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How to Make the Oil Industry Go Bust

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Abstract
Can the oil industry afford to clean up its mess? If by 'mess' we mean fossil-fuel-induced climate change, the answer is almost certainly 'no'. But what if we look at a more limited cleanup scenario, restricted to the remediation of conventional oil and gas wells? Even then, it seems that the oil industry may already be bankrupt.

As a case study, this paper estimates the solvency of the (conventional) oilpatch in the Canadian province of Alberta. By law, Albertan oil companies are required to pay for well remediation. To date, however, the oil industry has saved little for this expense. Instead, it has assumed that future oil production will pay for existing cleanup liabilities. But will it?

Using cleanup estimates from the Alberta Liabilities Disclosure Project, I estimate the past, present and future solvency of the (conventional) Alberta oil industry. I find that at present, the oilpatch sits on the precipice of insolvency.

The cost of doing business

Environmentalists often argue that if we accounted for the 'true' costs of the fossil-fuel business, the industry would go bankrupt. While I understand this sentiment, I think the idea of 'true' costs is dubious. Costs exist not because they are 'true', but because someone has the power to enforce them. That's why Apple can impose a 30% commission on everything in its app store (Perez, 2020). It has the power to do so.

Back to fossil fuels. Yes, we should make fossil-fuel companies pay for the damage they have wrought. But since doing so will involve a messy power struggle, we need to be pragmatic. On that front, here's a clever option: look for under-enforced legislation that if fully enforced, would make the fossil-fuel business go bankrupt. True, this type of law sounds far-fetched. But it's actually quite common. Here's why.

When fossil-fuel companies extract resources, they are usually required to cleanup their (local) mess. For example, when an oil company drains a well, it's supposed to plug the hole and return the well site to its original condition. Since this cleanup is a legal obligation, you'd think that oil companies — being law-abiding corporate citizens — would have been diligently cleaning up their defunct wells. But for the most part, they let these obligations slide.[1] And so their cleanup liabilities have slowly accumulated.

[1] To avoid their cleanup responsibility, oil companies employ a variety of tactics. The most basic is to simply *delay*. This strategy works because oil companies get to choose when a well is 'done'. Much like when you drink water through a straw, when you pump oil from a well, there are always dregs left over. If you want to delay paying for cleanup, you simply keep the 'straw' open, claiming there are a few more sips of oil to be had.

For years, researcher and activist Regan Boychuk has been watching this crisis unfold (Boychuk, 2010; Boychuk, Anielski, Snow, & Stelfox, 2021). A resident of the oil-rich province of Alberta (Canada), Boychuk is one of the few people paying attention to the oil industry's growing cleanup liabilities. He thinks the procrastination strategy is nearing its end game. If current cleanup liabilities were called in, Boychuk suspects that the oil industry couldn't cover them — not even if it drained every existing well. In other words, Alberta's conventional[2] oil business is *bankrupt*.

Now, you would think that for government regulators, the oil industry's impending bankruptcy would be top of mind. But in Alberta, the regulator is asleep at the wheel. (It's an industry lapdog.) And so Boychuk set out to measure the oil industry's solvency himself. An intrepid muckraker, he acquired the necessary data. But he needed someone to crunch the numbers.

That's where I come in.

Last year, Boychuk asked me if I wanted to join his project, and I immediately said yes. (I grew up in Alberta, so this issue is close to home for me.) This paper is the second entry in our ongoing collaboration. The first piece (Fix, 2022), took a deep dive into Alberta's production of (conventional) oil and gas. In this piece, I'm going to build on that research to analyze the oil patch's solvency.

Speaking of (in)solvency, Boychuk's hunch seems to be correct. According to my estimates, Alberta's (conventional) oil industry now sits on the precipice of bankruptcy. If the government called in the outstanding cleanup liabilities, the oil patch would probably go bust.
And that brings me back to 'true' costs. To bankrupt the oil business, we don't need an expansive new cost framework. By letting its cleanup liabilities pile up, the oil industry has dug its own grave. Now we just need to push it in.

The Alberta oil patch: A brief history

The province of Alberta is a unique place. It sits on the Western edge of the Great Plains — the point where bald prairie gives way to the majestic Rocky Mountains. If we could pick up this landscape and look beneath it, we would see something equally breathtaking. Below Alberta lies a vast web of porous rock containing one of the world's great deposits of oil.

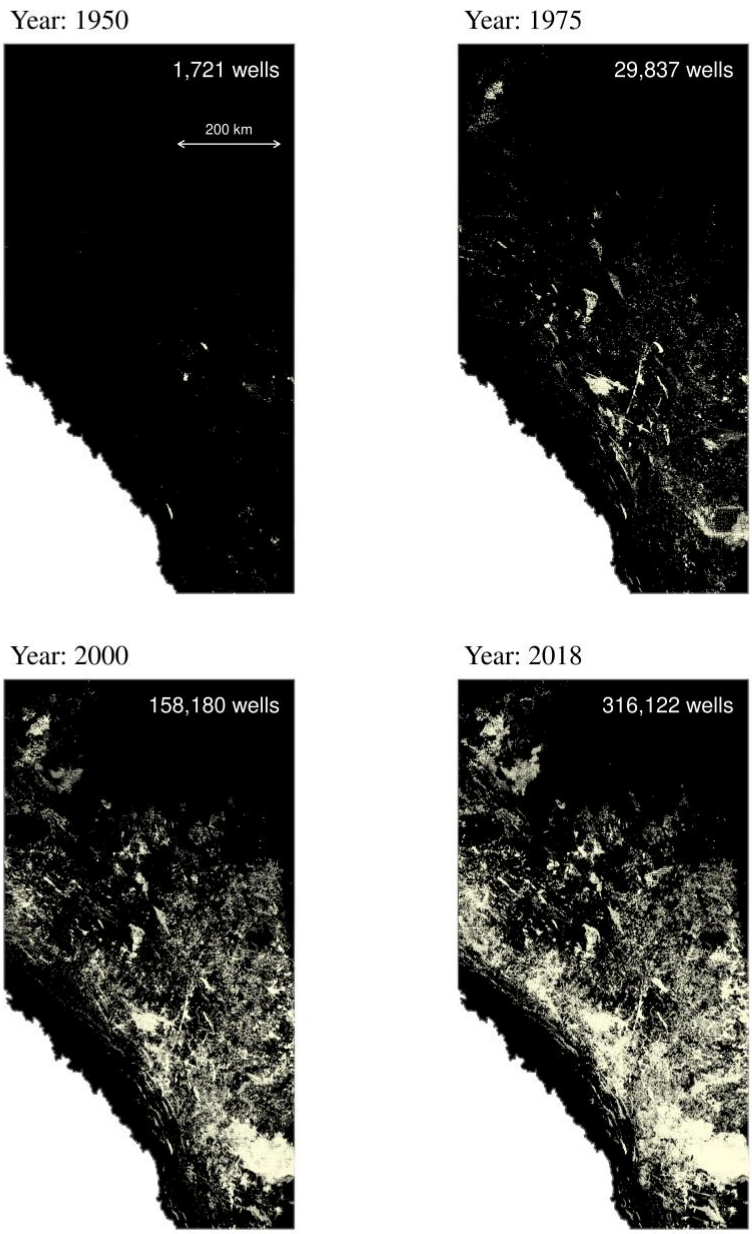
Another tactic is to use creative accounting to get fallow wells off the books. A tried-and-true method is to bundle your defunct wells and sell them to a shell company whose purpose is to do one thing: go bankrupt. Seriously, this happens.

For example, in 2016, Calgary-based oil company Perpetual Energy came up with a clever scheme to get its cleanup liabilities off the books. It took thousands of defunct natural gas wells and lumped them into a bundle of what it called 'mature legacy assets'. Then it created a shell company, Sequoia Resources, which purchased these 'assets' for the price of $1. (Yes, $1 for the whole lot.) A year later, the shell company went belly up, freeing Perpetual of its cleanup debt. In the legal proceedings that followed, we learned that roughly $87 million in cleanup liability was at play (Paperny, Watson, & Frans, 2021).

