

MINERALS ARE THE NEW OIL

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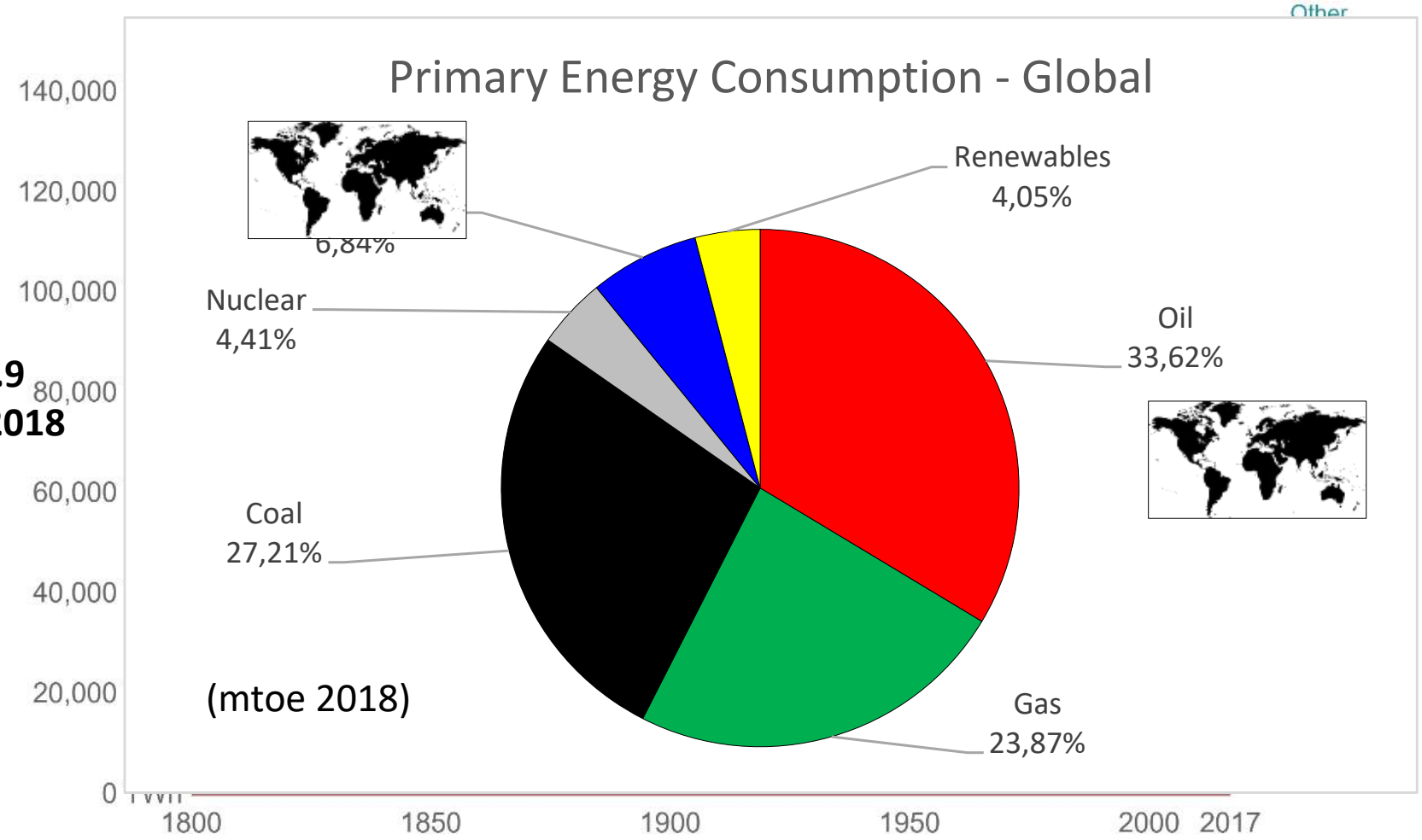
SUMMARY

- We are heavily dependent on fossil fuel energy, oil in particular
- Oil production may soon become unreliable
- The plan to phase out fossil fuels
- How much extra electrical power will be needed
  - *How much solar, wind, etc. capacity*
  - *How many EV's & H_2-Cell's*
- How much metal will we need for just one generation of post ICE technology
- Can we do this with recycling?
- Mining of minerals
  - *Current production*
  - *Current reported reserves*

