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Reservoir Engineering

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SPE Seminar – Introduction to E&P
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Star Energy

Outline

1 Fundamentals of Reservoir Management

2 Reserves & Resources

3 Pathway to Net Zero World

4 Conclusion – Q&A

O&G Field Life Cycle

Exploration
- Seismic
- Regional Geoscience
- Drilling

Appraisal
- Drilling and Testing
- Investment Decision

Development
- Drilling
- Construction
- Production Facilities

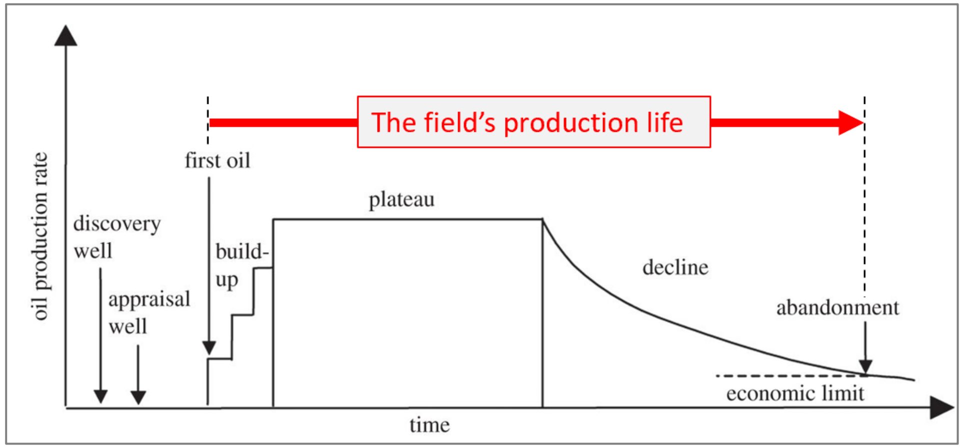
Production
- Flow Wells
- Sell Hydrocarbons
- Return on Investment

Abandonment
- Remove and Restore

- Reservoir engineers are involved throughout, from exploration to abandonment.
- After a discovery is made and appraised, **Development planning starts**:
  - ➢ Number of wells, type of production facilities, production forecasts and reserves
  - ➢ Data acquisition plan (for real-time reservoir monitoring)

Then production can start...

- Development plan may require updating
- Has each well flowed as expected?
- Do we need to optimise well performance?
- What can be done to enhance reservoir performance and prolong the field life?



Hook et al (2014)

Reservoir Engineering is the …

study of fluid flow in porous media.

Some applications are:

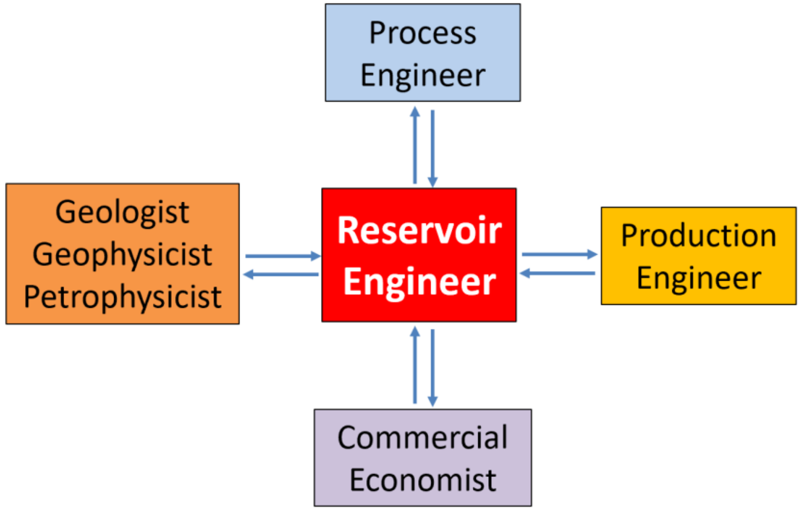
- Hydrocarbon production
- Geothermal energy
- Waste disposal – CO_2, chemicals etc
- Energy storage (Natural gas, Hydrogen etc)
- Groundwater use

The Pathway to Net Zero goes through Reservoir Engineering!

It focused on the primary source of value – the reservoir.

Reservoir Engineers

- We work very closely with the other disciplines to develop and manage reservoirs.
- Continuously **gather data**, build **digital twins of reservoirs** and **forecast** production.
- In essence, **reservoir engineers are the strategists** of sustainable resource management.
- Our expertise in **production forecasting is critical** to an E&P company's long-term success.



