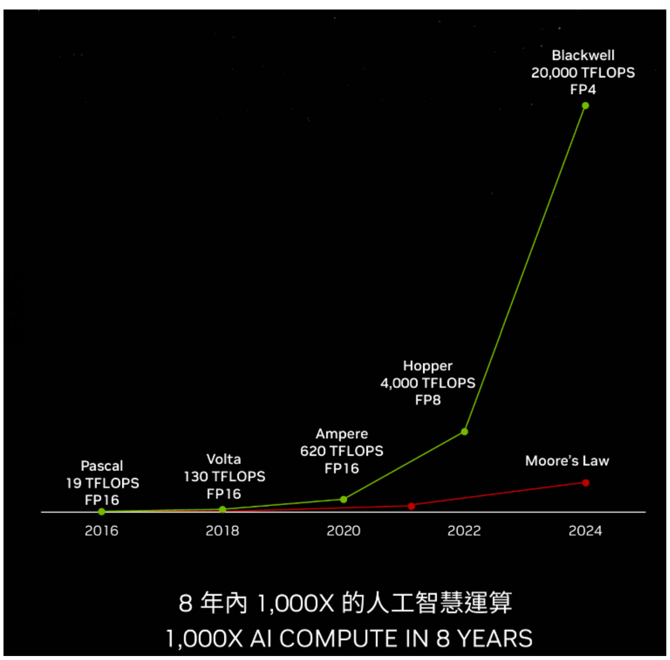
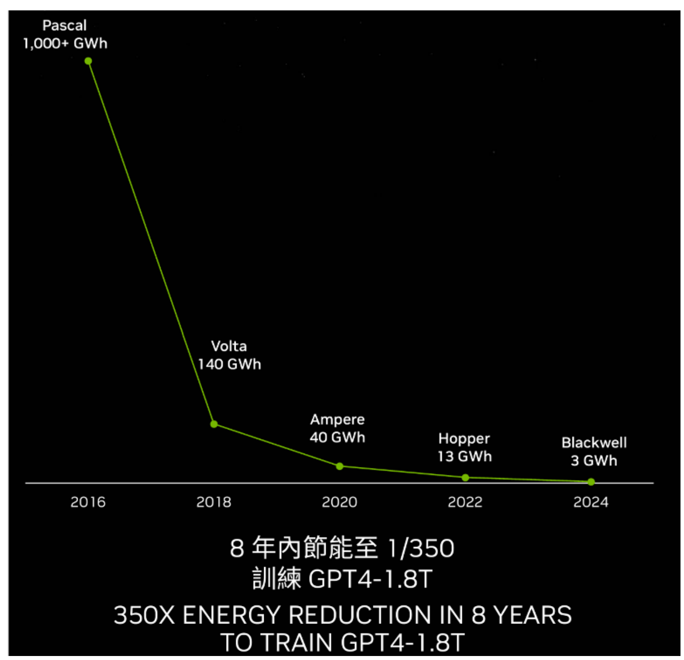
Jevons Paradox

