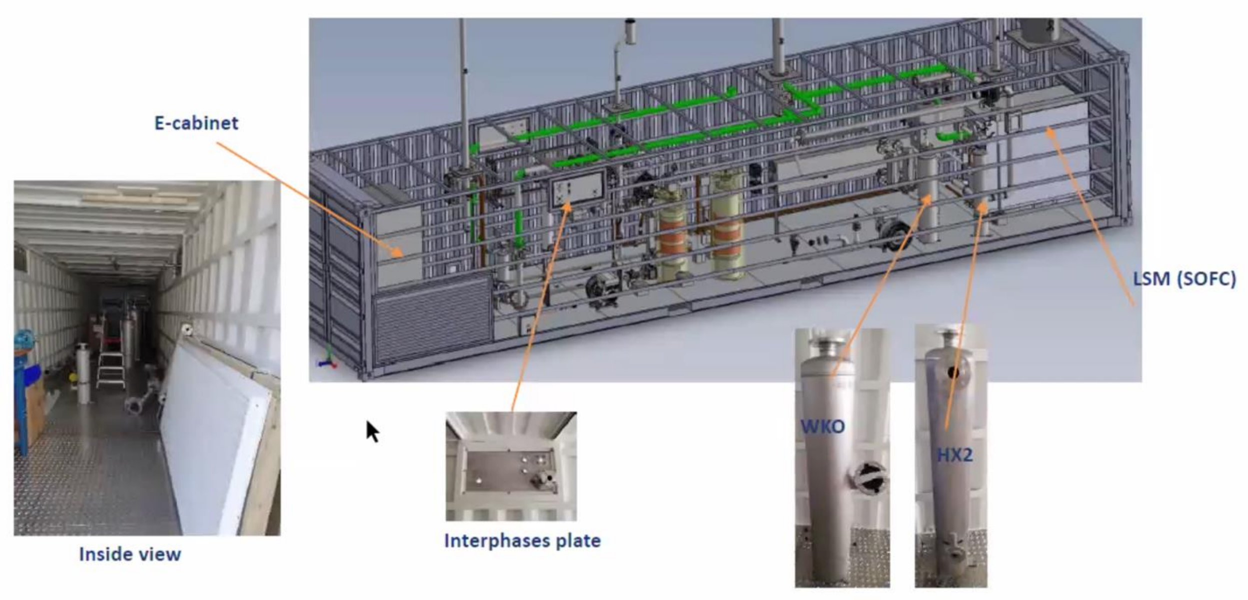


Figure 3. Containerised plant (llaria Mirabelli at Hygear).

3 Introduction & Methodology

In simple terms, a combined heat and power (CHP) plant generates both heat and electricity (or mechanical) energy simultaneously. Unlike the separate production of power and heat, which results in lower efficiencies ranging from 20-45% for power and 75-90% for heat, using solid fuels, the CHP plant boasts an overall efficiency of 80-95%. This is because the heat, which is usually wasted during power generation, is captured and transferred to consumers. The advantage of CHP is like getting two products at the cost of one, as illustrated in the accompanying figure.

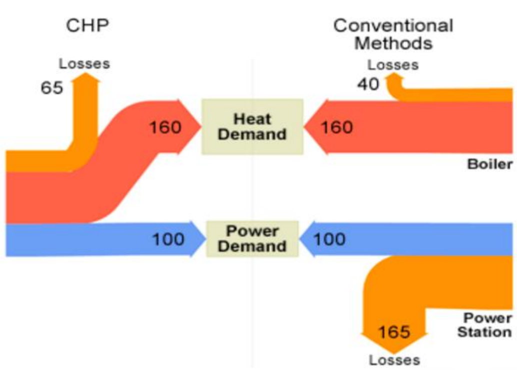


Figure 4. Difference between separate production of power and heat versus CHP

The right side of the image illustrates that 465 units of energy are required in traditional separate production with boilers and power stations to fulfil two different energy demands, giving 160 units for heat and 100 units for electricity. However, the major drawback of this conventional process is that 62% (165 units, the orange arrow) of energy is lost in power stations due to the thermodynamic process with steam turbines.

On the other hand, the left side of the picture shows how CHP collects the heat that is discarded in power stations, to meet (a local) heat demand, with only minor losses during production and transportation (65 units in total, the orange arrow). As a result, the energy demands for both heat and power are met with only 325 units, resulting in a 30% reduction in the original amount of 465 units. CHP is a common technology for achieving energy efficiency, but it is not directly related to renewable energy since until today it primarily relies on fossil fuels. However, Blaze is an example that integrates biomass in this already excellent practice, combining the advantages of renewable energy and energy efficiency into one solution.

In certain industrial settings, it is possible to maintain a consistent ratio between the consumption of **H** and **P** of CHP, thanks to continuous production where heat and power are required, for example a milk factory, where there are many electric motors and chillers, while the heat is employed for pasteurisation. However, if the demand ratio deviates from the standard 160/100 (ratio between **H** and **P** for CHP with engines on fossil fuel), additional energy can be obtained from alternate resources such as a boiler for **H** or the grid or PV for **P**.

If this constant ratio is not possible on the demand side, full exploitation of **H** & **P** in any CHP installation can be obtained by **storage** of **H** or **P**. This is a crucial condition for success of CHP in the market, because the fixed ratio in a CHP plant between **H** & **P** is often seen as a complication of this technology and can be a reason to abandon a good opportunity. Therefore, it is useful to shed some light on the collateral benefits of energy storage and show that it is not only a question of saving on the energy bill, even if this is already a good argument in times of inflation of energy prices as we are currently experiencing. Instead, it can be a real game changer.

One collateral benefit that will convince decision-makers much quicker than cost savings is the *Security of Supply*. Let's take cooling as an example. For users like food factories, hospitals, hotels, shopping malls and fresh food stores, cooling is essential and a cold storage in the form of water (or much better ice) will help them to pull through black-outs or periods of extreme hot weather without losing clients, getting complaints or discarding large quantities of food. Avoiding these setbacks has a higher priority than decreasing costs and can tip the balance towards the investment in an energy storage, which is therefore a key factor for the acceptance of CHP. Considering that a great part of global electricity is eventually converted in a thermal form (20% for cooling according to www.IEA.org), such a thermal storage can be considered as a low cost alternative to electrical batteries for this part of power consumption. The convenience is not only due to the much lower investment per kWh for thermal than electrochemical storage, but also because batteries need still an electric chiller to produce cold. This is a limitation on the cold production capacity. The cold storage, on the other hand, has the needed commodity already in its final form and needs little energy to pump it around.

Figure 5. Ice storage.

Another key to CHP flexibility is tri-generation. This is a way to convert the H of CHP into cold, through an absorption chiller with an efficiency of about 70%. That is a big advantage compared to generating first the electricity with an efficiency of 40% and then still needing a chiller! Moreover, the absorption chiller will run on low temperatures, even down to 80 degrees, which is below the output temperature of most

CHP systems. This technology is an interesting option to extend the application of CHP to more yearly hours (including the summer, when there is less or no interest in heat). Some buildings like shopping malls and hospitals, even in a colder climate, need many more kWh for cooling than heating through the year. For those situations an absorption and an electric chiller can be placed next to each other to nearly double the cooling capacity of the fuel. When heat demand occurs, the absorption chiller can be switched off or work in part load.

These opportunities are available since many years but are still underutilised in CHP installations. This is a lost chance because as we will see in section 6 (THE ROLE OF COGENERATION IN EUROPE), that the progress of CHP in the **decade** 2010 – 2020 has been only 11% in the EU, against 50% progress in Renewable Energy. Thermal storage will remove hurdles for CHP and help it grow. This will obviously also work for Biomass CHP.

Biomass

CHP and Biomass are often considered two distinct technologies. Biomass is Renewable Energy, CHP is Energy Efficiency. Is it possible to have both of these worlds? The Blaze technology can make the bridge. Deliverable D2.1 of this project (Biomass selection and characterization for small-to-medium scale gasification-SOFC CHP plants) shows that the Blaze technology can realise CHP with many different kinds of biomass. This creates an opportunity to apply CHP in a way quite different from the actual situation, where it works on very few types of ready to use, standard fossil fuels.

Not only **fossil** fuel based CHP but also today's **bio**-CHP projects are very selective in the type of available feedstock, so each new project goes through its own unique and complex processes of decision making and that is one of the reasons that biomass CHP has a hard time of being recognised as a practical alternative to the current CHP technology, where the fuel question is very simple (gas or diesel. And even that "simple" situation is not enough for real CHP take-off, as we'll see later.

Solid biofuels with Blaze include an ample menu of possibilities:

1. Wood, forestry and forest industry residues
2. Agricultural and agro-industrial residues
3. The biological humid fraction of waste streams like manure, sewage water residue or residues from food processing (including restaurants, households and waste of food stores like out-of-date products)
4. Organic fraction of waste from households, industry, agriculture or forestry. This is not the same as item 3. Here are meant the human made products that chemically belong to organic compounds (carbohydrates, containing Carbon, Hydrogen, Oxygen) and include paper, wood, plastic, tyres).

Therefore, the amount of possible feedstock in the EU becomes very broad and comparable with the fossil fuel market.

Diversity, an advantage or an obstacle?

As long as one and the same process can deal with diversity there is no problem, in the case of the shown picture it is our stomach.

As soon as each different feedstock requires another type of technology, decision making becomes a challenge. With bioenergy there aren't luckily as many technologies as biomass types, but it is already very complicated to find the way to rational exploitation and authorisation. The smaller portions of specific types of EU biomass fall from the table and become… real waste, good for nothing and a cost for society.

The majority of biofuels contains liquid industrial wastes, like molasses and black liquors, and can be directly burned in a combustion unit to produce heat. This heat powers a thermodynamic steam or ORC turbine cycle. Advanced combustion plants have the capability to meet strict environmental standards. Partial combustion can be used to gasify relatively dry biomass feedstocks, particularly at smaller capacities, into fuel gas. Wet biomass residues and wastes, such as sludges, vinasse, and manure, along with crops and by-products, like molasses, can be transformed into biogas with methane as the primary energy component through anaerobic digestion. Fuel gas and biogas, once cleaned, can be utilized in internal combustion engines (ICE) at greater efficiencies than steam and ORC turbines at capacities less than 5 MWe. Cost considerations prevent the use of liquid biomass fuels, such as biodiesel or ethanol, as a primary fuel source for stationary applications. However, various industrial by-products and residues, including bark, bagasse, black liquor, molasses, stillage, vinasse, and others, are commonly used as fuel in combined heat and power (CHP) installations ranging from 1 to over 100 MWe. Additionally, ICE machines can be adapted for use with liquid fuel derived from solid biomass, as demonstrated in the SmartCHP project under Horizon 2020. See also this video.

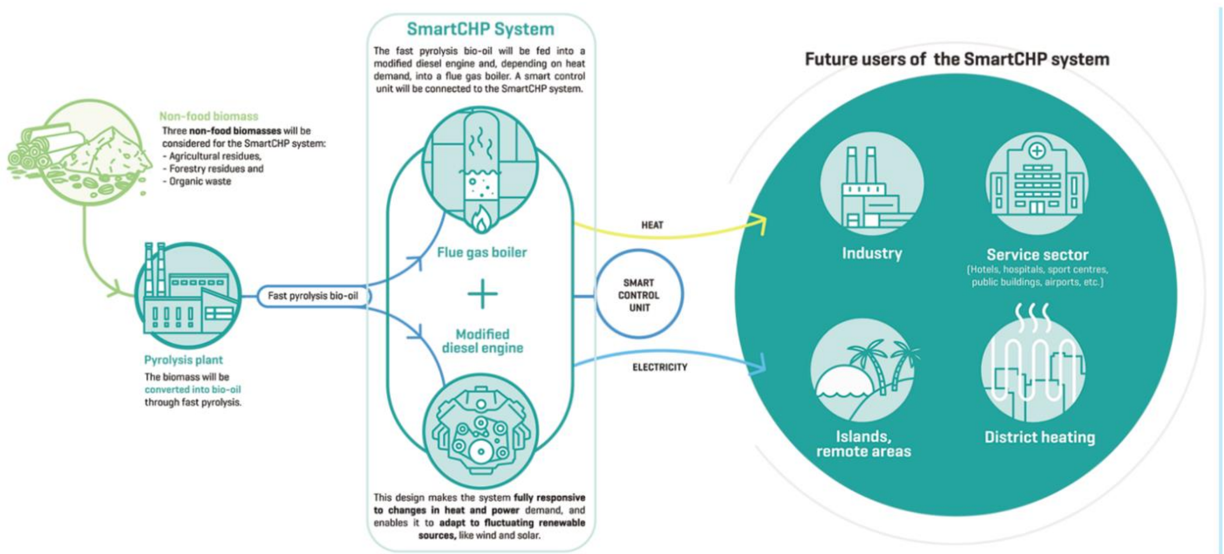


Figure 6. SmartCHP technical flow diagram

Figure 7 Convergence of many types of biomass into one standard format, like pellets.

