

World Energy View



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World Energy View

Presentation Objectives:

- Provide an overview of Global Energy Supply/Demand; now and relative to the last ten years
- Give a bit of basics on Energy Data Sources (and pitfalls therein)
- Empower you to go look for yourself!



World Energy Importance

Why this talk about Energy?

- It is a primary factor in life and the global economy
- It is politically supercharged and MIS-representation in the media

• As engineers we can understand and explain energy complexities; and we have a certain ethical responsibility to do so

"You have to face the facts, BECAUSE the facts are facing YOU!" Winston Churchill

World Energy Data

There are various sources for your use; for decades, the BP View of World Energy was my consistent source

- BP gave up this service a few years ago
- It is now provided by the Energy Institute, EI; annual data updates typically available ~June the following year <the latest is 2023 data released in mid-2024> "The 2024 Statistical Review of World Energy – 73rd Edition" <El second year>
- This presentation will cite all data sources (mostly **EI**, otherwise noted). I accept the data as reliable as published



Energy Dimensions

There are many dimensions used to measure energy. Various energy sources traditionally use different customary dimensions further differentiated by measurement systems (SI, Imperial, etc.)

- 1 Joule = energy dissipated as heat when an electric current of one ampere passes through a resistance of one ohm for one second
- A common energy dimension is **Exajoules**
 - 1 Exajoule = 10¹⁸ joules
 - I Exajoule is ~948 million million BTU
 - I Exajoule is ~160 million Oil Equivalent Barrels <using 6 million BTU per OEB>
- This presentation will use Annual Exajoules as the common dimension for all types of energy



Energy Dimensional Mystification

It is challenging to find consistent energy data; here are a few encounters:

- Primary Energy vs Electric Power Generation
- Dimensions: megawatts, cubic meters <perhaps 60F 1 bar for gases>, barrels <perhaps 60F>, metric tons, exajoules, BTU's, cubic feet, calories, terawatts... per year? per day?
- Reporting basis: year? footnotes? report date? Record month? Record day? Record hour?
- Grouping/Lumping
 - Renewables: include used cooking oil? Nuclear included/excluded
 - Oil consumption includes/excludes biofuel ethanol, biodiesel, bioether?
 - Biomass solid fuels *or* includes/excludes biofuels?
- Production vs Consumption: nil difference for nuclear; can be significant for coal
- Capacity vs Production: especially for wind and solar
- Conversion factors; calorific value(s)
- Energy vs Chemical: most natural gas is fuel; some is feedstock <GTL, hydrogen, carbon black>
- Losses/Efficiency/Inventory: power generation vs end consumption
- Error bars? Always applicable; NEVER reported!!! Use the data as best estimates

Energy Dimensional Mystification - 2

- This presentation will compare **Primary Energy Exajoules per year** as the dimension for all types of energy
- Other dimensions may be shown for relative comparison
- Rounding is used to tell the story and avoid small differences in numbers
- I would rather be approximately correct than precisely wrong

My Auburn Chemical Engineering ChE 201 prof would be pleased with the successful beatings flogged upon me to drill dimensional analysis 🖄 Also, thanks to Dr. David Himmelblau "Basic Principles in Chemical Engineering" 🏹

Energy Dynamics

Advance Apologies:

- Tremendously broad scope; huge SCALE
- My conversion factors WILL differ from yours
- Reporting differences and assumptions add a lot of complexity
- I have VERY limited graphics skills

So please take my results with a little salt!



What Got My Attention

In 2023, the World set an all-time **HIGH record for COAL Consumption!**

Several reports in The Economist (UK International News source)

• Other reports about Europe, India and China **COAL** increases

So, what is going on?

Global Energy Balance

Why talk about Energy Balance? - it is HUGE and so change is gradual!



2023 was an all-time RECORD!

