EOR Techniques Smart Screening for Selected Reservoir

An Advisory System

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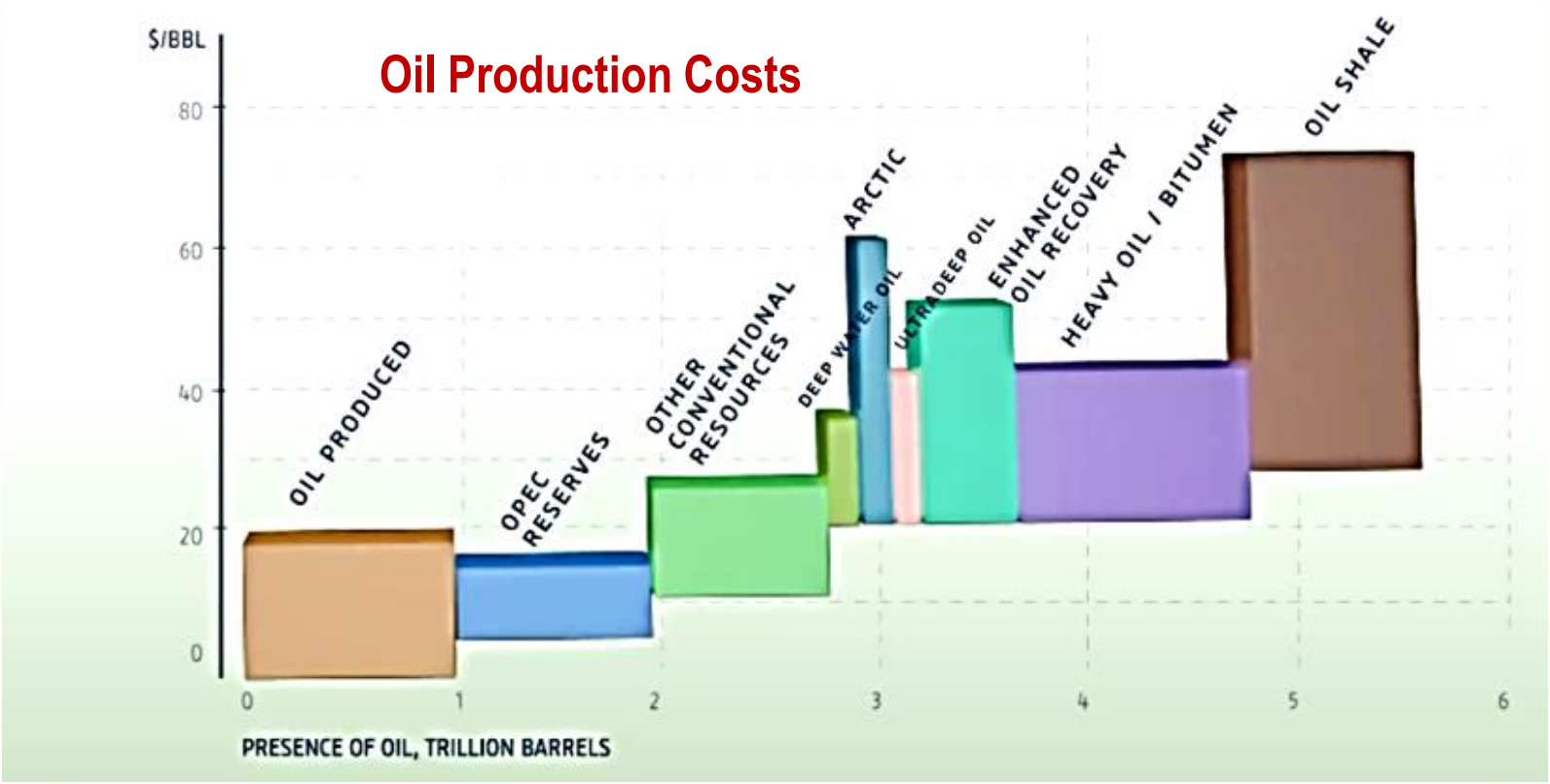
Presentation Outline

- Global Oil Production Costs
- Lifecycle of EOR Practices
- New Screening Advisory System
- Recent Examples – Aberdeen
- Conclusion

Oil Production- Today and Tomorrow

- By 2050, energy demand will double or even triple.
- The "Easy Oil" era is over; fields entering the production decline phase

- State of the art technologies which make it possible oil to produce where it was impossible before are costly. Government incentives and support are required