[2] The term 'conventional' refers to oil and gas that flows from (non-fracked) wells, as opposed to oil from sources like shale deposits or oil sands. Alberta is an interesting case because it has major deposits of conventional oil, but also a monumental reserve of non-conventional bitumen in the Athabasca oil sands. Today, the conventional oil patch is waning, but the exploitation of the oil sands is still accelerating. My analysis here refers only to the 'conventional' oil patch.

Over the last century, Albertans have built a massive web of infrastructure designed to suck this oil and gas from the Earth's depths. Thousands upon thousands of wells have been drilled. If each one of these wells had a bright light on its top, Alberta's nighttime landscape would glow like a bustling metropolis. Figure 1 shows how this satellite view would have evolved.

Figure 1: Illuminating Alberta's oil patch.
This figure imagines what Alberta's nighttime landscape would look like if each oil-and-gas well had a bright light on its top. From 1950 onward, a burgeoning metropolis of wells sprawls across the land. For more details about the data, see the Sources and methods.



From high above, there is a terrible beauty to Alberta's oil-and-gas sprawl. But when we zoom in on the oil business, the picture grows less serene. As you can imagine, drilling for oil is not the cleanest of activities. Figure 2 shows a particularly dirty example — oil leaking from a storage tank east of Calgary.

Figure 2: An oil spill on a well site east of Calgary.
This was the scene in 2016 at an oil well operated by Lexin Resources. The photo was taken by landowner Jim Robins (from Boychuk, 2017).

Because oil companies make a mess when they drill, it's only fair that they clean it up. In Alberta, that's the law. When wells are done producing, they must be plugged, and their surrounding land returned to its original state.

Unfortunately, this responsibility is quite easy to avoid.

In Alberta, the problem has two parts. First, oil companies are responsible for saving for cleanup. (The government doesn't collect funds on their behalf.) Unsurprisingly, most companies save nothing. Second, well cleanup has no definite timeline, meaning companies can delay their responsibilities with little fear of punishment.[3] This strategy works because Alberta's energy regulator is (arguably) an arm of industry. It is 100% industry funded (AER, 2022) and its first board chair was an oil-industry lobbyist.[4]

With the regulator wrapped around its finger, the Alberta oil industry has the power to shirk its cleanup responsibilities … and so it does.

[3] Yes, there are exceptions. For example, the leaking storage tank shown in Figure 2 was operated by Lexin Resources — a company that had accumulated dozens of flagrant environmental violations. In 2017, Lexin was shutdown by the Alberta Energy Regulator (Johnson, 2017).

[4] When the government created the Alberta Energy Regulator in 2013, it appointed Gerry Protti as the board chair (Grandia, 2013). The trouble was, Protti happened to also be the founding president of the Canadian Association of Petroleum Producers — an industry lobby group. He was also the former executive vice-president of Encana, a major Canadian oil company. Critics likened the appointment to putting a fox in charge of the hen house.

Tallying the cleanup bill

After decades of avoiding its cleanup obligations, the Alberta oil industry has racked up an impressive tab. In a moment, I'll show you the bill. But first, let's look at the story behind the data.

Ideally, the Alberta government would maintain a public database to record the oil industry's outstanding cleanup liabilities. No such database exists. Instead, the Alberta Energy Regulator gives cagey estimates based on methods that are unclear. For that reason, Regan Boychuk has always doubted the government's official cleanup numbers. But he had no way of producing a better estimate.

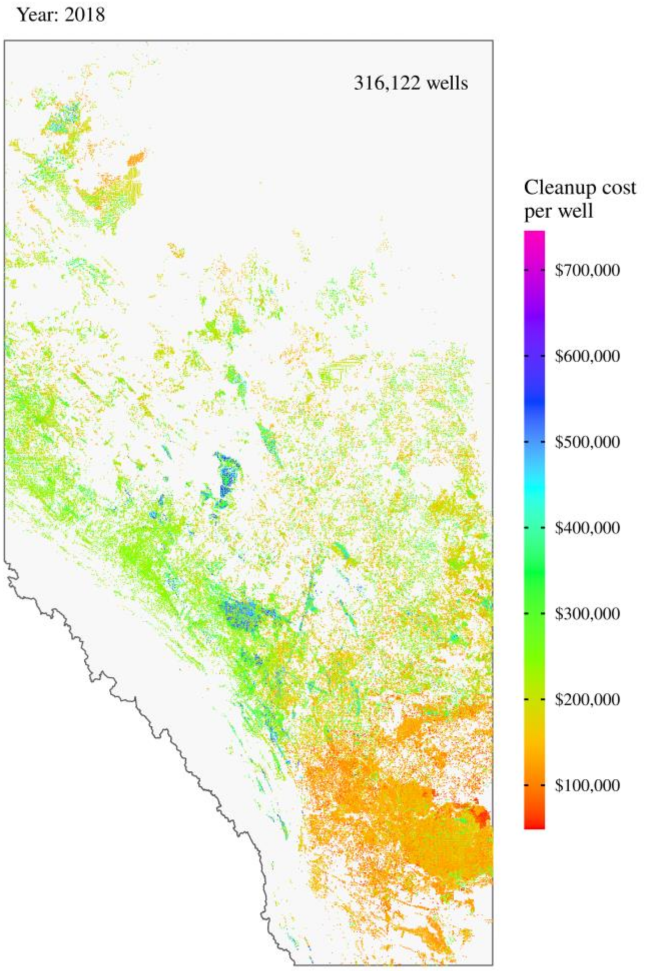
That changed in 2018. During a private presentation in February of that year, Robert Wadsworth — a VP with the Alberta Energy Regulator — revealed some stunning numbers. According to his estimates, the oil industry's cleanup liability was an order of magnitude larger than the regulator's official figure (De Souza, McIntosh, & Bruser, 2018). When news of these estimates made headlines, the government responded by throwing Wadsworth under the bus, claiming his numbers were an 'error in judgment' (Bellefontaine, 2018). His cleanup estimates were never published.

With Wadsworth's data suppressed, the story could have ended there … had Boychuk not been on the case. Luckily, Boychuk filed a freedom-of-information request to ensure that the cleanup estimates saw the light of day. When he got the data, he was floored by its detail. The government database included third-party estimates of a host of cleanup scenarios. And it detailed the features of each Alberta well — features that would affect the cost of remediation. Oddly, however, the government hadn't bothered to apply the cost scenarios to individual wells. Instead, it had come up with some hand-waving averages and called it a day.

And so Boychuk set out to do the job right. Over the next few years, he worked with the Alberta Liabilities Disclosure Project (ALDP) to create rigorous estimates of the Alberta oil industry's cleanup liabilities. They recently published their results in a report called 'The Big Cleanup' (Boychuk et al., 2021). The numbers are astonishing.

Figure 3 illustrates the scale of the problem. Here I've mapped the ALDP cleanup estimates for each well in Alberta (as of 2018). The cost per well ranges from a low of $100,000 to a high of $700,000. If we take these estimates and apply them to the over 300,000 unremediated wells, we have a massive liability. The total bill is between $40 to $80 billion.

Figure 3: A costly legacy.
This map shows the estimated cleanup costs of every conventional oil-and-gas well in Alberta, as of 2018. Each colored point represents a single well. The estimated cleanup cost is shown in color. For more details about the data, see the Sources and methods.