GLOBAL PRIMARY ENERGY CONSUMPTION. UNITS MEASURED IN TERAWATT-HOURS (TWH) PER YEAR

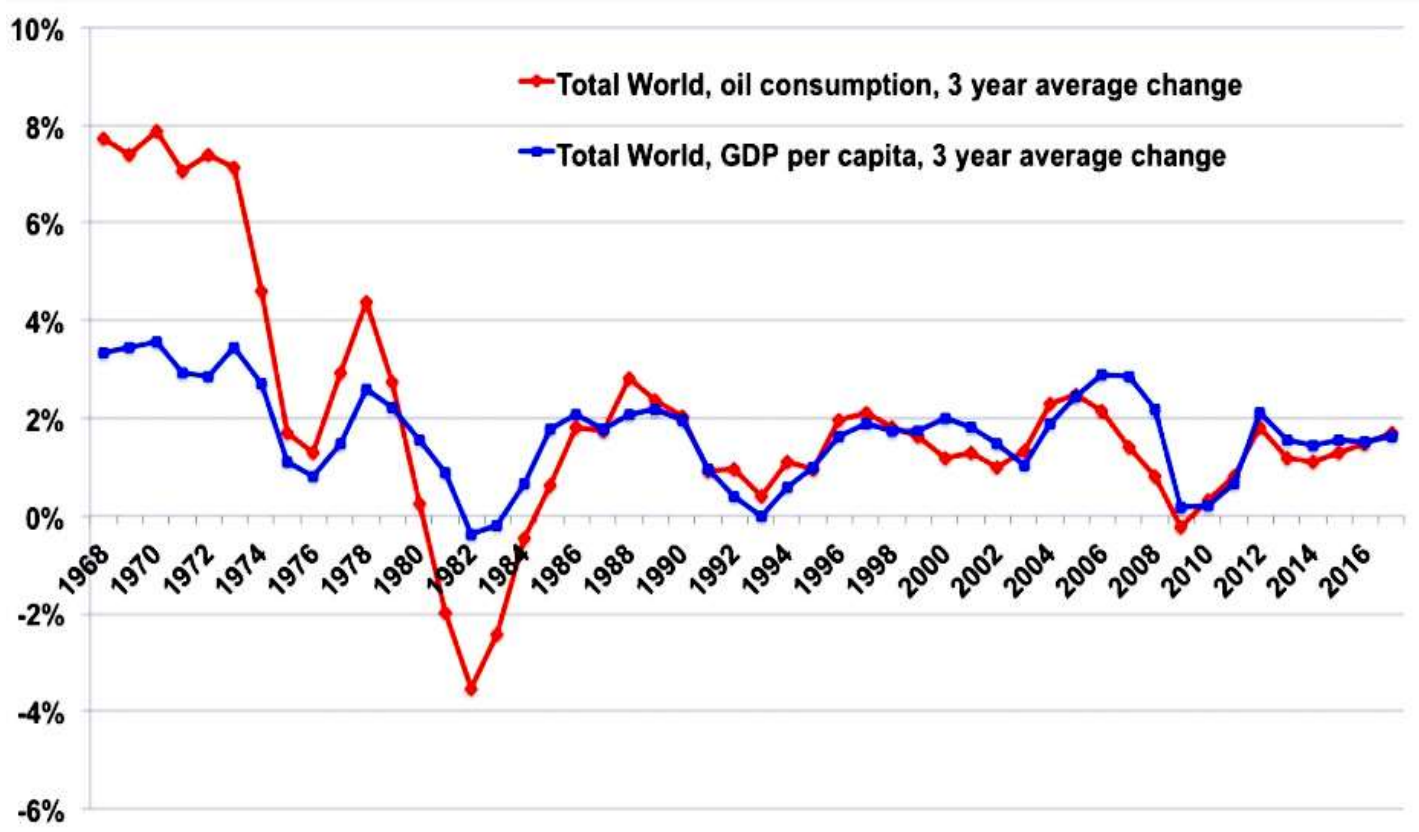
13 864.9 Mtoe in 2018



84.7% Fossil Fuels in 2018

(Source: Our World in Data, BP Statistical review of World Energy 2019)

CORRELATION BETWEEN THE ANNUAL RELATIVE CHANGE IN WORLD OIL CONSUMPTION AND GDP PER CAPITA AVERAGED OVER THREE YEARS



(Source: Data from BP Statistical Review 2018, World Bank)

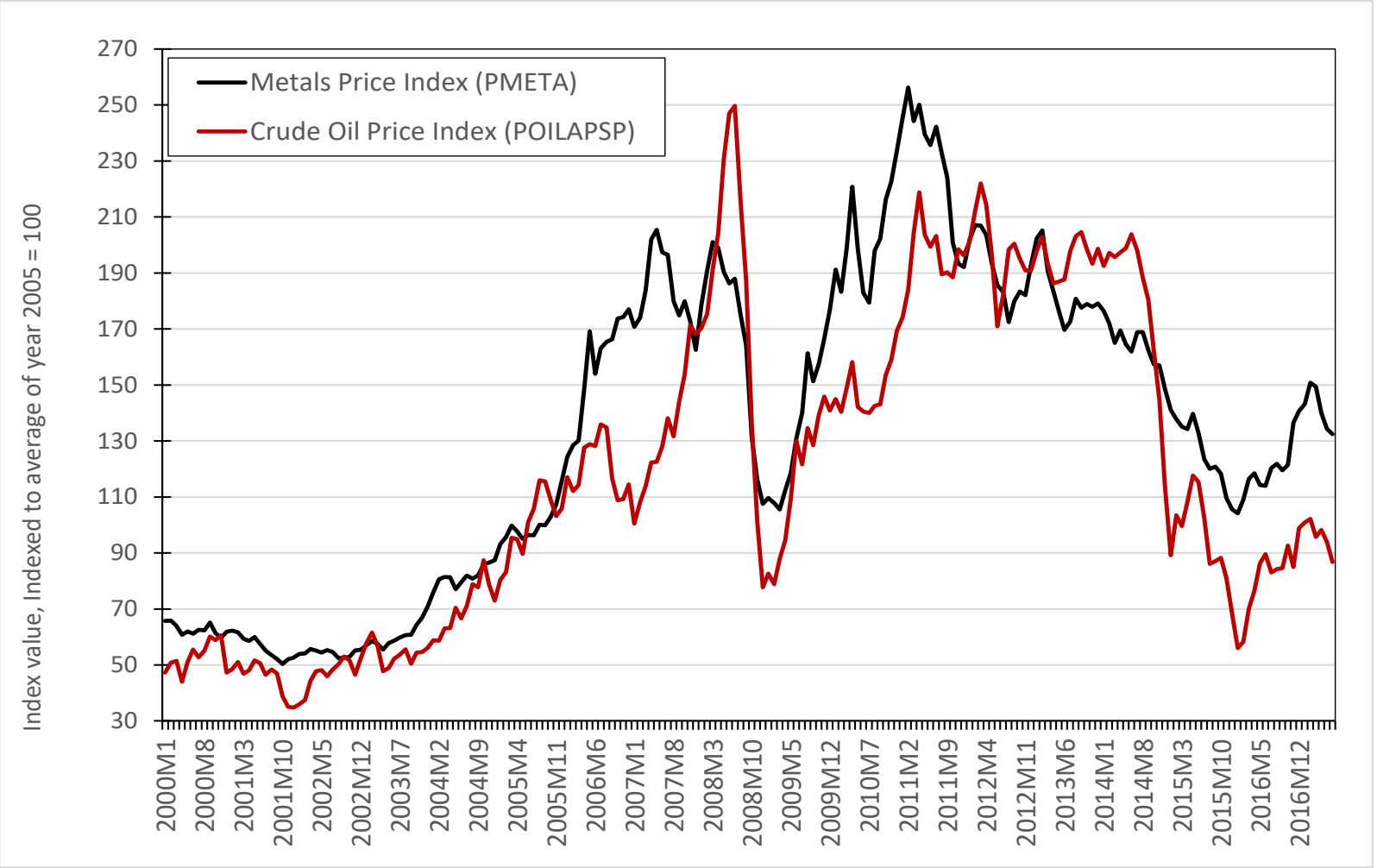
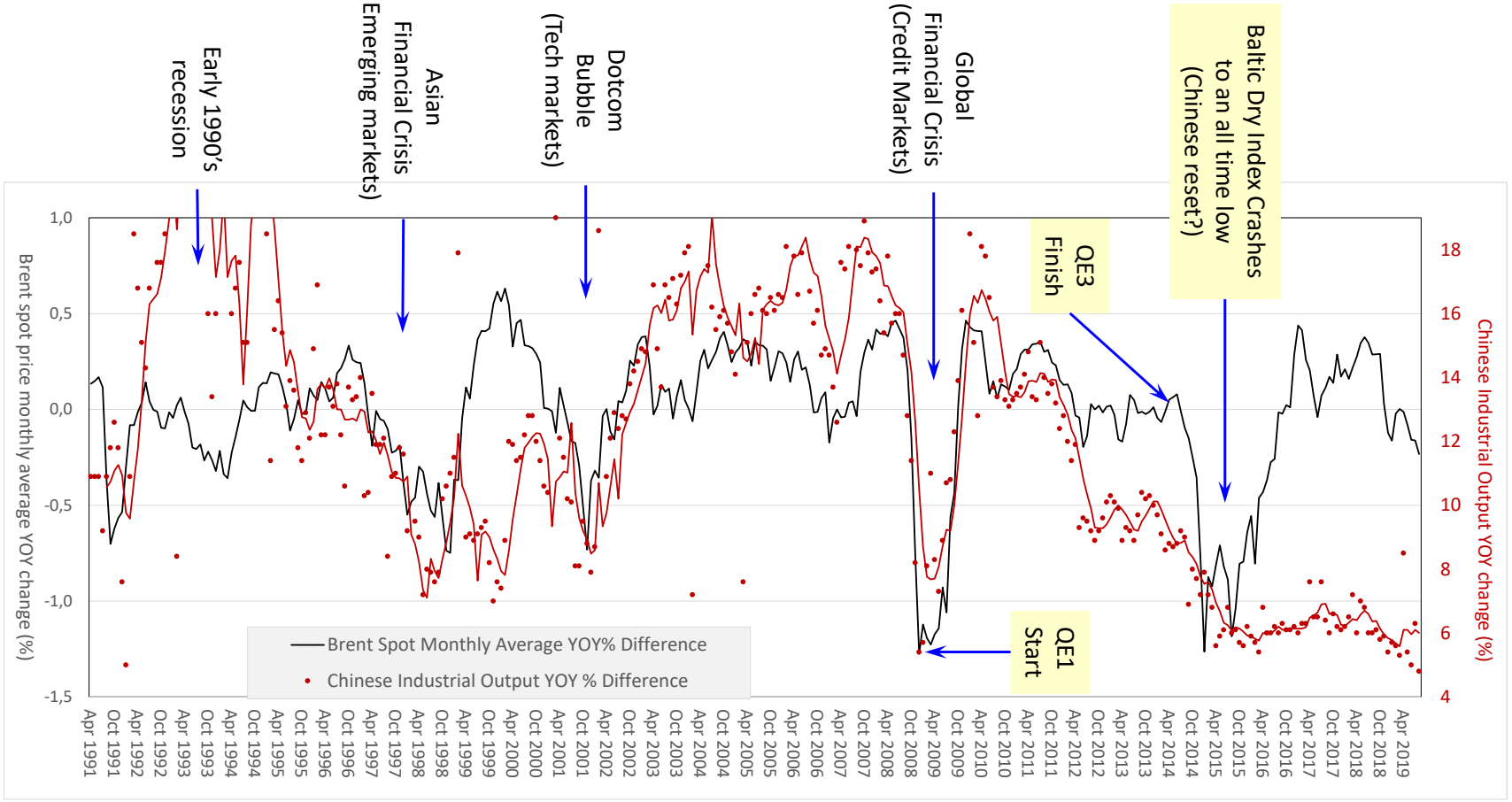


