

EOR Screening Including Technical, Operational, Environmental and Economic Factors Reveals Practical EOR Potential Offshore on the Norwegian Continental Shelf

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Overview

1. Why an enhanced screening tool?
2. Overview of screening tool
 - Operational, environmental and economic screening
3. Results for 85 reservoirs on Norwegian Continental Shelf (NCS)



Motivation

NPD needed to estimate, for NCS, the EOR opportunity and rank the opportunities to enable deeper study of most attractive ones

2018: screening of technically recoverable resources

- SPE-190230-MS, presented at IOR Norway in 2018

But were these resources practically recoverable?

- *Operationally feasible*
- *Commercially attractive*
- *Environmentally acceptable*



Solution: An enhanced screening tool

- Most screening tools are ‘technical’
 1. Compare the reservoir, rock and fluid properties with suitable properties for each EOR process
 2. Calculate screening score
 3. Eliminate unsuitable processes
 4. Estimate incremental recovery based on screening score
- Economics evaluated afterwards
 - Costly and time-consuming detailed study
 - Not practical if many fields

Technical screening factors used previously:

- Temperature
- Oil API gravity and viscosity
- Oil acidity and wetting behaviour
- Permeability
- Reservoir thickness
- Fracturing
- Heterogeneity
- Clay content and clay type
- Formation water and injected water salinity
- Remaining oil
- Current recovery process



Construction of advanced screening framework

For Norwegian Continental Shelf



EOR processes considered (as focus on offshore)

- HC miscible/immiscible WAG
- Nitrogen and flue gas WAG
- CO₂ miscible/immiscible WAG
- Alkaline
- Polymer
- Surfactant, Surfactant/polymer
- Low salinity water injection,
- Low salinity/polymer
- Smart Water
 - modified water ionic composition
- Thermally activated polymers (TAP)
 - deep-acting
- Gels
 - near-well treatments
 - colloid dispersion gels, linked polymer solutions



Operational screening

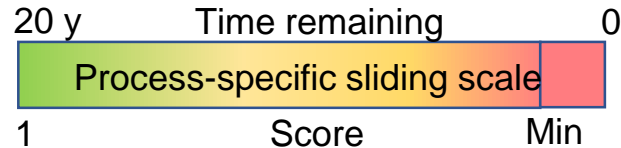
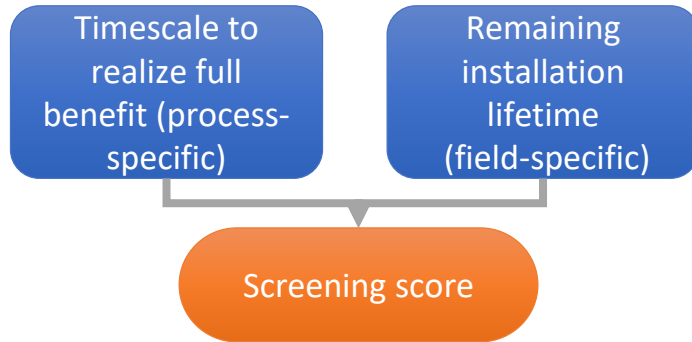
- Offshore installation
 - Installation lifetime, type, location
- Topsides facilities
 - Injection equipment, processing equipment, materials (CO₂ resistance)
- Wells
 - Spacing, position, materials
- Injectant access
 - Gas supply

