Bio-FlexGen

# Market Analysis Report

D6.6

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# Technical References

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[1] PU = Public
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# Summary

## Summary of Deliverable

The Bio-FlexGen Deliverable 6.6 Market Analysis Report delves into how biomass and renewable hydrogen are integrated to jointly generate heat and power. It highlights the project's novel approach, which fuses gasification technology with gas turbines, promoting efficient and flexible renewable energy-based CHP systems. This document covers from the research methodology and analysis of the market environment, to a SWOT analysis (strengths, weaknesses, opportunities and threats), identification of market barriers, strategies for market positioning, and a comprehensive competitor analysis, providing a holistic view of project results, market potential and innovation strategies for energy sustainability.

# Disclaimer



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# 1 Introduction

The Bio-FlexGen (BFG) project focuses on the highly efficient and flexible integration of biomass and renewable hydrogen for low-cost combined heat and power (CHP) generation, aimed at decarbonising the energy system. Faced with the challenge of climate change, Bio-FlexGen seeks to replace fossil fuels through the optimal use of diverse renewable sources, combining bioenergy with hydrogen to provide a secure and plannable energy source. This innovative project uses a unique combination of gasification technology and gas turbines, allowing the use of hydrogen for rapid start-up and biomass to reduce operating costs, thus improving the efficiency and flexibility of renewable energy-based CHP. This is why the relevance of the Market Analysis within this context lies in applying a concrete market research methodology in the energy sector. It will assess the market environment (global trends, market dynamics...), and both the competition and demand in Europe. Finally, it will establish a series of recommendations or conclusions around the research carried out. This deliverable also aims to identify market opportunities, analyse the economic viability and promote the adoption of this advanced energy solution. This will contribute significantly to the transition towards a more sustainable and low carbon energy system.

The work carried out in Bio-FlexGen will lead to the generation of new knowledge that can be used by partners, as input to further studies, projects or the development of other product or services. However, given the low TRL levels, 4 that will be achieved by the solutions of the project, further developments will be necessary to address beyond the project scope to reach the market.

Conducting thorough Market Analysis is crucial to identify potential applications and commercialisation opportunities for the project results. Thus, the goal of this deliverable is to provide insights about the project's exploitable results and their reference markets, including potential early adopters and preliminary investors selection and assessment criteria. It also includes analysing the market environment (global trends, market dynamics), analysing competition and demand in Europe.

## 1.1 Glossary

**BFG** - Bio-FlexGen
**CHP** - Combined Heat and Power
**H2020** - Horizon 2020
**WP** - Workpackage
**TRL** - Technology Readiness Level
**BTC** - Biomass-fired Top Cycle
**IPCEI** - Important Project of Common European Interest
**SGT** - SES Gasification Technology
**HFB** - High-Pressure Hybrid Fluidised Bed
**MSW** - Municipal Solid Waste
**IEA** - International Energy Agency
**IRENA** - International Renewable Energy Agency
**TVAB** - TEKNISKA VERKEN I LINKOPING AB
**CEMEX** - CEMEX ESPANA OPERACIONES SL
**SULQUISA** - SOCIEDAD ANONIMA SULQUISA S.A.

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# 2 Methodology

The methodology for the market study is based on desk research with an extensive literature review and analysis of secondary data. Information has also been collected from the responsible/owners of the exploitable results.

**Desk Research:** A range of updated reports, including those published by the European Commission, were reviewed to understand global and regional trends in renewable energies, biomass, and hydrogen. This step was crucial for gathering relevant and up-to-date information as the foundation for further analysis.

**Analysis of Reports and Official Sources:** We meticulously examined reports and official documents from the European Commission (Papers, policies reports) to ensure the research aligns with the European Union's policies and strategic directions. This analysis helped identify market opportunities and understand the existing regulatory framework and support policies.

**Information provided by consortium partners:** Regarding the current developments of the results in Bio-FlexGen, some information has been gathered in order to provide insights on the project's results along with the Market Analysis.

**Technical and market expert revision of the report:** The technical and market expert revision of the report is crucial for ensuring accuracy, relevance, and strategic alignment. This process involves a thorough analysis by specialists in both technical fields and market dynamics, aimed at validating the methodologies used, the data presented, and the feasibility of the recommendations. It enhances the report's credibility.

**Establishing a Narrative:** Based on the collected data and information, we worked on constructing a coherent narrative that explains the current state of the renewable energy market, especially in the context of its volatility and rapid changes. This narrative approach allowed us not only to present data but also to provide a deeper understanding of market dynamics and the driving forces behind them.

**Market and Competitive Environment Analysis:** A detailed analysis of the market environment was conducted, including global and regional trends, technological advancements in renewable energies and biomass, hydrogen market dynamics, competitor analysis, and supply analysis. This analysis enabled identifying market barriers, opportunities, threats, and key success factors for the project.

**Market Strategies and Positioning**: Based on the above analysis, market strategies and positioning were developed, considering entry and exit barriers, regulations, and risk analysis. These strategies aim to promote the adoption of the Bio-FlexGen solution and maximise its market impact.

The methodology implemented is characterised by its holistic and multidimensional approach, ensuring all relevant facets of the renewable energy market are considered and establishing well-founded recommendations for the Bio-FlexGen project.

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# 3 The project's Exploitable results

This section provide insights about the project's exploitable results (Hydrogen and CO2 Unit: Design and model Development, BTC Model and New Models, Data And Designs for BTC Systems, Components, Parts. To commercialise the Bio-FlexGen solution the exploitable results generated in the Bio-FlexGen project need to be used as input to further studies, projects and technology development.

