ASSESSMENTS OF THE PHYSICAL REQUIREMENTS TO GLOBALLY PHASE OUT FOSSIL FUELS

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30/05/2022

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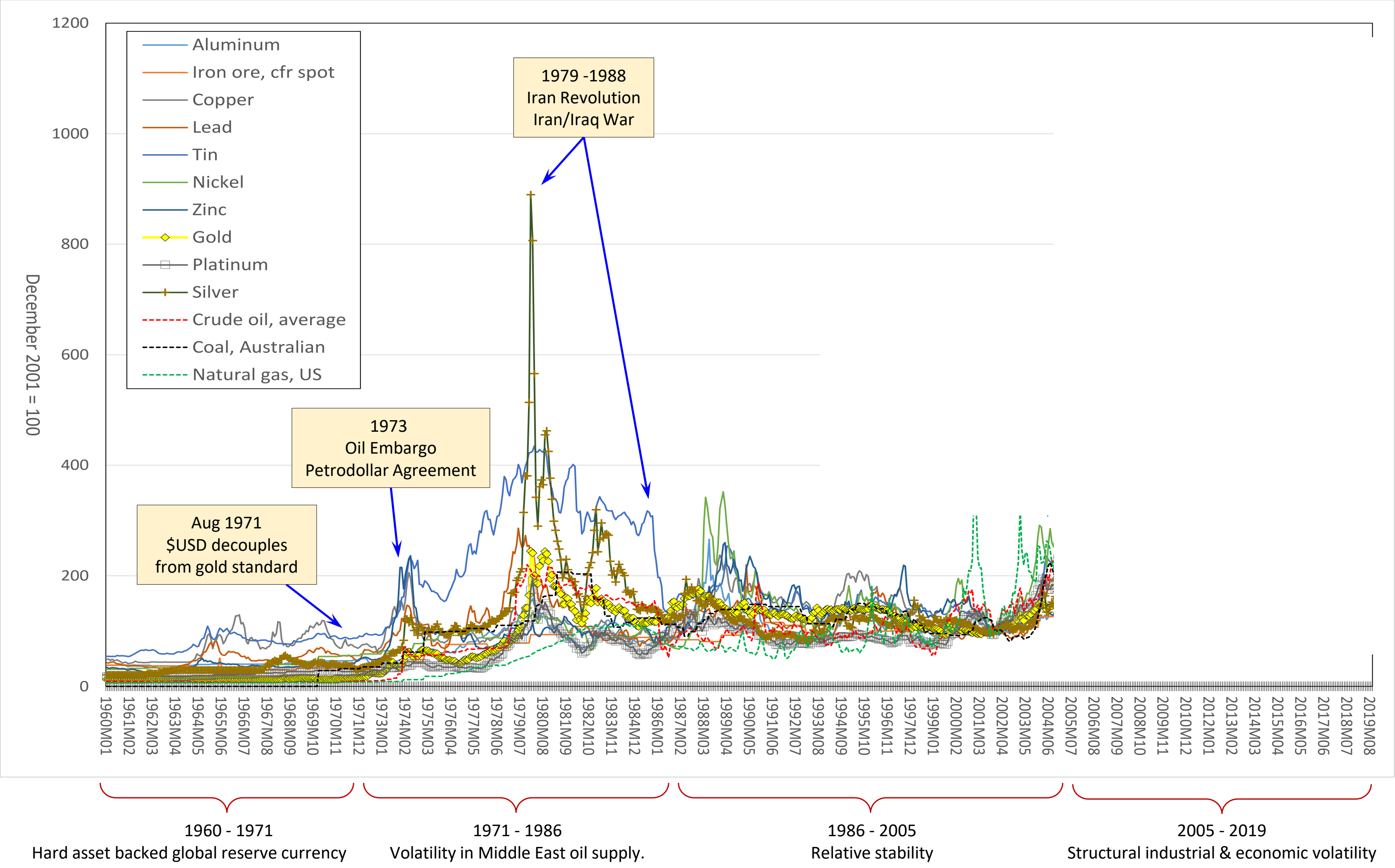
THE INDUSTRY CHANGED IN 2005



A case can be made that this blow out was a chain reaction started in the oil industry

A major economic correction (GFC 2008) did not resolve the problems

The change started something like 17 years in our past

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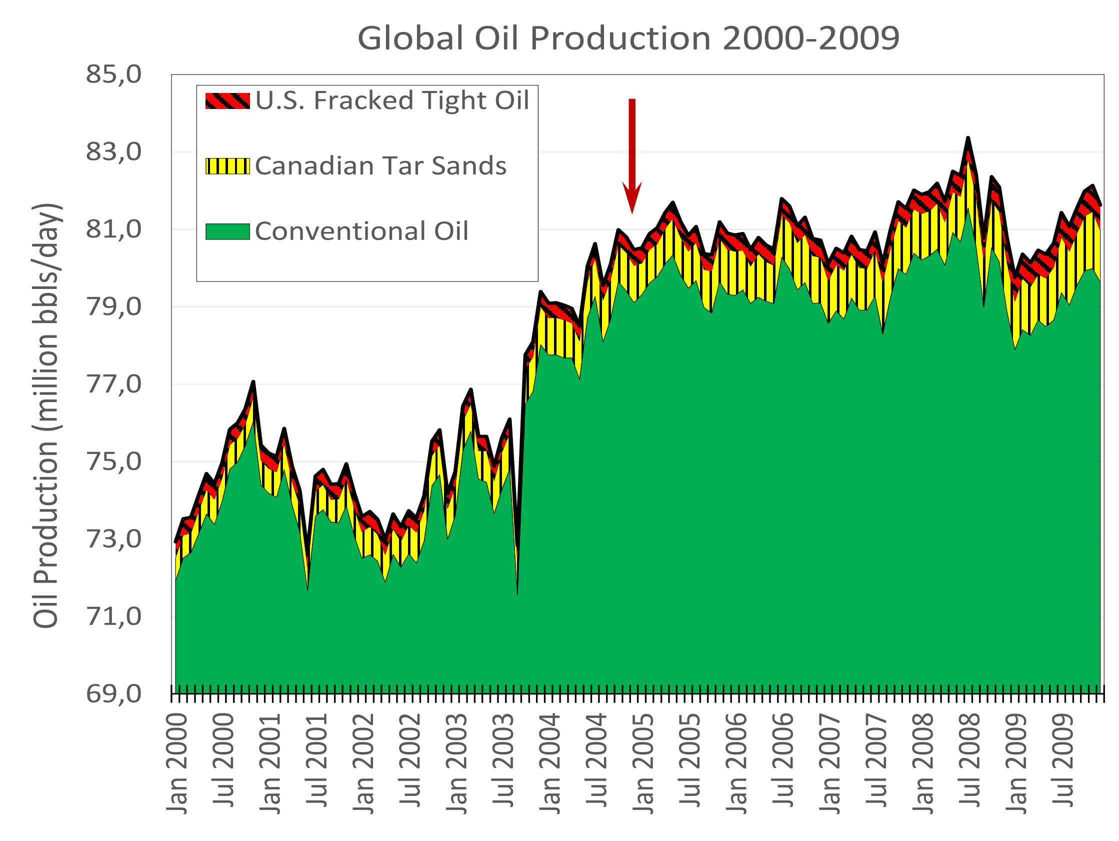
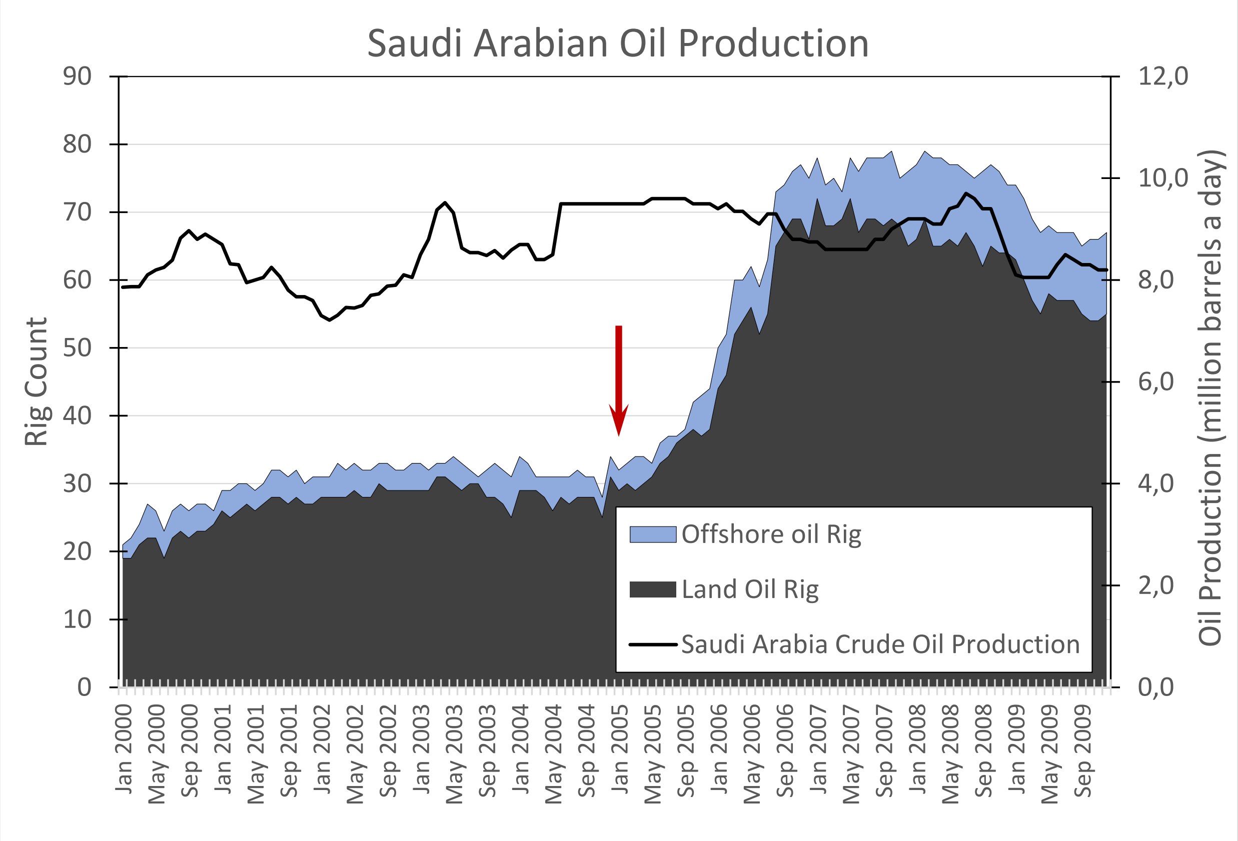
WHAT HAPPENED IN 2005?

Oil supply was not able to expand and plateaued, yet demand continued to increase after a short pause



(Source: EIA monthly oil production statistics 2019, Canadian Association of Petroleum Producers 2019, Shale Profile 2019)

The global industry 'Swing' producer, Saudi Arabia was not able to increase supply



(Source. Baker Hughes Rig Count data, EIA monthly production data)

