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Advanced Techniques for Enhancing Hydrogen Availability in Refineries

Sanjiv RATAN, Group DVP, H2 Product-line & Technologies
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Air Products and Chemicals

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take it further®

AIR PRODUCTS

Presentation Overview

- Global Hydrogen (H_2) demand projections
- Ways to enhance H_2 Availability
  - Advanced Hydrogen Management
  - Step capacity Revamping & Feed switching to NG
  - Mega H_2 concept
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  - Reliability Enhancement
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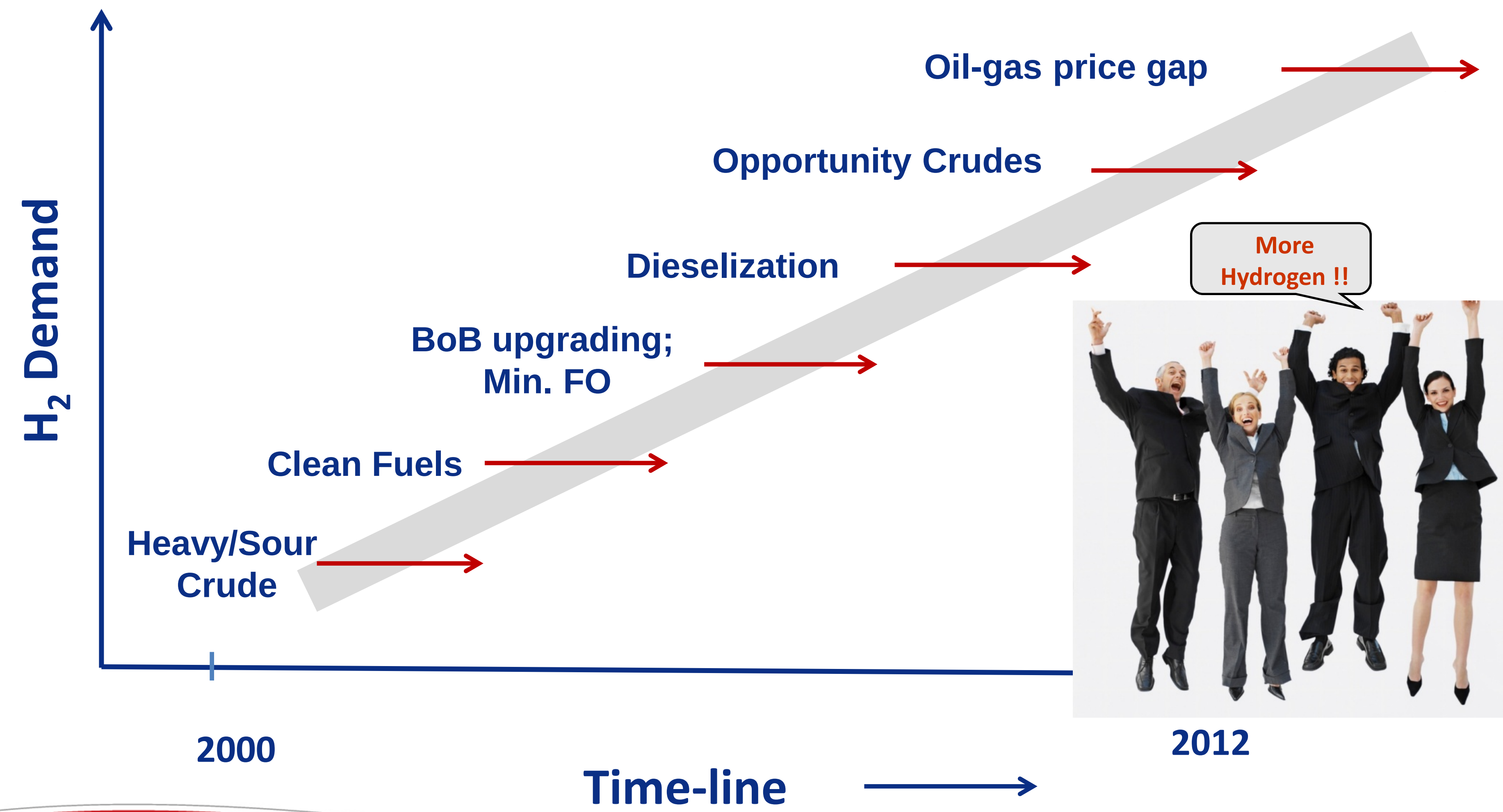
Drivers for Refinery Hydrogen

- Volume growth
  - Global fuels demand growth + clean fuels catch-up
  - Increasing proportions of ‘Opportunity and/or Unconventional’ crudes
  - Bottom-of-the barrel strategies
- Economies of scale
- Multi-client hydrogen franchise networks
- Hydrogen considered as an asset in refinery
  - Optimization and not minimization of hydrogen usage
  - Focus on ‘operating margins’ rather than ‘operating costs’

Mega H_2 plant typically ranges 100 - 250 kNm3/h in a single train

"Refinery Hy-way" Intensification



Global Refinery Hydrogen Demand Growth

Year →	2001	2011	2021
Global H2 Demand, (Captive; On-purpose) BCFD	**12.8**	**18.5**	**26.5**
North America:	4.7	5.8	7.1
Western Europe	3.1	3.2	3.7
Asia/Pacific:	3.0	5.7	9.6
- China	*0.6*	***1.8***	***3.7***
- India	*0.3*	***0.9***	***1.7***
- Japan	*1.0*	*1.0*	*1.0*
- Other Asia/Pacific	*1.1*	*2.1*	*3.2*
Other Regions (SA, ME, AFR)	2.0	3.8	6.1
% growth (2011 – 2021) Global		**~ 4 %**	
India + China		**~ 7 %**	
Global H_2 growth (2011-2021) : Captive + 20% Merchant		**10 bcfd**	
Average bcfd/yr		**~1**	

