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Getting the Most From Your Hydrogen Plant
Use of H_2 for the production of green fuels

Part 1: Repurposing and optimizing existing H_2 plants
December 3, 2020

2020 AFPM SUMMIT
Excellence in Plant Performance

What is the AFPM Webinar Series?

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Agenda High Level Overview

1. Use of H2 in the production of green fuels?
2. Considerations to repurpose existing H2 plants and increase capacity

MATHESON
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3. Performance and Optimization of the Reformer during transitional operations

JM Johnson Matthey
Inspiring science, enhancing life

4. CI incentives to be considered in developing the existing and new hydrogen capacity for renewable hydroprocessing projects
5. The H2bridge™ case for additional H_2 capacity

HALDOR TOPSØE

Speaker

Marco A. Márquez
Director of Business Development – Refining
mamarquez@mathesongas.com

MATHESON

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Consideration for the Use of Hydrogen in the Production of Green Fuels

Marco A. Márquez

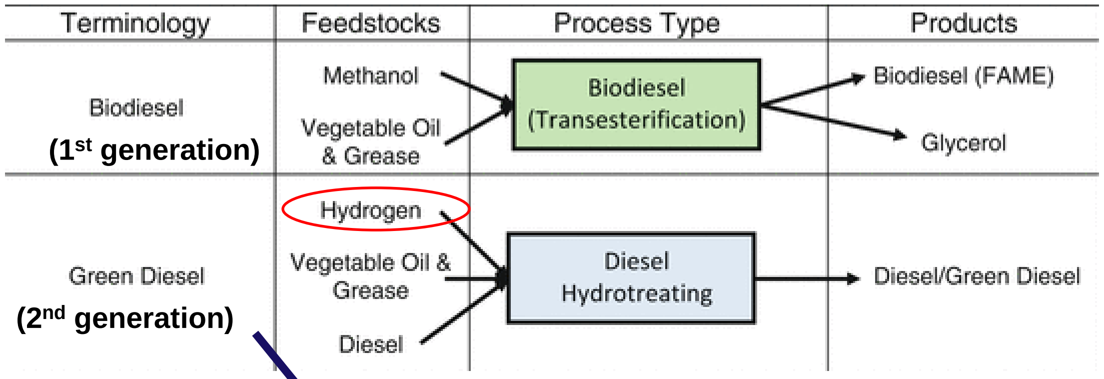
Agenda

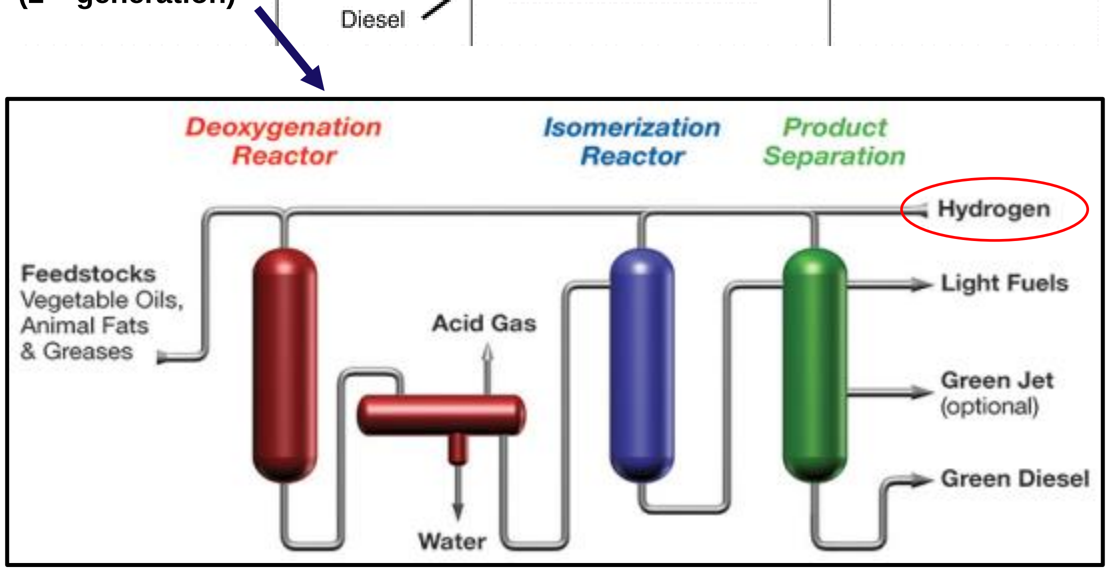
1. **Why is H2 needed in the production of green fuels?**
2. **Examples of System integration (use of off-gases from green fuel unit in H2 plant)**
3. **Hydrogen requirements and sources (existing sources, on-purpose H2, third party vs. new -next webinar-)**
4. **Advantages of third-party outsourcing (OTF)**
5. **Potential issues/needs for repurposing H2 plants to make green fuels**
6. **Possibilities to increase H2 capacity in existing units**

Why is Hydrogen needed for Green Fuel Production?

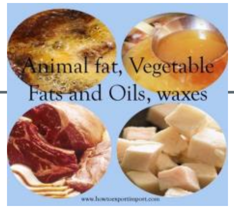
- **Renewable fuels: 1st vs. 2nd generation renewable fuels**
- **Green fuels: Converts renewable fats, oils, and greases into renewable diesel, jet and naphtha.**
- **This process is unique in that it produces fuels that are molecularly nearly identical to fuels produced from petroleum**
- **Multiple animal/vegetable feedstocks have been successfully tested:**
  - **waste oils (cooking oil), tallow, and distillers corn oil, camelina, canola, carinata (grapeseed), castor, coconut, corn, peanut, soybean, tung oil.**
- **Green diesel process requires large amounts of hydrogen: severe hydrotreating**

Renewable Diesel

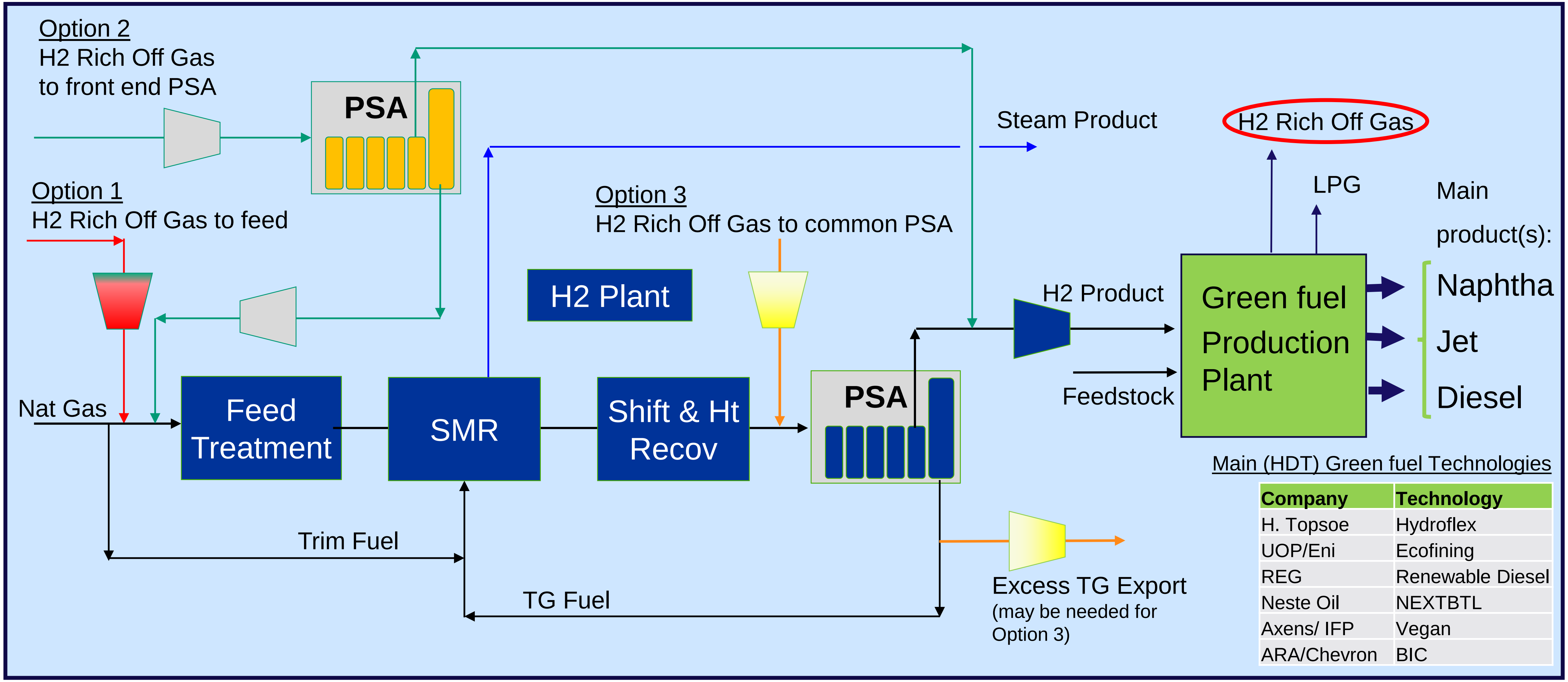




Source: https://www.greencarcongress.com/2017/03/20170317-uop.html



Example of System integration: use byproduct off-gases from green fuel in H2 plant



