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Field Development plan optimization with Integrated production modelling (IPM):

An example of giant ultra-deepwater pre-salt oil field

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1. **Overview of Ultra-Deepwater E&P projects**

2. **Integration of Engineering domains in DP conception**

3. **Production modelling**
   - *Standard workflow*
   - *IAM/IPM*

4. **Case Study (IAM implementation)**
   - *Impact of different subsea architectures and artificial lift options*
   - *Subsea processing technologies*

5. **Conclusions and Way Forward**

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Ultra-deepwater E&P projects

GALP's production assets important exposure in the Brazilian pre-salt (Santos Basin)

World Class Partnerships

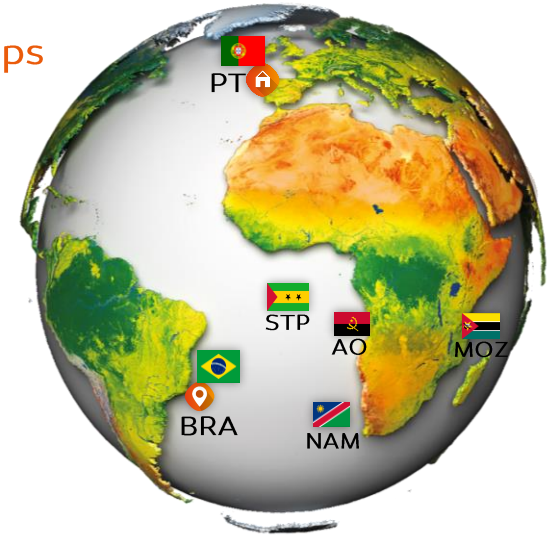
Petrobras, Shell, *Sinopec*
Total, Equinor, Exxon, BP
Chevron, Eni

Fluids

26 – 32°API
Presence of CO_2

World Class Reservoirs

Large volumes in place
Heterogeneous carbonates
Depth > 5 km
Beneath a thick salt layer



