

Supplementary Material: Orphaned oil and gas well stimulus – maximizing economic and environmental benefits

Mary Kang^{1,*}, Adam R. Brandt², Zhong Zheng³, Jade Boutot¹, Chantel Yung¹,
Adam S. Peltz⁴, Robert B. Jackson⁵

¹Civil Engineering, McGill University, Montréal, Québec, Canada

²Energy Resources Engineering, Stanford University, Stanford, CA, USA

³State Key Laboratory of Ocean Engineering, Shanghai, China, and School of Naval
Architecture, Ocean and Civil Engineering, Shanghai Jiao Tong University, Shanghai, China

⁴Environmental Defense Fund, New York, NY, USA

⁵Earth System Science, Woods Institute for the Environment and Precourt Institute for Energy,
Stanford University, Stanford, CA, 94305 USA

*mary.kang@mcgill.ca

Supplemental material

Orphaned wells

Using available state data, we compile the number of wells newly orphaned per month from September 2019 to December 2020 in two states and two provinces: Texas, Louisiana, British Columbia, and Manitoba (Fig. S2). These four states/provinces are plotted because the number of newly orphaned wells per month is available for more than 10 months. The orphaned well counts are determined from state/provincial orphaned well lists or well statuses in oil and gas well databases indicating that the well is orphaned. Comparing the orphaned well numbers to the WTI oil price, Texas and Manitoba appear to show increases in the number of orphaned wells following the drop in oil prices in April 2020, while no clear relationship appears to exist in Louisiana or British Columbia.

To evaluate multi-year variation in orphaned well numbers across the U.S., we compile the numbers of orphaned wells reported by the Interstate Oil and Gas Compact Commission (IOGCC) from 1992 to 2019 (IOGCC, 1992; 1996; 2000; 2008; 2009; 2019) (Fig. S6 and Tab. S5). The most recent report published in 2019 and updated in March 2020 finds 56,594 orphaned wells across the 30 surveyed states (Fig. S6 and Tab. S5). Over the past thirty years in which the IOGCC has been compiling these reports, the number of orphaned wells remained at 50,000

to 60,000 wells (Fig. S6).

We compare the orphaned well numbers in the two most recent reports (IOGCC, 2009; 2019) to evaluate trends among states. Although there has been a 5% decrease in orphaned well numbers nationwide in the past 11 years, the trend among states is not consistent (Tab. S5). Slightly more than half, 14 out of 27 states, show an increase in the number of orphaned wells, whereas 12 states indicate a decrease. The number of orphaned wells remains constant in only one state - Alaska. The maximum increase in the number of orphaned wells is 3,386 (West Virginia) and the maximum decrease in the number of orphaned wells is 4,935 (Texas). Another notable state is Wyoming where the number of orphaned wells increased from zero in 2008 to 3,083 in 2019.

We also analyze data from the Alberta Orphan Well Association and present the number of wells that stopped production per year from 1961 to 2020 and eventually became orphaned (Fig. S2). Data from Alberta suggest that a decrease in oil price leads to an increase in the number of orphaned wells over the next several years. Following the decrease in oil price in 2015, 1315 wells (0.8% of active wells) in Alberta stopped production in 2016 to 2018 and eventually became orphaned (Fig. S3).

Plugging costs

For plugging costs of \$1,000, \$10,000, and \$100,000 per well, we estimate the cost per tonne of carbon emissions avoided (Tab. S6). We consider 20-, 50-, and 100- year lifetime for the plug following the approach in Kang et al. (2019), and we assume methane flow rates of 10,000, 100,000, and 1,000,000 mg/hour per well based on available measurements (Kang et al., 2019; Williams et al., 2020). These high-emitters make 9% and 2% of measured abandoned wells using a threshold of 10,000 mg/hr/well and 100,000 mg/hr/well respectively (Williams et al., 2020). We use a global warming potential of 25 for a 100-year time frame, as used by the U.S. Environmental Protection Agency in the Greenhouse Gas Inventory (U.S. Environmental Protection Agency, 2019). We find plugging costs per tonne of CO₂e to vary from \$0.10 USD per tonne CO₂e to \$2,283 USD per tonne CO₂e.