146% increase in rig count in exchange for -4.2% decrease in oil production

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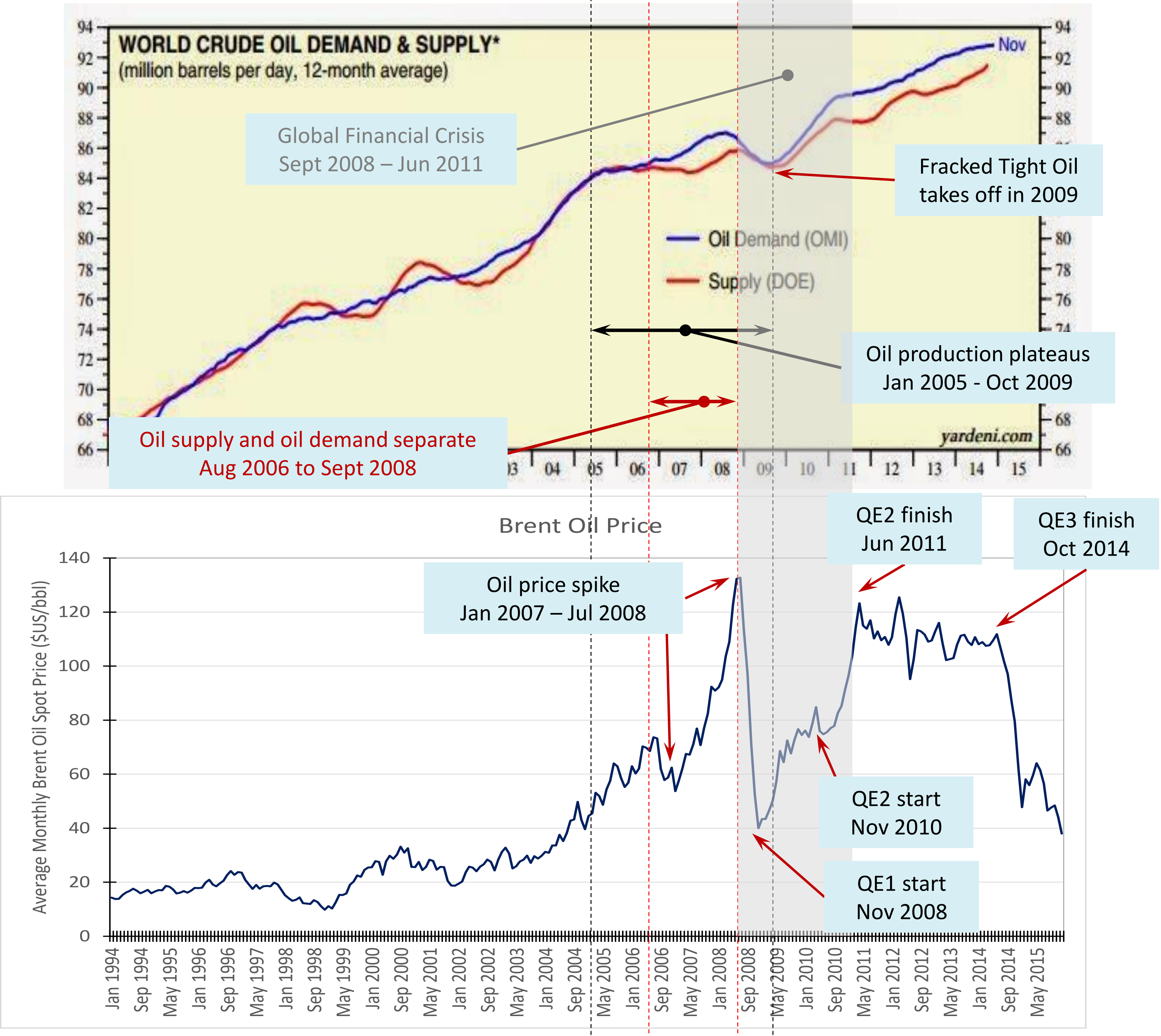
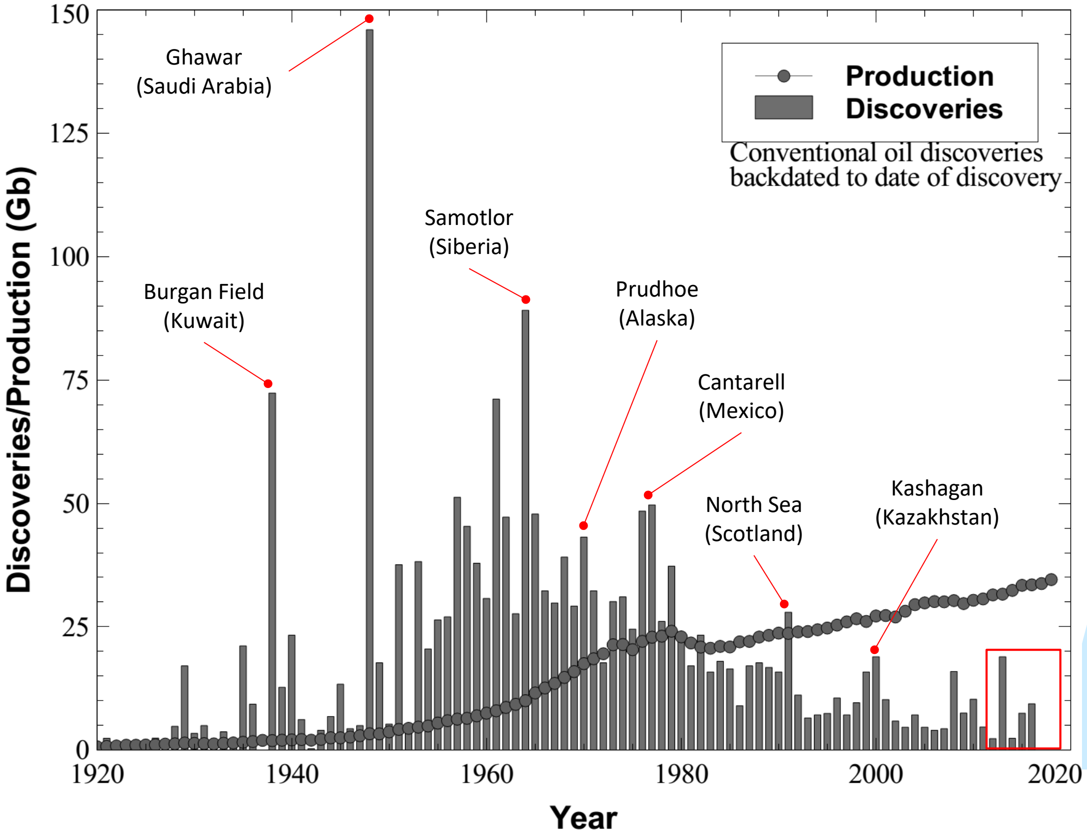
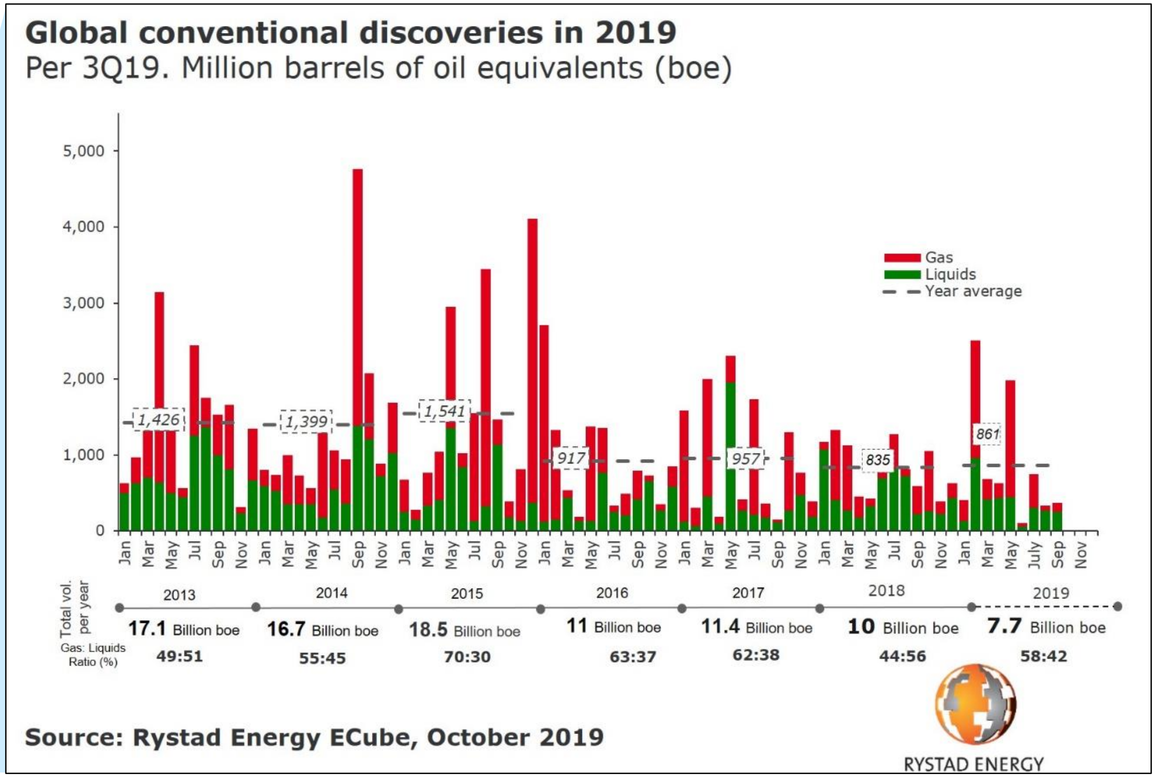


- A case can be made that the GFC was caused by a chain reaction with its genesis in the oil industry
- Quantitative Easing resolved the GFC crash
- Fracking or Tight Oil was able to make up the supply short fall
- US is now the global industry swing producer, with the majority of growth coming from Tight Oil

WE ARE NOT DISCOVERING ENOUGH NEW OIL DEPOSITS





81% of existing producing fields are in decline at an average rate of 5-7% p.a. (HSBC 2016)

Of the largest 10 modern producing fields, the youngest was discovered in 1976 (Hirsch 2011)

Record low discoveries in 2020 (Rystad 2021)

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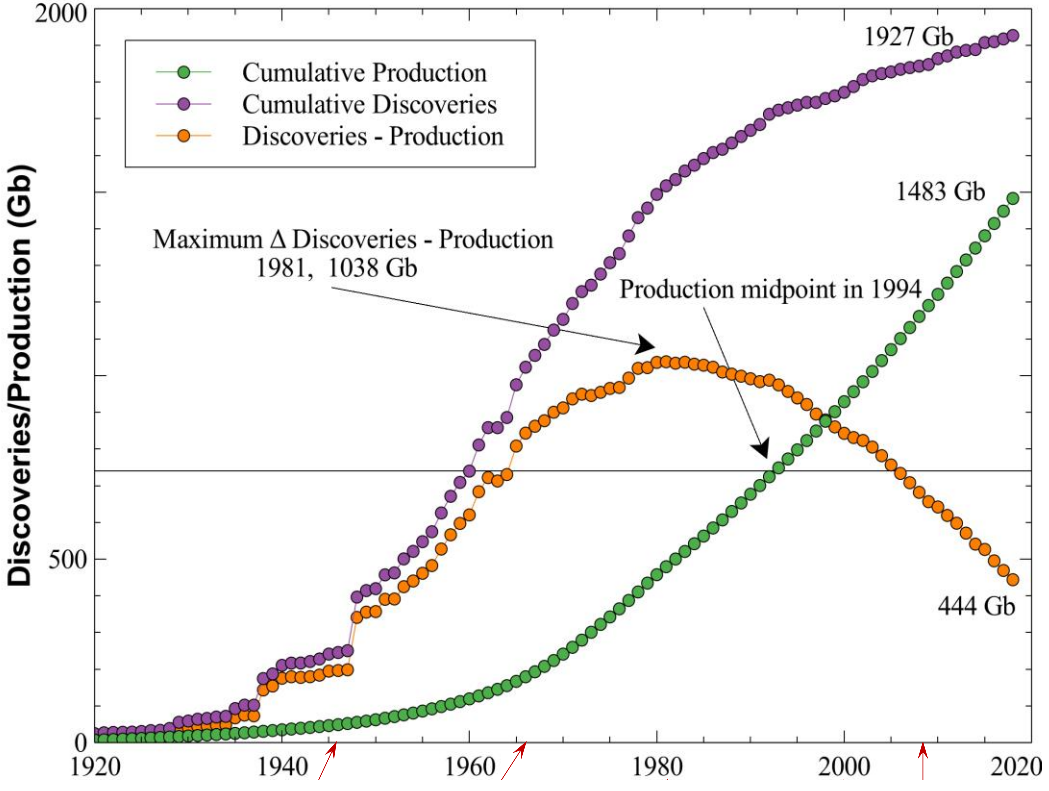
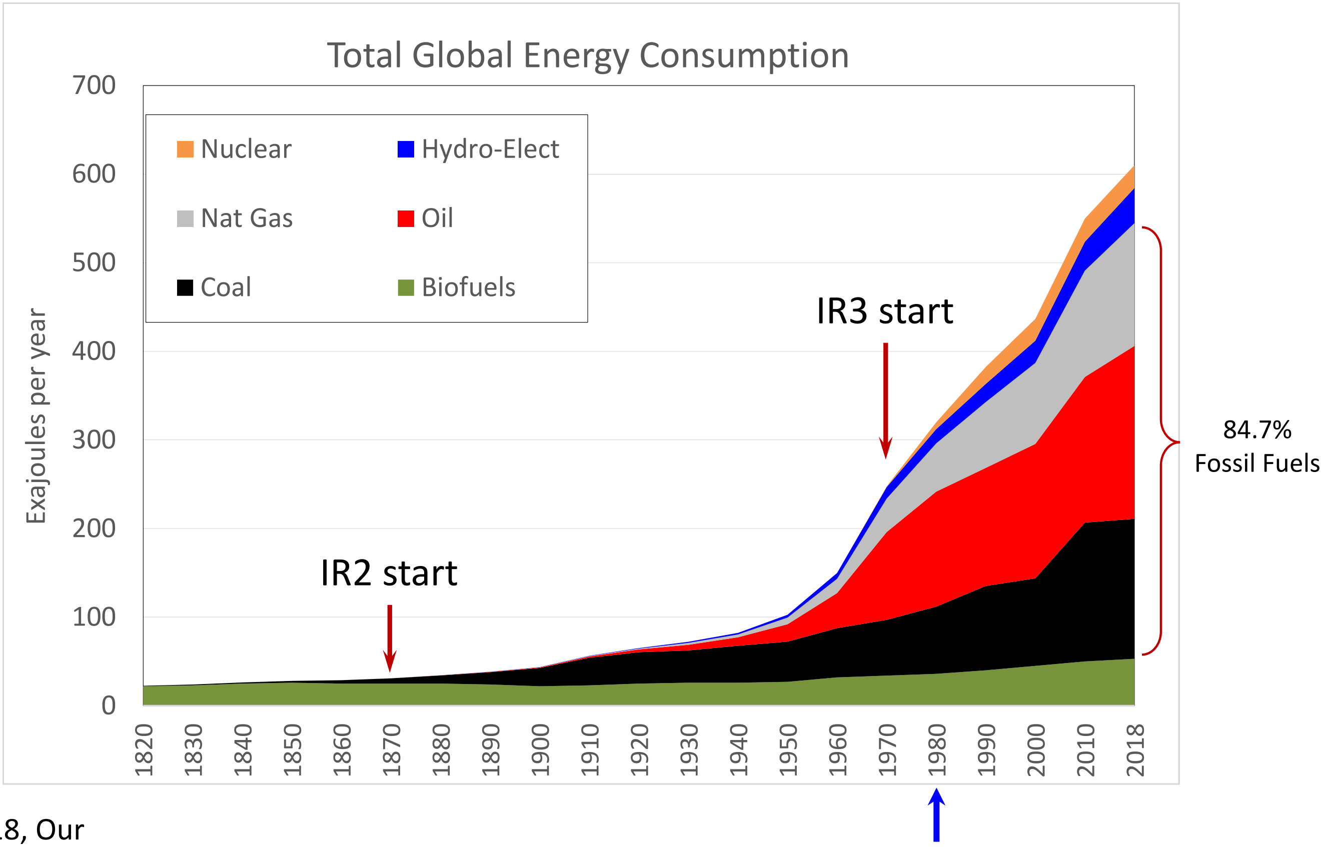
FOSSIL FUEL DEPENDENCY



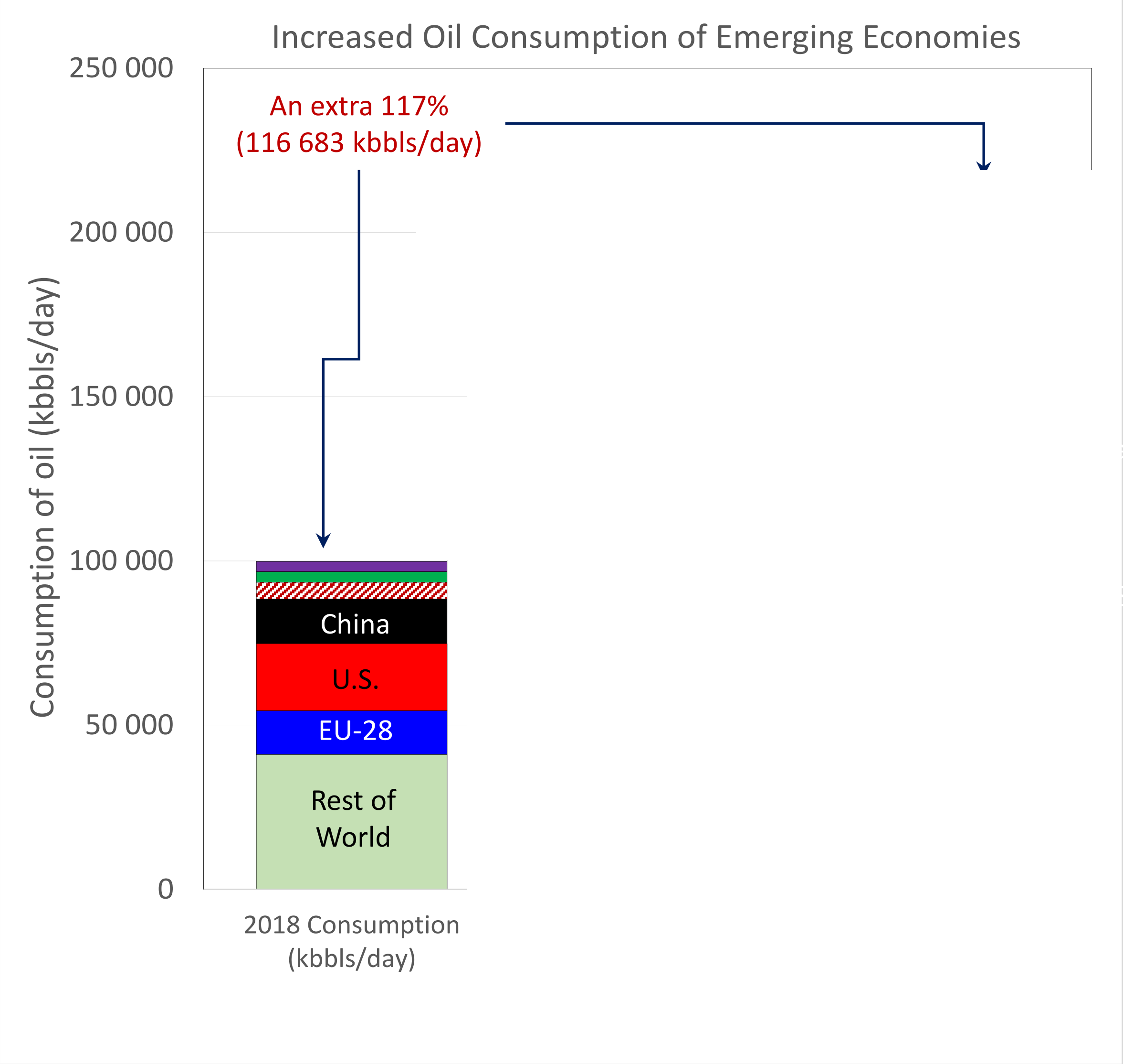


(Source: data from ASPO 2019, Wood and Mackenzie, Oil Price 2017, Rsytad Energy 2018, Our World in Data 2019, BP Energy Statistics 2019 CNBC 2017)

