Acknowledgement of Country

The University of Queensland (UQ) acknowledges the Traditional Owners and their custodianship of the lands on which we meet.

We pay our respects to their Ancestors and their descendants, who continue cultural and spiritual connections to Country.

We recognise their valuable contributions to Australian and global society.

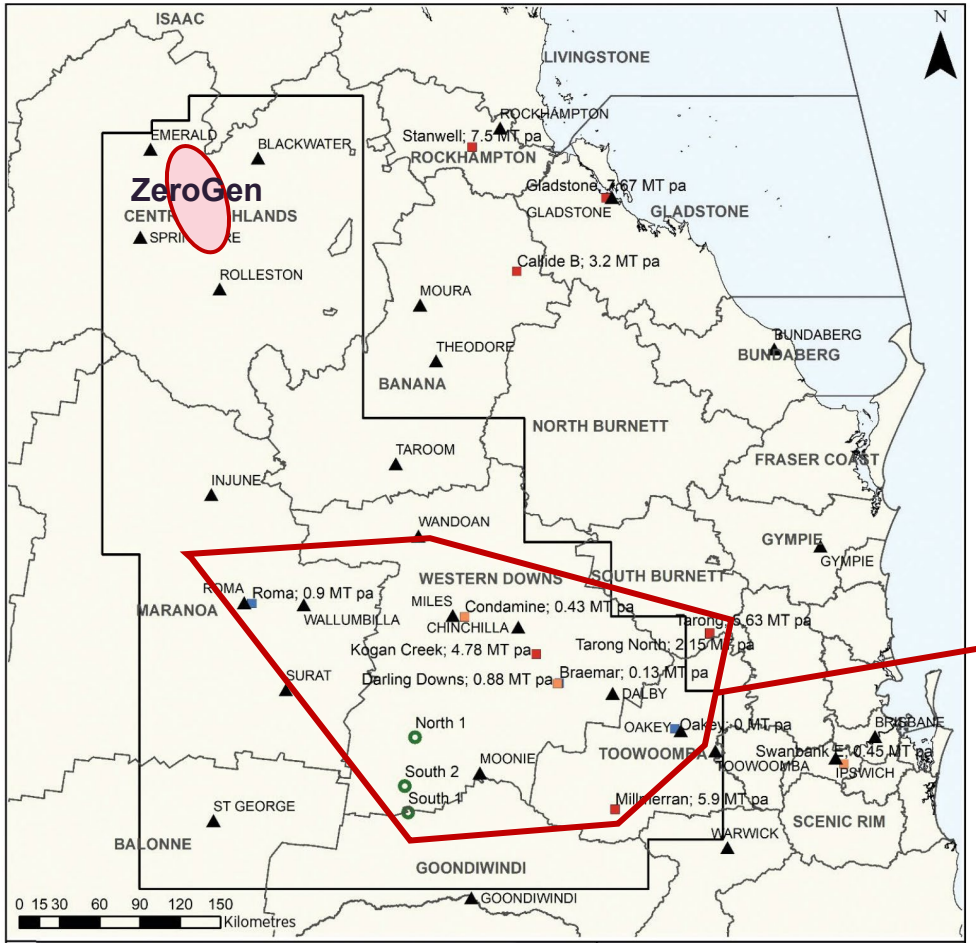
The Brisbane River pattern from *A Guidance Through Time*
by Casey Coolwell and Kyra Mancktelow.

Including Sub-surface Uncertainties in CCS Hub Investment Decision Making - A Case History.

