PHOENIX BIOPOWER

Business Plan

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Contents

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1 Executive Summary

Phoenix Biopower (PBP) is developing a highly efficient biopower technology that can radically improve the economics of plannable, local, and renewable power; the so-called BTC concept. A standardized plant at approximately 11 MWe capacity is a targeted first plant that can utilize woody residues, as a first step towards lower quality fuels.

The BTC plant technology can achieve electrical efficiencies of 40-53% (LHV), depending on scale, by combining high pressure biomass gasification with a gas turbine featuring massive steam injection. The company is therefore developing three key technology systems: the Top Cycle gas turbine, the Hybrid Fluidized Bed gasifier, and the BTC plant technology.

The revolutionary Top Cycle gas turbine is a platform technology that may be applied for hydrogen, fossil gas and biopower applications and is, through its design, optimal for CCS/BECCS with superior cost and performance in power generation and CO2 capture. The expected roll-out of a hydrogen-based energy system is perfect for the TopCycle gas turbine. With inherently superior flexibility, economics and emissions, with NOx levels second to none, the Top Cycle will be the heart of cost-effective, plannable power plants with multifuel capacity.

The Hybrid Fluidized Bed (HFB) gasifier is a new, patented, gasification technology that addresses the challenges posed by high pressure gasification. Through its design, the negative effects of high pressure on conventional fluidized bed gasifiers are addressed, resulting in an cost-efficient and effective gasifier with a wide feedstock flexibility. The HFB is therefore well-suited to pressurized synthesis and production processes like hydrogen production with BECCS, methanol, sustainable aviation fuel, etc, as well as steel industry and other consumers of green gases.

The BTC technology, Biomass-fired Top Cycle, is a high efficiency technology based on pressurized biomass gasification integrated with the Top Cycle gas turbine. The BTC nearly doubles the electrical efficiency compared to a traditional steam cycle, thus offering a revolutionary step-change in biopower economics and market potential.

Electricity generated from bioenergy in 2019 increased 5% and reached 589 TWh. IEA Sustainable Development Scenario projections are 922 TWh in 2025 and 1168 TWh in 2030, a near doubling in a decade.

A new, green hydrogen market is emerging. It is expected that green hydrogen will replace fossil-derived hydrogen and fossil fuels for propulsion and power generation. Biomass is a source of producing hydrogen through gasification. Furthermore, The BTC with its superior fuel flexibility can run on 100% hydrogen.

The BTC represents a great business opportunity to the gas turbine industry where gas turbines become associated with CO2 neutral/negative power generation. Especially since current market forecast points towards a decline after 2023-2025 in GT unit orders and the main market drivers for new capacity are coal and nuclear plants retirements and electrification of societies through the energy transition.

Glossary

MWe	Electrical power produced for a plant. Megawatt is a unit of power
MWh	Heating power supplied from a plant
MWf	The thermal effect released from the fuel when it is burned
Electrical efficiency	Ratio of electricity produced to fuel consumed (MWe/MWf)
Alpha value	The ratio of electricity produced to heat supplied (MWe/MWh). Alpha can be varied with steam cycles to maximize electricity or heat production.
Total efficiency	Ratio of all energy produced (electricity and heat) to fuel consumed $(MW_{e+}MWv)/MW_{br}$
Energy Density	MWe divided by airflow in the process. A number used to compare how compact a plant can be expected to be. Most often, it indicates the trend of cost per MWe
MWh, TWh	Megawatt hours. A measure of the amount of energy delivered over time. A terawattatt (TWh) is one million MWh, one billion kilowatt hours. For example, Sweden consumes about 140 TWh every year.
NOT	Exa-Joules. Also a measure of how much energy is delivered over time. For example, the annual global energy consumption is 550 EJ.
Production cost	Total cost for the plant owner per kWh of electricity. Including capital, operations, maintenance, fuel and other materials. Can be reported with or without policy instruments (taxes, etc.).
Marginal cost	The cost of producing one kWh of electricity, i.e. exclusively fixed and capital costs. A plant can run if the market price exceeds its marginal costs
LCOE	Levelized Cost of Energy. Production cost of electricity, including CapEx, OpEx, fuel and taxes.
Steam cycle	A power cycle in which water is boiled at pressure and the water vapor drives a steam turbine as it expands.
Boiler	A unit where biofuel is burned and water is boiled
Gas turbine	An aggregate or power cycle in which air is compressed and then heated by the combustion process and then expanded. Typically, twice as much air as is needed for combustion is compressed.
Combined Cycle, CC	A power cycle in which the waste heat of the exhaust gases from a gas turbine is used to power a steam cycle.
Top Cycle	A new power cycle, owned by Phoenix BioPower, where waste heat in the exhaust gases is recycled to the gas turbine in the form of water vapor. Only the amount of air required for combustion is compressed.
BECCS / Bio-CCS	Bio Energy Carbon Capture and Storage. Combining biopower with carbon capture to achieve CO2 negative emissions
DAC	Direct Air Capture, capturing CO2 directly from the atmosphere
CDR	Carbon Dioxide Removal – Technologies to remove cardon dioxide form the air or emissions.

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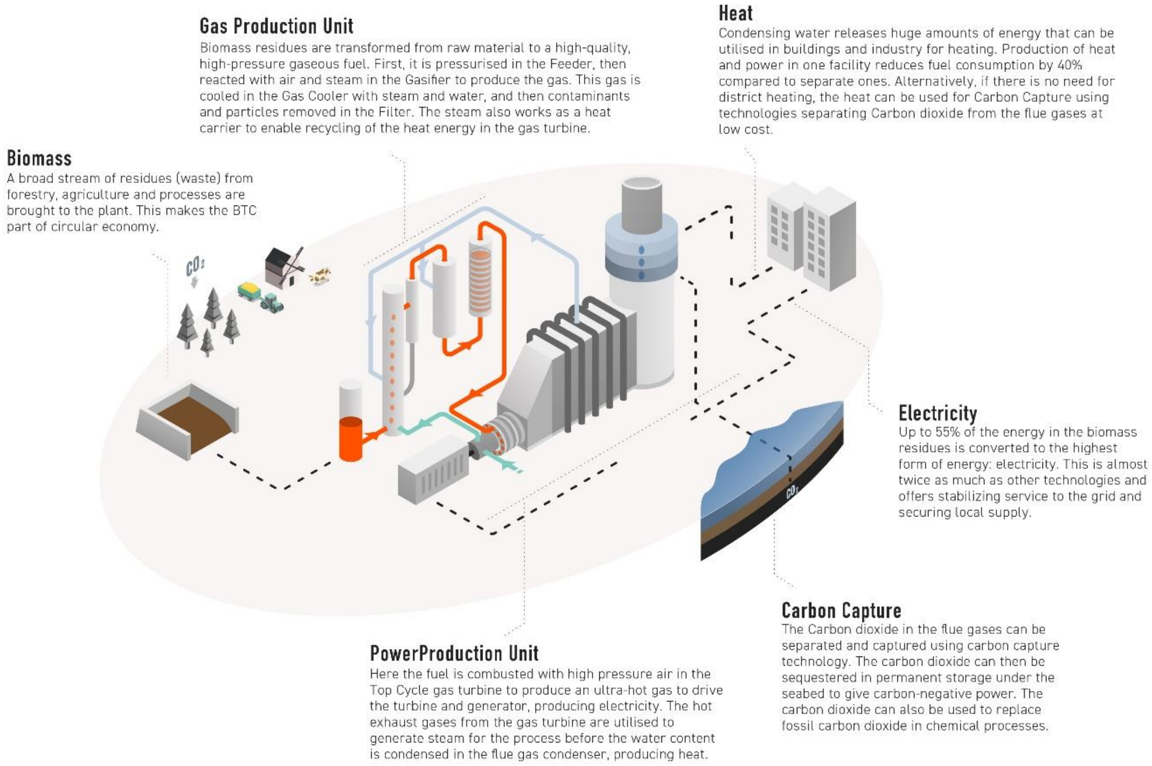
2 Phoenix BioPower and BTC Overview

2.1 Vision for BTC Technology

Phoenix BioPower AB is developing a new platform technology for the decarbonized economy to provide plannable, local and cost-effective renewable power production as an alternative to variable and weather dependent renewable energy. This technology, called the Biomass-fired Top Cycle (BTC), has the potential to almost double the electrical efficiency from biomass compared to state-of-the-art plants and therefore nearly halves operating costs. At the same time CO2 can be captured with lower relative power penalty and up to 60 % more electricity producer per ton CO2 captured, enabling very low costs for achieving negative emissions.

The Top Cycle itself is a gas turbine platform that can utilize a variety of fuels, including biomass, bio-methane, hydrogen, and even concentrated solar-thermal energy. Similarly, the gasification technology is also a platform that can be utilised in segments requiring pressurised synthesis gas, i.e., the production of methanol, methane, or hydrogen from biomass.



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2.2 Phoenix BioPower

Phoenix BioPower was founded in 2016 to commercialise the BTC technology. The core technology was taken over from Euroturbine AB, who had focused on natural gas applications and developed the gas turbine technology in co-operation with Vattenfall and MTU Aero Engines with support from the Swedish Energy Agency. Phoenix has since secured ~16 M€[1] for developing the BTC technology, and the Company now has a team of 12. This has resulted in several technical results and advances, expressed in part by a large patent portfolio consisting of 8 families and 21 granted patents where the latest gasification patent was published on February 28, 2023. The company team, as well as the Board of Directors, all have long and relevant experience of entrepreneurship, finance, product development and R&D in the energy sector.

Woody fuels like forest residues are targeted short-term, with agricultural residues and waste wood targeted in the longer term. The technology is scalable for plants from tens of megawatts to over hundreds of megawatts electricity. The Company sees that the Nordic and EU markets are ideal entry points due to focus on clean energy, availability of fuel, and support schemes. Our business model is to develop key components and systems for the BTC plant and offer them through large plant- and equipment suppliers to utilities. These key components are within the biomass pressurization system, the gasification system, combustion system and the TopCycle gas turbine. The system integration shall ensure high efficiency and good operability.

Plants will be built in standardised modules to best fit customer requirements while minimising manufacturing and customer costs and generating economies of scale. We judge the optimal plant sizes for market entry to be in the 10-15 MW_e range to secure reasonable economies of scale while still addressing the fragmented nature of biomass on the global market. Following the introduction plant size, we also see good market fit for plants of 40-50 MW_e and 80-100MW_e without significant product cannibalization while at the same time enabling for modular application of each size.

2.3 Outline of the BTC Concept for High-Efficiency Biopower

The core approach in the BTC is to combine high-pressure gasification integrated with a novel gas turbine process – the Top Cycle – such that all heat is recovered at optimal temperatures by way of steam. In this way, the BTC concept can achieve electrical efficiencies up to 53% at large scales (100+ MW_e) and 45-50% at 10-40 MW_e scale. As the flue gas consists of 50% steam, the total efficiency can reach 100% in CHP applications by utilizing flue gas condensers. Further, this 75-78°C heat from the condenser can, with heat pump booster, be efficiently utilized for CO_2 capture, giving a unique performance with carbon-negative emissions (so called BECCS) at unrivalled net electrical efficiencies. The BTC can utilise gaseous fuels for flexible, fast response to prices and switch to biomass residues to allow lower production costs and higher margins.

[1] 12 M€ in direct funding and 4 M€ in indirect funding via partners towards the development of Phoenix' technology platform.

The Biomass-fired Top Cycle (BTC) plant consists of a Feedstock Preparation Unit (FPU), Gas Production Unit (GPU) and Power Production Unit (PPU), whereby:

- The Feedstock Preparation Unit consists of fuel handling, screening and sizing, a low temperature biomass drier and any eventual densification steps, e.g., pelleting or briquetting
- The Gas Production Unit consists of a biomass pressurisation and feed system, gasifier, hot gas cooler and hot gas filter
- The Power Production Unit consists of a high-pressure gas turbine with steam-injection, called the TopCycle. Flue gas energy is recovered in a Heat Recovery Steam Generator (HRSG) to produce steam, and a Flue Gas Condenser (FGC), where the water is recovered and treated before recycling to the plant and low temperature heat is recovered.

2.4 Complementary applications

In addition to applications with biopower and combined heat and power, the Company's technology platform can provide considerable benefits in other areas, outlined below.

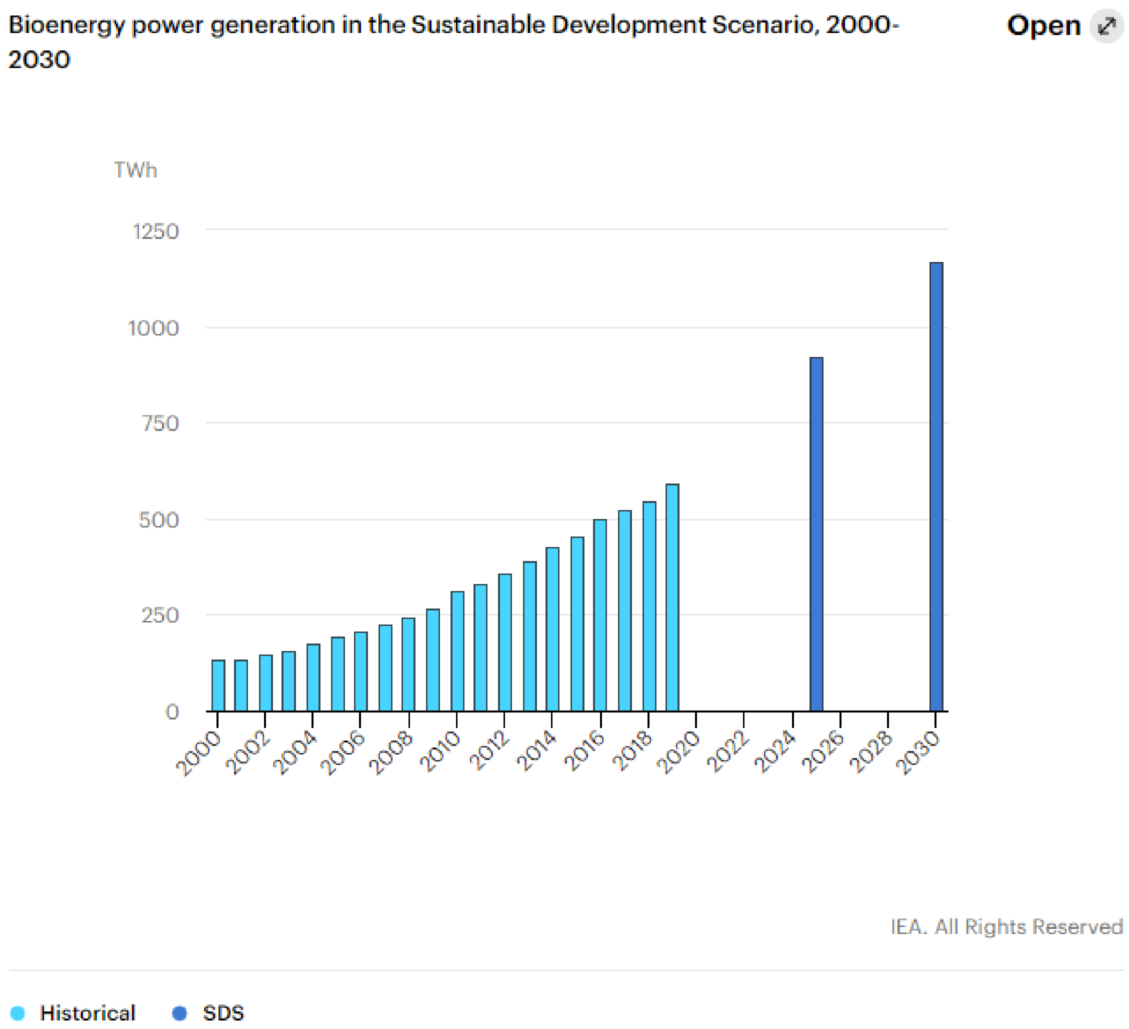
Application	Advantage	Core Benefits
BECCS	Biopower plant can drive CCS with waste heat	60% more electricity per CDR. 30-50% lower levelized costs. Potentially more profitable application than CHP with district heating. Enables 24/7/365 BTC operation.
H2-peaker	TopCycle can utilise hydrogen with good operability and low emissions. Unique flexibility, same hardware. Ultra-low NOx, CO emissions.	Higher performance and better load response with H2 as a fuel in peaking applications. Balance to variable wind. Broad operation window
Natural gas CCS	Top Cycle can drive CCS with waste heat	75% lower energy penalty and low cost of CCS for natural gas plants, e.g. in industry. Primarily for plants smaller than 200 MWe/unit/block.
Biofuels/ Green Hydrogen	De-couple fuel from electricity price. Higher pressure syngas production	Avoid need for hot gas pressurization. CO2 negative H2 potential. No crowding-out of renewable power consumption. Very competitive economics and CO2-negative H2.
Co-production of pellets	The waste heat from the BTC can dry excess fuel and pelletise for sales either locally or on global market	Additional revenue. 1 – 2 times as much fuel can be dried as is consumed by a BTC unit from waste heat.
Water purification	Waste heat can be used to drive water purification technologies for efficient and low-cost production of potable water	Some water purification technologies require large amounts of energy. Specific technologies can utilize the BTC waste heat for water purification at low costs and high capacity. Enables 24/7/365 BTC operation.

3 Market

The global energy transition requires the introduction of new power generation on a massive scale. The majority of the energy transition is about electrification, direct, like electrification of transport, or indirect, like fossil-free steel through green hydrogen from electrolysis. For markets like Sweden, electricity consumption is expected to more than double in the coming 25 years, to be compared with a stable level for the past 40 years around 150-160 TWh/a. At the same time, over ¾ of existing production capacity must be replaced due to retirements, meaning that new capacity representing 2X of current consumption must be erected in the same period.

The BTC technology and the company's technology platform addresses and touches on several markets as has been described in the previous section of the possible applications. The key markets that the company is looking at are the Biopower market, the Gas Turbine market and the Industrial gases/green hydrogen markets. For more in-depth details on biopower and gas turbine markets, please check Appendix I.