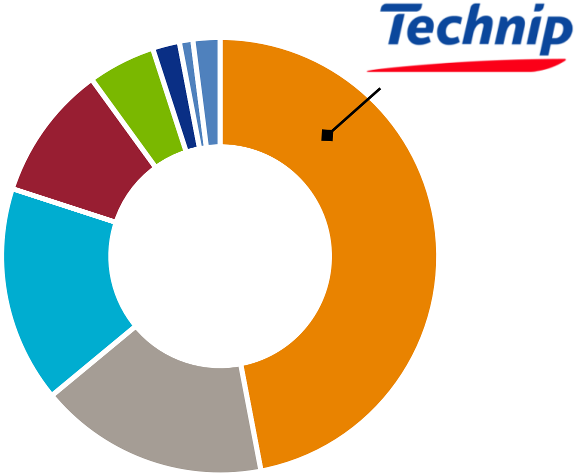
Refinery Hydrogen: Asian Trends & Needs

- **Technical**
  - Larger plant capacities
  - Catch-up against US & Euro norms
  - Lack of NG : Multiple / Liquid feedstocks flexibility
  - Power (un)reliability
  - Increasing HSE requirements and CO_2 focus
  - Need for enhanced RAM (Reliability, Availability and Maintenance)
- **Commercial**
  - Higher demand growth v/s domestic crude scarcity
  - Product slate and demand pattern; Diesel v/s Gasoline
  - Lower cost of ownership for H_2 critical for refinery profitability
  - Larger domestic portion in execution of projects (materials and labour)

Technip Catering for Hydrogen Demand

- Custom-optimized Solutions
- State-of-the-art technology

Global Market Share



Leading Global Hydrogen Technology and Plant Supplier

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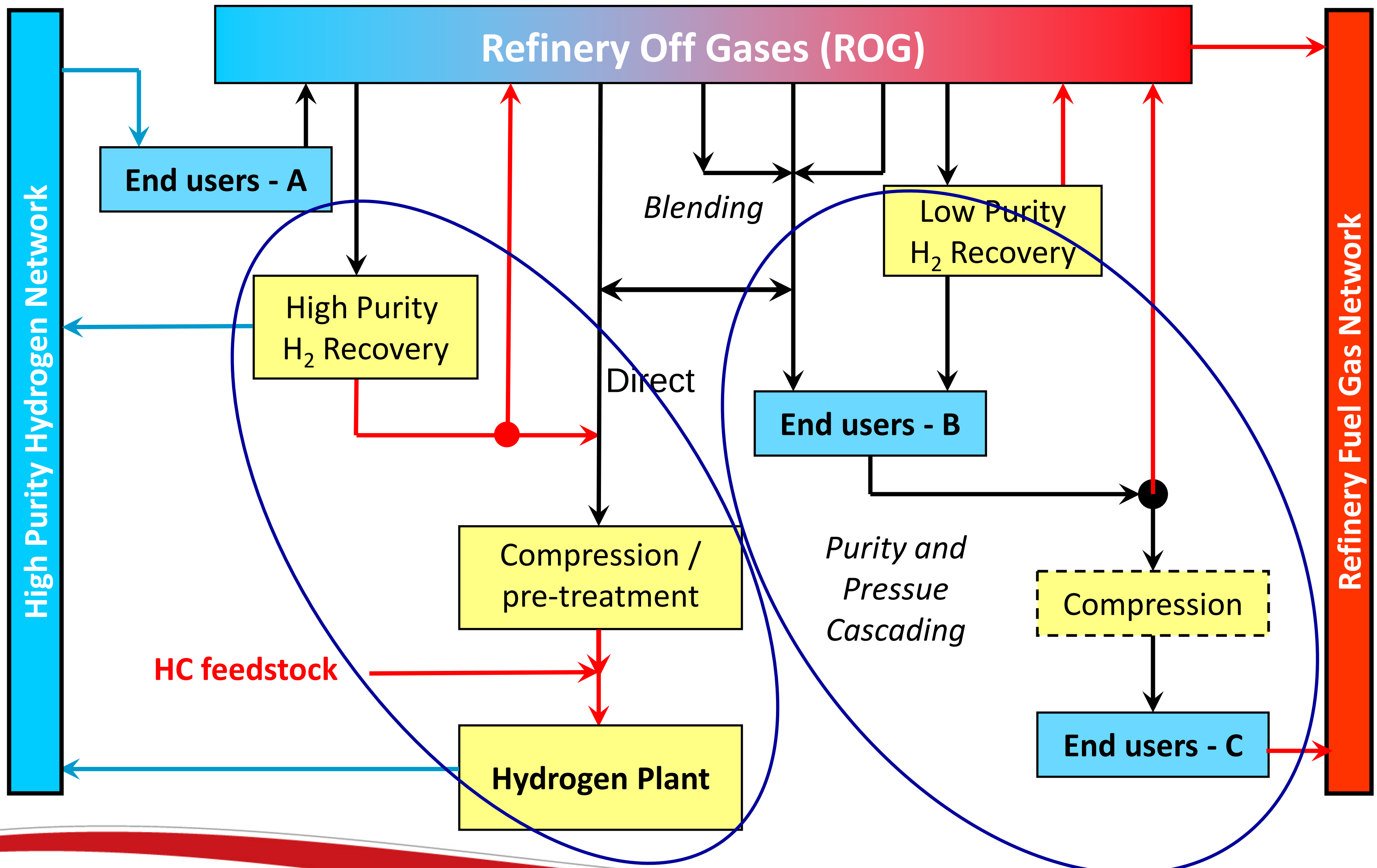
Refinery Off Gas (ROG) H_2 Recovery and Utilization



Advanced Hydrogen Management

HyN•DT™ developed by Technip

Hydrogen Network Design Tool

- Specific methodologies combined with transversal competences
  - Advanced LP programming using PIMS platform
  - Suite of tools includes H_2-pinch analysis and purity / pressure cascading
  - Rigorous unit operation modelling simulator, data import and reconciliation
  - Global cost database for realistic economic analysis and case evaluation
- Tailored to specific objective functions for grassroot refineries as well as revamps, expansions & retrofits of existing refineries
- No compromise on safety, reliability and operational flexibility