Growth over ten years was ~2+% PA

Global Energy Balance

So, here is TOTAL PRIMARY ENERGY data over ten years:

								Delta		
								2023-		
							Delta 2023-	2014, %		
	2023	2022	2021	2020	2017	2014	2014	over 2014		
	619.6	607.4	596.6	567.6	566.1	543.2	76.4	14%	Exajoules	PA
vs prev	2.0%	1.8%	5.1%	0.3%	4.2%				Average 2.	7%
	Record									
	77.0	76.7	75.4	72.4	74.5	74.0	3	4%	Gigajoule	s per capita
vs prev	0.4%	1.7%	4.1%	-2.8%	0.7%					

2023 Fossil Fuels fell to 81.5 % of Total Primary Energy vs 81.8 % in 2022

Coal Consumption

Here is Global **Coal** data over ten years:

							Delta		
							2023-		
						Delta 2023-	2014, %		
2023	2022	2021	2020	2017	2014	2014	over 2014		
9095.6	8821.3	8169.1	7751.2	7704.9	8183.0	913	11%	Million To	nnes
Record									
164.0	161.5	160.6	152.3	155.5	161.6	2	1%	Exajoules	

> 2023 Coal consumption in just India exceeded Europe + North America for the first time

- > China and India set production records (2710 and 1011 Million MT) and also imported
- ➢ US/North America consumption peaked in 2014; Europe peaked in 2013

My COAL heritage: I am the son of a coal miner's daughter

Natural Gas Consumption

Natural Gas peak was 2021; Global data over ten years:

									Delta	
									2023-	
								Delta 2023-	2014, %	
		2023	2022	2021	2020	2017	2014	2014	over 2014	
		4010.2	4008.7	4023.9	3871.4	3651.8	3396.2	614	18%	BCM
		11.0	11.0	11.0	10.6	10.0	9.3			BCM/D
VS	s prev	0.0%	-0.4%	3.9%	6.0%	7.5%				
				Record						
		144.4	144.3	144.9	139.4	131.5	122.3	22.1	18%	Exajoules

Standardized for T, P and calorific value

Excludes natural gas to liquids

Nordstream Pipeline Outage September 2022; 55 BCMPA for each N/S 1 and 2

Will Natural Gas growth resume pre-Ukraine Conflict trend?

Liquified Natural Gas

LNG continues to **GROW**:

1.0											
									Delta		
									2023-		
							Delta	a 2023-	2014, %		
	2023	2022	2021	2020	2017	2014	2	2014	over 2014		
	549.2	539.3	515.9	490.0	393.3	333.6		216	65%	BCM	
	Record		11%	NS1 capac	ity vs 2021 l	LNG					
	19.8	19.4	18.6	17.6	14.2	12.0				Exajoules	
	13.7%	13.5%	12.8%	12.7%	10.8%	9.8%				% of WW NG	Consumption

How will clean Natural Gas compete with Coal in the future?

Nuclear Power

Nuclear Power is all primary energy; NO carbon emissions; PERHAPS radioactive effects

								Delta			
								2023-			
							Delta 2023-	2014, %			
2023	2022	2021	2020	2017	2014		2014	over 2014			
2738	2680	2803	2689	2637	2541		197	8%	Terawatt hou	urs	
		Record									
9.8	9.6	10.1	9.7	9.5	9.1		0.7	8%	Exajoules		
9.1%	9.2%	9.8%	9.9%	10.2%	10.6%	< pc	ortion of WW	total powe	er		
USA											
816.2	812.1	820.7	831.5	847.3	839.1		-23	-3%	Terawatt hours	in 2023 US wa	s 30% of WW
China				Record							
434.7	417.8	407.5	366.2	348.1	133.2		302	226%	Terawatt hours	in 2023 China	16% of WW;
Record										France was 12	2%
Germany											
7.2	34.7	69.1	64.4	76.3	97.1		-90	-93%	Terawatt hours	other capacity	y being retired?

China is clearly the growth leader

Homework: Summarize the UK Hinkley Nuclear Power Venture

Hydro Power

Hydro Power is all primary energy; NO carbon emissions; PERHAPS environmental effects

								Delta	
								2023-	
							Delta 2023-	2014, %	
2023	2022	2021	2020	2017	2014		2014	over 2014	
4240	4323	4289	4359	4068	3889		351	9%	Terawatt hours
14.1%	14.8%	15.0%	16.1%	15.8%	16.2%	< p	ortion of WW	total powe	er
			Record						
15.3	15.6	15.4	15.7	14.6	14.0				Exajoules

Data is energy production; NOT capacity

Hydro depends on recent years' weather and upstream water demand

Hydro Power – A few details

Here are a few highlights:

							Delta	
							2023-	
						Delta 2023-	2014, %	
2023	2022	2021	2020	2017	2014	2014	over 2014	
Norway	a lot of brag?							
136	128	143	141	142	140	-4	-3%	Terawatt hours
China	Nr One							
1226.0	1298.1	1300	1321.7	1165.1	1059.7	166	16%	Terawatt hours
29%	30%	30%	30%	29%	27%	< portion of	WW Hydro	
			Record					
Brasil	Nr Two							Terawatt hours
428.7	427.1	362.8	396.4	370.9	373.4	55	15%	
10%	10%	8%	9%	9%	10%	< portion of	WW Hydro	
Record								

China plus Brasil make up ~40% of WW Hydro energy production

Oil Consumption

Peak in 2023; demand recovered from COVID19 impact: 10-year data:

							Delta	
							2023-	
						Delta 2023-	2014, %	
2023	2022	2021	2020	2017	2014	2014	over 2014	
103.4	100.6	97.5	92.1	99.2	93.1	10.3	11%	Million B/D
2.8%	3.2%	5.9%	-7.2%	6.6%	vs prev			
Record								
196.4	191.6	185.5	175.5	190.7	180.4	16	9%	Exajoules
2.5%	3.3%	5.7%	-8.0%	5.7%	vs prev			

- Calorific value varies with composition
- Includes EtOH, Bio Diesel, other

Transportation segment was significantly impacted by COVID19

Biomass Energy

Difficult to find consistent data



2023	2022	2021	2020	2017	2014			
			57.5	<all bioma<="" th=""><th>ss includin</th><th>g liquid fuels</th><th></th><th>Exajoules</th></all>	ss includin	g liquid fuels		Exajoules
49	<inferred 2<="" for="" td=""><td>2023 balance</td><td>49</td><td><86% Soli</td><td>d sources (</td><th>(dung, wood, cha</th><td>arcoal, bag</td><th>(asse, pellets)</th></inferred>	2023 balance	49	<86% Soli	d sources ((dung, wood, cha	arcoal, bag	(asse, pellets)
			10%	vs TOTAL V	W Primary	Energy Exajoule	s <567 EJ>	

- Biomass sometimes includes liquid fuels <EtOH; Biodiesel>
- Often reported Renewable energy; category "Other"
- > Difficult to determine consumption <a pulp mill maybe; your fireplace probably not>
- > None the less at ~10% of WW Primary Energy "Biomass" is significant
- >In this presentation, Solid Biomass will mean solid fuels

Data source: https://www.worldbioenergy.org/

Biofuels Energy

Separating Bio Liquids (gasoline/jet/diesel) from Biomass Solids...

							Delta		
							2023-		
						Delta 2023-	2014, %		
2023	2022	2021	2020	2017	2014	2014	over 2014		
2,072	1,907	1,815	1,731	1,564	1,463	609	42%	KBD Oil Equivale	ent
2.1	1.9	1.8	1.7	1.6	1.5	0.6	42%	Million BD Oil Ec	quivalent
3.9	3.6	3.4	3.3	3.0	2.8			Exajoules	
2.0%	1.9%	1.9%	1.9%	1.6%	1.6%	< portion of	WW Oil (w	hich incl Biofuels	5)
USA									
804	729	685	632	701	618	186	30%	KBD Oil Equivale	ent
39%	38%	38%	37%	45%	42%	< portion of	WW Biofue	els	
Record									

Bio gasoline + Bio diesel are supported by government subsidies

The USA is the big player in Biofuels at ~40% of WW

> Bio jet is small; 0.2% of all 2023 commercial jet, www.iata.org/flynetzero

Oxygenates MAY reduce combustion emissions

Renewables Energy Details

Drill into 2023 Renewables DATA

			% of	% of WW
	Exajoules	terawatthr	Renewables	Total EJ
Hydro	15.3	4240	17%	2.5%
Wind	8.4	2325.3	9%	1.4%
Solar	5.9	1641.6	7%	1.0%
Biomass	49		55%	7.9%
Geothermal	0.1	17	0%	0.01%
Other	10.9		12%	1.8%





Biomass: wood, charcoal, dung, pellets.... <solids>

> Ah, the pitfalls of mixing data sources

Data source: https://www.statista.com/statistics/274101/world-renewable-energy-consumption/

