PIVOT 2022 SPE Datathon

Kick-off Meeting

June 21, 2022

Agenda

- Welcome – Silviu Livescu
- Utah FORGE – John
- Problem Introduction and Data Description – Andy
- Problem Description – Luke
- Competition Logistics - Pushpesh
  - Learning
  - Slack Channel
  - Competition

Welcome

- SPE Gulf Coast Section
- SPE Calgary, SPE Netherlands, SPE London
- Project InnerSpace
- Committee: Andy Adams, Manisha Bhardwaj, Tom Blasingame, John Boden, Birol Dindoruk, Promise Ekeh, Luke Frash, Amir Hossein Fallah, Yasin Hajizadeh, Kevin Jones, Sarath Ketineni, Keivan Khaleghi, Timur Kuru, Silviu Livescu, Adele Martin, Nefeli Moridis, Luca Motti, James Ng, Sean Porse, David Shackleton, Pushpesh Sharma, Pejman Shoeibi Omrani, Junichi Sugiura, Esteban Ugarte Daza

Introduction to GDR

U.S. DEPARTMENT OF ENERGY
Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Geothermal Data Repository (GDR)

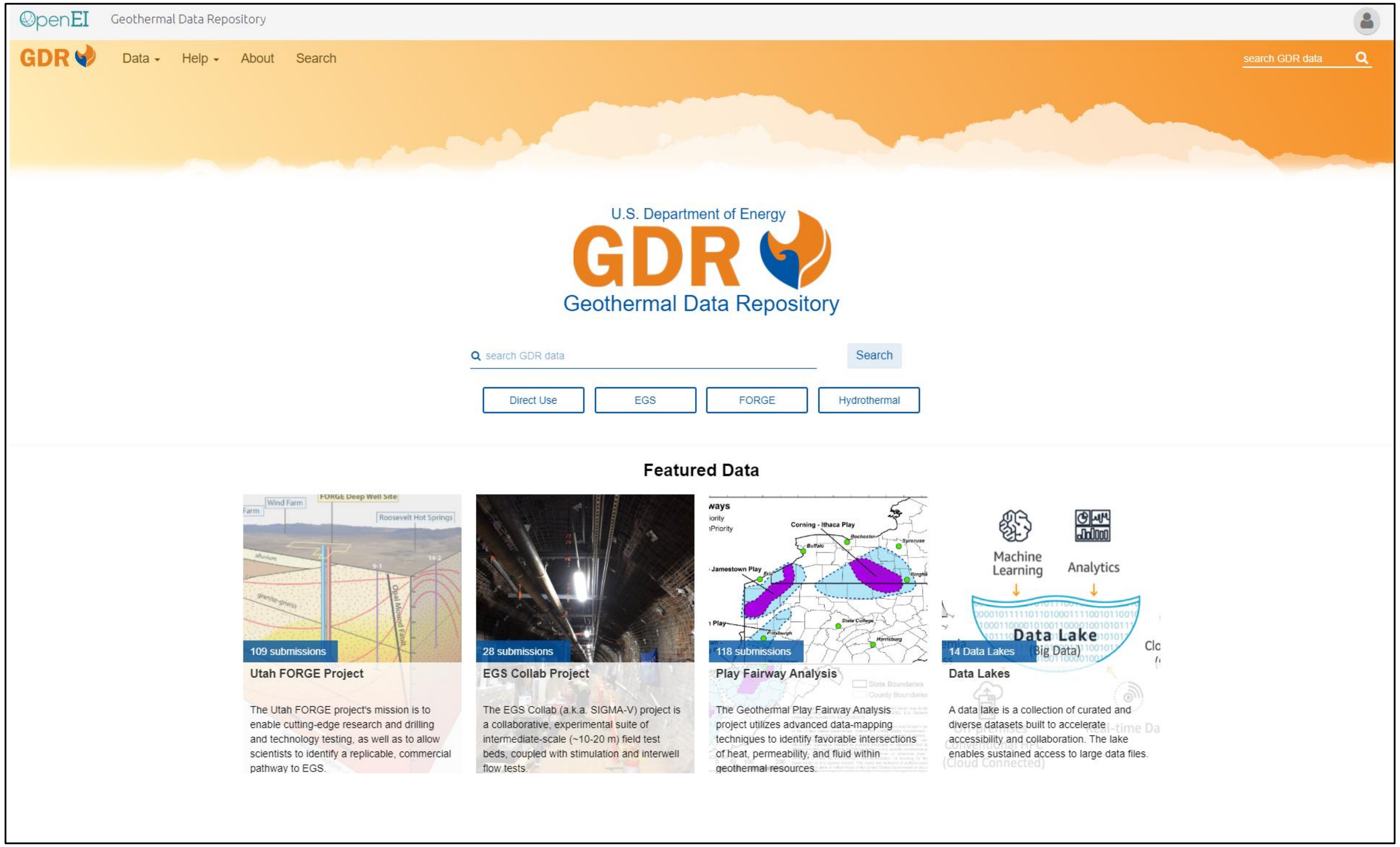
Andy Adams – Technical Project Monitor for the Geothermal Technologies Office (GTO)

Geothermal Data Repository

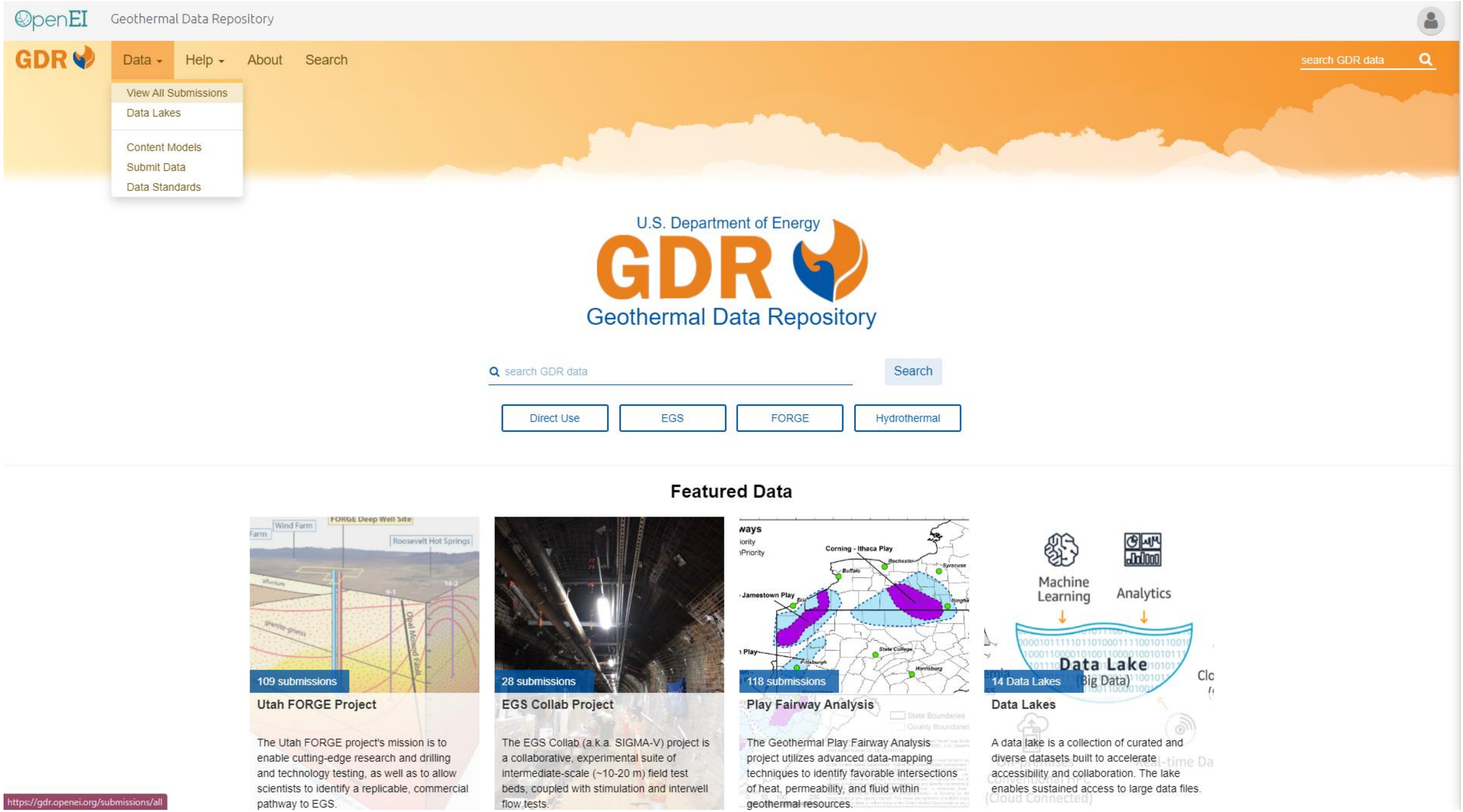
- "Open, transparent, universal access to public data" – Jon Weers, NREL

- Data available to "innovate and discover new insights through data science and machine learning"