3.1 Biopower Market



Source: IEA

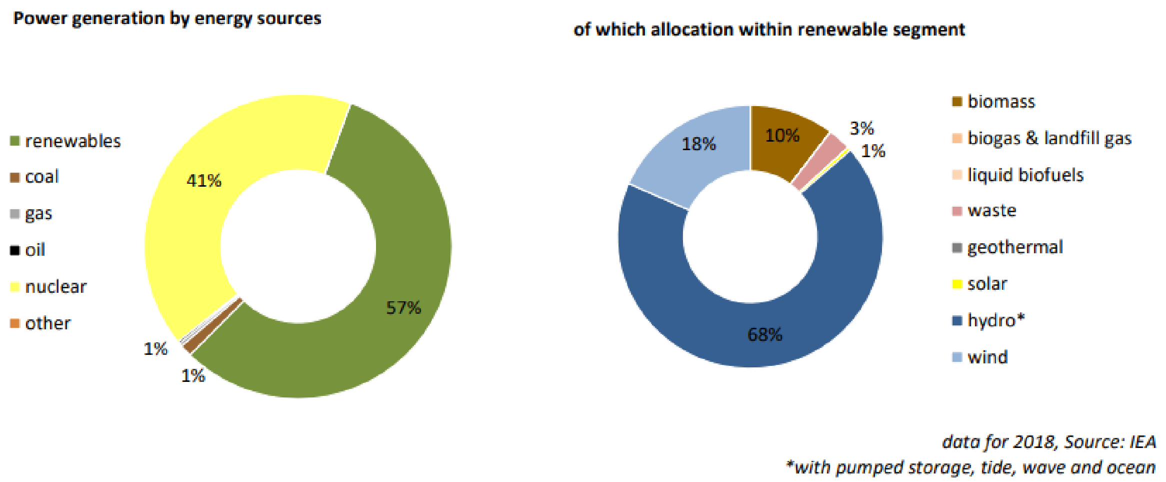
According to IEA and IRENA the biopower market is expected to grow 10-15 % annually until 203 and beyond, with an estimated total energy capacity of up to 150 EJ. TWh, with SDS projections of 922 TWh in 2025 and 1168 TWh in 2030 as shown in figure.

According to a study by Research and Markets, the biomass power generation market size in 2021 is expected at BU$ 45.74, and BU$ 65.55 by 2026 with CAGR of 7.39%.

IEA indicate that the growth is influenced by policy changes and market developments around the globe. For example, China introduced a new clean-heat initiative that is anticipated to increase the demand of biomass- and waste-fuelled co-generation plants. In addition, China is promoting the use of agricultural residues where solid biomass-based electricity generation currently receive feed-in tariff support.

The report states that “In India, fiscal support and capital subsidies underpin capacity expansions of existing plants and greenfield investments, mainly in bagasse co-generation plants utilising by-products of the sugar and ethanol industries.”

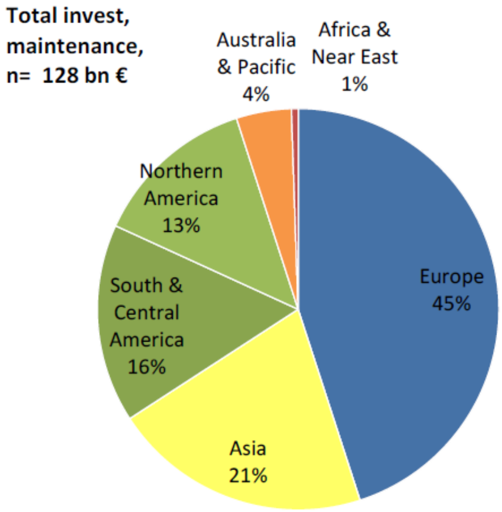
In Sweden, 10% of electricity is produced from biomass as shown in below figure.



Energy production in Sweden 2018 by source. Source: ecoprog

The expected high-growth markets are also reflected in the markets where most investments are expected in the coming years, with China taking the lead as the largest expected market for new plants. India is also planning to invest significantly in comparison to the market size. In Europe, much of the expected investments are driven by subsidy schemes, many promoting small scale (<2MW) CHP solutions. For the Nordics, investments are primarily driven by rebuild and replacement of existing CHP plants as the economics for power plants are not good enough for steam cycle plants.

Worldwide investments in new constructions & modernisation and maintenance 2018-2027



Country	mln Euro - new construction	mln Euro - maintenance	mln Euro - total invest
Brazil	7,100	8,800	15,800
China	11,400	3,900	15,300
UK	8,900	4,300	13,200
USA	6,700	4,700	11,400
India	4,600	3,400	8,000
Sweden	3,100	3,900	7,000
Finland	2,700	3,500	6,200
Canada	2,900	2,700	5,600
Japan	3,100	1,500	4,600
Italy	1,200	4,000	4,400

Source: ecoprog 2018

Plants and electricity generation capacities in Europe. Source: ecoprog 2018

3.1.1 BECCS market

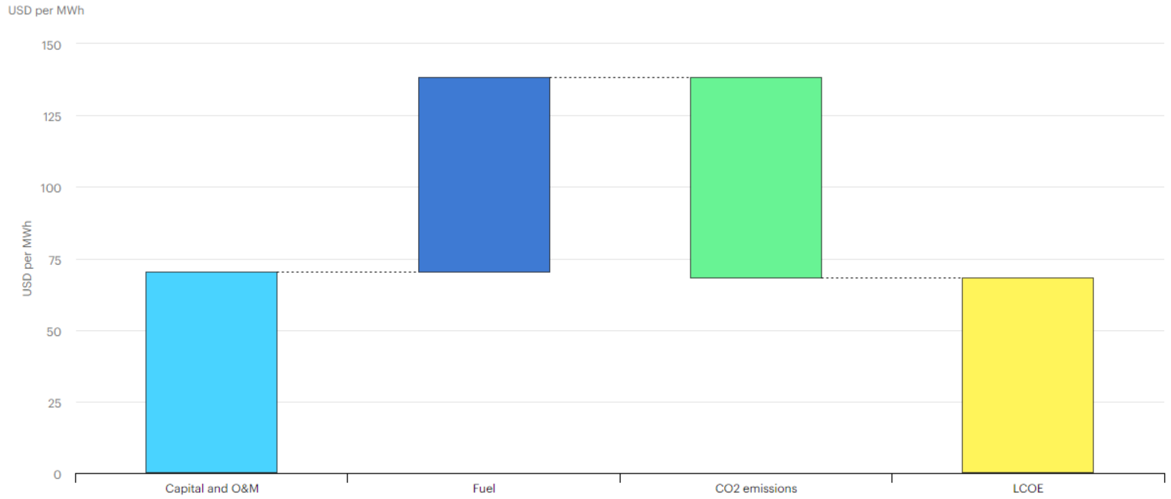
BECCS in now getting a lot more attention from both regulations and investment points of view, as it is considered one of the main pathways to achieve the Net-Zero goal.

In addition, IEA considers CCUS an enabler of least-cost low-carbon hydrogen production.

IEA reports that "Plans for more than 30 new integrated CCUS facilities have been announced since 2017, mostly in the United States and Europe, although projects are also planned in Australia, China, Korea, the Middle East and New Zealand". In just 2022 and 2023 several large scale BECCS projects have been announced, like BECCS-Stockholm by Stockholm Exergi, looking to capture 800 000 tons of CO2 per year.

Research and Markets estimates the global market size for CCS at US$2.8 Billion in 2020, with projection to reach a US$4.9 Billion by 2026, indicating at a CAGR of 9.9% over the analysis period. CCS will continue to grow and BECCS is expected to form 22% of CCS according to IEA Sustainable Development Scenario, 2020-2070.

CO2 capture will impact LCOE of biopower and is demonstrated below for a theoretical[2] biomass IGCC plant equipped with CCUS, where Capital and O&M: $ 70/MWh. Fuel cost: $ 68/MWh. Co2 cost: $ -70/MWh ($80/ton), resulting in LCOE: $68/MWh. Since the study was published, CO2 carbon pricing until 2022 increased drastically where most BECCS models now apply 150 – 250 €/ton CO2 captured by 2030. Following the economic downturn in the EU the EU ETS pricing for CO2 emissions currently trading at 55-60 €/ton, down from over 100€/ton a year ago in February 2023.



Impact of a carbon price of USD 80 per tonne CO2 on the LCOE of BECCS. Source: IEA

BECCS started to ramp up worldwide and there are currently many leading projects as shown in in below table and figure. This includes several larger scale projects like Stockholm Exergy's 800 000 t/a of carbon captured, project BECCS Stockholm.

Leading bioenergy with CCS/CCU projects currently operating worldwide

Plant	Country	Sector	CO_2 storage or use	Start-up year	CO_2 capture capacity (kt/year)
Stockholm Exergi AB	Sweden	Combined heat and power	-	2019	Pilot
Arkalon CO_2 Compression Facility	United States	Ethanol production	Storage (EOR)	2009	290
OCAP	Netherland	Ethanol production	Use	2011	<400*
Bonanza BioEnergy CCUS EOR	United States	Ethanol production	Storage (EOR)	2012	100
Husky Energy CO_2 Injection	Canada	Ethanol production	Storage (EOR)	2012	90
Calgren Renewable Fuels CO_2 recovery plant	United States	Ethanol production	Use	2015	150
Lantmännen Agroetanol	Sweden	Ethanol production	Use	2015	200
AlcoBioFuel bio-refinery CO_2 recovery plant	Belgium	Ethanol production	Use	2016	100
Cargill wheat processing CO_2 purification plant	United Kingdom	Ethanol production	Use	2016	100
Illinois Industrial Carbon Capture and Storage	United States	Ethanol production	Dedicated storage	2017	1000
Drax BECCS plant**	United Kingdom	Power generation	-	2019	Pilot
Mikawa post combustion capture plant	Japan	Power generation	-	2020	180
Saga City waste incineration plant	Japan	Waste-to-energy	Use	2016	3

* The OCAP plant receives its CO2 from a fuel refining facility (hydrogen production) and from an ethanol production plant. Therefore only part of the total CO2 (400 kt/year) qualifies as bioenergy with CCU. ** The project is currently releasing CO2 after its capture, but the long-term plan is to focus on offshore storage as part of the Zero Carbon Humber project.

[2] Theoretical as no commercial IGCC plants exist today.

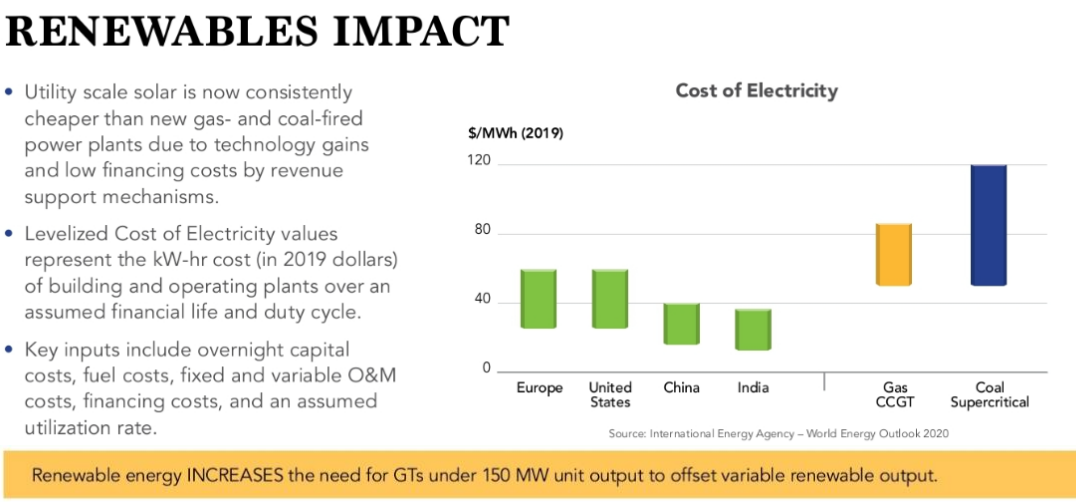
Figure 1: Map of CCS projects from CO2RE by the Global CCS Institute, https://co2re.co/FacilityData.

3.2 Gas Turbine Market

According to Gas Turbine World global market forecast 2021-2030, it is expected that equipment-only purchases for heavy-frame to reach $36.3 B in the next 5 years, and $2.8 B for light industrial unit orders in the same period. Notable trends based on the last 5 years data indicate that "in the Electrical Power Utility Sector: units in 30-40MW range (mobile units) are up and 300MW+ have rocketed; the 40- 150MW range is down over 50%".

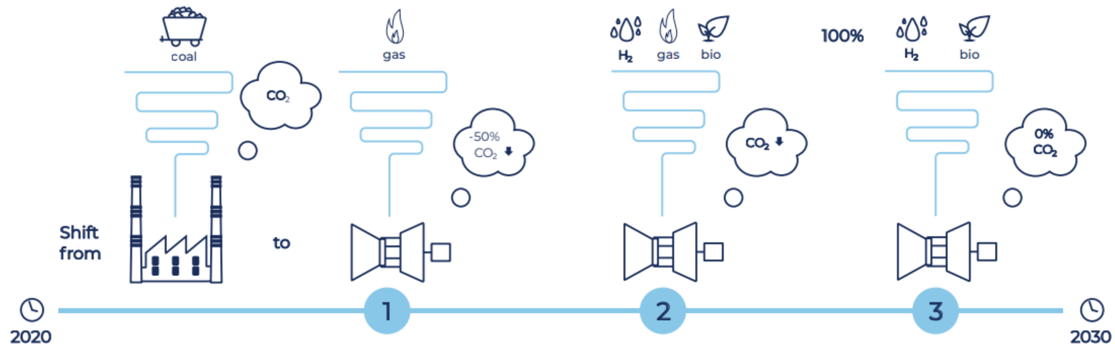
Global projections for energy mix indicate an increase in natural gas and renewables. A main market driver for this trend is the coal and nuclear plants retirements. However, in recent year, a renewed drive towards new Nuclear has begun in EU and US, where it's more and more becoming a cornerstone in the energy transition in some countries.

The BTC represents a great business opportunity to the Gas turbine industry where gas turbines become associated with CO2 neutral/negative power generation. GTW forecast indicates that renewable energy increases the need for GTs under 150MW, and the renewables impact as is shown in below figure.



GTW 2021 Market Forecast

Gas turbines can play an important role in the shift towards zero-carbon power generation as demonstrated in below figure from ETN hydrogen gas turbines report.

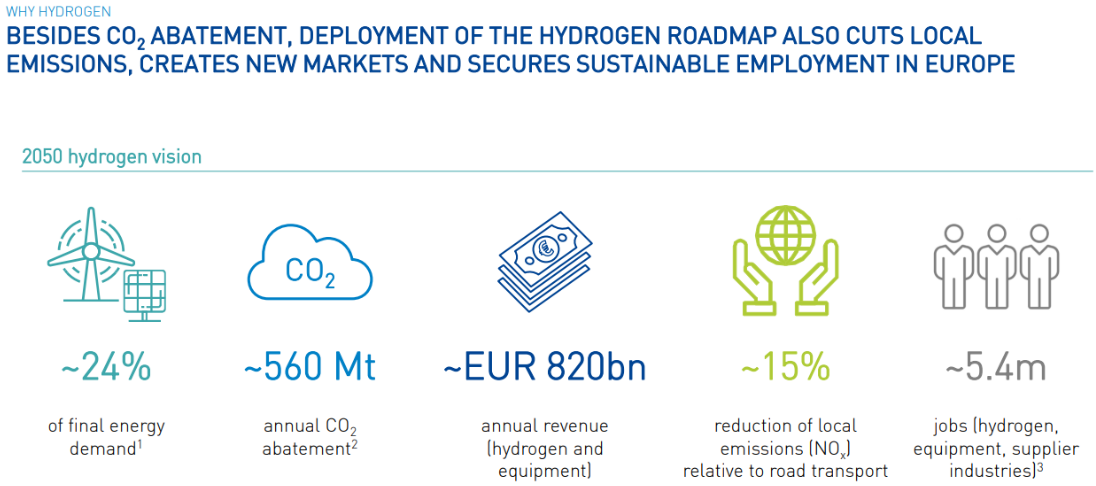


Source: ETN Global

3.3 Hydrogen Generation Market

With the recent initiatives in the EU, China and US, a new, green hydrogen market is emerging. From all corners of the world, it is expected that green hydrogen will replace fossil-derived hydrogen and fossil fuels for propulsion and power generation. In addition, industrial applications for green hydrogen are getting increasing attention, like Hybrit for fossil-free steel and Project Air for Fossil free methanol, both in Sweden. The amounts required for industrial uses in many markets far outweigh that of transport and power generation. For this reason, such uses will most likely be for hard-to-abate sectors and applications where alternative methods are unavailable. Two examples of this are shipping and aviation.

An example is Hydrogen Roadmap Europe to achieve deep decarbonization as shown below along with 2050 vision.



Source: Hydrogen Roadmap Europe- Fuel Cells and Hydrogen Joint Undertaking (FCH JU)

Biomass is a source of producing Hydrogen through gasification. Furthermore, the BTC with its superior fuel flexibility can run on 100% Hydrogen.

In the projection by FCH JU, the percentage of energy produced by hydrogen could double by 2030 in the ambitious scenario.

Internal studies by Phoenix BioPower show that green H2 production with CCS has potential to become very competitive in the market. Depending on assumption, a production price of 2.9€/kg is estimated. To be compared with market estimates of 2.5 to 7 €/kg depending on technology and market. In addition, higher Carbon Credits will drive down the LCOH2 further. A Carbon Credit of 205€/ton would result in a production price of 1€/kg, far lower than any other technology.

	Cost (€/kg H_2)	Reference
Phoenix Biopower biomass gasification	2,9	Updated HYFLEX Case 1 from Bio-FlexGen Project*
H_2 from solar and wind, Europe, 2030	2,5 - 3	Levelised Cost of Hydrogen Maps – Data Tools - IEA
Green H_2, Sweden, 2030	3,75 - 4	Green hydrogen economy - predicted development of tomorrow: PwC
Green H_2, Central Europe, 2030	5 - 8	Hydrogen Insight

For a more detailed review and competition analysis on the hydrogen production market, please contact the company for a more detailed discussion.

3.4 Competition

Addressing two very large markets; the gas turbine market and the biopower market inevitably means competition. In addition, the green hydrogen market is expected to grow significantly in the coming decades, driven by increasing costs for CO2 emissions. In the very

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short-sighted perspective, the company know of no other actor developing similar technology as the Top Cycle or the BTC. However, a wider perspective is needed for a more accurate view on the competitive landscape for the Top Cycle and BTC.

Top Cycle competition (engine)

For the Top Cycle as a power production unit in gaseous fuel markets, the competition stretches from reciprocating gas motors at smaller scales (1-20 MW) to traditional Single Cycle gas turbines (5-100 MW) and Combined Cycle (70-600 MW) plants at larger scales. Single cycle gas turbines operate with electrical efficiencies of 30 – 42 %, and gas motors at 38-48%. Combined cycle plants are normally larger and operate with around 57-63%. These latter plants are today supplied by manufacturers of large gas turbines like GE, Siemens, Ansaldo and Mitsubishi-Hitachi PS. Mid-/small size turbines are supplied by companies like GE, Solar, Siemens, MAN Energy Solutions, Mitsubishi-Hitachi PS, and Zorya-Mashpoekt along with small actors like OPRA, Aurelia, Capstone. Gas motors are supplied by e.g., INNIO, Wärtsila. In addition, there are a number of Chinese and Indian companies producing gas turbines and gas motors under license from some of the above, like Harbin Turbine Co. Ltd.

