Challenges and Bottlenecks for the Green Transition

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It was possible that at some point in the near future, the European captains of industry would turn to the European geological surveys and ask:

WHY WAS THIS WORK DONE?

There was no credible feasibility plan for fundamental industrial reform that recognized the current physical industrial requirements to phase out fossil fuels **– anywhere in the world**

There was a clear lack of **hard numbers** in all publicly available strategic planning for the future

There was very little discussion about current industrial and economic **dependency on fossil fuels energy**

There was no discussion or visible situation awareness of the quantity or type of **minerals** to phase out fossil fuels

The whole commodity sector was **considered to be a market phenomenon**, not a series of finite non-renewable natural resources, that had engineering bottlenecks in extraction

Assumptions were being made regarding the mining, smelting & recycling industrial capabilities to **deliver the required volumes of metals,** that were not appropriate

“why did you not tell us of the mineral supply shortfall?”

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ALTHOUGH IT IS WELL KNOWN THAT
OIL, GAS AND COAL RESERVES ARE FINITE

THE GLOBAL STRATEGIC DECISION ADOPTED BY MOST NATIONS

TO PHASE OUT FOSSIL FUELS SYSTEMS AND REPLACE THEM WITH RENEWABLE ENERGY GENERATION SYSTEMS

21.2.2023

IS LARGELY DRIVEN BY

CO2 EMISSIONS & ASSOCIATED CLIMATE CHANGE

NOT BY

DWINDLING FINITE RESOURCES

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GLOBAL SYSTEM –
2018 scope

Oil

Gas

Coal

Self propelled vehicles in the transport grid

- Class 8 Trucks HCV
- Maritime Shipping
- Inter city Freight Rail
- Buses & Delivery Trucks
- Light Trucks & Commercial Vans
- Passenger Cars
- Motorcycles
- Aircraft

Hydrogen cells

12 835.4 TWh
(H_2 production)

Electric Vehicles EV

4 495.7 TWh
(battery charging)

65.19 TWh
of batteries

Possible biofuel

Petrochemical plastics manufacture

Bioplastics

Petrochemical fertilizer manufacture

No viable replacement

Electricity power generation

802.8 TWh (Oil)

6 182.8 TWh (Gas)

10 100.5 TWh (Coal)

Heating

2 816.0 TWh (Gas)

Steel Manufacture

51.4 TWh (Coal)

Possible hydrogen replacement solution

Increased power draw from the electricity generation grid 37 289.7 TWh (Accounting for 10% loss in transmission in power grid)

19 958.6 TWh

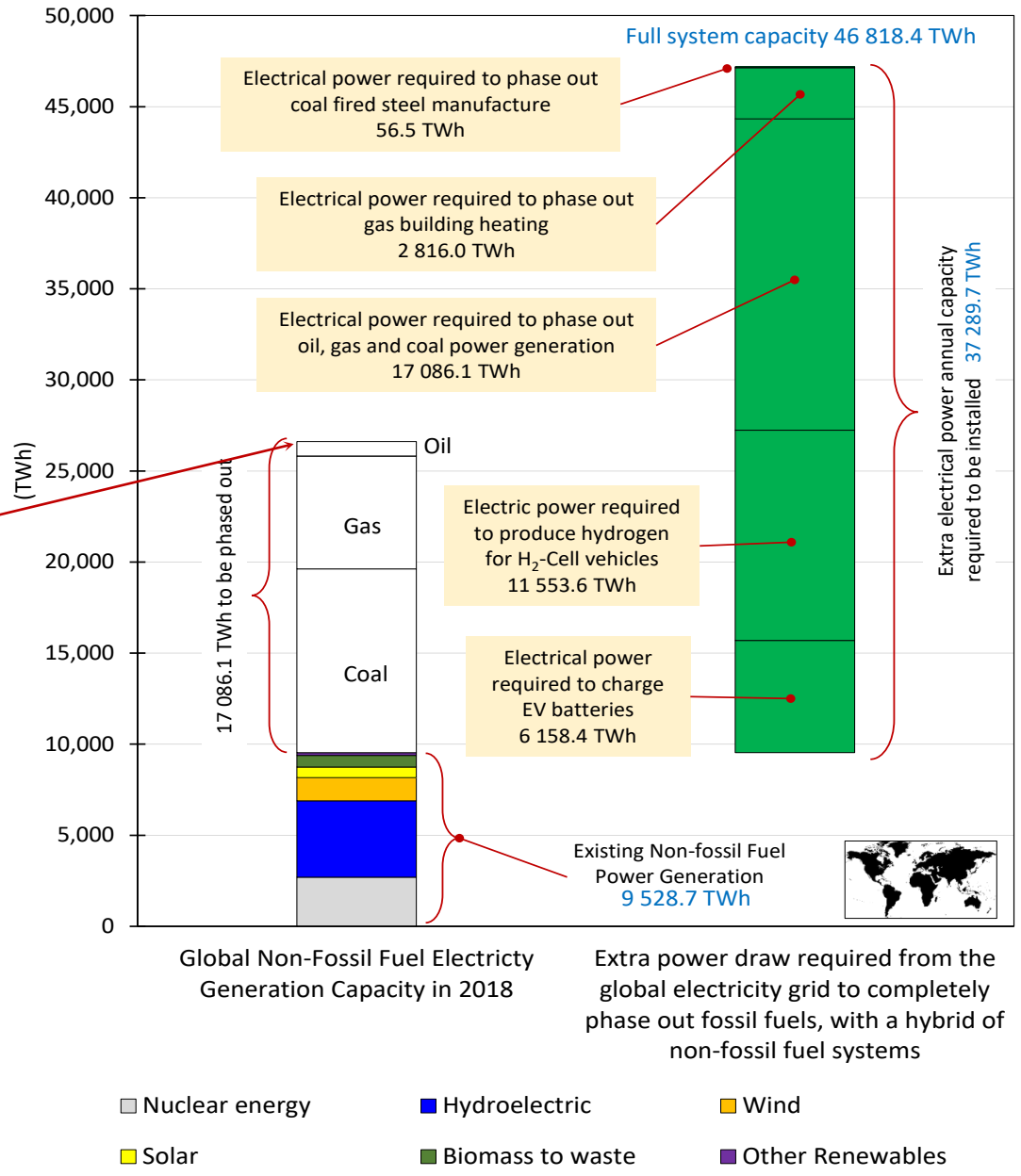
Non-fossil fuel electric power generation options

