

DECIPHERING OPTIMAL CARBON DIOXIDE PLUME GEOTHERMAL (CPG) SYSTEMS

ANALOGIES FROM OIL AND GAS WELL DESIGN AND ENGINEERING

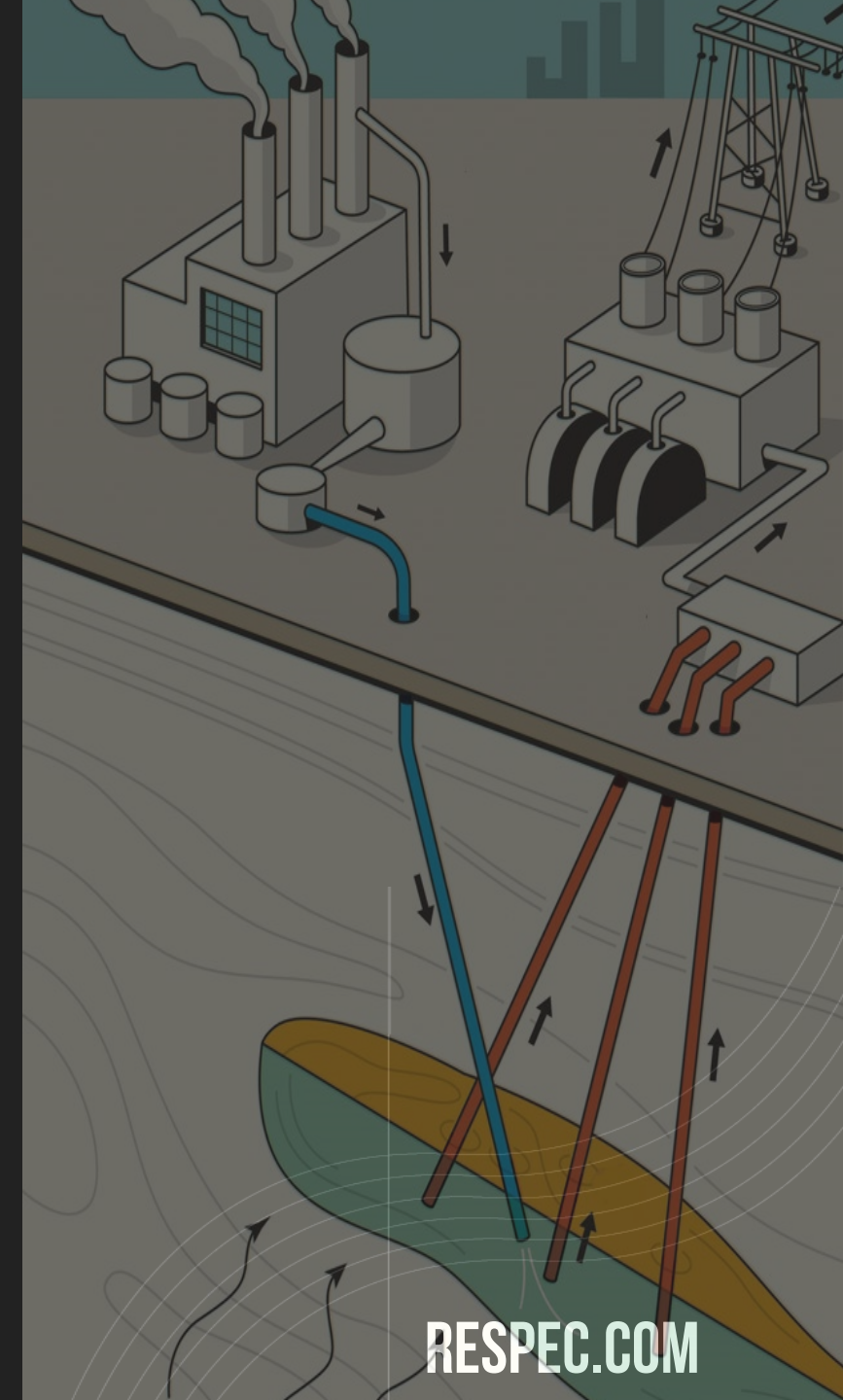


DEVIN HARSHAD, P.ENG

Drilling Engineer

Williston Basin Petroleum Conference, Regina SK

3rd May 2023



RESPEC.COM

PRESENTATION OUTLINE

- › **OUR NET ZERO GOALS**
- › **WHAT ARE CARBON DIOXIDE PLUME GEOTHERMAL (CPG) SYSTEMS?**
- › **THE CHALLENGES FACING CPG SYSTEMS**
- › **SOLUTIONS FROM OIL AND GAS ENGINEERING**



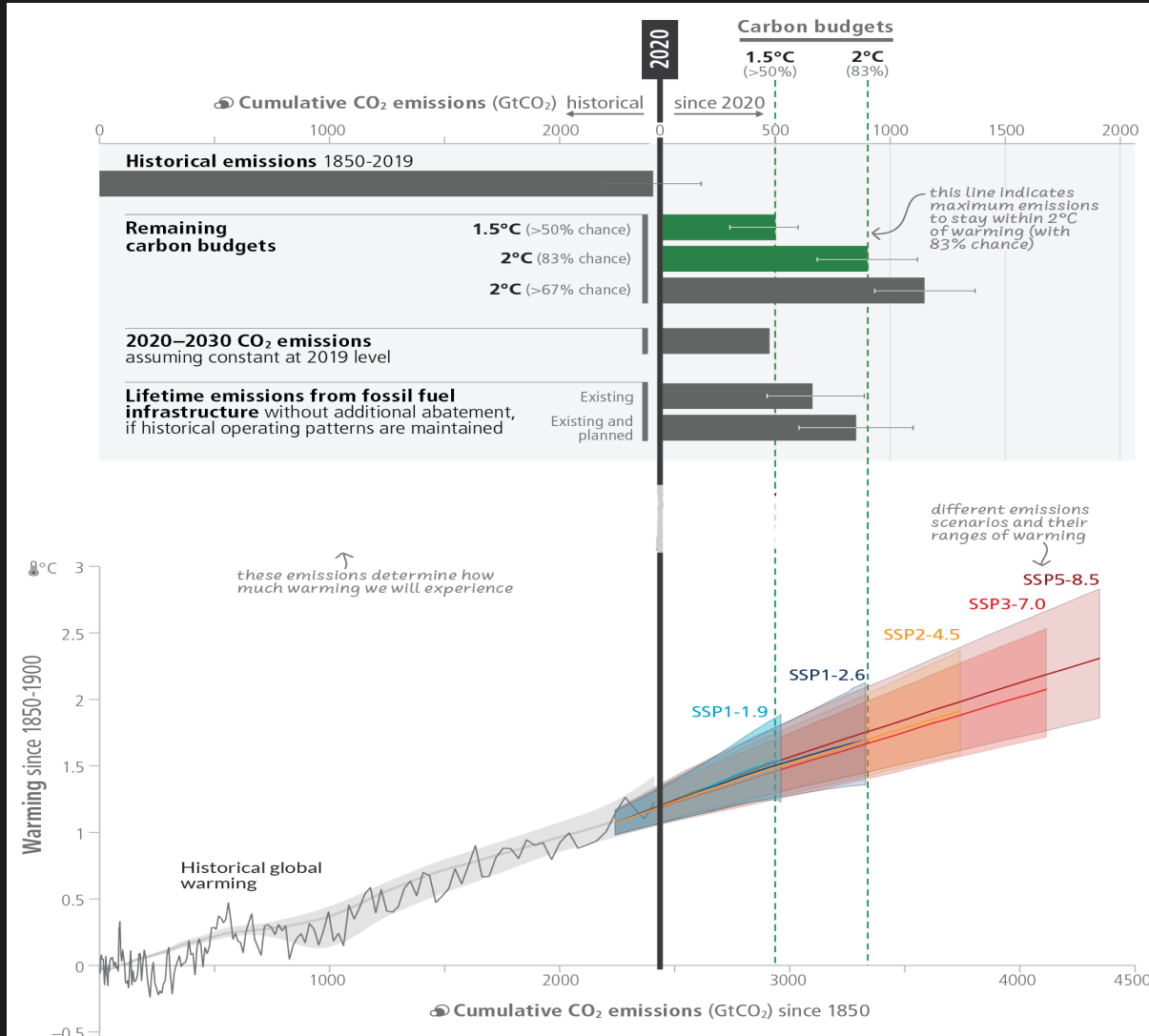
› **OUR NET ZERO GOALS**

› WHAT ARE CARBON DIOXIDE PLUME GEOTHERMAL (CPG) SYSTEMS?