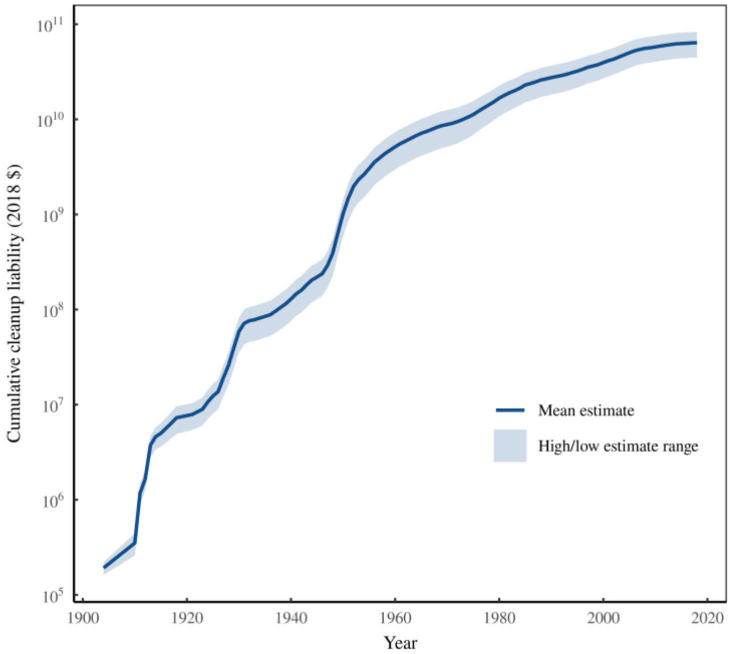
Looking at this billion-dollar liability, you have to wonder — can the oil business afford to pay it off? On that front, what ultimately matters isn't the bill's total size, but how it has (not) been financed.

For example, throughout my lifetime, I will probably spend hundreds of thousands of dollars on groceries.[5] If that bill came due all at once, I'd struggle to pay it. But when administered in small (weekly) doses, I find a way to finance my groceries. I have no other choice.

In Alberta, the oil patch's cumulative cleanup bill is like a grocery tab built up over a lifetime. When you look at the final tally, it's shockingly large. But the bill accrued in small doses. Figure 4 illustrates how it happened. Here, the blue line shows the oil industry's growing cleanup liability, tallied in 2018 dollars. (Note that the vertical axis uses a log scale.)

[5] Suppose you spend $100 per week on food. After 80 years, your grocery tab would be $416,000.

Figure 4: Accumulating a century's worth of cleanup liabilities.
This figure plots the growth of the Alberta oil sector's cumulative cleanup bill, measured in constant 2018 dollars. The blue line shows the mean estimate. The shaded region shows the range for the high/low estimates. Note that the vertical axis uses a logarithmic scale. Moving up the scale, each tick mark indicates that cleanup costs have increased by a factor of 10. For more details about the data, see the Sources and methods.



As of 2018, the oil industry's cleanup liabilities stood somewhere between $40 to $80 billion — a hefty chunk of cash. Surprisingly, most companies haven't saved a dime for this expense. Worse still, their reserves of oil are dwindling, meaning revenues are headed south. So here's the question: how do you finance a growing liability with a diminishing income?

The answer is, you don't. As we'll see, my analysis suggests that the Alberta oil patch is on the verge of insolvency.

To arrive at this end game, we'll take a meandering path. We'll first look under the hood of the oil industry's revenue pump and measure its production of oil and gas. Then we'll use this production data to estimate how much revenue the oil industry raked in throughout its history. As you'll see, it was more than enough money to foot the cleanup bill. Finally, we'll visit real-world Alberta, where the oil business decided to finance cleanup costs using magical thinking. Today, the illusion is about to die.

The revenue pump

Although the logistics of resource extraction can be complex, the oil industry's business model is surprisingly simple. It drills holes in the ground and sells what comes out. In other words, an oil company's revenue depends on two things:

1. the quantity of oil and gas it produces;
2. the price of this oil and gas.

Putting this thinking into an equation, we get the following revenue formula:

$$\text{Revenue} = (\text{Quantity of oil and gas}) \times (\text{oil-and-gas price})$$

To measure revenue, we obviously need to measure both of its components — oil-and-gas production and oil-and-gas prices. And because we're interested in the oil industry's solvency, we need to estimate these components both in the past (which is easy) and in the future (which is harder).

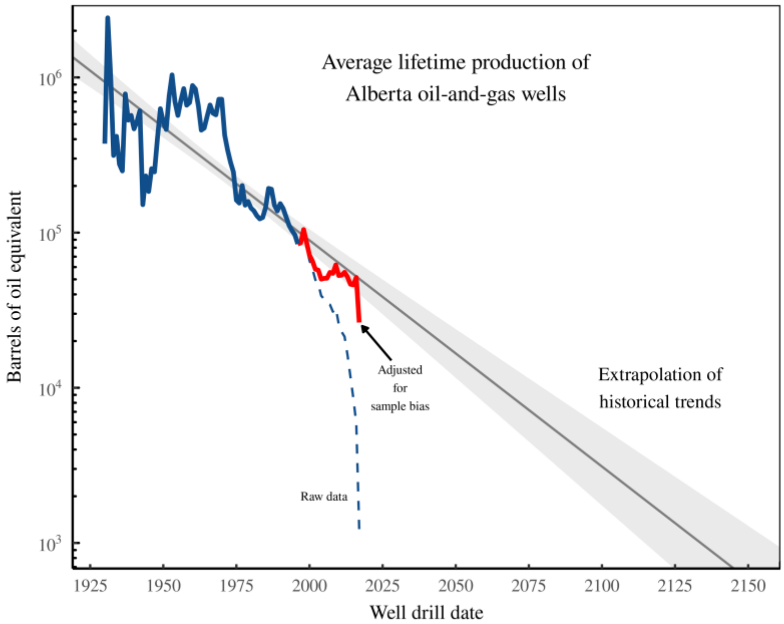
Looking to the future, here's my approach.

Let's start with *prices*. Despite what some analysts claim, no one knows what future oil prices will be … at least not in nominal terms. Yes, we can constrain the price of oil relative to people's income. (For a discussion, see Fix, 2020.) But that doesn't help us predict its nominal price. So when judging the oil industry's future revenue, the best we can do is guess a range of prices that seems plausible. On that front, I'm going to assume oil and gas sells for somewhere between $5 per barrel of oil equivalent (BOE) to $500 per BOE. Note that these values more than cover the historical price range. (See Figure 13 for details.)

Let's move on to the *quantity* of oil and gas produced. Unlike prices (which are a social construct), oil and gas is a non-renewable resource, which means that its extraction follows predictable patterns. As a biological rule, no animal does more work than it must. And so if there is a choice between hard-to-get resources and easy-to-get resources, animals will go for the latter. It's only once the easy stuff is gone that organisms move on to the hard-to-get-stuff.
Humans are no exception to this rule. When it comes to our exploitation of oil and gas, we tap the biggest reserves first. After these reserves are exhausted, we tap the smaller ones. Eventually, there is nothing left but 'puddles'.

Figure 5 illustrates this pattern in Alberta. Here I've plotted the average lifetime production of oil-and-gas wells. Notice how this production declines with time — a nice illustration of our tendency to tap the biggest resources first. During the 1950s, the average well produced the equivalent about one million barrels of oil over its lifespan. Today, that value has fallen by more than an order of magnitude.

Figure 5: The declining lifetime production of Alberta's oil-and-gas wells.
This figure analyzes the lifetime production of Alberta oil-and-gas wells that were, as of 2018, either abandoned or suspended. The blue line (both solid and dashed) shows estimates from raw data. The problem with this raw data is that it becomes biased as we approach the present. By looking only at abandoned/suspended wells, we are selecting wells with the smallest reserve (while those with a larger reserve remain active). The red line shows my attempt to correct for this selection bias. The grey line shows an extrapolation using an exponential fit to historical trends. For details, see the appendix in Fix (2022).

