Reservoir Modelling & Value Maximizing of Field Redevelopments under Uncertainty

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OMV Exploration & Production

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The energy for a better life. OMV

Redevelopment of a super-mature oil field

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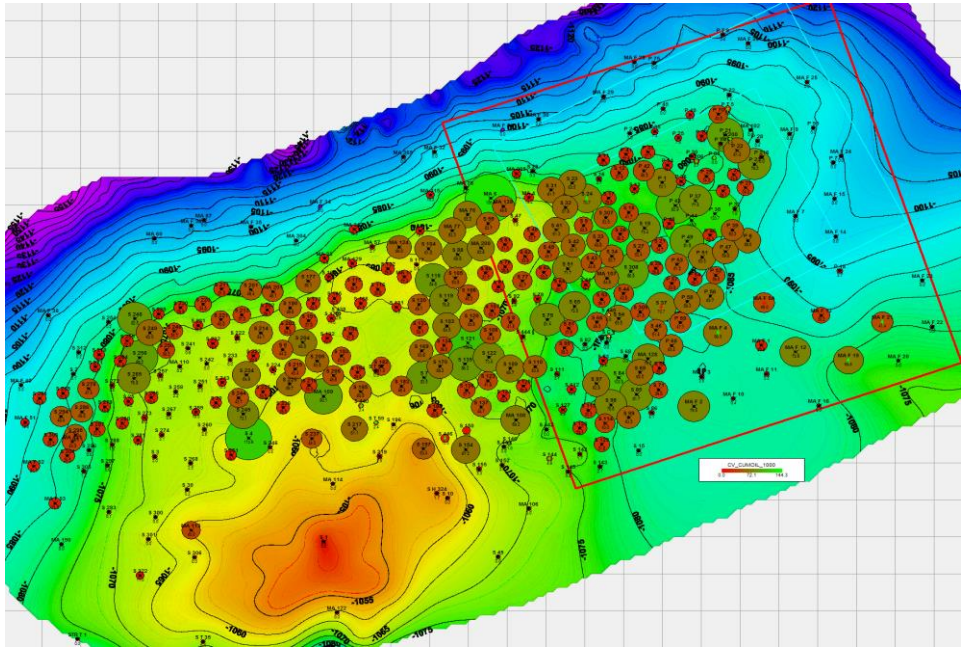
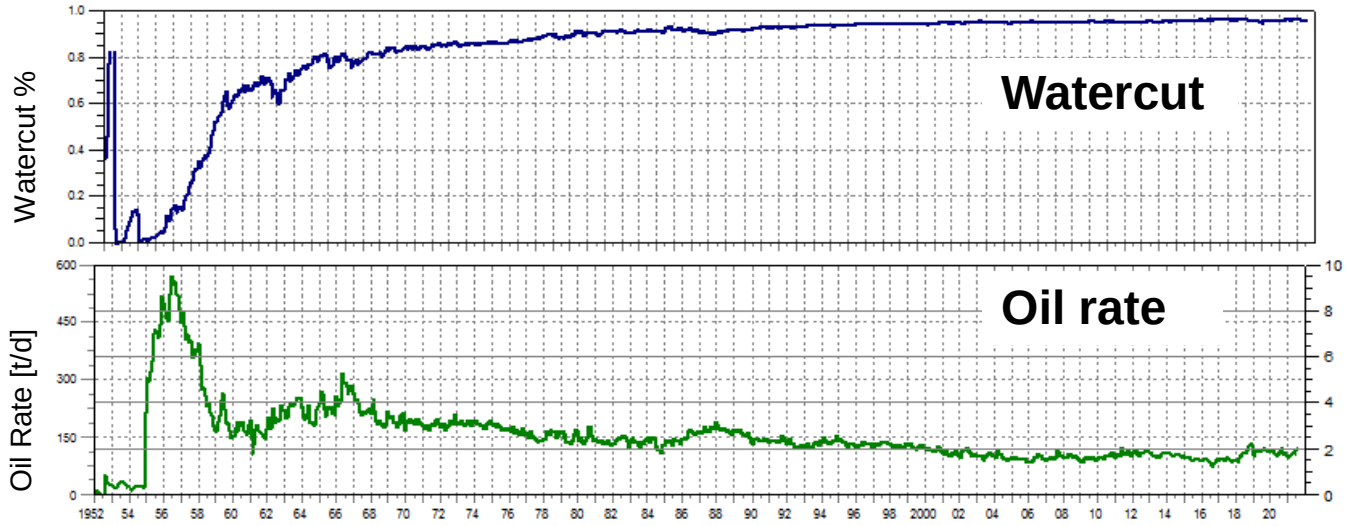
- Production start: Mar-1951
- Water injection start: Nov-1968
- Current oil production: ~125 t/d from sector
- Current water cut: 96-97%





