Economic analysis of CO_2-EOR under uncertainty

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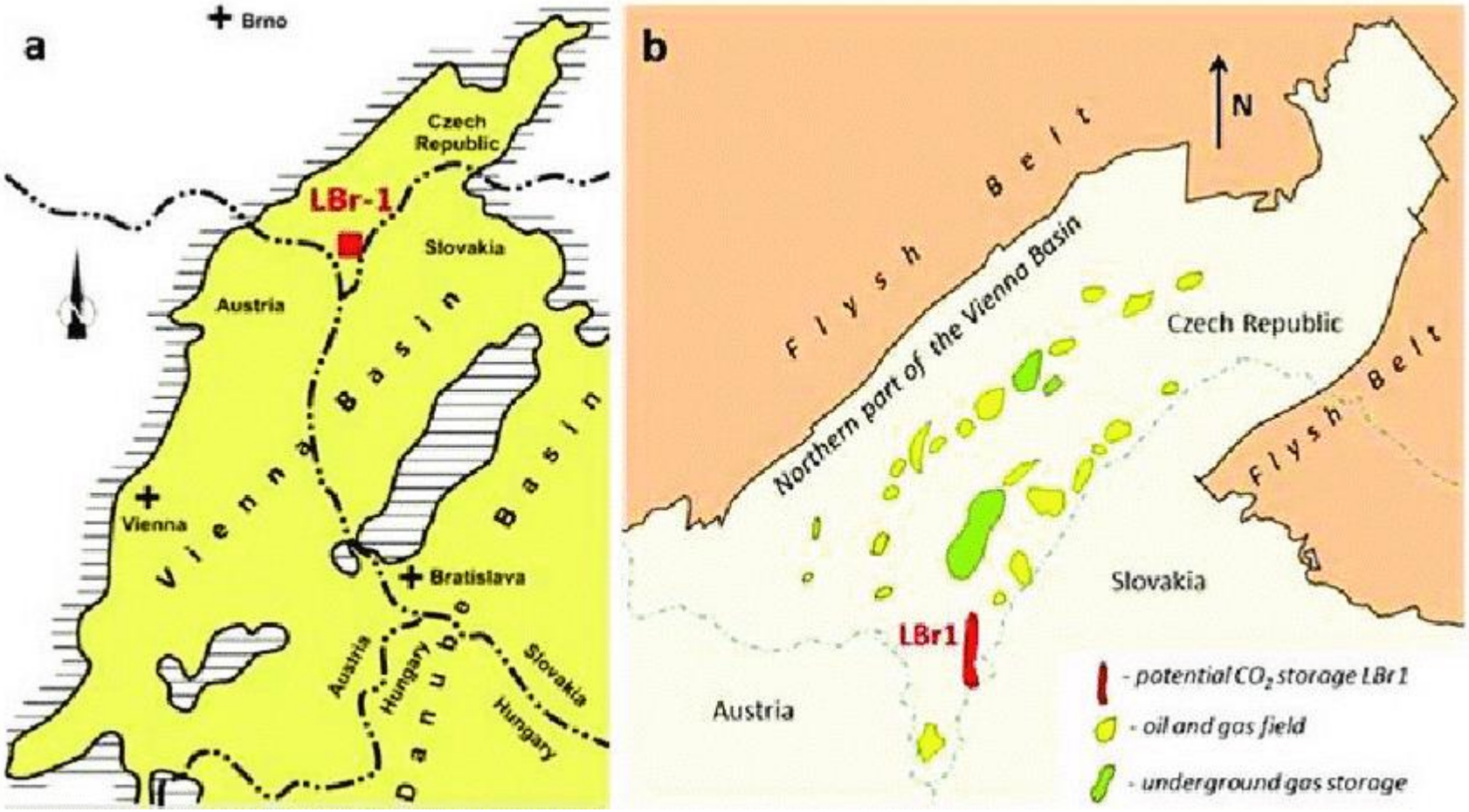
Enabling Onshore CO_2 Storage

