

END-OF-LIFE MANAGEMENT OF OIL WELLS

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Inactive Wells and Methane Workshop
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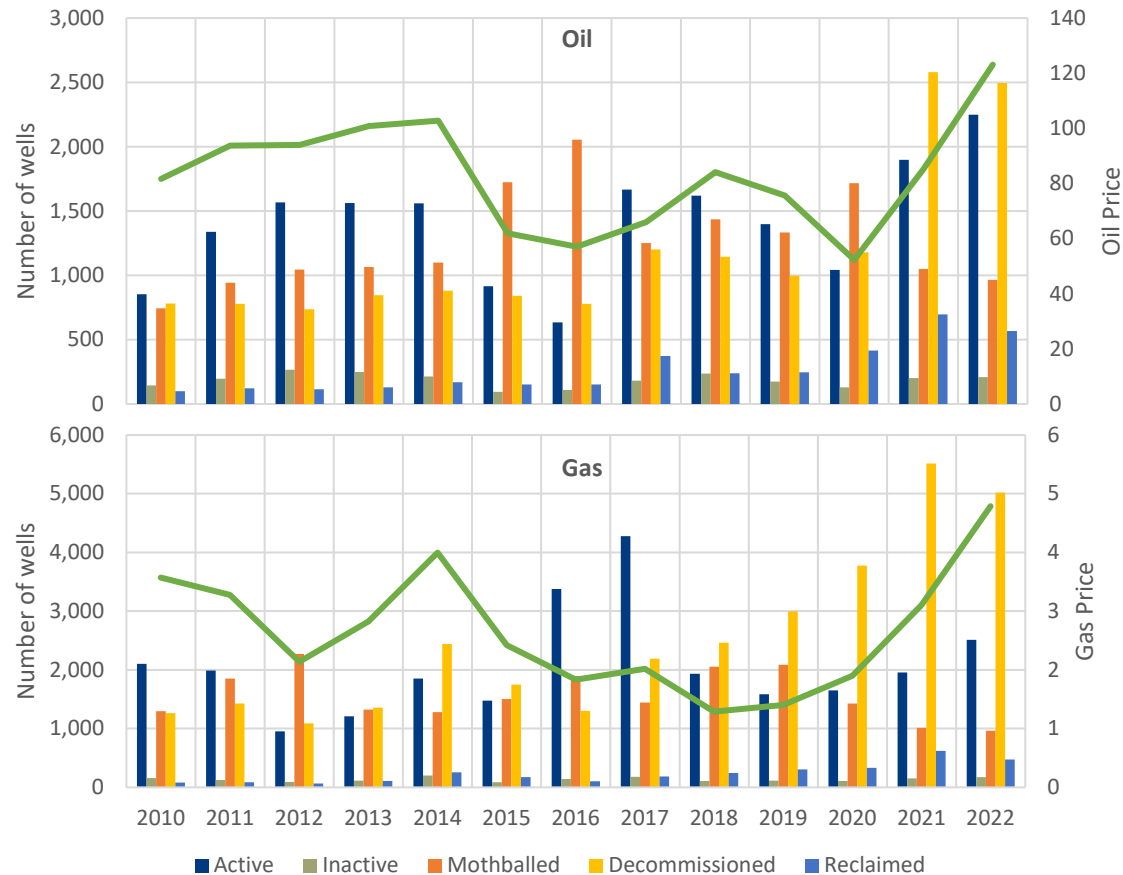
Acknowledgement:

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LIFE-CYCLE OF A TYPICAL OIL & GAS WELL

Exploration	<ul style="list-style-type: none">• Estimate reserves and potential production
Appraisal	<ul style="list-style-type: none">• Assess economic viability
Development	<ul style="list-style-type: none">• Development drilling• Construction of facilities, roads, pipelines, etc.
Active (Producing)	<ul style="list-style-type: none">• Well reports volumetric activity (extraction, injection, or disposal of fluids)
Inactive	<ul style="list-style-type: none">• Well reports no volumetric activity
Mothball (Suspend)	<ul style="list-style-type: none">• Long-term inactive well that has met regulatory requirements
Decommissioned (Abandoned)	<ul style="list-style-type: none">• Well plugged and wellhead cut and capped• Removal of surface facilities
Reclamation	<ul style="list-style-type: none">• Return the land back to its original state

INACTIVE OIL AND GAS WELLS



- Alberta has a large inventory of inactive O&G wells
 - In 2022 there were 82,837 inactive wells and 90,460 decommissioned wells (AER)
 - As of March 1, 2023 there are 2,356 orphan wells for decommissioning (OWA)
- O&G wells are inactive or decommissioned for long periods of time
 - The average decommissioned oil well is in that state for 14.8 years; 11 years for gas wells
 - The average mothballed oil well is in that state for 9.3 years; 10.2 years for gas wells
- Reclamation work has not kept pace with growth in inactive wells
 - From 2010-2022, 1,440 oil wells are decommissioned each year but only 268 are reclaimed.
 - From 2010-2022, 2,740 gas wells are decommissioned each year but only 233 are reclaimed.

Well data is from Evaluate Energy's CanOils Well and Land Database

CLEANING UP OIL & GAS WELLS

- Alberta's *Environmental Protection and Enhancement Act* requires firms to reclaim O&G wells at the end of their life
- The Alberta Energy Regulator (AER) has suspension requirements for wells
 - Do not specify how long a well can be suspended or abandoned.
 - To remain in compliance with the directive wells are inspected every 5 years (high-risk wells every year)
- Alberta has a long and unsuccessful history of trying to clean up nonproducing wells
- Recently, significant public dollars have supported decommissioning and reclamation efforts