Location

> 2000 m WD
~ 250 km from coast

Highly productive Wells

Typical deliverability:
~ 20 - 30 kbopd

Standardized Subsea Concept

Satellite wells
Flexible lines
Gas Export Network

Complex Processing Units

Large FPSOs (100 – 150 kbopd)
CO2 removal
Gas Plants ~ 60% of total footprint

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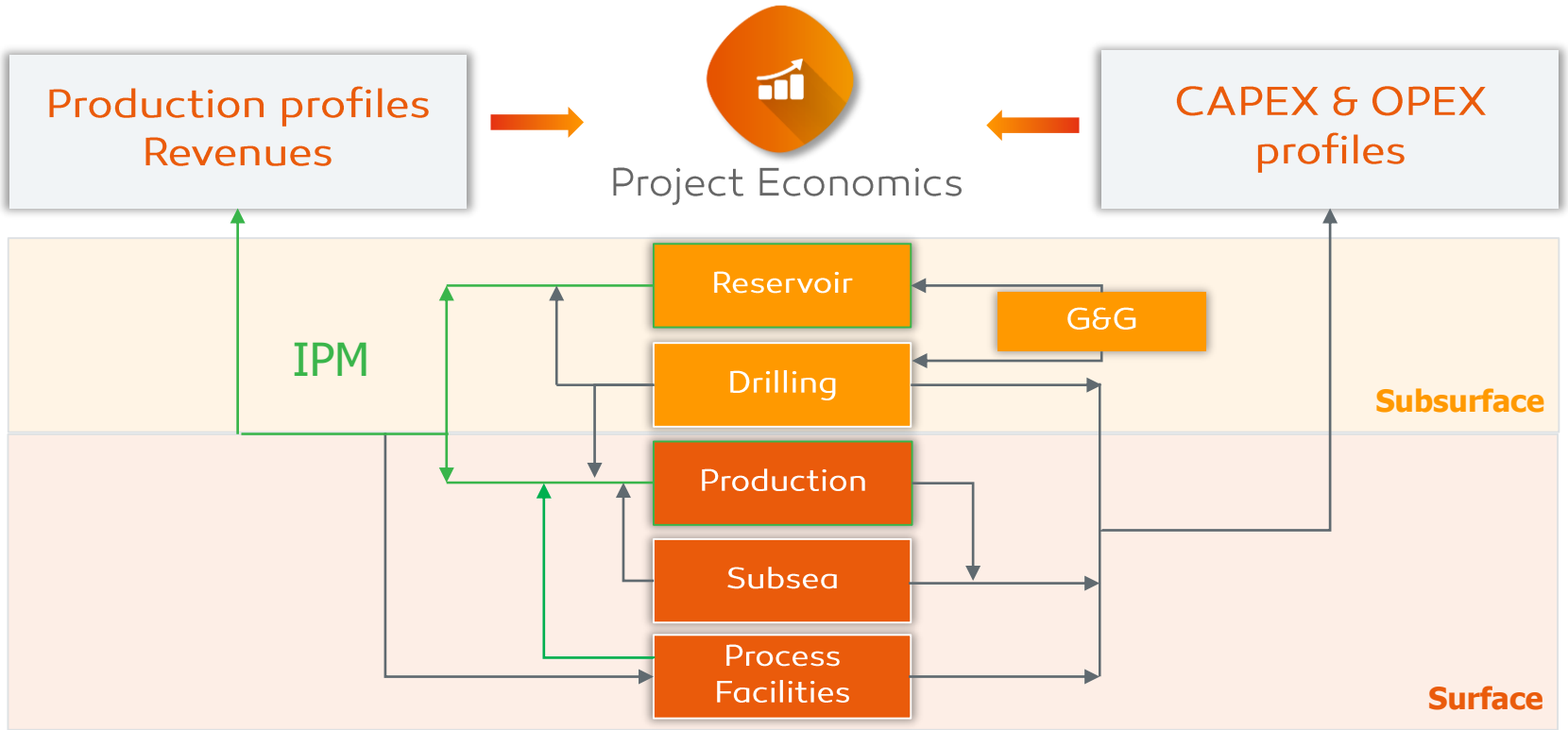
Project feasibility evaluation

Integration of multidisciplinary efforts towards a robust screening of solutions



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Production modelling building blocks

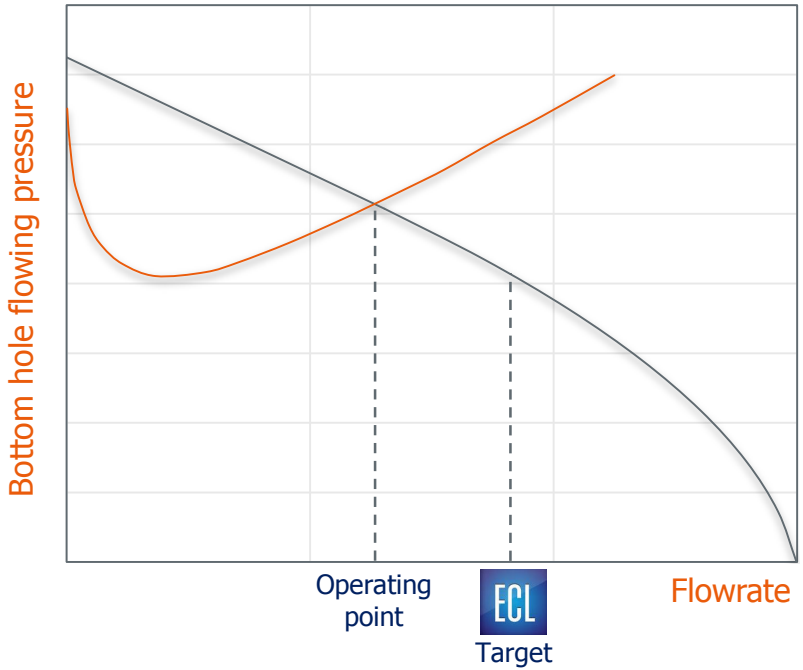
Robust profiles must honor both reservoir and facilities constraints