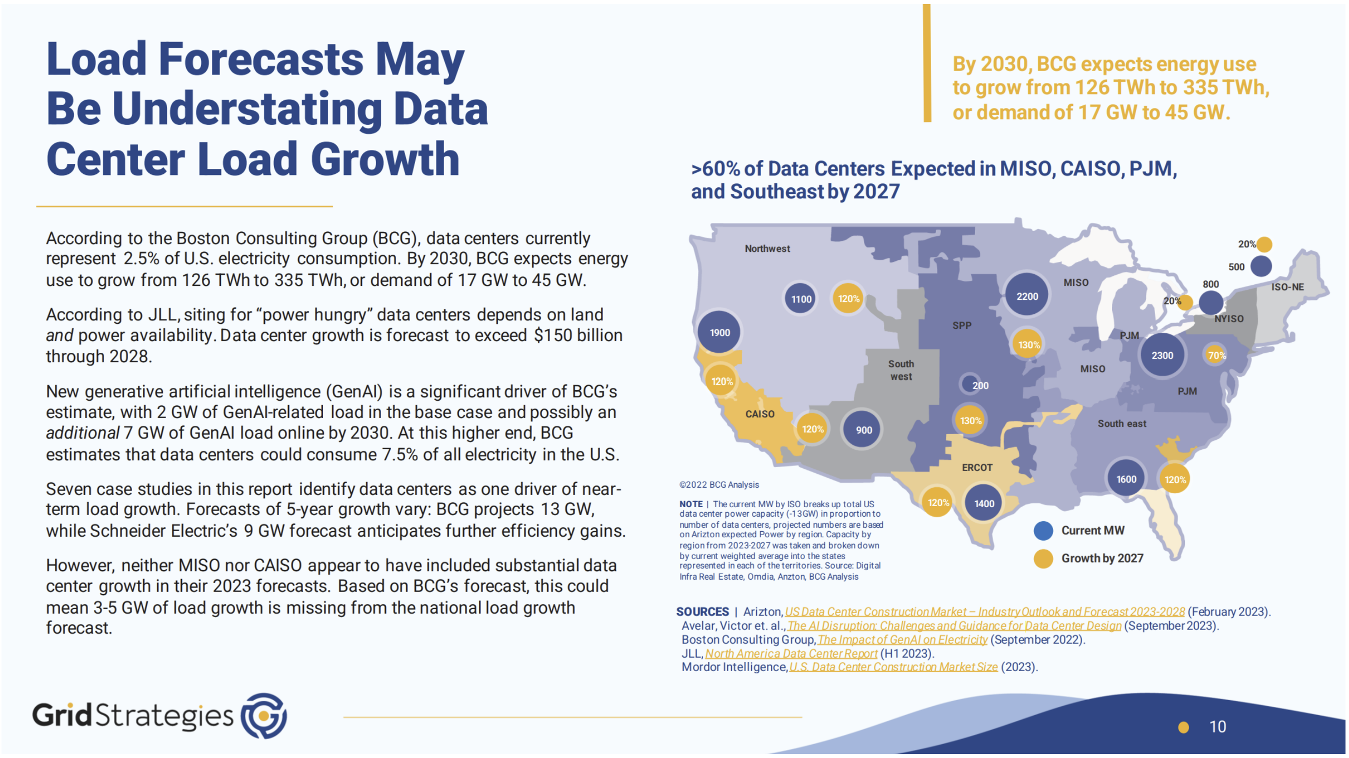
In the mid-19th Century, Britain was undergoing rapid industrialization, powered by coal and the adoption of steam engines. Many at the time worried that declining coal reserves threatened the nation's economic vitality. However, amongst experts, there emerged a consensus that increases in steam engine fuel efficiency would eventually reduce coal consumption. Into the debate stepped a young economist named William Stanley Jevons, who published "The Coal Question" in 1865.[1] In his treatise, Jevons argued that improvements in fuel efficiency and cost-effectiveness would lead to the rising use of industrial steam engines, paradoxically increasing the demand for coal. History proved Jevons right, with coal production in Britain more than doubling from the time of his publication to its peak of 258 million tons by 1913.[2] In homage to Mr. Jevons' insights, the phenomenon of efficiency gains leading to higher consumption became known as the "Jevons Paradox."

Today, many are starting to sound alarm over the rising power consumption needs of data centers, in large part due to increased demand for training and operating artificial intelligence models. Nvidia touts that its future generation of chips will be far more powerful and energy efficient than previous generations, with 1000x increase in compute power and 350x reduction in electricity consumption for its Blackwell generation of GPUs (see below graphics from Nvidia).[3] Other semiconductor firms like AMD and Intel, as well as internal chip design teams at companies like Alphabet, also tout their chip efficiency gains. So, will this lead to overall less power consumption? Unlikely. As the Jevons Paradox would predict, efficiency gains and cost improvements for AI chips are likely to result in higher demand and more power consumption over time.





In our March correspondence, we discussed an influential industry report suggesting that current trends in computing, along with industrial and transport electrification, could increase what has been stagnant U.S. power demand by 4.7% over the next five years, with data centers consuming as much as 7.5% of all U.S. electricity by the end of the decade (see below excerpt).[4] Given some recent commentary by technology industry leaders, these projections now seem quaint.



