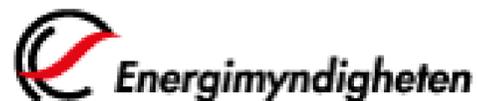




# 2X EFFICIENCY SET4Bio Stakeholder WS

Henrik Båge

June 2022



# GLOBAL POWER GENERATION

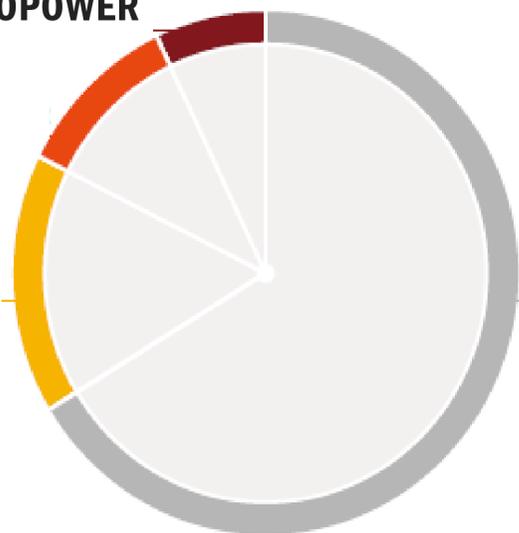
Source: IEA World Energy Outlook 2017

WIND, SOLAR & BIOWPOWER

NUCLEAR

HYDROPOWER

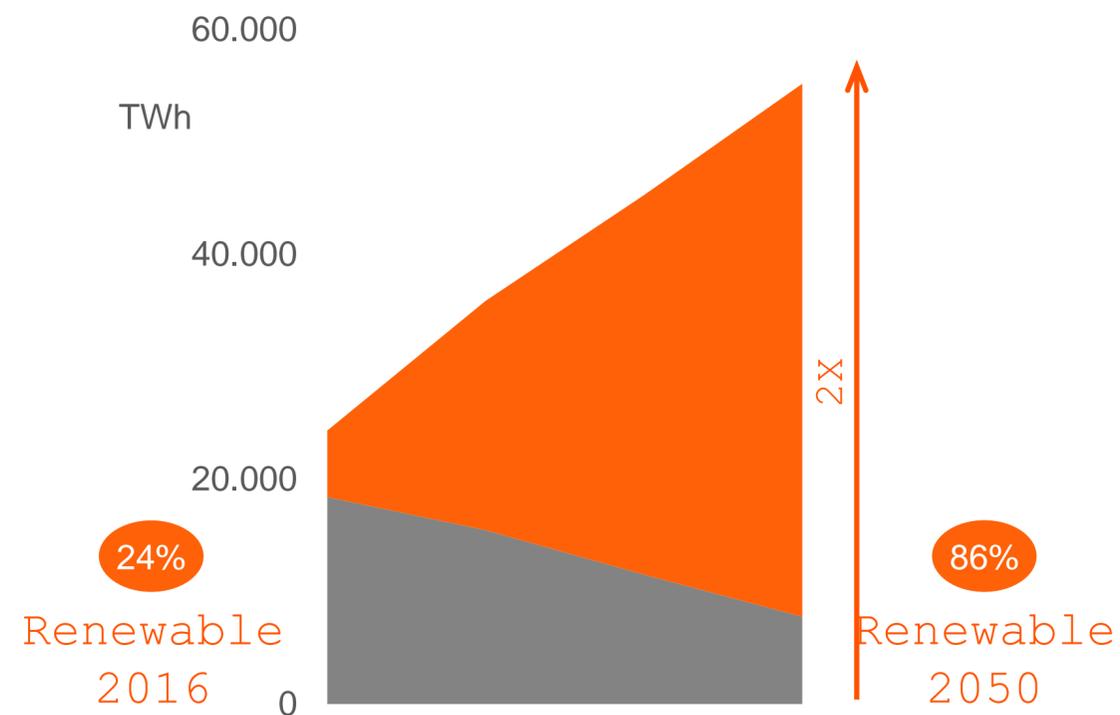
FOSSIL POWER



2/3

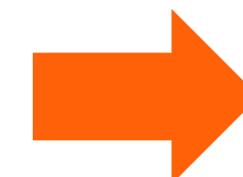
PRIMARILY COAL

1000 TWh/a represents:



■ Non-renewable ■ Renewable

1000 TWh/a growth



3.5 UK

or

1 USA/3 years

**5 200 TWh**

**1/2 for biopower @ 50%**

**1 300 TWh**

Imperial College  
London  
Consultants

Sustainable biomass  
availability in the EU, to 2050

Ref: RED II Annex IX A/B

Independent analysis provided by:  
Dr Calliope Panoutsou from the Centre for Environmental Policy,  
Imperial College London and Dr Kyriakos Maniatis.

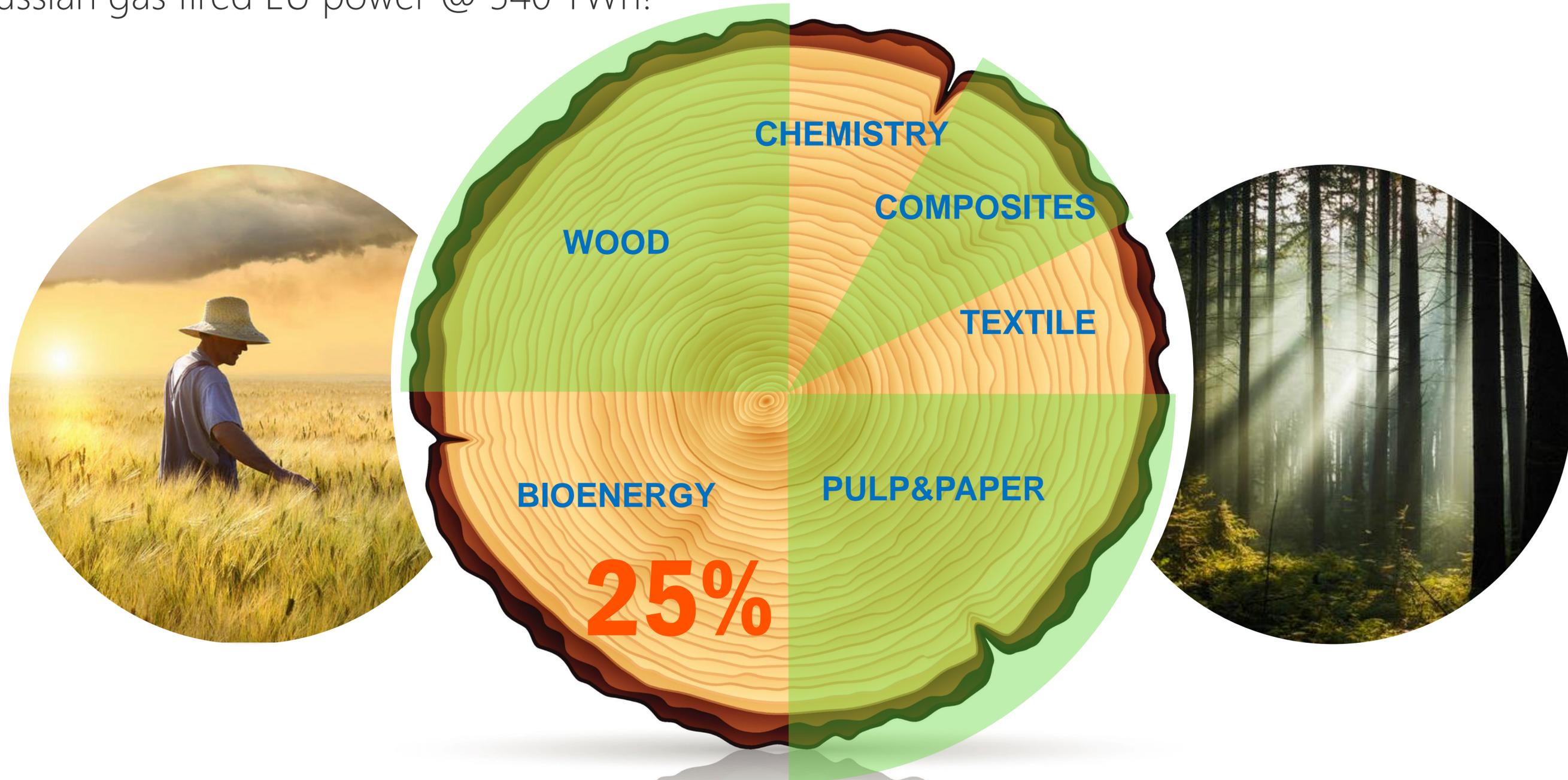
August 2021

contracted by Concawe



# ----- AVAILABLE BIOMASS

- 5 200 TWh Biomass waste available in EU+UK\*
- 50% usage for BioPower @ 50% = 1 300 TWh
- + 2X Russian gas fired EU power @ 540 TWh!