Canada's orphan well stimulus funding

The \$1.7-billion stimulus fund of 2020 was distributed as follows: \$1.2 billion to Alberta, \$120 million to British Columbia, and \$380 million to Saskatchewan. Of these funds, \$1 billion has been allocated to Alberta's Site Rehabilitation Program,

which “provides grants to oil field service contractors to perform well, pipeline, and oil and gas site closure and reclamation work”. In British Columbia, \$100 million (out of the \$120 million allocated to the province) is being spent to decommission wells for which a permit holder still exists.

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Table S1. List of oil and gas exploration and production companies filing for bankruptcy in 2020 in the U.S.

Company	Reason for default	Date	Total Debt (Haynes & Boone)	Court	Source
Bridgemark Corporation	Chapter 11	14-Jan-20	\$53,663,450	C.D. Cal.	S&P Platts, Haynes & Boone
Southland Royalty Co. LLC	Chapter 11	27-Jan-20	\$625,047,200	D. Del.	S&P Platts, Haynes & Boone
Dalf Energy	Chapter 11	17-Feb-20	\$1,218,273	W.D. Tex.	S&P Platts, Haynes & Boone
Sheridan Holding Company I, LLC	Chapter 11	23-Mar-20	\$618,485,147	S.D. Tex.	S&P Platts, Haynes & Boone
Echo Energy Partners	Chapter 11	24-Mar-20	\$91,260,516	S.D. Tex.	S&P Platts, Haynes & Boone
Whiting Petroleum Corp	Chapter 11	1-Apr-20	\$3,566,815,493	S.D. Tex.	S&P Platts, Haynes & Boone
Sklar Exploration	Chapter 11	1-Apr-20	\$41,000,988	D. Colo.	S&P Platts, Haynes & Boone
Amazing Energy		6-Apr-20	\$13,489,109	S.D. Miss.	Haynes & Boone
Sable Permian Resources Holdings	Missed Interest	8-Apr-20			S&P Platts
Temblor Petroleum Company		9-Apr-20	\$12,198,912	E.D. Cal.	Haynes & Boone
Yuma Energy		15-Apr-20	\$28,270,794	N.D. Tex.	Haynes & Boone
Buzzards Bench		30-Apr-20	\$16,092,638	S.D. Tex.	Haynes & Boone
SM Energy	Distressed Exchange	30-Apr-20			S&P Platts
Victerra Energy Holdings		6-May-20			Haynes & Boone
Freedom Oil & Gas, Inc.		11-May-20	\$26,942,930	S.D. Tex.	Haynes & Boone
Callon Petroleum	Distressed Exchange	11-May-20			S&P Platts
Freedom Oil & Gas, Inc.		14-May-20	\$26,942,930	S.D. Tex.	Haynes & Boone
New Emerald Energy		14-May-20	\$30,000,000	N.D. Tex.	Haynes & Boone
Fieldwood Energy	Missed Interest	15-May-20			S&P Platts
Gavilan Resources	Chapter 11	15-May-20	\$587,139,471	S.D. Tex.	S&P Platts, Haynes & Boone
Ultra Petroleum	Chapter 11	15-May-20	\$3,569,200,000	S.D. Tex.	S&P Platts, Haynes & Boone
Centennial Resource Development	Distressed Exchange	21-May-20			S&P Platts
Unit Corporation		22-May-20	\$789,000,000	S.D. Tex.	Haynes & Boone
Templar Energy LLC		31-May-20	\$465,700,000	D. Del.	Haynes & Boone
Extraction Oil & Gas	Missed Interest in May; Chapter 11 in June	14-Jun-20	\$1,944,700,000	D. Del.	S&P Platts, Haynes & Boone
Chisholm Oil & Gas Operating	Chapter 11	17-Jun-20	\$534,720,927	D. Del.	Haynes & Boone
Sable Permian Resources	Chapter 11	25-Jun-20	\$1,383,690,140	S.D. Tex.	Haynes & Boone
Chesapeake Energy	Chapter 11	28-Jun-20	\$9,169,000,000	S.D. Tex.	Haynes & Boone
Lilis Energy, Inc.	Chapter 11	28-Jun-20	\$441,750,000	S.D. Tex.	Haynes & Boone
California Resources Corp	Chapter 11 (Distressed Exchange/Seeking Bankruptcy, Feb. 24, 2020)	14-Jul-20	\$5,000,000,000		S&P Platts, https://www.desertsun.com/story/news/environment/2020/07/15/crc-californias-largest-oil-and-gas-company-files-bankruptcy-protection/5446329002/