On the technology-focused [Dwarkesh Podcast] in April, Meta CEO Mark Zuckerberg [spoke about] investing upwards of $100 billion in AI infrastructure and remarked that right now energy constraints were the greatest bottleneck in planning for investment. He opined that building gigawatt ("GW") data centers was only a matter of time (emphasis added):[5]

> Right now a lot of data centers are on the order of 50 megawatts or 100MW, or a big one might be 150MW. Take a whole data center and fill it up with all the stuff that you need to do for training and you build the biggest cluster you can. I think a bunch of companies are running at stuff like that.
>
> But when you start getting into building a data center that's like 300MW or 500MW or 1 GW, no one has built a 1GW data center yet. I think it will happen. This is only a matter of time but it's not going to be next year. Some of these things will take some number of years to build out. Just to put this in perspective, I think a gigawatt would be the size of a meaningful nuclear power plant only going towards training a model.

This interview came on the heels of Microsoft and OpenAI announcing plans for a data center and AI supercomputer project that could cost as much as $100 billion – codenamed "Stargate" – that could launch in 2028.[6] This project could cost as much as 100x today's largest data centers and presumably would be much larger than just 1GW.

Earlier this week, former OpenAI employee and technology investor Leopold Aschenbrenner published a 162-page collection of essays, entitled "Situational Awareness: The Decade Ahead," in which he predicted that by the end of the decade we may see AI training clusters costing as much as $1 trillion and consuming 100GW of power, which is equivalent to roughly 20% of current U.S. electricity consumption.[7] Aschenbrenner also appeared on an episode of the Dwarkesh Podcast (which we recommend) to discuss his industry views.

AI Training Compute (per Aschenbrenner)

Year	OOMs	# of H100s-equivalent	Cost	Power	Power reference class
2022	~GPT-4 cluster	~10k	~$500M	~10 MW	~10,000 average homes
~2024	+1 OOM	~100k	$billions	~100MW	~100,000 homes
~2026	+2 OOMs	~1M	$10s of billions	~1 GW	The Hoover Dam, or a large nuclear reactor
~2028	+3 OOMs	~10M	$100s of billions	~10 GW	A small/medium US state
~2030	+4 OOMs	~100M	$1T+	~100GW	>20% of US electricity production

**OOM stands for orders of magnitude.*

So long as investors keep rewarding companies for increasing their capital expenditures on AI infrastructure (data centers, chips, networking equipment, power, etc), these projects are likely to move forward at breakneck pace. After all, there is a competitive dynamic and strategic business advantage to having the best model (or at least having models on par with competitor firms) – not to mention geopolitical considerations. As a thought experiment, imagine if the U.S. were to put up roadblocks over AI safety concerns or data center power consumption and emissions. Do you think China or other potential adversaries would follow suit? We do not.

Based on these recent commentaries and industry trends, it seems like the Jevons Paradox is alive and well. However, given the immense ramp-up in U.S. power generation, we are skeptical that 10 to 100GW data centers are feasible in the near-term. To put this into perspective, the entire U.S. installed power generation base is about 1,250 GW.[8] And last year, the U.S. only added 40.4GW total of utility scale generation to the grid (compared to beginning of year plans for 54.5GWof power additions).[9] Even Mr. Zuckerberg acknowledged constraints to bringing just a single GW data center online – but directionally we have no reason to doubt where the industry is heading over time.