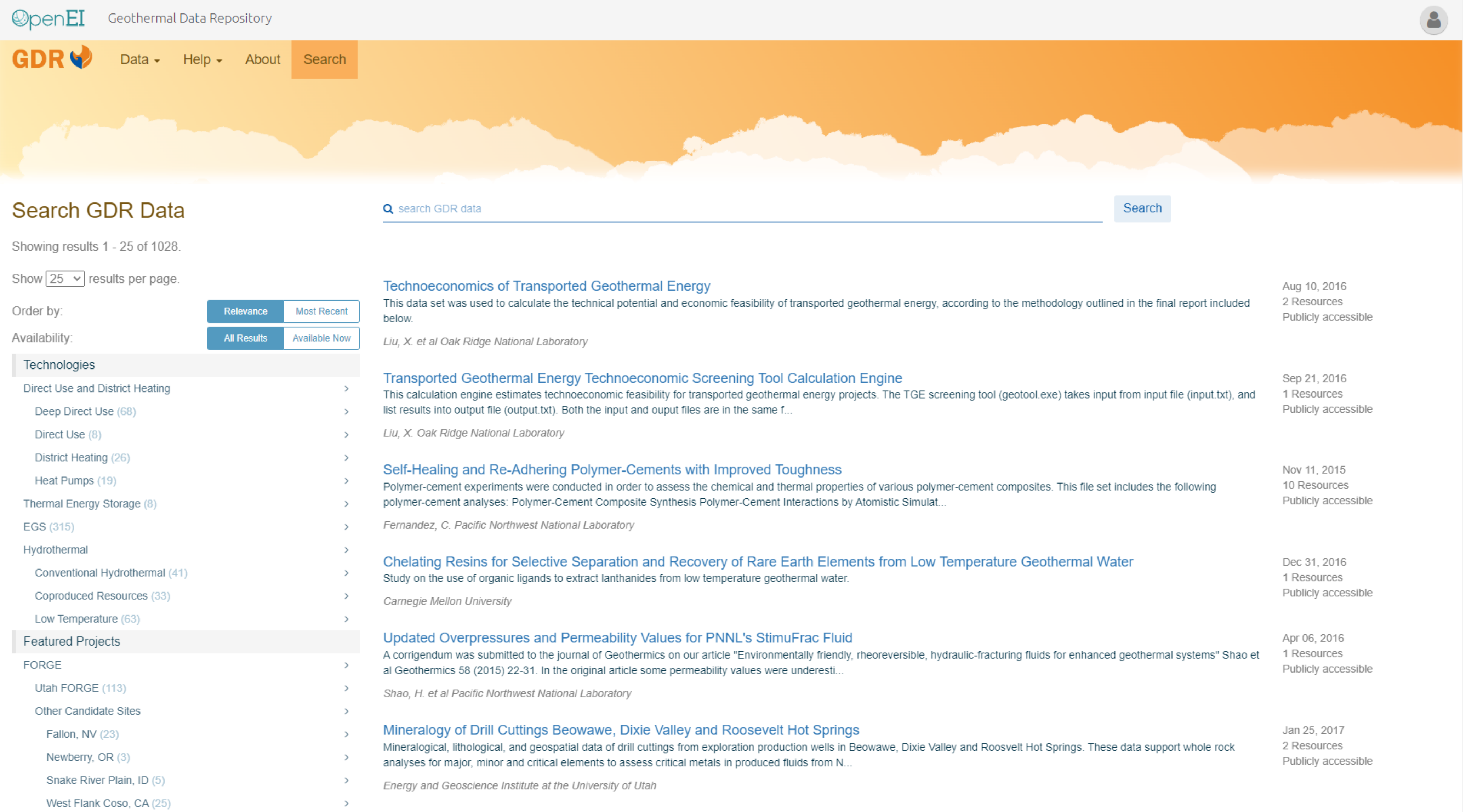
https://gdr.openei.org



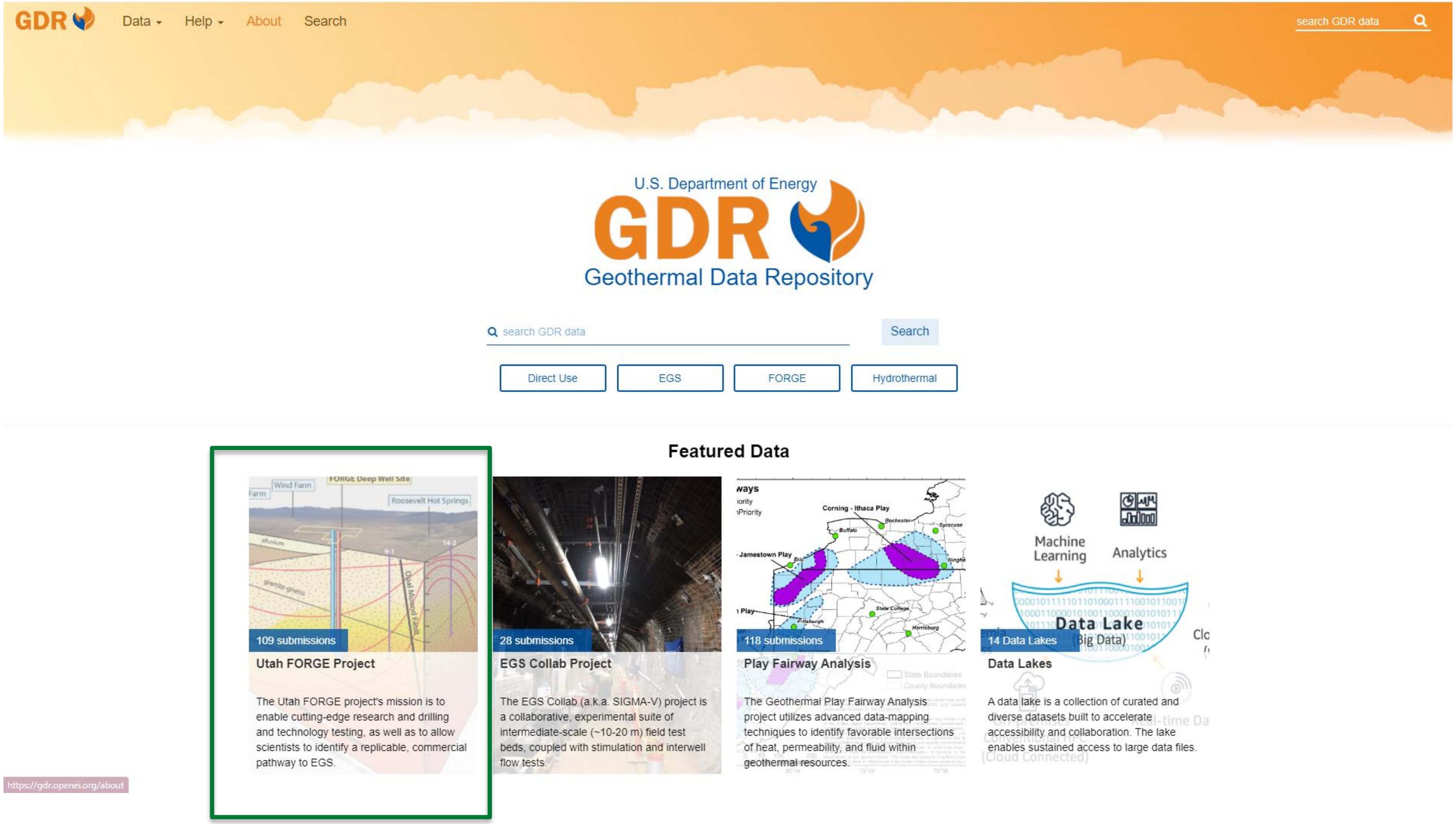
GDR – Data Querying



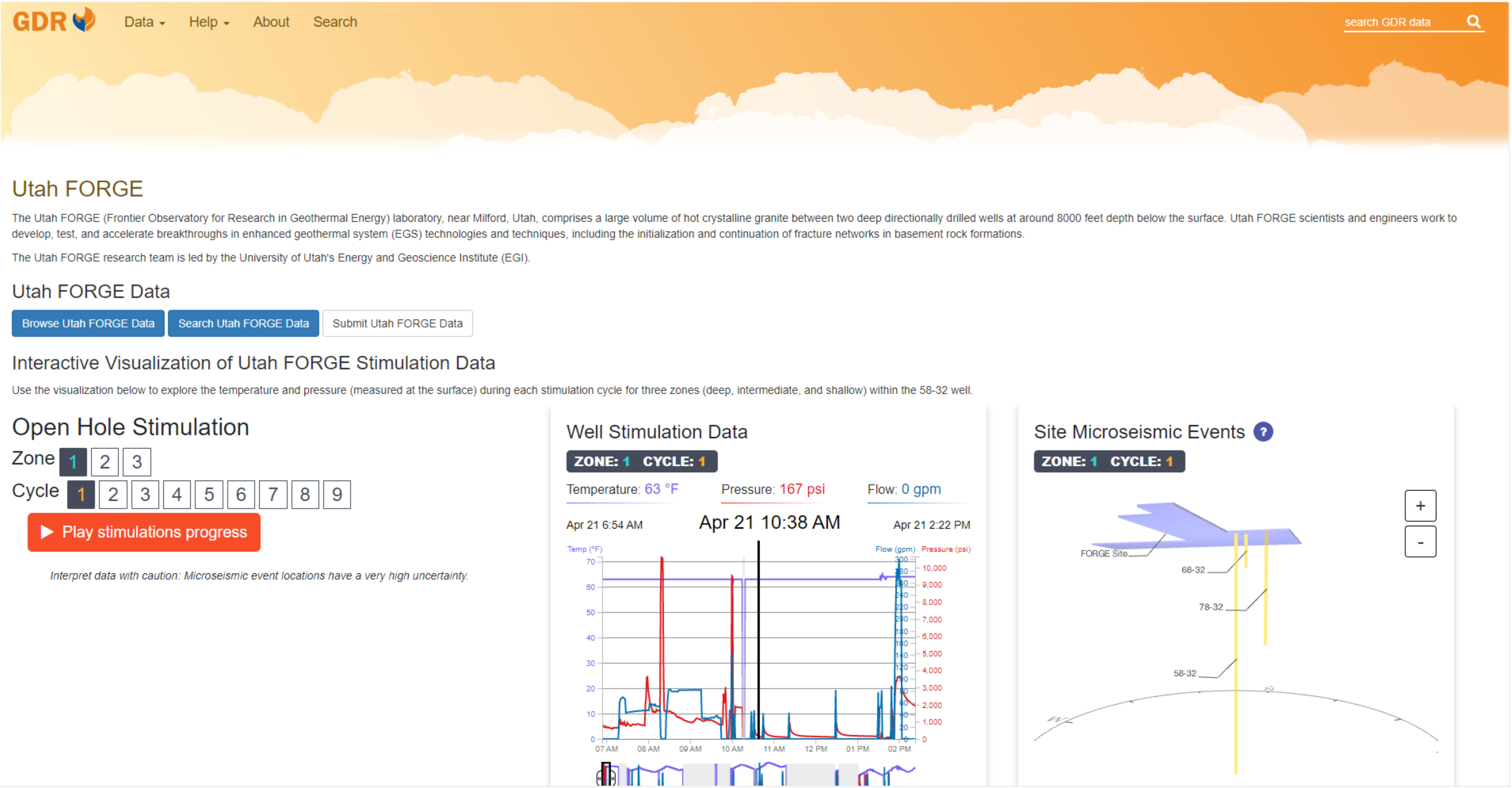
GDR - Search


OpenEI
Geothermal Data Repository
GDR
Data
Help
About
Search
Search GDR Data
Showing results 1 - 25 of 1028.
Show 25 results per page.
Order by:
Relevance
Most Recent
Availability:
All Results
Available Now
Technologies
Direct Use and District Heating
Deep Direct Use (68)
Direct Use (8)
District Heating (26)
Heat Pumps (19)
Thermal Energy Storage (8)
EGS (315)
Hydrothermal
Conventional Hydrothermal (41)
Coproduced Resources (33)
Low Temperature (63)
Featured Projects
FORGE
Utah FORGE (113)
Other Candidate Sites
Fallon, NV (23)
Newberry, OR (3)
Snake River Plain, ID (5)
West Flank Coso, CA (25)
search GDR data
Search
Technoeconomics of Transported Geothermal Energy
This data set was used to calculate the technical potential and economic feasibility of transported geothermal energy, according to the methodology outlined in the final report included below.
Liu, X. et al Oak Ridge National Laboratory
Aug 10, 2016
2 Resources
Publicly accessible
Transported Geothermal Energy Technoeconomic Screening Tool Calculation Engine
This calculation engine estimates technoeconomic feasibility for transported geothermal energy projects. The TGE screening tool (geotool.exe) takes input from input file (input.txt), and list results into output file (output.txt). Both the input and ouput files are in the same f...
Liu, X. Oak Ridge National Laboratory
Sep 21, 2016
1 Resources
Publicly accessible
Self-Healing and Re-Adhering Polymer-Cements with Improved Toughness
Polymer-cement experiments were conducted in order to assess the chemical and thermal properties of various polymer-cement composites. This file set includes the following polymer-cement analyses: Polymer-Cement Composite Synthesis Polymer-Cement Interactions by Atomistic Simulat...
Fernandez, C. Pacific Northwest National Laboratory
Nov 11, 2015
10 Resources
Publicly accessible
Chelating Resins for Selective Separation and Recovery of Rare Earth Elements from Low Temperature Geothermal Water
Study on the use of organic ligands to extract lanthanides from low temperature geothermal water.
Carnegie Mellon University
Dec 31, 2016
1 Resources
Publicly accessible
Updated Overpressures and Permeability Values for PNNL's StimuFrac Fluid
A corrigendum was submitted to the journal of Geothermics on our article "Environmentally friendly, rheoreversible, hydraulic-fracturing fluids for enhanced geothermal systems" Shao et al Geothermics 58 (2015) 22-31. In the original article some permeability values were underesti...
Shao, H. et al Pacific Northwest National Laboratory
Apr 06, 2016