One of the largest trends in these segments is decarbonization and H_2 combustion. It is a staple topic at most industry conferences these days, and even more so following the war in Ukraine and the sanctions on Russian energy. Hydrogen is a very fast reacting fuel, generating very high local temperatures and fast flame fronts. This together makes traditional combustion systems unable to utilize more than very small fractions of H_2 in the fuel mix (low single digit %) while being safe against flashback and meeting emissions regulations. There are advances being made and new combustion systems are under development and have been introduced to the market. While current engines can, with significant adaptations, operate with 100% hydrogen, significant losses in power and efficiency usually result. There are no combustion systems that the company is aware of that are able to switch between natural gas, hydrogen and blends, which the Phoenix technology aims to achieve, while maintaining emissions and performance.

It is in the H_2 combustion space that the Top Cycle will have the best opportunity to compete with traditional gas turbine suppliers with its ultra-wet combustion, high pressure combustion and combined cycle performance. Proof of the efficiency of the combustion process were given at the testing of 100% hydrogen in Stockholm in November 2023 with ultra-low NOx emissions detected and stable flame conditions. Natural gas operation with Top Cycle in combination with CCS also constitutes a very competitive proposition with lower LCOE and 50% lower cost of CO2 avoided resulting from the superior electrical efficiency with CCS.

BTC Competition (high efficiency biopower)

The biopower market today primarily rests on the steam cycle technology dating back to 1775 and James Watt's steam engine. Current large-scale plants all use the same basic principle, boil water to generate steam to produce physical motion to generate electricity. Even if the technology has improved since the 18th century, the most efficient and very largest biopower plants (500MW_e+) only perform at 35-40 % of LHV. This is limited by corrosion issues in the boiler, which limits temperatures for the steam cycle, compared to coal boilers that can reach up to 48%. Generally, the installed fleet operates at 15-30 % of LHV in the range 500kW-50 MWe. This constitutes the main competition for the BTC technology: existing and well-known technologies. Key companies involved in steam cycle plants often have both EPC and boiler competence, e.g, Andritz, Valmet, B&W Völund, Burmeister & Wain, Sumitomo FW, Ameresco, Jernforsen.

Plants for high efficiency biopower usually involve gasification of biomass first and then combustion. This is done to be able to clean the resultant gasified biomass and avoid corrosion issues in the power plant. In commercial applications, the power engine can then either be a boiler / steam cycle at large scale or a gas motor at small scale. The latter have become popular at scales under 500kW with standardised fuels, e.g. Burkhardt GmbH. The former can be found at very large scales to handle very difficult waste fuels, e.g. Valmet, Andritz, but is otherwise limited in application.

To date, the company only knows of one large-scale attempt at integrated biomass gasification with gas turbine: the Värnamo plant in southern Sweden in the 90:s. This was a 20 MW_f plant with CFB gasification, operating at 18-22 bar pressure with a Siemens GT with combined cycle for power generation. (very small for CC but it was a test plant). This is a technology that, still not commercial, promises electrical efficiencies of 37-47% on LHV basis. This project ran as an alternative to nuclear power in Sweden at the time, but when the decision to phase out nuclear was reversed, the project was mothballed, despite good technical results. IP ownership of the technology used and invented during the project is unclear, making that specific concept difficult to commercialize. In addition, key actors in the projects that still have know-how from the project have strategically moved away from the concept focusing on other technologies.

The last concept with high efficiency biopower is to utilise high temperature fuel cells with gasified biomass. Such fuel cells (solid oxide or molten carbonate) are not yet commercial for conventional, clean gases, and struggle tremendously with the contaminants found in biomass, e.g. sulfur. No demonstration-scale systems exist today.

There are several companies with pressurized gasification systems that are proven for biomass utilisation at scale. The technologies are, however, primarily used for coal gasification commercially, e.g. SES, GI Dynamics, GTI/Sungas. The company is in contact with these to examine the potential for cooperation.

Except for the above, the company is not aware of any commercial technology that directly competes with the company's technology but is acutely aware of that it is entering a very competitive market with existing, less efficient, technology.

Green Hydrogen Competition

Green Hydrogen form biomass is a very new market in the context of gas turbines and biopower. Only a few large-scale commercial plants are fully operational on a global basis. There are three primary technologies to achieve green hydrogen from biomass, Fixed-Bed, BFB and CFB gasifiers, with some variations to each technology. The respective technologies have their respective benefits and drawbacks. Below is a list of the primary actors in the biomass gasification for hydrogen/Biofuels market that have been identified by the company.

	Company	Location	Tech	Competition area	Strengths	Weaknesses
1	Gidara Energy	Netherlands	Pressurised BFB (HTW)	Production of syngas and methanol	Commercial projects in pipeline. HTW tech from 80's.	No commercially operational plant
2	Sungas Renewables	USA	Pressurised BFB (GTI)	Production of clean syngas	Commercial projects in pipeline. GTI tech from 70-80's.	No commercially operational plant
3	Sumitomo Foster Wheeler	Finland	CFB	Production of clean syngas	Large corp, commercial. Värnamo experience at pressure.	Atmospheric or low P. Gas compression needs (high CapEx/OpEx)
4	Enerkem	Canada	BFB	Production of syngas, ethanol, methanol, H2 & CO2	Commercial, Feed-stock flexibility, scalability	Atmospheric, Gas compression needs (high CapEx/OpEx)
5	Synthesis Energy Systems	USA	Pressurized BFB	Coal gasification. Production of syngas, ethanol, methanol, H2	Commercial in coal, pilot in biomass	Focused on fossil in AU and PL. Not commercial in Biomass
6	Valmet	Finland	CFB, DFB	Production of syngas, biofuels & CO2	Large corp, commercial. Built Gobigas.	Atmospheric, Gas compression needs (high CapEx/OpEx)
7	Andritz	Austria	CFB	Production of syngas, biofuels & CO2	Large corp, commercial	Atmospheric, Gas compression needs (high CapEx/OpEx)
8	Nexterra Systems	Canada	Fixed-bed	Energy	Several commercial plants	Scalability
9	Cortus Energy	Sweden	Wood-Roll	Production of syngas, H2, biochar	High level of H2 in syngas	Scalability, Atmospheric, Gas compression needs (high CapEx/OpEx)
10	Renergi Pty Ltd.	Australia	Fixed-Bed	Production of syngas, H2, biochar	Utilize MSW	Start-up. First Pilot under construction
11	Wildfire Energy	Australia	"Moving-bed"	Production of syngas & H2	Fuel flexibility	Scalability

						Pre-commercial
12	MEVA Energy AB	Sweden	Cyclone-gasifier (Fixed-bed)	Energy & Burner gas	2nd commercial plant in planning	Scalability, Atmospheric, Gas compression needs (high CapEx/OpEx)
13	SUNY Cobleskill/Caribou Biofuels	USA	Fixed-Bed (?)	Biofuels	Fuel flexibility	Scalability, Pre-commercial
14	TreaTech SARL	Switzerland	Catalytic Hydrothermal gasification	Production of syngas, biofuels & CO2	Seems well funded	Start-up, pre-commercial
15	Advanced Plasma Power (APP)	United Kingdom	Plasma gasification	Production of syngas, biofuels & CO2		Start-up, Scalability, Pre-commercial
16	Repotec	Germany	Steam-blown BFB	Energy & Burner gas	Tested technology	Still not commercial. Last news in 2011, still operational?
17	Omni Conversion Technologies	USA	2-step Fixed-bed	Biofuels	3 Feed projects, MSW	Not-proven. Scalability
18	SGH2 Energy	USA	Plasma Gasification	H2	Large plant under development in CA	Is it really proven?

As can be seen from the table, many actors are new and are in project development/piloting, reflecting the immaturity of the market and market actors. Primarily Andritz, Valmet and Sumitomo FW could be considered large players having been in the game very long. However, they have primarily been in the boiler/energy markets rather than H2/green gases markets until recent years In their focus on gasification and the production of gases, it is primarily targeted on municipal solid waste (MSW) streams rather than biomass.

4 Business Model

Marketing and selling the technology will require a multitude of contacts, partners and network to realize the sale and erection of a BTC plant. For mature CHP/biopower markets like the Nordics, Baltics, Germany and Eastern Europe, the company will initially seek market position in the replacement/refurbishment programs of existing biomass and fossil plants, i.e. brownfield projects. This way both the utility and PBP can capitalize on existing infrastructure for district heating, power grid, staff, fuel- handling and supply chain.

Phoenix BioPower's primary business model is based on a three-source income method:

- Sales of key equipment / hardware / systems and/or licenses thereof (€/kW, capacity basis)
- Royalty on energy produced. (€/MWh, energy produced basis)
- The Buyer's Club /BOO – Build, Own Operate (partial ownership of plants)

In addition, some consultancy revenues emanating from pre-studies and plant installations are expected but are estimated to be less than either of the above revenue sources. Engineering work and services in conjunction with plant sales are included in the €/kW revenues.

Launching a new, large-scale technology with significant elements of risk faces the challenge of what is sometimes called "first bleeder" aversion, that no single actor is willing to assume the high technical and thus associated financial risk with being first to try and test a new technology. As a tool to address this challenge, the company is launching a concept called The Buyer's Club. The concept of The Buyer's Club is that a number of end users, let's say 5, join together to buy the first 5 plants, sharing the risk of the first and also sharing the benefits for the following 4 as the risk reduces with each plant. Phoenix biopower will be a partner in the buyer's club as an additional way to reduce end-user risk through supplier involvement.

4.1.1 Key equipment supply

The company will develop the key components and systems for the BTC plant and supply them to an EPC system integrator who supplies a turnkey solution to utilities. Identifying and recruiting these partners will be done as part of the technology development phase as well as part of the setting up co-development co-operations. This work will be done using existing networks, conferences and trade shows, tenders and other active contact seeking activities.

The first product for Phoenix is the 10 MW plant. It is envisioned that the first units will be sold in nearby markets, i.e. EU, with the above outlined business model for supply and royalties. Within the total plant scope of the 10 MW-class plant, Phoenix will supply key equipment, i.e. the gasification, gas turbine, combustion, and the control systems, and receive component revenues for these (hardware, software sales). This results in roughly 6 M€ margin per plant, based on the following revenues and costs:

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System Supply Model, 10 MW Plant M€	
Phoenix revenues per plant	24,29
Phoenix costs per plant	18,12
Phoenix Margin per plant	6,16

For global expansion into, for example, Asian markets, a license model is envisioned. This allows local partners with established businesses in the market to roll-out the BTC technology at a pace much faster than Phoenix could achieve. These licenses are not based on physical supply, but rather are based on the IP needed to establish a full plant, including hardware and software. The royalty is taken in form of a capacity fee of 6% of the investment cost. For a 10 MW class plant, this gives a revenue of approximately 3,5 M€.

4.1.2 Royalty on Energy produced

With the radically higher efficiency in power generation, both in CHP and BECCS application, the company sees an opportunity to receive a production royalty on power produced, €/MWh. With 30 – 100 % higher net electrical efficiency, a royalty of 3-5 €/MWh is foreseen. This will only marginally affect the merit-order of the plant in a flexible and diverse power system as well as the overall profitability of the plant for the end user when compared to alternative technologies. As an example, for a 40 MWe BECCS plant, operating 8 000 h/a. This plant would produce approx. 245 GWh/a. With a royalty payment of 4€/MWh, this would represent a recurring revenue of almost 1 M€/a. This would be a very stable revenue stream for the company on top of pant sales revenues. The 4 €/MWh should be compared to the current wholesale price of power in central Europe currently trading around 100€/MWh, so less than 5% and as prices rise, the share will decrease.

The final structure of the royalty is to be defined later but will include elements of minimum operational hours/y as well as being tied to warranty and guarantees for the plant. It is also expected that the first commercial plant will operate without royalty, or with an initial grace period of 5-10 years. The royalty is expected to be in force for the initial 20 years from commissioning and hand-over to owner.

4.2 The Buyer's Club

First-Bleeder aversion is a very big challenge that must be addressed in order to realize the commercialization of a new, large-scale technology with elements of risk like the BTC technology. Most end users would like to buy "plant no 5". But without plants 1-4 there will not be any no 5. So how to get around this "chicken or the egg "conundrum?

To address this, the company will be launching The Buyer's Club, a mechanism to address first-bleeder aversion and at the same time facilitate for a fast roll-out of the first generation of plants. The basics of the concept is that a group of end users form a joint ownership

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company/structure that will order and procure the first set of plants, e.g five plants for five end users, located at their respective sites. At the same time, an identified customer is created for the Company.

The Buyer's Club enables the members to share the risk of the first plant, should it have large and unforeseen "teething problems" between the members. It also enables them all to share in the benefit and the gradually reduced risk from the following 4 plants. No single "bleeder" no single "winner" but five winners!

The Buyers's Club will function much as a BOT/BOO[3] mechanism for the first set of plants function and execution can be summarized as follows:

- Risk and benefit sharing mechanism for first generation of plants
- Utilites, industrial consumers, PBP and investors as members
- Order 5+ plants together where all plants are equal in basic configuration (modular design)
- Buyer's Club owns all plants 100 % (basic principle, but may need adapting)
- Partners owns shares in Buyer's Club
- Phoenix BioPower owner in buyer's Club
- Close Cooperation with Supplier's Club
- Upon completion of BTC1, BTC2 is ordered, followed by BTC 3-5
- Upon completion of BTC5, Buyers Club is maintained as a BOO, unwound and assets distributed, or the portfolio of plants sold to third party

This structure is not without its challenges as risk, ownership principles, risk sharing and return distribution will be a challenge to manage. As a company we recognize this challenge but see it as a tool for the commercialization of the technology. In discussions with utilities, we have received positive feedback as it is a novel way to introduce new technology and sharing of risk.

4.3 The Supplier's Club

Building the first set of plants will generate significant experience and know-how, both among the supplier partnership network as well as within Phoenix BioPower. As a mechanism to supply a first set of plants to The Buyer's Club, Phoenix is working on the model of having a Supplier's Club as counterparty, or the supplier consortium. The Supplier's Club is made up of key component and system suppliers as well as EPC, financing partners and Phoenix BioPower. The Supplier's Club is expected to have a consortium type of structure between members.

The function of, and the reason behind the Supplier's Club is that since each plant is expected to as identical as possible in the basic configuration, experience and cost drivers

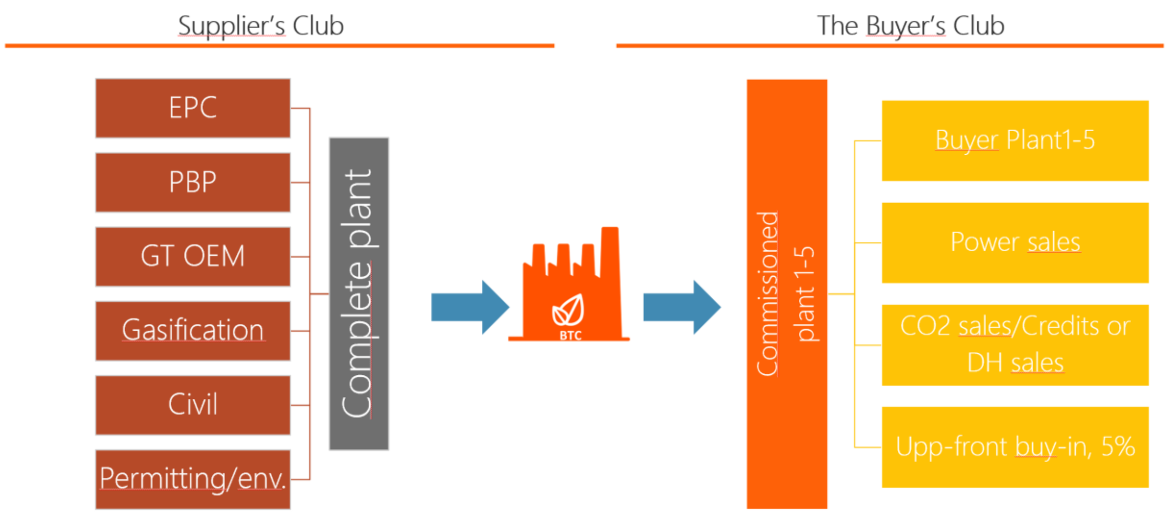
[3] BOT: Build, Own and Transfer. A company that builds and commissions a plant and then transfers the plant to the end user/utility upon commissioning or after a set period, like 10 years.
BOO: Build, Own and Operate. A company finances and erects a plant and sells the energy & services produced by also operating the plant. Such company becomes the end user of a plant.

for each new plant is reduced to a minimum, enabling for a more competitive plant offering through standardization.

The basic structure and function of the Supplier's Club can be described as:

- Plant builder –Consortium structure between partners
- PBP + Key Suppliers of components/ systems/ services etc
- After market services
- Revenue sharing; CapEx and Royalty
- Private and public funding for Demonstration plant
- Supplier's Club owns the plant during Pilot Phase of Demonstration project through SPV mechanism
- Pilot sold to BC as BTC 1
- Close cooperation with Buyer's Club

Commercial Outline Buyers' Club and Suppliers' Club



4.4 BOO – Build, Own and Operate

Once the technology is proven and the first generation of plants are commissioned, the company is evaluating a concept for building plants for own ownership, BOO, and sell the energy and services produced, much like The Buyer's Club. The purpose of this business model is to integrate vertically in the value chain and also gain higher margin control for the company.

BOO concepts are very capital intense and will require specific conditions for off-take agreements and fuel sourcing to be realized. However, the company sees this as an excellent way to introduce the BTC plants, with or without CCS, to new markets where the need for decarbonization is high. In the early estimates that the company has done, the IRR for a BTC-BECCS is 10-14% with rather stable market conditions reducing risk.

4.5 Partner Strategy: Push-Pull

A push-pull strategy shall be utilised to enable the development and commercialisation:

- Push (technical basis): retire largest technical risks in pre-studies, feasibility studies and prototypes, while engaging suppliers as sub-contractors to form acceptance for the technology in their organisation. This will be done by actively informing the market, market stake holders and alike on the supply side.
- Pull (market basis): ensure a clear customer voice from utilities in the BTC project and form a demand for the technology and demonstration plant, initially through our reference group. This will be done in a similar way, directed to end users/plant owners (i.e. utilities)

The purpose of the push-pull strategy is to engage the large actors required for the network of partners and suppliers needed for both pre-commercial co-development and the commercialisation phase.

This push-pull strategy has for the first years of the company been more focused on the pushing of information of the technology onto the market actors like utilities and potential supplier partners, where our key partner för gas turbine has been recruited and development is ongoing. However, following the summer of 2023, response from market actors, especially utilities, has changed and interest in more detailed discussions and evaluations of potential plants have begun. The company is currently in such discussions with 5 actors, both private and municipal utilities where up to three possible sites for the Demo plant project, or portion of it, have been identified.

