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GRIDWELL Atlas: a self-updating screen to find the abandoned oil and gas wells best placed to add Enhanced Geothermal System electricity to the U.S. grid

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GRIDWELL Atlas: a self-updating screen to find the abandoned oil and gas wells best placed to add Enhanced Geothermal System electricity to the U.S. grid

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GRIDWELL Atlas version 1.0.0. All figures in this paper are computed from the GRIDWELL build of 12 October 2026 (doi:10.5281/zenodo.24155830).

Abstract

Drilling is the largest single cost of geothermal electricity, and the United States already has about 4.1 million abandoned oil and gas wells. However, the potential of these wells for Enhanced Geothermal Systems (EGS) has been screened at each well's own depth only for documented orphaned wells. Earlier screens treated orphaned wells as a separate population, although an orphaned well is an abandoned well that no operator can be required to plug. This paper presents GRIDWELL Atlas, a self-updating screen that places orphaned wells and all other abandoned wells in one inventory.

GRIDWELL Atlas assembles 948,992 abandoned wells from six state registries (Oklahoma, Kansas, California, New York, Colorado and North Dakota) and the U.S. Geological Survey (USGS) list of documented orphaned wells for 26 states. Each well is assigned one of four abandonment types: 1) inactive and unplugged with an operator of record (57,765 wells); 2) orphaned and unplugged (130,813); 3) plugged and abandoned (518,750); and 4) dry and abandoned (241,664). Formation temperature is then estimated at the 382,424 wells that report a usable vertical depth, using a depth-matched bottom-hole temperature field. On 20,000 held-out measurements deeper than 8,202 ft (2,500 m), the median error of the depth-matched field is 14 °F (7.8 °C), compared to 16 °F (9.1 °C) for the all-depth interpolation it replaces.

The results show that only 1,869 graded wells (0.49%) reach 302 °F (150 °C) at total depth. Inactive, unplugged wells are the most accessible type and also the type most often hot, with 1.3% of the graded wells of this type reaching EGS temperature. The 300 inactive,

unplugged wells that reach EGS temperature are the best-fit wells. They are located in the Piceance Basin of Colorado and the Williston Basin of North Dakota, at a median depth of 12,108 ft (3,690 m) and a median temperature of 319 °F (160 °C). Only 7 of these wells are within 6.2 mi (10 km) of a grid interconnection at 69 kV or higher, and none is in a county that is a 2026 energy community. This paper also documents the wellbore, thermal, seismic and legal barriers that apply to each abandonment type, with the evidence for each barrier. The atlas downloads the state registries again every month, so wells are added as agencies record them as abandoned.

1. Introduction

Geothermal power supplied about 0.4% of U.S. utility-scale electricity in 2025, according to the U.S. Energy Information Administration (EIA). This electricity came from 66 operable plants with 4,133 MW of nameplate capacity (computed in this study from Form EIA-860, 2025). Almost all of this capacity comes from naturally permeable hydrothermal reservoirs. The U.S. Geological Survey (USGS) estimated 9,057 MWe of identified hydrothermal potential, compared to 517,800 MWe that could be produced by engineering reservoirs in hot, low-permeability rock (Williams et al., 2008). An Enhanced Geothermal System (EGS) extracts heat from hot rock in which natural permeability or fluid saturation is too low for a conventional hydrothermal system (DOE, 2012). In an EGS, fluid is pumped down an injection well at controlled pressure to reopen existing fractures in the rock. The reopened fractures let the fluid circulate through the hot rock, and the heated fluid returns to the surface, where its heat is used to generate electricity (DOE, 2012). The Enhanced Geothermal Shot of the U.S. Department of Energy (DOE) targets a 90% cut in the cost of EGS power, to $45/MWh by 2035.

The technology has advanced quickly. For example, Fervo Energy's Project Red in Nevada circulated about 1,000 gal/min (63 L/s) of water at 376 °F (191 °C) through horizontal wells with 3,250 ft (991 m) laterals, which was enough for 3.5 MW (pv magazine, 2023). At Utah FORGE, a nine-hour circulation test in May 2024 returned about 70% of the injected water at about 282 °F (139 °C). The injection well at Utah FORGE reaches 8,559 ft (2,609 m) true vertical depth (Utah FORGE, 2024). In October 2026, Fervo's Cape Station in Beaver County, Utah, declared commercial operation, with its first block producing 33 MW net (Energy Global, 2026). The 2025 appraisal well at this site reached 15,765 ft (4,805 m) true vertical depth and a projected 500 °F (260 °C) (ThinkGeoEnergy, 2025b).

The main cost of geothermal power is still drilling to the hot rock. DOE's Geothermal Technologies Office estimates that drilling makes up at least half of the capital cost of a geothermal power plant (DOE, 2017). However, the oil and gas industry has already drilled

into much of this rock. The 2025 memorandum of the U.S. Environmental Protection Agency (EPA) counts about 4.1 million abandoned wells in the United States, and roughly 40% of them are plugged (EPA, 2025). In the 2021 report of the Interstate Oil and Gas Compact Commission (IOGCC), states reported 92,198 documented orphaned wells at the end of 2020 and estimated 310,000 to 800,000 undocumented orphaned wells (IOGCC, 2021). Additionally, the USGS compiled 117,672 documented unplugged orphaned wells in 2022 (Grove and Merrill, 2022).

DOE's Wells of Opportunity initiative aims to retrofit oil and gas wells that are idle or no longer productive. In 2022, the initiative selected four projects for up to $8.4 million, including one project to generate power from 11 existing wells in the San Joaquin Valley of California (DOE, 2022b). Site studies show both the potential and the limits of reuse. For example, Caulk and Tomac (2017) found bottom-hole temperatures of 104–163 °F (40–73 °C) at about 3,281 ft (1,000 m) in three California counties. At the national scale, Gardner et al. (2025) converted more than 1.4 million bottom-hole temperatures into corrected temperature–depth profiles. They estimated the temperature at the total depth of each documented orphaned well with a recorded depth, and graded the potential of each well as low below 194 °F (90 °C), moderate, or high above 302 °F (150 °C). However, a 2022 review found that no full-scale EGS project had yet been built from abandoned oil and gas wells (Santos et al., 2022).

Three gaps remain between this stock of wells and an EGS project. First, the national screen at well depth by Gardner et al. (2025) covers documented orphaned wells only, and its USGS record lists no data release. Inactive, plugged and dry wells make up most of the stock, and they have not been screened at their own depths. For example, Ugarte and Salehi (2023) screened abandoned wells in Oklahoma at a single depth, the average true vertical depth of 6,000 ft (1,829 m), and found that 26.7% of the wells (4,292) exceed 150 °F (66 °C) at that depth. Second, earlier screens limited to orphaned wells, at the national scale (Gardner et al., 2025) and in Alberta, Canada (Alexander et al., 2020), treat orphaned wells as a population separate from other abandoned wells. This separation hides the two factors that decide reuse: the condition of the wellbore and the party with legal authority to transfer the well. Third, well registries change every month, while published screens are fixed snapshots. This study addresses the three gaps with four objectives:

1. Build one inventory of abandoned wells, with each well assigned to one of four abandonment types and orphan status recorded as a liability attribute.
2. Estimate the temperature at each well's own vertical depth from a depth-matched field, and validate the field against held-out measurements.

3. Assign each well an EGS fit rating that combines abandonment type and temperature, and document the barriers for each type from regulations, statutes and the literature.
4. Refresh the inventory automatically each month: download the state registries again, record which wells joined the inventory, and publish a dated release.

2. Abandoned versus orphaned wells

The Interstate Oil and Gas Compact Commission defines **idle wells** as wells that are no longer used for production, injection or any other purpose for which they were drilled. It defines **orphan wells** as idle wells whose operator cannot be identified or is insolvent (IOGCC, 2021). On federal or tribal land, federal law treats a well as orphaned when it serves no authorized use and either has no operator that can be found or has an operator that is unable to plug the well and reclaim the site. For other land, federal law defers to the definition of each state (42 U.S.C. §15907(a)(5)). Similarly, the EPA inventory of abandoned wells lists "ORPHAN" as one well-status code among its unplugged wells (EPA, 2021).

