TECHNIP ENERGIES

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Technologies to Decarbonize Hydrogen Production

The Future of Gas

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Technip Energies

A Changing World…

Requiring a low-carbon and sustainable future

Energy Transition is our business

Applying our core capabilities to today and tomorrow's key energy challenges

LNG
Onshore and offshore liquefaction

Sustainable chemistry
Biofuels, biochemicals, circular economy

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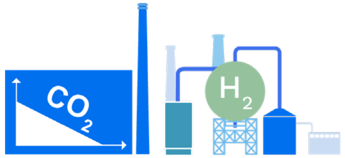
Carbon-free energy solutions
Green hydrogen, offshore wind, nuclear



Decarbonization
Energy efficiency, Blue hydrogen, CCUS[1]

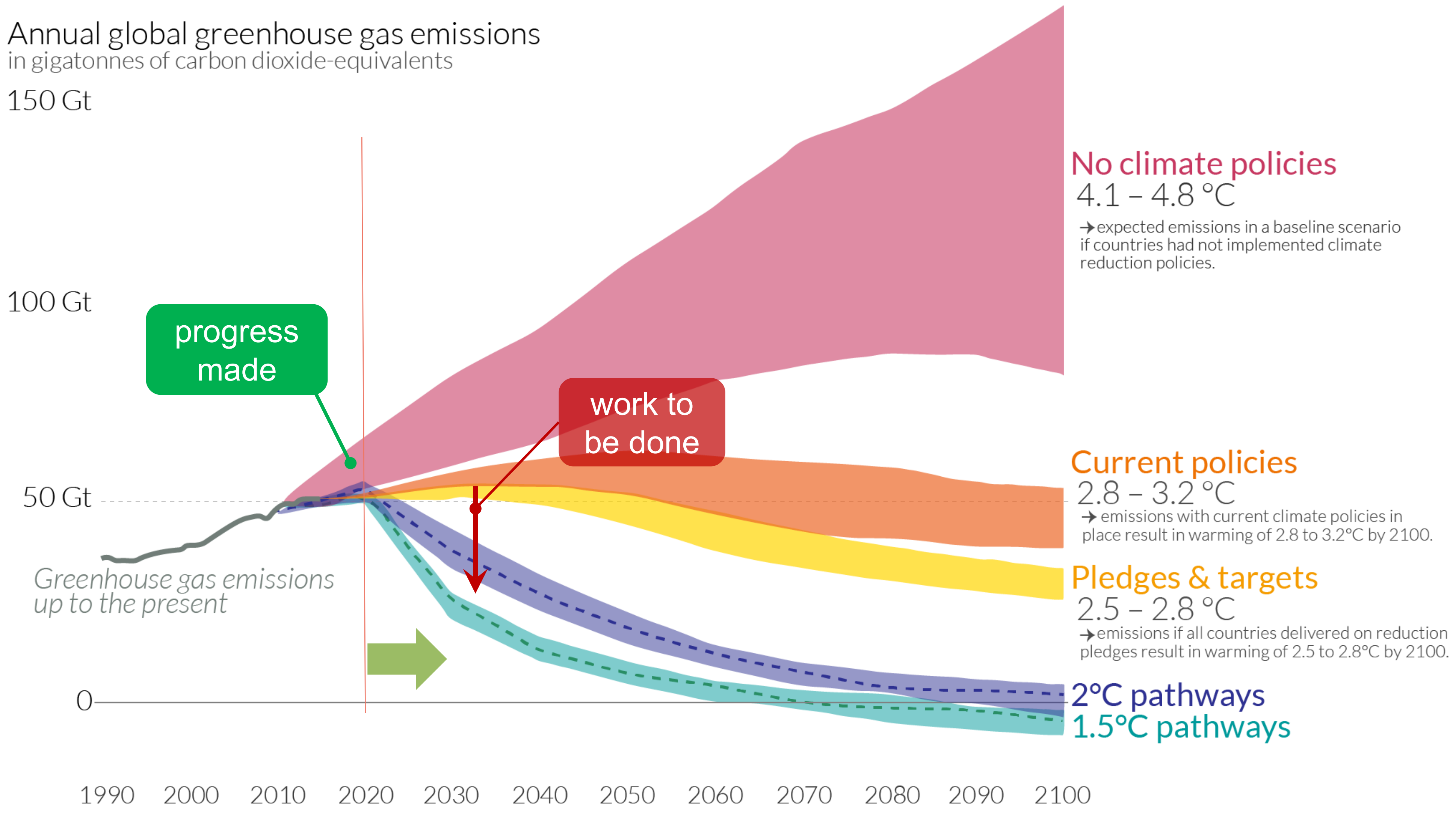
Strategic flexibility – 'architect mindset' meeting customer needs from energy source to end-use

