INTEGRATED DECISION SUPPORT SYSTEM

- Force and Petroleum Economics of IOR/EOR

General integrated work process for economic evaluation of IOR/EOR projects
- Reserve reporting and IOR/EOR projects
- Economic models of drilling versus IOR/EOR projects
- Effect of new tax system and possible other changes in the future

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IPRES

Setting the Scene for IOR/EOR

"Most of the world's future oil and gas reserves won't come from new discoveries, but by finding ways to get more oil from regions the industry already has developed.

We've probably reached the time, amazingly, when there's as much to be got extra out of the oil fields we have discovered as there is to be found in new fields,"

David Eyton, BP's Group head of research and technology, said in an interview at the Offshore Technology Conference in Houston 2014.

Setting the Scene for IOR/EOR

"*Based on existing technology the industry expects to leave more than half the oil it discovers in conventional reservoirs.*

BP, however, has embarked on a number of projects it believes will significantly boost the amount of oil it can extract from its existing wells or oil fields, helped in part by its new super computer in Houston that can make 2,200 trillion calculations in one second The behemoth calculator is designed to create much better images of reservoirs in places like the Gulf of Mexico, where salt canopies had forced oil companies to drill almost blind for decades

It's the lab for seismic we do it in the virtual world. And then when we find out that something works, we can build models and fields and geology. We can go out and try it for real."

.

David Eyton, BP's Group head of research and technology, said in an interview at the Offshore Technology Conference in Houston 2014.

Setting the Scene for IOR/EOR

"BP's also planning on expanding a new water-flooding technique across its offshore portfolio. One of BP's big "ah-hah" moments came two decades ago when it discovered that injecting fresh water into offshore oil fields inexplicably harvested more oil.

High-salinity sea water – the kind of water close at hand at offshore drilling sites – doesn't get the job done as well.
When we realized that fresh water in some occasions helps you to get more oil out, we set out almost for 20 years to figure out why is that. That insight and advancements in nano-scale measurement techniques paved the way for BP to deploy its first low-salinity water-injection technology to an oil field 200 miles north of the UK mainland.

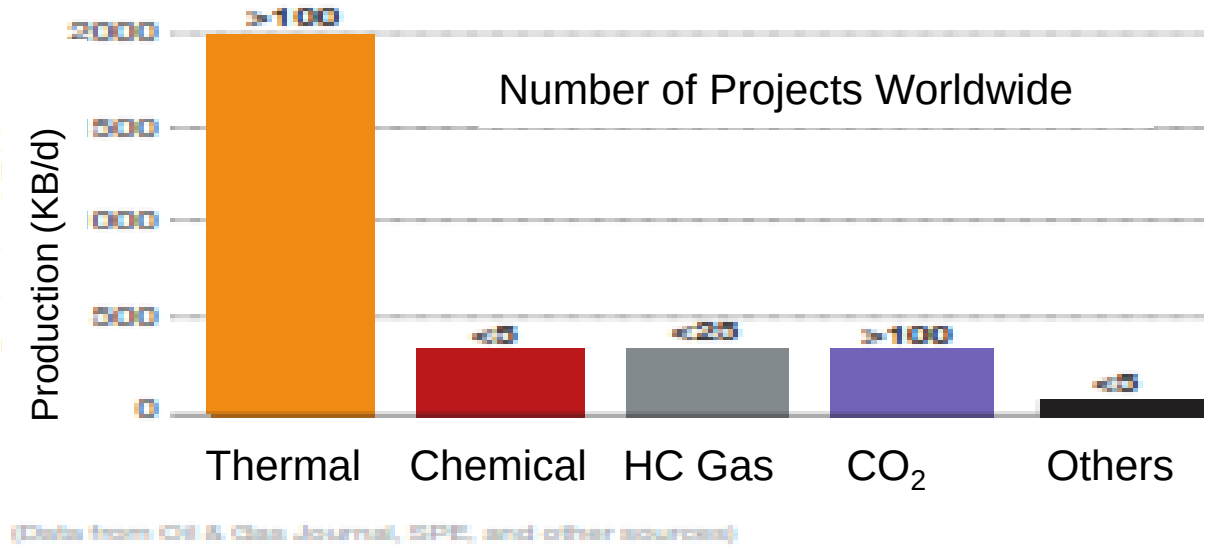
The industry is still in the early stages of understanding the full potential of advanced chemistry applied to water-flooding in oil and gas reservoirs.
Our focus is on low-cost techniques with water flooding to get more oil out.

Low-salination is well known. But actually, all the money we're now spending on research and development in this area is on things that nobody yet knows about. There's a lot more going on behind the scenes."

David Eyton, BP's Group head of research and technology, said in an interview at the Offshore Technology Conference in Houston 2014.

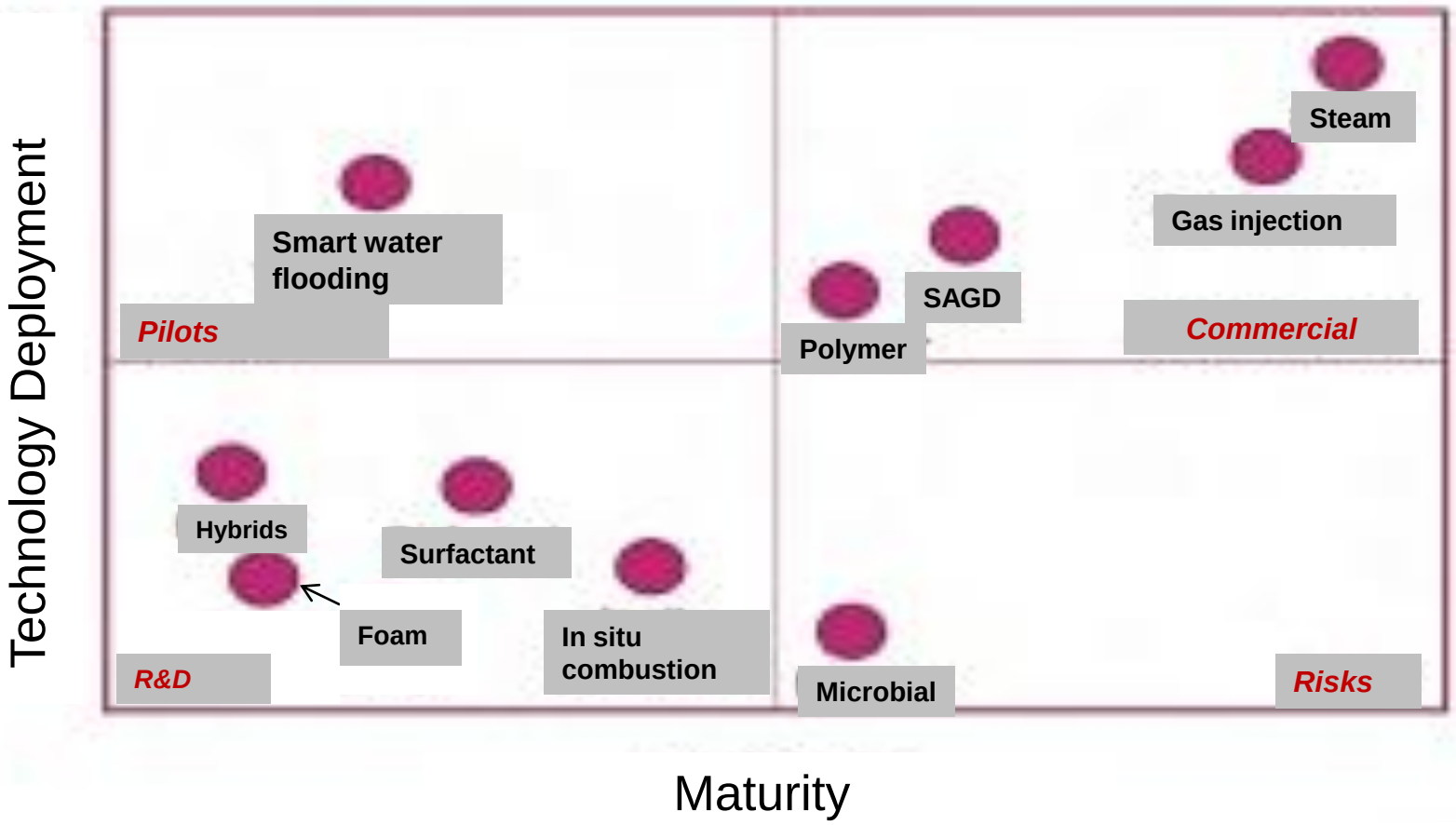
Status IOR/EOR globally (World Oil Official publ. 2010, page 64)

Figure 2. Worldwide EOR Production Rates



Status IOR/EOR globally (World Oil Official publ. 2010, page 68)

IOR/EOR Maturity and deployment globally



INTEGRATED DECISION SUPPORT SYSTEM

General integrated work process for economic evaluation applied to IOR/EOR projects

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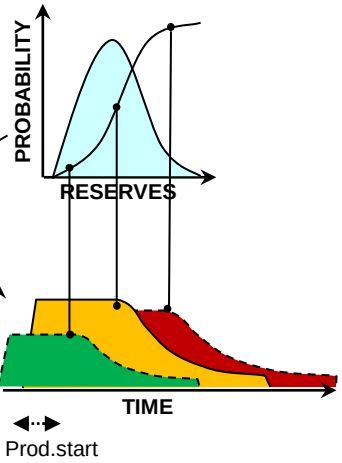
Integrated Development Assessment

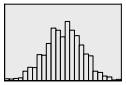
Primary Recovery

Secondary Recovery

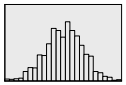
Tertiary Recovery



Reserves / Resources – Drilling and Completion plans

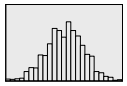


Natural flow

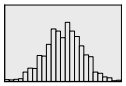


Artificial lift

Water flooding



Pressure maintenance Gas – Water injection



Chemical

Solvent

Thermal

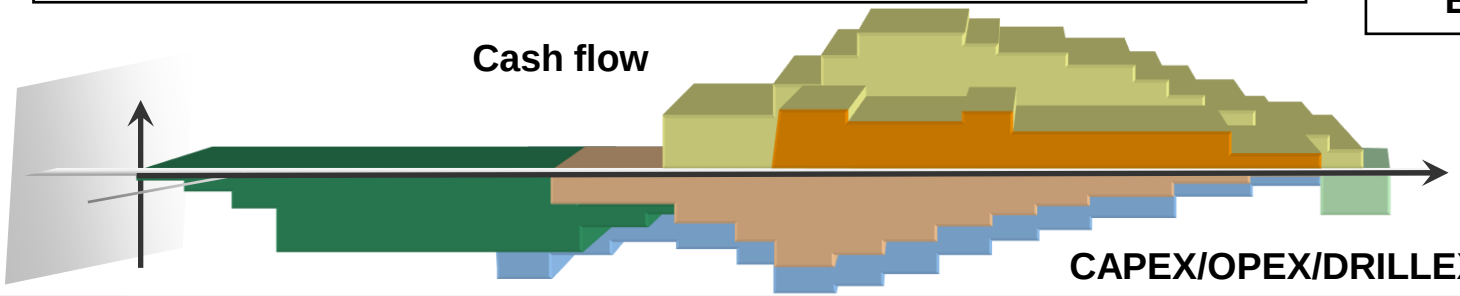
Other

Nitrogen
CO_2
Air
SAGD
Bacteria
Etc.