Once energy becomes much more expensive, the economics of all other raw materials will change

All raw materials will have this profile eventually

PROJECTED OIL CONSUMPTION AS ALL ECONOMIES BECOME AS DEVELOPED AS THE GERMAN ECONOMY

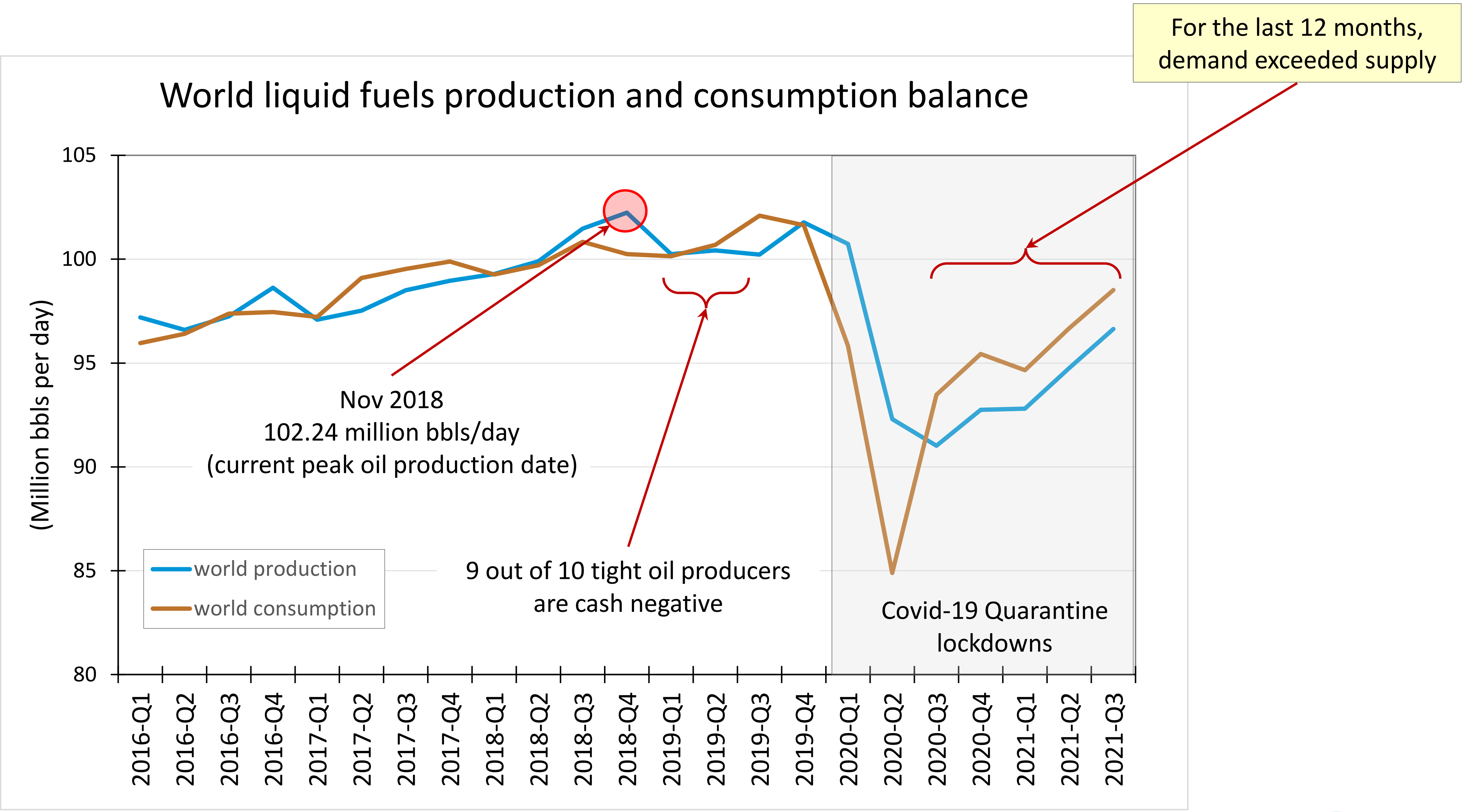


- BRIC economies increase by 254%
- Rest of world increase by 71%
- United States would decrease by 54%
- So we will need an extra 117 mbpd of oil
- If Saudi Arabian Ghawar field produces 3.8 mbpd, then we need to discover and then develop...

…31 new Ghawar deposits

(Source: data from BP Statistical Review of World Energy 2019, Appendix C and D, World Bank data, United Nations, Department of Economic and Social Affairs, Population Division (2017). World Population Prospects: The 2017 Rev)

GLOBAL OIL PRODUCTION & CONSUMPTION



(Source: U.S. Energy Information Administration, Short-Term Energy Outlook, October 2021)

SUMMARY

Physical Tasks done industrially by fossil fuels

↓

Determine the true scope of useful work done

↓

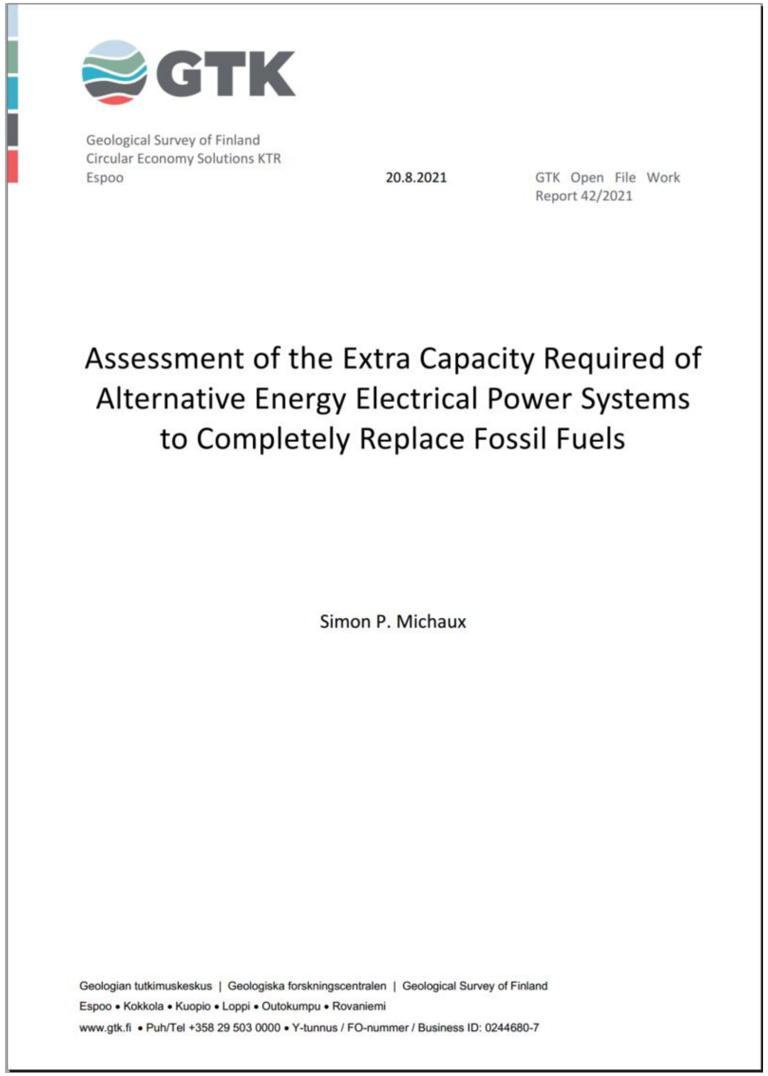
Assemble non-fossil fuel systems that could do the same useful work

↓

Calculate the quantity of electrical power needed

↓

Using same energy mix as 2018, determine how many new non-fossil fuel power stations are needed



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Geological Survey of Finland
Circular Economy Solutions KTR
Espoo

20.8.2021

GTK Open File Work Report 42/2021

Assessment of the Extra Capacity Required of Alternative Energy Electrical Power Systems to Completely Replace Fossil Fuels

Simon P. Michaux

Geologian tutkimuskeskus | Geologiska forskningscentralen | Geological Survey of Finland
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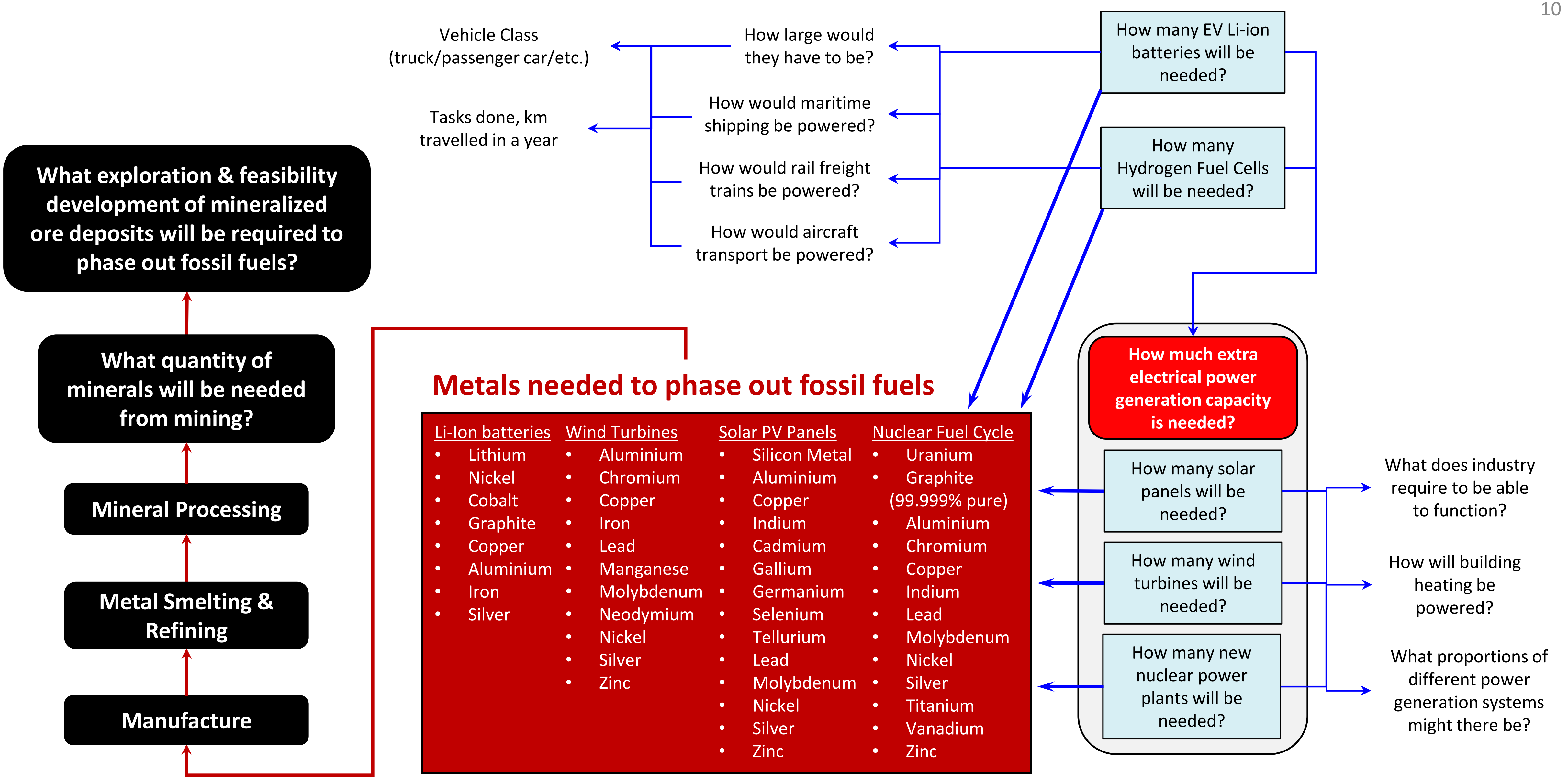
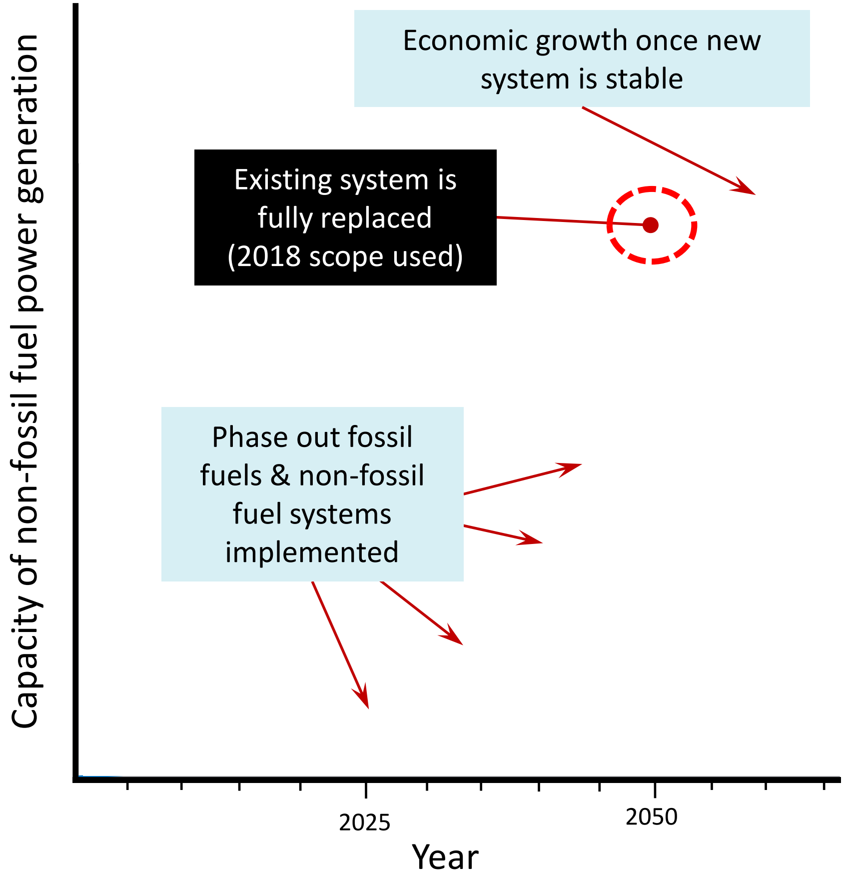
Link to full report below
https://tupa.gtk.fi/raportti/arkisto/42_2021.pdf

Link to 8 page summary
https://mcusercontent.com/72459de8ffe7657f347608c49/files/be87ecb0-46b0-9c31-886a-6202ba5a9b63/Assessment_to_phase_out_fossil_fuels_Summary.pdf

- Number of vehicles, by class
- Number and size of batteries
- An understanding of the EV to H_2-Cell split
- Estimates of EV & H_2-Cell rail transport
- Estimates of an EV & H_2-Cell maritime shipping fleet
- Estimates of phasing out of fossil fuel industrial applications
- Examination of the feasibility of expanding the nuclear NPP fleet
- Assessment of the feasibility of global scale biofuels
- Plastics & fertilizer industries


What exploration & feasibility development of mineralized ore deposits will be required to phase out fossil fuels?
What quantity of minerals will be needed from mining?
Mineral Processing
Metal Smelting & Refining
Manufacture
Vehicle Class (truck/passenger car/etc.)
Tasks done, km travelled in a year
How large would they have to be?
How would maritime shipping be powered?
How would rail freight trains be powered?
How would aircraft transport be powered?
How many EV Li-ion batteries will be needed?
How many Hydrogen Fuel Cells will be needed?
Metals needed to phase out fossil fuels
Li-Ion batteries
Lithium
Nickel
Cobalt
Graphite
Copper
Aluminium
Iron
Silver
Wind Turbines
Aluminium
Chromium
Copper
Iron
Lead
Manganese
Molybdenum
Neodymium
Nickel
Silver
Zinc
Solar PV Panels
Silicon Metal
Aluminium
Copper
Indium
Cadmium
Gallium
Germanium
Selenium
Tellurium
Lead
Molybdenum
Nickel
Silver
Zinc
Nuclear Fuel Cycle
Uranium
Graphite (99.999% pure)
Aluminium
Chromium
Copper
Indium
Lead
Molybdenum
Nickel
Silver
Titanium
Vanadium
Zinc
How much extra electrical power generation capacity is needed?
How many solar panels will be needed?
How many wind turbines will be needed?
How many new nuclear power plants will be needed?
What does industry require to be able to function?
How will building heating be powered?
What proportions of different power generation systems might there be?