› THE CHALLENGES FACING CPG SYSTEMS

› SOLUTIONS FROM OIL AND GAS ENGINEERING

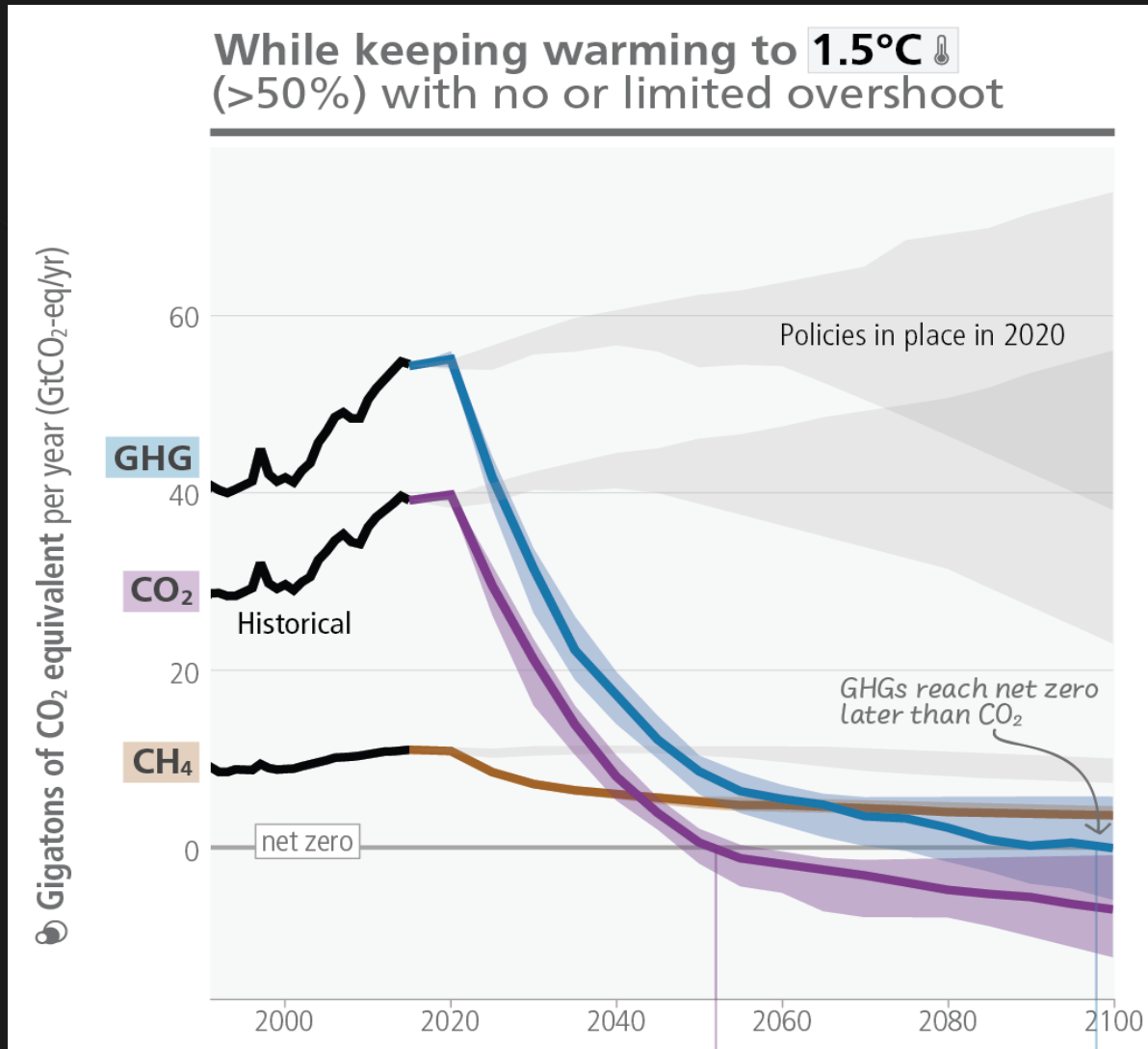
OUR NET ZERO GOALS



Source: Intergovernmental Panel on Climate Change (IPCC) 6th Assessment Report March 2023

- › Remaining carbon budgets to limit warming to 1.5°C by 2030 almost exhausted
- › Carbon budgets to limit warming 2°C to 2030 largely depleted
- › Every ton of CO₂ adds to global warming with various scenarios up to 2050

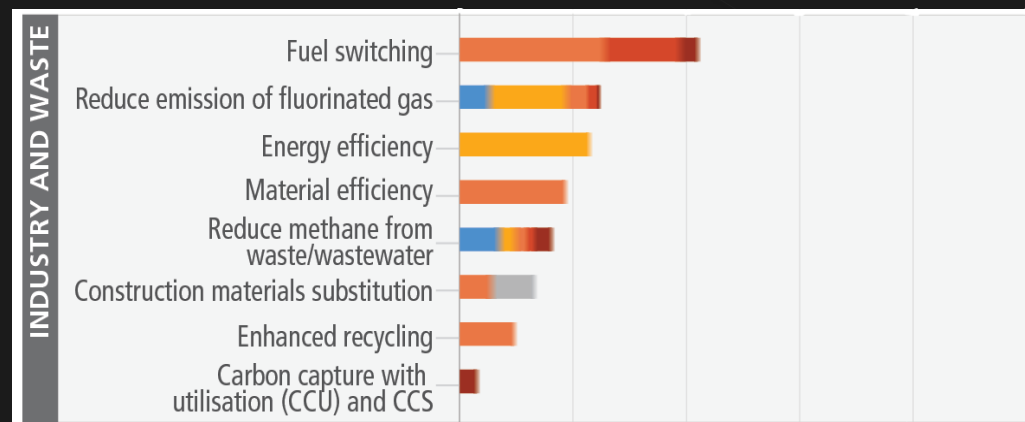
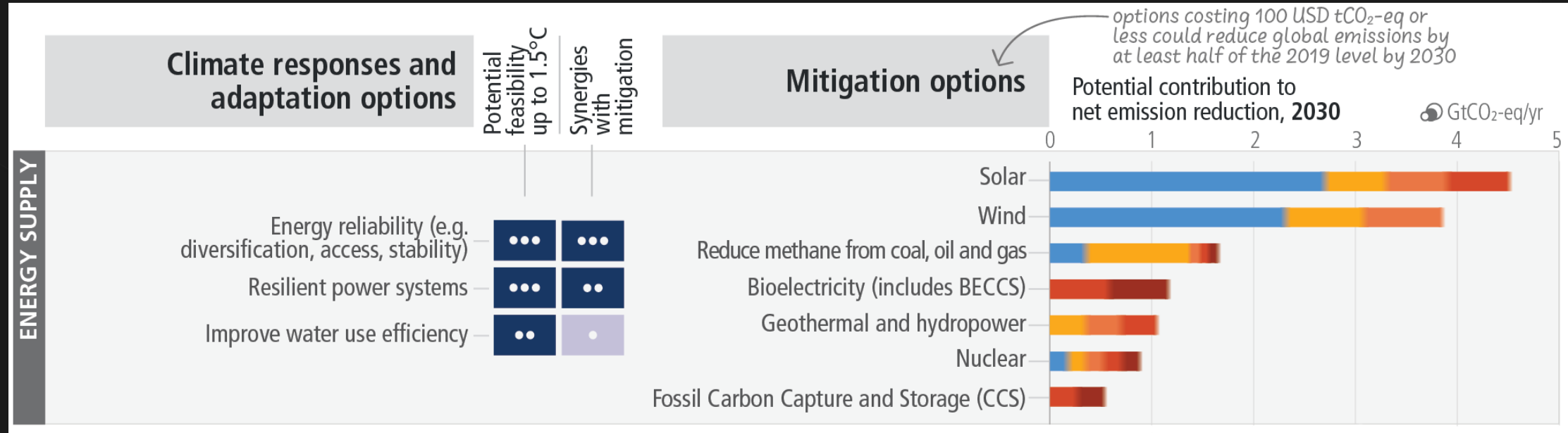
OUR NET ZERO GOALS



Source: Intergovernmental Panel on Climate Change (IPCC) 6th Assessment Report March 2023

