PHOENIX BIOPOWER

DOUBLE THE EFFICIENCY

Renewable Power On-Demand

December 2024

Energimyndigheten

HORIZON 2020

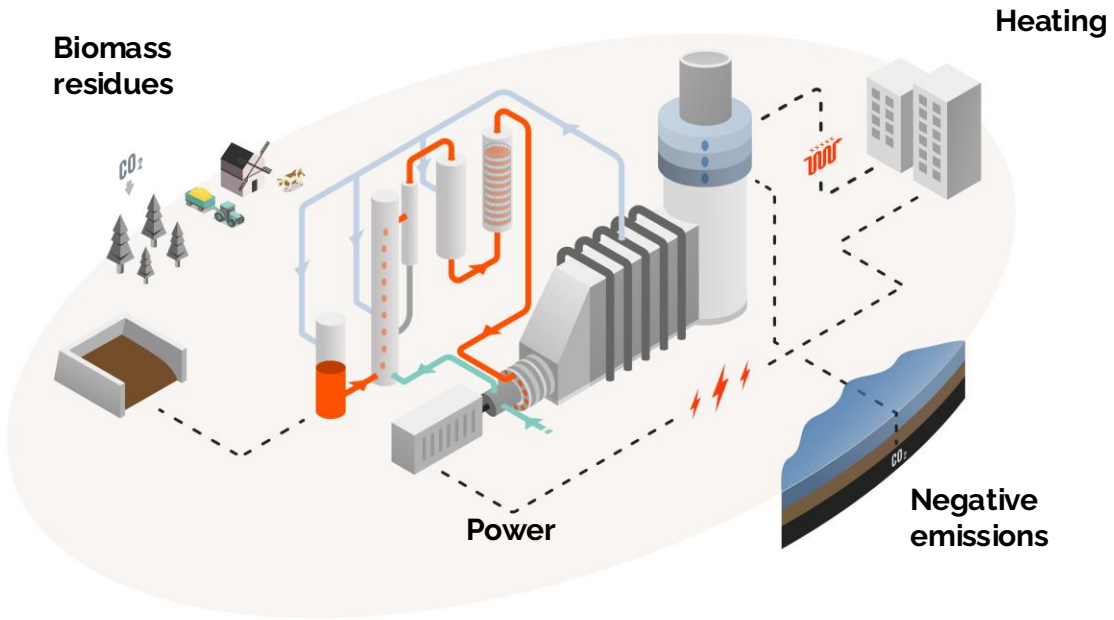
SUPPORTED BY eit InnoEnergy

DeepTech Alliance.

Bio-FlexGen

EXECUTIVE SUMMARY

- Phoenix develops a revolutionary solution for on-demand renewable power that converts biomass wastes at ultra-high efficiencies giving 100+ Mt climate impact potential.
- Up to double the efficiency of biopower from solid biomass residues. Local, plannable, renewable power and heat. Cost-effective CO_2-negative option
- 30-50% lower levelized cost of electricity (LCOE) than conventional biopower, with or without CO_2 removals
- Technology platform for biopower, biofuels (H2, SAF, etc) and peaking power.
- Real impact: 100+ Mton avoided + removed CO2 per year
- Unlocks a 150 bn€/a market growing over 10% CAGR
- 12+ M€ invested, 10 employees, 17 patents
- Completing TRL4, executing on plan to TRL5 by 2026
- MOUs in place. 10 MW plant



BTC power plant: biomass gasification and gas turbine with massive steam injection. 10, 40 and 100 MWe standardised units.

DRIVERS

Critical 2050 Goals

55 000 TWh/a
more renewable production

10 EJ/a
more renewable district heating

1,7 Gt/a CO_2
removals from atmosphere

- Global energy transition driving massive increase in renewable electricity demand
- Wind and solar are intermittent and impose large system costs
- Durable carbon removal technologies too expensive
- Security of supply more critical than ever

IEA, Net Zero Scenario

NEED

- One system that can provide cost-efficient
  - Renewable power on-demand
  - Efficient, low-cost carbon dioxide removals (NET)
  - Renewable heat supply
  - Grid stability services
  - Local energy source