Prof. Andrew Garnett, Iain Rodger, & Joe Lane

UQ Centre for Natural Gas. May 2023

Surat Hub Study Location

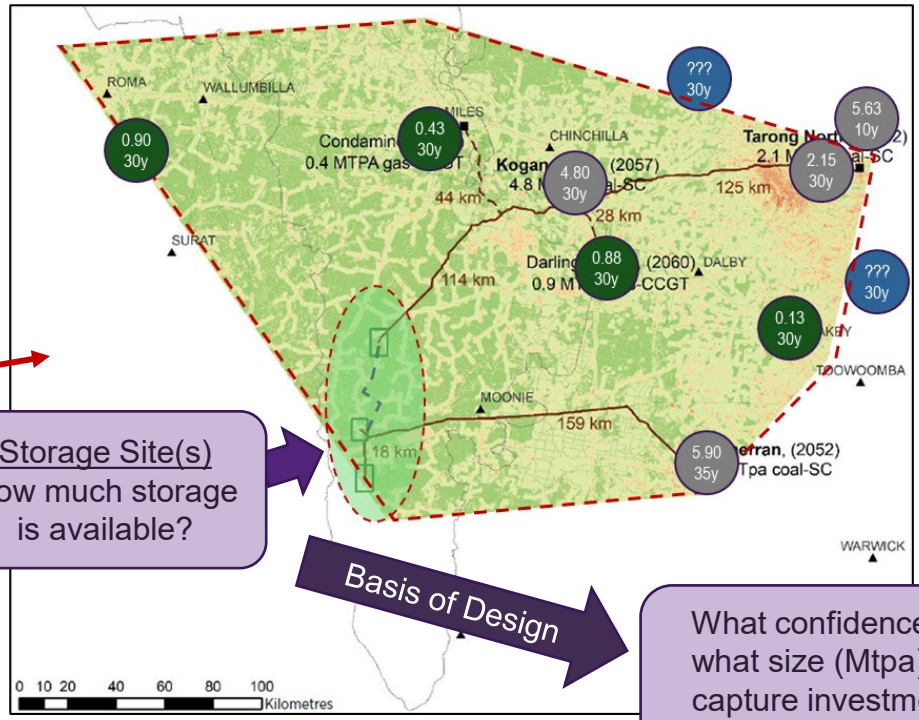


Time frame >30 yrs

>10 possible major emitters

Size for 5 Mt pa or >20 Mt pa ?

Capture & transport cost $2B to >$10B



Storage Site(s)
How much storage is available?

Basis of Design

What confidence in what size (Mtpa) of capture investment and hub build?

So, how much storage is there?

Static, corrected pore volume estimate

3 Gt

B. E. Bradshaw *et al.*, (2011).

Queensland CO2 Geological Storage Atlas

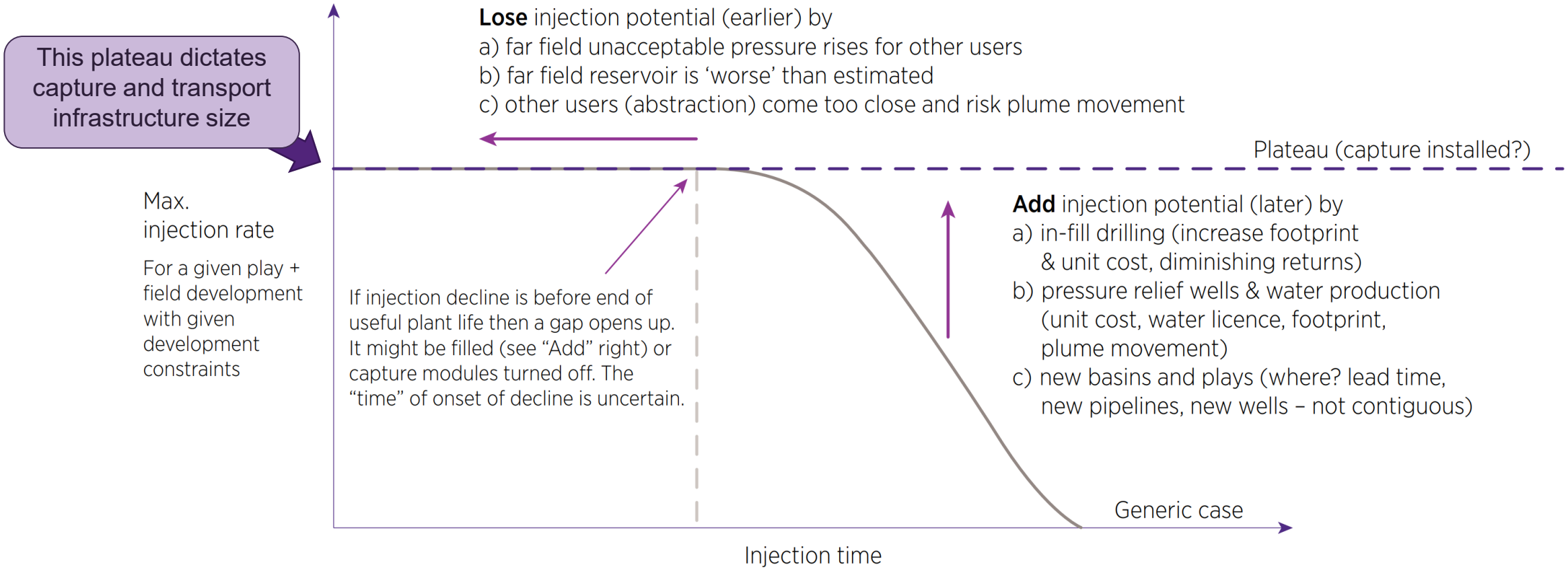
Suggests 100 million tonnes/year for 30 years!

About as useful as this:

Or not!

https://www.bbc.com/news/uk-england-york-north-yorkshire-29126161

Concept: plateau and decline ...management options



Basis of Design for the *Hub* Size?

What is the *right-sizing* & *right-phasing* of investment in capture & transport?