Reservoir Dynamic Model

- Drainage plan / Well locations
- Reservoir dynamic properties
- Well/group controls, targets and constraints

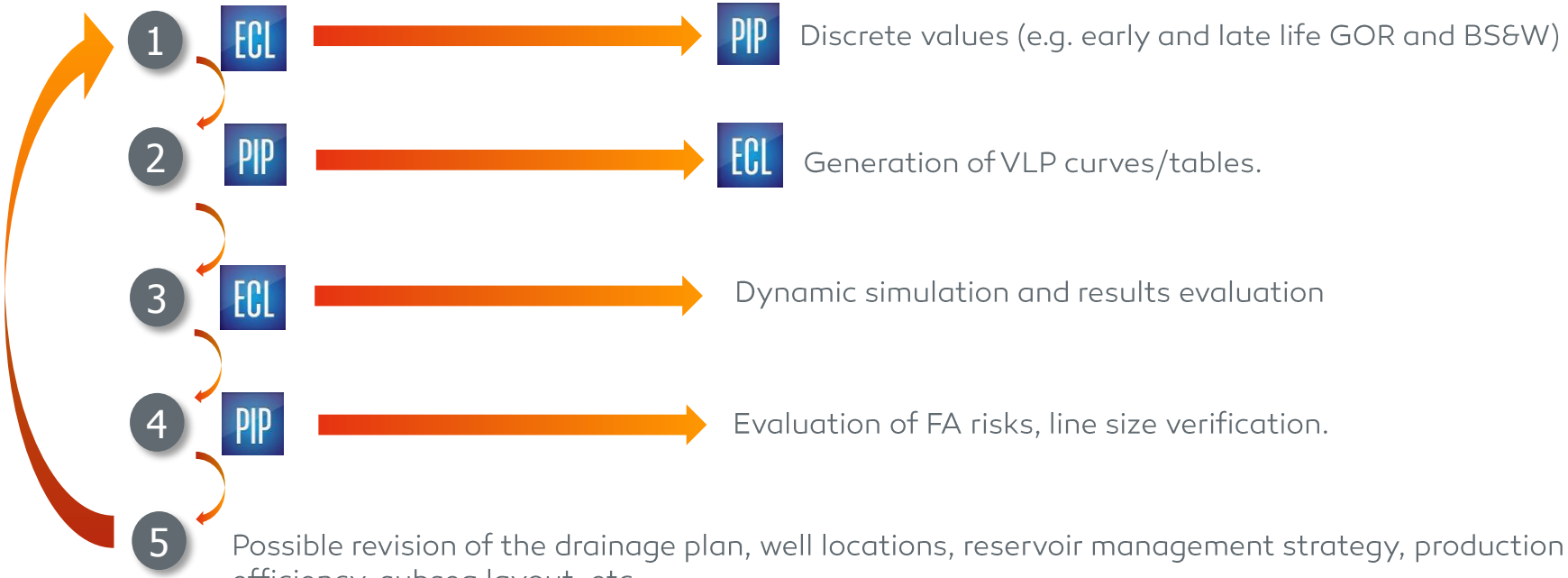
Production System Model

- Well geometry
- Subsea architecture
- Topsides constraints (e.g. separator pressure)



Production modelling

Workflow between Reservoir and Production Engineering: an intrinsically iterative process