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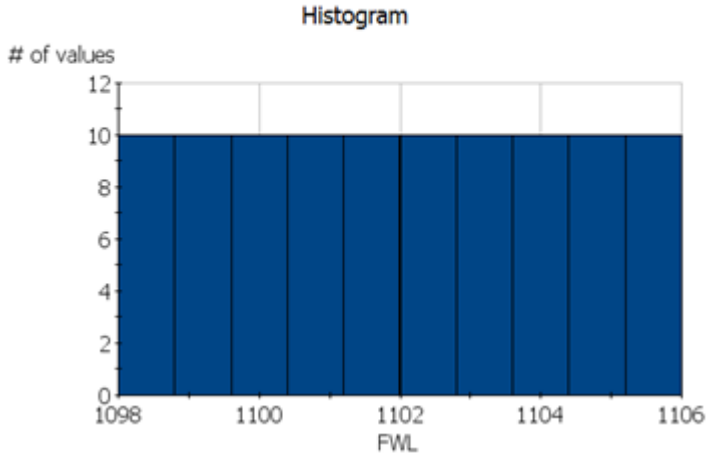
Uncertainty & ranges

Variable	Description	Range/Values
MUE	Oil Viscosity (at 113 bar)	13 – 20 cP, integer
FWL	Free Water Level	1098 m – 1106 m TVDss
GOC	Gas Oil Contact (Pc = 0 for oil-gas)	1078 m – 1080 m TVDss
AQVN	Aquifer volume in north (c =1.0e-5 1/bar, PI = 1500 m³/d/bar)	1.3e10 - 1.7e10 m³
AQVE	Aquifer volume in east (c =1.0e-5 1/bar, PI = 500 m³/d/bar)	5.0e9 - 10.0e9 m³
AQVS	Aquifer volume in south (c =1.0e-5 1/bar, PI = 500 m³/d/bar)	5.0e7 - 5.0e8 m³
KX1	Permeability for porosity 0 - 0.05	0.1 mD – 6 mD
KX2	Permeability for porosity 0.05 - 0.1	0.5 mD - 50 mD
KX3	Permeability for porosity 0.10 - 0.15	1 mD - 200 mD
KX4	Permeability for porosity 0.15 - 0.20	2 mD - 500 mD
KX5	Permeability for porosity 0.20 - 0.25	5 mD - 4000 mD
KX6	Permeability for porosity 0.25 - 0.30	50 mD - 7000 mD
KX7	Permeability for porosity >0.3	500 mD - 15000 mD
KZM345	Vertical Permeability = Horizontal Permeability / KZM345 for porosity 0.1 – 0.25	10 - 100
KZM67	Vertical Permeability = Horizontal Permeability / KZM67 for porosity 0.25 – max.	3.333 - 25
TZ	Steepness of oil-water transition zone (1~broad, 3~steep)	1, 1.5, 2, 3
SWR1	Irreduceable water saturation of SATNUM 1 (worst rock class)	0.5 - 0.65
SWR2	Irreduceable water saturation of SATNUM 2	0.4 - 0.6
SWR3	Irreduceable water saturation of SATNUM 3	0.35 - 0.5
SWR4	Irreduceable water saturation of SATNUM 4	0.25 - 0.4
SWR5	Irreduceable water saturation of SATNUM 5 (best rock class)	0.1 - 0.25
RPERM_1	Relative Permeability applied to “worst rock” (lowest rock quality indicator RQI out of 5 RQI classes) (9 ~ water wet, 4-5 ~ intermediate wet)	5,6,7,8,9
REL_SOR	Change of best-rock-class Sor relative to worst rock class	-0.06 to -0.02
REL_KRW	Change of best-rock-class Krw relative to worst rock class	0.05 to 0.15
REL_KRO	Change of best-rock-class Kro relative to worst rock class	-0.15 to -0.05
REL_NW	Change of best-rock-class nw relative to worst rock class	-1.0 to -0.2
REL_NO	Change of best-rock-class no relative to worst rock class	0.2 to 1.0
SGR	Residual Gas Saturation	0.05 - 0.1