\* Imperial College London, Sustainable Biomass Availa

# RENEWABLE POWER ON DEMAND



## PLANNABLE

Power and heat on-demand.



## SCALABLE

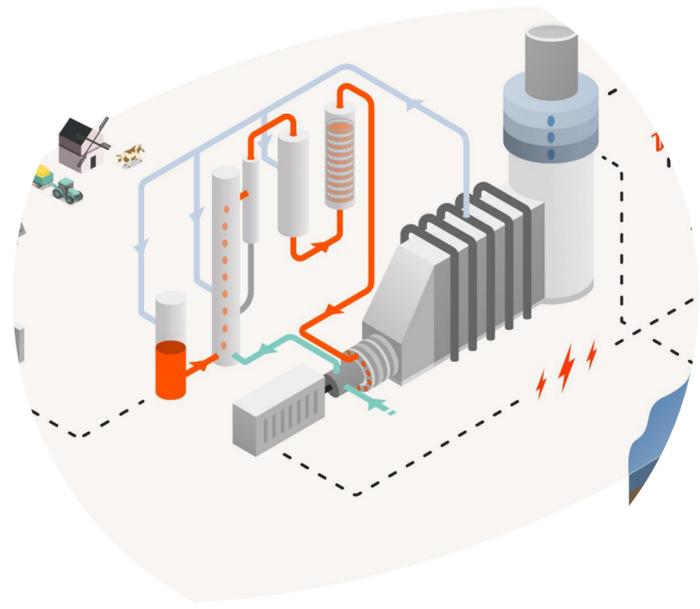
Cost-effective and highly efficient.



## SUSTAINABLE

Consume half the biomass.

# ----- TREE PRODUCT AREAS



**THE BTC PLANT**



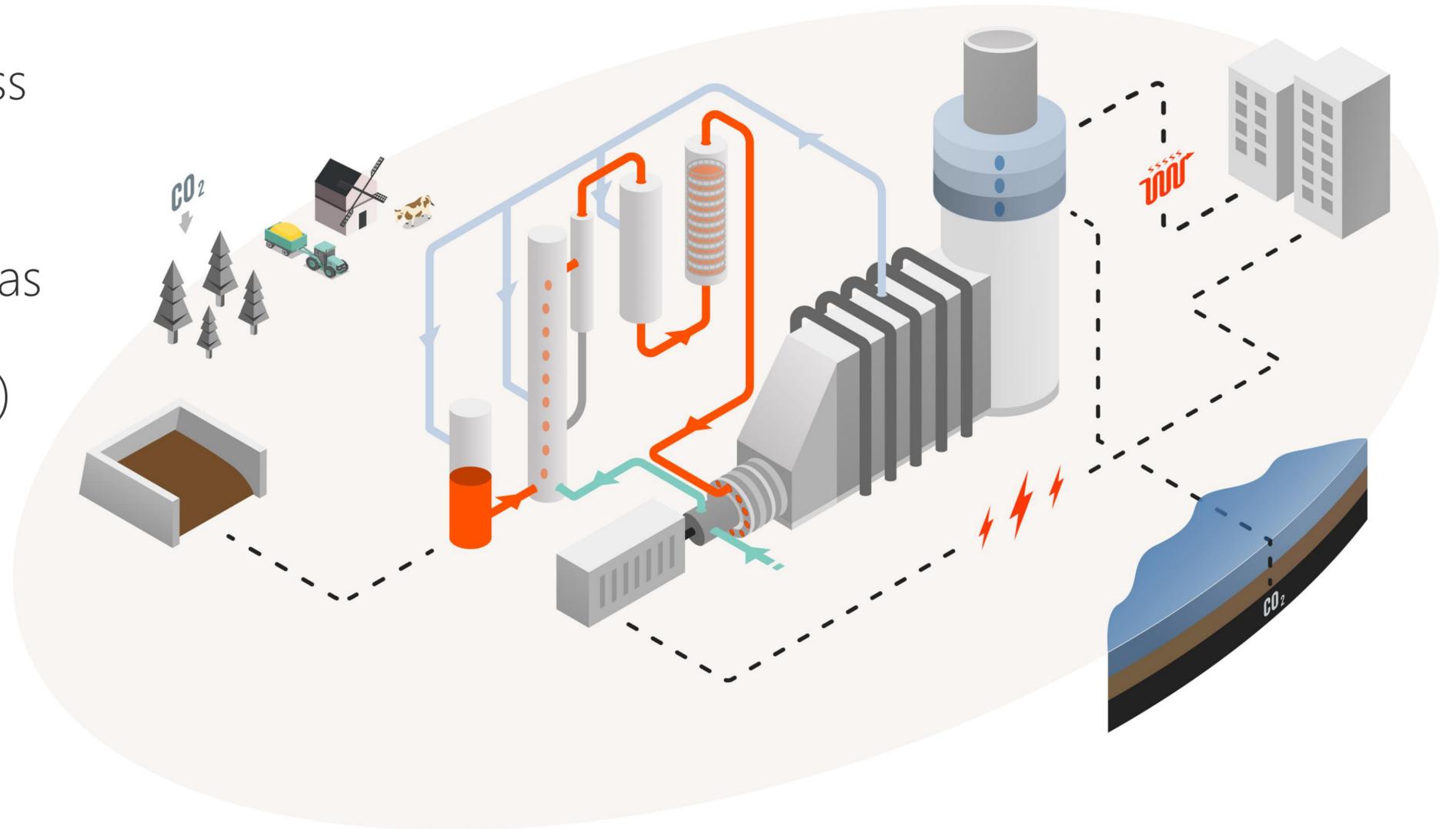
**GAS TURBINE**



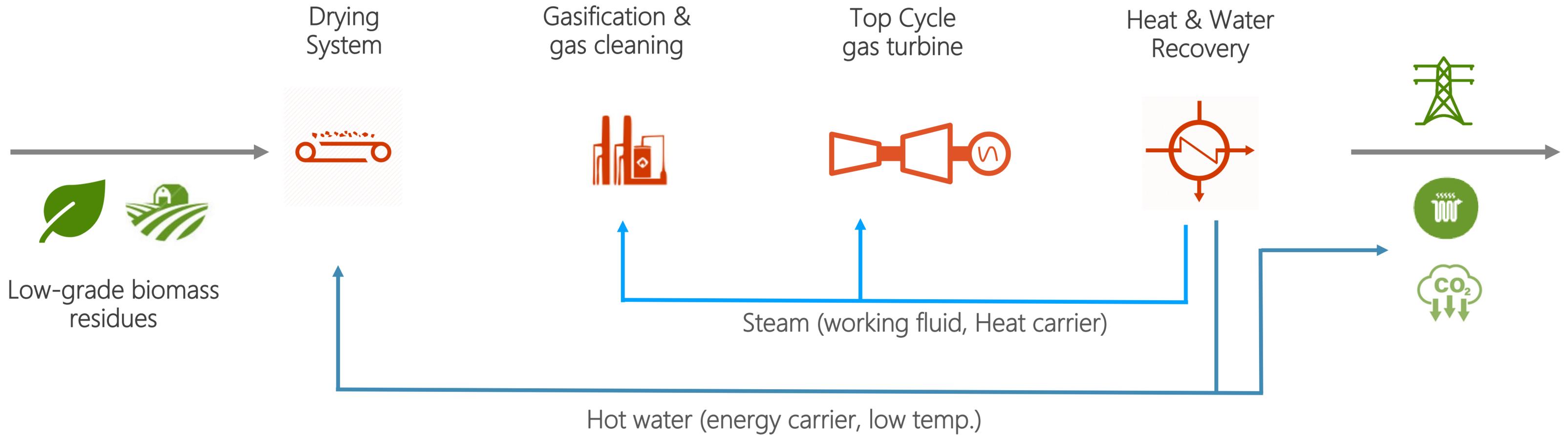
**HFB GASIFIER**

# ----- INTRODUCING THE BTC PLANT (BIOMASS-FIRED TOP CYCLE)

- Doubled electrical efficiency from biomass (50-60 % vs. 25-34 %)
- Integrated pressurized gasification and gas turbine combustion (vs. boiler incineration and steam turbine)
- 100 % hydrogen capable
- Superior BECCS economics (waste heat not penalizing power cycle)
- Plannable and renewable power



# ----- BTC: A NEW POWER CYCLE



# ----- HYBRID FLUIDIZED BED GASIFIER (HFB)

Novel fluidized bed gasification technology for high pressure gasification

Main features:

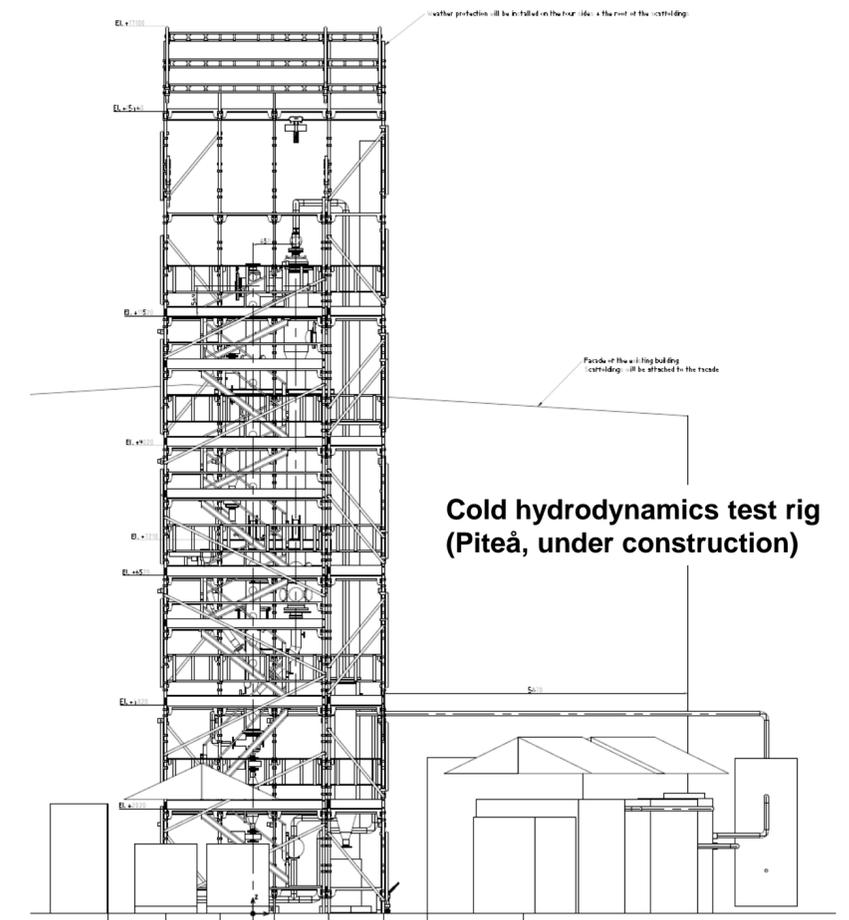
- Keep high reliability of fluidized bed technologies.
- Innovations to address challenges of BFB and CFB technologies at high pressures.
- Very wide operation load range (25% to 100%) and flexibility.
- Achieve a good fuel feedstock flexibility (e.g. particles sizes)

## Air-blown gasification

- Application: gas turbine integration for power and heat production
- Feedstock: forest residues, demolition waste wood, agricultural waste
- Operating pressure: ~30-50 bar

## Oxygen-blown gasification

- Application: hydrogen, gasoline, jet fuel, methanol, etc
- Feedstock: forest residues, demolition waste wood, collected and sorted urban waste (RDF), agricultural waste
- Operating pressure: ~20-25 bar



# MARKET APPLICATIONS

## LOCAL POWERGEN AND CHP

10 -30MWe units 43-50%  
25-60 MW bio

Half the fuel costs  
3 times more local power

Powergen Global  
CHP: Nth and East Europe

Municipal & large utilities, e.g. Tekniska  
verken, Vattenfall

Forest, agricultural residues  
Hydrogen / natural gas

## CO2-NEGATIVE POWER

150 MWe units 45-50% with CCS  
300 MW bio

Half the capture penalty and 30%  
lower costs

Nth EU, Nth America

Large utilities, e.g. Drax, Uniper

Forest residues, imported pellets  
Hydrogen / natural gas

## CO2-NEGATIVE H<sub>2</sub> AND BIOFUELS

25-300 MW bio

Decouple H2 from electricity prices  
CO2 negative

EU, Nth America, Japan

Chemical, Refinery, Steel industry, e.g.  
Perstorp, BASF, SSAB, ArcelorMittal

Forest residues, imported pellets

# SCALING INFRASTRUCTURE

## Atmospheric Systems

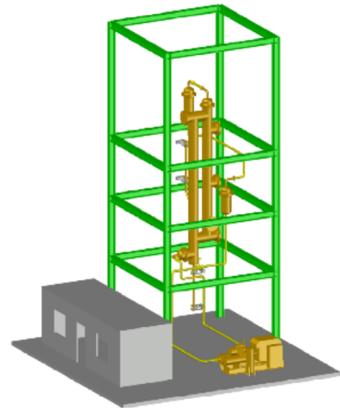


- Integrated combustor and gasifier
- TRL3
- 50 kW<sub>f</sub> biomass and up to 200 kW<sub>f</sub> hydrogen

**IN COMMISSIONING**

EPC: 2021-2022  
Testing: 2022-2023

## Cold-flow HFB Gasifier

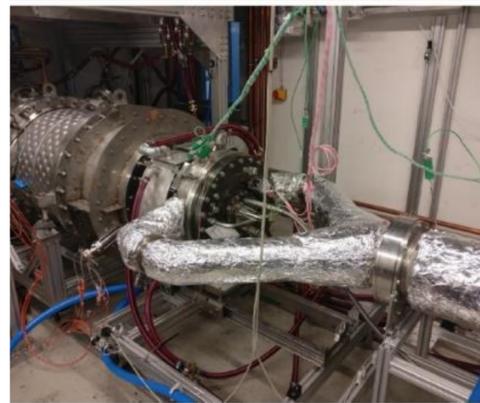


- Hydrodynamics for high pressure gasifier
- 5 MW<sub>f</sub> scale (no fuel) at RISE, Piteå

**UNDER CONSTRUCTION**

EPC: 2021-2022  
Testing: 2022-2023

## Pressurised Combustion



- Key validation rig for burner at pressure (TRL4)
- 1 MW<sub>f</sub> 10 bar combustion rig at TU Berlin
- Syngas, natural gas, hydrogen

**UNDER CONSTRUCTION**

EPC: 2021-2022  
Testing: 2023-2024

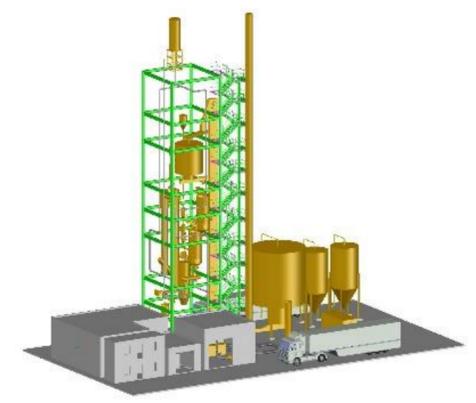
## High pressure HFB Gasifier



- Key validation rig for gasification system (TRL5)
- 36 bar 500kW HFB gasifier
- O<sub>2</sub> or air blown
- Combustion of real syngas up to 500 kW<sub>f</sub>

EPC: 2022-2024  
Testing: 2025 onwards

## BTC Pilot Plant



- Full system with gasifier and gas turbine
- 10 bar 2 MW<sub>f</sub> 0.5 MW<sub>e</sub>
- BTC pilot plant, TRL6/7
- Re-purposed gas turbine, not optimised