- Nuclear
- Hydroelectric
- Geothermal
- Biowaste
- Wind
- Solar PV
- Solar Thermal
- Tidal

Power Storage to manage intermittent supply fluctuations

4 weeks capacity for wind & solar only
2 192.9 TWh of batteries
17 million 100MW/129MW capacity storage stations

Total electrical power production in 2018 was **26 614 TWh**



We wish to construct an electrical system much larger than the existing power grid, using energy that is more expensive and not as effective as what we have now

This does not include coal and gas used directly by industry to generate heat for manufacture (more than half of coal)

GLOBAL SYSTEM III

Additional Annual Electrical Power Requires **37 289.7 TWh**

=

607 052 NEW Non-Fossil Fuel Power Stations

Power plant fleet in 2018 was **46 423** stations

HYDRO POWER 4 981.9 TWh 3 758 stations	**NUCLEAR POWER** 2 796.7 TWh 218 stations	
WIND POWER 14 293.1 TWh 175 933 stations	**SOLAR POWER** 14 293.1 TWh 407 922 stations	**Power storage buffer**
OTHER RENEWABLES Geothermal & Tidal 275.9 TWh 457 stations	**BIOWASTE TO ENERGY** 648.8 TWh 18 762 stations	

11 to 357 x amount of today

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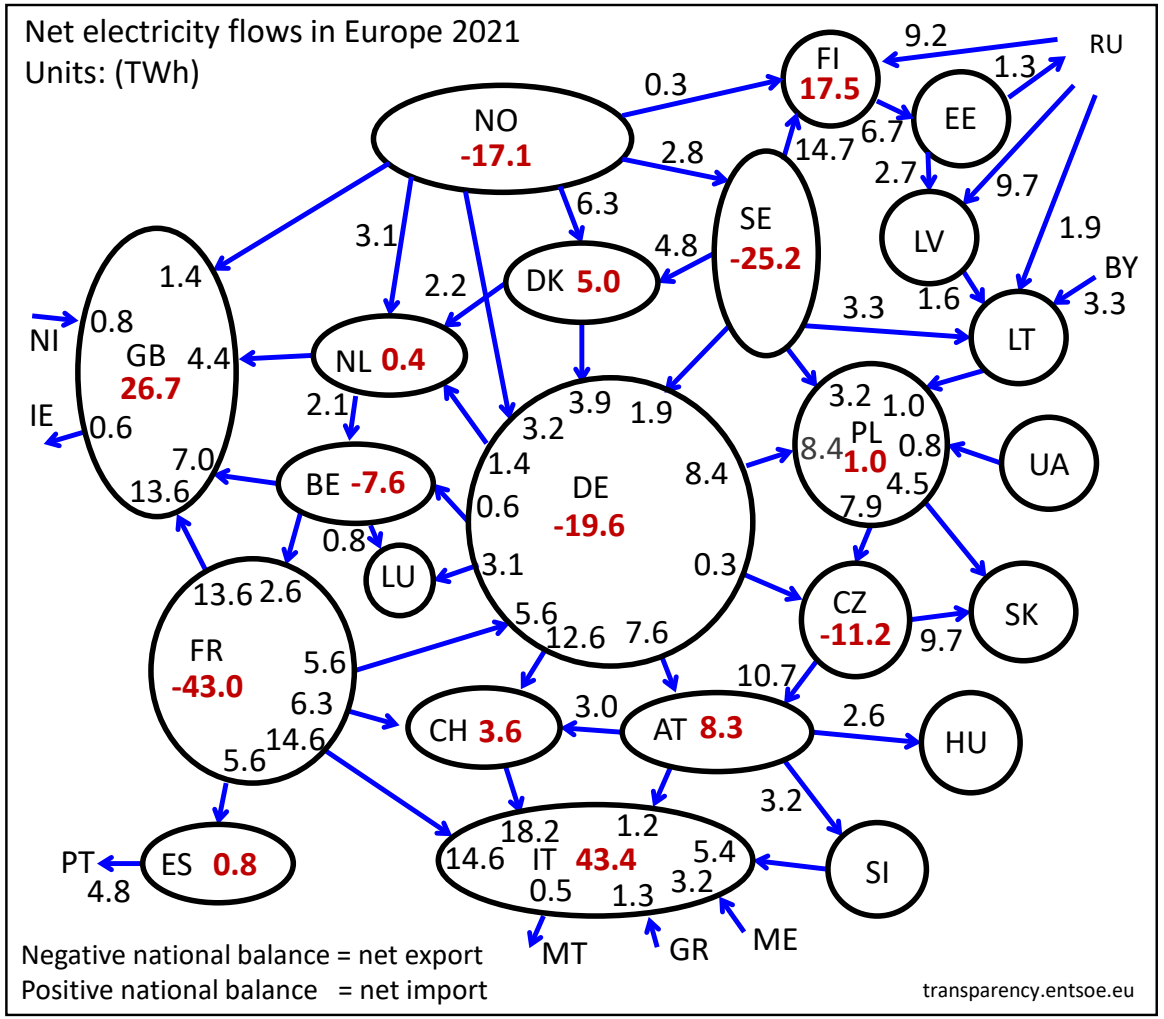
European net electricity exchanges in 2021



(Source: Entsoe)

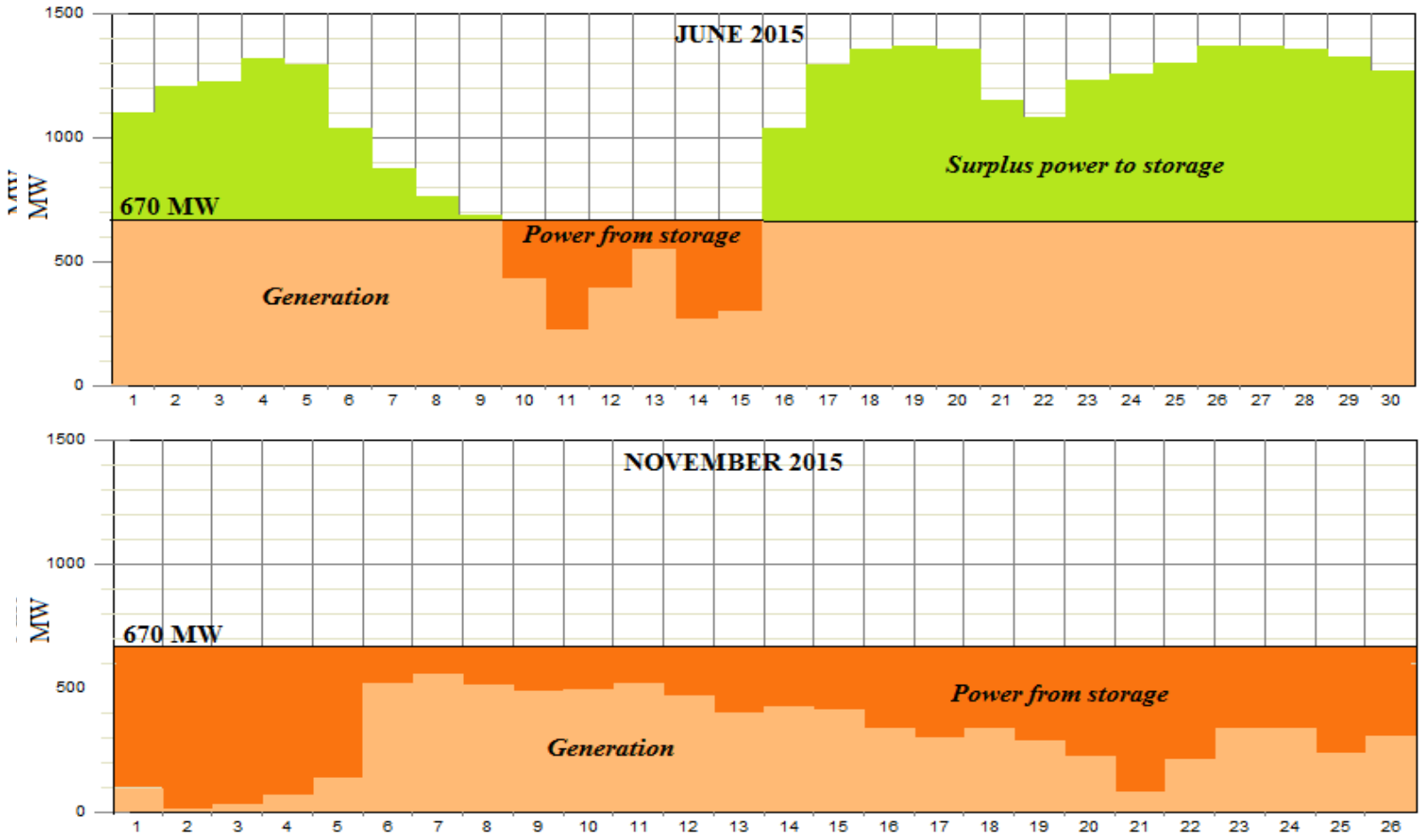
All networks are balanced and buffered by other external networks