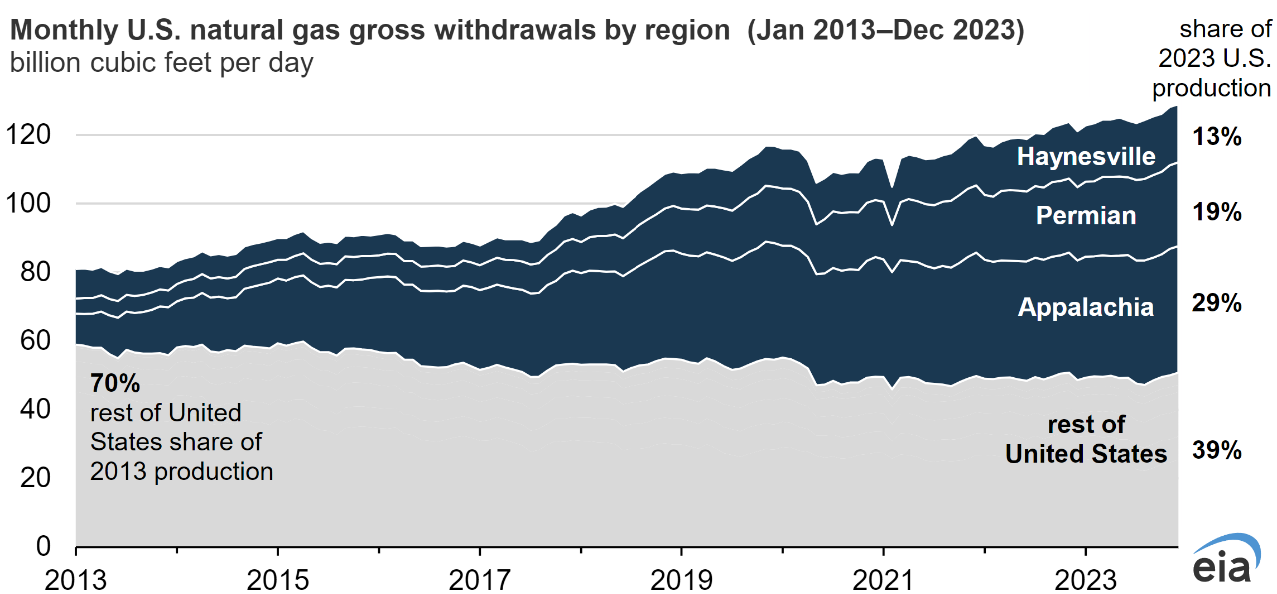
If AI leads to a substantial increase in power demand over the coming years and decades, the question of how to meet that demand arises. After all, the extra energy needs to come from somewhere. Unfortunately, the options are limited.

We think nuclear would be ideal and we are confident it will play an important role in meeting power demand, but building reactors takes years and is costly. The nearly 5GW Vogtle nuclear project that recently became operational in Georgia took 15 years to complete at a cost of $35 billion (well behind schedule and over budget).[10] New construction of nuclear needs to begin now to power facilities that will come online in 5-10 years. Although the Biden administration recently announced a plan to accelerate new large-scale nuclear plant construction,[11] to our knowledge there are no current plans for new nuclear capacity in the U.S.

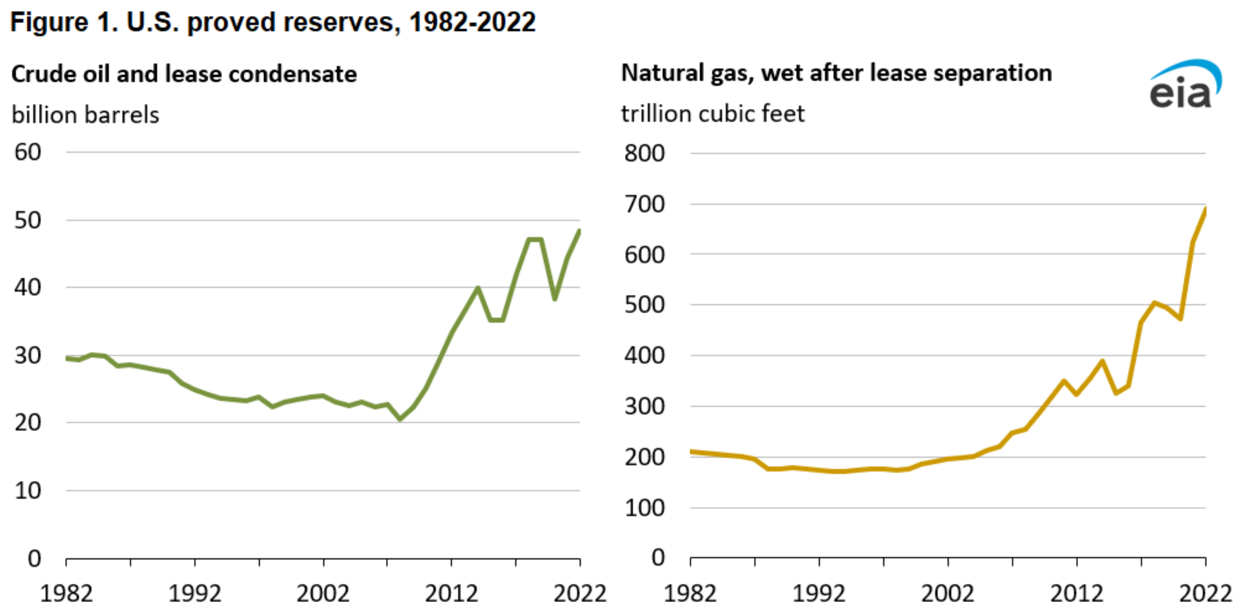
Wind and solar make up the majority of new U.S. power capacity additions in recent years – and many like them for their zero-emissions attributes – but they do not have the 24/7 reliability required to power data centers nor is grid-scale battery storage technology commercially viable. Adding coal to the grid is a non-starter today given its carbon intensity. In the near-term, that leaves us with natural gas as the most flexible and environmentally satisfactory solution to quickly adding reliable and cost-efficient power capacity. We appreciate natural gas an imperfect solution for those who prioritize emissions standards; however, we think that for geopolitical reasons the U.S. will prioritize bringing necessary power online over environmental considerations. We highly doubt that geopolitical competitors such as China will halt AI development due to previously announced pledges (which it already is disregarding).