EPC: 2023-2025  
Testing: 2025-2027

Risk-staged scale-up process

# ----- AGGRESSIVE DEVELOPMENT UNDERWAY

## Invested: 7.5 M€



AKADEMISKA HUS

Private Investors

## Site



## Reference Group



## Pre-Studies



Global CHP operator



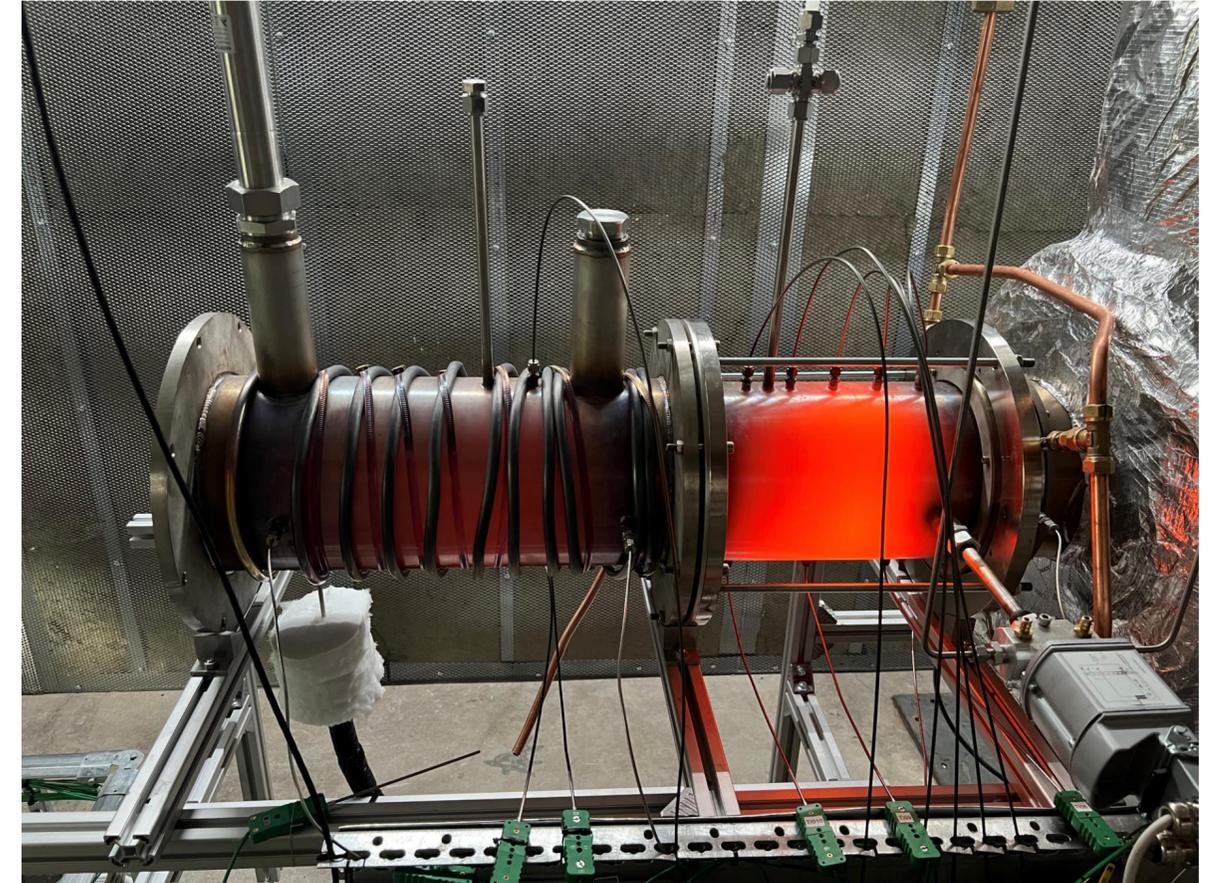
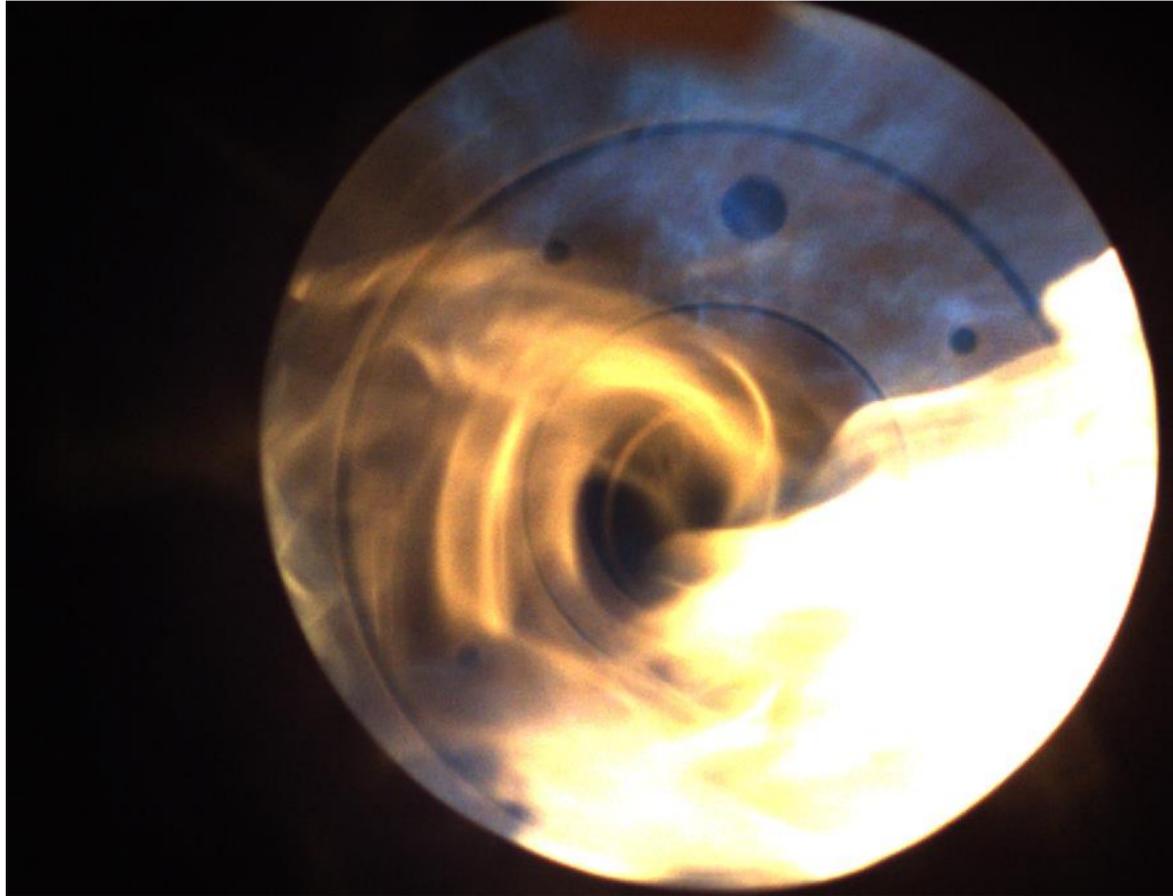
ЗОРЯ-МАШПРОЕКТ  
(Global gas turbine supplier)

## Competence



Accelerating: 7.5 M€ additional funds secured for next phase in R&D

# PHOENIX ADVANCED COMBUSTION SYSTEM: FIRST FIRE!



- 2022-06-22: We had first fire of test rig at Stockholm facilities
- Linked gasifier hot commissioning begins this week
- Integrated operation after summer

# PHOENIX BIOPOWER



7 direct

6 indirect

## Direct influence



## Indirect influence



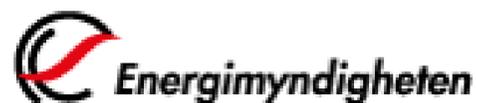
# 2x EFFICIENCY

Henrik Båge, CEO

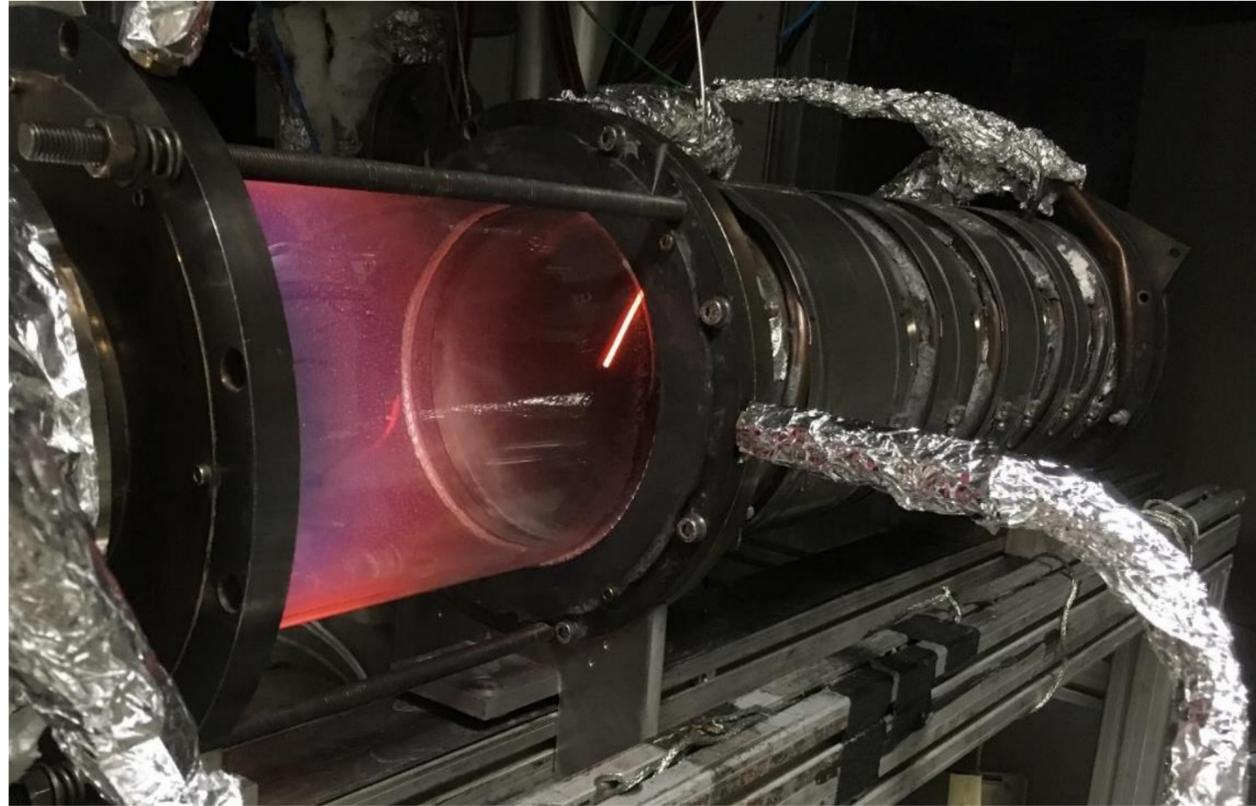
[henrik.bage@phoenixbiopower.com](mailto:henrik.bage@phoenixbiopower.com)