The Swedish company Phoenix BioPower that is part of Bio-FlexGen is the developer of the Bio-FlexGen solution called Biomass-fired Top Cycle (BTC) technology. As this plant is based on a new thermodynamic cycle, new principles are applied, and new technology needs to be developed. The basis of the BTC plant in the integration of pressurised gasification with gas turbine combustion and massive steam injection is what allows the BTC plant to perform at the radically higher efficiency levels that it does compared to traditional technologies like the steam cycle. As a basic configuration, the BTC plant is CHP plant for production of heat and power at the same time.

The roadmap and time to reach a full-scale demo plant can be seen in figure 1. In Bio-FlexGen components are developed and next step is development of a 2 MW pilot plant from 2027.

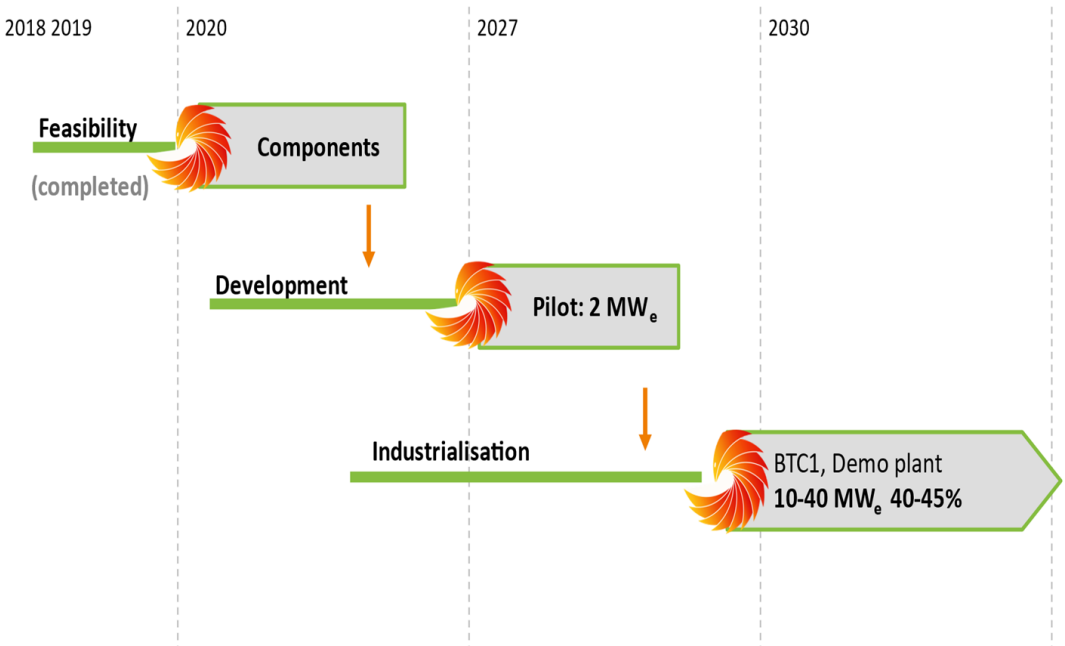


*Figure 1. BTC roadmap to full scale demo plant*

The Technology exploitable results in Bio-FlexGen include:

- Development of design and models
- Experimental and simulation data for process and components (subsystems of gasification and combustion)
- New models to predict performance of systems, components, parts

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Some key points to consider in the development of the projects exploitable results are:

- Innovativeness introduced compared to already existing products and services
- Product market size and positioning
- Competitors analysis
- Adopters/Customers
- Costs after the project end and before commercial exploitation
- When is the time to market
- Status of IPR: Background (type and partner owner)
- Status of IPR: Foreground (type and partner owner)
- Which partner contributes to what (main contributions in terms of know-how, patents, etc.)?

The sections below will focus on the project results, with the info gathered from the project partners (Phoenix BioPower and COMILLAS specifically).

## 3.1 Target market analysis for the exploitable results

### 3.1.1 Hydrogen and CO2 Unit: Design and model Development

#### 3.1.1.1 Technology

New designs for BTC gasification system and combustion system. New integration possibilities with H2 production and CO2 separation. Dominating H2 and CO2 production methods are based on fossil feedstocks or require large amounts of electricity/energy. Current solutions for H2 production generally emit large amounts of CO2 directly or indirectly, adding to the carbon emissions.

H2/CO2 suppliers like Air Liquide and Linde Gas represent some of the largest CO2 emitters and supply end users of industrial gases for use in industrial processes. With the Bio-FlexGen technology, end users can secure sustainable production of H2/CO2 on site using biomass as feedstock and at the same time decouple the production of H2 from electricity capacity supply and pricing.

#### 3.1.1.2 Competitors

Competitors that offering alternative solutions are existing suppliers of biomass-derived industrial gases. Their strength lies primarily in that most of them can offer solutions on near-commercial terms (TRL7, 8) whereas BFG is still in development. Some of the actors are limited to specific, high cost, feedstocks like sawdust. Some of them are limited in size to less than 20 MWth per unit.
Atmospheric gasification requires expensive HW for gas compression for down-stream methanisation processes. In a broader sense, green hydrogen can also be produced from electrolysis and green CO2 from many types of bioenergy and biorefinery plants.

| CORTUS ENERGY (SE)[1] |
| --- |
| Cortus has developed a solution for replacing fossil fuels where it is most needed. The solution is based on existing technologies that are combined into a new and innovative system. A ground breaking approach of how to gasify biomass in a fully integrated process. |

[1] https://cortus.se/solution-2/

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**Meva Energy (SE)[2]**

Meva Energy is the world's leading provider of gasification technology for renewable energy production based on small fraction fuels. Their system, according to their website, enables power and heat providers to utilise biomass in a uniquely efficient and profitable way.