1 Resources
Publicly accessible
Mineralogy of Drill Cuttings Beowawe, Dixie Valley and Roosevelt Hot Springs
Mineralogical, lithological, and geospatial data of drill cuttings from exploration production wells in Beowawe, Dixie Valley and Roosvelt Hot Springs. These data support whole rock analyses for major, minor and critical elements to assess critical metals in produced fluids from N...
Energy and Geoscience Institute at the University of Utah
Jan 25, 2017
2 Resources
Publicly accessible

FORGE - https://gdr.openei.org/forge



FORGE Main Page



FORGE – Browse FORGE Data

Utah FORGE is a dedicated underground field laboratory sponsored by DOE. The lab is located near the town of Milford in Beaver County, Utah, on the western flank of the Mineral Mountains.

View Utah FORGE Site

The Energy Department envisions Utah FORGE as a dedicated site where scientists and engineers will be able to develop, test, and accelerate breakthroughs in enhanced geothermal system technologies.

View GTO Utah FORGE Site

An extensive volume prepared by Drs. Rick Allis and Joseph Moore on the geothermal characteristics of the Roosevelt Hot Springs system and adjacent FORGE EGS Site near Milford, Utah.

View Site Characteristics Report

Utah FORGE Data

113
Submissions

13414
Downloads
(this year)

204.56 GB
of Utah FORGE Data

Search this table

Show 10 entries

Submission	id	Submitted	Downloads Last Month	Downloads This Year	Resources	Size	Status	Updated Date
Utah FORGE Seismicity Associated with the 2019 Well 58-32...	1385	06/13/2022	0	0	1	10.18 kB	Publicly accessible	06/13/2022
Utah FORGE Well 16A(78)-32 Stimulation Data (April, 2022)	1379	05/25/2022	0	0	11	288.94 MB	Publicly accessible	06/06/2022
Utah FORGE Groundwater Levels: Updated March 2022	1371	03/17/2022	0	19	1	19.81 MB	Publicly accessible	03/21/2022
Utah FORGE FSB4, FSB5, & FSB6 Shallow Seismic Well Lo...	1370	03/08/2022	1	20	1	433.00 kB	Publicly accessible	03/24/2022
Utah FORGE Updated Well, Well Pad, and Seismic Station G...	1358	12/14/2021	1	42	1	4.33 kB	Publicly accessible	01/06/2022
Utah FORGE Well 78B-32 Core Photos: Wet and Dry in Boxes	1342	10/22/2021	0	44	1	355.14 MB	Publicly accessible	11/08/2021
Utah FORGE Raw Microgravity Composite Data: Updated 10/...	1337	10/14/2021	0	4	1	7.98 kB	Publicly accessible	10/15/2021
Utah FORGE Groundwater Levels: Updated 2021	1335	10/12/2021	0	32	1	19.24 MB	Publicly accessible	10/14/2021
Utah FORGE Well 78B-32 Daily Drilling Reports and Logs	1330	08/20/2021	0	577	21	11.89 GB	Publicly accessible	02/14/2022
Utah FORGE Well 16A(78)-32 Core Photos	1328	08/11/2021	0	60	1	50.05 MB	Publicly accessible	08/12/2021

Showing 1 to 10 of 113 entries

Previous 1 2 3 4 5 … 12 Next

FORGE – Browse FORGE Data (continued)