Rock & Fluid Properties

Do **rock and fluid properties** affect fluid flow?

Basic reservoir rock properties:

- **Porosity (%)** is the proportion of void space in rock that might contain fluids
- **Permeability (k)** is a measure of a rock's ability for fluid to flow

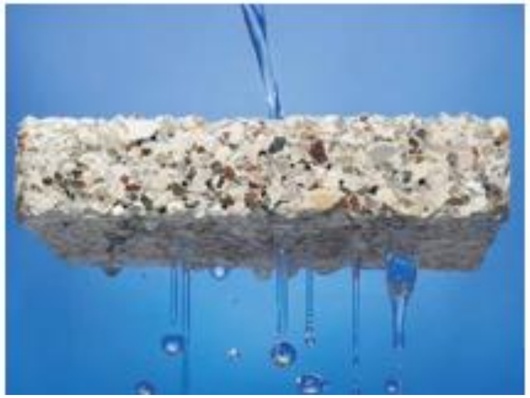
Basic reservoir fluid properties:

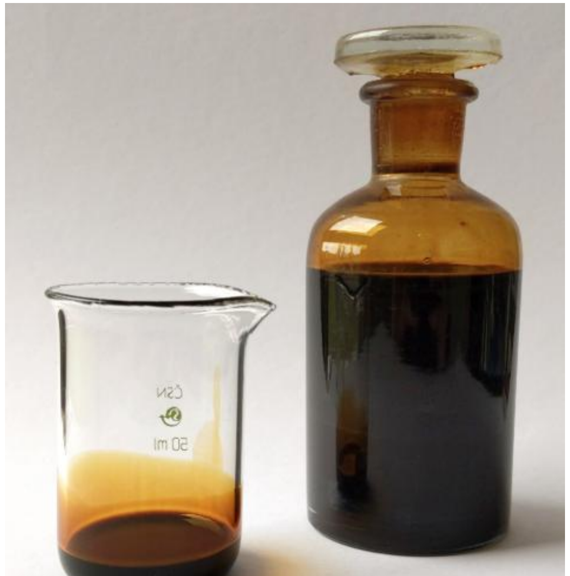
- **Viscosity (μ) -** resistance to flow
- **Expansion Factor -** surface volume compared to volume in the reservoir
- **Fluid Density –** how heavy for a given volume

Fluid properties change over time:

- Pressure can be **>15,000 psi** i.e. 1,000x atmospheric pressure!
- Temperature can be **>300 degF**

Porous Rock





Crude Oil

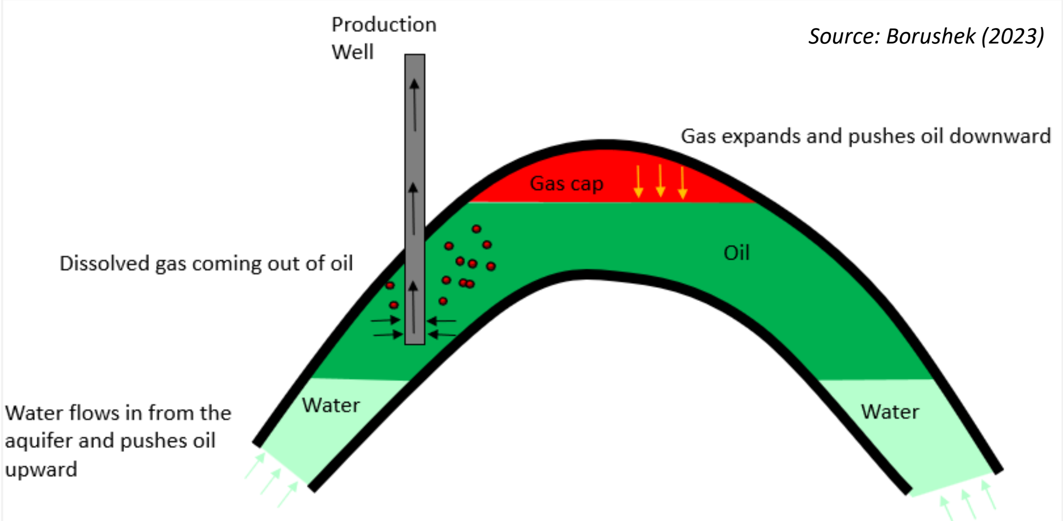
Reservoir Drive Mechanism

- Energy that transports hydrocarbons from a reservoir to a well.
- Different in every field and rely on the oil, gas, aquifer, pressures and geometry.