Almost always using fossil fuel sourced power generation (gas in particular)

Most existing renewable power grids are balance with fossil fuels systems

We have never had to run a large renewable network in a self sufficient manner

Average daily CSP generation, June and November 2015



Spain

Power storage and release requirements that would have been needed to maintain a constant 670 MW of baseload generation during June and November (equivalent to 5.9 TWh per year)

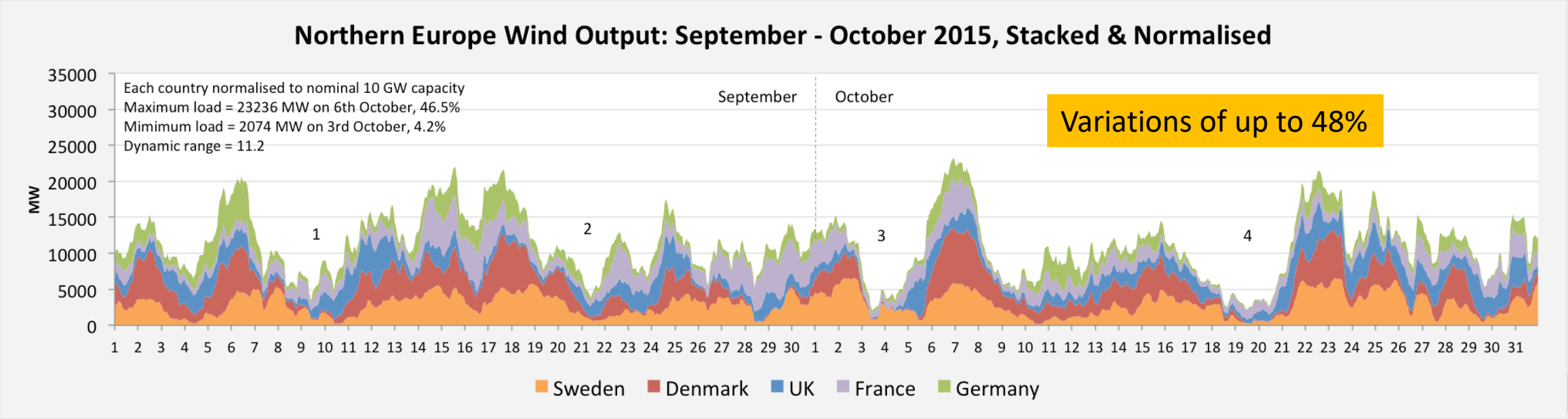
Approximately 260 GWh of storage would have been needed to cover the shortfalls in November alone. This is 16.2 days of buffer capacity, to be stored for approx. 4-6 months.

Mearns, E. (2015, Nov 17): A review of concentrated solar power (CSP) in Spain, Energy Matters blog, http://euanmearns.com/a-review-of-concentrated-solar-power-csp-in-spain/

Wind is highly variable

- Reliable capacity as a % of max capacity for wind 7-25% (UK Parliament 2014)
  - *Power production was so erratic it could not be predicted*
- Variations in power produced can last weeks and, in some cases, months
- In practical terms, global power generation operating hours in 2018 (Global Energy Observatory)
  - *Solar PV units produced 11.4% of the calendar year*
  - *Wind units produced 24.9% of the calendar year*