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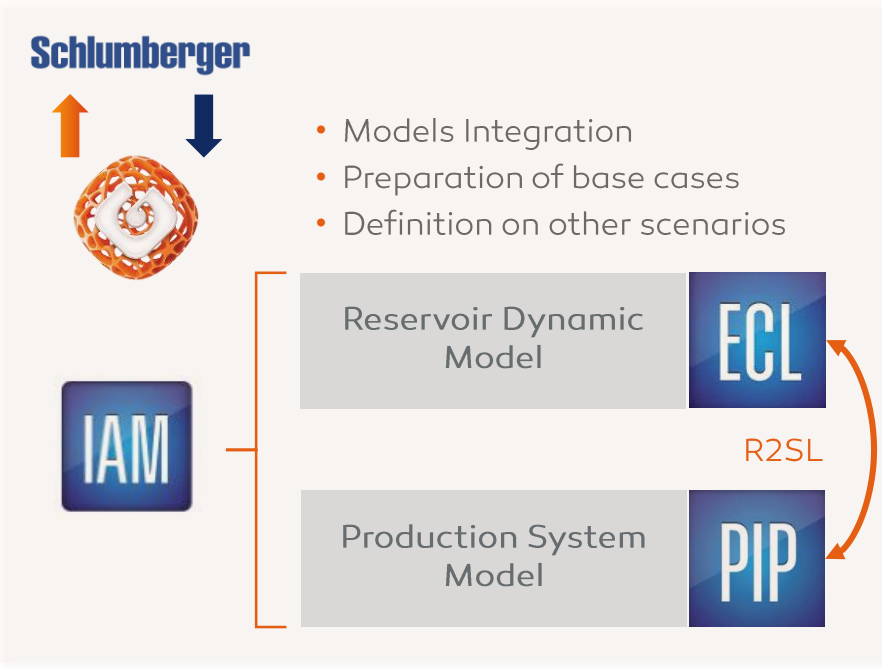
Integrated Asset/production Modelling (IAM/IPM)

Novel approach to expedite asset understating by coupling models

Knowledge Transfer



Key Benefits / Value Extraction

Time Saving

- More comprehensive assessment of concept scenarios.

S2 seamless Integration

- Impact of facilities on reservoir deliverability / performance.
- LOF evaluation of FA risks and CPF bottlenecks.

Flexibility

- Adding third party tools (process, economics, etc.)

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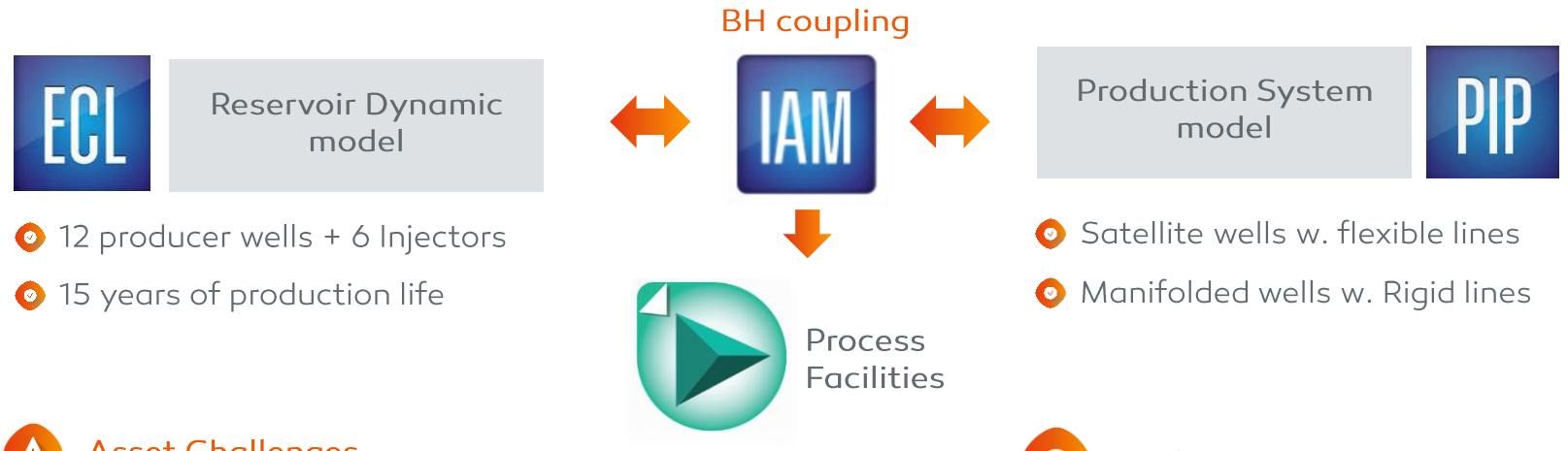
Case Study Description