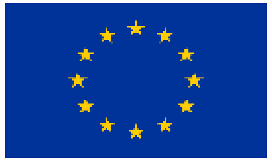
WHAT WOULD IT TAKE TO REPLACE THE EXISTING FOSSIL FUEL SYSTEM?



- What does fossil fuels do for us now?
- How much extra electrical power capacity is required to phase out fossil fuels completely?
- How many cars, trucks, ships, trains & aeroplanes are there?
- How many new power stations will be needed?
- How many batteries will be needed?
- How many solar panels will be needed?
- How many wind generator turbines will be needed?
- **What quantity of minerals will be needed to do this?**

CALCULATION ARC

- What is the true scope of tasks to fully phase out fossil fuels, and the complete replacement with non-fossil fuel powered systems?
- Existing ICE transport fleet size
  - *Cars & Trucks*
  - *Rail*
  - *Maritime shipping*
  - *Aviation*

- What is the number and size of required batteries/hydrogen cells/solar panels/wind turbines
  - *In what proportional mix?*
  - *In 2018, 84.5% of global primary energy consumption was fossil fuel based*
- Required power grid expansion to charge the needed number of batteries, and make hydrogen
  - *Number of new power stations*
  - *Required power storage to manage intermittent supply*

Current plans are not large enough in scope, the task before us is much larger than the current paradigm allows for

BASELINE CALCULATION

- The global fleet of vehicles is estimated to be 1.416 billion, which travelled an estimated 15.87 trillion km in the year 2018
  - *0.7% is EV in 2020*
- For the same energy output:
  - *…an Electric Vehicle system requires **battery storage** mass **3.2 times** the fuel tank (@700bar) mass of a hydrogen H-Cell system*
  - *…meanwhile a hydrogen H-Cell system will require **2.5 times** more **electricity** compared to a Electric Vehicle system*
- All short-range transport could be done by Electric Vehicle systems
  - *All passenger cars, commercial vans, delivery trucks and buses (1.39 billion vehicles), would travel 14.25 trillion km in 365 days*
  - *This would require 65.19 TWh of batteries (282.6 million tonnes of Li-Ion batteries)*
  - *An annual additional 6 158.4 TWh of electricity will be required from the global power grid to charge those batteries*
- All long-range distance transport could be powered with a hydrogen fuel cells
  - *All Class 8 HCV trucks, the rail transport network (including freight), and the maritime ship fleet*
  - *In total, 200.1 million tonnes of hydrogen would be needed annually*
  - *This would require, 11 553.6 TWh of additional electricity*

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GLOBAL SYSTEM I

1.39 billion Electric Vehicles	Charging Batteries
695.2 million Passenger Cars 5.4 trillion km	1 128.5 TWh
29 million Buses & Delivery Trucks 803 billion km	1 166.1 TWh
601 million Vans, Light Trucks 7.9 trillion km	2 181.7 TWh
62 million Motorcycles 160 billion km	19.4 billion kWh

4 495.7* TWh

*updates in EV energy efficiency reduced this number by 4% from (Michaux 2021)

Industry	
Electrical Power Generation	17 086.1 TWh
Building Heating	2 816.0 TWh
Steel Manufacture	56.5 TWh

19 958.6 TWh

GLOBAL SYSTEM II

Hydrogen Economy

H_2-Cell Vehicles	Hydrogen		Manufacture of H_2
28.9 million Class 8 HCV Trucks Travelled 1.62 trillion km	129.9 million tonnes	200.1 million tonnes	7 503.7 TWh
Rail Transport 9 407 billion tkm freight 1 720 billion passenger-kilometers	18.5 million tonnes		1 066.5 TWh
Maritime Shipping cargo 72 146 billion tonne-km	51.7 million tonnes		2 983.4TWh

→ 11 553.6 TWh

Biomass Economy

Biomass Sustainably Sourced from the Planetary Environment

Aviation	Biofuel ??? liters
Plastics Manufacture	Biomass Feedstock ??? tonnes

Sustainability audit

GLOBAL SYSTEM III

EV 4 495.7 TWh

Industry 19 958.6 TWh

H_2 11 553.6 TWh

Additional Annual Electrical Power Requires 36 007.9 TWh

=

211 813 NEW Non-Fossil Fuel Power Stations

Power plant fleet in 2018 was
46 423 stations

Hydro Power
15 845.2 TWh
11 952 stations

Nuclear Power
10 208.3 TWh
797 stations

Wind Power
4 926.9 TWh
60 645 stations

Solar Power
2 209.1 TWh
66 502 stations

Other Renewables
Geothermal & Tidal
351.4 TWh
583 stations

Biowaste to Energy
2 466.9 TWh
71 334 stations

Power storage buffer 548.9 TWh

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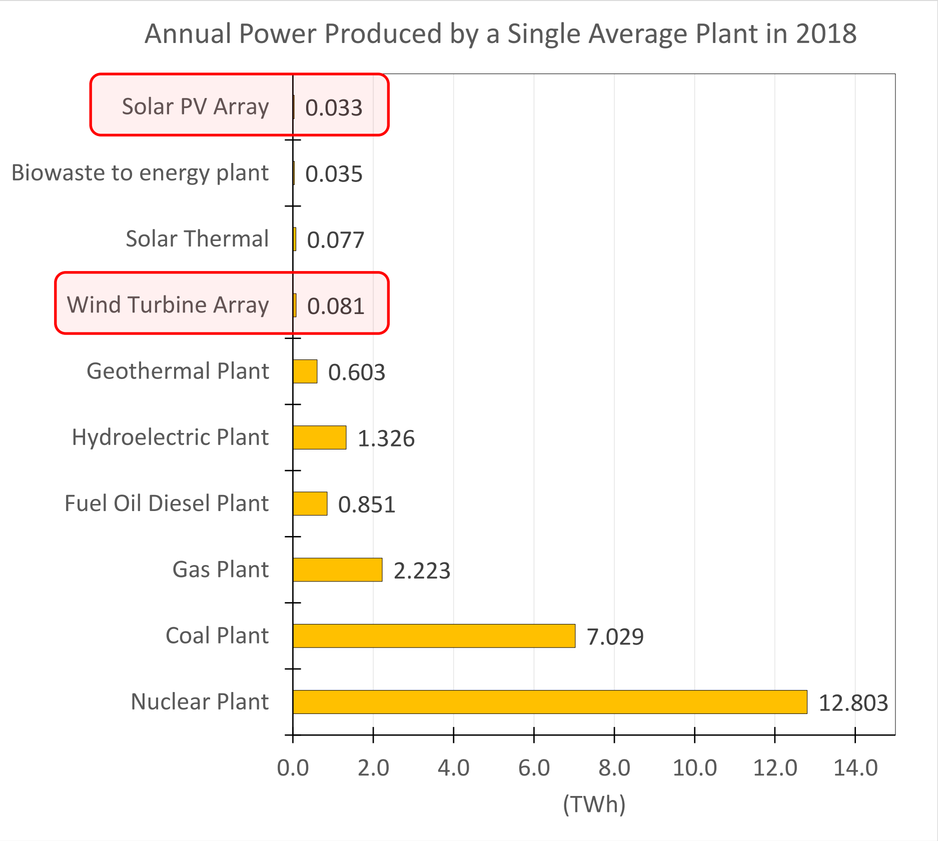
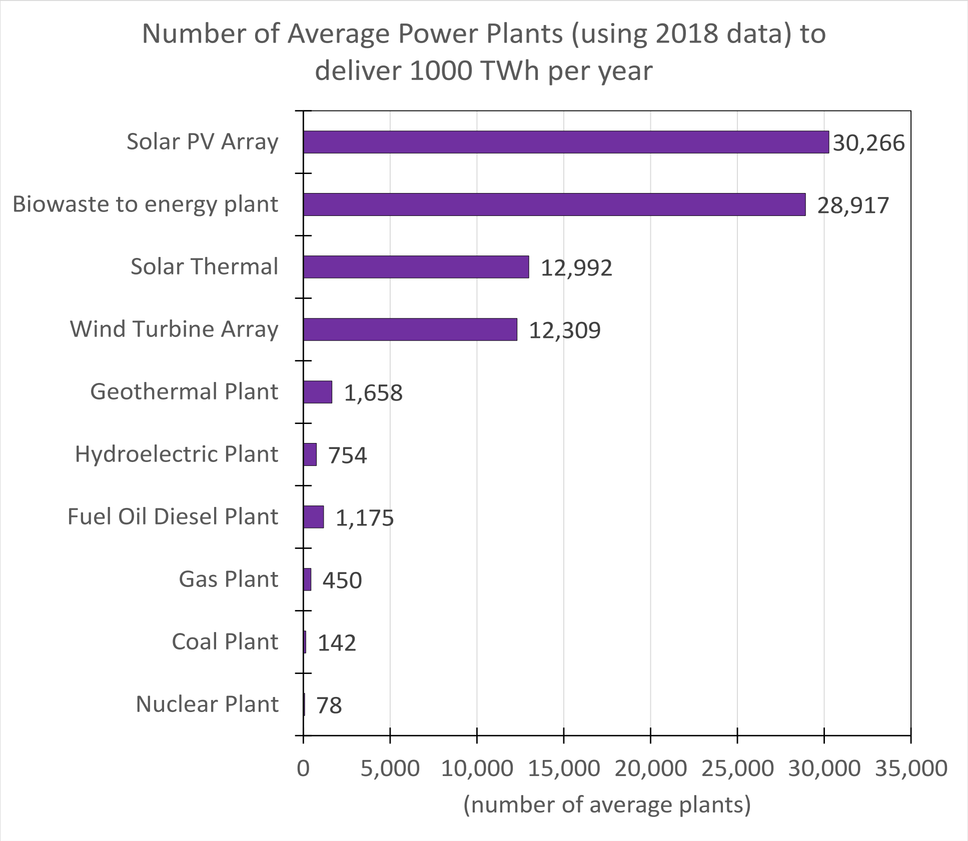
TO DELIVER 1000 TWH OF POWER TO THE GRID OVER 1 YEAR…





(Source Data: Global Energy Observatory, Agora Energiewende and Sandbag 2019)

Renewables have a much lower ERoEI ratio than fossil fuels and may not be strong enough to power the next industrial era