Figure 45. Correlation between global metal price and crude oil

(Source: IMF Primary Commodity Price System, http://www.imf.org/external/np/res/commod/External_Data.xls)

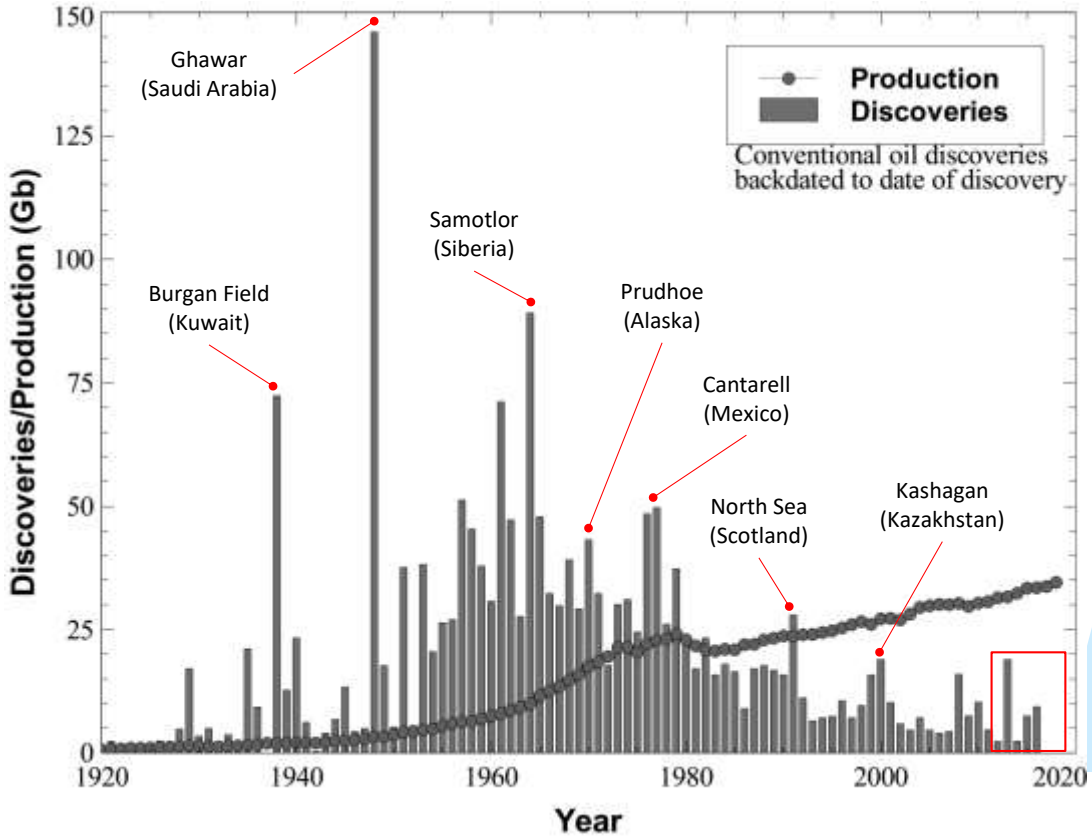
CHINESE INDUSTRIAL OUTPUT AND THE PRICE OF OIL, 1991 - 2018