- **Feedstock agnostic** – outstanding energy molecule transformation capabilities
- **Technology-driven** – integrate complex technologies, including proprietary, to meet project specificities and economic hurdles

Exceptional execution – proven operating model, highly applicable to sustainable energy solutions

[1]CCUS: Carbon Capture, Utilization and Storage.

The Energy Transition - from 50 Gta CO_2eq emissions to…



Data source: Climate Action Tracker (based on national policies and pledges as of December 2019).
OurWorldinData.org – Research and data to make progress against the world's largest problems.

Why hydrogen?

Because it holds promise to decarbonize so many "hard-to-abate" sectors

H_2

Storage, distribution, Conversion

Storage
Salt Caverns, Tanks, Others

Transportation
Pipeline, Compression, Liquefaction

Conversion
Ammonia, Methanol, LOHC and other Hydrogen Carriers

Syngas or Blending
Methanation
Gas Network

H_2 / Carrier

End Use

Mobility
Cars, Buses, Trucks, Trains, Ships, Aviation

Residential, Commercial
blending in gas network, municipal scale CHP

Industry
(feedstock, heat)
Refining, Steel, Cement etc.

Power Generation
Re-electrification

Why hydrogen?

Because it holds promise to decarbonize so many "hard-to-abate" sectors

- Extreme large market potential for hydrogen in near term as…
  carbon-free fuel substitute & clean carrier
  - ➔ Some forecasts show 'pure' market volume growing from 75 Mta to >500 Mta by 2050

- If 10% of European natural gas consumption were replaced by H_2…
  - ➔ ~500 BCM/y ÷ 8760 h/y × 10% = 5.7 Mln Nm^3/h NG
  - ➔ × 3.4 (volumetric LHV ratio) = **~20 Mln Nm^3/h H_2**
  - ➔ 20,000 kNm^3/h | or ~100 large scale plants of ~200 kNm^3/h

- Largest CO_2 emitting slice is power generation - clean hydrogen has a large role to play here (e.g. intermittency and topping for renewable electricity)

- Large potential to retrofit and repurpose existing hydrogen manufacturing fleet