Impact of different subsea architectures and artificial lift options



Asset Challenges

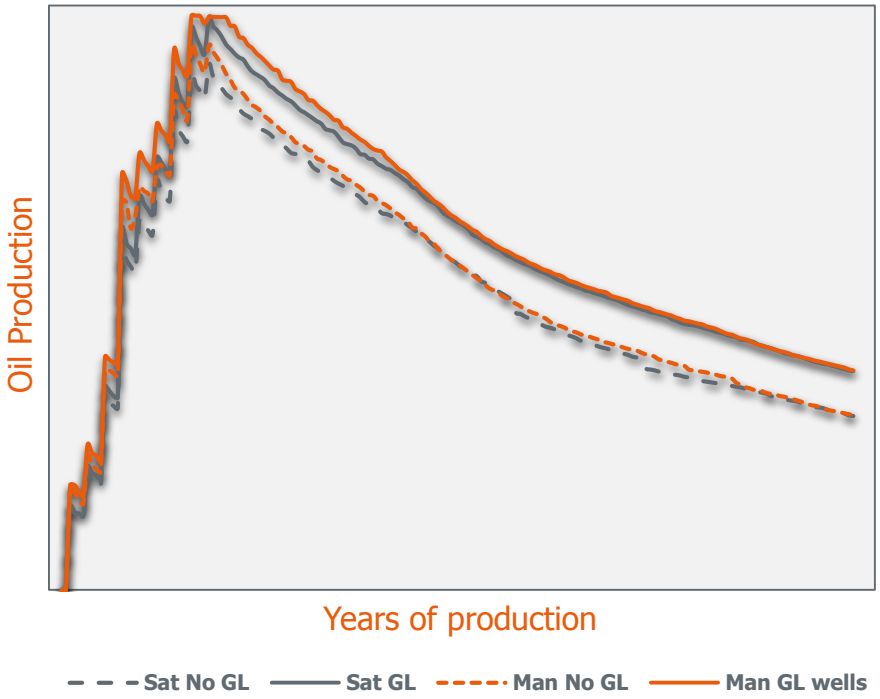
- Relatively modest reservoir properties (compared with other assets in the basin)
- High risk of wax deposition in flowlines.

Evaluation Criteria

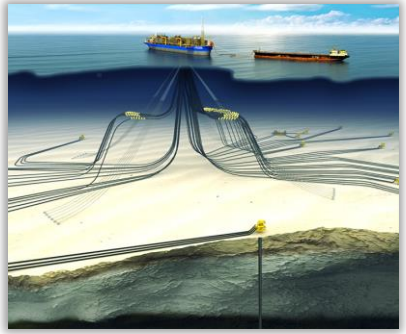
- Ultimate recovery volumes.
- Production assurance risk mitigation.

Impact of different subsea architectures and gas lift

Gas lift since early life, rigid lines and manifolded to maximize ultimate recovery.

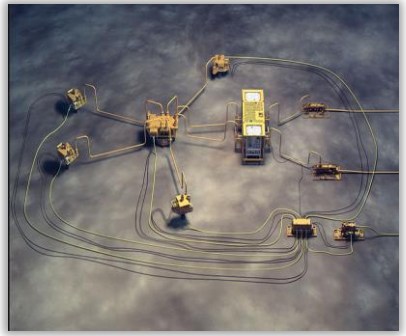


Satellite wells w/ flexibles



Source: Petrobras website

Manifolded wells w/ Rigids



Source: OneSubsea website

Recoverable volumes impact

- Manifolding the wells : + 3 % Rec. Vol.
- Gas Lift since early life : + 11 % Rec. Vol.