**GI Dynamics (NL)[3]**

The High-Temperature Winkler (HTW) technology is the most highly developed gasification technology utilising bio-based feedstocks. The process was originally developed in the 1920s by the German energy company Rheinbraun AG utilising lignite coal. Over the years, the technology has been significantly improved to achieve better results and has been re-engineered to handle a broad range of feedstocks. GIDARA Energy acquired the technology in 2019 and has further developed it for modern, bio-centric applications.

**Synthesis Energy Solutions (US)[4]**

The SES Gasification Technology (SGT) process is differentiated from other commercially proven gasification technologies due to its ability to cleanly and economically convert nearly all solid carbonaceous fuels into synthesis gas, or "syngas"—the building block of a multitude of energy and chemical products. SGT is a single-stage, bubbling fluidised-bed gasification system for the production of low-to-medium heating value syngas from a wide array of feedstocks including coals, coal wastes, biomass and municipal solid waste (MSW) using oxygen, oxygen-enriched air, or air in the gasification reaction. It was developed over 35 years of research, testing, piloting and demonstration, and SES has taken the technology to a new commercialised level during the last decade.

#### 3.1.1.3 Adopters

Early adopters are assumed to be small-to-medium sized actors as they are generally more agile in decision making and are looking for an edge compared to large players. Also, investment amounts are lower, lowering barrier of entry.

#### 3.1.1.4 Investors

In anticipation of a revolution in Hydrogen and CO2 unit model design and development, investors will be sought who value technological innovation and long-term market potential, as well as interest in sustaining. Criteria for selection could include:

- **Commitment to Sustainability:** Investors who prioritise clean technologies and negative emissions solutions.
- **Long-Term Vision:** Partners willing to invest in emerging technologies with an extended time horizon and pending validations.

[2] https://mevaenergy.com/

[3] HTW - High Temperature Winkler technology - GIDARA Energy (gidara-energy.com)

[4] Synthesis Energy Systems, Inc

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- **Advanced Technology Investment Capacity:** Funds dedicated to supporting disruptive and scalable technology developments.

More info on BFG investors' approach → Investors - Bio-FlexGen (bioflexgen.eu)

### 3.1.2 BTC Model

#### 3.1.2.1 Technology

This result is characterised by unique specifications that may be attractive for specific use cases and to support power system operation. Two models will be delivered: one at the micro level to evaluate different use cases at CEMEX, TVAB and Sulquisa, and one at the macro level to consider the potential at the power system level. Industries using medium to high temperature processes are candidates for adopting BTC technology and require detailed modelling of the technology for specific use cases.

#### 3.1.2.2 Competitors

Competitors to BTC technology include existing cogeneration technologies and modelling tools. These alternative solutions may be more mature and less costly, but with lower efficiency.

#### 3.1.2.3 Adopters

Early adopters are project participants, such as CEMEX, TVAB and Sulquisa, who will evaluate the potential in their processes. Spanish and Swedish Governments, as well as policy makers, will be able to incorporate the technology into their energy plans.

#### 3.1.2.4 Investors

The BTC Model focuses on harnessing biomass for renewable energy. Ideal investors will be those who:

- **Support the Energy Transition:** Encourage investment in energy solutions that contribute to the post-fossil economy.
- **Have an Interest in Efficiency and Innovation**: Seek projects that offer solutions with high energy efficiency and market potential.
- **Are Committed to Sustainable Growth:** Focus on projects with clear environmental and social benefits.

More info on BFG investors' approach → Investors - Bio-FlexGen (bioflexgen.eu)

### 3.1.3 New Models, Data and Designs for BTC Systems, Components, Parts

#### 3.1.3.1 Technology

The project uses two renewable energy sources: green hydrogen from variable renewables and biomass. The BTC (Biomass-fired Top Cycle) plant converts biomass to electricity with efficiencies of 40-55%, which are 50-80% higher than standard steam cycle technology. The high-pressure hybrid fluidised bed (HFB) gasification system converts biomass into a clean gaseous fuel (syngas) at high temperatures, which is then burned in a steam-injected gas turbine. Optimal waste heat recovery maximises electrical efficiency. The plant is capable of operating with multiple inputs (residues and

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waste streams) and the gas turbine can operate with syngas (from the biomass), or independently of the gasifier with natural gas or hydrogen.

#### 3.1.3.2 Competitors

Competitors include plants based on steam cycles and engine-driven gasification. Steam cycle suppliers include players such as Andritz, Valmet, Aalborg, Standard Kessel, among others, offering solutions at different scales. Smaller scale engine gasification solutions are provided by companies such as Syncraft, Cortus, Meva Energy. Larger scale plants are less common, with examples such as Repotec. These systems have limitations in electrical performance, efficiency, and input flexibility, which limits their ability to electrify society and balance variable renewable electricity.

#### 3.1.3.3 Adopters

The initial adopters identified are municipal utilities, which require stable local generation and offer a lower required return on capital. This indicates a preference for solutions that can be adapted to local production using local biomass.

#### 3.1.3.4 Investors

For new developments in BTC systems, investors will be considered who:

- **Promote Innovation in Renewable Energy:** Investors dedicated to supporting research and development of new technologies in the energy sector.
- **Have a Strong Focus on Research and Development:** Partners interested in funding the exploration of new models and designs to improve power generation.
- **Commit to the Integration of Advanced Technologies:** Encourage the adoption of innovative solutions in the global energy market.