Highly variable of when power was produced



Number of technology units

Renewable Technology Unit or Service	Number (number)	Estimated total battery capacity (TWh)	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		7.75	
Maritime Medium Vessel (500 GT to 24 999 GT) ♣	44 696		131.73	
Maritime Large Vessel (25 000 GT to 59 999 GT) ♣	12 000		255.72	
Maritime Very Large Vessel (>60 000 GT) ♣	6 307		379.70	
Nuclear Power (Annual Production)			2 796.7	447 037
Hydroelectricity (Annual Production)			4 981.9	847 010
Geothermal Power (Annual Production)			275.9	43 320
Wind Turbines				
3MW Onshore wind turbines (70% share)	1 527 101		10 005.2	4 581 304
3MW Offshore wind turbines (30% share)	654 472		4 287.9	1 963 416
Solar Panels				
450 Watt commerical grade solar panels	28 640 112 291		12 864.9	12 888 051
Stationary power storage buffer				
28 days capacity for wind & solar PV only		2 192.92		
	Total	**2 258.1**		

♣ Numbers drawn from Michaux 2023, and Michaux 2021

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

Number of technology units

WIND TURBINES | SOLAR PANELS | POWER STORAGE BATTERIES

All of these tech units are to replace a fossil fuel technology system

They harvest renewable energy like wind and sunshine. The units themselves are not renewable as they wear out (20 years). **They are replaceable.**

Each one is **manufactured from metals.**

As this system has yet to be constructed, it **cannot be recycled.**

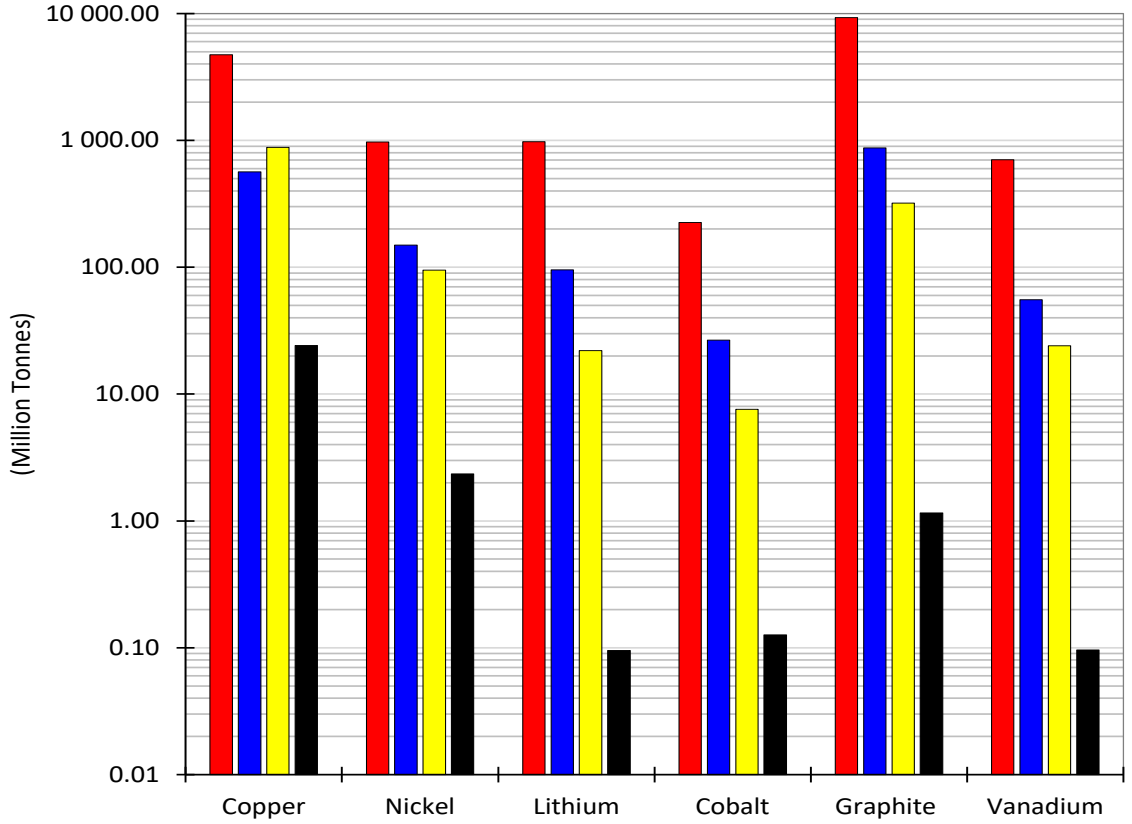
The first generation at least will be sourced from the **mining of minerals.**

