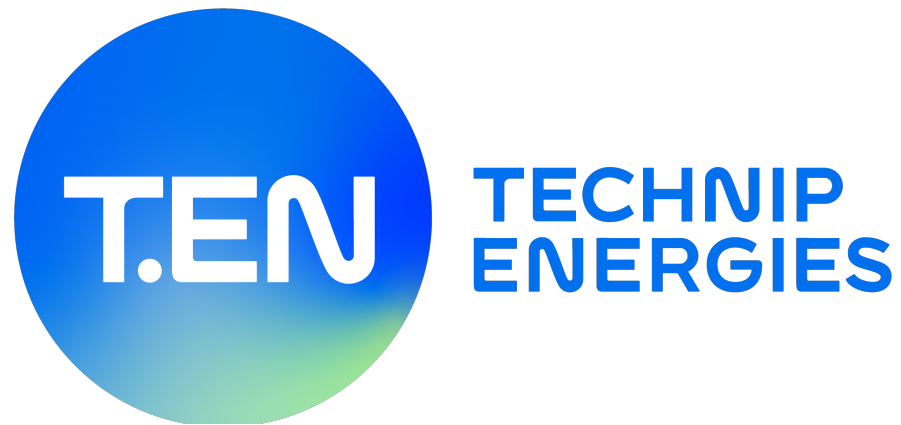


Where energies make tomorrow ●



**CLARIANT** 



# EARTH<sup>®</sup> : Enhancing Steam Reforming Operation and Reducing Carbon Footprint

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01

# Introduction



# Clariant is a Global catalyst manufacturer with a broad portfolio, building on innovation and partnerships

## Production sites

15 production sites on 4 continents

## Locations

31 locations in 15 countries

## R&D Centers

10 R&D centers worldwide

## Sales in 2023

1 000 in million CHF

## People

2,161 Staff in FTEs at year-end

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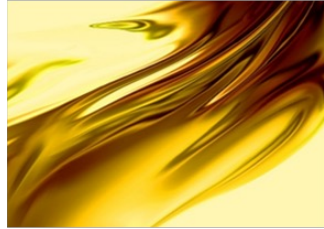
CONFIDENTIAL – T.EN EARTH® Technology

# Catalysts Applications



## SYNGAS

- Ammonia
- Methanol
- Hydrogen
- **Fuel Cell**
- GTL/Fischer-Tropsch
- Low-carbon ammonia
- Low-carbon methanol



## REFINERY / FUELS

- Gasoline Isomerization
- Gasoline from Olefins
- Diesel from Olefins
- Diesel Dewaxing
- Fuels from alternative feedstocks
- Purification of gaseous and liquid streams



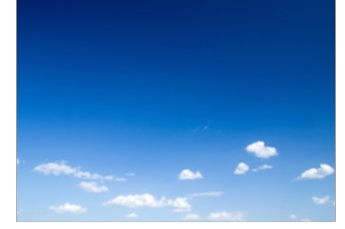
## PETROCHEMICALS

- Steam cracker
- Olefins purification
- Ethylene derivatives
- Styrene
- On-purpose Propylene
- On-purpose Butylene
- Polypropylene



## CHEMICAL CATALYSTS

- Oxidation
- Hydrogenation
- Bio-based feedstock
- Fine Chemicals
- Custom Catalysts



## EMISSIONS CONTROL

- Industrial off-gas treatment
- Exhaust gas treatment for stationary engines
- Zeolite powders for diesel exhaust applications

# Technip hydrogen heritage

Member of



Hydrogen Council

~60 years of T.EN hydrogen technology and product leadership

280+

H<sub>2</sub> and Syngas references

50+

References of carbon capture (CO<sub>2</sub>) from H<sub>2</sub> plants

40+

Plants for Air Products \*

\* Global alliance since 1992

14+

H<sub>2</sub> plants with TPR®

>30%

Global installed H<sub>2</sub> capacity

50+

Years of extensive H<sub>2</sub> experience

40+

H<sub>2</sub> plants w/ pre-reformer for multi-feedstock

3+ applications of

EARTH®

- **Leading-edge hydrogen technology** with high-temperature reaction kinetics expertise
- **Numerous in-house technological advances**, e.g., in steam reforming and feed flexibility (>60 plants)
- **Presenting many industry's firsts**, e.g., PSA, pre-reformer, high quality steam, cost effective revamp for capacity increase/ more efficiency, etc.
- **Decarbonized (Hydrogen) fuel**: a) 100% H<sub>2</sub> firing successfully tested for LSV burners; b) implemented in T.EN steam crackers with up to 85% H<sub>2</sub> firing