HyN-DT Analysis Cluster Output

HYDROGEN BALANCE

USERS	Mass Rate	Nm3/h
H2 for Naphtha HDT	6.39 t/d	2985 Nm3/h
H2 for Kero HDS	2.25 t/d	1052 Nm3/h
H2 for Diesel HDS	17.12 t/d	7994 Nm3/h
H2 for Hydrocracker	508.22 t/d	237297 Nm3/h
H2 for ARO Complex	17.00 t/d	7936 Nm3/h
Tot	551.0 t/d	257264 Nm3/h

PRODUCERS	Mass Rate	Nm3/h
CCR-H2 (High purity)	-151.93 t/d	-70937 Nm3/h
H2 from Gasification	-241.96 t/d	-112977 Nm3/h
HC-H2 PSA	-38.86 t/d	-18146 Nm3/h
Hydrogen Generation Unit	-118.23 t/d	-55204 Nm3/h
Tot	-551.0 t/d	-257264 Nm3/h

Hydrogen Unbalance	0.0 t/d	0.0 Nm3/h

(+/-; shortage/overproduction)

STOP BLINK

Naphtha Warning

NO SHORTAGE

SYNGAS DISTRIBUTION

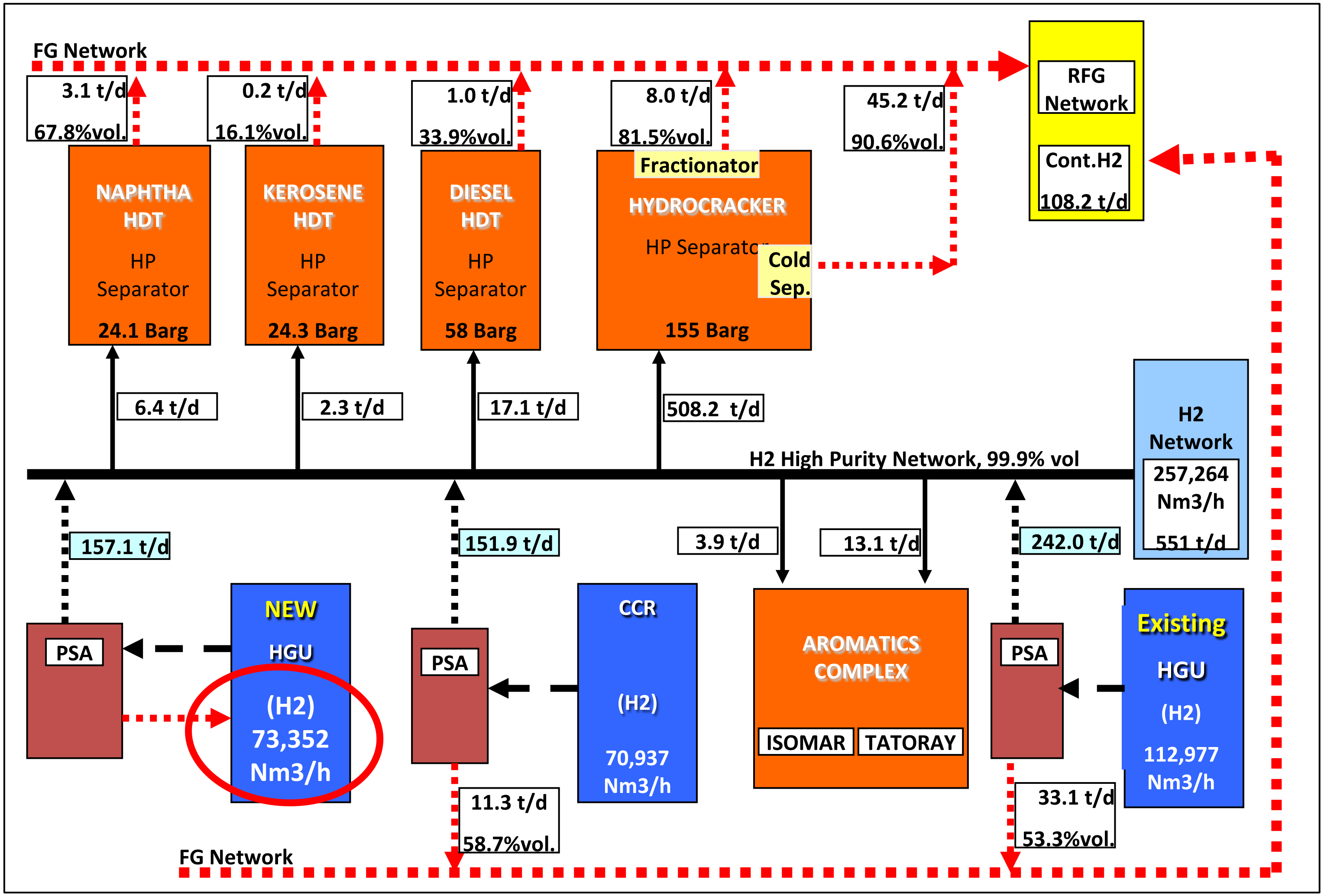
Default

Sweet Syngas distribution	T/Day	DEFAULT SPLIT		
Feeds		%	%	% wt
Sweet Syngas to Power	2943.0 t/d	52.65	52.65	52.65%
Sweet Syngas to Hydrogen	2646.3 t/d	47.35	47.35	47.35%
Sweet Syngas to Fuels	0.0 t/d	0.00	0.00	0.00%
Tot	5589.3 t/d		100.00	100.00%

