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AVEVA™ Process Simulation performance of Shell C3-MR LNG plant model

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AVEVA

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This **presentation** may contain certain forward-looking non-GAAP measures such as **cash capital expenditure** and **divestments**. We are unable to provide a reconciliation of these forward-looking Non-GAAP measures to the most comparable GAAP financial measures because certain information needed to reconcile those Non-GAAP measures to the most comparable GAAP financial measures is dependent on future events some of which are outside the control of Shell, such as oil and gas prices, interest rates and exchange rates. Moreover, estimating such GAAP measures with the required precision necessary to provide a meaningful reconciliation is extremely difficult and could not be accomplished without unreasonable effort. Non-GAAP measures in respect of future periods which cannot be reconciled to the most comparable GAAP financial measure are calculated in a manner which is consistent with the accounting policies applied in Shell plc’s consolidated financial statements.

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Contents

Introduction: Background

LNG & Cryogenics CoE (Centre of Expertise) is sponsoring a study to assess AVEVA Process Simulation(APS) as a future-proof simulation platform for the Shell Integrated Gas (IG) business needs:

- For process modelling and optimization needs; to support design, asset support, and technology development of the IG business.
- Capable of integration with Digital engineering workflows and within the Digital Twin ecosystem.

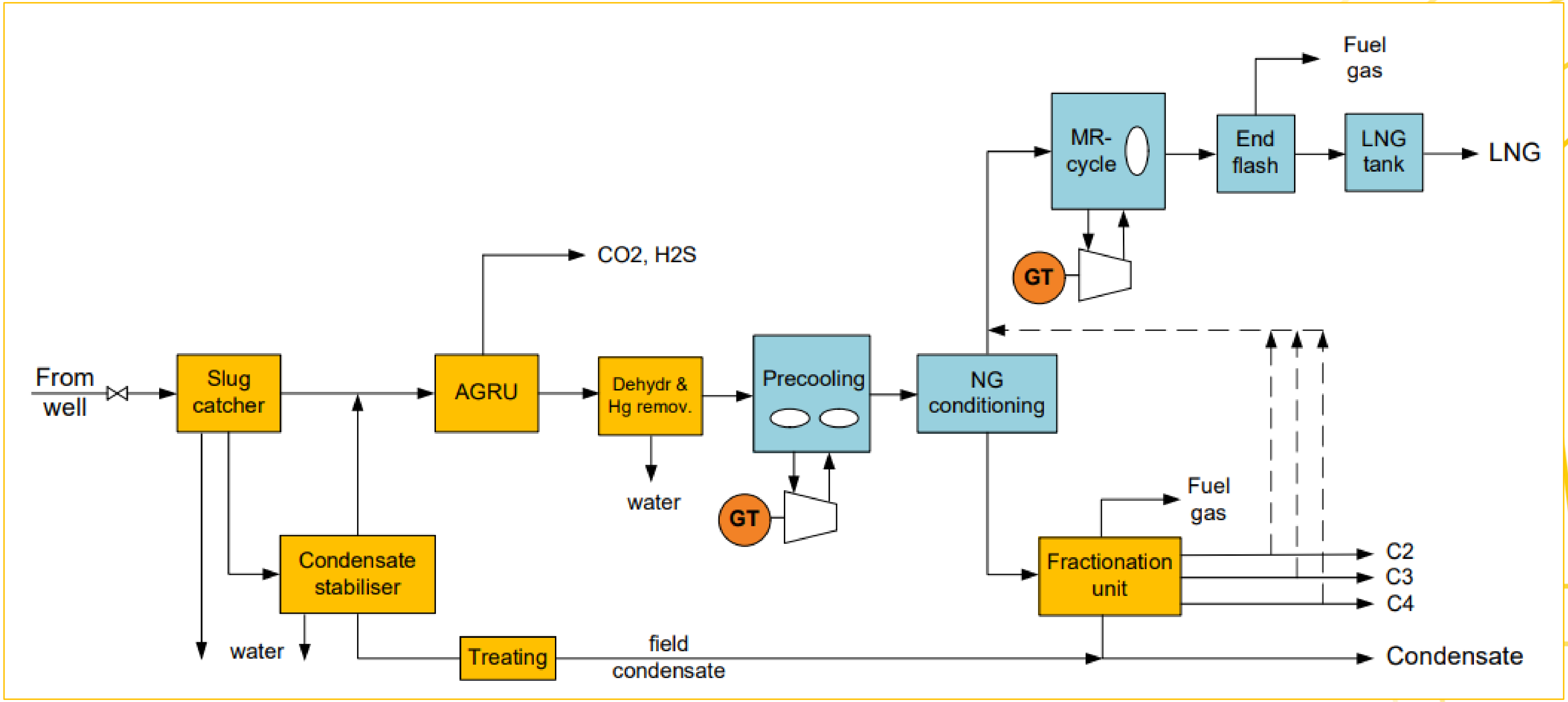
For this purpose, a detailed simulation model for a Shell C3-MR LNG plant was built in APS. The following capabilities were evaluated:

- Modelling of an Shell C3-MR LNG plant model and “closing” the precool and MR refrigerant loops
- Model Convergence, performance
- Sensitivity analysis: running scenarios with the model
- Design Optimization