However, the general impression with many technologies is that technology is adapted to biomass instead of the other way around. To meet the challenges of complying with EU environmental regulations and reducing dependence on traditional fuel suppliers, it is essential to use **all** available biomass residues and replace a higher percentage of fossil fuels. However, in order to achieve this goal, many different types of biomass must be made compatible with CHP. A convergence approach can be useful in converting a variety of solid biomass types into a single standardized fuel, allowing Bio-CHP to compete with fossil fuel-based CHP. This approach enables a wider range of biomass to be applied for energy production, using a smaller number of technologies.

The many types of biomass are not only a problem for energy transforming. Also the handling, storage and transport is specific for each type. It will be unpractical to collect many types of biomasses in a capillary way if each type needs its own technology to transport and to store it. Here too, convergence is necessary so that not the technology is adapted but the biomass.

Pelletisation of biomass

For a long time, Eubia has been developing the concept of pelletisation as a means of simplifying the logistics and storage of biomass. Biomass in its origin has different forms and varying levels of moisture, which makes transportation and handling problematic. Specific equipment is required for each type of biomass. The moisture content of the feedstock also increases the risk of degradation. Additionally, transporting large amounts of water in wet biofuel makes no sense. Pelletisation can be applied to many types of biomass, resulting in increased energy density and longer storage times. Pellets can be easily transferred between storage rooms and even blown through ducts like a liquid. Although pelletisation is not a straightforward process for every type of biomass, small units specialised for various types of biomass close to their origin, will make it easier to collect and safely store them at fewer central locations. One could even bring identification grains in each production lot so that mixtures can be easily identified automatically.

Figure 8 Pellets are ideal for transport and storage of bio-energy

The utilization of small pelletising machines will bridge the gap between small-scale biomass producers and consumers, leading to a significant increase in the practicality of biofuel production in the EU. By adapting the biomass to technology rather than the other way around, through fuel transformation processes such as cleaning, gasification (Blaze) and Fast Pyrolysis (SmartCHP), authorities have less to study and can easily scrutinize and approve each new project. Additionally, granting small and medium prosumers easier access to

Bio-CHP by creating small scale flexible technology like Blaze & SmartCHP will increase market penetration. Finally, a marketplace with a limited number of standard and easily recognisable fuels will significantly simplify operation for the supplier and end user of feedstock.

Concluding, the aim of this study is to assess the market standpoint for small-medium scale (100 kW_e – 5 MW_e) CHP facilities in general and the BLAZE gasifier plant in particular in the European market. This technology is suitable for small-scale applications and can utilize various types of biomass. Funded by Horizon 2020, the BLAZE project has successfully developed a low-cost, advanced, zero-emission, small-to-medium-scale integrated gasifier-fuel cell CHP plant. Although further efforts are required to make it commercially available, significant progress has been made in integrating various technologies and identifying compatible biomass types for installation.

The following analysis will present a comprehensive summary of the CHP market in Europe, including its current state, regulatory framework, and future projections until the year 2050. Additionally, the analysis will concentrate specifically on the most favorable markets and applications for the BLAZE technology, as well as conducting both SWOT and competition analyses.

4 The Context

Usually, CHP is considered as a technology from the Energy Efficiency field as we saw in the flow diagram at the start of the previous chapter. With the Blaze and any other Bio-CHP technologies we are however in both realms of Energy Efficiency and Renewable Energy at the same time. It can get therefore the tailwind from different EC objectives as we will see in this description of the context.

According to KPMG, the European Union aims to make Europe the first climate-neutral continent by 2050, following the climate targets set in the Paris Agreement,. On 12^{th} December 2019, the European Council, together with the European Commission, established the European Green Deal (EGD), the core EU strategy to fight climate change and achieve climate neutrality. As a first step, the Commission proposed an initial set of targets to be met by 2030.

"Fit for 55" policy package of the European Commission

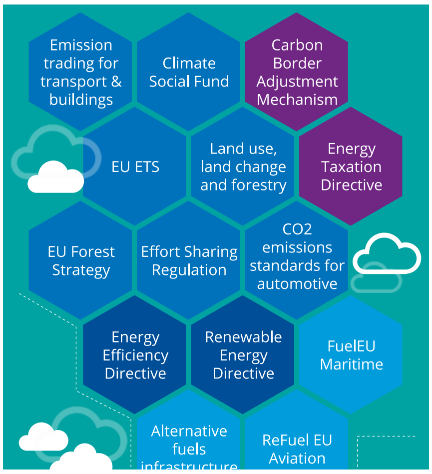


Figure 9 Focus areas of Fit for 55 (KPMG)

While the EGD represents a general action plan to fight climate change, the **Fit for 55** package offers the preparatory path to meet the targets of the EGD. More specifically, **Fit for 55** focuses on specific topics that need particular attention (see figure) and need a strong green transition to achieve climate neutrality.

The figure shows energy-related areas in dark blue. The "Fit for 55" package, which aims to reach at least 55% net greenhouse gas emissions reduction by 2030 compared with 1990 levels, is still far from its objective. In 2021 the EU was at about a quarter reduction compared with 1990, so there are yet 30% to realise in 8 years!

Another part of the "Fit for 55" package is the **Renewable Energy** Directive (RED II). Proposals for RED II cover renewables targets, targets for the industrial sector, the use of green hydrogen, transparency obligations, renewable power purchase agreements (PPAs), transportation and credit systems.

RED II, Fit for 55 and Green Deal all focus on Sustainable Development. On the other hand, in the last two years, the economy of the EU has been hit by Covid-19 and the RU-UA conflict.

After the COVID-19 health crisis, many Governments and the EC took the decision to leverage Sustainable Development as cornerstone for the economic recovery from the economic slowdown. As recently as 17/05/22, the EU Commission therefore published its REPowerEU plan. This date is after the outbreak of the war between Russia and Ukraine, so it includes the objective of becoming independent from Russian natural gas, coal and oil. In 2021, the EU imported more than 40% of its total gas consumption, 27% of oil imports and 46% of coal imports from Russia. Energy represented 62% of EU total imports from Russia and costed €99 billion. The Commission published its plan, part of REPowerEU, outlining measures to drastically (not yet defined) reduce Russian gas imports from its 2021 level of 155 billion m^3 (bcm) before the end of this year – and reach even complete independence from Russian fossil fuels well before the end of 2029. For the natural gas part, this means a transition from 155 to 0 bcm in 8 years.

Comparing this purchase of natural gas from Russia (leaving aside oil & coal) with the amount of energy that is contained in EU biomass resources, we can look to the Blaze report D2.1 "Biomass selection and characterization for small- to-medium scale gasification-SOFC CHP plants". It estimates the potential of dry biomass in the EU per year at 678 878 kTon among a number of types, which are compatible with the Blaze technology. See the chapter on BIOMASS AVAILABILITY, further on in this document.

Taking the specific energy content from each of these and multiplying with the amount in the EU, one obtains an amount of 179% of the above-mentioned energy in the 155 bcm gas, imported from RU into the EU in 2021. This doesn't take into account the imported Russian coal and crude oil but it is still a great potential to exploit. Blaze is one of the EU supported technologies that is able to do that on a small to medium scale, reducing the logistic effort and giving chance to local initiatives and economy. This is exactly what is needed to repower the economy after the slowdown from Covid 19 and the conflict between RU and UA.

REPowerEU also refers to the important role that biomethane can play, providing an additional 18 bcm by 2030. The digestate, remainder from its process (anaerobic digestion) is also a possible feedstock for Blaze, after some processing. Renewable hydrogen (an intermediate product of the Blaze project, by the way) is also seen by the EC as a major new alternative supply source, with the potential to reach 10 bcm by 2030, with scope for an additional 10 bcm through imports. So, it's evident that Blaze has a greater potential than only bringing the mentioned types of biomasses into the reach of CHP.

The Commission is aware of the need to address the different bottlenecks that hinder the roll out of renewable energy projects. To address this issue, it will publish in May a recommendation on fast permitting for renewable energy projects, which aims to support the use of all flexibilities already granted by EU legislation and to remove remaining obstacles. This may become an important instrument to address the hesitation of the market with new technologies. Especially potential users of *smaller* systems and local authorities are often conservative in their choices. This perceived obstacle is also the reason that we recommended before to convert many types of biomass in a few standard types of pellets.

The EC states in a press article that "The measures in the REPowerEU Plan can respond to this ambition, through energy savings, diversification of energy supplies, and accelerated roll-out of renewable energy".

Blaze responds to all these 3 elements:

- Energy Efficiency by combining heat and power instead of producing them separately. The message is here: if we produce renewable energy, let's consume it also in an efficient way.
- Diversification of energy supplies by using the resources within EU borders that were considered waste until now.
- Accelerated roll-out of renewable energy, by opening the gates for many more types of biowaste.

No longer is it necessary to limit the feedstock to a particular kind of biomass, increasing the risk of price fluctuations, negative side effects or scarcity. The Insecurity of Supply from not only Russia but also from other countries (not all of which are politically stable) will certainly have its impact on the use of fossil fuels that soon might become the "alternative energy". It will do so by setting higher prices on fossil fuels and its (electric) derivatives but also by working on the risk perception of these supplies. The actual energy crisis will make the scenario for technologies like Blaze much more positive than what even at the start of the project could have been foreseen.

The Recovery and Resilience Facility (RRF) is at the heart of the REPowerEU Plan, supporting coordinated planning and financing of cross-border and national infrastructure as well as energy projects and reforms.

The Commission is also giving guidance on renewable energy and power purchase agreements (PPA) and will provide a technical advisory facility with the European Investment Bank.

The PPA is a kind of cooperation that gives financial security to the power producer during a number of years. The purchasing party for the energy can be a local authority (LA), while (local) private parties may produce & sell the energy. Many local resources like agricultural residues and forests are managed by LAs, which have also a major influence on permitting. In this way, LAs can help local producers to have a stable income and feedstock, agreeing on an interesting energy price for the LA that might be stabler than energy prices on the international markets. So, there is a clear win-win situation. The author has been stakeholder in a PV plant on a sport centre. A cooperative of citizens was the owner of the PV plant of 225 kW and the municipality was happy to close a PPA for 20 years and a nice tariff. This tariff was certainly an excellent alternative for standard investments, where interest was very low. Today this tariff would have been less advantageous but with a form of inflation correction, a PPA can be made attractive and be a good instrument for financing a project like Blaze, especially because the steady demand for biomass and even e part of municipal waste is a big plus for local communities.

Figure 10 PV cooperative of citizens on sports hall of Ruswil (near Luzern).

5 The role of cogeneration in Europe

Cogeneration supplies currently 11% of electricity and 15% of heat in Europe. Relevant data was produced in the SmartCHP project, which is similar to the Blaze project in that it is combining CHP with Biomass feed stock. It is also a Horizon 2020 funded project. In its market analysis https://www.smartchp.eu/report/ it writes: the share of CHP in total electricity generation at EU-27 level has made a progress of 11.5% during the **last decade**, going from 11% to 12,4%. During the same period, the overall CHP electrical capacity has increased by approximately 20%, while CHP thermal capacity has virtually remained the same, leading to a reduction -at EU-27 level- of the Heat-to-Power Ratio. In other words, our interest for the electricity from CHP grew faster than our interest for its heat. This explains also why electrical/thermal energy was only 11% resp. 15% as said above (usually, electricity production is two thirds of heat, in CHP).

