29th June 2023

EARTH® - an Advanced Reforming Technology to reduce the Carbon Footprint in Hydrogen Production

Lecture Dinner Meeting
AIChe Netherlands/Belgium Section

Jan-Jaap Riegman – Sr. Product Development Engineer

01 Introduction

TECHNIP ENERGIES

Requiring a low-carbon and sustainable future

Technip Energies at a glance

Listed on **Euronext Paris** Stock Exchange	Headquartered in **Paris**	**60+** Years of operations
€6.4B Full year 2022 adjusted revenue	A leading Engineering & Technology company for the Energy Transition	**€12.8B** Backlog at end 2022
~15,000 Employees in 30 countries	**25+** Leading proprietary technologies	**450** projects Under execution

Technip Energies Strategic Framework

Our 4 strategic pillars

LNG and low-carbon LNG

Onshore and offshore liquefaction

Sustainable chemistry

Biofuels, biochemicals, circular economy

Carbon-free energy solutions

Green hydrogen, offshore wind, nuclear

Decarbonization

Energy efficiency, **Blue hydrogen**, CCUS

Our ambition

Technologies, Products & Services (TPS)

Expand through organic growth, partnerships and acquisitions

Project Delivery

Sustain leadership and execution excellence

Technology and R&D focus

Decarbonization and CCUS

Blue and green H_2 and NH_3

Sustainable chemistry

Data-Centric Execution

ESG

ESG roadmap

Net Zero project execution

Circularity

02 Why decarbonizing hydrogen production?

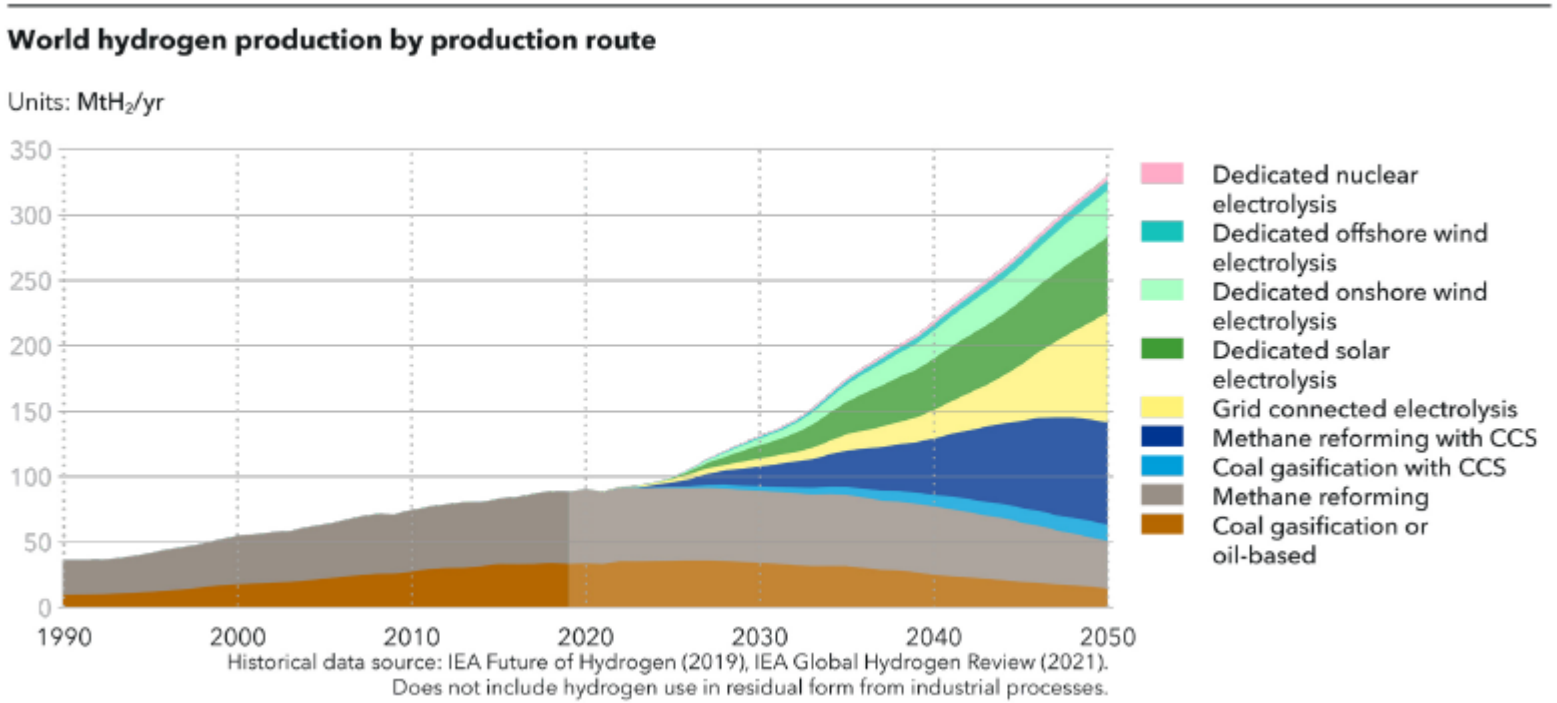
Why hydrogen?