[www.phoenixbiopower.com](http://www.phoenixbiopower.com)

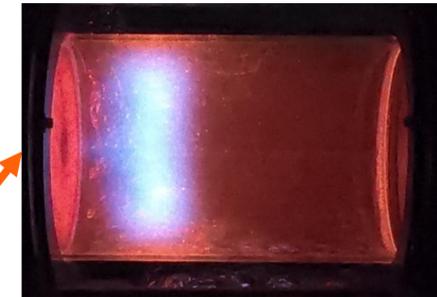
Tel: 0046 (0)8 663 58 00



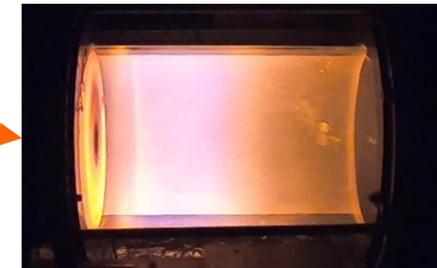
# PHOENIX ADVANCED COMBUSTION SYSTEM: FUEL FLEXIBLE COMBUSTOR



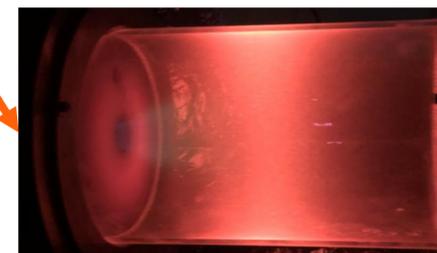
**ONE COMBUSTOR**



• Natural gas



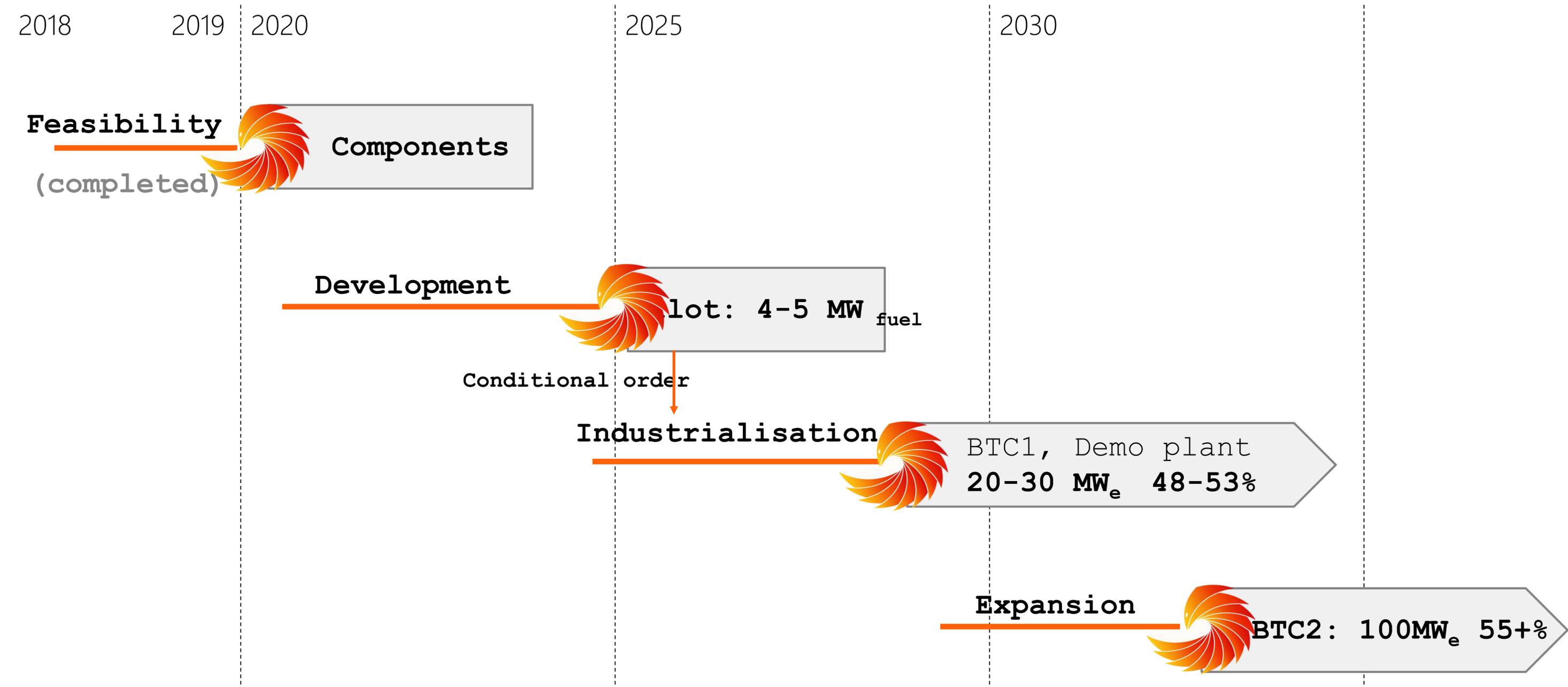
• Biomass syngas



• 100% hydrogen

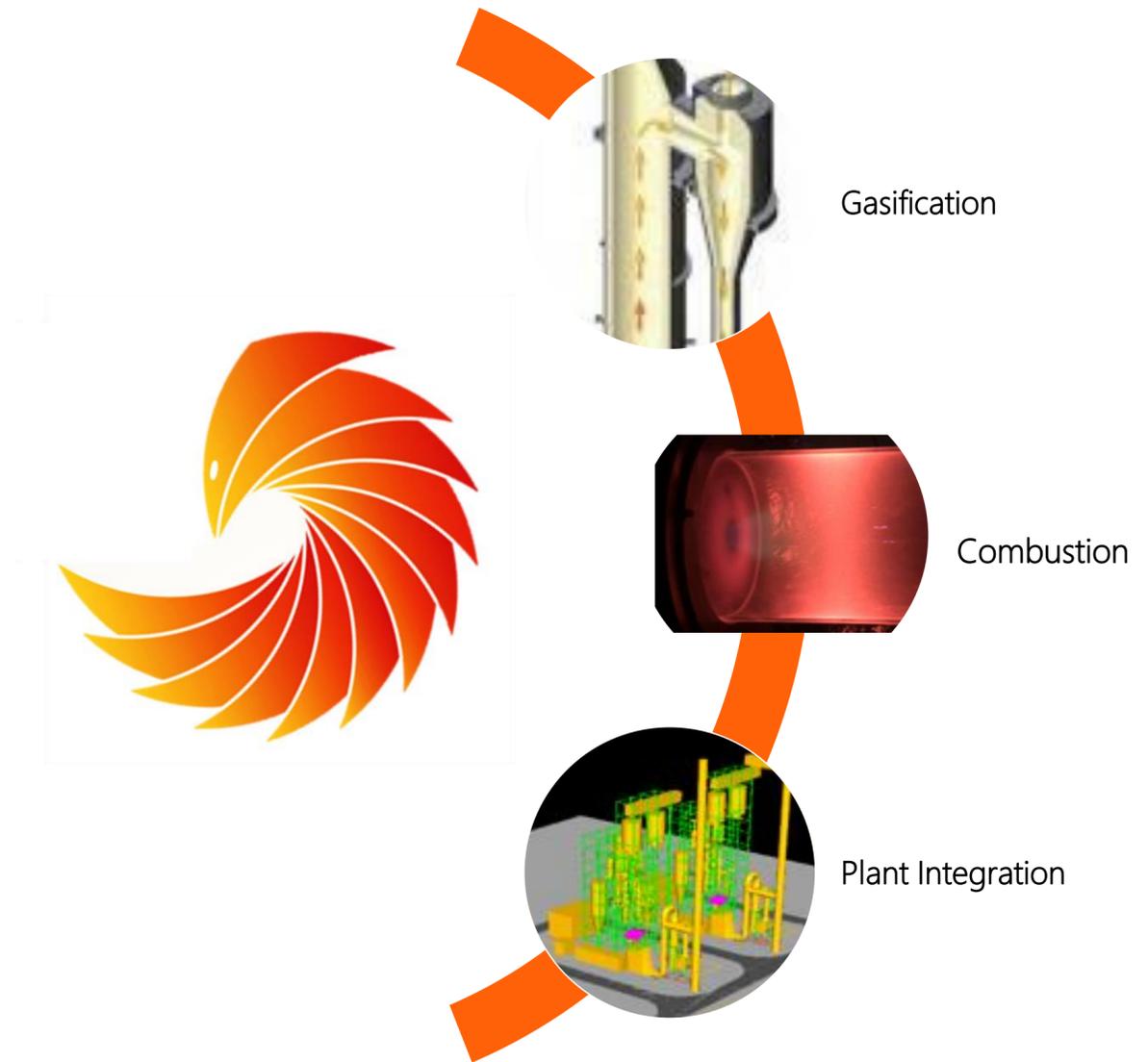
- One GT combustion system for multiple fuels
- Ultra-low NO<sub>x</sub> with natural gas and / or hydrogen
- Much lower H<sub>2</sub> flashback risk and very robust behavior with H<sub>2</sub> for start-up
- Near-stoichiometric, high steam content
- Swirl stabilized and mild combustion