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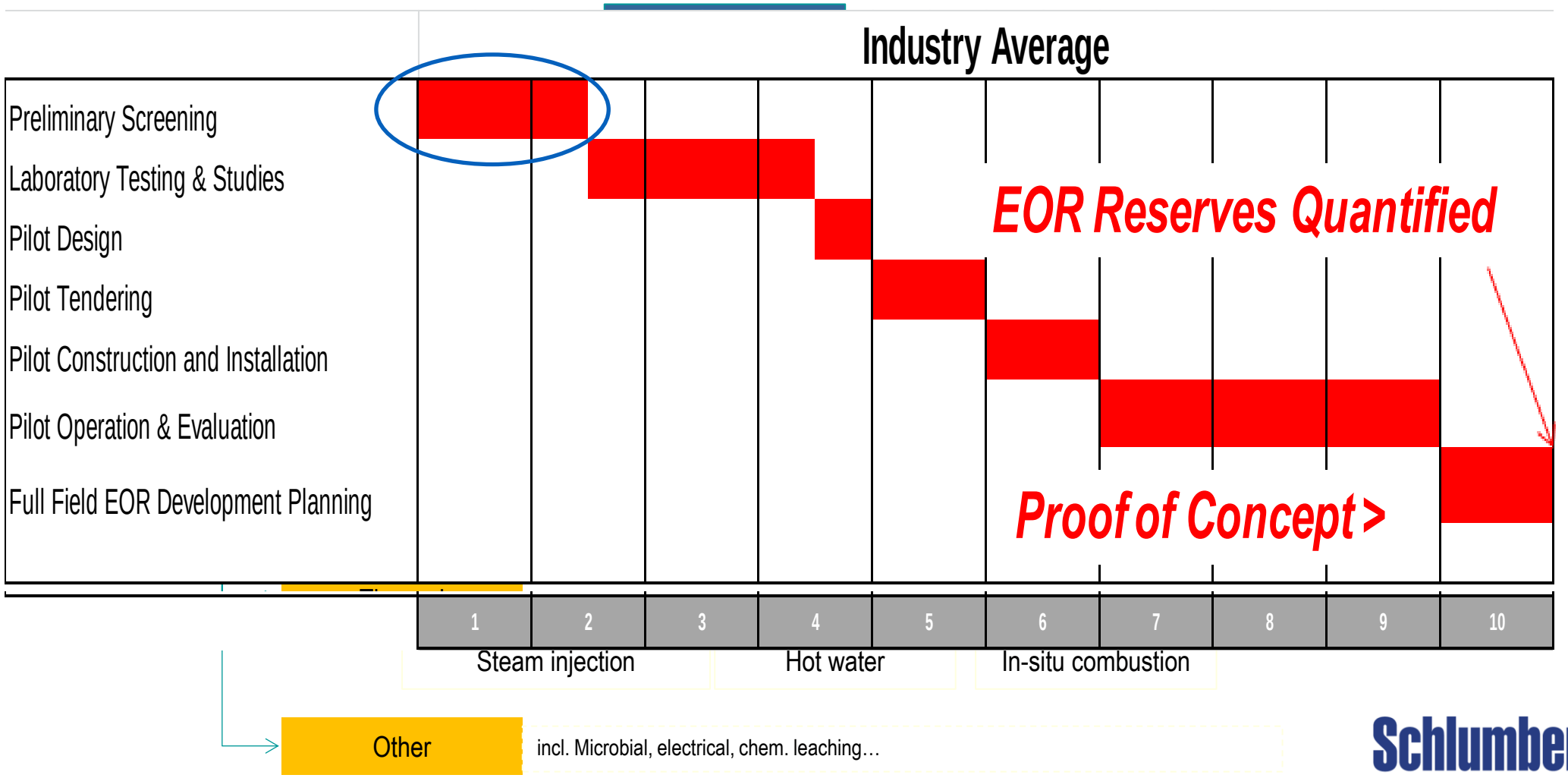
Lifecycle of EOR Practices

Industry Average Trend- EOR Techniques



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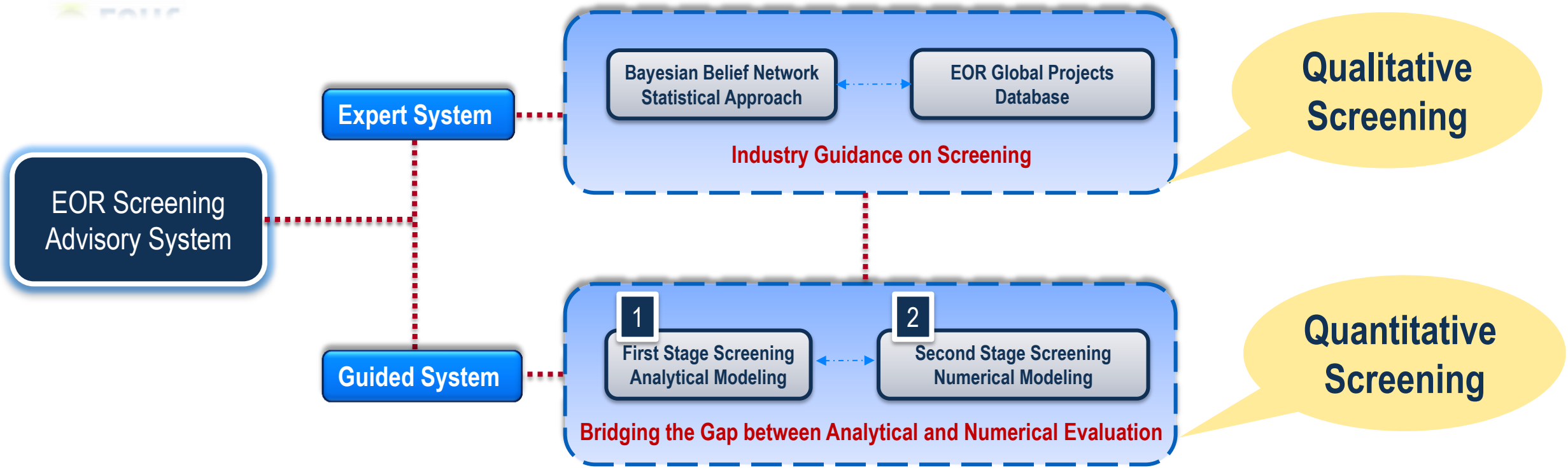
New EOR Techniques Screening Approach

EORt



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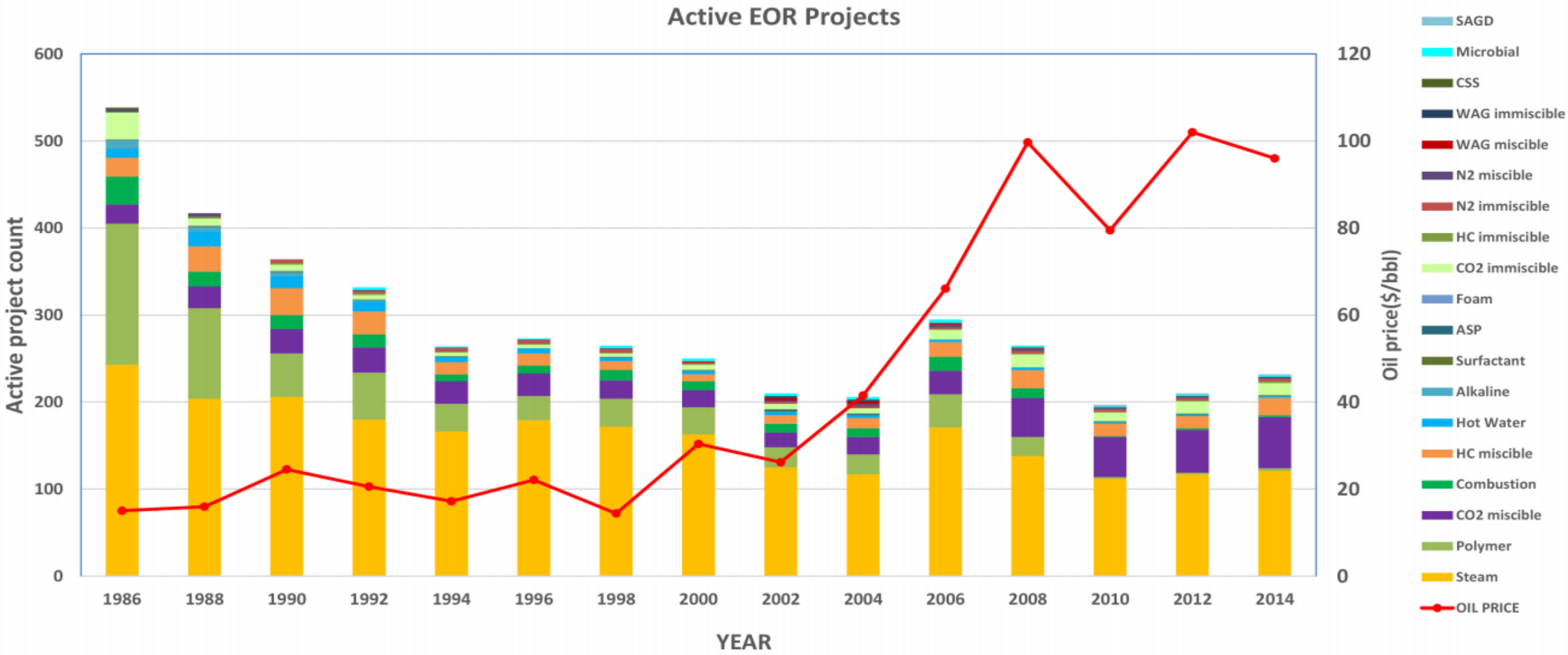
Expert System