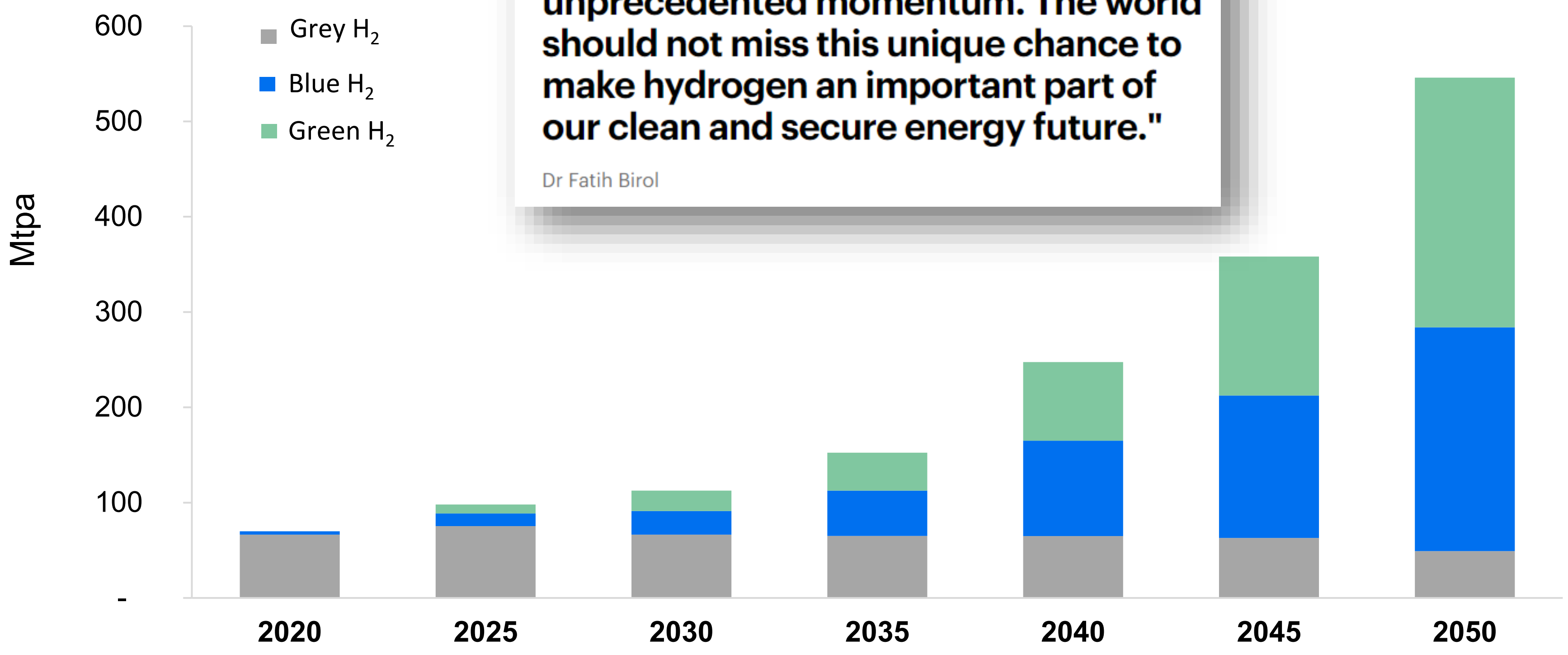
The changing role of hydrogen

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: IEA, Hydrogen Council, Barclays



"Hydrogen is today enjoying unprecedented momentum. The world should not miss this unique chance to make hydrogen an important part of our clean and secure energy future."

Dr Fatih Birol

Forecasts vary, and depend heavily on expectations for transport and heating
Many anticipate electrolysis to take 10-15 years before significant market share
Legacy + decarbonized hydrogen seen to dominate share for foreseeable future

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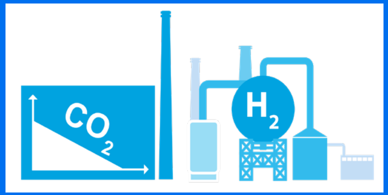
Colors of hydrogen

Blue Hydrogen

produced from non-renewable sources with a **low** or **mitigated** carbon footprint.

Produced Carbon Dioxide is captured from high pressure process gas or low-pressure flue gas for subsequent use or sequestration ("CCUS") to arrive substantially reduced GHG footprint.

Blue H_2 will play a role in the Energy Transition, as an immediate and affordable step to reduce carbon footprint.



Green Hydrogen

produced from renewable energy sources, such as renewable electricity or carbon-neutral feedstock.

Green H_2 is associated with the "Hydrogen Economy", a future scenario where hydrogen is widely used as a carbon-free energy carrier, and a fundamental alternative to fossil fuels.