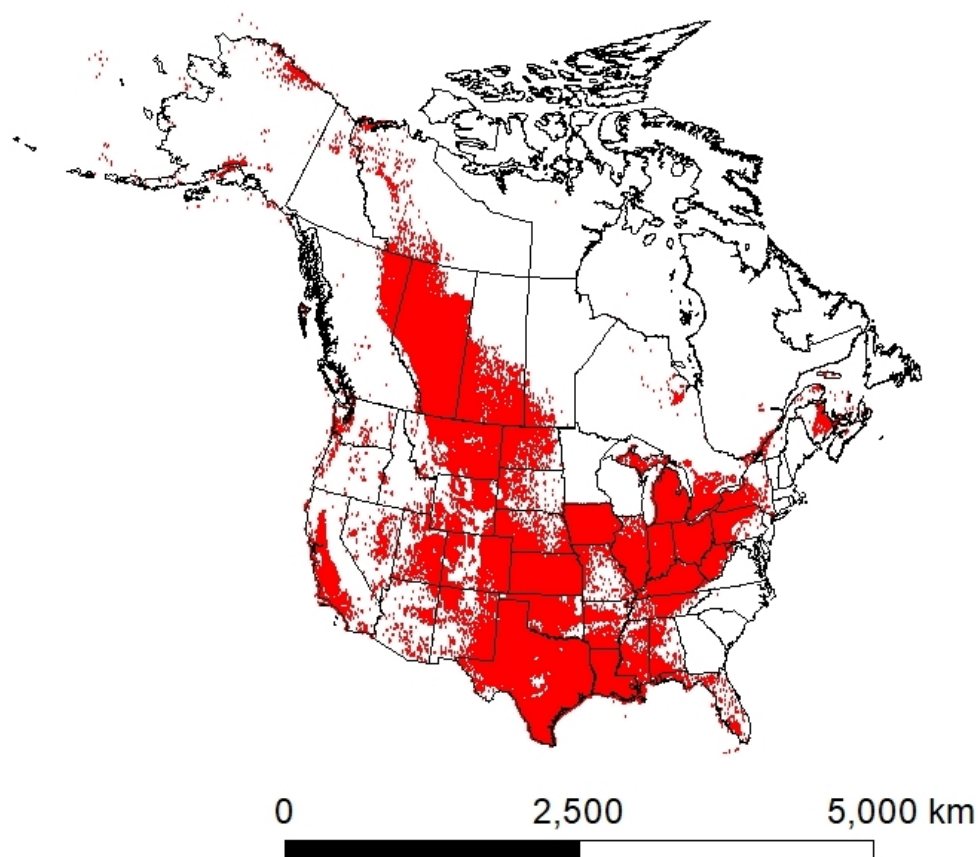


Figure S1. Distribution of drilled oil and gas wells, including historic and active wells, across Canada and the U.S. based on state/provincial/territorial databases listed in Tab. S3 and S4.

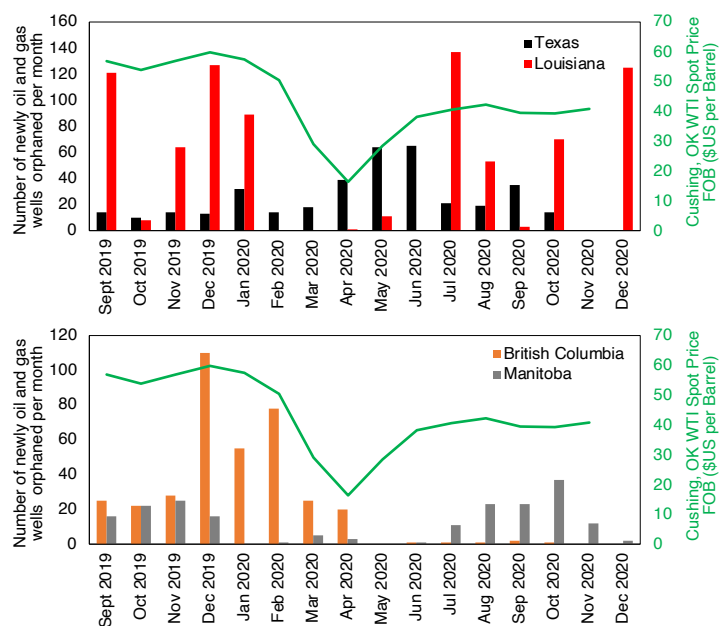


Figure S2. The number of oil and gas wells newly orphaned per month in states/provinces with more than 10 months of data from September 2019 to December 2020.