A changing role for Hydrogen

H_2 Tomorrow

Part of an expanded energy portfolio of low/no carbon vectors:

- Fuel substitute e.g. fossil → H_2
- Energy carrier
- Energy storage and transport media
- Chemical building block
- Synfuel building block



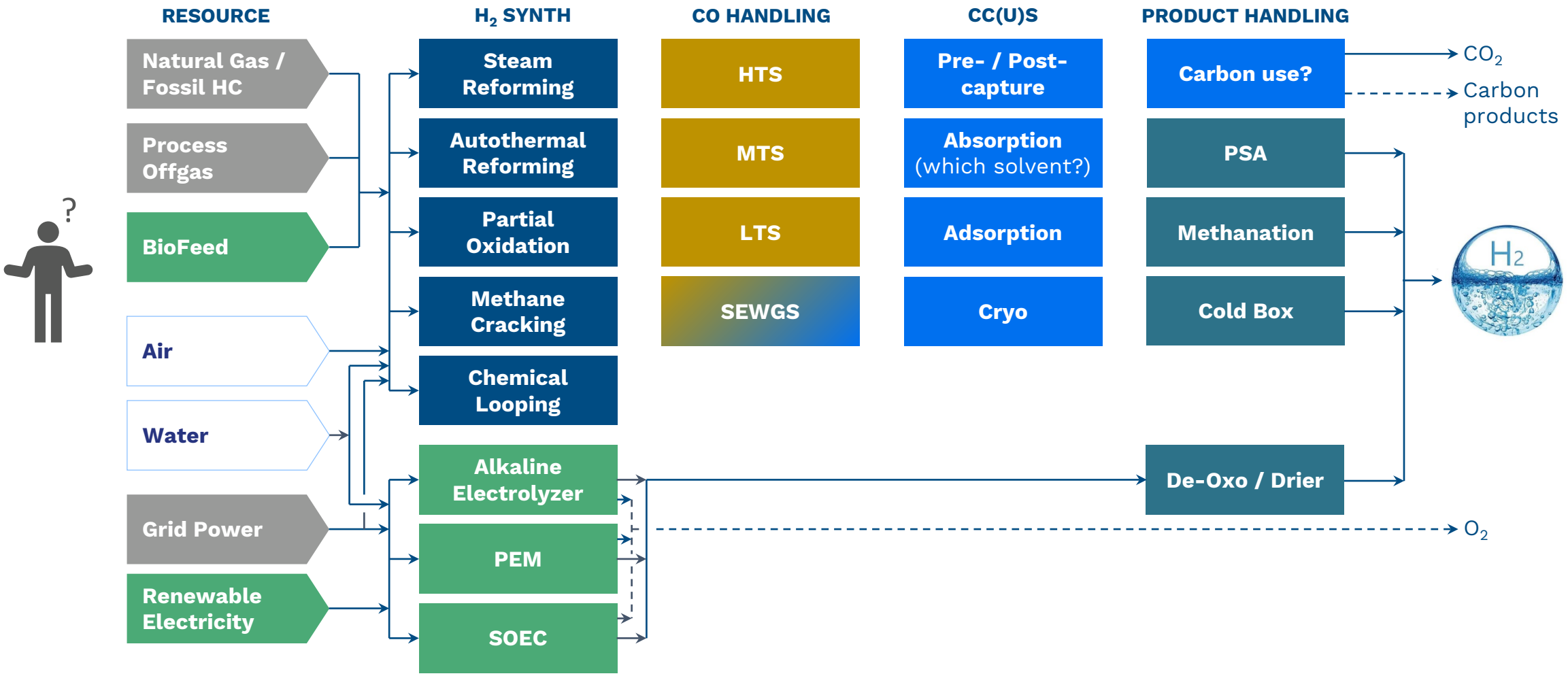
Source: DNV Hydrogen Forecast to 2050 (Energy Transition Outlook 2022)

Forecasts vary, and depend heavily on expectations for transport and heating

Many anticipate legacy + decarbonized hydrogen remain important in foreseeable future

Pathways to hydrogen generation

how to navigate?



Typical CO_2 emissions for hydrogen plants

Sources

Reforming

$CH_4 + H_2O \rightarrow CO + 3H_2$

Partial Oxidation

$2CH_4 + O_2 \rightarrow 2CO + 4H_2$

Water-Gas Shift

$CO + H_2O \rightarrow CO_2 + H_2$

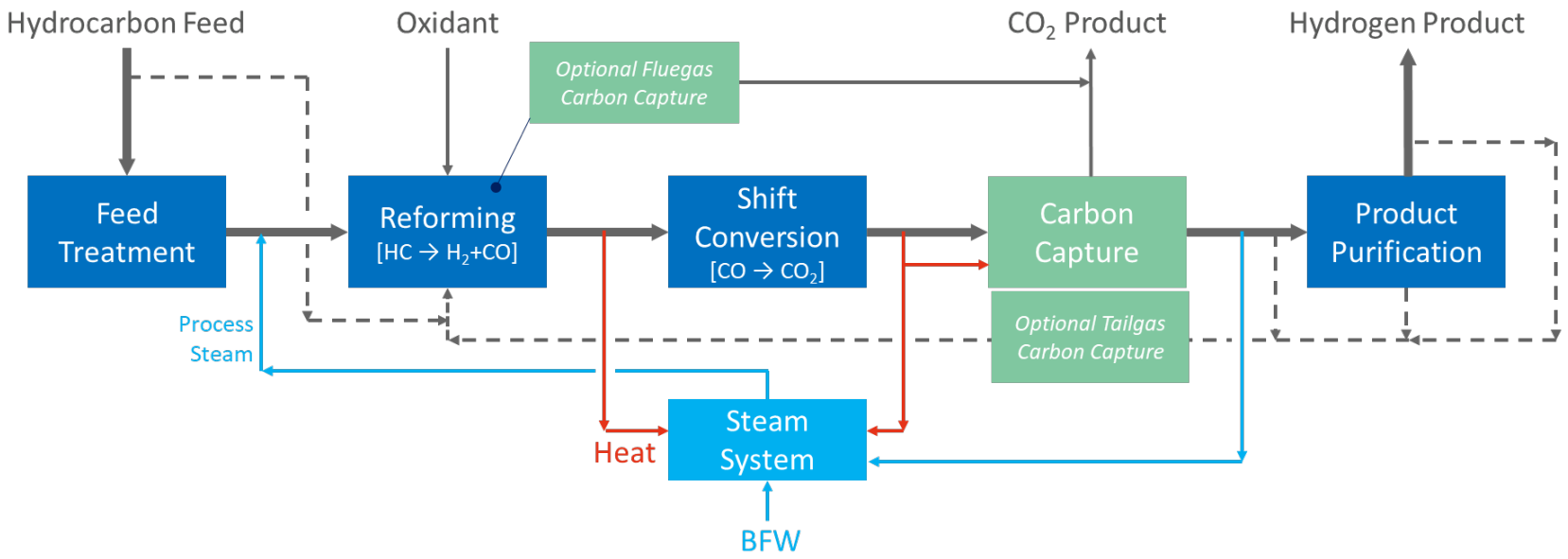
Hydrocarbon Combustion

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

For GREY hydrogen:

- **1 kg of H_2 production typically emits 9-12 kg CO_2**

  > **CO_2 present in process gas and flue gas (where carbon emitting fuel is fired)**



Our H_2eritage

~60 years' hydrogen technology and product leadership

Hydrogen

275+
H_2 references

50+
References of carbon capture from H_2 plants

>30%
Global installed H_2 capacity

60+
Green H_2 References

Ammonia and Fuels

20+
Ammonia references over last 15 years

30+
Grassroots refineries with capacities up to 400 k BPD

Electrolysis & Electrical Expertise

100+
Electrolysis references for Electrochemicals plant

150
electrical engineers

3,5 GW
of power plants built and operated

BlueH2 by TEN | GO.H2 by TEN

Member of Hydrogen Europe | France Hydrogène | Hydrogen Council | HY2GEN

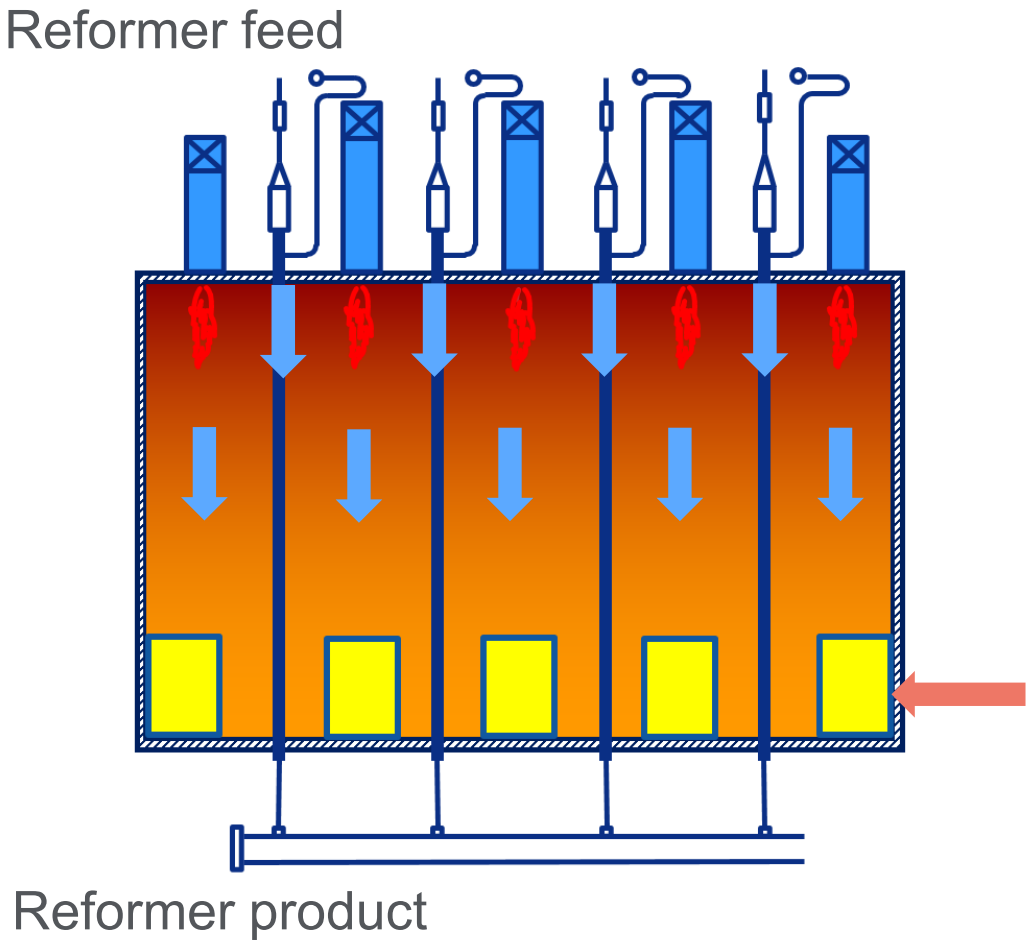
03 Decarbonizing Steam reforming

Effective production of hydrogen with EARTH®

TECHNIP ENERGIES

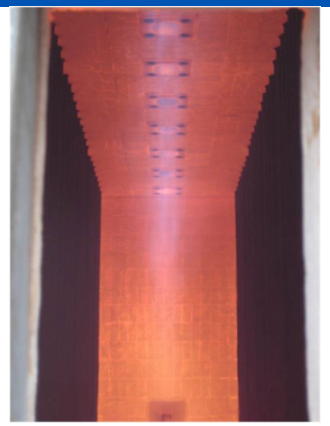
Basic principles for steam reformer

Top Fired Reformer – Basic Principles



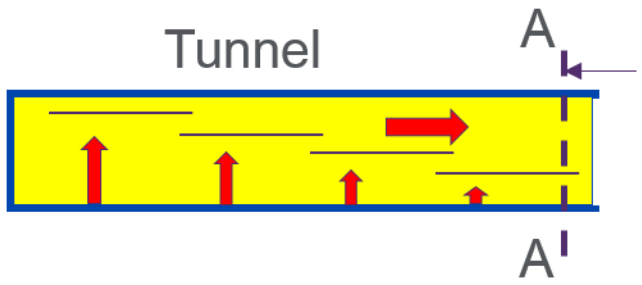
Process gas co-current with flue gas

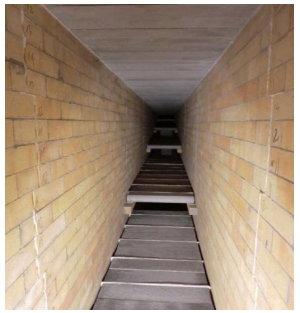
- Downward flow of flue gas
- Design either based on induced draft or balanced draft, often with air preheat