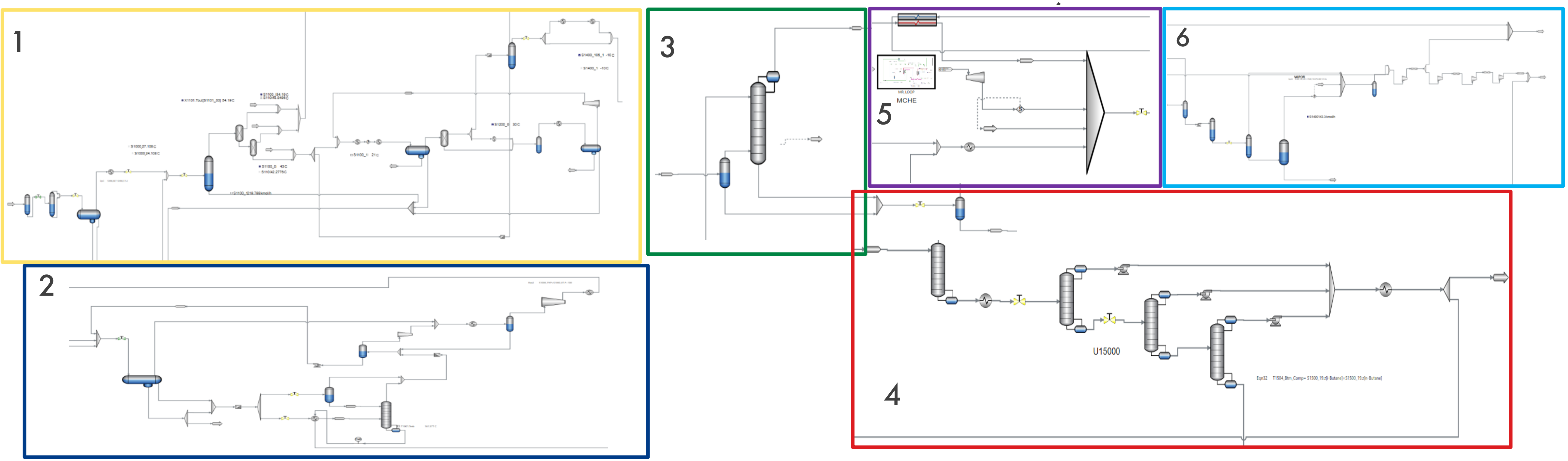
Introduction: Why APS ?

- Next generation open-equation based platform that has the capability to combine steady-state, dynamics, and hydraulics into one simulator.
- Enables faster convergence of complex simulation models with multiple closed process loops/recycles, inherent in LNG process schemes.
- Potential to do design/operation optimization and what-if studies with features like PI Integration and real-time system (RTS).
- Integration with AVEVA Engineering for integrated digital workflows: design, simulation, training, and operations. Build an integrated digital twin for your entire plant lifecycle and use the same process model throughout every engineering phase.

Shell C3-MR LNG Process Flow Scheme



Simulation Process Scope



- 1: Feed gas receiving facilities
- 2: Stabilization Section
- 3: Scrub Column
- 4: Condensate Units
- 5: MR (Mixed Refrigerant) Loop
- 5: C3 (Propane) Loop
- 6:LNG/Fuel gas production unit

Component Slate and Thermodynamics

Thermodynamic Model Settings

- Phase behaviour, Entropy: SRK Equation of State (EOS)
- Liquid density: COSTALD
- Enthalpy: Lee-Kesler