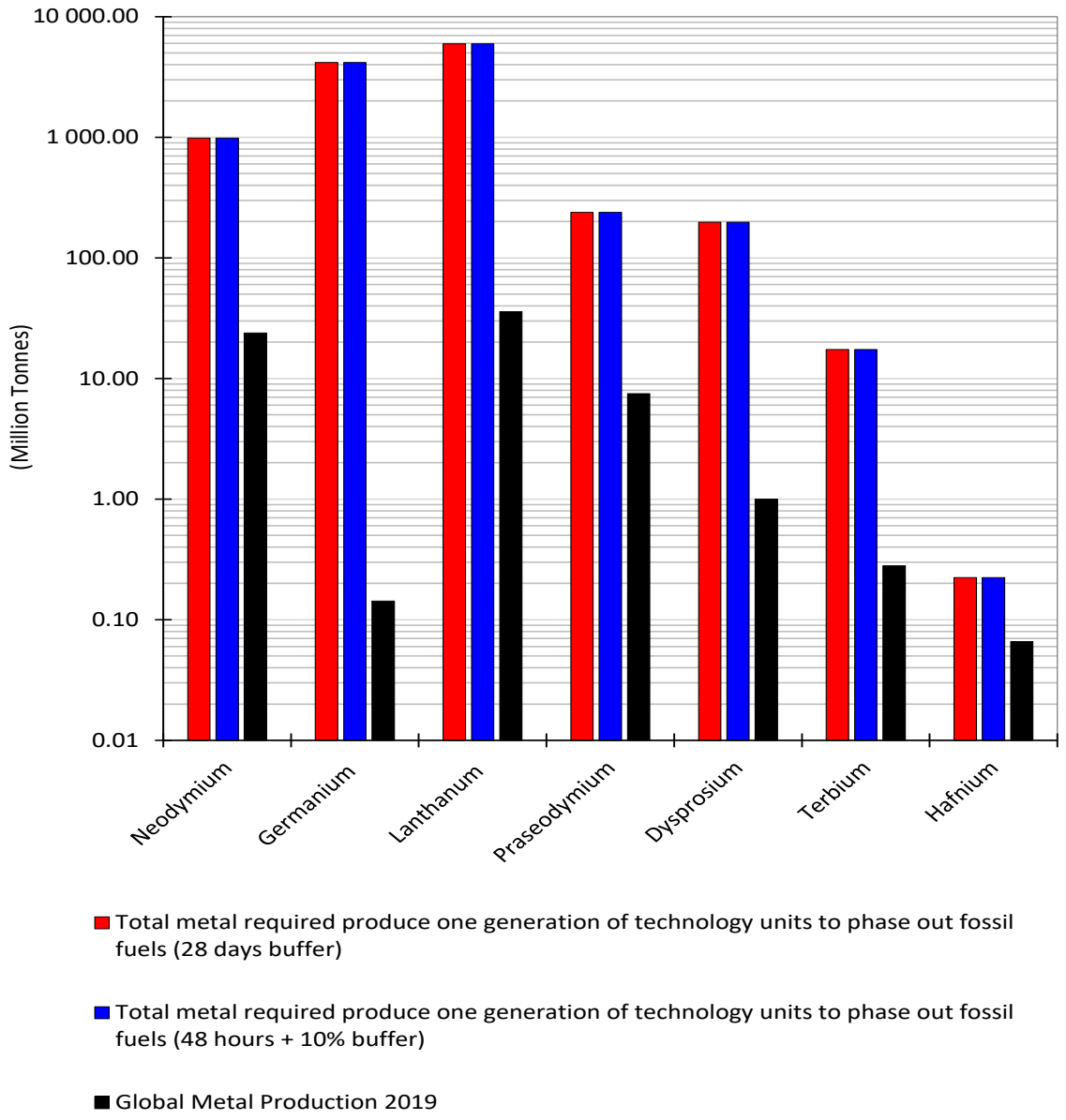
Minerals are the new oil

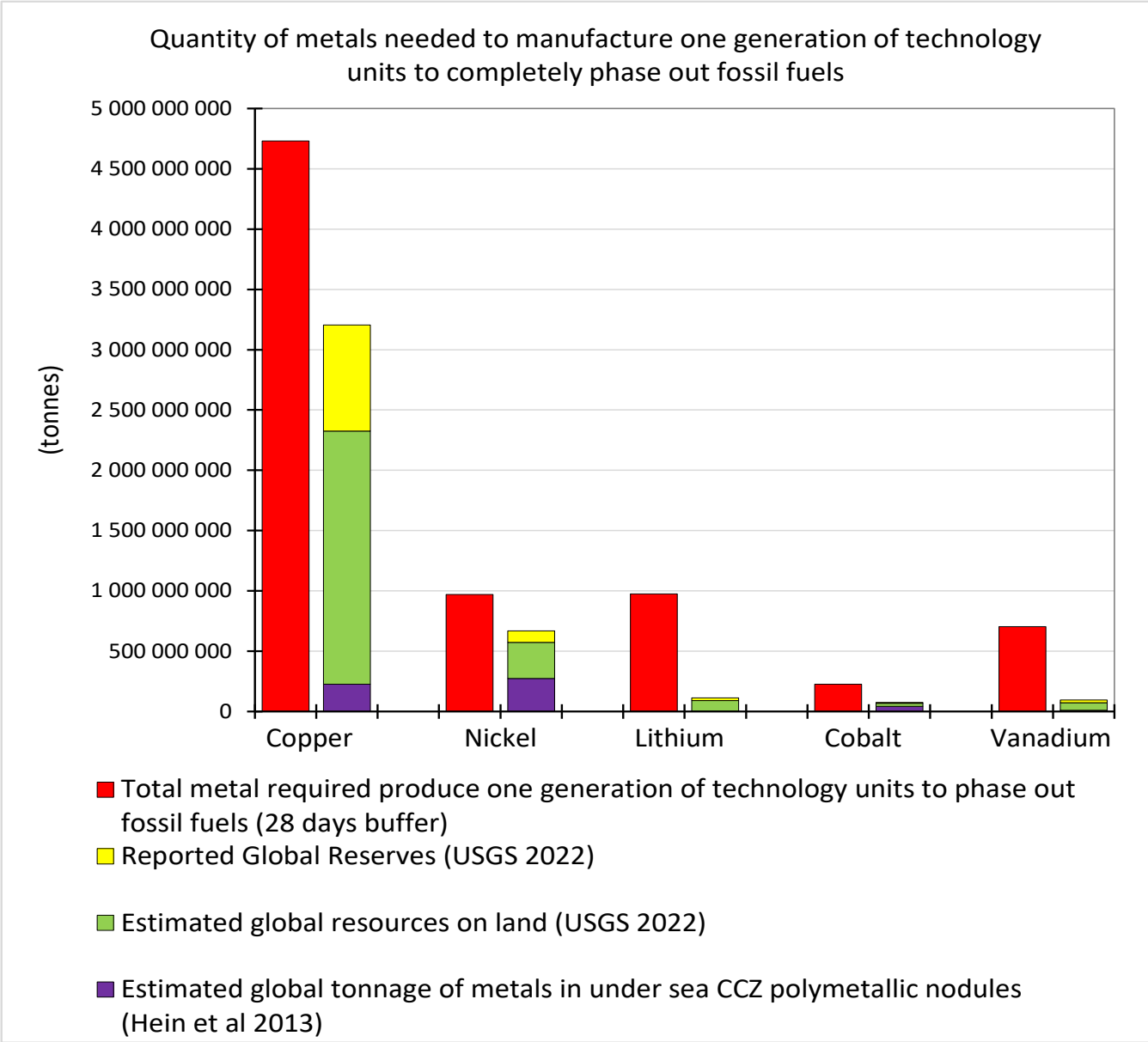

Mining production & existing reserves are not enough to manufacture the first generation of renewable technology