Investment/ Cash flow/Value

Results

Cash flow



CAPEX/OPEX/DRILLEX

Resource Group Classification on NCS

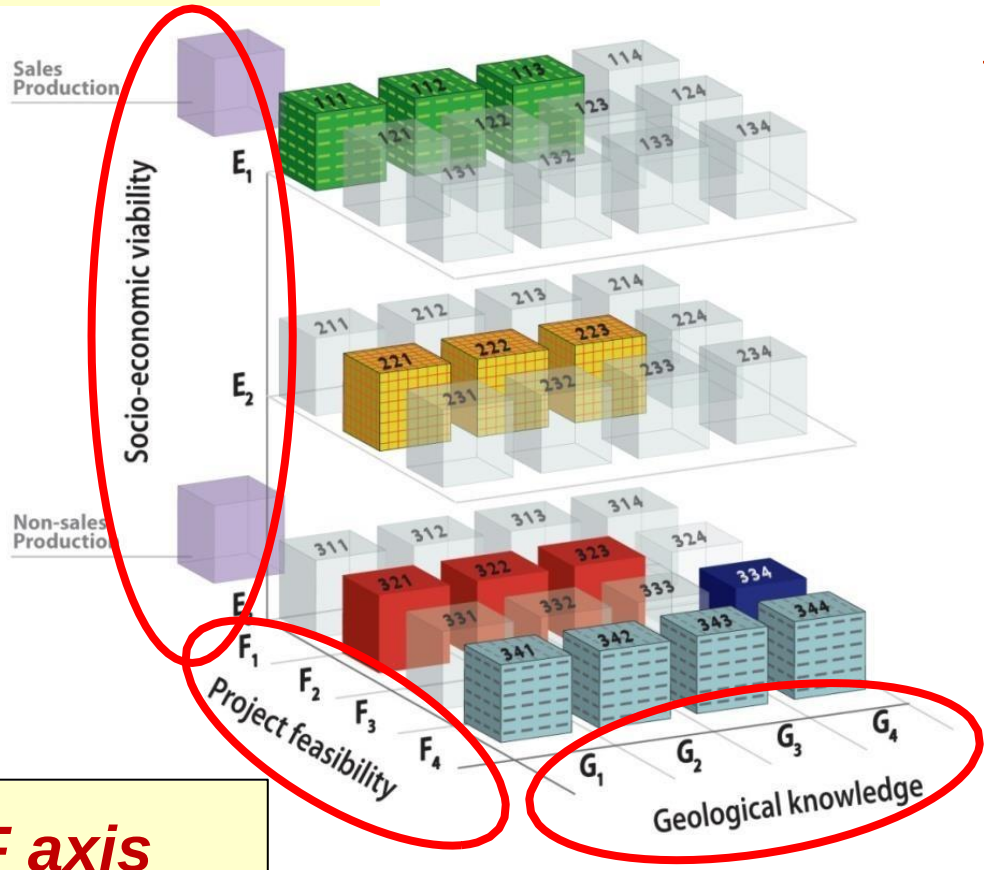
A – Additional Resources from IOR/EOR

Resource classes NPD	Definition	SEC	SPE/WPC/ AAPG
0	Historical production		
1 A	Reserves in production	Developed Reserves	Discovered Commercial *(Reserves)*
2	Reserves with an approved plan for development and production	Undeveloped Reserves	
3 A	Reserves which the licensees have decided to recover		
4 A	Resources in the planning phase (approval within 4 years)	Technical Resources	Discovered Uncertain Commerciality *(Contingent Resources)*
5 A	Resources whose recovery is likely, but not clarified		
6 A	Resources whose recovery is not likely		
7 A	Resources that not have been evaluated, i.e. new discovery		
8	Prospect. Not drilled		Undiscovered
9 A	Lead		

Definitions based on Norwegian Petroleum Directorate (NPD). SPE-PRMS texts can be substituted.

UN Categories and Classes

E axis categories

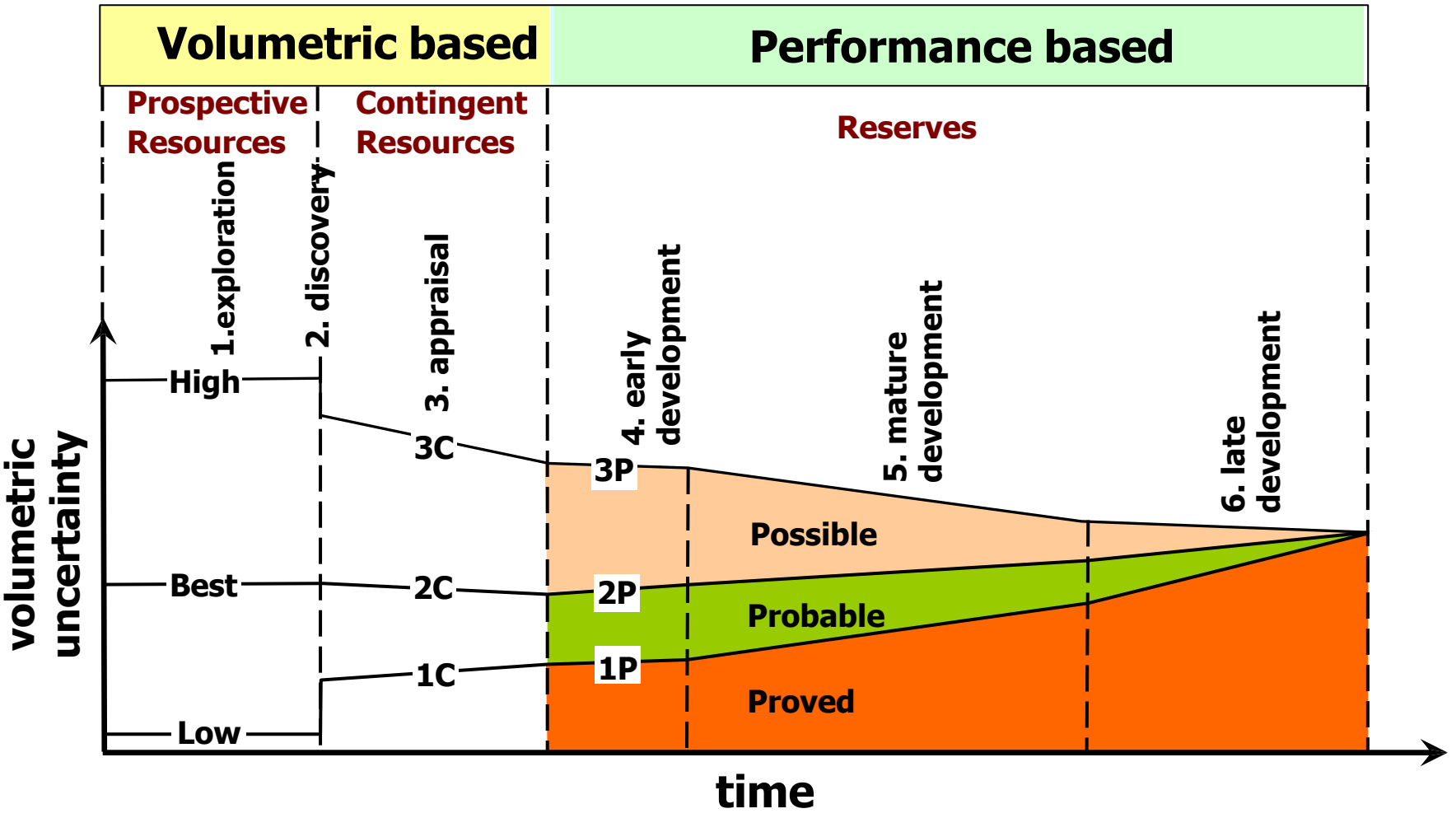


F axis categories

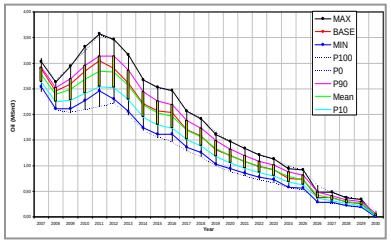
G axis categories

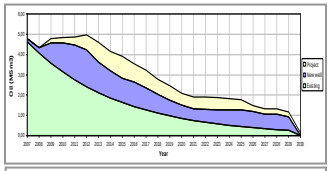
UNITED NATIONS
ECONOMIC COMMISSION
FOR EUROPE

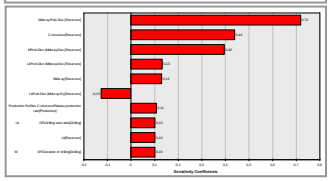
Project maturation pipeline



Typical Model Elements and Schedule Challenges







RIG B
2007
K-2 Drill
K-8 D&C
P9 D&C
K-9 D&C
K-5 Interv.
P-17AH D&C
RIG SCHEDULE

RIG A
2007
P-7 P&A
P-12 WO
P-7A D&C
P-8 D&C
P-6 Interv.
P-11AH Drill
RIG SCHEDULE

PIPELINE CAPACITIES

NEW WELLS
K-2

IOR/EOR PROJECTS
PROCESS MOD.