Our Hydrogen Heritage

280+

H_2 references

50+

References of carbon capture (CO_2) from H_2 plants

40+

Plants for Air Products *

* Global alliance since 1992

10+

H_2 plants with TPR®

>30%

Global installed H_2 capacity

50+

Years of extensive H_2 experience

40+

H_2 plants w/ pre-reformer for multi-feedstock

1st Industrial application of

EARTH ®

- **Leading-edge reforming 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, prereformer, high-quality steam, cost effective revamp for capacity increase, etc

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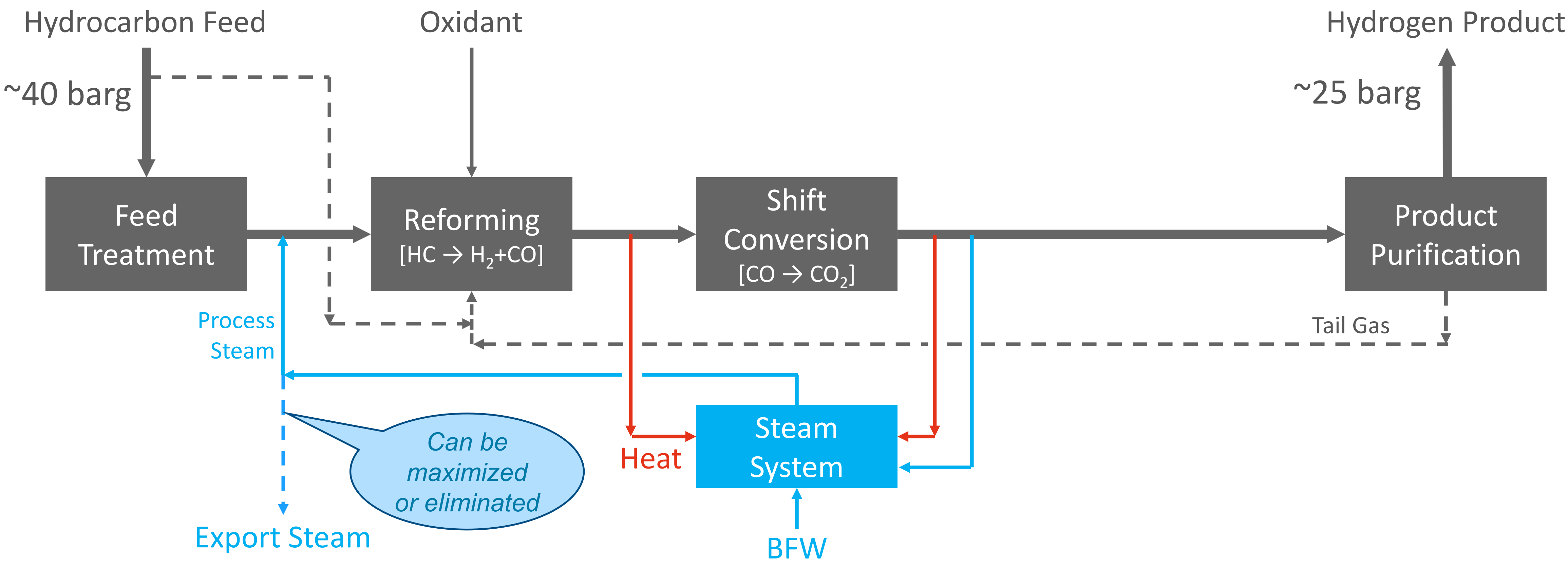
Basic (grey) hydrogen plant

block scheme



Most hydrogen plants are **co-generation** plants:
energy exported in multiple forms: hydrogen, steam, power…

Sources of CO_2 in hydrogen production from hydrocarbons

Sources

Steam Methane Reforming

$CH_4 + H_2O \rightarrow CO + 3H_2$

Water Gas Shift Reaction

$CO + H_2O \rightarrow CO_2 + H_2$

Combustion

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

1 kg of H_2 production typically emits 8-12 kg CO_2 (grey hydrogen)

- Methane reacting with steam in overall reforming and shift 5.5 kg CO_2 / kg H_2
- Methane reacting with oxidant 1.7 kg CO_2 / kg H_2
- Co-produced export steam 0 - 4 kg CO_2 / kg H_2 (Typical 0.15-0.20 kg CO_2 / kg steam)

Baseline depends on:

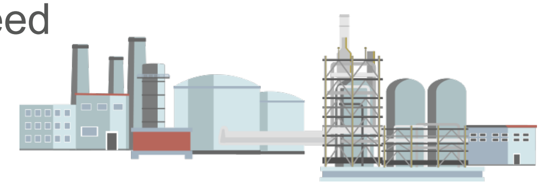
- feedstock quality (H/C ratio, fossil C content)
- process scheme
- quantity of export steam/power etc.
- quantity/dependency on imported resources, and their carbon footprints

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

CO_2 avoidance & capture

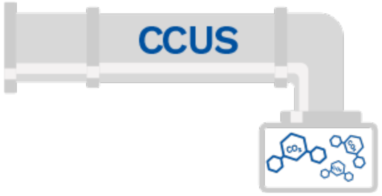
CO_2 Avoidance (proactive abatement)

- Objective – reduce baseline CO_2 intensity of the process
- Reduce reformer firing
- Maximize efficiency
- Maximize direct yields
- Minimize specific hydrocarbon and energy consumption ("pinch the unit")
- Utilize carbon-neutral feed



CO_2 Capture (reactive abatement)

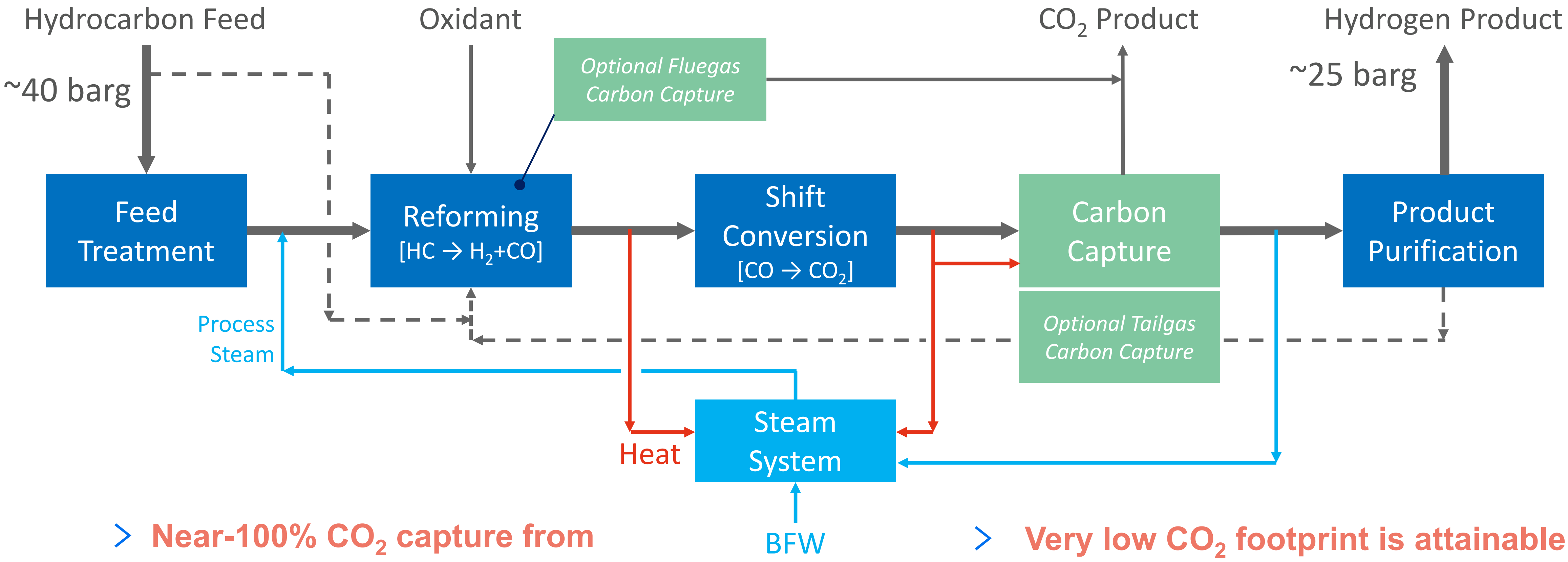
- Pre-combustion CO_2 capture from process
  - Many references on syngas, high capital efficiency
  - LP tail gas alternative – few references
- Post-combustion CO_2 capture from flue gas
- Applications:
  - Carbon use and/or storage (CCUS)
  - Enhanced Oil Recovery
  - Chemical end-products
  - Agriculture
  - Synfuels