Flue gas extraction through end wall

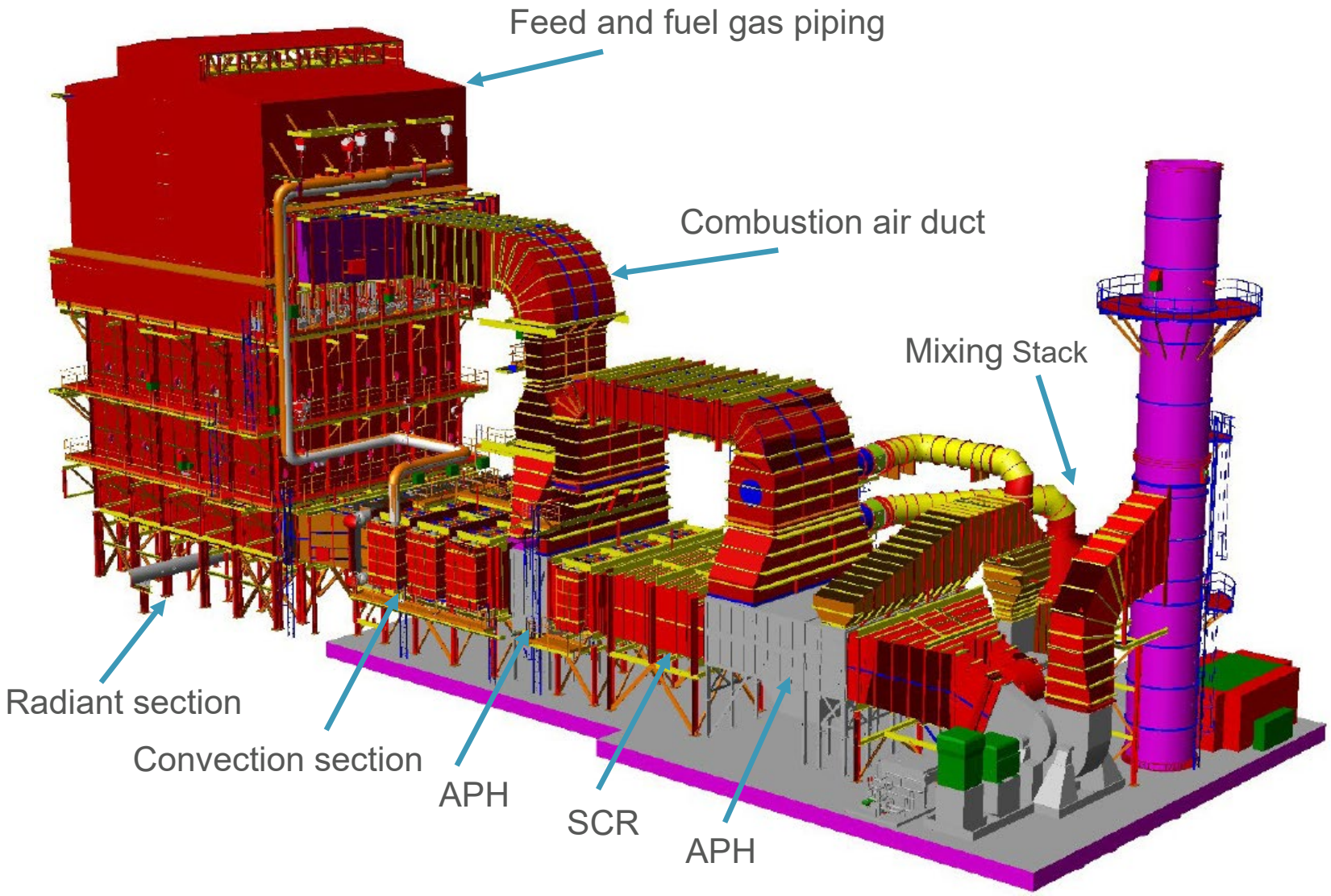
- Flue gas extraction tunnels



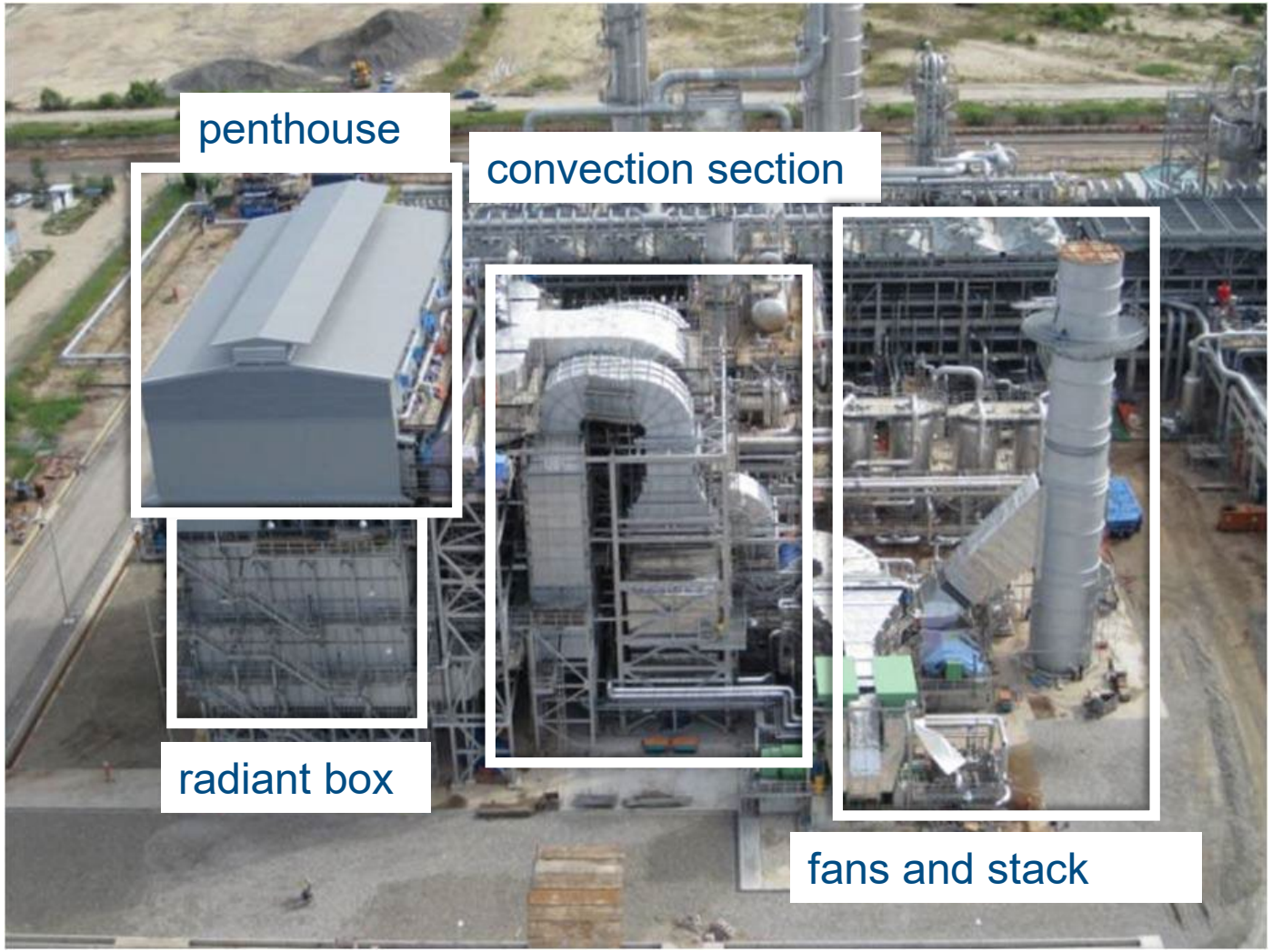


View AA

Example reformer model

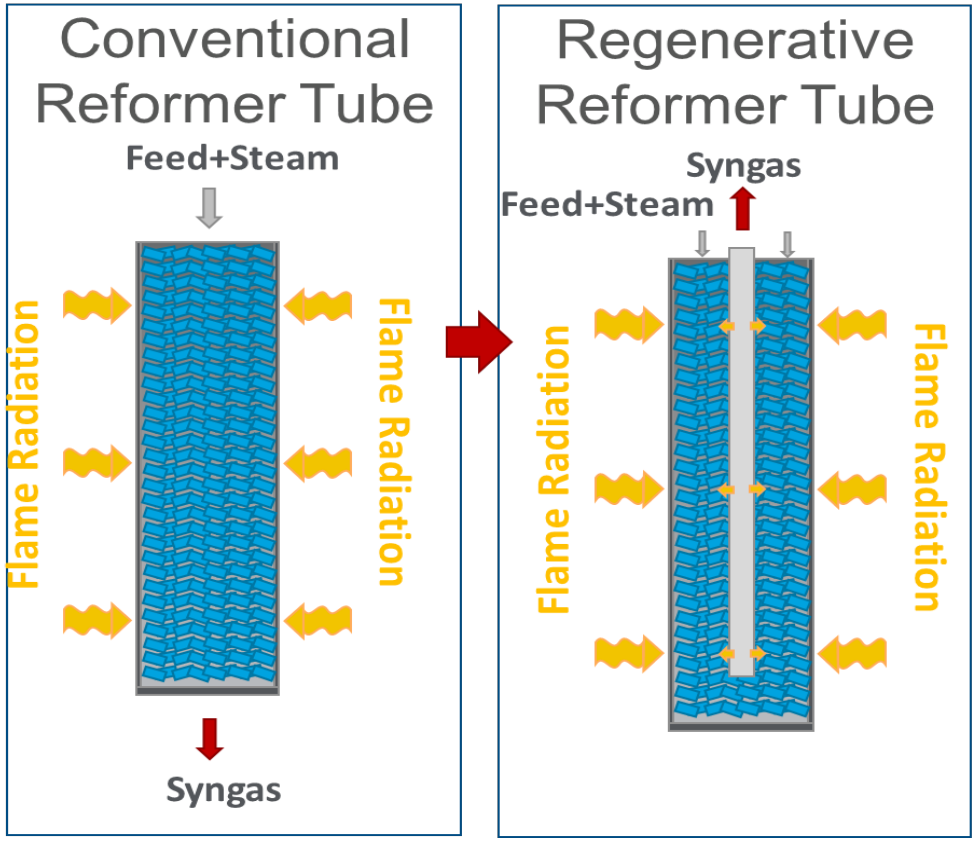