# Technip Portfolio summary

leading suite of low-cost, low-carbon hydrogen generation solutions

BlueH<sub>2</sub><sup>™</sup>  
by T.EN 2



Up to 99+% reduction in carbon footprint compared to traditional hydrogen production

- from ~10 down to ~0.1 kilogram CO<sub>2</sub> per kilogram H<sub>2</sub>
- carbon-negative KPI in case of renewable feedstock



Maximum hydrogen yield



Minimum energy demand (fuel + power)



Highly-efficient carbon avoidance and capture utilization & storage (CCUS) techniques



Lowest (levelized) cost of hydrogen “LCOH”



Comprised of “flight proven” proprietary technologies and equipment



Full suite of solutions, flexibility to be tailored to every application

- decarbonization of refining, power, chemicals, LNG etc.

**Built upon T.EN’s proven suite of technologies for a (ultra-) low-carbon flowsheet  
→ for both grassroots and retrofit applications**





02

# Background and Technology

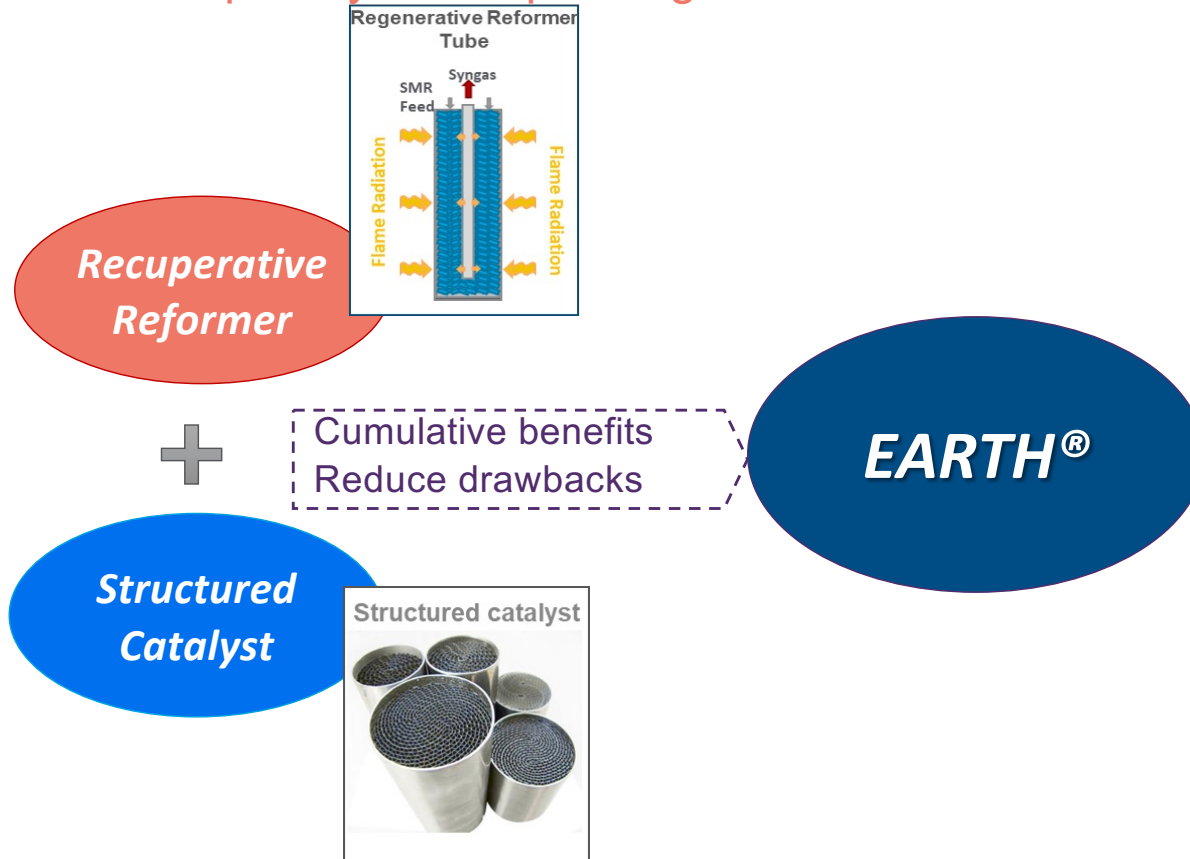