PURPOSE OF THIS RESEARCH

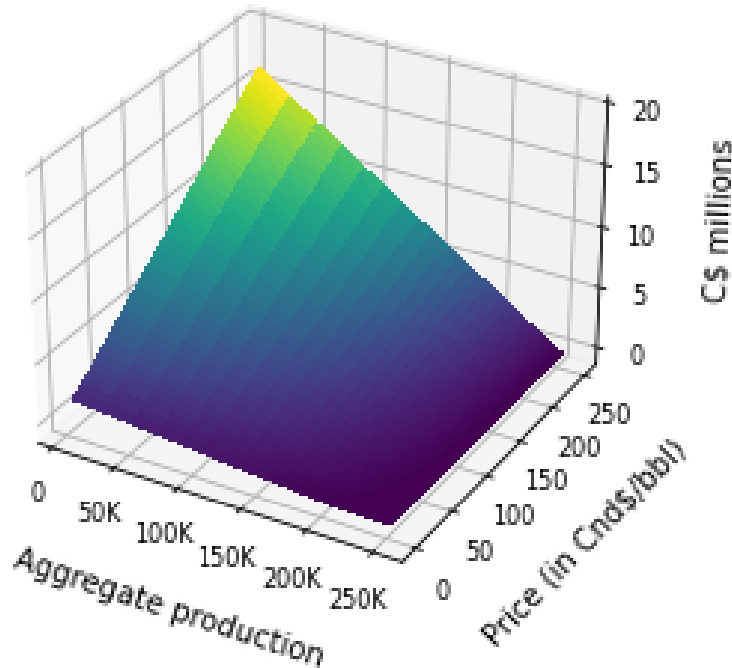
1. Value typical oil wells in Alberta that are subject to price uncertainty using real options analysis
2. Identify thresholds where an oil well will be mothballed, restarted, decommissioned and reclaimed
3. Evaluate the effect of different policies (time limit on inactivity, carbon price, etc.) have on the value of an oil well and thresholds

OBJECTIVES OF THE FIRM

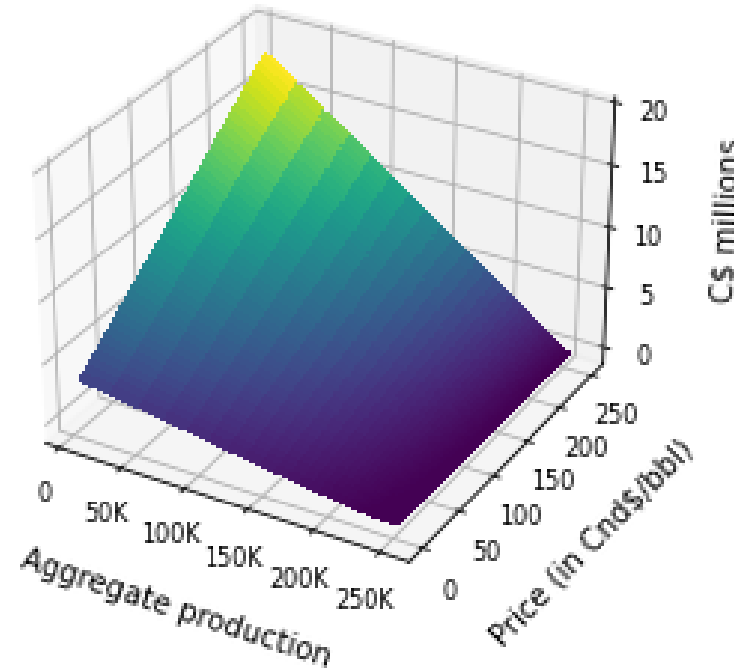
- Maximize the value of an oil well subject to a mean-reverting oil price process and exponential decline in production
- Determine the optimal time for production, temporarily halting production, restarting production, mothballing, decommissioning, and reclamation
 - The decisions to move between stages are costly decisions that are not easily reversed
 - Decommissioning requires the well to be permanently shut down, plugged, and the wellhead to be removed
 - Reclamation requires the firm to remove all equipment from the site, and decontaminate and return the land to the state it was in before development

VALUE OF A HORIZONTAL OIL WELL

Low-price regime



High-price regime

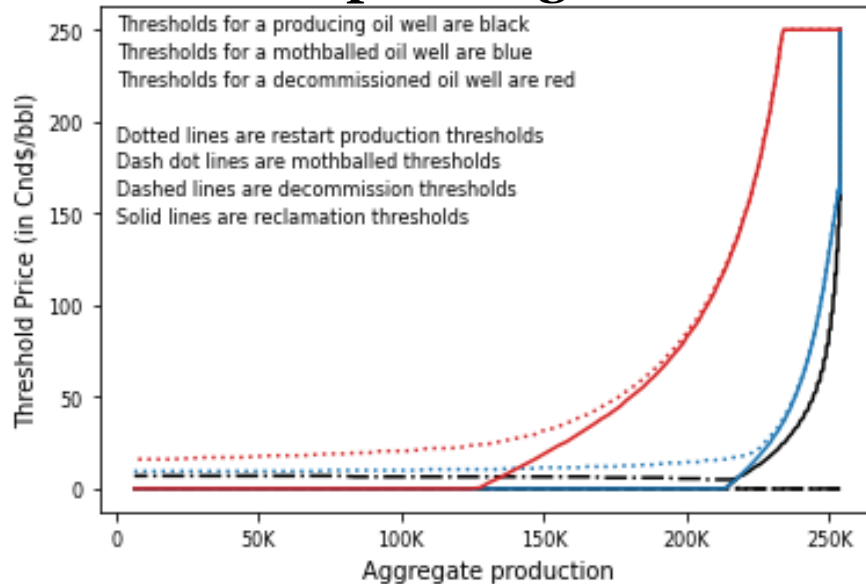


How to interpret the figures

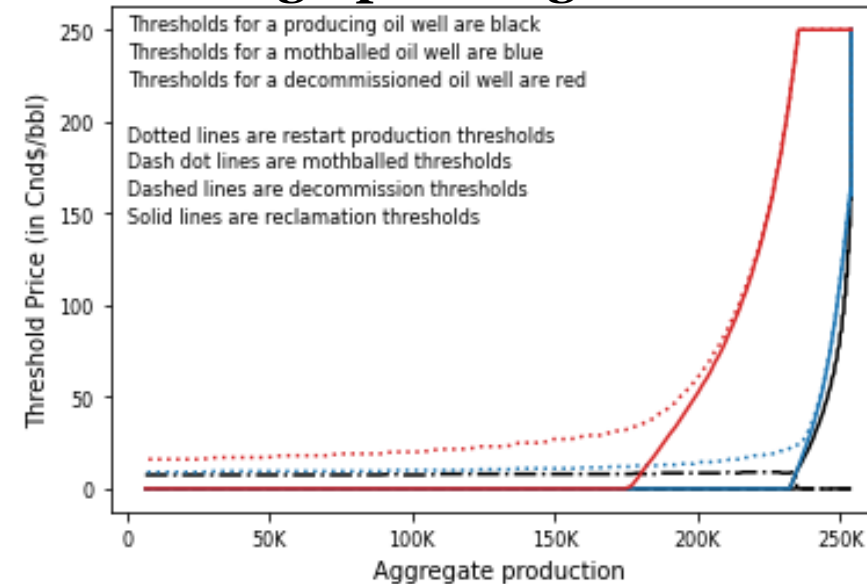
- The figures show the value of an oil well at different oil price levels and as reserves are extracted
- We assume the well is reclaimed at the end of its life (i.e. aggregate production is 250,000 bbls)
- We consider two price regimes:
 - Average price in the low-price regime is \$72.49
 - Average price in the high-price regime is \$107.56