- › There are modelled pathways that limit global warming to 1.5°C and net zero by 2050 (>50% chance) for CO₂ emissions.
- › A scenario with net negative CO₂ emissions is preferred
- › CO₂ removal is necessary to achieve net negative emissions along with durably stored removal of CO₂

OUR NET ZERO GOALS

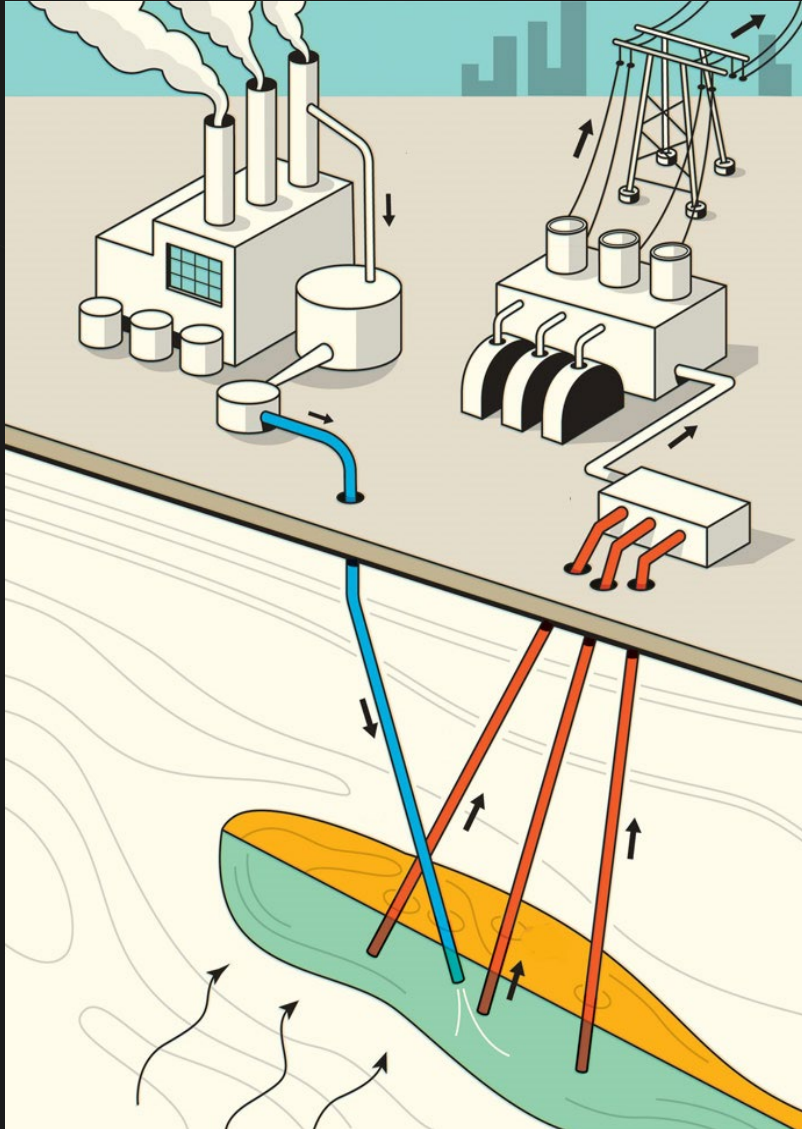


There are multiple mitigation and mitigation options with differing levels of feasibility, potential, confidence and net effects to achieving emission targets



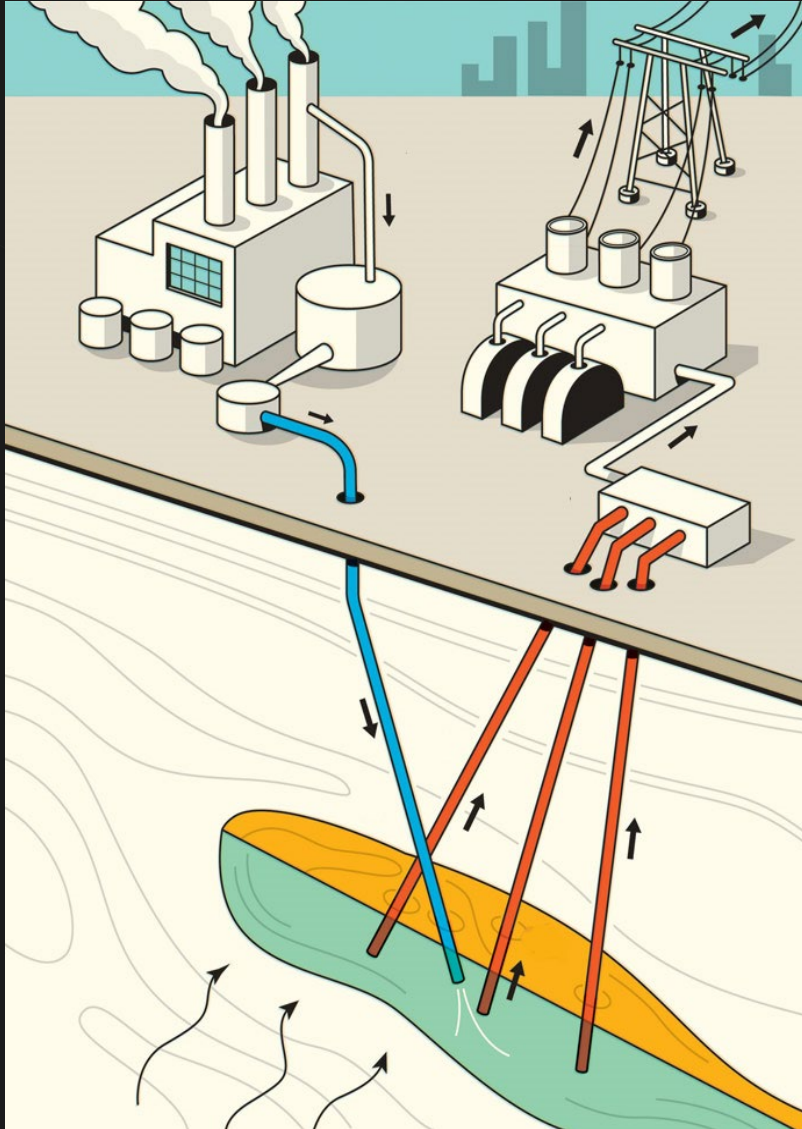
- › OUR NET ZERO GOALS
- › **WHAT ARE CARBON DIOXIDE PLUME GEOTHERMAL (CPG) SYSTEMS?**
- › THE CHALLENGES FACING CPG SYSTEMS
- › SOLUTIONS FROM OIL AND GAS ENGINEERING

CARBON DIOXIDE PLUME GEOTHERMAL SYSTEMS



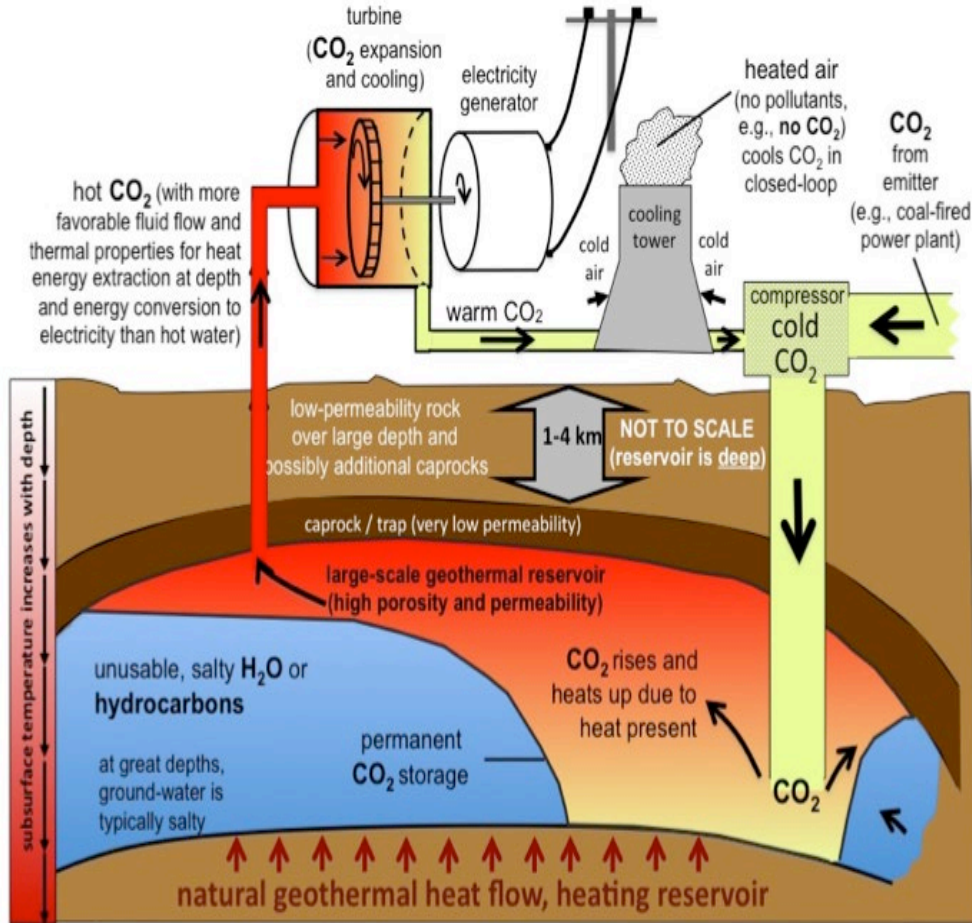
- › Carbon Dioxide Plume Geothermal (CPG) systems combine the use of CO_2 as a working fluid, the extraction of heat and pressure energy from sedimentary basins and the generation of clean renewable electricity
- › The CPG concept has been investigated as far back as 2009
- › Hydrocarbon industry has long used CO_2 in Enhanced Oil Recovery (EOR) systems