Under these definitions, an orphaned well is a type of abandoned well, and it is defined by **liability**. Whether a well is plugged, never completed or idle is a separate question about the **wellbore**. Both questions matter for EGS reuse, in different ways. The wellbore condition decides how much drilling, cementing and casing work is needed to reach a hot reservoir from the well. Liability decides who can sell, lease or transfer the well, and on what terms. For this reason, GRIDWELL keeps one inventory and assigns each well one of four abandonment types (Table 1). Orphan status is recorded on every well as a separate attribute. For example, a well that was orphaned and later plugged by the state is counted as plugged, and it still carries the orphan flag.

Table 1. The four abandonment types and the agency codes assigned to each type. Codes that are not listed are excluded rather than guessed.

Type	Meaning	Agency codes used
IN · Inactive, unplugged	Not producing or injecting, not plugged, with an operator of record	OK: TA; AC on a dry well. KS: Inactive Well, Unplugged Former Injection Well, OTHER(TA, SHUT-IN, TEMP ABD). CA: Idle (no production or injection for 24 consecutive months). NY: IN, SI, TA. CO: SI, TA, AB. ND: IA, TA, TAO, TASC, AB
OR · Orphaned, unplugged	No operator able to plug; in the state's custody or plugging queue	OK: OR, STFD, SIFORDER, SFFO, SFAW. KS: ON LIST, Federal Plugging Project. Every well in the USGS documented unplugged orphaned-well list; an IN well matched to that list becomes OR
PA · Plugged and abandoned	Cement plugs set, surface casing cut; had produced, injected or been used	OK: PA, PASF, PAFF, PASUR, PASURSF. KS: P&A. CA: Plugged, PluggedOnly. NY: PA. CO: PA. ND: PA, PANF
DA · Dry and abandoned	Drilled and logged, never produced	OK and CA: plugged with well type dry hole. KS: D&A. NY: PA with type DH or DW. CO: well class DA. ND: DRY

The status definitions are taken from each agency: the Oklahoma Corporation Commission (OCC), the Kansas Geological Survey (KGS), the California Geologic Energy Management Division (CalGEM), the Colorado Energy and Carbon Management Commission (ECMC), the North Dakota Industrial Commission (NDIC) and the data dictionary of the New York State Department of Environmental Conservation (NYS DEC).

3. Data and methods

3.1 Sources

Table 2. Inputs to the build of 12 October 2026. All inputs are public, and their checksums are published with the atlas.

Layer	Publisher and dataset	Vintage	Refresh
Abandoned wells	Oklahoma Corporation Commission, RBDMS well data	Downloaded 2026-10-12	Monthly
	Kansas Geological Survey, master well list with KCC status	Downloaded 2026-10-12	Monthly
	CalGEM, WellSTAR wells layer	Downloaded 2026-10-12	Monthly
	NYS DEC, oil, gas and other regulated wells	Downloaded 2026-10-12	Monthly
	Colorado ECMC, well spots	Downloaded 2026-10-12	Monthly
	North Dakota DMR, OGD_Wells	Downloaded 2026-10-12	Monthly
Documented orphaned wells	USGS DOW, 26 states (CC0), deduplicated in ORPHANHEAT v0.1	2022	Release watched
Bottom-hole temperatures	Stanford Thermal Earth Model input set (CC BY 4.0)	2024	Pinned
Grid tie-in points	Form EIA-860, schedules 2 and 3.1	2025 final	Pinned; new vintage flagged
Counties, places, population	Census Bureau 2025 boundaries and Gazetteer; Vintage 2025 estimates	2025	Pinned; new vintage flagged
Energy communities	Treasury data sets; IRS Notice 2026-39, Appendix 1	2023–2026 status	Pinned; page watched

3.2 One inventory

The six registries contain 863,758 records in the four abandonment types or on a state orphan list. Records that share a 10-digit American Petroleum Institute (API) number belong to one wellbore, and the 14-digit suffix marks a sidetrack or a later event. For this

reason, only the latest record of each wellbore is kept. This step removed 11,523 duplicates in Kansas, 50 in New York and 5 in Colorado, and left 852,180 records. Each USGS orphaned well in a registry state is matched to its registry record by API number. In Kansas, the USGS rows carry commission numbers instead of API numbers, so each Kansas row is matched to a state orphan-program well within 328 ft (100 m). The 17,274 matches (Oklahoma 11,560; California 3,243; Kansas 1,325; North Dakota 640; Colorado 399; New York 107) keep the newer status from the registry and gain the orphan flag. The other 96,812 USGS wells are added as type OR. In Kansas, at most 697 of the added wells have an unmatched orphan-program well within 1,312 ft (400 m), which is an upper bound on the remaining double counting. The final inventory holds 948,992 wells. Of these, 134,138 carry the orphan flag, and 3,325 of the flagged wells have since been plugged.

Each well is assigned the county recorded by its agency. Where no county is recorded, the coordinates of the well place it within the Census 2025 county boundaries. Where both a recorded county and coordinates exist, the two methods agree for 99.72% of registry wells and 99.71% of USGS wells.

3.3 Vertical depth

Temperature is evaluated at true vertical depth where the agency reports it (Colorado and New York), and at the recorded total depth otherwise (Kansas, North Dakota and older Colorado wells). North Dakota reports only measured depth, which overstates vertical depth along a horizontal lateral. For example, a Bakken well is about 20,000 ft (6,096 m) in measured depth but only about 10,500 ft (3,200 m) in vertical depth. As a result, a measured-depth record is not graded when it appears deviated. The rules are: 1) in North Dakota, a depth of 12,500 ft (3,810 m) or more with a spud date in 2005 or later, or a horizontal-style well name; 2) in Kansas, a depth of 7,500 ft (2,286 m) or more with a spud date in 2010 or later; 3) in Colorado, a spud date in 2008 or later (or no date) with a horizontal-style name or a depth of 10,000 ft (3,048 m) or more, or any measured-only record of 15,000 ft (4,572 m) or more; and 4) in New York, a slant field that the agency marks as horizontal or directional (code in Appendix A.2). The rules remove 2,647 records from grading (North Dakota 2,324; Colorado 224; Kansas 94; New York 5). After this step, 382,424 wells have a usable vertical depth: Kansas (291,292), Colorado (61,196), New York (17,442) and North Dakota (12,494). The registries of Oklahoma and California publish no total depth.

3.4 Temperature at depth

The Stanford Thermal Earth Model input set contains 400,134 bottom-hole temperatures (BHT). Readings shallower than 492 ft (150 m) or deeper than 29,528 ft (9,000 m) are removed, together with readings that imply gradients outside 0.27–6.58 °F/100 ft (5–120 °C/km). This filter leaves 355,384 readings. Each reading is corrected for drilling disturbance with the polynomial of Harrison et al. (1983), with a mean correction of 13.6 °F (7.6 °C). Each corrected reading is then converted to a gradient G from a surface temperature of 59 °F (15 °C), so that T(z) = 15 °C + G · z.

The author's earlier orphaned-well screen (ORPHANHEAT v0.1) interpolated one gradient per location from the 12 nearest readings within 46.6 mi (75 km), at any depth. This method is suitable for fixed reference depths. However, at the bottom of a specific well, it allows shallow readings, which carry the largest correction error, to set deep temperatures. It also allows a single reading at the same location to decide the temperature of a well on its own. For this reason, GRIDWELL matches readings by depth. For a target depth z, the field uses only readings measured between 0.75 z and 1.25 z, and takes the 12 nearest within 46.6 mi (75 km). Readings more than three scaled median absolute deviations from the local median are rejected, and the remaining readings are weighted by inverse distance squared with a 0.62 mi (1 km) floor (code in Appendix A.1). Where fewer than three readings match, the field falls back to readings at all depths. The results show that 80.3% of graded wells are depth-matched.