DECISION THRESHOLDS HORIZONTAL OIL WELL

Low-price regime



High-price regime



How to interpret the figures

- The lines show the threshold price where a firm will switch from one stage to another for a given amount of reserves
 - For example, the red dotted line shows the minimum price required to restart production when the well is currently decommissioned

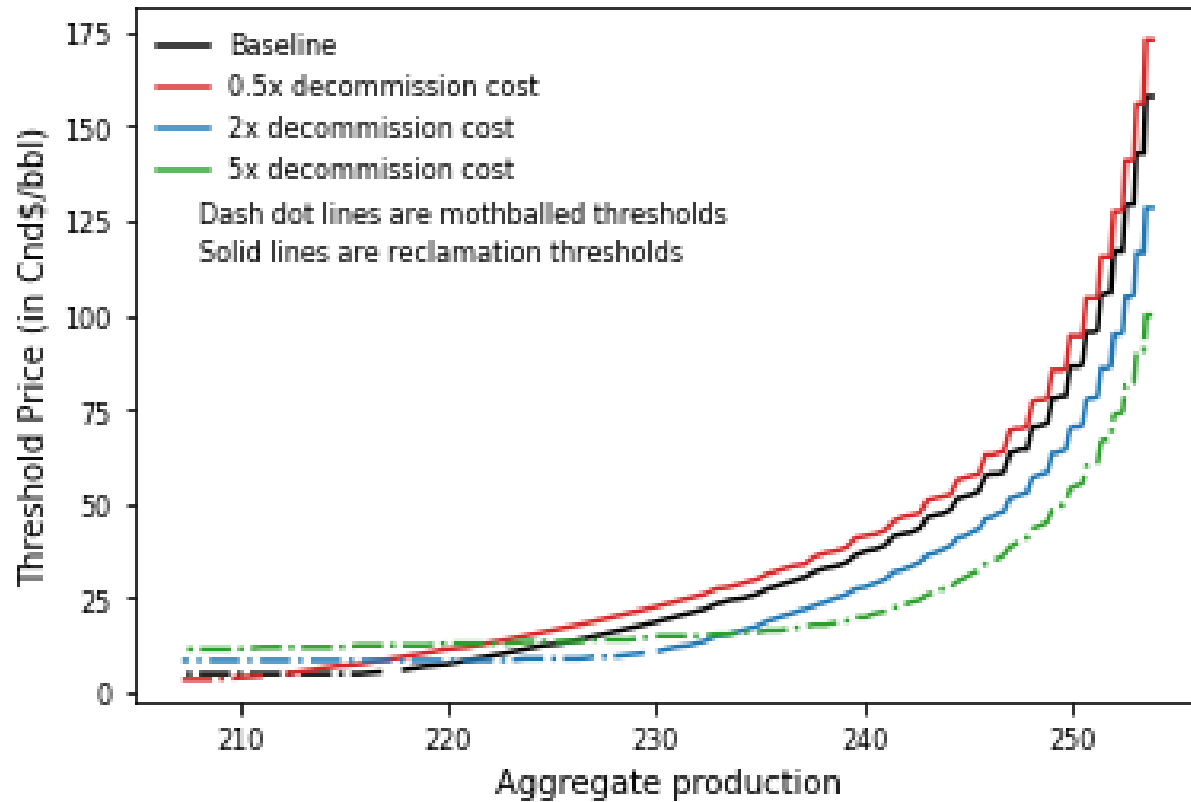
ADJUST DECOMMISSION AND RECLAMATION COSTS

- We adjust decommission and reclamation costs to evaluate how decision thresholds change.

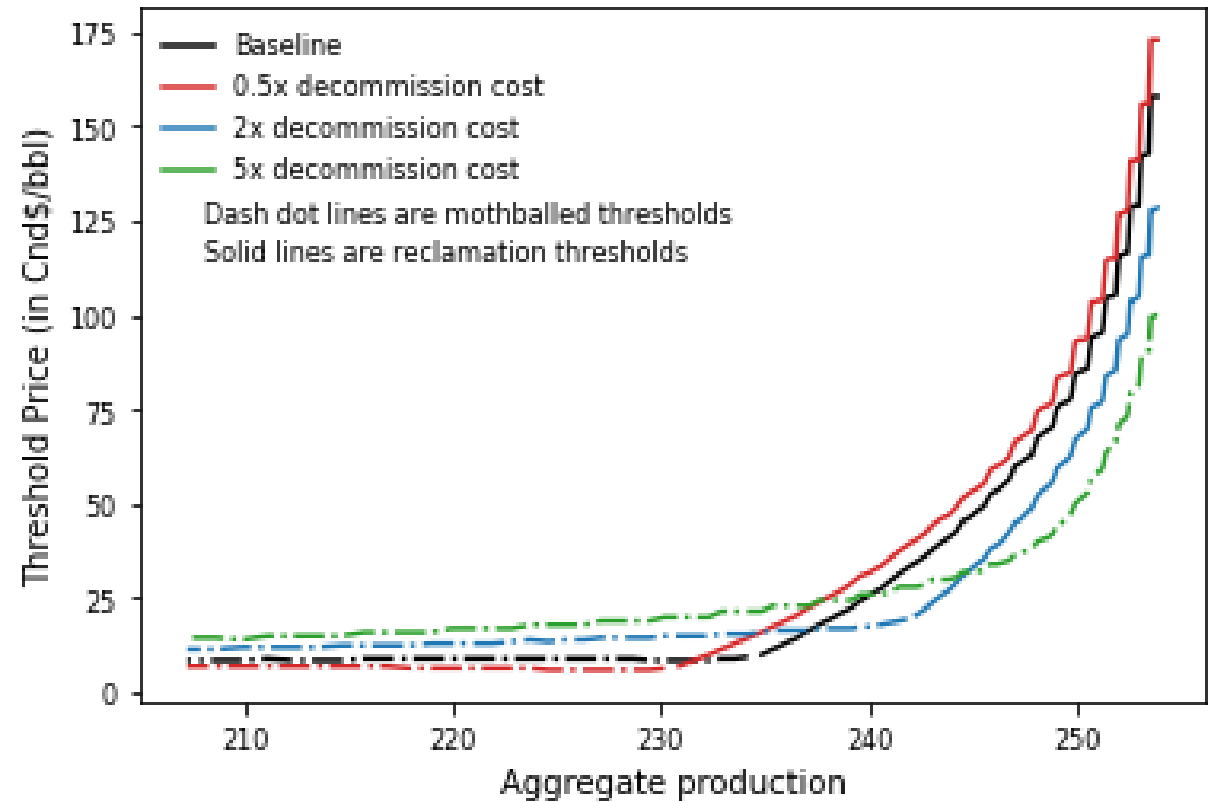
Horizontal well	Baseline Cost	0.5x	2x	5x
Decommission cost	124,403	62,201	248,806	622,015
Reclamation cost	25,914	N/A	51,828	129,570