Primary Drive

The first stage of production when recovery is due to the natural energy in the reservoir:

- Gas cap expansion
- Water influx
- Solution gas drive
- Gravity drainage
- Combination drive



A cross-section through a reservoir showing the gas cap, oil, water and one well

Recovery Factor

Proportion of the initial hydrocarbon volumes that we can recover.

It depends on the drive mechanisms, rock & fluid properties, etc

For primary drives, it is typically between 10-20%.

How could more be recovered?

Secondary Drive

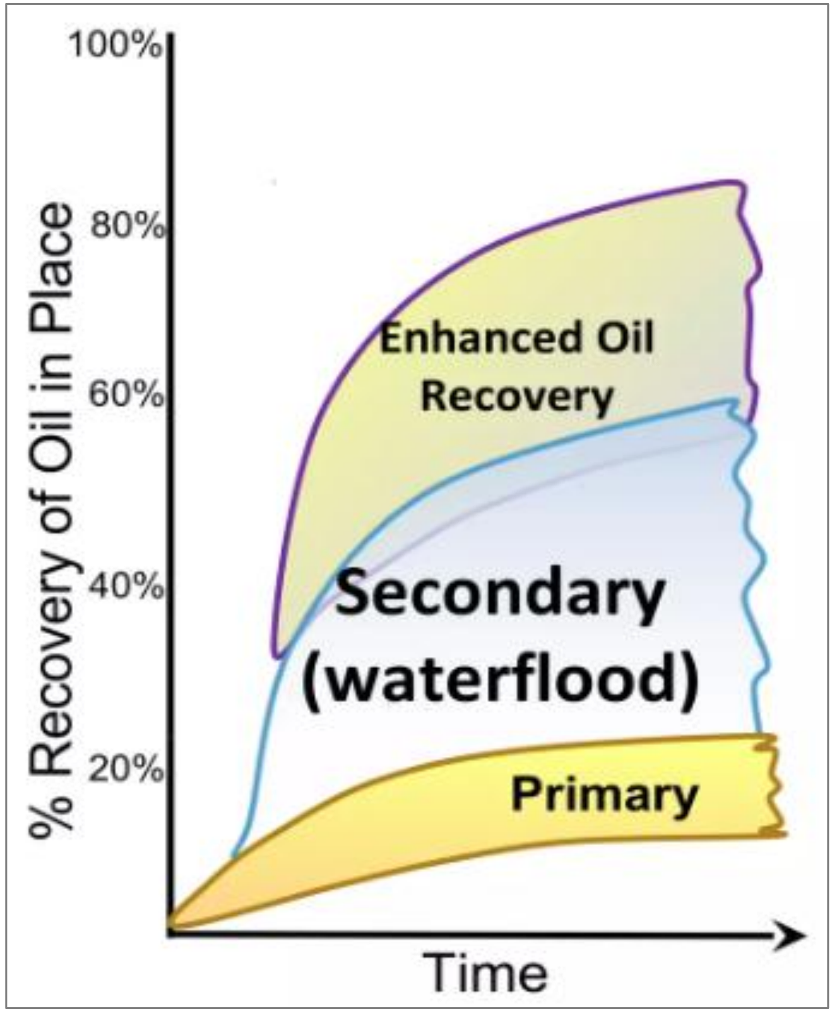
Water and/or gas can be injected into a reservoir.

- To re-energise it and mobilise more oil.
- In water drive reservoirs, 40% can be achieved.

Enhanced Oil Recovery (EOR)

- CO_2 or chemicals can be injected to enhance it by an additional 20% but it may be costly

However, not all oil & gas in a reservoir can be produced!



Reserves and Resources

What are Reserves?

Resources are **all quantities** of hydrocarbon, whether discovered or undiscovered, recoverable or unrecoverable, conventional or unconventional.

Reserves are subsets of resources.

The main tangible asset of an E&P company!

It is required for financial reporting, asset valuation, investment decision-making, government policy etc.

Four criteria that must be satisfied:

- **Discovered -** not exploration
- **Recoverable -** the oil or gas can be produced
- **Commercial -** economically attractive, with all approvals granted by decision-makers and regulators
- **Remaining -** excludes volumes already produced

Contingent Resources

Definition: Quantities of petroleum estimated, as of a given date, to be potentially recoverable from **known accumulations** by the application of development project(s) **not currently considered to be commercial** owing to one or more **contingencies** *(PRMS 1.1.0.6)*.