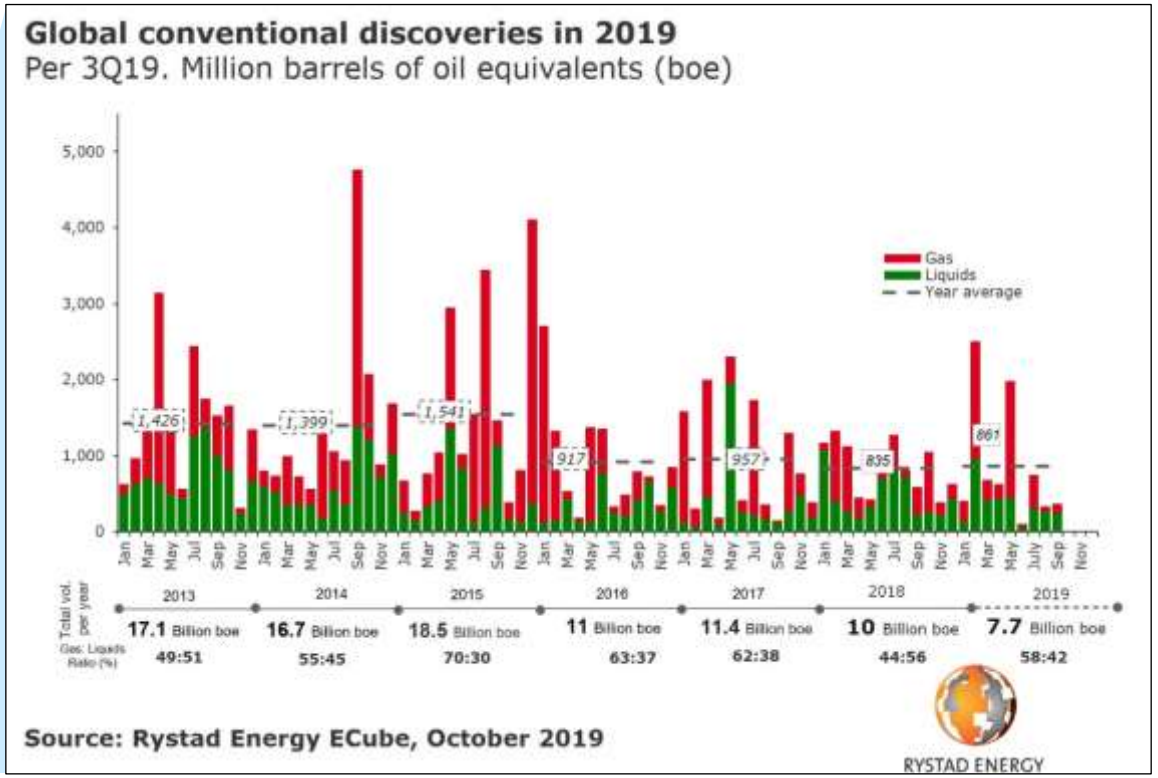




Chinese Industrial output and the price of oil, 1991 - 2018
(Source: National Bureau of Statistics of China, Nasdaq Stock Exchange, https://www.nasdaq.com/markets/crude-oil-brent.aspx)

