



Renewable Power On Demand

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Highly efficient biopower

– challenges and possibilities in the future energy system

- The WHY: Phoenix BioPower pitch
- The WHAT: Concept, Performance, Opportunities and Challenges
- The HOW: Development work & way forward

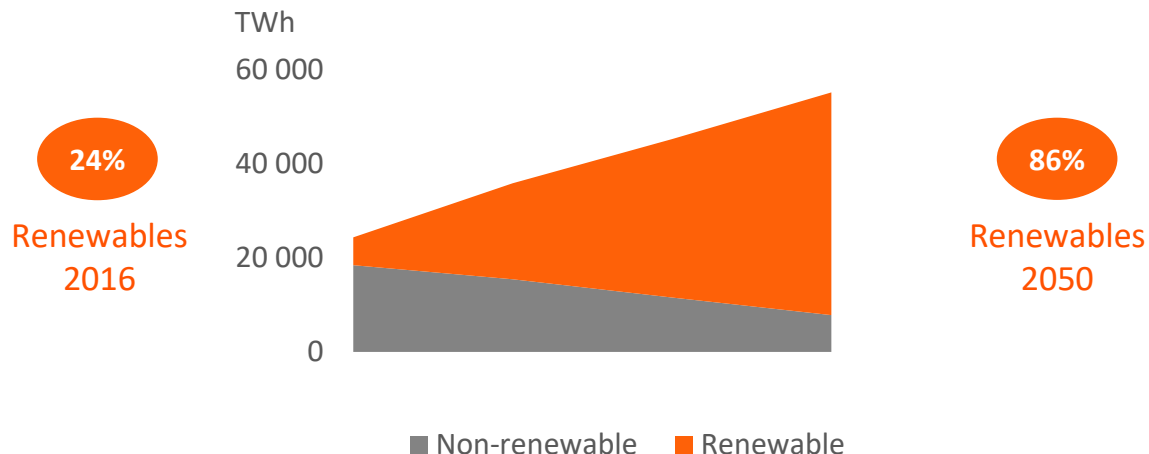
THE PITCH

1.5 °C



THE ENERGY TRANSITION: 1,5°C scenario

Electricity Generation. Source, IRENA 2019, REMap 2050



1000 TWh/år growth

SOLAR & WIND ?



- X Increased volatility in supply & prices
- X Capacity & grid issues
- X Enormous investments in grid, storage, etc

BIOPOWER REBORN

DOUBLE THE EFFICIENCY



PLANNABLE

Power and heat on-demand.



SCALABLE

Cost-effective and highly efficient.



SUSTAINABLE

Consume half the biomass.

