QUANTITY OF METALS TO MANUFACTURE ONE GENERATION OF RENEWABLE TECHNOLOGY TO COMPLETELY REPLACE FOSSIL FUELS

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SUMMARY

Physical Tasks done industrially by fossil fuels

↓

Determine the true scope of useful work done

↓

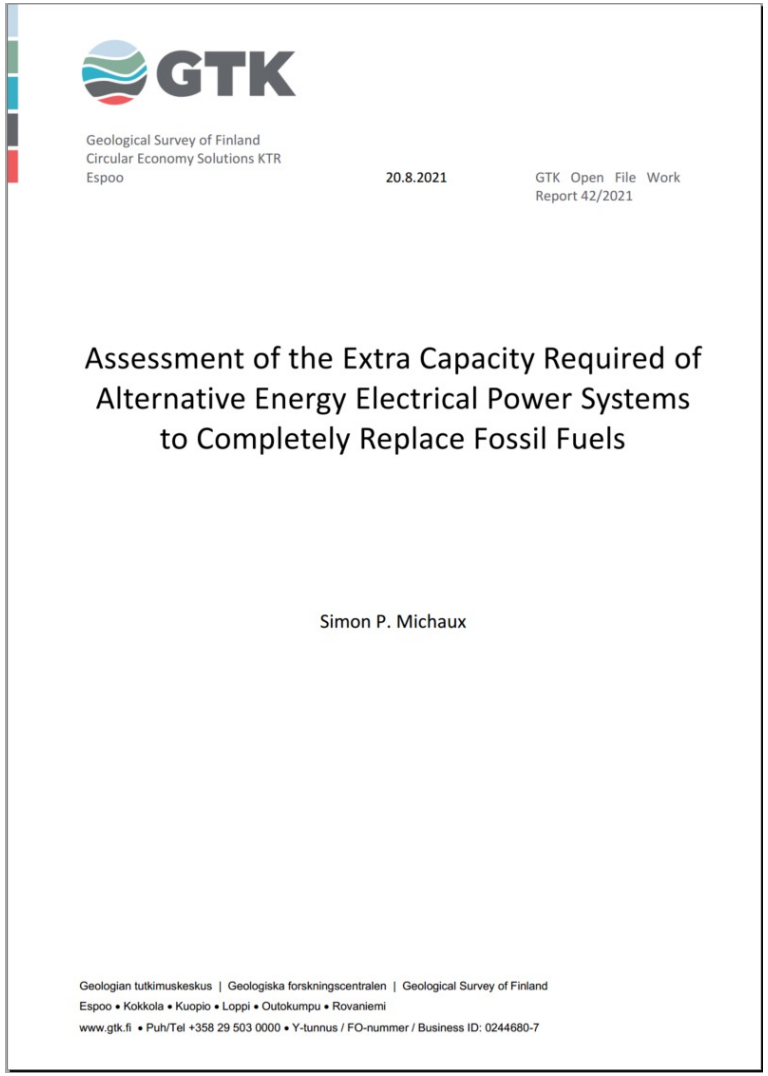
Assemble non-fossil fuel systems that could do the same useful work

↓

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

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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