Company	Technology
H. Topsoe	Hydroflex
UOP/Eni	Ecofining
REG	Renewable Diesel
Neste Oil	NEXTBTL
Axens/ IFP	Vegan
ARA/Chevron	BIC

Hydrogen Requirements and Sources

- Hydrotreating animal/vegetable oils requires high-severity conditions to cope with the nature of the raw material.
- H2 consumption to produce green fuels is comparable/ higher than petroleum-based hydrocracking.
- Possible on-site H_2 source:
  1. Existing H2 from refinery process (e.g., CCR, PSA, H2 recovery from off gases, purges, other streams)
  2. Existing steam methane reformer (SMR)
     A. Owned/operated by customer (refiner)
     B. Owned/operated by Industrial Gas Company
  3. New SMR and synergies (Series 2 of webinar -2021-)
  4. Combination of the above

Process	Typical H2 use scf H_2/bbl
Isomerization, jet hydrotreating	50–150
Gasoline hydrotreating	100–150
Lube polishing	250–350
Heavy/coker naphtha hydrotreating	50–500
Gasoline hydrotreating (ULSG)	450–650
Diesel hydrotreating (ULSD)	450–1,200
Hydrocracking	1,800–2,000
Hydrocracking (residual upgrading)	1,400–2,500
Green fuels	**1,700–2,900**

H2 plant is a key contributor to the cost and overall environmental emissions.

Hence, it is important to optimize the H_2 process and its overall integration in the green fuel facility.

Slido Question #1

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Advantages of third-party outsourcing (OTF)

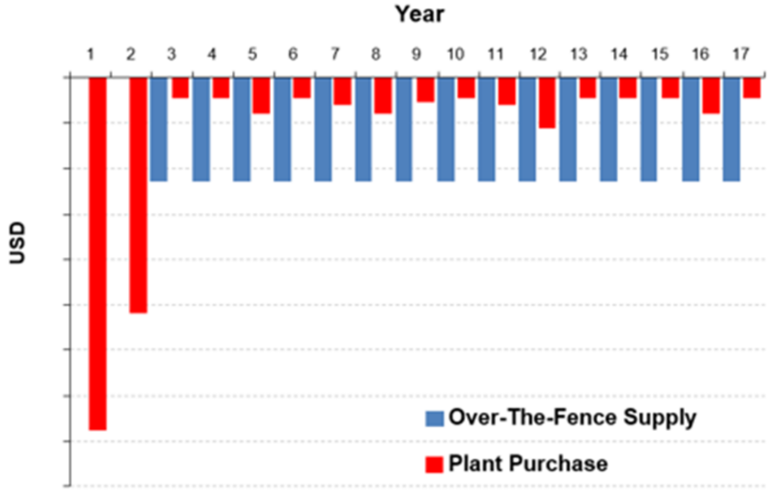
Main benefits: shift of risks, cash flow management and leverage operational experience from experts

- Project Execution: Cost and Schedule guaranteed. Avoid capex outflow.
- Operation & Maintenance (O&M): labor cost, routine/planed/unplanned/ turnaround included and guaranteed.
- Performance: guaranteed efficiency (H_2 cost), reliability, safety, O&M, of the unit during the life of the contract.

Purchase and reconditioning existing H_2 units from customer:

- Refiner may consider outsourcing its own plant. Possible reason(s):
  - Wants to focus on its core business (make fuels)
  - Is unable to operate the hydrogen plant as expected by design
  - Has high operating and/or maintenance costs
  - Needs cash/cash flow management
  - Understand/wants benefits of the outsourcing (Over The Fence or OTF)

Customer (Refiner) Cash Flow Comparison OTF vs. Ownership



Slido Question #2

Potential issues/needs/considerations for repurposing existing H2 plants

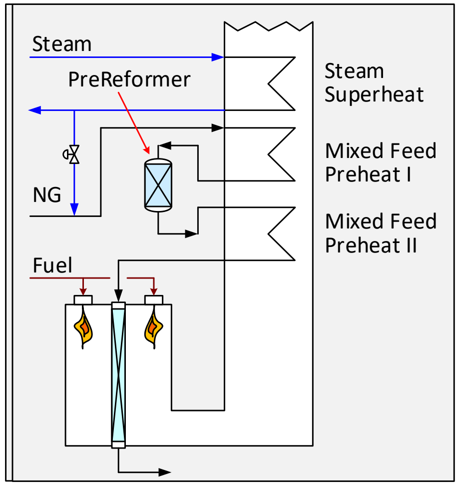
- Existing H2 source is old/inefficient, not able to operate reliably/meet capacity
- Need incremental capacity; substantially more (e.g., 5 - 25% more H2)
- Plant has bottlenecks: reformer, heat recovery, PSA, compression, other
- Plot space availability for additional equipment/expansion
- Air permit limitations
- Needs flexibility (turn down)
- Refinery steam balance unable to tolerate a change in SMR export steam
- Downtime unacceptable to accommodate modifications (loss of revenue)

Possibilities to increase plant capacity

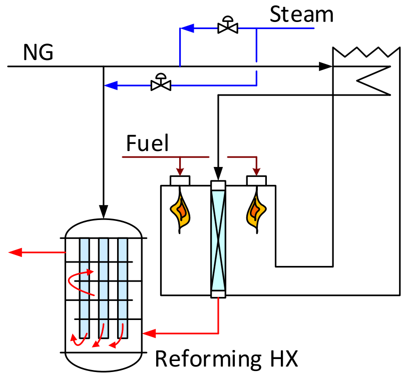
0-5% more H2	5-10% more H2	10-25% more H2

• Catalytic Options:
  • Structured SMR Catalyst
  • Non Iron based HTS
  • Add LTS Reactor
• Non-Catalytic Options:
  • SMR Tubes
  • ID Fan
  • PSA
  • Convection coils
  • Burners / Air enrichment
 	
Depending on the original design, the balance of plant (BOP) may be ok or a combination of changes needed
	• Depending on bottlenecks, could consider a combination of modifications from 0-5% range, or,
	• Addition of Pre-Reformer
	  • Moves radiant reforming duty to convection zone
	  • Convection coil(s) revamp
	  • Lowers steam export
	• Address BOP (ΔP, PSV, PSA)
		"Possible" Solution(s):
		• Post Reforming
		  • ATR / HX reforming
		• PSA (add beds, new adsorbent, valve skid)
		• Hydraulic study with smart modifications
		• Hurdles
		  • SMR limitation
		  • ΔP can double
		  • Design P's & PSV's
		  • HX area
		  • PSA capacity
		  • Permit

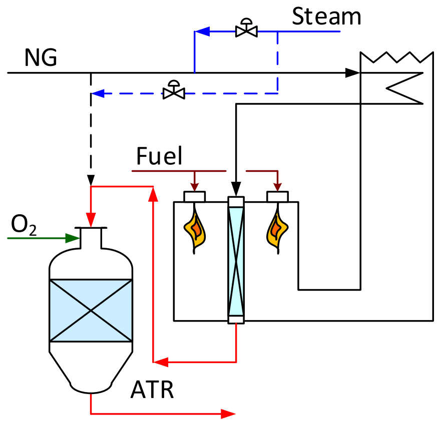
Pre-reformer



Post-reformer options



HX reforming



ATR

Source: AFPM Paper (Summit 2019)

Key take away

- **H2 plant is a key contributor to cost and emission in “green project”**
- **Integration (H2 + green diesel) offers advantages (byproduct use, emissions)**
- **Existing H2 source may be repurposed for green project… But is it worth? (plant age, efficiency, reliability, cost, emissions, permit, etc.)**

Speaker

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Inspiring science, enhancing life

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Johnson Matthey
Inspiring science, enhancing life