FIELD AREA B
-CAPACITIES
-REGULARITY
-SERVICE AVAILABILITY
-ETC

EXISTING WELLS

NEW WELLS

FIELD AREA A
-CAPACITIES
-REGULARITY
-SERVICE AVAILABILITY
-ETC

EXISTING WELLS

DISCOVERY
PROSPECT
?

PROSPECT
?

IOR/EOR PROJECTS
PUMP INSTALL.

Development Project Uncertainties (offshore example)

Main Project

Drilling rig(s)?

Development/ redevelopment solution?

CAPEX?

Processing capacity/phasing ?

OPEX?

New Seismic ?

Pre-drilled wells?

Seismic reinterpretation?

production wells?

Depth conversion?

Production rate per well?

Cost per well?

Revise reservoir model?

Injection wells?

Regularity?

Petrophysical Challenges ?

Fault location?

GOC?

WOC?

Communication between layers?

Reserves

Production Profiles?

Additional Projects

Pipeline capacity?

Pipeline cost?

templates?

Cost per template?

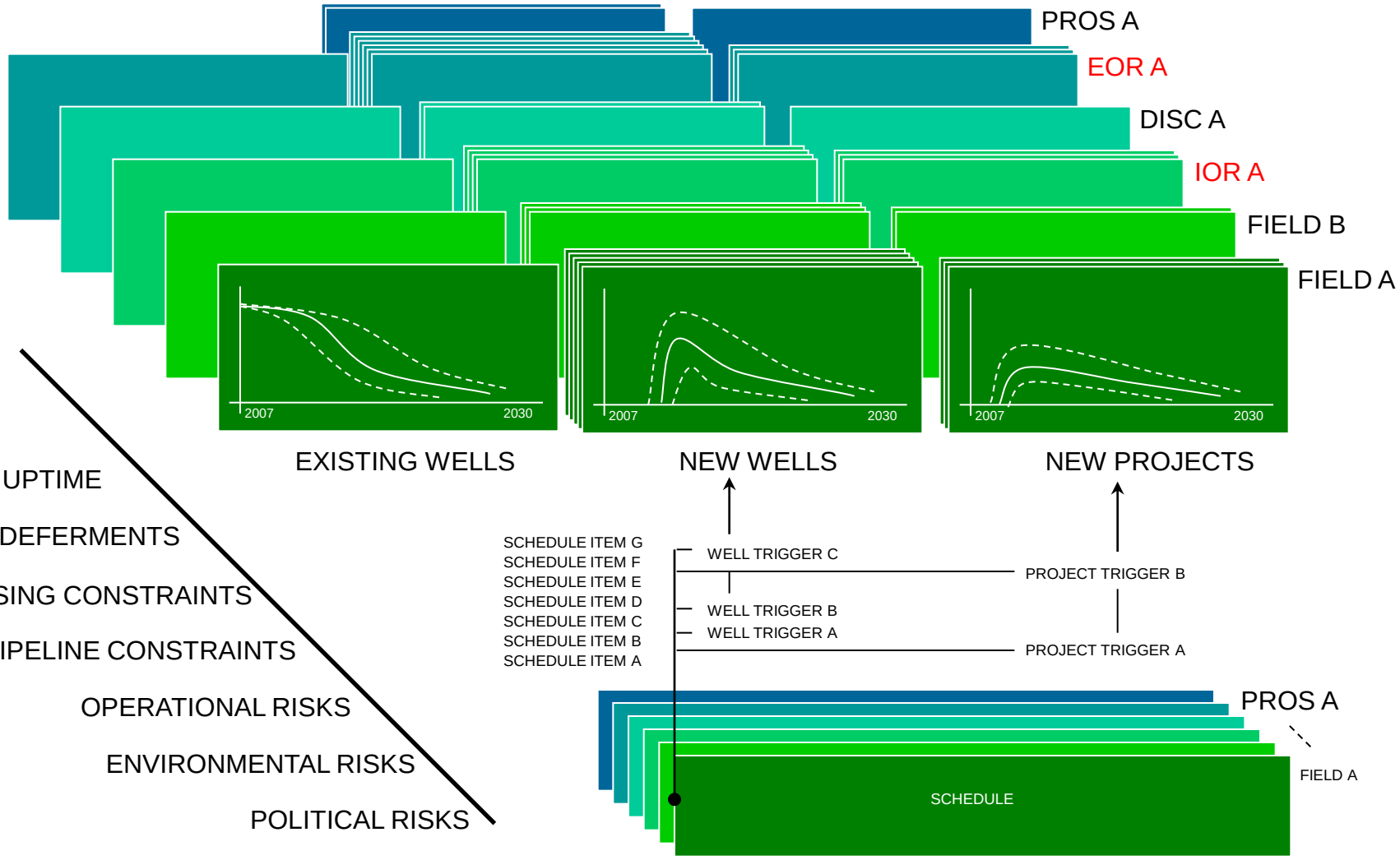
Drill exploration well?

Appraisal well(s)?

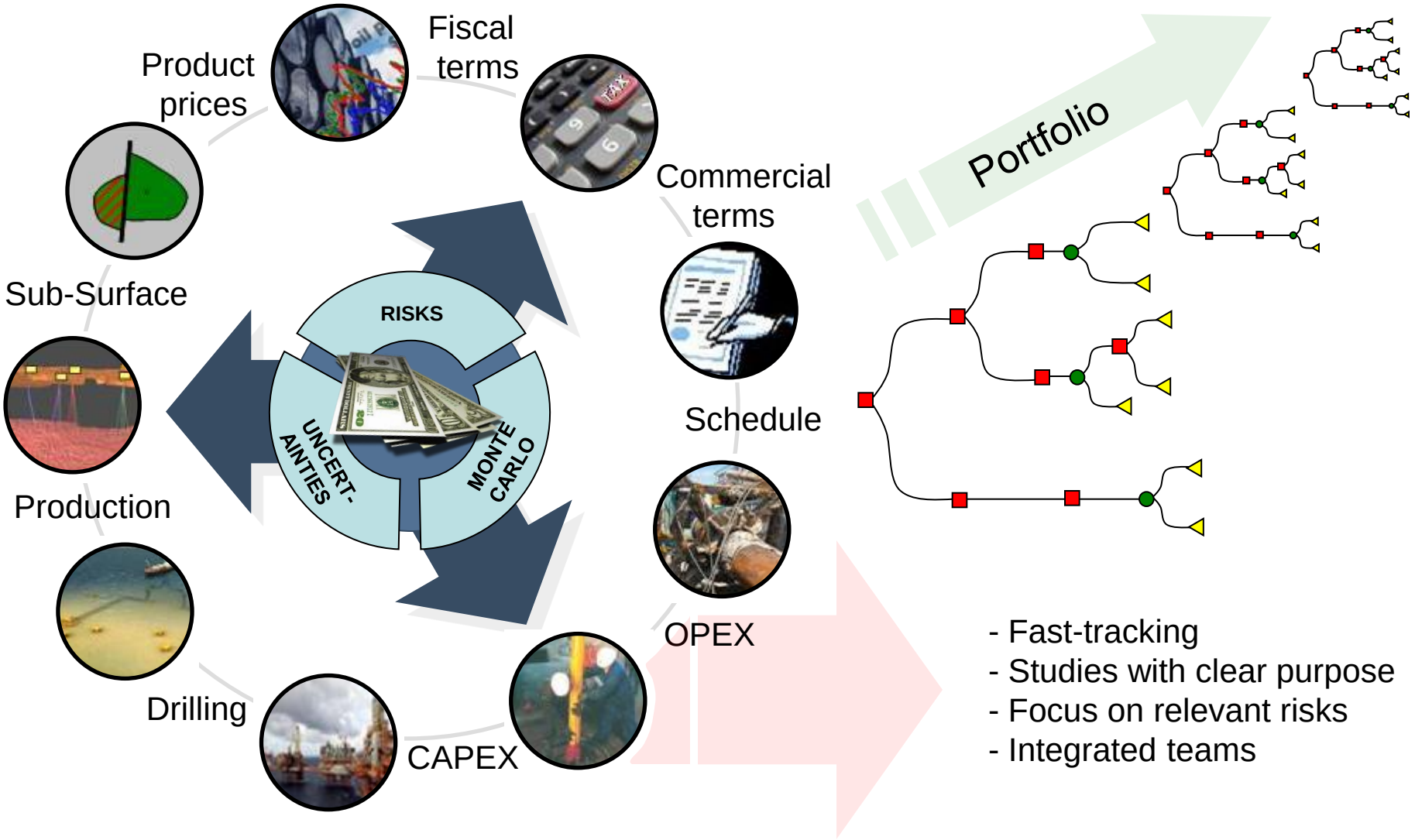
Oil price?