Again, over time, it is likely that additional nuclear capacity will supplant natural gas and coal in the baseload power stack (by which we mean non-variable electricity resources) – perhaps advances in battery storage technology will make wind/solar more viable baseload options as well. But that could take decades and this investment in AI is happening now. An interim solution is necessary.

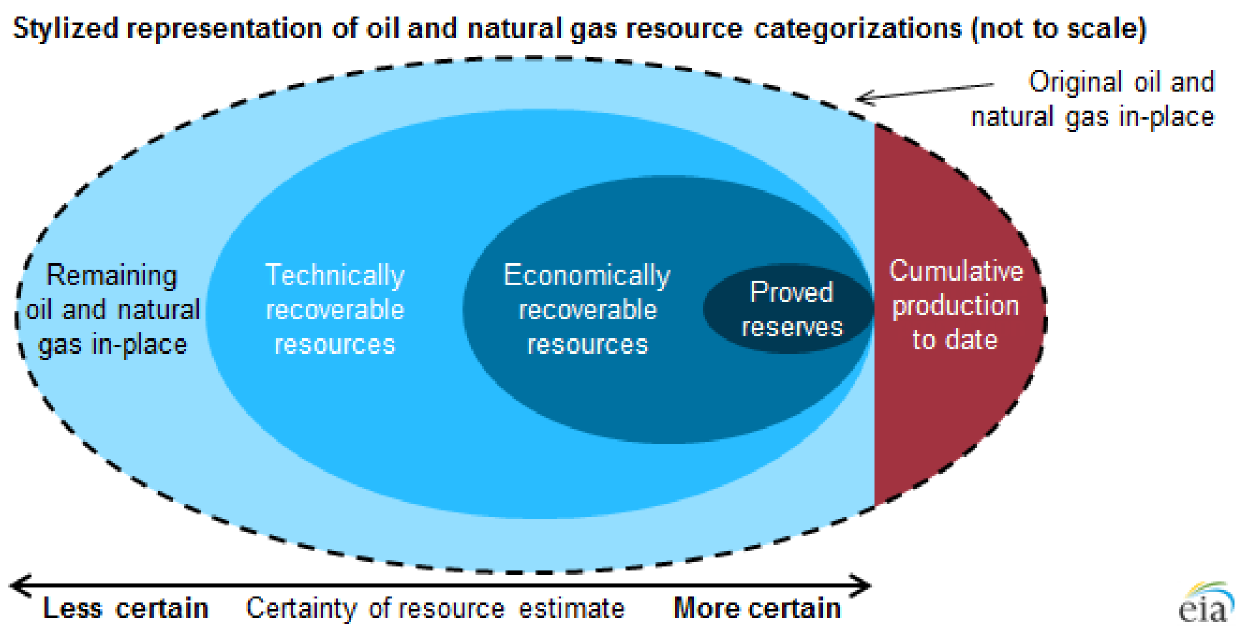
Fortunately, the U.S. has substantial natural gas reserves. We wanted to share a few charts to hit this point home. First, below is a chart showing U.S. natural gas production rose to 120 billion cubic feet per day in 2023, from around 80 million cubic feet per day in 2013, with growth coming from shale basins.[12]