Qualitative Screening; EOR Projects Database



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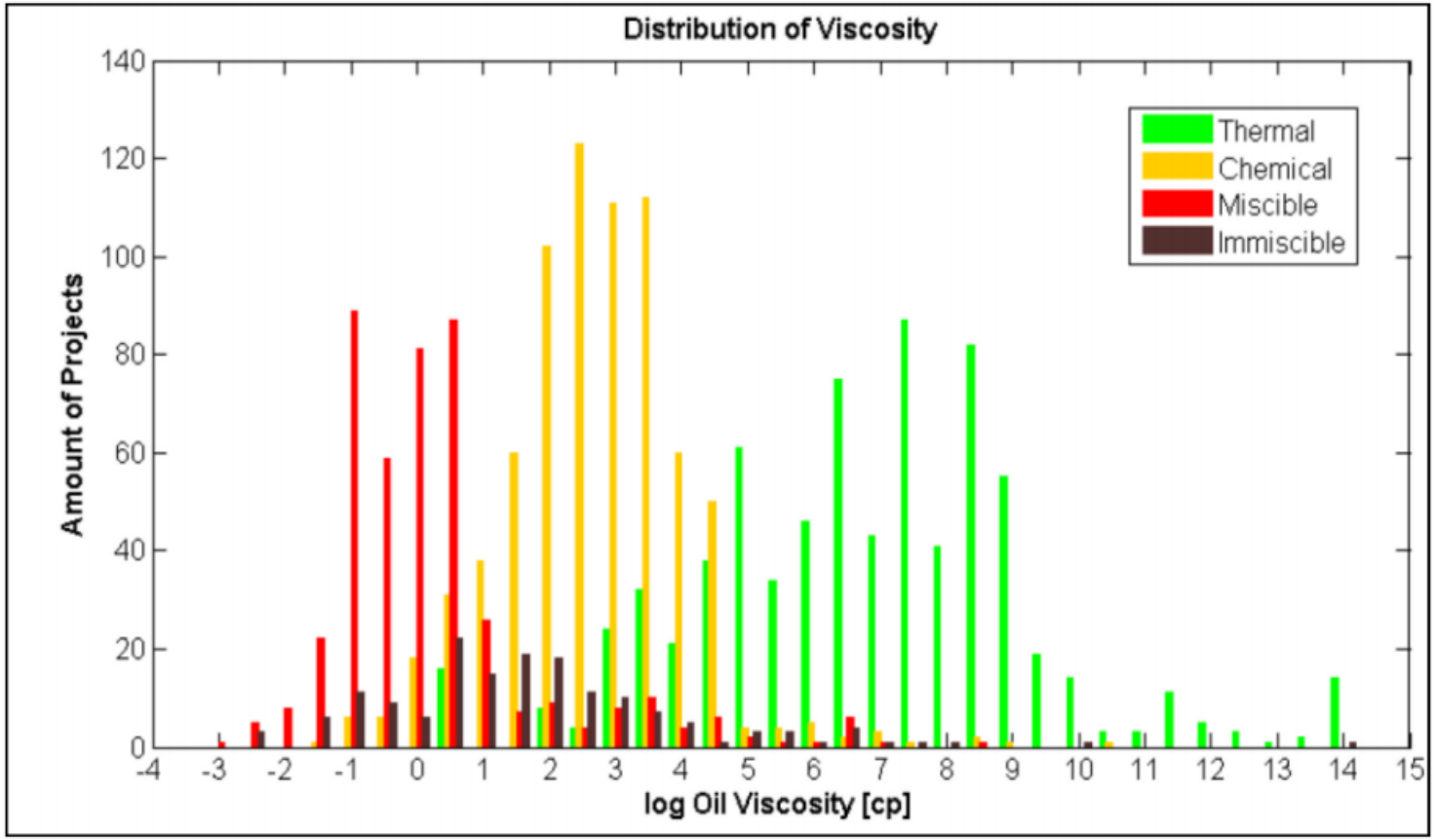
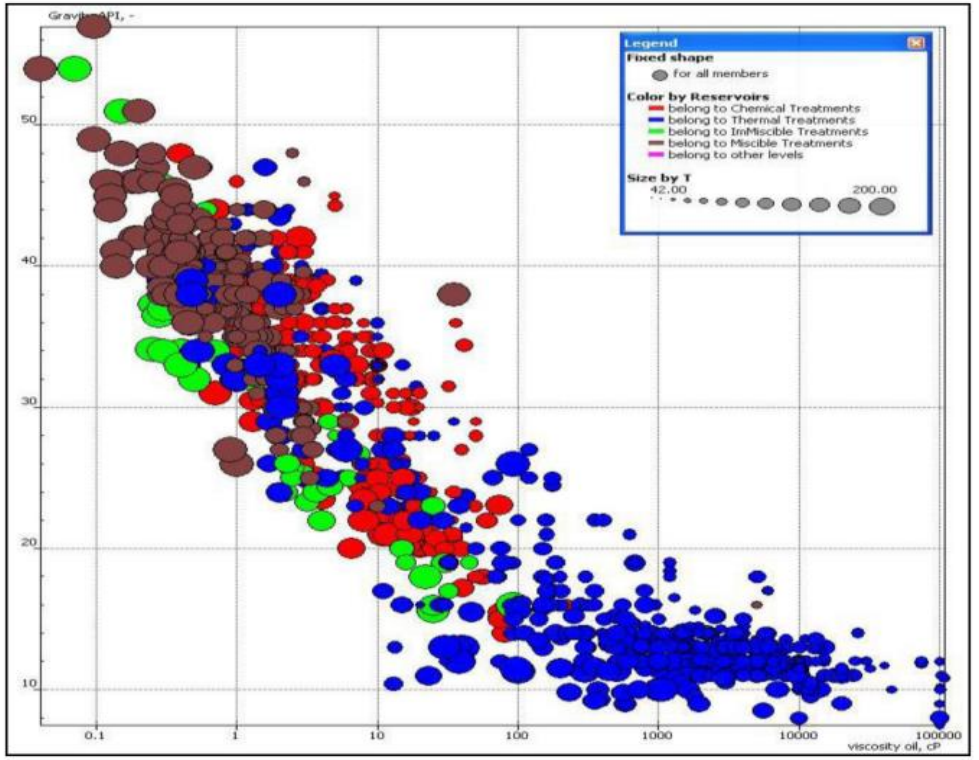
Expert System