Schedule

Key elements in mature field development

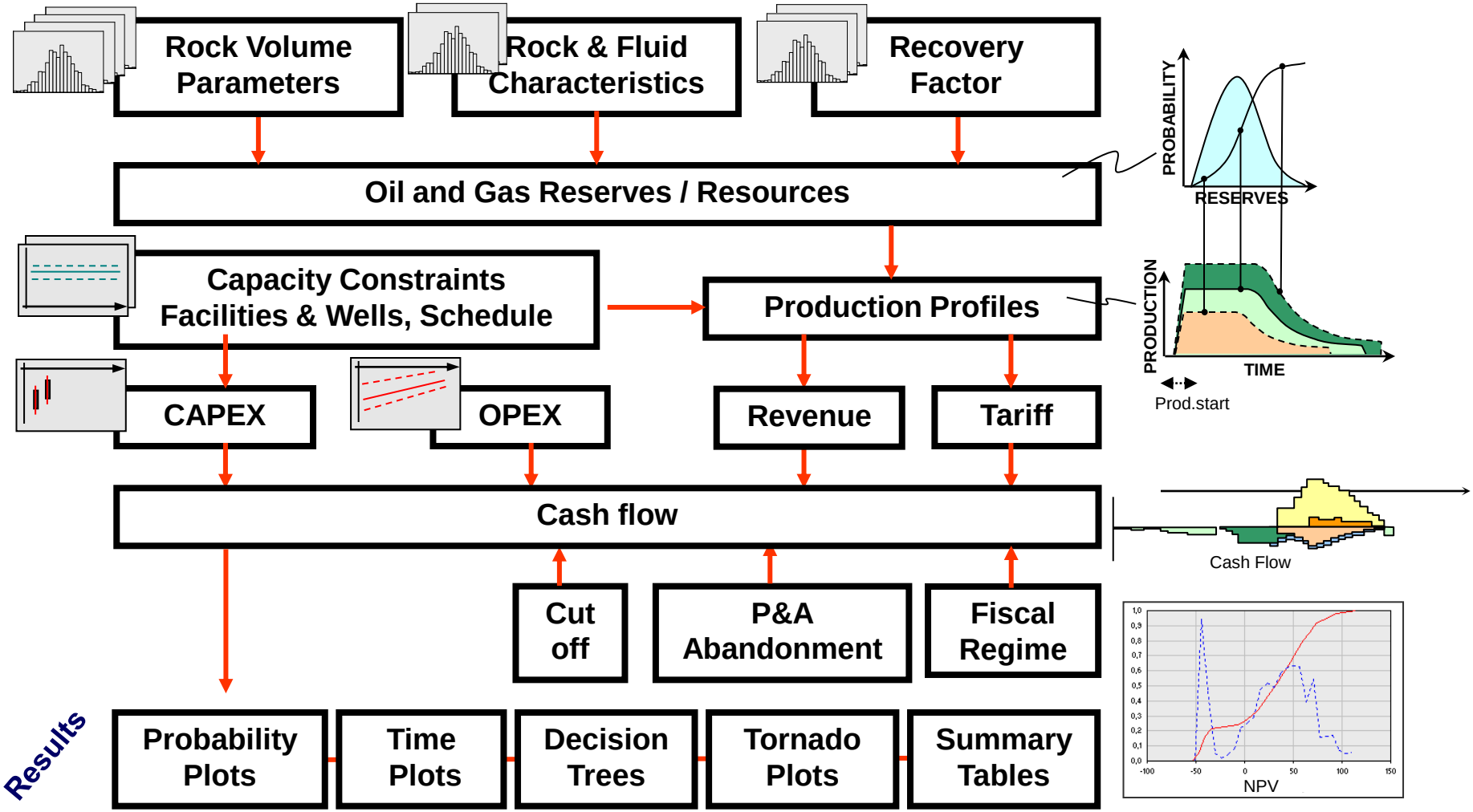


Integrated Petroleum Risk Management work approach

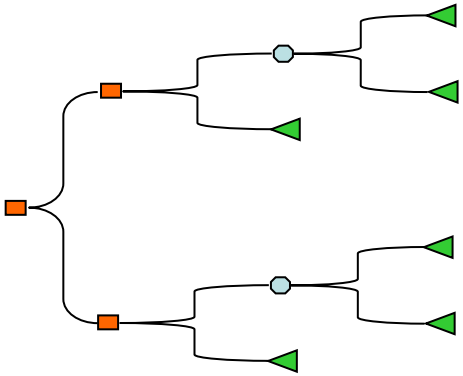


- Fast-tracking
- Studies with clear purpose
- Focus on relevant risks
- Integrated teams

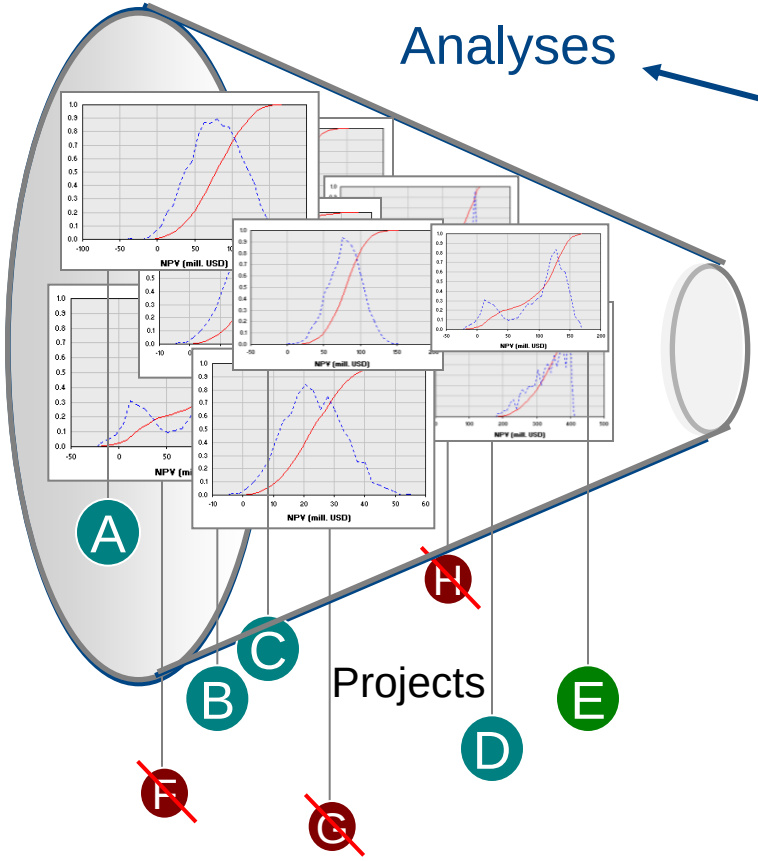
Integrated Project Development Work Process to screen and rank IOR/EOR alternatives – a consistent approach



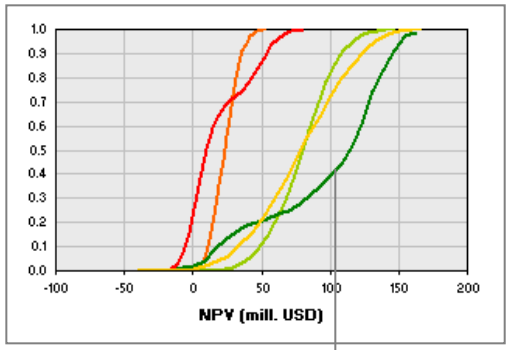
Compare and rank IOR/EOR alternatives



Decision tree analyses for structuring

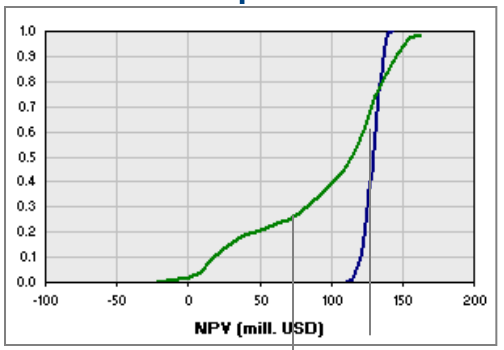


Compare and rank



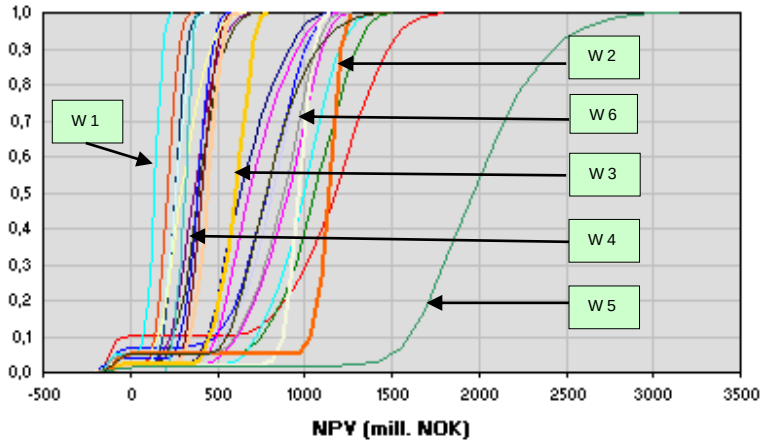
E
HIGHEST EMV

Optimize and update

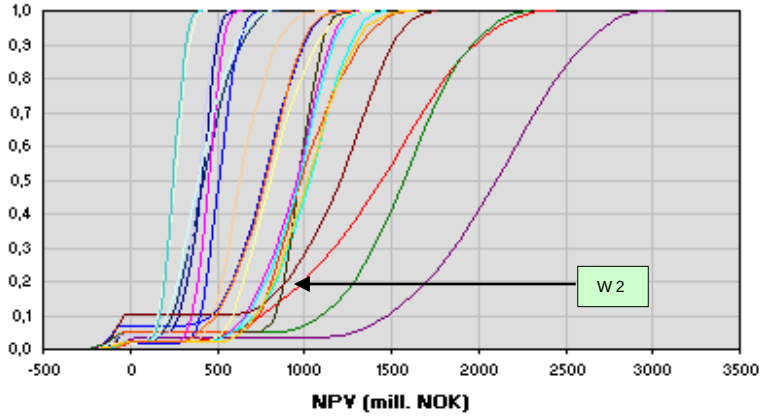


E'
E

Drilling Campaign portfolio evaluation necessary to optimise production and recovery