DECOMMISSIONING COSTS

Low-price regime

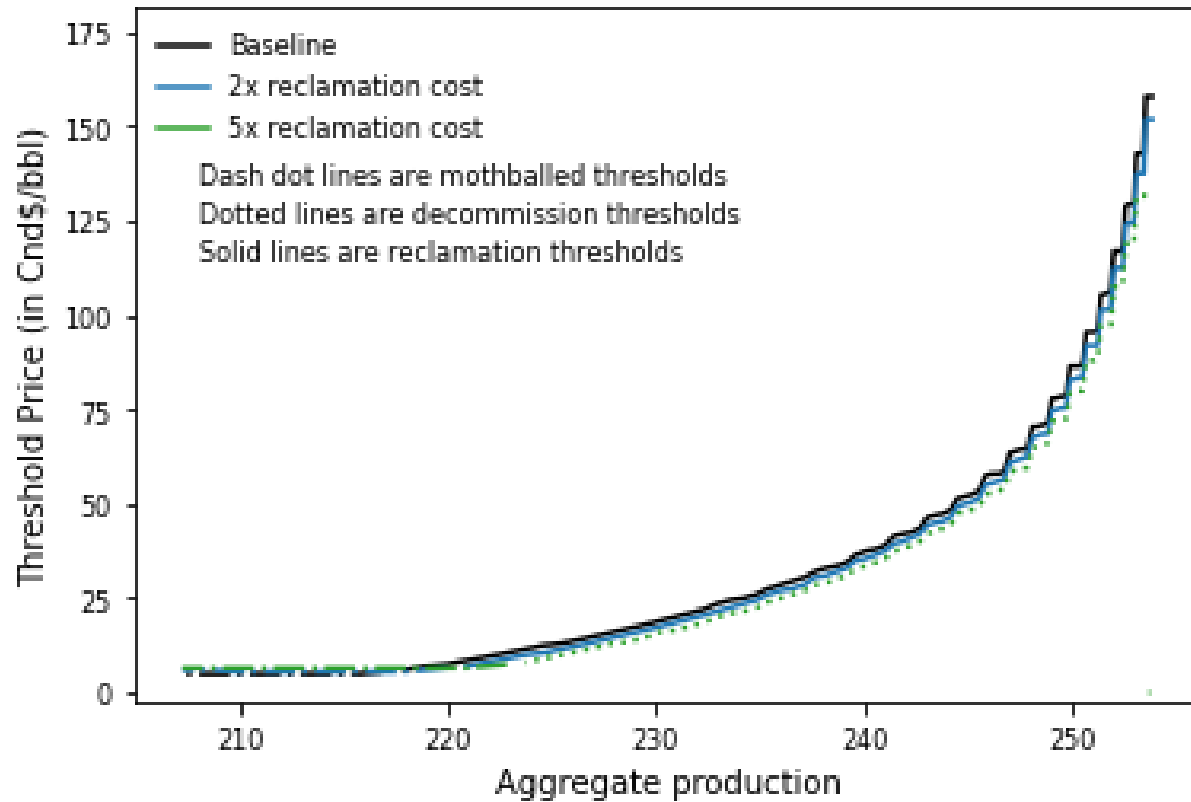


High-price regime

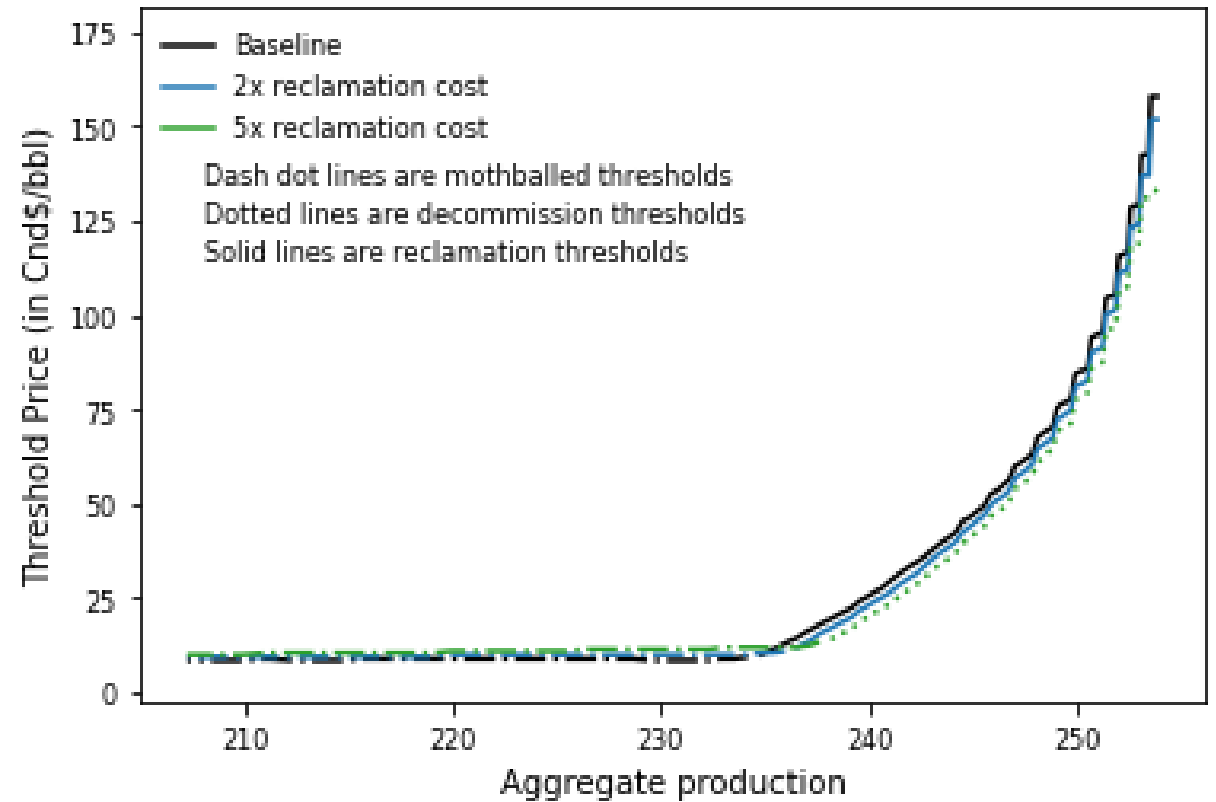


RECLAMATION COSTS

Low-price regime



High-price regime

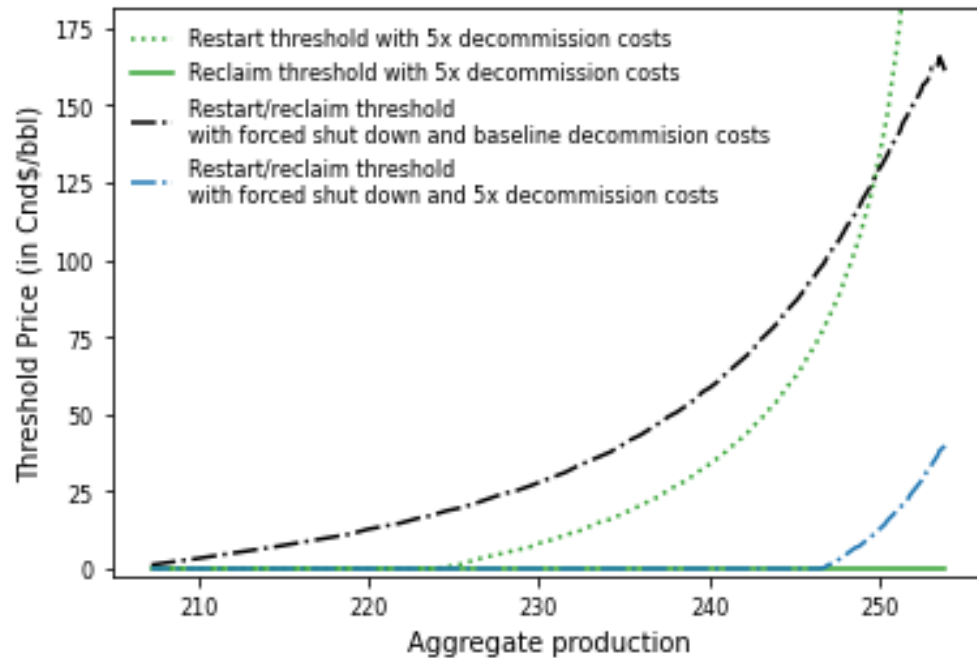


FIRMS ARE FORCED TO CLEAN UP AFTER A PERIOD OF INACTIVITY