…How do I avoid over (or under) build of Capture & Transport capacity? ...or,

... For a given capture rate, what is the ***confidence* that injection can be sustained ...**

[1] for the productive economic lifetime of the major capital assets?

[2] and, at or below an economic target e.g. UTC($/t)?

2- It's understanding injection uncertainty over time that counts ...

Consider well 'type curves'

#1 Single well ... *(c.p.)*

- Informed by wireline, dynamic analogues, models, and EWTs
- An initial injection rate (& unc. pdf)
- Pressure transient (build-up) and consequential injection decline factor (& unc. pdf)

#2 Multiple wells over time ...

- Informed by dynamic analogues, extended well tests & sector models
- Modification to initial rate (& its pdf) e.g. depending on cumulative injection to date
- Modification to decline rate (& its pdf) due to cross-well pressure interference over time (reservoir dependent)
- *REMEMBER* that space to drill / well count is constrained

Example* – *hyperbolic

q is rate (q_i – initial rate)

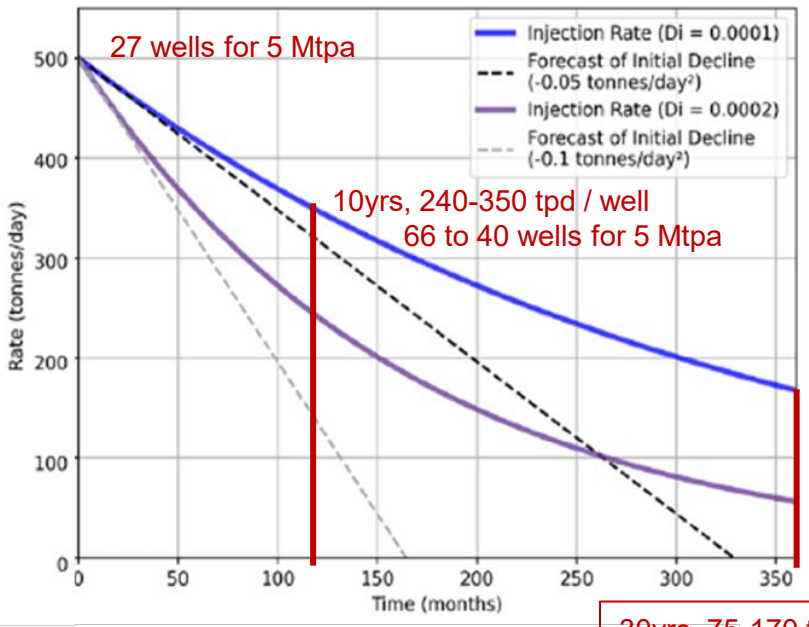
Q is cumulative injection at time t

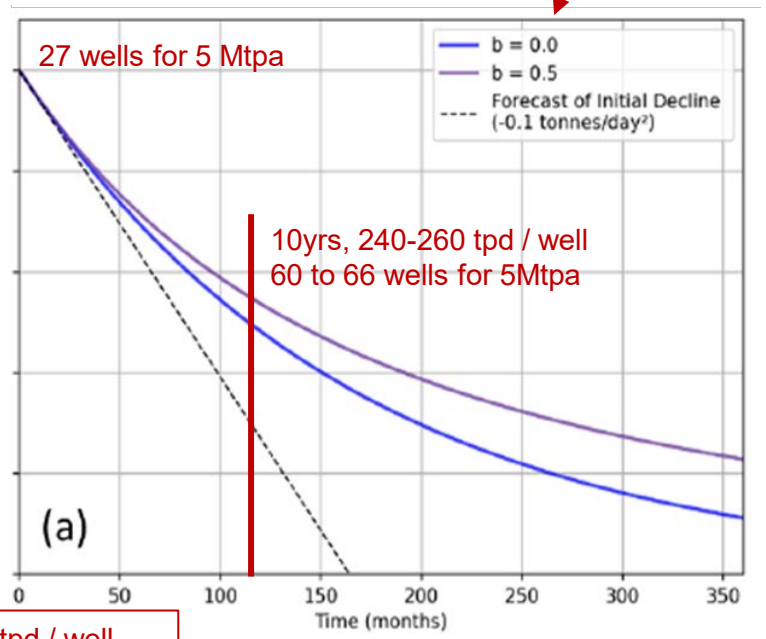
D_i is initial decline rate

b is decline exponent

□ *denotes* pdf *derived from data and multiple model runs*

$$q = \sqrt[1-b]{q_i^{(1-b)} - \frac{Q D_i (1-b)}{q_i^b}}$$



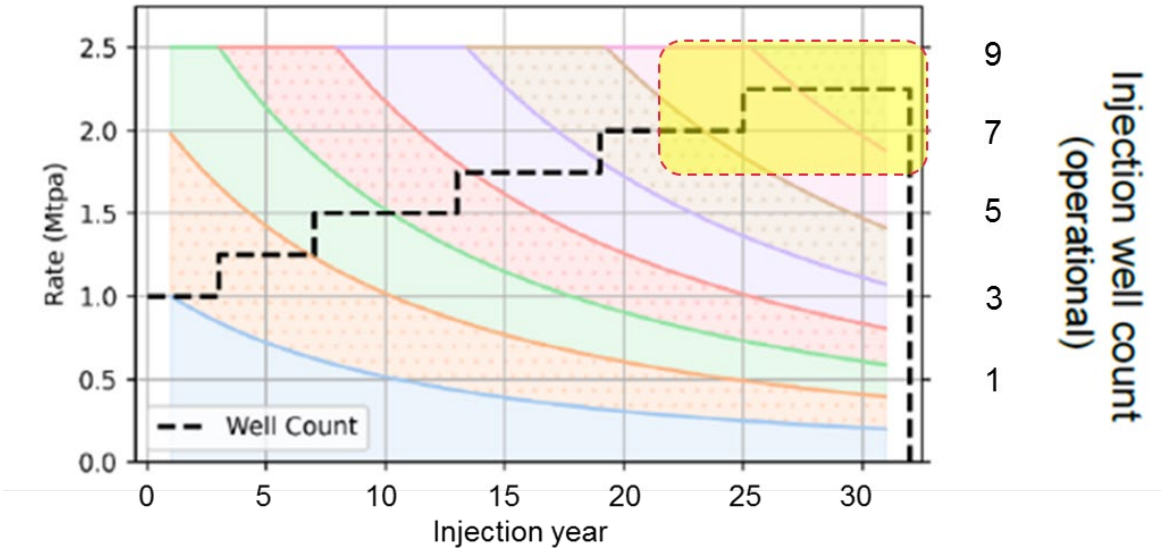


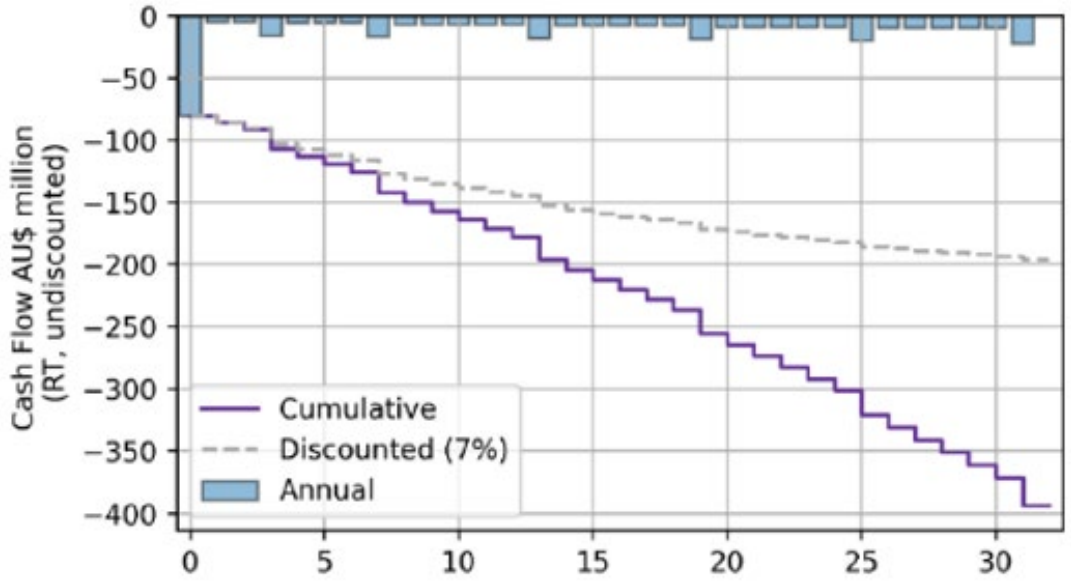
30yrs, 75-170 tpd / well
80 to 180 wells for 5 Mtpa

2- It's understanding injection uncertainty over time that counts ...

- **"Drill" & install injection capacity (plus a redundancy)**
- **Inject: then drill more as decline tends to target rate**
- ***Simulate* this with initial and decline uncertainty pdfs**
- **Constrain well-count by surface & sub constraints**
- ***Some scenarios will not be able to sustain the required rate (technical failure)*** **-** *TPOS*