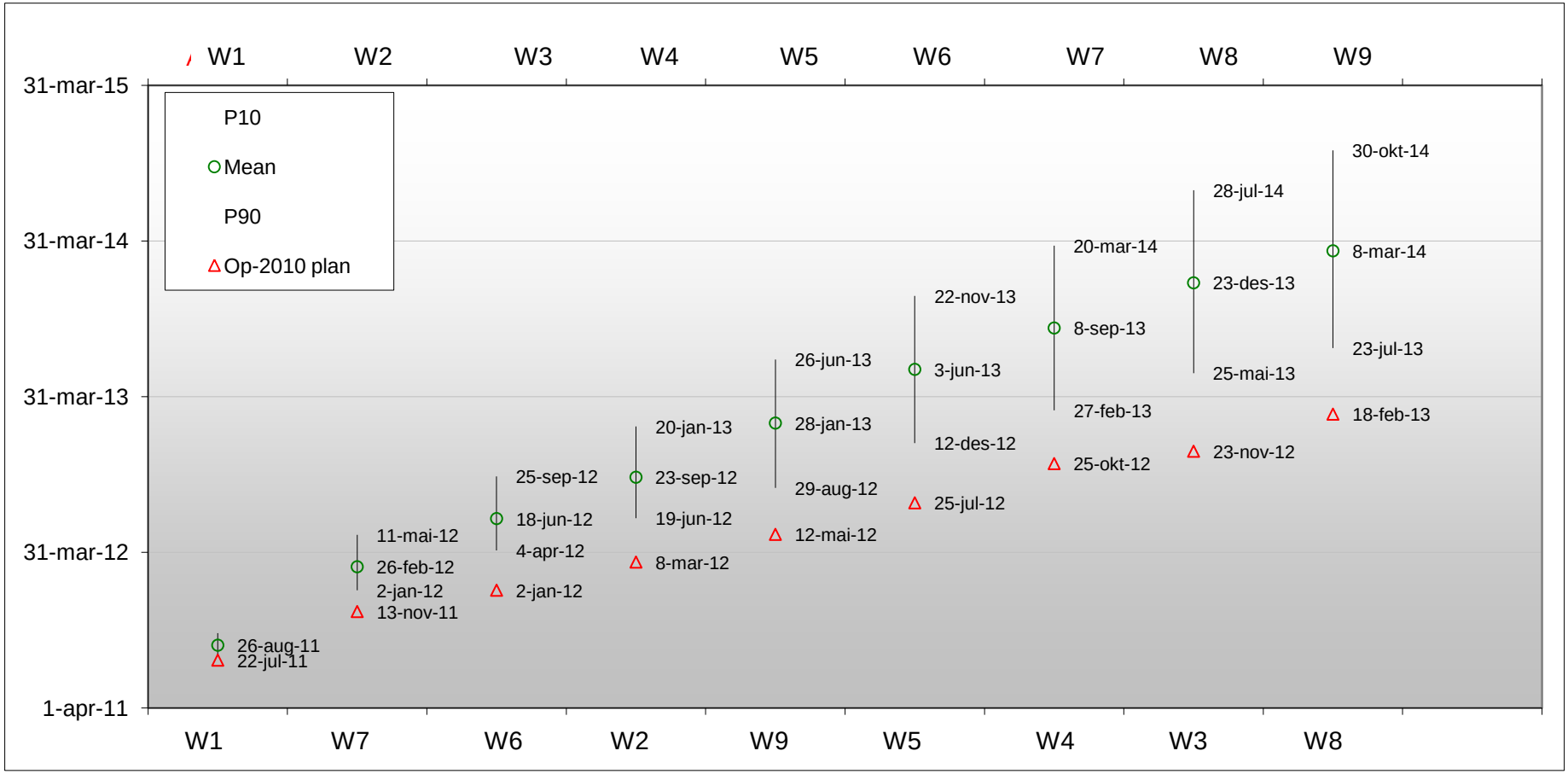
Screening simulations of all well options to evaluate data quality – check for Inconsistencies
Well options to include pilot wells for IOR/EOR ?



Simulations with several **different portfolio scenarios** (well projects) to optimise drilling campaign
Several scenarios of wells for IOR/EOR projects
Needs aggregation capability for each well scenario !

Timing of wells critical for all development economics !

Normally huge range from P10 to P90 estimates of number of wells and effect on production profiles



Well planning and decision making: Status and future
Actual Troll 6 branch well overlain picture of Rio de Janeiro

<u>Multiple reservoir targets defined</u>

Single wells, Bi-laterals, Advanced multilateral wells

How many branches in the future: 7 now and 25+ in 2030 ?

INTEGRATED DECISION SUPPORT SYSTEM

IOR/EOR Project Challenges to obtain acceptable economic results

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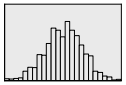
Integrated Development Assessment

Primary Recovery

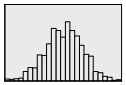
Secondary Recovery

Tertiary Recovery

Reserves / Resources – Drilling and Completion plans

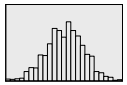


Natural flow

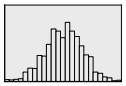


Artificial lift

Water flooding



Pressure maintenance Gas – Water injection



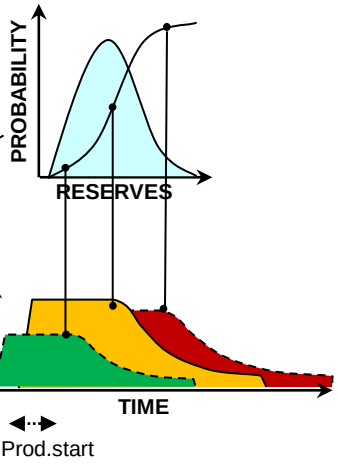
Chemical

Solvent

Thermal

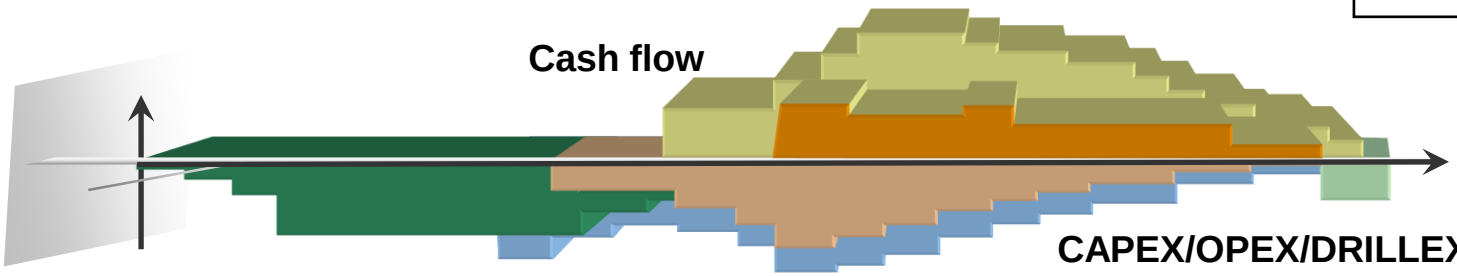
Other

Nitrogen
CO_2
Air
SAGD
Bacteria
Etc.

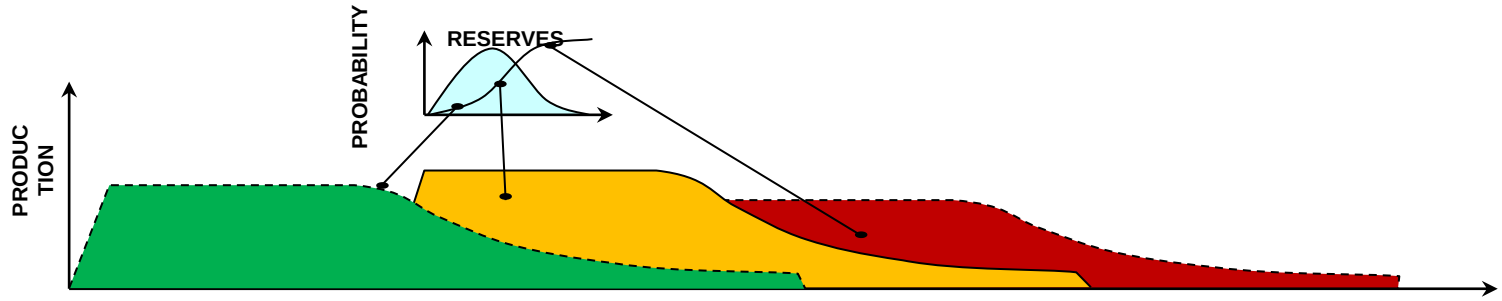


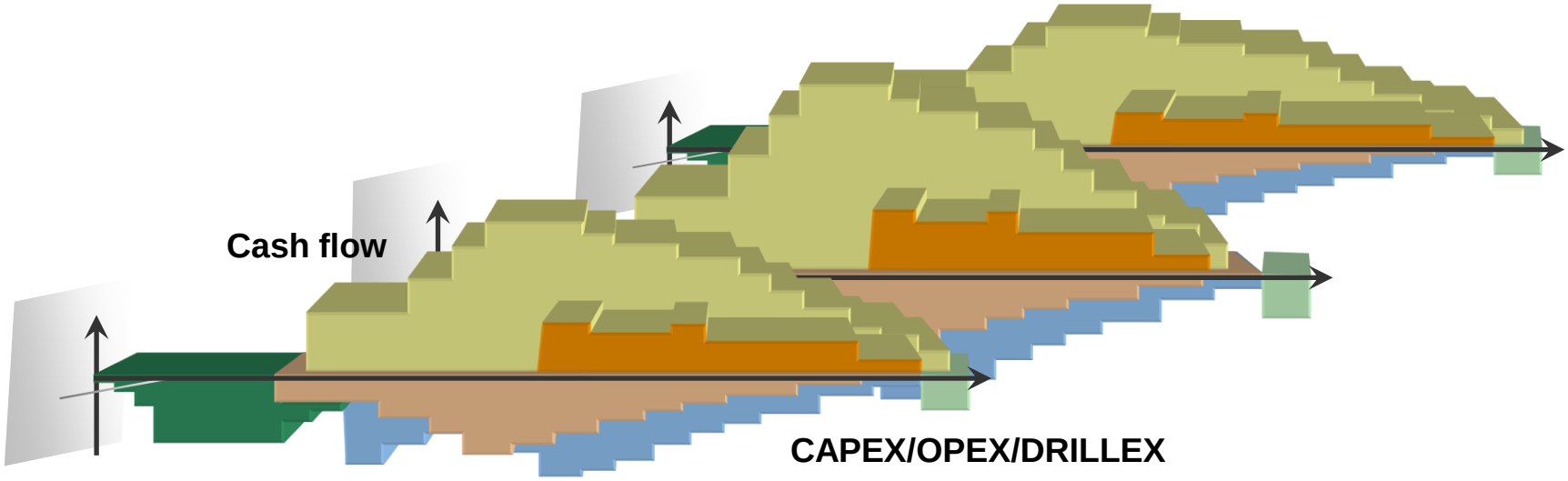
Investment/ Cash flow/Value

Results

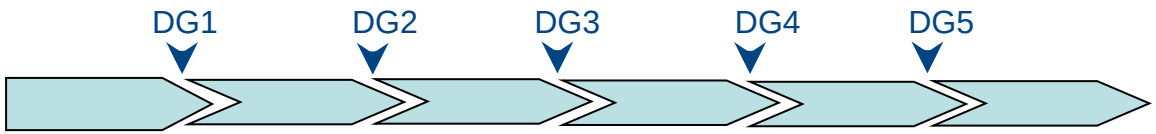


Primary, Secondary and Tertiary recovery

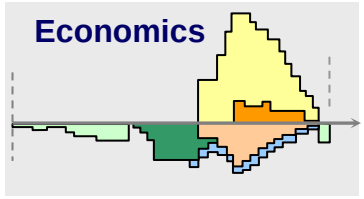




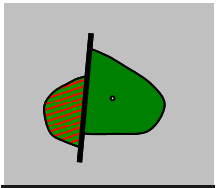
Well Established DECISION-MAKING PROCESS Primary – Secondary Recovery