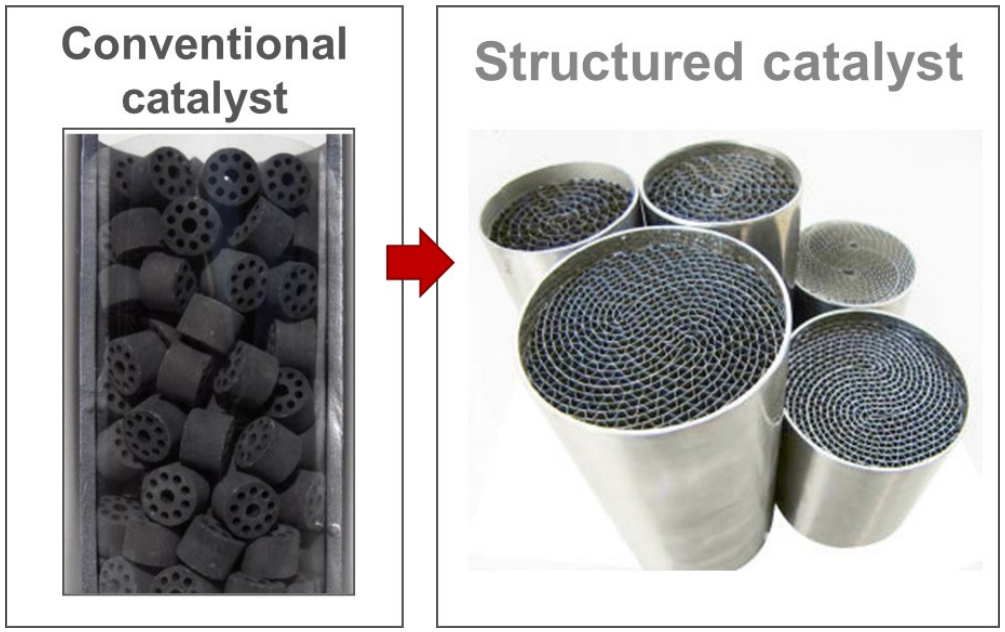
Example reformer



Improving the SMR performance

Recent Developments



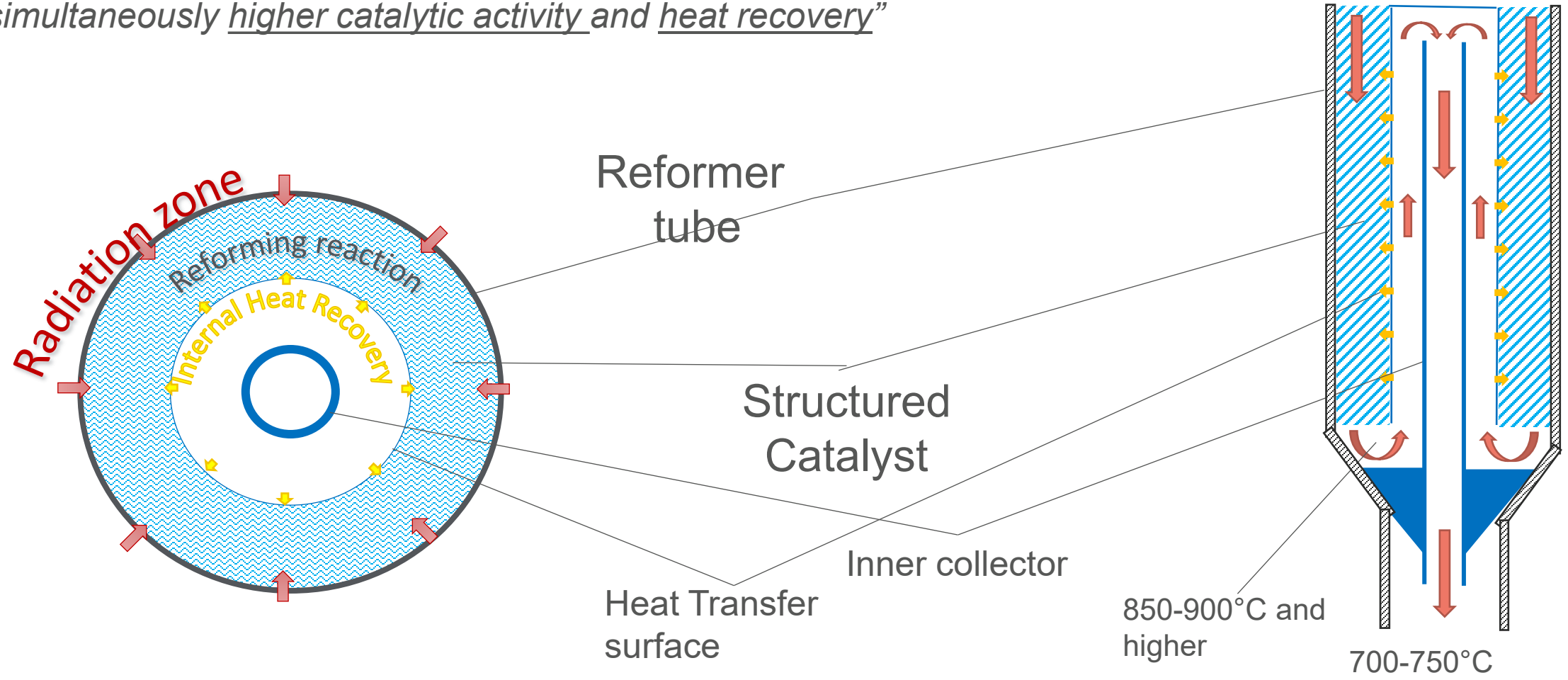


Combining benefits and eliminate drawbacks with EARTH®

EARTH® Technology

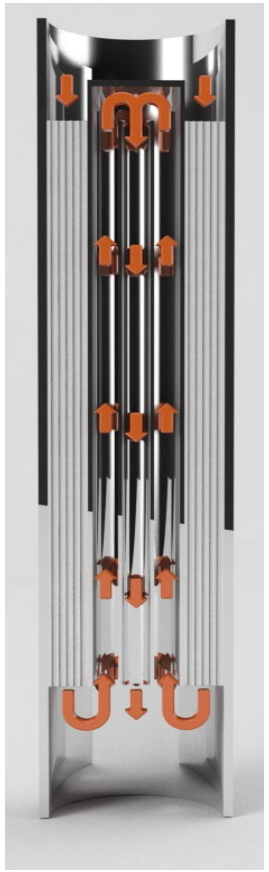
Enhanced Annular Reformer Tube for Hydrogen and Syngas

"It is a removable annular structure installed inside reformer tubes to achieve simultaneously higher catalytic activity and heat recovery"