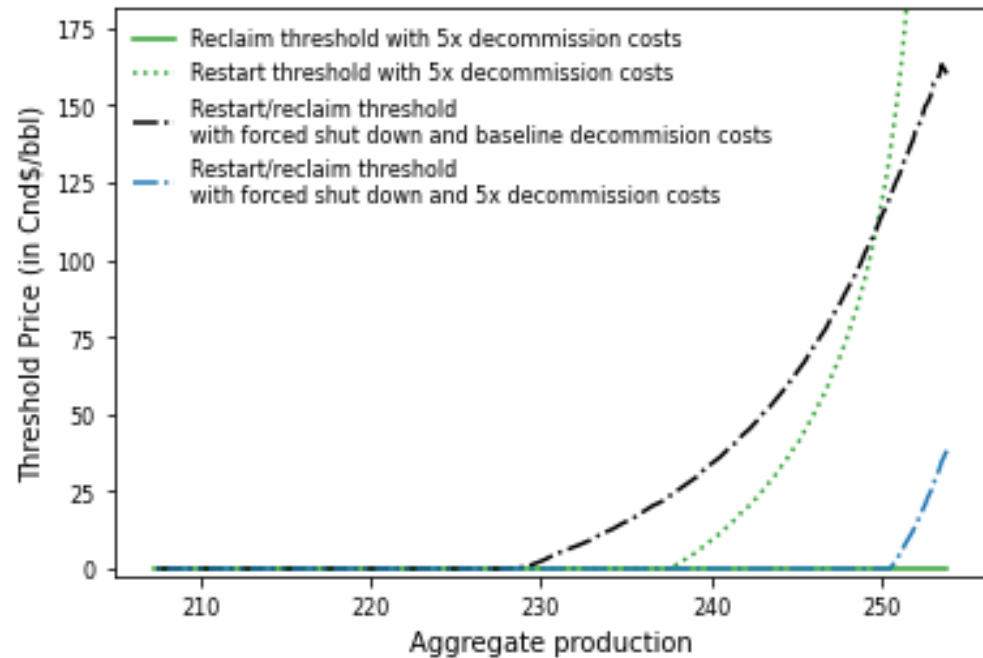
- We have assumed firms would reclaim when reserves are exhausted but they can remain mothballed or decommissioned if there are some reserves remain
- We now impose a limit on how long a well can be mothballed or decommissioned before it has to restart production or be reclaim