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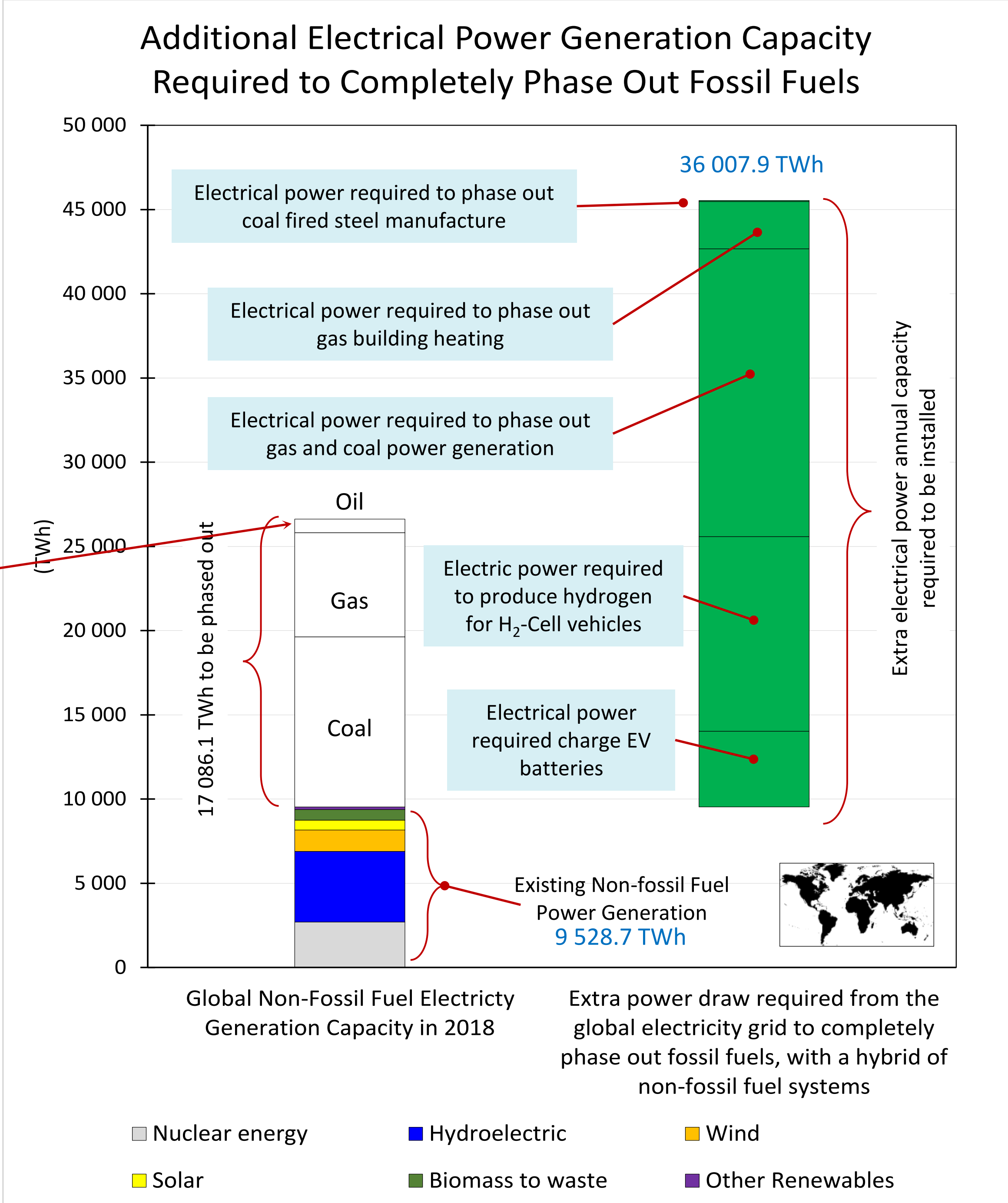
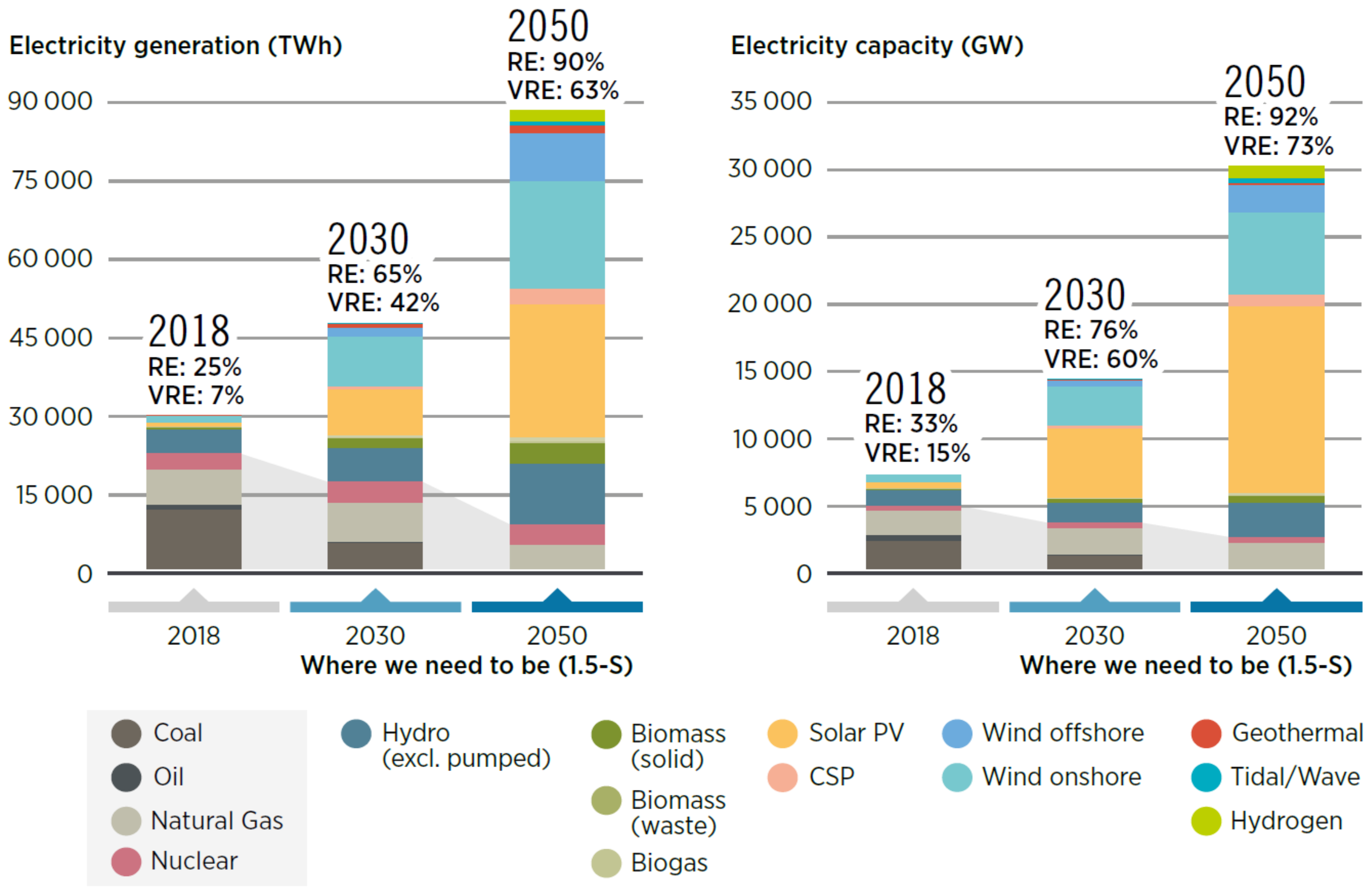
Total electrical power production in 2018 was 26 614 TWh





Note: 1.5-S = 1.5°C Scenario; CSP = concentrated solar power; GW = gigawatts; PV = photovoltaic; RE = renewable energy; TWh/yr = terawatt hours per year; VRE = variable renewable energy.

Global total power generation and the installed capacity of power generation sources in 1.5°C Scenario in 2018, 2030 and 2050 (Source: IRENA 2022)

NEW ENERGY SPLIT

28.9 million trucks (H_2-Cell)

695.2 million passenger cars (EV)
46.8 kWh battery

29 million buses (EV)
227.5 kWh battery

36 007.9 TWh
New annual capacity

601.3 million commercial vans (EV)
42 kWh battery

62 million motorcycles (EV)
12 kWh battery

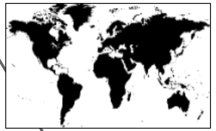
Electrical Power Generation,
heating & steel manufacture

11 553.6 TWh

4 495.7 TWh

19 958.6 TWh

36 007.9 TWh
New annual capacity

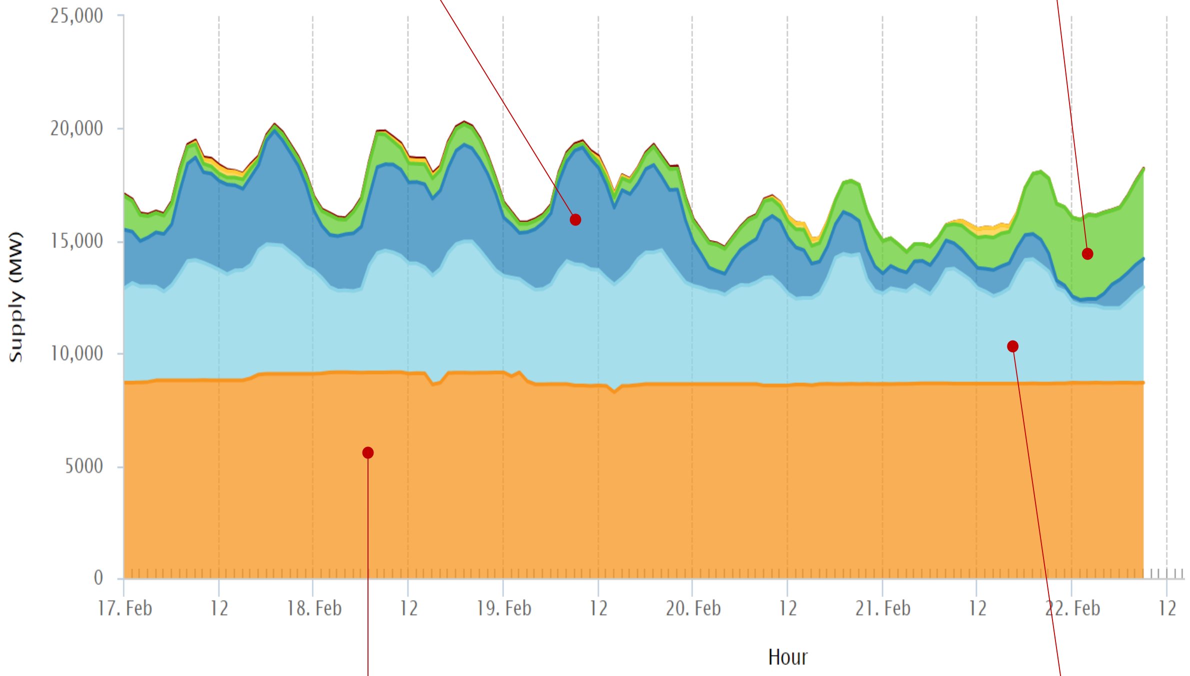
Power Generation System 	Proposed Proportion of Energy Split on new annual capacity (%)	Extra required annual capacity to phase out fossil fuels (TWh)	Estimated number of required new power plants of average size to phase out fossil fuels (number)
Nuclear	7,50 %	2 701,4	211
Hydroelectric	13,36 %	4 809,6	3 628
Wind Onshore (70% share)	26,83 %	9 660,3	118 907
Wind Offshore (30% share)	11,50 %	4 140,1	50 960
Solar PV (90% share)	34,50 %	12 420,3	375 910
Solar Thermal (10% share)	3,83 %	1 380,0	17 930
Geothermal	0,74 %	266,7	442
Biowaste to energy	1,73 %	624,0	18 044
		36 007,9	586 032

Developed from a combination of an IEA 2021 projection and some of my own assumptions

GAS AND HYDRO ARE THE EXISTING BUFFER

Important role of gas-fired units in making the balance

Maximum wind generation occurred in the demand valley

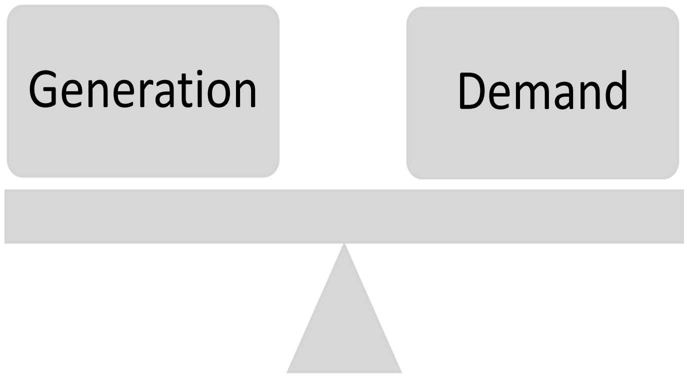


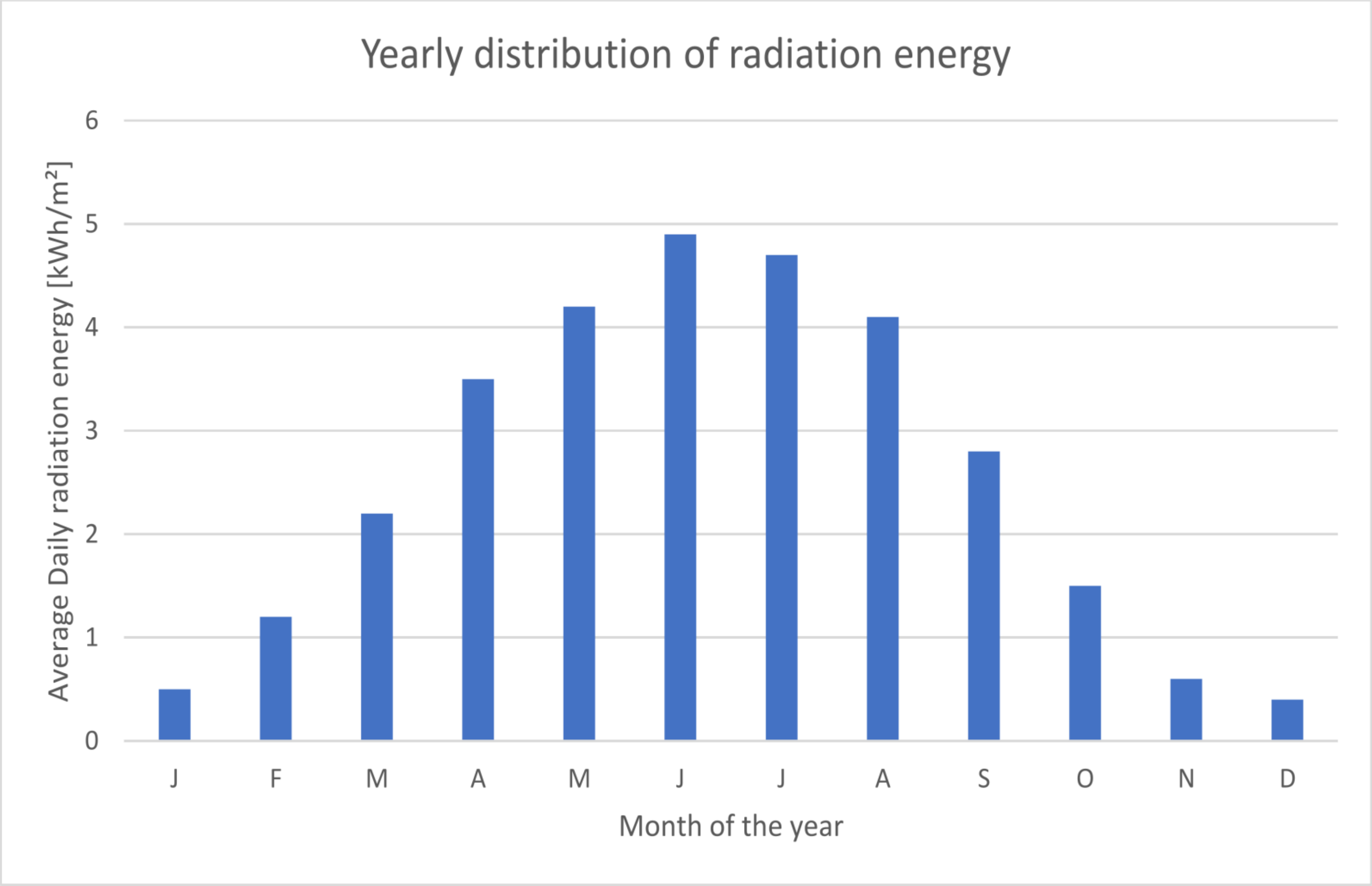
Monday, Feb 22, 04:00

Biofuel:	**17** MW
Solar:	**0** MW
Wind:	**3,595** MW
Gas:	**647** MW
Hydro:	**3,324** MW
Nuclear:	**8,686** MW

Electrical production by nuclear power plants is optimized to stay constant due to technical operational limitations

Average daily production of hydro units is dictated by their reservoir condition





Distribution of the sun’s radiation energy over the year in Germany (Wesselak & Voswinckel 2016)

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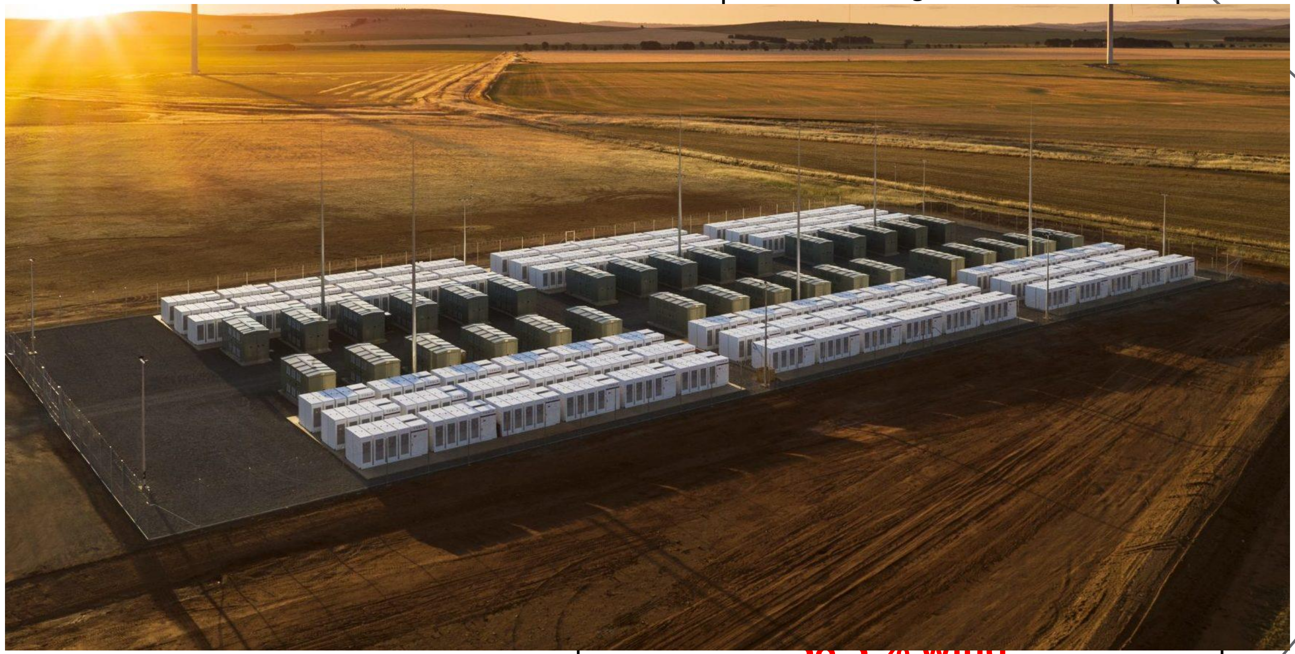
STATIONARY POWER STORAGE BUFFER