Prior distributions:



History matching of model ensembles

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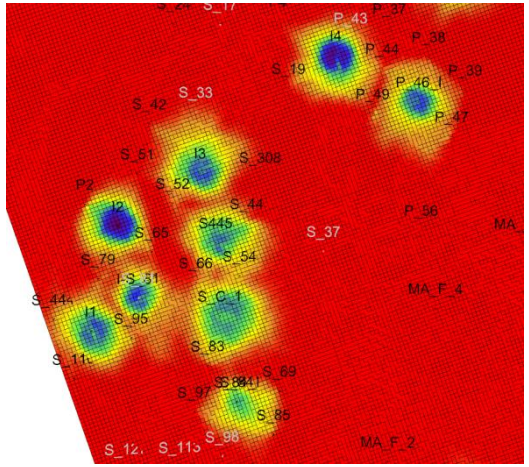
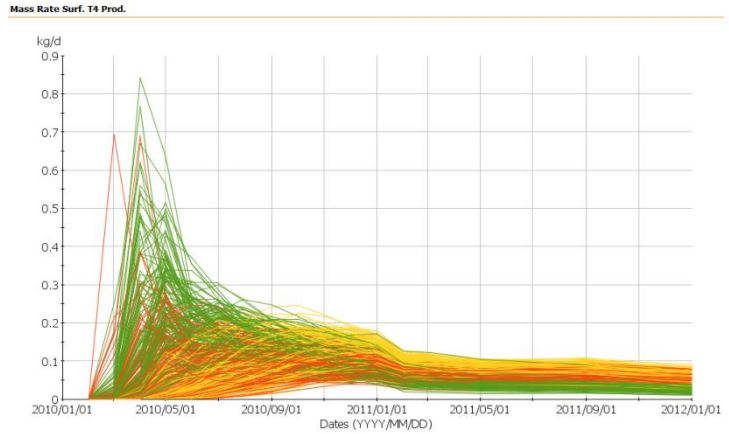
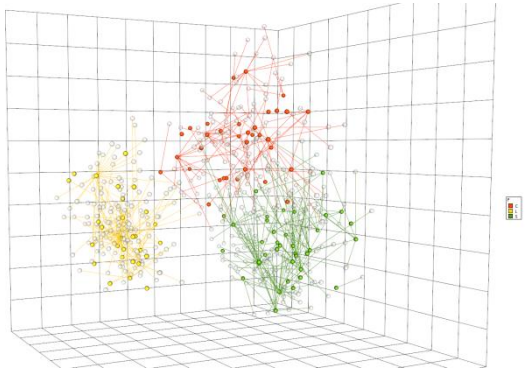
1) Simplified physics for dynamic response of 1453 geo-models.



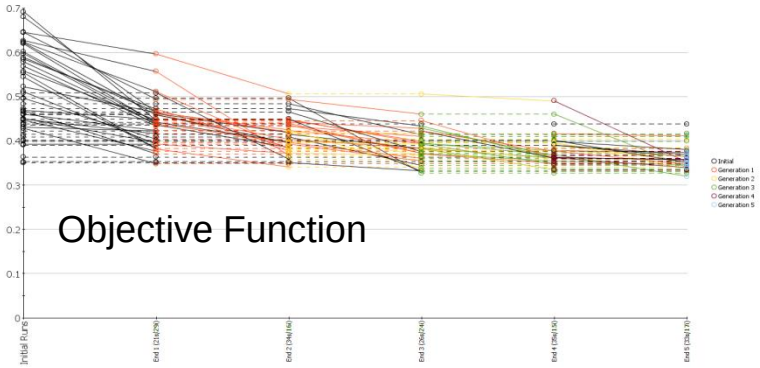
2) Tracer response of individual wells



3) Clustering in multi-dimensional space



4) Differential Evolution to history match ensembles.
Result: 62 static models but 100 sim run!