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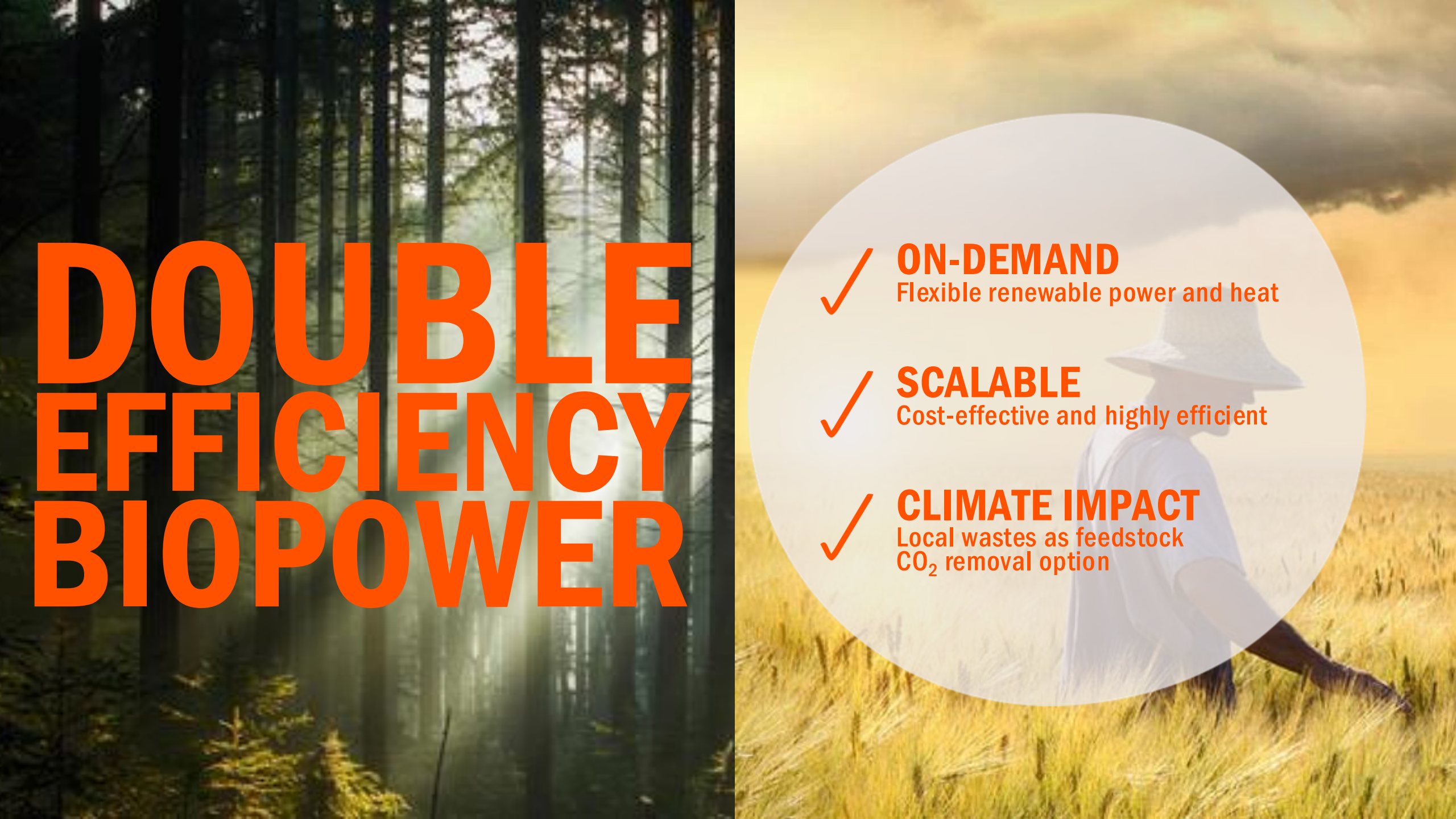
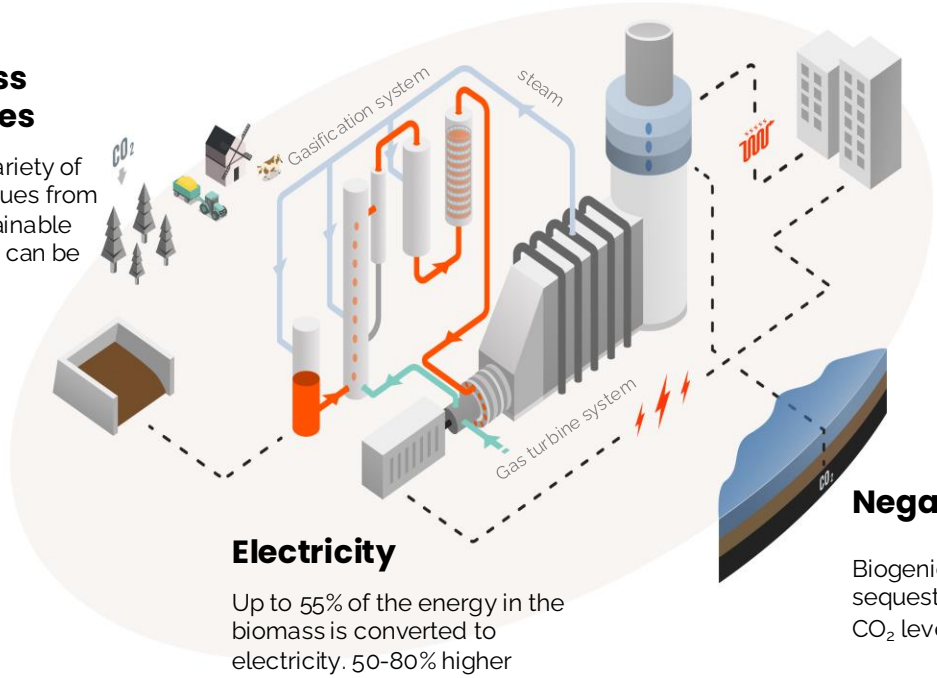

DOUBLE
EFFICIENCY
BIOPOWER
✓ ON-DEMAND
Flexible renewable power and heat
✓ SCALABLE
Cost-effective and highly efficient
✓ CLIMATE IMPACT
Local wastes as feedstock
CO_2 removal option

PHOENIX BIOPOWER: RENEWABLE POWER ON-DEMAND

Transforming biomass residues to electricity, heat and negative emissions in the novel BTC power plant

Biomass Residues

A broad variety of solid residues from local sustainable processes can be utilised.



Heating

Combined production of district heating and power (CHP). For a given heat supply, 3 times more electricity is generated.

Electricity

Up to 55% of the energy in the biomass is converted to electricity. 50-80% higher than conventional plants.