----- CONVENTIONAL STEAM CYCLE

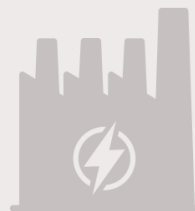
25-30%
ELECTRICAL EFFICIENCY



BIOMASS RESIDUES



**BURN FUEL,
MAKE STEAM,
DRIVE A GENERATOR**



BTC TECHNOLOGY

BTC: Biomass-fired Top Cycle

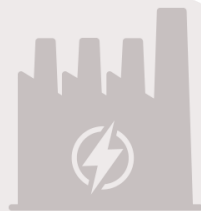
50-60%
ELECTRICAL EFFICIENCY



BIOMASS RESIDUES



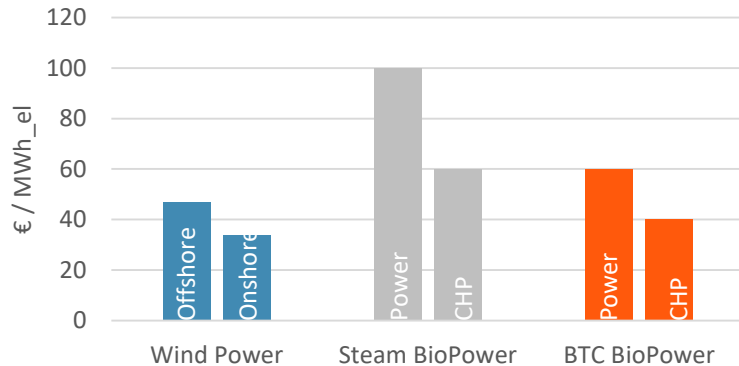
GASIFY FUEL,
USE IN TOPCYCLE GAS TURBINE,
DRIVE THE GENERATOR



2X

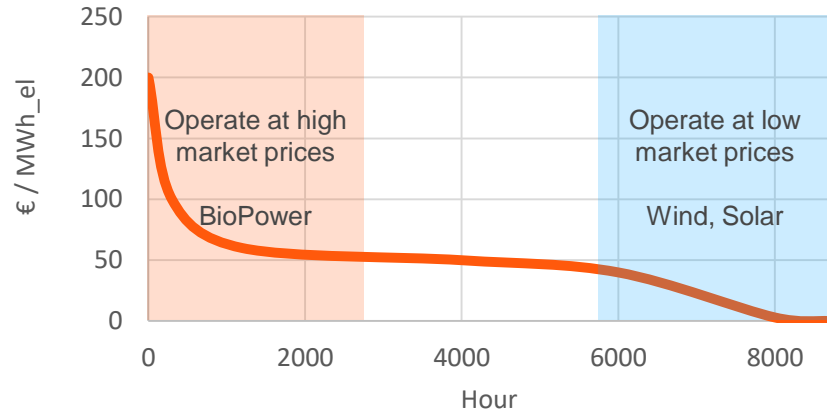
ECONOMIC ADVANTAGE

LEVELISED COSTS AS WIND POWER



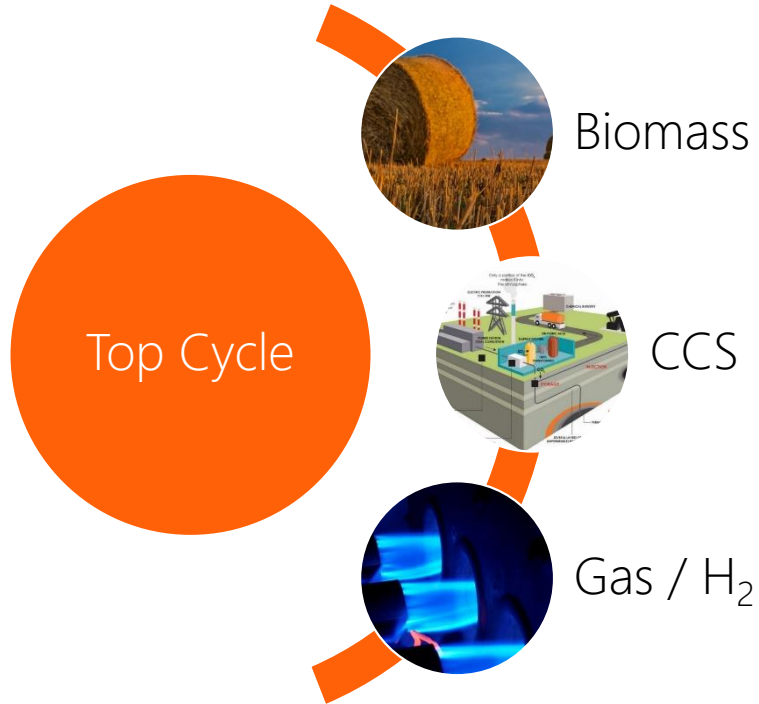
2030 prices, 20 €/MWh biomass

BUT HARVESTING HIGHER MARKET PRICES



NEPP: German electricity price: standard deviation of 70 €/MWh by 2030

TOP CYCLE: A PLATFORM TECHNOLOGY

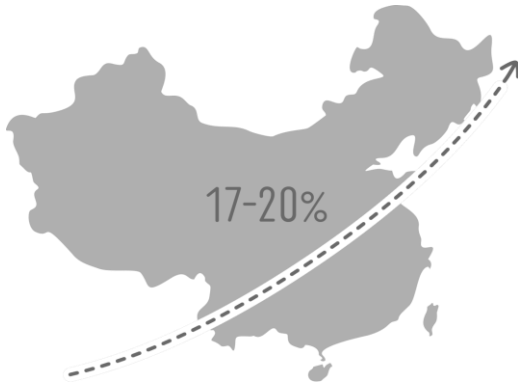


Advantage vs Combined Cycle

- +10-15 % pts electrical efficiency
- +10% pts total efficiency in district heat
- Halve the cost of CO₂ avoided
- 70% lower power penalty
- 30-40 % lower capital costs.
- Low NO_x, no flashback with H₂
- +15% pt total efficiency in district heat

KEY MARKETS

ANNUAL GROWTH RATE FOR BIOPOWER IN CHINA

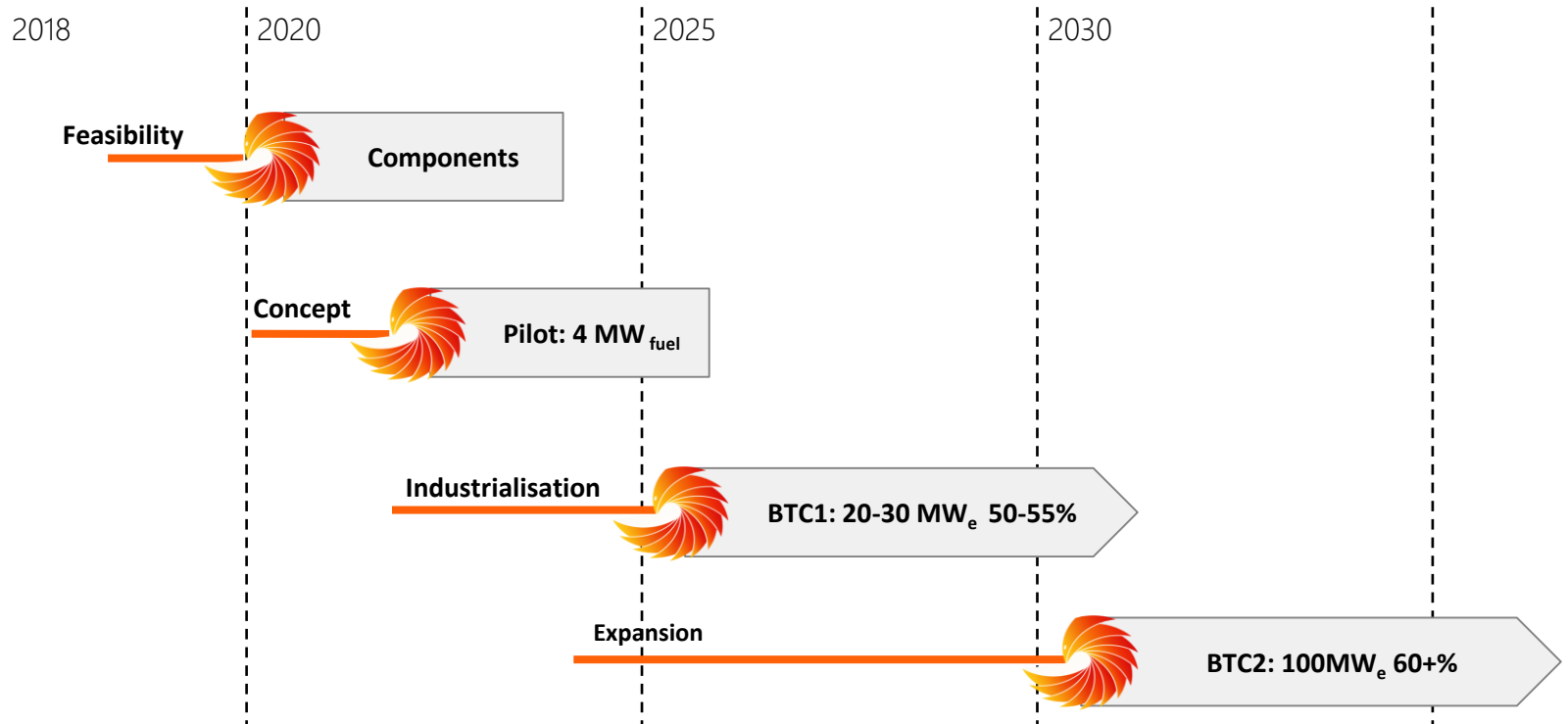


- 600 Mton residues per year available
- 6000 plants 5-100 MWe scale



- NREAP plans: 40% of CHP will be biomass-fired by 2050
- 2500 plants at 5-100 MWe