Carbon capture from process gas is proven technology, for both grassroots & retrofits

Low-carbon (blue) hydrogen unit

block scheme



- **Near-100% CO_2 capture from process (proven in HyCO units)**
  → more cost-efficient than low pressure capture

- **Very low CO_2 footprint is attainable**
  → below 1 $kgCO_2/kgH_2$ direct + indirect
  → 50+ pre-combustion CO_2 Capture references so far

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Air Products/Repsol refinery

CO_2 capture in hydrogen unit (solvent absorption)

Hydrogen Project

Contract: Hydrogen & CO_2 Capture Plant

Start-up: 2002

Client: Air Products/ Repsol,

Location: Tarragona, Spain

Key figures

Capacity: ~60,000 Nm^3/h Hydrogen

Natural Gas & Naphtha feed

CO_2 capture ~ 210 TPD

Food-grade CO_2 product

Project was executed under long-term alliance agreement.

Air Products for Bharat Petroleum

Two SMR trains with cryogenic purification of syngas byproduct

Hydrogen Project

Contract: EPC Services
Status: Start-up 2016
Client: Air Products
Location: Kochi, India

Key figures

Capacity: 15 t/h hydrogen
(in 2 trains) + approx. 14 t/h syngas

Naphtha + Natural Gas feed

Gas turbine integration in reformer firing

280 TPD CO_2 removal

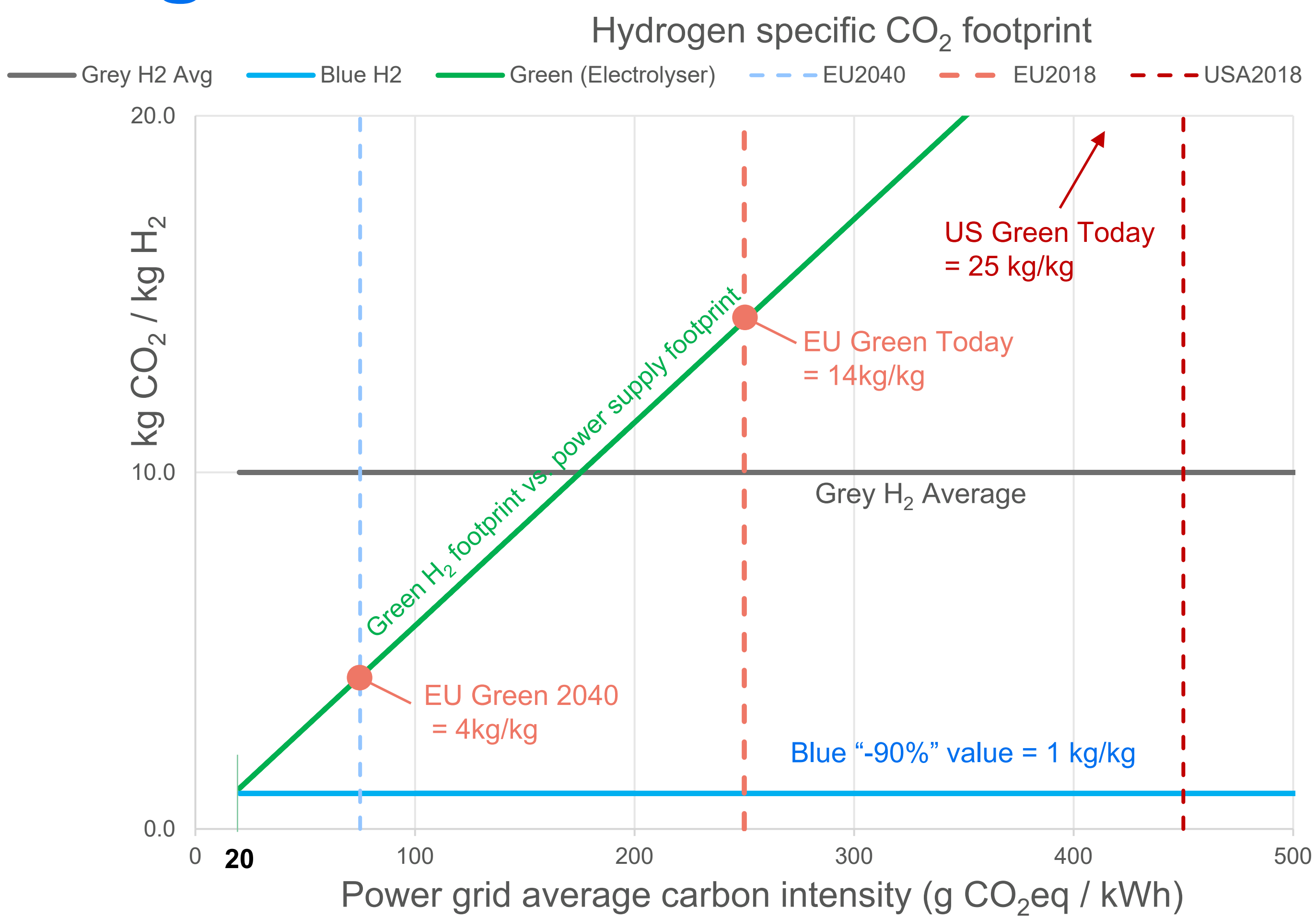
What defines “clean hydrogen”?