# BTC ROADMAP - BTC BASE CASE



# ----- PHOENIX'S ROLE AND TECHNOLOGY

- Develop, design and supply
  - biomass gasification system
  - combustion system
  - plant integration
- Catalyse the partnerships and developments needed to commercialise the Top Cycle technology





**MICHAEL BARTLETT**

Co-Founder, CTO  
Ph. D. Gas Turbines  
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  
Sw Energy Agency  
Industrifonden



**CATHARINA LAGERSTAM**

Board member  
S.E.C Lux.  
ICA Bank



**BIRGITTA RESVIK**

Board member  
Fortum  
Svenskt Näringsliv



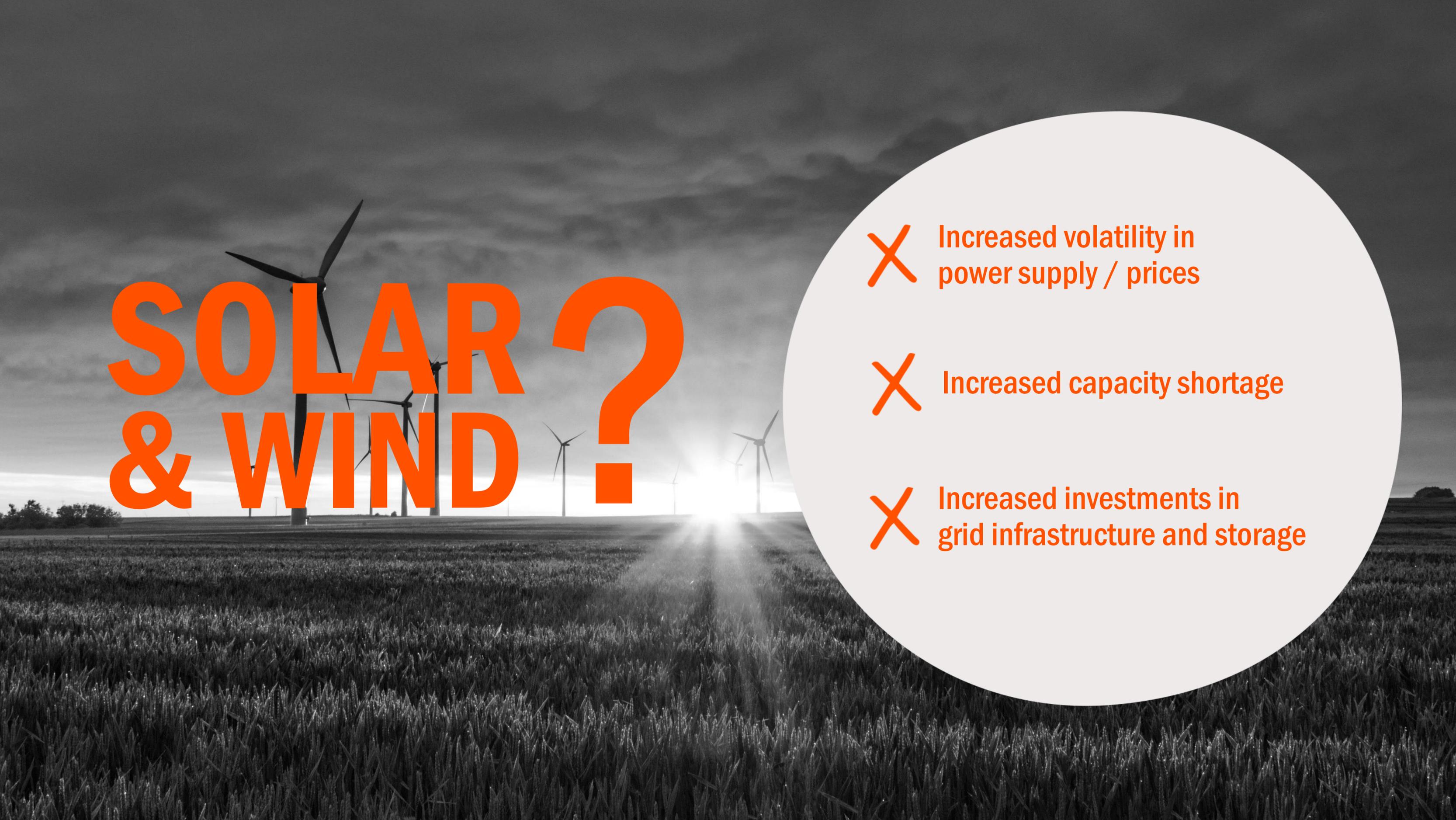
**OLA JOHANSSON**

Board member  
Siemens Turbo Machinery  
Epishine

# NATURAL- GAS?

- ✘ Russian gas to EU: 1 300 TWh/y  
(45% of all EU gas)
- ✘ EU power w Russian gas ~550 TWh/y  
(almost 4x Sweden)
- ✘ Sustainable?!?