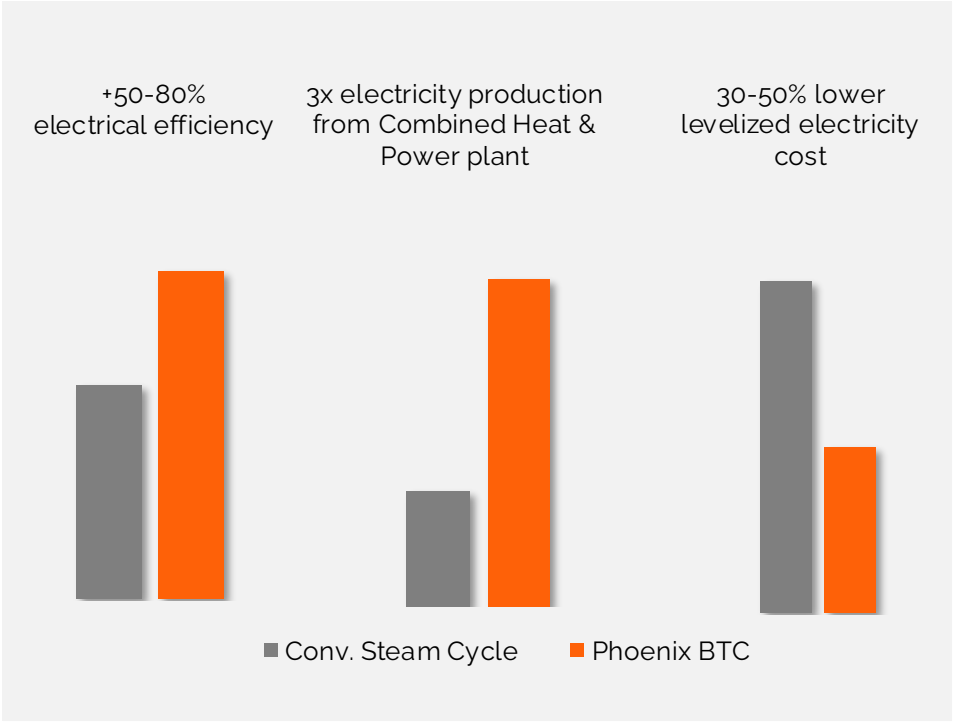
Negative emissions

Biogenic CO_2 capture and sequestration decreases the CO_2 level in our atmosphere.

The Biomass-fired Top Cycle (BTC)

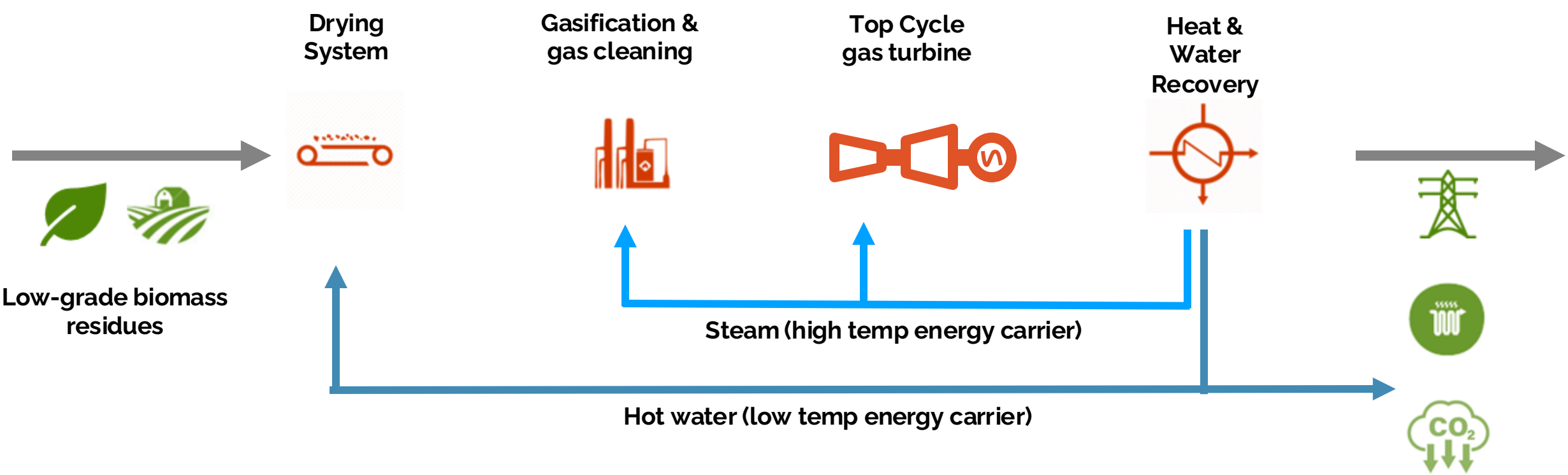
A gasification system transforms solid biomass residues to a clean gaseous fuel at pressure, which is combusted in a gas turbine at high temperatures, allowing high efficiencies. Steam, generated from exhaust and gasifier waste heat, is injected in the gas turbine to boost efficiency further by minimising air compression. At the end of the process, all steam is condensed; allowing water recycle and releasing low temperature heat for district heating, CO2 capture and biomass drying, all with minimal penalty to electricity output.

Our USP: Highly Efficient Biopower



Typical feedstocks:
Forest residues: (branches, tops, stumps, bark pest damaged etc.
Agriculture waste: Bagasse, corn stover, kernels
Demolition wood: Return wood with low pollution levels

BTC: A NEW POWER CYCLE



- Drying <15% humidity
- Belt dryer
- Waste heat

- Lock-hopper pressurization
- 25-40 bar pressure
- Thermal gasification 850-900C
- Steam injection to cool gas
- Hot gas clean-up

- Combustion of syngas in gas turbine
- 50 % volume steam in turbine
- Less air is compressed
- Higher output to generator, higher efficiency

- 500-550C flue gases
- HRSG for steam
- Flue gas condenser for water recovery and hot water production
- Hot water for fuel drying, district heating &/or CO_2 removal