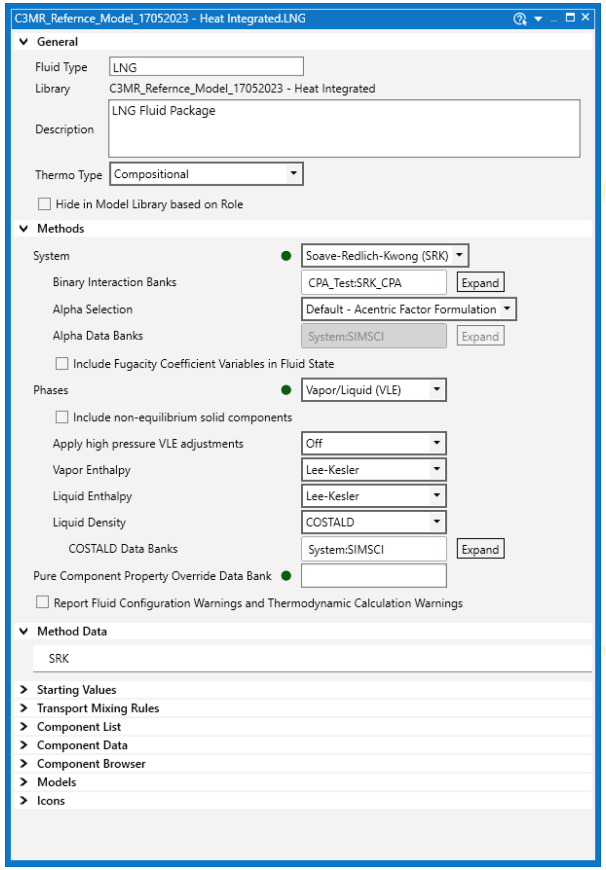
Pure Component Properties

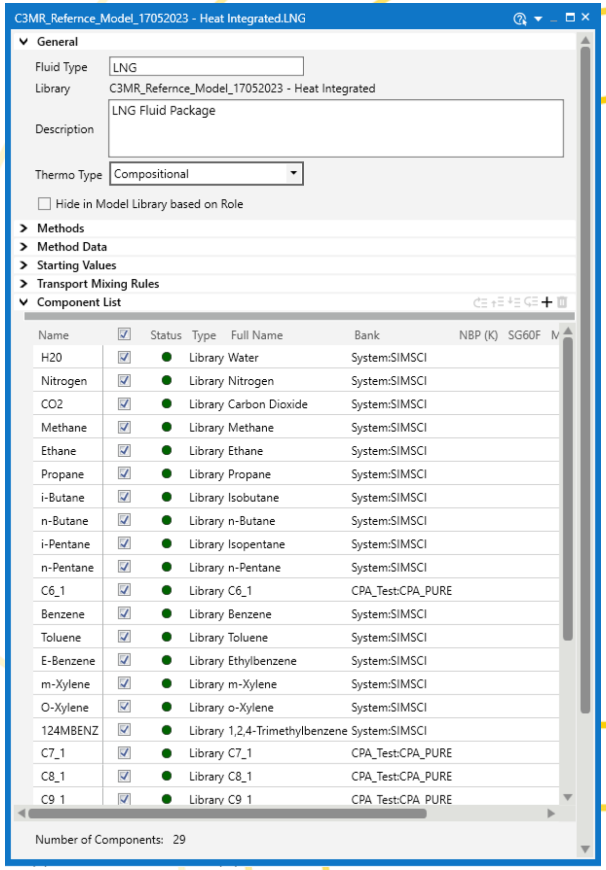
- Component slate created using APS standard library based on legacy model.

BIP: Binary Interaction Parameters

- Shell CPA (Cubic Plus Association) EOS BIP's in legacy model used as SRK BIPs in APS.

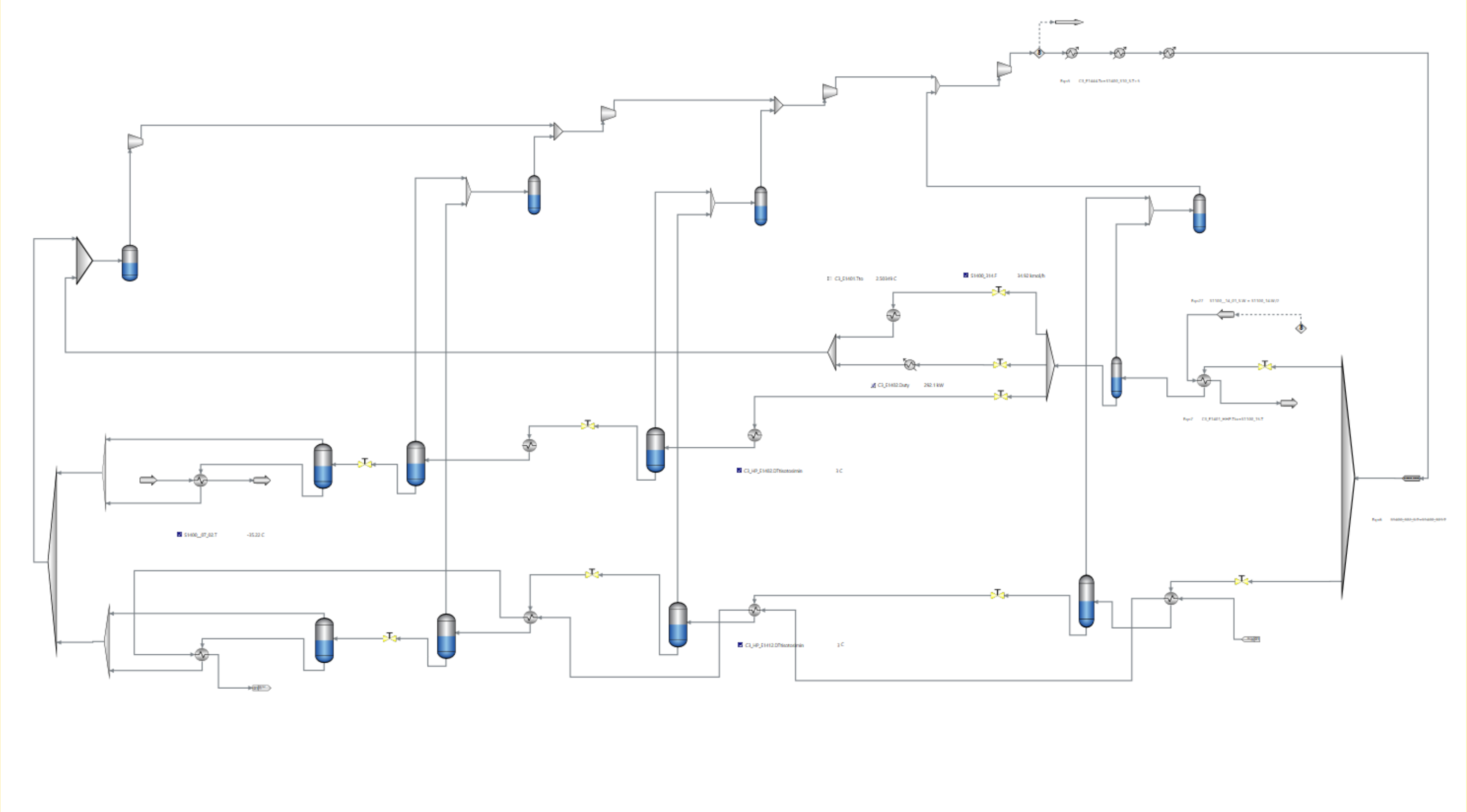
Note: CPA EOS reduces (no association term) to SRK EOS in absence of associating/polar molecules.