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Utah FORGE Data

113
Submissions

13414
Downloads
(this year)

204.56 GB
of Utah FORGE Data

58-32

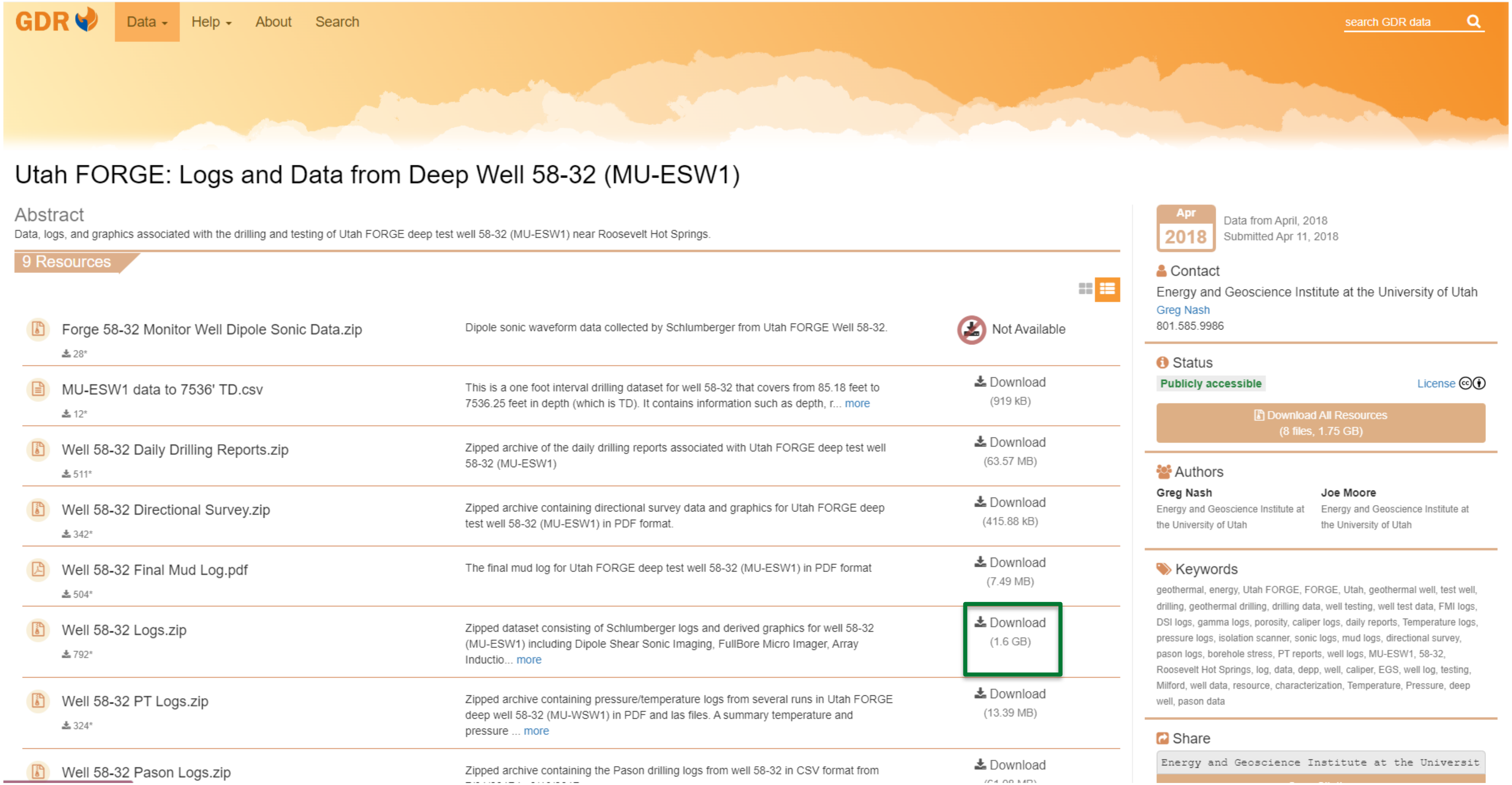
Show All entries

Submission	id	Submitted	Downloads Last Month	Downloads This Year	Resources	Size	Status	Updated Date
Utah FORGE Seismicity Associated with the 2019 Well 58-32…	1385	06/13/2022	0	0	1	10.18 kB	Publicly accessible	06/13/2022
Utah FORGE: Well 58-32 (MU-ESW1) FMI Log Fracture Res…	1299	04/04/2021	0	41	1	4.55 kB	Publicly accessible	04/13/2021
Utah FORGE: 58-32 Injection and Packer Performance, April …	1210	03/25/2020	0	85	1	832.08 kB	Publicly accessible	04/13/2021
Utah FORGE: Well 58-32 Core Analyses	1162	07/22/2019	0	57	1	24.23 MB	Publicly accessible	03/12/2020
Utah FORGE: Well 58-32 Stimulation Data	1149	06/28/2019	0	502	16	61.50 MB	Publicly accessible	03/12/2020
Utah FORGE: Well 58-32 Stimulation Conference Paper and …	1146	06/25/2019	4	106	2	1.80 MB	Publicly accessible	07/12/2021
Utah FORGE: Well 58-32 Injection Test Data	1109	12/07/2018	0	62	2	3.71 MB	Publicly accessible	03/09/2020
Utah FORGE: Milford Deep Test Well 58-32 (MU-ESW1) Pres…	1101	11/21/2018	0	16	1	1.23 MB	Publicly accessible	03/12/2020
Utah FORGE: Well 58-32 Schlumberger FMI Logs DLIS and …	1076	07/17/2018	0	112	3	2.40 GB	Publicly accessible	07/08/2021
Utah FORGE: Deep Well 58-32 (MU-ESW1) Core Data	1007	04/11/2018	0	87	5	6.34 GB	Publicly accessible	03/12/2020
Utah FORGE: Logs and Data from Deep Well 58-32 (MU-ES…	1006	04/11/2018	0	387	9	2.32 GB	Publicly accessible	02/15/2022

Showing 1 to 11 of 11 entries (filtered from 113 total entries)

Previous 1 Next

FORGE – Downloading Datasets



Questions?

Helpful Links:

- GDR - https://gdr.openei.org
- Utah FORGE Project Website – https://utahforge.com

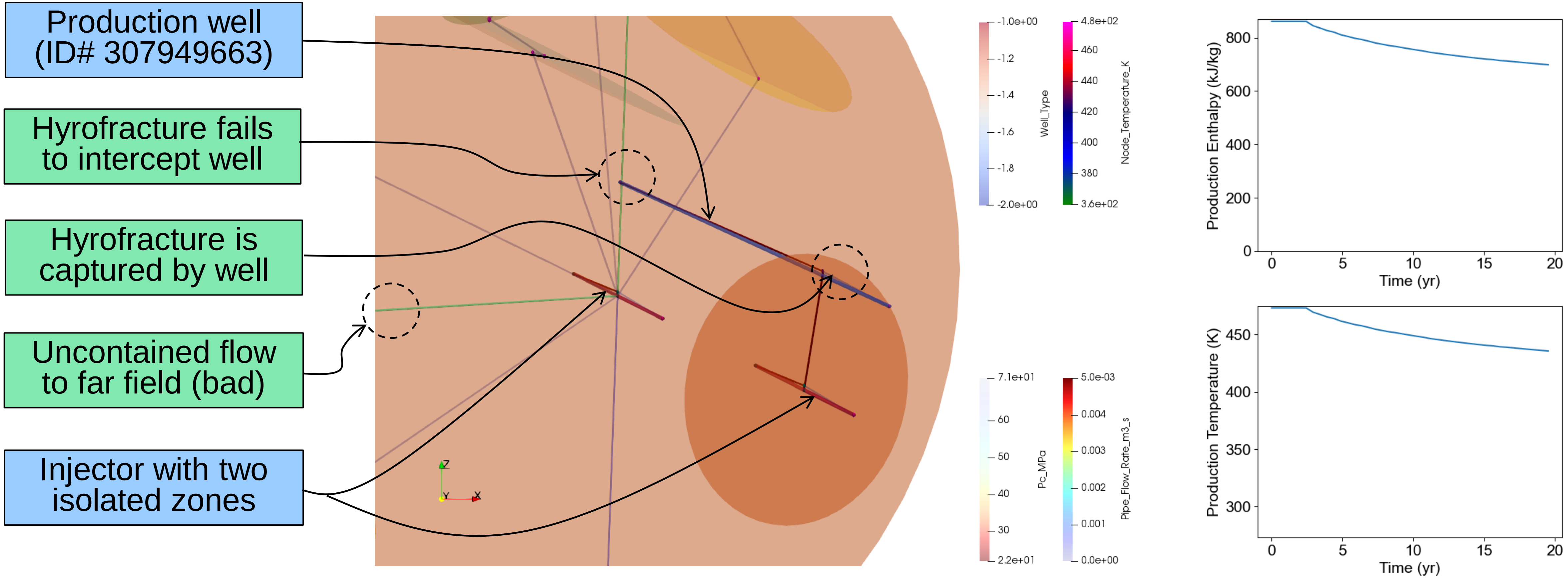
For any additional questions regarding FORGE, GDR, or DOE GTO questions, please send an e-mail to:

andy.adams@ee.doe.gov

Problem Description

PIVOT 2022 Datathon

FORGE Performance Predictions by Well Placement



In this competition, we evaluate a hypothetical scenario where the FORGE location is an EGS production field and the first FORGE highly deviated well (16A) is the injection well. Based on the provided model results, we seek the theoretical <u>optimum placement of the production well</u> that maximizes the likelihood of achieving maximum net-energy and electrical-power output over a 20 year project lifespan, accounting for parasitic losses.