LBr-1 case



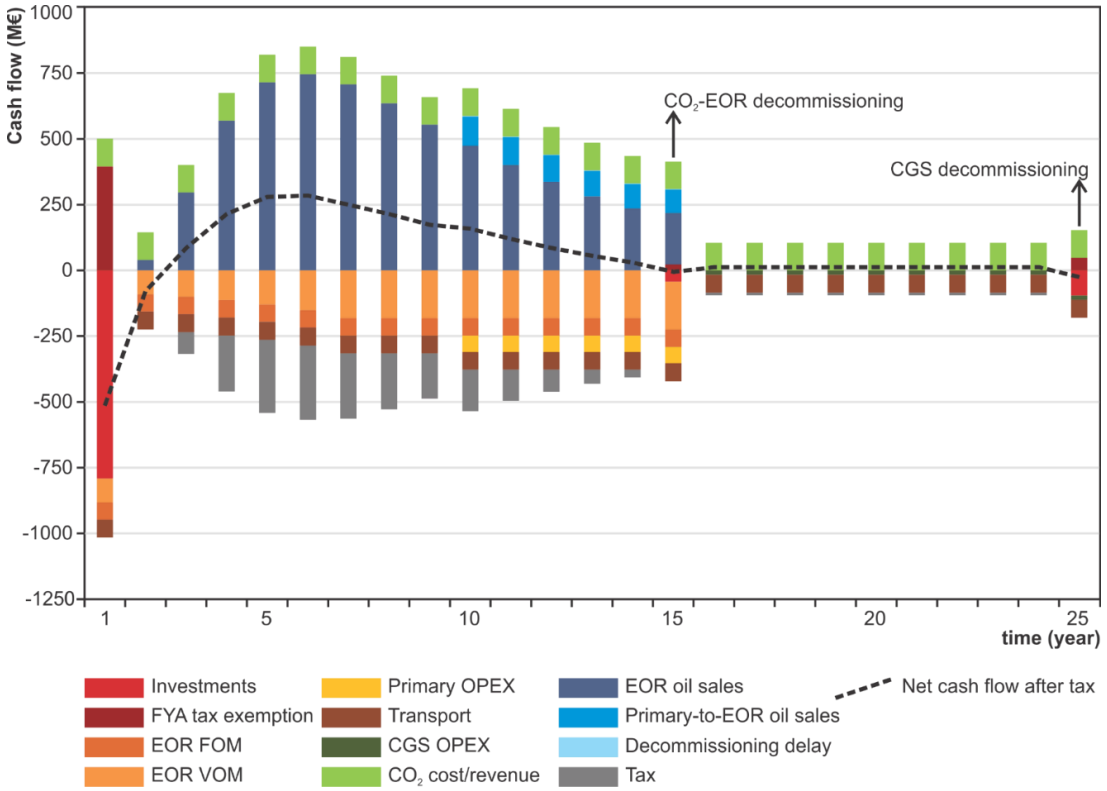
Juraj et al. (2017) Energy Procedia

Methods for economic analysis

Calculate Net Present Value (NPV) *(Easy approach)*

- Determine economic and reservoir scenario
- Map cash flows
- Apply discounting

Result: project value

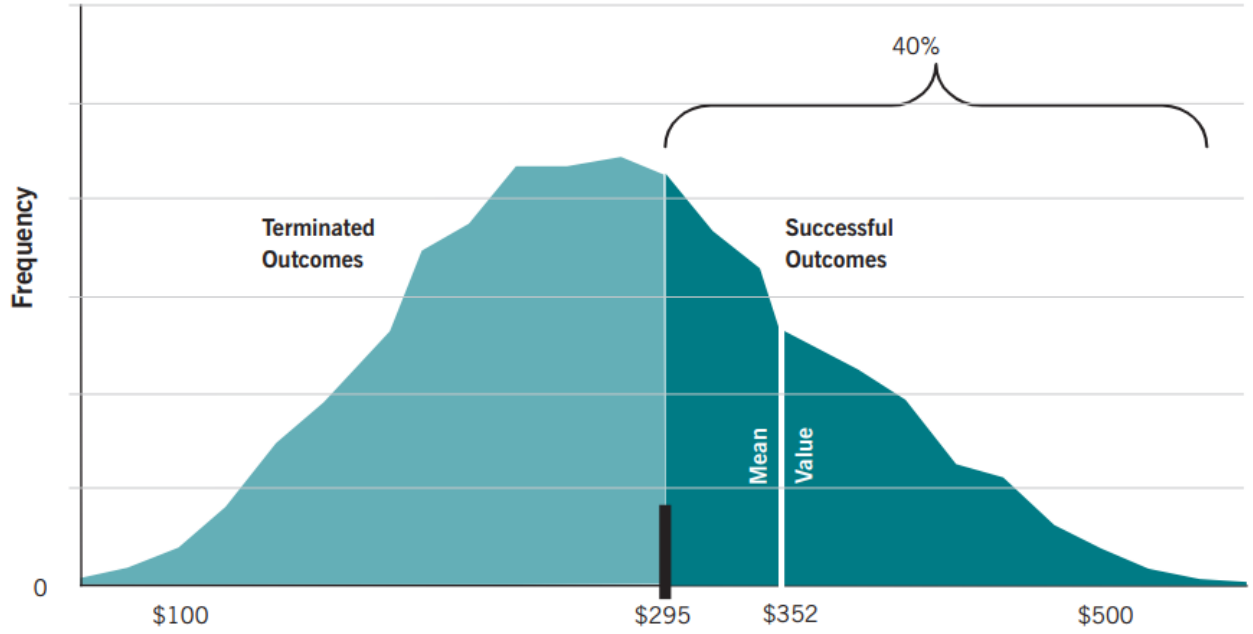


Methods for economic analysis

Economic optimization *(Classical approach)*

- All of the above
- Introduce variable parameters, e.g. reservoir operation
- Optimise towards a set goal, e.g. highest project value
- Do sensitivity analysis

Result: optimal pathway for reaching the goal



Methods for economic analysis

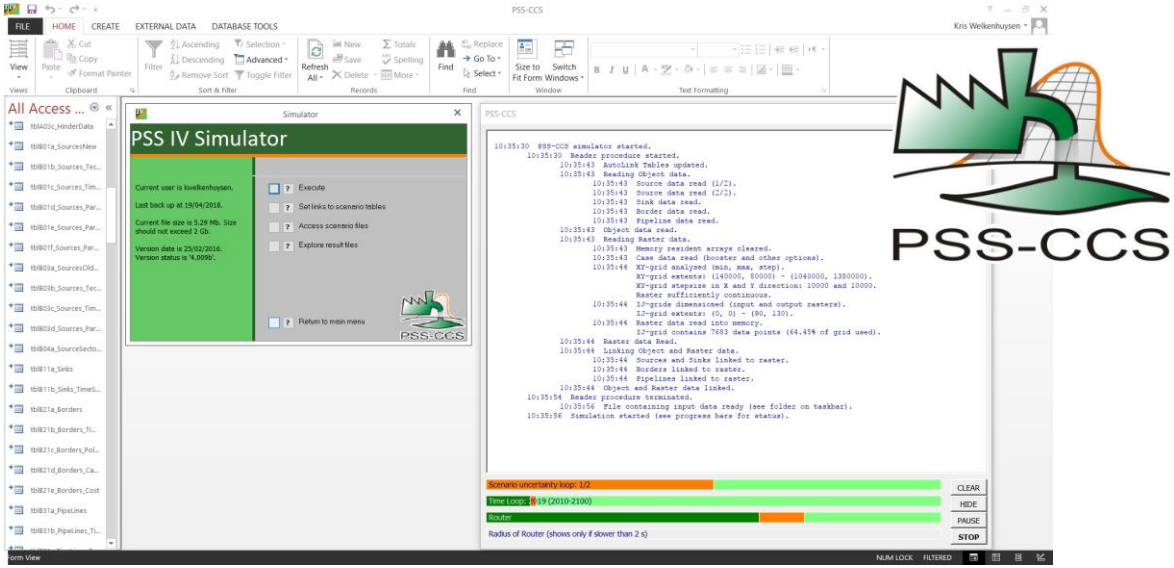
Techno-economic simulation/forecasting *(our approach)*

- Provide technological **options** and economic scenarios to a **decision** framework
- Consider technological, economic and reservoir **uncertainties**
- Project flexibility to balance uncertainty
- **Non-deterministic** simulation
- Simulating investment decisions under uncertainty

Result: Predict the likelihood a goal is reached given circumstances

PSS, the Policy Support System

- RBINS-GSB **in-house built** MS Access & VBA-based software
- **Geo-techno-economic forecasting** simulator for CO_2 storage
- **Monte Carlo**-based uncertainty approach
- Simulating **investment decisions** through time
- True **limited foresight**: decisions based on limited data
- Result: forecast how projects will evolve (**no optimisation**)
- Typical simulation takes 1 week of 10-20 parallel processes



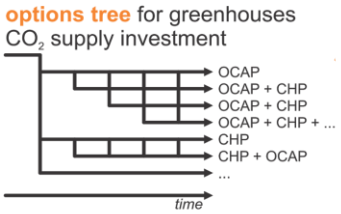
PSS, the Policy Support System

- CO_2 supply options
- Reservoir simulator
- Exploration & exploitation options (cost & operational data)
- Economic & policy scenario
- Pipeline cost grids
- Pipeline routing

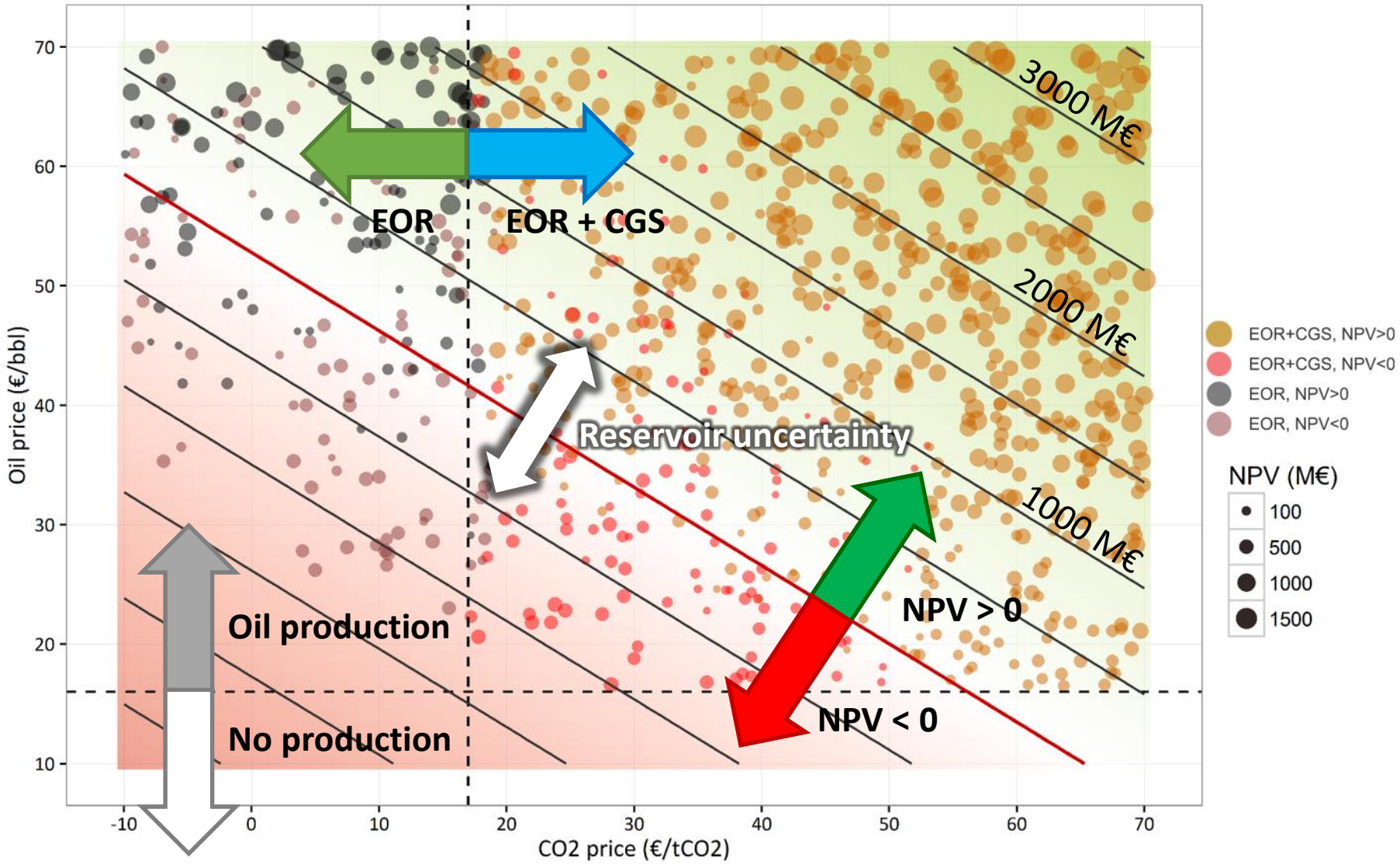
Economic decision making under uncertainty