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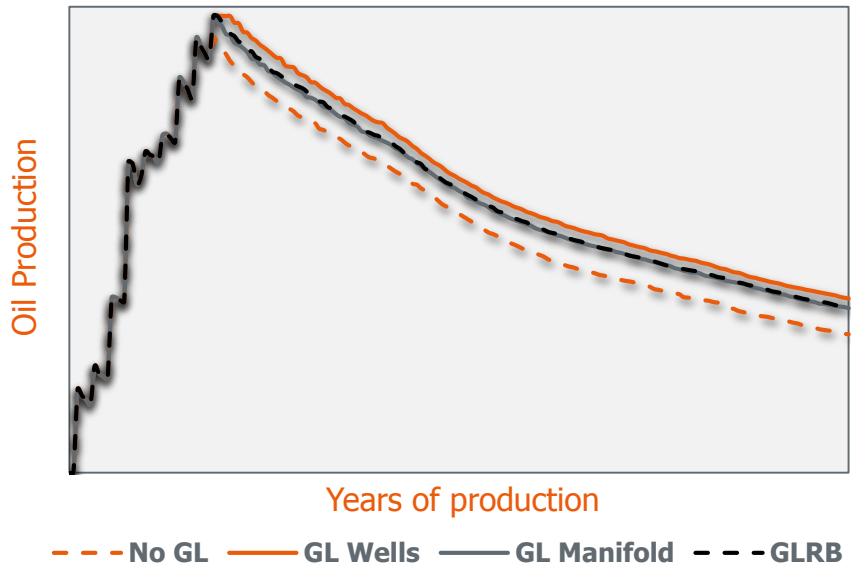
IAM enable quick assessment of Gas lift injection point

Option between GL in wells or at Riser base to be further assessed in terms of economics



Recoverable volumes impact

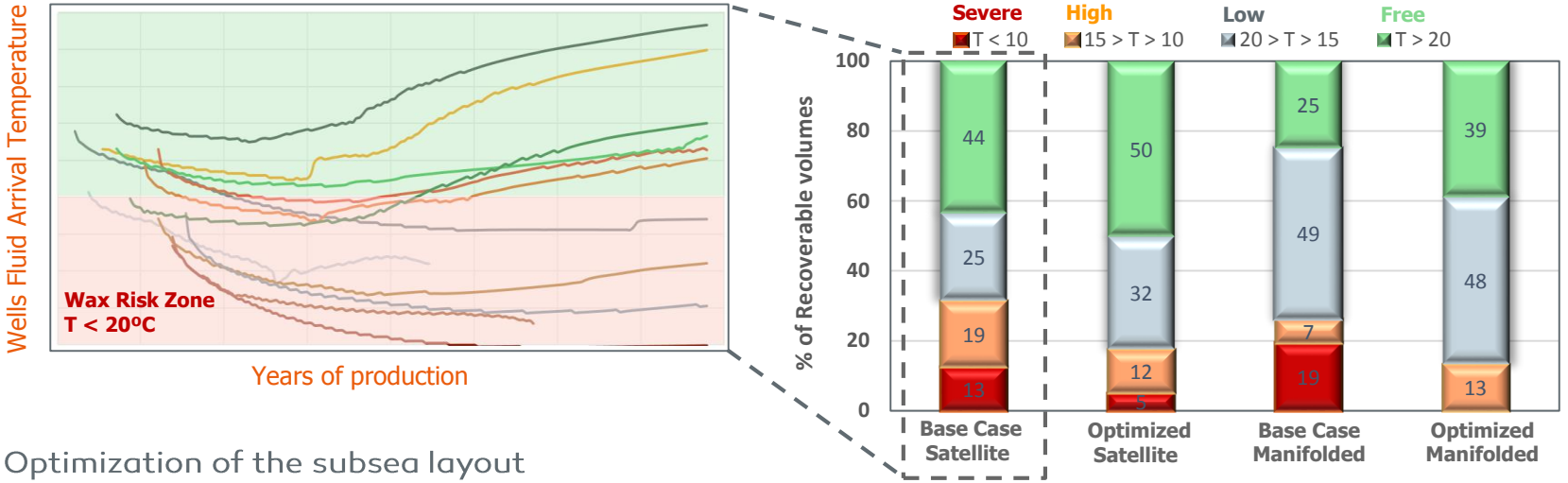
- Gas lift in the manifold: + 7 % Rec. Vol.
- Gas lift in the Riser Base: + 8 % Rec. Vol.
- Gas lift in the Wells: + 11 % Rec. Vol.