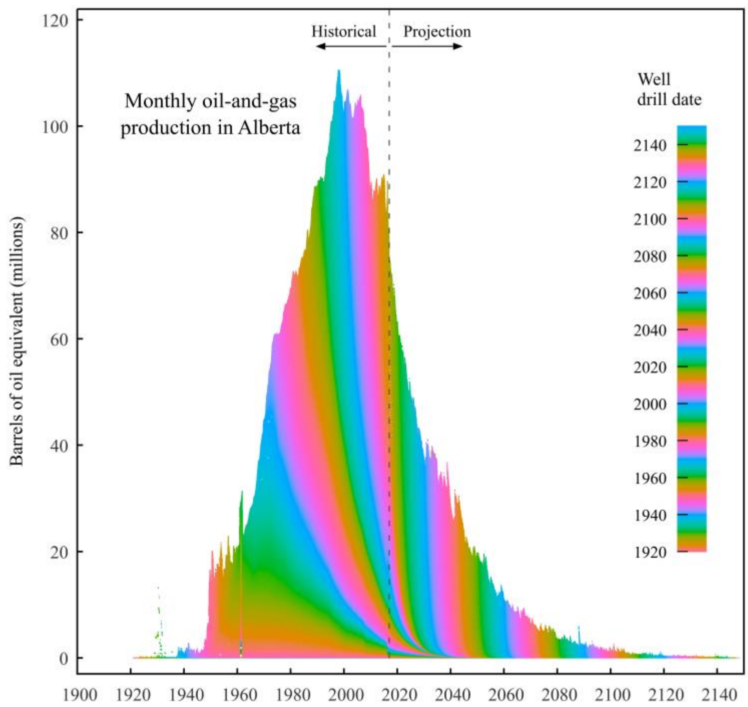


Because oil is a finite resource, we expect that the trend in Figure 5 will continue. After all, once the big reserves are gone, they don't come back. So it's inevitable that, on average, new wells will produce less oil than older ones. Extrapolating this pattern into the future gives us the grey line — a grim prediction of how per-well production will decline over the coming century. By the early 2100s, we predict that the average Alberta well will produce less than 1000 barrels of oil equivalent during its lifetime.

'So what?' you say. Even if per-well production declines, oil companies can counteract the problem by drilling more wells. Yes they can. And historically, that is exactly what oil companies have done. Unfortunately, this strategy solves one problem by creating another. You see, when you drill more wells, you incur more cleanup liabilities … on wells that will themselves produce less oil. And so as you follow the 'drill, baby, drill' strategy, your finances inevitably worsen.
The lesson is this: if we want to understand the oil industry's (in)solvency, we need to model oil-and-gas production (both past and future) at the level of individual wells.

In a previous piece on Alberta oil (Fix, 2022), I developed a model that does exactly that — it resolves Alberta's oil production (past and possible future) down to the individual well. The model is based in part on the production trends shown in Figure 5. I won't review the details here. Instead, I'll cut to the results, shown in Figure 6. Here I've plotted Alberta's monthly production of conventional oil and gas, with color indicating the contribution of individual wells (organized by drill date). The data prior to 2017 is historical. Afterwards, I've used my model to project oil-and-gas production into the future.

Figure 6: Alberta's production of conventional oil and gas — past and possible future.
This figure plots monthly oil-and-gas production in Alberta, resolved to the individual well. The color contours show the production profile as a function of well drill date. Data before 2017 is historical. Data after 2017 is a projection based on an extrapolation of the trends in the empirical data. For more details, see Fix (2022).



Looking at the contours in Figure 6, we can see the well-level trends in action. Over time, the production contours become steeper, indicating that newer wells are exhausted faster than older wells — a pattern that happens almost from day one. But because more wells are drilled, total production does not decline … for a while. Eventually, however, the pace of drilling slows, and production starts to collapse.

If cleanup liabilities are to be funded from future oil-and-gas revenue, this pattern spells disaster. And yet the bankruptcy endgame was not inevitable. As we'll see, the Alberta oil industry had more than enough revenue to cover its cleanup bill. To meet its cleanup obligations, it merely had to save some of its profits.

The Anti Norway

The idea that Alberta oil companies have saved nothing for their cleanup liabilities seems strange … until you understand Alberta's politics. On that front, let's defer to the inimitable Stephen Harper. In 1997, Harper described Canada as "a northern European welfare state in the worst sense of the term" (Mallick, 2015). Unsurprisingly, Harper was both an economist and former employee of Imperial Oil. In 2006, he became Canada's Prime Minister.

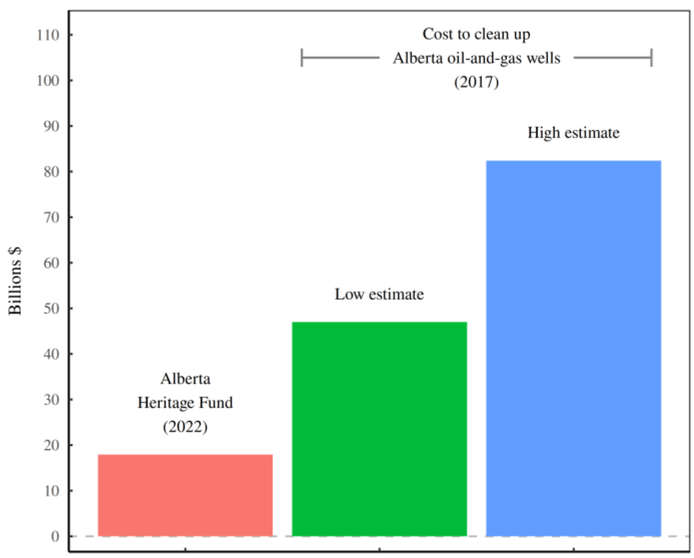
In his disparaging remarks, Harper was railing against 'wasteful' government programs like universal healthcare and public education. But had he described Alberta's regulation of the oil business, he would surely have sung a different tune. When it comes to the oil patch, it would be more accurate to call Alberta a 'North American corporate welfare state'. More specifically, it is the 'anti Norway'.

Like Alberta, Norway has grown rich from its reserves of oil. But unlike Alberta, the Norwegian government chose to *save* most of its oil money. Starting in 1990, it put its oil revenue into a national trust fund. Today, this fund is valued at over $1.2 trillion (NBIM, 2023). The lesson is simple: when we tally the revenue earned from oil and gas, the sum is gargantuan.[6]

Back to Alberta. To be fair, the province does have an oil-and-gas trust fund; it's called the Alberta Heritage Savings Trust Fund.[7] But unlike Norway's colossal trust, Alberta's heritage fund is quite modest. Some history: the heritage fund was created in 1976 by Premier Peter Lougheed with the intention to save 30% of Alberta's oil royalties. A decade later, however, Lougheed's plan was dismantled and trust-fund contributions were abolished. As a result, Alberta's heritage fund is today worth a mere $18 billion (Alberta, 2022).

Now, the phrase 'a mere $18 billion' may sound like an oxymoron. But in this case, the expression is appropriate. According to the government's internal data — data used by Regan Boychuk and the Alberta Liabilities Disclosure Project — the Alberta oil industry is on the hook for a cleanup tab that is between $40 to $80 billion. And unfortunately, the industry hasn't saved a dime. And although the Alberta government *has* saved money, its heritage fund is drowning in the oil-industry's liabilities. Figure 7 shows the water's depth.

Figure 7: The Alberta Heritage fund is smaller than the oil industry's cleanup tab.
The $18-billion heritage fund is what the Alberta government has managed to save from a half-century of oil-and-gas exploitation. Earmarked as 'rainy-day money', the fund is comparably small — less than the oil industry's outstanding cleanup liability. For more details about the data, see the Sources and methods.



[6] In addition to spending their oil revenues differently, Alberta and Norway have very different ways of collecting it. For details, see Wilt (2017).

[7] Alberta does have a cleanup fund of sorts. But it too is laughably small. It's called the 'Orphan Fund', an industry-sponsored plan that currently collects an annual levy of $70 million … for the whole Alberta oil sector (AER, 2021). At that rate, the Orphan Fund will have enough money to cover the oil-sector's present cleanup liability (on the order of $60 billion) in roughly 800 years.

The path untraveled

Clearly, Alberta and Norway took different approaches to managing their oil revenues. Norway used the 'welfare state' model, saving its oil revenue for the people. Alberta opted for the 'corporate welfare' model, sending most of its oil money to the private sector. The difference comes down to politics. On the political spectrum, Alberta is more like Texas than like Norway.