Qualitative Screening; Key Parameters





Dependencies between API Gravity, Viscosity

Thermal/chemical projects selected for higher end viscosity
Miscible/immiscible projects selected for lower end viscosity

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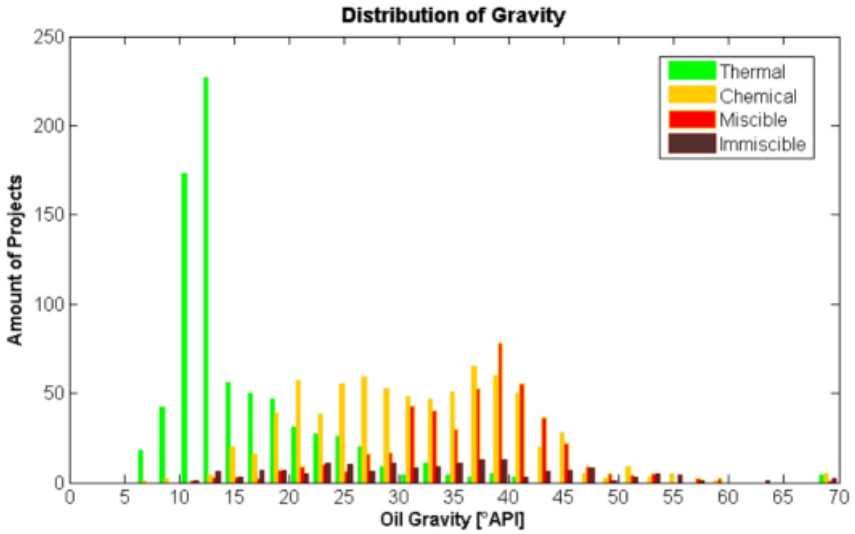
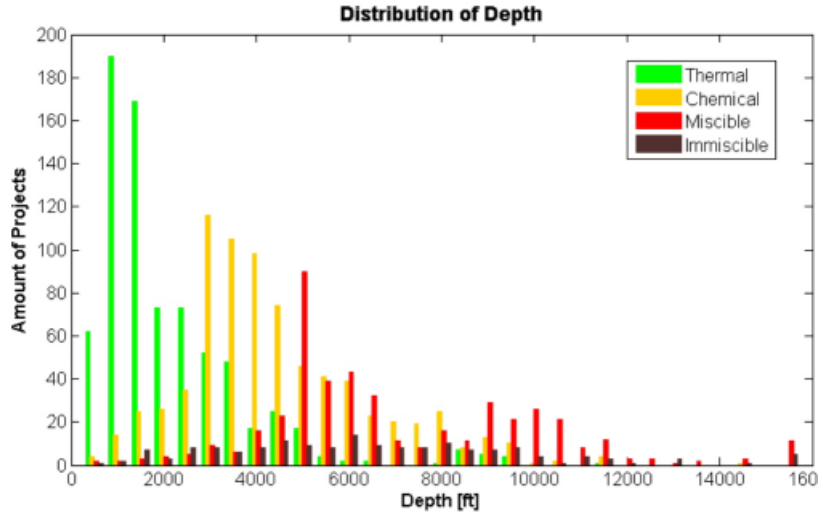
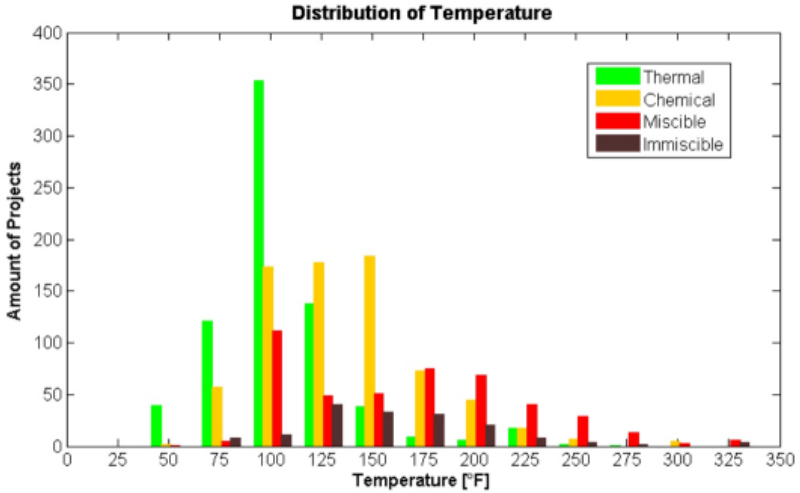
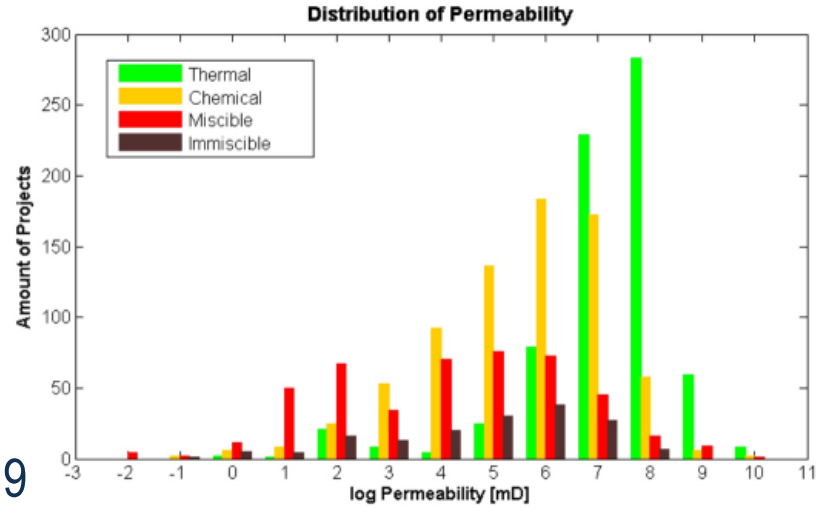
Expert System