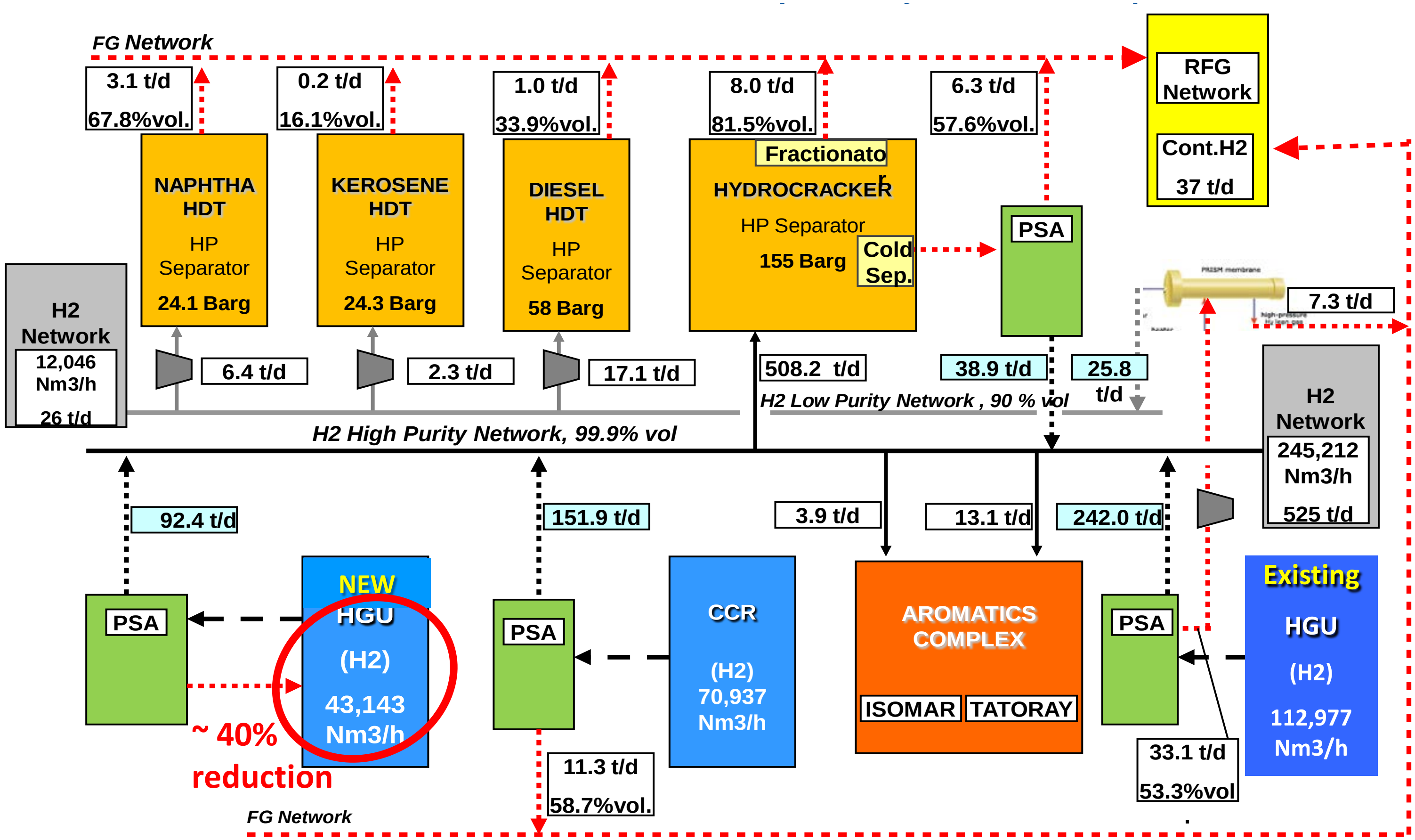
REFINERY FUELS BALANCE

REFINERY ENERGY BALANCE			
REFINERY FUELS AVAILABILITY	MMKcal/h	503.24	
REFINERY FUELS DEMAND	MMKcal/h	755.84	
DELTA (+import/-excess)	MMKcal/h	252.60	
FUELS IMPORT	LHV		
Feeds	Kcal/Kg	T/Day	MMKcal/h
NATURAL GAS	11700.00	518.16 t/d	252.60
Fuel Oil M 100	10680.00	-	-
FUELS EXPORT	LHV	OTHERS	
Feeds	Kcal/Kg	T/Day	MMKcal/h
Refinery Fuel gas (flare)	12464.55	0.00 t/d	0.00
Fuel Oil M 100	10680.00	0.00 t/d	0.00