no universally accepted definition

Grey	=	8 - 12	$kgCO_2/kgH_2$
Blue	=	0.5 - 4.0	"
		[<0.4 is technically feasible]	
Electrolyser	=	0.5 - 45	$kgCO_2/kgH_2$

According to IPCC 2014 A.III.2, lifecycle basis:

• Coal	820	g CO_2eq / kWh
• Solar PV	45	"
• Geo	38	"
• Hydro	24	"
• Ocean	17	"
• Nuclear	12	"
• Wind	11	"



Where CCUS is possible, Blue defines most effective technique (MET) today.

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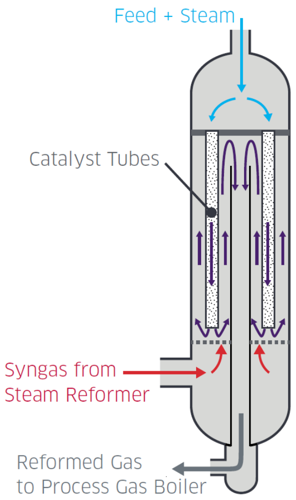
Recuperative Reforming

TPR®

Technip Parallel Reformer

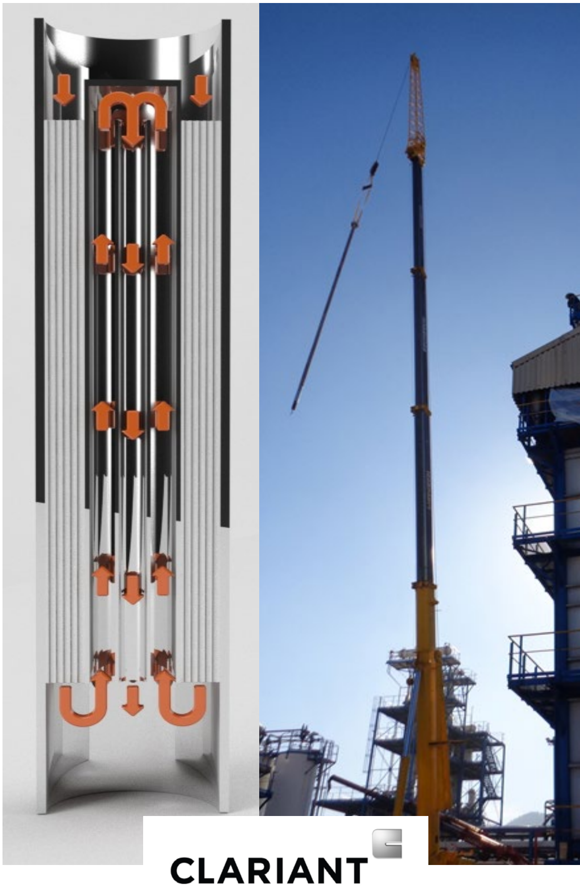
- Lower hydrocarbon & energy consumption
- Deployed up to 160kNm^3/h capacity and growing
- 13 installations and counting; successful operation for over 20 years