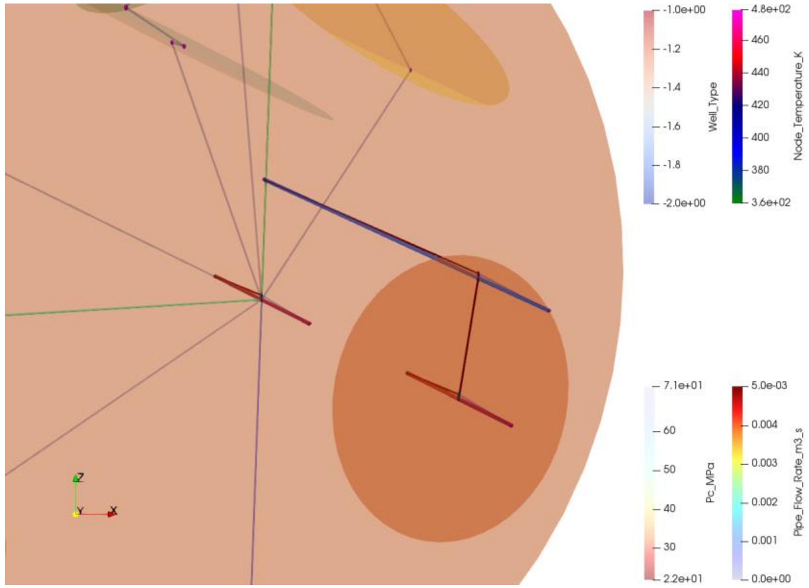
Data Sets that Informed Our Stochastic Simulations

Competitors are encouraged to refine the model space using a more detailed look at FORGE site data

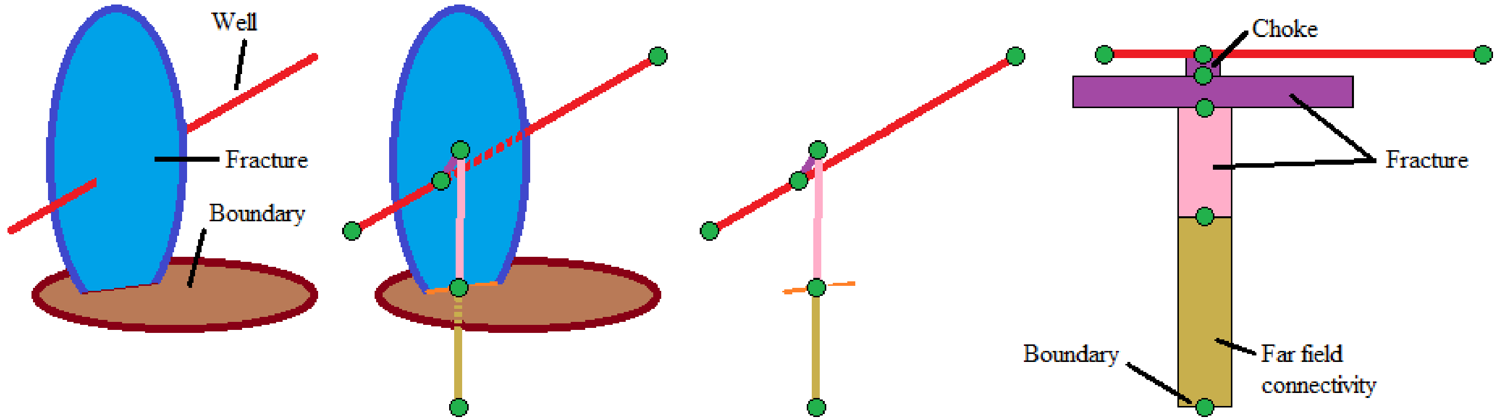
1. Rassenfoss, S. (2022). Drillers vs. Granite: Hard Rock Is Losing Its Edge. Journal of Petroleum Technology.
2. Allis, R., Gwynn, M., Hardwick, C., Hurlbut, W., Moore, J. (2018) Thermal Characteristics of the FORGE site, Milford, Utah. GRC Transactions.
3. Well 16A78-32 Points Depths.csv. (2020). Geothermal Data Repository.
4. Native State Modeling: Modeled Granitoid Parameters (*and references therein*). (2022). https://utahforge.com/laboratory/numerical-modeling/
5. UTAH FORGE INDUCED SEISMICITY MITIGATION PLAN, DE-EE0007080, University of Utah.
6. Xing, P., McLennan, J., Moore, J. (2020). In-Situ Stress Measurements at the Utah Frontier Observatory for Research in Geothermal Energy (FORGE) Site. Energies.
7. Frash, L.P. (2022). Optimized Enhanced Geothermal Development Strategies with GeoDT and Fracture Caging. 47th Workshop on Geothermal Reservoir Engineering.
8. 16A78-32 Summary of Daily Operations.pdf. (2021). Geothermal Data Repository.
9. {There is ample opportunity to refine site parameters using FORGE data or measurements from additional sources}

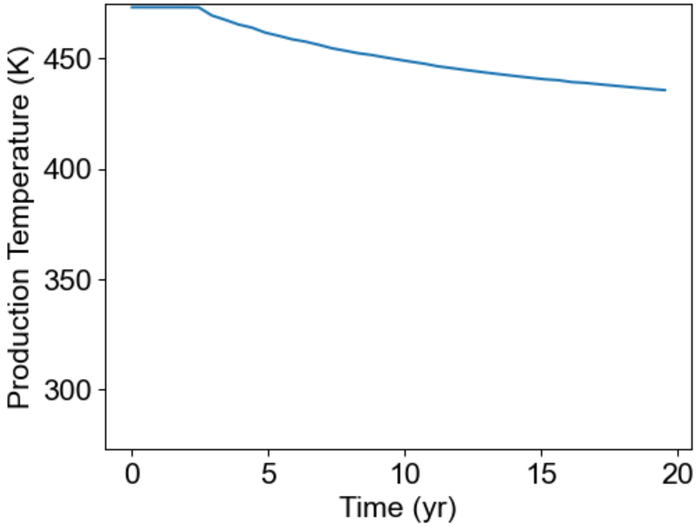
Stochastic Model Workflow with GeoDT

- System Parameters
- Fracture & Well Placement
- Fracture & Well Intersections
- Boundary and Initial Conditions
- Static Fracture Properties or Dynamic Fracture Properties
- Flow
- Heat Transfer
- Energy Withdraw
- Energy Output

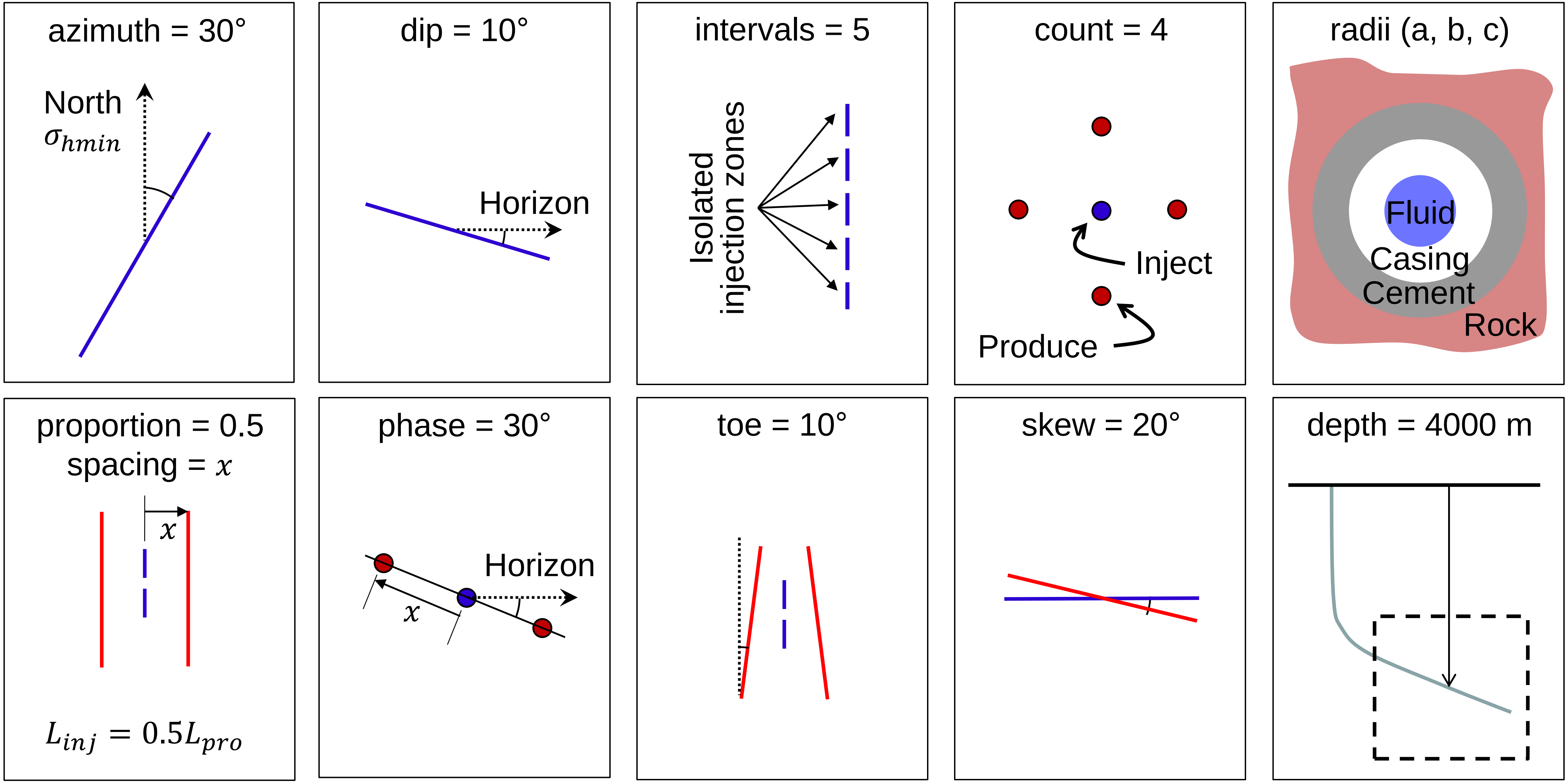


3D geometry | Intersections | "Pipes" & "Nodes" | Near well choke





Well Design Variables



GeoDT Input-Output Data Structure

SUMMARY "Inputs_Outputs_FORGE.csv"