BTC ROADMAP



AGGRESSIVE DEVELOPMENT UNDERWAY

Invested: 2.5 M€



PRIVATE INVESTORS

Reference Group



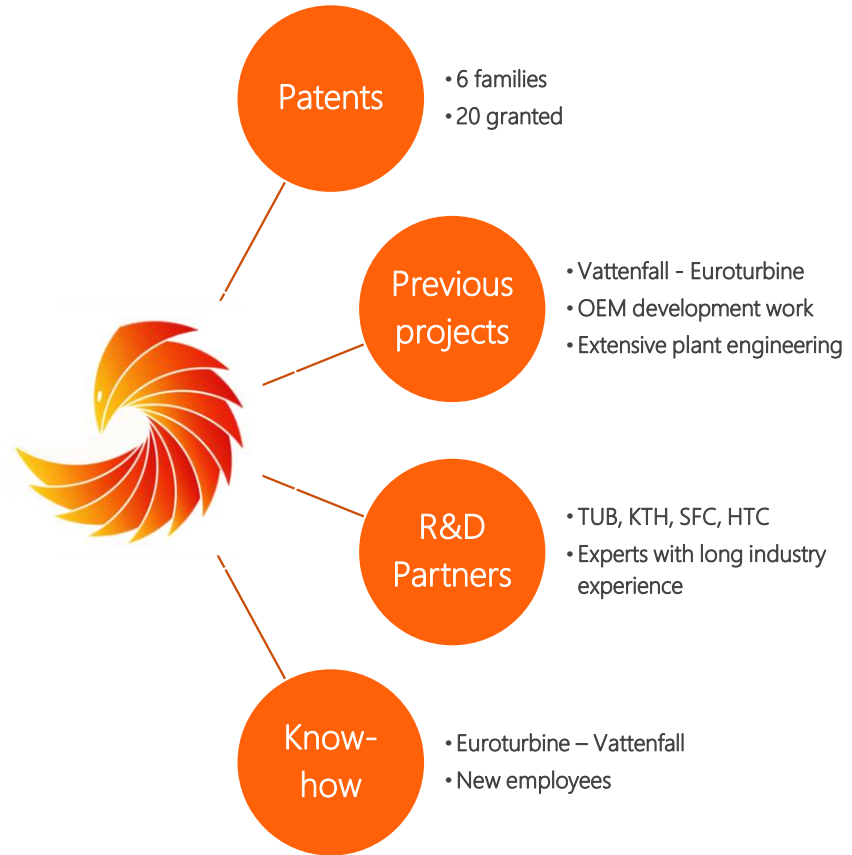
Site



Competence



BUILDING FROM A SOLID PLATFORM





MICHAEL BARTLETT

Co-Founder, CTO

Project Management, R&D
(GE, Vattenfall, Scania)



HENRIK BÅGE

Co-Founder, CEO

Entrepreneur
(15 years in cleantech)



HANS-ERIK HANSSON

Co-Founder

Entrepreneur & Innovator
(ABB/Alstom)



STEFAN JAKÉLIUS

Chairman

(Industrifonden)



CATHARINA LAGERSTAM

Board member

(S.E.C Lux, ICA Bank)



BIRGITTA RESVIK

Board member

(Fortum, Svenskt Näringsliv)