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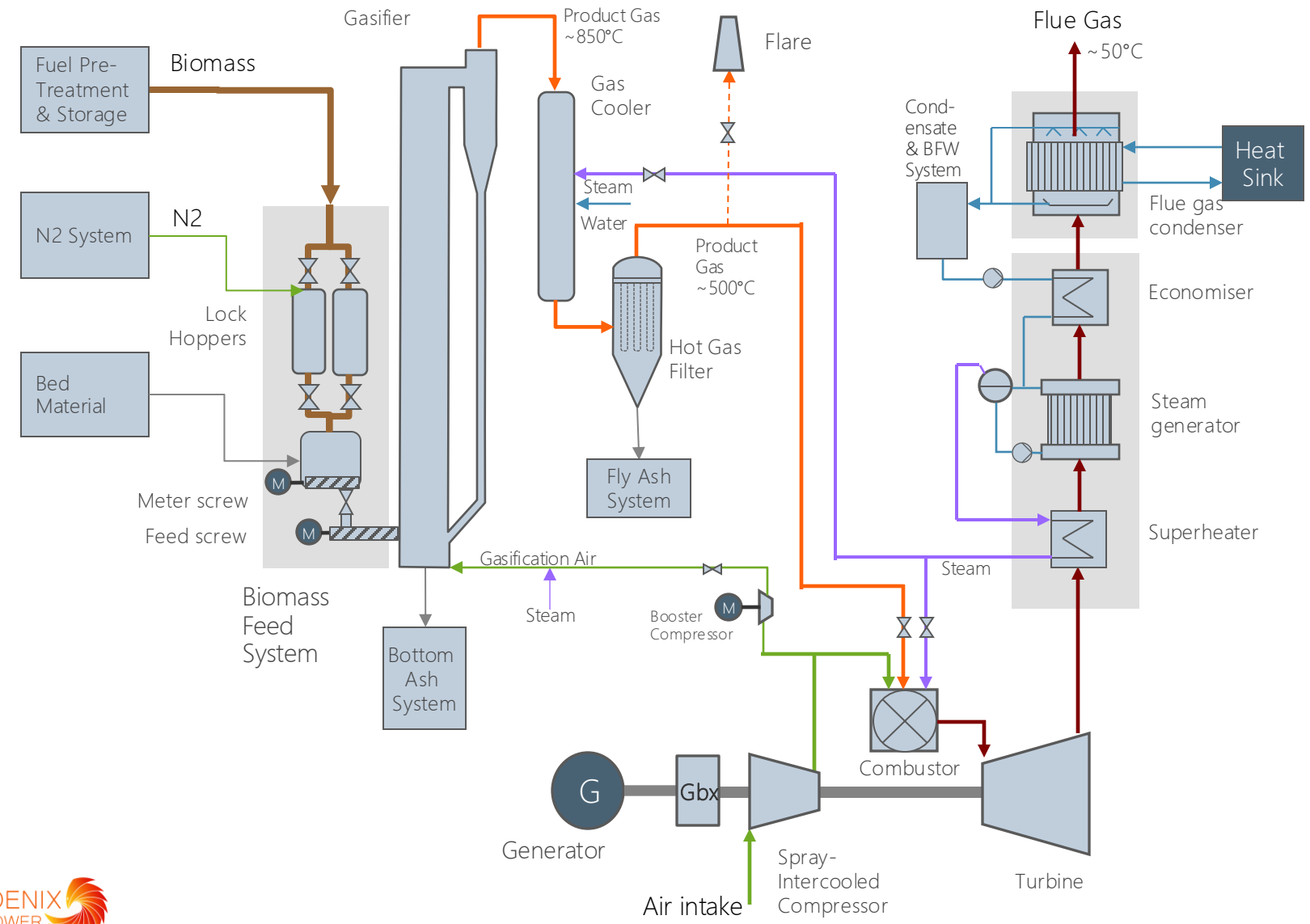
BTC SIMPLIFIED PROCESS SCHEMATIC



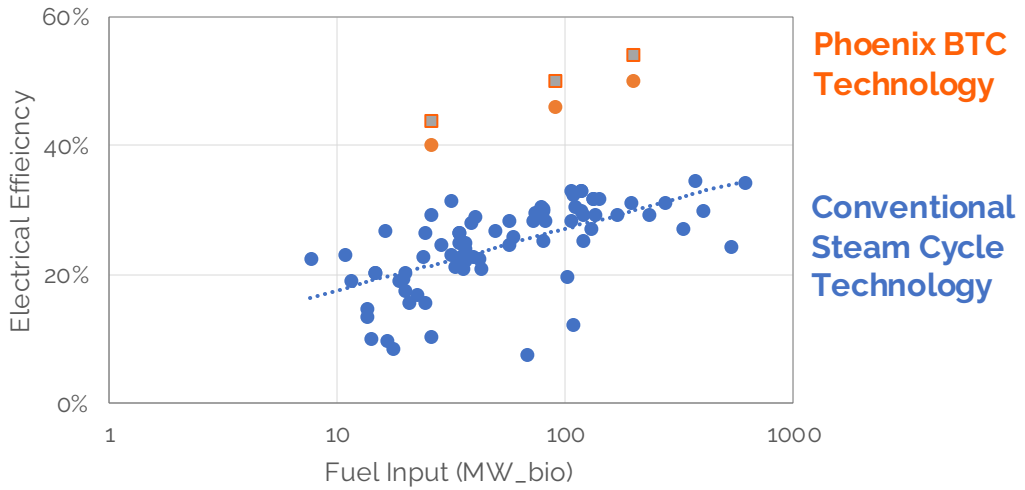
- High-efficiency power cycle with integrated gasification and steam-injected gas turbine
- Near-stoichiometric combustion and high GT pressure ratio
- Hot gas clean-up of syngas, including partial quench with saturated steam
- Water self-sufficient with flue gas condenser at useful waste heat levels (50-75 C)
- High fuel flexibility: both biomass and gaseous fuels
- Applications for powergen, CHP (district heat), BECCS

STANDARDISED BTC UNITS OUTPERFORM COMPETITORS ACROSS SCALE

- Next-generation biomass power plant, the BTC, **doubles the electrical efficiency** in the market
- **95+% total efficiency** (electricity + heat) from pellets
- **3 standardized sizes** for best market fit and cost efficiency
- Phoenix **develops** the innovative **gasification and combustion systems, the plant integration** and specifies gas turbine.

	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

10 MW BTC plant (P10)



*CHP plants. LHV basis. Forest residues 50%MC. Performance depends on gas turbine technology level. CAPEX depends on maturity, application, site, inflation. No CCS included.