In each build, the field is tested on 20,000 randomly held-out readings. Each held-out reading is predicted from neighbors more than 0.31 mi (0.5 km) away, so that other logging runs in the same well cannot leak into the prediction (Table 3).

Table 3. Error in predicted formation temperature at held-out BHT locations (prediction minus corrected measurement).

Held-out readings	Estimator	Median absolute error	Mean absolute error	Bias	90% of errors within
20,000 deeper than 3,281 ft (1,000 m)	All depths (ORPHANHEAT v0.1 form)	7.3 °F (4.1 °C)	13.3 °F (7.4 °C)	+0.8 °F (+0.5 °C)	32.2 °F (17.9 °C)
	Depth-matched (GRIDWELL)	6.5 °F (3.6 °C)	11.6 °F (6.4 °C)	+0.7 °F (+0.4 °C)	28.5 °F (15.8 °C)
20,000 deeper than 8,202 ft (2,500 m)	All depths (ORPHANHEAT v0.1 form)	16.3 °F (9.1 °C)	24.0 °F (13.3 °C)	+4.6 °F (+2.6 °C)	53.1 °F (29.5 °C)

Held-out readings	Estimator	Median absolute error	Mean absolute error	Bias	90% of errors within
	Depth-matched (GRIDWELL)	14.0 °F (7.8 °C)	20.2 °F (11.2 °C)	+2.6 °F (+1.4 °C)	45.4 °F (25.2 °C)

The results show that the depth-matched field reduces the mean error at depth by 16% and the bias by 44% (Table 3). However, a well rated within a few tens of degrees Fahrenheit of a threshold should still be checked against its own logs. Additionally, the two main contributing compilations in North Dakota disagree systematically. At 4,921–6,562 ft (1.5–2.0 km), the median corrected reading from the Association of American State Geologists (AASG) compilation is about 39 °F (22 °C) hotter than the median reading from the Southern Methodist University (SMU) compilation, and the field uses both compilations.

3.5 EGS grade and fit rating

EGS resources are generally taken to start at about 302 °F (150 °C) and to extend to 572 °F (300 °C) (Simmons, 2015). Gardner et al. (2025) used the same lower bound for the high-potential class of orphaned wells. In this study, each well with a vertical depth is graded by its modeled temperature at total depth: 1) EGS grade, 302 °F (150 °C) or more; 2) near-EGS, 248–302 °F (120–150 °C), within reach of binary-cycle plants or of EGS after deepening; 3) moderate, 194–248 °F (90–120 °C); and 4) low, below 194 °F (90 °C). For comparison, the 2026 well-repurposing bill of Oklahoma set its geothermal threshold at 250 °F (121 °C) (KOSU, 2026). The abandonment type and the grade combine into a fit rating (Table 4). The ratings are ordered by the amount of drilling, cementing and legal work needed to reach an EGS reservoir from the well (Section 6 gives the evidence; code in Appendix A.3).

Table 4. EGS fit ratings.

Rating	Rule	What has to happen first
A · Best fit	Inactive, unplugged, operator of record, at least 302 °F (150 °C) at total depth	Integrity logging and pressure testing; agreement with the operator
B · Strong fit after transfer	Orphaned, unplugged, at least 302 °F (150 °C)	A state route to transfer the well and its liability; integrity work

Rating	Rule	What has to happen first
C · Conditional	Plugged well at EGS grade, or unplugged well at 248–302 °F (120–150 °C)	Drilling out plugs and re-permitting, or deepening
D · Limited	Dry hole at 248 °F (120 °C) or more, or plugged well at 248–302 °F (120–150 °C)	Largely a new well; value as data or a sidetrack start
E · Below EGS grade	Under 248 °F (120 °C) at total depth	Deepening beyond the existing wellbore
U · Not graded	No usable vertical depth	Records research

For every well, including ungraded wells, the atlas also reports the temperature at 5,000, 10,000 and 15,000 ft (1,524, 3,048 and 4,572 m), and the depth at which the field reaches 302 °F (150 °C).

3.6 Grid, load and energy-community layers

Grid tie-in is measured to the nearest of 14,327 operable plants in Form EIA-860 (2025 final), and to the nearest of the 5,394 plants that connect at 69 kV or above. A well within 6.2 mi (10 km) of a plant in the second group is called "near grid". Federal open data on substations was withdrawn when Homeland Infrastructure Foundation-Level Data (HIFLD) Open closed on 26 August 2025. For this reason, plant interconnections are used as the documented proxy for substations. Community load is measured to the nearest of 19,479 incorporated places with a Vintage 2025 population estimate. Energy-community status for 2023–2026 and the list of coal-closure census tracts are copied from the files of the U.S. Department of the Treasury. The 2026 county list matches IRS Notice 2026-39 Appendix 1 exactly (867 counties).

3.7 Units

The data files keep SI units. The atlas and this paper report field units first, with SI units in brackets: feet (meters) for depth, °F (°C) for temperature, °F per 100 ft (°C/km) for gradient, and miles (kilometers) for distance. The atlas also has a switch to show SI units first.

4. A self-updating screen

State agencies update their registries continually. For example, the Oklahoma file is regenerated nightly and the Colorado file daily. Wells enter the inventory when operators report them as temporarily abandoned, shut in or plugged, or when states add them to orphan lists. Wells also move between types when an idle well is orphaned or plugged. Additionally, regulators are pushing long-idle wells toward plugging. In Texas, from 1 September 2027, an operator can no longer obtain a routine plugging extension for a well that has been inactive for more than 15 years and was completed more than 25 years earlier, unless the operator commits to plug the well or return it to operation by 1 September 2042 (Texas SB 1150, enrolled). A screen that is not refreshed misses the wells that are closest to being plugged, which are the wells with the least time left for reuse.

For this reason, GRIDWELL is published as a repository whose data rebuild themselves (github.com/AshrafM-SubSurf-Eng/gridwell-atlas). A scheduled GitHub Actions workflow runs at 09:17 UTC on the 3rd of each month and performs five steps:

1. **Fetches** the six registries from the download addresses of the agencies, and records the size, server date and SHA-256 checksum of each file. The California layer is paged through the CalGEM map service, 2,000 records at a time.
2. **Guards the reference layers.** Federal inputs (temperatures, Census, EIA-860 and Treasury files) are pinned by checksum. A file that changes upstream is not used. Instead, the build stops and opens an issue, because a reference file that is replaced without notice would change the results without a record. Exact copies of the pinned files are kept in the repository, so a build does not depend on a federal server being available. Additionally, the workflow checks whether the next annual Census and EIA-860 releases have appeared, and whether the USGS orphaned-well page and the Treasury energy-community page have changed. When they have, the workflow opens a review issue.
3. **Rebuilds** the inventory, the temperature field and its validation, the fit ratings and the county files, but only when at least one registry has changed. If the well count of a state falls by more than 20% or rises by more than 50% compared to the published build, the published data are kept and a review issue is opened. A change of this size more often means that an agency changed its file layout than that the wells changed.
4. **Compares** the new inventory with the snapshot of the previous month, keyed on state and 10-digit API number (or the USGS identifier). It lists the wells that joined the inventory, the wells that changed type (for example, inactive to orphaned, or inactive to plugged) and the wells that left the inventory (code in Appendix A.4).

5. **Publishes** the page to GitHub Pages, commits the data, adds one line to the changelog and creates a dated release with the snapshot, statistics and source manifest. As a result, every past state of the atlas can be recovered and cited.