C3 Loop: Propane Condensing Duty

- This model section simulates multi-stage compression, de-superheating and condensing of Propane, integrated with MR Loop and NG process side (through C3-MR and C3-NG kettles)

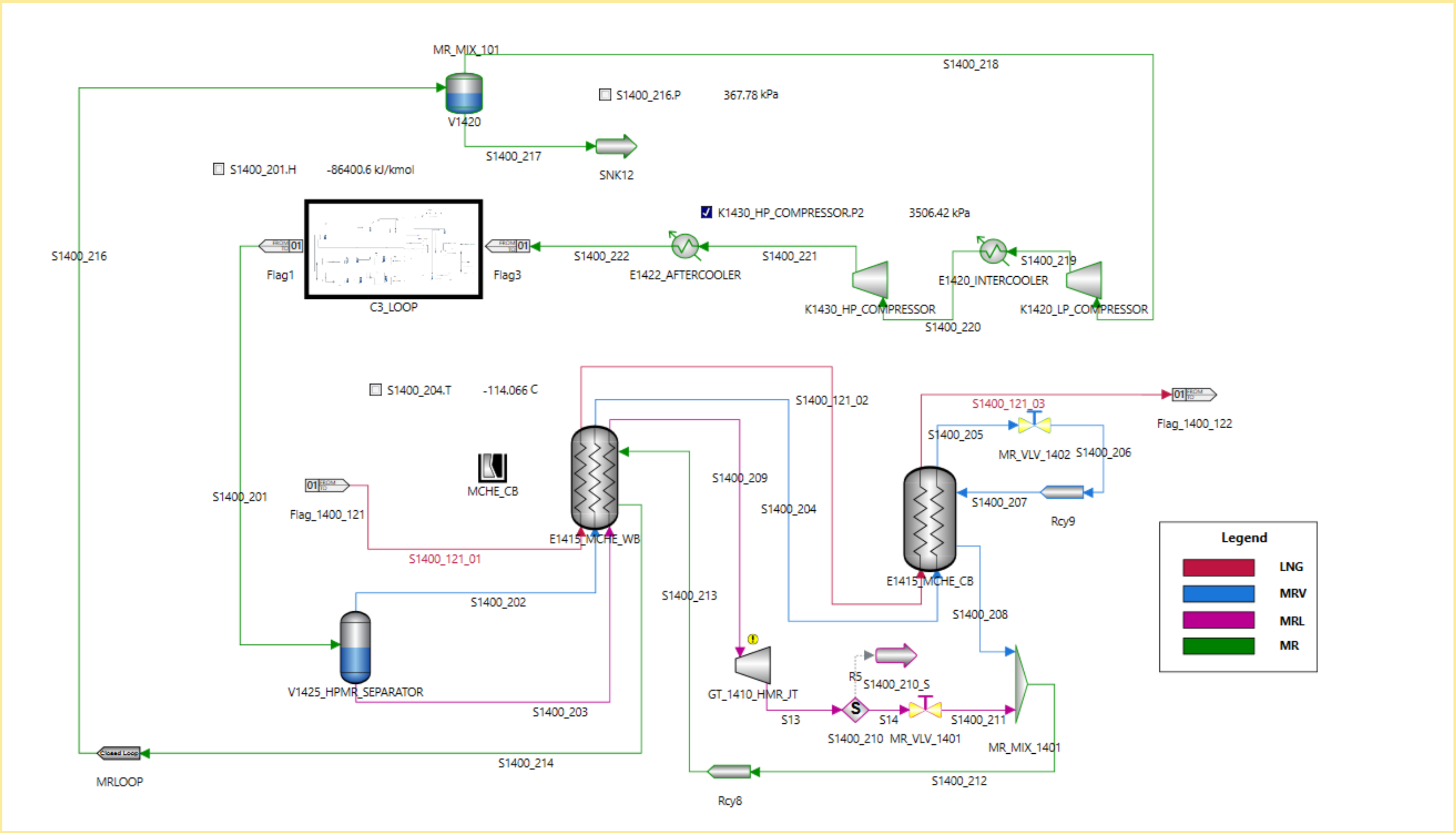


APS vs Reference Model Deviations

C3 Loop	% Rel. Dev. {APS-Reference}
HHP compressor exit	
Pressure, bar	-0.01%
Temperature, °C	0.02%
Flow rate, kg/h	-0.52%
Desuperheater	
Duty, MW	-0.99%
Tin, °C	0.02%
Tout, °C	0.05%
Pin, kPa	-0.01%
dP, kPa {Spec}	0.00%
Condenser	
Duty, MW	-0.66%
Tin, °C	0.05%
Tout, °C	0.06%
Pin, kPa	-0.01%
dP, kPa {Spec}	0.00%