Solar Power Energy

Need to understand CAPACITY vs PRODUCTION; Energy (MWHr) = Power (MW) * Hours

							Delta 2023-	
						Delta 2023-	2014, %	
2023	2022	2021	2020	2017	2014	2014	over 2014	
1,418,969	1,073,136	873,858	728,405	396,316	180,759	1,238,210	685%	Megawatt
1.4	1.1	0.9	0.7	0.4	0.2	1.2	685%	Terawatt
Record								
Power Pr	oduction							
1641.6	Terawatthr	2023 El report	ted					
12,430	TWh 1 year @	24 hour full g	en	1.4*365*24				
1641.6	1242	1011	843	458	209	terawatthr	< implied by ra	atio of 2023 TWh:TW
Record								
5.0		0.0	3.0	1.6	0.8			Exaioules
5.9	4.5	3.6	5.0	1.0	0.0			,
5.5%	4.5 4.3%	3.6	3.1%	1.8%	0.9%	< portion of WW	Total Powe	er

Solar Production is all Primary Energy

Data shows Energy Production vs Solar Capacity is ~13.2%

Geothermal Energy

Difficult to find any data

2023	2022	2021	2020	2017	2014	2000		
14,846						8,273	WW Insta	lled <u>capacity</u> MW
4.9		90%	assumed efficiency					Terawatt hours
0.02								Exajoules
1,418,969	<2023 installed solar capacity							
1.05%	< Geotherma	l relative to <u>So</u>	<u>lar Capacit</u>	У				

Geothermal can be reported Renewable energy; or category "Other"

- > Data is reported as MW capacity; not efficiency; excludes local thermal heat?
- > By any comparison, Geothermal is very small; "a minnow"

Data source: https://ourworldindata.org/grapher/installed-geothermal-capacity

Wind Power Energy

Need to understand CAPACITY vs PRODUCTION; Energy (MWHr) = Power (MW) * Hours

								Delta	
								2023-	
							Delta 2023-	2014, %	
2023	2022	2021	2020	2017	2014		2014	over 2014	
1,017,199	901,231	824,602	733,719	515,045	349,417		667,782	191%	Megawatt
1.0	0.9	0.8	0.7	0.5	0.3		0.67	191%	Terawatt
Power Production									
2325.3	terawatthr	2023 El reporte	ed						
8,911	TWh 1 year @	24 hour full ge	en	1.0*365*24					
26.1%	of Full Gen	f Full Gen 2325/8911			3.8	Rat	io TW installed:TWh		
2325.3	2060	1885	1677	1177	799		terawatthr < implied by r		atio of 2023 TWh:TW
7.8%	7.8% 7.1% 6.6%		6.2%	4.6%	3.3%	< pc	< portion of WW total power		er
Record									
8.4	7.4	6.8	6.0	4.2	2.9				Exajoules
1.3%	1.2%	1.1%	1.1%	0.7%	0.5%	< re	lative to WW	Total Prim	ary Energy

Wind Production is all Primary Energy: Wind Energy is larger than Solar

- > ? Windmill energy for pumping water ? Insignificant?
- > Data shows Energy Production vs Wind Capacity is 26.1%

Total Global Primary Energy Recap

The DATA for 2023; Exajoules:

	EJ	
TOTAL	619.6	
Oil	196.4	32%
NG	144.4	23%
Coal	164	26%
Nuclear	9.9	2%
Other	104.9	17%

Fossil Fuels sum 81%

Other includes "Renewables"

2023 WW Primary Energy



• Oil • NG • Coal • Nuclear • Other



What Got My Attention

Putting Energy Mix Change in Perspective

- \Rightarrow WW Population and Economies continue to grow
 - \Rightarrow WW Population grew from to 8.09 to 8.16 Billion 2022 to 2023 up 0.9%
 - \Rightarrow WW TOTAL energy requirement increased by 2% 2022 to 2023 (up 12.3 Exajoules)
- \Rightarrow Renewables *are* the fastest growing energy segment (up 4.5 Exajoules)
 - \Rightarrow Renewables grew at SIX times the *rate* of total primary energy
- ⇒ BUT Global energy demand continues to GROW faster than Renewables can keep pace (much less displace fossil fuels)

Forbes Magazine August 18, 2024

What Got My Attention

Parsing the Change in Primary Energy 2022 to 2023



 \Rightarrow Caution in 1-year snapshot data



 \Rightarrow Oil was #1, Coal #2, Solar #3, Wind #4; NG had pipeline issues

Electricity Generation (all sources)