Data from state/provincial orphaned well lists or statuses in state/provincial oil and gas well databases: Texas Railroad Commission, Louisiana Department of Natural Resources, Manitoba Petroleum, and British Columbia Oil and Gas Commission. The number of wells orphaned per month is always greater than zero when the data is available. In other words, months indicating no wells orphaned per month are months with no data available. Monthly oil prices are obtained from the U.S. Energy Information Administration (<https://www.eia.gov/dnav/pet/hist/rwtcM.htm>).

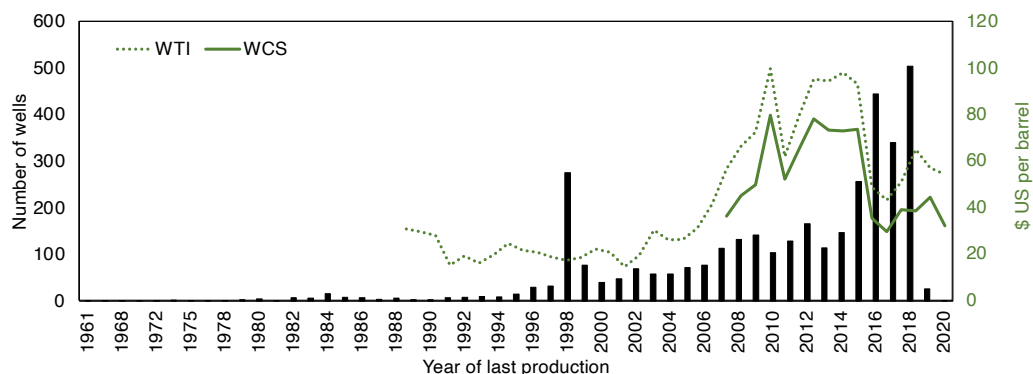


Figure S3. The number of orphaned wells in Alberta based on the year of last volumetric activity date, compared to oil price.

Data for 1961 to 2020 are obtained from the Alberta Orphan Well Association. We do not have data on when the wells became orphaned. The year in which the well became orphaned can be any year beginning from the year of last production to 2020. The monthly Western Texas Intermediate (WTI) and Western Canadian Select (WCS) oil prices are obtained from the Alberta Government Economic Dashboard from April 1983 to February 2020 for WTI and from January 2005 to February 2020 for WCS.

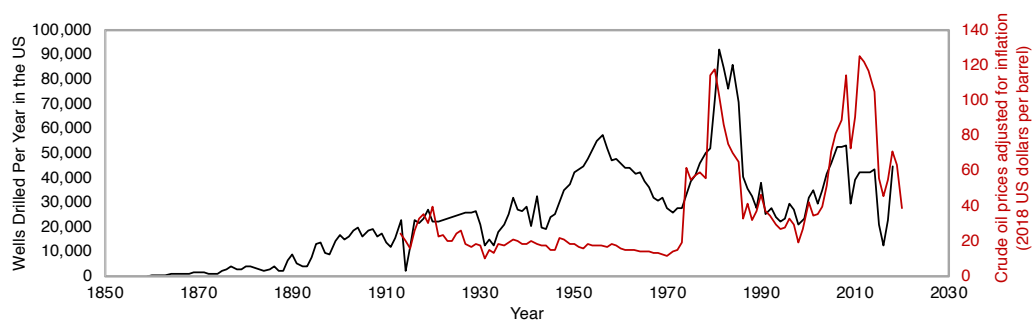


Figure S4. The number of historic and active oil and gas wells drilled per year in the US from 1859 to 2018 and crude oil prices adjusted for inflation (2018 US dollars per barrel) from 1861 to 2020.

The oil price is obtained from Our World In Data (OWID) for 1861 to 2018 and the U.S. Energy Information Administration from 2019 to 2020 (Brent Crude). We adjust the oil prices for inflation using the U.S. Bureau of Labor Statistics Consumer Price Index Inflation Calculator to 2018 U.S. dollars.