If the server of an agency is down, the copy from the previous month is used, and the page marks the data of that state as stale. The change detection was tested by rebuilding against a synthetic previous snapshot with 500 wells removed and 300 type changes. The build reported exactly 500 wells joined and 300 type changes. The figures in this paper come from registry files downloaded on 12 October 2026. In the first live run of the workflow, on 13 October 2026, all six registries were downloaded again from the agency servers, the atlas was rebuilt, release data-2026-10-13 was published and the page was redeployed in about eight minutes. One day of updates to the Colorado registry had already moved six inactive wells into the inventory (three in La Plata County and three in Weld County) and four wells out of it, including one conditional (C) well in Rio Blanco County. The 300 best-fit wells were unchanged.

5. Results

5.1 The inventory by type

The results show that plugged and dry wells make up 80% of the 948,992 wells (Table 5). The types differ in age and in the amount of information on record. Inactive, unplugged wells are the youngest, with a median spud year of 2006, followed by orphaned (1990), plugged (1980) and dry wells (1972). A usable vertical depth is on record for 39.5% of inactive wells, 39.6% of plugged wells and 61.3% of dry wells. However, only 4.8% of orphaned wells have a usable vertical depth, and almost all of them are Kansas orphan-list wells with a median depth of 1,002 ft (305 m). The public USGS orphaned-well dataset has no depth field.

Table 5. Wells by state and abandonment type.

State	Inactive, unplugged	Orphaned, unplugged	Plugged and abandoned	Dry and abandoned	All
California	27,295	2,742	130,455	16,602	177,094
Colorado	7,179	22	30,398	25,396	62,995
Kansas	15,280	9,634	158,415	115,768	299,097
New York	2,559	6,930	18,440	2,096	30,025
North Dakota	1,898	475	6,480	6,348	15,201

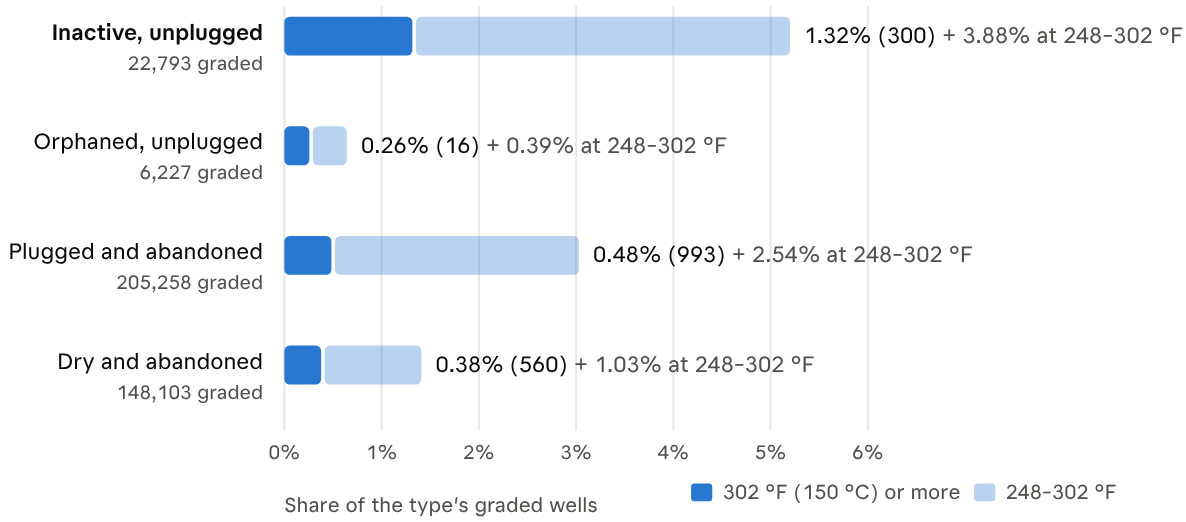
State	Inactive, unplugged	Orphaned, unplugged	Plugged and abandoned	Dry and abandoned	All
Oklahoma	3,554	27,252	174,562	75,454	280,822
20 other states (USGS list only)	—	83,758	—	—	83,758
All	**57,765**	**130,813**	**518,750**	**241,664**	**948,992**

5.2 Temperature at each well's own depth

Abandoned wells are mostly shallow. The median usable vertical depth is 3,338 ft (1,017 m), and only 3,538 graded wells (0.93%) reach 10,000 ft (3,048 m). Of the 382,381 wells the field can grade, 91.0% are below 194 °F (90 °C) at total depth, 6.5% are at 194–248 °F (90–120 °C), 2.0% are at 248–302 °F (120–150 °C), and 1,869 wells (0.49%) are at 302 °F (150 °C) or more. The share at EGS temperature is highest among inactive, unplugged wells, which are younger and were drilled to deeper targets (Figure 1).

Figure 1. Inactive, unplugged wells are the type most often at EGS temperature

1,869 of 382,381 graded wells (0.49%) reach 302 °F (150 °C) at their own vertical depth



GRIDWELL build, 2026-10-12 · 382,381 wells with a usable vertical depth in Kansas, Colorado, New York and North Dakota

5.3 The best-fit wells

The 300 wells rated A are inactive, unplugged wells with an operator of record that reach 302 °F (150 °C) at total depth. Their median vertical depth is 12,108 ft (3,690 m), and their median modeled temperature is 319 °F (160 °C), with 80% of the wells between 306 and

348 °F (152 and 175 °C). Most were spudded between 1984 and 2013 (median 2007). The wells are located in two basins. In the Piceance Basin of Colorado, 224 wells, mostly shut-in wells, are in Rio Blanco (112), Garfield (107), Mesa (3) and Moffat (2) counties. In the Williston Basin of North Dakota, 76 inactive, temporarily abandoned or abandoned-unplugged wells are mainly in McKenzie (45), Billings (16), Williams (5) and Bowman (4) counties. All 16 wells rated B, which are orphaned wells at EGS temperature, are also in the Williston Basin, and 12 of them are in McKenzie County.

The North Dakota count is a minimum. Of the 1,898 inactive, unplugged wells in North Dakota, 1,387 report only measured depth on what appear to be horizontal wells, and they are not graded (Section 3.3). Bakken horizontal wells typically have a vertical depth near 10,500 ft (3,200 m), which is close to the depth at which the field reaches 302 °F (150 °C) in the center of the basin.

5.4 What deepening would reach

Another 909 unplugged wells are at 248–302 °F (120–150 °C) and are rated C. The median well in this group has already been drilled 83% of the way to the depth of 302 °F (150 °C), with a median of 1,753 ft (534 m) left to drill. Across all unplugged wells, 2,136 are within 3,281 ft (1,000 m) of that depth. Additionally, the rock below the shallow wells is hotter. At 15,000 ft (4,572 m), which is close to the depth of Fervo's Cape Station appraisal well, the field reaches 302 °F (150 °C) beneath 47.7% of all inventory wells and 72.8% of inactive, unplugged wells. In comparison, the field reaches 302 °F (150 °C) at 10,000 ft (3,048 m) beneath only 9.7% of all wells. As a result, most abandoned wells are not EGS wells in their current state. However, many of them mark locations where a deepened well or a new EGS well would reach EGS temperatures.

5.5 Grid and energy communities

The results show that hot wells are rarely near the high-voltage grid (Table 6). The median best-fit well is 33.5 mi (53.8 km) from a power plant that connects at 69 kV or more, compared to 11.2 mi (18.1 km) for the inventory as a whole. Only 7 best-fit wells, in McKenzie and Williams counties, North Dakota, are within 6.2 mi (10 km) of such a plant, and none is in a county that is an energy community for 2026. Among the conditional (C) wells, 215 are both near the grid and in a 2026 energy-community county.

Table 6. EGS fit ratings, grid proximity and 2026 energy-community status.