4.6 Partner network

To achieve commercial success for the Top Cycle and BTC technologies, a significant partner network is required. It is also through the partner network, the push-pull strategy is realized. Examples of areas where we are looking for co-development, and other, partners are (not limited to):

- Plant engineering, procurement and construction, EPC
  (2 identified)
- Biomass gasification technology
  (Own and external, first gen supplier identified)
- Gas turbine technology
  (Identified and dev ongoing)

- Plant control systems

  (Major suppliers identified)

- Gas clean-up technology

  (Identified)

- Fuel handling

  (3+ potential suppliers identified)

- Plant funding

  (EU IF, EIB, EBRD, Swedish Energy Agency, SEK etc. Needs further detailing)

The above-mentioned reference group represents a base upon the company since 2017 has contoured to build its partner network. As mentioned, the purpose of this Reference group is to gauge the interest, decision-making triggers, and opinions on biopower as a whole and the BTC technology in particular. The reference group will be instrumental in identifying the potential first customers in the Nordics, the suitable size and application of the BTC plant and other key requirements.

Other base industry actors in Sweden will be approached as the project progresses to recruit additional members to the reference group. Key actors that we are currently looking for are in the supplier, plant building and consumer sectors to complete participation from the value chain.

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5 Product Offering

The company will offer three main products:

- The BTC plant and related technologies and know-how, with or without Carbon Capture
- Top Cycle Gas turbine technology for non-biomass applications, including hydrogen
- The HFB gasification technology for high efficiency biomass gasification for supply of industrial renewable gases.

Where the primary product is the BTC plant and commercial studies for the TopCycle gas turbine and the HFB gasification technology have yet to be drafted and are therefore not included in the product offering and business plant.

5.1 Market entry product, BTC plant

Throughout the development of the technologies that Phoenix BioPower develops, market research and previous experiences has led us to choose a 10-12 MW_e product as the entry product. When looking at plant sizes in various markets in Europe and Asia, we have found that a plant with a biomass fuel supply of 50-60 MW_{th} is reasonable from both logistics and heat-offset perspective. However, current sizes of district heating units, both in the Nordics and outside, indicate a modular approach based on 25-30 MWe modules can cover a large range of applications at superior electrical efficiencies compared to the traditional steam cycle technology. However, when looking outside the district heating market, a better market fit is found in the 10-16 MW_e range with a complementary size around 40 MW_e. In this regard, some biopower regulations on size, such as the maximum 90 MW_{th} (very close to the fuel input for a BTC 40MW_e) in China, has also been taken into consideration. More details on market analysis can be found in section 3- Market.

In addition to the decision to choose a market entry product size based on biomass markets, district heating and regulations regarding biopower, we have also taken into consideration the market for gas turbines for gaseous fuels at 10-40 MWe capacity. Here the product is primarily targeted for the O&G sector as well as base load for specific industries and smaller utilities. With the increase of variable renewables in the energy systems, more cyclic power generation will be required, and gas turbines are optimal to balance against wind and solar thermal power. Those gas turbines are optimally fuelled with renewable fuels and equipped with CCS functionality. Combined cycle gas turbines scale poorly down to this size range, and instead, reciprocating gas motors and high efficiency aeroderivative gas turbines in single cycle mode compete.

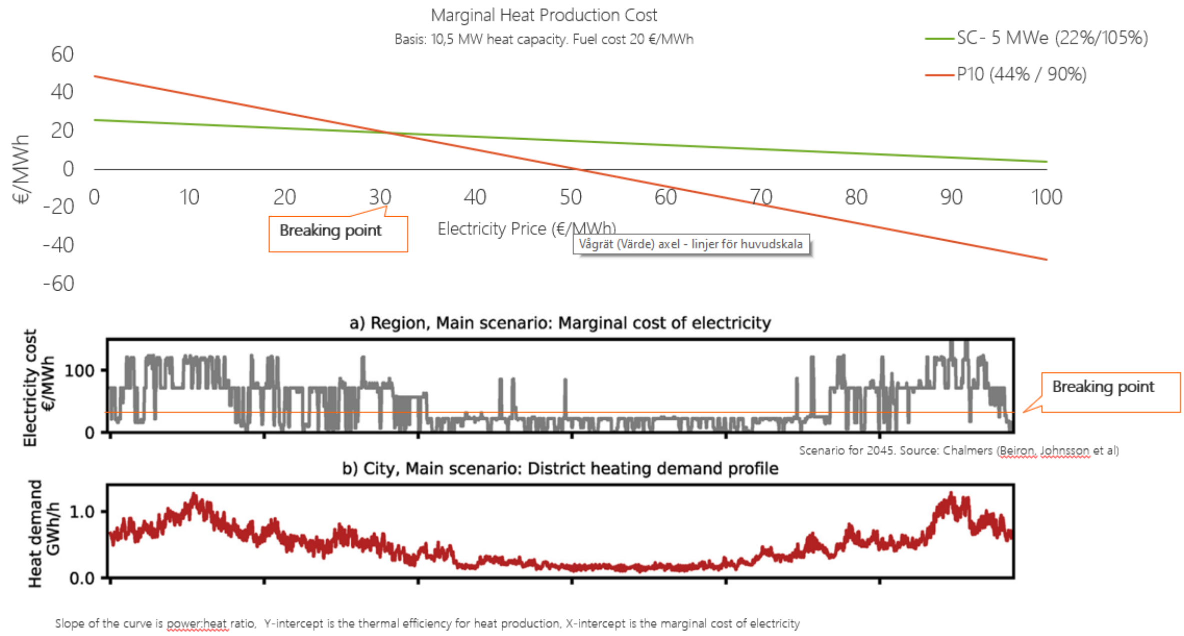
Plant model	P10	P40	P100+
Feedstock	Forest residues, pellets, blends with agri residues Gaseous fuels (H2, NG)		
Net power output* (MWe)	10	40	100
Thermal input (MWth)	25	90	200
Net electrical efficiency*	40-44%	46-50%	50-54%
Conventional plant	*20-30%*	*25-34%*	*28-36%*
CAPEX (M€/MWe)	3,5 – 5,5	2,5 – 3,5	1,5-2,5

Tabell 1: BTC plant sizes and details.

In conclusion of the above in connection to the technology development, primarily the development roadmap for the Top Cycle technology, the company has adopted the 10 MW_e plant as the market entry product as it meets many of the requirements and limitations identified for a first generation BTC and Top Cycle product. For this reason, the basis for all estimates and technical simulations for the first-generation plant will be a 10 MW_e unit unless otherwise specified. Some early calculation being used in this document though, are based on a 25 MW_e turbine but will have limited effect on overall market capture estimations.

5.1.1 Free district heating!

For the CHP applications, the BTC plant offers significant advantages over the traditional steam cycle plant, primarily due to significantly lower marginal district heating production costs.



For a BTC plant in a CHP application, the marginal DH production cost trends towards zero if the electricity price goes above 50 €/MWh. When comparing DH production needs over a year with power pricing scenarios to 2045, the match is almost perfect, with high prices and high DH demands overlap very well. This means that a CHP plants with BTC technology will see very high profits from both DH as well as power sales and the marginal cost for DH production is zero or less and power prices higher than the marginal production cost.

5.1.2 Low marginal cost off-season

When compared to traditional steam cycle biopower plants of equal size in terms of fuel capacity, the BTC plant is expected to have significantly more operating hours. With the increased share of intermittent power generation in the energy mix, the price fluctuations are expected to more than quadruple by 2050, enabling for higher utilization of the BTC plants as more hours become profitable, even without heat credits (hours above the orange line below).

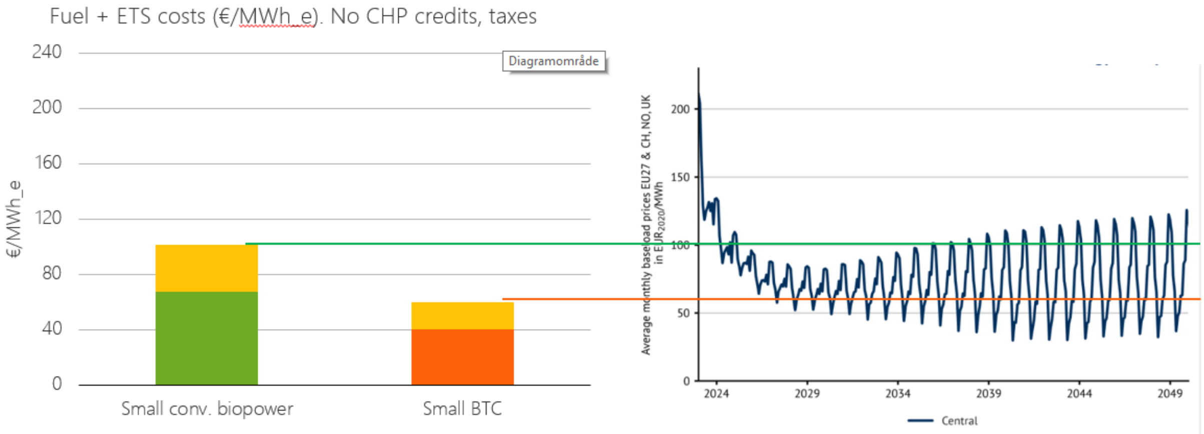
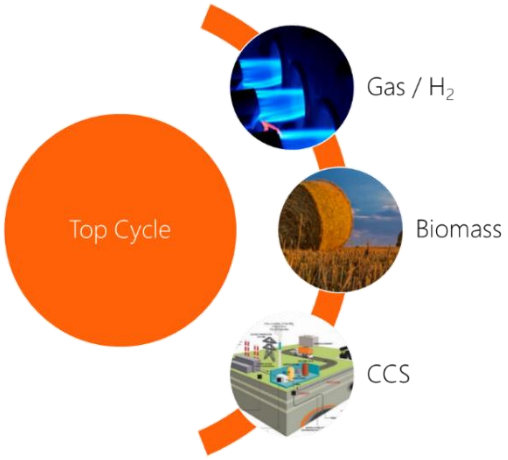


Figure 8: monthly baseload prices on average / SOURCE: Energy Brainpool, 2021

5.2 The Top Cycle gas turbine



<u>Advantages vs Combined Cycle</u>

- 30 % lower capital costs & footprint.
- Superior hydrogen combustion (ultra-low NOx)
- +15% pt total efficiency in district heat

- +5-15 % pts electrical efficiency
- +5-15% pts total efficiency in district heat

- 30% lower cost of CO2 avoided in natural gas
- 30% lower power penalty

A platform technology

The Top Cycle technology is a scalable platform technology for various applications with superior performance compared to traditional technologies. The Top Cycle gas turbine represents a radical shift in GT architecture and operational conditions. The Top Cycle is based on ultra-wet combustion coupled with high pressure operation. Key to the ultra-wet combustion and the very high single cycle efficiencies achieved by the Top Cycle is the replacement of excess air with steam and the subsequent reduced need for compression energy.

The principle of the TopCycle gas turbine is to replace all excess air with steam and to maximise performance by operating at the highest pressure feasible. In modern gas turbines, approximately half of the air compressed in modern gas turbines is excess, i.e. utilised to cool combustion and the turbine blades. Compressing this excess air reduces the power output and efficiency of the gas turbine. As water (steam) is easily pressurised with only pump work prior to boiling, up to 40% more turbine work can be sent to the generator for conversion to electricity in the TopCycle, which raises the efficiency dramatically.

Optimal for H_2 applications

The company has identified H_2 combustion turbines, with 100% H_2 or blends with natural gas, as a large potential market in parallel with the biomass BTC track. This opportunity, in combination with the superior CCS efficiency with fossil or biogenic hydrocarbon fuels, indicates a very large potential for the technology in the broader energy system. Conventional gas turbines have large issues with hydrogen due to the reactivity, causing flashback and destruction of the combustion system, along with hot spots, giving high NOx emissions. Initial tests with hydrogen blends and 100% hydrogen at Top Cycle conditions, i.e., with high steam levels, have shown extremely low NOx values and, importantly, that the flashback risk is very limited.

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Superior CCS and CCU performance

The IPCC has identified NET (Negative Emissions Technology) as a key tool to reach the 1.5°C or 2°C goals for climate change, either offsetting unabated emissions or removing past emissions from the atmosphere. The BTC, when combined with CO_2 capture and sequestration, is an extremely cost-efficient NET and, consequently, can play a key role in the energy transition. The cost of CO_2 capture is significantly lower than conventional plants as net electricity production per on CO_2 captured is up to 60% higher, 20-40 % lower specific cost for the plants and LCOE up to 30% lower. This applies especially for plants of units under 200 MW fuel capacity.

The background to this advantage is that the BTC plant provides waste heat that can be utilized for carbon capture with a heat pump booster. This heat can therefore drive a CO_2 separation process with lower relative penalties compared to a conventional plant, where low pressure steam from the steam cycle is utilised, reducing output and efficiency of a conventional plant where penalty is up to 1/3rd whereas for a BTC plant, starting at a higher electrical efficiency, the penalty is as low as half than that. The same advantage can be applied in natural gas applications as either part of a CCU case or for sequestration of fossil emissions.

5.3 BTC Plant offering

The BTC plant for high efficiency biopower offers plant owners and operators a utility scale renewable alternative to traditional, low efficiency technologies, enabling an increase in reliable, plannable renewable power from biomass.

Through its high electrical efficiency, the BTC technology enables power-only applications in locations where CHP is not normally installed, like southern Europe. Making biopower competitive to fossil fuels will be key in meeting the Paris Climate Accord targets. In addition will the BTC plant also offer superior performance for BECCS application with maintained high electrical efficiency (+45 %) and 60% lower cost for the CO2 emissions captured.

The BTC plant will be offered to utility owners and operators through a network of EPC contractors, subcontractors, and partners. Offering and erecting a complete power plant will require both global and local partners for the successful execution of the project. Phoenix BioPower does not aim to assume the role of plant builder, but rather supplier of key equipment / hardware and know-how. Co-development has already begun with Zorya-Mashpoekt on gas turbine development. Other BTC related co-development opportunities are currently under discussion within gasification, fuel pre-treatment, pressurization, and gas clean-up with several manufacturers.

5.4 BTC Plant Economics

An analysis of the levelized cost of electricity of a new-built power plant with standardised assumptions gives a useful comparison of BTC plant when compared to the closest market competitor, the biomass-fired steam cycle. Here we present simplified results from a more complex analysis across multiple applications and large sensitivity spans. For more details, please see PBP Economics Level 1 Rev a.pptx

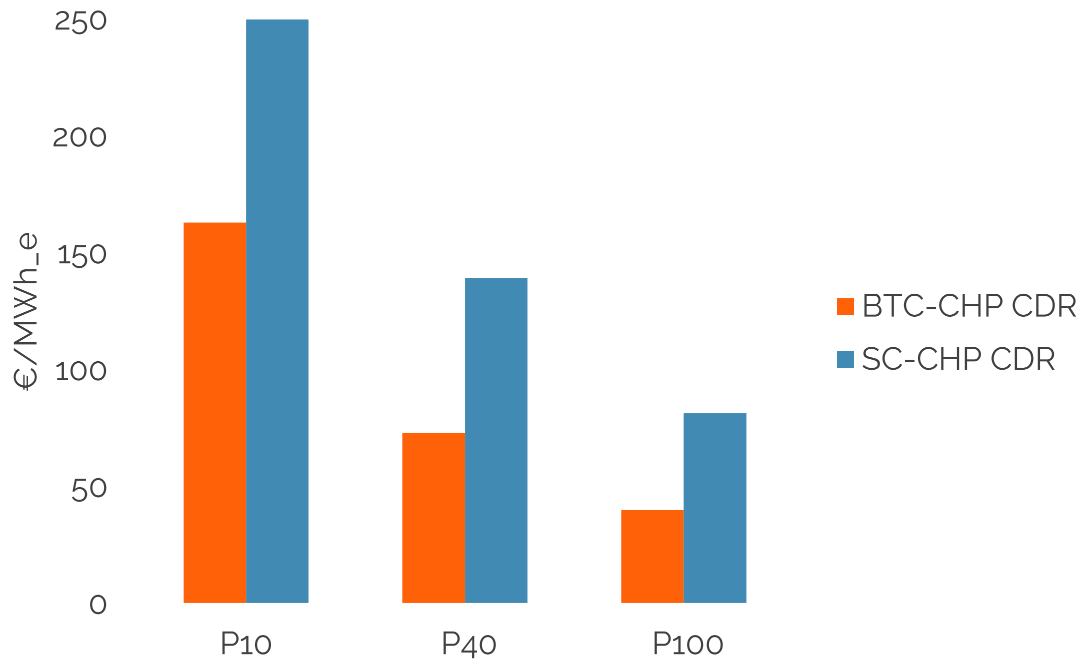

Figure 2: LCOE for Combined Heat and Power (CHP) with Carbon Dioxide Removal (CDR). Biomass-fired Top Cycle (BTC, Launch) vs Steam Cycle (SC). 7800 operating hours, of which 5000 CHP. Same heat output as basis. 5% effective discount rate (7% nominal), 30€/MWh fuel price, 150 €/MWh CO2 credit, 30 €/MWh heat credit, 35 €/tonne CO2 transport and storage costs.

As shown in the figure above, the BTC plant in combined heat and power applications and with BECCS achieves an LCOE of 40 – 162 €/MWh_e with standard assumptions. This is approximately half the LCOE as an equivalent newly built biomass-fired steam cycle, giving an IRR up to 5 % points higher. The main sensitivity of this case are the CDR credit price, discount rate and fuel price.

The table below presents the case for the P40 in four different market applications and compares it with the steam cycle benchmark. As seen a consistent and significant advantage is found compared to the benchmark, with a 33-50% lower LCOE. The CHP cases for BTC are consistently lower as they have better economies of scale. This is due to the high electric yield (ratio of electricity to heat), allowing in turn a 3 times larger electricity output and a lower specific capex.

Table 1: Comparison of LCOE for the P40. Powergen plants are based on same fuel input, CHP (district heating) plants are based on same heat output to the grid.

	Powergen	**Powergen + BECCS**	**CHP**	**CHP + BECCS**
BTC	122	91	132	73
SC	183	140	211	149
Decrease	**33%**	**35%**	**37%**	**51%**

The complete portfolio of BTC technologies is from 10 MW to 100 MWe units. For larger 100 MW unit, the LCOE drops to 40 €/MWh for CHP+BECCS and 55 €/MWh for powergen only.

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6 Development Roadmap

Taking the BTC technology to a commercial technology requires a focused development- and commercialization strategy. The company's roadmap is targeting the commissioning of a first commercial demonstration plant by 2031. The pathway to the demonstration plant is through a scaled pilot plant at ~30 % capacity on fuel basis and lower operating pressure. The pilot is then refurbished and upgraded to a first commercial demonstration plant once the pilot testing is completed, 1-1,5 years after completed commissioning. Commissioning of the commercial demo plant is expected to be significantly shorter as the complicated gasification unit is already in operation. With the demonstration plant, the pressure is increased from ~10 to ~30 bar.