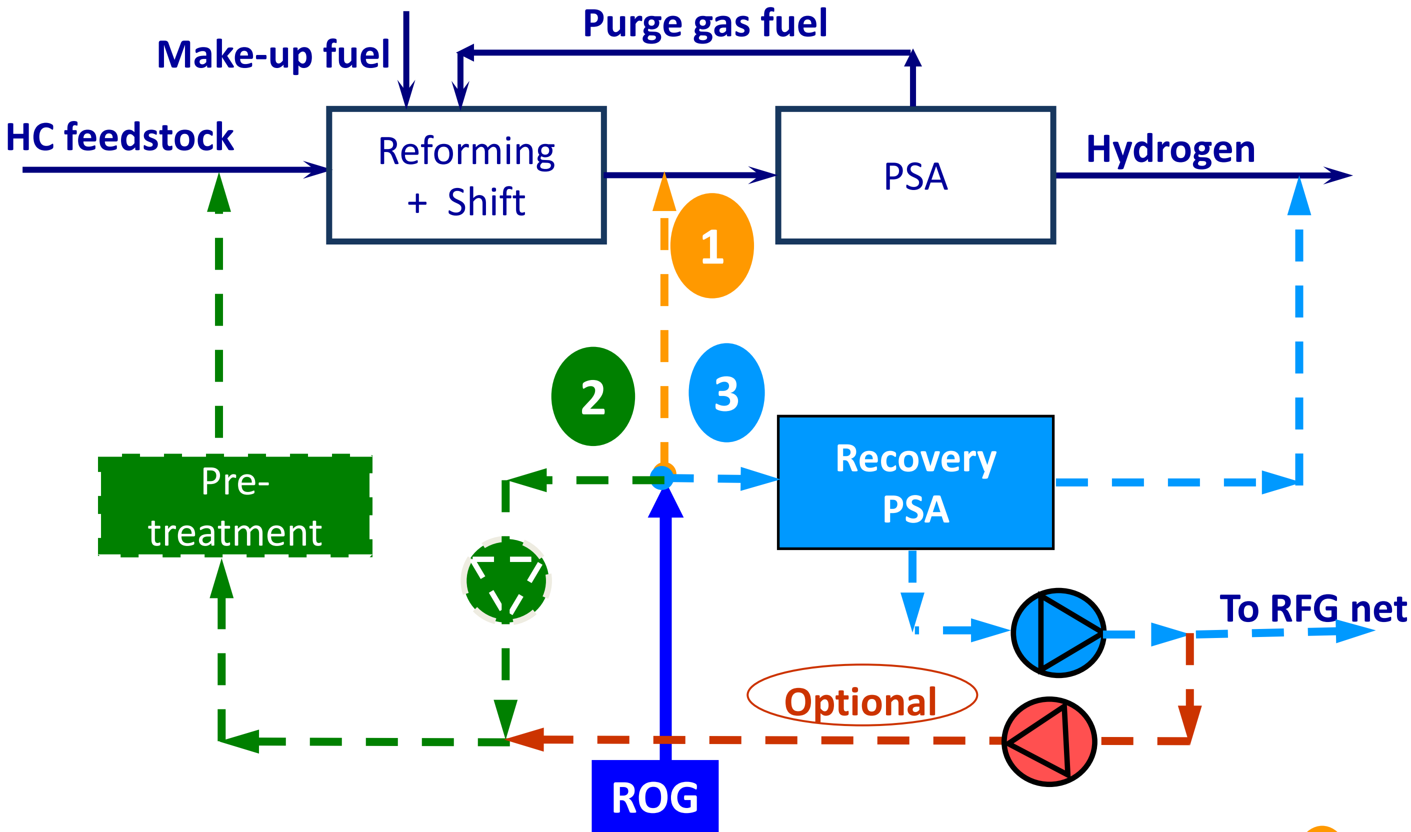
HyN•DT™ Example Analysis : Base Case



HyN•DT™ Analysis : Optimized Select Case



Refinery Off gases (ROG) Integration



Qualifiers

- **Available pressure**
- **Contaminants**

Potential H_2 Contribution (Quantitiy * H_2 fraction)

1 **Low**

2 **Medium**

3 **High**

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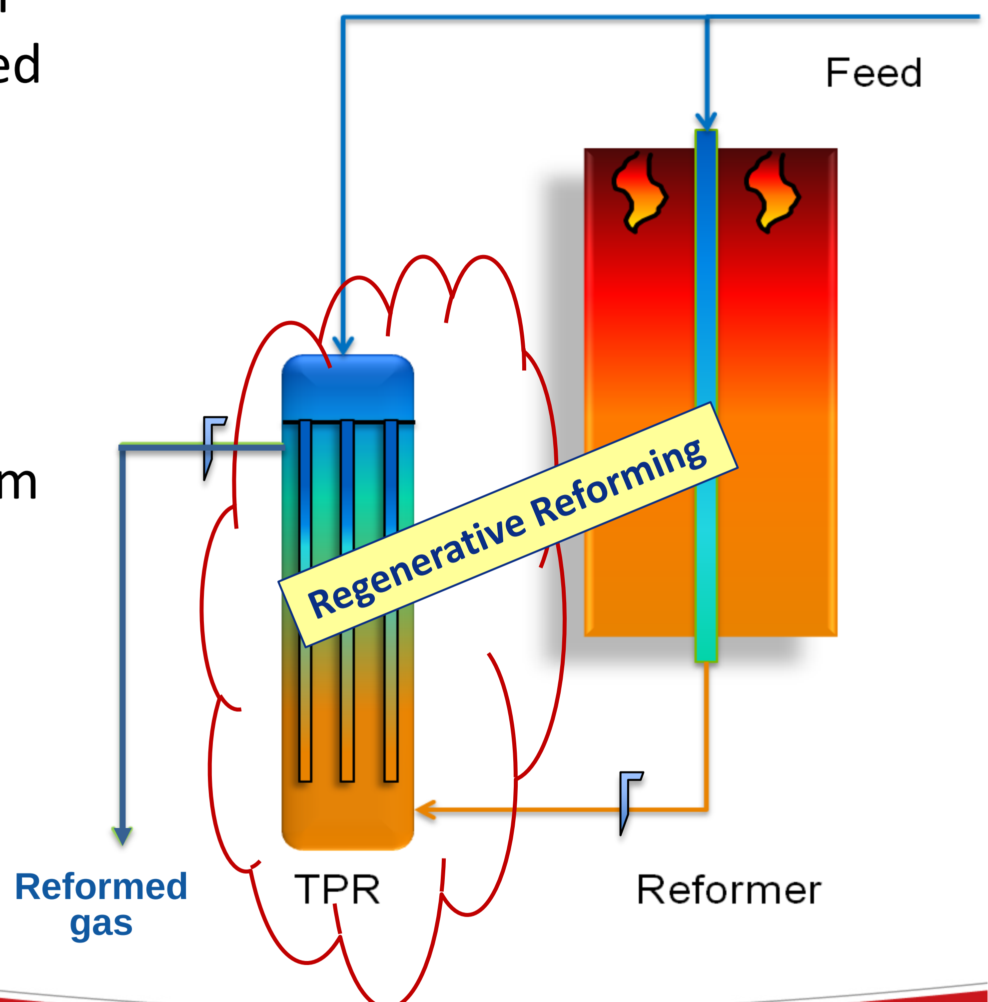
Hydrogen Step Capacity Revamp

- **Benefits**
  - Lower unit cost of (additional) hydrogen
  - Shorter schedule
  - No or smaller additional plot space
  - Utility interfaces and staff in place
- **Process Options**
  - Pre-reformer integration (up to 10%)
  - Reformer upgrade (up to 15%)
  - TPR reformer retrofit (up to 30%)