EARTH<sup>®</sup> at a glance



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# EARTH<sup>®</sup> Technology

Co-Developed by Technip Energies and Clariant



## Benefits of EARTH<sup>®</sup>:

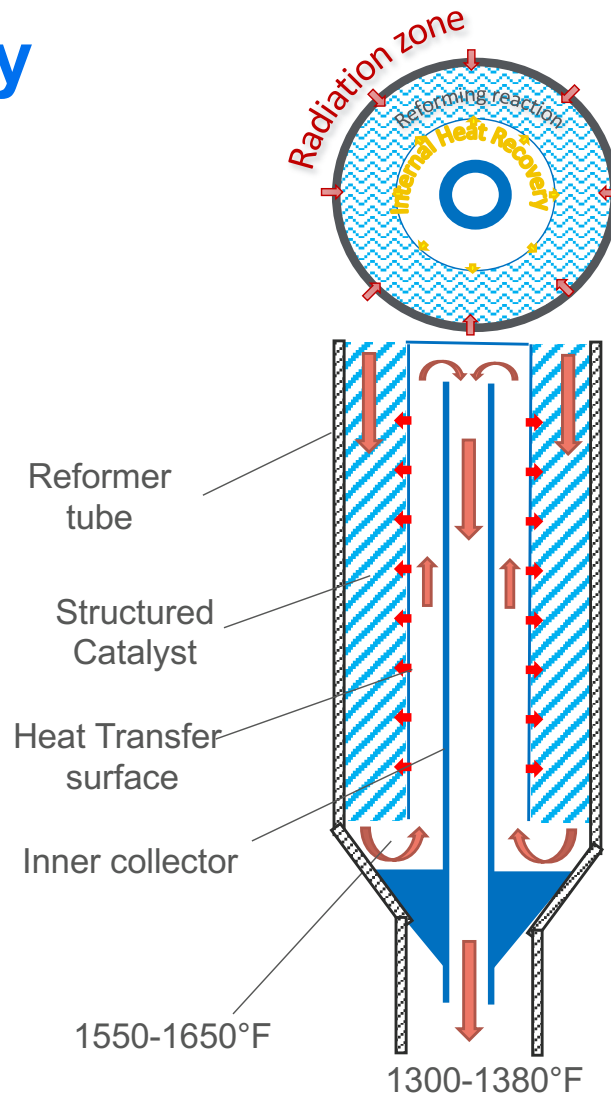
- Internal heat recovery resulting in reduced external heat demand;
- Highly active low pressure drop catalyst;
- Highly customizable towards client requirements;
- **Drop-in solution for existing plant revamps and new installations.**

# EARTH<sup>®</sup> Technology

## Enhanced Annular Reformer Tube for Hydrogen and Syngas

*Achieves simultaneously higher catalytic activity & heat recovery*

- Drop in solution applicable to new and existing reformer tubes
- Internal heat recovery resulting reduced firing demand
- Highly active low pressure drop catalyst
- Fuel savings and CO<sub>2</sub> footprint reduction;
- Enabling low carbon footprint hydrogen production in combination with CO<sub>2</sub> capture and utilization (Blue H<sub>2</sub>);