The development roadmap has two main tracks, the TRL project and the Demonstration Plant. These two tracks basically run in parallel, converging into the Top Cycle gas turbine, the HFB gasifier and the Demonstration plant.

6.1 TRL 5 project

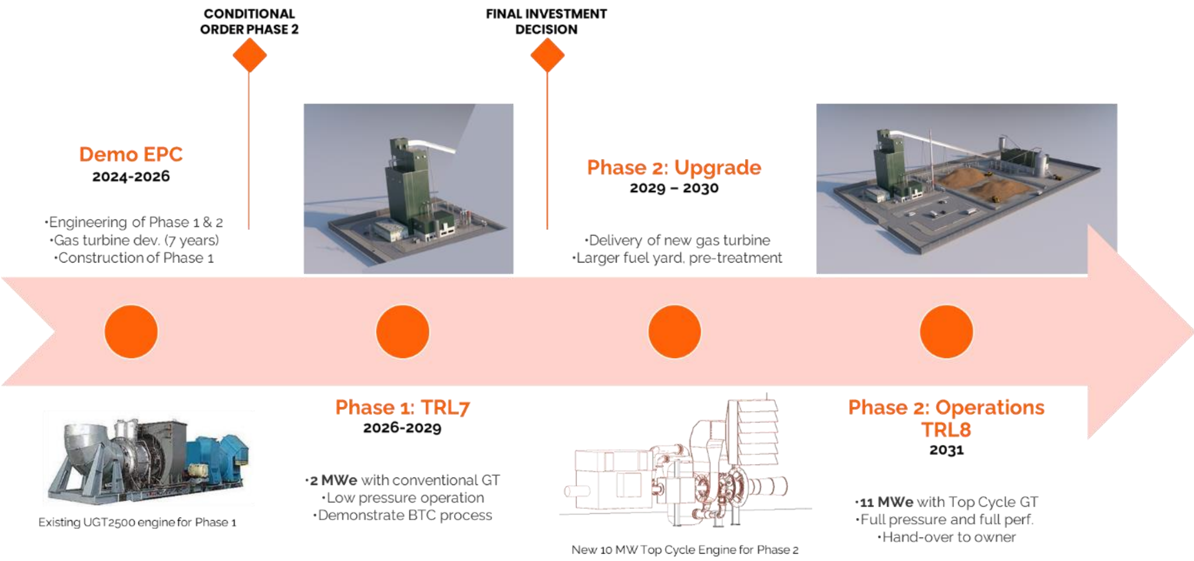
Currently, the technology platform is defined to be at, or just under, TRL 4 (*validated at lab scale*) and for the coming two years until first half of 2026, the company will be running a TRL 5 project *(Technology validated in relevant environment, industrially relevant environment in the case of key enabling technologies)*. Once TRL 5 is reached, the development moves from development to scaling of the technology and associated risks. To reach TRL 5, the company has defined the roadmap for the period 2024 to first half of 2026 in Table 2 below. The total budget for the TRL 5 project is 5 M€. Key work for the TRL project is planned to be carried out in Sween, Finland and Germany with different development partners, most of whom the company is already cooperating with, like KTH, TU Berlin and RISE.

In the TRL 5 project, our gasification technology is to be validated at low pressure, 5 bar, combustion at medium pressure, 8-10 bar and plant design verified in model.

Table 2: TRL 5 budget 2024 - 2026 (H1)

TRL 5 Project budget 2024 - 2026H1				
MILESTONE PLAN AND BUDGET	2024	2025	2026 (H1 only)	Phoenix Budget
Plant and Operations	**0,2**	**0,3**	**0,1**	**0,6**
Combustion and Gas Turbine	**0,8**	**0,8**	**0,5**	**2,1**
Gasification System	**0,7**	**0,6**	**0,2**	**1,5**
Sum of direct R&D costs	**1,7**	**1,7**	**0,9**	**4,2**
Other Phoenix costs (Sales & Bus Dev, Proj Mgmt, admin)	0,3	0,3	0,2	0,8
TOTAL PHOENIX TECHNOLOGY DEVELOPMENT BUDGET (TRL 5)	**2,0**	**2,0**	**1,0**	**5,0**
Pilot & Demonstration Project	**0,3**	**2,6**	**2,4**	**5,3**
Sum Pilot & Demonstration Project	**0,3**	**2,6**	**2,4**	**5,3**
TOTAL PHOENIX BUDGET	**2,2**	**4,6**	**3,5**	**10,3**

6.2 Demonstration plant



The roadmap to commercialization and the first commercial demonstration plant is based on a development plan of components, systems, and plant integration. The key driver in the timeline is the development of the gas turbine which requires some 6 years to develop from the start of the design engineering work. For this reason, this development work will run in parallel with the gasification, combustion, and plant integration development to meet the 2031 target of commissioning of the first commercial plant. In the project this technology will be demonstrated for the first time with a semi-commercial 11 MWe plant. The project is executed in two phases, where a first phase demonstrates the functioning of the BTC process at 2.5 MWe scale with a conventional gas turbine, while the second phase will demonstrate the BTC process's performance at 11 MWe. Since the technology is pressurized, the scaling of power is done through pressure and not geometry.

By constructing a pilot plant with lower operating pressure (scale) in phase 1, the same plant can be very cost-effectively upgraded to a full-scale commercial demonstration plant. In Phase 2, the gas turbine is replaced with an optimized one for full power and operational pressure to cost-effectively build a commercial demonstration plant while at the same time speeding up the commercialization by several years The total budget for the Demo plant project is estimated at 102M€ with completion and hand-over of the commercial unit in 2031. The estimated LCOE for the commercial unit is targeted at 133€/MWh, a level that should be viewed in the perspective of future energy prices in Northern Europe for 2030 - 2050. Efforts to reduce the LCOE for follow-on plants will focus on component performance, firing temperature and pressure in the gas turbine and carbon conversion efficiency for the gasification system to optimize the plant.

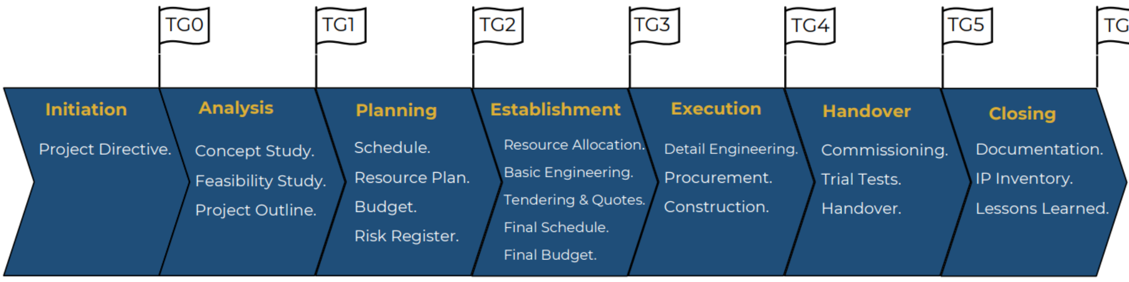


Figure 3: Project Process model

To realize this development and commercialization road map, the commercialization efforts like partner development will have to run in parallel with the technology development to secure both end-user as well as supplier involvement to drive the commercialization.

The specific development needs are outlined in the above road map and are focused on the three main technology areas: Gasification, Gas turbine and Plant integration. In the document

Pilot&Demo Project description.docx, the full Demonstration project is outlined with detailed timeline, milestones, investment and economics.

ID	Task Name	Duration	Start	Finish
0	**D010 BTC Demonstration Plant**	**2108 days**	**2023-03-01**	**2032-06-01**
1	**Phase 1: 2 MW BTC Plant**	**1761 days**	**2023-03-01**	**2030-12-18**
2	Phase 1 Initiation	74 days	2023-03-01	2023-06-12
3	TG0, Project Initiation	0 days	2023-06-12	2023-06-12
4	Phase 1 Analysis	381 days	2023-06-20	2025-03-03
5	TG1, Project Feasibility	0 days	2025-03-03	2025-03-03
6	Phase 1 Planning (Preparations)	119 days	2025-03-04	2025-09-25
7	TG2, Final Tender Decision	0 days	2025-09-25	2025-09-25
8	Phase 1 Establishment (Basic Eng.)	232 days	2025-09-26	2026-10-06
9	TG3, Final Investment Decision	0 days	2026-10-06	2026-10-06
10	Phase 1 Execution (Procurement and Construction)	317 days	2026-10-07	2028-03-14
11	TG4, Plant Delivery	0 days	2028-03-14	2028-03-14
12	Phase 1 Handover (Commissioning)	218 days	2028-03-15	2029-02-26
13	Commissioning Complete	0 days	2029-02-26	2029-02-26
14	Phase 1 Handover (Demonstration)	335 days	2029-02-27	2030-08-28
15	Phase 1 Demonstration Complete	0 days	2030-08-28	2030-08-28
16	Phase 1 Closing	80 days	2030-08-29	2030-12-18
17	TG6, Project Closed	0 days	2030-12-18	2030-12-18
18	**Phase 2: 10 MW BTC Plant**	**2108 days**	**2023-03-01**	**2032-06-01**
19	Phase 2 Initiation	74 days	2023-03-01	2023-06-12
20	TG0, Project Initiation	0 days	2023-06-12	2023-06-12
21	Phase 2 Analysis	381 days	2023-06-20	2025-03-03
22	TG0, Project Feasibility	0 days	2025-03-03	2025-03-03
23	Phase 2 Planning (Preparations)	119 days	2025-03-04	2025-09-25
24	TG2, Final Tender Decision	0 days	2025-09-25	2025-09-25
25	Phase 2 Establishment (Basic Eng.)	882 days	2025-09-26	2029-09-10
26	TG3, Final Investment Decision	0 days	2029-10-01	2029-10-01
27	Phase 2 Execution (Plant Upgrade)	324 days	2029-10-02	2031-02-21
28	TG4, Plant Delivery	0 days	2031-02-21	2031-02-21
29	Phase 2 Handover (Demonstration)	191 days	2031-02-24	2031-12-19
30	TG5, Plant Acceptance	0 days	2031-12-19	2031-12-19
31	Phase 2 Closing	108 days	2032-01-02	2032-06-01
32	TG6, Project Closed	0 days	2032-06-01	2032-06-01
33	Commercial Operations Start	0 days	2032-01-02	2032-01-02

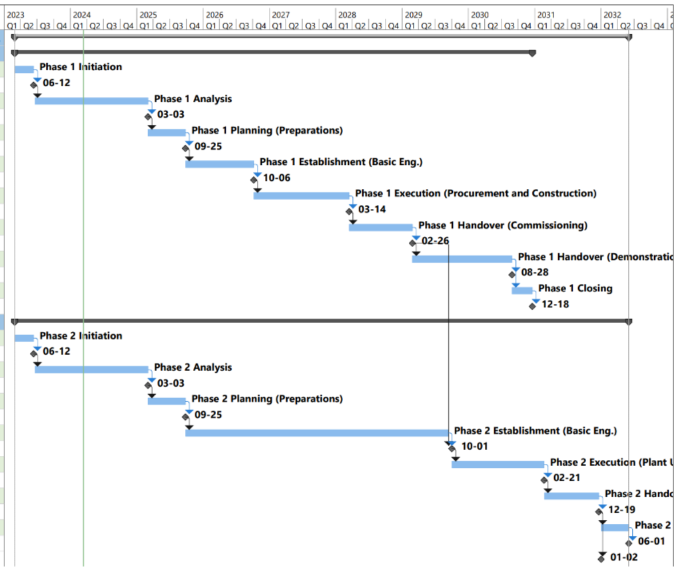


Table 2: Project development timelines for Phases 1 and 2.

6.2.1 Demo plant economics

The assumptions for the levelised cost of electricity are shown below.

The LCOE regards the commercial operations of the BTC plant after Phase 2 is completed and the plant is handed over.

Table 3: Assumptions used for levelised cost of electricity calculations

Assumption	Value	Unit	Remark
Exchange rate	11,5	SEK/€	
Effective discount rate	6	% p.a.	Assumes 2% CPI, i.e. 8% nominal discount rate
Depreciation period	20	years	
Variable operating costs	1,9	€/MWh_e	Excludes fuel costs.
Fixed O&M costs	4,8	% total inv. p.a.	Se Includes personnel, maintenance, overhead. Based on 50 M€ nominal investment cost.
Biomass purchase price	30	€/MWh	
Biogas purchase price	100	€/MWh	
District Heat credit	50	€/MWh	
Capital cost	46	M€	Actual investment cost, excluding demonstration costs, R&D, public support.

The technical and cost assumptions are found in the Demo Plant Project description.

Table 4: Levelised cost of electricity

Variable O&M	€/MWh_e	2,0
Fixed O&M	€/MWh_e	33,0
Fuel costs	€/MWh_e	77,3
Capital costs	€/MWh_e	55,5
District heat credit	€/MWh_e	-30,0
Levelised cost of electricity		**137,7**

As seen the LCOE is approximately 138 €/MWh, which should be seen from the perspective of future electricity prices in Northern Europe from 2030 – 2050. The value of firm renewable power in the market from the BTC will be comparable to firm power from technologies such as nuclear power plants or fossil power plants with CCS. No income is assumed for capacity, ancillary services or similar. If operating on the open market, the marginal costs will be somewhat over 79 €/MWh (2 + 77,3 + start-up costs) with the assumed fuel price of 30 €/MWh. Large benefits also arise as local power production clearly supports job creation and retention in the community, along with power quality and transmission capacity and the integration of larger quantities of variable renewable power.

Note that this is the first of a kind cost for the BTC plant. With an assumed power purchase agreement of 155 €/MWh for firm renewable power, the annual costs and incomes for the plant can be derived, shown in the table below.

Table 5: Plant annual operating margin

Operating costs	M€	-8 113 252
Electricity sales	M€	11 202 594
Heat sales	M€	2 169 908
Operating Margin	**M€**	**5 259 250**

6.3 Net Present Value

Conducting a net present value analysis of the investment costs from 2028 and the operating margin of almost 5,3 M€/a over 20 years (2032-2051) provides a NPV of 9 M€ with a 6% effective discount rate (8-9% nominal).

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7 Funding and Budget

7.1 Funding

The current technology development plan has a gross budget of approx. 116€ for 2024-2031 with an estimated net funding need topping out at of 39M€ by 2029. This includes the development and erection of the Demonstration plant in two phases, Phase 1 being an 8 MW_{th} pilot plant in 2024-2030 (TRL7) with an adapted gas turbine of 2.5 MW_e for industrially relevant conditions. In Phase 2, the plant is upgraded into a first commercial demonstration plant of 11 MW_e commissioned by 2031 (TRL 8).

Being an SME with significant technology development ahead, the company targets an average public funding share of 40-50 % for the period until 2030. The company is seeking a mix of equity investments, loans and public funding through agencies like the Swedish Energy Agency, Vinnova and different EU programs like Horizon 2020, Eurostars, RIA, the EU Innovation Fund, NEFCO and the EIB. To complement grants, soft funding and other public sources, private capital in the form of equity or debt will be raised until the company is cash flow positive.

To date, the company has raised approx. 6 M€ in private capital, primarily through pre-IPO offerings resulting in the company now having some 2 300 shareholders and having prepared the shareholder base for a successful IPO in the coming years. Decision on IPO and marketplace has not been made and is still subject for decision by the board and principal owners, including EIT InnoEnergy. Sweden is however primary country of listing.

The company has also succeeded in raising some 6M€ in public funding from the Swedish Energy Agency, Eurostars and the Horizon programs. In addition, some 4M€ has also been raised indirectly to development partners like RISE, TU Berlin and KTH Stockholm to do research and development on the company's technology. This means that in total, around 16M€ has been raised towards this development effort of providing plannable and flexible renewable power.

Following the company's commercial roadmap and plant roll-out, the business is expected to be cash-flow positive by 2030 with significant growth following. A level of 5 plants/a in new orders is expected by 2035. Combining sales of key hardware and software in combination with production royalties as well as licensing revenues for overseas markets provides stability in the long-term revenues. For more details on funding need, see budget section.

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7.2 Budget

In the budget for the development of the company, the total budget until 2031 is estimated at 116M€, before support or sales revenues. As this is a development effort with large potential impact, the company expects approx. 45 % in public support funding for the period, with an expected higher ratio in the initial first 4 years. The main funding need driver for the period is the Demonstration plant project with a gross budget for the two phases of 102M€.

M€	TOTAL	2024	2025	2026	2027	2028	2029	2030	2031
Combustion System	4,1	0,7	0,7	0,8	0,5	0,5	0,3	0,3	0,3
Gas Turbine	0,9	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1
Gasification System	3,7	0,7	0,6	0,5	0,5	0,4	0,2	0,2	0,5
Plant	1,7	0,2	0,3	0,3	0,3	0,2	0,2	0,2	0,2
Other (Bus Dev, Proj Mgmt, Sales)	3,4	0,3	0,3	0,4	0,4	0,4	0,5	0,5	0,5
Development Costs	**13,8**	**2,0**	**2,0**	**2,0**	**1,9**	**1,7**	**1,2**	**1,4**	**1,7**
Demo Plant Costs	102,0	0,3	2,6	10,1	17,9	23,1	21,0	19,0	8,1
Follow-on Plant Costs								0,9	8,2
Gross Funding Need	**115,8**	**2,2**	**4,6**	**12,1**	**19,8**	**24,8**	**22,2**	**21,3**	**17,9**
Public Support	52,1	1,0	2,1	5,4	8,9	11,1	10,0	9,2	4,4
Sales	34,9	0,0	1,6	0,0	0,0	3,6	6,4	8,9	26,6
Net Funding Need	**28,8**	**1,2**	**0,9**	**6,6**	**10,9**	**10,1**	**5,8**	**3,3**	**-13,1**
Acc funding need		1,2	2,2	8,8	19,7	29,7	35,5	38,8	25,7

Following the completion and subsequent of Phase 1 of the Development roadmap, the company expect the first follow-on orders for BTC plants, resulting in sales revenues from 2028 and onwards.

For full details on the Demo plant budget and investments, please see Pilot&Demo Project description.docx where details and schedule is presented in detail.

Beyond the technology development through the TRL 5 and Demo plant projects, the company is increasingly focusing on project development and commercialization for the realization of the first generation of BTC plants, the P10. Complementary revenue tracks are under evaluation, primarily gasification for production of carbon-negative gases and Hydrogen-ready combustion systems for retrofit onto existing gas turbines or other applications. In particular hydrogen production from biomass with carbon capture has shown very interesting preliminary economics. These tracks require additional investigation and development before being included in the commercial and technology development road maps.

8 Team and IP

8.1 Team

Phoenix Biopower has now 11 full-time 2 part-time team members, and hiring is ongoing to add 3-4 team members to join after summer 2024.