Operating at low rates and maintaining unit efficiency

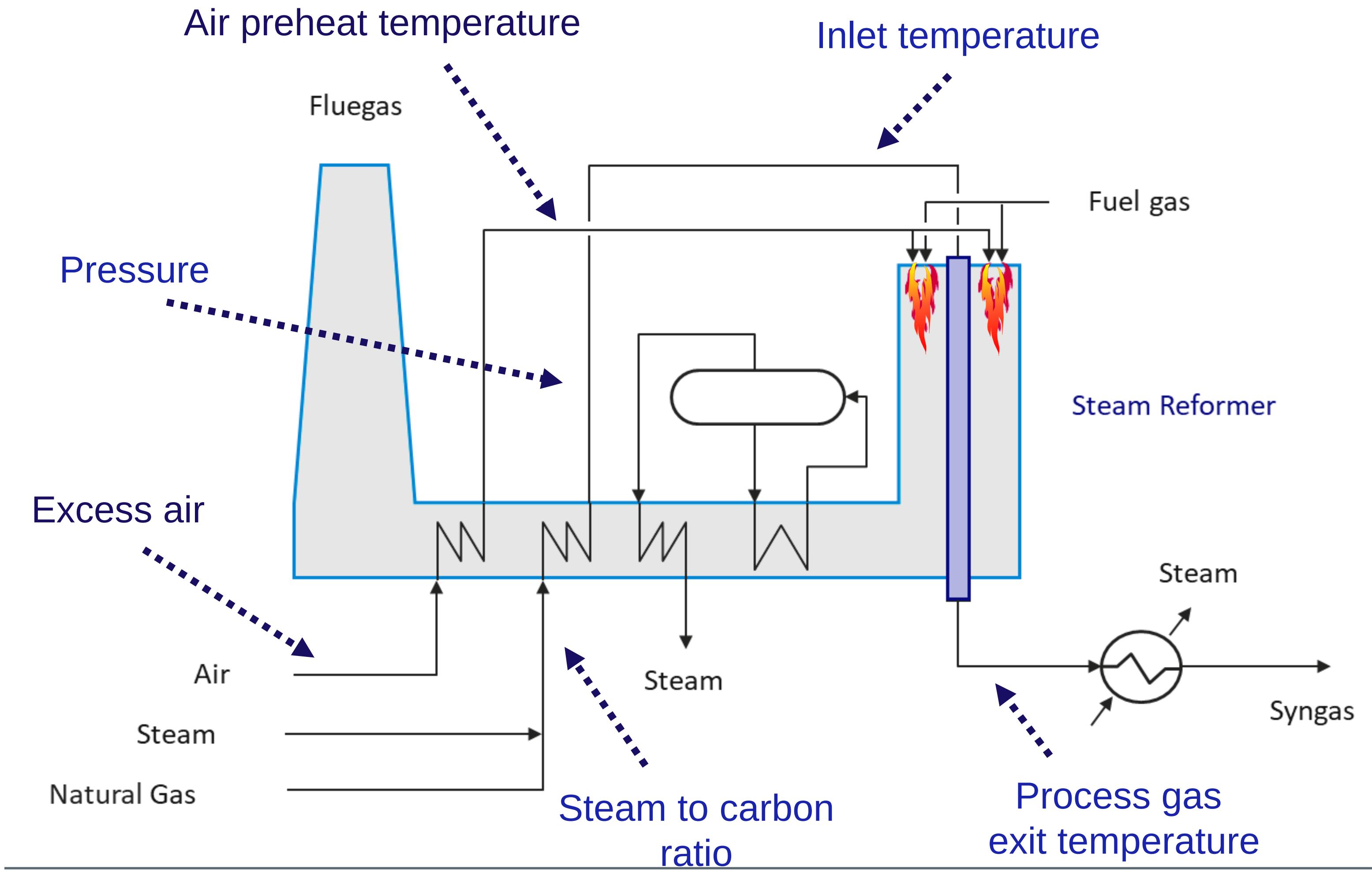
Joshua E. Siegel

Slido Question #3

Agenda

01	Process control variables and KPIs
02	Consequences of low rate operation
03	Mitigating risks of low rate operation
04	Summary

Control variables and performance indicators



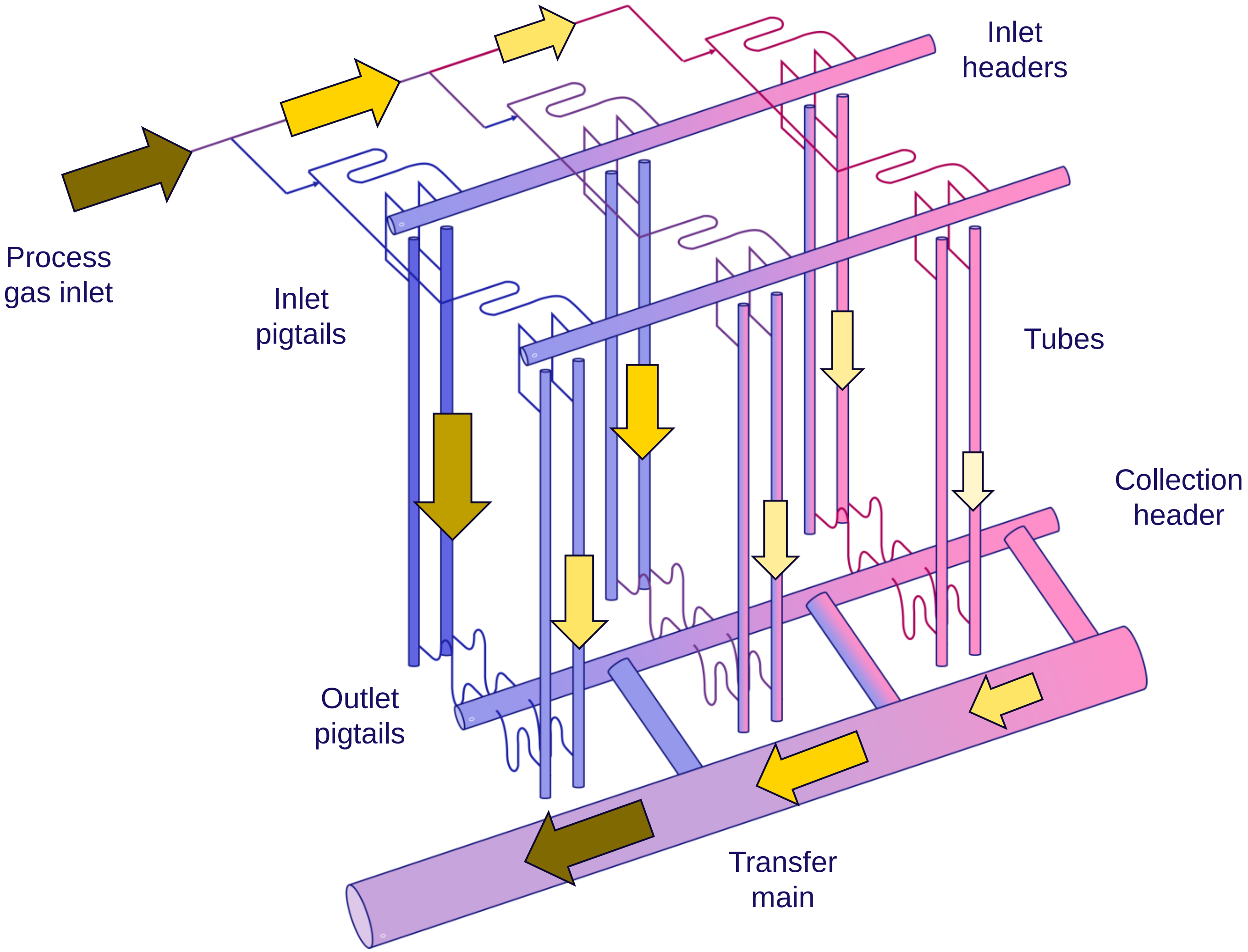
Performance indicators:

- CH_4 Methane Slip
- ATE Approach to Equilibrium
- TWT Tube Wall Temperature

Process gas maldistribution

- Operation at low rates:
- Low pressure drop across system
- Preferential gas flow

- Variations in conditions:
- Between tubes
- Between row (top fired)
- Between cells (side fired reformers)



Balanced firing

Potential for fuel, combustion air and flue gas maldistribution due to low pressures