More info on BFG investors' approach → Investors - Bio-FlexGen (bioflexgen.eu)

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# 4 Market Environment Analysis

This section delves into the evolving landscape of the global and regional energy sector, with a particular emphasis on the advancements and market dynamics of renewable energies and biomass. Thus, this section offers a holistic view of the current state and future prospects of the renewable energy sector, emphasising the importance of innovation, policy, and market development in shaping a sustainable energy landscape.

## 4.1 Global And Regional Trends

In recent years, there has been an increase in support policies for renewable energies both at the European level and globally, with a specific focus on reducing carbon emissions. For instance, the World Energy Outlook 2022 by the International Energy Agency (IEA) (IEA (International Energy Agency), 2022) indicates how the new policies implemented in the main energy markets contribute to driving annual investment in clean energies to exceed $2 trillion by 2030 in the STEPS scenario[5], representing an increase of more than 50% compared to current levels. Clean energies are presented as a significant opportunity for growth and job creation, as well as an important area of international economic competition.

In Europe, the acceleration of the deployment of renewable energies and the improvement of efficiency in the European Union will lead to a 20% reduction in the EU's demand for natural gas and oil this decade, and a 50% reduction in coal demand, a push that becomes more urgent due to the need to find economic advantages and industrial competitiveness.

Globally, and outside of European competition, in the USA, the forecast is that by 2030, largely thanks to the Inflation Reduction Act, the increase in solar and wind energy capacity in that country will multiply by two and a half times compared to current levels, and electric car sales will increase by seven. New targets continue to stimulate large-scale deployment of clean energies in China. In Japan, the Green Transformation (GX) programme represents a significant boost to financing technologies such as nuclear, low-emission hydrogen, and ammonia, while South Korea also aims to increase the proportion of nuclear and renewable energy in its energy mix. India continues to progress towards its national renewable capacity target of 500 gigawatts (GW) by 2030, with renewable energies covering almost two-thirds of the country's growing electricity demand.

In Europe and beyond, many governments are implementing policies to encourage the transition to cleaner energies, including subsidies for renewable technologies, carbon taxes, and emission reduction targets. These policies favor the development and adoption of technologies like Bio-FlexGen. Additionally, it is also important to specifically mention the support and analysis that the European Commission provides to biomass (Bioenergy). In its brief on biomass for energy in the European Union (European Commission, 2019), biomass remains the primary source of renewable energy in the EU, accounting for nearly 60% of the total, with the heating and cooling sector being its largest consumer. Biomass, mainly from forestry, is the principal source, with wood pellets for heating and electricity standing out. Countries such as Germany, France, Italy, Sweden, and the United Kingdom are the largest consumers, while bioenergy per capita is highest in Scandinavian and Baltic countries, as well as in Austria. In the report, the Commission specifies how bioenergy is key to achieving the EU's renewable energy targets for 2030, but it must be produced and used sustainably to maximise greenhouse gas savings and protect ecosystems, without causing deforestation or loss of biodiversity.

[5] STEPS (Stated Policies Scenario) makes reference to the trajectory that current policies imply and what the world governments have stated in their policies declarations.

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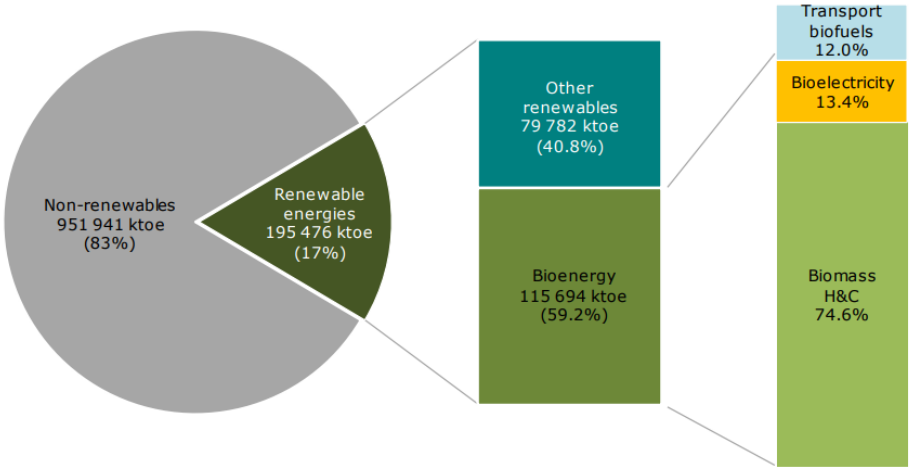


*Figure 2. Share of renewables in the EU's gross final energy consumption (2016)*

### 4.1.1 Technological Advances in Renewable Energies and Biomass

Technological advancements in renewable energies and biomass are leading the shift towards a more sustainable and resilient energy system. In Europe, as previously mentioned, the transition to renewable energies is accelerating thanks to ambitious EU policies. In 2021, more than 22% of the final gross energy consumed came from renewable sources. Biomass, in particular, is growing as an alternative to fossil fuels, utilising forest, agricultural, urban, and industrial waste to generate thermal energy, electricity, or biofuel.

Biomass technology plays a crucial role in the transition to a more sustainable and resilient energy system, especially within the European context, where ambitious policies are being implemented to increase the use of renewable energies. Biomass refers to any organic material of recent origin that can be used as an energy source. This organic material includes a wide variety of materials, such as forest residues (branches, leaves, tree remains), agricultural residues (straw, fruit shells, crop waste), urban waste (organic trash), and industrial waste (residues from industrial processes), as well as energy crops specifically planted for this purpose, like miscanthus or willow.