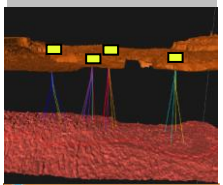
Integrated work approach



Geology
Geophysics



Reservoir
engineering

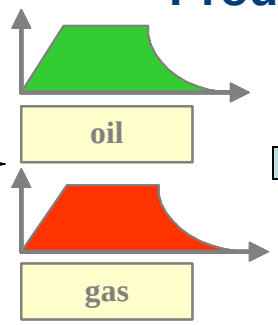


Drilling
engineering

Field
Development

Economic analysis

Production



Commercial premises

Rules
Regu-
lations

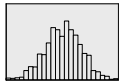
Tax

Market

Cost elements

Qualification of important IOR/EOR data for economic evaluation for one field, group of fields – operational area

Screening of Subsurface criteria



- Geoscience, petrophysical: rocks, liquids, gases
- Reservoir technical: injection of gases & liquids, production delta performance

  - **STOOIP, RECOVERY FACTOR, RESERVES, PRODUCTION PROFILES**

IOR/EOR well planning

- Existing wells, New wells for production and injection

  - **NUMBER, TYPE OF WELLS, SCHEDULE - DRILLEX**

Facility modifications, new technology

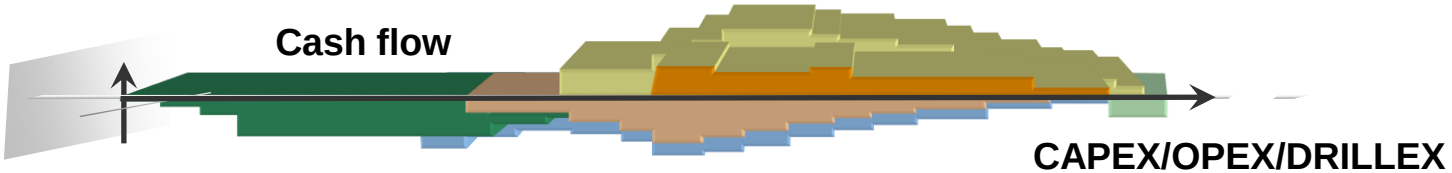
- Platform, subsea, pipeline modifications
- Process and transport enhancements by new technology

  - **CAPEX, OPEX**

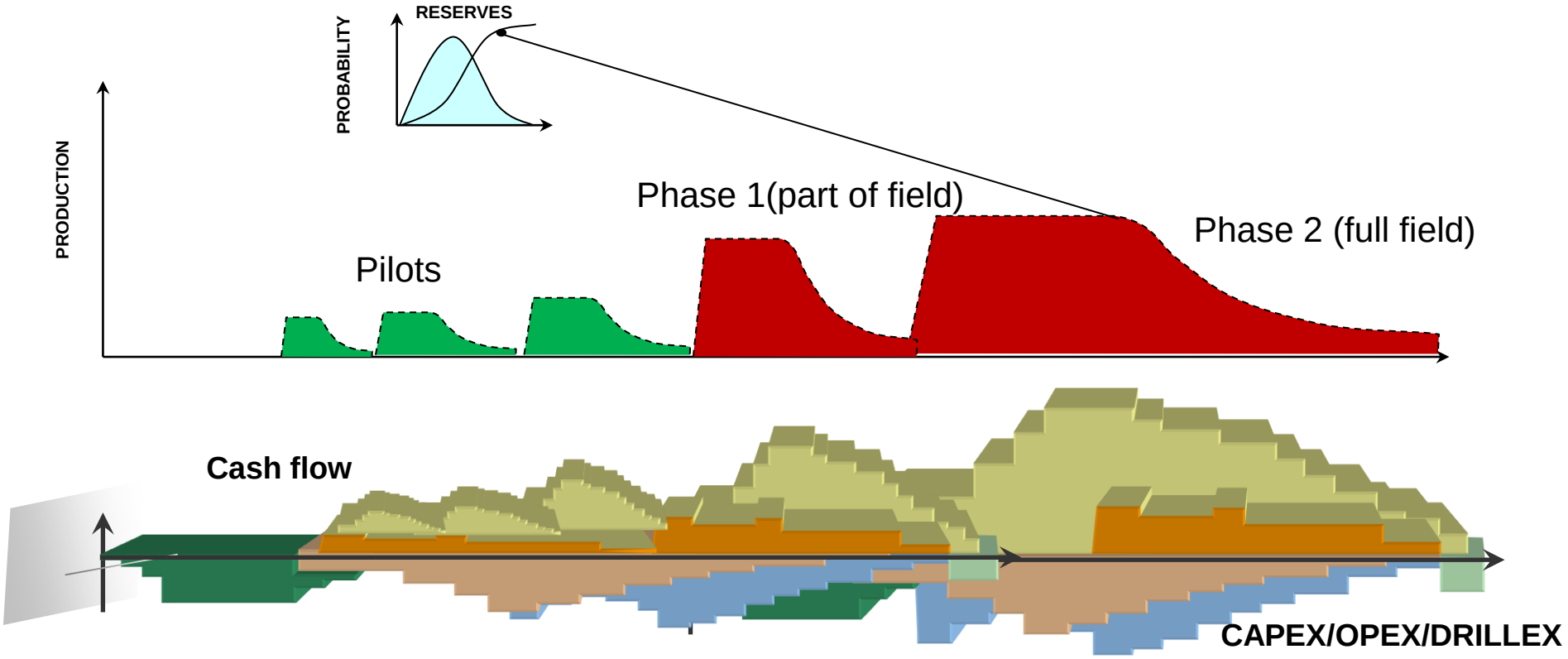
Combination of several fields, area planning

- Synergies between fields with similar possibilities for EOR methodology
- Area plan to optimise technical and economic solutions over field life time

  - **CAPACITY CONSTRAINTS, TARIFFS , LOGISTICS, OTHER SERVICES ?**



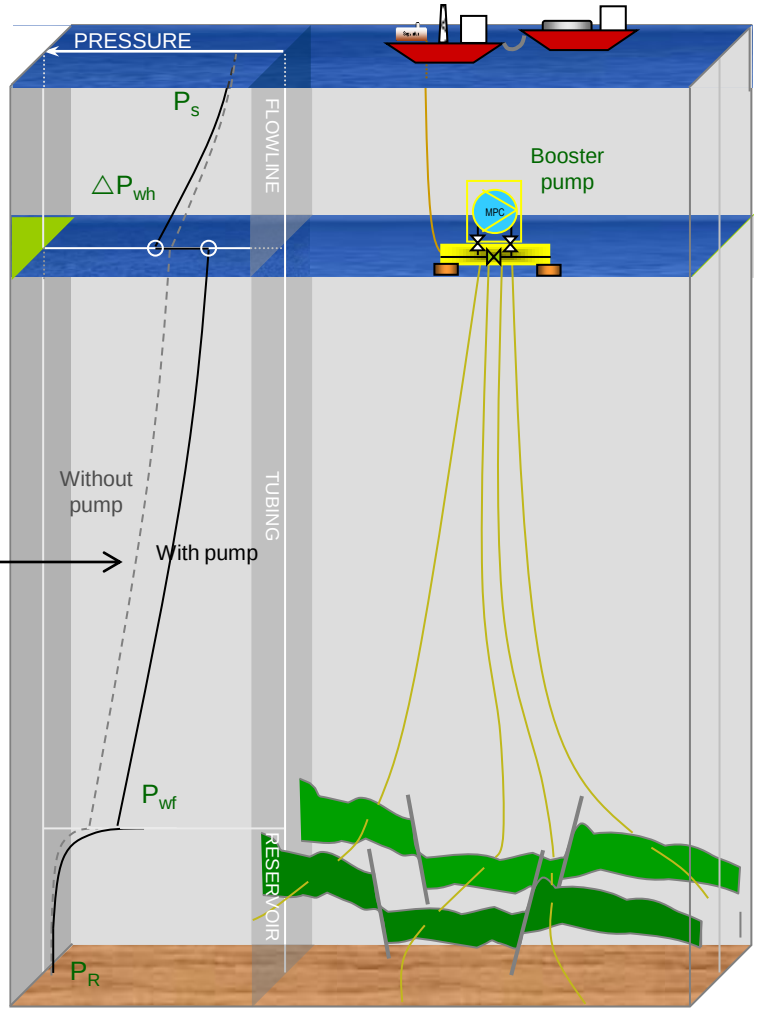
Stepwise Implementation of Tertiary recovery: Laboratory, Field Pilots, Production in Phases?