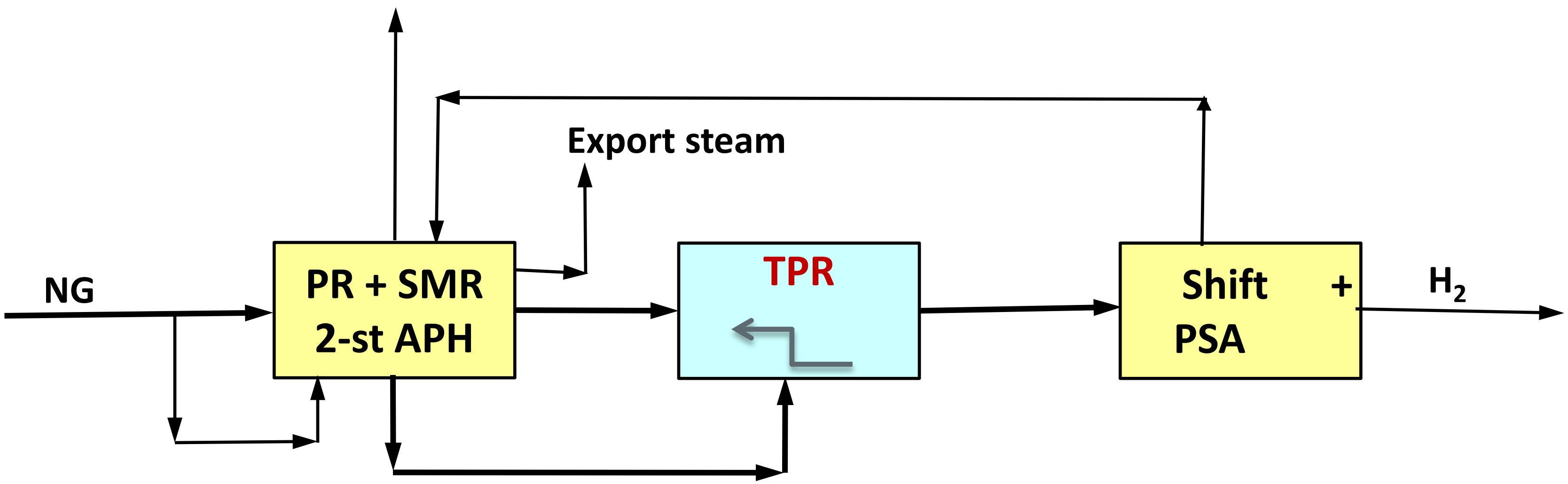
Attractive additional Hydrogen with
No compromise on HSE and Reliability

Technip Parallel Reformer (TPR) Retrofit

- Uses high grade heat of reformer effluent to reform additional feed
- More reforming without increasing radiant duty, thus lowering firing and related CO_2 per unit H_2
- Off-loads the whole steam system despite higher capacity
- Allows near ‘Zero’ export steam
- Installation within a typical refinery turnaround (4-6 weeks)



TPR Regenerative Reforming Cycle



- Up to 30% more H_2
- Lower Export Steam
- Lower corrected Specific CO_2 Emission

Recent TPR Revamps Overview

	Project 1	Project 2	Project 3	Project 4	Project 5
Start-up	2003	2009	2010	2010	2012
Pre-revamp capacity (kNm3/h)	13.5	34	16.5	38	96
Incremental capacity (kNm3/h)	3.4	9	5	9	21
Capacity increase (%)	**25**	**26**	**30**	**24**	**22**
Feedstock	Naphtha/ NG	Naphtha	NG	NG	NG

Feed Switching (from Naphtha) to NG

- Expanding NG networks
- Higher H2 yield due and improved process efficiency
- NG feed Opex generally lower than for Naphtha, when latter credits higher premium as Petrochemicals feedstock
- Reduced CO_2 emission (~ 15%)
- Easier to operate (even more with fuel substitution)
  - No residue on evaporation / fouling
  - Easier desulphurization
  - No liquid pockets or slugs , esp during transient conditions
  - Reduced risk on carbon formation in SMR even with lower S/C
  - More stable composition and quality
  - Easier to recover from upsets
- On-line feed change-over well referenced (as alternative and/or mixed feed)

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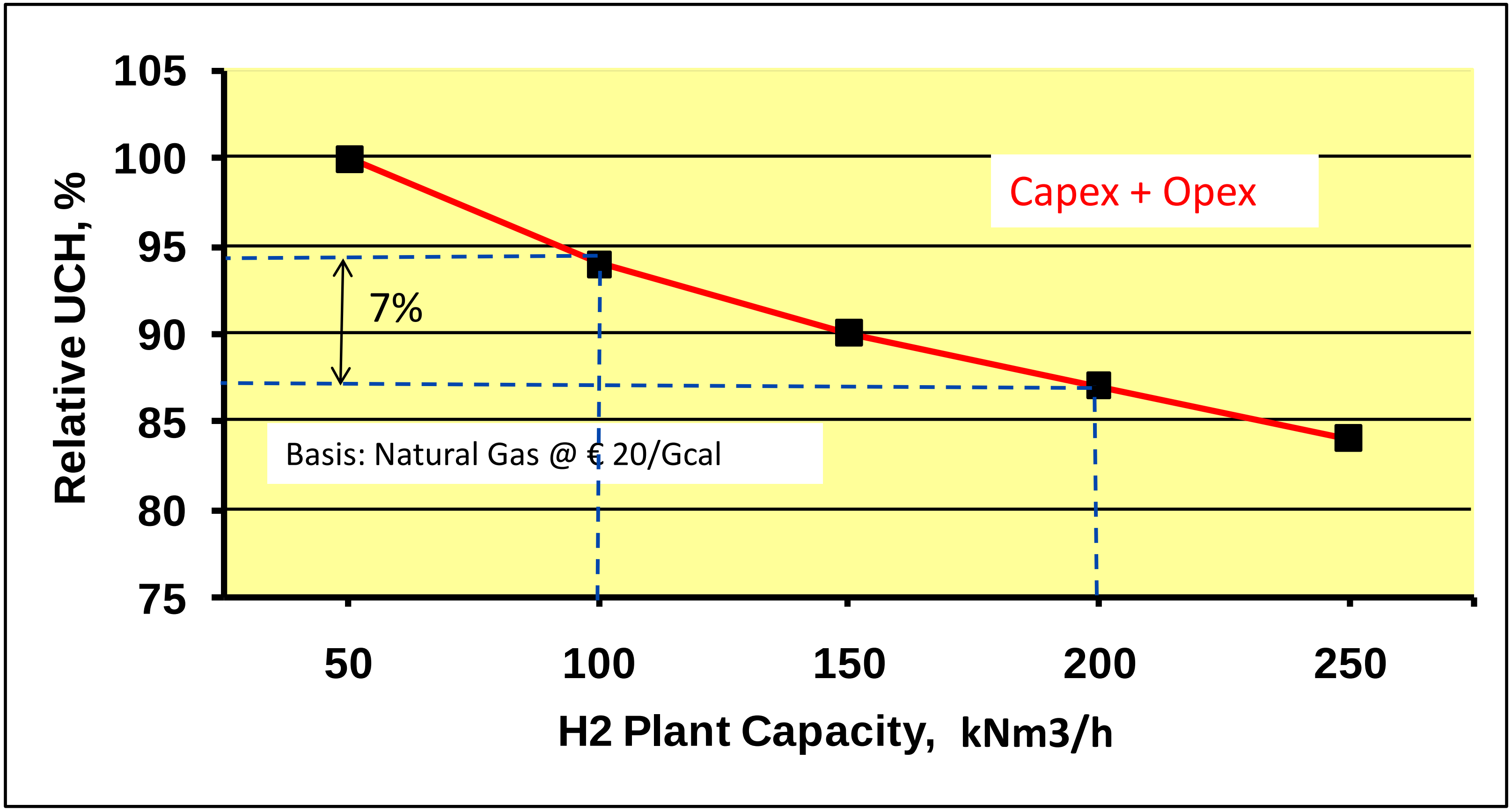
Hydrogen Generation : Economy of Scale