USE CASES: HIGH EFFICIENCY DRIVES LOWER COSTS

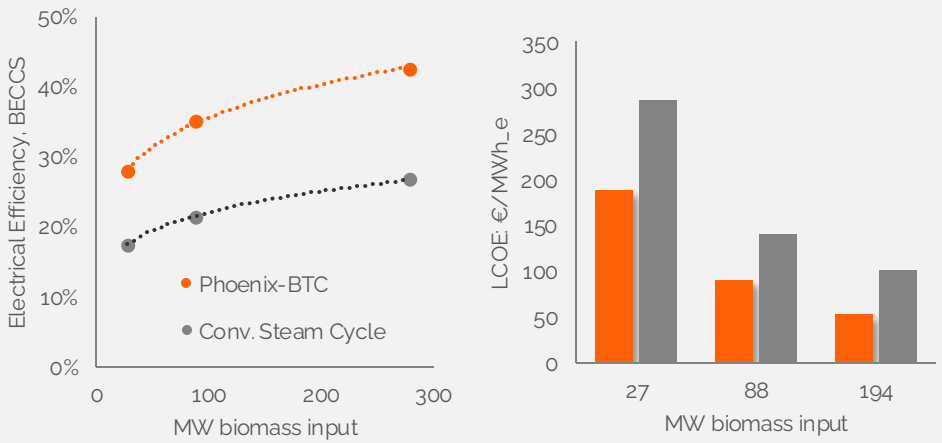
Power with Carbon Dioxide Removals (CDR)

- Produce renewable power while **reducing CO2 in the atmosphere.**
- **60% more electricity per tonne negative CO2** than conventional plants.
- Markets emerging **for carbon dioxide removal (CDR) trading** with prices above carbon dioxide emission costs.
- **30% lower levelized cost** of electricity, e.g. 100 vs 143 €/MWh.
- **Negative marginal operation cost**

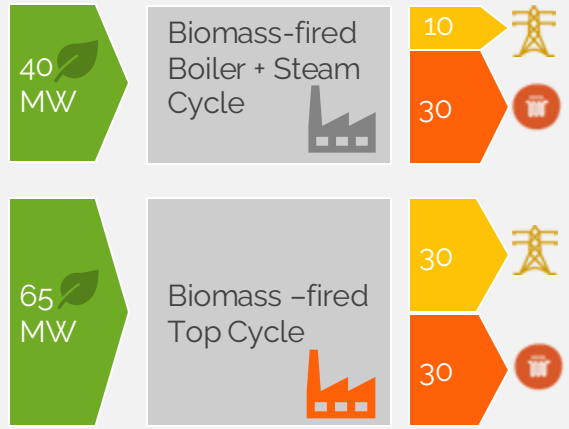
Combined Heat and Power (CHP)

- **Utilize waste heat** from the plant with no penalty to electricity output.
- **2-4 times more** local, renewable electricity than conventional plants due to **better ratio between heat and electricity production**.
- **Marginal fuel efficiency 70-100%** when changing from traditional plants (ratio of increase in fuel to increase in electricity).
- **30-50% lower levelized cost of electricity** (50 – 140 €/MWh).