What are the Contingencies?

- Market access e.g. A stranded gas field
- Economic e.g. A deepwater field with high capital costs making development uneconomic
- Commitment to development – A reasonable timeframe (usually 5 years) applies.
- It could be political, legal, social or regulatory issues etc

Reclassification - They can become reserves when the contingencies are resolved.

We often **assess** that to gauge the likelihood of commerciality:

- Chance of Commerciality = Chance of Discovery multiplied by Chance of Development
- Since there is a discovery, Chance of Commerciality = Chance of Development

Prospective Resources

These are exploration projects… before oil and gas discoveries are made.

Definition: Quantities of petroleum estimated, as of a given date, to be potentially recoverable from **undiscovered accumulations** by applying **future development projects** *(PRMS 1.1.0.6)*.

Reclassification - They can become Contingent Resources and possibly Reserves in the future after discovery and commerciality criteria are met.

Risk Assessment - But there is a chance that there may not be a discovery at all!

Example:
If a gas field has a Chance of Discovery of 50% and a Chance of Development of 20%,

then the Chance of Commerciality = 50% x 20% = 10%.

Estimation Methods

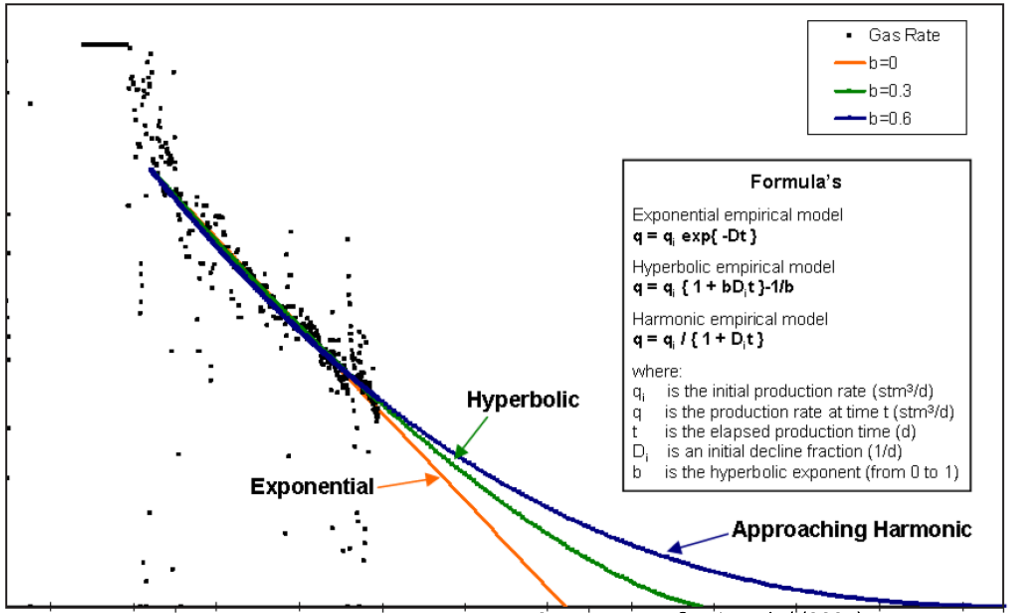
- Volumetric
- Analogues
- Performance Analysis
  - **Decline curve analysis (DCA)**
  - Rate transient analysis (RTA)
- Material balance analysis (MBAL)
- **Reservoir simulation**
  - Sector modelling
  - Full field modelling

Decline Curve Analysis

It requires a good understanding of the **main driver of reservoir behaviour**.

It is based on the **fundamental assumptions** that the drive mechanism and **future conditions will remain the same**.

Hence, it is **simple to use** and has widespread application.



Source: Dean & Mireault ((2007)

Reservoir Simulation

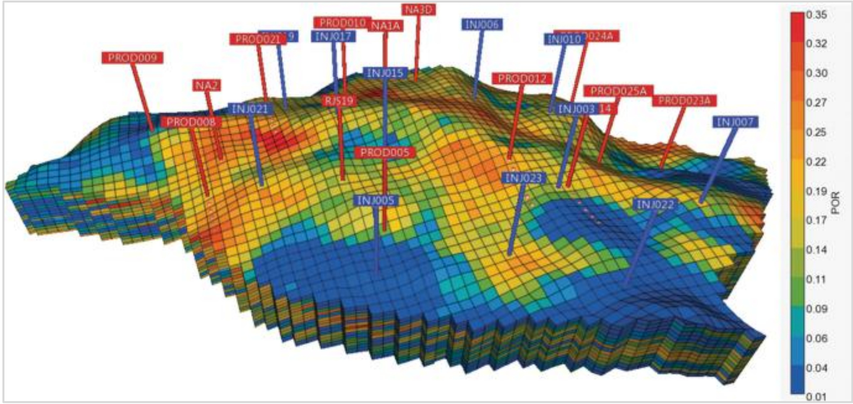
A critical tool for integrating all technical data to develop **digital twins of reservoirs**:

- Based on **geological/static model**
- All existing and planned wells are included.
- Conditioned to production and pressure data.
- Labour-intensive task but **a fun thing to do!**

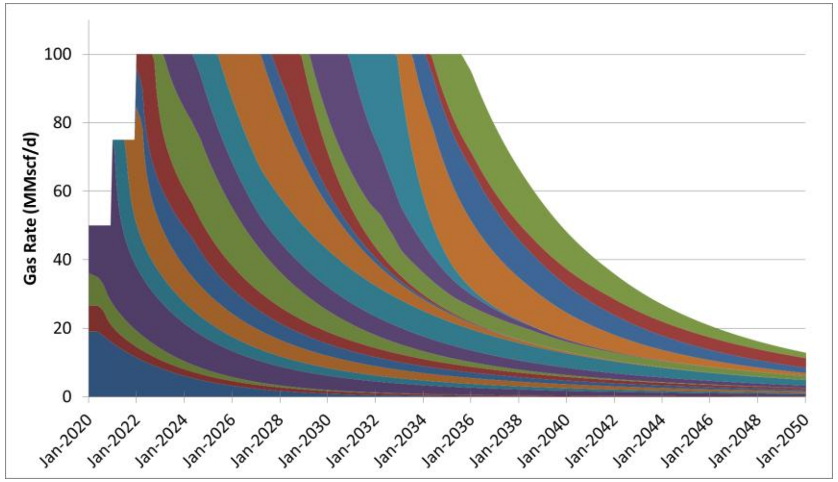
It allows **investigation of 'what if' scenarios,** well planning, secondary recovery etc.

Very useful for **reservoir management**

Remember **Garbage in garbage out (GIGO)!**



Source: Portella & De Souza (2023)



Source: Borushek (2023)

How Resources are Reported… PRMS Process

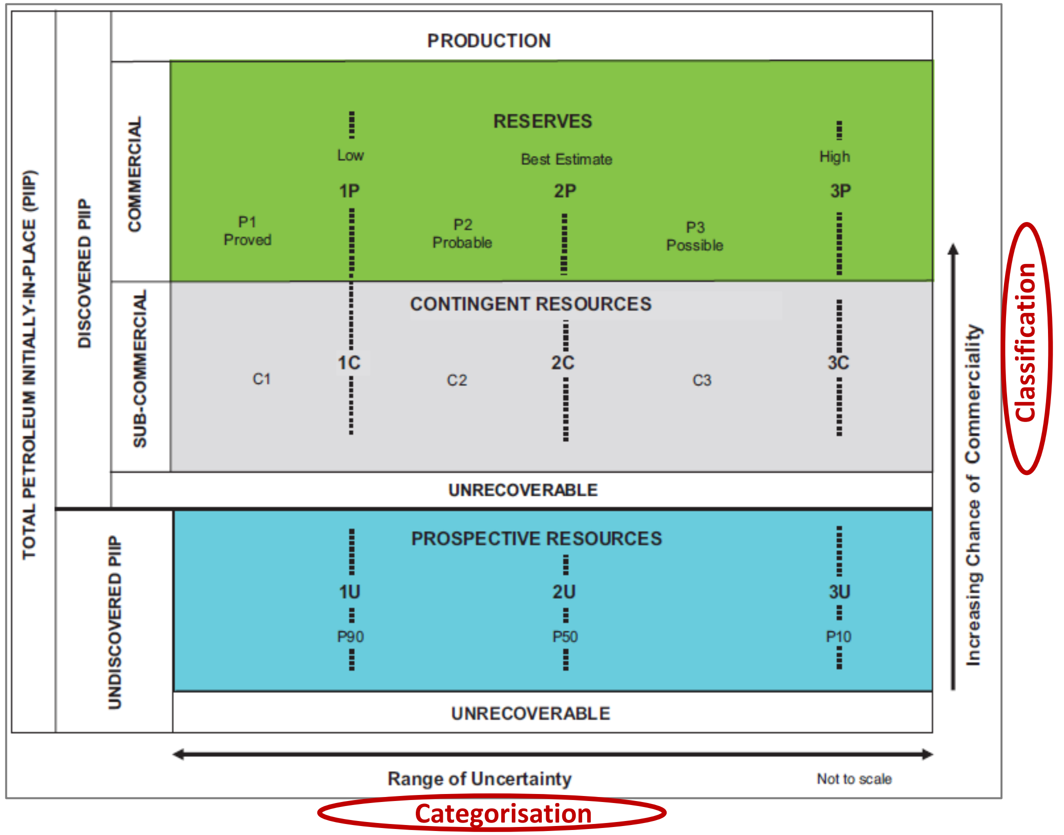
The **Petroleum Resources Management System** (PRMS) is a globally recognised standard developed for consistent and reliable estimation, classification, and reporting of hydrocarbon resources. Most UK-listed companies follow the guidelines, including banks.