EARTH®

Enhanced Annular Reforming Tube for Hydrogen

- Latest addition to technology portfolio
- Technip Energies IP
- Simple drop-in, minimum CapEx
- Install in existing or new reformer tubes
- Intensify throughput and heat integration
- Proven in operation



Increase H_2 yield | Reduce CO_2 footprint | Retrofit for up to +30% capacity

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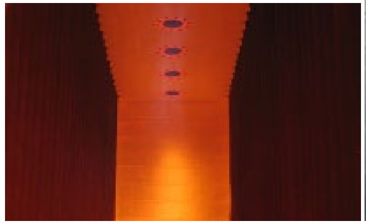
Technip Large Scale Vortex LSV® Burner

Features	Benefits
Unique nozzle to rapidly dilute fuel	Flameless combustion Ultra-low NOx
Very flexible fluidic flame stabilizer	Ultra-lean and cool primary flame
Robust design	Reliable
Versatile orientation	Applications in wide range of furnaces
Shielded fuel lances	Low maintenance tips
Adjustable and uniform flame heat release profile	Heat release matching process requirements Lower radiant tubeskin temperatures
Wide range of fuels	natural gas, hydrogen PSA purge gas, refinery fuel gas etc.



- **Reduced NOx and CO_2**
- **Improved efficiency or heat distribution**

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Our blue hydrogen solutions

Building blocks for low-carbon solutions

BlueH$_2$™ by T.EN

High Conversion Reforming

- Enhanced SMR “ESMR”
- TPR® / EARTH®
- Oxidative Reforming

- **SMR (incl. recuperative reforming through TPR®/ EARTH®) achieves complete steam balance & reduced carbon footprint**

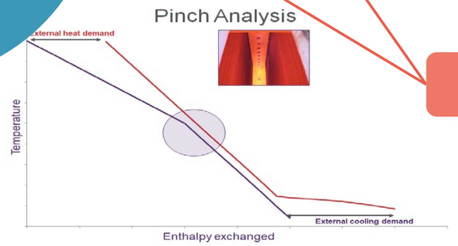
T.EN Proprietary

Tailored Product Purification

High-Efficiency Carbon Capture

Deep CO Shifting "DeepShift”

Heat Integration & High Efficiency



T.EN know-how

- **95+% CO_2 capture based on advanced solutions (up to 99% feasible)**
- **Lowest capex & LCOH blue H_2 plant**
- **Low energy & power demand**

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Blue H_2 by Technip Energies

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

BlueH™ 2 by T.EN

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

- from ~10 down to ~0.1 kilogram CO_2 per kilogram H_2
- 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.

Hydrogen production options – comparative overview

KPI	Grey (Baseline)	Zero Steam (TPR®/EARTH®)	Basic Blue Process	Blue H_2 by T.EN
Net specific energy demand	1	1.03	1.06	1.1
Steam export?	Y	N	N	N
Carbon capture?	N	N	Y	Y
Carbon footprint	**1**	**0.8**	**0.2-0.3**	**<0.1**
Investment burden	1	1.1	1.2	1.3
Levelized cost of hydrogen (LCOH)	1	1	1.2	1.5
Plot area	1	1	1.2	1.3

- **T.EN Blue H_2 is based on our best suite of technologies for a low carbon flowsheet**
- **T.EN Blue H_2 is for now the most (cost) effective solution, particularly as CO_2 pricing increases**

Main Take-aways

Main takeaways

The H_2 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.

BlueH$_2$™ by T.EN

Deeply decarbonized, "Blue H_2" is available and affordable for new plants and retrofits

Thank you