Rating	Wells	Within 6.2 mi (10 km) of ≥ 69 kV	In a 2026 energy-community county	Both
A · Best fit	300	7	0	0
B · Strong fit after transfer	16	0	0	0
C · Conditional	1,902	273	251	215
D · Limited	7,308	2,311	2,825	2,053
E · Below EGS grade	372,855	58,024	21,011	7,730
U · Not graded	566,611	203,523	220,254	132,533
All	**948,992**	**264,138**	**244,341**	**142,531**

Energy-community status in this study is the county-wide statistical-area test. A well can also qualify through a coal-closure census tract or a brownfield site, and the atlas shows these per county.

6. Barriers by abandonment type

A suitable temperature is a necessary condition for EGS reuse, but it is not the only condition. This section sets out the other barriers between each type of abandoned well and an EGS reservoir, with the evidence for each barrier (Table 7).

Table 7. Barriers to EGS reuse by abandonment type (● major, ◐ moderate, ○ minor or none).

Barrier	Inactive, unplugged	Orphaned, unplugged	Plugged and abandoned	Dry and abandoned
Work to regain the wellbore	○ wellhead in place	◐ open but neglected	● plugs to drill out, casing may be gone	● open-hole plugs, often no production casing
Casing and cement condition	◐ unknown until tested	● oldest, least maintained	◐ unknown below plugs	● little or none to test

Barrier	Inactive, unplugged	Orphaned, unplugged	Plugged and abandoned	Dry and abandoned
Records (depth, logs)	○ usually on file	● USGS list has no depths	○ usually on file	○ logged before abandonment
Temperature at existing depth	● 1.3% at EGS grade	● 0.26%	● 0.48%	● 0.38%
Who can sign	◐ operator agreement	● needs a state transfer route	◐ new permit and bond	◐ new permit and bond
Deadline pressure	● plugging clocks	● state plugging queues	○	○

Four barriers apply to every abandonment type and are discussed below: geothermal resource ownership, federal leasing, injection permitting and induced seismicity.

6.1 Wellbore condition

Integrity. Loss of well integrity is common and affects about 35% of wells worldwide, and a well with poor integrity can stop a repurposing project or require major workover before the project begins (Santos et al., 2022). Across the data sets reviewed by Davies et al. (2014), between 1.9% and 75% of wells showed a barrier or integrity failure. Similarly, in Pennsylvania, statewide inspection records showed a sixfold higher incidence of cement or casing problems in shale gas wells than in conventional wells (Ingraffea et al., 2014). An inactive well can be logged and pressure-tested before a developer commits to it. However, an orphaned well usually cannot be tested in this way, because no one has maintained it. Additionally, a workshop of state plugging programs heard that well-depth data exist for only about half of documented orphaned wells, and that many older wells with no records and damaged wellbores are unsuitable for repurposing (NASEM, 2025).

Cement at EGS temperature. Ordinary Portland cement becomes weaker and more permeable above about 230 °F (110 °C) unless 35–40% silica flour by weight of cement is added. Additionally, injection and fracturing pressures and thermal stress can weaken the bond between the cement and the casing (Kemoi, 2017). An oil or gas well completed at a moderate temperature may not have silica-stabilized cement. Furthermore, an EGS well cycles between injection-cooled and production-hot conditions. Every well rated A, B or C is hotter than 230 °F (110 °C) at depth.

Heat lost through the wellbore. Gaps between the casing and the cement, or between the cement and the formation, can lower the produced temperature, and many abandoned oil and gas wells are cemented over only part of their length (Santos et al., 2022). For example, in one conversion described in a Society of Petroleum Engineers webinar, a microannulus between the cement and the casing reduced the output temperature well below the expected value (Dahi Taleghani, 2023). Fracture-sealing and annulus-sealing treatments are designed to close this path of heat loss.

Plugged wells. Plugging rules allow the production casing to be pulled, and they require the surface casing to be cut below ground and capped. For example, the Mississippi rule sets out which plugs are required when the production casing is pulled (26 Miss. Code R. §2-1.28). Santos et al. (2022) conclude that a wellbore is difficult to access after plugging and abandonment (P&A), so the decision to repurpose a well has to be made before the surface site is decommissioned. However, plugged wells keep their records, and plugging lowers the leakage risk. Among abandoned wells, being an unplugged gas well is the strongest predictor of high methane emissions (Kang et al., 2016).

Dry holes. A dry hole is usually plugged in open hole below the surface casing. The same Mississippi rule also sets out how wells drilled without casing must be plugged. As a result, the reuse of a dry hole is close to drilling a new well. Dry holes can still be converted. For example, a 6,562 ft (2,000 m) dry hole drilled in 1960 at Kiskunhalas, Hungary, became a closed-loop heat well in 2021 (Dahi Taleghani, 2023). However, a closed loop extracts heat by conduction only, so its output is usually small (Santos et al., 2022). For EGS, the main value of a dry hole is its log and its bottom-hole temperature, which locate hot rock.

Diameter. Geothermal power generation needs wider wells than many oil and gas wells at the end of their life (NASEM, 2025). For example, the DOE evaluation of EGS targeted sustained production of 392 °F (200 °C) fluid at 176 lb/s (80 kg/s) (DOE, 2007), and Fervo's Project Red produced about 1,000 gal/min (63 L/s) from purpose-drilled wells. No registry in GRIDWELL publishes casing sizes, so the diameter of each well must be checked individually.

6.2 Heat, flow and fracture short-circuiting

Most abandoned wells are too shallow for EGS: 99.5% of graded wells are below 302 °F (150 °C) at their bottom (Section 5.2). Where a well is hot enough, an EGS reservoir still has to sweep heat evenly. Circulating water follows the most conductive fractures, which cool first and create a thermal short-circuit in the reservoir. For example, at Rosemanowes in the United Kingdom, proppant improved connectivity so much that it was considered a

cause of a worse thermal short-circuit (Shiozawa and McClure, 2014). At Newberry, Oregon, multiple zones were stimulated with a thermally degrading chemical diverter. Shiozawa and McClure (2014) also note that it is technically easier to plug short-circuiting intervals in wells completed with cemented casing, which favors wells that still have casing over dry holes. Additionally, modeling shows that placing conductivity-tuning agents between the wells can prevent flow and thermal short-circuits and delay early thermal breakthrough (Zhang et al., 2024).

Biopolymer treatments are one method to seal these short-circuit fractures, but temperature limits their use. In laboratory tests, xanthan lost about half of its viscosity at 194 °F (90 °C), while schizophyllan lost little viscosity up to 212 °F (100 °C) (Gao, 2016). However, EGS-grade wells start at 302 °F (150 °C). As a result, a biopolymer sealing treatment for these wells must be formulated and tested for stability well above the range of conventional polymer flooding. Alternatively, the treatment must be placed where circulating water has cooled the rock, such as in fractures near the injector. The temperature at total depth and the temperature–depth profiles exported by GRIDWELL provide the starting conditions for this design work.

6.3 Induced seismicity

Stimulating an EGS reservoir requires injection at high pressure. The 2017 Mw 5.5 Pohang earthquake in Korea was triggered after small earthquakes caused by high-pressure injection into the PX-2 well reactivated a fault that had not been mapped (Ellsworth et al., 2019). The DOE protocol for EGS projects sets out how to assess and manage this hazard (Majer et al., 2012). This barrier applies to every abandonment type. It depends on the faults and stresses at each site, which GRIDWELL does not screen.

6.4 Legal and regulatory

Who owns the heat. Ownership of geothermal energy is set by state law, and it can differ from ownership of the oil and gas. For example, Texas Senate Bill 785 (2023) made geothermal energy the property of the surface owner where the surface and mineral estates are severed, and it excluded oil, gas and minerals from geothermal energy. The bill took effect on 18 June 2023 without the signature of the governor (ThinkGeoEnergy, 2023; bill analysis). As a result, an operator who holds an oil and gas lease may not hold the right to produce heat from the same well.