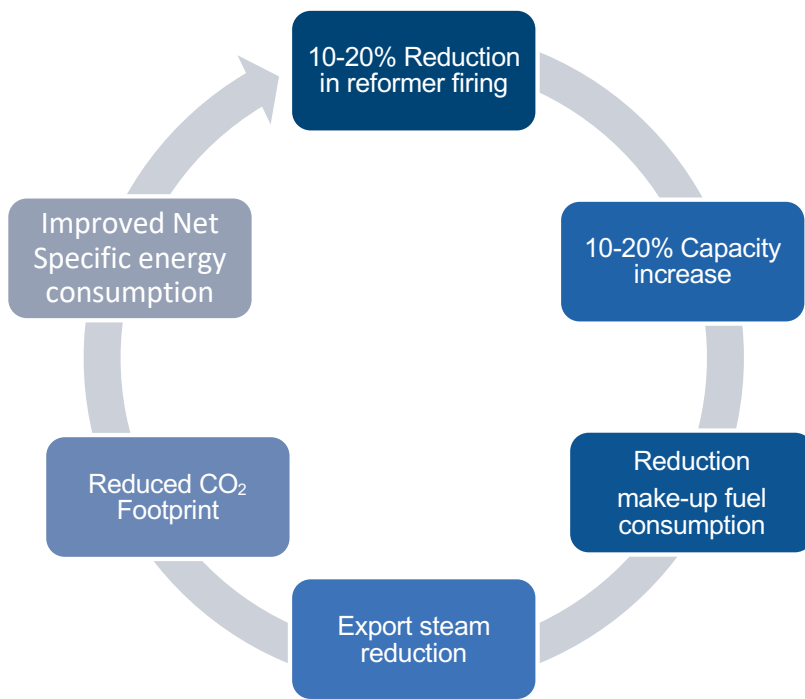


EARTH<sup>®</sup> tubes in-tube thermocouples



# EARTH<sup>®</sup> Technology

- Innovative, proprietary reforming technology by Technip Energies
- High Performance Structured catalyst co-developed by Clariant



EARTH<sup>®</sup> is a drop-in solution - can be applied to new and existing reformer tubes.

- Heat recuperative technology – reduced fired heat demand resulting in reduced fuel consumption.
- Increased productivity by higher throughput and improved heat utilization in SMRs;
- Fuel savings and CO<sub>2</sub> footprint reduction;
- Enables low-carbon hydrogen production (Blue H<sub>2</sub>);
- Applicable for revamp and grassroot applications;
- Proven in operation.



03

# First Applications

References

# First application of EARTH®

## Revamp of existing syngas plant in southern Europe

- 10 tube top-fired reformer with conventional tube dimensions
- Goal: energy savings
- Short project time for executing
- Combined with catalyst tube replacement

### Short execution time – Minimum time at site

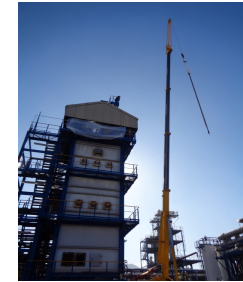
- Catalyst changeout or Tube replacement
- Conventional start-up

## First Application timeline

Month 0: design internal and catalyst



Month 6: installation and start-up



Tube installation with EARTH® inside and EARTH® in operation

# EARTH® References

## References

### 1<sup>st</sup> reference Ak-Kim, Turkey

- Syngas plant in operation since 2019

Akkim



	Conventional pellet catalyst	EARTH®
CO <sub>2</sub> emission	Base	-20%*
Fuel consumption	Base	-37%
Approach to equilibrium	< 10°C	< 3°C
Export steam	Base	-57%
Catalyst lifetime	>4 years	>>6 years
Pressure drop	~2 bar	<1.5 bar
Tube metal temperature	base	-10°C

\* CO is part of product so no CO<sub>2</sub> from process gas to fuel



### 2<sup>nd</sup> reference, Europe

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

### 3<sup>rd</sup> reference Repsol, Europe

- Start-up Q1 2024
- Grassroot reformer
- Biofuels application







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# EARTH<sup>®</sup> benefits

Capacity increase  
Energy Savings  
New Hydrogen Plants

# EARTH<sup>®</sup> benefits

## Installation

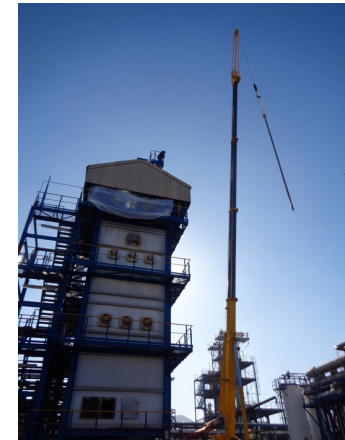
EARTH<sup>®</sup> is a drop-in solution and can be applied to new as well as existing reformer tubes.