CARBON DIOXIDE PLUME GEOTHERMAL SYSTEMS



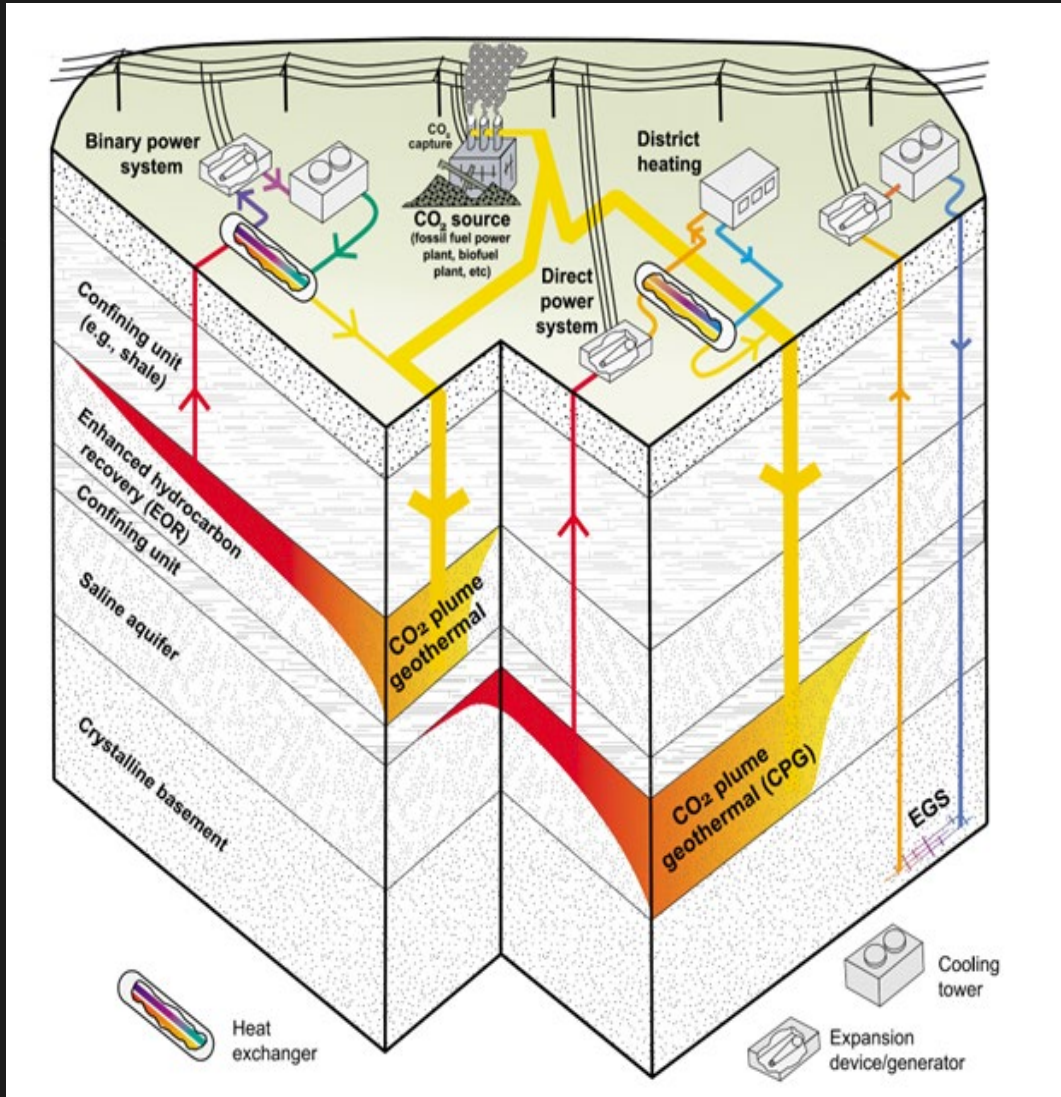
- › There are multiple carbon capture and storage (CCS) operations around the world however the utilization of captured carbon could improve to generate value
- › If proven successful at scale, it would not only achieve carbon abatement goals through CO₂ removal (CDR) but also generate non fossil fuel-based renewable electricity including during periods of peak demand
- › Decades of learnings from the generation of electricity from conventional geothermal energy
- › CPG system has good potential for stored energy and intermittent power generation

HOW CPG WORKS



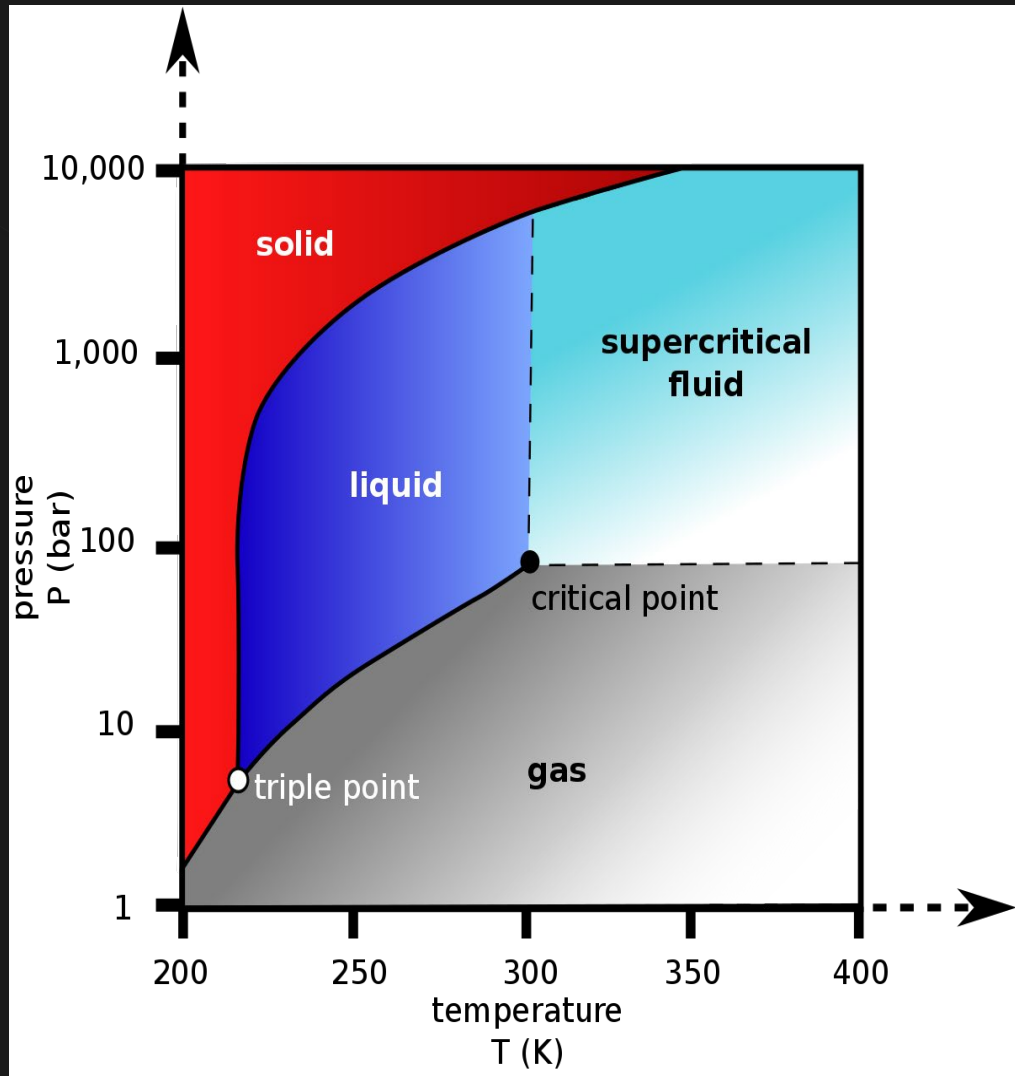
- › Supercritical CO₂ from an emissions source is injected into a porous and permeable reservoirs in sedimentary basins
- › Injected CO₂ is heated by the geothermal heat influx from the Earth's interior
- › CO₂ expands and transported back to surface through the effects of thermosiphoning
- › CO₂ utilized at surface either for electricity generation through turbine, binary systems or district heating systems