inputs_results_FORGE.txt - Notepad

File Edit Format View Help


```
pin,size,ResDepth,ResGradient,ResRho,ResKt,ResSv,AmbTempC,AmbPres,ResE,Resv,ResG,Ks3,Ks2,s3Azn,s3AznVar,s3Dip,s3DipVar,fNum0,fDia_min0,fDia_max0,f
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9819e+02,4.09458e+02,4.09106e+02,4.08771e+02,4.08450e+02,4.08141e+02,4.07844e+02,4.07558e+02,4.07283e+02,4.07017e+02,4.06761e+02,4.06513e+02,8.491
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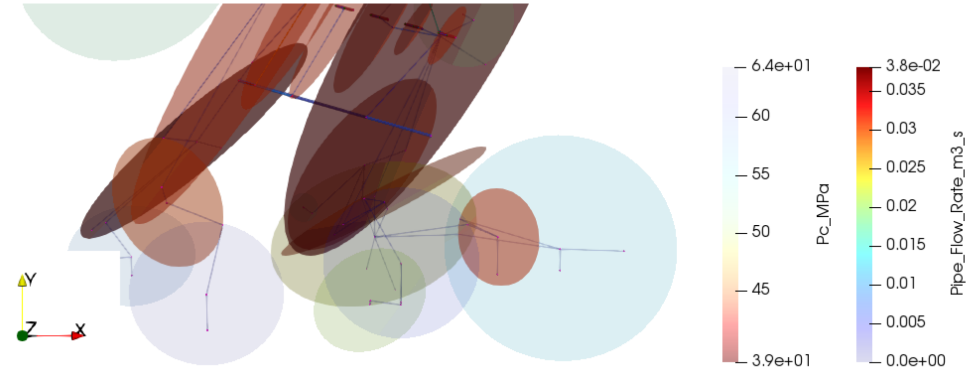
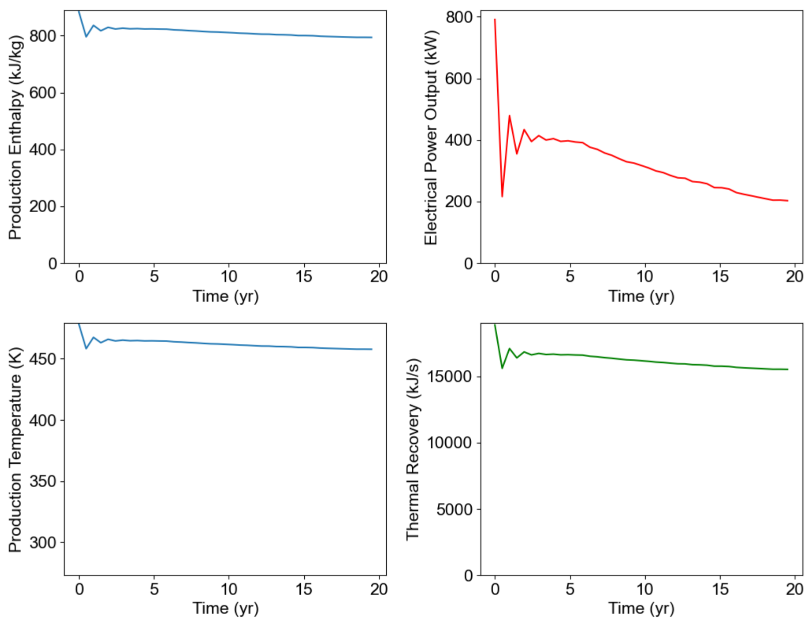
	B	C	D	E	F	G	H	I	J	K
1										
2	Variable	Parameter	Unit	Min Value	Nominal val	Max Value	Uncertainty (±)	Distribution	Source	Notes
3	size	Domain size (i.e., cubic side lengt	m		1600			-	Native State Modeling: Mc	
4	ResDepth	Nominal reservoir depth	m	2340		2360		Uniform	Well 16A78-32 Points Dept	
5	ResGradient	Geothermal gradient	K/km	83.1		87.4		Uniform	Allis, R., Gwynn, M., Hardv	
6	ResRho	Rock density	kg/m3	2550		2950		Uniform	Native State Modeling: Mc	
7	ResKt	Rock thermal conductivity	W/mK	1.78		3.32		Uniform	Native State Modeling: Mc	
8	ResSv	Rock volumetric specific heat capa	kJ/m3K	0.74/ResRho		1.20/ResRho		Uniform	Native State Modeling: Mc	
9	AmbTempC	Ambient surface temperature	C		0			Uniform	NOAA	
10	AmbPres	Ambient surface pressure	MPa		0.101			-	NOAA	
11	CemKt	Cement thermal conductivity	W/mK		2			Uniform	Asadi, I., Shafigh, P., Hassa	
12	CemSv	Cement volumetric specific heat c	kJ/m3K		2000			Uniform	Kodur, V. (2014) Propertie	
13	GenEfficienc	Electrical generator efficiency	-		1			-	https://www.mpoweruk.c	
14	LifeSpan	Project lifespan	yr		20			-	Vitaller, A.V., Angst, U.M.,	
15	Tinj	Injection temperature	C	85		99		-	-	
16	p_whp	Power plant inlet pressure	MPa		1			Uniform	https://thermopedia.com,	
17	TimeSteps	Thermal analysis timesteps	steps		41			-	-	
18	ra	Casing inner radius	m		0.0889			Uniform	Rassenfoss, S. (2022). Drill	
19	rb	Casing outer radius	m		0.1016			-	Rassenfoss, S. (:	*1" casing
20	rc	Borehole radius	m		0.1143			-	Rassenfoss, S. (:	*2" annul
21	H_ConvCoef	Borehole thermal convection coe	kW/m2K		3			Uniform	Kosky, P., Balme	*Full CFD
22	rgh	Hazen-Williams friction coefficier	-		80			Uniform	Jeppson, R.W. (1974) Stea	
23	PoreRho	Water density for flow analysis	kg/m3	920		932		-	Cooper, J.R. and	*Don't cur
24	Poremu	Water dynamic viscosity	cP		0.2			-	Huber, M.L., Per	*Don't cur
25	dT0	Initial temperature gradient	K		1			-	-	*Used to s
26	dE0	Initial thermal energy withdraw	kJ/m2		50			-	-	*Used to s
27	BH_P	Reservoir pore pressure	MPa	calc		calc		Uniform	Native State Mc	*BH_P = PoreRho*g*
28	BH_T	Reservoir temperature	R	calc		calc		Uniform	Native State Mc	*BH_T = ResGradient
29	ResE	Rock elastic modulus	GPa	55		62		Uniform	Native State Modeling: Mc	
30	Resv	Rock Poisson's ratio	m/m	0.26		0.4		Uniform	Native State Modeling: Mc	
31	Ks3	Minimum lateral earth pressure c	Pa/Pa	0.216		0.637		Uniform	Xing, P., McLennan, J., Mo	