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History Match - Oil rate

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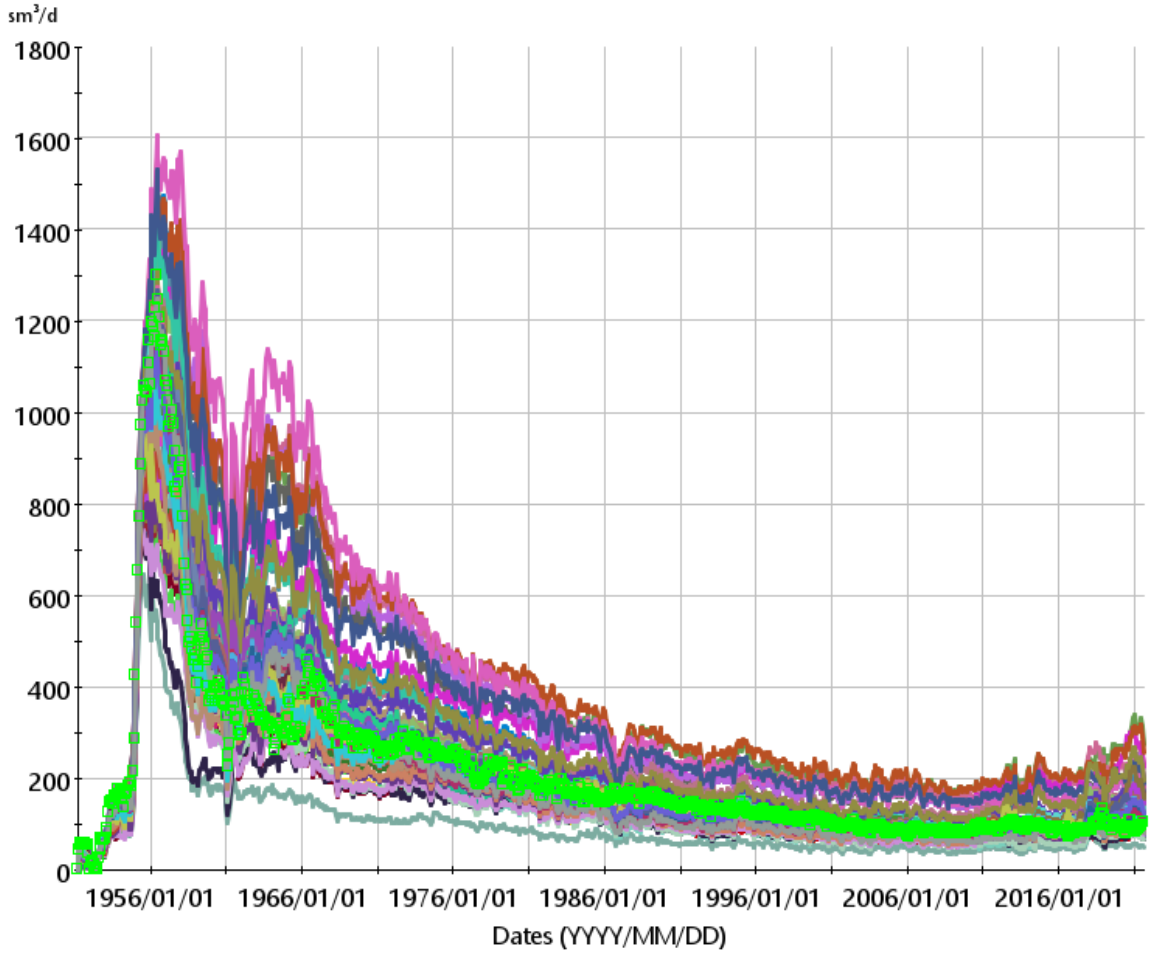
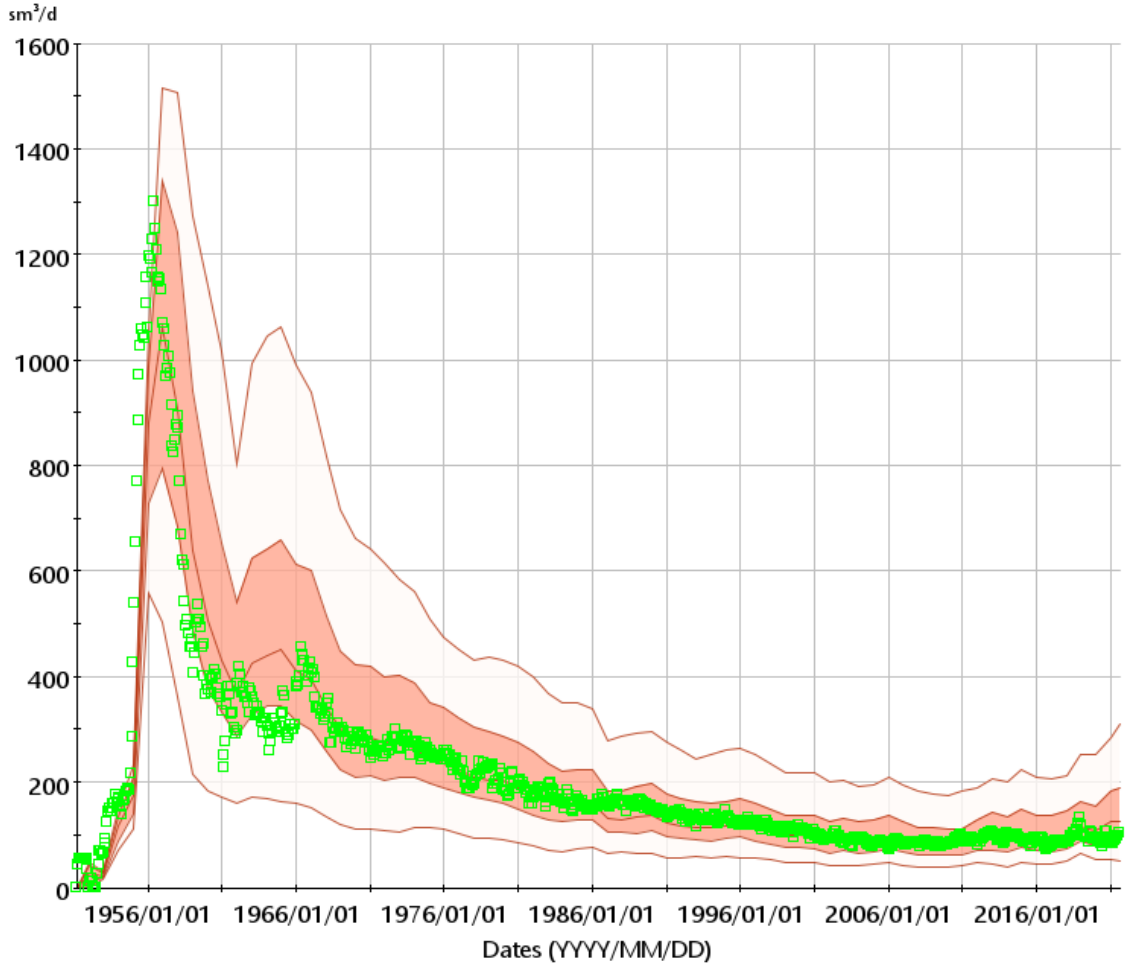
Rate Surf. Oil Prod.