1. **Options tree**: calculate every branch in Monte Carlo
2. **Only keep best branch** for every Monte Carlo
3. **Group** for next year's decision
4. **Calculate** return (average) and risk (variance)

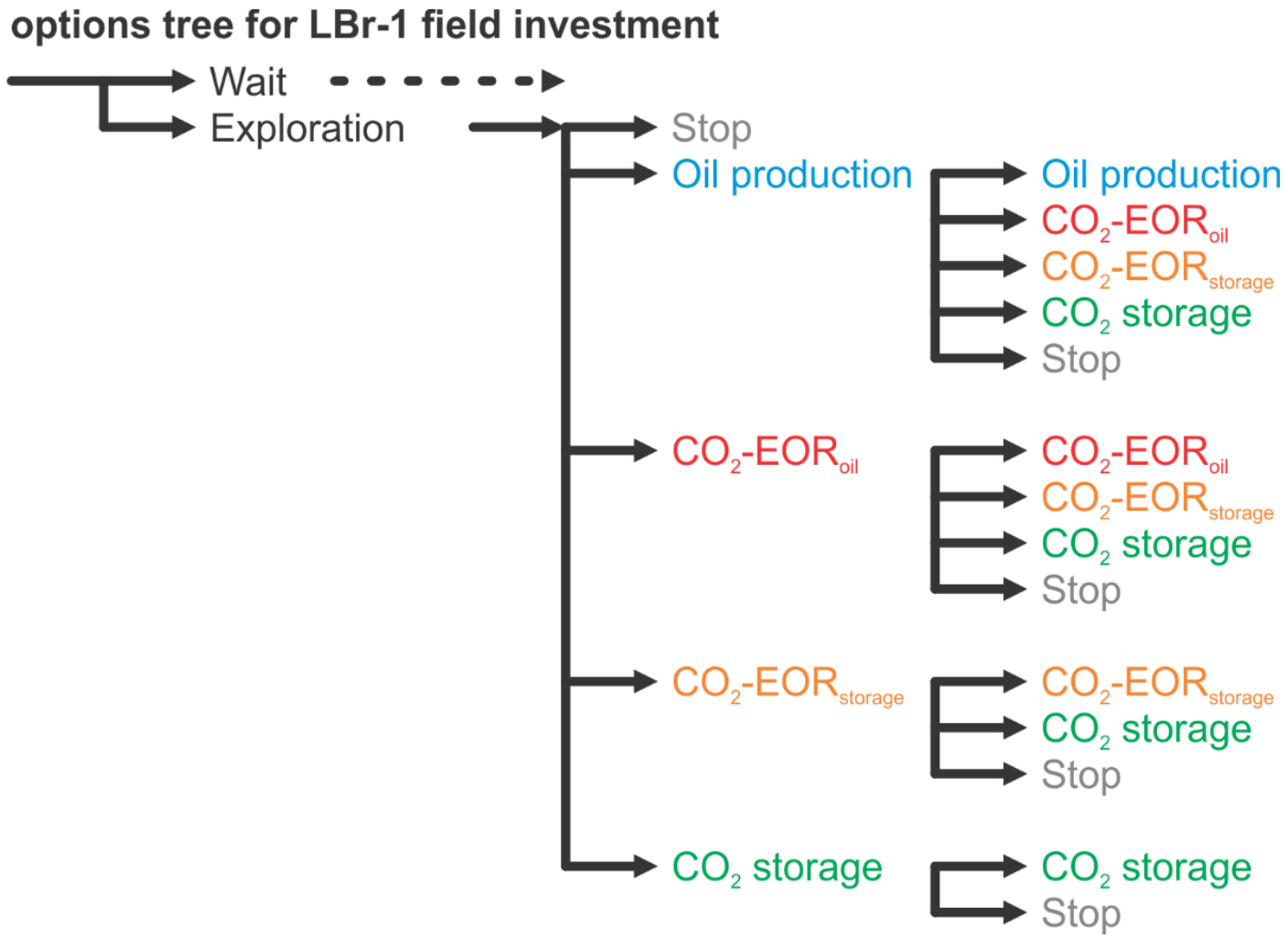
Repeat for next year
Repeat in Monte Carlo



PSS, the Policy Support System



LBr-1 options



LBr-1 options

Problem:

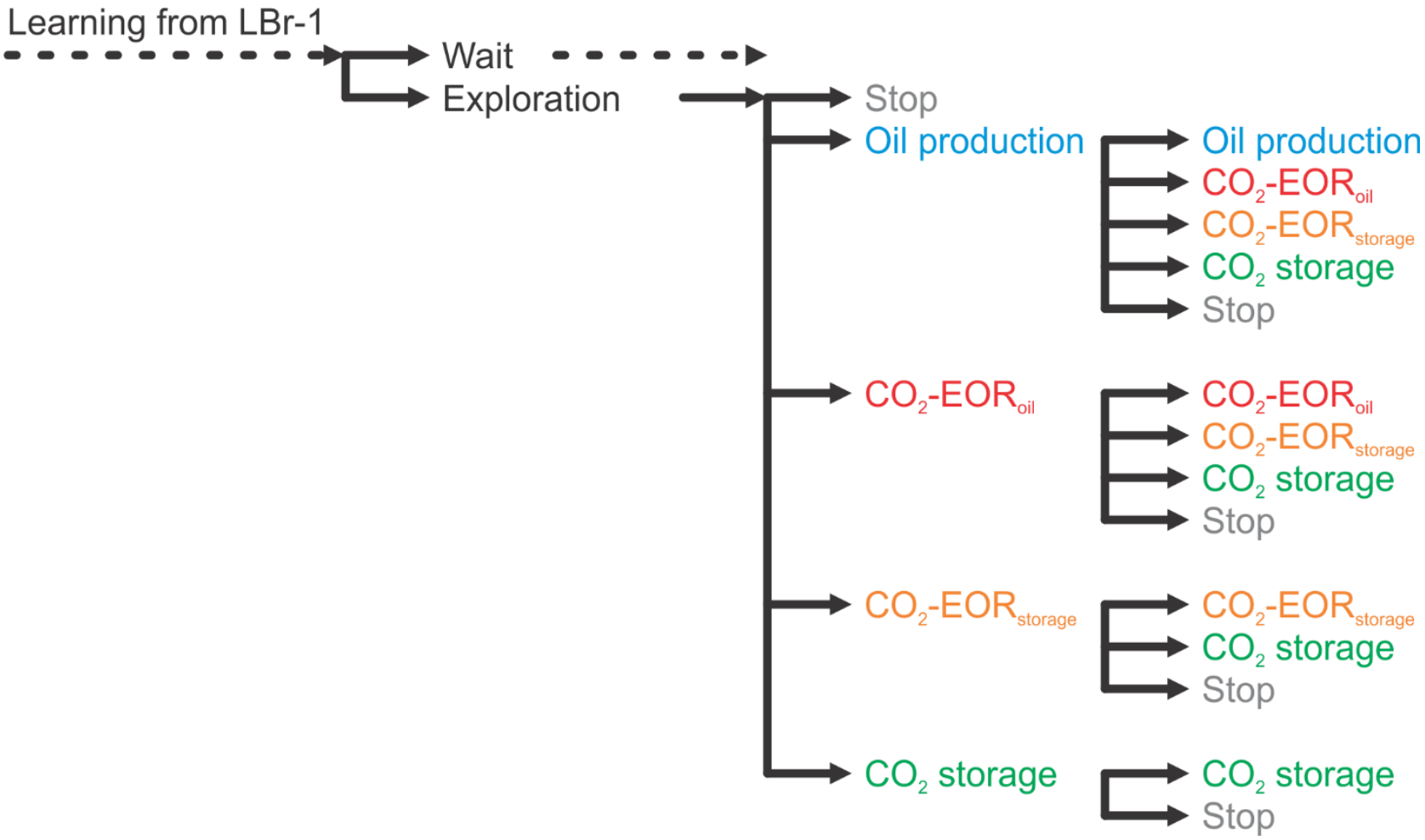
- LBr-1 as pilot project is most likely not economically viable.
- How to simulate project decisions of a non-economically viable project?