CONDITIONS FAVOURABLE FOR CPG TO WORK



- › Natural sedimentary and stratigraphic basins with high porosity and permeability reservoirs with temperatures as low as 65-70°C
- › Low permeability cap rock
- › Shallower reservoirs with large area for fluid flow and heat transfer rates
- › Availability of supercritical CO₂ as a working fluid
- › CO₂ emissions source, sedimentary basin and power system co-located

ADVANTAGE OF USING CO₂ OVER WATER AS A WORKING FLUID



- › CO₂ has better thermodynamic, and fluid mechanical properties compared to water
- › CO₂ systems have the potential to provide 3x heat extraction rates compared to water-based systems due to its lower viscosity
- › CO₂ is a poor ionic solvent for the minerals in the rock
- › CO₂ has higher compressibility and expansibility that can generate buoyancy forces thus reducing pumping consumption to maintain cycle
- › Sequestration of CO₂ is possible in deep reservoirs



- › OUR NET ZERO GOALS
- › WHAT ARE CARBON DIOXIDE PLUME GEOTHERMAL (CPG) SYSTEMS?
- › **THE CHALLENGES FACING CPG SYSTEMS**
- › SOLUTIONS FROM OIL AND GAS ENGINEERING

CHALLENGES FACING CPG SYSTEMS

- › Availability and integration of CCS systems
- › Availability of co-located point of emissions and suitable reservoirs and high cost of transporting CO₂ from source of emission to sequestration reservoir
- › More work is needed to understand the development (shape) of the CO₂ plume which depends on reservoir permeability
- › Injector and production well placement is an important consideration to understand reservoir heat depletion rates and energy production

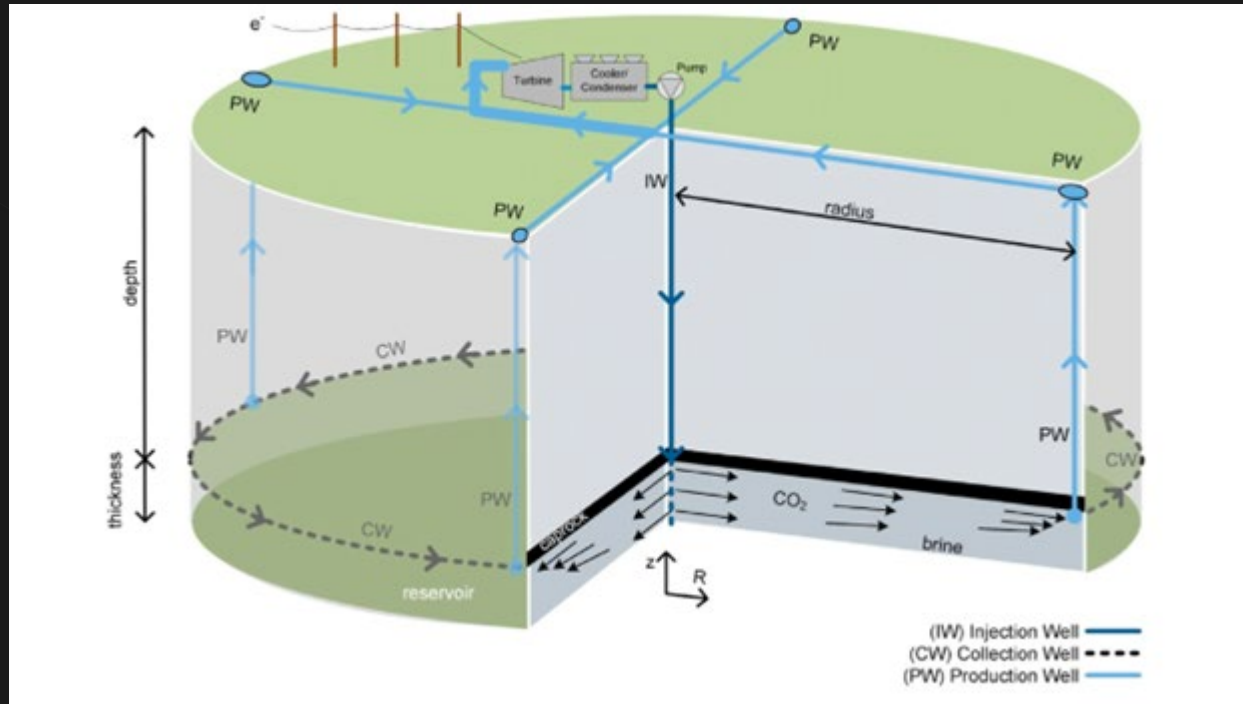
CHALLENGES FACING CPG SYSTEMS

- › Availability and integration of CCS systems
- › Availability of co-located point of emissions and suitable reservoirs and high cost of transporting CO₂ from source of emission to sequestration reservoir
- › More work is needed to understand the development (shape) of the CO₂ plume which depends on reservoir permeability
- › **Injector and production well placement is an important consideration to understand reservoir heat depletion rates and energy production**



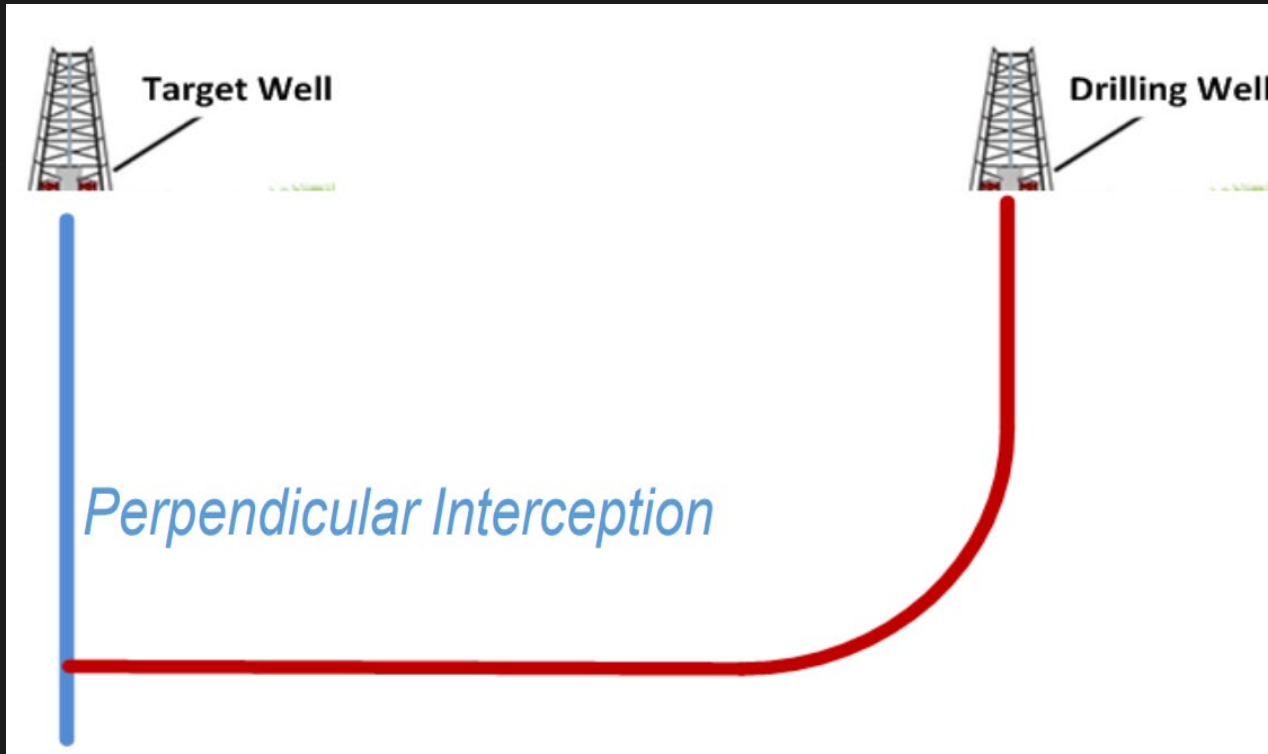
- › OUR NET ZERO GOALS
- › WHAT ARE CARBON DIOXIDE PLUME GEOTHERMAL (CPG) SYSTEMS?
- › THE CHALLENGES FACING CPG SYSTEMS
- › **SOLUTIONS FROM OIL AND GAS ENGINEERING**