EARTH®

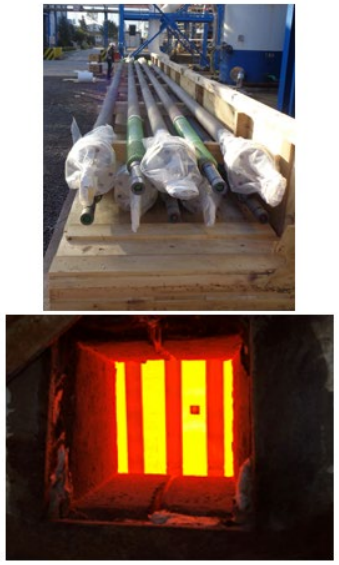
- EARTH® – patented by Technip Energies
- Intensify throughput and heat integration
- Structured catalyst co-developed with CLARIANT
- Saves energy, reduces CO_2 footprint by up to 10%
- Simple drop-in, minimum CapEx
- Install in existing or new reformer tubes
- Proven in operation



First Application timeline

M0: design internal and catalyst

M6: installation and start-up



Tube installation with EARTH® inside and EARTH® in operation

Up to 10 % reduction of CO_2 emissions | Retrofit for up to 20% capacity addition

EARTH® technology

References

Ak-Kim, Turkey

- Syngas plant in operation since 2019

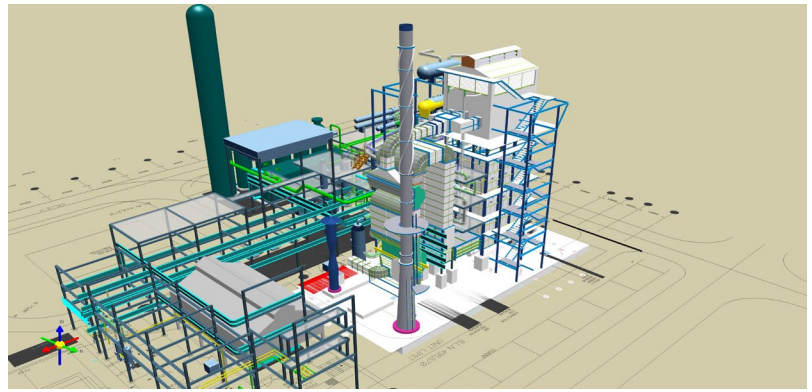
	Conventional pellet catalyst	EARTH®
CO_2 emission	Base	-20%
Fuel consumption	Base	-37%
Approach to equilibrium	< 10°C	< 3°C
Export steam	Base	-57%
Catalyst lifetime	>4 years	>>4 years
Pressure drop	~2 bar	<1.5 bar
Tube metal temperature	base	-10°C

2nd reference, Europe

- On-site delivery of EARTH® assembly (including catalyst)
- Installation inside existing reformer tubes within shutdown window
- In operation since summer 2022

Repsol, Europe

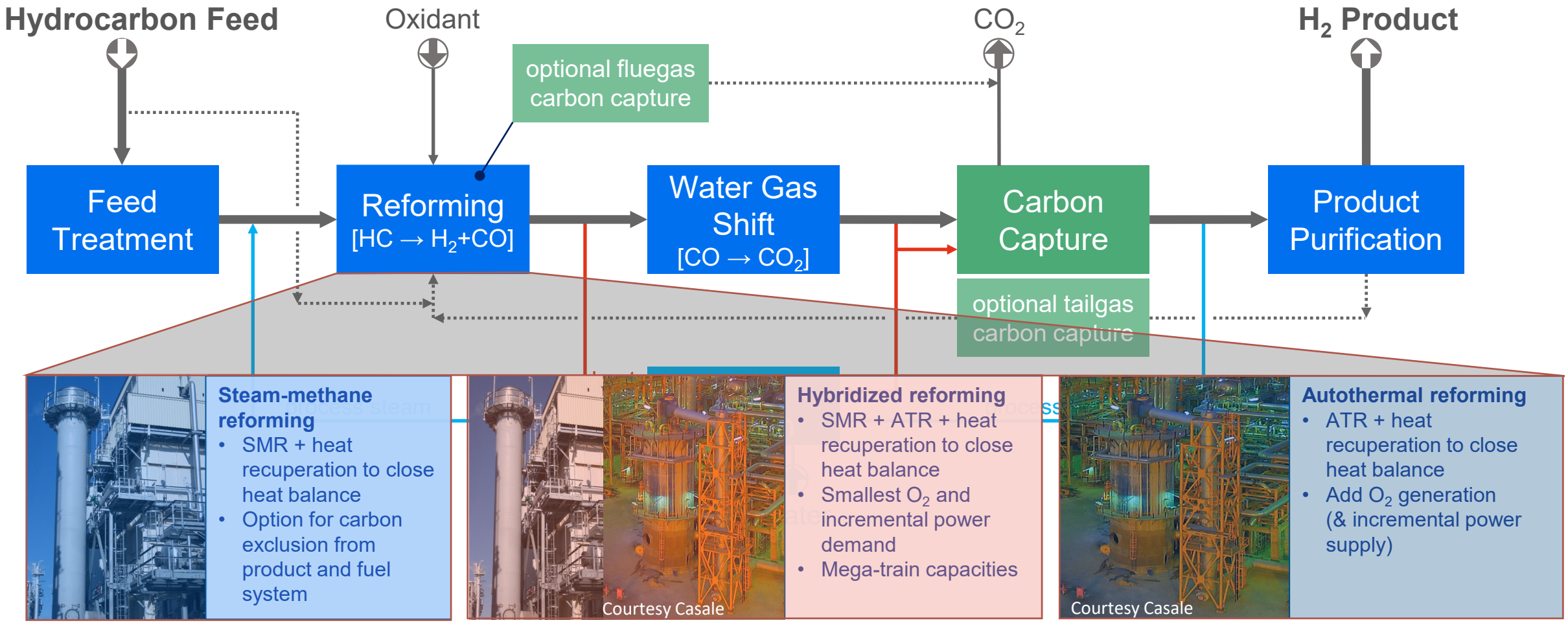
- Expected start-up 2023
- Grassroot reformer