Solution:

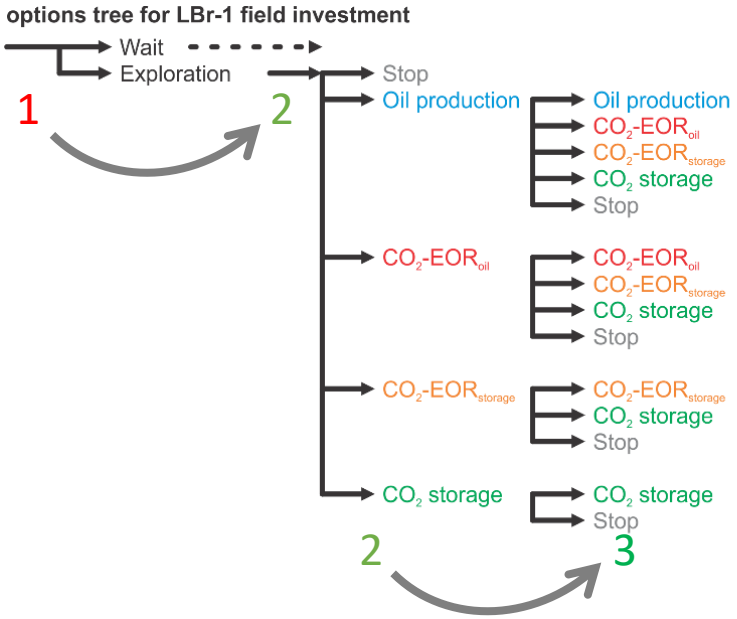
- Simulate LBr-1 ***as a pilot***: reduction of uncertainty for a scale-up of larger projects.
- Possible to determine the value of LBr-1 as a pilot project to the further development of CO_2 storage in the region.

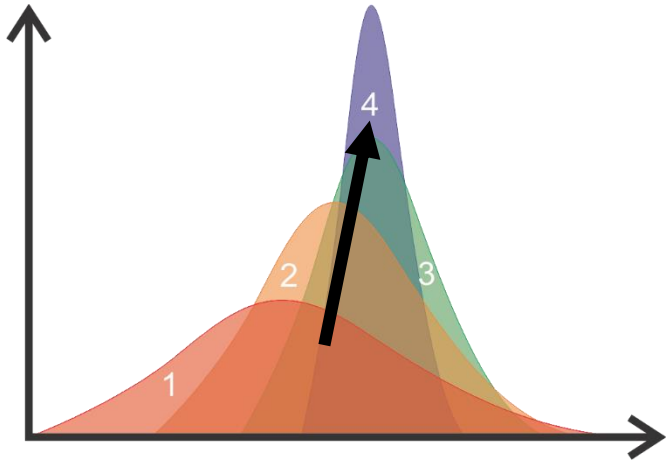
Cluster options

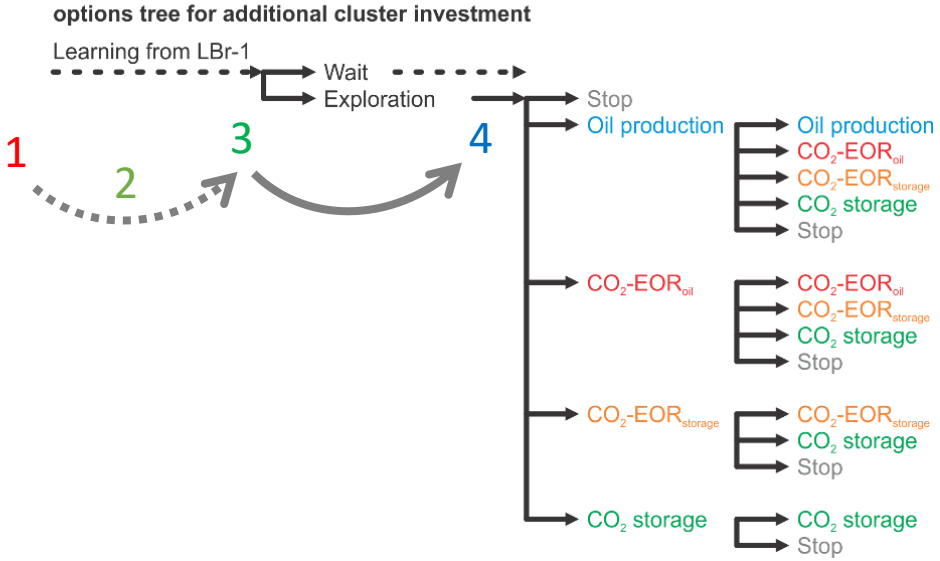
options tree for additional cluster investment



Learning

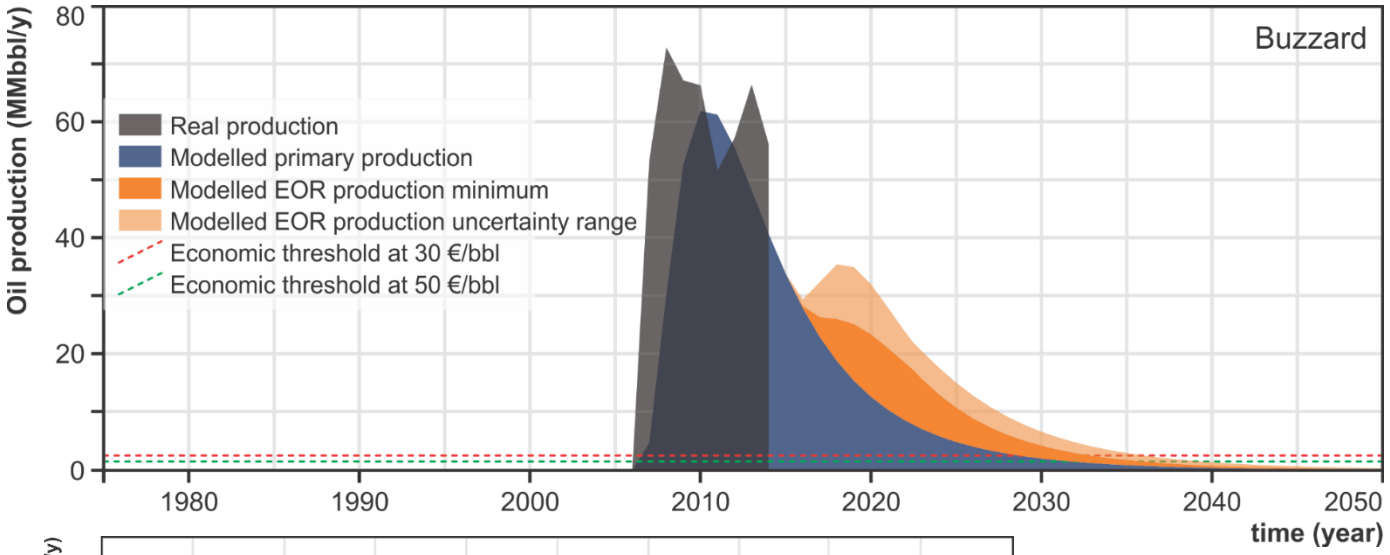

options tree for LBr-1 field investment
Wait
Exploration
Stop
Oil production
CO_2-EOR$_{oil}$
CO_2-EOR$_{storage}$
CO_2 storage
Stop
1
2
3