Fuel line pressures

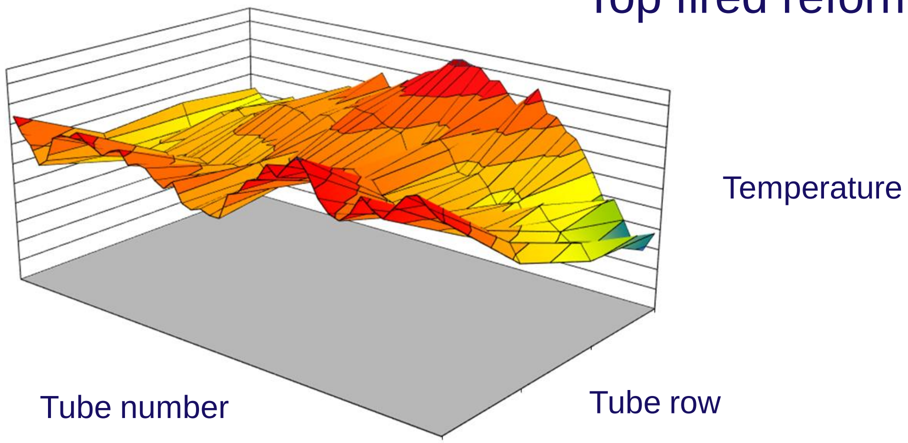
Air damper setting

Flue gas tunnel condition

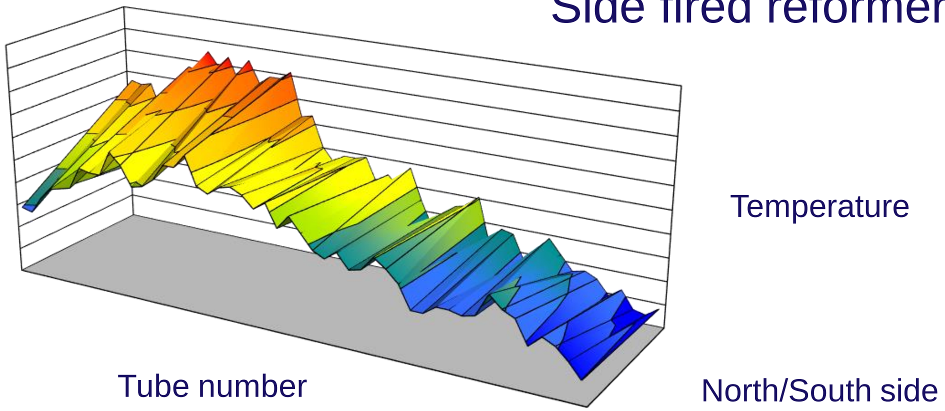
Burners adjustments

- Minimum turndown
- Isolation
- Flame detectors

Top fired reformer



Side fired reformer



Balanced firing – side-fired reformer

Often multiple burner levels

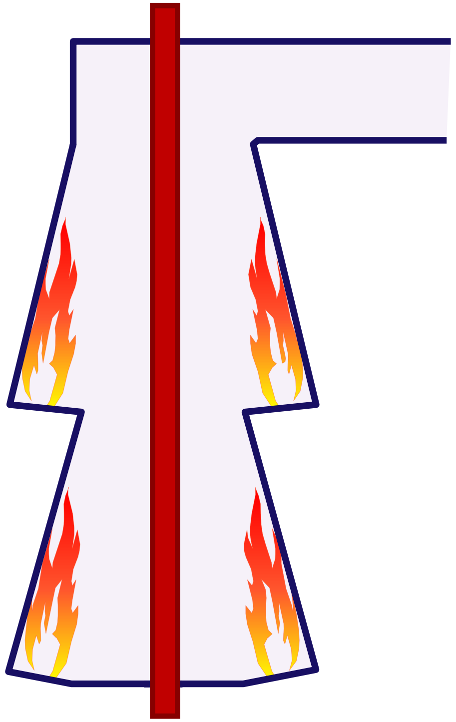
- Balance fuel between levels

Often two cells

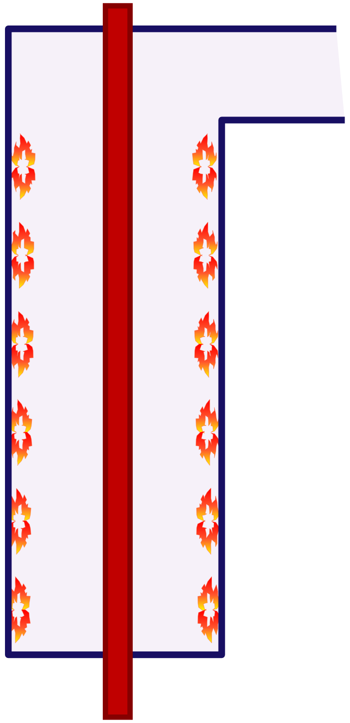
- Need to balance cells; check individual outlet TIs

Within a cell, often see tube wall temperature variation

Flue gas extraction ducts



Terrace wall



Side- fired

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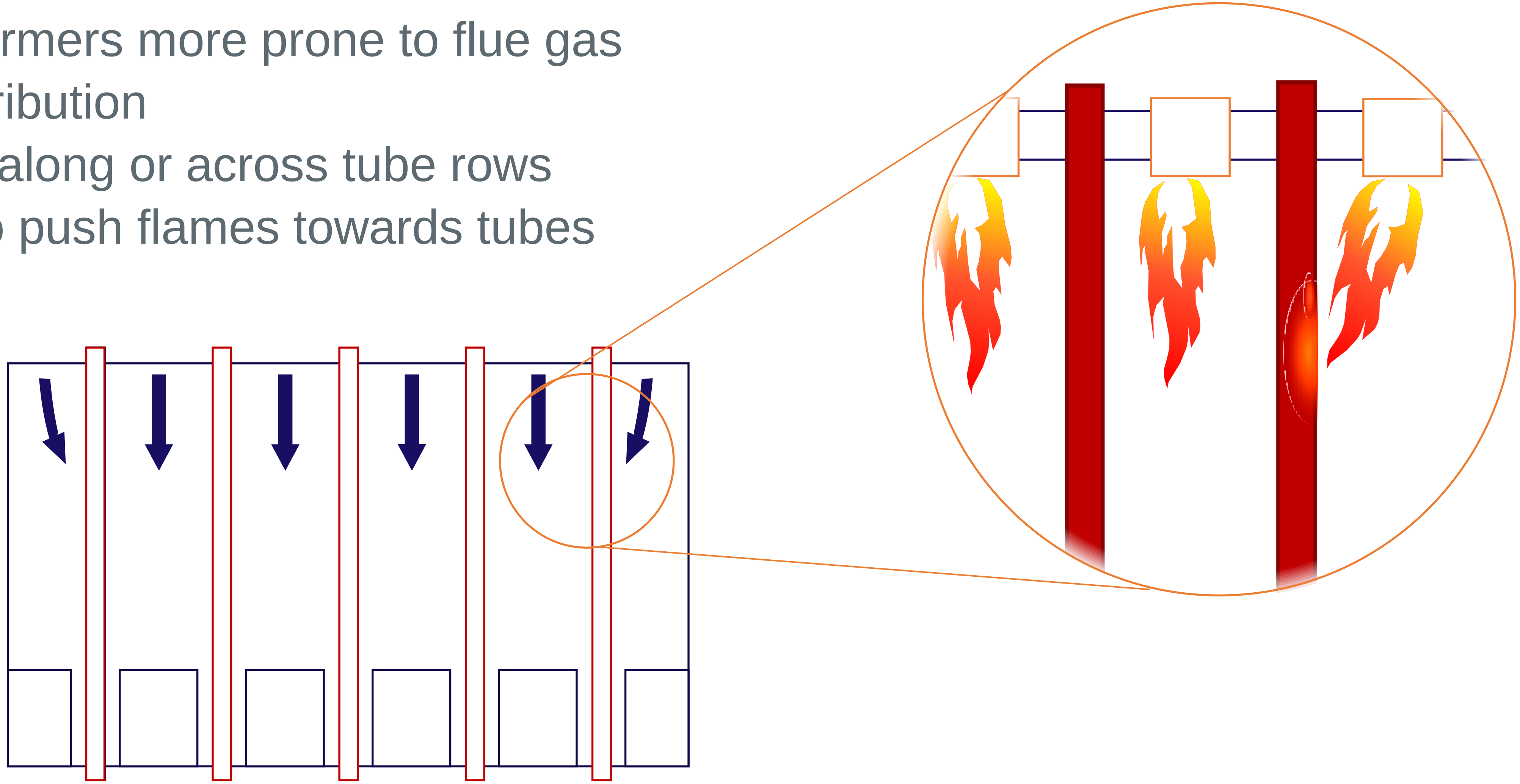
Flame impingement – top fired