Let us now compare this with the progress of Renewable Energy. On the following link we see this development:

https://ec.europa.eu/energy/sites/ener/files/renewable_energy_progress_report_com_2020_952.pdf

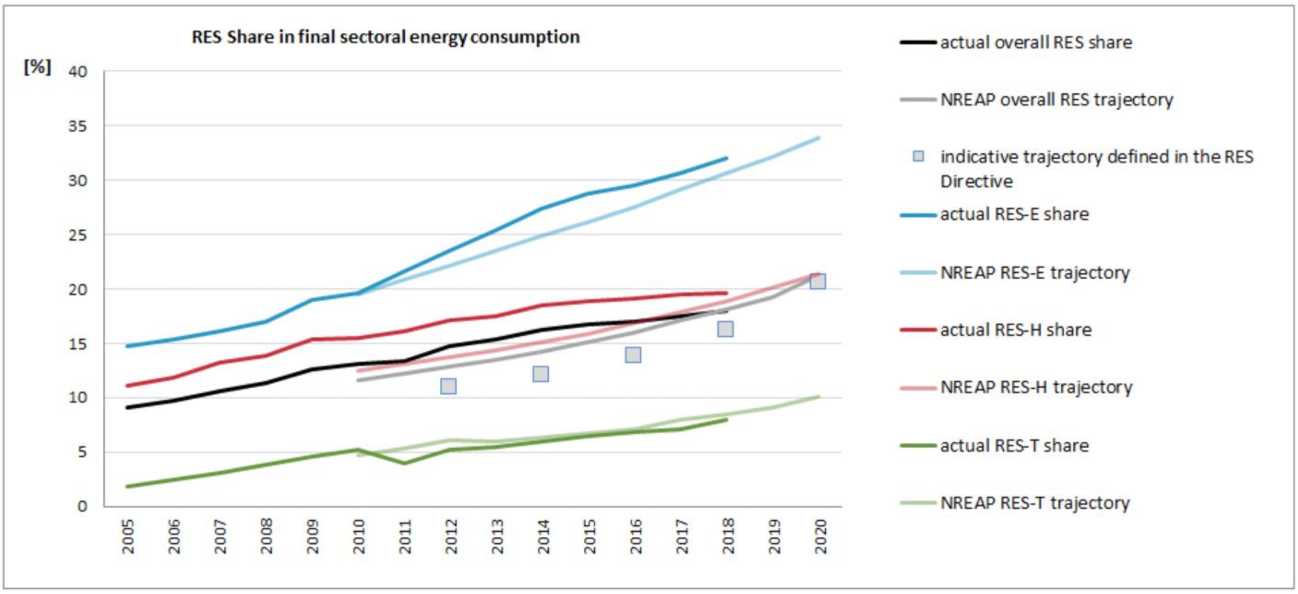


Figure 11. Actual and planned renewable energy shares for the EU(2005-2020, %). Source: Eurostat and National Renewable Energy Action Plans (NREAP)

In the graph can be seen that in the same period, "actual overall RES share" (black line) went from 12% to 18% in also a (5y shifted) decade, an increase of 50% or nearly 5 times as quick as CHP. That is a lost chance.

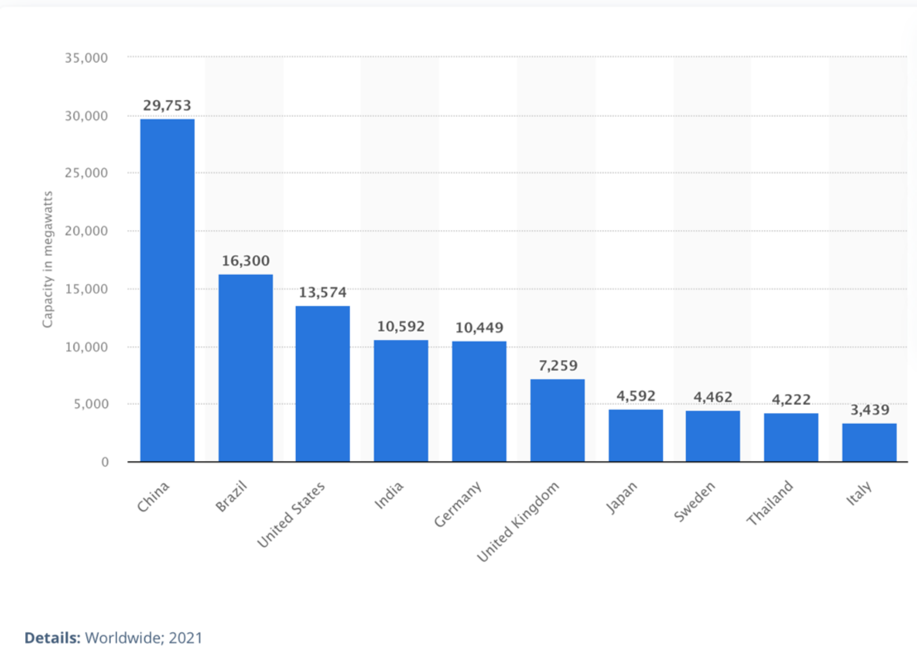
Within the general CHP scenario, ST (steam turbines), GT (gas turbines) and CC (combined cycle) are applied to medium-to-large scale while at small-to-medium scale ICE (internal combustion engines) are used. The CHP heating capacity is about 300 GW_{th} with a total heat production of 775 TWh, i.e. an average of ≈ 2.5 thermal/electrical power ratio and 2500 annual equivalent hours; Germany, Italy, Poland and the Netherlands have the largest capacity installed (Eurostat 2017, CHP data 2015). Unfortunately, data on CHP is not very recent: as of Dec 2022, Eurostat provides CHP data for the period 2005-2019.

Natural gas dominates the CHP fuel market with a share of about 45% (which is surely very different since the outbreak of the RU-UA conflict), followed by solid fossil fuels and peat at 18%, oil and oil products at 5%, other fuels at 13% (industrial wastes and coal gases).

Renewables, mainly biomass and in particular low-cost biomass or biomass waste, are becoming increasingly important having reached 20% of the market (Eurostat 2017, CHP data 2015). Now, with the energy crisis going on, the new and unknown data will surely give a quite different picture, which will change every month. Compare the current statistics (155 bcm gas imported from Russia in 2021 into the EU) with the equivalent value of 277 billion cubic meter (bcm) natural gas equivalent that is available already by taking only the Blaze compatible solid biomass, and it will be clear that potential for change is available.

Because biomass plants have energy storage capability in the form of feedstock, and as smaller units make it easier to modulate output, Biomass CHP can integrate and support grid penetration of volatile solar and wind power. Therefore, it is expected to have tailwind for significant growth in bio-CHP on all scales: small, medium and large. The bioenergy contribution for heating and cooling has currently the largest share (88%) of all RES used for heat and cooling with 76 Mtoe, not far from the 2020 Member States objective of 90 Mtoe (SET-PLAN, action 8, issue paper, 2016). CHP systems have already a significant penetration in the EU industry, producing approximately 16% of the final industrial heat demand (Green Public Procurement, CHP Technical background report, 2010). It is worth noting that cogeneration (CHP) plants account for about 60% of EU-28's bioenergy production from solid biomass (EurObserv'ER, 2017). The total EU28 energy demand for Heating and Cooling (H/C) equals 51% of the total final energy demand; the majority of the demand for H/C is due to space heating (52%), followed by process heating (30%) and water heating (10%) with ambitious policy objectives which include, for instance that all new buildings must be Nearly Zero Energy Buildings (NZEB) from 31st December 2020 (public buildings from 31st December 2018, SET-PLAN, action 5, issue paper, 2016. The European bioenergy objective derived from residues is 314 Mtoe; the currently consumed share is less than half of this value (Solid biomass barometer, 2017). Compared with the above mentioned 277 bcm of gas equivalent, this is 314 * 1,20 bcm = 376 bcm, that means it is of the same order of magnitude as the Blaze compatible solid biofuels (32% more) and probably includes most of it.

Looking to the **bioenergy power** (till now we discussed **energy**), it has been steadily increasing during the past decade, globally. As presented in the figure below from 2021, the world bioenergy capacity was estimated at 139 gigawatts (GW, see figure below) (Statista.com, 2022).



This is to compare with the 7 172 GW of global electricity power in 2020 (statista.com, all technologies included) or only 2%.

Now it is interesting to note that this 7+ TeraWatt is going to double, up to 2050. That is 12.4% growth each 5 years. This is about the growth rate in a whole decade for the entire CHP sector. So, this growth must be added to the ambition (in %) that we have for the relative growth of CHP to total power capacity.

Here, the saying "Who stands still is going backwards" is really true. In view of the political situation of present and future, there should come more pressure on CHP development.

Bio-CHP in the context of the general European CHP scenario

In this section we will see what the proposed Blaze technology will bring.

Considering the state of art of *current* small-medium solid biomass power plants (where Blaze offers an alternative), the major limitations to optimal use of the bioenergy potential are caused by:

- **Low annual operating time**: only 4000 hours
- **Low Electrical efficiency:** 25%
- **Difficult permitting:** high local and environmental impact & complexity
- **Expensive:** capital cost higher than 5.000 €/kW$_e$.

They cannot compete with the liquid or gaseous fossil fuels small-medium CHP, where, even if the fuel cost is higher, the CAPEX is much lower (around 1000-3000 €/kW$_e$ depending on the type, size and feeding fuel system. ST can have lower CAPEX but are large and need a boiler or other steam source. The annual operating time of these systems are higher and also local emissions (CO, OGC, NOx, PAH and PM) are lower (EPA Combined Heat and Power Partnership). That is a lot of factors to compete with.

6 The regulatory framework

Under the EU's CHP Directive, also known as the 2004/8/EC, the European Commission set an agenda for promotion of the use of cogeneration, as the means of improving the security of energy supply across EU as well as increasing the overall energy efficiency (EC, 2004). After the conflict between Russia and Ukraine, the Security of Supply (yes, SOS) has become really a significant driver.

Figure 12 Complicated legislation in EU for Energy Efficiency.

According to the CHP Directive, the Member States were required to report on their respective national potential for the development and promotion of CHP. In 2012 the CHP directive was revoked and replaced by the much more **encompassing Energy Efficiency Directive (EED)**. The main instruments of this EED were energy efficiency obligation schemes, requiring 'obligated parties' determined by Member States – energy distributors and/or retail energy sales companies – to reduce the volume of energy sales to final customers by 1,5 % annually. This had to go beyond the existing energy efficiency standards regulated by other EU legislation. Gradual phase-in is allowed, as are some exemptions (for instance, the calculation can exclude energy for industrial activities), provided that the exemptions do not add up to more than 25 % of required savings. Member States can decide to achieve the same savings by alternative measures, such as CO_2 taxes, financing schemes, fiscal incentives, training and education, energy efficiency standards, norms and labelling that goes beyond those mandated by EU law. Ultimately, Member States are free to choose how they will achieve the savings; currently, there are 477 different measures in use (EPRS 2019). It seems, in comparison with Renewable Energy legislation a bit more complicated to make progress with Energy Efficiency technology and support. This complexity explains possibly the limited success of Energy Efficiency in EU and the world.

The EED was further revised following the presentation of the Clean Energy Package by the European Commission in 2016. In its revised version, it entered into force in December 2018 (Member States were required to transpose the directive into their national legislation by June 2020). The EED set the headline EU target of at least 32.5 % efficiency improvements by 2030, a non-binding goal to be achieved through indicative national contributions reflecting final and/or primary energy consumption. This is consistent with a maximum limit of 1273 Mtoe of EU primary energy consumption or 956 Mtoe of EU final energy consumption by 2030. However, in case of substantial cost reductions or to meet international commitments (such as the Paris Agreement), this headline target may be revised upwards (but not lowered), on the basis of a new legislative proposal in 2023. The revised directive sets energy saving obligations of 0.8 % per annum between 2021 and 2030, which will then be calculated in terms of final energy consumption (not energy sales). Compare this with what iea.org wrote on euractive.com in Dec 2022: “After global electricity demand grew by a strong 6% in 2021, propelled by rapid economic recovery as COVID-19 lockdowns eased, we expect growth to slow to 2.4% in 2022 – about the same as the average from 2015 to 2019.” So an energy saving obligation of 0,8% per year seems very scarce and will not be able in itself to curb down the growth without end of energy consumption.

Obligations may include policy measures enacted before 2020 that impact on energy savings in the 2021-2030 period. More sectors would be covered by energy-savings obligations than under the previous EED, although Member States could still choose to exclude transport, certain industrial activities and some energy use in buildings (EPRS 2019).