The PRMS is "project-based" (with the associated maturity) and involves:

- Classification
- Categorisation

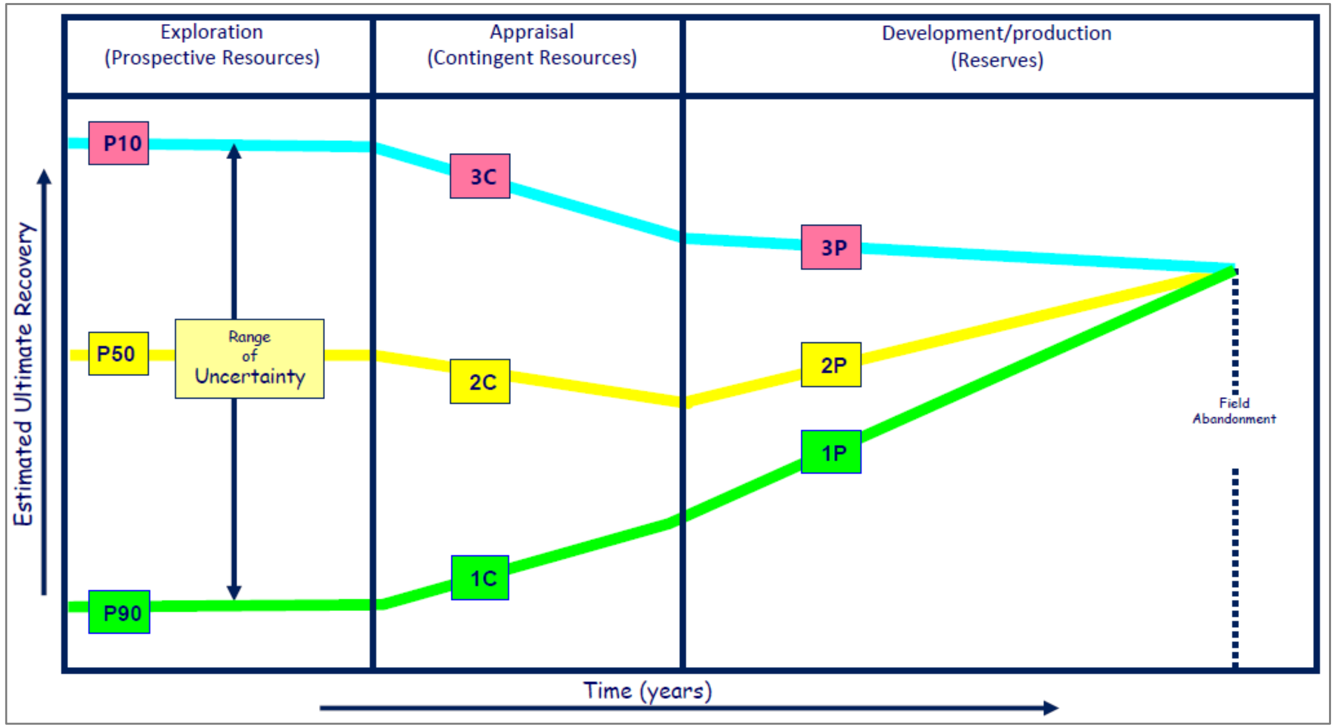
What is the project?

Committed investment(s) which can involve developing a single well, reservoir, or field to generate **a unique production and cash-flow schedule** at each level of certainty.



Managing Uncertainty

- Resources evolve with new information from exploration to production & abandonment.
- Uncertainty decreases but persists throughout field life. After production ends, reservoirs can be repurposed for CO_2 or energy storage.