These advances and projects not only demonstrate the potential of renewable energies and biomass to meet our energy needs sustainably but also highlight the importance of careful and strategic implementation to maximise environmental and economic benefits.

Moreover, technological advancements are making biomass and hydrogen more viable and efficient options, both in cost and performance. Bioenergy, in particular, is receiving attention for its ability to provide continuous energy, complementing intermittent sources such as solar and wind. In this regard, it is important to mention the gain in energy efficiency in Bio-FlexGen as traditional Combined Heat and Power plants achieve 30% of energy efficiency while the BioFlexGen Biomass-fired Top Cycle technology (BTC) achieves up to 50%.

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### 4.1.2 Hydrogen Market Dynamics

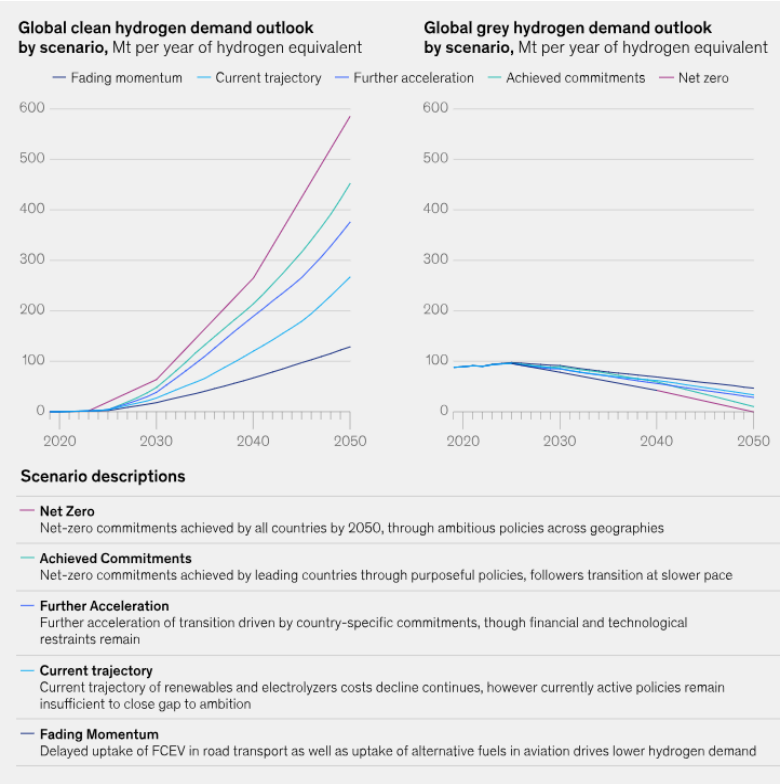


*Figure 3. Global clean and grey hydrogen demand (2020-2050) Mt per year hydrogen equivalent*

The hydrogen market is experiencing significant growth, driven by the increasing demand for energy storage solutions and clean fuels for transport and industry. This growth is supported by a focus on green hydrogen, produced from renewable sources, as a key solution for transitioning towards more sustainable energy sources. However, a challenge is observed in reconciling the projected hydrogen production capacity with the current demand, with only a small percentage of the production projected for 2030 having found buyers. This imbalance underscores the need to identify new end uses and markets for clean hydrogen. According to McKinsey, the European Union and the United Kingdom are expected to phase out grey hydrogen by 2050, moving towards a cleaner hydrogen economy. This shift reflects Europe's broader commitment to clean energy and decarbonisation. The industry is projected to drive the majority of clean hydrogen uptake until 2030, with a significant increase in demand for clean hydrogen in mobility, industrial heating, and other new applications by 2050. This transition highlights the critical role of infrastructure development and technological advancements in meeting clean hydrogen demand and ensuring the competitiveness of the hydrogen economy. Despite the challenges, Europe's focus on clean hydrogen production and consumption underscores its potential to lead in green energy and sustainable industrial practices. (McKinsey & Company, 2023).

The European Commission has been actively promoting the hydrogen economy through initiatives such as the European Hydrogen Week[6], emphasising the importance of strengthening the market and accelerating the scale and speed of hydrogen development. The EU has invested significantly in hydrogen projects and announced the launch of the world's first hydrogen bank, signalling strong support for renewable hydrogen production and hydrogen-based industries. This aligns with the EU's goals of enhancing competitiveness, fostering growth opportunities, and creating jobs, thereby underscoring hydrogen's pivotal role in Europe's future economy.

These developments indicate a significant focus on green hydrogen as a cornerstone of Europe's energy strategy, addressing both climate change and energy security challenges. The concerted efforts by the EU to invest in hydrogen technologies, infrastructure, and regulatory frameworks are pivotal steps towards establishing a robust, competitive, and sustainable hydrogen market in Europe.

[6] Home - European Hydrogen Week (euhydrogenweek.eu)

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## 4.2 Competitors analysis

Through an analysis of the current competition in a general overview, an idea can be drawn regarding the current state of the sector at a global business level. Although this competitive analysis is not typical, given that BioFlexGen is a multi-partner project and not a private company per se, it is interesting to observe the current state (both in terms of technical development and market penetration) of companies with similar solutions and/or least operating in the same sector. This analysis is a general view and differs from the results' competitor analysis in the scope, given that a specific analysis has been carried out in the results section.