Given the legislative framework of the EED, CHP technology can expect a fertile ground and no significant regulatory hindrances given their high impact on energy efficiency and capacity to create heat and power at the same time from a single feedstock. However, biomass has faced other issues in the past years, especially relating the biofuel application and the land-use, including the controversy in indirect land use. In this regard, the revised Renewable Energy Directive (RED II) has updated the conditions upon which renewable biomass can be used. BLAZE makes use of biomass waste and residues, so it is not subject to the Biomass sustainability criteria listed by RED II. Other requirements listed by RED II with regards to cogeneration plants are not of concern for BLAZE given that they apply to plants with installed capacity equal to and above 20 MW, which is outside the range of Blaze.

6.1 Supporting schemes

Supporting schemes can be divided into central support from the European institutions (not only the Commission but also the EIB and other funds) and indirect support, for example (EU coordinated) national support and approval for and monitoring of national initiatives. So, in each case the European institutions have a major influence on the kind of support.

6.2 Central European support

The European Commission has several central instruments to support CHP, Bio-Energy or a combination thereof.

The site with the title "EU funding possibilities in the energy sector" contains most if not all the central support methods. This site is interesting for organisations in search of direct funding, R&D institutes, investors and the public sector that is interested to implement Sustainable Energy (Renewable Energy & Energy Efficiency) in its own activities. It has also objectives of strengthening the economy in the current hard times and to balance green energy performance and social wellbeing between member states.

A few of them are described in more detail below before we focus on national schemes.

6.2.1 R&D

There is a central website with all Funding and Tenders for research and development and a search function to get to various areas, for example "energy", "CHP" or "biomass". After getting the search results, filters can be applied that help to tune in on Open or Forthcoming calls, funding programs and funding period.

For example Horizon Europe will have a budget of around €95.5 billion for 2021-2027 (current prices) for research and development.

6.2.2 EU Structural Funds

The European Structural and Investment Funds (ESI Funds, ESIFs) are financial tools governed by a common rulebook, set up to implement the regional policy of the European Union, as well as the structural policy pillars of the Common Agricultural Policy and the Common Fisheries Policy.

An example of an ESIF project with bio energy is described in a NEWS ARTICLE of 3 December 2020:

"Commission approves €23 million investment aid to support high efficiency cogeneration fuelled by biomass in Poland".

The support takes the form of a direct grant from EU Structural Funds managed by the national agency.

As in the 2014-2020 ESIF OVERVIEW, 740 billion was spent in the 7 years (2014 – 2020). For the next 7 years [2021-2027], € 392 billion has been allocated to 5 objectives, among which "A **greener**, low-carbon transitioning towards a net zero carbon economy". Biomass CHP is certainly a candidate of such an objective.

The **ESIF**s are subdivided in sub-funds ERDF, CF, ESF+ JTF as explained in The European Structural and Investment Funds – ESIF [2021-2027] and it is good to integrate also the objectives of as much as possible of these programmes into each proposal for biomass energy in order to raise chances for funding.

6.3 European Investment Bank

The EIB declares on its web site "The EIB is the first international finance institution to **end financing for fossil fuel** projects and to focus its support on projects that are fully aligned with the Paris Agreement."

The EIB supports these projects with Loans and Equity (or both). It is important to know the difference. Also Guarantees belong to the products, in order to cover the risks of large and small projects. The support amount per project or program is mostly in the 2 to 200 million range. Supported countries are world wide, not only EU member states.

The EIB finances billions of euros in loans every year directly by themselves, but do a lot of work with mandates and partnerships. This allows them to better serve existing clients, find new partners, enter new markets and help more people across the world. Especially for new clients that need smaller sums under, say, 10 M€ it is recommended to contact these aggregators, which are able to group several projects under one larger so called "blending" program. See for example REGIONE EMILIA-ROMAGNA EU BLENDING PROGRAMME.

6.4 National support

The European Union institutions provide also indirect support through the Member States, for example by monitoring and coordinating national support, legislation and initiatives.

6.5 Guidance for (national) renewables support schemes

(From https://energy.ec.europa.eu/)

The EU adopted guidance for EU countries, while these are designing and reforming renewable energy support schemes. This guidance suggests that:

- financial support for renewables should be limited to what is necessary and should aim to make renewables competitive in the market.
- support schemes should be flexible and respond to falling production costs. As technologies mature, schemes should be gradually removed.
- unannounced or retroactive changes to support schemes should be avoided as they undermine investor confidence and prevent future investment.
- EU countries should take advantage of the renewable energy potential in other countries via cooperation mechanisms. This keeps costs low for consumers and boosts investor confidence.

6.6 Tenders for renewables

A relatively new trend is to open calls for realising Renewable Energy installations with a certain technology that will be able to produce energy at a certain price. This is mostly known in the area of wind and solar power. The message of a Member State to the tender participants can be like "Present a PV project of more than 10 MW in Regio X that will produce electric energy at a price of 0,04 €/kWh". With Biomass projects, it makes sense to add an additional requirement to guarantee a minimum power that is always available, as bio-energy is not as volatile as solar and wind power and the feedstock can be stored.

A study published in November 2022 analyses how tendering procedures, as one of the forms of public support, are fostering the deployment of renewables as part of the wider transition of the energy system.

6.6.1 Feed in tariffs

The OECD says about Feed-in tariffs (FITs): …are prevalent support policies for scaling up renewable electricity capacity. They are market-based economic instruments, which typically offer long-term contracts that guarantee a price to be paid to a producer of a pre-determined source of electricity per kWh fed into the electricity grid. The link above gives the FIT for all countries in the world. Scroll through 4 pages with the page overview on the bottom.

Feed in tariffs are well known and one of the first instruments to support Renewable Energy. One of the most known is the German EEG (with here an article of Wikipedia in English).

How to make it work better for biomass energy

A good way to grant a premium for non-volatile power, like biomass technology, is to vary the feed in tariff according to the market. Volatile power supply is becoming a problem because on top of the insecurity of volatile demand, also the supply side adds insecurity, which must both be compensated by the grid. This causes the price on the spot market to vary wildly. This price signal can be fed back to the Renewable Energy supplier to incentivize supply in moments of high demand. There is already an aggregator (**Next Kraftwerke**) that works in a few Member States and connects supply with demand on a very short time base. This aggregator collects several smaller suppliers in order to become a market player that is large enough to interact with the grid operators (aggregator function). Biomass energy suppliers can obtain a significant financial boost by filling in the gaps between supply and demand, using feedstock as an energy storage. Obviously, also biomass plants have to run a certain number of hours per year at high capacity to have a reasonable Return on Investment, but at least they have one parameter more than wind & solar to influence profitability and that is the flexibility in time.

6.7 Power purchase agreement (PPA)

A PPA is a contract between two parties, one which generates electricity and one which purchases it. In many cases also "PPPA" would be a good term, adding "Public" to PPA. It is indeed a way to get long term support from a public entity for Renewable Energy, so that investors have security for their capital. It is also a way for the public entity to connect with the citizens, which may have a share in the power plant.

An example of such a PPA between a municipality and local citizens with a PV plant on a sport centre was given in chapter 4 (Context). The dividend was variable but usually around 4% of the share.

It is obviously easier to get permissions for such a plant, as the Local Authorities (LA) are stakeholders and are aware of the advantages for local development. In case of biomass energy, the LA influences also the feedstock, if this is local. This is often an additional incentive as it can both decrease the cost of waste management and provide income for local farmers or forest operators. Finally, the LA can facilitate the necessary permissions.

A special fund for Sustainable Energy (Renewable Energy & Energy Efficiency) for the public sector is the EEEF. Halfway the page of this link is written “The eeef facilitates sustainable investments in the public sector, where projects are often hindered or decelerated due to budget restrictions and lack of experience with this kind of investment.”

6.7.1 Investment support

Investment support is direct subsidy into the realisation of the plant, for example the 50% law in Italy, where half of the plant is not even paid by the user but directly invoiced by the technology supplier to the state. Also, tax benefits belong to investment support.

It was difficult to find statistics on this, but the next figure of the European Commission gives in green the subsidy for Renewable Energy investments, per country.

Subsidies for different energy sources, as a percentage of GDP in 2015 and 2020, and in billion euros in 2020, source https://energy.ec.europa.eu

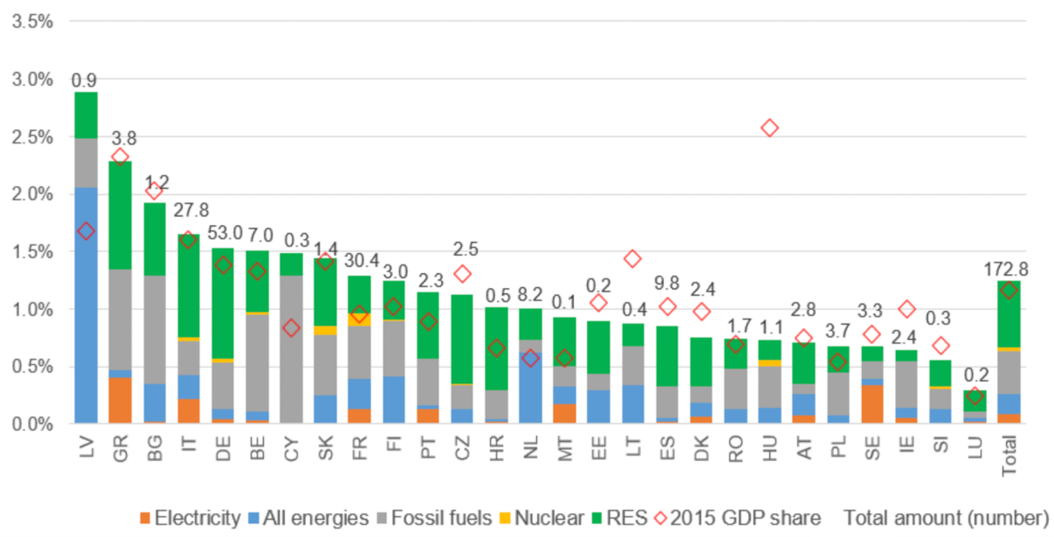


Figure 13. Subsidy for investment in energy sources.

Another source is the IEA. This link already contains a search of Renewable Energy within www.iea.org/policies.

6.7.2 Certification schemes

With certification on Renewable Energy, the producer is able to sell the physical energy separate from the ecologic premium and thus get two revenues. From the other side, the energy consumer that might not be able to produce Renewable Energy on the own site, is able to add the certificate to the own purchased “grey” energy and make it green. The motivation can be voluntary, or it can be imposed.

In this way, opportunities to produce Renewable Energy can be spread in a flexible way, rather than fixing an expectation of Renewable Energy to each consumer. In other words, wind energy can be exploited also by inhabitants and organisations in wind still regions.

6.7.2.1 European Renewable Energy certificates

The author has contributed to the start of recs.org, which in 2001 was still working as an European scheme but now supporting certification world-wide. In Europe, the certificates are now called Guarantees of Origin (GO) to designate the ability to track down, from which kind of Renewable Source the energy is coming.

The **European Energy Certificate System** (EECS) was developed to serve as the standardization system for the European GOs and is an integrated European framework for issuing, holding, transferring and otherwise processing EU energy certificates. The scope and focus of EECS now encompasses all forms of electricity and supports Directive 2012/27/EC (the Energy Efficiency Directive).

6.7.2.2 Voluntary national biomass schemes

Specifically for biomass, there are voluntary schemes to set standards for the (private) production of sustainable biofuels, bioliquids and solid biomass fuels. They help to ensure that **biofuels, bioliquids and biomass fuels are sustainably produced** by verifying that they comply with the EU sustainability criteria. For the certification process, an external auditor verifies the whole production chain from the farmer growing the feedstock to the biofuel producer or trader. This can be seen as concrete support, as actors in this field usually have difficulties to get trust for their products. The opinion of the author is that if the before mentioned pelletisation of most if not all types of biomass becomes common, it will become easier to create quality standards and also to fulfil the above mentioned EU sustainability criteria.

More information about the recognition process for these criteria can be found in the call for interest and the updated assessment protocol.

The European Commission has so far formally recognized 14 voluntary schemes. Examples can be seen in the table at the bottom of the web site "**Approved voluntary schemes and national certification schemes**".

7 The way ahead

7.1 Problem of the Blaze technology

The pressure of the society to deliver sustainable solutions is there, but it is not enough. We saw that Renewable Energy is not developing fast enough to attain the deadlines of the European Union; Energy Efficiency and CHP are developing even slower.