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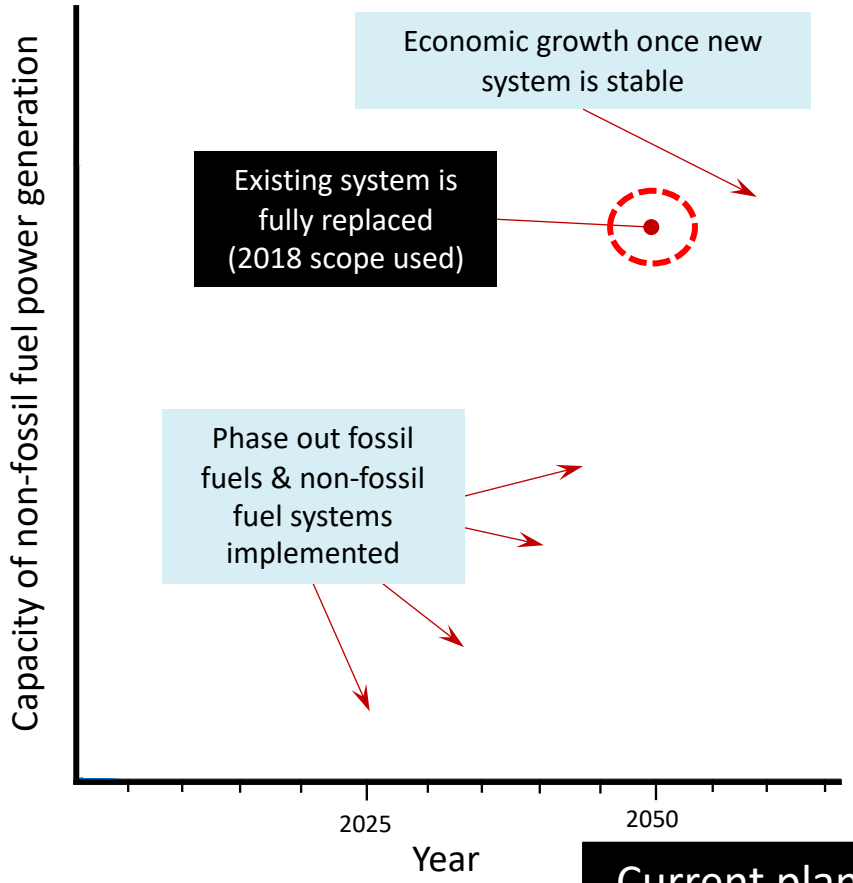
WHAT WOULD IT TAKE TO REPLACE THE EXISTING FOSSIL FUEL SYSTEM?



- 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 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)*

- 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*

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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

→ 4 500* 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

→ 20 000 TWh

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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	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

200.1 million tonnes

→ 11 560 TWh

Biomass Economy

Biomass Sustainably Sourced from the Planetary Environment	
Aviation	Biofuel ??? liters
Plastics Manufacture	Biomass Feedstock ??? tonnes

Sustainability audit

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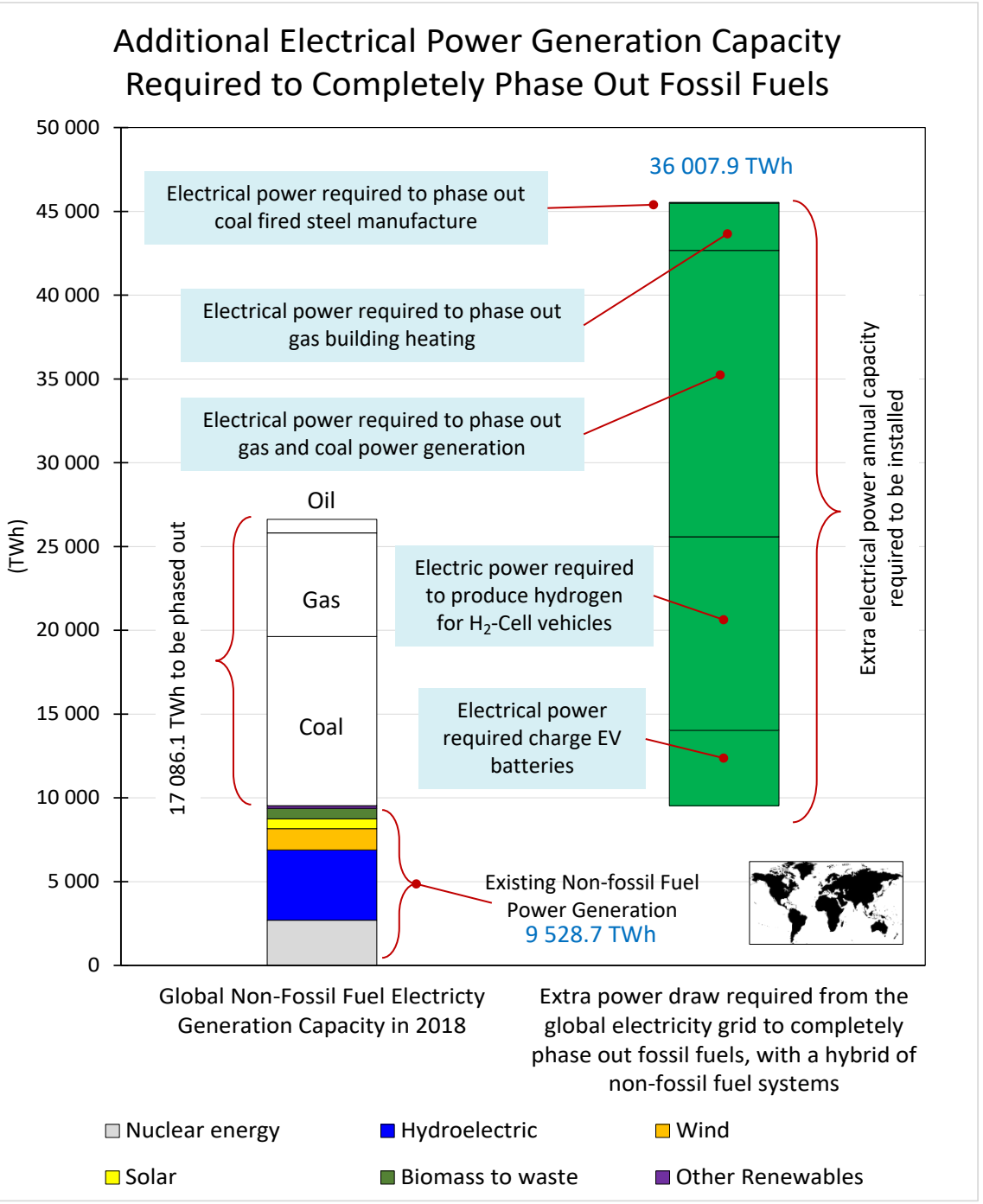