Second, despite the increase in daily gas production, U.S. proved reserves of natural gas (meaning gas recoverable based on existing geological, engineering, economic and operating conditions) have skyrocketed – nearly doubling over the same period to 700 trillion cubic feet as of year-end 2022, in large part thanks to advances in shale drilling technologies and new geological discoveries.[13]



Note that any increase in the commodity price would yield additional reserve increases (as proved reserves does not equate to technically recoverable resources).[14]



If the Jevons Paradox plays out again and the U.S. consumes far more power due to the rise of AI, we think many firms stand to benefit: from companies involved in data center infrastructure development, to U.S. power and utility firms, to semiconductor and networking firms – all of which have risen materially this year as the investors digest AI implications. What has not risen to the same degree, however, are natural gas firms. We think that is its own paradox – the AI story aside, the U.S. has become a more critical supplier of liquified natural gas (or LNG) to its European and East Asian allies in the wake of the Russia-Ukraine conflict. Unlike the few publicly traded nuclear-power related plays, upside from AI training and data center demand is hardly priced into stocks in the natural gas complex. In the appendix on the following page, we have included financial metrics for select companies involved in the productions and transportation of U.S. natural gas. Please note that we are still constructive on the energy, mining and industrial firms we discussed in our March correspondence (entitled AI and Energy Sobriety), which is available to access at the following link: **FS – March 2024 Letter**.

We hope you and your families are well. As always, please reach out with any questions or to discuss implementing any of the ideas we discussed in your portfolio.

Sincerely,

Peter Karmin
Managing Member

Stuart Loren
Director

June 6, 2024

Select Firms Involved in U.S. Natural Gas Production and Transportation

(USD in Millions)