The crisis of the trust in global suppliers of commodities like energy from one side and the worsening climate disasters from the other side will have to provide the pressure on society to create more incentives and on market players to move quicker. This pressure is needed to help the success of the Blaze technology as it is not in an easy technology. As shown above, CHP is still seen as a technical solution with limiting boundary conditions (there must be a contemporary demand of power and heat in a certain ratio), which explains why CHP is not growing as quick as expected. Blaze adds extra conditions (biomass supply and fuel quality) to this picture, thus complicating the acceptance by the market. So, it is clear that not every potential user will step forward as an early adopter.

7.2 Solution: create example projects for early adopters

The way ahead to come out of this dilemma is to set examples.

Therefore, an identikit of the ideal user must be created. This user must be very unsatisfied with their current situation and the Blaze technology must address exactly their pain points. They will be willing to take the uncertainty of a new technology and the support mechanisms mentioned in this report can help to convince them. Selecting such market players from not one but different economic sectors will create groups where lighthouse projects can be implemented in a systematic way. For example, such a project can be implemented in the following three types of users:

1. An agro- or food industry that needs heat and power, and where lots of biowaste is created.
2. A municipality in a rural area, where biomass is available, and heat & power are needed for a health care, education, recreation like swimming pools and other users like offices and street lighting.
3. Hotels, best of all when in a rural area, where the heat is used for space heating and cooling (absorption heat pump for the summer). Also hotels near airports are ideal because of the high and constant energy demand and of the available technical personal for the plant maintenance. Airports are also often in rural areas near large cities.

If these users are on an island, energy prices may be higher and the conditions for the experiment still better. Also waste management is more expensive here and an opportunity to supply the base material for the Blaze plant.

The variety of these 3 groups will make it easier for other market players to recognise their own situation and take the early adopter as an example.

It is known that a pool of early adopters will do much to convince the "Early Majority" (see the figure below) about a certain technology. This is also the objective of this market analysis: to identify the Early Adopters and to help them to identify themselves as such. Later in this report, the SWOT and other information will help technology providers to find early adopters.

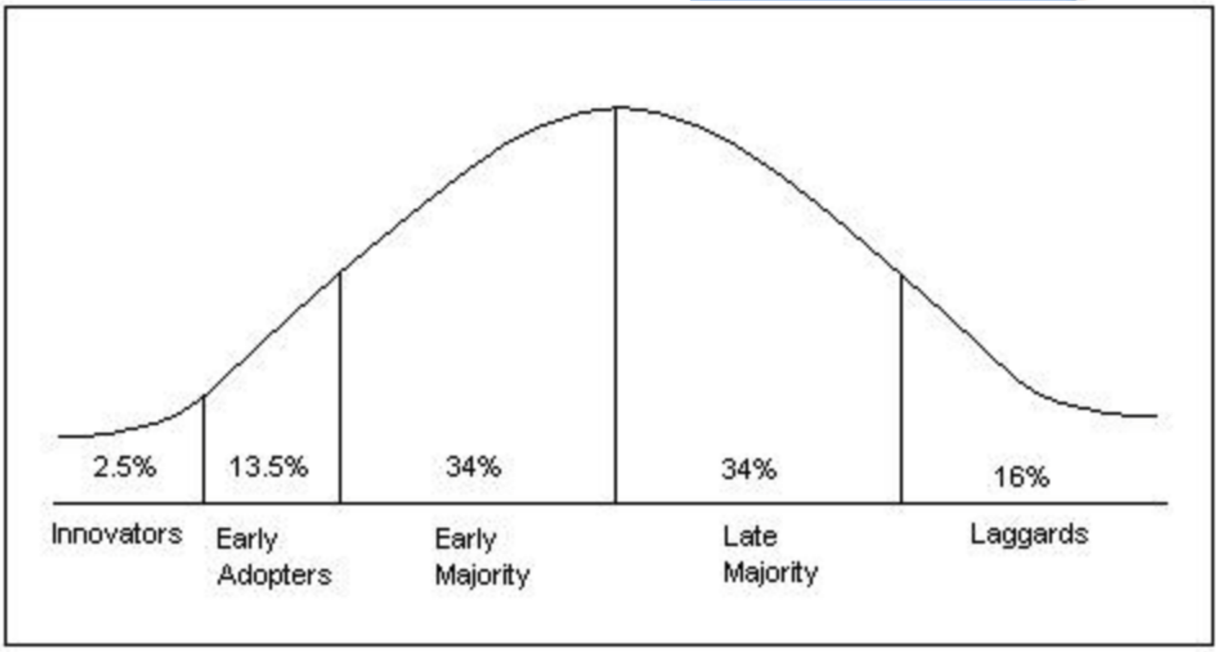


Figure 14. Adoption curve of Everett Rogers

7.3 Support schemes

After the previous section about support schemes, the first recommendation for the way ahead is to use this support in a more complete way than usual. We saw that support has many forms, so the potential bio-energy entrepreneur should not always look for investments grants only, as often happens. Indeed, the European Commission clearly indicates that state aid should be reduced and the market should take over. Therefore, all instruments of the previous section should be examined. Many are less known than direct investment support and often underutilised, so it will be probable there is not much competition to obtain support.

7.4 The need for action

The measures announced by Fit for 55 recognize the role of biomass and bioenergy in reaching the climate goals for 2030 and 2050, if the sustainability principles in biomass-sourcing are respected. With the existing framework and given the current prospects, we expect no relevant policy barriers for CHP plants running on biomass residues. At the moment of writing this report, the recast of the Renewable Energy Directive to 2030 is ongoing and the Fit 55 package has just started its legislative path. The EU Commission has made clear that sustainable biomass will continue to play a role in the path to decarbonization. This will give tailwind for biomass residues/waste to fuel systems like BLAZE. This tailwind will be necessary, because as the IEA notes in its Report of December 2022, Renewable Energy is growing, but much less than programmed in REPowerEU.

A recent study conducted by Artelys (Artelys-Presentation-Key-Findings---Study-Commissioned-by-CE-final.pdf) estimates that by 2050, CHP systems (including with fossil fuels) could save between €4-8 billion annually, generate energy savings between 150-220 TWh, reduce CO_2 emissions by 4-5 Mt, and provide 13-16% of total electricity and 19-27% of total heat. That is a goal that must not be missed. This requires a collaborative effort from local authorities, financial actors, technology suppliers and agricultural enterprises. Unfortunately, there is often a lack of understanding about the benefits of CHP projects and a lot of different actors that have a veto option in the whole process. To prevent this to be a reason for missing the objectives, it is important for all stakeholders to be well-informed and work together to create successful CHP projects. The before mentioned lighthouse projects are a good occasion to do this.

- Local authorities can provide support through policy and permitting processes, gaining easier access to affordable and reliable green power at the same time.
- Financial actors offer funding options, following the opportunities of the previous chapter.
- Technology suppliers can bring expertise in system design and implementation.
- Agricultural enterprises can provide a source of renewable biomass fuel.

By combining the strengths of each stakeholder group, CHP projects can be expanded efficiently and effectively.

Small is Beautiful

The “Small is Beautiful” campaign advocates for recognising the benefits of small-scale, clean, and locally owned installations to be central in driving a digitalised, decarbonised and increasingly distributed energy system, empowering energy consumers across Europe. “Small-scale installations deserve policies to make them thrive in Europe!” as the campaign says. It will enable the many types of compatible fuels (described in the D2.1 Blaze report) to be harvested, processed and used in the same region, stimulating efficiency and local ownership.

The Blaze project contains a few new and costly systems, where economy of scale currently hinders application on a small scale. However, after initial adoption of this technology by users with an electricity demand between 250 and 750 kW_e the pressure of the market towards smaller systems will incentivate suppliers to go down to units of even 25 kW_e on the longer run.

8 Biomass availability

In Deliverable D2.1, BLAZE partner ENEA analysed a wide selection of Biomass residues with the objective to find the most suited fuel types for a BLAZE type plant. With exception made for corn cobs, black liquor and digestate, **all** the feedstocks analysed (woody or herbaceous) are suitable as feedstocks for gasification in a BFB reactor.

Earlier in this document, we saw already that this document estimated the total amount in the EU on nearly 700 Mton/year (dry mass basis) of BLAZE compatible feedstock. The similarity of this advantage (a flexible menu) with the two pictures here is evident: who doesn't know that the panda's diet is extremely specific. With modern developments like Blaze, our energy diet becomes much broader and allows to replace a significant part of our fossil fuels with home grown feedstock.

A rough division of the possible biomass types is:

- Agricultural residues
- Primary residues from forest
- Municipal Waste (organic part, so paper, plastic, tyres, …)
- Secondary residues from wood industries
- Secondary residues of industry utilising agri-products
- Waste from wood
- Digestate from biogas production

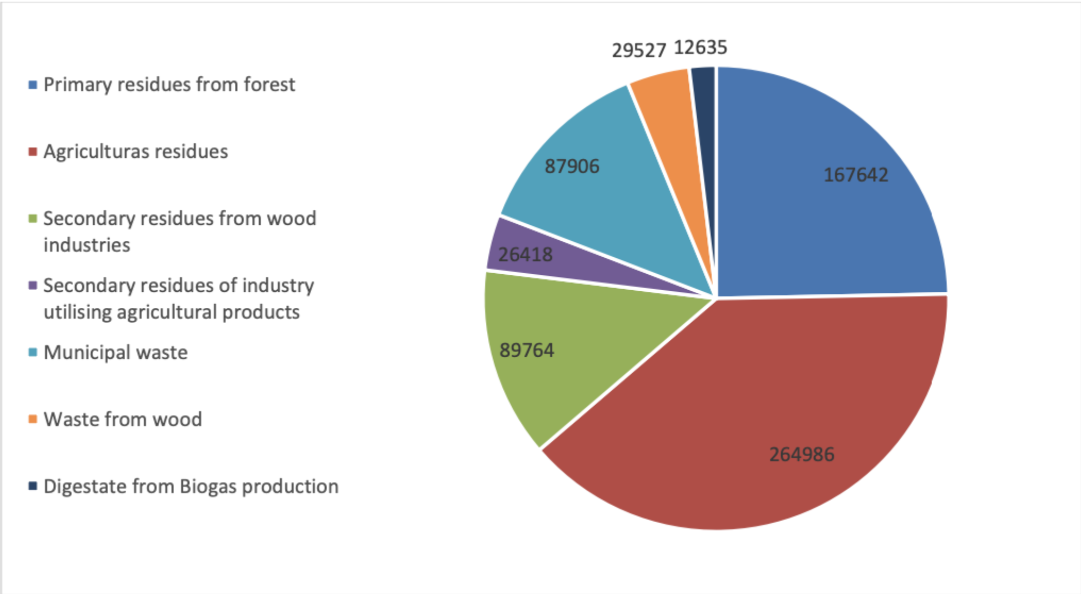


Figure 15. Total biomass in EU in kton/year (total 678 878).

The same study, based on the results of previous projects and analysis, estimates that agricultural residues are the most available type of biomass waste (265 MTon dry kt/y), split up as in the figure below. It is evident that cereals straw is her the biggest part.

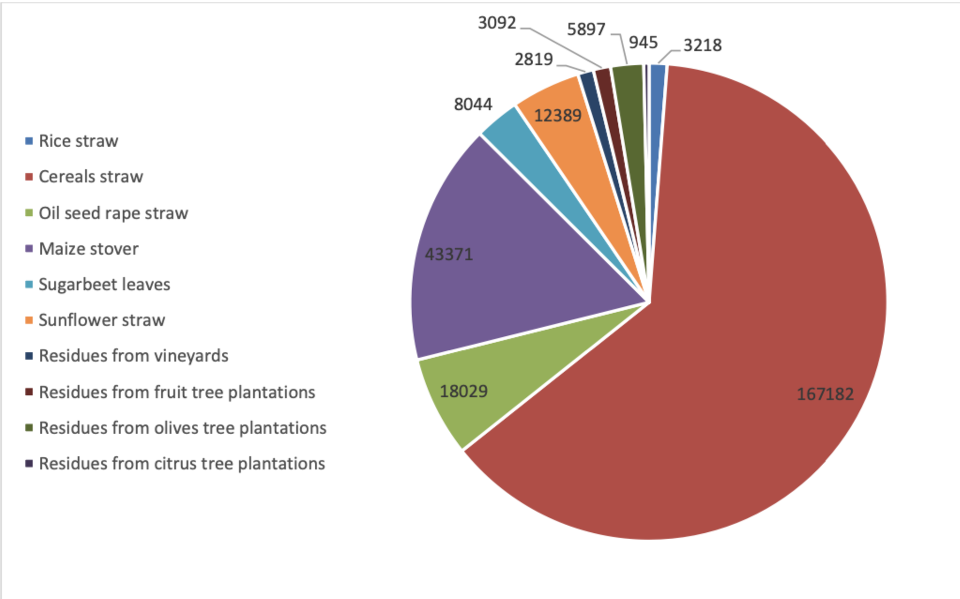


Figure 16. Subdivision of the greater part, Agrictultural residues, of the previous diagram

It's evident that agri-waste is a resource that is underutilised. Bioenergy constitutes 59% of all renewable energy sources, so it is a significant part, and over 60% of that was until now wood-based ([Eurostat]), or 36% of all Renewable Energy, putting too much pressure on trees. Now this can change, thanks to the technical progress with agri-biomass. Some of these materials have a relatively high content of S and Cl, which can be noxious to any traditional bioenergy equipment and now also for the new technologies like SOFC. However, this can be fixed with utilisation of specific chemical solutions, subject of the Blaze research. These results confirm the high fuel flexibility of the new technology, adding a significant amount of fuel to the existing feedstock.