SOLUTIONS FROM OIL AND GAS DRILLING ENGINEERING



- › Numerical modelling used to determine thermal depletion and electricity generation
- › Seeks to identify optimum well placement for peak electricity
- › Optimum placement of horizontal wells intersecting vertical production wells

HORIZONTAL TO VERTICAL INTERCEPT



- › Also known as Surface to Inseam (SIS) drilling
- › Technology exists in coalbed methane production in the oil and gas industry and solution mining in the minerals extraction industry
- › Involves directional drilling and magnetic ranging technologies

MAGNETIC RANGING TECHNOLOGY

- › Employed in Access Dependent and Access Independent intercepts to determine a well's distance and direction with accuracy
- › Access Dependent intercept – a magnetic source or receiver is placed in the target wellbore whilst the intersecting well is being drilled
- › Access Independent intercept – all ranging is performed from the well being drilled

MAGNETIC RANGING TECHNOLOGY

Active Magnetic Ranging

- › Generates an alternating magnetic field
- › Detection of magnetic field
- › Uses proximity vector between the vertical and intercepting wellbore
- › Current injection and downhole sensor

Passive Magnetic Ranging

- › Relies on remnant magnetic field of the steel or variations in the EMF
- › Static magnetic field signal
- › MWD gravity surveys and magnetic data to estimate location and orientation of target well

MAGNETIC RANGING TECHNOLOGY

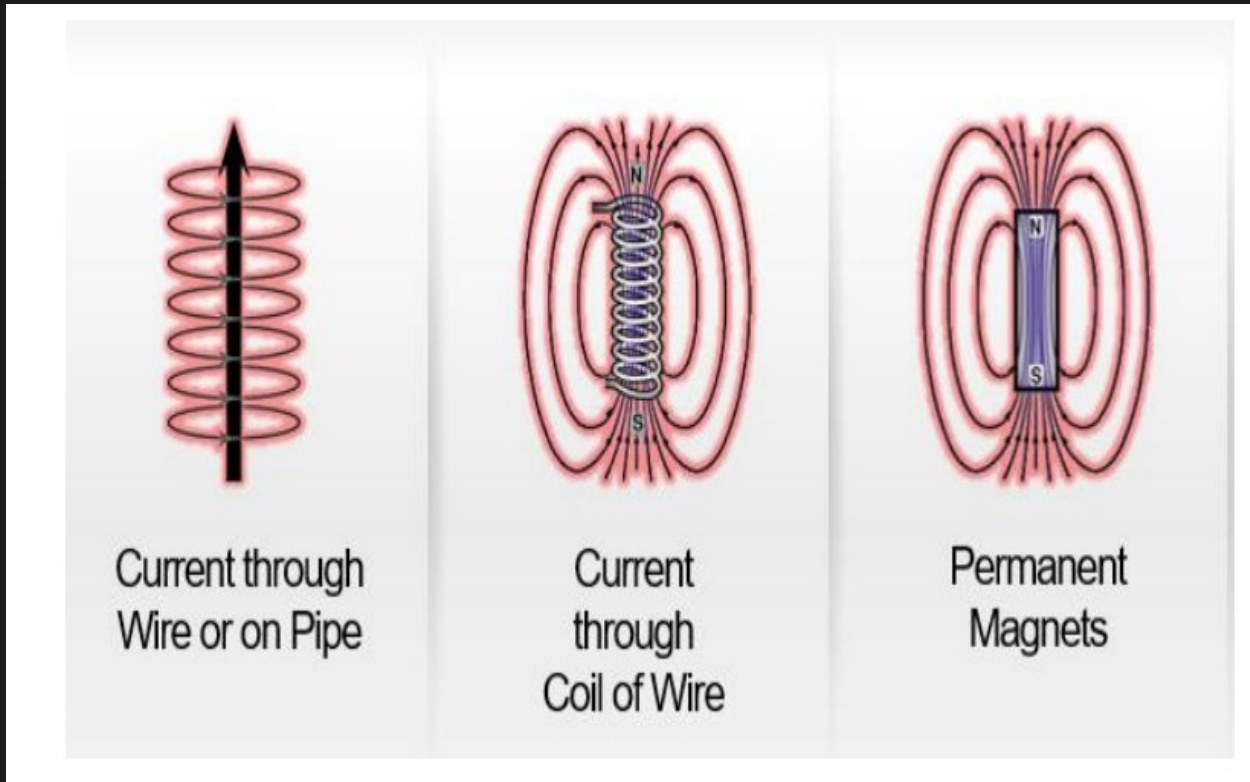
Active Magnetic Ranging

- › Generates an alternating magnetic field
- › Detection of magnetic field
- › Uses proximity vector between the vertical and intercepting wellbore
- › Current injection and downhole sensor

Passive Magnetic Ranging

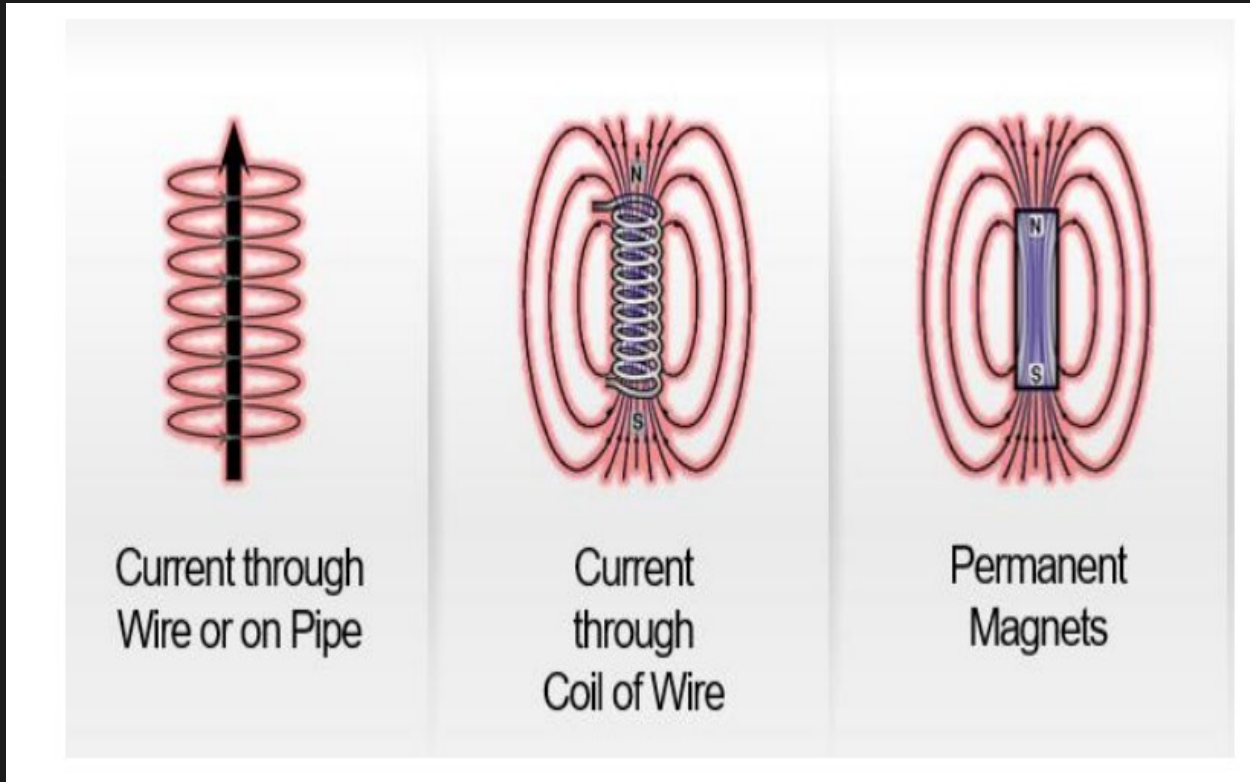
- › Relies on remnant magnetic field of the steel or variations in the EMF
- › Static magnetic field signal
- › MWD gravity surveys and magnetic data to estimate location and orientation of target well