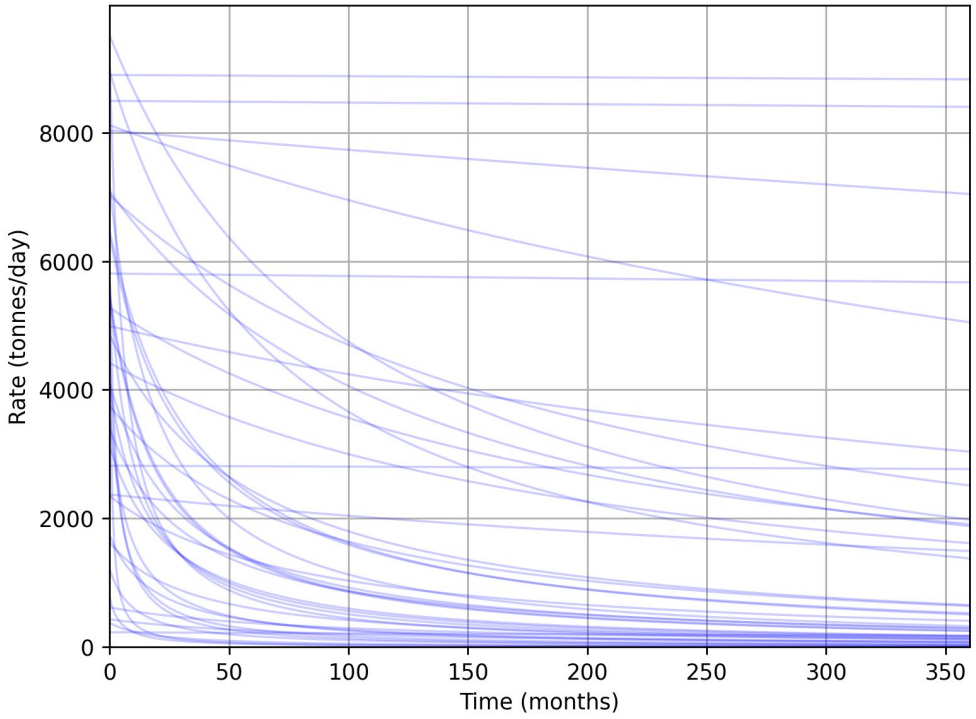
- **Build suitable cash-flow models**
- **Convert 'drilling sequence' into cash flow**
- **Calculate UTC *or pre-tax RT Break-even price ($/t)***
- **Repeat for all injection simulations**
- **Constrain vs pre-defined max-UTC *decision* criteria**
- ***Some scenarios will be more than the max UTC (economic failure)*** **-** *EPOS*





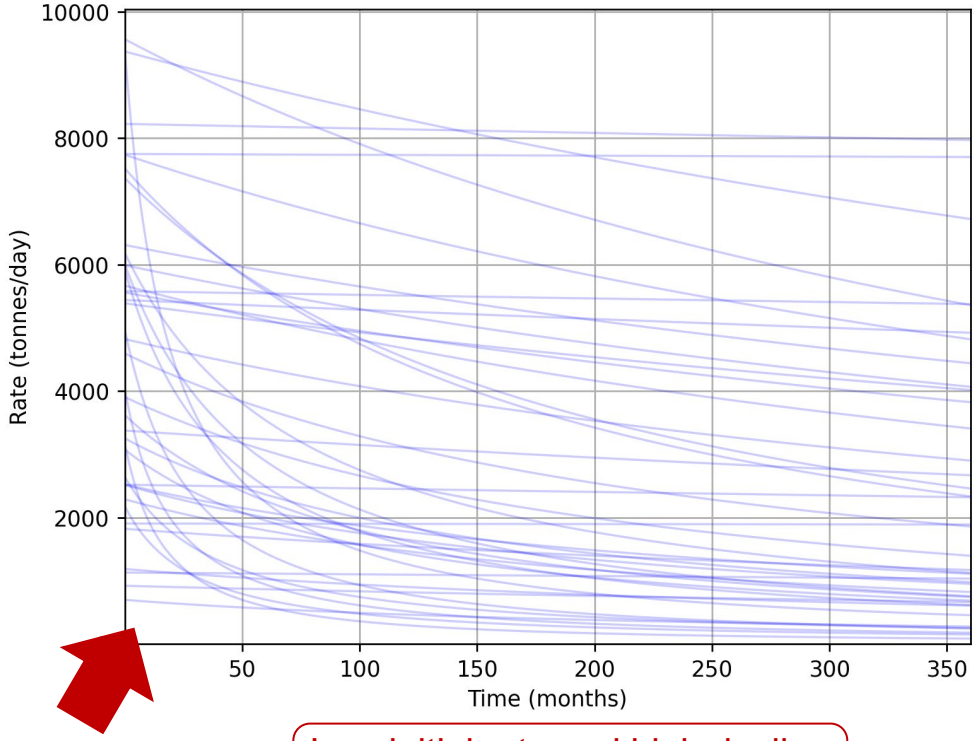
3 - Surat: simulated unc. & sequence for diff. project sizes

Pre Study (I)



Post Study (II)

- Major geology revision (seq)
- New core-wireline correl'n
- Production data calibration
- Managed aquifer injection calib.
- Drillable Area Constrained