As said in chapter 4 (The Context), taking the specific energy content from each of the EU biomass types and multiplying with the amount available, one obtains for energy an amount of 179% of the earlier mentioned natural gas import from RU into the EU in 2021 (which was 155 bcm gas). Therefore, we see again that the amount of biowaste in EU is a game changer in tomorrow's energy scenario.

9 SWOT analysis

Each SWOT analysis explores internal & external plus & minus factors (Strengths, Weaknesses, Opportunities, Threats) of a solution. See below the table with these factors for Blaze. Below the table is the rationale behind the terms in the table.

9.1 SWOT table

SWOT	Positive	Negative
Internal	**Strengths** - CHP is energy efficient - Storage - Blaze has good Bio-CHP characteristics - Smaller size	**Weaknesses** - CHP seen as complicated - Biomass supply complicated
External	**Opportunities** - Global Energy crisis - Local Autonomy is trendy - Climate Territory quality	**Threats** - Objections of decision-makers - Territory pressure

To start with the negative internal and external factors, the barriers for CHP are as follows:

- **CHP seen as complicated**
  - In the previous chapters it was already shown that the global CHP development is not going very fast, due to the fixed proportion between H and P. This is already a challenge for CHP with common fossil fuels.
- **Biomass supply complicated**

    - Compared with general CHP, biomass has the additional complication of biomass that is not standard available in the market, as with diesel oil or natural gas (the usual easy fuels for CHP).
- **Objections of authorities**
    - Decision-makers like local authorities or investors are afraid of risks related to feed stock supply, emissions, other health risks and fire hazard.
- **Territory pressure**
    - Whitin the external factors are fundamental the territory transformation and the agreement with urban planning tools (Bellone 2022). Thus, the territory can be a threat if BLAZE plant does not reduce the pressure in the territory (e.g. better use of waste biomass) and if BLAZE plant is not included in planning.

The positive factors, internal and external:

- **CHP is energy efficient**
    - With the current energy prices, energy efficient technologies will have a quicker return on investment.
- **Storage**
    - Nowadays, wind and solar electric power are very popular and have interesting production costs per energy unit. However, they have the disadvantages to be volatile. Feedstock for CHP like diesel or biomass can be stored and will make power generation more flexible to be adapted to the demand. This will also create the opportunity to supply energy during time slots when the spot market is offering (very) high prices.
- **Good Bio-CHP points for Blaze**
    - Compared with other biomass technologies for CHP, Blaze Technology has a few winning points, as summarised in the table. Some of these advantages need still some time to be developed.

Parameter	Current	BLAZE
Overall efficiency	≈ 65%	≈ 90%
electrical efficiency	≈ 25%	≈ 50%
investment cost	≈ 10,000 €/kWe	≈ 4,000 €/kWe
operating cost	≈ 0.10 €/kWhe	≈ 0.05 €/kWhe
electricity production cost	≈ 0.20 €/kWh	≈ 0.10 €/kWh
Negligible gaseous and particulate matter emissions		

- **Medium, small size**
    - In addition to their advantages in the table above, the Blaze technology is also medium size (and will become even small size in the future). This makes it interesting for smaller power users and local projects. It will increase application in smaller business models, enhance local ownership and create better financial

parameters. It will also make easier the deployment of local biomass, with less transport.

- **Global energy crisis**
  - The current situation will not only make it *financially* more interesting to increase the rational use of energy. Also, the need of *independency* from large global energy suppliers will stimulate the trend of using own resources.
- **Local autonomy becomes trendy**
  - Especially after the latest developments, people get anxious about their vulnerability of wide geological supply chains, even national. Apart from independency on large geopolitical scale (as in the previous point), decentralisation becomes trendy also on a more local scale.
- **Climate change is becoming a concrete threat, every year more**
  - With the increased flow of news from climate disasters, also from close nearby, the population starts to engage and pushing for climate friendly policies. Also, investors start to feel the costs of climate damage on their resources.
- **Territory quality**
  - Whitin the external factors are fundamental the territory transformation and the agreement with urban planning tools (Bellone 2022). Thus, the territory can be also a positive factor if BLAZE plant improves the territory quality (e.g. better use of waste biomass, CHP generation at high efficiency and low emission) a.

9.2 Evaluation

Let's compare the positive and negative points and their respective impacts. The negative points, at the right side of the table, are all related to risks. This is a strong driver, even more so than economic drivers. However, on the positive side, also the opportunities are all three related to risks, decreasing them. Therefore, they can be expected to offer a drive in the opposite direction.

9.3 Addressing the negative points in the SWOT table

If solutions can be found for the negative points **W** & **T** in the table, it will be easier to realise more biofuel CHP plants in the market.

9.3.1 CHP still perceived as an expensive and risky technology

1. **Challenge**
   - CHP is a well-known technology, but the market still has problems to embrace it. One of the most important barriers is the high investment and the need to consume heat and electricity demand at the same moment (take it or leave it). In the Adoption curve shown before, the world is still at the start of the Early Majority phase, considering that this phase ends at 50% and that projections and EU objectives go far beyond the present penetration levels of this technology.
2. **Solution**

- One of the best ways to tackle the need for synchronous heat and electricity demand is to adopt storage. This is not the same as electrochemical batteries, which is an expensive technology and can be avoided in this situation. Much of the electricity consumed in the market is eventually converted into thermal energy. Especially the production of cold is dependent on electrical compressors. Almost 12 million people are employed worldwide in the refrigeration sector, which consumes about 20% of the global electricity (Source). For some sectors cold is *essential*, like hospitals, food industry, hotels and supermarkets. By storing the cold of an electric (or absorption) chiller, the electricity production from CHP can be partly decoupled from its heat production. Therefore, the ratio between the **H** and **P** of CHP is not fixed anymore. Thermal storage (heat or cold) costs much less per kWh than batteries and makes CHP more interesting. Especially the mentioned kind of cold consumers are vulnerable for black-outs and will welcome a cold storage as a life saver. Therefore, it is obvious to include these type of users as early adopters of Blaze technology, especially if they have biomass feedstock available.
- In communities, this thermal storage can be shared among many users and lower the specific investment. Especially the combination of cold storage, hot storage, district heating & cooling and heat pumps (powered by Blaze CHP) can add huge value, especially on islands. The supply of energy and also the management of waste is always more expensive on islands than on the mainland. The organic part of the waste (which for Blaze is very broad and can even contain part of the household waste like paper and many plastics) can be used for CHP. The H part (heat) can be stored in a heat store or converted (at 70% efficiency) in an absorption heat pump and stored in a cold storage. The P part (power) can even "charge" – with heat pumps - the cold and hot storage at the same time, because each heat pump has a cold and a hot side.

- A heat storage can work with water or phase change material (still more heat capacity and that at constant temperature). In the same way, a cold storage can also work with water or phase change material (this latter can be water in the form of ice and gives a very high storage capacity per litre).
- In this way, thermal storage can shift both products (H and P) of CHP in time at a low cost. The heat, because it can be stored directly, the P because cold storage is a kind of electric storage, because it is charged with an electric chiller. This time-flexibility of both **H** and **P** makes CHP attractive for a greater portion of the market. Obviously, the chances of CHP and of the Blaze technology will increase if the perfect market actors are identified, which can act as the early adopters.

9.3.2 Biomass still perceived as complicated

1. **Challenge**
   - Biomass is not standard available in the market, as with diesel oil or natural gas (the usual easy fuels for CHP). There are too many types of biomass with completely different characteristics, which complicate realisation not only for the technical designers but also for local authorities and responsibles for safety.
2. **Solution**
   - Standardisation and certification of biomass types will help not only the users to choose but also producers to sell biomass. Pelletisation is a way of standardising the format, making logistics straightforward and decreasing decay. Dividing these pellets in clearly identified classes will enable the user and the producer to choose the right fuel quality for the own technology (user) and resources (producer). The section on Voluntary national bio

Figure 17. Biomass to pellets for standardisation

   - mass schemes is a good initiative in this direction. A market place of pellets, comprising all possible materials, must be created. Also, research and dissemination must help to make clear the application of each biomass standard. Technology providers must be informed so that they will guide their clients themselves in the choice of the right feed stock.

9.3.3 Objections of authorities

1. **Challenge**
   - Local authorities and certification institutions have a great responsibility and are risk averse. They will filter out a lot of projects that make technical and economic sense.
2. **Solution**
   - In order to ensure that progress is not hindered, it is crucial that the formalities regarding biomass are organized. Officials who hold responsibility for safety and compliance are fully aware of the significance of progress and are pleased when projects are well-prepared and free from unforeseen risks. Thus, it is advisable to initiate collaboration with them at an early stage of the lighthouse projects for early adopters, allowing them to assist with navigating the compliance process rather than postponing submission to them on the last moment. The previous two challenges contain already some solutions to make compliance easier.

10 Target sector

To find market actors as the Early Adopters, it is necessary to go beyond the economic arguments. Decision-makers are usually less sensitive to economics than to risk avoidance and ease of management. Actually, surveys among CEOs showed that the latter two are on the top of the priority list for top managers, while financial arguments come as # 5 or #6. So if for example a thermal storage can help to ensure cold supply even during a black-out for a business that highly depends on it, it will be much more likely to have their attention. Below will be given a potential list of early adopters, where not only the economic but also other benefits will address the real drivers for these potential adopters to choose for the Blaze technology.

Instead of giving abundant statistics showing how much the actual market for the Blaze technology can be, the current phase of Early Adoption has more benefit with the **identification of a few types of ideal customers**, which have so much benefit from the technology that they will accept the risks of a new technology. It will then be much easier to find specific user cases and start the take off for this technology. The three types given below are very common in society and it will not be difficult to find many of them, large and small.

The three types of early adopters that are chosen and described in the following sectors are:
- Food industry,
- Hotels,
- Local Government including islands.

Also, education and healthcare can be included, in particular with Local Government.

10.1 ideal customers

The identikit of a few ideal customers shall be a type of activity, which can be easily identified in the whole EU, like for example in this combination of conditions:

"find a food industry where the intermediate and final product must be kept cool and at the same time needs high temperature processing at 80°C or more, and where the heat and electricity consumption is resp. xxx and yyy MWh/month. These industries are in the neighbourhood of a forest or agricultural area and there is a district heating system. In order to mitigate risks, they have a back up technology for power and heat. Finally they have competent technical staff or there are specialists on chemical processes in the neighboorhood."

This description has many conditions and is only an example. If it does not result in a few candidates of early adopters, some condition can be left out.

Important is that such an identikit will, in combination with addresses of associations that represent the sector, help an agency and/or the suppliers of Blaze technology to start with a significant number of lighthouse projects, where decision-makers are cooperative not only with the realisation but also with information gathering and dissemination.

Here is a general filter of conditions that can be used to identify ideal customers for all 3 types, also with the cooperation of a sector organisation.

- Close to biomass sources,
- Energy intensive (see text box on amount of energy from a Blaze plant),
- Consumption of heat/cold and electric power are on the same time,
- Many hours of activity,
- Security of Supply is a top priority,
- The consumer is on an island where energy prices and waste management costs are higher. Even if the consumer doesn’t pay the island-premium of the cost, the difference might be paid by the energy supplier or government, this can become a driver to cooperate on a financial basis.
- A competent team for chemical technology for maintenance or modifications with the Blaze technology. This specialised personnel can be found in some food factories, where process technology is more advanced. Otherwise they might be in nearby specialised enterprises.