32	Ks2	Intermediate earth pressure coef	Pa/Pa	0.25 & >1.01Ks3		0.75 & >1.15Ks3		Uniform	Xing, P., McLennan, J., Mo	
33	s3Azn	Minimum stress azimuth	deg	258		338		Uniform	Xing, P., McLennan, J., Mo	
34	s3Dip	Minimum stress dip	deg	-20		20		Uniform	Xing, P., McLennan, J., Mo	
35	s1	Overburden stress	Pa	calc		calc		Uniform	-	*s1 = ResR
36	s2	Intermediate stress	Pa	calc		calc		Uniform	-	*s2 = (s1-E
37	s3	Minimum stress	Pa	calc		calc		Uniform	-	*s3 = (s1-E
38	w_spacing	Well spacing	m	50		1000		Uniform	-	

	P	Q	R	S	T
1			Outputs		
2	Category	Parameter	Parameter	Unit	Notes
3	Interpretation	type_last	Type of freshest fracture	-	1 = nat frac; 2 = hydrofrac
4	Interpretation	Pc_last	Critical pressure of freshest fracture	Pa	
5	Interpretation	sn_last	Normal stress on freshest fracture	Pa	
6	Interpretation	Pcen_last	Center pore pressure in freshest fracture	Pa	
7	Interpretation	Pmax_last	Max pore pressure in freshest fracture	Pa	
8	Interpretation	dia_last	Final diameter of freshest fracture	m	
9	Efficiency	qinj	Cumulatiove injection rate	m3/s	*should be close to Qinj
10	Efficiency	qpro	Cumulative production rate	m3/s	
11	Efficiency	qleak	Boundary outflow rate	m3/s	
12	Efficiency	qgain	Boundary inflow rate	m3/s	
13	Efficiency	recovery	Production rate / Injection rate	ratio	
14	Efficiency	pinj	Pressure of injected fluid	MPa	
15	Efficiency	hinj	Enthalpy of injected fluid	kJ/kg	
16	Efficiency	v5	Specific volume at injection well	m3/kg	
17	Intercepts	ixint	Number of fractures intercepting injectors	fractures	
18	Intercepts	pxint	Number of fractures intercepting producer	fractures	
19	Intercepts	hfstim	Number of stimulated hydraulic fractures	fractures	
20	Intercepts	nfstim	Number of stimulated natural fracutres	fractures	
21	Power	mpro	Production mass flow rate	kg/s	
22	Power	hpro - timeseries	Production enthalpy - time variable	kJ/kg	
23	Power	Pout - timeseries	Rankine electrical power - time variable	kW	
24	Power	dhout - timeseries	Extracted thermal power - time variable	kJ/s	
25	Power	q0	Volume flow rate into injection well	m3/s	
26	Power	m0	Mass flow rate into injection well	kg/s	
27	Power	T0 - timeseries	Temperature at injection well	K	
28	Power	h0 - timeseries	Enthalpy of injected fluid	kJ/kg	
29	Power	q0	Volume flow rate into production well	m3/s	
30	Power	m0	Mass flow rate into production well	kg/s	
31	Power	T0 - timeseries	Temperature at production well	K	
32	Power	h0 - timeseries	Enthalpy of produced fluid	kJ/kg	

GEOMETRY "_298143583_.vtk"

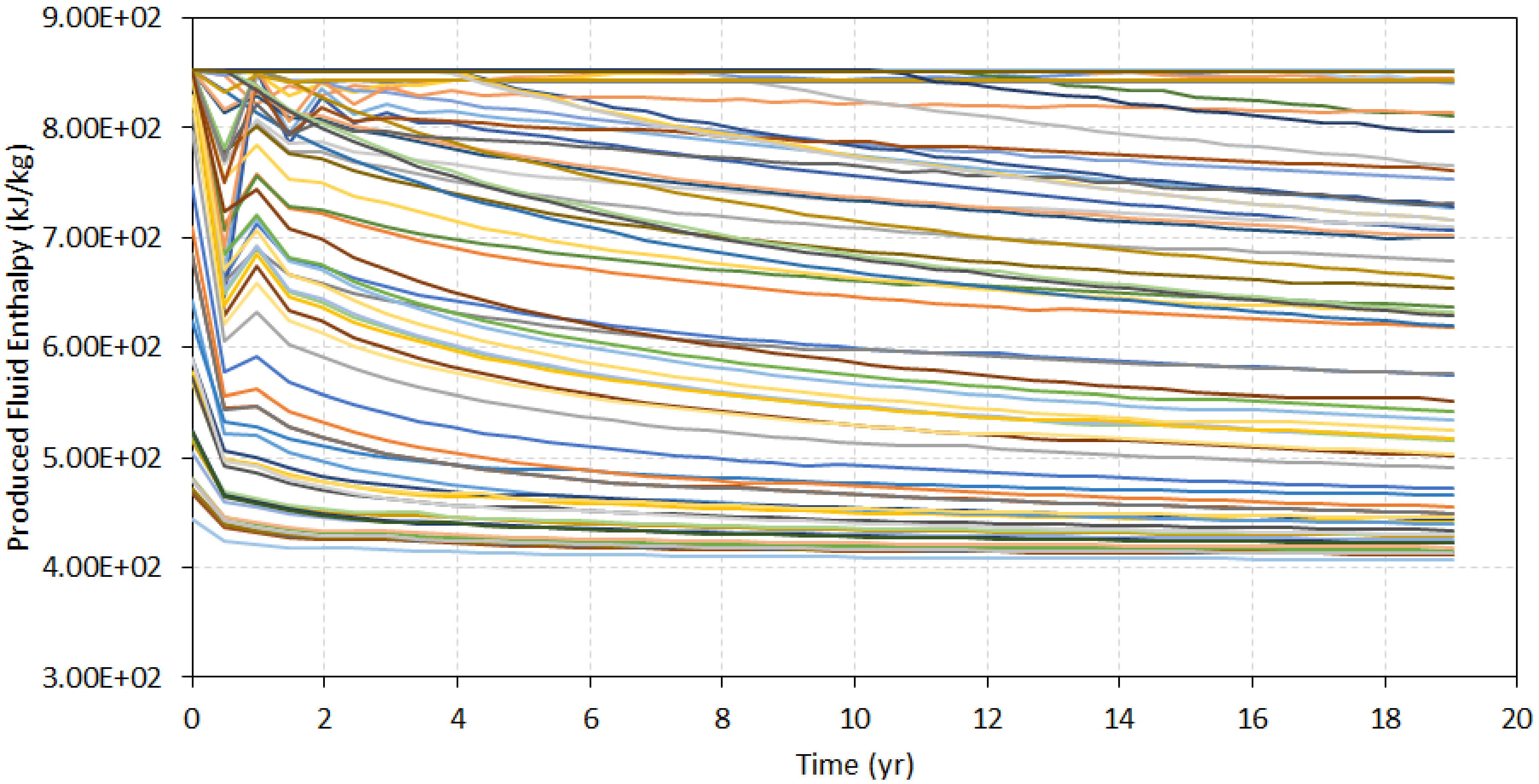


PLOT "_298143583_.png"



GeoDT Timeseries Data Structure

Enthalpy vs time for 90 simulation results out of 10,000+



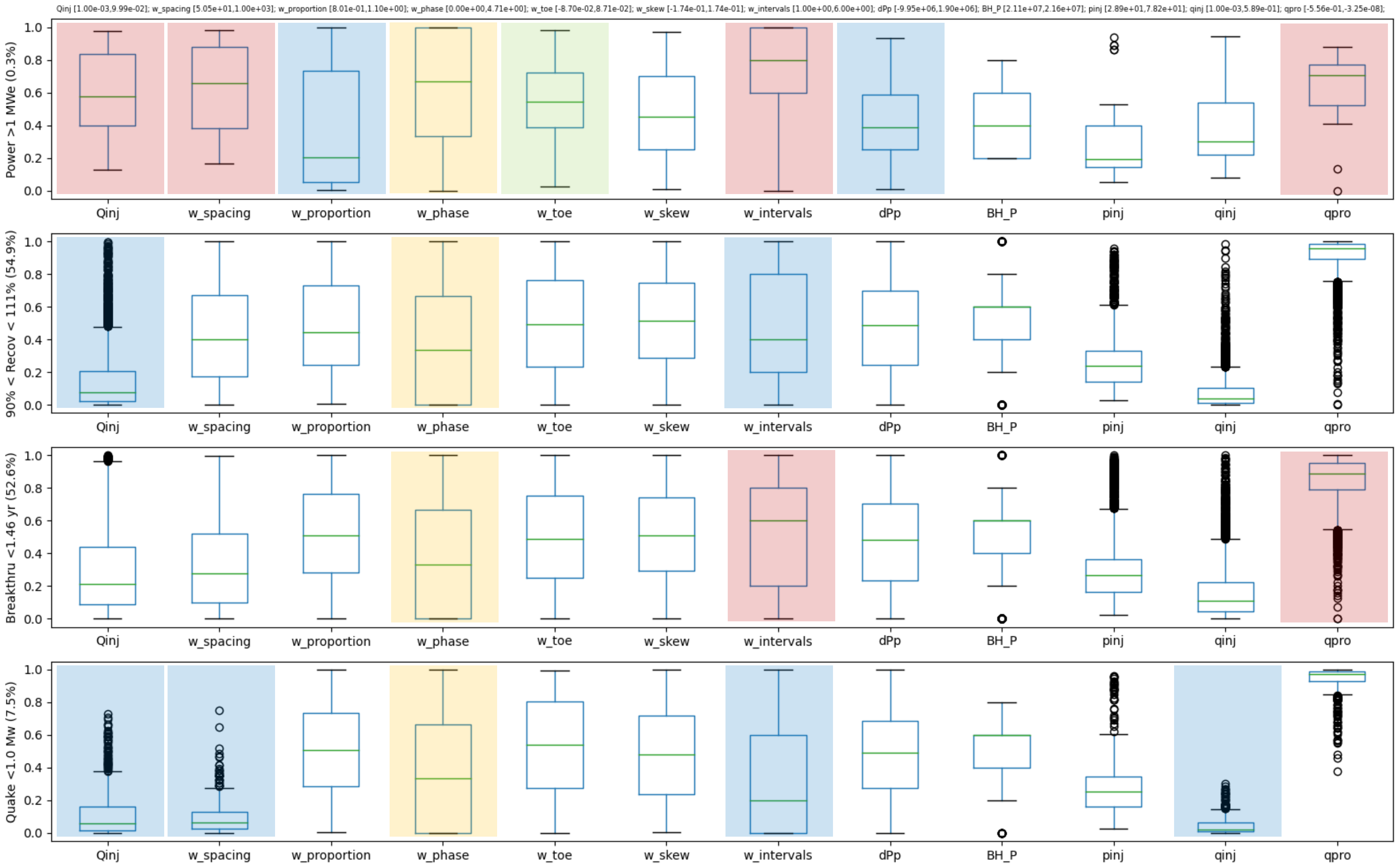
Valid vs Invalid Data Analysis Approaches

Valid	*Invalid*
• Multiparameter optimization of well geometry • Multidimensional success metrics • Verifiable site-parameter uncertainty reduction	• Filtering to best scenario(s) • Uncertainty not quantified • Unjustified rejection of outliers