Each assigned a screening score

- 0 to 1
- for each process in each reservoir



Installation lifetime criterion

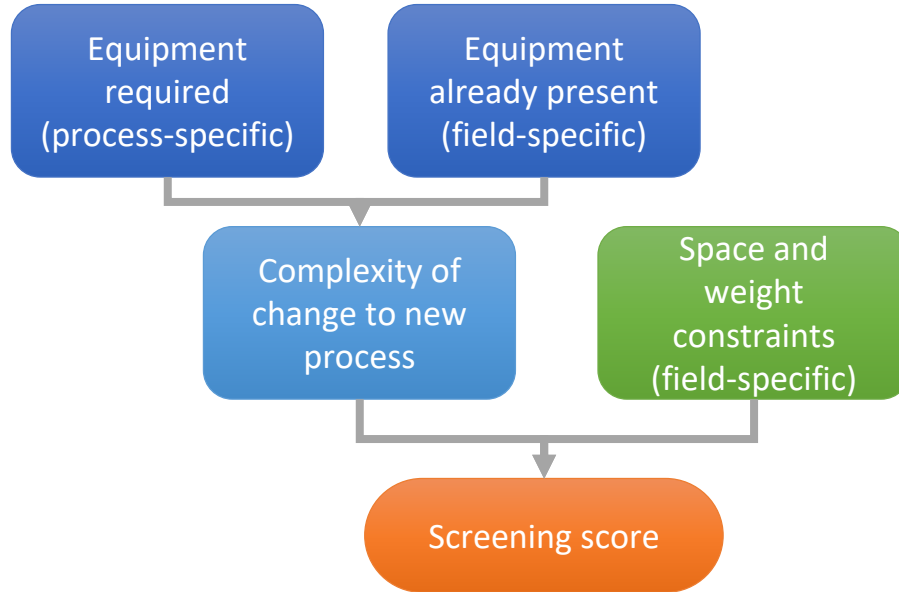


Logic:

- if there is less remaining lifetime to achieve the full EOR increment, the project is less likely to be successful



Topsides Injection and Processing



- Process-specific requirements
 - literature review
 - NPD experts



Environmental screening

How is project approval affected by perceived environmental acceptability of process?

- **Injectant hazard** – if spilled
- **Emissions** – Chance of emissions to sea
 - related to the current water-handling system type
- **CO₂ footprint** – net effect on CO₂ emitted per volume of oil produced
 - Power used => CO₂ emitted
 - CO₂ storage potential

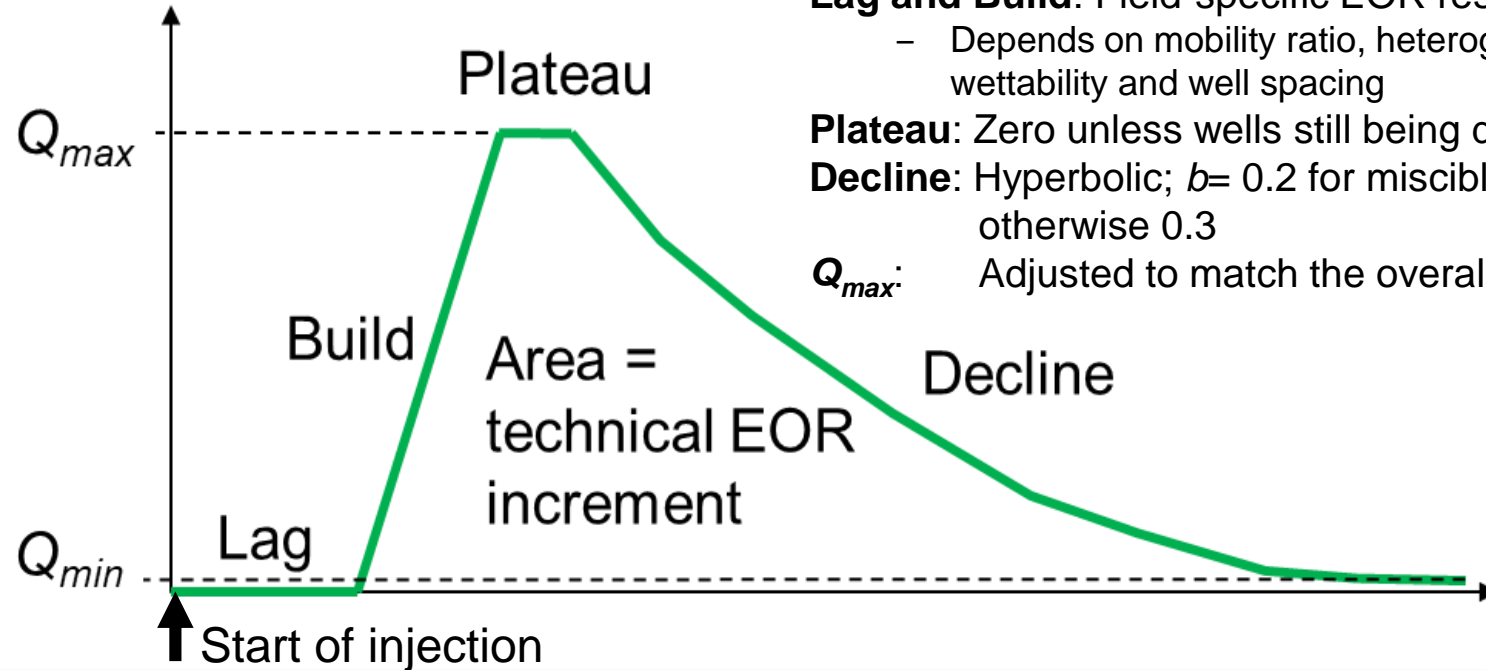


Economic screening

- **Net Present Value (NPV)**: industry standard measure of project materiality
 - Quantifies the time value of money
 - Estimates overall stakeholder value
- **Internal Rate of Return (IRR)**: standard measure of the average annual return on the cash investment.
 - A “good” IRR reflects a sufficient risk-adjusted return on cash investment given the nature of the investment
- Both calculated from predicted cash flow
 - = Annualized production volume × unit value - Capex - Opex