Benefits of Single v/s Dual Train H_2 Plant

- Total Installed Cost lowered by 10-15%
- Smaller plot space by 30-50%
- Enhanced energy efficiencies, apart from better justification for incremental investment
- Shorter implementation schedule and/or labor intensity
- Lower operating costs (staff, inventories and capital spares)
- More suitable for CO_2 capture readiness

- **Such merits outweigh the minor benefit on lower turn-down and plant availability of Dual-train units, with negligible impact on overall on-stream factor.**
- **Dual train configuration at times gets governed by phased investment and execution philosophy or case-specific requirements**
- **Large single-train H_2 plants do call for a higher degree of design optimization and competence as well as EPC capabilities and experience.**

Mega Hydrogen Plants with Feed Flexibility

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Hydrogen supply : Make v/s Buy

	Make Case	Buy Case
Key design objective	Low capital cost	Optimized UCH
Financing & insurance	Customer	Supplier
Project / construction risk	Customer / Contractor	Supplier
Permitting & commissioning	Customer	Supplier
Warranty	Typically 1 yr after ‘start up’	20 years
Performance guarantee	GTR within 2-12 months	20 years
On-stream guarantee	None	20 years
Opex liabilities	None	20 years
Major failure after warranty	None	20 years

Air Products- Technip Global H_2 Alliance

- Incepted in 1992
- Befitting Synergy
  - Technip's leadership in H_2 plant supply
  - Air Products' leadership in OTF H_2 supply
- 34 plants to date

  > 2.5 bcfd H_2 capacity

  > 1 bcfd H_2 in past 5 years

Longest and most successful Sale-of-Gas H_2 alliance

AIR PRODUCTS | Technip

H_2 Alliance

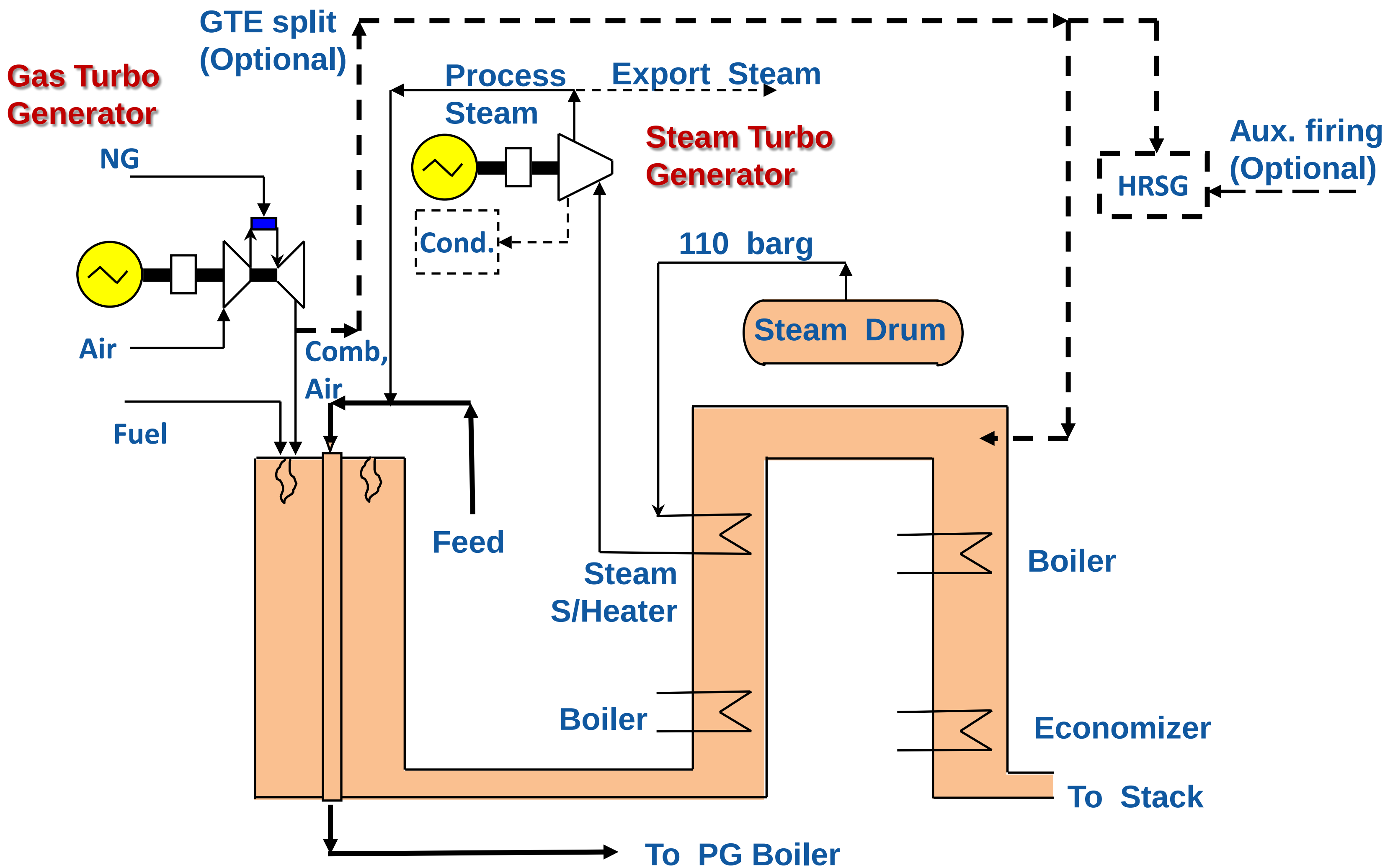
www.H2Alliance.com

H_2 2

Air Products and Technip.