Rate Surf. Oil Prod.



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Redevelopment forecast incremental to No Further Activity

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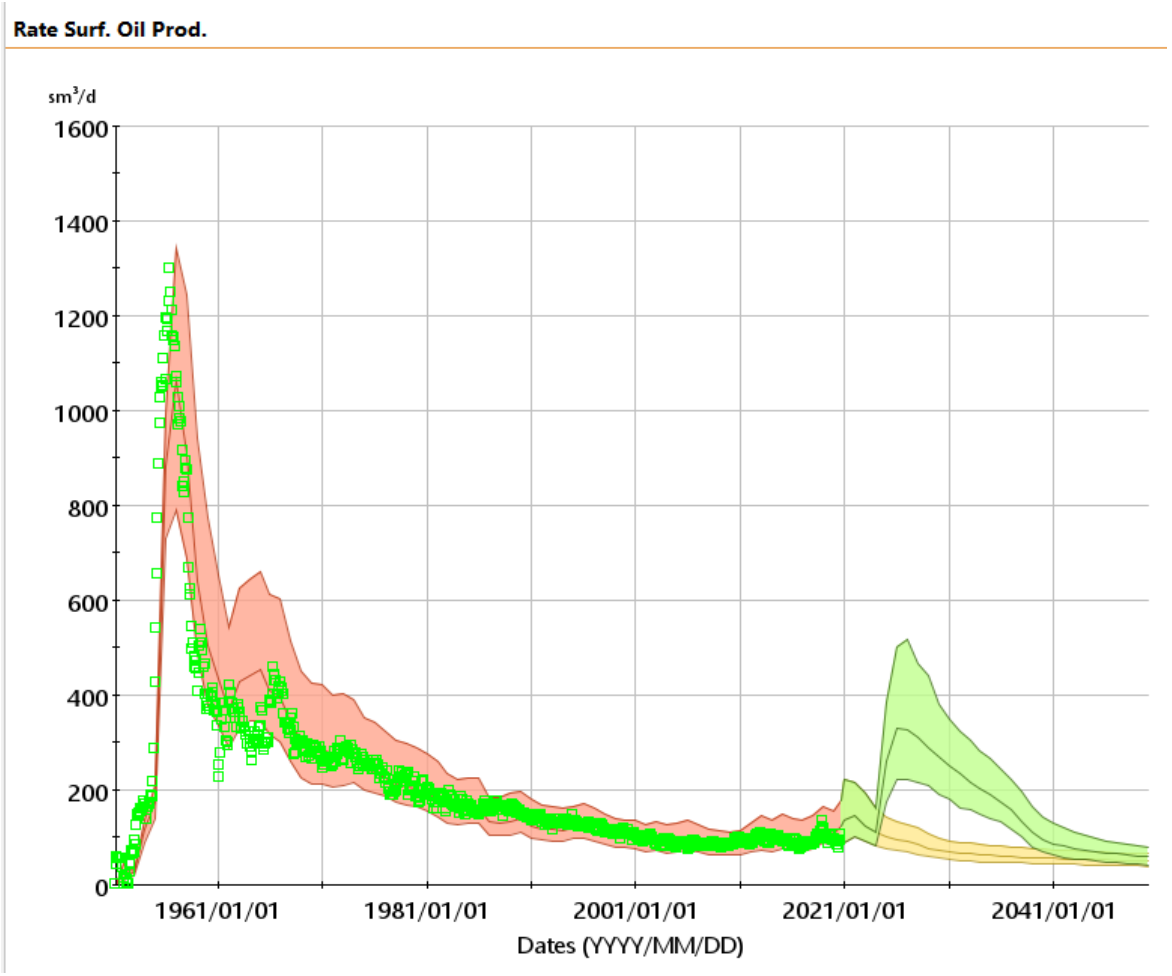