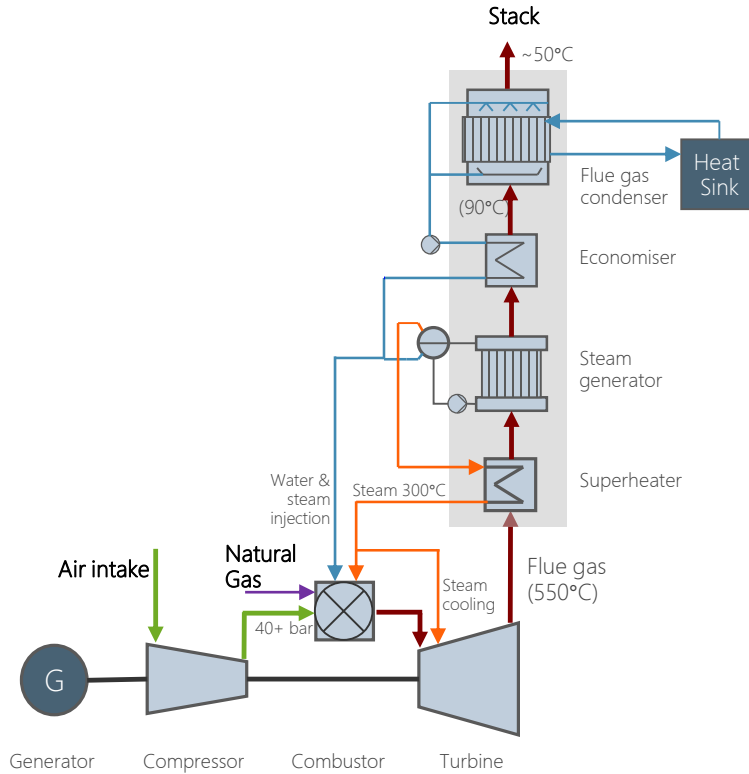


OLA JOHANSSON

Board member

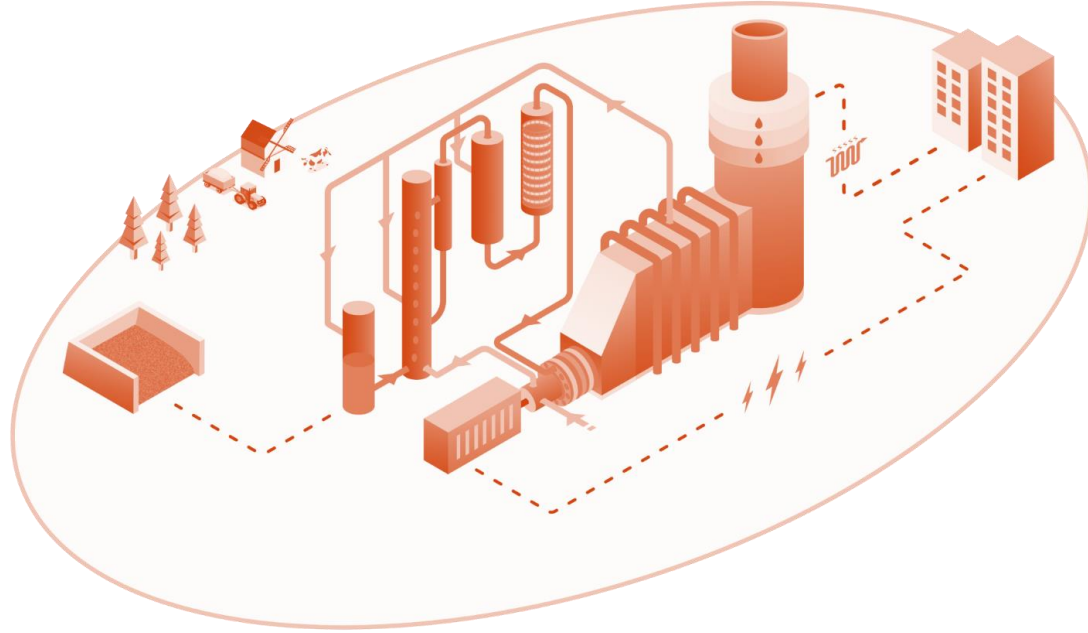
(Siemens, Epishine)

THE TOP CYCLE



TOP CYCLE: A NEW POWER CYCLE

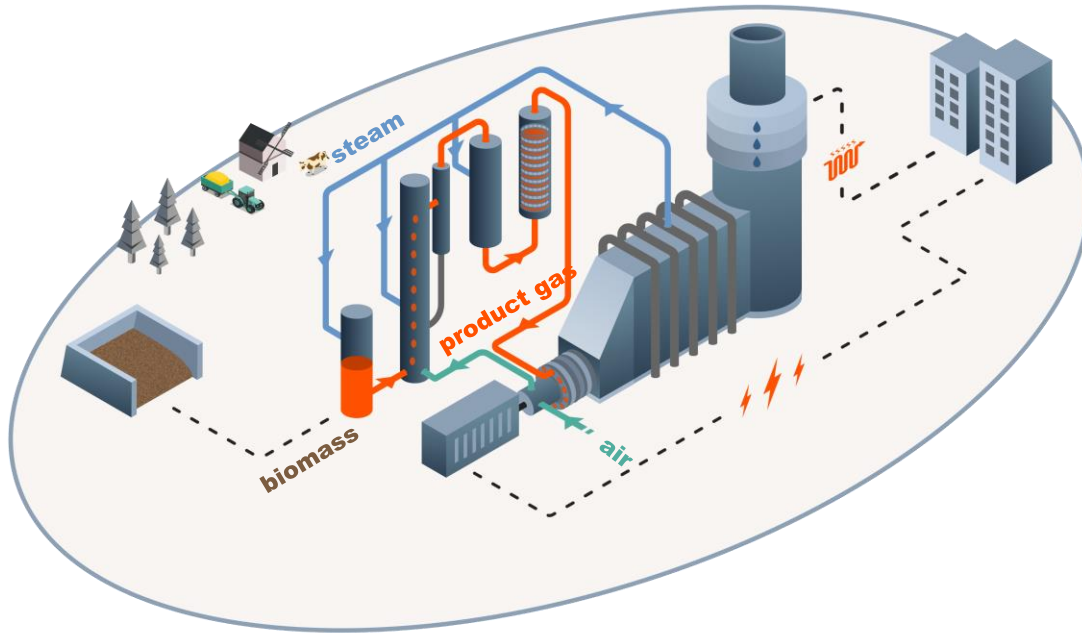
- Steam-injected, high pressure gas turbine
- Minimised air compression
- 50% steam in turbine
- Water recovered in flue gas condenser



THE BTC CONCEPT

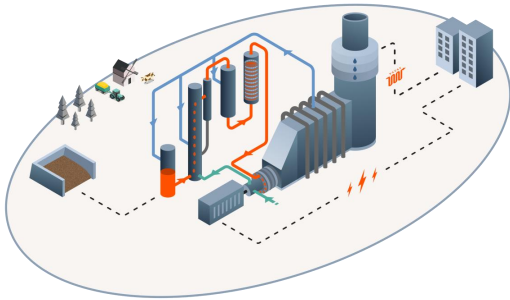
BTC: A NEW PROCESS FOR BIOPOWER

BTC: Biomass-fired Top Cycle



- High pressure, steam-injected gas turbine, stoichiometric combustion
- Pressurised gasification of biomass
- Hot gas clean-up of product gas
- Steam as working fluid and heat carrier
- Water recovered in flue gas condenser