04 Applying EARTH® in blue H_2

Blue H_2/Syngas

BlueH2™ by TEN



Very low CO_2 index practicable for <u>all</u> reforming schemes

0.1 - 1 $kgCO_2$ / kgH_2 CI direct + indirect

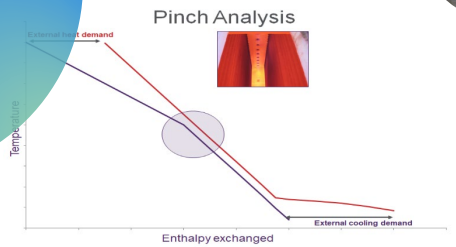
T.EN portfolio of solutions in Blue H2 / Syngas

greenfield projects & brownfield retrofits alike

High Conversion Reforming

- Enhanced SMR "ESMR"
- Oxidative Reforming
- Recuperative Reforming

Heat Integration & High Efficiency



Deep CO Shifting "DeepShift"

High-Efficiency Carbon Capture

Tailored Product Purification

- Adaptive approach
- Proven components

Key proprietary technologies in Blue H_2 by T.EN suite

LSV® burner

Emission reduction
Capable up to 100% H_2 firing

EARTH®

Emission reduction and/or capacity increase

TPR

Emission reduction and/or capacity increase

Recuperative reforming in Blue H_2/syngas

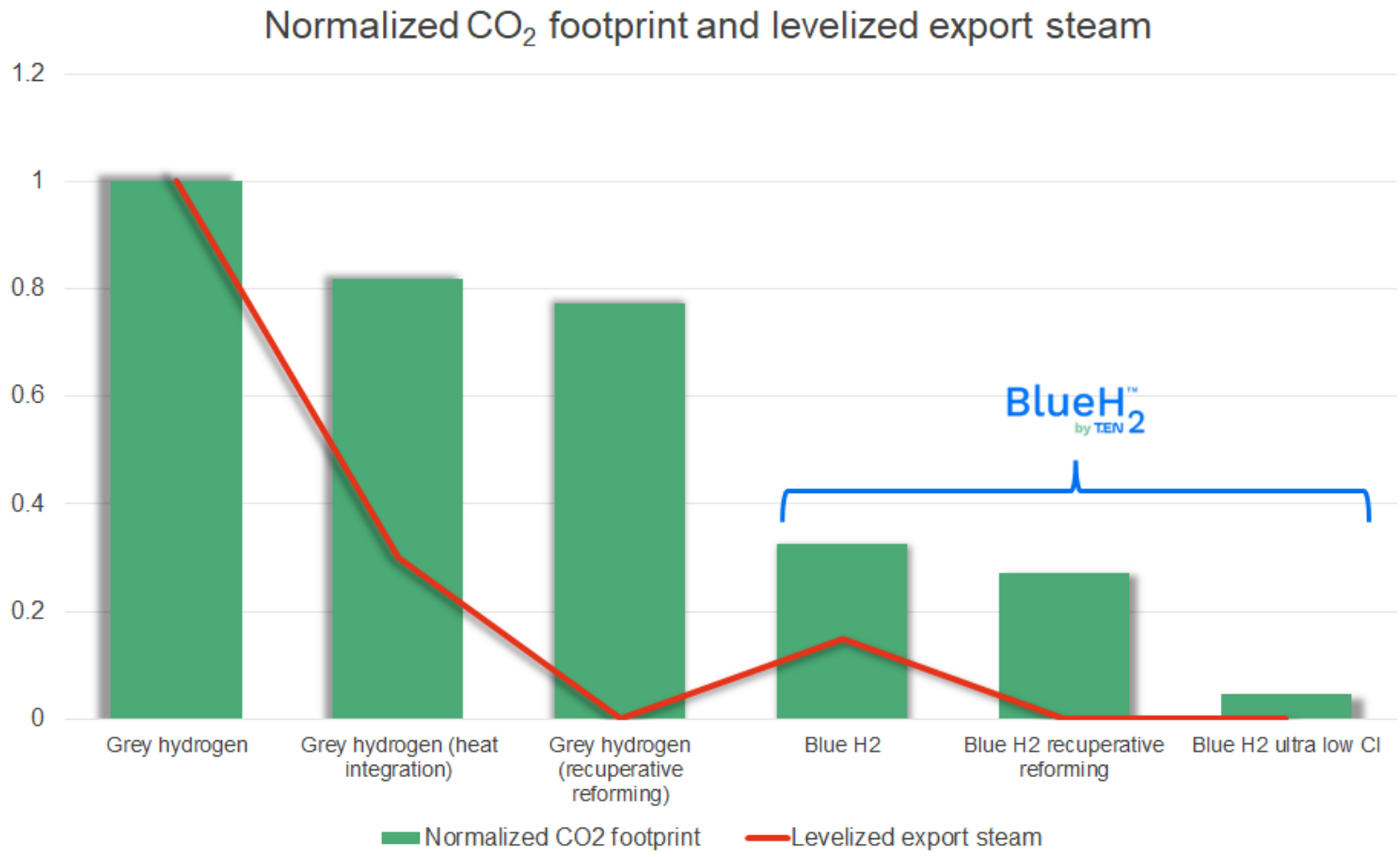
Essential for efficient blue hydrogen/syngas

Maximize curtailment:

- Balanced steam production
- High heat integration
- Recuperative reforming (utilize high level heat for reforming)

Minimize byproducts:

- Maximize feed conversion
- High severity reforming



05 Main takeaways

Main takeaways

The H_2/syngas market continues to grow and diversify under a number of evolving drivers.

In the initial transition there should be attention towards carbon effective solutions rather than defining challenging objectives.

EARTH® technology can play a significant role to decarbonize hydrogen

BlueH2™ by T.EN

Deeply decarbonized, “Blue syngas” is available and affordable for new plants and retrofits

Thank you