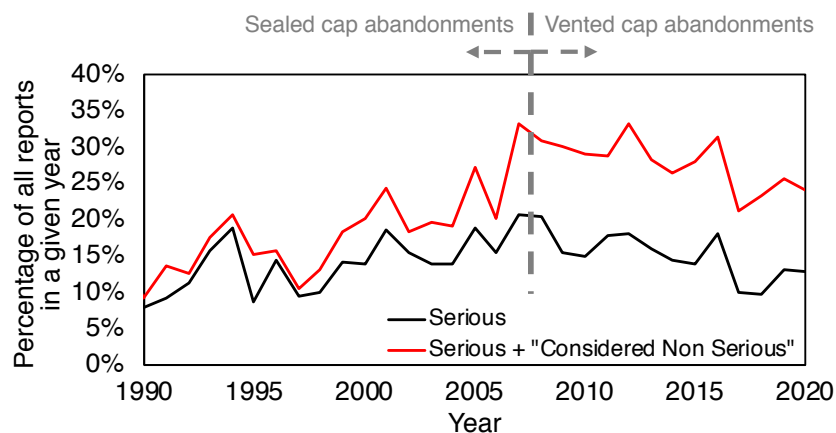


Figure S5. Reported leakage occurrences showing the impact of changing abandonment requirements from sealed caps to vented caps.

The data is from the Well Vent Flow/Gas Migration Report downloaded from the Alberta Energy Regulator (2020) and expands on Boyer (2015).

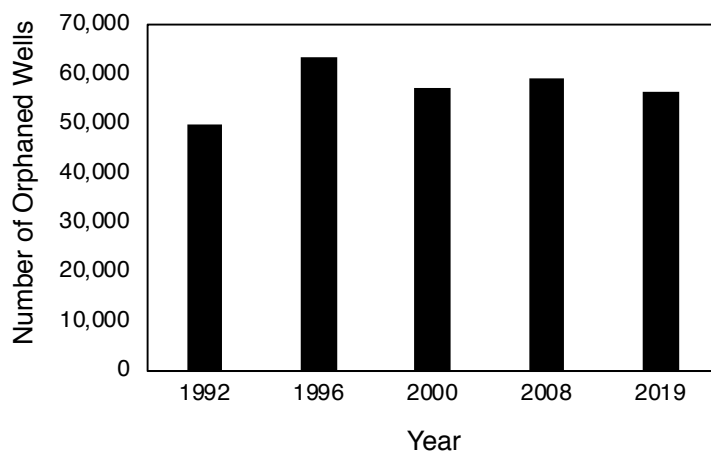


Figure S6. Number of orphaned oil and gas wells in state databases across the U.S .

The data is from IOGCC reports (IOGCC, 1992; 1996; 2000; 2008; 2009; 2019).

Table S2. List of oil and gas companies filing for receivership or bankruptcy under the Companies' Creditors Arrangement Act (CCAA) from 2018 to 2020 in Canada.

Company	Filing date
Cabot Energy	6/30/2020
Cequence Energy Ltd. (TSX:CQE)	6/11/2020
Q'Max Solutions	5/28/2020
Delphi Energy (TSX:DEE)	4/14/2020
Direct Oil & Gas Inc.	2/28/2020
Strategic Oil & Gas (TSX-V:SOG)	1/28/2020
Traverse Energy (TSX-V:TVL)	12/6/2019
Accel Canada	11/22/2019
Eagle Energy (TSX-V:EGL)	11/19/2019
Wolf Coulee Resources	11/18/2019
Kitnuma Petroleum and Kitnuma Proje	11/5/2019
Houston Oil & Gas	10/29/2019
ACCEL Energy	10/21/2019
Bellatrix Exploration (TSX:BXE)	10/2/2019
Bearstone Environmental Solutions	8/6/2019
Ajax Petroleum	7/31/2019
Petrocapita Oil and Gas	6/11/2019
Trident Exploration	5/3/2019
Patriot Equipment	4/11/2019
Strategic Oil & Gas (TSX-V:SOG)	4/10/2019
Dundee Energy Ltd	3/29/2019
Elcano Group	2/26/2019
Horseshoe Bay Resources	1/9/2019
R.I.I. North America	11/29/2018
Diagonal Oil & Gas	8/24/2018
Delfan Energy Resources	7/10/2018
The OpsMobil Group	7/10/2018
Mustang Well Services	5/17/2018
Clayton Construction	5/8/2018
Global Flow	5/1/2018
Requisite Energy Services	4/24/2018
Sequoia Resources Corporation	3/23/2018
Storm Rentals	3/21/2018
Sequoia Resources Corporation	3/2/2018

Table S3. Number of historic and active oil and gas wells in the U.S. according to state databases.