Incremental production profile



Lag and Build: Field-specific EOR response time

- Depends on mobility ratio, heterogeneity, injectivity, wettability and well spacing

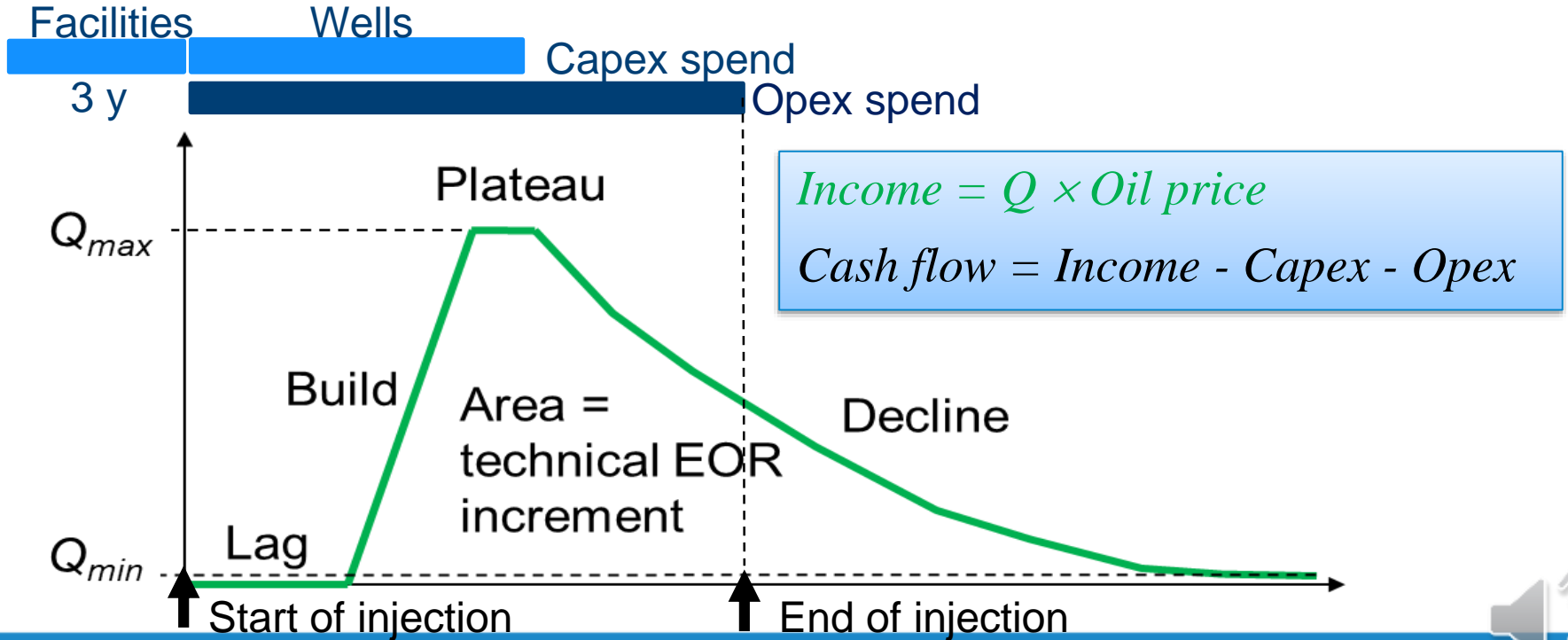
Plateau: Zero unless wells still being drilled or treated