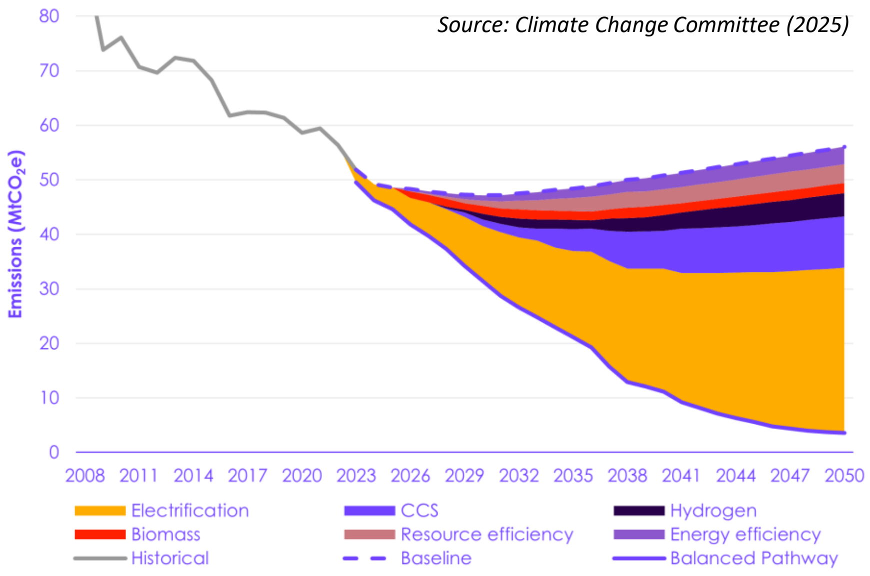


Source: Jankowski & Taylor (2018)

Reservoir Engineering for Net Zero

Pathway to Net-Zero

- Are reservoir engineers key enablers of net-zero?
- Pathway to net-zero includes subsurface fluid flow.
- Beyond **managing oil reserves**, they are playing critical roles in:
    - **Sequestering CO_2 -** up to 35Gt per year and could grow to a scale comparable to the oil and gas industry!
    - Harnessing **Geothermal energy** (heat) from underground fluids as a clean energy.
    - **Managing groundwater** stored in porous rocks to address global water demands.

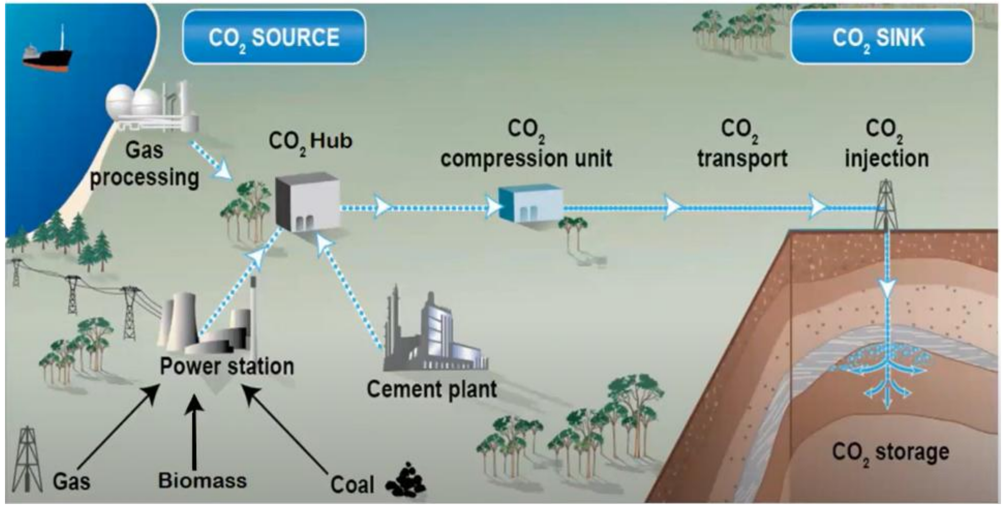


Could this be the sleeping giant of clean energy, waiting to revolutionise the energy transition industry?