Hydrogen supply to the second power.

GTE - SMR Cogen Integration / Combined Cycle



Benefits of SMR / Cogen Integration

- Better Economics compared to stand-alone units
  - Lower TIC by ~ 10%
  - O & M staffing synergies benefit ~ 5%
  - Improved thermal efficiency benefit ~ 3 %
- Reduced specific CO_2 and NOx by ~ 15%
- Island mode capabilities during special operational modes
  - Enhanced reliability for H_2 (>99.9%) as well as power supply for the refinery complex under various H2 / power load ratios

- **Upto 100 MW generation from 100 mmscfd H_2 plant**
- **Reliable and cost-effective (captive) power self-sufficiency**

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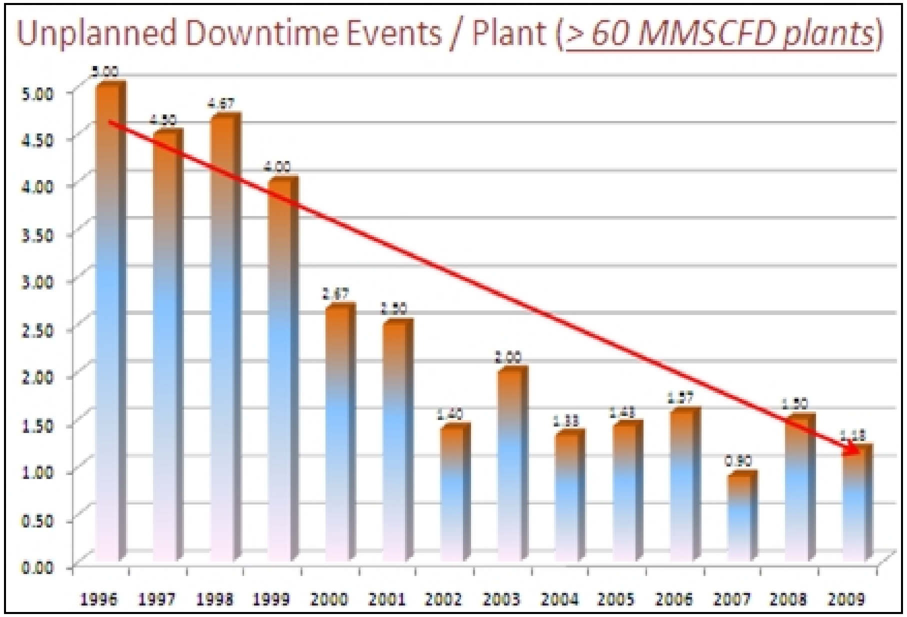
Air Products-Technip Reliability Program

- Reliability Focused Operations and Work Processes
  - Global Downtime and Cost of Non-conformance (CoNC) metrics
  - Advanced Model Predictive Control (MPC) control strategies
  - State of the art Condition Monitoring (CM)
  - Standardized outage planning and execution
  - Critical Spares management
  - Robust Electronic Management of Change (MOC) system
  - Best Practices sharing amongst sites worldwide
  - Extensive use of Continuous Improvement Tools
  - Site Reliability, Training, and Procedure Assessment Programs in place

On-Stream Reliability of AP-TP Large H_2 plants

Refinery H_2 underlines strong need for high reliability and availability



Start-up Year	Capacity MMSCFD	% On-stream *
1994	35	99.1
1995	88	99.3
1996	80	99.1
1997	17.5	99.2
2000	96	99.6
2002	100	99.9
2004	110	99.8
2006	82	99.9
2007	115	99.9+
2008	105	99.9+
2011	120	100.0 to date

*** Based on documented reliability data of AP-TP SOG H_2 plants, excluding scheduled outage**

Progression of "Cost-Effective Reliability"

	Early 90s	Mid 90s	2005 +
Single (SMR) train max. H_2 capacity, mmscfd	**75**	**100**	**200**
Relative Reformer box size (m x m x m), %	100	85	75
Relative Specific energy (GJ/kNm3), %	100	94	90
Relative Burner-NOx target (ppmV), %	100	65	30
Continuous operation / turnaround cycle, years	**~ 2**	**~ 3**	**~ 4**
Reliability (stand-alone on-stream) %	**> 95 %**	**> 97 %**	**> 99 %**
Relative Plot area ISBL (m x m), %	100	90	75
Relative EPC execution schedule (months), %	100	90	80
Relative TIC (ISBL; adjusted NPV; MM $), %	100	95	85
Relative 'Unit Cost of Hydrogen' ($/kNm^3), %	**100 %**	**94 %**	**88 %**

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Conclusions

- **The growing refining landscape and its emerging needs, especially in Asia, call for concerted strategies for ensuring H_2 availability efficiently and cost-effectively.**
- **In modern high-conversion integrated refineries, H_2 need can be satisfied starting with judicious hydrogen management, followed by potential capacity revamp of existing H_2 plants, and eventually efficient & reliable H_2 generation, furthered by 'buy' mode via over-the-fence supply.**
- **Asian refining and hydrogen markets carry few specific trends and needs to be addressed for meeting the ongoing and future goals.**
- **Technip as a global leader for supply of H_2 technology and plants, together with its trend-setting global alliance with Air Products , carries a comprehensive portfolio of proven technological options and advanced solutions for satisfying current and upcoming H_2 needs.**

Thank You !

Technip take it further®

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