Mixed refrigerant (MR) loop cooling cycle

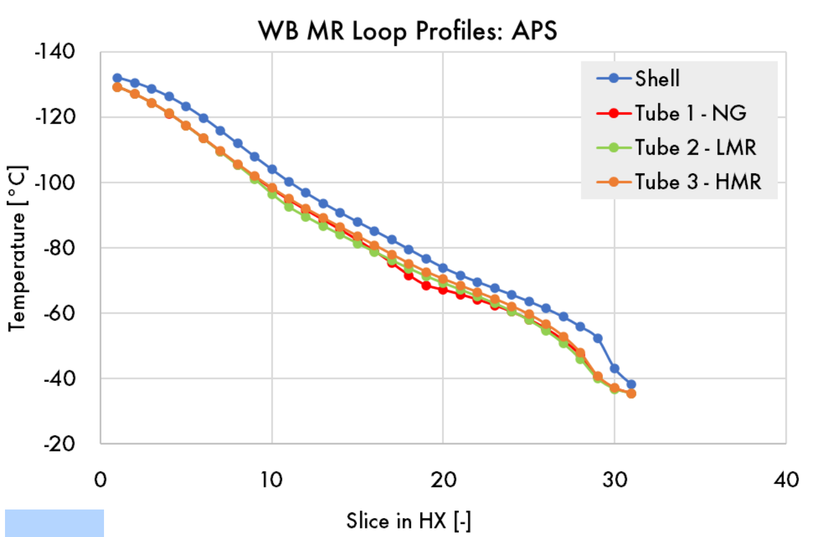
- The cooling cycle with a combined warm & cold bundle of MCHE is modelled and integrated with C3 Loop and Process.

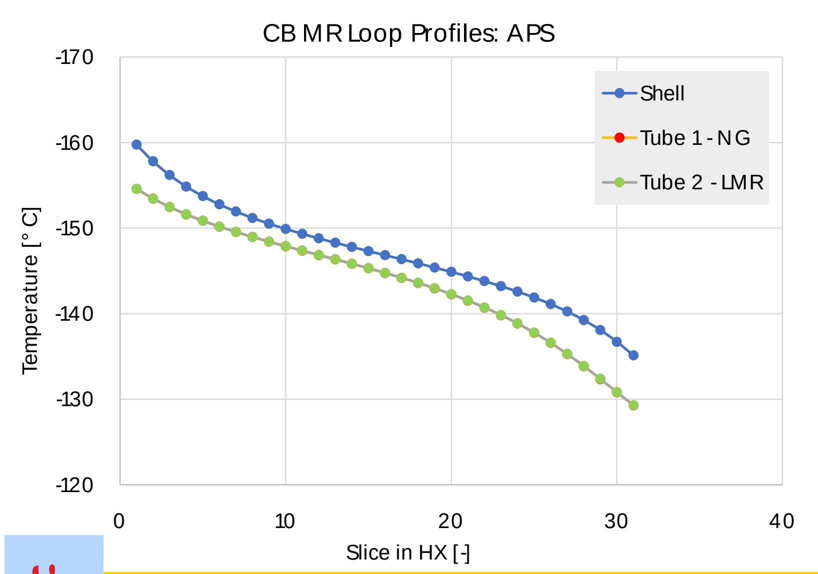


APS vs Reference Model Deviations

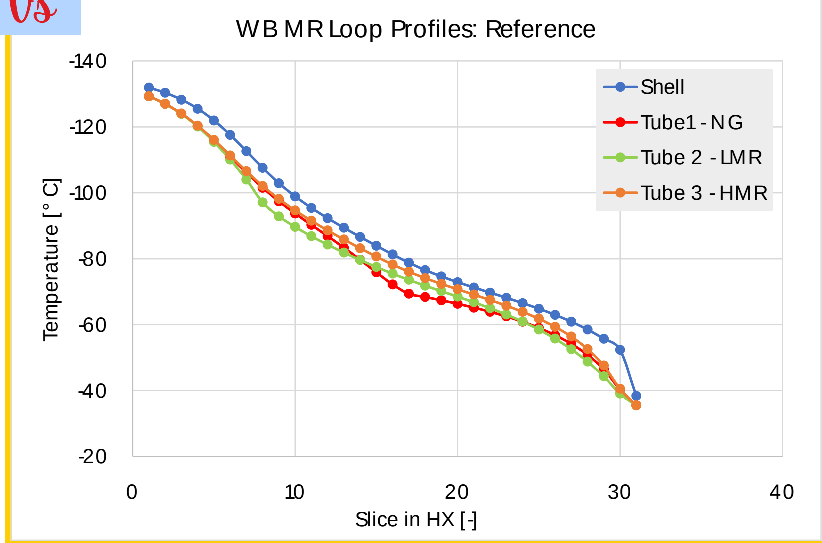
MR Loop	% Rel. Dev. {APS-Reference}
MR Flash Drum	
LMR Flow, kg/hr	5.18%
HMR Flow, kg/hr	2.01%
Warm bundle @ -129.28 °C	
Shell	
Tout, °C	0.52%
Duty, MW	0.25%
Tube 1 - NG	
Duty, MW	0.19%
Tube 2 - LMR	
Duty, MW	4.80%
Tube 3 - HMR	
Duty, MW	4.27%
Cold bundle @ -154.6 °C	
Shell	
Tout, °C	0.56%
Duty, MW	0.73%
Tube 1 - NG	
Duty, MW	0.54%
Tube 2 - LMR	
Duty, MW	3.59%