BTC – DOUBLE THE EFFICIENCY



ELECTRICAL EFFICIENCY

**Boiler with
Steam Cycle**



25-35%

**Combined cycle
with gasification**



37-47%

BTC

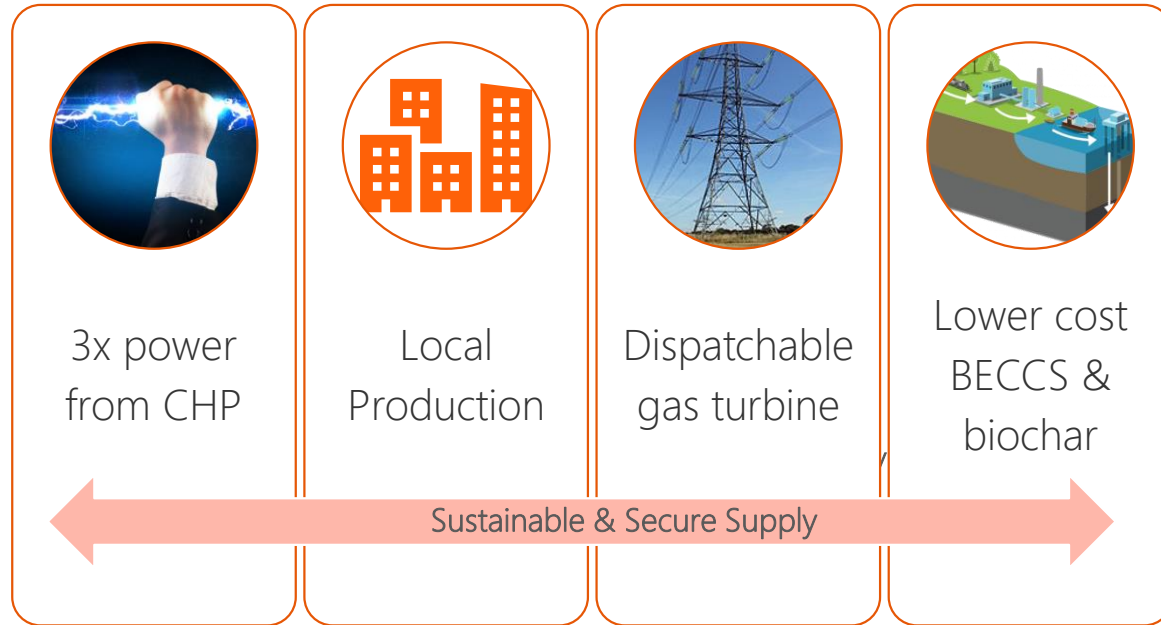


50-60%



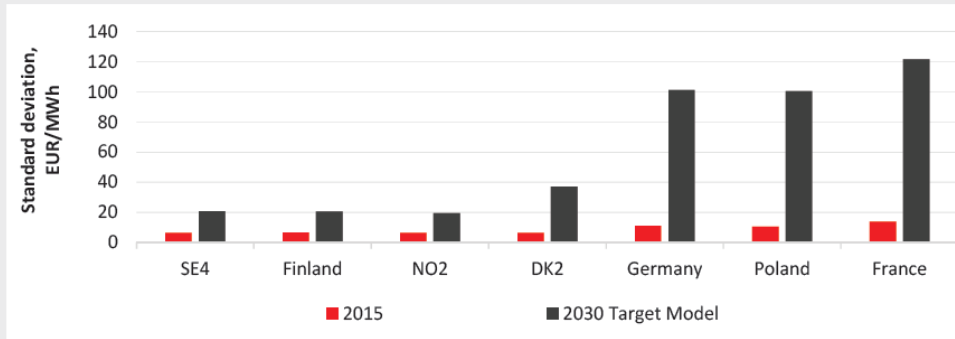
OPPORTUNITIES

BTC: ROLE IN THE ENERGY SYSTEM

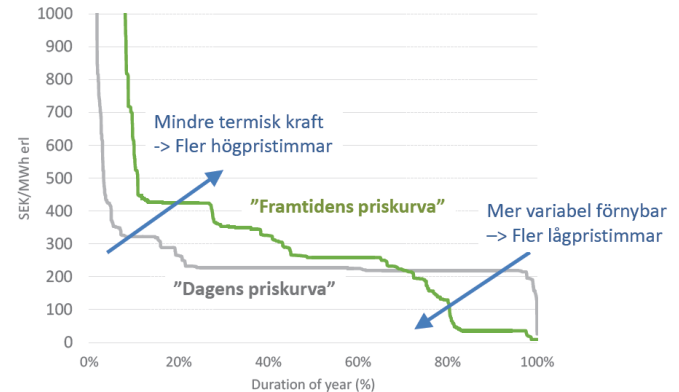


MARKET VALUE OF BIOPOWER

- Produce power when it has a high value: +15 to +70 €/MWh over average price
- Market design and technical constraints will determine exact earning capacity



Prisvolatilitet 2015 och 2030 i Norden och i kontinentala Europa

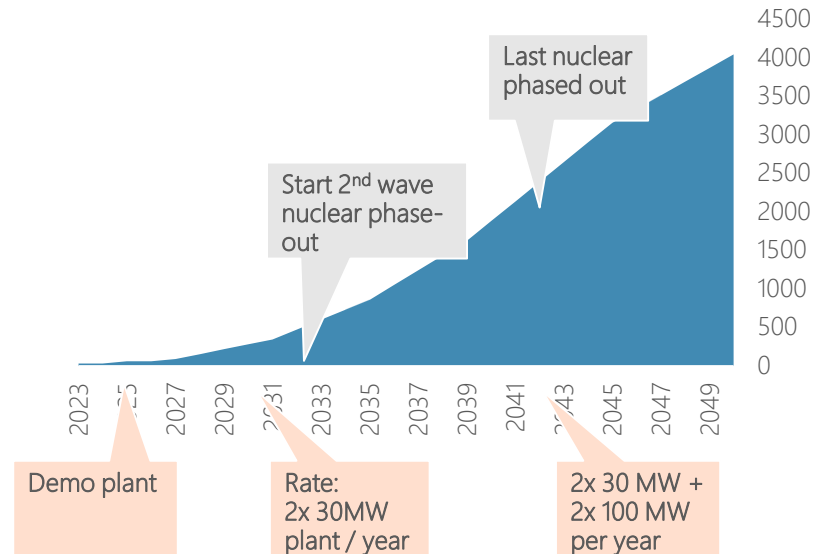


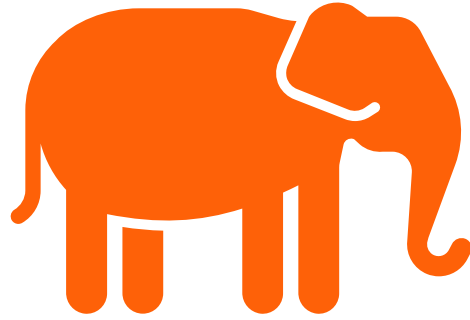
Source: NEPP Reglering av kraftsystemet

SWEDISH ROLL-OUT SCENARIO

Scenario: Convert 25% of district heating

- Build-out 2025-2050
- 4 GW_e of controllable power
- 20-30 TWh biopower
- Parallel development can be catalysed in Nordic and Baltic states