ACTIVE MAGNETIC RANGING TECHNOLOGY



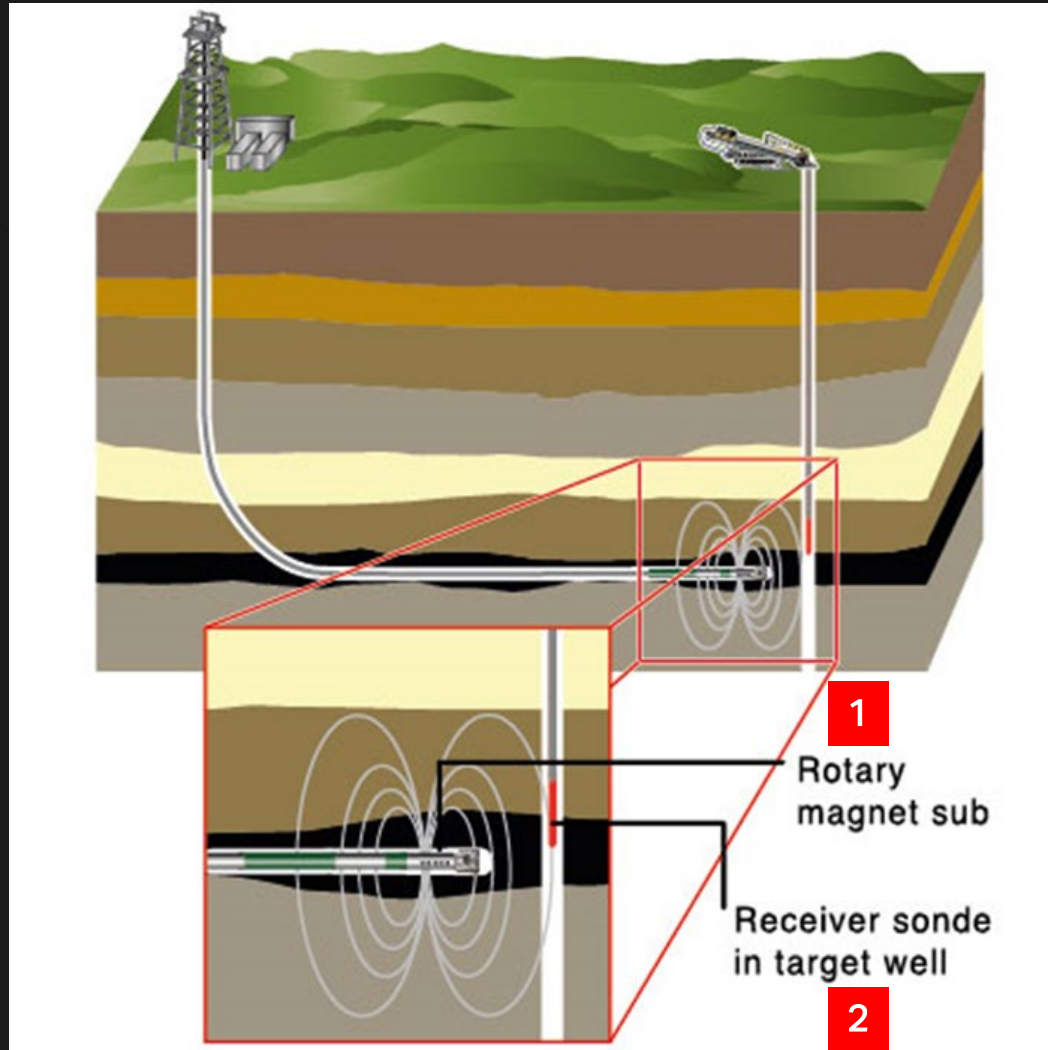
- › Multiple vertical wells can be perpendicularly intercepted by a single horizontal well
- › Access to the target well (vertical well)
- › Typically consists of a rotating magnet, single wire, solenoid or combinations
- › Point sources are preferred
- › Access Dependent (AD) and Access Independent (AI)

ACTIVE MAGNETIC RANGING TECHNOLOGY



- › Multiple vertical wells can be perpendicularly intercepted by a single horizontal well
- › Access to the target well (vertical well)
- › Typically consists of a rotating magnet, single wire, solenoid or combinations
- › Point sources are preferred
- › **Access Dependent (AD)** and Access Independent (AI)

AD ACTIVE MAGNETIC RANGING TECHNOLOGY



- › Rotary magnet sub (RMS) containing rare earth metals that act as magnets and creates a rotating AC magnetic field
- › RMS sits behind the bit in the drilling BHA; some designs allow a more integrated RMS in the drilling motor for greater accuracy
- › A 6-axis directional magnetic receiver/sonde is run via a monoconductor wireline logging in the target well
- › This system has demonstrated accuracy, repeatability, availability and cost effectiveness

AD ACTIVE MAGNETIC RANGING TECHNOLOGY



- › RMRS receiver/sonde has a useable range of up to 46m in casing and 80m in open hole
- › Provides distance and direction from the sensor to the drill bit
- › Data is processed in real time to generate distance and directions between wellbores to an accuracy of +5% of separation
- › Accuracy less than 12 inches
- › Some technologies have useable range of 91m in cased well and 128m in open hole

Source: Gunnar Energy Services

AD ACTIVE MAGNETIC RANGING TECHNOLOGY

Bottomhole Assembly

Wireline with monopole conductor

Above tool weight bar

RMRS sonde (6-axis)