Larger reformers more prone to flue gas maldistribution

Can occur along or across tube rows

Potential to push flames towards tubes



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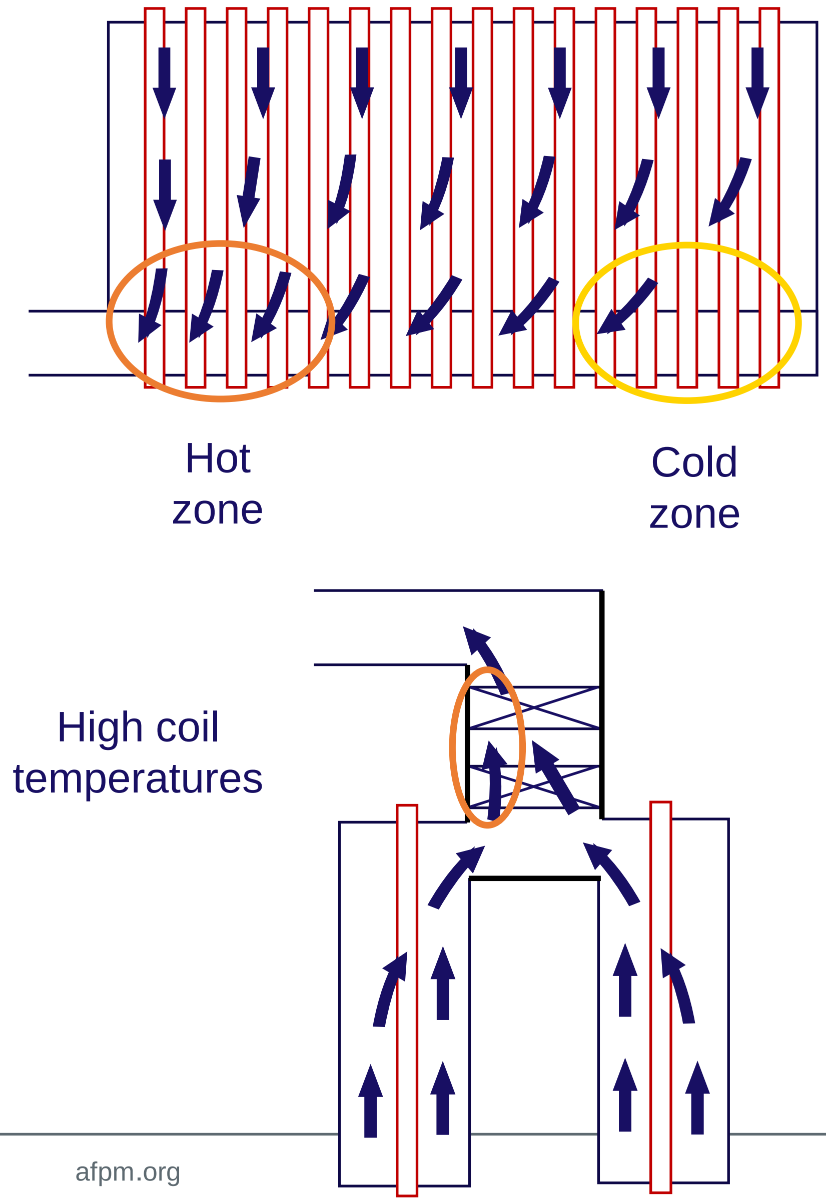
Heat distribution concerns

Even fuel distribution challenges, particularly for side fired units due to number of burners

Low pressure drop of combustion air, makes it particularly vulnerable to maldistribution

At low rates, tendency for the flue gas to be shift towards the extraction end:

- Top fired reformer, hot zone at extraction end
- Side fired reformer, high radiant coil temperatures



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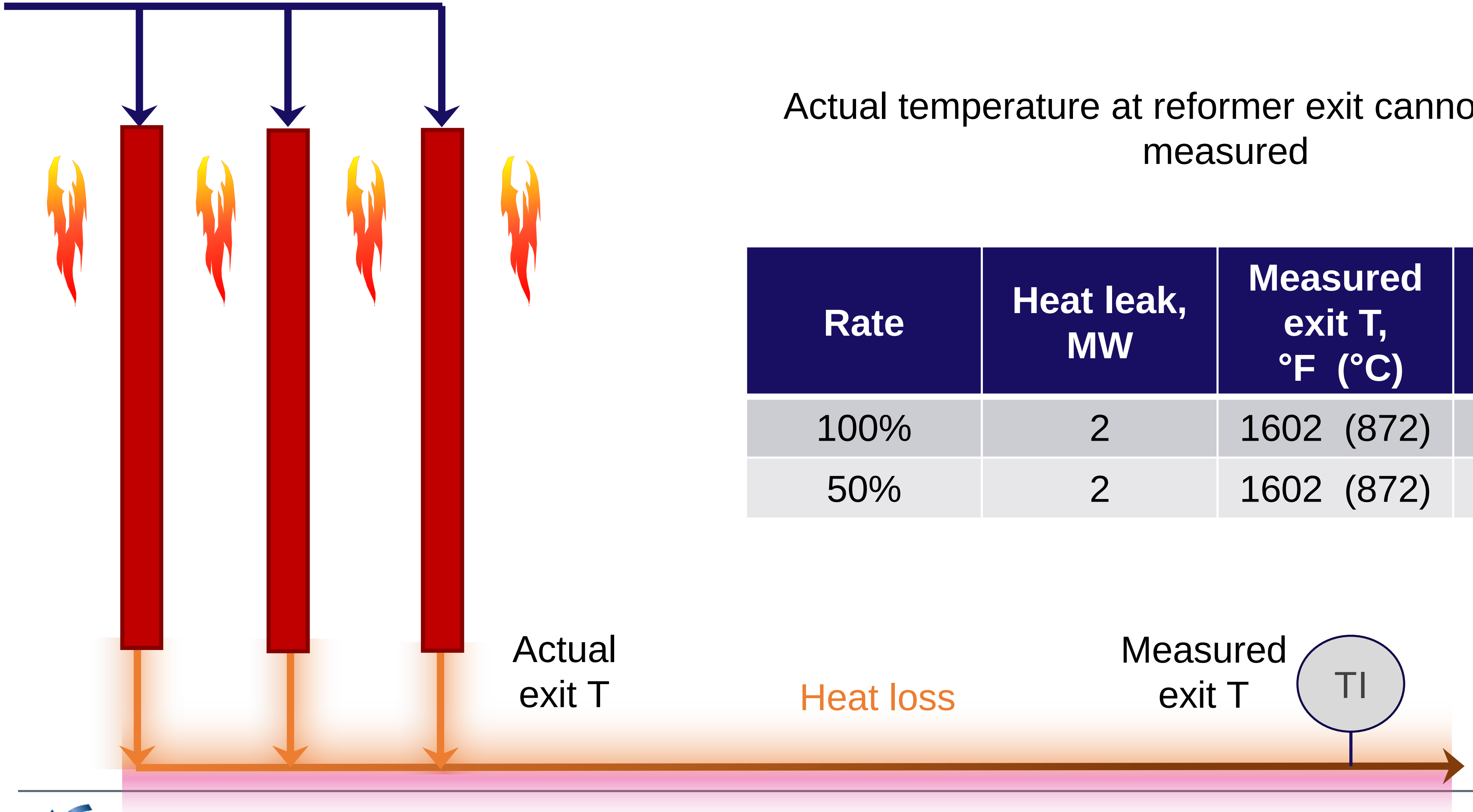
Plant temperature measurements at low rates



Actual temperature at reformer exit cannot be reliably measured

Rate	Heat leak, MW	Measured exit T, °F (°C)	Actual exit T, °F (°C)
100%	2	1602 (872)	1629 (887)
50%	2	1602 (872)	1656 (902)

Slido Question #4

Low rate operation concerns

Causes

- Low flow
- Low pressure drop
- Higher relative heat loss

Effects

- Instrument inaccuracy
- Preferential flow patterns of process gas, flue gas, combustion air and fuel flow
- Localised hot and cold zones
- Flame impingement
- High TWTs

Concerns

- Reduction in efficiency
- Carbon formation
- Catalyst damage
- Reduced tube life
- Coil failures

Operating conditions for lower flows

Minimum steam flow to be maintained, typically 40-50% of design.

Preference for higher than normal S:C operation:

- Helps maintain good process gas distribution.
- Reduces carbon laydown potential.

The maximum S:C is defined by the catalyst to keep it in the reduced state.

Be aware the heat loss between TI and tube is higher at low rate.

Burners minimum turndown and isolation procedures vary significantly.

A slight reduction in operating pressure, will improving flow distribution and reduce stress on the tubes.

Increase combustion air to improve flame shape and good flue gas flow.

The above is generic advice, please ensure you consult your equipment designer and catalyst vendor for specific advice for your plant

Monitoring high TWTs and signs of carbon laydown

Potential effects of low rates:

Maldistribution of process gas or flue gas causing localized overheating

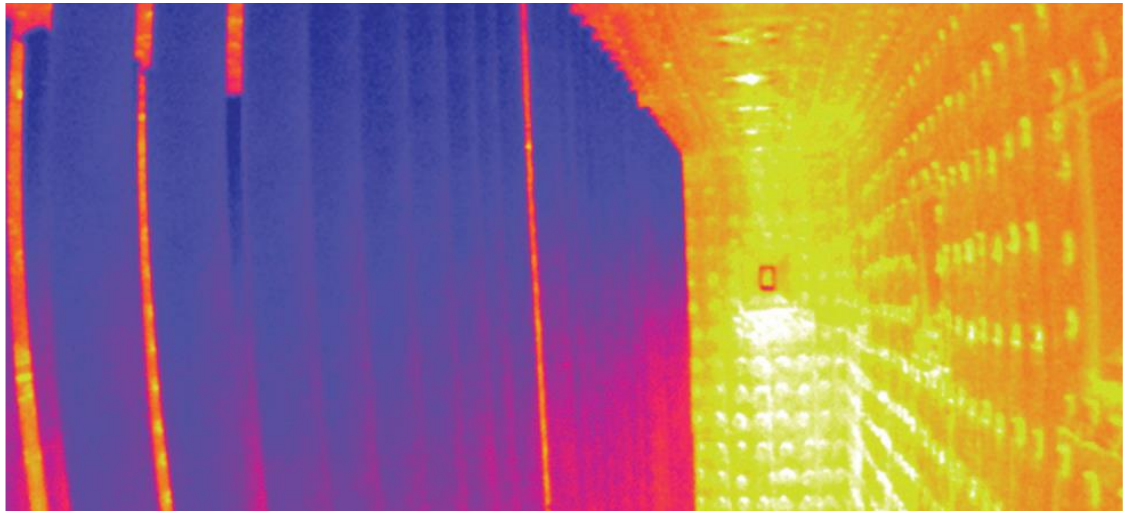
Maldistribution of flue gas causing flame impingement