Federal land. Geothermal leases on federal land are issued under the Geothermal Steam Act of 1970 and administered by the Bureau of Land Management. These leases fall under a different statute and different lease terms from oil and gas leases. Approval of a

geothermal drilling permit has typically taken one month with a determination of National Environmental Policy Act (NEPA) adequacy, two months with a categorical exclusion and ten months with an environmental assessment (Congressional Research Service, R48064).

Who can sign for the well. For an inactive well, the operator of record can sell or lease the well, but agreement is not automatic. For example, in reporting on a conversion in the Williston Basin, Gosnold named reaching an agreement with the well operator as one of the biggest challenges (as reviewed by Santos et al., 2022). The transfers themselves are routine, and the IOGCC notes that operators often transfer wells to other operators (IOGCC, 2021). However, Santos et al. (2022) found that administrative procedures are a major barrier to converting a hydrocarbon license into a geothermal license, and that projects can take 7–10 years to come online because of regulatory barriers.

Orphaned wells. Federal orphaned-well grants may fund the plugging, remediation and reclamation of orphaned wells, and the work to identify, rank and measure them (42 U.S.C. §15907). The 2025 grant guidance of the Department of the Interior lists the permissible uses, and reuse is not one of them (DOI, 2025). As a result, the reuse of an orphaned well requires a state process to transfer the well and its liability. New Mexico enacted such a process in 2025: House Bill 361 allows the Energy, Minerals and Natural Resources Department to authorize the conversion of an oil or gas well to geothermal or energy-storage use (ThinkGeoEnergy, 2025a; agency analysis). In 2026, the New Mexico House asked the Oil Conservation Division to study the transfer of orphaned wells to third parties and to report by 1 November 2026 (House Memorial 56). Similarly, Oklahoma House Bill 3173 would allow orphaned and abandoned wells to be converted for geothermal use at 250 °F (121 °C) or more, and would create a process for companies to acquire orphaned wells. The bill passed the House on 16 March 2026 (KOSU, 2026), and no Senate vote is recorded.

Injection. Wells that inject fluid to recover geothermal energy for electric power are Class V wells under the federal Underground Injection Control program (40 CFR §144.81(11)). As a result, a repurposed injector requires Class V authorization from EPA or from a state with primacy.

Plugging deadlines. Idle wells face increasing pressure to be plugged. California defines an idle well as a well with no production or injection for 24 consecutive months, and a long-term idle well as a well that has been idle for eight years or more. Its regulations require idle wells to be tested and, if necessary, repaired or permanently sealed (CalGEM). Texas Senate Bill 1150, signed on 20 June 2025, bars routine plugging extensions from 1 September 2027 for wells inactive more than 15 years and completed

more than 25 years earlier (Section 4; Texas SB 1150). These rules shorten the time in which an inactive well can be acquired with its casing intact, and a monthly screen shows which wells are approaching that limit.

6.5 What the evidence implies for each type

- **Inactive, unplugged wells are the best fit for EGS.** The wellbore is open, an owner exists, the records are on file, and this type is the type most often hot. The remaining barriers are integrity testing, cement rated for EGS temperature, well diameter and the agreement of the operator before the well is plugged.
- **Orphaned, unplugged wells are second, after a legal step.** Physically, they are similar to inactive wells, but they are older and less documented. Legally, no party can sign for them until the state creates a transfer process. Additionally, federal grants cannot fund their reuse.
- **Plugged and abandoned wells require re-entry.** Their records survive, and plugging reduced their leakage risk. However, the plugs must be drilled out, the casing may have been pulled, and the work requires new permits and bonding.
- **Dry holes are data wells.** Their logs and temperatures help locate a new EGS well. As wellbores, they are close to new drilling.

7. Economics

Firm power at a competitive price. Lazard's 2025 analysis puts unsubsidized geothermal electricity at $66–109/MWh, compared to $48–109/MWh for gas combined cycle, $38–78/MWh for utility-scale solar and $37–86/MWh for onshore wind. The analysis assumes a geothermal capital cost of $5,000–6,460/kW and a capacity factor of 80–90% (Lazard, 2025). The operating U.S. fleet ran at a capacity factor of 64.6% in 2024 (EIA, Table 4.08.B). Geothermal output is firm, but its capital cost places it at the top of the cost range, and drilling is the largest part of that capital cost.

Avoided drilling. If drilling is at least half of the capital cost (DOE, 2017), a project that avoids a fraction f of its drilling cost reduces its capital cost by at least $f/2$. An EGS doublet needs at least one injector and one producer. For this reason, the reuse of one existing well that already reaches 302 °F (150 °C) avoids the drilling of at most half of the wells, less the cost of re-entry, testing and any recompletion. Table 8 applies this calculation to the capital-cost range from Lazard.

Table 8. Minimum capital-cost reduction from avoided drilling.

Drilling cost avoided, *f*	Capital cost reduction, at least	On $5,000–6,460/kW
10%	5%	$250–323/kW
25%	12.5%	$625–808/kW
50% (upper bound for one well of a two-well doublet)	25%	$1,250–1,615/kW

For the 909 unplugged wells rated C, the median well has already been drilled 83% of the way to 302 °F (150 °C). However, the cost per foot rises with depth, so the share of drilling cost avoided is smaller than the share of depth already drilled. The deepening still has to be engineered and paid for.

Tax credit. For 2025, the §45Y production credit is 3.0 ¢/kWh for facilities that meet the prevailing-wage and apprenticeship rules (Federal Register 2025-16249), and a site in an energy community raises the credit by 10% (IRS Notice 2023-29). At the fleet capacity factor of 64.6%, one megawatt produces 5,659 MWh a year and earns $169,770 a year of §45Y credit. The energy-community bonus adds $16,977 a year, or about $0.17 million per megawatt over the 10-year credit period before inflation adjustment. Under §48E, a 30% investment credit becomes 40% in an energy community, which is worth $0.50–0.65 million per megawatt at $5,000–6,460/kW. Geothermal keeps the full §45Y and §48E credits for construction that begins by the end of 2033. After 2033, the credits phase down, with no credit after 2035 (NASEO summary of P.L. 119-21). The bonus has value, but it does not change which wells the screen rates highest. None of the 300 best-fit wells is in a 2026 statistical-area energy community, while 215 conditional wells are both near the grid and in such a community.

Plugging liability. Raimi et al. (2021) report median costs of about $20,000 to plug a well and $76,000 to plug it and reclaim the site, from data on up to 19,500 wells (Raimi et al., 2021). At those medians, the 130,813 orphaned, unplugged wells in GRIDWELL represent about $2.6 billion of plugging and $9.9 billion of plugging and reclamation. For comparison, the Infrastructure Investment and Jobs Act provided $4.7 billion for orphaned wells (DOI OIG, 2022). A repurposed well still has to be plugged at the end of its life. However, where state transfer rules allow it, repurposing delays the plugging cost and puts the well to productive use before it is plugged.

Scale per well. A single repurposed well is one component of an EGS and cannot serve as a power plant on its own. Modeled closed-loop output from one deep abandoned well is in the hundreds of kilowatts. For example, Wight and Bennett (2015) modeled 109–630 kW net at 13,780 ft (4,200 m). Field co-production projects reviewed by Santos et al. (2022) range from 19 kW in Mississippi to 310 kW from eight wells at 73 lb/s (33 kg/s) and 230 °F (110 °C) in China. In comparison, Fervo's 3.5 MW Project Red used purpose-drilled, stimulated horizontal wells. As a result, an existing hot well has the most value as one well in a stimulated multi-well system, and the fit ratings screen wells for this role.

National benefits

Repurposing abandoned wells for EGS serves five national aims: 1) firm power for rising demand; 2) a cheaper route to the DOE cost target; 3) work for the oil and gas workforce; 4) investment in energy communities; and 5) a smaller public plugging bill.