34.5% solar PV
12 420.3 TWh
375 910 average sized solar farms

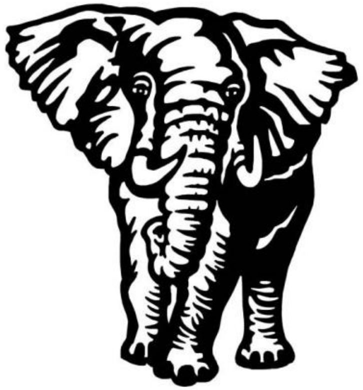


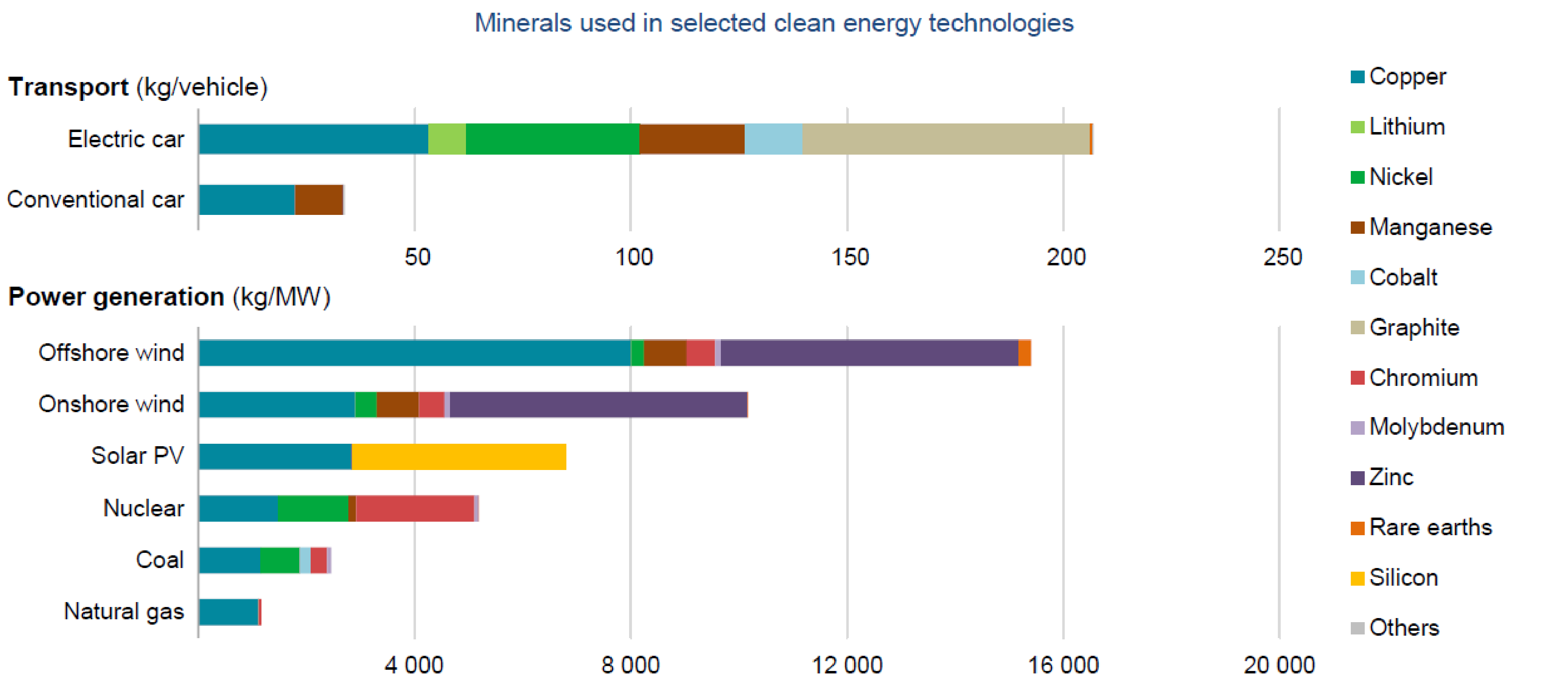
Hornsdale Power Reserve in Australia
100MW/129MWh
https://hornsdalepowerreserve.com.au/

38.5 % wind
13 800.4 TWh
2 106 361 wind turbines (3 MW) in 169 868 average sized arrays (37.2 MW installed capacity)
90% onshore, 10% offshore

4 weeks buffer power storage 548.9 TWh

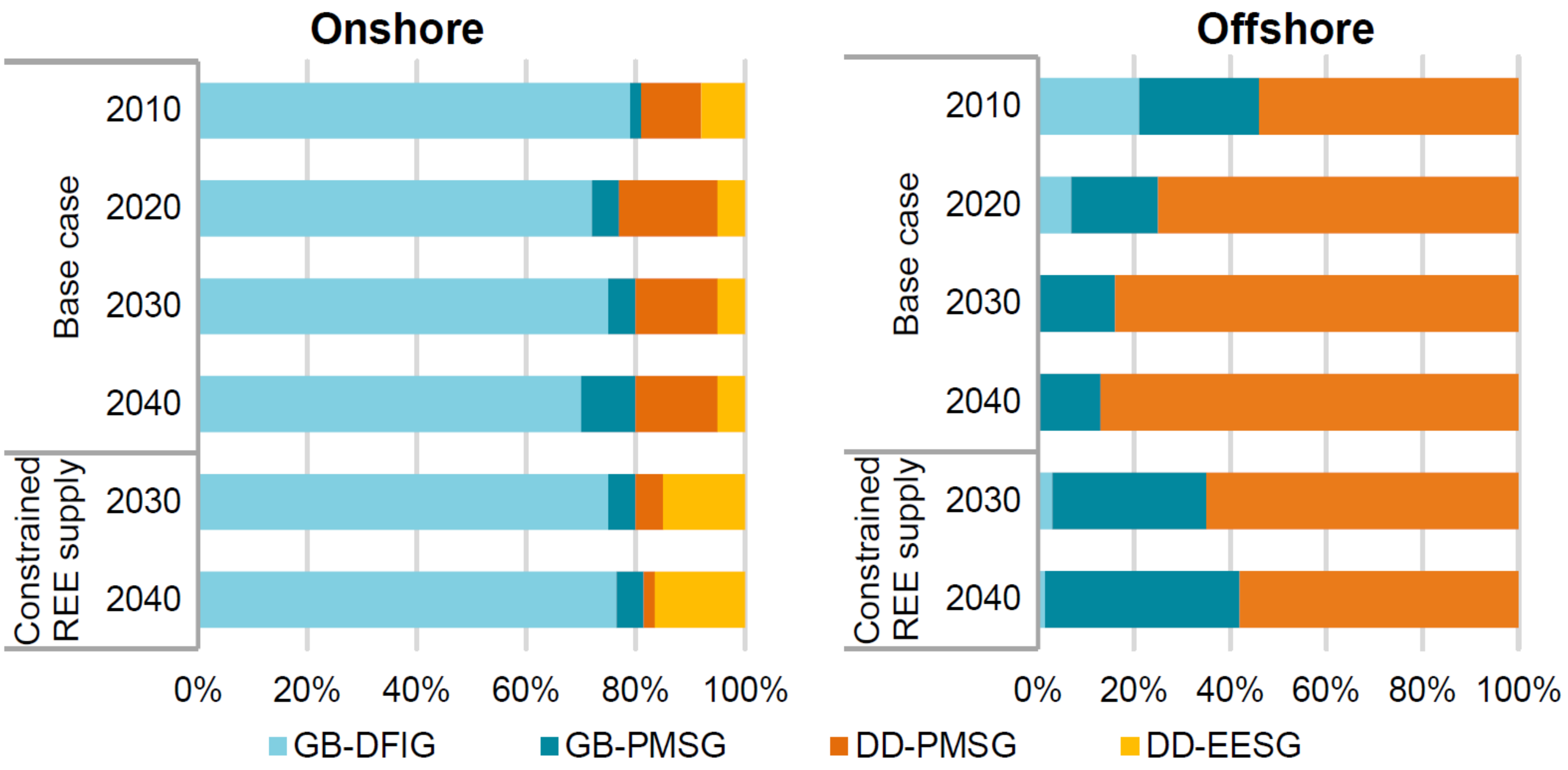
15 635 478
Hornsdale power stations



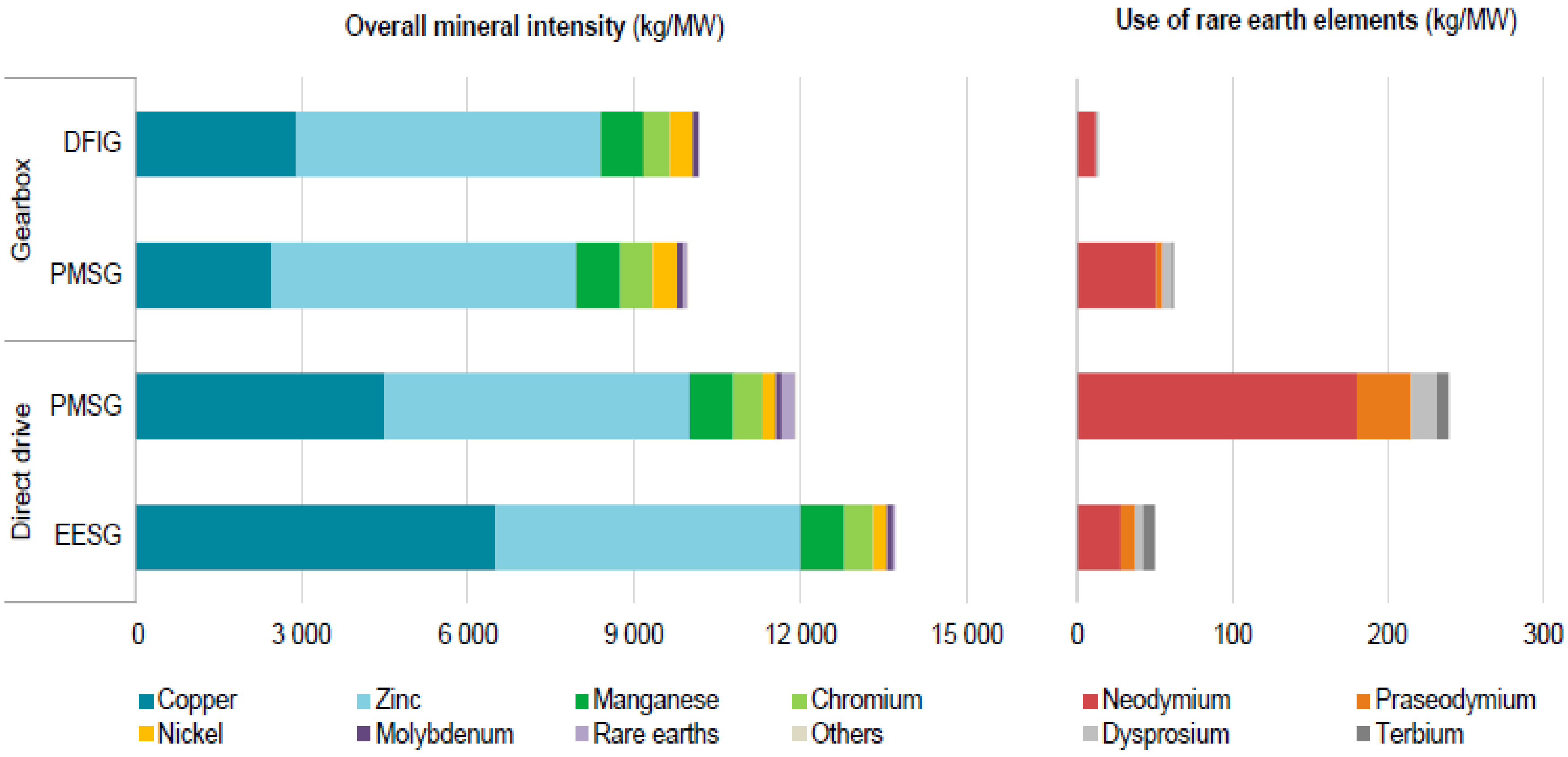


Notes: kg = kilogramme; MW = megawatt. Steel and aluminium not included. See Chapter 1 and Annex for details on the assumptions and methodologies.

(Source: The Role of Critical Minerals in Clean Energy Transitions IEA)

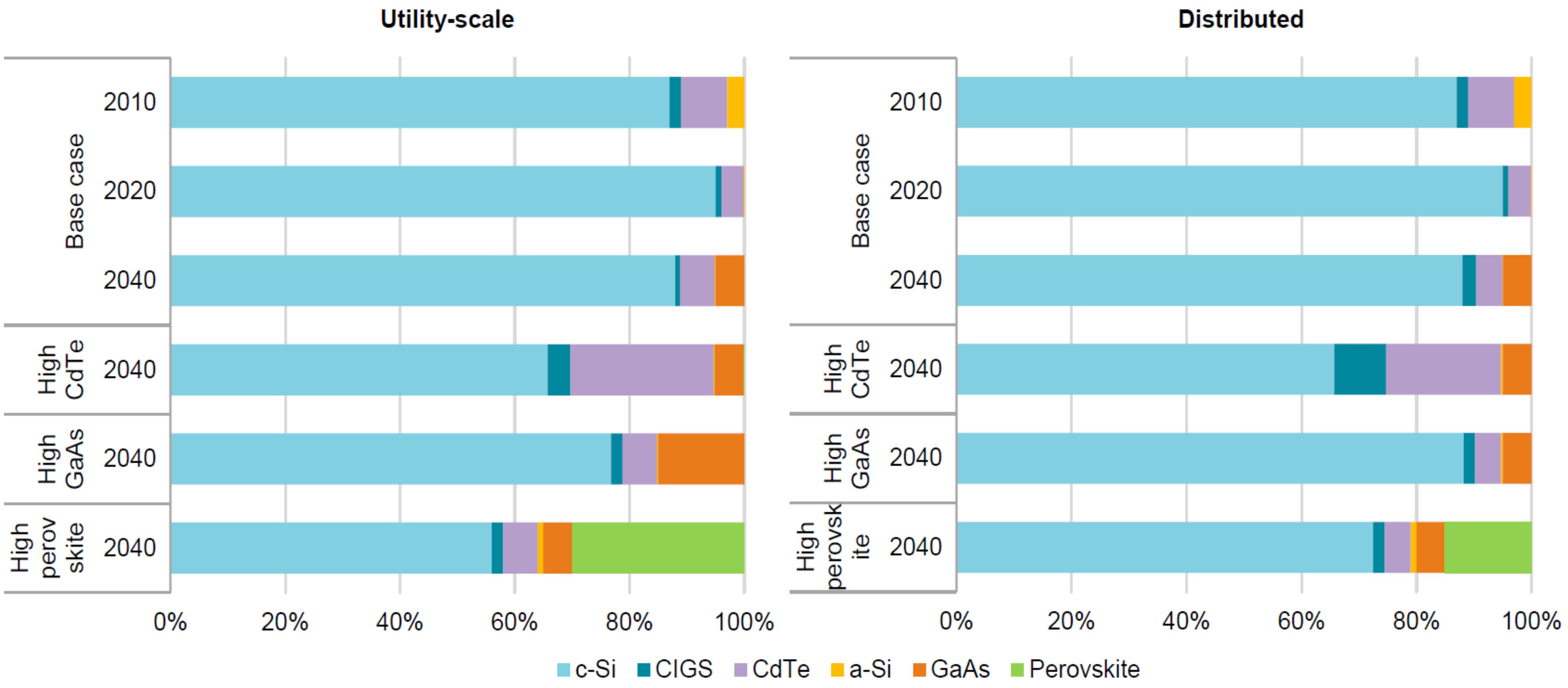


Projected wind turbine global market share (Source: IEA)
(Copyright IEA)



Metal content of different wind turbine units (Note: metal content intensity numbers are based on the onshore installation environment. More copper is needed in offshore applications due to much longer cabling requirements)

(Source: IEA) (Copyright IEA)



Notes: c-Si = crystalline silicon; CIGS = copper indium gallium diselenide; CdTe = cadmium telluride; a-Si = amorphous silicon; GaAs = gallium arsenide.