8.1.1 Founders

The founding team is Hans-Erik Hansson, Michael Bartlett, Oliver Paschereit and Henrik Båge.

Hans-Erik Hanson, Senior advisor
Inventor and initiator of the BTC technology. Hans-Erik has worked with gas turbine development for over thirty years at premier manufacturers like Siemens (previous Alstom/ABB). Hans-Erik has the role as senior technical advisor, supporting both the engineering development of the BTC technology and prototyping and testing. Hans-Erik holds a master's degree in engineering.

Michael Bartlett, CTO
Michael is a senior project manager for technology and product development and heads the R&D operations at Phoenix BioPower, coordinating all activities in-house and externally. Michael brings 15 years of experience from industrial R&D in the energy sector (General Electric, Alstom, Vattenfall) plus industrialization in the transport industry (Scania) and 6 years of high-quality research in academia. He led previous development efforts with the BTC and Top Cycle at Vattenfall 2008-2011. Michael has a PhD in Chemical Engineering from KTH (Stockholm) entitled "Developing Humidified Gas Turbines".

Henrik Båge, CEO
Henrik brings over 20 years' experience in business development and fundraising in clean tech companies. Henrik works with the business development, funding, sales and marketing at Phoenix. Henrik worked as head of business development at a leading Swedish solar energy company for 8 years. Henrik has for over a decade worked with private funding of small companies and has partaken in IPOs in both Sweden and the UK. Henrik holds a master's in economics.

Oliver Paschereit, Head of Combustion
Professor at TUB at the Institute of Fluid Dynamics and Technical Acoustics. Oliver heads the research of the burner and combustor technology. Oliver leads a world-leading group on high-steam levels in combustion, initiated together with Euroturbine and Vattenfall in 2008. He has a distinguished background in academia and from industry, where he was head of combustion for Alstom, Switzerland.

8.1.2 Key employees

Chunguang Zhou, Chief Engineer Gasification

Chunguang "Chun" Zhou holds a PhD from KTH Royal Institute of Technology in gasification and pyrolysis of waste. After his PhD, Chun has developed industrial-scale prototypes for plasma gasification plants in Canada and China before returning to Sweden to join Phoenix BioPower. Chun is leading the gasification development and plays a key role in the development of the BTC plant with his experience from both academia and industry.

Felix Güthe, Chief Engineer Combustion

Felix Güthe, PhD, is our Chief Combustion Engineer with an extensive background in combustion technology from companies such as Alstom and GE. Felix is responsible for the advanced development of combustion technology, including kinetics, design and operation.

Jens Pålsson, Senior plant and simulation engineer

Jens is the company's plant engineer and is responsible for the company's plant simulations. The area of responsibility includes detailed performance calculations, interfaces and defining requirements for the subsystems of a plant.

8.1.3 Board of Directors

In addition to founders Michael Bartlett and Henrik Båge, the Board of Director is made up of:

Stefan Jakélius, Chairman

Stefan passionate about developing companies and create real change. He has a deep sense for strategies that will work and is not afraid to tuck up the sleeves to make it happen. His background is from practical business development, leadership, organization, change management as well as venture capital investments and M&A in the SME sector.

Catharina Lagerstam, Member

Catharina holds a PhD in Financial Risks (invented the Value-at-Risk Models), and works as a board professional, independent advisor and private investor with an extensive experience in the Swedish banking and insurance industry. She is currently a member of the Board of Directors of ICA Insurance, Image Systems and Chairman of VOC Diagnostics AB.

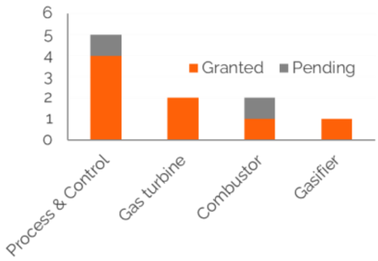
8.2 IP

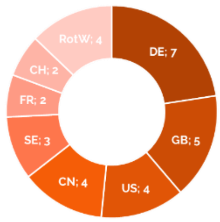
Phoenix patent portfolio has grown significantly since the founding of the company from six families of patents and 15 applications, with 9 granted and 6 pending to 8 families, 31 granted patents and 2 pending. The company's portfolio of patents covers the fundamental process elements and some optimal configurations of the gas turbine and gasification system. The latest awarded patent was for the HFB gasification technology invented by Chun Zhou.

High quality patents are, and will be, an important part of the company strategy. A thorough patent strategy has been developed with patent expertise at ADECT and is now being implemented. The patent strategy will assist the company in managing the IP portfolio, both patents and other IP, when navigating in the broad field as the BTC and Top Cycle technologies operate in and to mitigate the risks that comes as a consequence of development timelines being very long.

The patent strategy has provided the company with a comprehensive tool in managing IP and the IP portfolio beyond patents. It has also illustrated the geographical focus for the current and future IP landscape for the company. Key focal markets are markets with either manufacturing or components and technology needed for the BTC and Top Cycle technologies but also markets with an expected high demand for the technologies from a commercial perspective.

As can be seen from the mapping below, the geographical spread of the portfolio is global, having taken both commercial markets as well as manufacturing markets into account when applying for patent protection.





Name	Expiry date of patent
Base	2025-05-28
TopSpool	2030-02-24
SuperSpool	2030-02-24
IGWC	2031-03-11
SuperFeeder	2033-12-27
Combustor	2030-03-19
Solar	2032-12-15
HFB	2047-02-10
Dual Swirler	Pat pending
Plant integration	Pat pending

Patent distribution, geographic territory map and list of patent families. A number of patents wer abandoned in late 2023 reducing the portfolio from 9 families and 44 granted to the current 8 families an 31 granted patents.

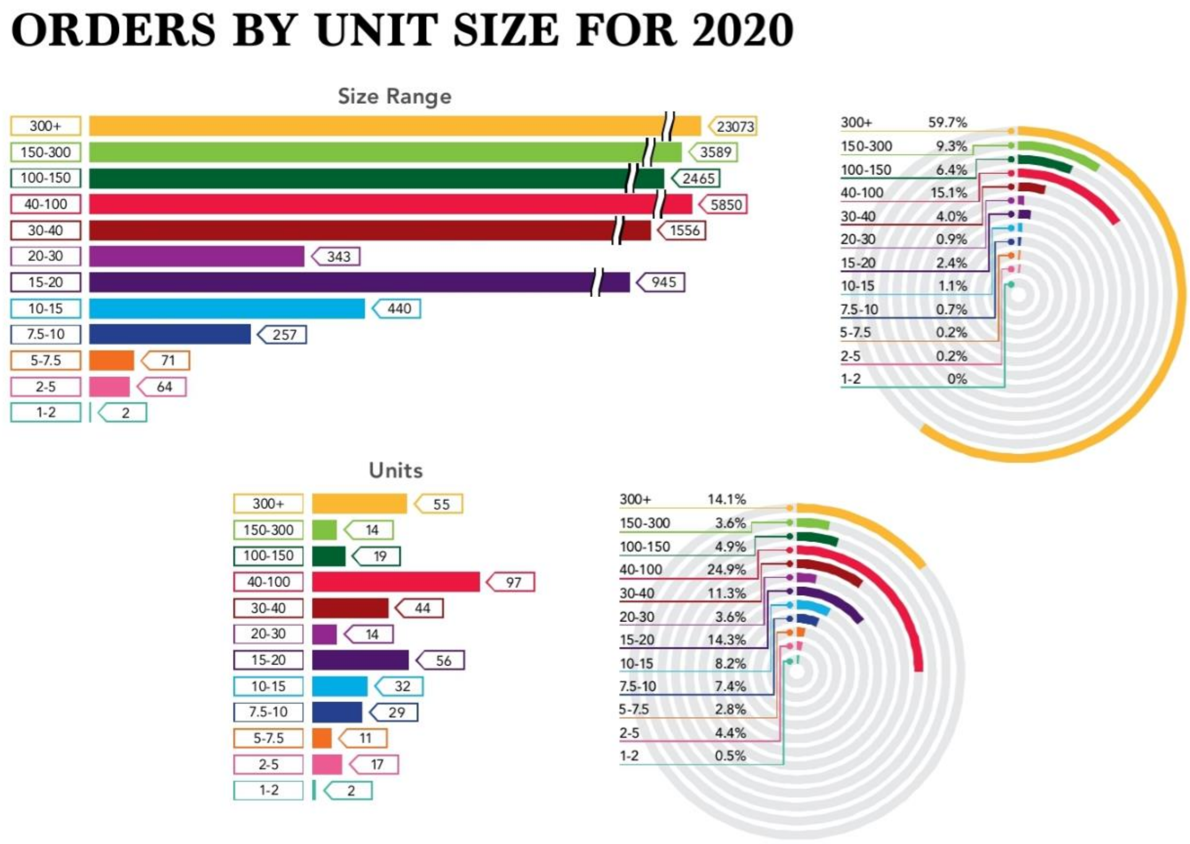
In addition to the current patent portfolio, the company continuously evaluate new inventions emanating from the developments work. Currently, there are two-three new patents being drafted and where at least one is planned for filing in 2023. Additionally, a number of patentable inventions have been identified and will be addressed in accordance with the company's patent strategy for new inventions. It is here, in new, unpublished, inventions, where much of the company's future value and commercial success is laid, building on the current portfolio of IP.

Appendix I – Full Market Analysis

The BTC technology and the company's technology platform addresses and touches on several markets as has been described in the previous section of the possible applications. The key markets that the company is looking at are the Gas Turbine market and the Biopower market.

Gas Turbine Market

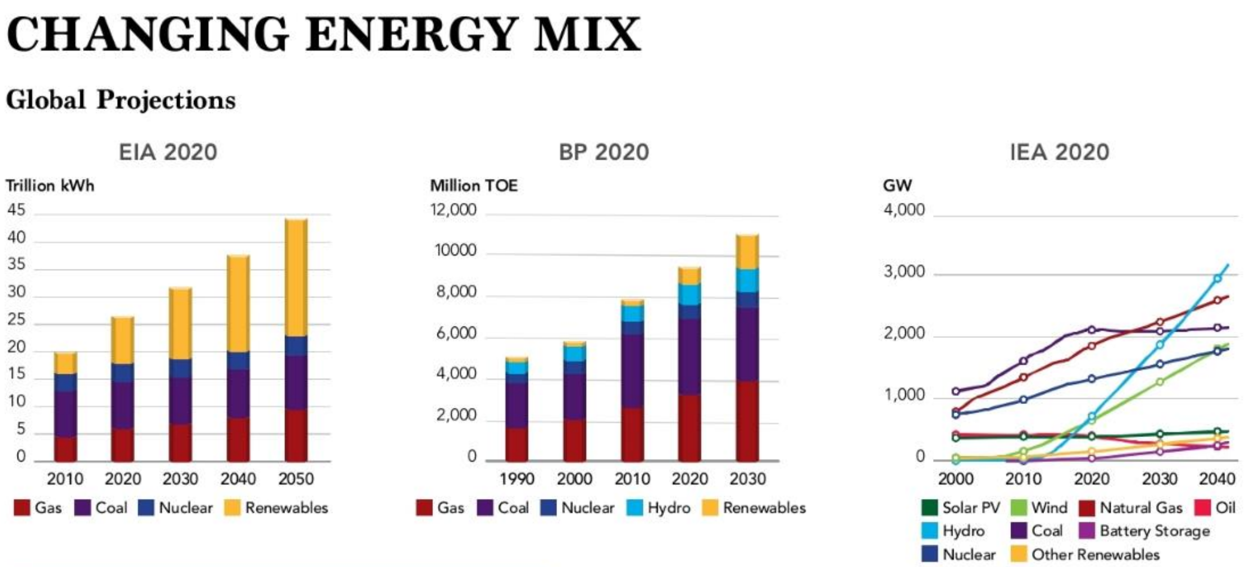
According to Gas Turbine World global market forecast 2021-2030, it is expected that equipment-only purchases for heavy-frame to reach $36.3 B in the next 5 years, and $2.8 B for light industrial unit orders in the same period. The following figure shows the orders by unit size for 2020.



GTW 2021 Market Forecast

In the same report, notable trends based on the last 5 years data indicate that "in the Electrical Power Utility Sector: units in 30-40MW range (mobile units) are up and 300MW+ have rocketed; the 40- 150MW range is down over 50%".

Global projections for energy mix indicate increase in natural gas and renewables as shown in the figure.



Change from 2020 to 2030

	EIA	BP	IEA
Nuclear	12%	10%	4%
Coal	1%	-3%	1%
Gas	12%	20%	23%
Renewables	54%	109%	115%

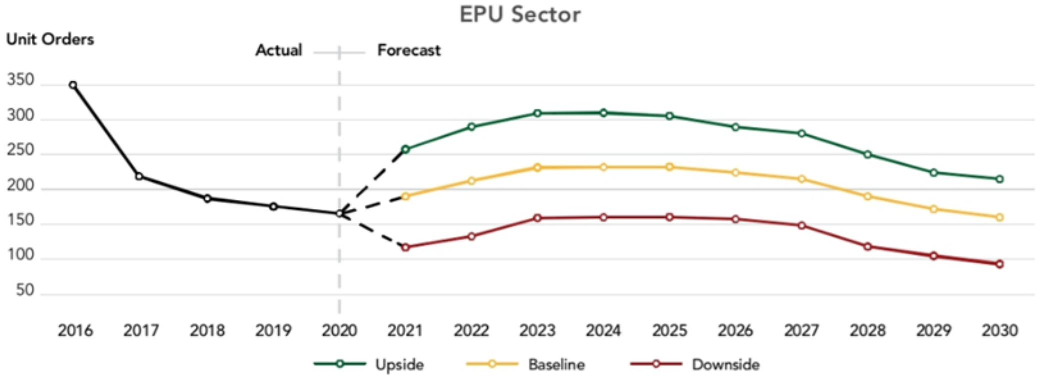
Source: GTW 2021 Market forecast

The 10-year forecast by Gas Turbine World indicate a decline in unit orders after the period 2023-2025 as shown in the following figure.

TEN-YEAR FORECAST

Power Generation Sector

- Downside assumes very aggressive fossil fuel and CO_2 restrictions coming sooner than Paris Climate agreements. Also assumes large increase in natural gas prices.
- Upside assumes China growth is stable/slightly improving.



This forecast uses a bottom-up methodology to evaluate over 85 gas turbine models by unit count and OEM.

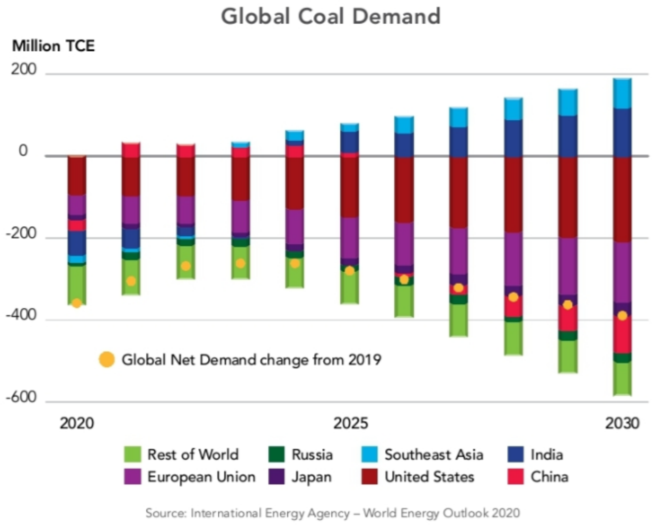
GTW 2021 Market Forecast

A main market driver is the coal and nuclear plants retirements. As shown in below figure, EU and US lead the declines in coal demand.

COAL RETIREMENTS IMPACT

Change in coal demand is shown relative to 2019 by region in the Stated Policies scenario.

- Coal plant retirements will be covered by Renewables and jumbo Gas Turbines.
- The world sees a rebound in coal demand after 2020, before demand falls.
- Coal use in China peaks in the middle of the decade.
- Europe and the United States lead the declines.



Aeroderivatives will largely benefit by 2022-23 from renewable additions (offset power).

GTW 2021 Market Forecast

The BTC represents a great business opportunity to the Gas turbine industry where gas turbines become associated with CO_2 neutral/negative power generation. GTW forecast indicates that renewable energy increases the need for GTs under 150MW, and the renewables impact is shown in below figure.

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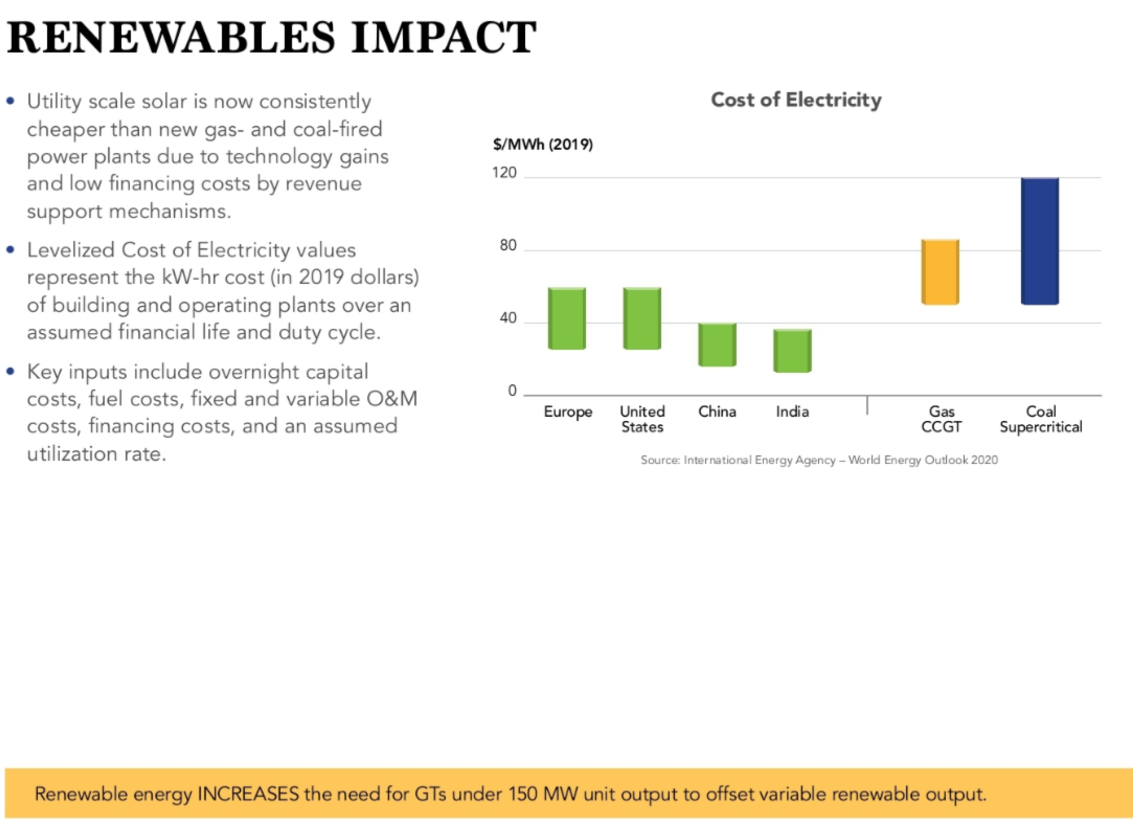
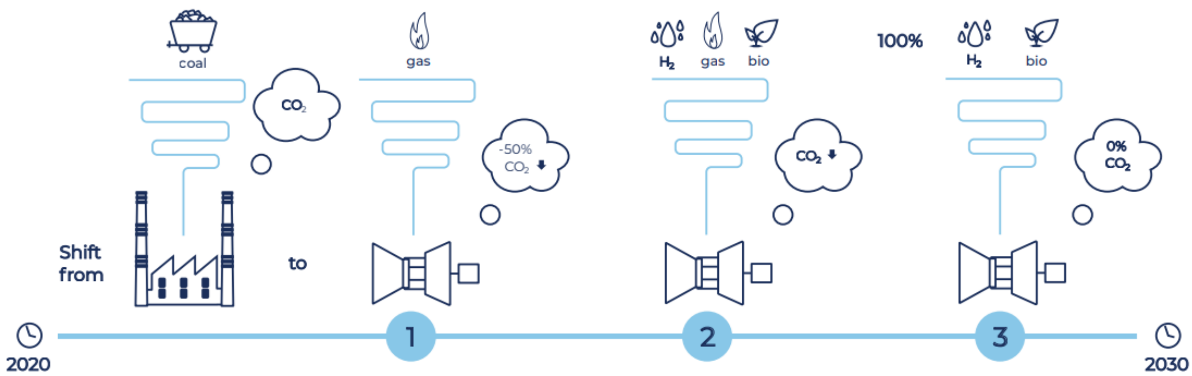


GTW 2021 Market Forecast

Gas turbines can play an important role in the shift towards zero-carbon power generation as demonstrated in below figure from ETN hydrogen gas turbines report.