WE ARE NOT DISCOVERING ENOUGH NEW OIL DEPOSITS



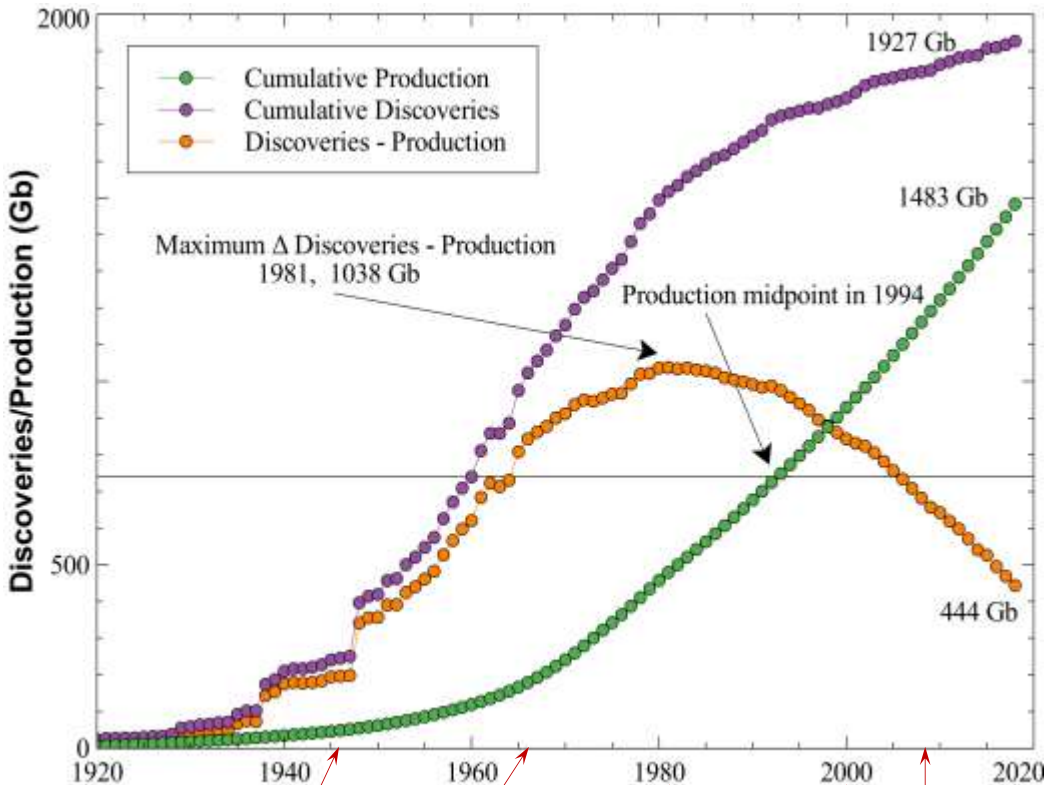


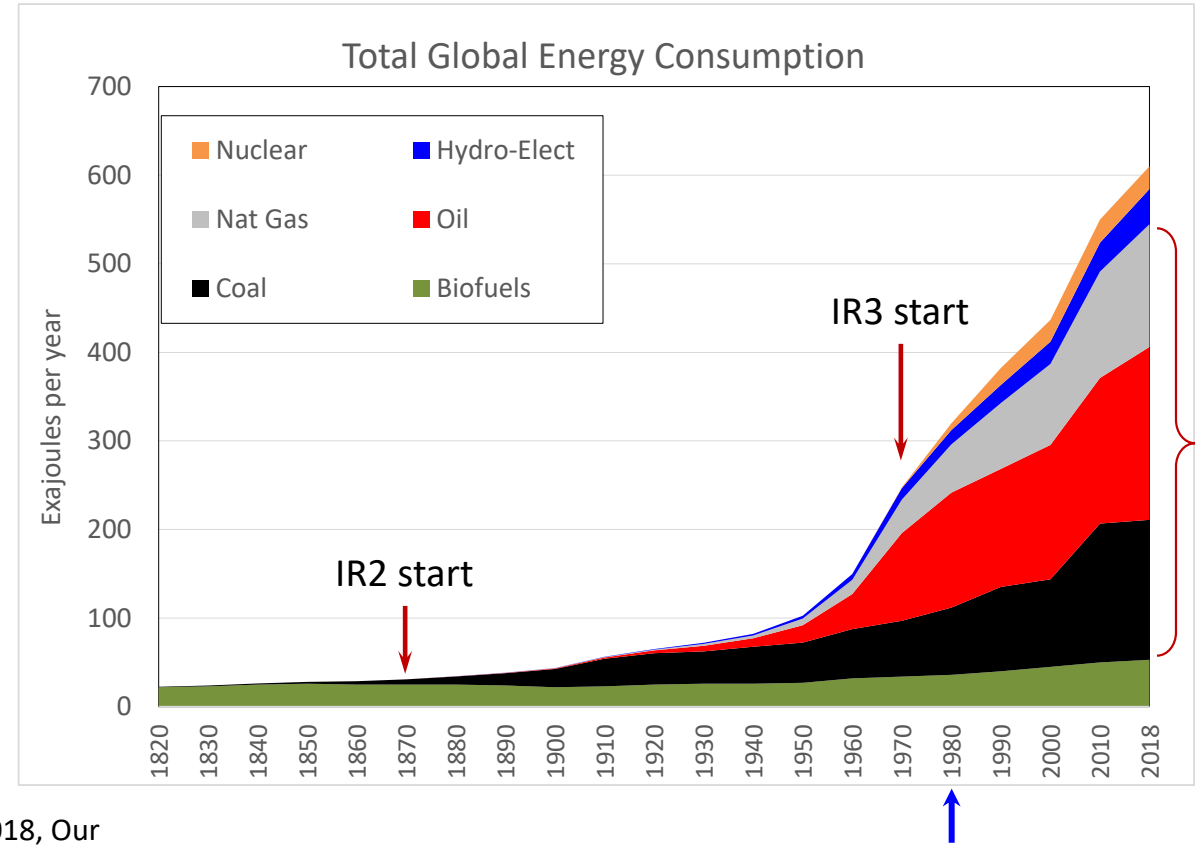
81% of existing producing fields are in decline at an average rate of 5-7% p.a. (HSBC 2016)

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

Record low discoveries in 2020 (Rystad 2021)

FOSSIL FUEL DEPENDENCY



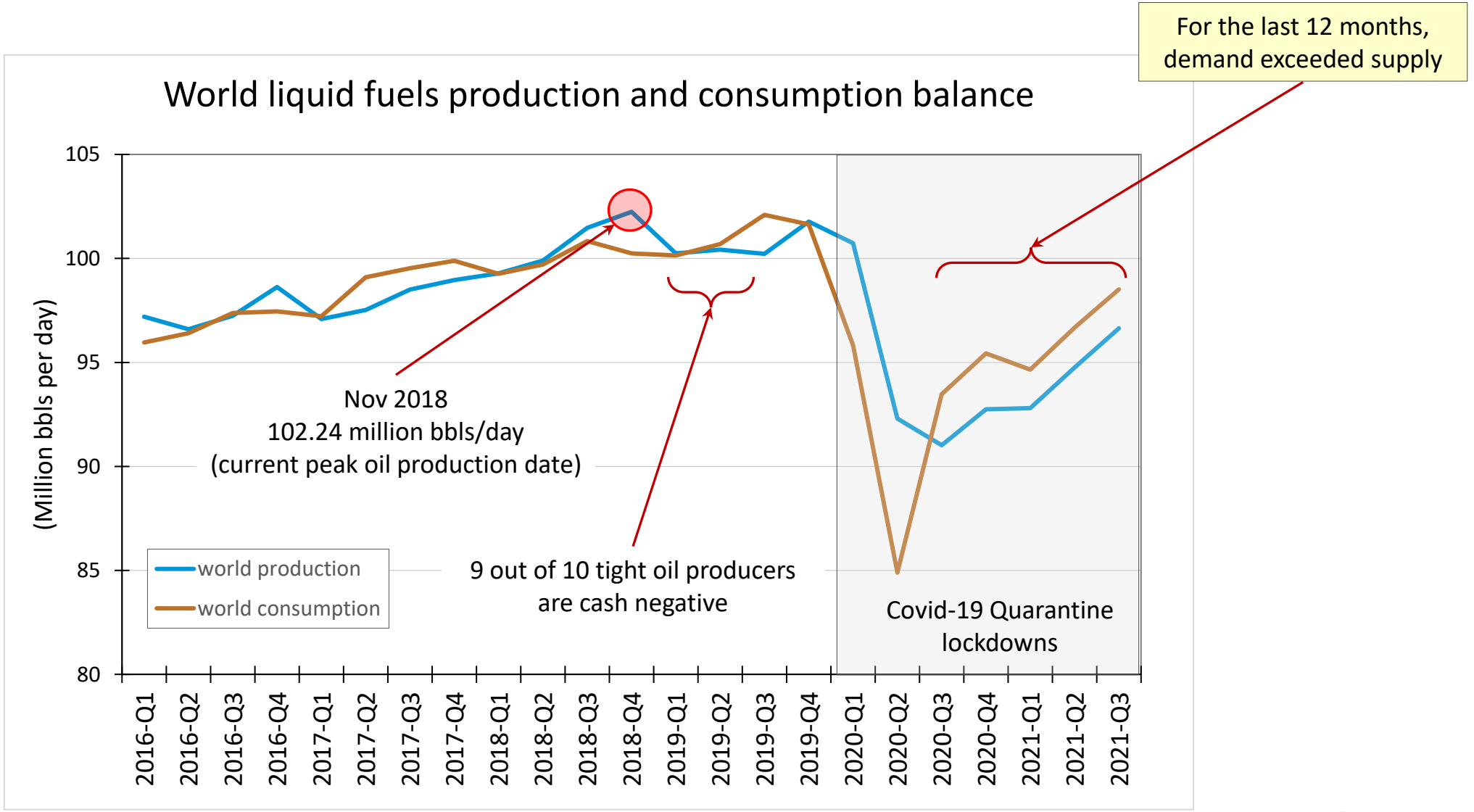


(Source: data from ASPO 2019, Wood and Mackenzie, Oil Price 2017, Rsytad Energy 2018, Our World in Data 2019, BP Energy Statistics 2019 CNBC 2017)