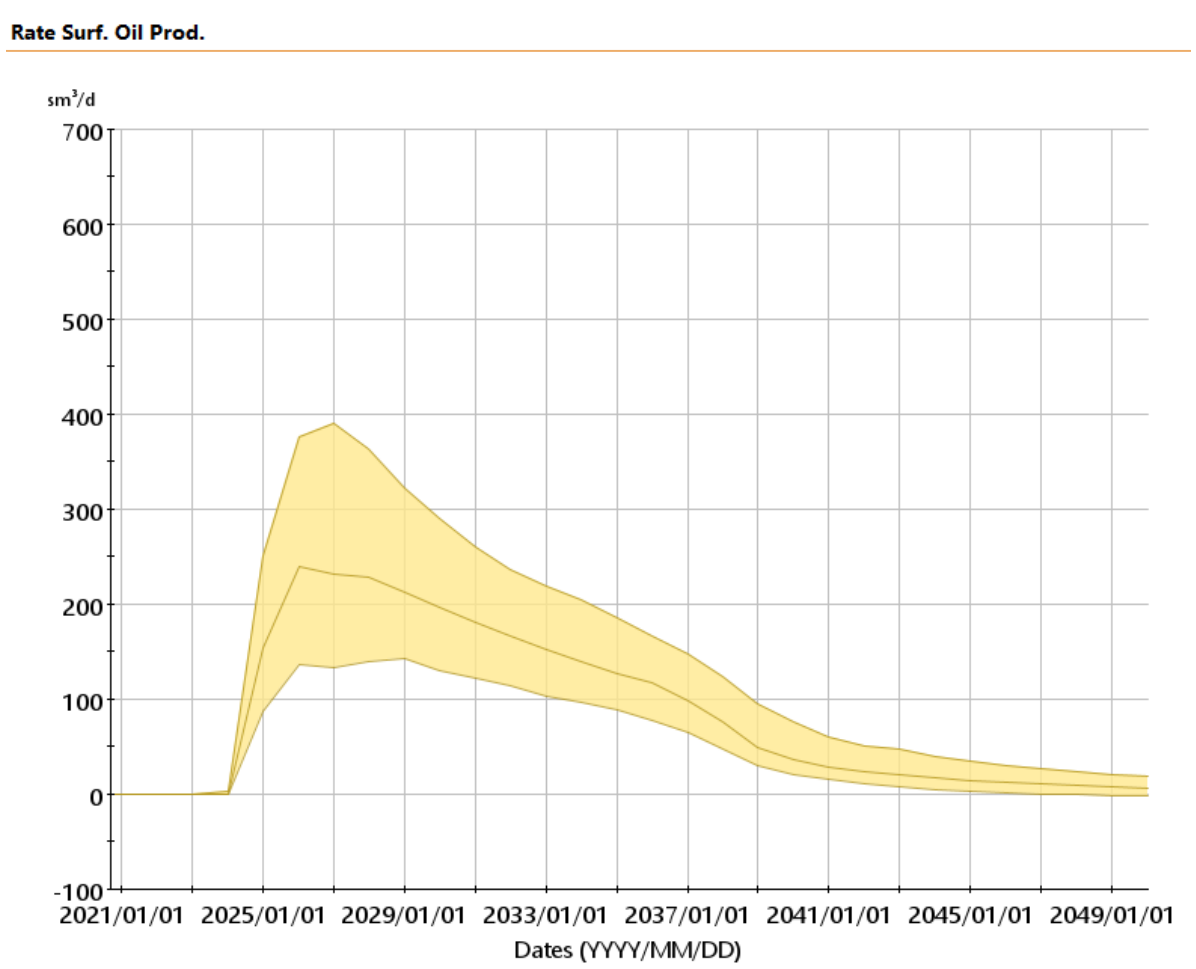

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Evaluating Redevelopment options

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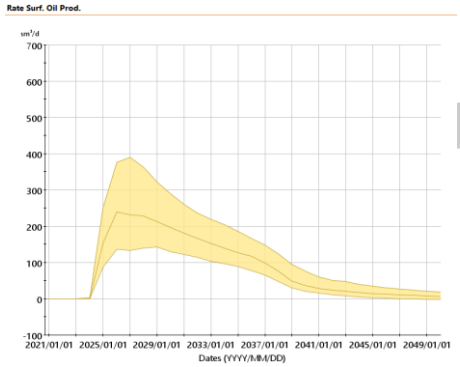
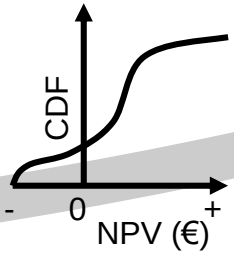
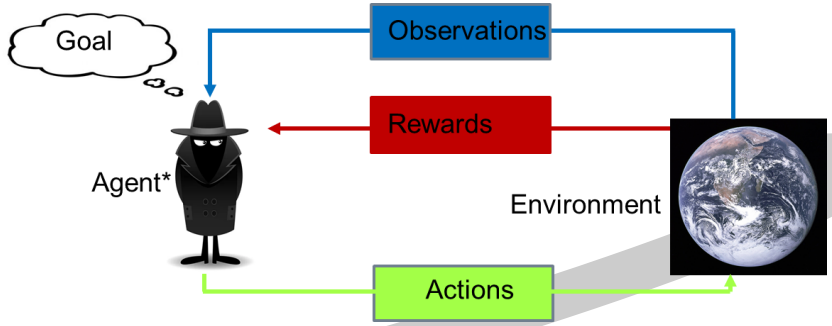


Over 140 of forecasts …



are combined with Bayesian economics …



and analyzed by Artificial Intelligence (Agent System)…

Highest value development

To find the highest value option under uncertainty!