WELLS CAN BE INACTIVE FOR 10 YEARS

Low-price regime



High-price regime



How to interpret the figures

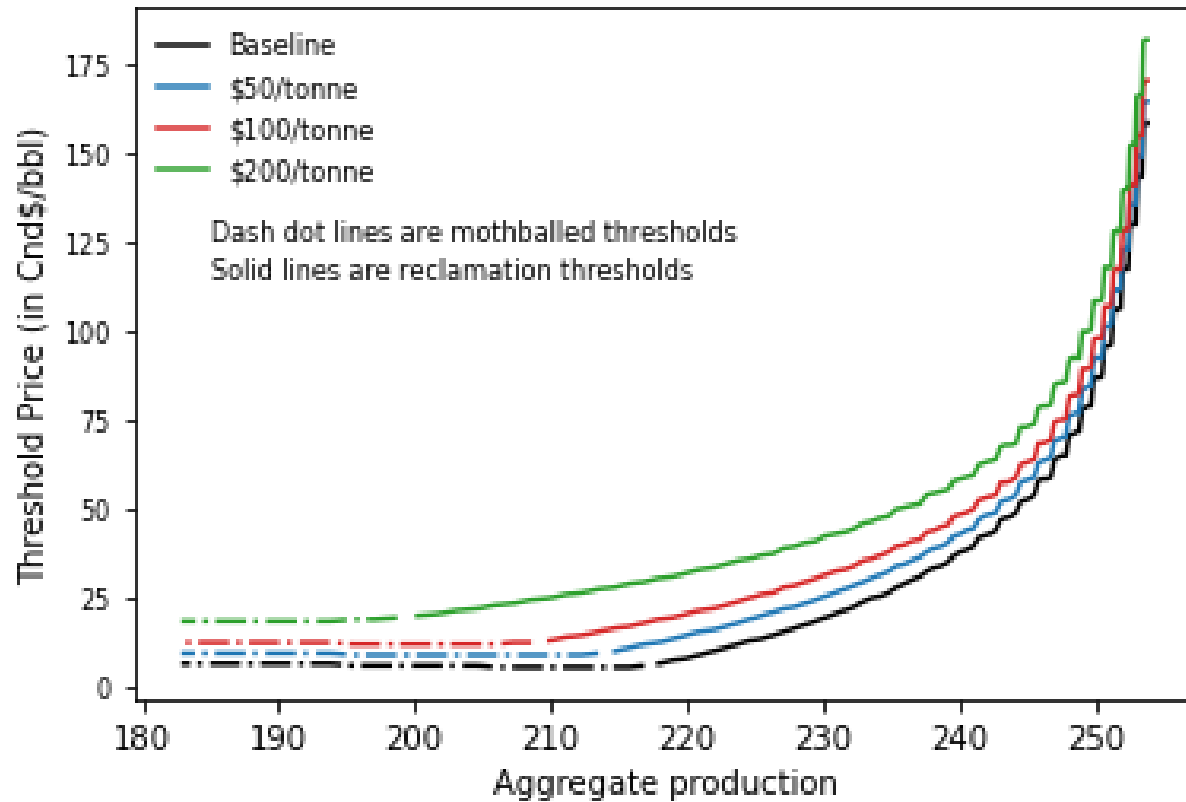
- The lines show what the firm would do at the end of 10 years if the oil well is mothballed

INTRODUCE A CARBON PRICE

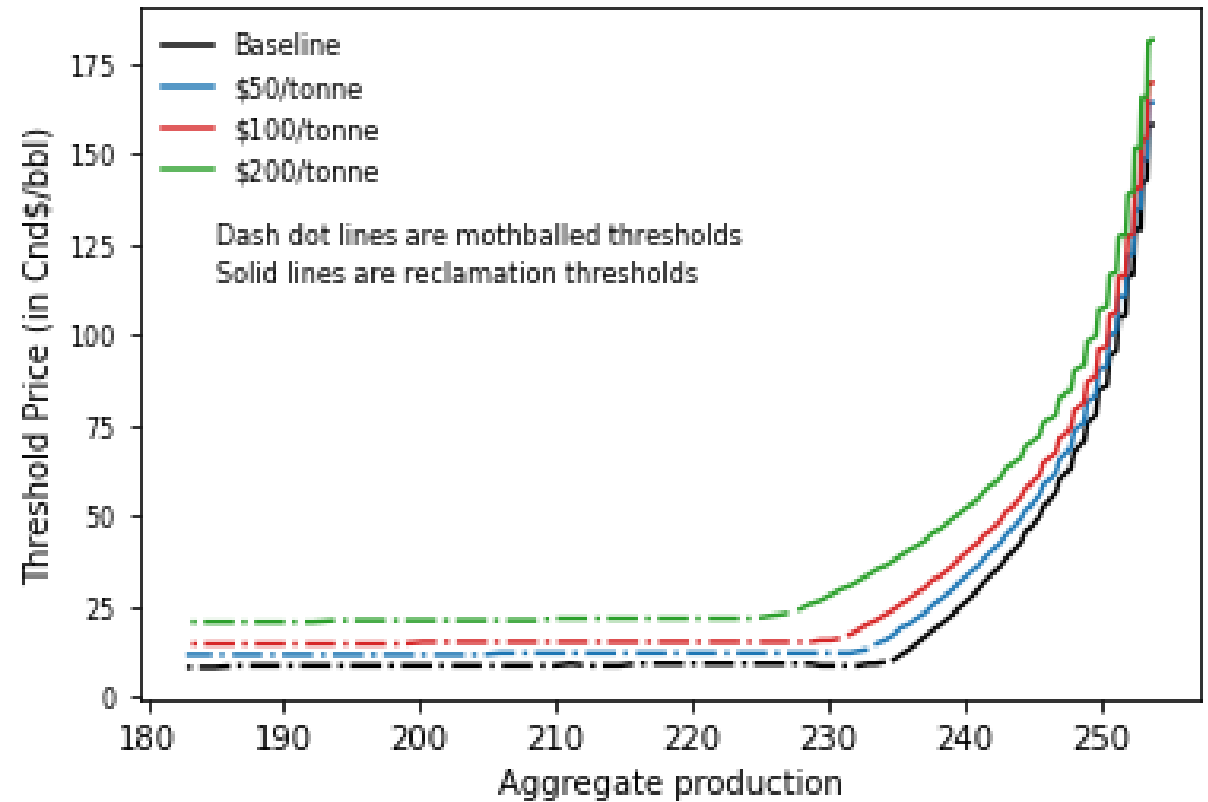
- Introduce a carbon price that the firm must pay.
- Price of carbon is constant over the life of the well.
 - We vary the price from \$50/per tonne to \$200/per tonne.
- Carbon intensity increases as reserves are depleted.
 - Ranges from 0.05 tCO₂/bbl to 0.12 tCO₂/bbl.