Production assurance risk

- GLRB may provide less reliability issues and WO requirements related to GLVs.

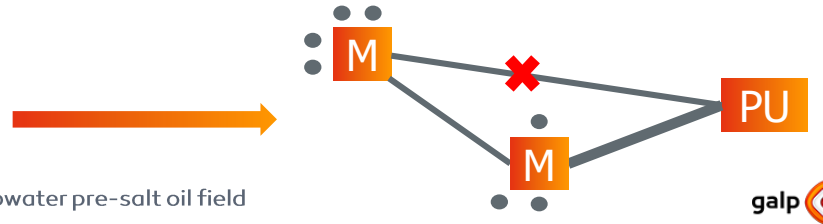
IAM enable Wax deposition risk evaluation over the entire field life

Comingling the wells and optimization of the subsea layout to minimize risks



Optimization of the subsea layout

- Both architectures: Total line length reduction by adjusting FPU position.
- Manifolded architecture: Tie-back between manifolds (wax risk and total line length reduction)



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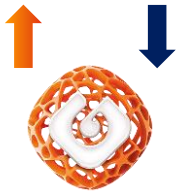
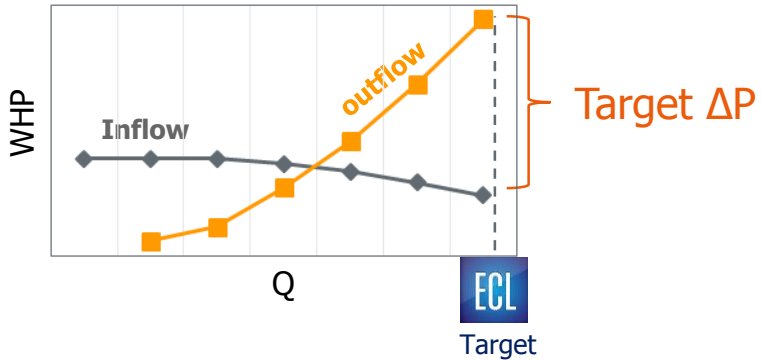
IAM allow for quick assessment of Subsea Processing options

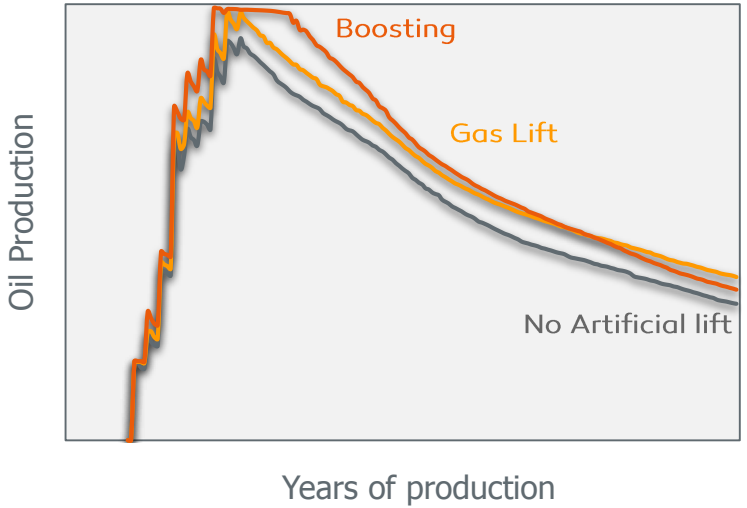
Subsea boosting opportunity to maximize recovery

Schlumberger



- MPP ΔP requirements
- Pump model selection
- Pump configuration





Recoverable volumes impact

- Gas lift in the Wells: + 11 % Rec. Vol.
- Subsea boosting: + 16 Rec. Vol.