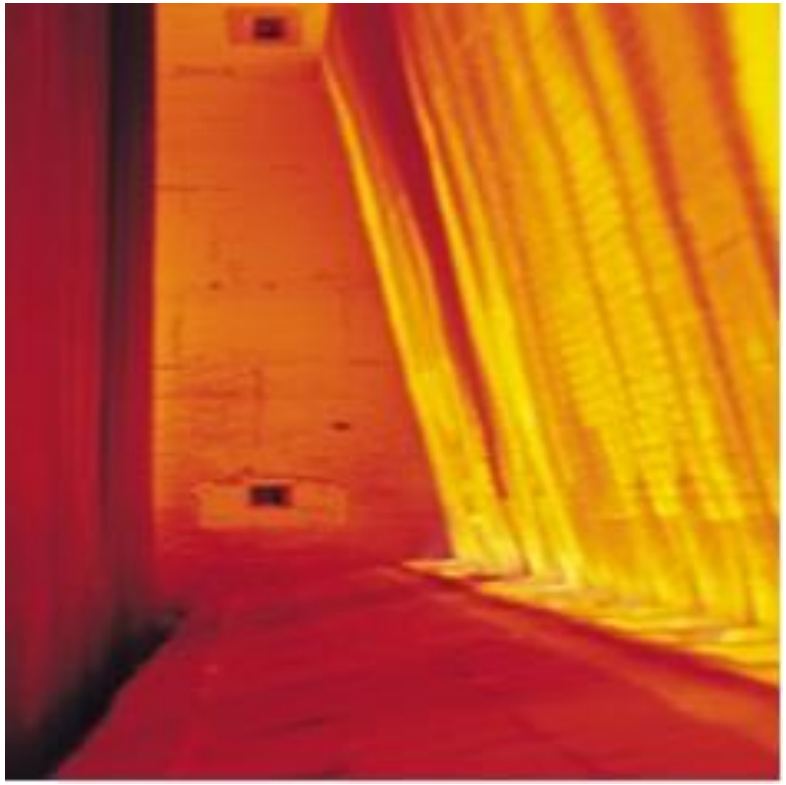
Error in steam/feed flow meter and high heat loss

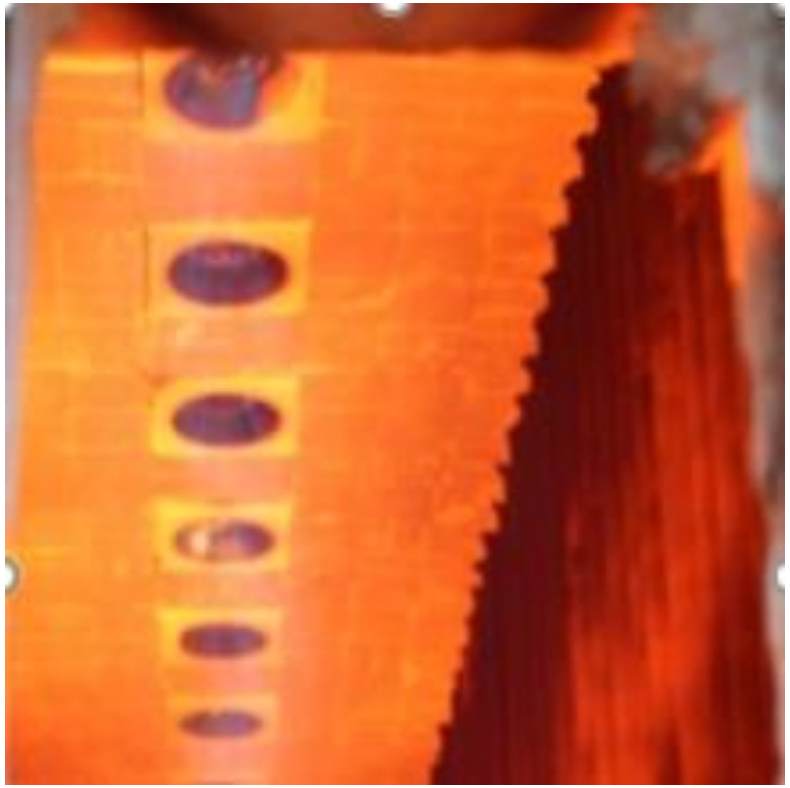
Measure and record TWTs regularly:

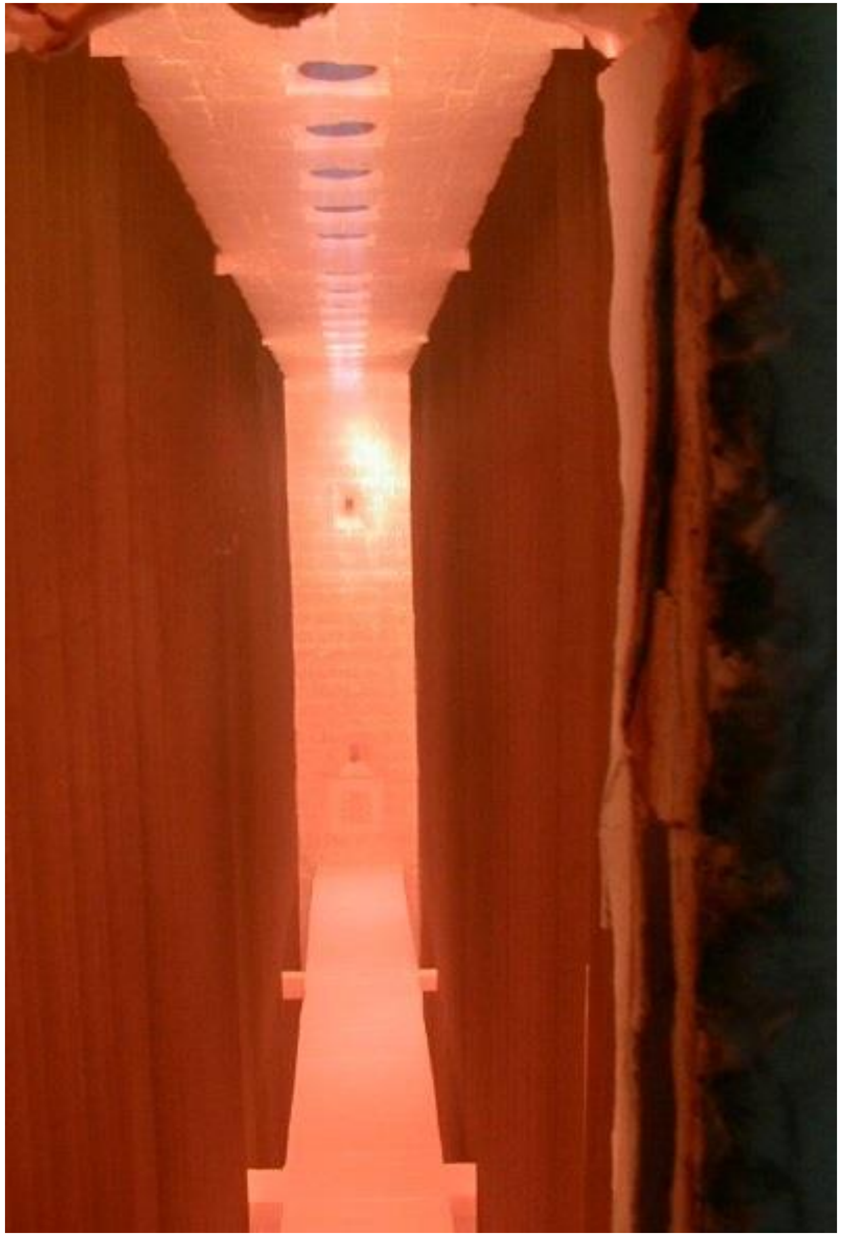
High TWT give concern to tube life and premature failure