IMPACT OF A CARBON PRICE

Low-price regime



High-price regime

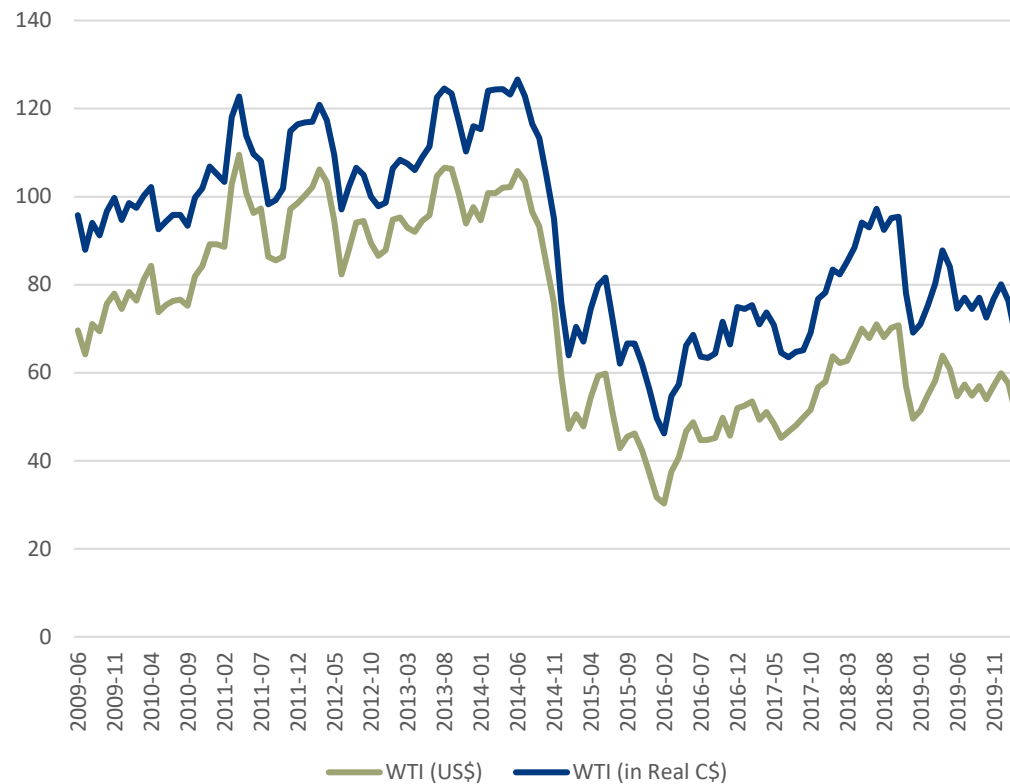


CONCLUSIONS

- Our typical oil wells (both horizontal and vertical) extracts nearly all of the reserves and is reclaimed regardless of the price regime
 - The number of years of production for oil wells that have been reclaimed is 12.6
- Not surprisingly, the introduction of a carbon price result in oil wells being shut down earlier but decline in aggregate production is small
 - We would expect anything that increases production costs to result in earlier shutting down earlier as profitability decreases
 - However, it will not have an impact on whether or not the well is reclaimed or not
- High reclamation costs and no clear requirements about when to reclaim results in wells being left mothballed or decommissioned
 - This could be the reason so many O&G wells are not being reclaimed, the ongoing cost of being mothballed or decommissioned are less than the costs of reclamation
 - A potential implication could be that, if reclamation costs are correlated with environmental risk, low risk wells are reclaimed but high risk wells are not

APPENDIX: SUPPLEMENTARY SLIDES

OIL PRICE ASSUMPTIONS



- Oil prices follow a mean reverting process.
 - $dP = \eta(\bar{P} - P)dt + \sigma dZ$
- There are two regimes for oil price: low and high.
- WTI was converted into real Canadian dollars.

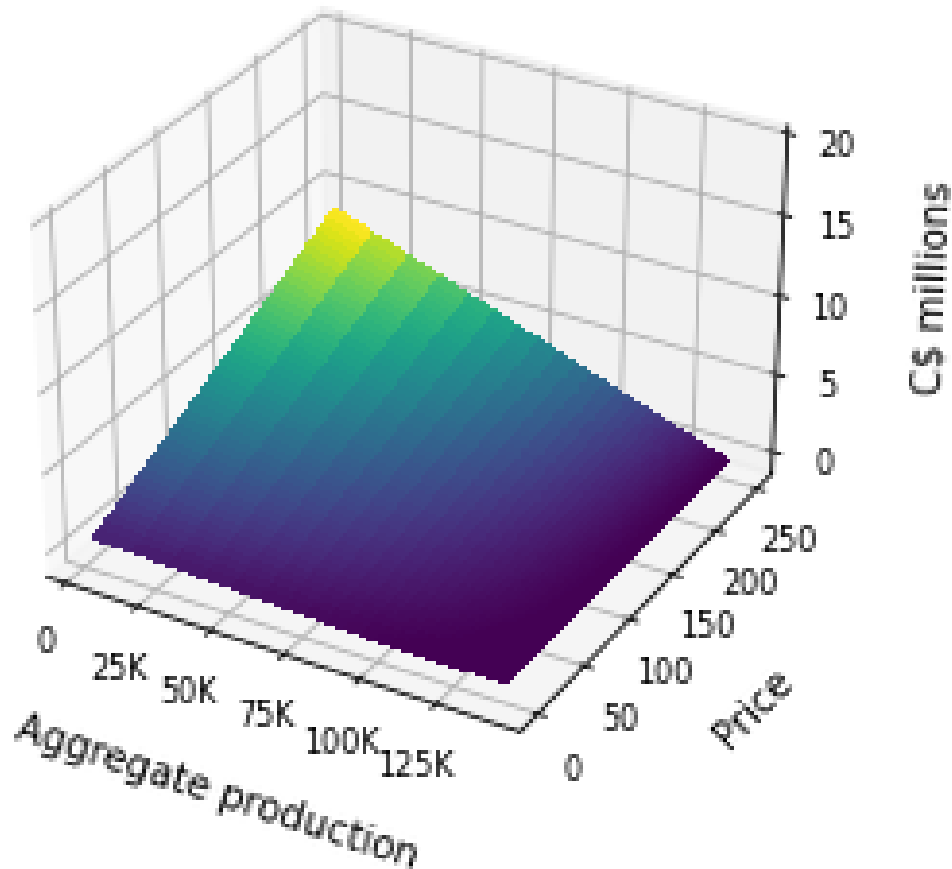
Parameters	Low price regime	High price regime
Average Price	72.49	107.56
Speed of Reversion	0.142	0.152
Half life	4.88 years	4.46 years
Standard Deviation	2.872	2.883