**SIEMENS[7]**

Siemens Energy and Air Liquide have embarked on a collaborative journey to revolutionise the hydrogen economy in Europe. Their joint efforts are aimed at the mass production of electrolysers, a crucial step towards making green hydrogen widely available and economically viable. They have inaugurated a gigawatt factory in Berlin, marking a significant leap in the commercialisation of green hydrogen technology. The factory, benefiting from the combined expertise of Siemens Energy and Air Liquide, aims to produce electrolysers on an industrial scale, ensuring the availability of large quantities of green hydrogen at competitive prices. This initiative is expected to accelerate the ramp-up of the hydrogen economy, essential for a climate-neutral future.
Their partnership also extends to the development and scaling of PEM electrolysers, critical for producing sustainable hydrogen. By jointly applying for large projects funding under the EU's Green Deal and Important Project of Common European Interest (IPCEI) scheme, they aim to meet the rapidly growing demand for green hydrogen, aligning with the European Union's objectives for CO2 and greenhouse gas emission reduction.

In addition to the Berlin factory, Siemens Energy and Air Liquide are working on several large-scale electrolyser projects across Europe, such as the Air Liquide Normand'Hy project in France. These projects are designed to produce hydrogen from renewable energies, contributing to the decarbonisation of various sectors and supporting the transition to a low-carbon society.

Furthermore, Siemens Energy has demonstrated its commitment to the hydrogen sector through its involvement in the first industrial-scale Green Hydrogen Project in the Middle East and North Africa. This project, in collaboration with DEWA and Expo 2020 Dubai, showcases the potential of green hydrogen in storing and re-electrifying solar power, highlighting the versatility and sustainability of hydrogen as an energy carrier.

**GENERAL ELECTRIC[8]**

General Electric (GE) has a strong presence in the hydrogen fuel sector for gas turbines, leveraging its extensive experience across more than 120 units worldwide. GE's gas turbines are capable of operating on a wide range of hydrogen concentrations, up to 100%, with over 8.5 million operating hours. Their technology allows for the adaptation of existing turbines to hydrogen fuel, supporting the transition towards a more sustainable and decarbonised energy future. GE continues to innovate and develop its hydrogen capabilities, contributing to the global effort to reduce carbon emissions in power generation.

**YANMAR HOLDINGS CO., LTD.[9]**

[7] Siemens
[8] The Next Generation and Future of GE | General Electric
[9] YANMAR

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Yanmar is advancing towards a carbon-neutral society with its development of maritime hydrogen fuel cell systems. These efforts include collaboration on safety guidelines for hydrogen fuel cell ships, verification tests with a test boat utilising Toyota's fuel cell vehicle technology, and the exploration of high-pressure hydrogen refueling technology. Yanmar's innovations in hydrogen fuel cells, aimed for commercialisation in marine applications and consideration for land-based generators, underscore their commitment to sustainable energy solutions and the transition to a carbon-neutral society.

### MAN ENERGY SOLUTIONS SE[10]

MAN Energy Solutions is advancing bioenergy by offering high-performance steam turbines for generating green, carbon-neutral energy from biomass. As global energy needs grow and environmental regulations tighten, biomass presents a reliable and eco-friendly solution. It's created through photosynthesis and converted to bioenergy using efficient steam turbines, reducing fossil fuel consumption and decarbonising the energy sector. MAN Energy Solutions works closely with customers to optimise plant performance, ensuring green and sustainable operations.

### BOSCH INDUSTRIEKESSEL GMBH[11]

Bosch is committed to fostering a sustainable, hydrogen-based economy, offering comprehensive solutions from production to utilisation of hydrogen. Their portfolio includes the SOFC fuel cell system for decentralised electricity and heat, and the PEM electrolysis stack for green hydrogen production, catering to a wide range of industrial needs. Bosch's holistic approach spans the entire value chain, providing scalable, ready-to-operate solutions that contribute to a climate-neutral future.

### CUMMINS, INC.[12]

Cummins is actively engaged in developing hydrogen internal combustion engine (ICE) technology, showcasing a commitment to achieving zero emissions. Their hydrogen engines are designed for a variety of applications, including medium and heavy-duty trucking, aiming to significantly reduce greenhouse gas emissions in the transportation sector. Cummins emphasises the environmental benefits of hydrogen engines, such as CO2-free operation and the reduction of other pollutants, leveraging their expertise to advance towards a more sustainable future.

### CAMLIN ENERGY[13]

MWM highlights the benefits and efficiency of using agricultural biogas for power generation. Their solutions for biogas use are designed to reduce carbon emissions through methane decomposition, reclaim land space, and eliminate odour and infestation problems associated with organic waste decomposition. MWM offers gas engines specifically engineered for biogas combustion, incorporating features to handle fuel variations and achieve high levels of efficiency.

### ENGIE[14]

ENGIE is committed to accelerating the transition to carbon neutrality through the development of green hydrogen, produced by water electrolysis using renewable electricity. This initiative aims to decarbonise various sectors including mobility and large-scale industrial uses, while enhancing the integration of renewable energies into the energy system. ENGIE operates along the entire hydrogen value chain, from renewable energy production to end uses, focusing on large-scale renewable hydrogen production, partnerships, and innovative technologies to support a sustainable hydrogen economy.

[10] Home MAN Energy Solutions (man-es.com)
[11] About Bosch Industriekessel GmbH – Producing boilers since 1865 (bosch-industrial.com)
[12] Cummins | A Global Power Technology Leader
[13] Camlin Group | Energy | Biogas & Gas | Camlin Energy
[14] World Energy Actor | ENGIE

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## 4.3 Similar BFG Solutions Supply Analysis

The demand for solutions like Bio-FlexGen, which combines biomass with renewable hydrogen production, is poised to increase significantly as regions worldwide seek to diversify their energy mix and reduce carbon emissions. The integration of biomass into the renewable energy sector complements the rapid growth of technologies like green hydrogen, enhancing the potential for renewable power solutions in hard-to-abate sectors.