Low initial rate and high decline rate cases now discounted

3 - Surat: simulated unc. & sequence for diff. project sizes

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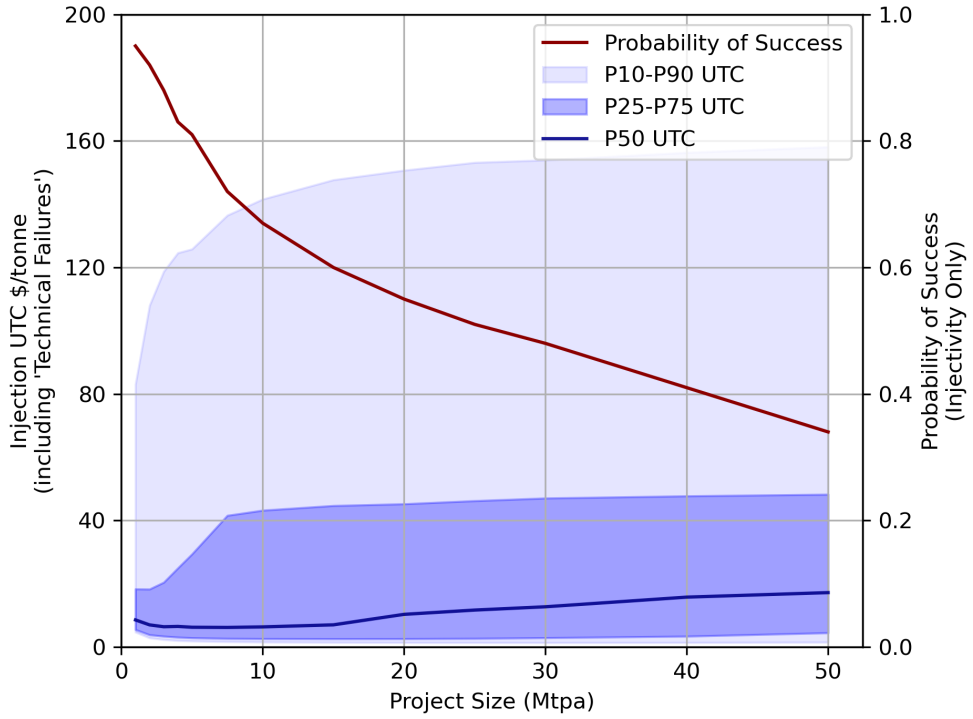

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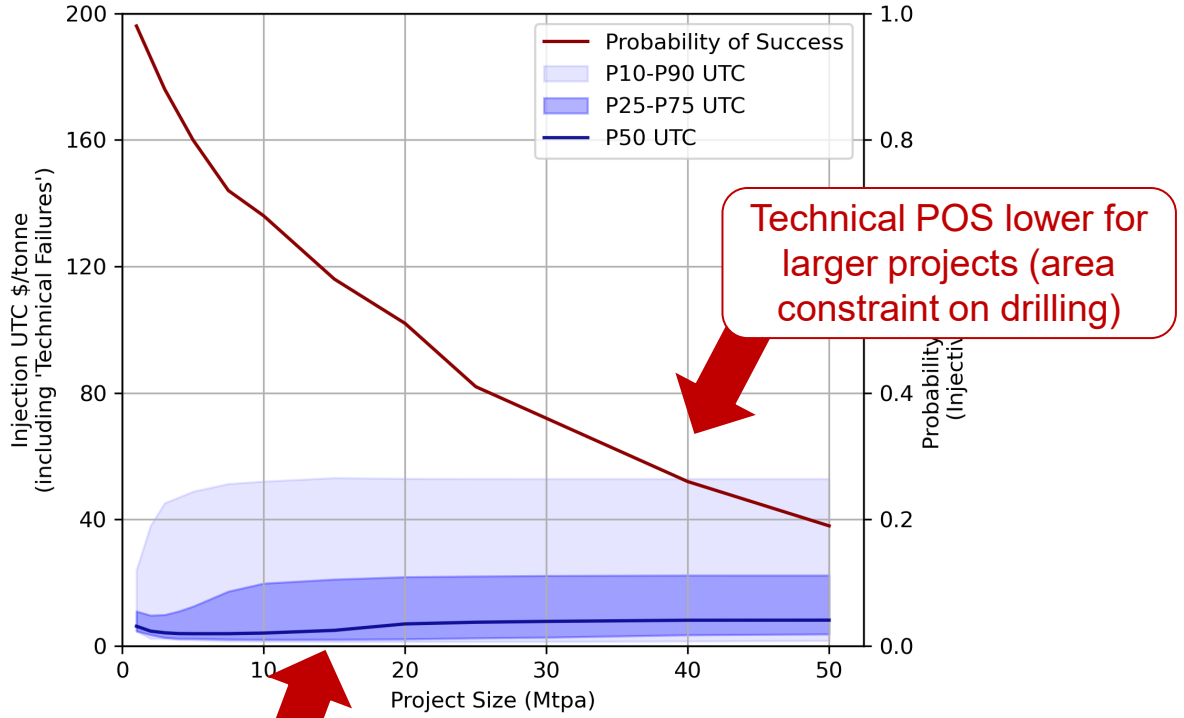