Example of identification of the right candidate, based on energy expenses per year.

Assumptions for the Blaze plant:

- 300 kW_e and thus 240 kW_{th} power, as de electrical efficiency is 50% and overall efficiency is 90%.
- 4000 hours/year at 100%, 1000 at 50%

Calculation:

- Power: 4000*300+1000*150=1 350 000 kWh_e
- Heat: 4000*240+1000*120=1 080 000 kWh_{th} or 120 000 m^3 gas (with efficiency of boiler)
- With normal prices of natural gas and electricity of resp. 0.8€/m^3 and 0.30€/kWh, this corresponds with about 501 000 € of total energy bill per year.

Therefore, a candidate with a total bill of half a million fits to the assumed Blaze plant size.

For more sector specific conditions for each of the early adopters, see the 3 sections below.

We propose hereunder 3 sectors where ideal customers can be found and will then specify central organisations where such energy consumers are members.

10.1.1 Ideal customer 1: Food industry

The food-processing industry is a major consumer of energy, with high energy consumption in both heat and power. This is particularly true for industries that rely on cooking, drying, and refrigeration processes. Examples of such industries include meat processing, dairy, bakery, and beverage production. However, there are many more industries where heat and power are consumed at the same time, which don’t produce food.

This document of the European Commission (Energy use in the EU food sector: State of play and ...) highlights that the food processing industry is well-suited for the implementation of combined heat and power (CHP) systems due to its high energy demands, usually at the same time for **H** and **P** and for many hours a year. This document provides examples of innovative energy management in the European food supply chain.

Figure 18. Food industry cannot accept black out

Filter for early adopters:

- Close to biomass sources
  - Because they process agricultural products themselves
  - There might be another industry in the neighbourhood that produces biowaste
- Security of Energy Supply is essential
  - Black-out must include the risk of discarding large quantities of food.

There are several resources where to find Early Adopters and by contacting the addresses below and propose the filter of conditions (given above), project managers of CHP technology can help the association to search their member database.

- FoodDrinkEurope, the confederation that represents the European food and drink industry. This association not only has blue chip industries like Unilever, Coca Cola, Danone,… as member, but also sub-associations. Total members close to 100.

10.1.2 Ideal customer 2: Hotels

Hotels and similar structures are numerous in the old continent, where tourists from over the world are looking for culture, the most various landscapes and well-being. Hotels are also a major consumer of energy and the results of a black-out can be serious for the image of the hotel (monitored with reviews on Internet for each of them) and the amount of discomfort associated with solving problems when it occurs.

Even the mere economic factor of energy counts much in these times. A hotel in a climatic area like Tuscany with about 100 rooms and a modest swimming pool, working 12 months/year will need about 1250 MWh electric and 1000 MWh thermal energy. With current prices this can amount to 1600 000€/y.

In 2010 there were around 205 thousand hotels and similar accommodations in the EU. The figures decreased in the following years. The average number of rooms per hotel in the market is 61.

Filter for early adopters:

- Close to biomass (a1
- ritourism)
- Open the whole year
- Services
  - Swimming pool and well-being
  - Restaurant
    - This is a consumer of energy and a (albeit limited) resource of bio-waste (250 gr per serving for preparation and remainders, on average).
- Green image
- Weak grid
- Size of the hotel
  - The European average of 61 rooms per hotel is close to the example with 100 rooms, described on the previous page
- Luxury level
- Close to the airport
  - High tech environment (maintenance)
  - Often close to agricultural activities
  - Visibility and keen on showing sustainability

The last element of this list needs a comment. Airports are often in rural areas and with their many structures requiring power, heat and cooling on a 24/7 basis, it will be an ideal consumer, which today has often a high mandate of sustainability. It will even allow to increase the scale of a Blaze pilot plant.

Moreover, an airport has expertise in technology that is close to that of Blaze, or at least the scale of the consumption justifies hiring expertise.

There are several hotel associations in Europe. One of them is the European Hotel Managers Association (EHMA), which is a non-profit association of Hotel Managers of first class and luxury hotels across Europe. EHMA currently gathers nearly 400 members in 23 European countries [2]. Another example is the European Hospitality Foundation (EHF). Here is the list:

- Members of the Hotelstars Union, European Hotel ...
  - This is an association of (national) associations
  - There is a news blog where one can find examples of best practices on energy (through "energy" in the search window)
- E.H.M.A. – European Hotel Managers Association – Pursuing ...
  - The association has a yearly "EHMA Sustainability by Diversey" award. "EHMA has recorded this year an unprecedented number of applications to our Sustainability Award, ...", according the president.
- European Hotel Forum (link)
  - Members include several major hotel chains such as Accor Hotels, Hyatt, Hilton, InterContinental Hotels Group, and Marriott International

10.1.3 Ideal customer 2: Local Government

The Local Government (LG) is also a major consumer of energy, with the possibility to spread the consumption over many hours, for example street lighting or heating swimming pools.

They are not only **consumers** but have also a saying in many **decisions** like permits, waste management, land use planning and local initiatives. An example of such an initiative is the cooperative of citizens (legal entity by the local authority) as described at the end of section four about PPA (Power Purchase Agreement), where the municipality was the owner of the PV plant of 225 kW on a sport centre, and willing to close a PPA for 20 years at a very reasonable tariff. Their role in land use planning and management of waste is important for the Blaze technology. It can help to guarantee the feedstock at a reasonable cost. The role in permitting is relevant for the realisation of the plant while also in the last phase of the biomass life cycle (consumption), heat & power can be used directly in the infrastructure of the LG, like buildings, district heating&cooling and street lighting. Finally, the LG is keen on a green image, because Central Government has its binding objectives and trickles that down to lower Government.

There are also many municipalities that sell energy to the citizens. CHP with biomass feedstock can be a good choice to produce this energy.

European Islands are also a form of Local Government and they are united in the European Small Islands Federation (see the list below). They are particularly keen on improving economics of energy (as well as waste management), which costs more than on the main land.

Filter for early adopters:

- Close to biomass with a role in the management of agriculture and forests,
- Consumption of heat and power at the same time
  - Sport centres, swimming pools,
  - Participation in health care and pension homes,
  - Street lighting, pumping water, water purification
  - Education
- District heating and cooling,
  - Having both grids, they can be used in combination with thermal storage and heat pumps that make it easier to convert heat into cold or vice versa, gaining flexibility with the **H** of CHP and with different seasons.
- Municipality is energy supplier to citizens,
- LG is an island,
- Keen on sustainable development,

Here is the list of useful associations:

- European Federation of Agencies and Regions for Energy and Environment
- European Small Islands Federation

- The **Council** of **European Municipalities** and Regions (CEMR)

10.2 Project user cases

Below are examples of projects for the 3 sectors of ideal customers.

10.2.1 Food industry

Introduction:

The food industry is a major consumer of energy, with the majority of this energy being used for industrial processes such as refrigeration, cooking, and cleaning. One of the most effective ways for the food industry to reduce its energy costs and improve its sustainability is by using combined heat and power (CHP) systems.

In this case study, we will explore the installation of a 300 kWe CHP system in a milk production plant. The aim is to reduce the plant's energy costs and increase the Security of Supply (SOS), while also decreasing its carbon footprint.

Background:

The milk production plant is a medium-sized facility located in a rural area, working non-stop during all but six weeks of the year, resulting in 7700 hours. It produces pasteurized milk, cream, and yogurt. The plant is currently powered by electricity and natural gas, with an annual energy cost of 500,000 €.

Challenge:

The plant was looking for ways to reduce its energy costs and improve its sustainability. They were also looking for a way to reduce their reliance on the grid, which was vulnerable to power outages during peak periods, especially during summer, considering the impact of increasing air conditioning needs in the whole region.

Solution:

After evaluating several options, the management decided to install a CHP system based on biomass from the region, where local cattle supplies the milk. The electrical capacity is 300 kWe. The system will generate electricity and heat simultaneously, using natural gas as fuel. The electricity generated by the system is used to power the plant's operations, especially lighting and cooling, while the heat generated is used for the plant's heating and (now, with absorption chillers) to assist the electric chillers. The possibility to produce cold with electricity or heat requires an extra investment but allows to change the cooling technology depending on the season and to have the CHP nearly always running at maximum speed. Also, the thermal storage contributes to this flexibility.

The CHP system was designed to operate at full capacity during peak energy demand periods and at partial capacity during off-peak periods. The thermal storage is charged during these periods. This ensures that the plant can operate smoothly even during peak periods while minimizing energy waste during off-peak periods.

The system was also designed with a high level of automation and monitoring to ensure optimal performance. The system's performance is monitored in real-time.

Result:

The CHP system was installed at a cost of 1,000,000 €, which will be recouped within four years through only energy savings. The obtained financial support will bring this down to 2 years. However, the Security of Supply is seen as a major strategic advantage and the avoiding of damage resulting from a blackout has a big impact on the financial picture. Moreover, the clients in this market and region are very sensitive to the marketing message of clean and local energy with the Blaze technology.

The system's efficiency has resulted in a 40% reduction in the plant's energy costs, resulting in significant cost savings for the company. Additionally, the plant has reduced its carbon footprint by 20%, which has further helped improve its sustainability.

The system has also improved the plant's reliability by reducing its reliance on the grid. The plant can now operate smoothly even during peak energy demand periods, reducing the risk of production downtime and lost revenue. As the Blaze technology is in an early phase, the contracts with the energy utilities have been adapted. Moreover, a project design has been made with a traditional CHP supplier that is able to install on short term a standard CHP solution, for which an insurance has been stipulated.

Conclusion:

The installation of a Bio-CHP system, based on the Blaze technology has been a highly effective solution for the milk production plant. The system has reduced the plant's energy costs, improved its sustainability, and increased its reliability. As such, it is a highly recommended solution for any food industry with similar characteristics.

10.2.2 Hotel Case Study: Installation of 300 kWe Bio-CHP System

Introduction:

This case study discusses the installation of a 300 kW_e Combined Heat and Power (CHP) system for a hotel. The main objective was to reduce the electricity and natural gas costs of the hotel, which were around 500,000 € per year. The CHP system was installed to generate electricity and thermal energy simultaneously, reducing the dependence on grid electricity and natural gas.

Background:

The hotel was a 100-room property in an agricultural area with also forests, operating throughout the year with a peak load of 300 kW_e. The hotel's electricity and natural gas costs were high, and the management wanted to find an alternative solution that would reduce these costs. After careful consideration, it was decided to install a Bio-CHP system.

Installation:

A 300 kW_e CHP system was installed in the hotel's basement, which would generate electricity and thermal energy simultaneously. The equipment used the Blaze technology, based on a gasifier and a fuel cell. The system was designed to operate around the clock, with minimum maintenance requirement.

Biomass feedstock contracts were arranged with some regional suppliers of food for the restaurant and the municipal waste management.

Results:

After the installation of the CHP system, the hotel's electricity and natural gas costs were significantly reduced. The CHP system generated approximately 2,520,000 kWh of electricity and 2,880,000 kWh of thermal energy per year. The electricity generated by the CHP system was used to power the hotel's electrical equipment, especially the chillers and the kitchen, while the thermal energy was used for space heating, domestic hot water, and pool heating. The hotel's energy consumption was reduced by 25%, leading to an annual saving of approximately 125,000 €.

Conclusion:

The installation of a 300 kWe CHP system was a successful solution for the hotel to reduce its electricity and natural gas costs. The CHP system generated electricity and thermal energy simultaneously, reducing the hotel's dependence on grid electricity and natural gas. The cooperation between hotel, Local Autorities and nearby agricultural enterprises is a good example for similar projects.

10.2.3 Local Government

Introduction:

This case study is about a whole island, Samos in Greece, and it will be clear that bio-CHP will be a game changer. As there are 310 inhabited European islands with an overall population of nearly 15 million inhabitants, this picture of Samos can easily be transposed to many of these.

The quest for a clean and quiet form of energy on Samos, very close to Turkey, resulted in the installation of one wind power plant of 2 MW and 5 PV plants with in total 5 MW. As these plants are usually producing on average between 20 and 25% of nominal power, the total average renewable power is 2,0 – 2,5 MW.

According to a report by the International Renewable Energy Agency (IRENA), the average installed power production capacity per capita on small islands (defined as having a population of less than 100,000) was approximately 0.3 kW per capita in 2018. However, it's worth noting that this figure can vary significantly depending on the island's specific circumstances and available energy resources.

Samos.