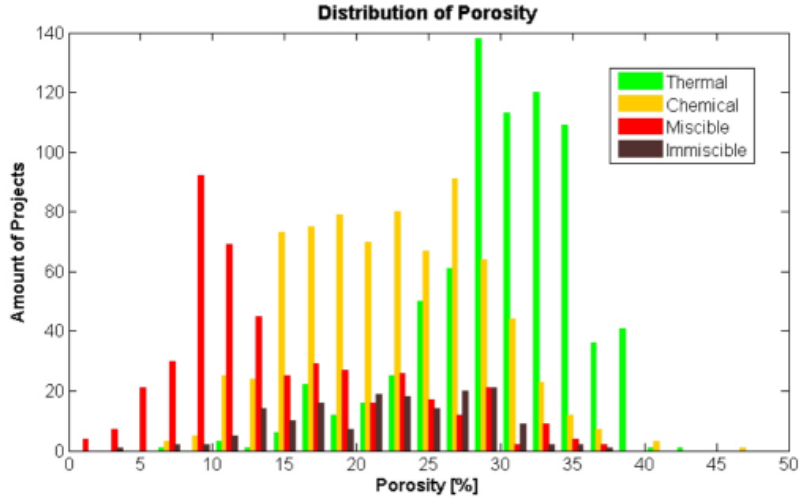
Qualitative Screening; Key Parameters











Key 6 Parameters

- Oil API Gravity
- Oil viscosity
- Reservoir temperature
- Reservoir depth
- Porosity
- Permeability

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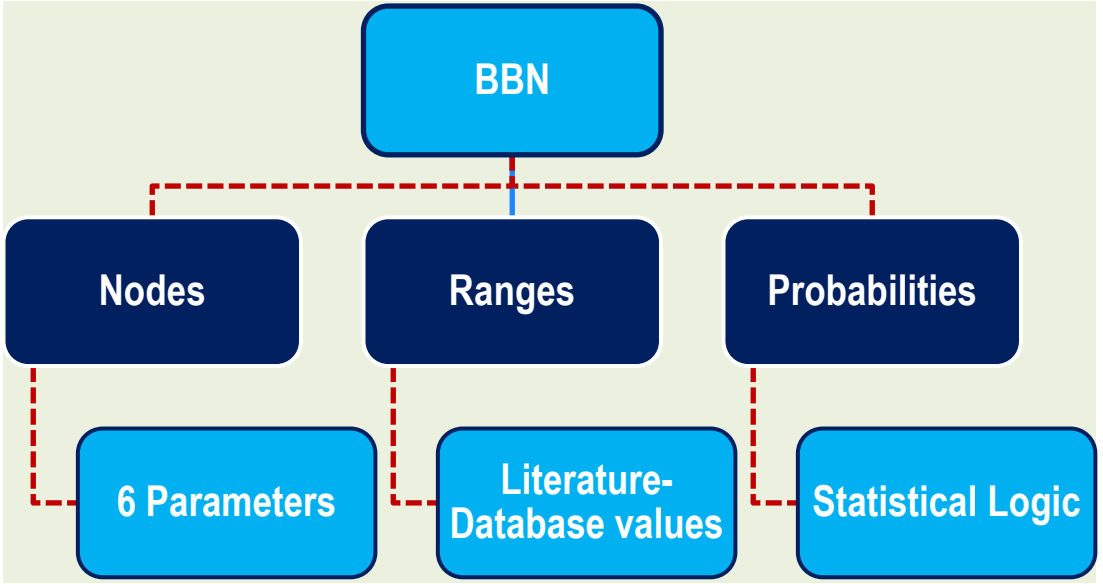
Expert System

Qualitative Screening ; Bayesian Networks

- Total of ~6700 projects data collected
- Data streamlined to ~2800 successful projects

  6 key parameters baseline
- BBNs added; Data uncertainty and Incompleteness
- For each EOR Method BBNs defined with:

Expert System-Advisory System Component
Screens EOR Methods Only Qualitatively



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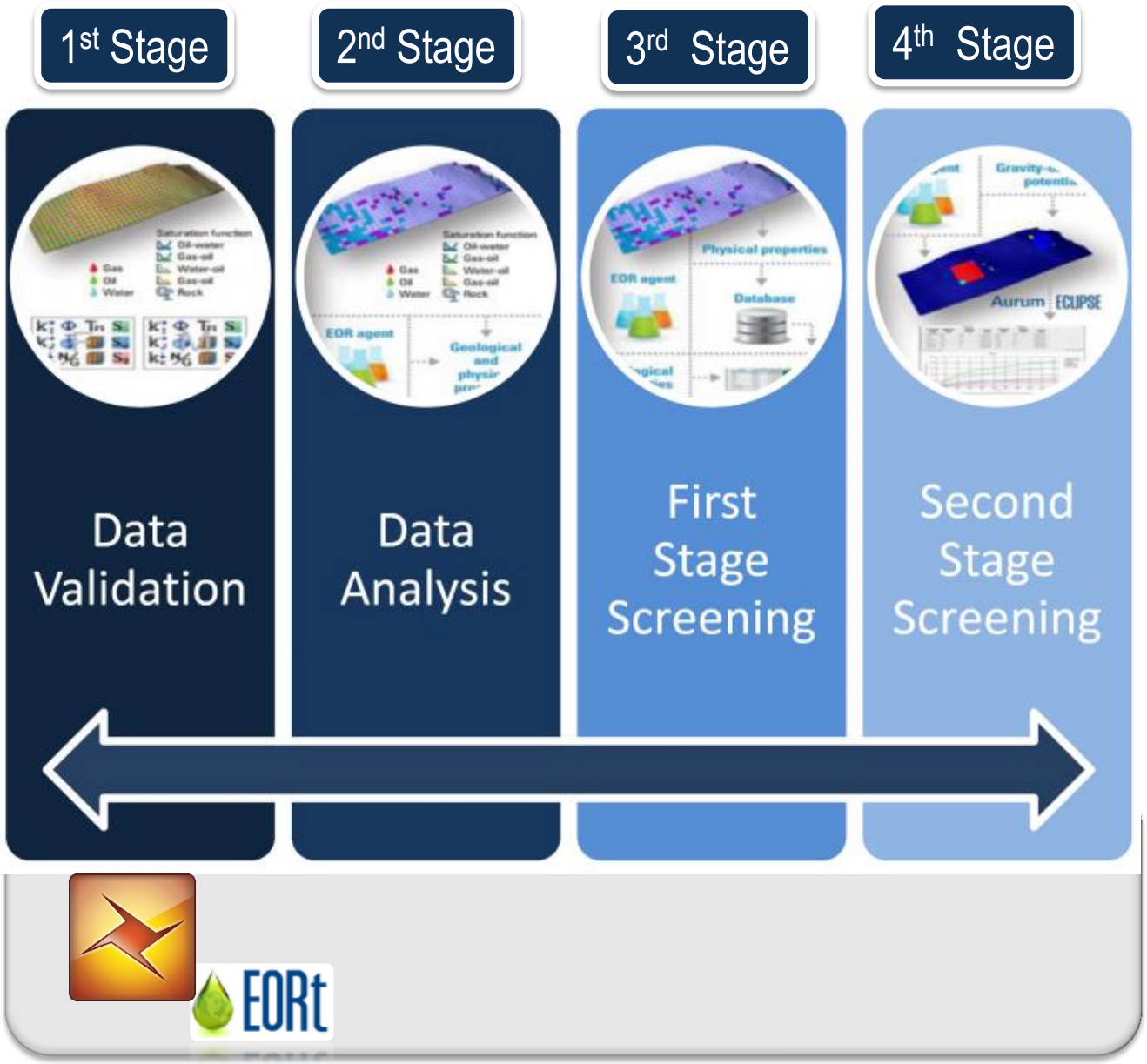
Guided System
Quantitative Screening

- Quantify the Potential increase displacement at pore level-LDE
- Complements the ranking of Expert System
- Staged approach
  - Reservoir architecture
  - Rock and fluid quality
  - Drive mechanism
  - Unswept area
  - Reservoir forces balance
  - Saturation distribution
- Analytical approach-BL Theory
- Numerical approach-Forecasting



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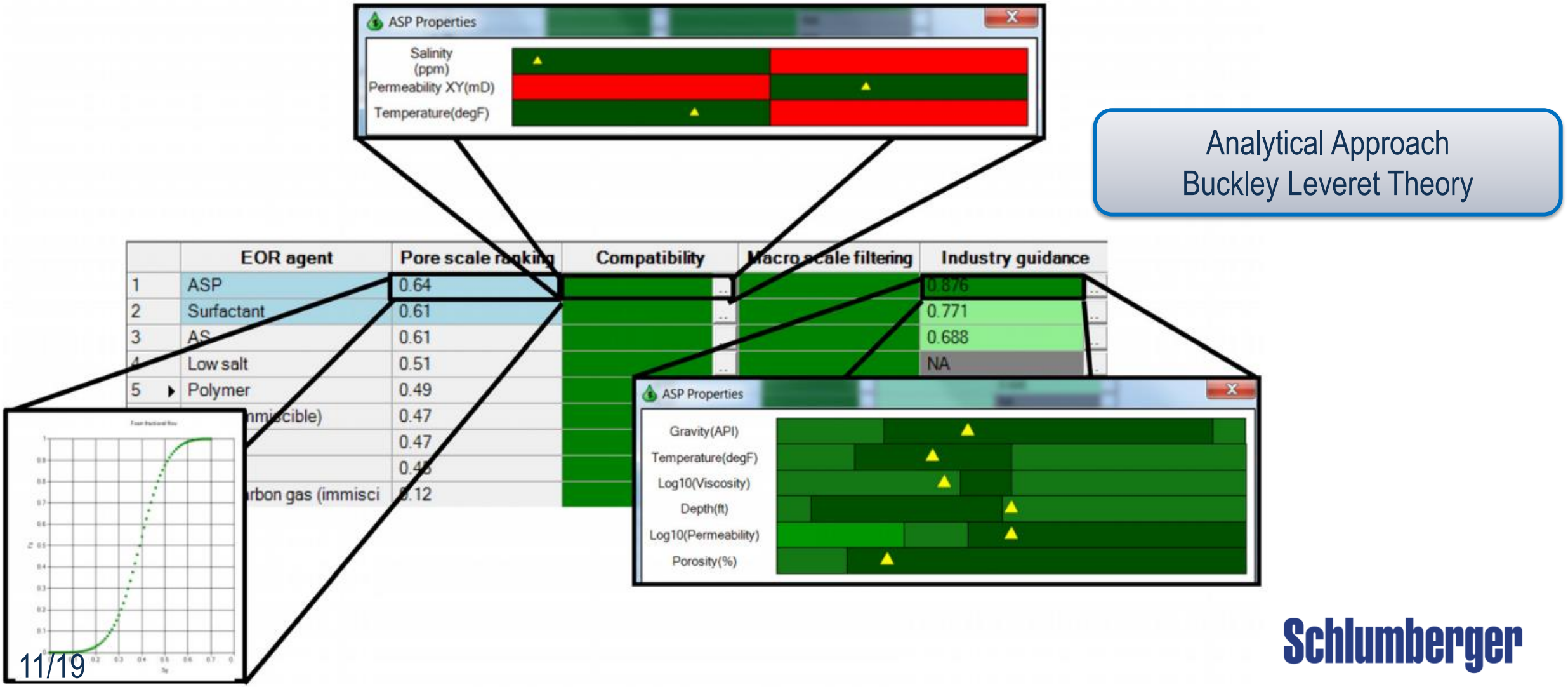
Guided System