Firm power for rising demand. The DOE Liftoff assessment finds that next-generation geothermal could reach 90 GW or more by 2050, compared to about 4 GW on the grid today. This capacity would be part of the 700–900 GW of clean, firm capacity that a decarbonized economy will need (DOE, 2025). Demand is already rising. According to Lawrence Berkeley National Laboratory (LBNL), U.S. data centers used about 4.4% of the electricity of the United States in 2023 and may use 6.7–12% by 2028 (LBNL, 2024). Geothermal plants burn no fuel and run around the clock (see Firm power at a competitive price above).

A cheaper route to the EGS cost target. The DOE Enhanced Geothermal Shot aims to cut the cost of EGS power by 90%, to $45/MWh by 2035. DOE states that geothermal could affordably power more than 40 million American homes (DOE, 2022a). Drilling is the largest cost of an EGS project, so each hot wellbore that is reused reduces the drilling cost of that project (Table 8).

Work for the oil and gas workforce. DOE estimates that a workforce of more than 300,000 people already has the skills that next-generation geothermal needs. DOE also estimates that geothermal power creates three to four times as many long-term jobs per megawatt as solar or wind (DOE, 2025). Similarly, the International Energy Agency (IEA) finds that more than three-quarters of the investment in next-generation geothermal is closely related to oil and gas skills and expertise (IEA, 2024). Repurposing creates this work in the basins where the abandoned wells were drilled.

Investment in energy communities. Of the 948,992 wells in GRIDWELL, 244,341 (26%) are in counties that are energy communities in 2026, and 142,531 of these wells are also within 6.2 mi (10 km) of a plant that connects at 69 kV or higher (Table 6). A project in an energy community earns the 10% energy-community tax-credit bonus. None of the 300 best-fit wells is in such a county. However, 215 conditional (C) wells are in such a county and are also near the grid.

A smaller public plugging bill. Plugging and reclaiming the 130,813 orphaned, unplugged wells in GRIDWELL would cost about $9.9 billion, more than twice the $4.7 billion that Congress provided for orphaned wells. Plugging alone would cost about $2.6 billion (see Plugging liability above). Each orphaned well that is reused in an EGS project delays its share of this cost and becomes a productive asset.

8. Discussion and limitations

From screen to simulation. GRIDWELL reduces nearly one million wells to a few hundred wells that justify a records review and a site visit, and it records the reason each well was kept or removed. For a selected well, the atlas exports the modeled temperature–depth profile in both unit systems, together with the support of the gradient (the number of bottom-hole readings and the distance to the nearest reading). This profile serves as the initial condition for a reservoir or wellbore heat-transfer simulation. It is also the input needed for the author's biopolymer-flooding simulations: the formation temperature that the sealing of fractures and annuli around an old wellbore is meant to preserve, and the temperature range in which a sealing agent must remain stable.

Who it serves. A developer can start from the A and C ratings and filter the wells by grid distance and energy-community status. A state regulator can identify which inactive wells are hot before plugging deadlines require them to be plugged. A program such as Wells of Opportunity can find candidate fields, and any user can check how the wells in a county changed since the previous month. Additionally, operators, landowners and regulators can look up a single well by its API number, the permanent public identifier of a U.S. well, and see its abandonment type, reported status, depth, modeled temperatures and fit rating.

Limitations.

- **Coverage.** Six state registries are loaded. In the other 20 states, only documented orphaned wells are counted. As a result, Texas, Pennsylvania, Ohio, West Virginia, Wyoming, New Mexico and Louisiana are under-represented until their registries are added.

- **Depth.** The Oklahoma and California registries and the USGS orphaned-well list publish no total depth, so 59.7% of wells are not graded at depth. These wells are still shown at 5,000, 10,000 and 15,000 ft (1,524, 3,048 and 4,572 m). The rule that excludes apparently horizontal measured-depth records (2,647 wells) is conservative, and it removes most of the inactive wells in North Dakota.
- **Temperature.** Modeled temperatures carry the errors in Table 3, and the contributing BHT compilations disagree in places (Section 3.4). Between readings, the geotherm is assumed to be linear from a surface temperature of 59 °F (15 °C), and the Harrison correction was fitted to data from Oklahoma.
- **Wellbore.** No registry publishes casing size, cement design or integrity test results, and Section 6 shows that each of these can rule a well out.
- **Status.** Statuses are taken as each agency reports them. Some shut-in or temporarily abandoned wells will return to production, and the monthly refresh records these changes.
- **Grid and tax layers.** Plant interconnections are used in place of substations, and energy-community status is shown by county. Coal-closure tracts and brownfield sites must be checked for each site.
- **De-duplication.** In Kansas, at most 697 USGS orphaned wells may duplicate a state orphan-program well that could not be matched.
- **Automation.** The change detection was tested offline. The full workflow (live downloads, rebuild, release and page deployment) has run three times: by hand on 13 and 17 October 2026, and on its monthly schedule on 3 November 2026. Each run completed and published a dated release. An agency can change its file layout or status codes without notice. In that case, the refresh keeps the last good download, or keeps the published data if the well count of a state changes sharply, and opens a review issue. A person still has to review and resolve the issue.

Release status. This paper describes version 1.0.0 of GRIDWELL Atlas. The release is archived on Zenodo at doi:10.5281/zenodo.23408754.

9. Conclusions

The conclusions of this study are as follows:

1. Orphaned wells are abandoned wells. They differ from other abandoned wells in liability, and they do not form a separate population of wells.

2. Sorting the 948,992 abandoned wells in GRIDWELL by wellbore condition and by the party with legal authority over the well gives a clear order of fit for EGS. Inactive, unplugged wells with an operator of record are first. Orphaned, unplugged wells are second, once a state provides a transfer process. Plugged wells are third, by re-entry, and dry holes are last, as sources of data.
3. At the vertical depth of each well, 0.49% of graded wells are hot enough for EGS. The best-fit group consists of 300 inactive wells in the Piceance and Williston basins at a median temperature of 319 °F (160 °C). Most of these wells are far from the high-voltage grid, at a median distance of 33.5 mi (53.8 km) from a plant that connects at 69 kV or more.
4. After temperature, the remaining barriers are well integrity, cement rated for EGS temperatures, casing diameter, fracture short-circuiting, induced seismicity, ownership of the heat and the lack of a transfer process for orphaned wells.
5. Registries change every month, and plugging deadlines are approaching for long-idle wells. For this reason, GRIDWELL rebuilds itself each month and records which wells joined the inventory, so the screen stays current while these wells can still be reused.

Declarations

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Data and code availability. The atlas is published at ashrafm-subsurf-eng.github.io/gridwell-atlas, and its code, data and monthly releases are published at github.com/AshrafM-SubSurf-Eng/gridwell-atlas (code under the MIT license, derived data under CC BY 4.0). Every input, its download address and its SHA-256 checksum are listed in the sources.json and data/manifest.json files of the repository. The numbers in this paper are from the build of 12 October 2026, which is kept unchanged in the archive/build-2026-10-12 folder of the repository, copied from commit fca14b6 with SHA-256 checksums, and archived on Zenodo with the release paper-data-2026-10-12 (doi:10.5281/zenodo.24155830). Later monthly builds will differ as the registries change, and each build is preserved as a dated release, starting with data-2026-10-13. The software is archived on Zenodo at doi:10.5281/zenodo.23408754.

Use of AI tools. The author used Claude (Anthropic), an AI assistant, as a tool to get and process the data and to write the code and the atlas page.

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Appendix A. Code excerpts

These excerpts are copied from the GRIDWELL Atlas repository (github.com/AshrafM-SubSurf-Eng/gridwell-atlas), release v1.0.0, and the functions shown are unchanged in later releases. The comments are from the source code, except comments that begin with “Note:”, and `# ...` marks lines that are left out. The code works in SI units (meters, °C and kilometers), and the atlas converts the values to field units for display.