Biomass, as a renewable energy source, plays a crucial role in the global transition to a more sustainable energy system. It offers a unique advantage of being able to provide both baseload and flexible renewable energy, which is essential for balancing the variability of other renewable sources like solar and wind. Given this, the International Renewable Energy Agency (IRENA) identifies green hydrogen, produced from renewable sources including biomass, as a key enabler for expanding the renewable energy sector's capabilities. Green hydrogen serves multiple purposes in future energy systems, notably replacing the nearly 100 Mt of hydrogen currently produced from fossil fuels and meeting new demands in sectors such as steel, chemicals, aviation, and shipping (International Renewable Energy Agency (IRENA), 2023). Moreover, the World Economic Forum underscores the importance of renewable energy, including biomass, in global electricity generation, signalling a shift towards more sustainable power solutions.

Finally, the global combined heat and power (CHP) market is projected to experience significant growth in Europe, with a CAGR (Compound annual growth rate) of 8.1%, reaching a forecasted market size of $ 32,000 million by 2031. This growth is driven by the growing adoption of sustainable and cost-effective energy solutions as well as the increasing demand of district heating. Europe's CHP market expansion is fuelled by carbon reduction goals and energy security policies, highlighting the importance of CHP in achieving a greener future.

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# 5 SWOT Analysis

The SWOT Analysis identifies the project's internal and external factors: strengths include technological innovation and the ability to provide stable energy, complementing intermittent renewables, while weaknesses involve high initial investments and technical integration challenges. Opportunities arise from the increasing demand for clean energy and supportive policies, whereas threats encompass policy changes, competition with established renewables, and price variability of biomass and hydrogen, potentially impacting project viability.

*Table 1. SWOT ANALYSIS*

| STRENGTHS | WEAKNESSES: |
|---|---|
| -Technological innovation that combines biomass with renewable hydrogen to generate energy, improving efficiency and reducing costs.<br><br>-Ability to provide continuous and manageable energy, complementing intermittent sources of wind and solar energy.<br><br>-Flexibility | -High initial investment and potential dependence on subsidies or governmental incentives.<br>-Technical challenges associated with the integration of technologies and the need to develop biomass and hydrogen supply infrastructures. |
| **OPPORTUNITIES** | **THREATS** |
| -Growing demand for clean and renewable energy solutions<br><br>-Growing fraction of intermittent electricity production<br><br>-Favourable policies for carbon emission reduction, and advances in renewable energy technologies that can open new markets. | -Changes in governmental policies or subsidies.<br><br>-Competition with other more established and known sources of renewable energy.<br><br>-Variability in the prices of biomass and hydrogen that could affect the economic viability of the project. |

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# 6 Market Barriers

The renewable energy sector, focusing on biomass and hydrogen, is at the forefront of the transition to a more sustainable and carbon-neutral future. However, entering and exiting this market presents unique challenges. O one hand, entry barriers are the factors that make it difficult for new firms to enter a specific industry or market. These barriers can take various forms and significantly affect a firm's ability to compete effectively. On the other hand, exit barriers are all those elements that hinder, hinder or delay a company's exit from a market or industry sector. In this way, entry barriers are already established and therefore some measures can be leveraged in order to tackle them. Exit barriers can be established by the established companies in the sector to prevent others.

**ENTRY BARRIERS**

- **Regulations and compliance:** Navigating through environmental, safety, and energy efficiency regulations requires investment and specialised knowledge. **Mitigation measure:** Develop partnerships or alliances with stakeholders specialising in environmental, safety and energy efficiency regulation. These partnerships can facilitate access to expertise and best practices to comply with regulations more efficiently and cost-effectively. Project communication activities as well as networking of partners are key.
- **Advanced technology and specialisation:** Integrating biomass and renewable hydrogen demands innovative technologies and technical expertise, limiting entry without these resources. **Mitigation measure:** We have integrated our project within an existing cross-cutting consortium, which includes active collaboration with academic institutions, research centres and other leading companies in the sector. This consortium, whose work plan has been approved by the European Commission, focuses on sharing expertise, resources and developing joint innovations. Through this partnership, we have made significant progress, with tangible results already achieved in crucial technical aspects of the project. This collaborative and well-structured approach ensures not only the technological progress of the project but also its long-term sustainability and success.
- **Capital investment:** Renewable energy projects with integrated technologies require significant initial investment. **Mitigation measure:** Exploring alternative financing options, such as government grants, crowdfunding, public-private partnerships, or impact investment that seeks social and environmental returns in addition to financial returns. Using scalable or modular business models that allow projects to be started on a smaller scale and scaled up can also reduce the need for large upfront investments. In this aspect, the European Commission support that funds this project is key for its development.
- **Interdependence in the value chain:** The need for collaboration and established networks can be a barrier without access to these resources. **Mitigation measure:** Build a strong network through active participation in industry associations, trade fairs, and industry events. This can facilitate the establishment of partnerships and access to networks of suppliers and customers. Negotiating long-term partnerships or cooperation agreements with suppliers and customers can also enhance stability and positive interdependence in the value chain.

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## EXIT BARRIERS

- **Recoverable capital investment:** Initial investments may not be transferrable to other projects, complicating cost recovery upon exit.
- **Technical specialisation and adaptability:** Specialisation in specific technologies can reduce a company's flexibility to adapt to market changes or pivot to other sectors.
- **Commitments in the value chain:** The complexities of unravelling established collaborations and contracts can make exiting the sector challenging.