Decline: Hyperbolic; $b= 0.2$ for miscible processes, otherwise 0.3

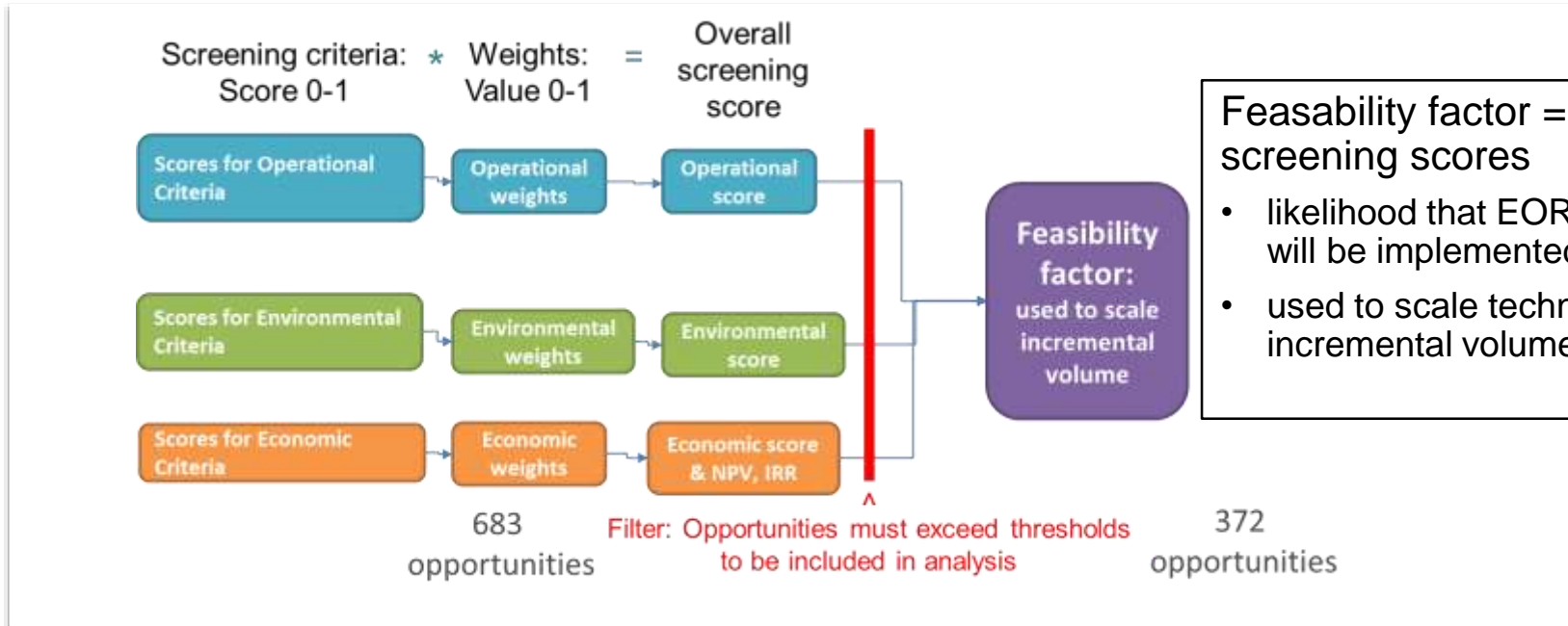
Q_{max} : Adjusted to match the overall EOR increment



Capex and Opex profile assumptions



Screening Overview



Feasibility factor = Product of screening scores

- likelihood that EOR opportunity will be implemented
- used to scale technical incremental volume



Results: application to the Norwegian Continental Shelf

Operational score > 0.5
Environmental score > 0.7
Economic score > 0.1

- NPV > 0, IRR > 7%

Field-specific information

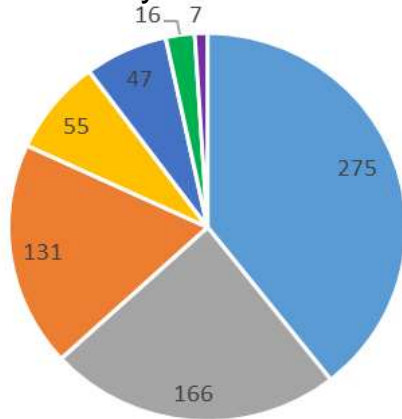
- supplied by field operators via a purpose-built questionnaire