A century ago, however, Alberta was quite different. At the time, it had a budding social credit movement whose goal was to make money creation public by wresting the supply of credit from private banks (see Finkel, 1989 for details). In 1935, the Alberta Social Credit party even won a majority government. But soon after gaining power, the party's politics were co-opted by the flow of oil money. The Social Credit party eventually became a right-wing dynasty — staying in power until 1971.[8]

For arguments sake, let's suppose that history had played out differently. Imagine that Alberta's social credit movement had never died, and that the province remained a bastion of leftist politics. How might this counterfactual Alberta have funded its oil-and-gas cleanup? I think the answer is obvious. The government would have collected money from oil companies and put the funds into a cleanup trust. When wells ran dry, the province would use these funds to pay for remediation.

To investigate how this policy could have worked, let's return to Alberta's real-world accumulation of cleanup liabilities — the trend that I plotted in Figure 4. We're going to compare these growing cleanup costs to the oil industry's cumulative revenue. We'll imagine that *every dollar* of oil-and-gas income is dumped into a simple (interest free) savings account. Then we'll ask: how would this savings account grow with time? And would it cover the industry's growing cleanup liabilities?

To answer these questions, I'll use the oil-and-gas production data shown in Figure 6. (Remember that this data is partly historical and partly a projection.) Here's my method:

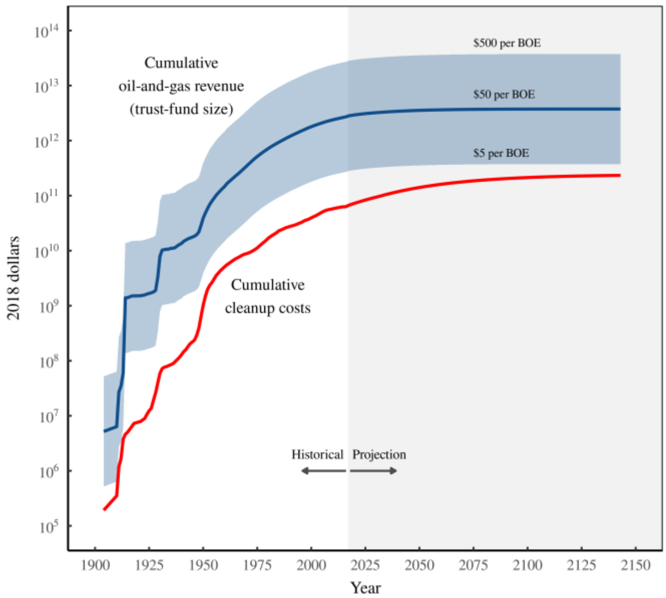
1. To calculate the size of our savings fund in a give year, I first sum the cumulative production of oil and gas up to that year.
2. I then multiply this cumulative production by a hypothetical price. To cover a wide range of scenarios, I'll assume that oil and gas varies between $5 per BOE (barrel of oil equivalent) and $500 per BOE, with a midpoint of $50 per BOE. (Note that these values generously cover the historical range of oil and gas prices. See Figure 13 for details.)

Using this method, Figure 8 shows how the oil industry's finances would have played out. The blue curve and shaded region show the size of the cleanup trust fund (measured in 2018 dollars, and assuming various prices of oil and gas).[9] The red curve shows the growth of cleanup liabilities.

[8] After losing power in 1971, the Social Credit party moved to the fringes. From 1982 onward, it failed to win any seats in the provincial legislature. In 2017, the party was renamed the Pro-Life Alberta Political Association, indicating its sole focus on the issue of abortion.

[9] My trust-fund calculation is what physicists would call a 'Fermi estimate'. By ignoring interest and inflation, I'm simplifying the real world to get a ballpark estimate of how much oil-and-gas revenue Alberta could have collected.

Figure 8: A counterfactual Alberta with a cleanup trust fund.
This figure imagines a counterfactual Alberta in which all oil revenues are dumped into a cleanup trust fund. The blue curves show the growth of this fund for various prices of oil and gas. (To create this curve, I use the oil-and-gas production data from Figure 6.) The red curve shows the growth of cumulative cleanup costs. Data prior to 2017 is based on historical oil-and-gas production. (Oil-and-gas prices are counterfactual.) Data beyond 2017 is based on projected oil-and-gas production. See Figure 6 for details. For more details about the data, see the Sources and methods.



Looking at Figure 8, we can see that our (counterfactual) trust fund grows faster than the oil industry's cleanup costs. That's good. It means that if the Alberta oil industry had planned ahead, it could have easily funded its own cleanup.

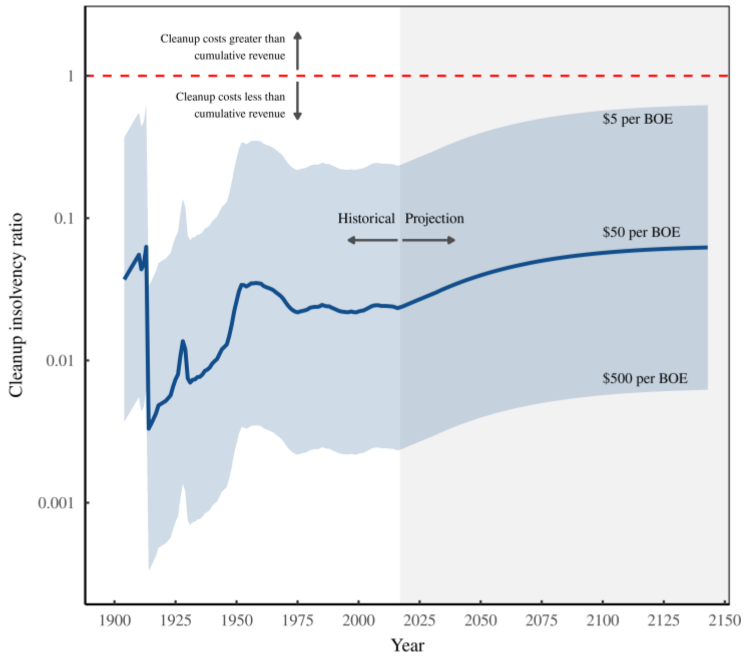
To dive into these finances further, we can calculate something that I call the 'cleanup insolvency ratio'. This is the ratio between the oil industry's cumulative cleanup liability and its cumulative revenue:

$$\text{cleanup insolvency ratio} = \frac{\text{cumulative cleanup liability}}{\text{cumulative oil-and-gas revenue}}$$

The cleanup insolvency ratio measures the oil industry's ability to fund its own cleanup. To avoid bankruptcy, the oil business must keep its insolvency ratio below one.

As Figure 9 illustrates, our counterfactual Alberta meets this criterion easily. Even for the low oil-and-gas price of $5 per BOE, the insolvency ratio remains below one. In other words, the oil industry is solvent for its entire lifespan.

Figure 9: The cleanup insolvency ratio in a counterfactual Alberta.
The cleanup insolvency ratio (blue line and shaded region) measures the oil industry's ability to finance its own cleanup. In this counterfactual scenario, the insolvency ratio divides the oil industry's cumulative cleanup costs by its cumulative revenue. When the insolvency ratio is less than one (i.e. below the dashed red line), the oil industry can afford to fund its own cleanup. Here, I calculate the insolvency ratio for various prices of oil and gas. Note that data prior to 2017 is based on historical oil-and-gas production. (Oil-and-gas prices are counterfactual.) Data beyond 2017 is based on projected oil-and-gas production. See Figure 6 for details. For more details about the data, see the Sources and methods.



With this thought experiment, we've shown that the Alberta oil industry made more than enough money to fund its own cleanup. To avoid the real-world crisis that it now faces, the industry merely needed to save some of its revenue. On that front, the insolvency ratio tells us the required savings rate. For example, if the insolvency ratio is 0.1, we know that cleanup costs represent 10% of cumulative revenue. Flipping things around, it follows that if the industry saved 10% of its revenue, it could finance its own cleanup.

Looking at Figure 9, we can see that the necessary savings rate depends on the price of oil and gas. As an example, suppose that oil and gas sells for a constant $50 per BOE. At that price, Alberta's cleanup insolvency ratio averages 0.04. In other words, the oil business could have funded its own cleanup by saving 4% of its revenue.