First Level Quantitative Screening



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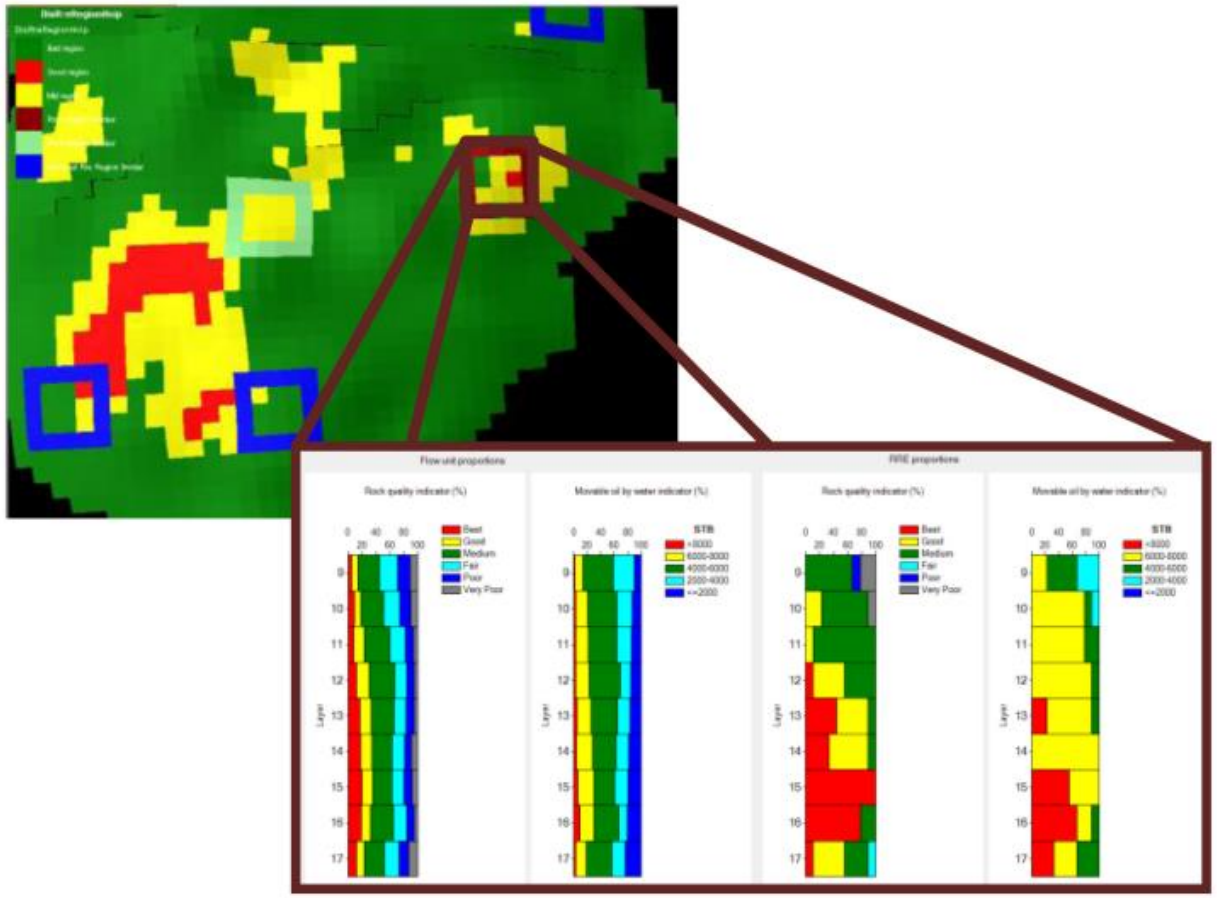
Guided System

Second Level Quantitative Screening



Numerical Approach
Representative Reservoir Element

Better understanding
Pore, Vertical and Areal Sweep Efficiency

Two RREs
Region with Good rock quality & More remaining oil
Region with Fair rock quality & Average remaining oil

Flow unit potential area indicator (**PAI**) divide cells into three HCIP regions (good, medium, poor).

$$PAI = [S_{OIL}(T) - S_{OWCR}] \times \frac{PORO}{PORO_{MAX}} \times \frac{PERM}{PERM_{MAX}} \times NTG \times Dz$$