Carbon formation will progressively get worse









Visual inspection of the reformer

Tube appearance
Refractory condition
External hot-spots
Flame characteristics

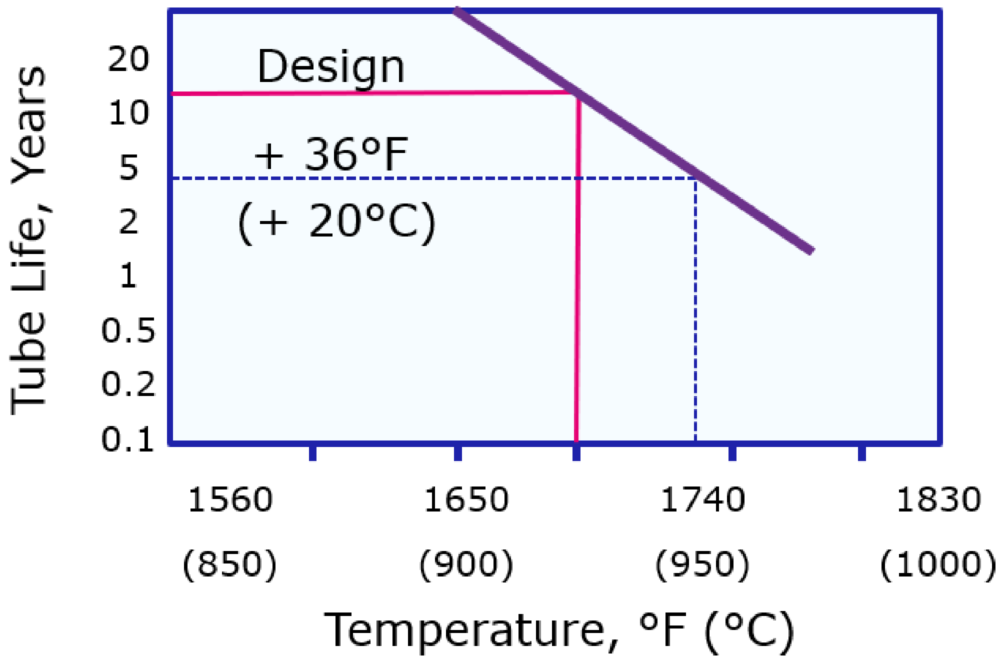
Importance of TWT measurement

Tube repair/replacement is expensive – want to maximize life

Tube life is a function of time at temperature (for a given pressure)

Accurate measurement is vital

- If measured high, might artificially limit plant rate
- If measured low, tube life shorter than expected



*Note design temperature is at design pressure (normal operation is generally below design pressure)

Summary

Low rate impacts

- Potential for maldistribution at low rates
- Heat loss before TI will be higher

Control variables

- Maintain minimum flow (consider S:C increase)
- Reduce exit pressure to improve flow distribution and reduce stress on tubes
- Keep TWT as low as practical
- Follow burner vendors guidance for turndown
- Optimize operating envelope for efficiency

Management

- Regular visual inspection of tubes
- Training and awareness of operators


Hydrogen Capacity Increase:
Tips to Maximize Renewable
Diesel Revenues
December 2020
Haldor Topsoe Inc
1

Speaker

HALDOR TOPSØE

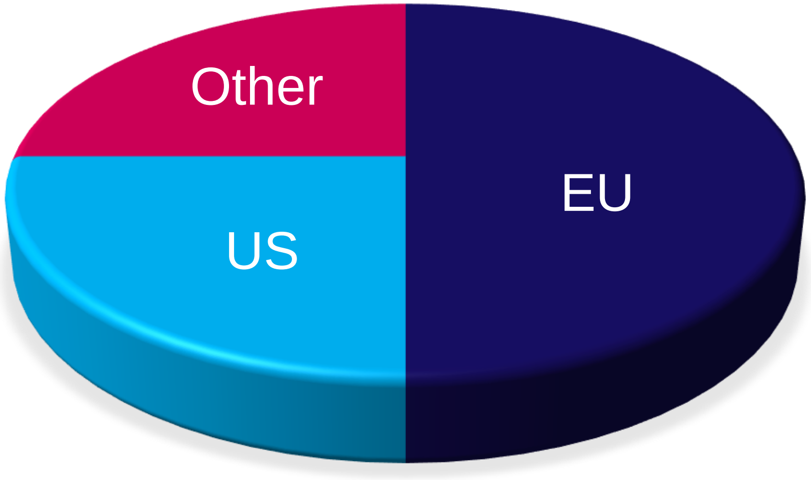
Thor Martin Gallardo

Technology Licensing Manager North America

tmg@topsoe.com

Agenda

Current Renewable market status



Globally

40 units/refineries

are processing renewable feedstocks to produce renewable diesel or jet fuel

US renewable processing capacity: 70,000 BPSD

US Trend in Renewable Fuels trends and impact on Hydrogen demand

2021-2024

US additional renewable processing capacity: **300,000 – 350,000 BPSD**

50% new capacity in Oil Refinery retrofits or new units which will need increase of hydrogen capacity by 30-50%

50% new capacity from new Renewable Refineries with integrated hydrogen plants to gain up to 10 CI points (8-10$/bbl diesel). New players: Renewable feedstock suppliers, biodiesel producers, fuel distributors, etc.

Carbon Intensity Incentives

(Simplified reading of the California Low Carbon Fuel Standard)

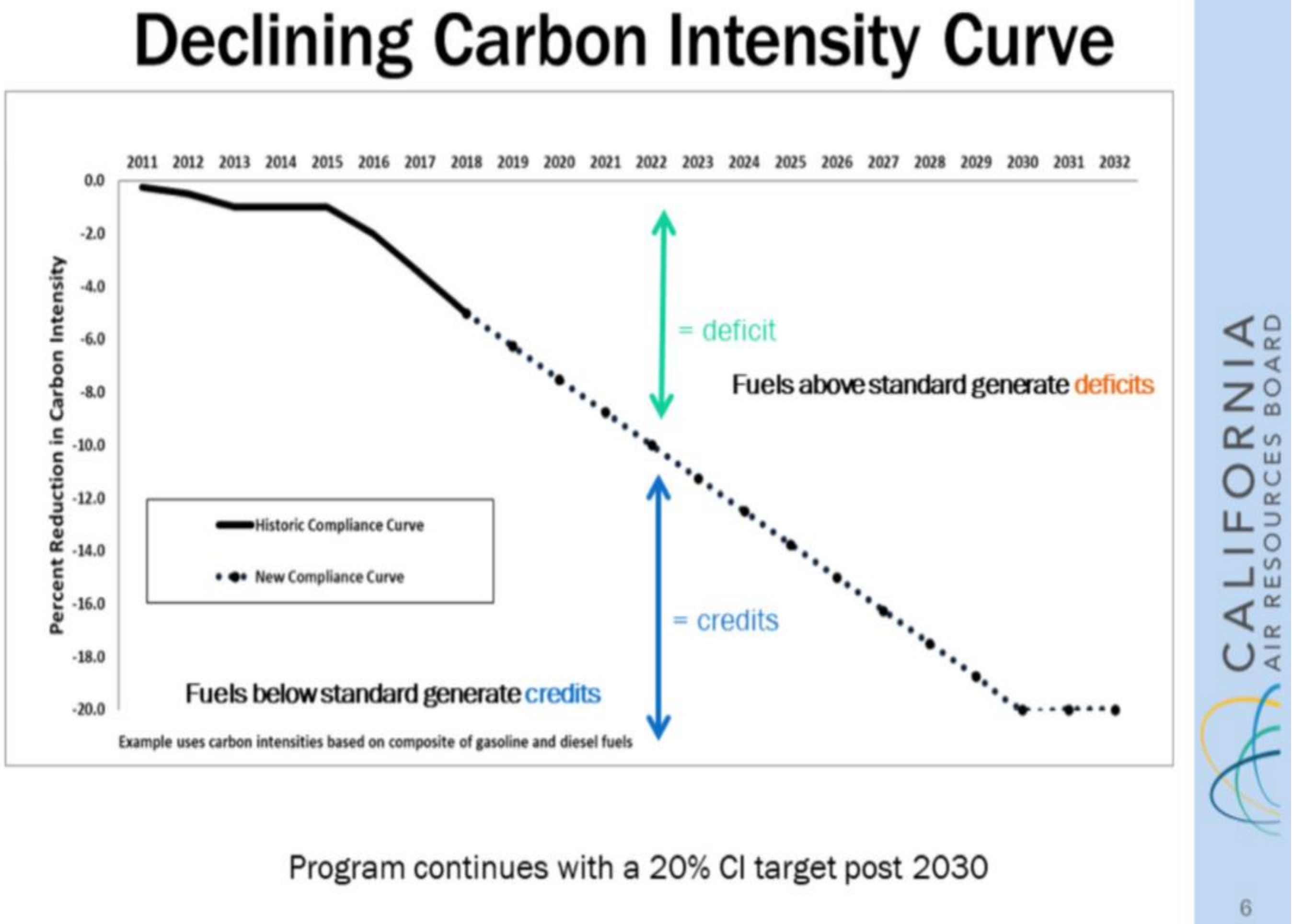
LCFS

Growth

- **LCFS credits are obtained by producing diesel with a smaller well-to-wheels carbon footprint than the reference petroleum-derived diesel (~100 CO_2e gr/MJ Diesel or ~30 lb CO_2e / gal ULSD)**
- **If the existing hydrogen plant uses more than 380 BTU Natural Gas (Feed+Fuel) to make 1 SCF of Hydrogen, then the CI score will be reduced hurting profitability**
- **In practice: For each 10% lower natural gas consumption in the hydrogen plant an extra revenue of $1/barrel of diesel is gained!**
  - Big incentive to be energy efficient
  - Big incentive to displace natural gas with renewable sourced streams
  - Minimize steam production