The current example is the island of Samos, Greece, with 33,000 inhabitants but with a diesel generator of not less than 48 MW. Samos is indeed one of the most beautiful islands of the Eastern Aegean region, with nearly 240 hotels, many of which have a high luxury level. Therefore, the above calculation with 0.3 kW per capita might be tight for Samos, but with a premium for the luxurious properties of 50%, a total installed power of 15 MW for the whole island is probably enough most of the time. The above value of 7 MW total (but volatile) installed power on Samos is in comparison not too much.

Figure 19. Location of Samos

Therefore, a Blaze system of 1 MW_e is a good size, in view of the current need and existing (diesel) supply. But where to find the feedstock for this technology?

One potential source of biomass on Samos is olive oil waste, which is generated during the production of olive oil. There are already projects with this waste as a fuel in biomass boilers to generate heat and electricity. Another potential source of biomass on Samos is the island's forested areas, which could be used for sustainable forestry practices that promote both biodiversity and biomass production. However, any forestry practices on the island must be carefully managed to avoid overexploitation of the island's natural resources and to protect the island's fragile ecosystems.

To protect the island against the price fluctuations of the diesel price, it is here recommended to start producing agri-pellets on the mainland and start a gradual replacement of fuel import from diesel to agri-pellets. Even if the relationship with very nearby Turkey has been impacted, there is trade between Samos and Turkey, particularly in the areas of tourism and agriculture. For example, Samian agricultural products such as olives and wine are exported to Turkey. It can be exchanged against agri-pellets, adding to the import from mainland Greece and other countries, because Turkey may offer competitive prices and transport costs are very low. Also, Samos can increase the agricultural production for its own population, given the extra price on the bio-residues on top of the revenue from the food itself. Moreover, as the

Figure 20. Imaginary producer of biofuel from agri-residues and selected househole waste.

organic part of household waste (plastic, paper and other carbon containing materials) is mostly compatible with the Blaze technology, it is recommended to start recycling this. Historically, the island has relied on landfilling as the primary method of waste disposal, but this approach has become increasingly unsustainable in recent years due to concerns over environmental and health impacts. In response, there have been efforts to improve waste management practices on the island, including the implementation of recycling programs, the construction of a new waste transfer station, and the development of plans for a new sanitary landfill. These initiatives have a high cost and will make the Blaze solution more interesting.

The waste disposal problems of Samos will be the same on other islands. Therefore, this case study is relevant on a large scale. See the introduction of this section for the statistics on European islands.

The draw back of an island is that it can be difficult to have technical assistance for the specific Blaze technology. Therefore, the pilot plant must have ways to ensure timely technical support in case of problems or a back up power supply like the grid (in this case the 48 MW diesel station with one or more units adapted to work with the principle of SmartCHP).

11 Cost breakdown

To break down the costs of a CHP plant of 500 kW electric and 400 kW thermal, working on biomass, we need to consider several factors. In the experimental phase, the cost of the CHP plant is higher: 1 500 000 €, and we assume it operates for 5000 hours per year. The cost breakdown is in the table below.

The production cost of electric energy has been taken as double the cost for thermal energy, just to be able to divide the item “Total operating costs” in some way over the total production. This ratio can be chosen in another way. Actually, in the market this ratio is now as high as 4.

The cost of capital is 9% and represents not only the interest paid or received on a loan but also the lost opportunity of investing the capital in another way.

As can be seen, the CHP plant is profitable, as the operating costs are far below the revenue generated (compare 297 k€ with 1200 k€). The Net Present Value or NPV is a superior financial metric, compared to the Simple Payback Time, because it considers the whole life span, which we chose short in this case: only 10 years.

Blaze plant				
			Assumptions	
Cost (€)	1 500 000		Price elec. double of thermal	
Power input chemical (kW)	1 000		Price m3 natural gas (€)	1
Power electric (kW)	500		boiler efficiency	95%
Power thermal (kW)	400		energy gas (kWh/m3)	10.5
Operating hours/year	5000		Rate of interest	9%
Conversion efficiency electric	50%			
Conversion efficiency thermal	40%		Cash flow	
			year	
Biomass cost per kg	0.2		1	- 1 500 000
Energy density kWh/kg	4.5		2	903 279
Biomass cost per kWh	0.044		3	903 279
Biomass input (kg/hour)	222		4	903 279
Fuel cost per year (€)	222 222		5	903 279
			6	903 279
Maintenance cost (% of Cap)	5		7	903 279
Maintenance cost (€/year)	75 000		8	903 279
			9	903 279
Total operating costs (€/year)	297 222		10	903 279
Total production of energy per year				
Electric (kWh)	2 500 000		Thermal seen at half value	
Thermal (kWh)	2 000 000		1 000 000	
Production cost per kW(e) in €	0.085			
Production cost per kW(th) in €	0.042			
Market price of energy				
Electric (€/kWh)	0.40			
Thermal (€/kWh)	0.10			
Revenue (€/year)	1 200 501			
Net present value (€)	3 592 092			

12 Potential competitors of BLAZE

This chapter gives an analysis of the competing technologies, existing ones and in development.

The tables below show a basic range of similar and other technologies with some of their strength and weaknesses.

The first table shows a comparison with similar technologies, based on gasification of biomass.

Technology	Strength	Weakness
Gas turbine combined cycle (GTCC)	Known technology with high efficiency.	High capital cost, only large scale.
Gasification & CHP with ICE	Medium scale, economically advantageous	High initial investment cost
Biomass to fuel & CHP with ICE, like SmartCHP	Medium scale, economically advantageous, other biomass types	High initial investment cost, now in development
Stirling engine CHP	External combustion, so easier to prepare fuel	Lower (electric) efficiency
Molten carbonate fuel cell CHP	More tolerant to impurities in the fuel	Lower (electric) efficiency for fuel cell than SOFCs
Alkaline fuel cell CHP	Also compatible to syngas from biomass	Lower (electric) efficiency for fuel cell than SOFCs
Direct carbon fuel cell CHP	New type of fuel cell that can use solid carbon as fuel directly. So, biomass without the need for gasification.	DCFCs are still in the research and development stage

In summary, while there are several competing technologies for a CHP system based on biomass gasification and also on (alternative) fuel cell technology, SOFCs remain the most efficient and promising option for such systems. However, the other technologies may have their advantages in certain applications, and there may be room for further development and optimization of these technologies in the future. Below is the second table, comparing the Blaze technology with completely other types of systems to produce heat and/or power.

Technology	Strength	Weakness
Boilers	Low investment costs	Only heat.
CHP	Heat and power, more complete deployment of chemical energy.	High initial investment cost
District Heating (w/ CHP)	Primary energy factor, comfort for the user	Big infrastructure, not available for single users
Geothermal energy	Near-surface geothermal energy ready to use, Renewable energy, low emissions	High investment. Deep geothermal energy not ready for market, unknown effects to the groundwater and geotechnic consequences
Solar heating/cooling	Supply and demand at the same time, renewable energy	Expensive (cooling)
Solar energy	Decreasing prices, still financially supported, reliable	Much space needed, volatile energy
Water power	Renewable energy	Small potential in most regions
Sewage gas	Renewable bio-energy	Limited application

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13 Competitive advantages and disadvantages

Combined Heat and Power (CHP) systems are becoming increasingly popular as they provide a more efficient and cost-effective way of generating electricity and heat. CHP systems that are based on gasification and solid oxide fuel cells (SOFC) are among the most promising technologies in this field, as they offer several competitive advantages over conventional systems. As seen before, the table below presents the project data of the achievable Blaze advantages.

Parameter	Current	BLAZE
Overall efficiency	≈ 65%	≈ 90%
electrical efficiency	≈ 25%	≈ 50%
investment cost	≈ 10,000 €/kWe	≈ 4,000 €/kWe
operating cost	≈ 0.10 €/kWhe	≈ 0.05 €/kWhe
electricity production cost	≈ 0.20 €/kWh	≈ 0.10 €/kWh
Negligible gaseous and particulate matter emissions		

Several of these key parameters have still to be reached as the development is not yet complete. In particular the 4 k€ per kW_e. mark will take time. Another key parameter is the size of the technology: in a range of 100 – 5000 kW_e. This is unique in the field of similar technologies with the same fuel flexibility and based on gasification.

One of the main competitive advantages of CHP systems based on gasification and SOFC is their high efficiency. Gasification is a process that converts biomass, waste, or coal into a gas that can be used for electricity and heat production. SOFCs are electrochemical devices that convert the chemical energy in fuels directly into electricity and heat, with high efficiency levels of up to 60%. This means that CHP systems based on these technologies can achieve efficiency levels of up to 90%, which is significantly higher than conventional systems. In comparison with for example an ICE CHP, which is in the same range of power, the Blaze technology gives less noise. This is a plus for the non-industrial environment, opening a whole new market in the service sector, including tourism, hospitals and pensioners homes. The latter are smaller than hospitals and are oft in the urban centres, so noisy plants are even more a problem than in hospitals, which are often in the peripheral or have more space for technical installations.

Another advantage of CHP systems based on gasification and SOFC is their flexibility. These systems can work in a range of sizes, from 100 to 5000 kW_e, and in the future down 25 $kW_{e,}$ to making them suitable for a wide range of applications, from small residential units to large industrial complexes. They are also versatile in terms of the types of fuels they can use, including biomass, certain types of households and enterprise waste, coal, and natural gas. This flexibility makes them an attractive option for both the energy industry and individual consumers.

However, CHP systems based on gasification and SOFC also have some disadvantages that need to be considered. One of the main disadvantages is their high cost. These systems require expensive materials, such as ceramics and metals, which can make them more expensive to produce than conventional systems. Additionally, the technology is still relatively new, and there are few manufacturers producing these systems, which can make them difficult to obtain and service.

Another disadvantage of CHP systems based on gasification and SOFC is their complexity. These systems require careful management and maintenance to ensure they operate efficiently and safely. This can require specialized training and expertise, which can be a challenge for smaller organizations or individuals, especially in remote areas or islands.

In conclusion, CHP systems based on gasification and SOFC offer several competitive advantages over conventional systems, including high efficiency, low noise and flexibility. However, these systems also have their own set of disadvantages, including high costs and complexity. As with any technology, it is important to carefully weigh the advantages and disadvantages before deciding on whether to adopt it.

14 Conclusion

In conclusion, the market analysis of the new small/medium CHP technology based on gasification and solid oxide fuel cell (SOFC), developed during the Blaze project, shows that it has significant potential to become a key player in the energy industry. The high efficiency and flexibility of this technology make it an attractive option for a wide range of applications, from small residential units and service sector to large industrial complexes.

The growing demand for clean energy, the urgency of independence from instable energy suppliers and the need for cost-effective and reliable power generation are driving the demand for CHP systems based on gasification and high efficiency SOFC. This technology can help organizations reduce their carbon footprint while also lowering their energy costs and employing own resources instead of importing fuel from global players, making it an ideal solution for environmentally conscious societies.

The market for CHP systems based on gasification and SOFC is expected to grow significantly in the coming years, driven by initiatives and incentives from the EC and member states. The increasing demand for decentralized energy solutions and the need for reliable backup power sources are also expected to be a driver for this market. Finally, the EU biomass resources are very large, if we include the materials that were considered waste until now. Therefore, the waste sector, until recently considered mostly an economic sink, will turn into a source of renewable energy.

However, the high cost and complexity of this technology may limit its adoption by smaller organizations and individuals, at least until now. To overcome these challenges, manufacturers and suppliers of CHP systems based on gasification and SOFC need to focus on improving the efficiency of these systems and reducing their costs. This can be achieved through economies of scale, increased competition, and improvements in manufacturing processes.

They must also become active to find Early Adopters: these are market players that are currently outside there comfort zone, where the specific advantages of this technology are so convincing that they will accept the disadvantages and risks of a new technology. Three different types of these early adopters from important economic sectors have been identified in this market analysis and guidelines were given to turn them into lighthouse projects. These examples are expected to trigger many later adopters to accept the technology.

In addition, manufacturers and suppliers of these CHP systems based on gasification and SOFC need to invest in research and development to improve the reliability and durability of these systems. This will help to build trust and confidence in the technology, which will bring it from the early adopters to the majority of the market.

Overall, the market analysis of the new small/medium scale CHP technology based on gasification and SOFC shows that it has the potential to become a game-changer in the energy industry and decrease our dependency on energy suppliers outside the European Union. However, it will require the support and investment of both the private and public sectors to overcome the challenges and realize its full potential.