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# 7 Market Strategies and Positioning

Given that the Deliverable (D6.1 Communication and Dissemination Strategy) has been already developed regarding the market positioning strategies and market approach, a summary of that document has been elaborated below.

The Deliverable 6.1 "Communication and Dissemination Strategy" detailed the communication activities that were implemented to raise awareness about the project, engage stakeholders, potential end-users, and the public, as well as to promote the project's activities. To ensure a coherent and professional message across communication channels, an impactful visual identity was created that includes the logo, social media icons, templates, and a written identity that includes a tagline and key messages “Making the Green Deal real!” The communication and promotion strategy also includes: es

1. A project website that serves as a meeting point for all stakeholders, providing general information and highlighting key results to make the Bio-FlexGen research attractive to a non-expert audience.

2. Creative social media campaigns to drive traffic to the website and build a community of relevant stakeholders, including the creation of a Twitter/X account and a LinkedIn page.

3. A communication package that provides partners with professional and original quality material to promote the project, such as factsheets, posters, and roll-up banners, as well as short videos to explain the concept and potential impact of Bio-FlexGen to non-technical audiences and to present the key technologies and their integration through animated videos.

4. National and international media outreach to increase general awareness and public acceptance of the Bio-FlexGen concept. As of new, a website section for investors was created, accompanied by two webinars: https://bioflexgen.eu/investors/

These strategies were pre-identified by the consortium as part of its communication strategy and were guided by the project's progress, adapting over the course of the project. These actions were fundamental to communicate the benefits and uniqueness of Bio-FlexGen to the stakeholders and ensure the adoption and impact of the project on the relevant market segments.

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# 8 Risk Analysis and Regulations

In the Risk and Regulation Analysis section, a critical evaluation of factors that can influence the viability and success of Bio-FlexGen is conducted. This analysis is crucial for understanding the complex dynamics and challenges faced by these emerging technologies. It ranges from identifying potential risks that could impact the economics of projects to a detailed examination of the current regulations and norms that dictate the operational framework. By considering both risks and regulations, the aim is to provide a solid foundation for strategic decision-making, thereby ensuring that projects are not only technically viable but also sustainable from an environmental, legal, and social perspective, in line with the expected project objectives and the expectations of the European Commission. This comprehensive approach is essential for successfully navigating an increasingly competitive and regulated market, allowing for the anticipation of challenges and aligning projects with regulatory requirements and market expectations.

1. **Price Volatility:** The economic foundation of projects leveraging biomass and hydrogen can be significantly affected by price fluctuations. The volatility in the costs of these resources can introduce uncertainties in budgeting and financial forecasting, making it challenging to maintain project viability over time.

2. **Emerging Technologies:** While innovation is at the heart of advancing renewable energy solutions, dependency on nascent technologies carries inherent risks. These include uncertainties regarding the technologies' performance, their ability to scale effectively to meet demand, and the challenges associated with integrating them into existing energy systems.

3. **Supply Chain Challenges:** A stable supply of biomass and hydrogen is essential for the consistent operation of renewable energy projects. However, vulnerabilities in the supply chain, such as logistical issues, resource scarcity, or geopolitical factors, can pose significant risks to project stability and scalability.

4. **Market Acceptance:** The introduction of new energy solutions often faces hurdles in terms of market readiness and acceptance. Consumer preferences, industry standards, and the competitive landscape can influence the adoption rate of innovative technologies, affecting their potential for widespread implementation.

5. **Policy Evolution:** The regulatory environment for energy and environmental policies is continually evolving. Changes in legislation, incentives, or compliance requirements can have profound impacts on project feasibility, necessitating ongoing monitoring and adaptability.

6. **Environmental Compliance:** This project, and any other in the same sector, must adhere strictly to regulations concerning emissions and the use of renewable resources. This compliance encompasses not only the minimisation of carbon footprints but also the responsible management of resources and ecosystems impacted by energy production.

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7. **Energy and Safety Standards:** Adhering to both local and international standards that govern energy safety is paramount. This includes regulations that ensure the safe production, distribution, and usage of energy, as well as the protection of workers and communities involved in or affected by these processes.

8. **Hydrogen-Specific Requirements:** Given its unique properties and potential for energy storage and transportation, hydrogen production, storage, and usage are subject to specific regulatory frameworks. These frameworks are designed to ensure safety, efficiency, and environmental protection, addressing aspects such as infrastructure integrity, leakage prevention, and the minimisation of potential hazards.

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# 9 Conclusions and Recommendations

The Bio-FlexGen Market Analysis Report delves into the integration of biomass and renewable hydrogen for combined heat and power generation, emphasising the innovative combination of gasification technology and gas turbines. It includes research methodology, market environment analysis, SWOT analysis, market barriers, market positioning strategies, and competitor analysis.

This report concludes that the Bio-FlexGen project is poised to significantly contribute to the decarbonisation of the energy sector by leveraging biomass and renewable hydrogen. The innovative approach offers a viable solution to enhance energy efficiency and sustainability. However, the sector is facing important challenges such as high initial investments, regulatory compliance, and market acceptance.

Given the research and the conclusions of this document, some recommendations can be done:

- **Enhancing collaboration with industry stakeholders (technical, financial) to facilitate technology integration and scalability of the project's results.**
- **Advocating for supportive policies and incentives to mitigate initial investment risks and stimulate market demand.**
- **Continuous innovation and research to improve system efficiency and reduce costs.**
- **Continuing developing targeted communication strategies to increase awareness and acceptance among potential users and the broader public.**

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