Power Generation System 	Proposed Proportion of Energy Split on new annual capacity (%)	Extra required annual capacity to phase out fossil fuels (TWh)	Estimated number of required new power plants of average size to phase out fossil fuels (number)
Nuclear	7,50 %	2 701,4	211
Hydroelectric	13,36 %	4 809,6	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

Power plant fleet in 2018 was 46 423 stations that generated Total electrical power production in 2018 was 26 614 TWh

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 (1.39 billion)
- EV Batteries
- Hydrogen fuel cells (29.1 million)
- Wind Turbines
- Solar Panels
- Power Storage Batteries (for 4 weeks of wind & solar capacity only)

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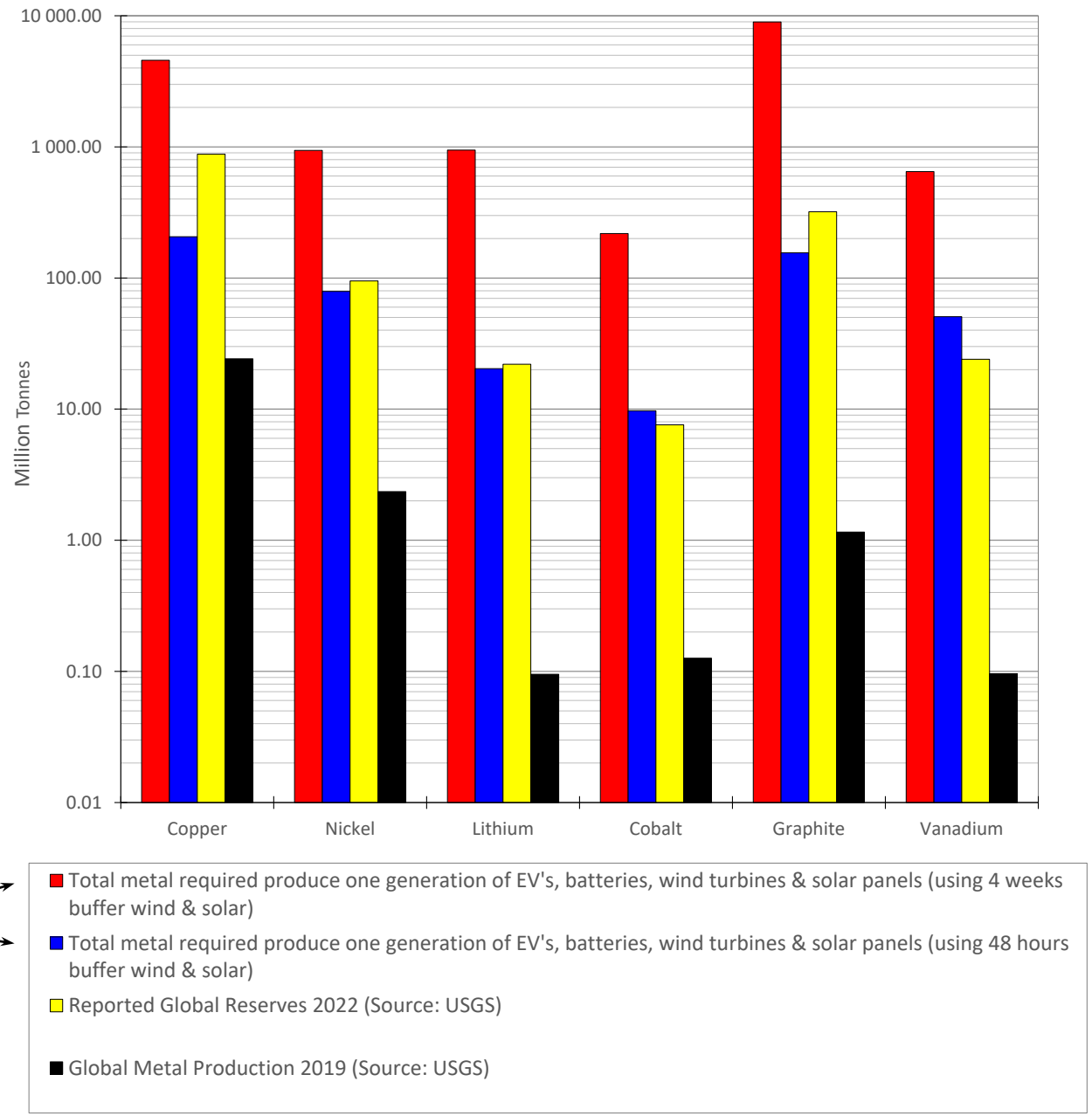
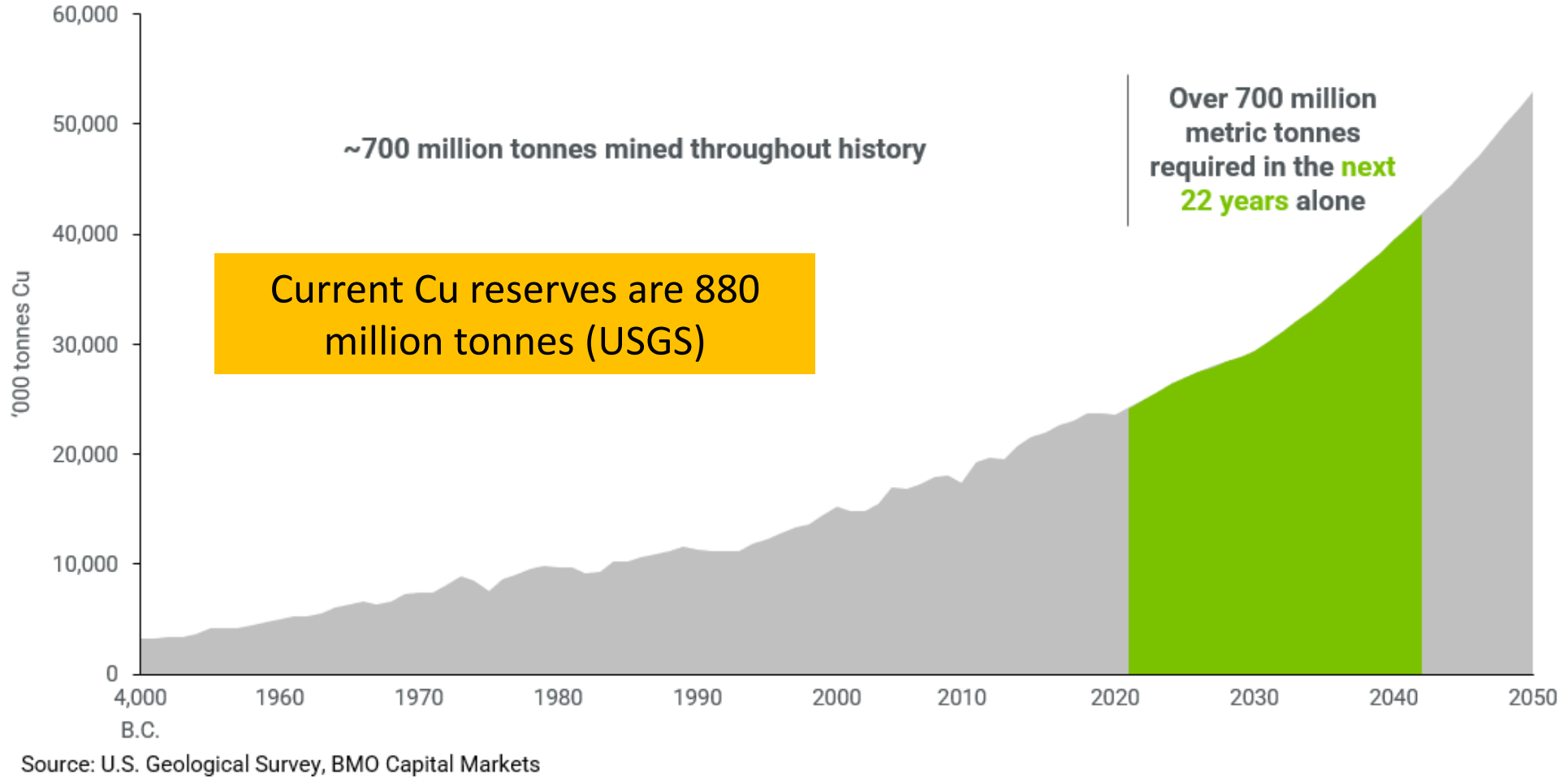
- 0.7% of passenger cars were EV in 2020
- In 2018, renewables accounted for 4.05% of the global energy generation.
- What is not constructed yet, cannot be recycled
- If it was all constructed next year, it would not be until 2033 when large volumes would be available for recycling
- The 1st generation at least must come from mining