Remember,
this is for just the first generation of units.

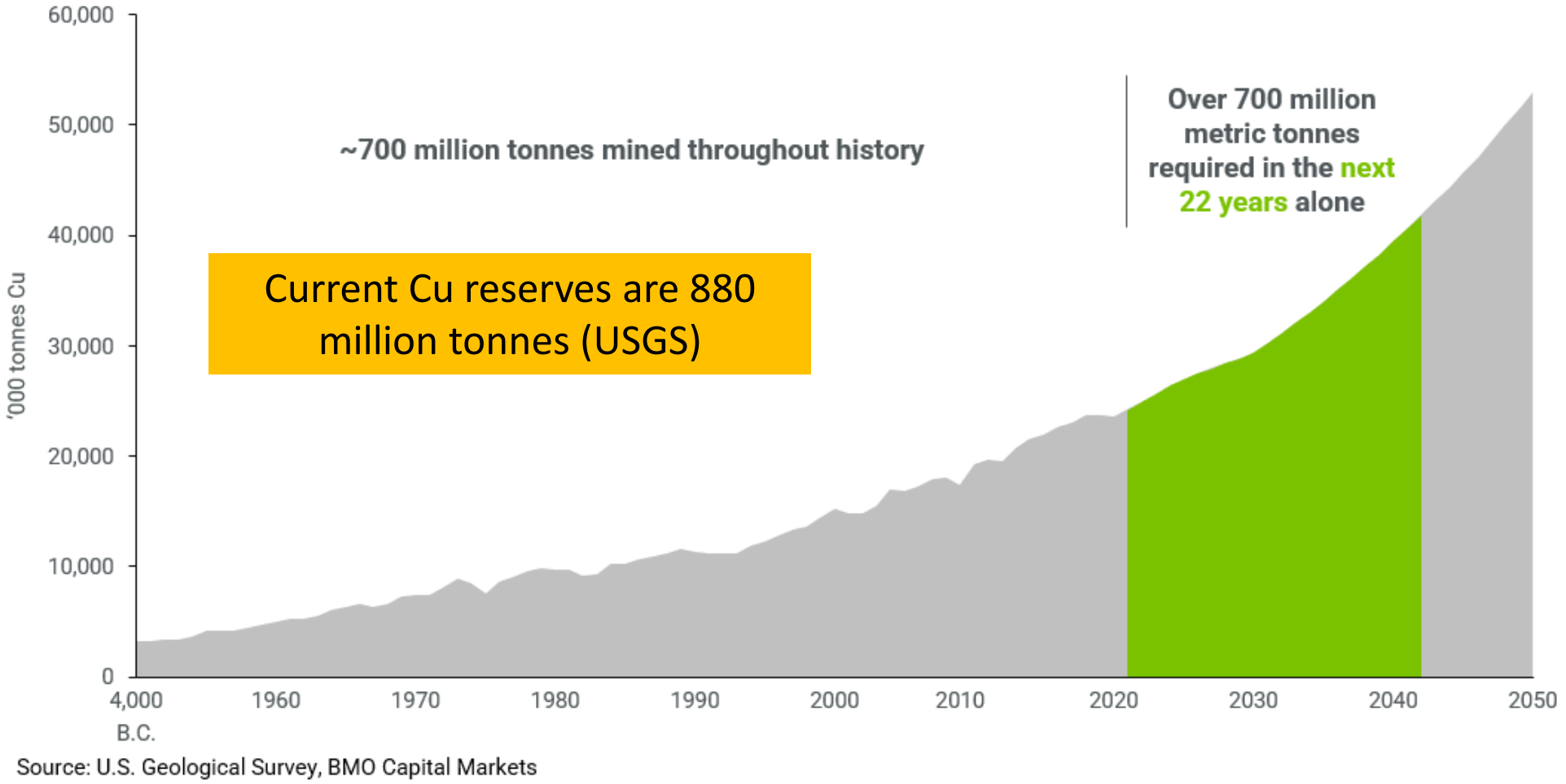
They will wear out in **10 to 25 years**, after which they will need to be replaced