1
2
3
4

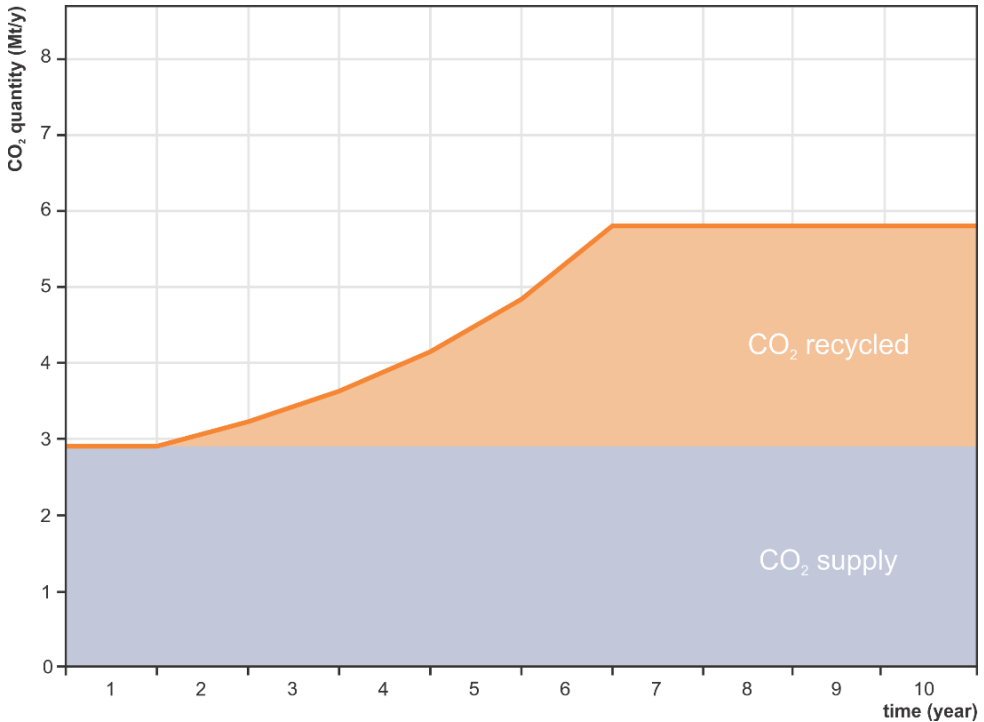

options tree for additional cluster investment
Learning from LBr-1
Wait
Exploration
Stop
Oil production
CO_2-EOR$_{oil}$
CO_2-EOR$_{storage}$
CO_2 storage
Stop
1
2
3
4