State	Drilled	Active	Plugged	Source	Last Updated	Date Accessed
Alabama	17,167	6,970	4,987	State of Alabama Oil and Gas Board- OGB GIS Data (https://www.gsa.state.al.us/ogb/wells)	Dec 18, 2020	2020-12-21
Alaska	9,014	5,228	3,445	Alaska Oil and Gas Conservation Commission (https://www.commerce.alaska.gov/web/aogcc/Data.aspx)	Dec 22, 2020	2020-12-22
Arizona	1,015	28	7	Arizona Oil and Gas Conservation Commission-Oil and Gas Well Viewer (http://welldata.azogcc.az.gov/)	Not specified	2020-12-22
Arkansas	30,455	13,412	12,418	Arkansas Oil and Gas Commission-Maps-GIS Data (https://gis.arkansas.gov/product/arkansas-oil-and-gas-wells/)	Oct 16, 2014	2020-12-22
California	226,730	87,892	121,496	California Department of Conservation-All O&G Wells (https://secure.conservation.ca.gov/WellSearch)	Dec 22, 2020	2020-12-22
Colorado	116,080	39,141	24,526	Colorado Oil and Gas Conservation Commission (https://cogcc.state.co.us/data2.html#/downloads)	Dec 22, 2020	2020-12-22
Florida	1,458	155	973	Florida Department Of Environmental Protection-Oil and Gas Permit Database (https://floridadep.gov/water/oil-gas/content/oil-and-gas-permit-database)	July 10, 2020	2020-12-22
Idaho	25	8	13	Idaho Oil and Gas Conservation Commission (http://welldata.ogcc.idaho.gov/)	Dec 22, 2020	2020-12-22
Illinois	159,063	51,016	47,045	Illinois Geospatial Data Clearinghouse-Location Points from the ISGS Wells and Borings Database (http://clearinghouse.isgs.illinois.edu/data/geology/location-points-isgs-wells-and-borings-database)	Dec 22, 2020	2020-12-22
Indiana	64,825	35,015	26,057	Indiana Geological and Water survey/Indiana University (https://lgws.indiana.edu/pdms/WellSearch.cfm)	July 15, 2020	2021-01-03
Iowa	21,093	6,216	14,877	Iowa Geodata-Iowa Geological Survey Well Database (https://geodata.iowa.gov/datasets/iowadnr::all-wells?geometry=-108.461%2C-93.035%2C-78.116%2C-44.753)	April 18, 2018	2020-12-22
Kansas	477,706	159,374	148,726	Kansas Geological Survey-Master list of oil and gas wells (http://www.kgs.ku.edu/PRS/petroDB.html#ASCII)	Dec 17, 2020	2020-12-22
Kentucky	140,260	76,291	46,141	University of Kentucky/Kentucky Geological Survey (https://kgs.uky.edu/kgsweb/main.asp)	August 10, 2020	2020-12-22
Louisiana	235,805	38,245	157,927	Louisiana Department of Natural Resources-SONRIS Interactive Maps Oil/Gas Wells and Data Portal (http://sonlite.dnr.state.la.us/pls/apex/f?p=108:2700:11268402984114::NO:2700::)	Not specified	2020-12-22
Maryland	184	10	n/a	Maryland Oil and Gas Viewer- from Maryland Department of Environment (https://www.arcgis.com/home/webmap/viewer.html?webmap=437d27c219604f61a8e2573f20a0b89e)	June 29, 2017	2020-12-23
Michigan	82,965	16,592	1,459	Michigan Department of Environment, Great Lakes, and Energy-GeoWebFace FTP Site (https://www.michigan.gov/egle/0,9429,7-135-3311_60700---00.html)	Dec 22, 2020	2020-12-23
Mississippi	31,309	6,440	23,786	Mississippi State Oil and Gas Board (https://www.ogb.state.ms.us/wellsearch.php)	Not specified	2020-12-23
Missouri	10,547	1,091	4,411	Missouri Department of Natural Resources, State Oil and Gas Council (https://dnr.mo.gov/geology/geosrv/oilandgas.htm)	June 2, 2020	2020-12-23