MR Loop MCHE Heating (Shell), Cooling (Tube) curves

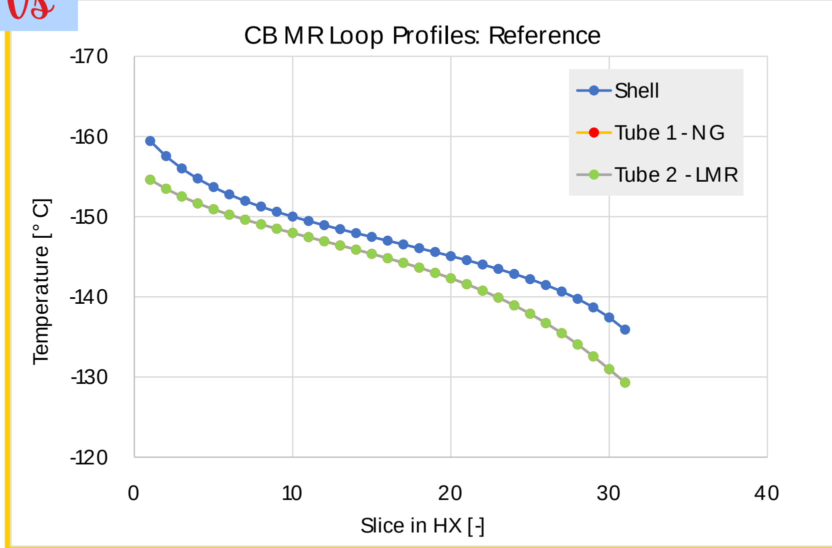




Vs



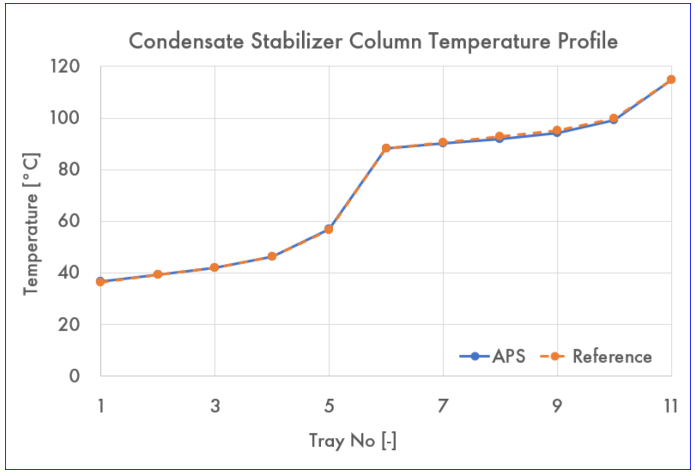
Vs

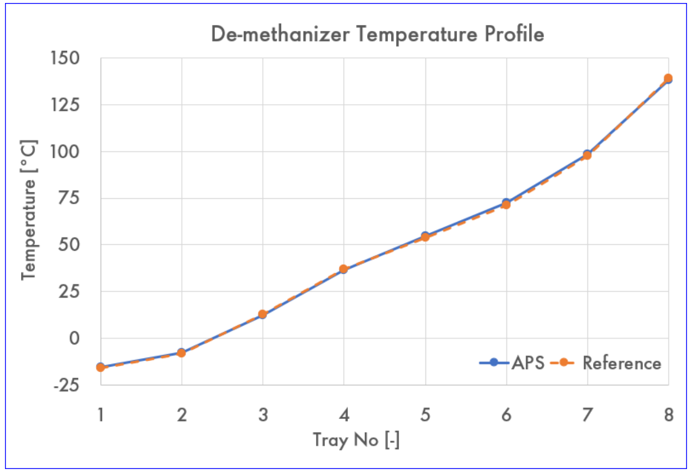


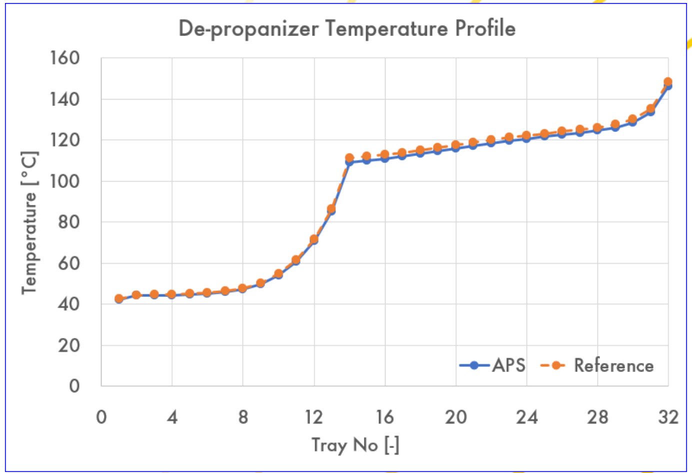
- The heating / cooling curves of the warm bundle (WB) & cold bundle (CB) generated by APS match well with the reference model.