THE ELEPHANT IN THE ROOM

GASIFICATION IN SWEDEN



- 18 MW fuel: Pressurised autothermal gasifier
- Hot gas clean-up, combined cycle gas turbine
- Blends of forest residues, bark, straw, RDF pellets, wood pellets
- No commercialisation as nuclear fleet kept



- 20 MW fuel: Dual bed gasifier
- Cold gas clean-up, methanation
- Pellets, bark, forest residues
- Abandoned as no support / market for SNG

GASIFICATION ISLAND FEATURES

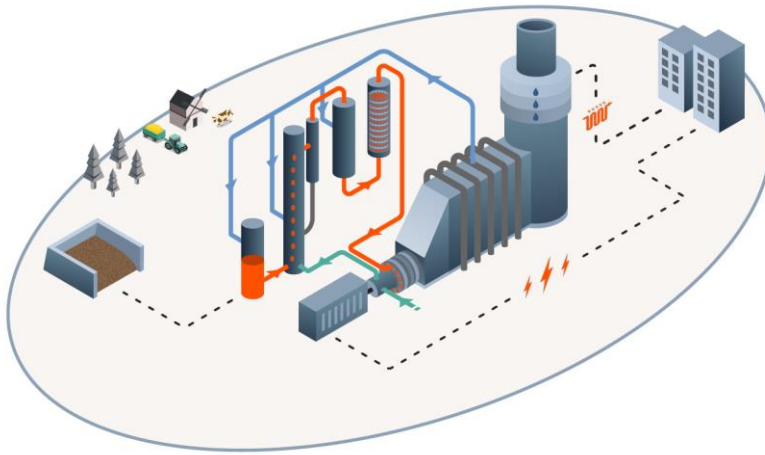
| Area | GobiGas | Värnamo | BTC |
|----------------|--|--------------------|-----------------------|
| Gasifier | Dual reactors: steam gasifier & air combustion | Air CFB | Air/steam BFB |
| Pressurization | None | Lock-hopper: N2 | Lock-hopper: N2/steam |
| Gas cooler | Convective Cooler | Convective Cooler. | Steam injection |
| Gas clean-up | Scrubber, pre-adsorber, 3 bulk adsorbers, compressor, S & COS removal, CO2 removal, water gas shift reactor, hydrogenation | Hot Gas Filter | Hot Gas Filter |



PHASE 1: 2019



HIGHEST RISKS FOR BTC



- Reliable fuel conversion
 - Feeder, Gasifier, Filter, Combustion
- Materials in new environment
- Plant integration and control

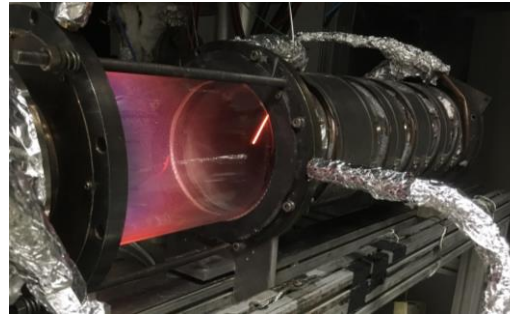
CURRENT DEVELOPMENT WORK



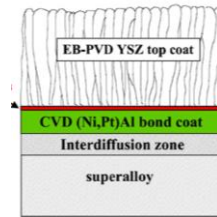
FEEDER



GASIFIER



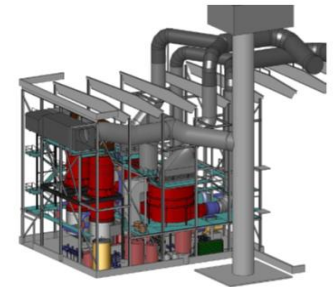
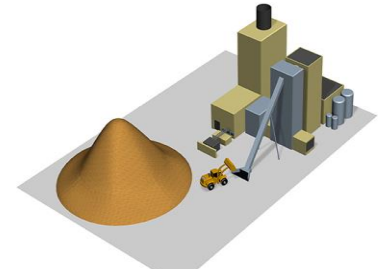
COMBUSTOR



> system [15]

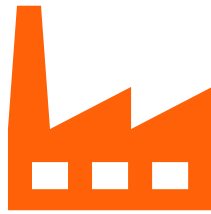


GAS TURBINE



**PLANT &
ENGINEERING**





PHASE 2: 2020+

4 MW PILOT PLANT



- 2 site candidates
- Operation 2022
- 1 t/h fuel
- 1/10 scale gasification
- Full scale combustor system and airfoil cooling tests