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

All raw materials will have this profile eventually

GLOBAL OIL PRODUCTION & CONSUMPTION



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

THE AFTER OIL PLAN WILL BE NEEDED SOON

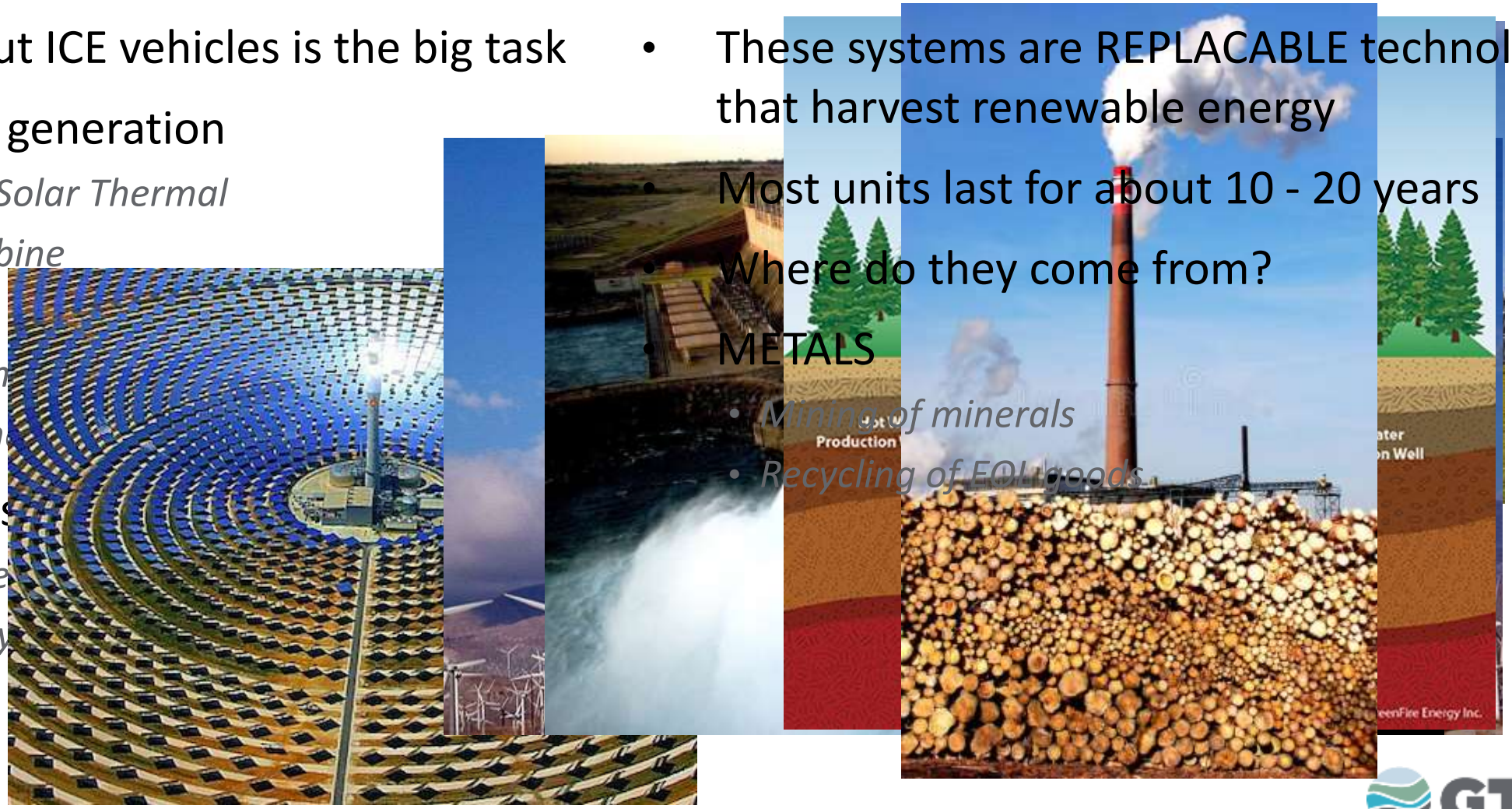


WTI Texas Crude Oil Price ($USD) (Inflation Adjusted)

The window is closing

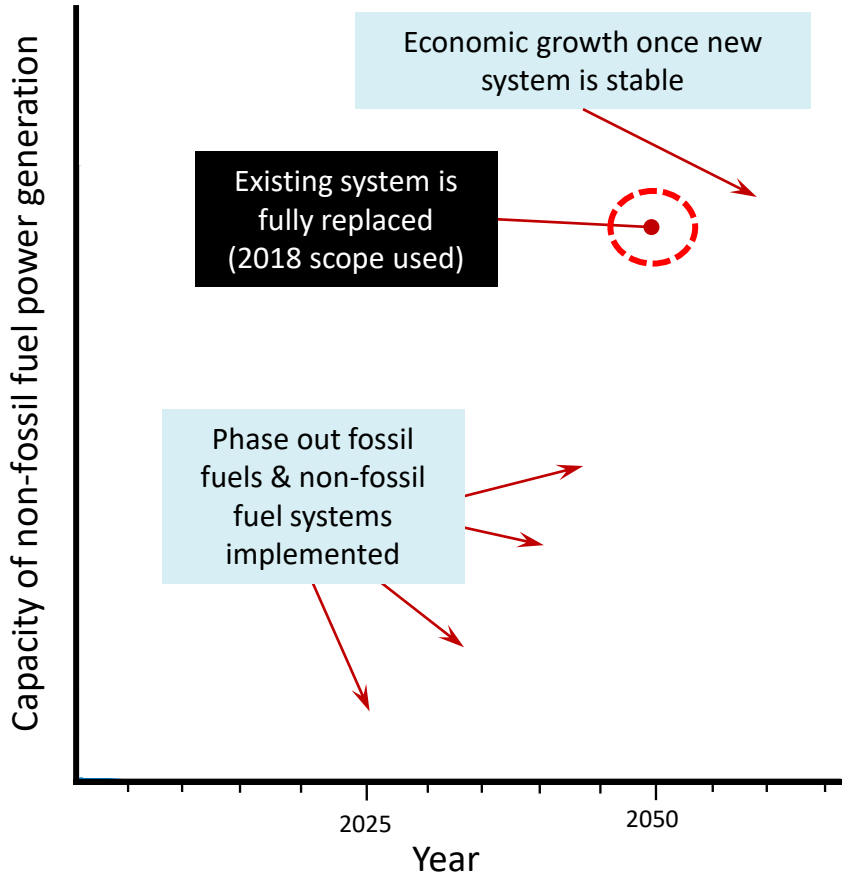
SO, WHAT IS THE PLAN TO PHASE OUT FOSSIL FUELS?