CO_2 Sequestration & Gas Storage

To **permanently store** CO_2 in porous rocks, there are **three Key questions** for reservoir engineers:

- **Injectivity -** At what rates can it be injected?
  - Injection planning, testing and surveillance
- **Capacity -** What is the storage potential?
  - Estimate and report CO2 storage resources
- **Containment -** Can it escape after the injection?
  - Simulation modelling, lab work & seismic monitoring

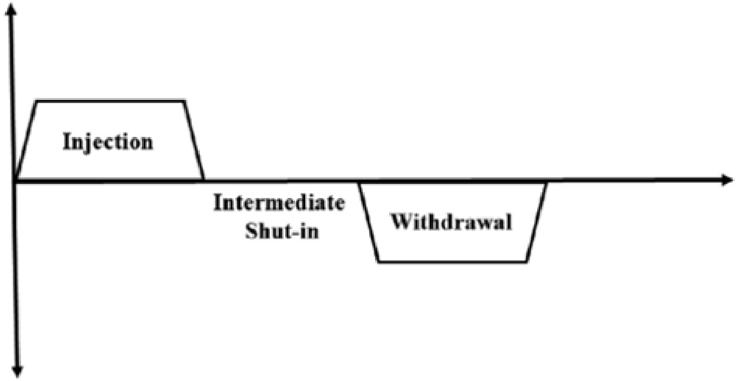


Source: Dixon (2024)

To **temporarily store energy** (e.g. natural gas), porous rocks are used for repeated cycles of injection and withdrawal.

Reservoir Engineers are tasked with:

- Building simulation models to predict reservoir behaviour under energy storage operations.
- Optimising reservoir performance and assessing risks.
- Overseeing reservoir monitoring and improving operational efficiency.



Unlocking Geothermal Energy

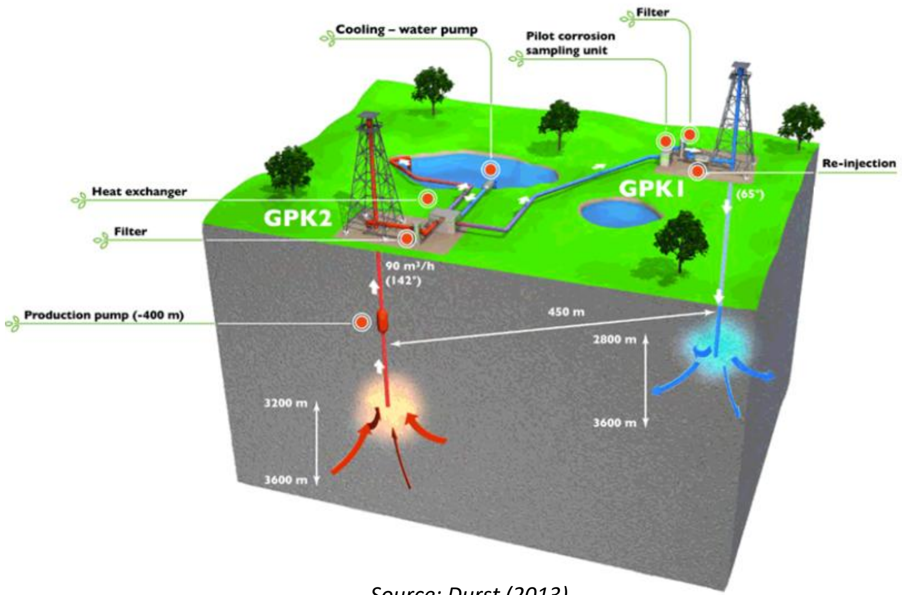
Heat from porous rocks (shallow & deep) to provide heating and cooling or generate electricity:

- **Low-enthalpy systems** (warm & hot water) are common
- More **complex than oil & gas reservoirs**
- Lower operating costs and stable energy production
- Can be **co-produced with oil & gas** to reduce costs

What do reservoir engineers contribute?

- Assess technical viability - flow rates and project life
- Conduct reservoir monitoring - to track fluid movement
- Design optimal water re-injection and drilling schedule
- Perform resource estimation and reporting

Category (system type)		Temperature (T) (°C)	Enthalpy (h) (kJ/kg)
Warm water (low temperature)		$T < 120$	$h < 504$
Hot water (intermediate temperature)		$120 < T < 220$	$h < 943$
Two phase, liquid dominated	Low enthalpy	$220 < T < 250$	$943 < h < 1100$
	Medium enthalpy	$250 < T < 300$	$1100 < h < 1500$
	High enthalpy	$250 < T < 330$	$1500 < h < 2600$
Two phase, vapour dominated		$220 < T < 300$	$2600 < h < 2800$



Source: Durst (2013)

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From hydrocarbon recovery to CO_2 storage and geothermal energy, we continue to manage the world's most valuable resource
- the reservoir.

The pathway to net zero runs through what reservoir engineers do.

Thank you.

Q & A

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