Source: ETN Global

Hydrogen Generation Market

With the recent initiatives in the EU, China and US, a new, green hydrogen market is emerging. From all corners of the world, it is expected that green hydrogen will replace fossil-derived hydrogen and also fossil fuels for propulsion and power generation.

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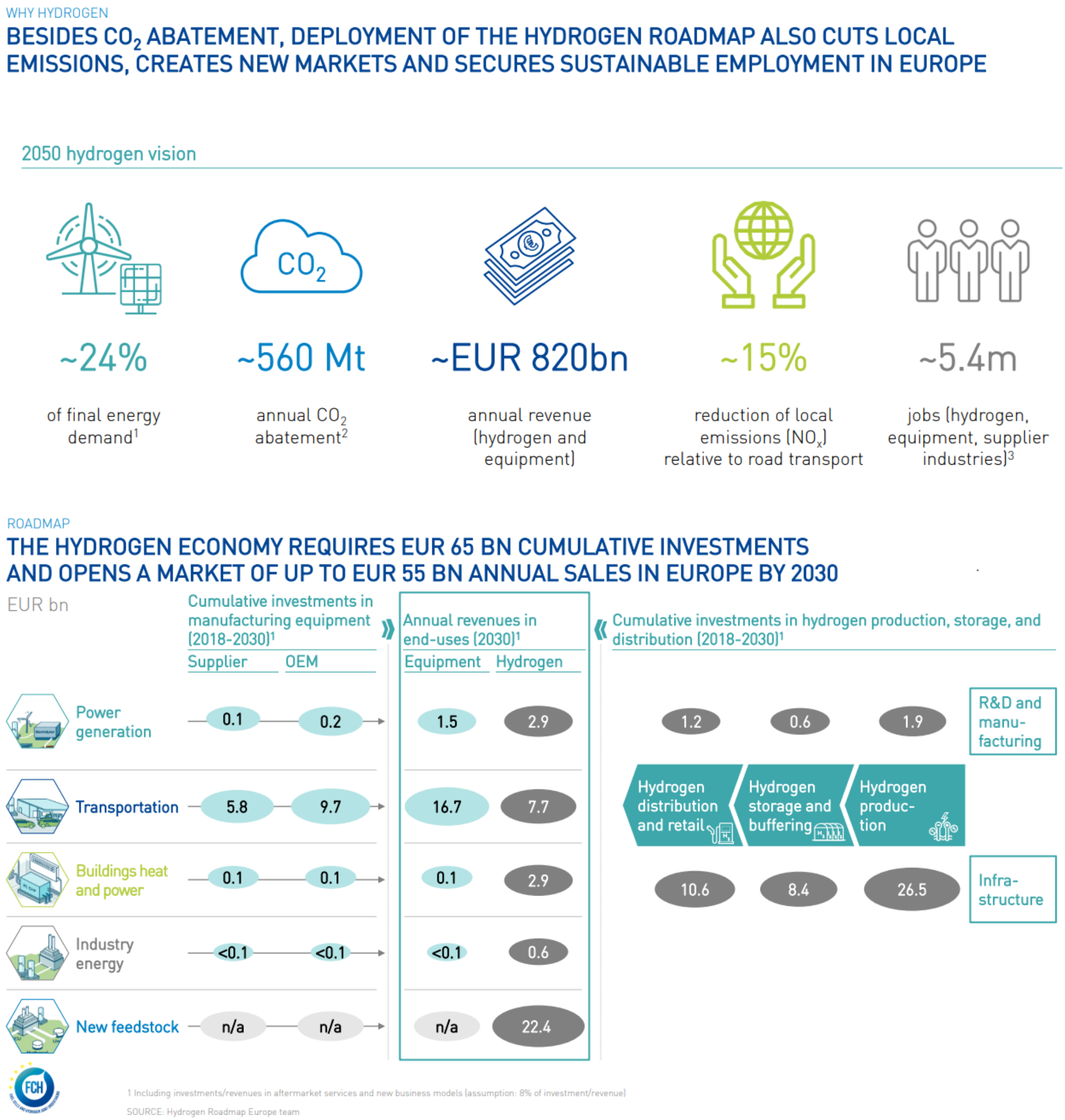
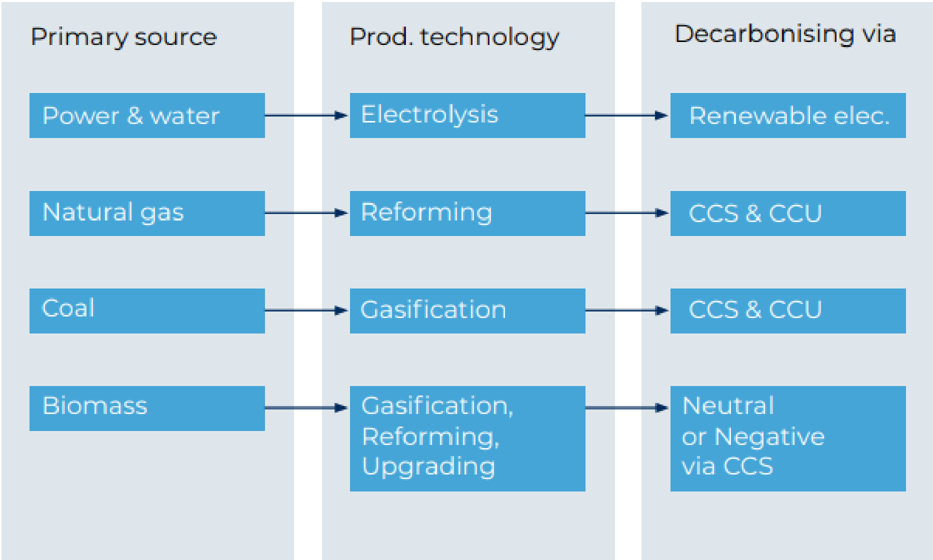
An example is Hydrogen Roadmap Europe to achieve deep decarbonization as shown below along with 2050 vision.



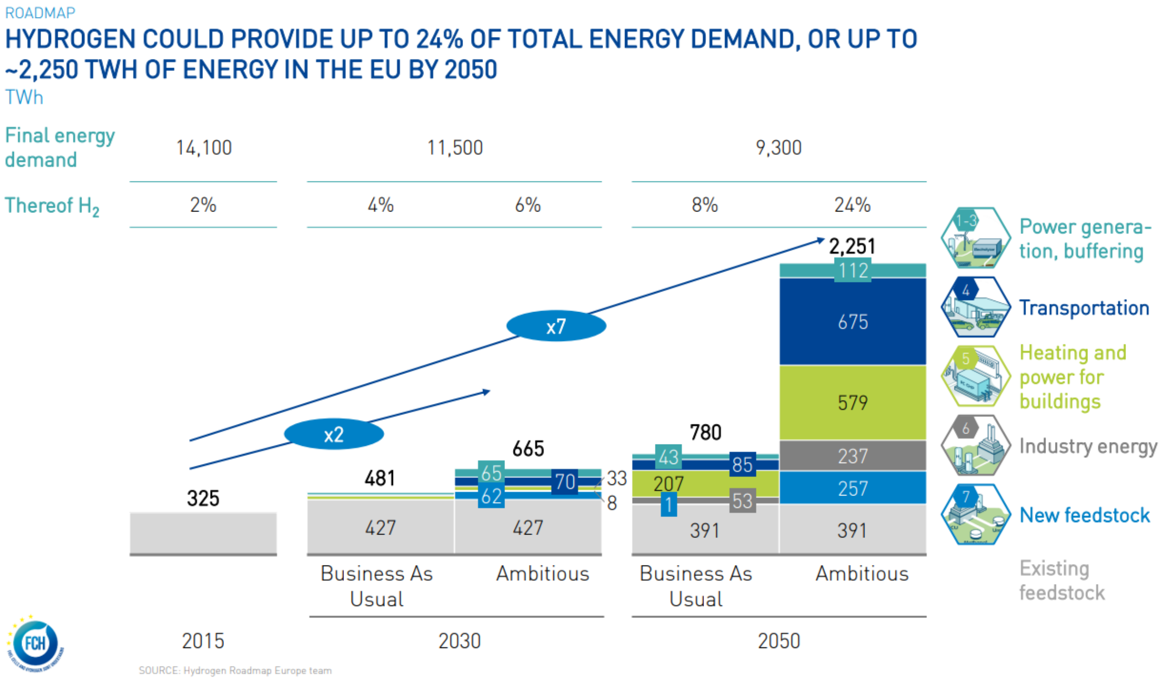
Source: Hydrogen Roadmap Europe- Fuel Cells and Hydrogen Joint Undertaking (FCH JU)

Biomass is a source of producing Hydrogen through gasification as demonstrated in below figure. Furthermore, the BTC with its superior fuel flexibility can run on 100% Hydrogen.



Source: ETN Global

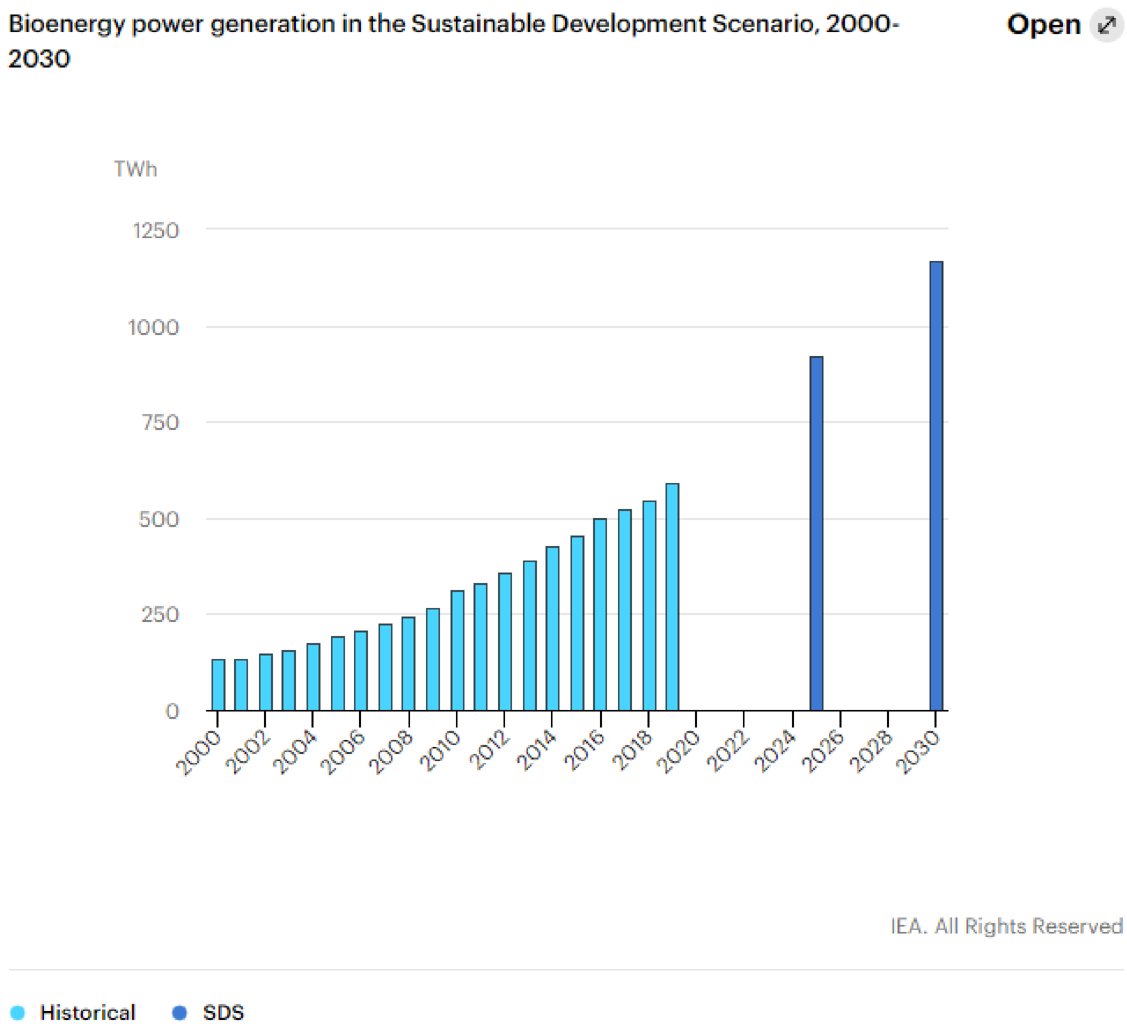
In the projection below by FCH JU, the percentage of energy produced by hydrogen could double by 2030 in the ambitious scenario.



Source: Hydrogen Roadmap Europe- Fuel Cells and Hydrogen Joint Undertaking (FCH JU)

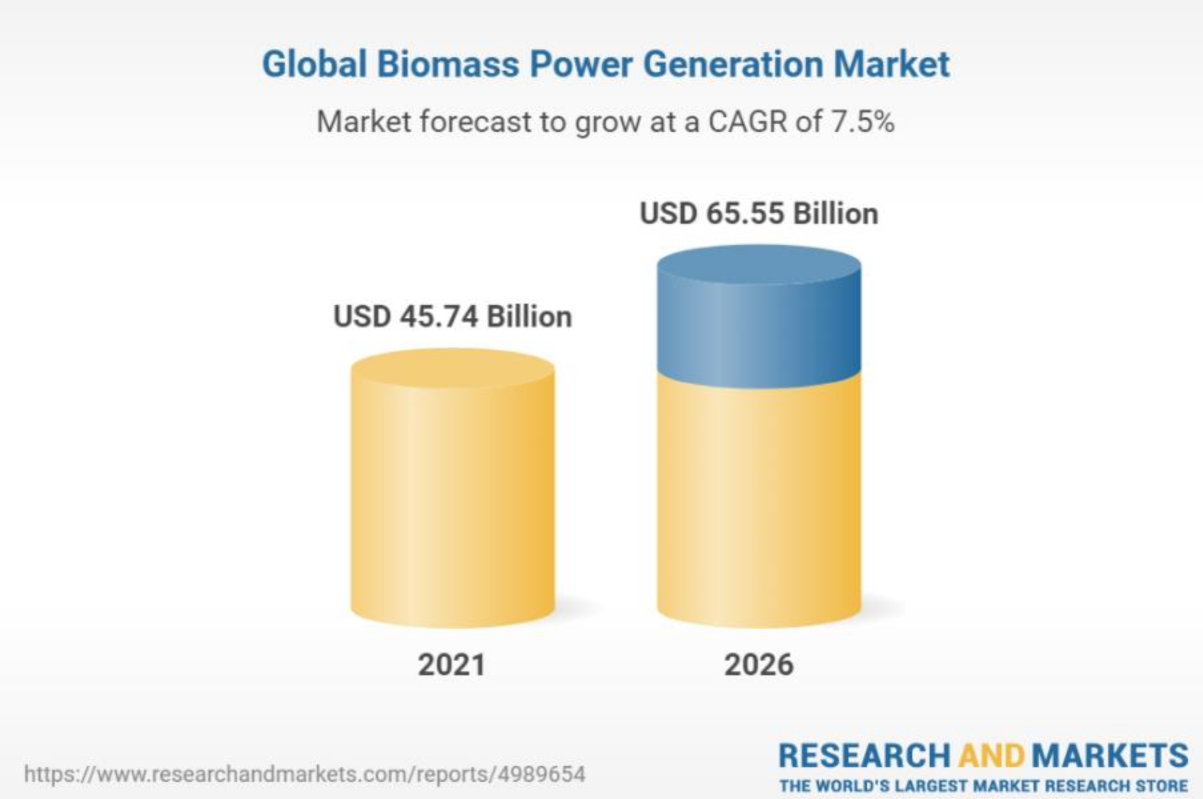
Biopower Market

According to IEA, electricity generated from bioenergy increased by 5% in 2019, which was just 1% less than the Sustainable Development Scenario (SDS) projected until 2030. Electricity produced in 2019 reached 589 TWh, with SDS projections of 922 TWh in 2025 and 1168 TWh in 2030 as shown in figure.



Source: IEA

According to a study by Research and Markets, the biomass power generation market size in 2021 is expected at BU$ 45.74, and BU$ 65.55 by 2026 with CAGR of 7.39% as shown in the following figure.