Reservoir simulation 1.0

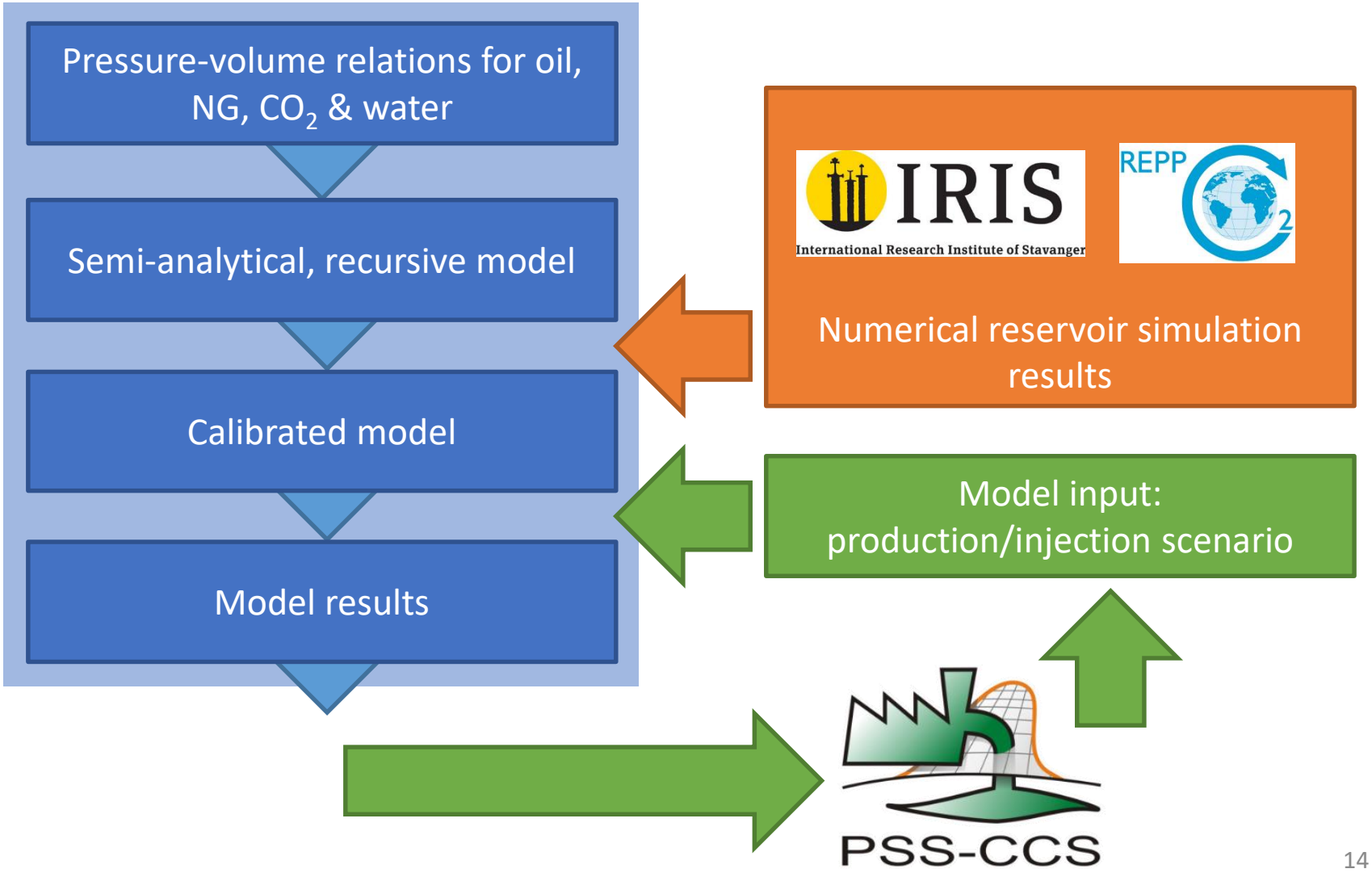
Oil production



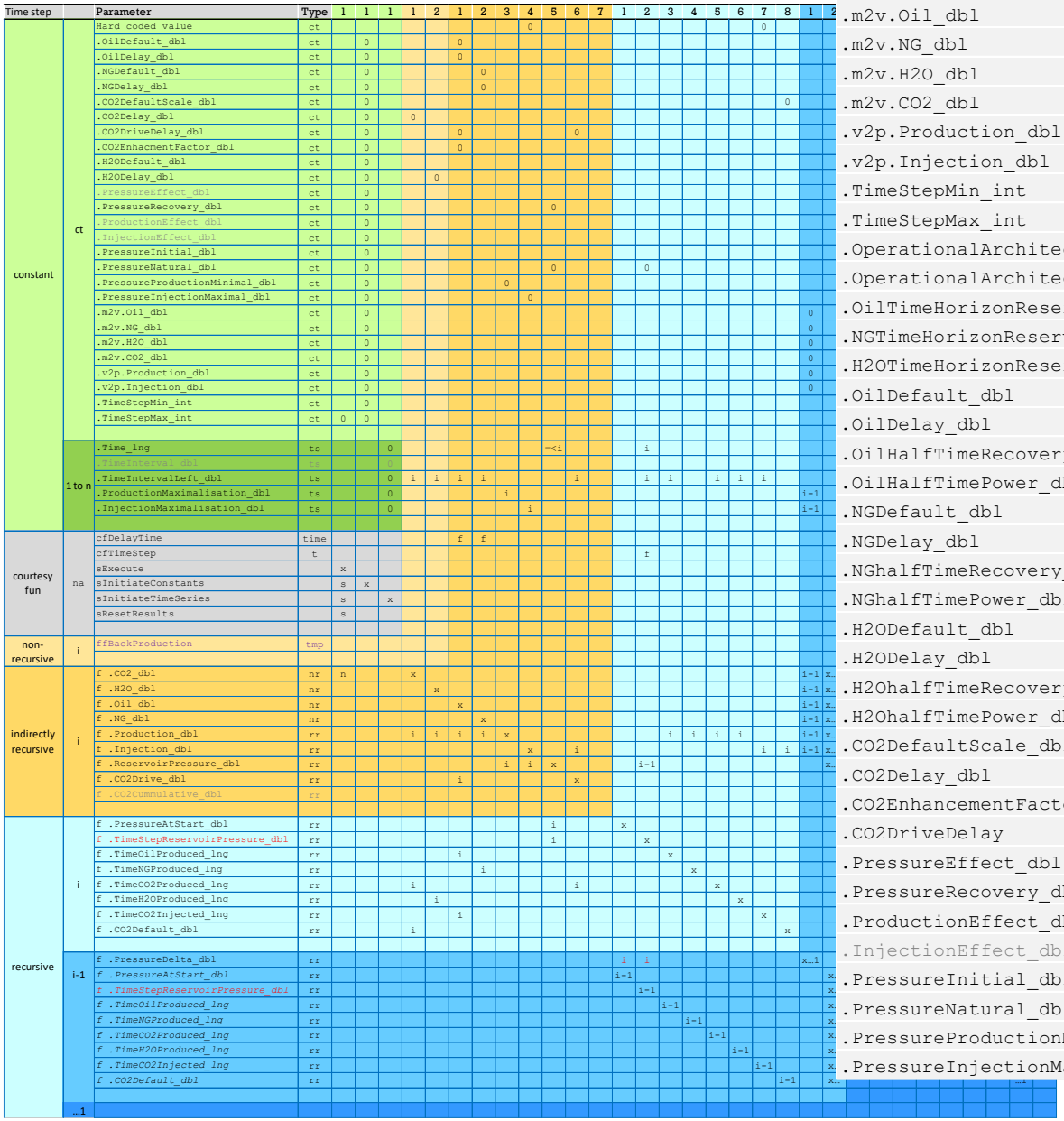
CO_2 injection & production



Reservoir simulation 2.0

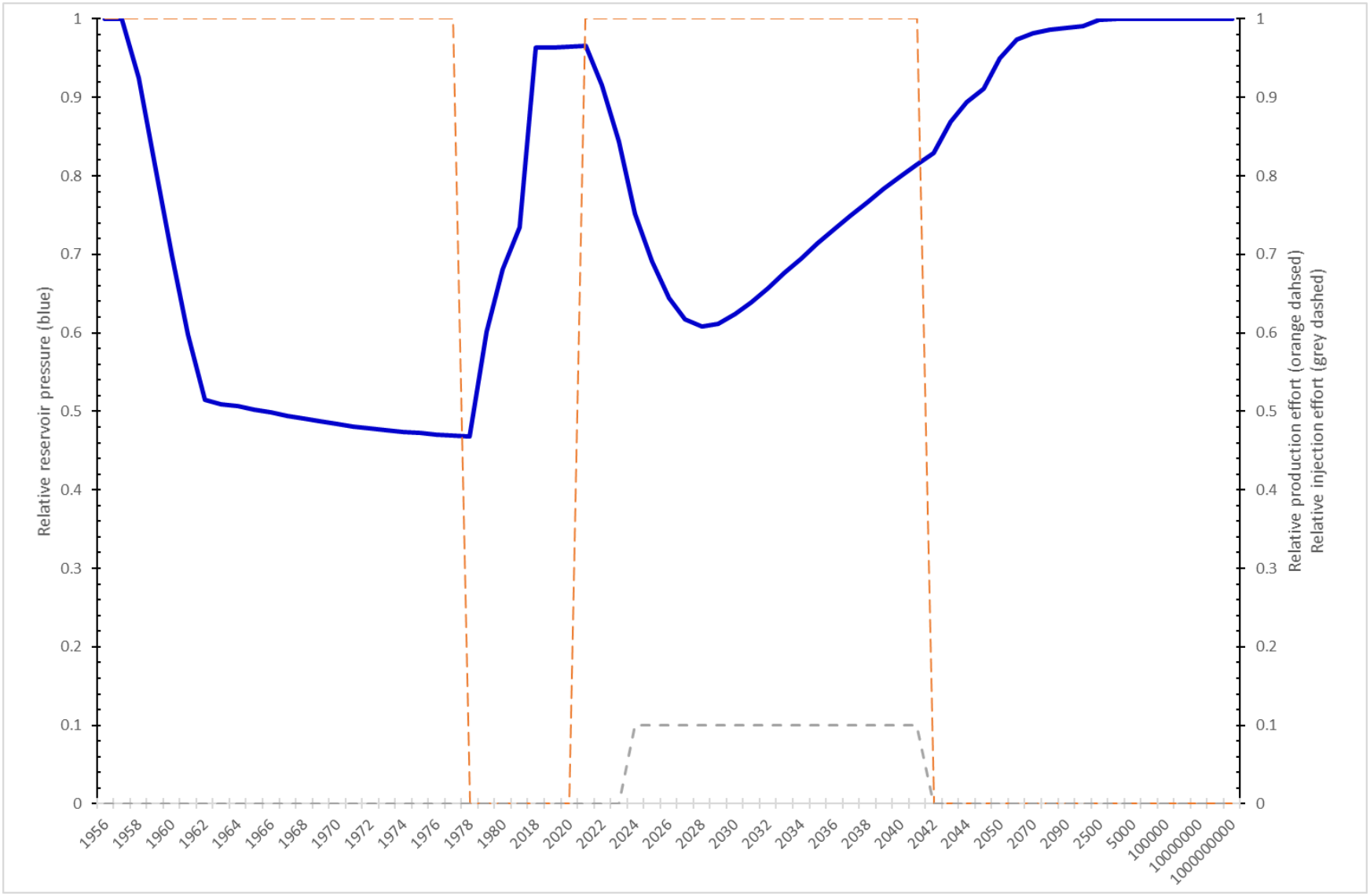


PSS mimic: parameters, functions and relations

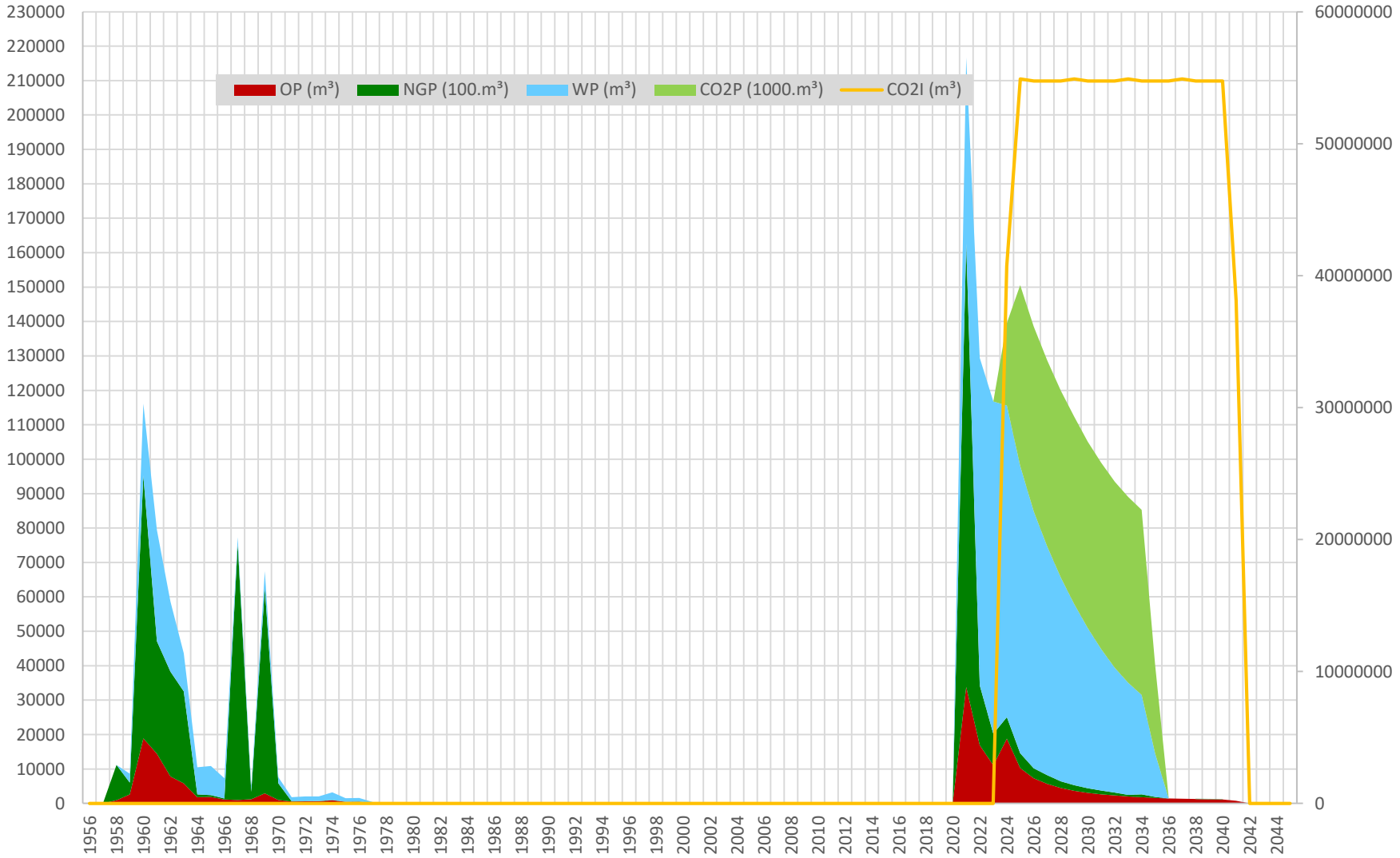


Parameter		Reservoi	
	ct	1	2
.m2v.Oil_dbl	1	1	
.m2v.NG_dbl	1	1	
.m2v.H2O_dbl	1	1	
.m2v.CO2_dbl	1	1	
.v2p.Production_dbl	1	1	
.v2p.Injection_dbl	1	1	
.TimeStepMin_int	1		
.TimeStepMax_int	105		
.OperationalArchitectureMin_int	1		
.OperationalArchitectureMax_int	2		
.OilTimeHorizonReservesYears_lng	50 (2056)	50	
.NGTimeHorizonReservesYears_lng	100 (2056)		
.H2OTimeHorizonReservesYears_lng	100 (2056)		
.OilDefault_dbl	30	30	1300
.OilDelay_dbl	5	5	4
.OilHalfTimeRecovery_dbl	40		40
.OilHalfTimePower_dbl	4		20
.NGDefault_dbl	750	750	30000
.NGDelay_dbl	5	5	2
.NGhalfTimeRecovery_dbl	40		
.NGhalfTimePower_dbl	4		50
.H2ODefault_dbl	1000	1000	70000
.H2ODelay_dbl	5	5	0
.H2OhalfTimeRecovery_dbl	40		10
.H2OhalfTimePower_dbl	4		1
.CO2DefaultScale_dbl	1		500000
.CO2Delay_dbl	2		0
.CO2EnhancementFactor_dbl	800000		6000
.CO2DriveDelay	1		
.PressureEffect_dbl	1		
.PressureRecovery_dbl	1	1	1
.ProductionEffect_dbl	0.001	0.001	0.001
.InjectionEffect_dbl	0.5		
.PressureInitial_dbl	1		
.PressureNatural_dbl	1		
.PressureProductionMinimal_dbl	0.01		
.PressureInjectionMaximal_dbl	1.35		