Proving the Negative: Scenario

In the subsurface, measurements are always sparse. Wells of 4” to 12” diameter are used to estimate formation rock properties 100’s of ft away. Also, very few rock features (e.g., permeable faults) can be detected prior to commencement of drilling. When combined with the “K.I.S.S.” design principle, this can lead designers to omit features that could exist and instead keep only the features that are known to exist. For example, if no known faults are in the area, there is a tendency to treat the area as faultless. However, the only verifiable way to prove this simplifying assumption is to prove that no faults are present. This requires proving a negative which is prohibitively expensive and difficult. In this challenge, we ask you to more closely follow the design principle of Murphy’s Law: if a complication can exist, then the analysis should include this possibility. We seek the optimum placement of a production well that maximizes the probability of developing a successful enhanced geothermal system.

Preliminary Analysis



<u>Good to Increase</u>

Injection rate

Production rate

Injection intervals

Production well length

Well spacing

<u>Good to Decrease</u>

Injection rate

Injection intervals

Bottomhole pressure

Well spacing

<u>Its Complicated</u>

Position (phase & toe)

Everything that is good to increase and decrease

Example Output Power Objective Functions

Timeseries without Losses

$$P_{usable} = 0.13(dhout + (h_{95C} - h_{120C})mpro)$$

Cumulative without Losses

$$P_{usable} = \frac{1}{20yr}\int_{0}^{20} 0.13(dhout + (h_{95C} - h_{120C})mpro)\,dt$$

Timeseries with Losses

$$P_{usable} = 0.13\big(dhout + \big(h_{95C} - h_{120C} - v5(Pinj - Pwhp)\big)mpro\big)$$

<u>Notes</u>

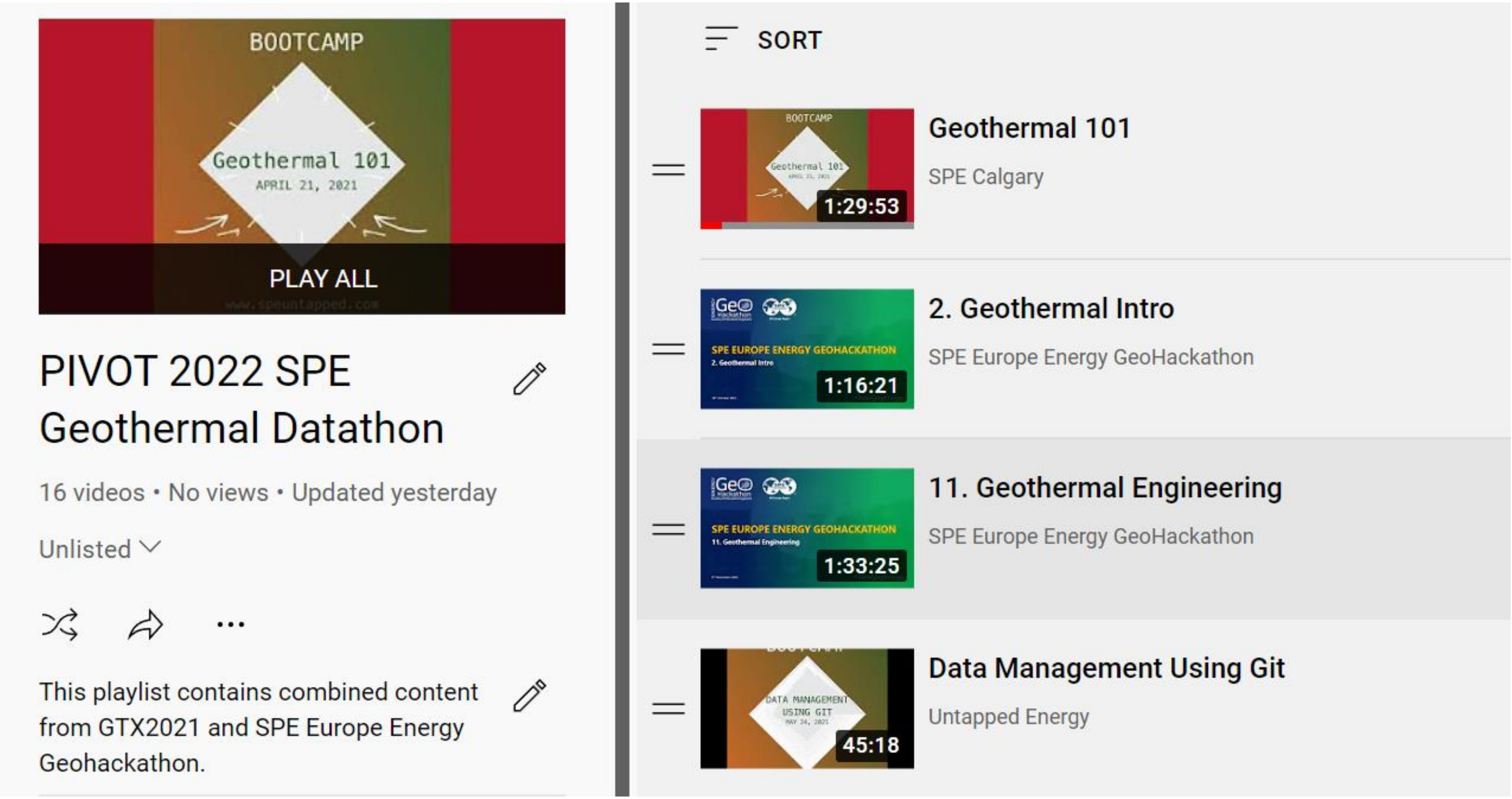
1. “dhout" accounts for enthalpy-rate change from injection to production (kJ/s)
2. “net power” would also account for pumping losses (not shown)
3. “Pout” accounts for single-flash Rankine cycle net electrical power output with 100% generator efficiency, but requires higher enthalpy fluid than the binary power cycle. FORGE would likely benefit significantly from including a binary (e.g., organic Rankine) power cycle.
4. 0.13 (i.e., 13%) Rankine efficiency is a placeholder in the above. Actual efficiencies can be much different, depending on enthalpy and machinery specs.

Logistics

Learning

Combined repository of webinars conducted as part of past datathons.

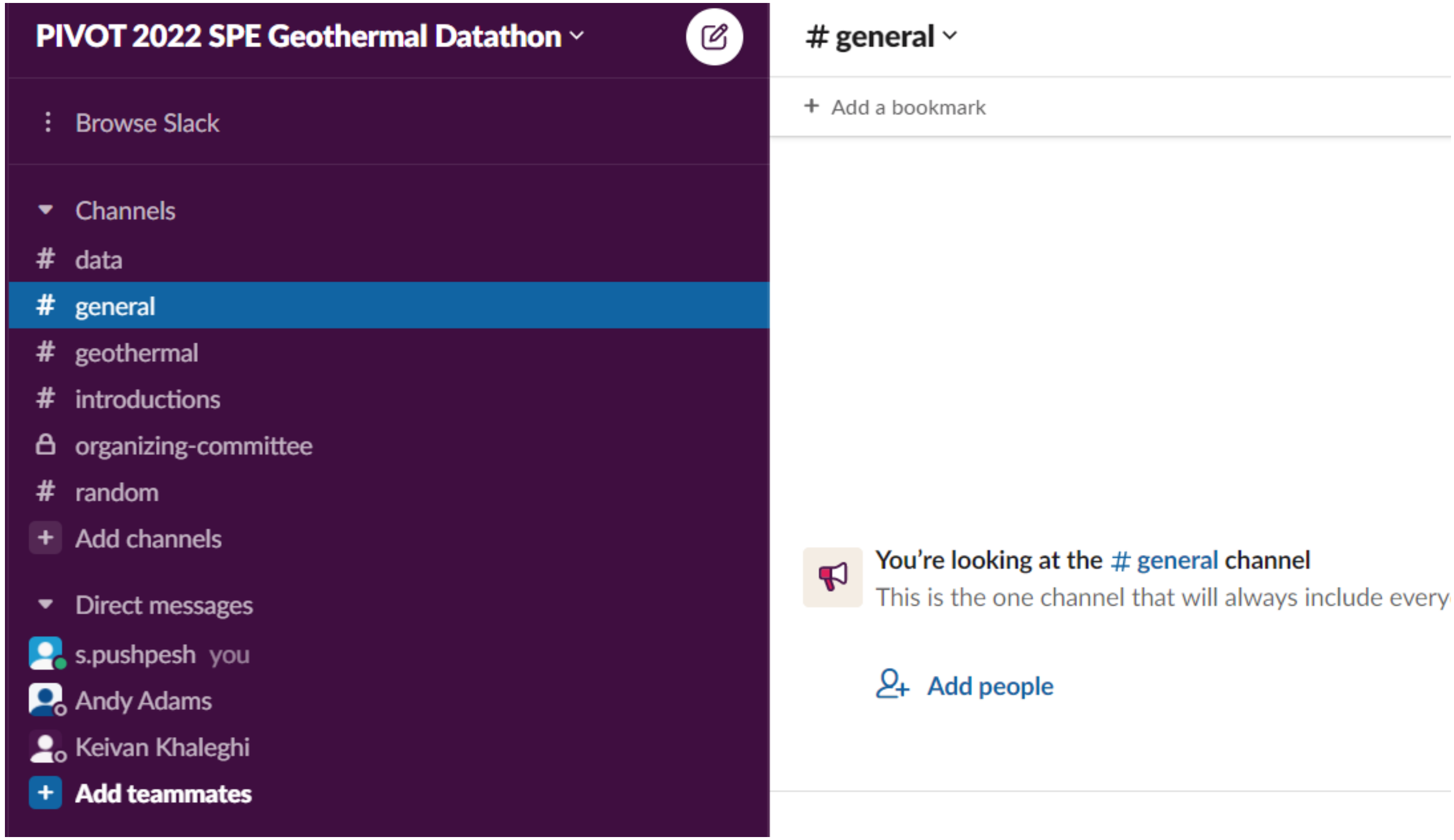
- Introduction to Geothermal Energy
- Data Science
- Soft Skills



Networking and Team Creation

Slack channel – Datathon Central

Submit your teams by Monday June 27th, 2022, 8 AM Central



Competition

Competition Data will be released on 8 AM Central, June 27th, 2022

Submission – 5-minute video

Power Point Presentation

Submission Due Midnight Central July 22nd, 2022

Questions ?