Montana	41,651	10,033	24,461	Montana Board of Oil and Gas Conservation (http://www.bogc.dnrc.mt.gov/WebApps/DataMiner/Wells/Wells.aspx)	Dec 17, 2020	2020-12-23
Nebraska	21,442	2,110	5,507	Nebraska Oil and Gas Conservation Commission (http://www.nogcc.ne.gov/NOGCCPublications.aspx)	Dec 23, 2020	2020-12-23
Nevada	1,134	n/a	617	Nevada Bureau of Mines and Geology-Open Data: Oil and Gas Wells (http://www.nbmgs.unr.edu/Oil&Gas/NVWWellInfo.html)	May 7, 2020	2020-12-23
New Mexico	110,928	64,915	44,856	State of New Mexico Oil and Gas Conservation Division (ftp://164.64.106.6/Public/OCDD%20GIS%20Data/Shapefiles/)	Dec 21, 2020	2020-12-23
New York	42,556	11,895	20,001	New York State Department of Environmental Conservation, FracTracker (https://www.dec.ny.gov/energy/1603.html)	Dec 23, 2020	2020-12-23
North Dakota	33,921	17,515	4,934	North Dakota Oil and Gas Division (https://www.dmr.nd.gov/OaGIMS/viewer.htm)	Dec 21, 2020	2020-12-23
Ohio	241,309	65,232	72,833	Ohio Department of Natural Resources (https://ohiodnr.gov/wps/portal/gov/odnr-core/divisions/division-e-oilgas/div-oilgas/features/featured-content-3)	Dec 18, 2020	2020-12-23
Oklahoma	731,527	680,745	40,401	Oklahoma Corporation Commission-Oil and Gas (http://www.occeweb.com/og/ogdatafiles2.htm)	Dec 31, 2010	2020-12-23
Oregon	544	92	n/a	State of Oregon Department of Geology and Mineral Industries-Oil and Gas Well Log Index (https://www.oregongeology.org/mlrr/oilgas-logs.htm)	Feb 12, 2020	2020-12-24
Pennsylvania	214,337	127,227	68,870	DEP Office of Oil and Gas Management- Spud Data (Spud date ranges from January 1700 to July 7 2020) (https://www.dep.pa.gov/DataandTools/Reports/Oil%20and%20Gas%20Reports/Pages/default.aspx)	Dec 24, 2020	2020-12-24
South Dakota	2,037	504	1,372	South Dakota Department of Environment and Natural Resources (http://www.sdgs.usd.edu/SDOIL/oilgas_databases.aspx)	Not specified	2020-12-24
Tennessee	16,293	16,293	n/a	Tennessee Department of Environment and Conservation (http://environment-online.state.tn.us:8080/pls/enf_reports/f?p=9034:34300:0::NO::)	Nov 10, 2020	2020-12-24
Texas	1,334,722	286,110	533,889	Texas Railroad Commission (https://www.rrc.state.tx.us/oil-gas/research-and-statistics/)	Not specified	2020-12-24
Utah	34,923	11,283	8,724	Utah Department of Natural Resources, Oil, Gas and Mining Division (https://oilgas.ogm.utah.gov/oilgasweb/data-center/dc-main.xhtml#online)	Dec 24, 2020	2020-12-24
Virginia	12,472	10,204	1,386	Virginia Department of Mines, Minerals, and Energy and Virginia Department of Environmental Protection (https://www.dmme.virginia.gov/dgo inquiry/frmmain.aspx)	Not specified	2020-12-24
Washington	830	716	112	Washington State Department of Natural Resources (https://www.dnr.wa.gov/programs-and-services/geology/energy-mining-and-minerals/oil-and-gas-resources#more-information)	Feb, 2019	2020-12-24
West Virginia	129,207	66,919	45,782	West Virginia Department of Environmental Protection GIS Server (https://tagis.dep.wv.gov/site/GISData)	Dec 24, 2020	2020-12-24
Wyoming	57,497	39,818	6,634	Wyoming Oil and Gas Conservation Commission (http://pipeline.wyo.gov/urecordsMenu.cfm?Skip=%27%27&oops=ID27881)	Dec 7, 2020	2020-12-24
Total	4,653,031	1,954,735	1,518,673			