PRODUCTIVITY AND COST ASSUMPTIONS

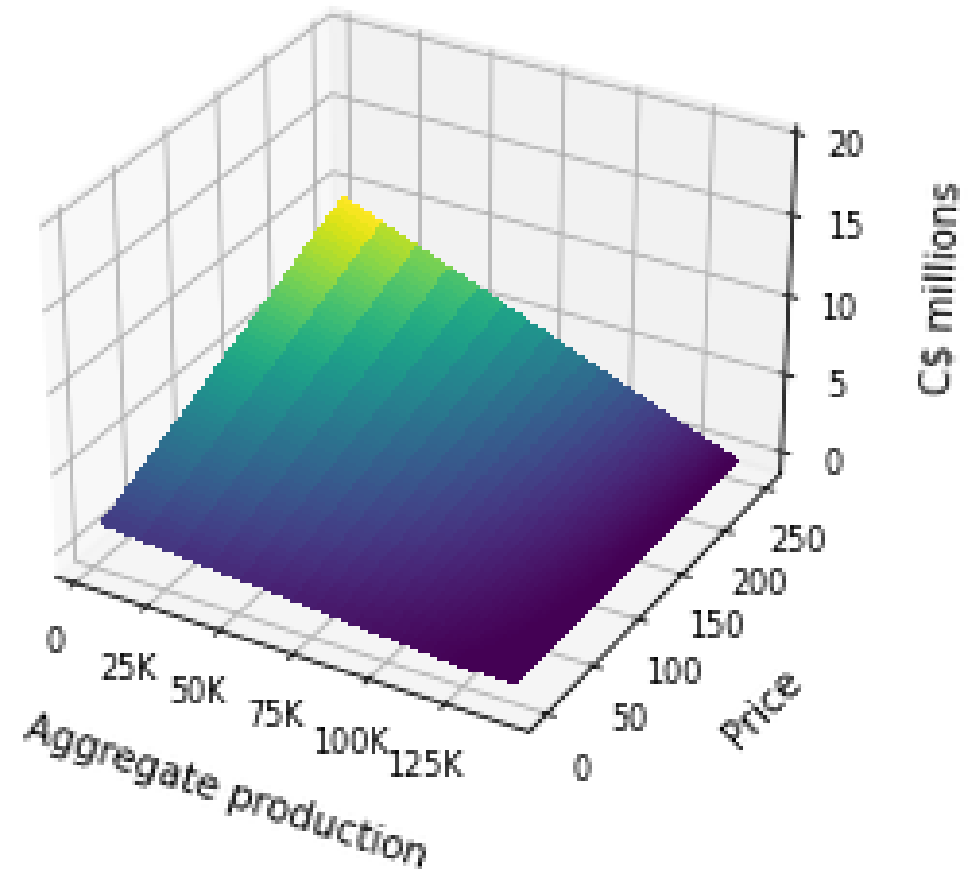
Parameter	Horizontal	Vertical	
Initial productivity (bbl/year)	25,765	14,406	Decline rate in productivity is 10% per year Income Taxes equal 23% Real discount rate is 10%
Variable cost (/bbl)	7.302	11.962	
Fixed cost (/year)	78,997	56,972	
Monitoring costs – Mothballed (/year)	39,498.5	28,486	
Monitoring costs – Decommissioned (/year)	7,899.7	5,697.2	
Decommissioning cost	124,403	102,189	
Reclamation cost	25,914	26,184	

VALUE OF A VERTICAL OIL WELL

Low price regime

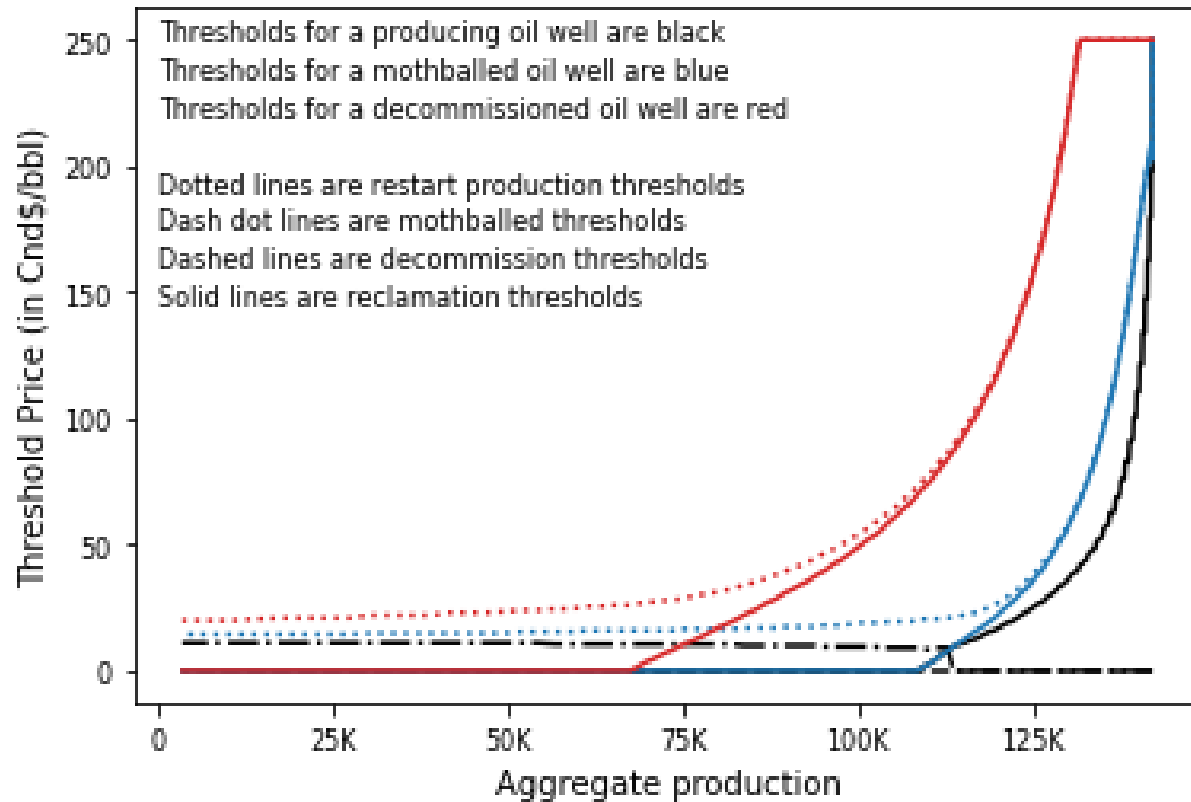


High price regime



DECISION THRESHOLDS VERTICAL OIL WELL

Low price regime



High price regime