Now, Alberta's history shows that when oil companies are left to their own devices, they won't put this money away. Fortunately, we have things called *taxes* that allow governments to collect non-optional payments from citizens and businesses. For example, Canadian consumers pay a 5% federal sales tax on most purchases. Had the Alberta government applied the same tax rate to the oil business (and saved the resulting income), there would likely be no cleanup crisis.
To wrap up this counterfactual journey, my estimates confirm what you probably expected: the Alberta oil business has historically bathed in riches. If the industry had saved a small fraction of its revenue, the cleanup crisis wouldn't exist.

Funding cleanup with magical thinking

Back to real-world Alberta. Instead of choosing the tedious (but effective) method of saving for its looming cleanup, Alberta's oil industry opted for a more inventive approach; it appealed to magic.

Here's a step-by-step guide for how it works:

1. Drill a well.
2. Record the cleanup cost.
3. Put this liability aside and forget about it.
4. Drain the well and distribute the profit to shareholders. Save nothing.
5. Assume that future income will magically cover the cleanup costs.
6. Realize that your well has run dry and there is no future income.
7. Declare bankruptcy and (magically) walk away.

Now, I'm ridiculing this let-the-future-pay-for-cleanup funding model because at its core, it is ridiculous. Oil is a finite resource, which means that in the future, oil revenue will inevitably dwindle. When that happens, it becomes impossible to finance the cleanup liabilities for which you've saved nothing. In other words, the magic of this model is its appeal to *corporate bankruptcy*, which lets you magically wipe liabilities from the books. Over the long term, the let-the-future-pay-for-cleanup model is a catastrophe waiting to happen.

What's interesting, though, is that in the early days of oil exploration, this funding model seems to work. That's because when you continuously discover new oil reserves, your assets (future oil income) grow faster than your cleanup liabilities. So even though you've saved nothing to cover your cleanup costs, your finances look sound. The problem, of course, is that new discoveries eventually dry up. When they do, your finances head south.

Adding up the future

To track the oil industry's finances, we need to quantify the value of its future income. Now, this kind of valuation is something that investors do all the time. But we will *not* do what they do.

Investors start by assuming that today's income stream will continue indefinitely. So if a company averaged a million dollars of annual profit over the last few years, investors assume that the company will continue to receive this income forever. The problem with this assumption is that when you add up a perpetual income stream, you get a value that is infinite. That's no good. To sidestep the infinity, investors 'discount' the future. They look at income that will be received ten years from now and value it less than the same income earned tomorrow. By doing so, the investor converts an infinite stream of revenue into a finite present value.

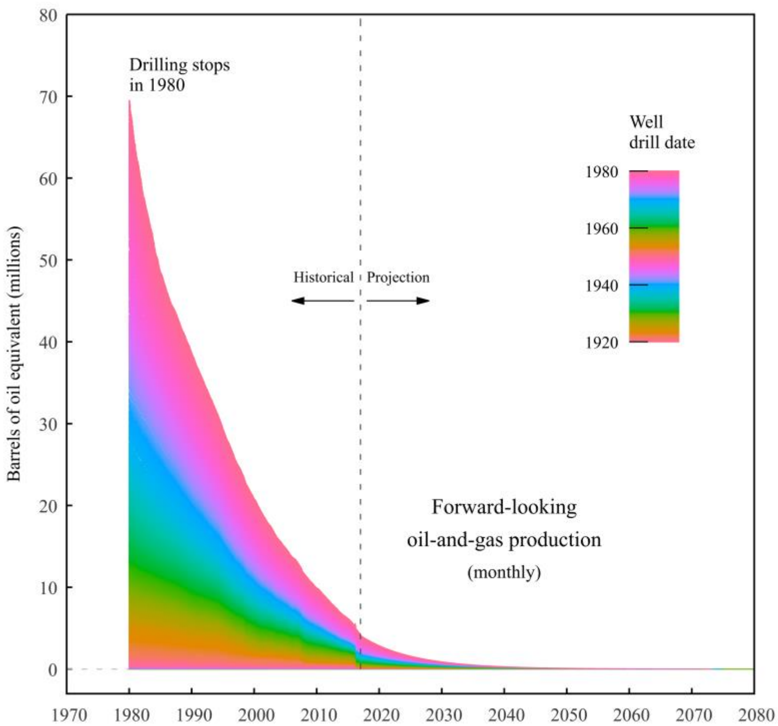
This practice is called 'capitalization', and it is *not* appropriate for valuing the future income of the oil industry.[10] That's because the oil business has an income stream that is decidedly non-perpetual. Oil companies sell a finite, non-renewable resource. So their future income is, by definition, finite. In other words, we (the analysts) don't need to discount the oil industry's revenue stream. Nature does that for us.

[10] Actually, capitalization is not appropriate for *any* scientific valuation. Capitalization is a ritual — part of the ideology of capitalism. For a detailed discussion, see Fix (2021).

Nature's discount rate is part of the dynamics of oil production. As you drain a well, its production tends to decline exponentially with time. This decline means that even if a well was operated forever, its cumulative production of oil will still be finite. (That's how the mathematics of exponential decay work.) So when calculating an oil company's future income, we simply need to observe the rate by which production is declining, and extrapolate this rate into the future. When we sum the resulting production, we're left with a finite quantity of oil — a finite quantity that serves as the oil industry's sole source of income. If we then multiply this quantity of oil by an assumed price, we've estimated the industry's total future income.

To see these exponential dynamics in action, let's turn to Figure 10. Here, I've imagined a counterfactual Alberta in which oil-and-gas drilling stops in 1980. Given this drilling moratorium, we then observe how oil-and-gas extraction would play out (as existing wells are drained). It's a future marked by continuous exponential decline. (Note that data prior to 2017 is historical. Data afterwards is a projection.)

Figure 10: Alberta's monthly production of oil and gas, supposing that drilling stopped in 1980.
This figure imagines a world in which the Alberta oil industry halts drilling in 1980, and then drains its existing wells. The color contour shows the monthly oil-and-gas production that would result. Production data is from the scenario shown in Figure 6. Data prior to 2017 is historical. Data after 2017 is a projection. For more details about the data, see the Sources and methods.



Now, in real-world Alberta, there was no drilling moratorium. Instead, oil companies drilled many more wells, which allowed them to produce much more oil than shown in Figure 10. So when considering the oil industry's future income, shouldn't we include the production from future wells?

When it comes to evaluating cleanup (in)solvency, the answer is *no*. That's because drilling more wells means incurring more cleanup liabilities. So it's not fair to compare the revenue from future wells to today's cleanup liabilities. The bottom line is that if the income from existing wells won't cover your outstanding cleanup costs, then drilling more wells will only make the problem worse.

Back to Figure 10. The area under the production curve represents the oil industry's biophysical assets as of 1980. By my estimates, it amounts to about 12.5 billion barrels of oil equivalent waiting to be extracted. To convert this biophysical quantity into a monetary value, we must assume some price of oil. Supposing that oil and gas sells for $50 per BOE, we find that as of 1980, the Alberta oil industry had about $625 billion of future income sitting in its existing wells.

As it happens, $625 billion was more than enough money to pay for the industry's cleanup liability. In 1980, that liability stood at $17 billion (measured in 2018 dollars). So here we see the initial appeal of the let-the-future-pay-for-cleanup funding model. In 1980, the Alberta oil industry had plenty of big reserves to exploit. So it had lots of future income to cover its existing cleanup liabilities. In short, had the oil business thrown in the towel in 1980, it would've had a cushy landing. It could have drained its existing wells, put a small portion of the resulting revenue towards well cleanup, and then pocketed the rest.

Of course, the Alberta oil industry did not throw in the towel. Instead, it kept drilling. By doing so, it slowly dug its own grave.