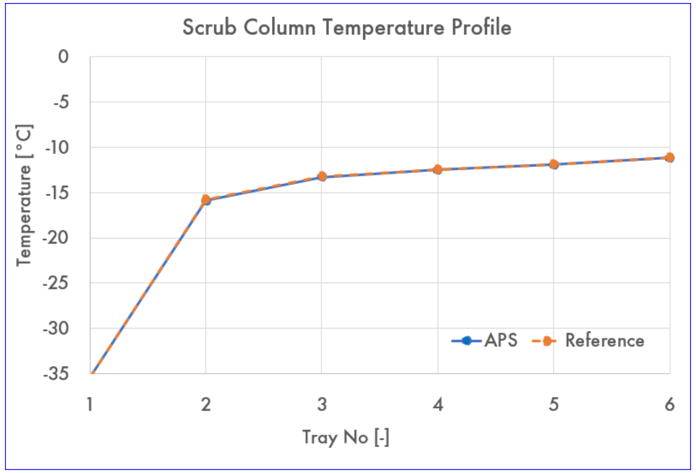
Column Results: Overview of Temperature Profiles

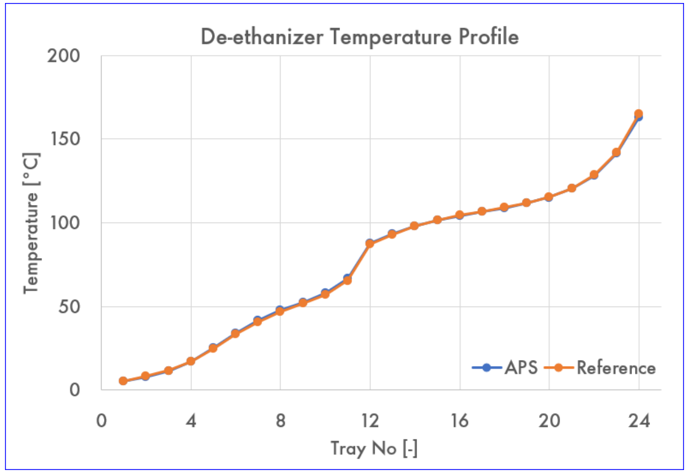
- Profiles: Temperature [shown here], match well for APS against the reference model.
- Other profiles [not shown here] such as Pressure, Column loading, Condenser duty and Reboiler duty also match well.

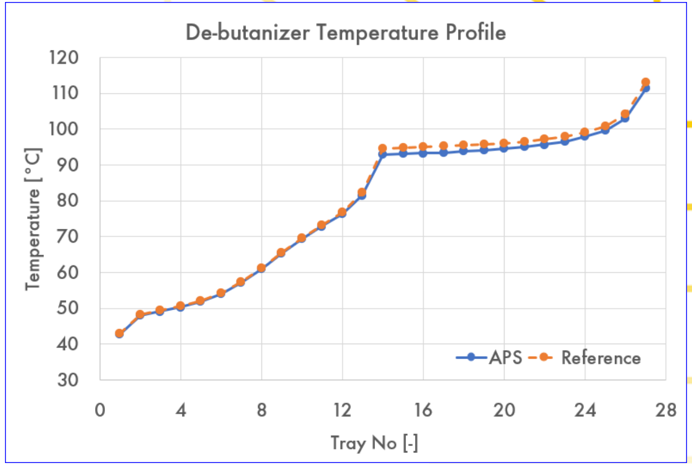












Column Results: Comparison (APS vs Reference) Overview

- Most relative deviations are low (< 2.5%).
- Higher deviations such as duty condenser can be attributed to different thermodynamic methods (Ref: CPA/LKP/SMIRK) and (APS: SRK-COSTALD) and platform flash.

Parameters	Relative Deviations{APS-REF} [%]				
	Scrub Column	Demethaniser	Deethaniser	Depropaniser	Debutaniser
	Rel Dev%	Dev%	Dev%	Dev%	Dev%
Feed Rate	2.3%	0.7%	1.1%	1.0%	1.3%
Duty Reboiler	N/A	3.1%	2.3%	1.3%	0.1%
Duty Condenser	0.8%	NA	5.4%	0.9%	1.1%
Reflux Rate	6.8%	NA	6.6%	1.0%	0.5%
Bottom Product Rate	0.0%	1.1%	1.0%	1.3%	2.3%
Top Product Rate	0.0%	4.2%	1.1%	1.4%	4.5%
Top Product Composition					
MW	0.0%	0.3%	0.1%	0.0%	0.0%
C1, mol%	0.0%	0.2%	1.3%	0.0%	0.0%
C2, mol%	0.0%	1.3%	0.2%	0.0%	0.7%
C3, mol%	0.1%	2.1%	0.0%	0.0%	2.3%
i-C4, mol%	0.5%	3.2%	2.5%	0.1%	1.3%
n-C4, mol%	0.5%	3.8%	3.6%	1.7%	0.8%
i-C5, mol%	3.3%	6.7%	2.1%	5.9%	0.2%
n-C5, mol%	6.6%	5.8%	0.4%	9.0%	3.2%
Bottom Product Composition					
MW	2.0%	1.2%	1.4%	1.4%	1.4%
C1, mol%	3.8%	1.0%	0.0%	0.0%	0.0%
C2, mol%	1.2%	1.4%	1.1%	3.5%	1.3%
C3, mol%	0.8%	1.2%	1.1%	0.0%	1.5%
i-C4, mol%	0.4%	2.3%	2.2%	2.4%	3.3%
n-C4, mol%	1.0%	4.0%	3.9%	4.1%	0.8%
i-C5, mol%	0.2%	4.1%	4.0%	4.2%	2.1%
n-C5, mol%	2.0%	3.2%	3.1%	3.2%	1.8%

Sensitivity study

- For better understanding of model convergence and robustness of APS, selected input variables
  - NG Feed rate, temperature and Pressure
  - MR (Mixed Refrigerant) Composition