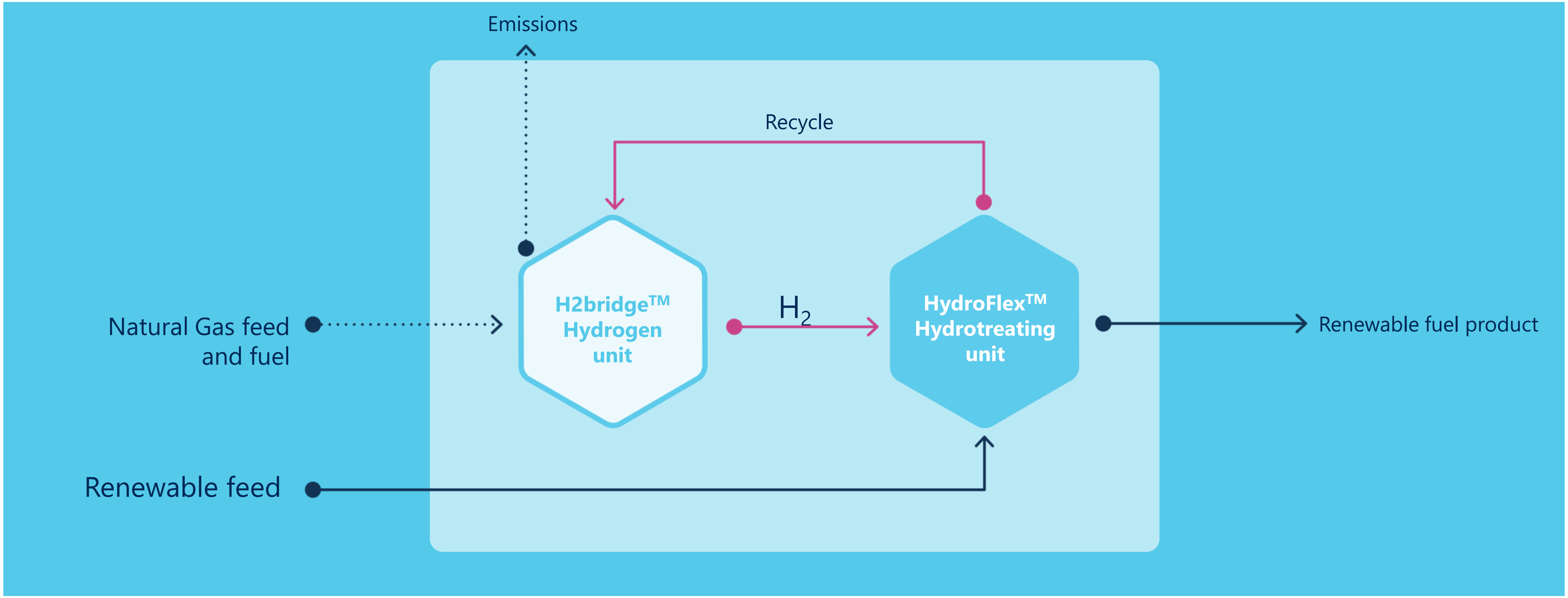
CA-LCFS Carbon Intensity (CI) Standard for Diesel per Compliance year

- **The CI standard is stricter through time**
-
- **Today renewable diesel gets LCFS credit if <93 gCO2e/MJ**
- **The most energy efficient technology and layout will keep the producer profitable the longest**
- **Last man standing**



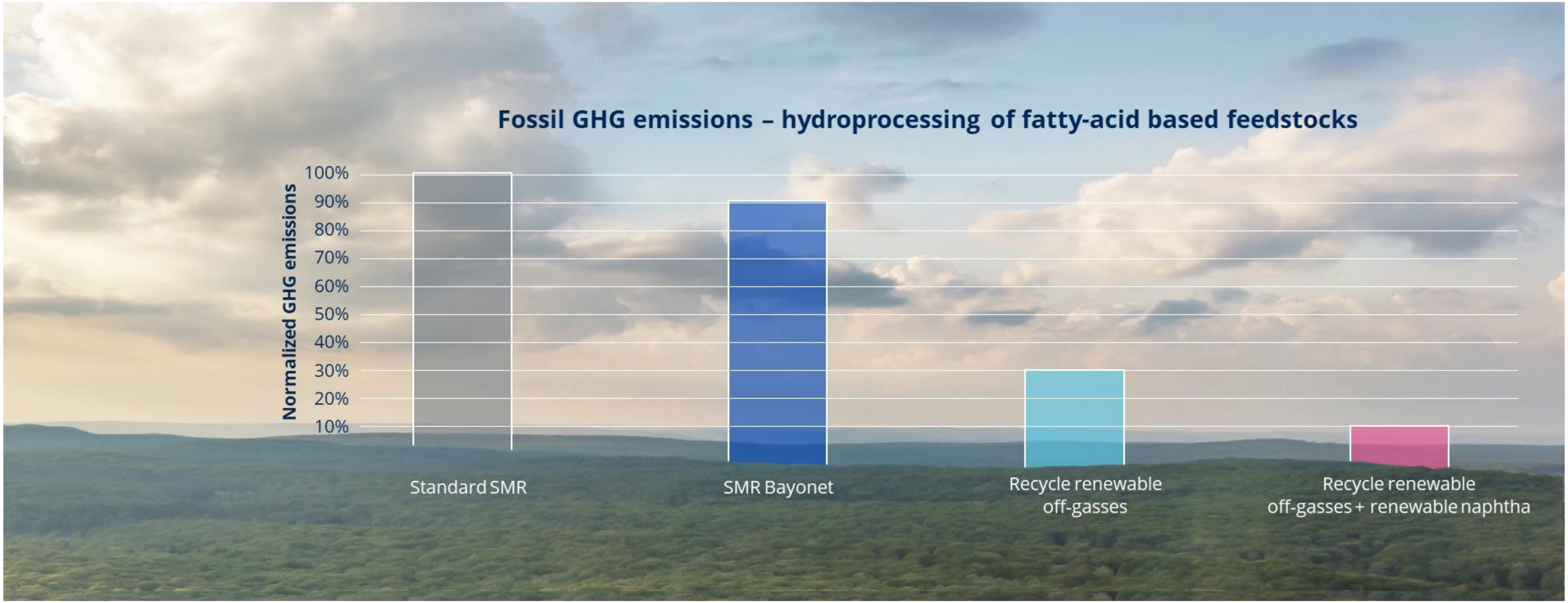
Topsoe H2bridge™ How it works

- A circular system integrating hydrogen and renewables hydrotreating



90 % fossil carbon reduction

Gain unprecedented greenhouse gas savings



Recommendations:
Tips for using existing Hydrogen Plant facilities

If you can choose, preferably operate the most energy efficient of the existing plants

Compare existing hydrogen carbon footprint versus new hydrogen plant. In most cases the extra LCFS revenue will pay-back for a state-of-the-art plant in 1-2 years

If renewable offgases are fed to the NG-based hydrogen plant, may need to change metallurgy of front end

Watch for new types of impurities in renewable offgases fed to the hydrogen plant

Purchase renewable power to reduce CI of of facility. Non-renewable power has an average carbon emission load of 1559 lb CO_2/MWh

Conclusion

Unique value by integration of HDP (HydroFlex™) and H_2 (H2bridge™)

Understanding how to minimize CI at lowest CAPEX/OPEX of the industry to maximize profits

Future proof

Q&A with the Speakers

MATHESON
ask. . .The Gas Professionals™

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UPCOMING WEBINARS –

SEE AFPM EVENTS PAGE FOR MORE DETAILS AND 2021 DATES

"Engaging Maintenance in Walk the Line"

December 8, 2020
2:00 PM Eastern

Register Here

Description

This webinar will review newly published practice sharing documents. A company case study will be presented, focusing on engaging Maintenance in WTL.

Intended Audience
Maintenance, Operations, Safety

Participants

- Amir Anderson, AmSty
- Tjokro Hermanto, AmSty
- Wesley Farrell, LyondellBasell
- Michael Vopatek, LyondellBasell

"Molecular Management in the Gasoline Pool"

January 26, 2021
2:00 PM Eastern

Register Here

Description

Future trends in gasoline, focusing on molecular management. Additional details to follow.

Intended Audience
Process Engineers, Strategic Planners, Refiners and Midstream, Investors

Participants

- Representatives from Axens

"Hydroprocessing Webinar Part 2"

April 28, 2021
2:00 PM Eastern

Register Here

Description

Part 2 of the December 2020 Hydroprocessing Webinar.

Details to follow!