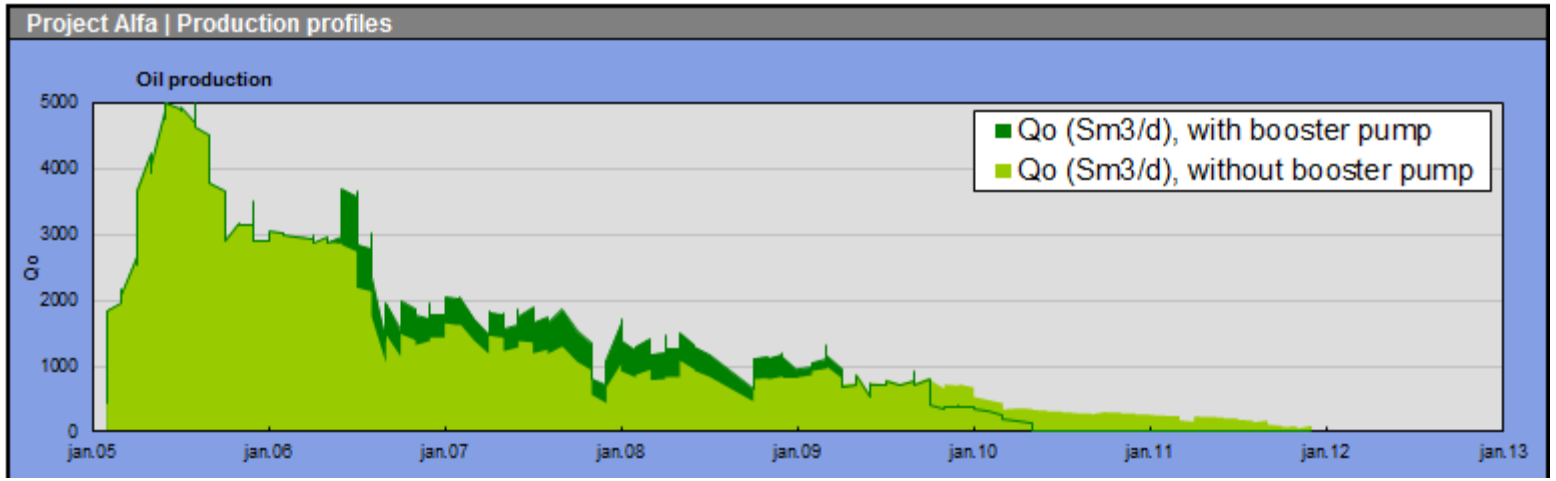
Stepwise implementation and integration of R&D, technology, staff to move projects from laboratory scale tests, single well tests, pilot tests and on to full –field scale implementation reduces risks, but add time and complexity to decision process and reduce NPV.

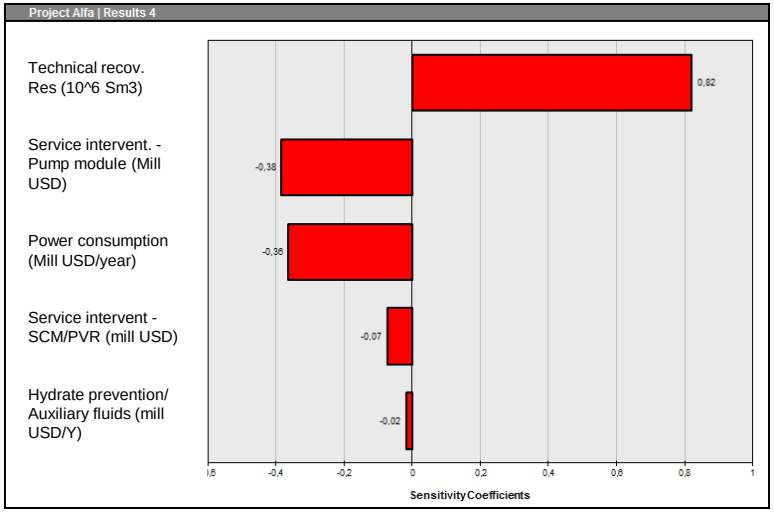
Typical IOR/EOR evaluation applied on Booster Pump Case

Pressure profile with and without booster pump.

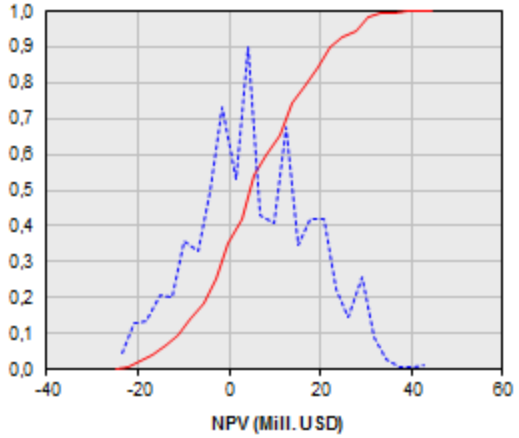


Typical IOR/EOR evaluation applied on Booster Pump Case





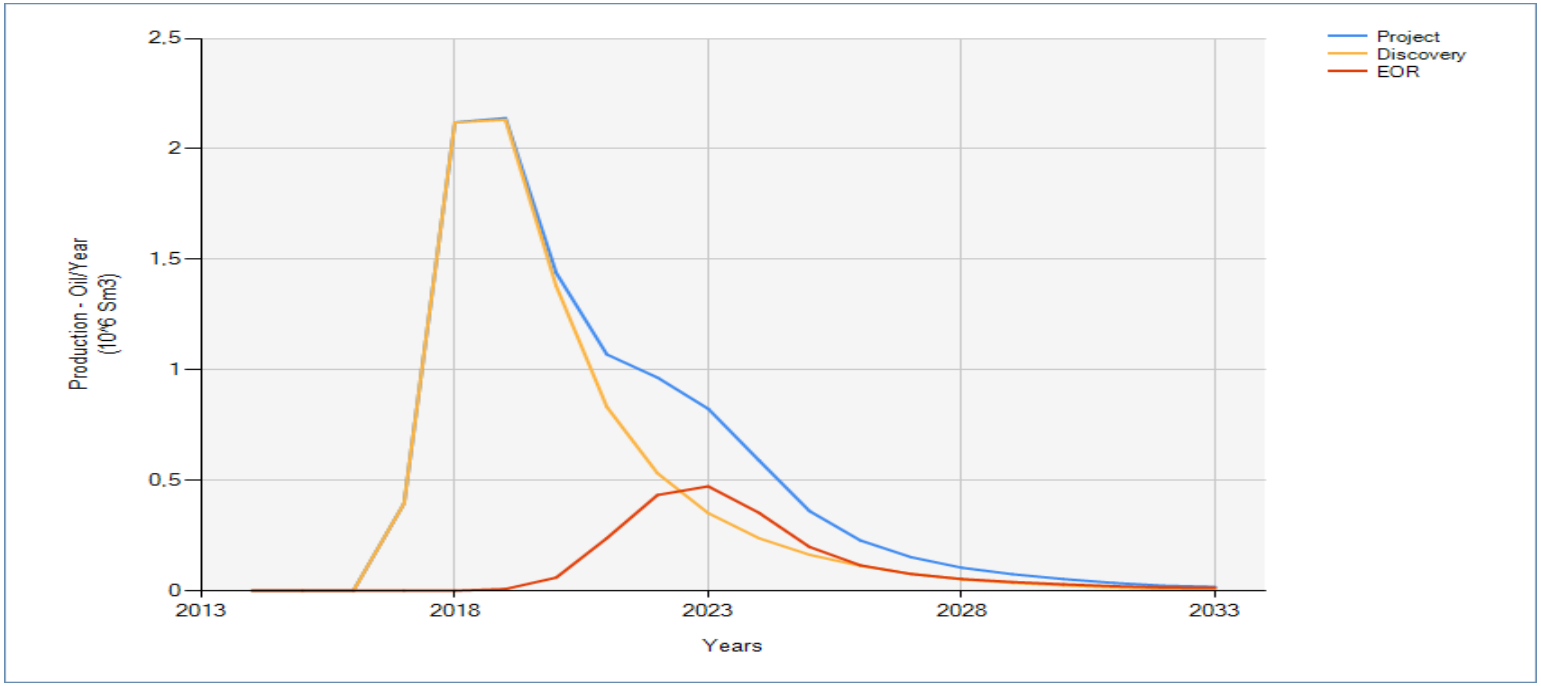
NPV	
Mean	5,553
Mode	4,033
St.dev	4,033
P0	-25,07
P5	-15,25
P10	-10,93
P25	-3,016
P50	4,541
P75	14,47
P90	22,25
P95	27,96
P100	44,22



Expected project NPV: 5,55 mill USD

Development of Discovery with IOR/EOR (Project)