Quantity of REE metals needed to manufacture one generation of technology units to completely phase out fossil fuels
10 000.00
1 000.00
100.00
10.00
1.00
0.10
0.01
(Million Tonnes)
Neodymium
Germanium
Lanthanum
Praseodymium
Dysprosium
Terbium
Hafnium
Total metal required produce one generation of technology units to phase out fossil fuels (28 days buffer)
Total metal required produce one generation of technology units to phase out fossil fuels (48 hours + 10% buffer)
Global Metal Production 2019


Quantity of metals needed to manufacture one generation of technology units to completely phase out fossil fuels
(tonnes)
5 000 000 000
4 500 000 000
4 000 000 000
3 500 000 000
3 000 000 000
2 500 000 000
2 000 000 000
1 500 000 000
1 000 000 000
500 000 000
0
Copper
Nickel
Lithium
Cobalt
Vanadium
Total metal required produce one generation of technology units to phase out fossil fuels (28 days buffer)
Reported Global Reserves (USGS 2022)
Estimated global resources on land (USGS 2022)
Estimated global tonnage of metals in under sea CCZ polymetallic nodules (Hein et al 2013)

Economic growth and resource supply



Current Cu reserves are 880 million tonnes (USGS)

Source: U.S. Geological Survey, BMO Capital Markets

We want 4.73 billion tonnes of Cu, just to manufacture one generation of renewable technology (6.75 x historical Cu mining)

DISCUSSION

WHAT DOES IT MEAN?

The current plans for ‘after oil’ are **simply not good enough** on multiple levels

- Complexity of supply chain needed
- Energy requirements of manufacture
- Logistical capability of existing fossil fuels

Current thinking has **seriously underestimated** the scale of the task ahead

Battery chemistries other than lithium-ion should/will be developed, each with **different mineral resources required**

The ERoEI ratio for renewable energy systems is much lower than fossil fuel energy systems. Renewable energy technology **may not be strong enough to replace** fossil fuels

Hopes for future technology breakthroughs to ‘somehow’ deliver more commodity resources do not seem to consider the nature of **what mineral resources that are left**

The current ecosystem has no concept of its **dependency on minerals** and does not consider long term concepts like continuous growth in production against finite resources

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IN CONCLUSION

THIS REPORT SUGGESTS

Replacing the existing fossil fuel powered system (oil, gas, and coal), using renewable technologies, such as solar panels or wind turbines, **will not be possible for the entire global human population.**

There is simply just **not enough time, nor resources** to do this by the current target set by the world's most influential nations.

What may be required, therefore, is **a significant reduction of societal demand** for all resources, of all kinds.

This implies a very different social contract and **a radically different system of governance** to what is in place today.

Inevitably, this leads to the conclusion that the existing renewable energy sectors and the EV technology systems are **merely steppingstones to something else**, rather than the final solution.

It is recommended that some thought be given to this and **what that something else might be.**

Ecological reality and biophysical limitations will reassert itself

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The whole system is about to evolve, we in response need a better plan

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Kiitos & Thank you