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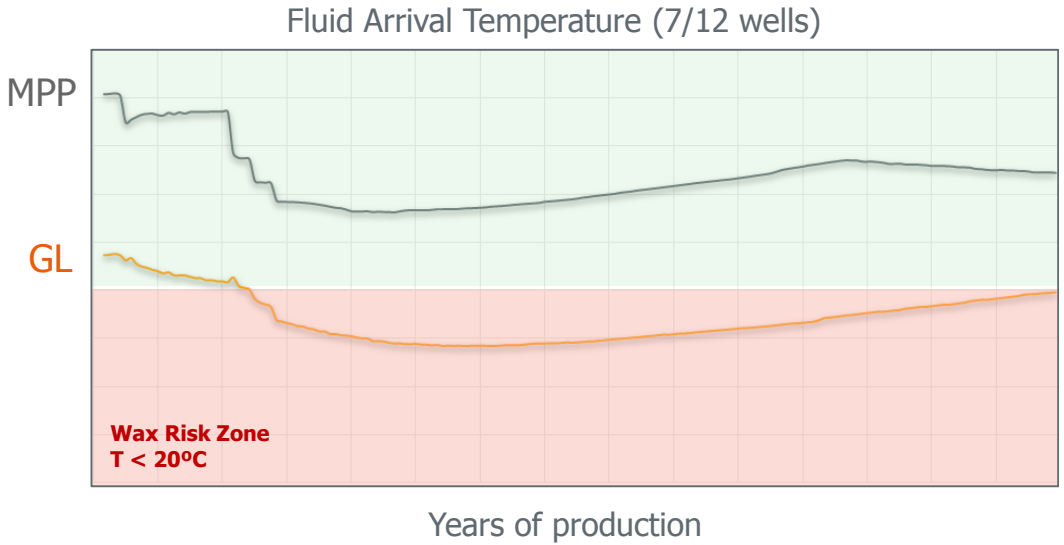
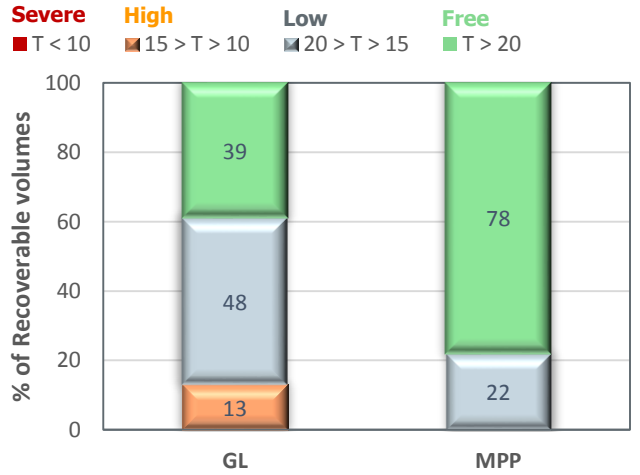
IAM allow for quick assessment of Subsea Processing options

Subsea boosting opportunity to minimize flow assurance risks





Flow Assurance Impact

- The higher deliverability driven by the MPP as well as the warming effect on the produced fluids contribute to reduce wax deposition risk.

Final Remarks

IAM as a tool for deeper and more expedite asset understanding and evaluation

- Higher degree of engagement between multidisciplinary teams.
- Deeper understanding of recovery maximization opportunities.
- More robust and comprehensive screening of development concepts.
- Extend application of IAM approach for other assets in company portfolio.

We are committed to continue to develop knowledge and application of state of the art tools, to generate value to the world class partnerships where we participate

the future is open

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