Bottom weight bar

Tool foot



Bottomhole Assembly

Drilling bit

Rotating Magnet Bit Sub

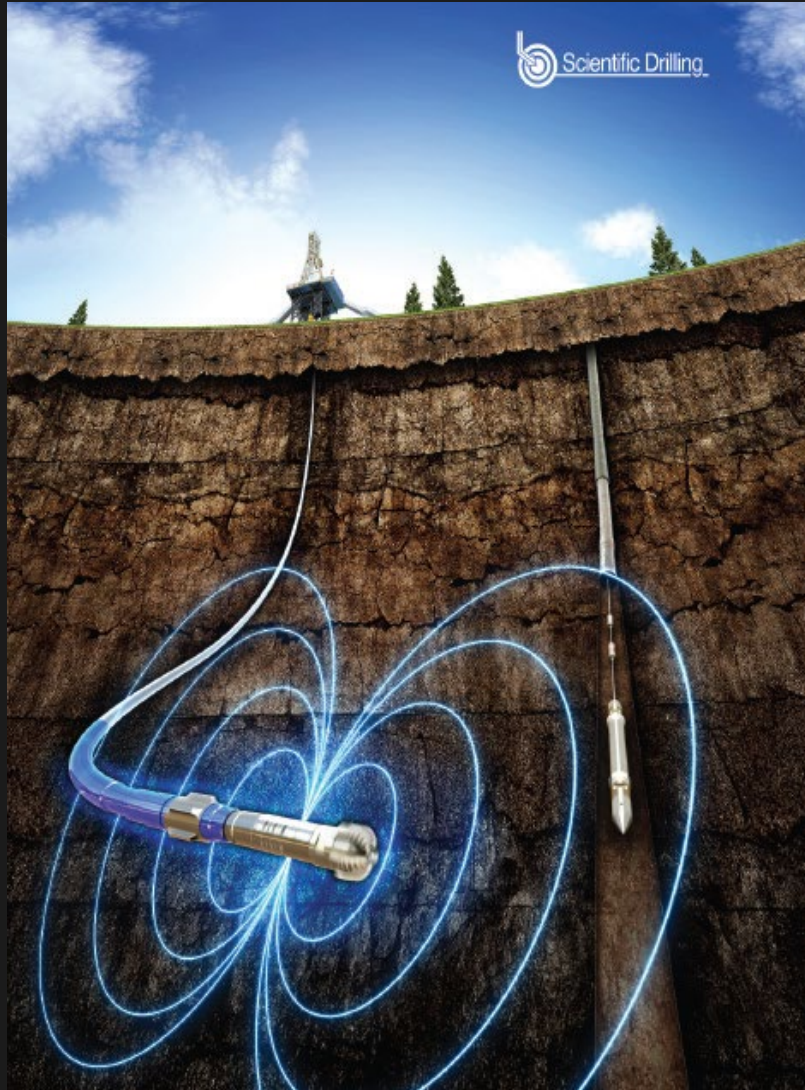
Drilling Motor

UBHO Sub

NM Drill Collars

Drillpipe with X/O

AD ACTIVE MAGNETIC RANGING TECHNOLOGY

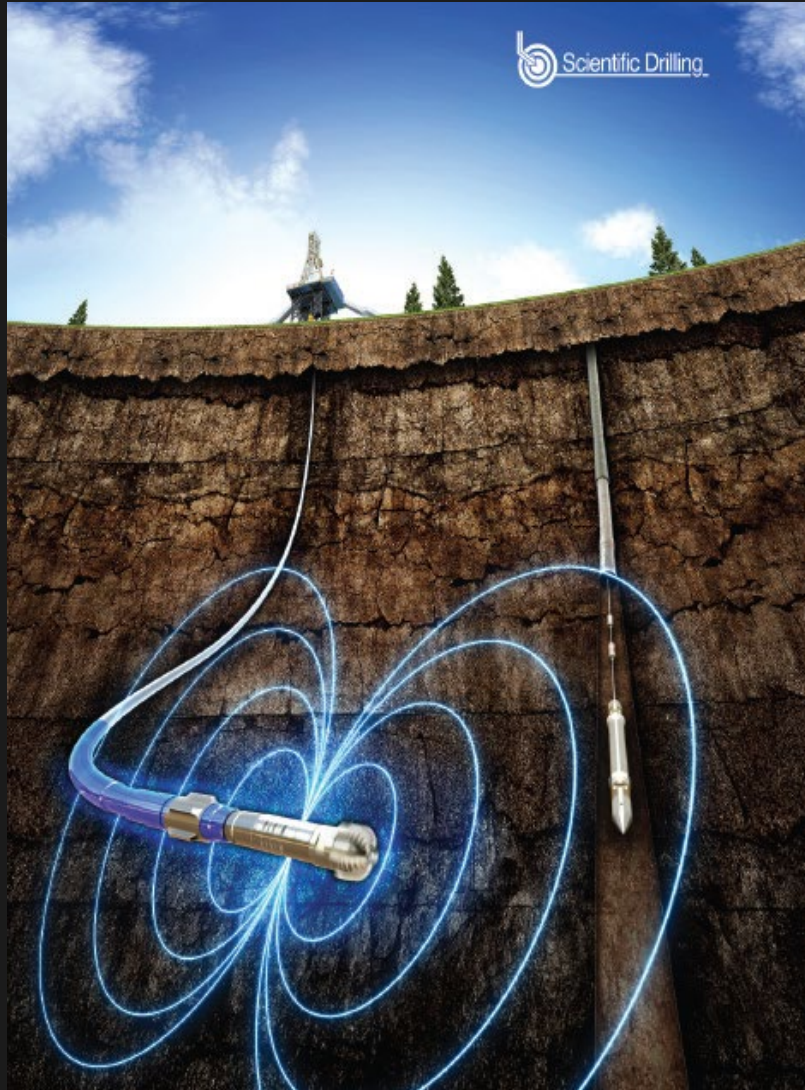


Source: Scientific Drilling Services

› Magnetic Ranging Protocol

- / RMRS receiver sonde is positioned in target well
- / Follow normal drilling practices until approximately 90m from the pass by of the target well
- / If the RMRS receiver is detecting a flux in the AC field, data will be recorded and an RMRS determination will be made at the next survey point
- / To record a rotary magnet AMR shot:
 - » Take a bottom hole survey
 - » DD to make an extrapolation to bit and inform Ranging Specialist (Real Time)
 - » Ranging Specialist processes and analyses the recorded shot data

AD ACTIVE MAGNETIC RANGING TECHNOLOGY

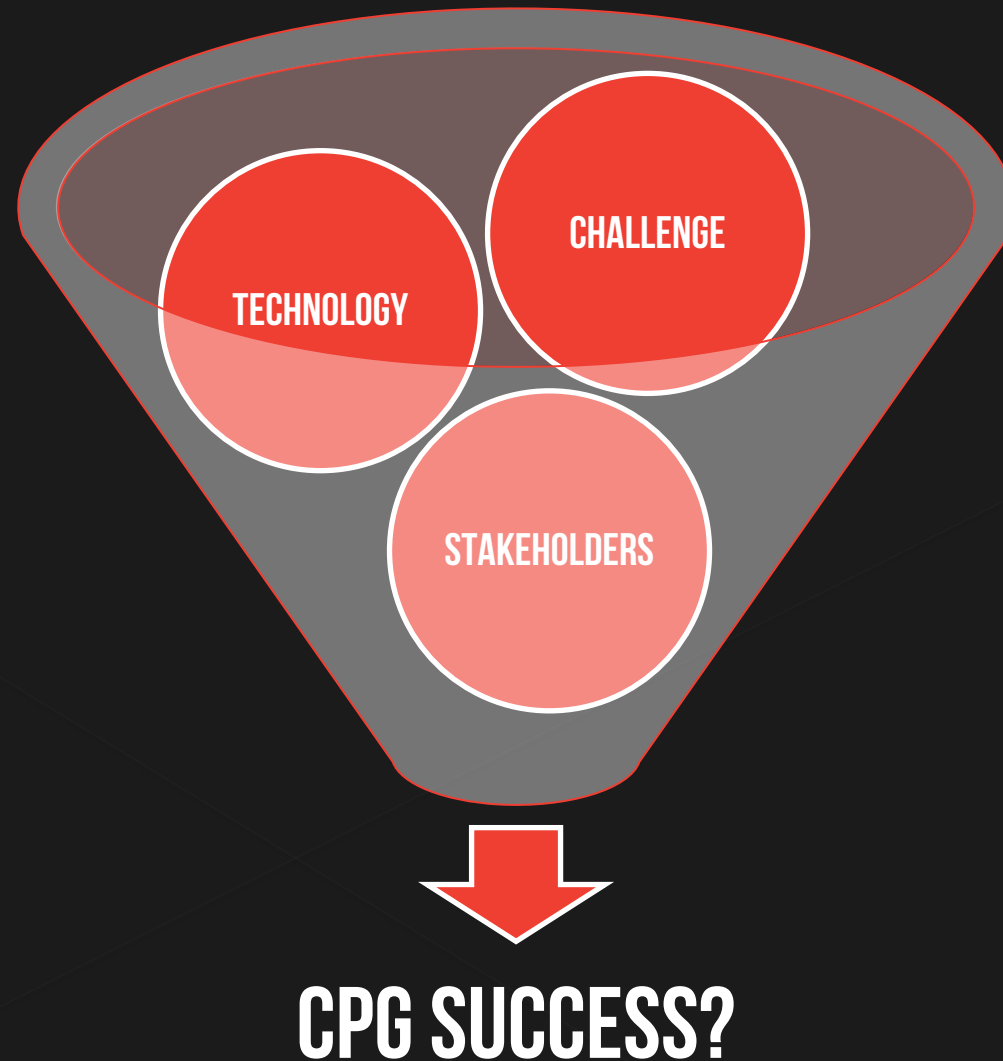


Source: Scientific Drilling Services

› Magnetic Ranging Protocol

- / Depending on the results the Ranging Specialist will determine if more RMRS data is needed to be taken at a given hole depth
- / Once enough data has been acquired at a given point, the Ranging Specialist will advise the Company Representatives on the status of where the drilling well is relative to the offset well
- / The Ranging Specialist will also recommend a distance to drill ahead, typically 3 – 10m (10 – 33 ft.)
- / These steps will be repeated until the objective has been completed and well has been intercepted

SUMMARY





QUESTIONS?

DEVIN.HARSHAD@RESPEC.COM