60% HIGHER EFFICIENCY WITH CDR
30-40% LOWER COST OF ELECTRICITY

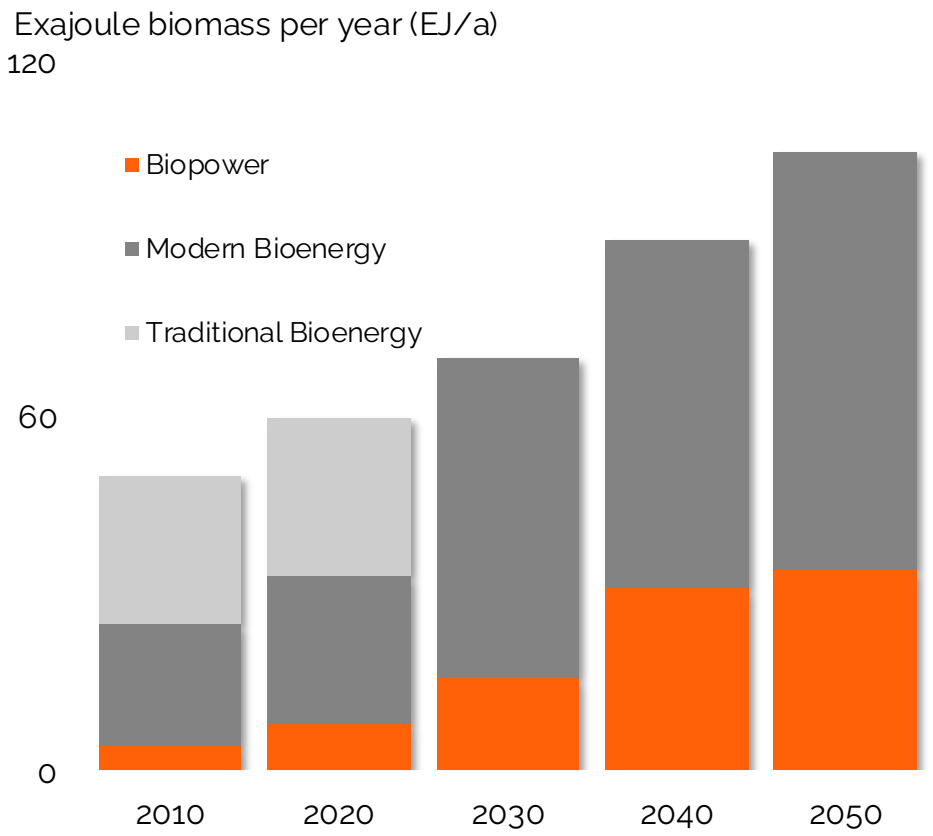


2-4 TIMES MORE LOCAL ELECTRICITY IN CHP
Basis: same district heating capacity



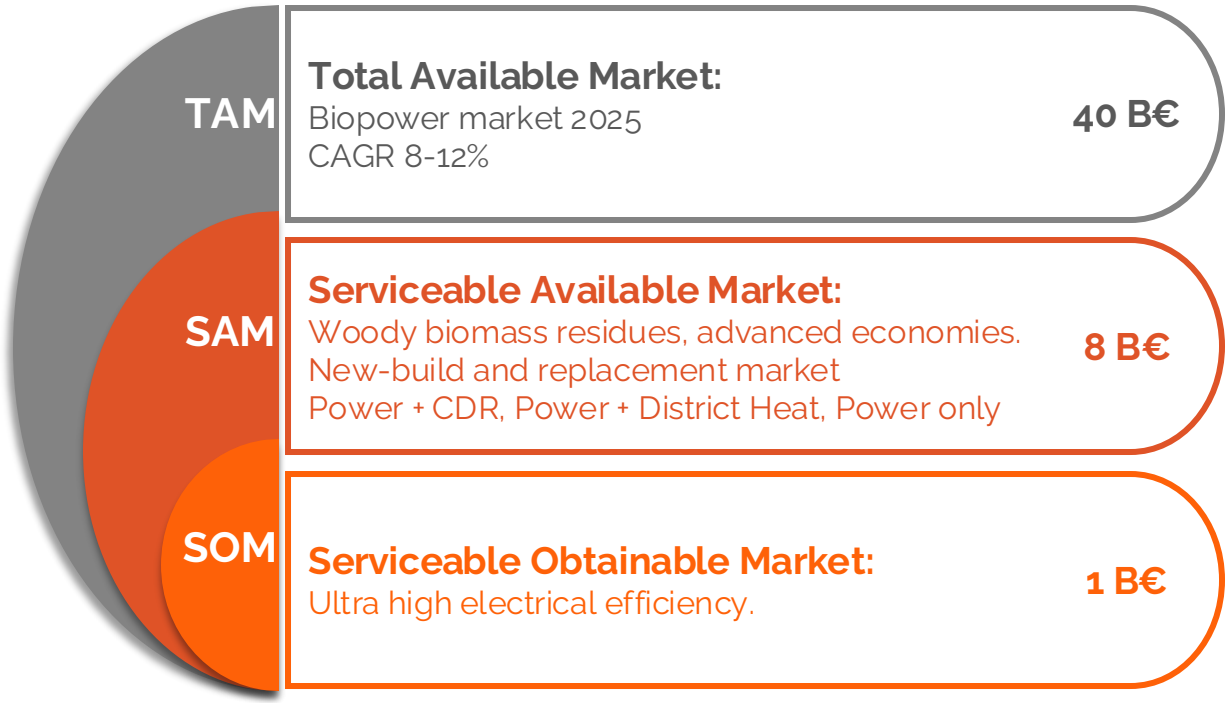
EFFICIENT SOLUTION UNLOCKING A 150 B€/YEAR MARKET

Biopower plays a critical part in the energy transition, 34 EJ biomass/a



Source:: IEA NZE Scenario. Biopower growth 2010-2022 over 10% CAGR.
World primary energy consumption 2021 was 595 EJ/a

Immediate opportunity is 1 B€/a entry market, long term TAM is 150 B€/a



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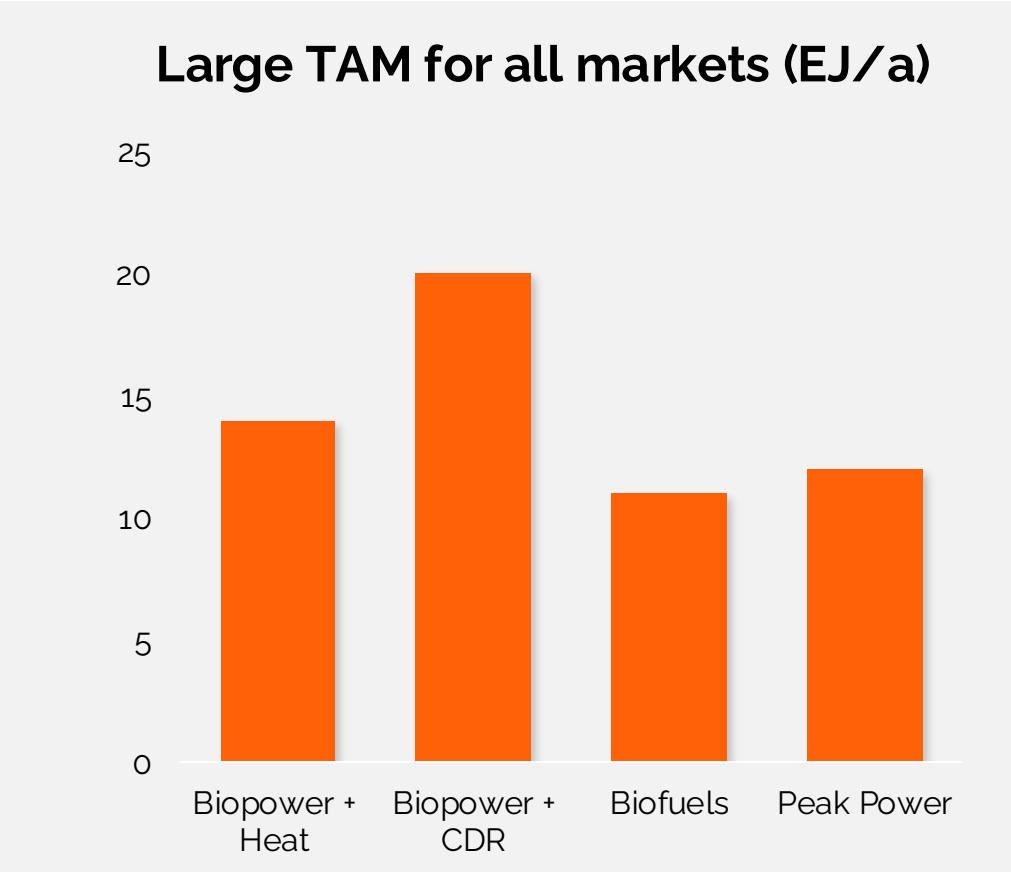
BTC PLATFORM TECHNOLOGY ADDRESSES SEVERAL MARKETS



Market	Outline	USP	Market Need (IEA)
Biopower & heat	Local power biopower and combined heat and power (CHP) plants	3x electricity production for fixed heat supply.	Only 5% district heating renewable. 14 EJ/a DH 2017.
Biopower with Carbon Dioxide Removals	Large-scale biopower with negative CO2 emissions	60% more electricity per CDR 30-50% lower levelized costs	2 Gt/a CDR by 2050. Requires 20 EJ/a biomass.
Biofuels	Gasification plants for biofuels and hydrogen production.	De-couple fuel from electricity price Higher pressure syngas production	Bio-kerosene requires 11 EJ/a biomass by 2050
Peak Power	Utilise 100% H2 and other renewable fuels in the gas turbine for peak power supply	Unique flexibility, same hardware. Ultra-low NOx, CO emissions. Broad operation window.	Hydrogen and e-fuels input to power generation to reach over 12 EJ/a 2050