Oil production – Mean profiles

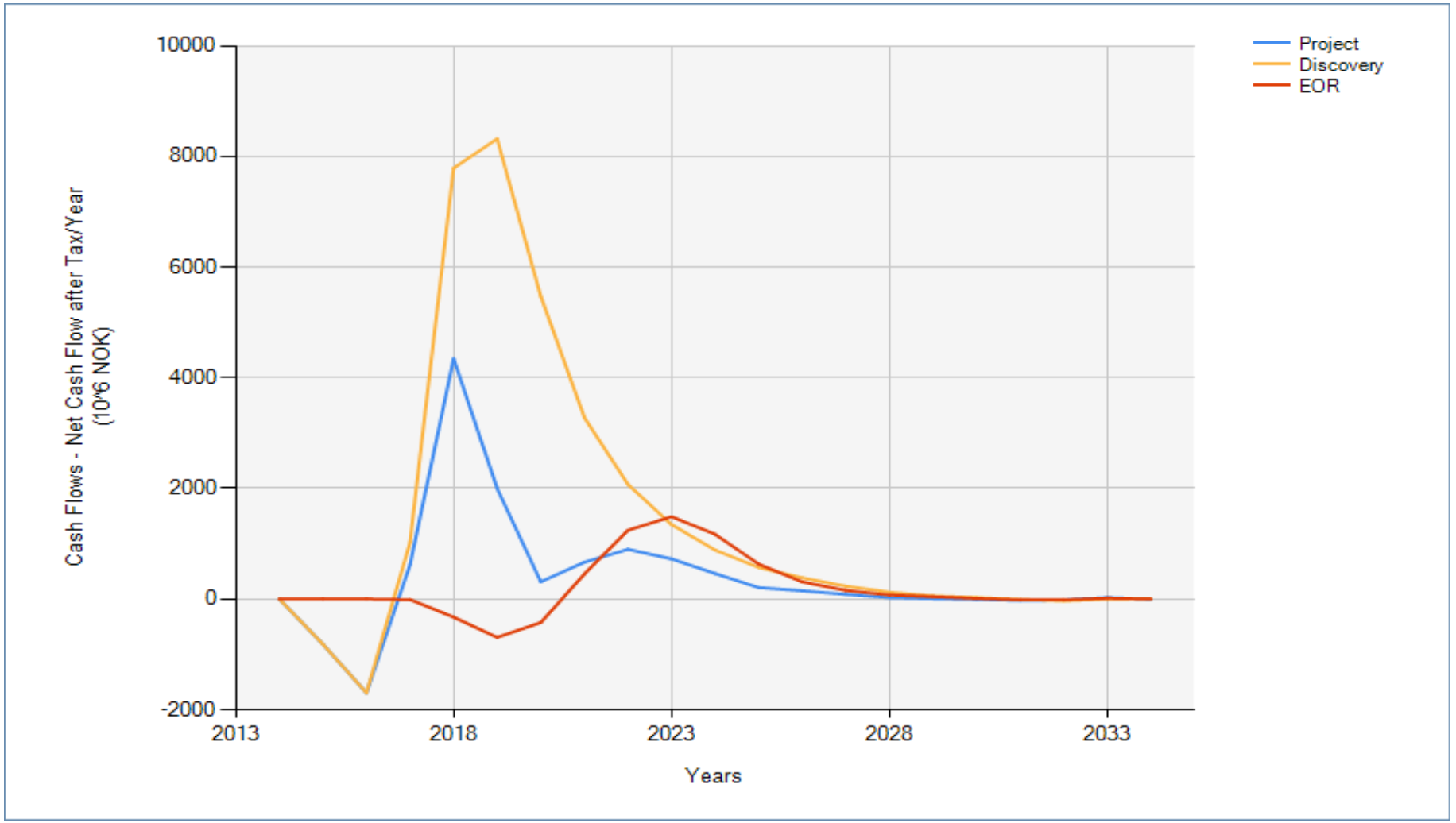


	P10	Mode	P90
STOIIP	14 MSm3	20 MSm3	40 MSm3
Recovery factor Rf	21 %	30 %	45 %
Additional EOR Rf *	3 %	10 %	15 %

* Negative correlated

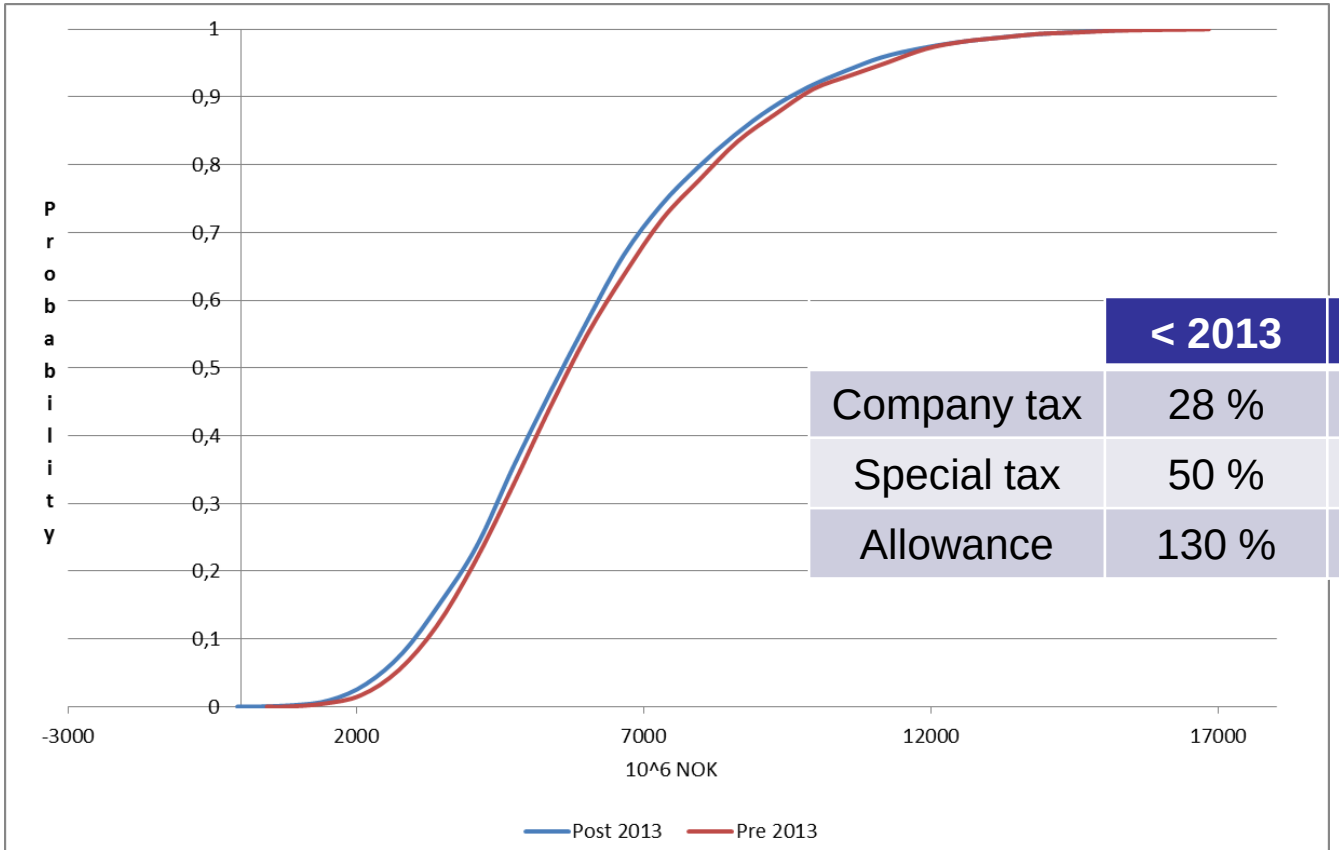
Effect of Fiscal Regime

Net cash flow after tax for Project; before tax for Discovery/EOR



New 2013 NCS tax rates vs. Pre 2013 tax rates

NPV distribution with full uncertainty

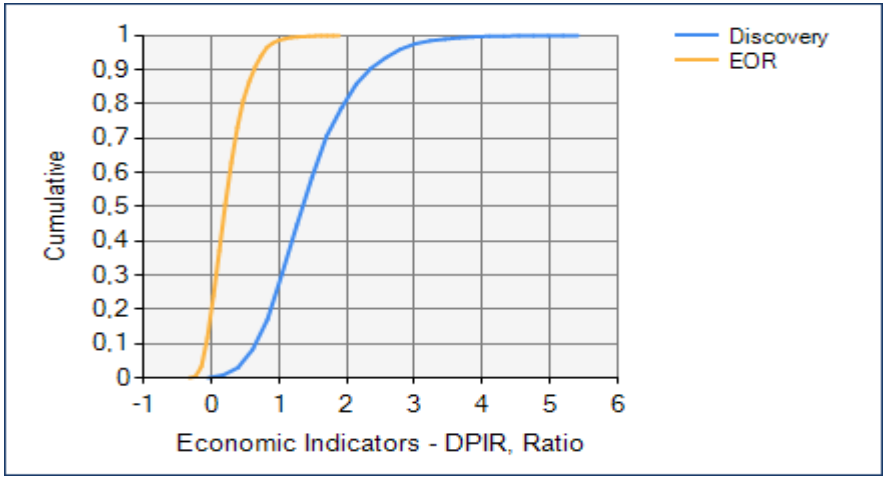


	< 2013	2013
Company tax	28 %	27 %
Special tax	50 %	51 %
Allowance	130 %	122 %

	Mean	Mode	P10	P90	Unit
Tax consolidation post 2013	5655	4095	2683	9242	10^6 NOK
Tax consolidation pre 2013	5826	4704	2863	9372	10^6 NOK

Tax changes and EOR projects

- New tax rates and reduced uplift increase downside risk in general
- EOR projects, will normally have higher uncertainty than initial development phase
- Low return on capital combined with higher risk will not be an incentive to invest in EOR projects on a stand alone basis
- If the oil company goes out of tax position during the initial development phase, this increases the downside risk of the EOR project



DPIR:
Discounted Profit to Investment Ratio
Tax calculated on Discovery and EOR project

Corporate Project portfolio

Rank IOR/EOR projects and compare with conventional projects

- Overview of total project portfolio economics NPV, EMV for ranking of all projects
- Resource/ reserve/production/revenue/CAPEX/OPEX for long term forecasting scenarios

- Ranking of IOR/EOR projects within the portfolio
- Area plan to optimise technical and economic solutions of IOR/EOR over field life time
- Initial field development planning of IOR/EOR projects for Stepwise decisions from laboratory tests, pilots in field to full field deployment to establish realistic project implementation schedule

- Comparison between IOR/EOR projects within different fiscal regimes
- Comparison with NPV, EMV on conventional projects including drilling of new, more advanced development wells and exploration/appraisal wells for tie in of new satellites

Summary

EOR investment projects are complex and challenging:

- **Decision process** require high level of expertise in a large number of technical, economic and management professions to perform an integrated economic modelling with advanced uncertainty/risk handling to satisfy management.

Stepwise implementation and integration of R&D, technology, staff to move projects from laboratory scale tests, single well tests, pilot tests and on to full –field scale implementation reduces risks, but add time and complexity to decision process and reduces NPV.

- **EOR compete with Primary development and IOR**
  - Improved reservoir modelling combined with infill drilling, improved injection of gas and water, and upgrade of process (capacity, pumps, compressor) adds "easy" reserves.
  - Several new discoveries for tie back on most fields at the NCS.

- **Effects of fiscal regime**

- So far no special incentives regarding IOR/EOR in the fiscal regime for NCS.
- Latest changes in fiscal regime has a negative effect.

Future changes?

- To achieve more EOR projects it is necessary to plan these projects in an early phase, when developing the Primary – Secondary recovery.

  With simultaneous maturation of EOR knowledge from reservoir, drilling, process, transport and logistics can be directly applied.

- Coordination of field operations can probably increase EOR projects, in particular in business areas where it is similar drainage strategies and technical infrastructure solutions.

- Companies need to specialise in building capabilities on certain types of EOR projects to be able to successfully implement EOR projects economically. This will require both technical, economic and management top expertise.

- Selective Fiscal incentives can probably boost the activity / production from EOR.

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