Share of annual capacity additions by PV technology under different technology evolution scenarios

(Source: IEA 2021) (Copyright: IEA)

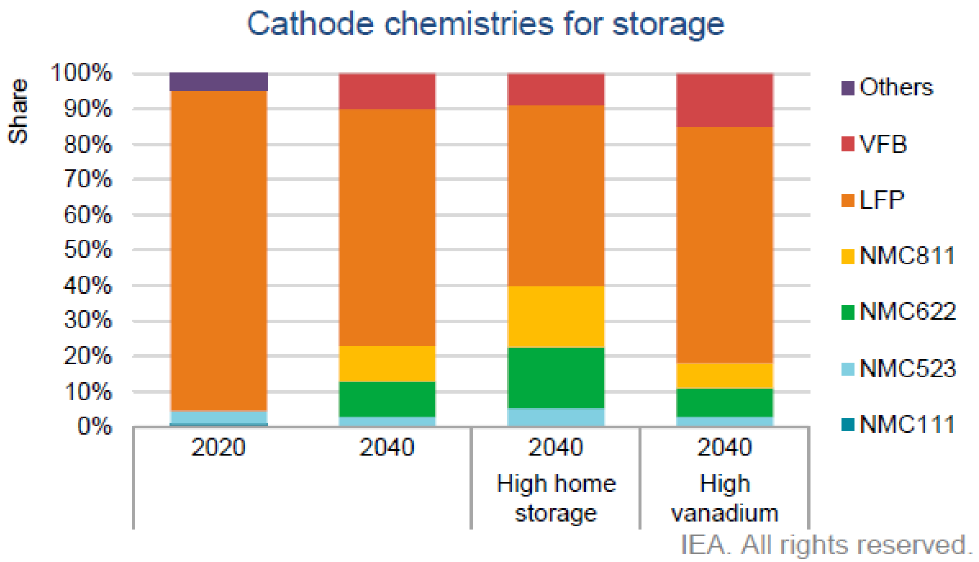
EVs use around six times more minerals than conventional vehicles

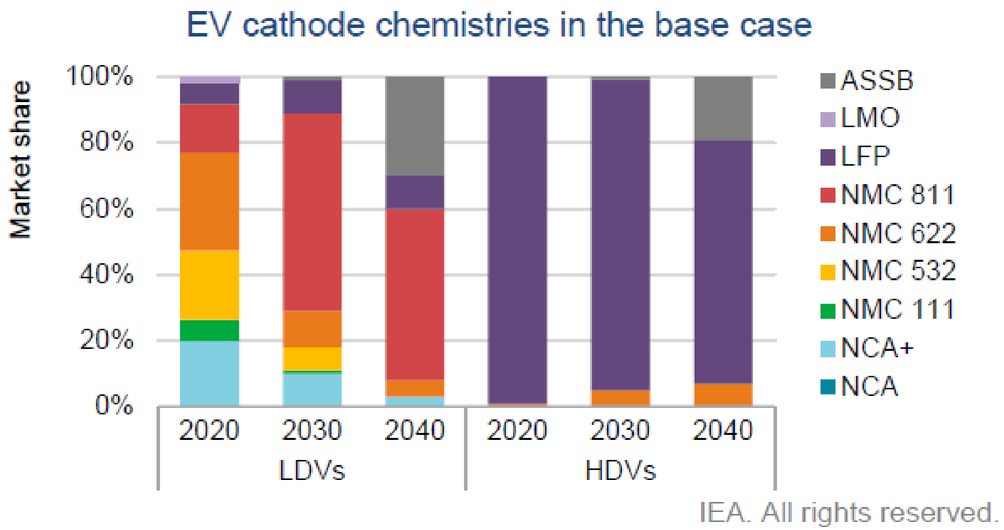
Typical use of minerals in an internal combustion engine vehicle and a battery electric vehicle

Notes: For this figure, the EV motor is a permanent-magnet synchronous motor (neodymium iron boron [NdFeB]); the battery is 75 kilowatt hours (kWh) with graphite anodes.

Sources: Argonne National Laboratory (2020b, 2020a); Ballinger et al. (2019); Fishman et al. (2018b); Nordelöf et al. (2019); Watari et al. (2019).

(Source: The Role of Critical Minerals in Clean Energy Transitions IEA)





Notes: LDVs = light-duty vehicles (passenger cars and vans, light commercial vehicles, and 2- and 3-wheelers); HDVs = heavy-duty vehicles (trucks and buses).
Sources: IEA analysis complemented by Adamas Intelligence (2021a) and EV-Volumes (2021).

(Source: The Role of Critical Minerals in Clean Energy Transitions IEA)

NUMBER OF TECHNOLOGY UNITS

Renewable Technology Unit or Service	Number (number)	Estimated total battery capacity (TW)	Estimated extra annual power output required (TWh)	Estimated extra total installed power generation capacity (MW)
Electric Vehicles				
Bus + Medium Delivery Truck	29 002 253	5,98		
Light Truck/Van + Light-Duty Vehicle	601 327 324	25,32		
Passenger Car	695 160 429	32,53		
Motorcycle	62 109 261	1,34		
Hydrogen Fuel Cells				
HCV Class 8 Truck	28 929 348		1 949,0	
Rail Freight Locomotive	104 894		277,0	
Maritime Small Vessel (100 GT to 499 GT)	53 854		7,7	
Maritime Medium Vessel (500 GT to 24 999 GT)	44 696		131,7	
Maritime Large Vessel (25 000 GT to 59 999 GT)	12 000		255,7	
Maritime Very Large Vessel (>60 000 GT)	6 307		379,7	
Nuclear Power (Annual Production)			2 701,4	431 800
Hydroelectricity (Annual Production)			4 809,6	817 720
Geothermal Power (Annual Production)			266,7	41 867
Wind Turbines				
3MW Onshore wind turbines (70% share)	1 474 452		9 660,3	4 423 357
3MW Offshore wind turbines (30% share)	631 908		4 140,1	1 895 725
Solar Panels				
450 MW solar panels	27 650 301 276		12 420,3	12 442 636
Stationary power storage buffer				
4 weeks capacity for wind & solar PV only		2 017,0		
	Total	**2 082,1**		

- Electric Vehicles
- EV Batteries
- Hydrogen fuel cells
- Wind Turbines
- Solar Panels
- Power Storage Batteries

METAL NEEDED

Metal	Metal content in Geothermal power plant construction (tonnes)	Metal content in Electric Vehicle construction (tonnes)	Metal content in hydrogen fuel cell construction (tonnes)	Metal content in EV batteries (tonnes)	Metal content in stationary storage batteries (tonnes)
Steel		1 683 027 473			
Aluminium		150 427 661			
Copper		74 081 275		63 251 302	4 369 586 145
Zinc				936 769	
Magnesium Metal		499 536			
Manganese				9 317 586	213 641 893
Chromium	2 701 097				
Nickel	5 016 323			70 999 668	861 628 338
Lithium				20 291 293	923 858 999
Cobalt				9 713 426	208 683 564
Graphite				155 212 457	8 818 427 799
Molybdenum	434 105				
Silicon (Metallurgical)					
Silver					
Platinum			2 682		
Vandium					681 865 986
Zirkonium				2 614 126	
Rare Earth Metals					
Neodymium		471 784			
Germanium				4 163 162	
Lanthanum				5 970 738	
Praseodymium		152 636			
Dysprosium		152 636			
Terbium					
Hafnium					
Yttrium					

METAL PRODUCED IN 2019

Metal	Element	Total metal required produce one generation of technology units to phase out fossil fuels (tonnes)	Global Metal Production 2019 (tonnes)	Years to produce metal at 2019 rates of production (years)
Copper	Cu	4 575 523 674	24 200 000	189,1
Nickel	Ni	940 578 114	2 350 142	400,2
Lithium	Li	944 150 293	95 170 *	9920,7
Cobalt	Co	218 396 990	126 019	1733,0
Graphite (natural flake)	C	8 973 640 257	1 156 300 ♦	3287,9
Graphite (synthetic)	C		1 573 000 ♦	-
Silicon (Metallurgical)	Si	49 571 460	8 410 000	5,9
Vandium	V	681 865 986	96 021 *	7101,2
<u>Rare Earth Metals</u>	-			
Neodymium	Nd	965 183	23 900	40,4
Germanium	Ge	4 163 162	143	29113,0
Lanthanum	La	5 970 738	35 800	166,8
Praseodymium	Pr	235 387	7 500	31,4
Dysprosium	Dy	196 207	1 000	196,2
Terbium	Tb	16 771	280	59,9

* Estimated from mining production. All other values are refining production values.

♦ Natural flake graphite and synthetic graphite was combined to estimate total production

(Source: BGR 2021, USGS, Friedrichs 2022)

METAL IN 2022 GLOBAL RESERVES

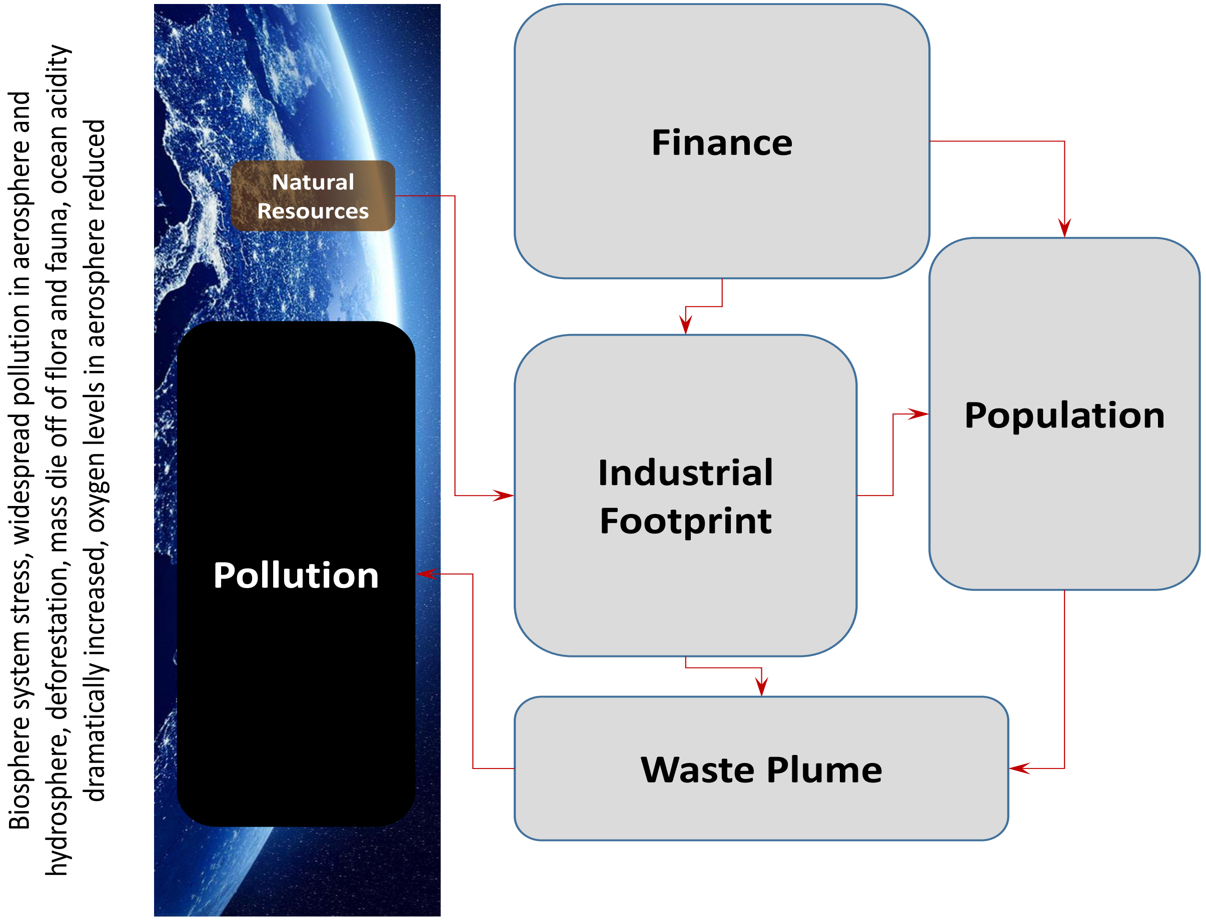
Metal Source: USGS	Total metal required produce one generation of technology units to phase out fossil fuels (tonnes)	Reported Global Reserves 2022 (tonnes)	Global Reseves as a proportion of metals required to phase out fossil fuels (%)	Number of generations of technology units that can be produced from global reserves
Copper	4 575 523 674	880 000 000	19,23 %	
Zinc	35 703 918	250 000 000		7,0
Manganese	227 889 504	1 500 000 000		6,6
Nickel	940 578 114	95 000 000	10,10 %	
Lithium	944 150 293	22 000 000	2,33 %	
Cobalt	218 396 990	7 600 000	3,48 %	
Graphite (natural flake)	8 973 640 257	320 000 000	3,57 %	
Silicon (Metallurgical)	49 571 460	-		
Silver	145 579	530 000		3,6
Vandium	681 865 986	24 000 000	3,52 %	
Zirkonium	2 614 126	70 000 000		26,8

- For every 1000 deposits discovered, 1 or 2 become mines
- Time taken to develop a discovered deposit to a mine 20 years
- For every 10 producing mines, 2 or 3 will lose money and shut down