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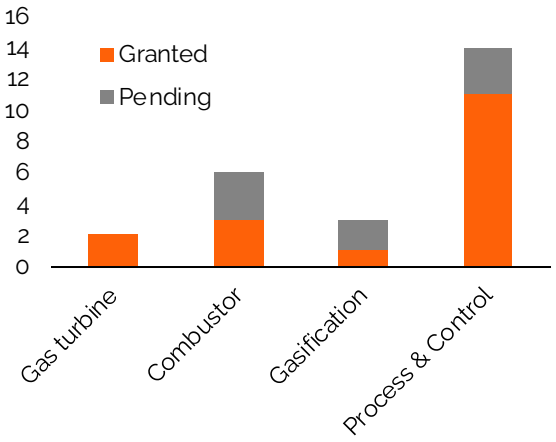
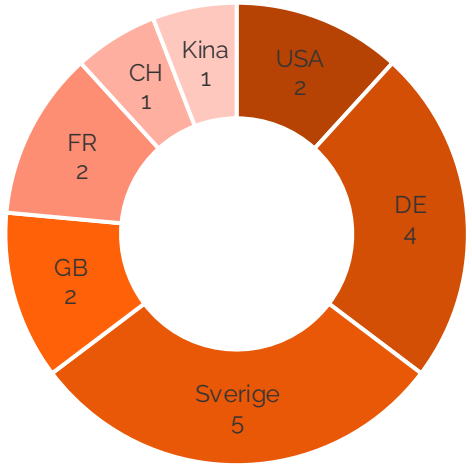
BROAD PATENT COVERAGE

Technology areas for patent families



- 7 families of patents
  - One new family pending (combustion)
- 17 granted patents
- 8 pending patents

Geographic Territory Map (2023)



- Further 2 patents in drafting
- Global patent coverage
- Patent spending:
  - 2022: 80 K€
  - 2023: 65K€

Patent families and expiration dates

Name	Expiry date of patent
SuperSpool	2030-02-24
IGWC	2031-03-11
SuperFeeder	2033-12-27
Combustor	2030-03-19
Solar	2032-12-15
HFB	2041-02-23
Plant integration	2042-03-08
Dual Swirler	Pat pending

* note: Decrease from 9 patent families and 39 individual patents as the portfolio was rationalised 2023/24

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TEAM

- Founded in 2016.
- 10-Person Professional Team.
- 6 Nationalities.
- 5 PhDs + 1 Professor.
- Strong Engineering Focus
- 100+ Man-years in energy & cleantech

BOARD

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Chairman
Sw Energy Agency
Industrifonden

CATHARINA LAGERSTAM
Board member
S.E.C Lux.
ICA Bank

HENRIK BÅGE
Co-Founder, CEO
Entrepreneur
15 years in cleantech

MICHAEL BARTLETT
Co-Founder, CTO
Ph. D. Gas Turbines
GE, Vattenfall, Scania

Background : TU berlin KTH SCANIA ALSTOM CATERPILLAR® GE VATTENFALL Soltech

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TESTIMONIALS ABOUT BTC TECHNOLOGY

Deep cooperation with utilities over the last 3 years

"Our findings so far indicate that this is a very promising technology which has the **potential to deliver the next phase in BECCS technology**. Drax Group has an interest in continued evaluation of the technology for its potential application by Drax, once commercialised."

Steven Drayton, Director of Development Projects

Drax

Owner of the largest biopower plant in the world, UK

"The technology aligns with VEAB's own strategic planning to realize **more local renewable power**, adding to attractiveness and **competitiveness of the region**."

"The study shows annual renewable power could be increased significantly"

Eric Tellgren, CEO

VEAB

100% renewable municipal utility in Sweden utilizing biomass CHP plants

" The ability to utilize low-grade biomass […] at **high efficiency and low environmental impact** would be important to **decrease production costs** and competition for higher grade biomass.."

Henrik Lindståhl, R & D Manager

Tekniska Verken

Municipal utility in Sweden utilizing WtE CHP & bioenergy plants

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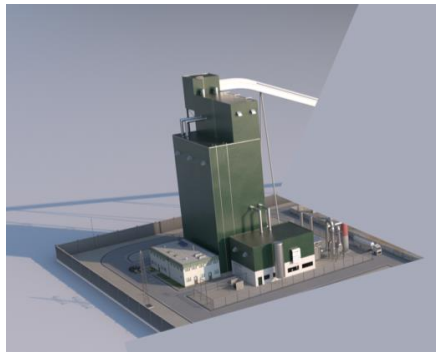
BTC MARKET ENTRY – 10 MW DEMONSTRATION PLANT

CONDITIONAL ORDER PHASE 2

FINAL INVESTMENT DECISION

Demo EPC
2023-2026

- Engineering of Phase 1 & 2
- Gas turbine dev. (7 years)
- Construction of Phase 1



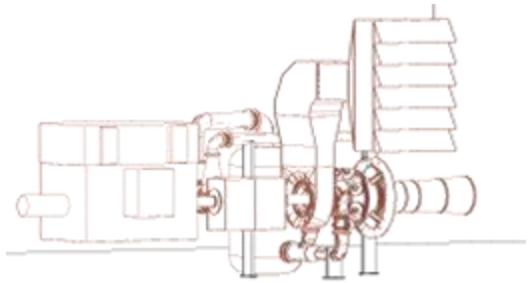
Upgrade
2028 – 2029

- Delivery of new gas turbine
- Larger fuel yard, pre-treatment

Existing UGT2500 engine for Phase 1

Phase 1: TRL7
2026-2029

- **2 MWe** with conventional GT
- Low pressure operation
- Demonstrate BTC process



New 10 MW Top Cycle Engine for Phase 2

Phase 2: TRL8
2029-2031

- **10 MWe** with Top Cycle GT
- Full pressure and full perf.
- Hand-over to owner

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IMPACT TECHNOLOGY: BUSINESS MODEL

Staged business model

Part-ownership of first generation as market-entry strategy.