A.1 Temperature at a well's own depth

For a well with a vertical depth z, the field uses only bottom-hole readings measured between 0.75z and 1.25z, and it takes the 12 nearest readings within 46.6 mi (75 km). Readings more than three scaled median absolute deviations from the local median are rejected, and the remaining readings are weighted by inverse distance squared, with a 0.62 mi (1 km) floor. If fewer than three readings match, the field falls back to readings at all depths. The temperature at depth is then T(z) = 15 °C + G·z (Section 3.4).

```
# pipeline/tfield.py
K_USE = 12
RADIUS_KM = 75.0
FLOOR_KM = 1.0
MIN_MATCHED = 3
DEPTH_LO, DEPTH_HI = 0.75, 1.25       # use BHTs measured within +/-25% of
the target depth
DEPTH_FLOOR_M = 300.0
MAD_K = 3.0

# Note: from DepthMatchedField.query(), for one chunk of target wells
            km, idx, valid = self._neigh(_xyz(lat[sl], lon[sl]))
            gz, zz = self.g[idx], self.z[idx]
            zt = z_m[sl][:, None]
            # ...
            lo = np.maximum(DEPTH_LO * zt, DEPTH_FLOOR_M)
            m = valid & (zz >= lo) & (zz <= DEPTH_HI * zt)
            g, n, near, sd = self._robust_idw(km, gz, m)
            ok = n >= MIN_MATCHED
            out['grad'][sl] = np.where(ok, g, out['grad_all'][sl])

    @staticmethod
    def _robust_idw(km, g, m):
        rank = np.cumsum(m, axis=1)
        use = m & (rank <= K_USE)
        gg = np.where(use, g, np.nan)
        with np.errstate(all='ignore'):
            med = np.nanmedian(gg, axis=1)
            mad = 1.4826 * np.nanmedian(np.abs(gg - med[:, None]), axis=1)
            mad = np.where(np.isfinite(mad), np.maximum(mad, 2.0), 2.0)
# >= 2 degC/km so tight clusters keep their members
            keep = use & (np.abs(g - med[:, None]) <= MAD_K * mad[:, None])
            w = np.where(keep, 1.0 / np.maximum(np.where(keep, km, 1),
FLOOR_KM) ** 2, 0.0)
```

```
            ws = w.sum(1)
            grad = np.where(ws > 0, (w * np.where(keep, g, 0)).sum(1) / ws,
np.nan)
            # ...
        return grad, n, near, sd

# pipeline/inventory.py: temperature at the well's vertical depth vd (m)
    inv['t_td'] = np.where(vd.notna(), SURFACE_T + g * vd / 1000.0, np.nan)
```

A.2 Measured-depth records that look horizontal

A record that reports only measured depth and appears horizontal or deviated is not graded at total depth, because the depth along a lateral overstates the vertical depth (Section 3.3).

```
# pipeline/states.py
H_NAME = re.compile(r'(?:\d+H\b|\d+HR\b|[0-9A-Z]-?\d*
[NS]H\b|\bH\d*$|HZ|HORIZ|\bXH\b|TFH\b|MBH\b|\d+ ?H$)', re.I)


def likely_deviated(st: str, basis, td_ft, spud_yr, name, slant=None) ->
np.ndarray:
    """True where only measured depth is reported and the record looks
deviated.

    Measured depth along a horizontal lateral overstates vertical depth, and
so
    temperature, by a factor of up to two (a Bakken well is ~20,000 ft
measured,
    ~10,500 ft vertical). These rules are deliberately narrow and state-
specific:
      ND  MD >= 12,500 ft and (spudded 2005 or later, or a horizontal-style
name)
      KS  MD >= 7,500 ft and spudded 2010 or later (Mississippian/Hunton
horizontal era)
      CO  MD only, spudded 2008 or later (or spud year unknown), and
(horizontal-style
          name or MD >= 10,000 ft); and any MD-only record of 15,000 ft or
more
      NY  MD only and the DEC 'Slant' field says Horizontal or Directional
    """
    b = pd.Series(basis).astype('string').fillna('')
```

```
    md = b.str.startswith('MD').to_numpy()
    td = np.asarray(td_ft, float)
    yr = np.asarray(spud_yr, float)
    nm =
pd.Series(name).astype('string').fillna('').str.contains(H_NAME).to_numpy()
    if st == 'ND':
        return md & (td >= 12500) & ((yr >= 2005) | nm)
    if st == 'KS':
        return md & (td >= 7500) & (yr >= 2010)
    if st == 'CO':
        # spud year unknown counts as possibly modern; very deep MD-only
records are never trusted as vertical
        return md & (((yr >= 2008) | np.isnan(yr)) & (nm | (td >= 10000)) |
(td >= 15000))
    if st == 'NY' and slant is not None:
        sl = pd.Series(slant).astype('string').fillna('').str.lower()
        return md & sl.str.contains('horiz|direc').to_numpy()
    return np.zeros(len(td), bool)
```

A.3 EGS grade and fit rating

The temperature at total depth of each graded well sets its grade, and the grade and the abandonment type together set its fit rating (Table 4). Later rules override earlier rules, so the rules are ordered from the weakest rating to the strongest.

```
# pipeline/inventory.py
GRADES = (('egs', 150.0), ('near', 120.0), ('mod', 90.0), ('low', -1e9))


def grade(t_c: pd.Series) -> pd.Series:
    out = pd.Series('nd', index=t_c.index, dtype=object)
    for name, lo in reversed(GRADES):
        out[t_c >= lo] = name
    out[t_c.isna()] = 'nd'
    return out


def add_fit(inv: pd.DataFrame) -> pd.DataFrame:
    g = grade(inv.t_td)
    c = inv.cls4
    fit = pd.Series('U', index=inv.index, dtype=object)
    fit[g.isin(['mod', 'low'])] = 'E'
```

```
    fit[(c == 'DA') & g.isin(['egs', 'near'])] = 'D'
    fit[(c == 'PA') & (g == 'near')] = 'D'
    fit[(c == 'PA') & (g == 'egs')] = 'C'
    fit[c.isin(['IN', 'OR']) & (g == 'near')] = 'C'
    fit[(c == 'OR') & (g == 'egs')] = 'B'
    fit[(c == 'IN') & (g == 'egs')] = 'A'
    inv['grade'] = g
    inv['fit'] = fit
    inv['grid'] = inv.plant69_km <= GRID_KM
    return inv
```

A.4 Monthly change detection

Each refresh gives every well a stable key and compares the new inventory with the snapshot of the previous month. Wells with a new key joined the inventory, keys that disappeared left the inventory, and wells whose type changed are counted as transitions, such as IN→PA (Section 4).

```
# pipeline/inventory.py
def make_key(inv: pd.DataFrame) -> pd.Series:
    """Stable well key used to detect wells that join the inventory between
refreshes:
    state + 10-digit API where there is one, else the DOW id, else rounded
location."""
    api = inv.api10.astype('string')
    dow = inv.dow_id.astype('string')
    loc = (inv.lat.round(5).astype('string') + ',' +
inv.lon.round(5).astype('string'))
    k = inv.st.astype('string') + ':' + api.where(api.notna(), 'dow' +
dow.where(dow.notna(), 'xy' + loc.fillna('?')))
    # records without API, DOW id or coordinates: disambiguate by row order
within the state
    dup = k.duplicated(keep=False)
    if dup.any():
        k[dup] = k[dup] + '#' +
inv[dup].groupby(k[dup]).cumcount().astype('string')
    return k


# pipeline/diff.py, from compare(prev, cur, inv)
    p = prev.set_index('key')
    c = cur.set_index('key')
```

```
    added = c.index.difference(p.index)
    removed = p.index.difference(c.index)
    both = c.index.intersection(p.index)
    moved = both[(c.loc[both, 'cls4'] != p.loc[both, 'cls4']).to_numpy()]
    # ...
    trans = (p.loc[moved, 'cls4'].astype(str) + '→' + c.loc[moved,
'cls4'].astype(str)).value_counts().to_dict()
```