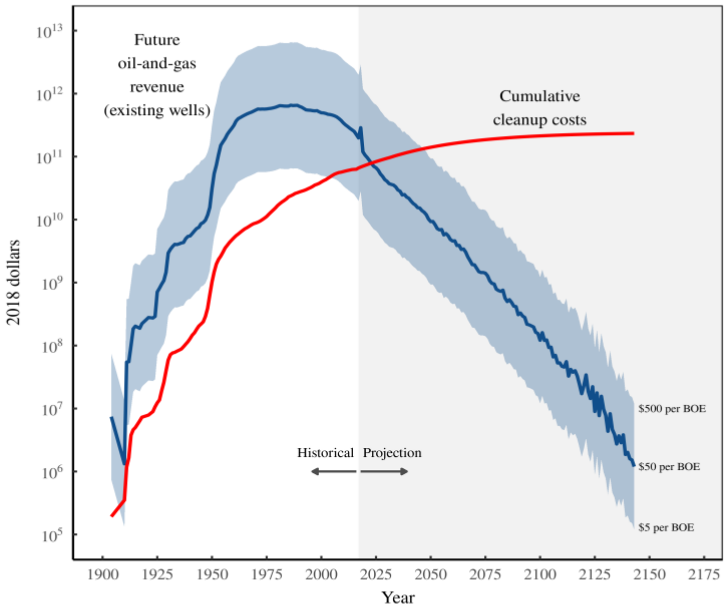
Drilling down to insolvency

We're now ready to look under the hood of the Alberta oil patch's finances. On that front, let's take a peek at Figure 11. What it shows is rather alarming.

Conceptually, this chart is similar to Figure 8, which as a reminder, analyzed the finances of a counterfactual Alberta that *saved* its past oil-and-gas revenue. The big difference with Figure 11 is that it's concerned with the oil industry's *future* income. Why? Because in real-world Alberta, past revenues have all been spent. The only option for funding well cleanup is to hope the future can pay for it.

On that front, this policy actually worked … for a while. In Figure 11, the blue line and shaded region show the Alberta oil industry's future income as a function of time (assuming various prices of oil and gas). Until the 1970s, future income actually grew *faster* than cleanup costs (which are shown in red). This pattern is expected — it's what happens when you discover big new reserves. But what's also expected is that as you exhaust these reserves, your fortunes will reverse. In Alberta, the U-turn took hold during the 1990s. At the time, the drilling pace remained furious, so cleanup liabilities kept piling up. But each new well sucked out less and less oil, meaning future income began to shrink. As a consequence, the oil industry's finances began to sprint south.

Figure 11: Alberta's let-the-future-pay-for-cleanup scheme worked … for a while.
This figure shows how Alberta's let-the-future-pay-for-cleanup funding model is playing out. The red curve shows the growth of cleanup liabilities, which accumulate as new wells are drilled and not cleaned up. The blue curve shows the assets that will pay for this cleanup — the industry's future income (assuming various prices of oil and gas). These estimates are based on the production scenario shown in Figure 6. Data prior to 2017 is based on historical oil-and-gas production. (Oil-and-gas prices are counterfactual.) Data beyond 2017 is based on projected oil-and-gas production. Note that since future income is forward looking, the dividing line between historical and projected revenue is fuzzy. For more details about the data, see the Sources and methods.



When we think through the let-the-future-pay-for-cleanup strategy, we can see that it's a game with only one end. At a certain point, cleanup liabilities become larger than future income. When that happens, the oil industry is sunk.

I suspect that government regulators know how this game works. But to the degree that they think about it, my guess is that regulators treat the oil industry's bankruptcy as a distant problem.
It is not.

Looking at Figure 12, we can see that the oil industry's cleanup costs surpass its future revenue right about now.

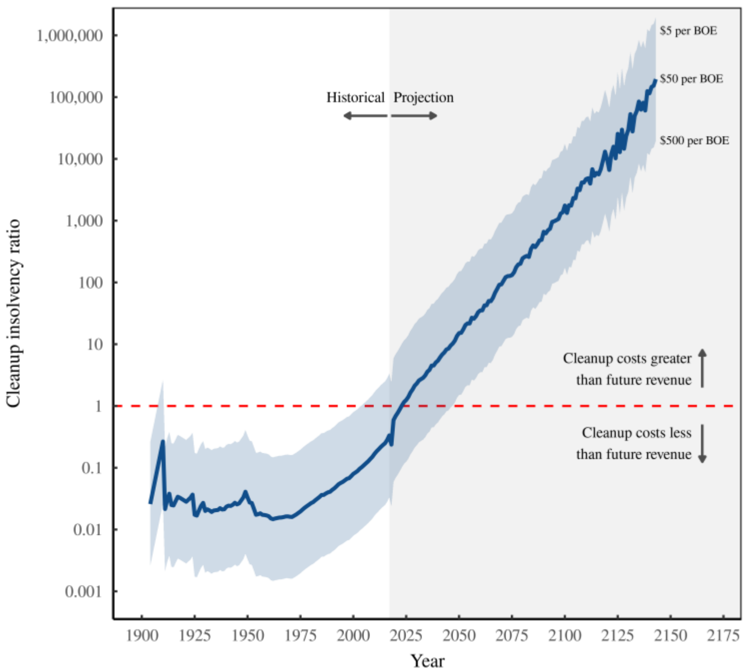
To show this timeline more clearly, let's return to the measure that I call the 'cleanup insolvency ratio'. This ratio takes the oil industry's cumulative cleanup liabilities and divides them by a measure of income. In my counterfactual example (Figure 9), that income came from *past* oil-and-gas revenue. But in real-world Alberta, cleanup costs are supposed to be covered by *future* oil-and-gas revenue. So the cleanup insolvency ratio becomes:

$$\text{cleanup insolvency ratio} = \frac{\text{cumulative cleanup liabilities}}{\text{future oil-and-gas revenue}}$$

As a reminder, the oil industry is solvent when the cleanup insolvency ratio is less than one. When the insolvency ratio surpasses one, the oil industry is formally bankrupt.[11]

Figure 12 shows how the insolvency ratio plays out in real-world Alberta. As anticipated, things start out well. During the early years of exploration, the Alberta oil industry had an insolvency ratio well below one. But after 1970, the insolvency ratio began to creep upward, slowly approaching the threshold for bankruptcy (the dashed red line). The exact timing of this bankruptcy depends on the assumed price of oil and gas. At $500 per BOE, the industry will be bankrupt in a few decades. At $5 per BOE, the industry is already bankrupt, and has been for two decades. And at $50 per BOE, the industry is going bankrupt *now*.

Figure 12: The cleanup insolvency ratio in real-world Alberta.
This figure plots the insolvency ratio for the oil industry in real-world Alberta. This ratio divides cumulative cleanup costs by the oil industry's future income. (I plotted the insolvency ratio's components in Figure 11.) The line and shaded region show the value for different prices of oil and gas. Data prior to 2017 is based on historical oil-and-gas production. (Oil-and-gas prices are counterfactual.) Data beyond 2017 is based on projected oil-and-gas production. Note that since future income is forward looking, the dividing line between historical and projected revenue is fuzzy. For more details about the data, see the Sources and methods.



Because the future price of oil and gas is unknown, we can quibble about the timing of the oil patch's insolvency. The truth is that we'll only know the exact date in hindsight. But by then, it will be too late; the prospect of an industry-funded cleanup will be dead. And so it behooves us to look at the big picture. If the status quo continues, what is certain is that the Alberta oil industry is headed for bankruptcy.

[11] A cleanup insolvency ratio of 1 is the hard limit above which the oil industry cannot possibly be solvent. Above this limit, cleanup costs exceed future revenue. In practice, however, oil companies will be bankrupt well below this threshold. After all, cleanup is but one of many costs that oil revenue must cover. Where this practical bankruptcy occurs depends on the particulars of each company's finances. At any rate, the Alberta oil industry is approaching (or may have already passed) the hard limit of insolvency. So the exact location of the softer limits is irrelevant.

Importantly, we're not talking about 'minor' bankruptcy either. No, the bankruptcy that awaits Alberta's oil patch is so complete that it boggles the mind.[12] On that front, notice that in Figure 12, the vertical axis uses a logarithmic scale, meaning each tick mark indicates a factor of ten. So as the cleanup insolvency ratio heads upward, it does so at an exponential pace. The results are catastrophic. In the not-so-distant future, there will come a day when the oil industry's cleanup liabilities exceed its future income by a *thousand-fold* (or more).