Installation comparable to a catalyst change-out

- Can be matched with typical turnaround schedule
- Saves tube lifetime for existing reformer tubes

Installation of EARTH<sup>®</sup> can be combined with high value maintenance

- When catalyst tube replacement required due to end of life condition, take benefit of new catalyst tube materials



Tube installation with EARTH<sup>®</sup>



EARTH<sup>®</sup> tubes in-tube thermocouples



# EARTH<sup>®</sup> benefits

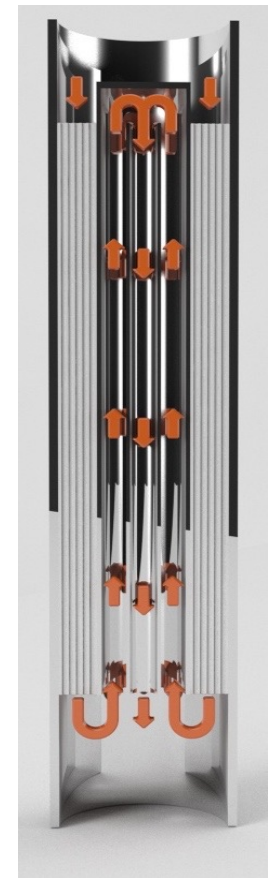
## Benefits compared to conventional SMR

### Heat recovery plus structured catalyst allows for increased throughput per tube

- Internal heat recovery reduces firing demand;
- High surface area catalyst ensures high catalyst activity;
- Low pressure drop catalyst avoids hydraulic limitations in reformer tube;
- Internal heat recovery combined with the structured catalyst reduces Tube Wall temperature.

### Heat recovery plus structured catalyst tailored to achieve specific plant requirements:

- Capacity increase scenario in existing plant;
- Energy savings scenario in existing plant;
- Low CO<sub>2</sub> footprint grassroots plant.



# EARTH<sup>®</sup> benefits

For capacity increase compared to conventional SMR

## EARTH<sup>®</sup> enables capacity increase with minimal in the plant:

- Avoiding limitations in firing system;
- No hydraulic limitations in the reformer;
- Decreased hydrocarbon consumption per hydrogen produced;
- Decreased CO<sub>2</sub> emissions per hydrogen produced.

**Minimal modifications in plant required.**

## EARTH<sup>®</sup> performance

- Feed 10-20% increase\*
- Fuel up to 30% lower\*
- Hydrogen CO<sub>2</sub> footprint up to 10% lower\*
- Ratio of feed + fuel to hydrogen improved\*
- Bridge wall T equal or lower\*
- Steam production lower or equal\*
- Pressure drop lower or equal\*
- Tube metal temperature usually lower\*

\*compared to base case

# EARTH<sup>®</sup> benefits

For Energy savings compared to conventional SMR

**EARTH<sup>®</sup> is a direct drop-in solution for energy savings:**

- Lower emissions;
- Lower hydrocarbon consumption;
- Lower steam production;
- Excellent fit with CO<sub>2</sub> capture technologies.

**Minimal modifications in plant required.**

## EARTH<sup>®</sup> performance

- Feed same or slightly lower\*
- Fuel up to 50% lower\*
- Hydrogen CO<sub>2</sub> footprint up to 10% lower\*
- Ratio of feed + fuel to hydrogen improved\*
- Bridge wall T lower\*
- Steam production up to 50% lower\*
- Pressure drop lower or equal\*
- Tube metal temperature lower\*

\*compared to base case

# EARTH<sup>®</sup> benefits

In grassroot compared to conventional SMR

## EARTH<sup>®</sup> enables further heat integration and thus highly energy efficient plant:

- Lower emissions;
- Reduced plot size;
- Tailor-made performance to match refinery steam demand.
- Excellent fit with CO<sub>2</sub> capture technologies.