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



ECONOMIC GROWTH AND RESOURCE SUPPLY



Current Cu reserves are 880 million tonnes (USGS)

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

We want 4.57 billion tonnes of Cu, just to manufacture one generation of renewable technology (6.4 x historical Cu mining)

COPPER DISCOVERY

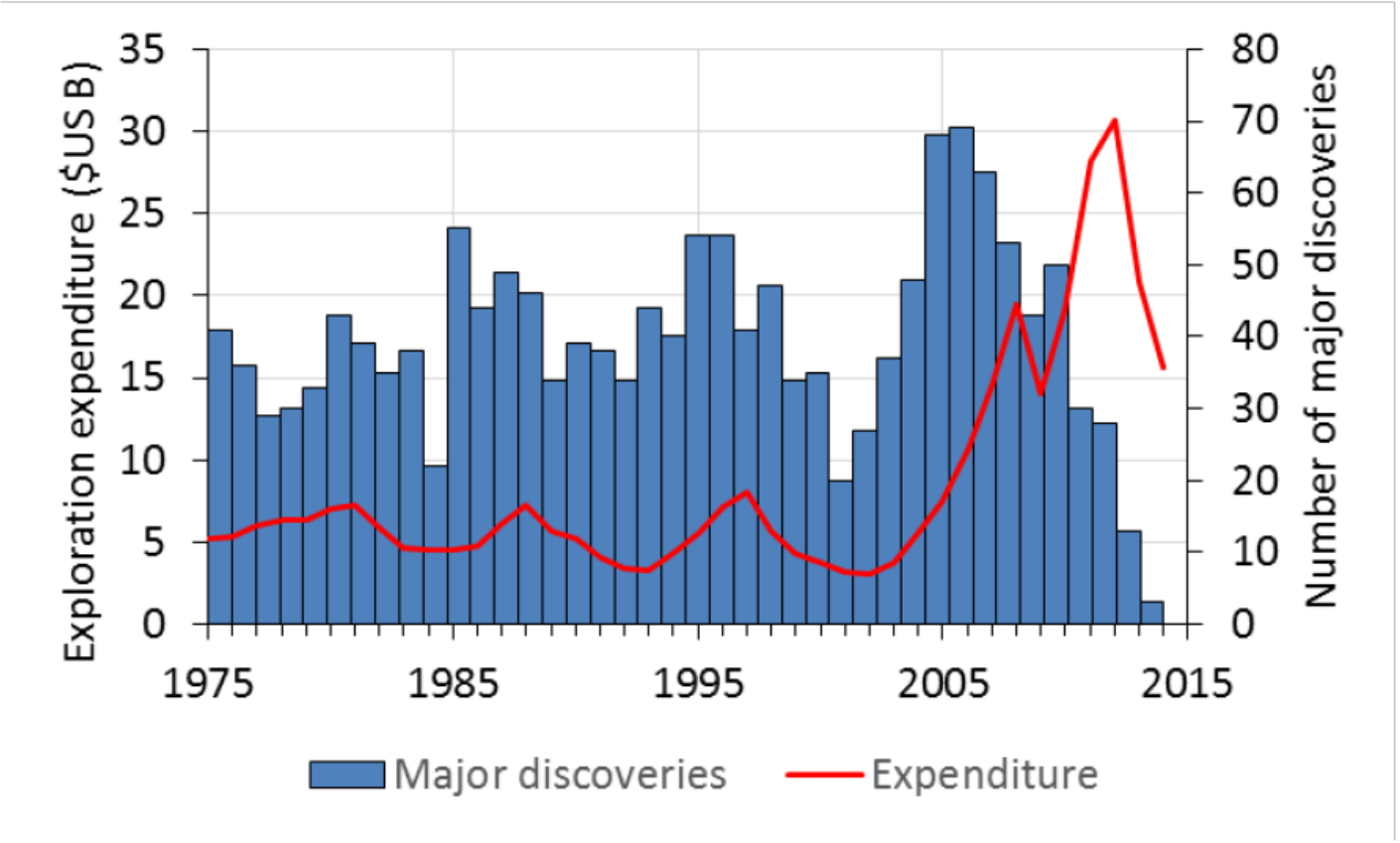
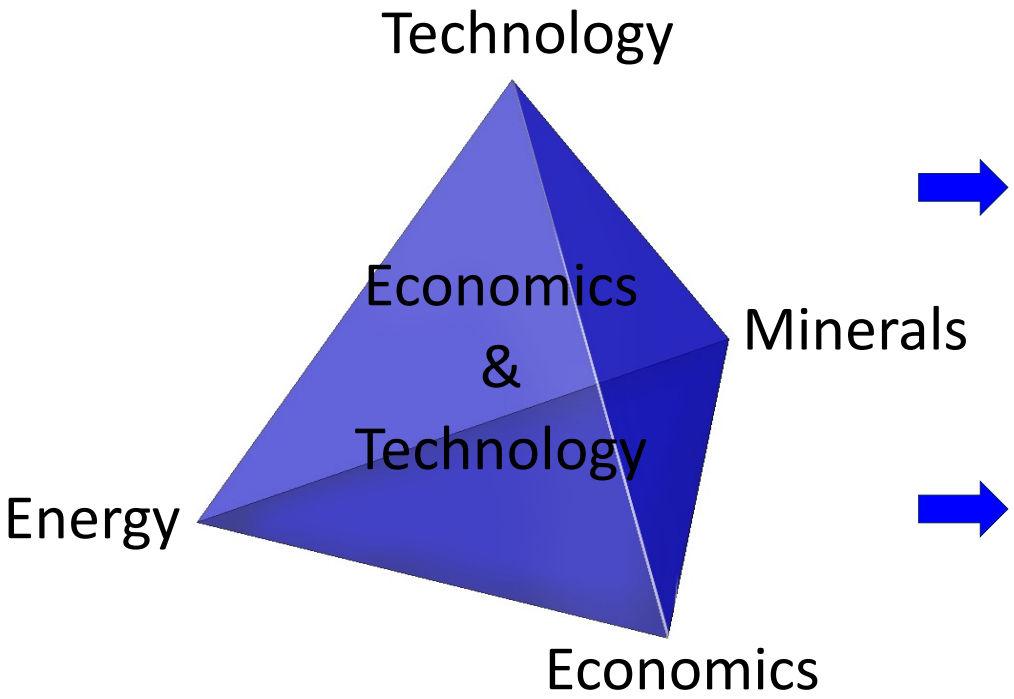


Figure 1: Exploration expenditures versus number of major discoveries, where major is defined as, for example, a gold deposit containing more than 1 Moz of gold or a copper deposit with more than 1 Mt of copper. (Data courtesy of MinEx Consulting)

(Source: Dunbar *et al.* 2016)

THE INDUSTRIAL ECOSYSTEM



This is how our system is really structured

Any new system will have to have a similar structure

All of these aspects and human society functions by harvesting feedstock from the planetary environment

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
- 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.
- Current mineral reserves are not adequate to resource the metal production to manufacture just one generation of renewable technology units
  - *2019 mining production is several orders of magnitude too small to be useful in transition away from fossil fuels*
  - *2022 mineral reserves are also not enough to manufacture just one generation of renewable energy technology units*

- 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

KIITOS
&
THANK YOU

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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.