- Risk mitigation effort (skin in the game).
- Asset **divestment opportunity.**

Supply of Patented Systems

- Gasification, Gas turbine, Combustion, Control Systems
- **Component revenues**: (HW, SW, plant).
- **Production royalties**: 4 €/MWh energy produced

License model for global growth

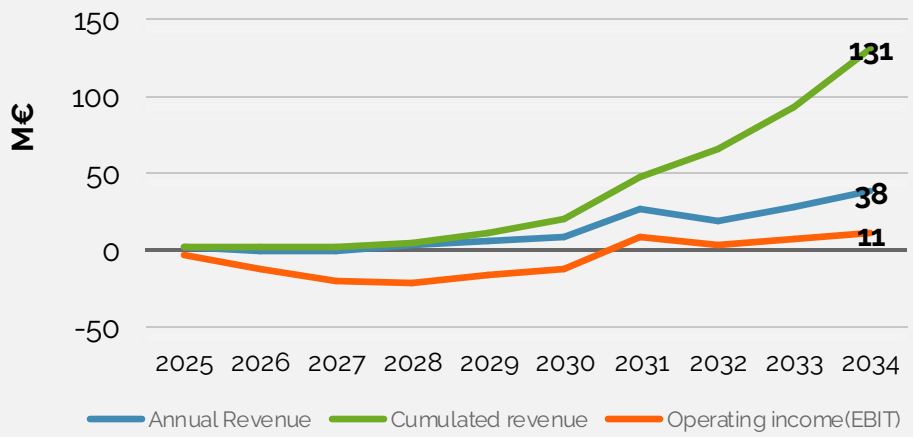
- Based on company IP, know-how and technology.
- **Capacity royalty**: 6% installed cost (HW, SW, plant).
- **Production royalties**: 4 €/MWh energy produced.

Analysis considers only 10 MW BTC in biopower market.

40 & 100+ MW plant, biofuels and peaking markets not included,

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

Analysis for 10 MW BTC product.
90% of revenues from system supply short term



	2025	2030	2031	2032	2033	2034
BTC Direct Supply	1	1	1	1	1	2
License sales	0	0	0	2	2	4
Production Royalty	0	0	0	0	1	1

PHOENIX BIOPOWER

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Direct influence

Indirect influence

Energimyndigheten

HORIZON 2020

InnoEnergy

EUCAN Win!

Bio-FlexGen

FUNDING- LONG TERM, BREAKDOWN

Commercialisation Company
Budget 2024 - 2031

AREA, M€	TOTAL	2024	2025	2026	2027	2028	2029	2030	2031
Combustion System	4,1	0,5	0,6	1,1	0,5	0,5	0,3	0,3	0,3
Gas Turbine	0,9	0,0	0,1	0,2	0,2	0,1	0,1	0,1	0,1
Gasification System	3,7	0,3	0,6	0,8	0,5	0,4	0,2	0,2	0,5
Plant	1,7	0,1	0,3	0,4	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	**13,9**	**1,2**	**2,0**	**2,8**	**2,0**	**1,7**	**1,2**	**1,4**	**1,7**
Demo Plant Costs	102,0	0,0	0,9	10,8	19,2	23,1	21,0	19,0	8,1
Follow-on Plant Projects	17,5	0,0	0,0	0,0	0,0	0,0	0,0	2,5	15,0
Gross Funding Need	**133,4**	**1,2**	**2,8**	**13,6**	**21,2**	**24,8**	**22,2**	**22,9**	**24,7**
Public Support	51,7	0,4	1,0	6,1	9,5	11,1	10,0	9,2	4,4
Sales	50,7	0,0	0,0	1,6	0,0	3,6	6,4	9,3	29,8
Net Funding Need	**31,0**	**0,8**	**1,8**	**5,9**	**11,6**	**10,0**	**5,8**	**4,4**	**-9,4**
Acc funding need		*0,8*	*2,6*	*8,5*	*20,1*	*30,2*	*36,0*	***40,4***	*31,0*

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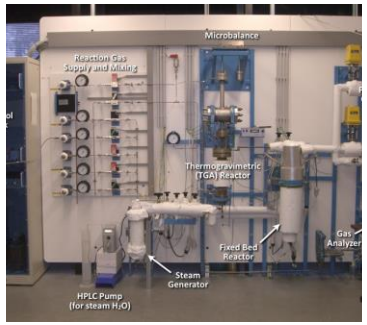
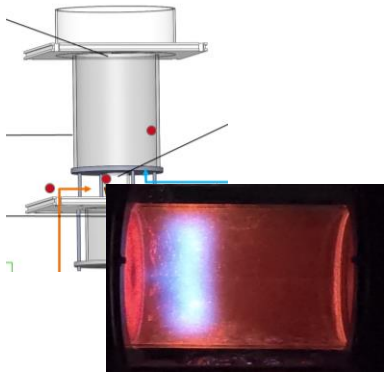
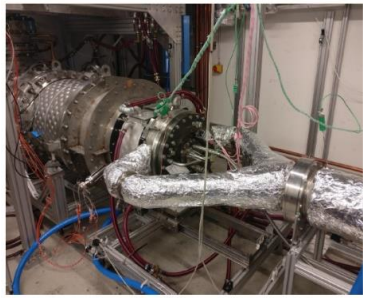
CLEAR DEVELOPMENT AND SCALING ROADMAP

	TRL3 (Complete)	TRL4 (Ongoing)	TRL5 2025-2026
GASIFI-CATION	 UU, Utah	 RISE, Piteå  KTH, Stockholm	 VTT, Esbo
	Fundamental lab tests. Concept rig tests	**5 MW_{th}-scale cold pressurised rig at 10 atm & 50 kW_{th} gasification rig at 20-30 atm**	**1 MW_{th} gasification system at 5 atm**
COMBUSTION		 Phoenix, Stockholm	 TUB, Berlin
	Generic burner tests and burner development	**Atmospheric gasifier-combustor rigs with industrial burner prototypes. Real bio-syngas, 50-200 kW_{th}**	**1 MW_{th} combustion rig at 5-10 atm**

10 MWth pilot plant TRL7