## EARTH<sup>®</sup> performance

- Feed same or slightly lower\*
- Fuel up to 50% lower\*
- Hydrogen CO<sub>2</sub> footprint up to 10% lower\*
- Ratio of feed + fuel to hydrogen improved\*
- Bridge wall T equal or lower\*
- Steam production lower or equal\*
- Pressure drop lower or equal\*
- Tube metal temperature usually lower\*

\*compared to base case



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# EARTH<sup>®</sup> case studies

Capacity increase scenario  
Energy savings scenario



# EARTH<sup>®</sup> case studies

## Capacity increase scenario for US based plant

PARAMETER	UNIT	ORIGINAL HMB	MAXIMUM CAPACITY WITH EARTH <sup>®</sup>	
H <sub>2</sub> Capacity	MMSCFD	65	<b>80</b>	(+23%)
NG per H <sub>2</sub> produced	ton/ton	3.53	3.40	(-4%)
RFG fuel per H <sub>2</sub> produced	ton/ton	0.60	<b>0.55</b>	(-7%)
Export steam per H <sub>2</sub> produced	ton/ton	8.07	<b>5.95</b>	(-35%)
Flue Gas Flowrate to fan	m <sup>3</sup> /h	base	<b>+ 15%</b>	
CO <sub>2</sub> emissions per H <sub>2</sub> produced	ton/ton	10.4	<b>9.9</b>	(-4%)
Catalyst outlet temperature	°F	1515	1549	
PGB inlet temperature	°F	1515	1335	
Bridge wall temperature	°F	1836	1904	
Tube wall temperature (TWT)	°F	1594	1645	

**Capacity increase from 65 to 80 MMSCFD is achieved with EARTH<sup>®</sup>:**

- No change in fans, convection section, reformer, steam system, etc;
- Minor drop absolute export steam flowrate
- Expected modifications: burner gun, PSA revamp, minor modifications in cooling train.
- With same reformer pressure drop as original capacity
- Decrease hydrocarbon consumption and CO<sub>2</sub> emission per hydrogen produced.

# EARTH<sup>®</sup> case studies

## Energy intensification with EARTH<sup>®</sup>

PARAMETER	UNIT	HIGH HEAT RECOVERY	HIGH HEAT RECOVERY WITH EARTH <sup>®</sup>	
H <sub>2</sub> Capacity	MMSCFD	45	45	(-0%)
NG feed per H <sub>2</sub> produced	ton/ton	2.7	2.7	(-0%)
NG fuel per H <sub>2</sub> produced	ton/ton	0.6	0.3	(-50%)
Export steam H <sub>2</sub> produced	ton/ton	6.1	1.2	(-80%)
CO <sub>2</sub> emissions per H <sub>2</sub> produced*	ton/ton	<b>9.1</b>	<b>8.2</b>	<b>(-10%)</b>
Catalyst outlet temperature	°F	1706	1706	
Tube outlet temperature	°F	1706	1346	

\*Conventional SMR based plant has CO<sub>2</sub> emissions of 9-11 ton CO<sub>2</sub>/ ton H<sub>2</sub> produced

## CO<sub>2</sub> emission reduction with EARTH<sup>®</sup>:

- Decrease in hydrocarbon consumption and CO<sub>2</sub> emission per hydrogen produced.
- Reduced tube metal temperature and thus longer tube lifetime.
- For grassroot plant, reduced reformer size with reduced emissions.
- Excellent fit with CO<sub>2</sub> removal technology



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# Summary EARTH®



# Conclusions

**EARTH<sup>®</sup> is a proven technology that plays an important role in today's world energy transition**



Tailor made tubes and internals



Reduced CO<sub>2</sub> emissions



High heat transfer and recovery



Energy savings (feedstock and fuel) of up to 10%



High activity and low pressure drop



Capacity Increase up to 20%



Stable and robust catalyst

# Thank You

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