- Phasing out ICE vehicles is the big task
- Electricity generation
  - *Solar PV/Solar Thermal*
  - *Wind Turbine*
  - *Hydro*
  - *Geotherm*
  - *CHP biom*
- Batteries i
  - *EV vehicle*
  - *Stationary*



- These systems are REPLACABLE technology that harvest renewable energy
- Most units last for about 10 - 20 years
- Where do they come from?
- METALS
  - *Mining of minerals*
  - *Recycling of EOL goods*

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?**

SUMMARY

Physical Tasks done industrially by fossil fuels

↓

Determine the true scope of useful work done

↓

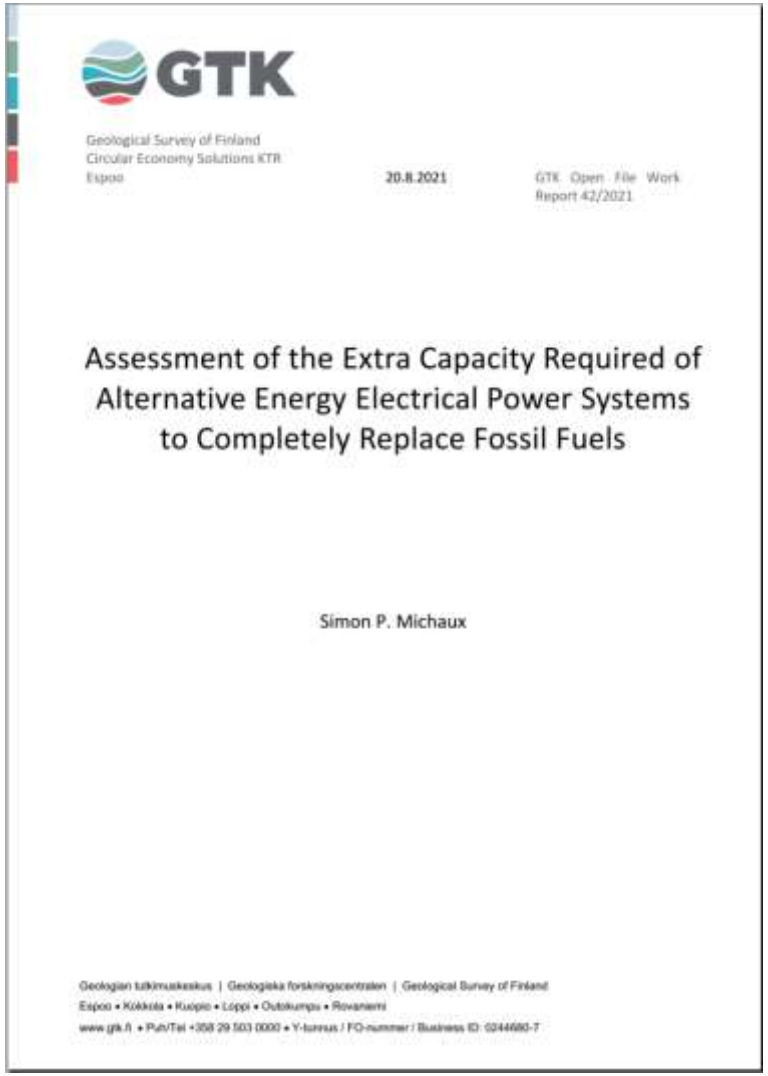
Assemble non-fossil fuel systems that could do the same useful work