Technical POS lower for larger projects (area constraint on drilling)

UTC uncertainty reduced (and lower)

3 - Surat: simulated unc. & sequence for diff. project sizes

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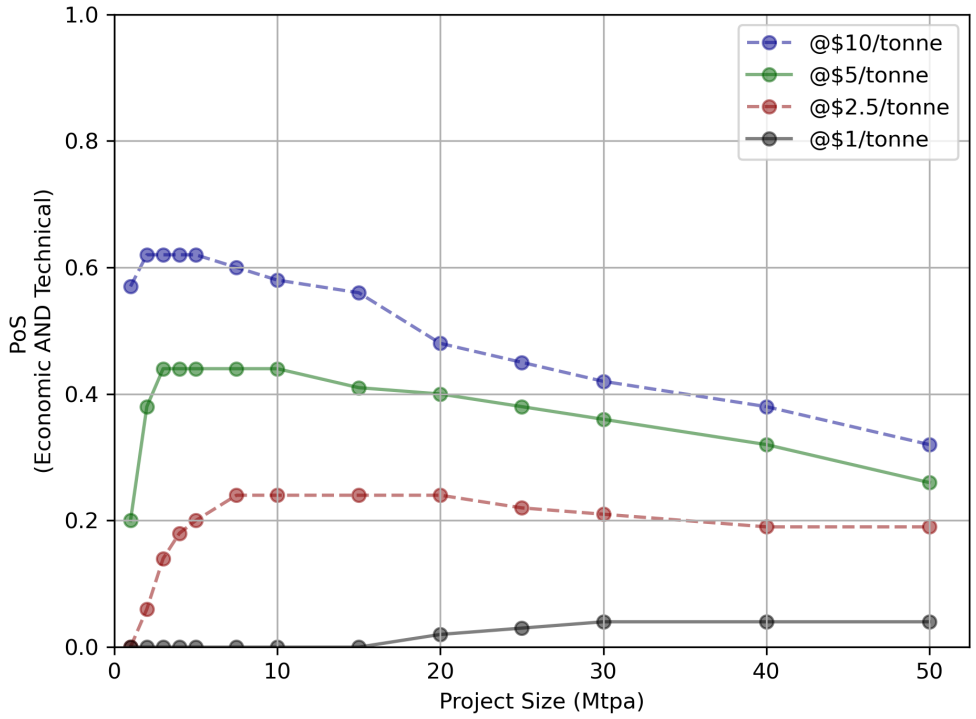

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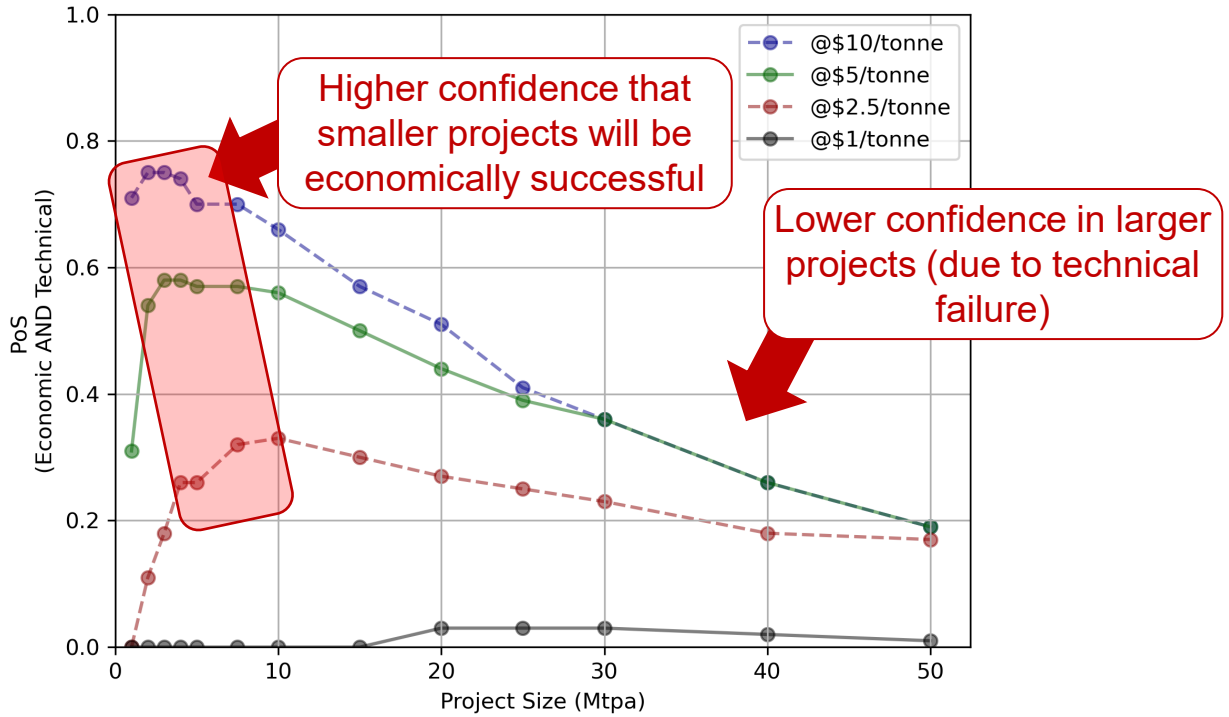