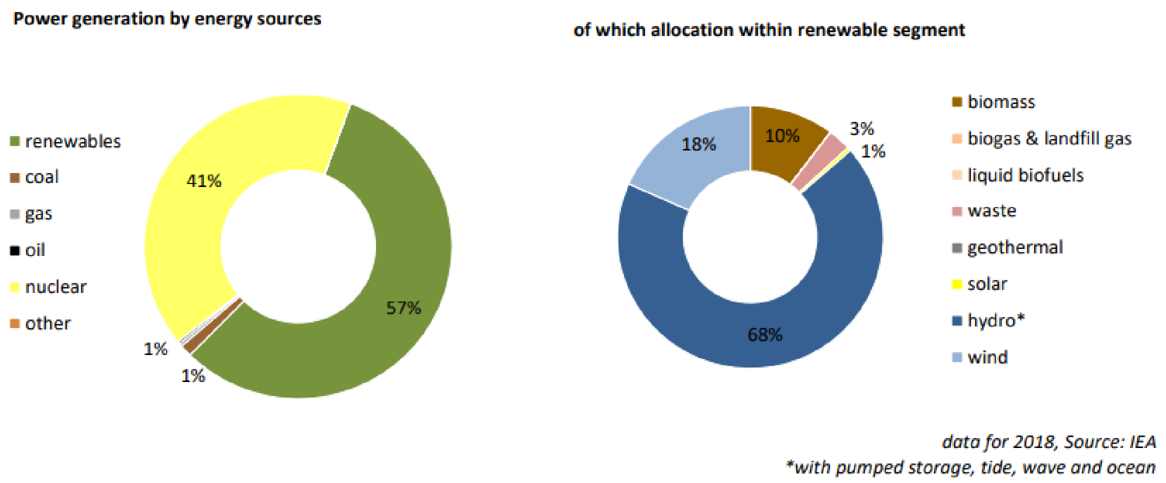


Source: Research and Markets

IEA indicate that the growth is influenced by policy changes and market developments around the globe. For example, China introduced a new clean-heat initiative that is anticipated to increase the demand of biomass- and waste-fuelled co-generation plants. In addition, China is promoting the use of agricultural residues where solid biomass-based electricity generation currently receive feed-in tariff support.

The report states that "In India, fiscal support and capital subsidies underpin capacity expansions of existing plants and greenfield investments, mainly in bagasse co-generation plants utilising by-products of the sugar and ethanol industries."

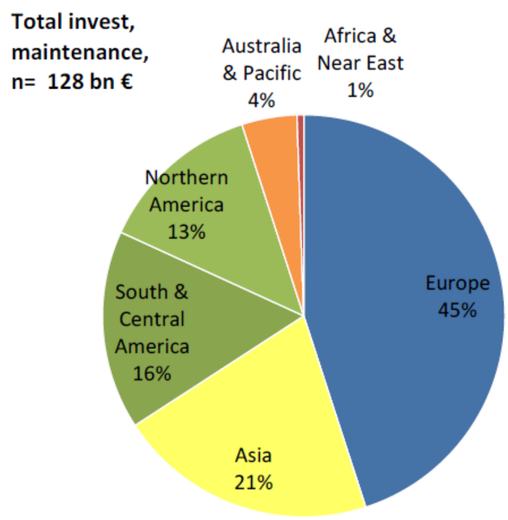
In Sweden, 10% of electricity is produced from biomass as shown in below figure.



Source: ecoprog

The expected high-growth markets are also reflected in the markets where most investments are expected in the coming years, with China taking the lead as the largest expected market for new plants. India is also planning to invest significantly in comparison to the market size. In Europe, much of the expected investments are driven by subsidy schemes, many promoting small scale (<2MW) CHP solutions. For the Nordics, investments are primarily driven by rebuild and replacement of existing CHP plants as the economics for power plants are not good enough for steam cycle plants.

Worldwide investments in new constructions & modernisation and maintenance 2018-2027



Country	mln Euro - new construction	mln Euro - maintenance	mln Euro - total invest
Brazil	7,100	8,800	15,800
China	11,400	3,900	15,300
UK	8,900	4,300	13,200
USA	6,700	4,700	11,400
India	4,600	3,400	8,000
Sweden	3,100	3,900	7,000
Finland	2,700	3,500	6,200
Canada	2,900	2,700	5,600
Japan	3,100	1,500	4,600
Italy	1,200	4,000	4,400

Source: ecoprog 2018

Plants and electricity generation capacities in Europe. Source: ecoprog 2018

BECCS market

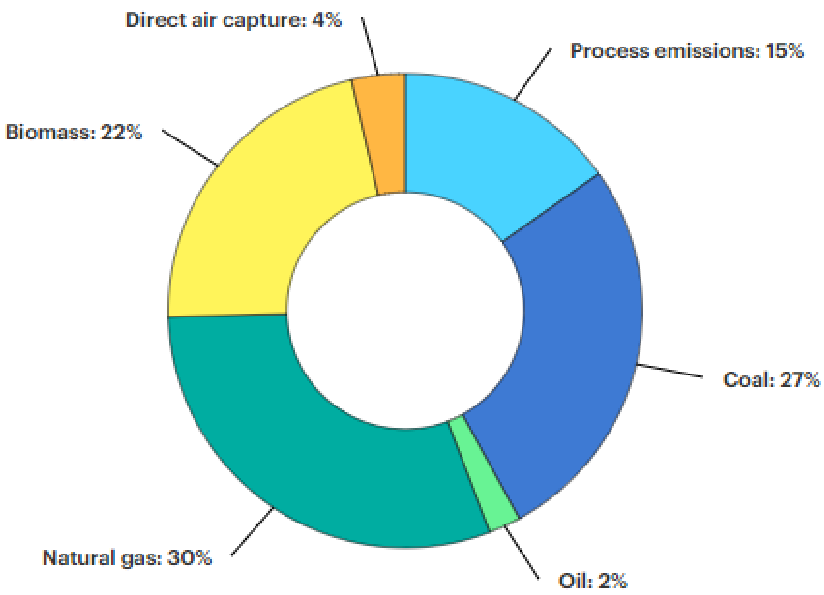
BECCS in now getting a lot more attention from both regulations and investment points of view, as it is considered one of the main pathways to achieve the Net-Zero goal.

In addition, IEA considers CCUS an enabler of least-cost low-carbon hydrogen production.

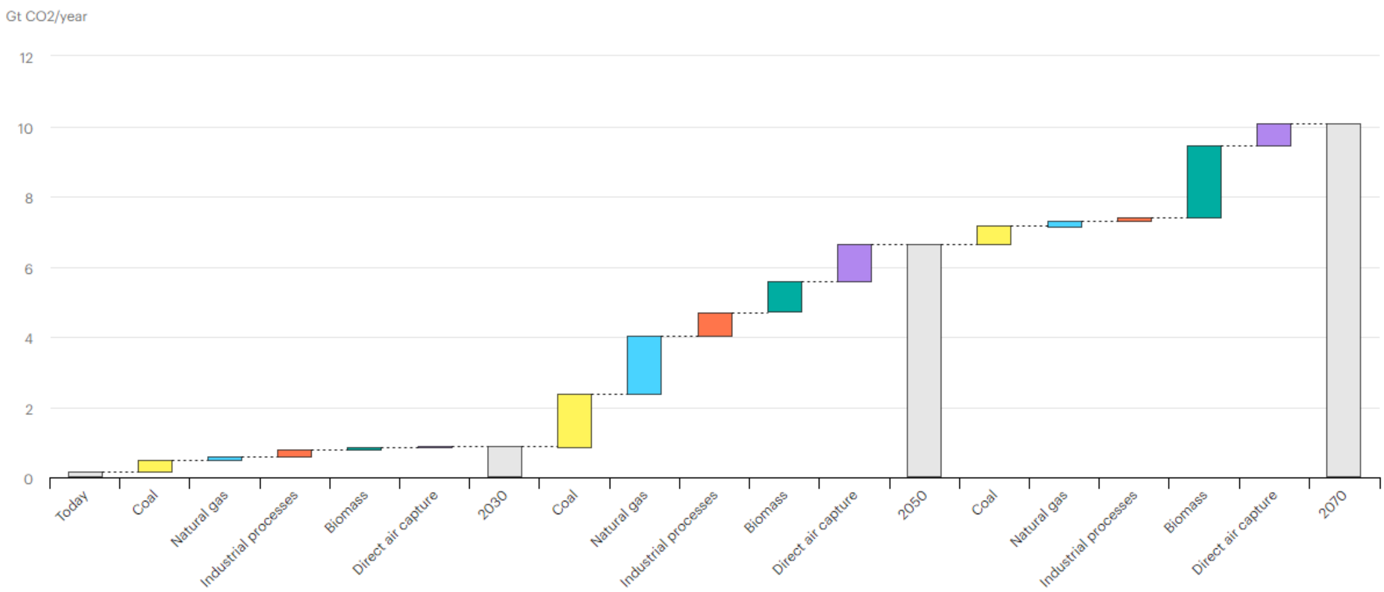
IEA reports that "Plans for more than 30 new integrated CCUS facilities have been announced since 2017, mostly in the United States and Europe, although projects are also planned in Australia, China, Korea, the Middle East and New Zealand".

Research and Markets estimates the global market size for CCS at US$2.8 Billion in 2020, with projection to reach a US$4.9 Billion by 2026, indicating at a CAGR of 9.9% over the analysis period.

CCS will continue to grow and BECCS is expected to form 22% of CCS according to IEA Sustainable Development Scenario, 2020-2070, as shown in the following figures.

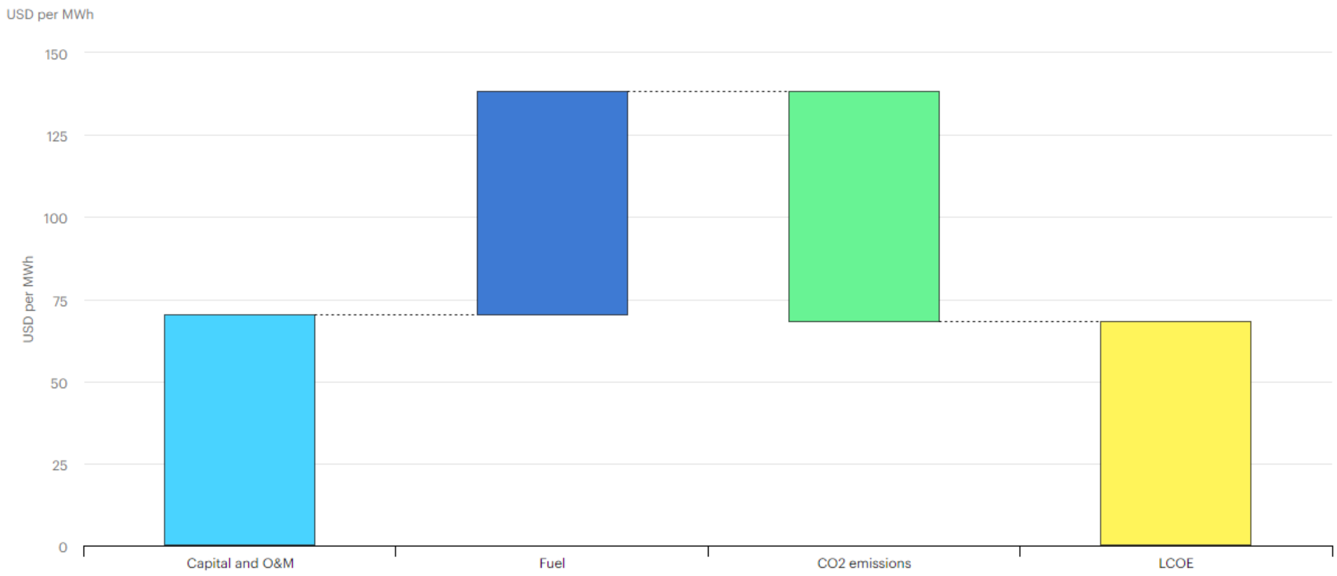


World cumulative captured CO2 by source in the Sustainable Development Scenario, 2020-2070. Source: IEA



Growth in world CO2 capture by source and period in the Sustainable Development Scenario, 2020-2070. Source: IEA

The following figure demonstrates how Co2 price impact the LCOE in a scenario of a biomass IGCC plant equipped with CCUS, where Capital and O&M: $ 70/MWh. Fuel cost: $ 68/MWh. Co2 cost: $ -70/MWh ($80/ton), resulting in LCOE: $68/MWh.



Impact of a carbon price of USD 80 per tonne CO2 on the LCOE of BECCS. Source: IEA

BECCS started to ramp up worldwide and there are currently many leading projects as shown in in below figure. Since the list was compiled, several larger scale projects have been launched, like Stockholm Exergy's 800 000 t/a of carbon captured project in Stockholm.

Leading bioenergy with CCS/CCU projects currently operating worldwide

Plant	Country	Sector	CO_2 storage or use	Start-up year	CO_2 capture capacity (kt/year)
Stockholm Exergi AB	Sweden	Combined heat and power	-	2019	Pilot
Arkalon CO_2 Compression Facility	United States	Ethanol production	Storage (EOR)	2009	290
OCAP	Netherland	Ethanol production	Use	2011	<400*
Bonanza BioEnergy CCUS EOR	United States	Ethanol production	Storage (EOR)	2012	100
Husky Energy CO_2 Injection	Canada	Ethanol production	Storage (EOR)	2012	90
Calgren Renewable Fuels CO_2 recovery plant	United States	Ethanol production	Use	2015	150
Lantmännen Agroetanol	Sweden	Ethanol production	Use	2015	200
AlcoBioFuel bio-refinery CO_2 recovery plant	Belgium	Ethanol production	Use	2016	100
Cargill wheat processing CO_2 purification plant	United Kingdom	Ethanol production	Use	2016	100
Illinois Industrial Carbon Capture and Storage	United States	Ethanol production	Dedicated storage	2017	1000
Drax BECCS plant**	United Kingdom	Power generation	-	2019	Pilot
Mikawa post combustion capture plant	Japan	Power generation	-	2020	180
Saga City waste incineration plant	Japan	Waste-to-energy	Use	2016	3

* The OCAP plant receives its CO2 from a fuel refining facility (hydrogen production) and from an ethanol production plant. Therefore only part of the total CO2 (400 kt/year) qualifies as bioenergy with CCU. ** The project is currently releasing CO2 after its capture, but the long-term plan is to focus on offshore storage as part of the Zero Carbon Humber project.

Source: IEA

Competition

Addressing two very large markets; the gas turbine market and the biopower market inevitably means competition. In the very short-sighted perspective, the company know of no other actor developing similar technology as the Top Cycle or the BTC. However, a wider perspective is needed for a more accurate view on the competitive landscape for the Top Cycle and BTC.

Top Cycle competition (engine)

For the Top Cycle as a power production unit in gaseous fuel markets, the competition stretches from reciprocating gas motors at smaller scales (1-20 MW) to traditional Single Cycle gas turbines (5-100 MW) and Combined Cycle (70-600 MW) plants at larger scales. Single cycle gas turbines operate with electrical efficiencies of 30 – 42 %, and gas motors at 40-48%. Combined cycle plants are normally larger and operate with around 57-63%. These latter plants are today supplied by manufacturers of large gas turbines like GE, Siemens, Ansaldo and Mitsubishi-Hitachi PS. Mid-/small size turbines are supplied by companies like GE, Solar, Siemens, MAN Energy Solutions, Mitsubishi-Hitachi PS, and Zorya-Mashpoekt along with small actors like OPRA, Aurelia, Capstone. Gas motors are supplied by e.g., INNIO, Wärtsila. In addition, there are a number of Chinese and Indian companies producing gas turbines and gas motors under license from some of the above, like Harbin Turbine Co. Ltd.

One of the largest trends in these segments is decarbonization and H_2 combustion. It is a staple topic at most industry conferences these days, and even more so following the war in Ukraine and the sanctions on Russian energy. Hydrogen is a very fast reacting fuel, generating very high local temperatures and fast flame fronts. This together makes traditional combustion systems unable to utilize more than very small fractions of H_2 in the fuel mix (low single digit %) while being safe against flashback and meeting emissions regulations. There are advances being made and new combustion systems are under development and have been introduced to the market. While current engines can, with significant adaptations, operate with 100% hydrogen, significant losses in power and efficiency usually result. There are no combustion systems that the company is aware of that are able to switch between natural gas, hydrogen and blends, which the Phoenix technology aims to achieve.

It is in the H_2 combustion space that the Top Cycle will have the best opportunity to compete with traditional gas turbine suppliers with its ultra-wet combustion, high pressure combustion and combined cycle performance. Natural gas operation with Top Cycle in combination with CCS also constitutes a very competitive proposition with lower LCOE and 50% lower cost of CO2 avoided resulting from the superior electrical efficiency with CCS.

BTC Competition (high efficiency biopower)

The biopower market today primarily rests on the steam cycle technology dating back to 1775 and James Watt's steam engine. Current large-scale plants all use the same basic principle, boil water to generate steam to produce physical motion to generate electricity. Even if the technology has improved since the 18th century, the most efficient and largest biopower plants only perform at 35-40 % of LHV. This is limited by corrosion issues in the boiler, which limits temperatures for the steam cycle, compared to coal boilers that can reach up to 48%. Generally, the installed fleet operates at 15-30 % of LHV in the range 500kW-50 MWe. This is the main competition for the BTC technology: existing and well-known technologies. Key companies involved in steam cycle plants often have both EPC and boiler competence, e.g, Andritz, Valmet, B&W Völund, Burmeister & Wain, Sumitomo FW, Ameresco, Jernforsen.

Plants for high efficiency biopower usually involve gasification of biomass first and then combustion. This is done to be able to clean the resultant gasified biomass and avoid corrosion issues in the power plant. In commercial applications, the power engine can then either be a boiler / steam cycle at large scale or a gas motor at small scale. The latter have become popular at scales under 500kW with standardised fuels, e.g. Burkhardt GmbH. The former can be found at very large scales to handle very difficult waste fuels, e.g. Valmet, Andritz, but is otherwise limited in application.

To date, the company only knows of one large-scale attempt at integrated biomass gasification with gas turbine: the Värnamo plant in southern Sweden in the 90:s. This was a 20 MW_f plant with CFB gasification, operating at 18-22 bar pressure with a Siemens GT with combined cycle for power generation. (very small for CC but it was a test plant). This is a technology that, still not commercial, promises electrical efficiencies of 37-47% on LHV basis. This project ran as an alternative to nuclear power in Sweden at the time, but when the decision to phase out nuclear was reversed, the project was mothballed, despite good technical results. IP ownership of the technology used and invented during the project is unclear, making the concept difficult to commercialize.

The last concept with high efficiency biopower is to utilise high temperature fuel cells with gasified biomass. Such fuel cells (solid oxide or molten carbonate) are not yet commercial for conventional, clean gases, and struggle tremendously with the contaminants found in biomass, e.g. sulfur. No demonstration-scale systems exist today.

There are several companies with pressurized gasification systems that are proven for biomass utilisation at scale. The technologies are, however, primarily used for coal gasification commercially, e.g. SES, GI Dynamics, GTI/Sungas. The company is in contact with these to examine the potential for cooperation.

Except for the above, the company is not aware of any commercial technology that directly competes with the company's technology but is acutely aware of that it is entering a very competitive market with existing, less efficient, technology.