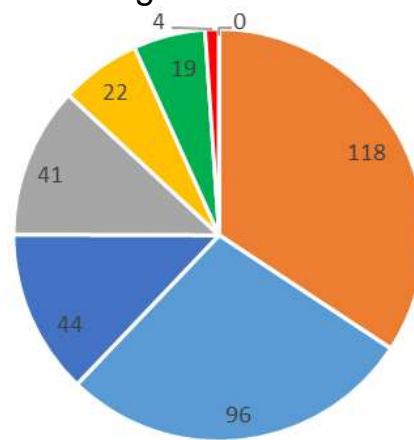
Overall NCS Volumes

Assumption: only the best (highest increment) process applied in each field

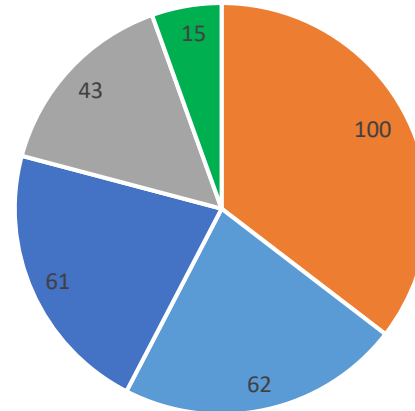
Technical screening
only: **698 MSm³**



Op & econ
screening: **344 MSm³**



Op, econ & envt
screening: **282 MSm³**



- HC miscible gas/WAG
- Low salinity/polymer
- Low salinity
- CO2 miscible/WAG
- Surfactant/polymer
- Gels
- Polymer
- Alkaline

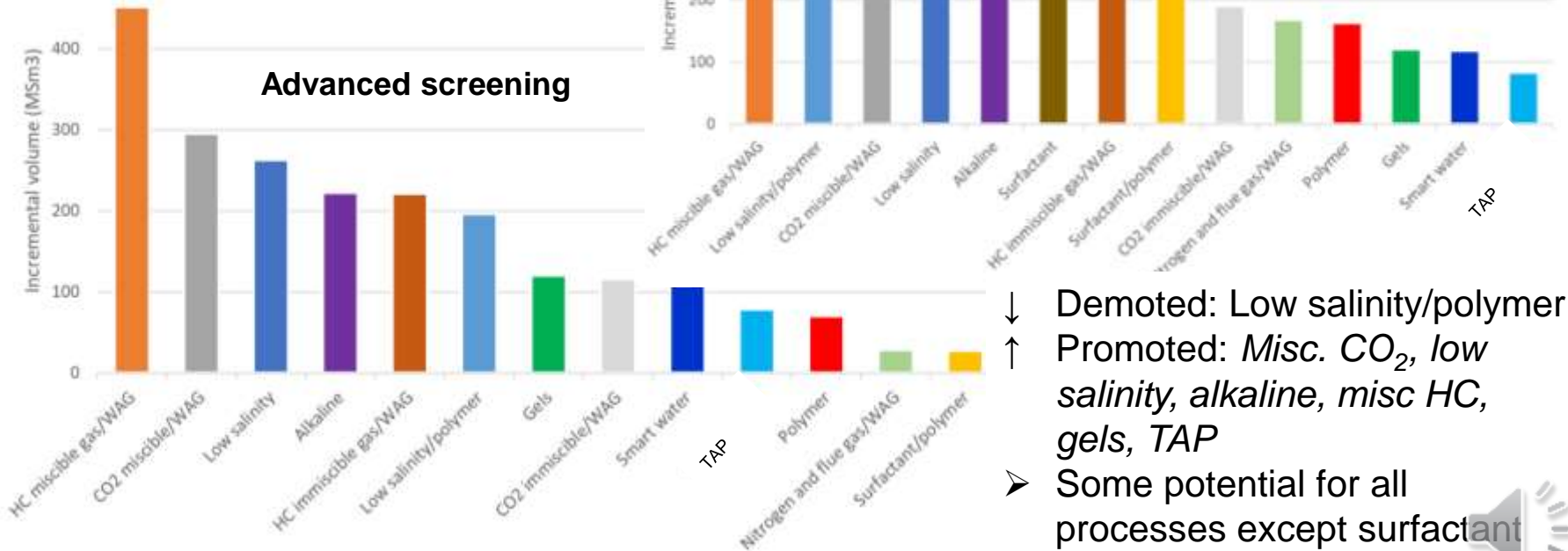
Selected from 683

410

372 opportunities



Total opportunity set by process



- ↓ Demoted: Low salinity/polymer
- ↑ Promoted: Misc. CO₂, low salinity, alkaline, misc HC, gels, TAP
- Some potential for all processes except surfactant

Includes competing opportunities – cannot be added



Summary

New framework for integrating operational, environmental and economic criteria into EOR screening

- Speeds up screening of large portfolios
- Opportunities that survive are more likely to be realized
- Will help focus subsequent effort on the most promising EOR opportunities

Applied to the NCS:

- 683 technically viable opportunities reduced to practically viable 372 ones
- Overall expected incremental volume reduced from 698 to 282 MSm³
- Still a large prize
- Further 62 MSm³ if environmentally benign EOR chemicals could be formulated



Acknowledgements

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Thank you for listening!