# SOLAR & WIND ?



✘ Increased volatility in  
power supply / prices

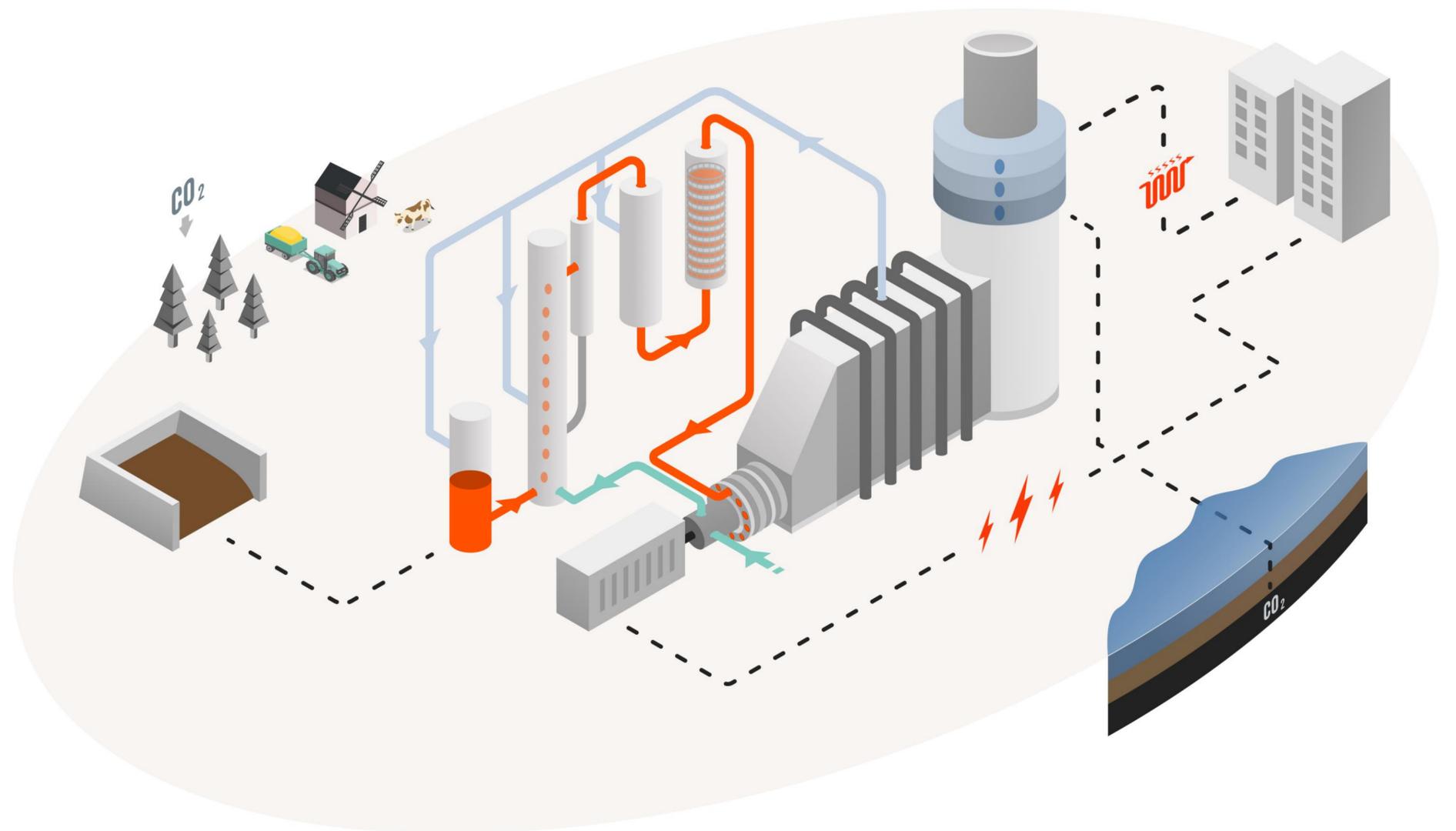
✘ Increased capacity shortage

✘ Increased investments in  
grid infrastructure and storage

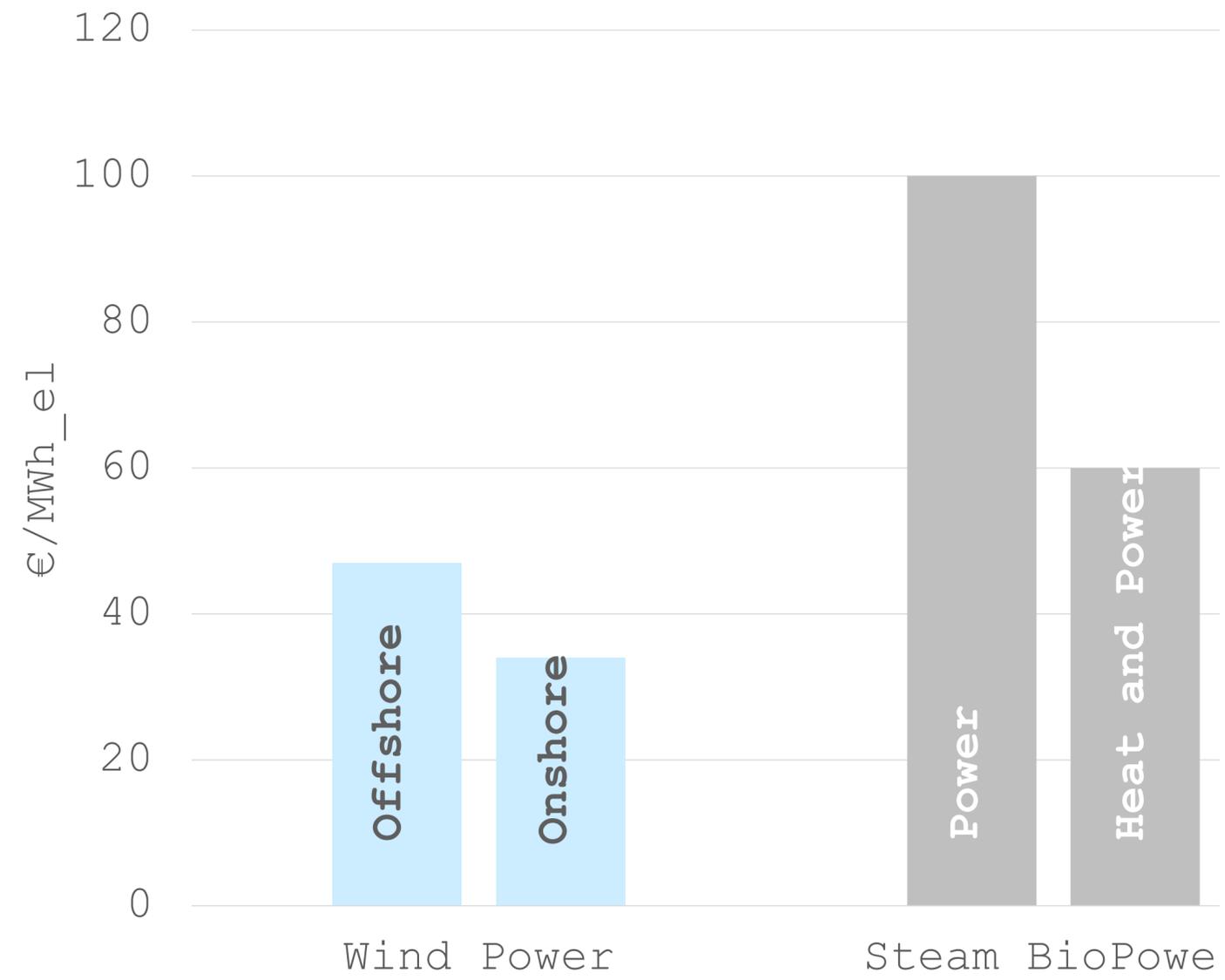
## ----- PERFORMANCE TARGETS

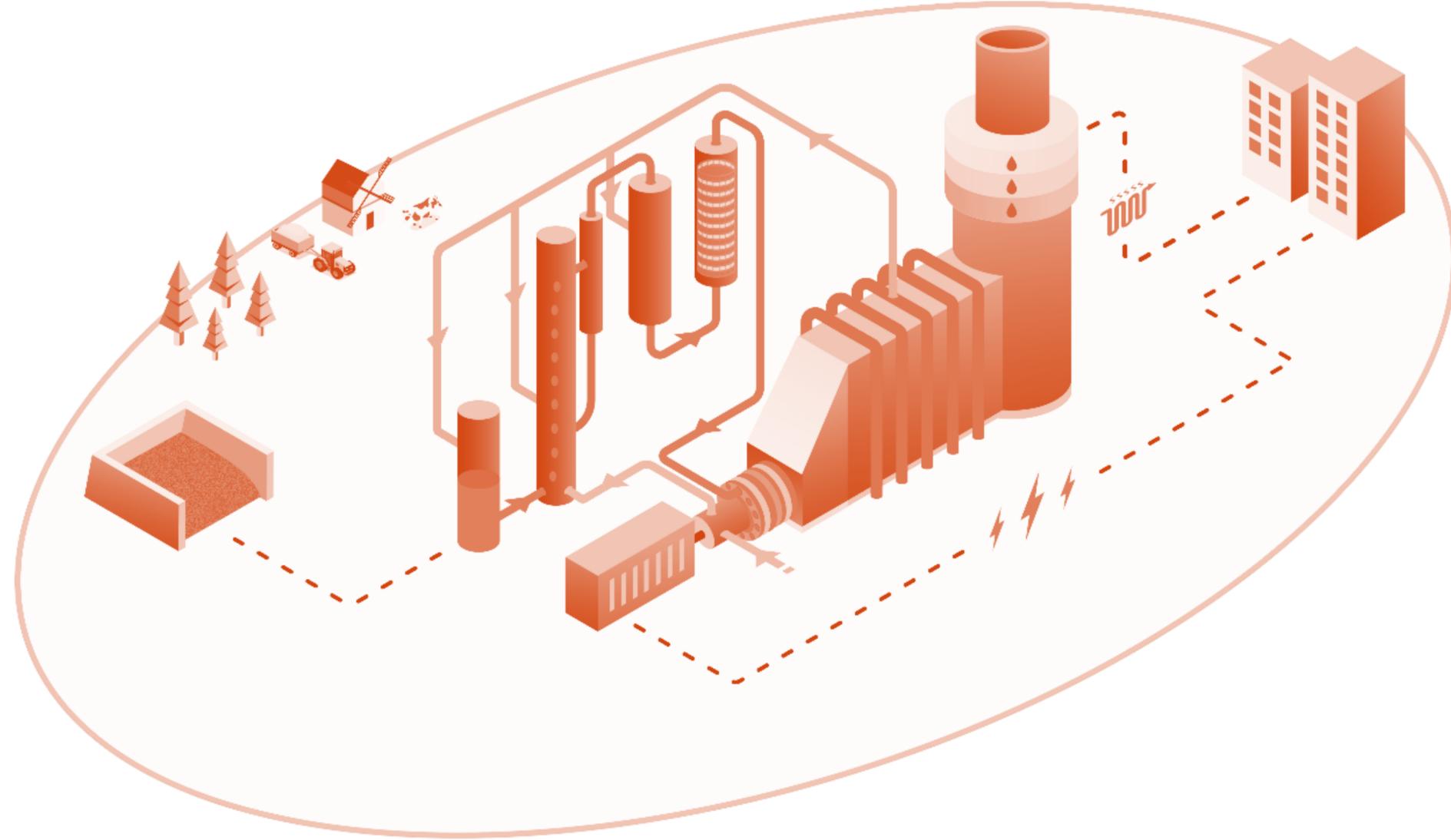
	P25	P150
Feedstock	Forest residues, agri. residues, blends. Gaseous fuels (H <sub>2</sub> , NG)	
Thermal input (MW <sub>th</sub> )	50	300
Net power output* (MW <sub>e</sub> )	25	165
Net electrical efficiency*	50%	55%
with CO <sub>2</sub> capture	45%	50%
Total efficiency	90-110%	90-110%