Company Name	Market Cap	Net Debt To EBITDA	Dividend Yield (%)	Sales 2024 E	Sales 2025 E	EBITDA 2024 E	EBITDA 2025 E	Net Income 2024 E	Net Income 2025 E	FCF Margin 2024 E	FCF Margin 2025 E	PE Ratio 2024 E	PE Ratio 2025 E	EV to EBITDA 2024 E	EV to EBITDA 2025 E	ROCE 2023 A	ROA 2023 A	ROIC 2023 A
Exxon Mobil Corp	$ 510,094.84	0.11	3.34	$ 344,274.81	$ 341,305.00	$ 78,587.13	$ 83,899.31	$ 39,743.75	$ 42,523.05	10.29%	11.66%	12.10	11.40	6.68	6.26	19.29%	10.35%	11.88%
Chevron Corp	$ 287,572.30	0.34	4.19	$ 197,422.56	$ 201,776.77	$ 50,039.79	$ 58,059.42	$ 24,088.90	$ 28,822.90	11.59%	14.55%	12.11	10.79	6.08	5.24	14.81%	9.13%	10.45%
EOG Resources Inc	$ 69,551.48	-0.07	3.01	$ 23,630.73	$ 24,174.40	$ 13,297.29	$ 13,277.56	$ 6,890.93	$ 6,925.11	23.39%	23.52%	10.04	9.80	5.12	5.13	22.52%	13.97%	15.96%
Antero Resources Corp	$ 10,551.90	1.65	-	$ 4,441.69	$ 5,400.23	$ 1,097.45	$ 2,000.90	$ 149.46	$ 867.71	6.06%	20.04%	61.62	11.63	11.20	6.14	-1.03%	-0.51%	0.41%
Range Resources Corp	$ 8,812.21	1.47	0.88	$ 2,693.96	$ 3,096.70	$ 1,217.87	$ 1,572.64	$ 563.21	$ 825.58	17.29%	22.81%	15.39	10.42	8.40	6.50	14.89%	7.15%	10.37%
EQT Corp	$ 17,835.90	1.83	1.56	$ 5,800.79	$ 8,274.36	$ 2,890.18	$ 5,365.67	$ 529.05	$ 2,219.85	5.81%	29.38%	36.79	10.49	7.85	4.23	7.21%	3.90%	5.98%
Coterra Energy Inc	$ 20,499.90	0.42	3.05	$ 5,809.84	$ 6,922.16	$ 3,744.11	$ 4,786.26	$ 1,517.55	$ 2,221.77	24.42%	31.10%	13.55	9.10	5.78	4.52	12.88%	8.16%	8.91%
Chesapeake Energy Corp	$ 11,573.55	0.43	3.24	$ 4,226.41	$ 8,882.00	$ 2,050.81	$ 4,788.29	$ 329.39	$ 1,448.29	8.06%	13.62%	48.66	14.54	6.06	2.59	7.19%	4.78%	5.31%
Comstock Resources Inc	$ 3,412.92	3.63	-	$ 1,395.82	$ 1,891.00	$ 910.93	$ 1,260.31	$ (24.26)	$ 307.62	-9.93%	4.41%	-	10.89	6.74	4.87	5.69%	2.21%	2.36%
Southwestern Energy Co	$ 7,968.05	1.50	-	$ 5,031.80	$ 6,216.50	$ 2,093.71	$ 3,132.93	$ 622.00	$ 1,233.36	0.98%	6.59%	16.16	6.42	5.70	3.81	14.57%	5.97%	-10.68%
Devon Energy Corp	$ 29,549.16	0.77	2.99	$ 13,955.43	$ 13,786.67	$ 7,594.63	$ 7,760.96	$ 3,292.48	$ 3,493.46	23.03%	23.69%	8.91	8.22	4.61	4.51	31.57%	15.21%	22.12%
NuScale Power Corp	$ 1,907.62	-	-	$ 46.97	$ 129.17	$ (129.00)	$ (95.63)	$ (112.60)	$ (95.78)	-271.53%	-47.45%	-	-	-	-	-56.08%	-20.35%	-125.74%
Cheniere Energy Inc	$ 36,608.83	2.42	1.09	$ 15,438.53	$ 18,703.27	$ 6,024.47	$ 6,491.63	$ 2,164.71	$ 2,531.93	16.56%	10.18%	19.54	16.26	10.25	9.52		12.50%	25.25%
Liberty Energy Inc	$ 3,797.99	0.37	1.23	$ 4,685.63	$ 4,998.50	$ 1,084.81	$ 1,194.88	$ 418.73	$ 498.93	8.06%	9.58%	9.15	7.45	3.81	3.46	33.13%	19.70%	27.26%
Schlumberger NV	$ 61,668.78	1.04	2.55	$ 37,284.69	$ 42,260.57	$ 9,164.00	$ 10,669.89	$ 5,108.46	$ 6,180.36	11.40%	12.98%	12.23	10.28	7.81	6.70	23.23%	9.66%	13.26%
Halliburton Co	$ 29,821.37	1.33	2.02	$ 24,315.30	$ 26,232.65	$ 5,436.93	$ 6,035.15	$ 2,972.72	$ 3,430.79	10.12%	10.65%	9.97	8.51	6.55	5.90	31.42%	11.36%	20.62%
Enterprise Products Partners L	$ 61,487.67	3.34	7.28	$ 55,189.25	$ 57,329.13	$ 9,887.63	$ 10,281.00	$ 5,938.67	$ 6,283.27	7.91%	8.64%	10.46	9.94	9.25	8.90	20.70%	8.08%	11.20%
Energy Transfer LP	$ 51,915.21	3.96	8.24	$ 87,664.13	$ 89,401.75	$ 15,256.24	$ 15,879.47	$ 5,855.08	$ 6,533.00	7.19%	8.07%	10.44	9.30	7.71	7.41	13.78%	4.02%	8.46%
Williams Cos Inc/The	$ 50,444.23	4.35	4.59	$ 10,246.25	$ 11,014.63	$ 7,021.53	$ 7,499.07	$ 2,204.92	$ 2,486.75	22.65%	28.57%	22.87	20.57	11.28	10.56	18.98%	4.48%	5.48%
ONEOK Inc	$ 46,230.67	4.71	5.00	$ 21,841.71	$ 22,782.71	$ 6,206.60	$ 6,614.27	$ 2,918.50	$ 3,261.17	13.08%	16.08%	15.94	14.16	10.98	10.31	24.22%	8.11%	10.14%
Kinder Morgan Inc	$ 43,899.43	4.96	5.81	$ 16,507.10	$ 17,224.10	$ 8,103.16	$ 8,303.68	$ 2,728.40	$ 2,781.20	16.06%	20.23%	16.46	15.80	9.54	9.31	7.81%	3.40%	5.00%

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6/6/2024

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Citations and Disclosures

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