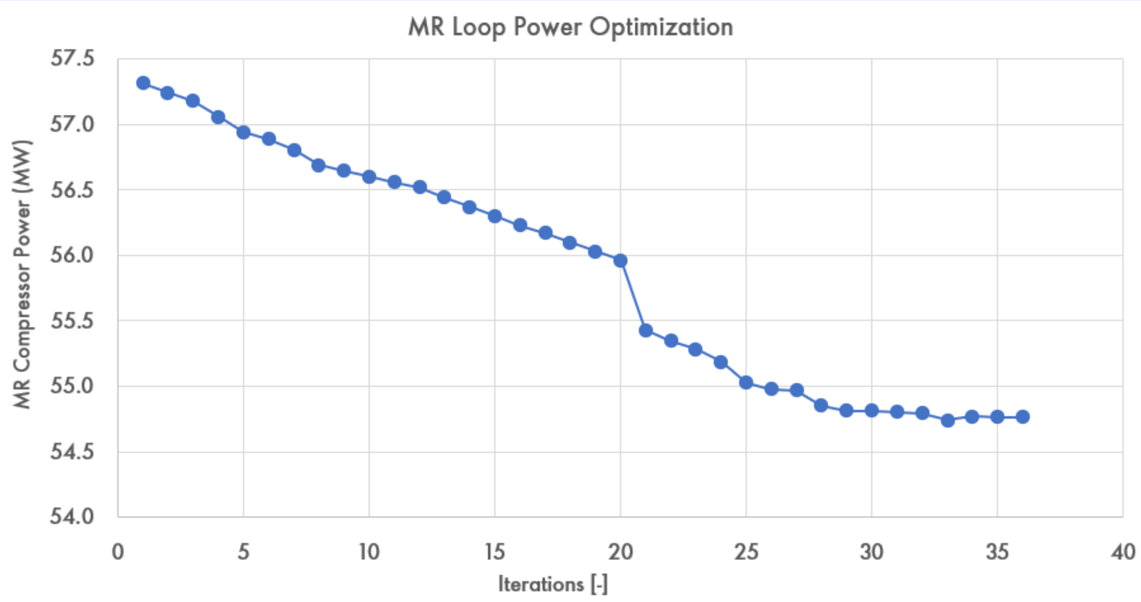
  were adjusted as given in Table

- Observation: The APS model converged faster.

Adjusted Parameter	%Change	Convergence Time Reference	Convergence Time APS
NG Feed Rate	0.1	~2 min	~3 s
	0.5	~4 min	~3 s
	1	~5 min	~5 s
	3	~15 min	~8 s
NG Feed Temp	0.1	~1.12 min	~4 s
	0.5	~2.32 min	~4 s
	1	~3.05 min	~4 s
	3	~7.0 min	~5 s
NG Feed Pressure	0.1	~36 s	~4 s
	0.5	~36 s	~4 s
	1	~50 s	~4 s
	3	~50 s	~4 s
MR Composition	C1 +/-2	~30 s	~20 s
	C2 +/-1	~20 s	~10 s
	N2 +/-1	~10 s	~4 s

MR (Mixed Refrigerant) Loop Optimization

- Aim of the study is to assess APS capability for process optimization.
- Objective Function: Minimize total compressor power with MR loop composition as optimization handles.



Results

- APS optimizer optimized the MR loop composition to minimize the compressor power.
- Optimizer achieved the solution in 37 iterations within 2 minutes.
- Optimum composition (Delta shown here) resulted in 4.6% reduction in power as compared to reference case, as shown in Table

Optimizing Variable	Unit	Optimization Setting	Low Bound	High Bound	Delta {APS-Ref}
MR Composition:Nitrogen	Mol Frac	Dependent	0	0.1	0.01
MR Composition:Methane	Mol Frac	Independent	0	0.5	-0.01
MR Composition:Ethane	Mol Frac	Independent	0	0.5	-0.04
MR Composition:Propane	Mol Frac	Independent	0	0.2	0.03
MR flow	kmol/h	Dependent			-1626.22
LMR/HMR Ratio	Frac	Dependent			0.03
Compressor Power	MW	Objective Function	52	58	-2.6

Conclusions & Future Work

- APS evaluation of the Shell C3/MR LNG model was positive in terms of performance and functionality.
- Next phase assessment: integration of Shell thermodynamic methods in APS and carry out similar studies.
  - Separate Shell-AVEVA R&D project to integrate Shell Thermodynamic package (SPPTS) with APS, commenced in September 2023.
  - Outcome of study would be further reviewed by LNG & Cryogenics CoE TA-2, TA-1 (technical authorities) for steer.

Other APS Features

- Capability to **integrate with PI Server** and provide PI Data filtering, as well as read and write access to PI system.
- Real time sequence (RTS) console capabilities for Real Time Optimization (RTO), offline and online studies.
- Convert design to rating model: match model to plant data.
- Currently limited number of Shell users have hands-on experience in APS or even EO modelling.
  - A face to face APS course arranged in Shell WoodCreek Center, Houston to increase interest, familiarity with features of new release: v2023.2.

- This study lays foundation for APS as future platform for LNG dynamic model-Digital Twin integration applications. [Separate Shell-AVEVA PoT (Proof of Technology) commenced in September 2023 to integrate DYNSIM Model with Digital Twin environment for what-if scenarios, troubleshooting, shadow plant modelling for wider user base]
- **Potential Future Use Case:** Trigger APS with API using LLM models (GPT-3) driven process model benchmarking, design, optimization studies.

Q&A