The number of plugged wells in Texas (shown in orange) is estimated using the average ratio of plugged to drilled wells of 0.40.

Table S4. Number of historic and active oil and gas wells in Canadian provincial/territorial databases.

Province / Territory	Drilled	Active	Plugged	Source	Last Updated	Date Accessed
Alberta	610,344	252,206	277,643	Alberta Energy Regulator-ST37: List of wells in Alberta (https://www.aer.ca/providing-information/data-and-reports/statistical-reports/st37.html)	Dec 1, 2020	2020-12-29
British Columbia	29,117	11,737	9,617	British Columbia Oil and Gas Commission- Well Surface Hole Locations [BCOGC-44513] (https://www.bcogc.ca/data-reports/data-centre/)	Dec 29, 2020	2020-12-29
Manitoba	10,485	6,125	4,070	Manitoba Petroleum-GIS Map Gallery-Well Locations (http://www.manitoba.ca/iem/petroleum/reports/index.html)	Oct 20, 2020	2020-12-29
New Brunswick	790	0	790	New Brunswick Department of Natural Resources - Borehole Database (https://www1.gnb.ca/0078/GeoscienceDatabase/Borehole/Search.asp)	July 18, 2016	2020-12-21
NWT	871	2	770	NWT Office of the Regulator of Oil and Gas Operations and Canada Energy Regulator (https://www.oro.gov.nt.ca/en/resources?f%5B0%5D=field_resource_type%3A74)	Nov 12, 2019	2020-12-29
Nova Scotia	125	0	115	Nova Scotia Department of Energy Geoscience Map and Data-Onshore Petroleum Wells (https://energy.novascotia.ca/oil-and-gas/onshore/petroleum-resources/geoscience-data-and-maps)	Dec 9, 2020	2020-12-25
Ontario	26,952	3,630	15,207	Ontario Oil, Gas & Salt Library-Petroleum Well Data (http://www.ogsrlibrary.com/data_free_petroleum_ontario)	June 13, 2019	2020-12-21
PEI	20	0	20	PEI Transport Infrastructure and Energy-Oil and gas exploratory well logs (https://www.princeedwardisland.ca/en/information/transportation-infrastructure-and-energy/oil-and-gas-exploration-prince-edward-island)	Nov 19, 2019	2020-12-21
Quebec	909	108	614	ArcGIS Home-Oil and gas wells in the Province of Quebec, Canada (https://www.arcgis.com/home/item.html?id=6eda0817bdbf405eafa55ce6c7f6398c)	July 7, 2014	2020-12-21
Saskatchewan	107,864	39,584	40,135	Saskatchewan Ministry of Energy and Resources -Mining and Petroleum GeoAtlas (https://gisappl.saskatchewan.ca/Html5Ext/index.html?viewer=GeoAtlas)	Ongoing	2020-12-21
Yukon	76	0	64	Government of Yukon Energy, Mines and resources- Yukon Well Listing (https://yukon.ca/en/doing-business/licensing/find-oil-and-gas-maps-and-data)	Dec 31, 2014	2020-12-21
Total	787,553	313,392	349,045			

Table S5. Change in the number of orphaned oil and gas wells in the U.S. from 2008 to 2019 (IOGCC, 2008; 2019).

State	IOGCC, 2008	IOGCC, 2019
	Surveyed states in 2006	Surveyed states in 2018
	Wait List	Documented Orphan Wells
Alabama	0	3
Alaska	15	15
Arizona		0
Arkansas	577	484
California	430	16
Colorado	45	275
Florida	17	
Idaho		0
Illinois	3900	4253
Indiana	598	1028
Kansas	7271	5709
Kentucky	10600	13266
Louisiana	3183	3966
Maryland		0
Michigan	100	98
Mississippi	49	18
Missouri	2000	
Montana	90	231
Nebraska	6	75
New Mexico	134	115
New York	4800	2000
North Dakota	4	0
Ohio	2089	910
Oklahoma	2089	1372
Pennsylvania	8700	8703
Tennessee		
Texas	11220	6285
Utah	8	33
Virginia	37	10
West Virginia	1260	4646
Wyoming	0	3083
Total	59,222	56,594

Table S6. Plugging costs in terms of tonnes of carbon emissions avoided (USD per tonne CO₂e).

GWP ₁₀₀		25	25	25
Plugging Costs (USD per well)		\$1,000	\$10,000	\$100,000
Lifetime of Plug (years)	Methane Flow Rate (mg/hr/well)	USD per tonne CO ₂ e		
20	1,000,000	0.2	2.3	23
	100,000	2	23	228
	10,000	23	228	2283
50	1,000,000	0.1	0.9	9
	100,000	1	9	91
	10,000	9	91	913
100	1,000,000	0.04	0.4	5
	100,000	0.4	5	46
	10,000	5	46	457

Methane flow rates selected are based on measurements and are taken as the possible orders of magnitude of high methane-emitting wells (Kang et al., 2019; Williams et al., 2020). Plugging costs are the orders of magnitude of average plugging costs reported by states (IOGCC, 2009).