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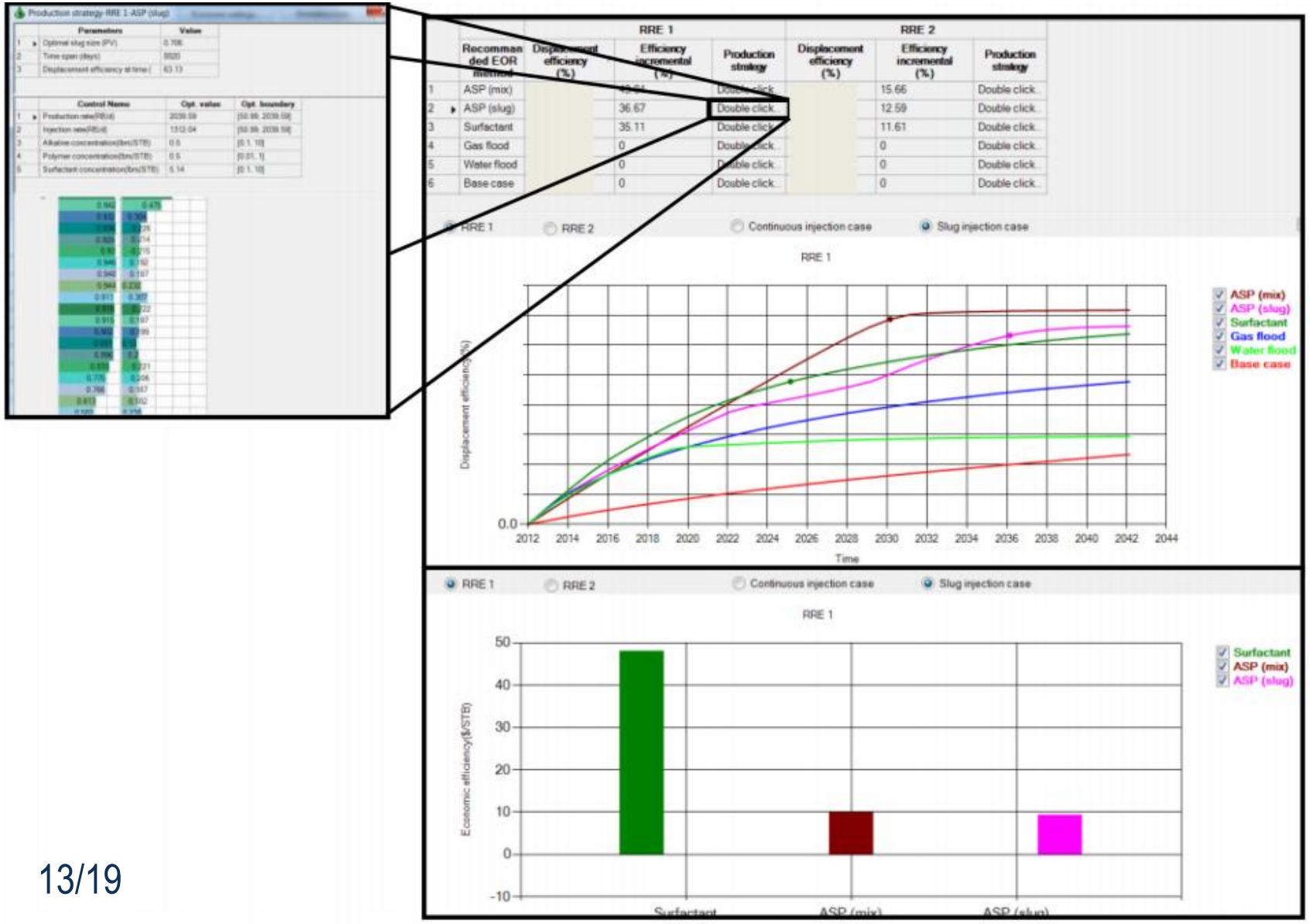
Guided System

Second Level Quantitative Screening



Simple Economic Analysis
Methodology Considers Economics
EOR Agent used
Injection, Production costs
Oil & Gas Prices

Net Present Values
Unit Total Costs

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Recent Examples from the Aberdeen Technical Center

Screening to identify EOR methods for a carbonate field

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Core Analysis: Rock Heterogeneity and Low Permeability

VDP Analysis					
Reservoir	# of Samples	Min Perm (mD)	Max Perm (mD)	Less than 20mD (%)	VDP
X	91	0.1	500	74	0.89
X	65	0.2	89	88	0.75
X	53	0.1	242	81	0.94
X	133	0.1	294	56	0.79
X	291	0.1	467	54	0.73
X	447	0.1	390	61	0.78
X	26	0.1	182	46	0.70
X	18	0.1	289	33	0.77
X	16	0.1	136	38	0.81
X	51	0.1	140	82	0.94
X	71	0.6	161	35	0.70

- The Dykstra-Parsons coefficient of heterogeneity VDP was calculated for each of the reservoirs based on RCAL.
- Also, the proportion of rock below 20 mD was estimated from core.

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Core Analysis: Rock Heterogeneity and Low Permeability

- VDP (per layer) varies between 0.70 and 0.94, and is generally quite high. This is to be expected with carbonate reservoirs, and the actual heterogeneity will be higher due to features not represented in simple RCAL permeability.
- A rule of thumb often used with Polymer / Surfactant is that heterogeneity greater than 0.6 is not suitable.
- The proportion of rock with permeability less than 20 mD is 60% overall, which is quite significant. There is a general guideline that rock with permeability < 20 mD does not respond well to Polymer EOR due to mobility issues.

EORt Screening Results for a Carbonate Reservoir

	EOR agent	Pore scale ranking	Compatibility	Macro scale filtering	Industry guidance
1	CO2 (miscible)	0.51			0.951
2	WAG (miscible)	0.46			0.964
3	Low salt	0.42			NA
4	Water	0.38			NA
5	WAG (immiscible)	0.38			0.964
6	Foam	0.38			0.994
7	N2 (immiscible)	0.14			0.864
8	Hydrocarbon gas (immisci	0.13			0.000
9	Surfactant	NA			0.000
10	Polymer	NA			0.996
11	ASP	NA			0.000
12	AS	NA			0.998

Screening results from both theoretical and engineering view

Saturation function definition

Name	Sf
SWCR	0.5
SOWCR	0.2
KRWR	0.5
KRORW	1
NW	3
NOW	3
SGCR	0.05
SOGCR	0.2
KRGR	0.6
KRORG	1
NG	3
NOG	3

Formation definition

Formation name	Arish
Top depth (m)	2
Thickness (m)	15
Formation type	Carbonate
Porosity (fraction)	0.2
Permeability XY (mD)	20
Oil API gravity (dAPI)	33.5
Oil viscosity (cP)	4.5
Water salinity (ppm)	170000
Pressure (bar)	185
Reservoir temperature (degC)	85
Oil saturation (fraction)	0.4

Input parameters

Compatibility	Macro scale filtering	Industry guidance
Good compatibility	High priority	Very well trained database(> 50 projects)
Moderate compatibility	Low priority	Well trained database(20 - 50 projects)
Incompatible		Poorly trained database(< 20 projects)
		No record in database

Screening analysis result

- CO2 and WAG miscible are the two best proven methods.
- Salinity of the reservoirs is above limits for chemical methods applicability.

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Conclusion

- Advisory system helps in quick initial screening
- Provides both qualitative and quantitative screening
- Uses both analytical and numerical approaches
- Considers industry guidance; past experiences and in-house EOR screening expertise
- Global projects database; continues addition
- Screens EOR mostly used methods; Thermal, Chemical, Miscible and Immiscible
- Used for different real-recent cases; time saving in optimum selection

Thanks

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