Electricity Generation is **NOT** Primary Energy

							Delta		
							2023-		
						Delta 2023-	2014, %		
2023	2022	2021	2020	2017	2014	2014	over 2014		
29975	29188	28549	27033	25738	24076	5899	25%	Terawatt hours	
Record									
107.8	105.0	102.7	97.2	92.6	86.6	21.2	25%	Exajoules	
Record									
17%	17%	17%	17%	16%	16%	EJ	EJ Power relative to TOTAL EJ		

Methinks media reports on Renewables Growth RATE (mostly Electricity) vs Total Energy QUANTITY can be confusing

- > Indeed! Electric Power grew steadily over the past 10 years (~2.5 % PA despite efficiency gains)
- Electric Power looks to be steadily ~17% of Total Energy

Electricity Generation by Sources

Electric Power Generation is **<u>NOT</u>** Primary Energy

Electricity by Energy Source						
	2023					
Fossil Fuels	60.0%					
Hydro	14.1%					
Nuclear	9.1%					
Wind	7.8%					
Solar	5.5%					
Other	3.0%					
	100%					

2023 Electricity By Source, %



> Indeed! Electric Power from Wind/Solar has grown steadily over the past 10 years

> That Fossil Fuels segment is mostly Coal and Natural Gas (very little Oil)

Another Comparison, Exajoules 2023

Solar + Wind

Same DATA for 2023; Exajoules:

TOTAL	619.6			
Electric Power	107.8			
Renewables	104.9	incl Hydro; nuclear		
Rnwebes ex Biomass	55.9	incl Hydro; nuclear		
Solar + Wind	14.3			Rnwe

TOTAL 619.6 Electric Power 107.8 Renewables 104.9

Another Comparison, Exajoules 2023



Comprehending the SCALE of Global Energy is challenging!

Some NEW LNG Capacity

- WW LNG Capacity grew by 27% from 2016-2022 6 Years
- Some projects of interest:
 - 2025 ExxonMobil/Qatar Petroleum Golden Pass, Port Arthur, Texas
 - Original LNG IMPORT plant started-up 2010
 - Three 6 MTPA trains; 18 MTPA or about 3% of total US NG production
 - LNG production expansion cost ~\$10 Billion US

• DOE Issues Export Approval to Golden Pass LNG Energy.gov March 5, 2025

- 2025 LNG Canada, Kitamat, British Columbia
 - Largest private investment in Canadian history; Montney BC NG field
 - JV of 5 companies: Shell, Petronas, PetroChina, Mitsubishi, Korea Gas
 - \$40 Billion US; 2025 start-up; 14 MTPA; 2 trains
 - Incoming LNG tanker marks near completion of Kitimat export terminal Vancouver Sun March 27, 2025

Energy from Now On - Back to the Future

Many SIGNIFICANT Future Factors

Global population/economic growth (or decline?)

- Especially growth in China and India huge populations; huge growth potential
- Impact of declining EUR and Japan populations ... and US?

Geo-Politics (If/when?)

- Allowing or Interfering Open Markets
- Resume open trade with Russia
- Economic investment risk: Venezuela, Argentina, Africa, others

Path of Carbon Emissions reduction world-wide

- Carbon capture and storage
- Wind/Solar/Battery Energy Storage development
- Logistics expansions; especially gas pipeline/LNG and electric power transmission
- Carbon Trading

Capital Investment

• BP announced reset away from renewables (cut 70%) back to oil/gas 1March25 The Economist

World Energy View – Wrap-Up

The DATA shows the FACTS:

Continued steady increases in ENERGY DEMAND

- All forms of energy production are growing
- Imbedded in the data are improvements in technology and efficiency
- Fossil fuels are the dominant man-made energy source
 - With ~10% of WW energy still carbonaceous biomass, the transition TO clean fossil fuels has a way to go
- COAL has been the **swing** fly wheel; significant spare production
- Nuclear is going **no** where (ex China); Geothermal **is** no where (ex a few hot spots)
- Solar & Wind Energy tremendous growth over ten years, but remain small
- Tremendous future developments; stay tuned

In God We Trust: All Others BRING DATA!

World Energy View – Wrap-Up

Thank God for the Sun!

The Earth receives as much energy from the Sun in one hour as ALL man-made energy produced is one year

https://explainingscience.org/2019/03/09/solar-energy/

In God We Trust: All Others BRING DATA!

World Energy View Information Resources

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Energy Institute (EI) - 2024 World Statistical Review of World Energy
https://www.energyinst.org/statistical-review

 Renewable Energy Consumption Hits New Record High (forbes.com) August 18, 2024



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