At that point, the oil industry has become a vampire. It sucks profit from society and leaves behind a trail of corpses that it cannot possibly cleanup. Let's hope that long before this day comes, someone finds a stake.

Hastening the inevitable

From the moment the first veins of coal were opened (thousands of years ago), one thing has been certain: the fossil-fuel business would eventually die. But what's always been uncertain is the when and the how. That's because there is no law of nature that tells us how much of a non-renewable resource humans will exploit.

One possibility is that we will harvest fossil fuels to the point of utter exhaustion. Of course, there will always be some scraps left over. But eventually, fossil fuels will become so sparse that we'll put more energy into harvesting them than we receive back. When that happens, the game is up. But although this end game is conceivable, the realities of climate change make it suicidal. There are likely enough fossil fuels left in the ground to render much of the Earth uninhabitable.

Faced with the specter of climate change, another possibility is that technology will come to the rescue. On that front, there is some historical precedent. Humans didn't stop riding horses because we ran out of grass. We stopped because grass-eating horses were replaced by gas-burning cars. So perhaps we'll stop harvesting fossil fuels because renewable energy renders them obsolete. Admittedly, this scenario is comforting. Unfortunately, there's little evidence that it is actually happening. Yes, humans have been ramping up our production of renewable energy. The trouble is, we've also been ramping up our exploitation of fossil fuels. In other words, renewable energy has mostly just added to the energy mix (instead of replacing non-renewable energy).

And that brings me to the most rational road forward. Yes, we should invest in renewable energy — far more than we're doing today. But we shouldn't just wait for this technology to replace fossil fuels. Instead, the fossil-fuel business should be actively dismantled.

How?

The most severe option would be to make fossil fuels illegal. Although such a ban might one day happen, today it seems far-fetched. More likely, the fossil-fuel business will die by a thousand cuts. We already have policies devoted to this task. Carbon taxes, for example, are supposed to discourage fossil fuel consumption by making it more expensive.

[12] For the company that goes bankrupt, its 'degree' of bankruptcy is irrelevant. But for *creditors*, the degree of bankruptcy determines how much of their credit they can get back.

What a carbon tax does not necessarily do, though, is make the fossil-fuel business less profitable. There's probably a good reason for that. When we dig into corporate profits, we poke the hornet nest of power. At present, it seems that few governments have the stomach to fight the corporate swarm.

And that brings me to the fossil-fuel industry's self-made mess. One of the most pervasive norms in capitalism is that if you damage other people's property, you're liable for the cost of repair. Speaking of damage, the oil-and-gas business promised to cleanup the mess that it created. But so far, it has reneged on this promise — largely because it has the power to do so. The result is that today, the oil business has a massive cleanup liability. In the case of Alberta, it's between $40 to $80 billion. If the Alberta government called in this debt, it would likely bankrupt the (conventional) oil industry.

Of course, the Alberta government could achieve the same outcome simply by *taking* $80 billion from oil companies. However, the optics of doing so are terrible. Language tells us why. If the government enforces cleanup costs, it is being 'repaid' for an outstanding debt. But if the government takes the money without pretext, we call that 'stealing'.

These optics matter because human society is built on morals. Today, many environmentalists feel that we have a moral obligation to end the fossil business. But for the bulk of the population, this moral is a hard sell.

Ironically, the fossil-fuel industry has backed itself into a corner where it is vulnerable to a much more pervasive moral: the belief that you should cleanup your own mess. If we enforced this moral (which is, conveniently, also the law), the fossil-fuel business would likely be in deep trouble. It has dug its own grave and now stands on the edge. We just need to give it a push.

Appendix

Cleanup scenarios

Here are some possibilities for how Alberta's cleanup battle might play out. One option is that cleanup liabilities are never enforced. Sadly, this is by and large what's happened to date. Oil companies play accounting games to get their cleanup liabilities off the books. So far, the Alberta government (and the court system) have been willing to play along.

Another option is that the Federal government will finance the cleanup — a process that's already occurring. In 2020, the Federal government announced a $1.7 billion fund to cleanup abandoned and orphaned wells (Anderson, 2017). While the cleanup itself is good, this method of financing it is pernicious. The federal funding essentially tells oil companies that they can bolster their bottom line by ignoring their cleanup obligations. Then the federal government will come to the rescue and cleanup the mess. So the federal government is basically subsidizing oil companies' profits. That's bad.

Now let's get more radical. If the Alberta government called in the oil industry's cleanup liabilities, it would likely bankrupt the (conventional) oil business. If this enforcement had real teeth, we can imagine the government putting the whole oil patch into receivership. The government could then stop new drilling and drain existing wells. Whatever income that resulted would be put towards the oil-and-gas cleanup. If there was money leftover (and that's a big if), it could help fund a transition to renewable energy.

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Sources and methods

Data and code

The data and code used in this paper is available at the Open Science Framework: https://osf.io/rhnyz/

Oil-and-gas production

Oil-and-gas production data is from Enverus (formally known as DrillingInfo). For details about how I created well-level production curves from this data, see Fix (2022).

Cleanup cost data

Estimates for well cleanup costs come from an internal review conducted by the Alberta Energy Regulator. Following a freedom-of-information request, Regan Boychuk obtained the raw data from this review. This data consisted of private sector cleanup estimates for a variety of well scenarios. Boychuk then worked with Eric Neilson to apply the correct scenario to each well in Alberta. The resulting dataset estimates the cleanup costs of over 300,000 wells. For each well, I use the average of the low and high estimates.

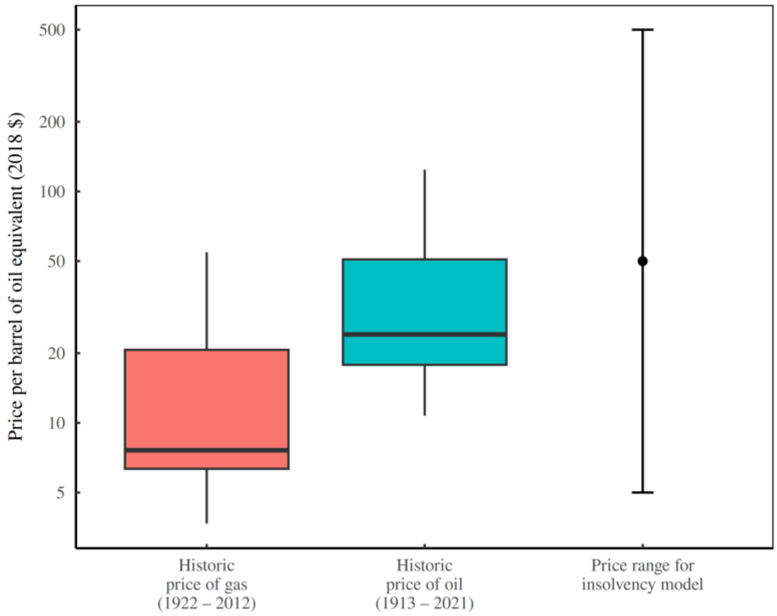
To construct the cumulative cost curve (Figures 8 and 11), I introduce each well's cleanup cost on the date the well was drilled. For simulated wells (those drilled after 2017), I assume a cleanup cost of $204,642 per well — the average of the historical estimates.

For more details about the cleanup estimates, see the Alberta Liabilities Disclosure Project's methods page: https://www.aldpcoalition.com/research

Historical oil-and-gas prices

Figure 13 gives you a sense for how my oil-and-gas price scenarios compare with historical data. Note that I've denominated prices in 'barrels of oil equivalent'.

Figure 13: Historical oil-and-gas prices. The box plots show the range of historical gas-and-oil prices, denominated in 2018 USD per barrel of oil equivalent. The error bars on the right show the price range used in my insolvency model. Oil prices comes from the BP Statistical Review 2021. Gas prices comes from Energy Information Agency, Table N9190US3a (wellhead price). I deflate both price series (to 2018 dollars) using the US Consumer Price index, obtained from the Bureau of Labor Statistics, series CUUR0000SA0.



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