\*LHV, forest residues 50%MC



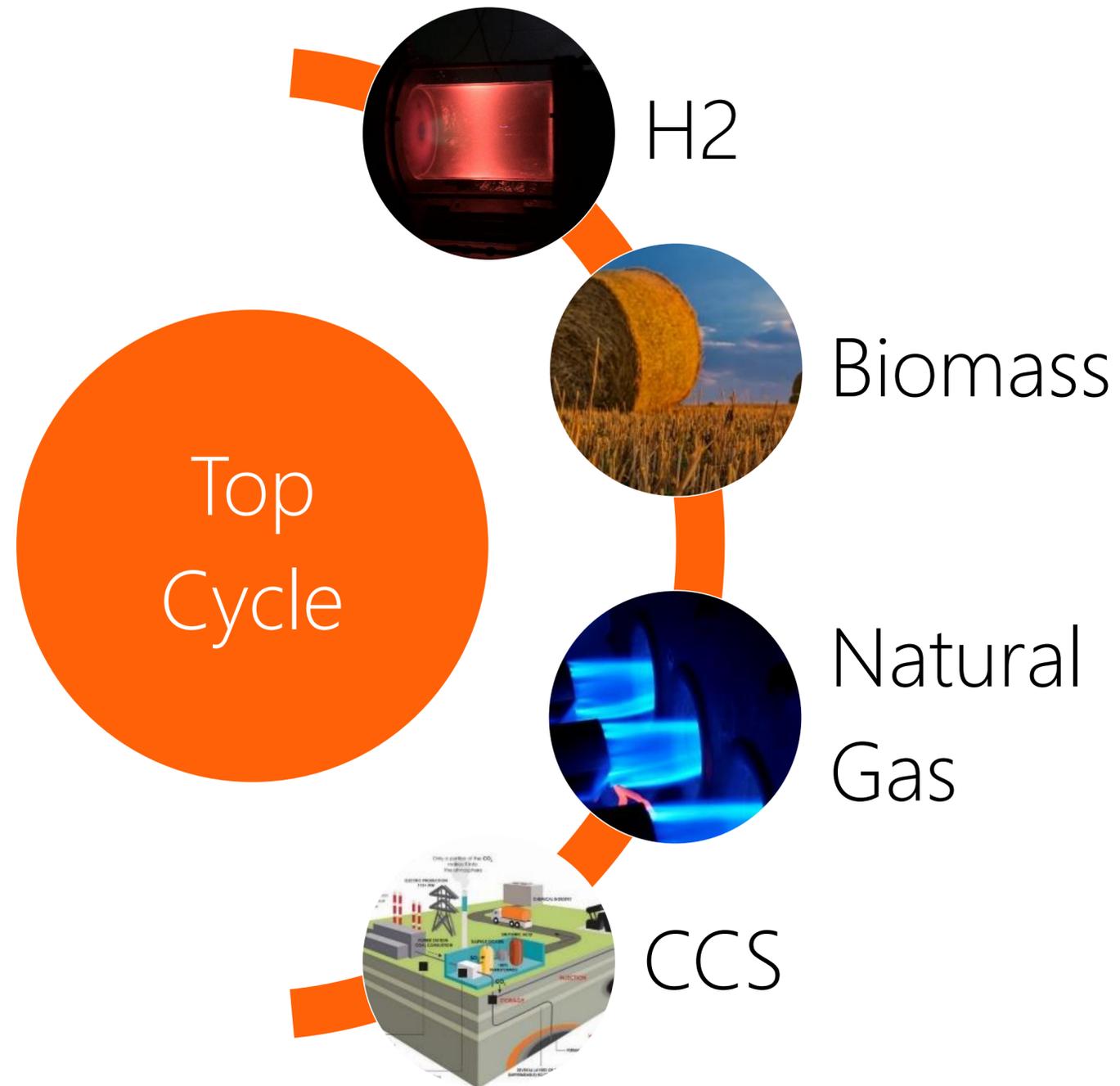
# ----- LEVELIZED PRODUCTION COSTS





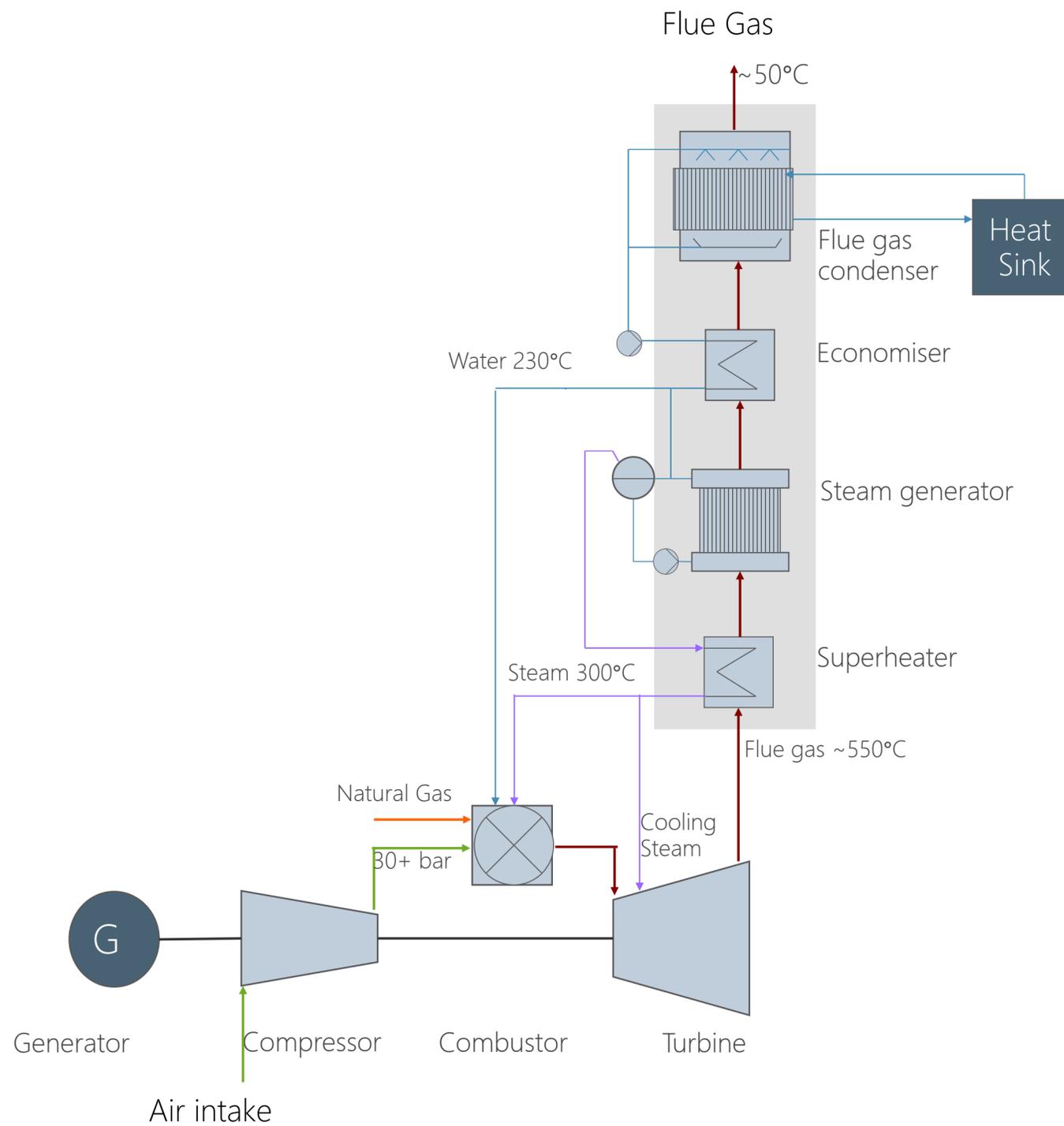
# THE BTC CONCEPT

----- **TOP CYCLE: a platform technology**



Advantage vs Combined Cycle

- Superior hydrogen combustion
- Ultra-low Nox
  
- +10-15 % pts electrical efficiency
- +15% pts total efficiency in district heat
  
- 30-40 % lower capital costs & footprint.
- +15% pt total efficiency in district heat
  
- One third the cost of CO<sub>2</sub> avoided
- 70% lower power penalty



## TOP CYCLE: A NEW POWER CYCLE

- High pressure gas turbine
  - Massive steam injection
  - Minimised air compression
  - Water recovered in flue gas condenser
- High power output and efficiency
- High heat output

# 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