How much capacity do we have? Depends what cost we can tolerate and how confident we want to be!

What if confidence is not “high enough” for full hub investment?

Five main investment options

1. Take (share?) the risk ... Equiv. to changing your risk tolerance (TPOS, EPOS, UTC).
2. No further activity ... walk away
3. **Invest in further dynamic appraisal ($10s mln) <u>focussed</u> on *reducing uncertainty* in LT decline factors:** especially EWTs and interference test, *possibly* 3D seismic for res. architecture ... this is not “proving up”
4. **Find and *dynamically* appraise more sites:** a portfolio
5. **<u>Phase</u> the hub development incrementally (appraise while developing, $2 bln):** build <5 Mtpa first and, with suitable monitoring and model updates, let that injection better define sustainable rate and decline ... may require over-sizing of a pipeline

Spend more on appraisal or take the risk and develop?

At any point

$$Risked\ Vaue, RV = POS \times NPV_s + (1 - POS) \times NPV_f$$

The NPV if we choose to develop and the project is successful (+ve)

The NPV if we choose to develop but the project 'fails' to sustain injection (-ve)

$$\boldsymbol{Value\ of\ Appraisal, VoA = RV\ (after\ appraisl) - RV\ (before\ appraisal) - Cost\ of\ Appraisal\ (AFR)}$$

Assuming that new information from appraisal mainly changes the Probability of Success (POS) => *(by the magic of algebra)*

Appraisal is justified if:

$$\Delta POS \times \left(NPV_{success} - NPV_{fail}\right) > AFR$$

The anticipated change in POS

Note that NPV_f is –ve,
So $\left(NPV_s - NPV_f\right) > NPV_s$

Or, adjusting to unit costs:

$$\Delta POS \times \left(UTC_{fail} - UTC_{success}\right) > UAC$$

Note: *dynamic* appraisal investment de-risks the full hub not just storage, so:

- Justifiable UAC is likely **much** higher when considering the whole project (not just storage) since

$$UTC_{transport} + UTC_{capture} >> UTC_{storage}$$

- *NB: this doesn't consider another "poor outcome" where injection declines later than expected. Still positive NPV, but not optimal (missed opportunity)*

Summing up

So how big (how many Mtpa) should I build my capture and transport infrastructure?

1) ***It depends ...*** **on how much risk you want to take** **i.e.** ***the risk that it will not be possible to sustain the injection of the captured rate for the life of the C&T assets*****.**

2) **You *can* evaluate this risk in a structured way *and* you need to focus on uncertainty not on answers**

3) **You should undertake a formal economic *Value of Information Appraisal* approach to investing in storage dynamic assessment**

   - Capture and transport costs are in $ billions and they scale with Mtpa
   - Dynamic appraisal costs are in $10s millions

4) **Dynamic appraisal (EWTs) not cheap ... but it's a lot cheaper than getting the size wrong.**

This might seem obvious, but…

…apparently not to everyone

"we have seen $100 million wasted on ZeroGen" - John-Paul Langbroek

https://www.theaustralian.com.au/news/bligh-says-ccs-spending-not-wasted/news-story/74c1fd7544c429f9b5f77a1553366745

> Former long-serving Queensland premier Peter Beattie said Australia would be "crazy" not to invest in clean coal technology despite the high-profile failure of the $4 billion ZeroGen coal gasification and carbon capture and storage project in central Queensland which he championed when he was in office.

https://www.afr.com/politics/peter-beattie-qld-crazy-not-to-back-clean-coal-20170224-gukapi

ZeroGen appraisal was successful – it demonstrated that it wasn't worth investing $4 billion!

For the uninitiated … appraisal does <u>not</u> mean spend money to "prove up" – it means spend money on key information to decide "whether or not" to develop.

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