GENOMFÖRBARHET

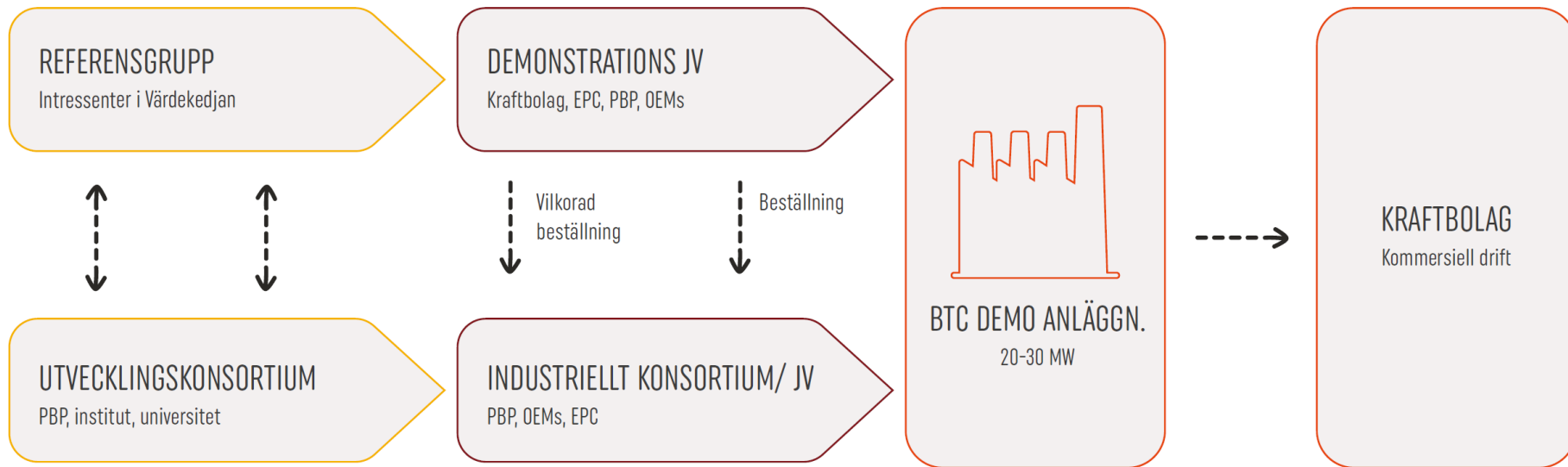
(fuel to flame), Fas 1+2

KONCEPT

(pilot), Fas 3

UTVECKLING & DEMONSTRATION

Fas 4



EXPANDING OUR PARTNERSHIP

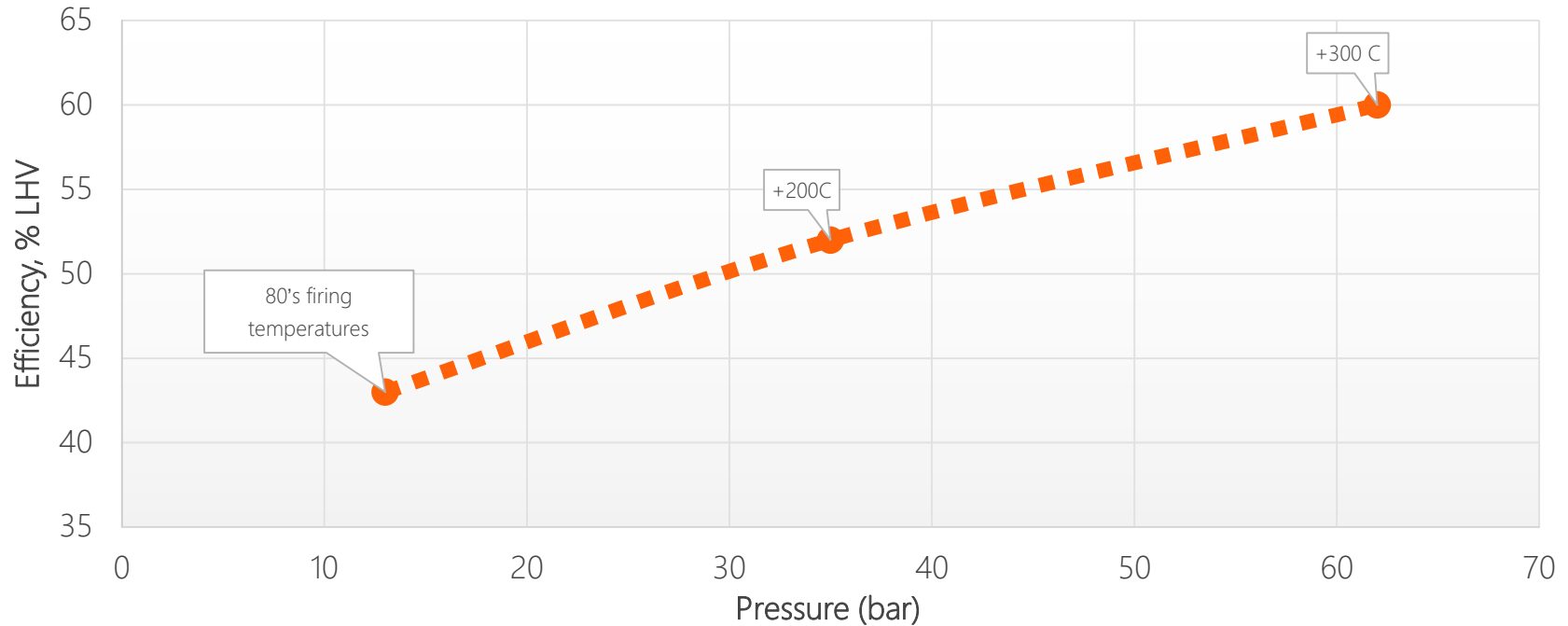
Reference Group





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BTC EFFICIENCY CHARACTERISTICS

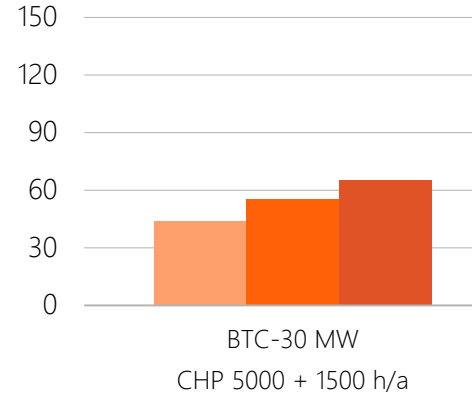


----- BTC – 30MW, FIRST GENERATION PLANT

- Forest residues 50% moisture content
 - 30 MW net power, 27 MW heat capacity
 - 50-55% net electrical efficiency
 - 100-110 % total efficiency
-
- 3 times capacity
 - 40% lower “marginal” costs, excluding heat
 - 45 €/MWh_e
-
- 40-45% lower levelised cost of electricity

2030 Levelised Cost of Electricity, €/MWh

27 MW heat delivery



■ Variable Costs ■ LCOE - 32 heat credit ■ LCOE - 20 heat credit

20 €/MWh fuel cost. 5000h/a steam cycle. 6500 h/a BTC (low marginal cost).
BTC with 5000/h gives 58 €/MWh_e for 32 €/MWh heat credit