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Selection of best development option based on Expected Monetary Value

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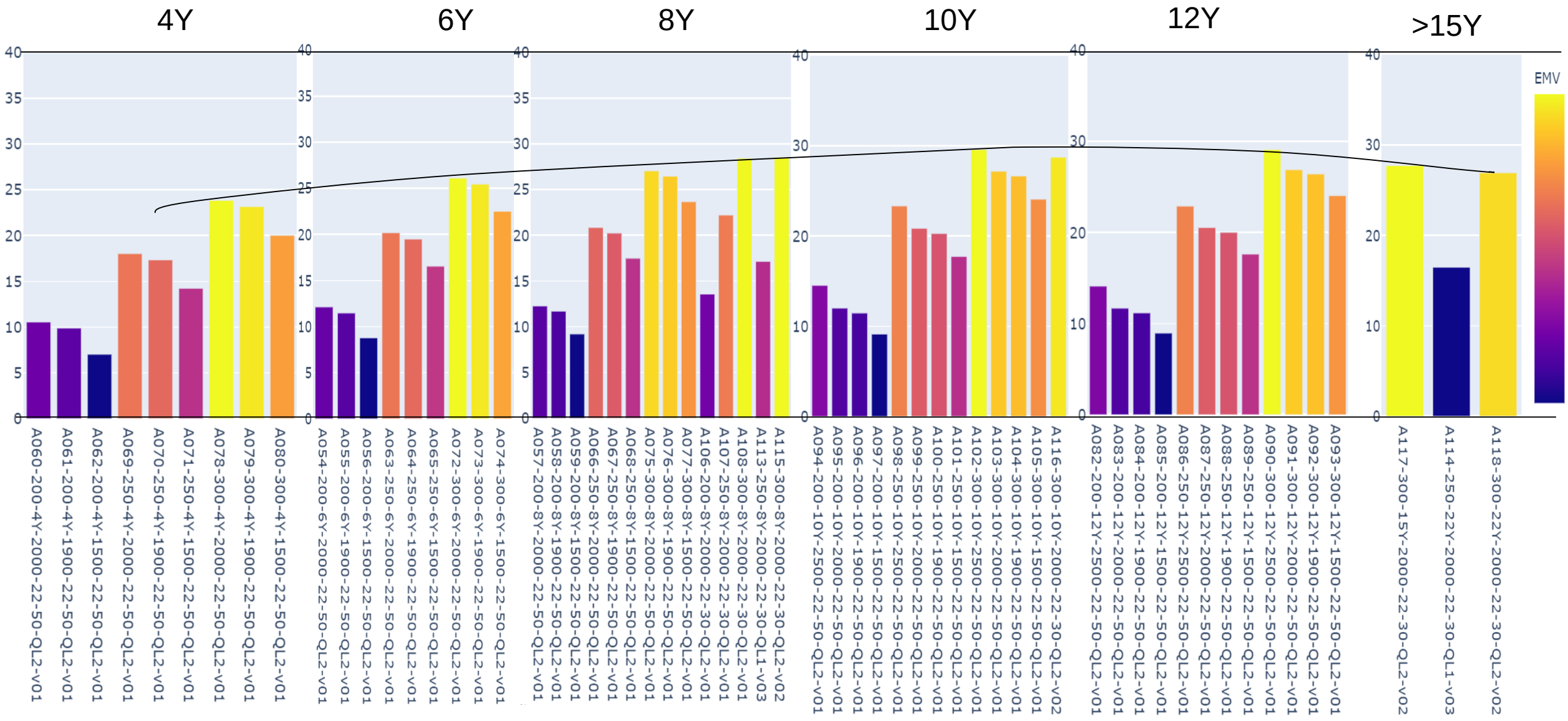

Conclusions

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- **Field redevelopments** need to take **uncertainty** into account.
- **Model ensembles** allow **forecasting** under **uncertainty**.
- **Forecasting** results need to be **combined** with **Bayesian economics**.
- **Artificial Intelligence** is applied for **decision analysis** under **uncertainty.**
- **Substantial value** was generated, increases in **Expected Monetary Value** of **more than 30 %** was achieved using seamlessly **integrated probabilistic forecasting - economic evaluation - decision analysis**.

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