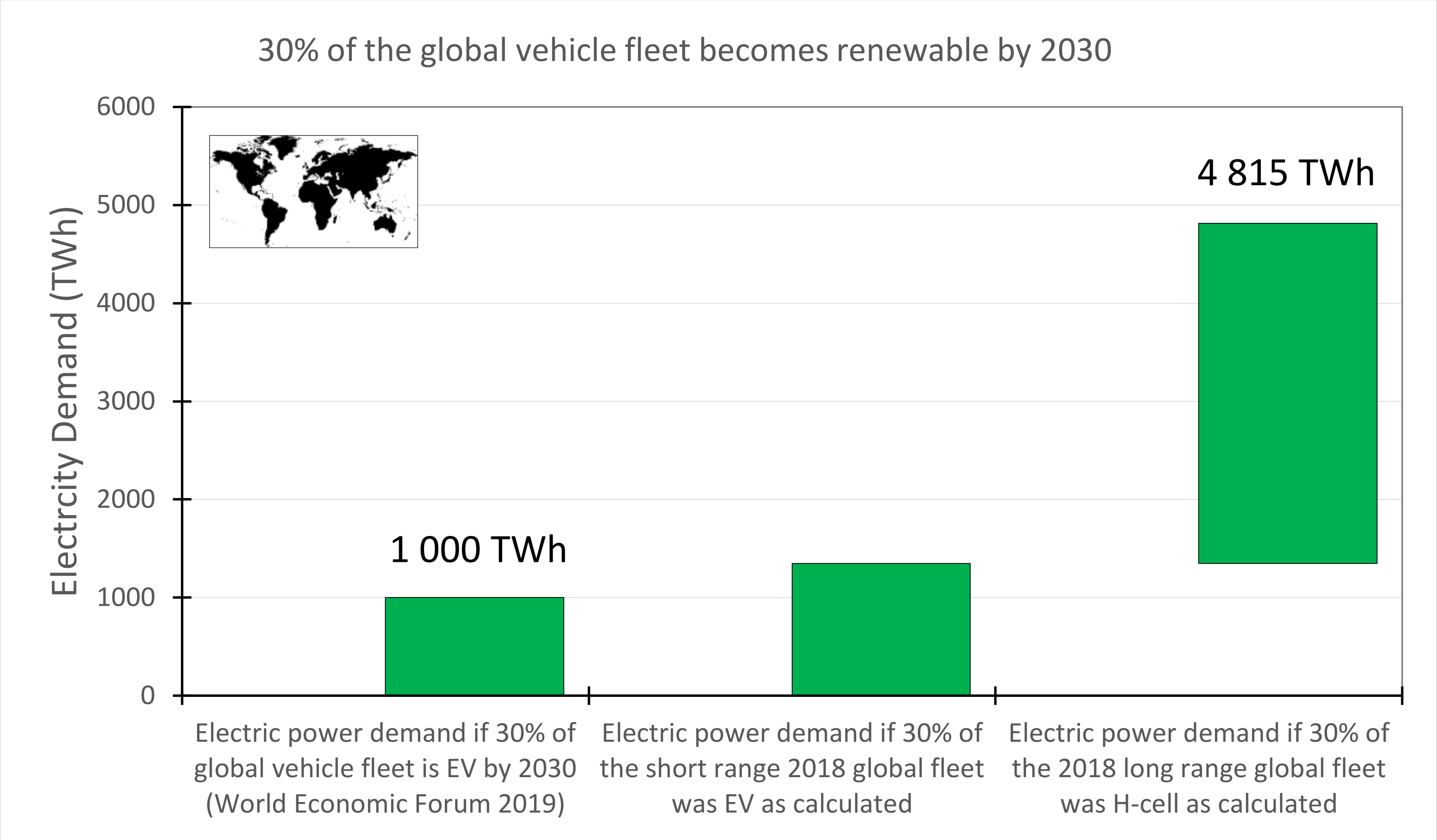
STEWARDSHIP OF PLANET EARTH

- An industrial ecosystem of unprecedented size and complexity, that took more than a century to build with the support of the highest calorifically dense source of cheap energy the world has ever known (oil) in abundant quantities, with easily available credit, and unlimited mineral resources

- We now seek to build an even more complex system with very expensive energy, a fragile finance system saturated in debt, not enough minerals, with an unprecedented number of human population, embedded in a deteriorating environment.



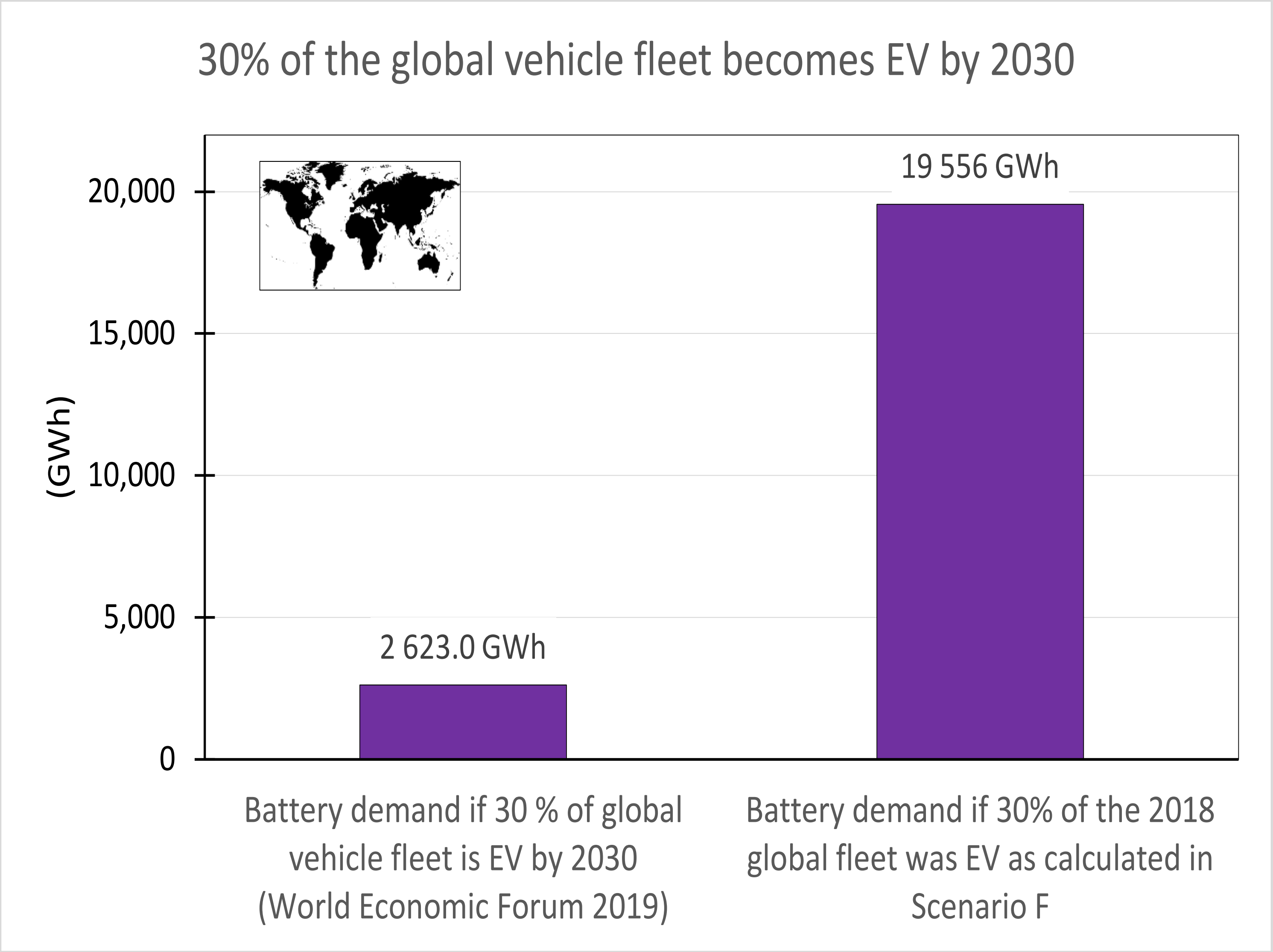
CURRENT THINKING UNDERESTIMATES THE SCALES



Comparison: current projections of required electric power demand to charge EV batteries vs. outcomes of Scenario F

(World Map Image by Clker-Free-Vector-Images from Pixabay)

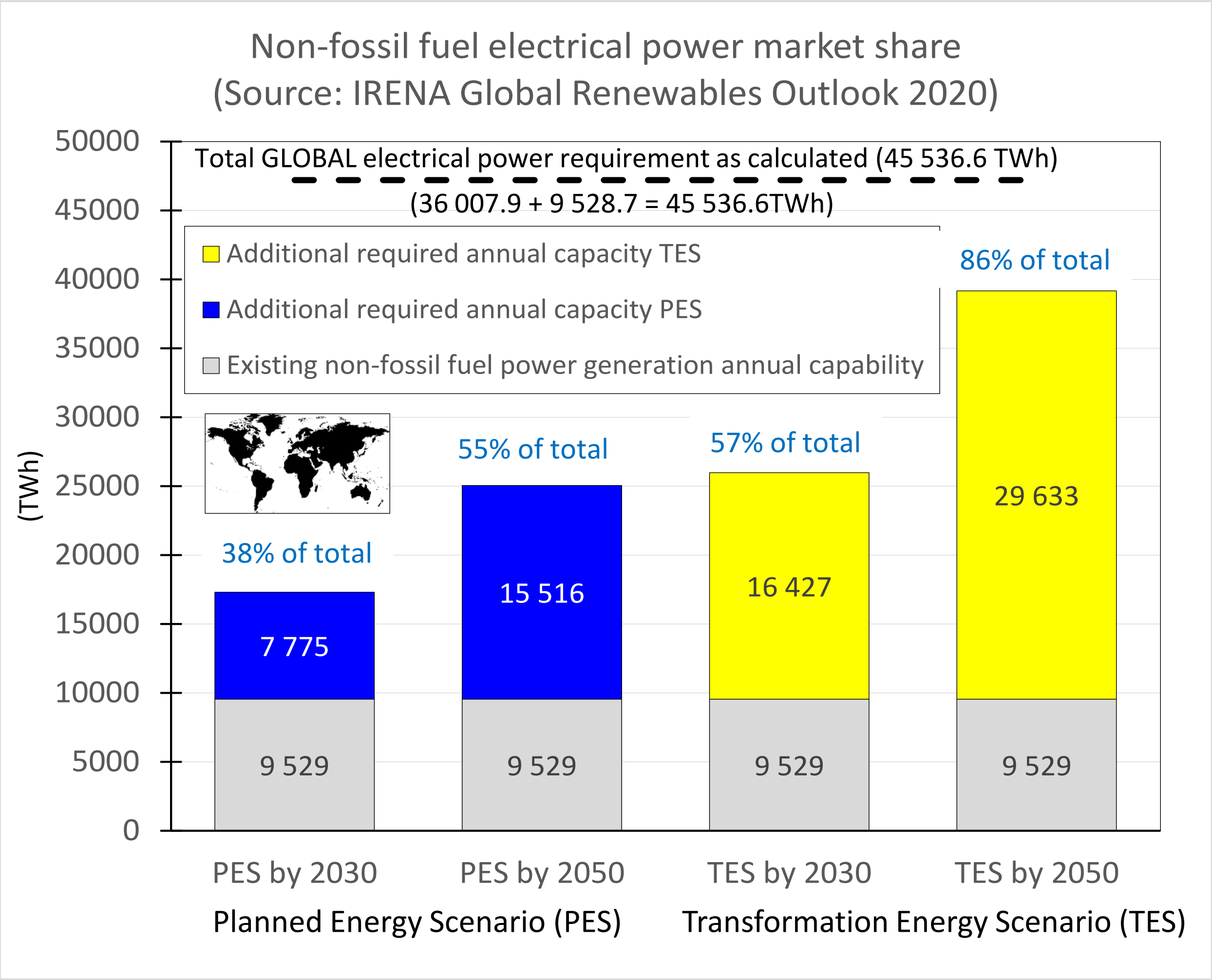
CURRENT THINKING UNDERESTIMATES THE SCALES



Comparison of current projections of required battery to be manufactured demand vs. outcomes of Scenario F

(World Map Image by Clker-Free-Vector-Images from Pixabay)

ESTIMATED ADDITIONAL ANNUAL GLOBAL NON-FOSSIL FUEL ELECTRICAL POWER CAPABILITY REQUIRED TO MEET PES AND TES SUSTAINABILITY TARGETS (SOURCE: IRENA GLOBAL RENEWABLES OUTLOOK 2020)



- **The Planned Energy Scenario (PES).** This is the primary reference case for the IRENA study, providing a prediction outcome based on current energy plans and other planned targets and policies (as of 2019).

- **The Transforming Energy Scenario (TES).** An energy transformation pathway based largely on renewable energy sources and steadily improved energy efficiency.

NEW AVERAGE SIZED POWER STATIONS

Non-fossil fuel generation System	Global PES non-fossil fuel power generation by 2030 (number of new average plants)	Global PES non-fossil fuel power generation by 2050 (number of new average plants)	Global TES non-fossil fuel power generation by 2030 (number of new average plants)	Global TES non-fossil fuel power generation by 2050 (number of new average plants)
Nuclear	80	118	120	181
Hydroelectric	1 379	2 032	2 068	3 120
Wind Onshore	45 185	66 588	67 777	102 260
Wind Offshore	19 365	28 538	29 047	43 826
Solar PV	142 846	210 510	214 269	323 283
Solar Thermal	6 813	10 041	10 220	15 419
Geothermal	168	248	252	380
Biowaste to energy	6 857	10 105	10 285	15 518
Total New Stations	222 692	328 178	334 039	503 988
Global annual electrical power generation capacity = 45 536.6 TWh	38% of global electrical power generation = 17 303.21 TWh	55% of global electrical power generation = 25 045.1 TWh	57% of global electrical power generation = 25 955.9 TWh	86% of global electrical power generation = 39 161.5 TWh
Additional new annual power capacity required	7 775.2 (TWh)	15 516.4 (TWh)	16 427.2 (TWh)	29 632.8 (TWh)

CONCLUSIONS

- Additional non-fossil fuel electrical power annual capacity is 37 670.6 TWh
- The same non-fossil fuel energy mix of 2018 translates into 221 594 new power plants
    - *To put this in context, the total power plant fleet in 2018 (all types including fossil fuel plants) was only 46 423 stations*
- Electrical power generated from solar and wind sources are highly intermittent, both across 24-hour cycle and in seasonal context.
    - *A power storage buffer is required if these power generation systems are to be used on a large scale.*
- A conservative estimate is a 4-week power capacity buffer for solar and wind
    - *From Scenario F, the power storage buffer capacity for the global electrical power system would be 573.4 TWh*
    - *The number of 100 MW stations would be 5.7 million, and the mass of lithium ion batteries would be 2.5 billion tonnes*
- The total mass of lithium ion batteries required to phase out fossil fuels is 2.78 billion tonnes

CONCLUSIONS

- Current thinking has seriously underestimated the scale of the task ahead
- Nuclear is vital to keep industry going but can't be scaled up to be the only energy source
- Biofuels may be the only way to power aviation and plastics. It cannot be scaled up to replace petroleum.
- Battery chemistries other than lithium-ion should/will be developed, each with different mineral resources required
- There is a projected mineral shortage to supply raw materials for battery manufacture
  - *2019 production rates are not even close to being appropriate*
  - *2022 mineral reserves are also not large enough to deliver the needed volumes*
- Metals of all kinds are about to become much more valuable
  - *Evolution of the industrial ecosystem and its market is likely*
- There is a coming Renaissance for the exploration for and mining of minerals

AITÄH, KIITOS
&
THANK YOU

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