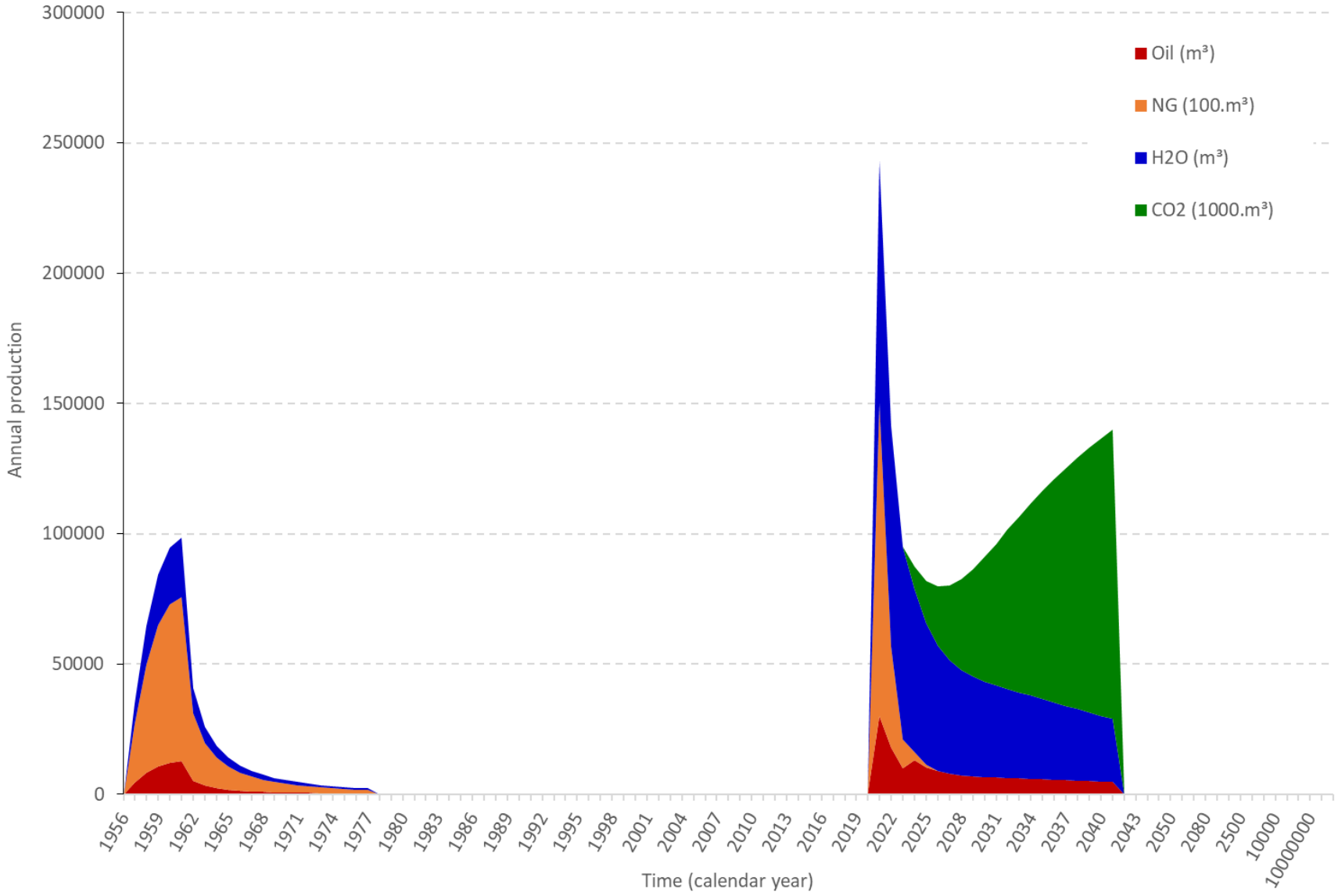
Reservoir pressure over 10^9 years



REPP-CO2 LBr-1 simulation

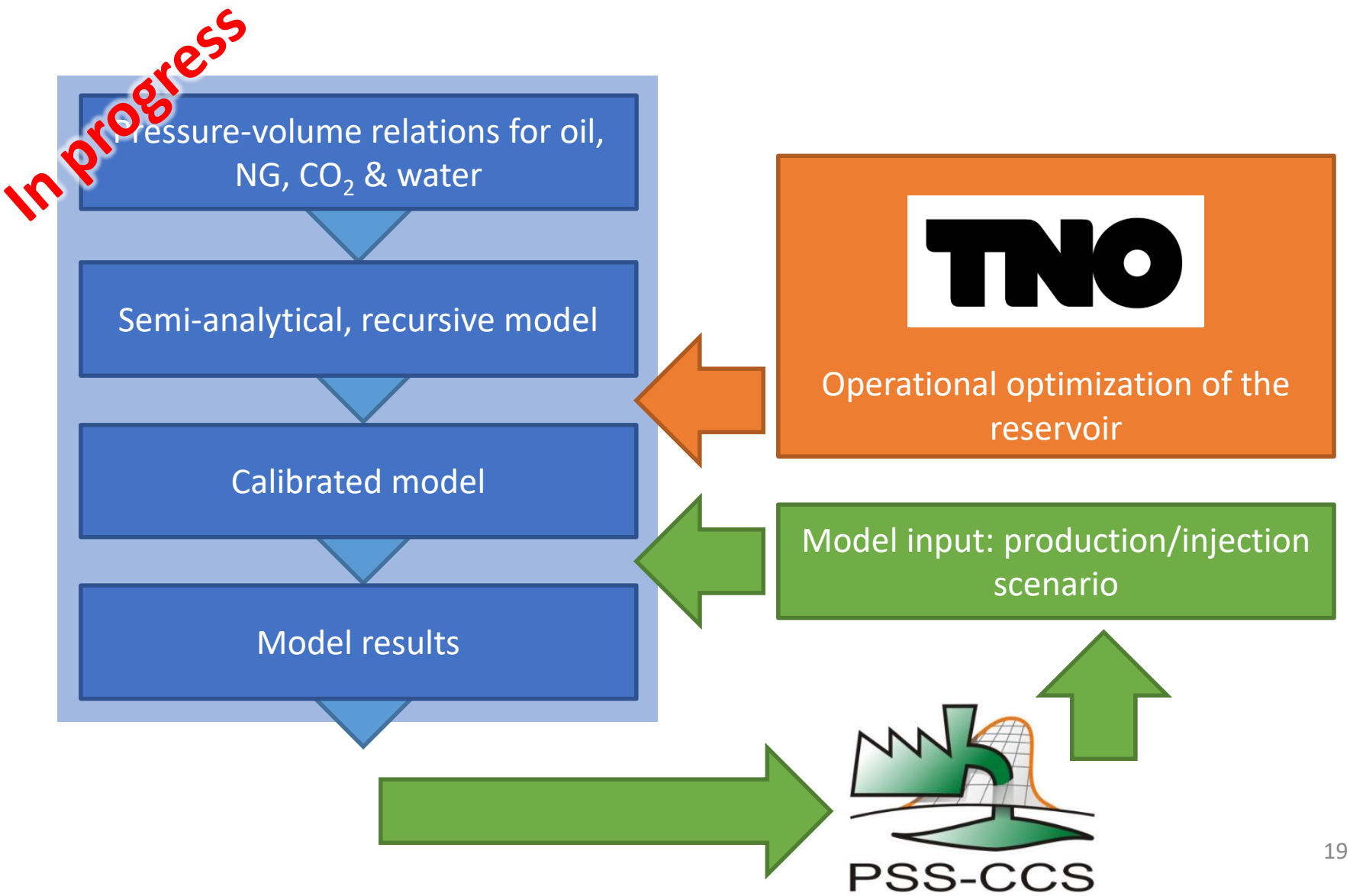


PSS mimic simulation



Reservoir simulation 3.0

More physical model - Machine learning- Switch programming environment

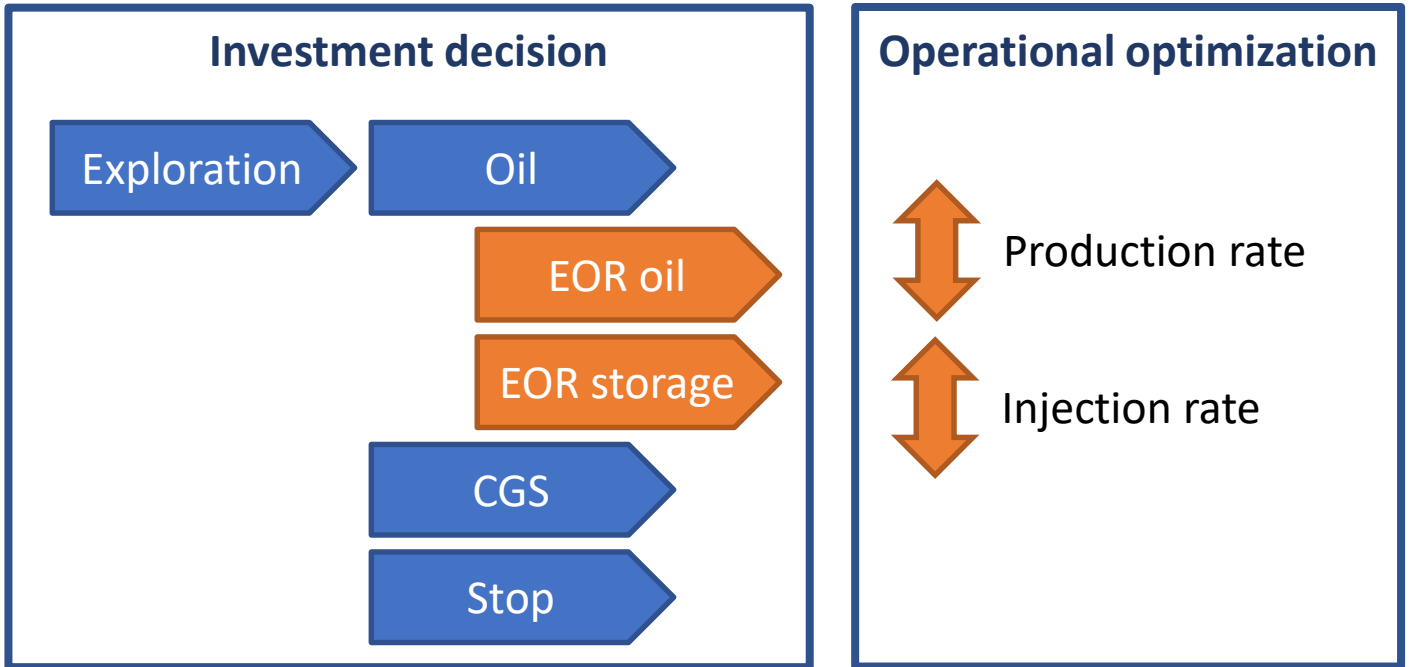


Reservoir simulation 3.0

Input: TNO reservoir operation/economic optimization with high time and space resolution: individual well on/off switching

Integration in PSS yearly decision making:

1. Make investment decision (EOR, CGS, Stop...)
2. If EOR: make yearly operational optimisation for production and injection rate



To do

Near future

- Finish development of PSS simulator for LBr-1
- Implement operational optimisation
- Development of final PSS mimic

“Far” future

- Calibrate PSS mimic with TNO reservoir optimisation
- Implement reservoir learning
- Determine (economic) scenarios

- Run simulations, interpret & compare results

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PSS: Simulating limited foresight