----- BTC – 100 MW, LARGE SCALE PLANT

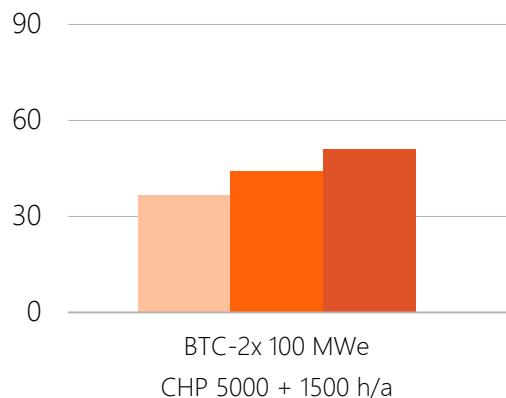
- Forest residues 50% moisture content
- 2x 100 MW net power units, 150 MW heat
- 60% net electrical efficiency
- 105 % total efficiency

- 3 times capacity
- 45% lower variable costs, excluding heat
 - 37 €/MWh_e

- 25-40% lower levelised cost of electricity

2030 Levelised Cost of Electricity, €/MWh

~150 MW heat delivery

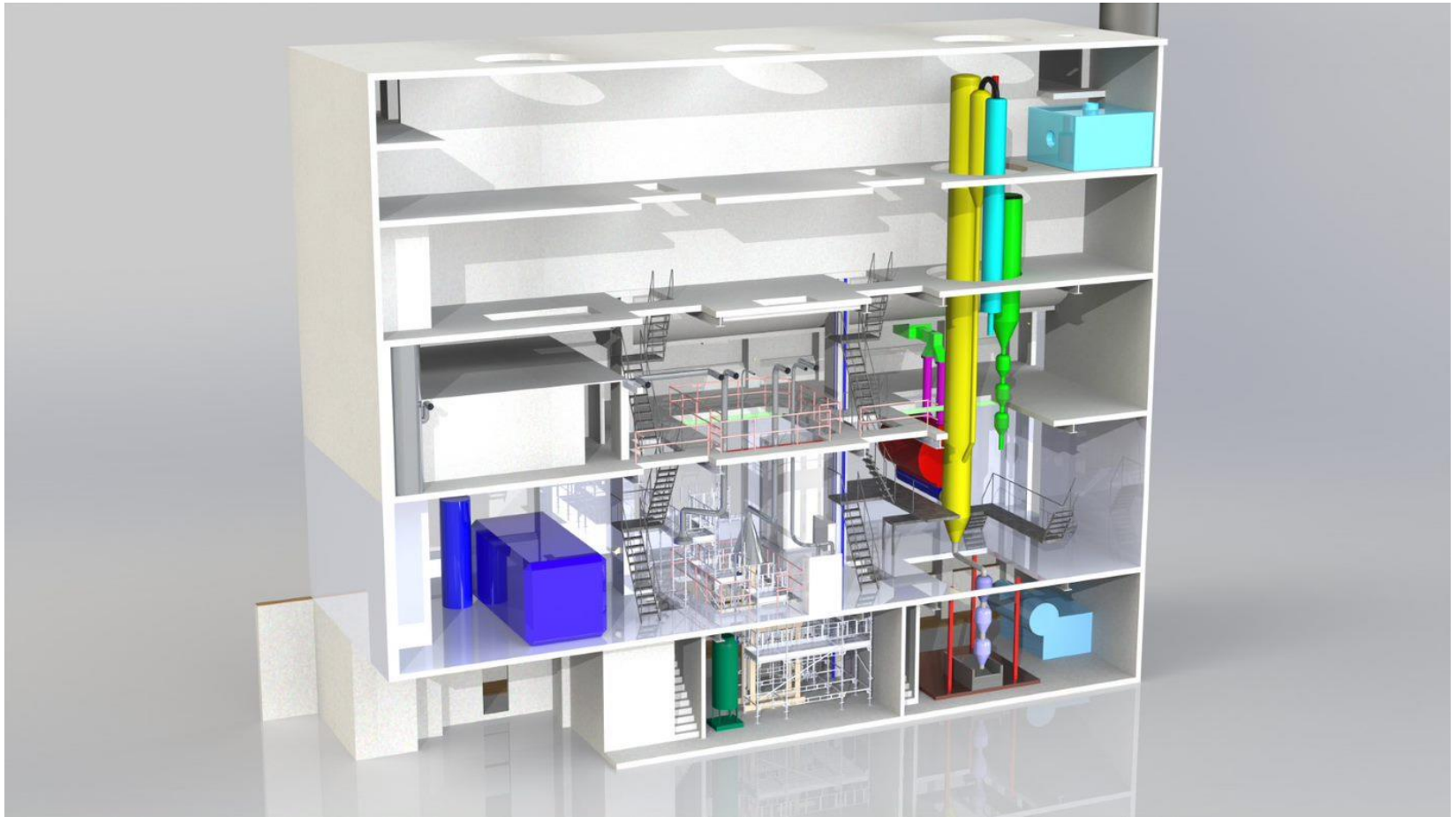


Variable Costs LCOE - 32 heat credit LCOE - 20 heat credit

20 €/MWh fuel cost. 5000h/a steam cycle. 6500 h/a BTC (low marginal cost).
BTC with 5000/h gives 70 €/MWh for 46 €/MWh heat credit

PROGRESS

| WORK PACKAGE | SCALE | HIGHLIGHTS / COMMENT | FORECAST |
|-----------------------|---------------------|--|--|
| PM | - | New IP identified, Reference Groups meetings | |
| Plant | - | Optimisations and initial engineering ongoing. | Case studies end Q4 |
| Gas turbine materials | Coupons | Steam environment effects on TBC, bond coat | Lifetime tests finalised Q4. |
| Feed System | 100 kW 45 bar steam | Concept chosen, initial 40 bar tests | Continuous 40 bar tests by Q4 |
| Gasification | 50 kW _f | First gasifier tests over 20 bars | 40 bar results by Q4 |
| Combustion | 100 kW | First 50 kW tests very successful | Atmospheric, 100kW operating window by Q4, CFD |



BIOMASS TO POWER PATHWAYS