↓

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

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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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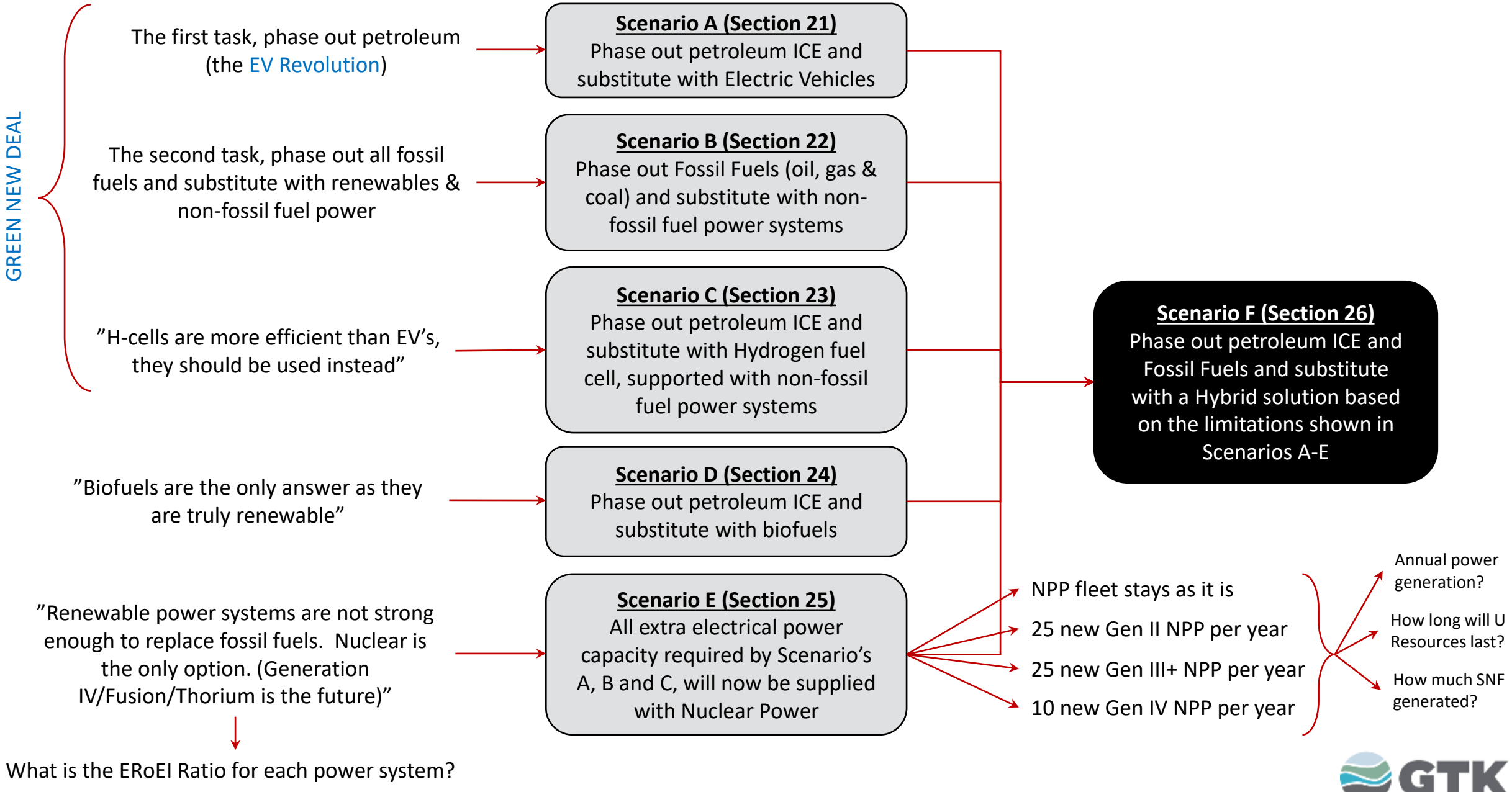
GREEN NEW DEAL
The first task, phase out petroleum (the EV Revolution)
The second task, phase out all fossil fuels and substitute with renewables & non-fossil fuel power
"H-cells are more efficient than EV's, they should be used instead"
"Biofuels are the only answer as they are truly renewable"
"Renewable power systems are not strong enough to replace fossil fuels. Nuclear is the only option. (Generation IV/Fusion/Thorium is the future)"
What is the ERoEI Ratio for each power system?
Scenario A (Section 21)
Phase out petroleum ICE and substitute with Electric Vehicles
Scenario B (Section 22)
Phase out Fossil Fuels (oil, gas & coal) and substitute with non-fossil fuel power systems
Scenario C (Section 23)
Phase out petroleum ICE and substitute with Hydrogen fuel cell, supported with non-fossil fuel power systems
Scenario D (Section 24)
Phase out petroleum ICE and substitute with biofuels
Scenario E (Section 25)
All extra electrical power capacity required by Scenario's A, B and C, will now be supplied with Nuclear Power
Scenario F (Section 26)
Phase out petroleum ICE and Fossil Fuels and substitute with a Hybrid solution based on the limitations shown in Scenarios A-E
NPP fleet stays as it is
25 new Gen II NPP per year
25 new Gen III+ NPP per year
10 new Gen IV NPP per year
Annual power generation?
How long will U Resources last?
How much SNF generated?

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	1 545.9 TWh
29 million Buses & Delivery Trucks 803 billion km	1 597.5 TWh
601 million Vans, Light Trucks 7.9 trillion km	2 988.6 TWh
62 million Motorcycles 160 billion km	26.5 billion kWh

→ 6 158.4 TWh

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

→ 19 958.6 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

→ 11 553.6 TWh

Biomass Economy

Biomass Sustainably Sourced from the Planetary Environment

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

Sustainability audit

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GLOBAL SYSTEM III



EV 6 158.4 TWh

Industry 19 958.6 TWh

H_2 11 553.6 TWh

Additional Annual Electrical Power Requires 37 670.6 TWh

=

221 594 NEW Non-Fossil Fuel Power Stations

Hydro Power
16 576.9 TWh
12 504 stations

Nuclear Power
10 679.7 TWh
834 stations

Wind Power
5 154.4 TWh
63 445 stations

Solar Power
2 311.1 TWh
69 573 stations

Other Renewables
Geothermal & Tidal
367.7 TWh
609 stations

Biowaste to Energy
2 580.8 TWh
74 628 stations

Power storage buffer 574.27 TWh

Power plant fleet in 2018 was
46 423 stations

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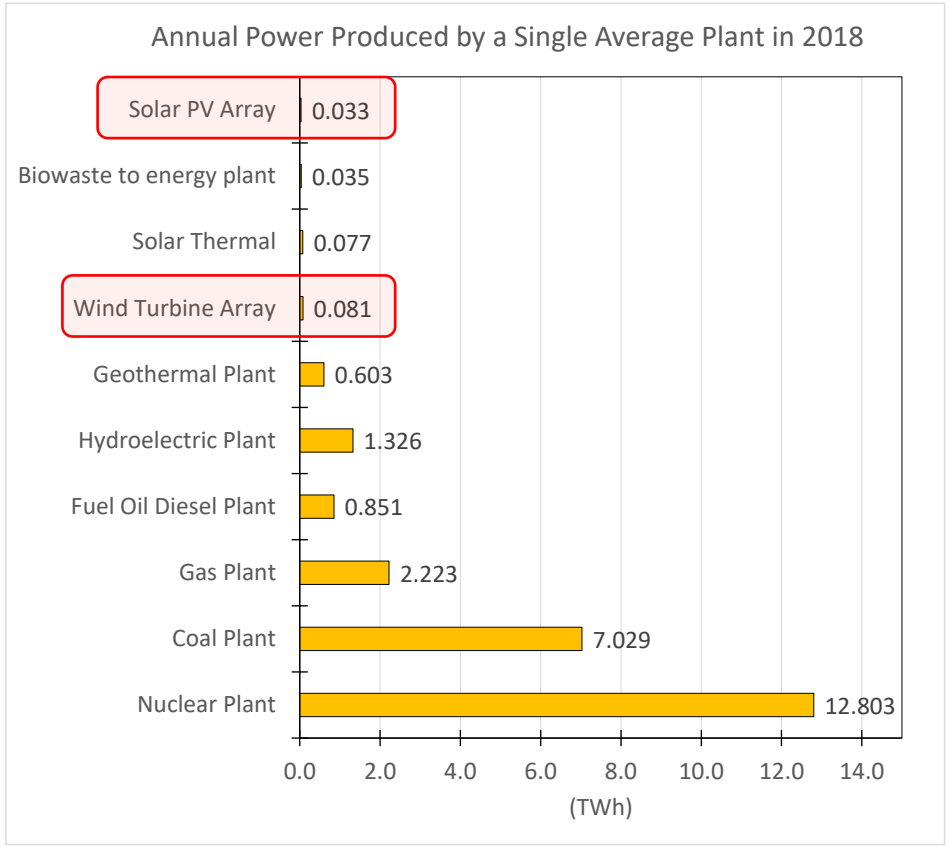
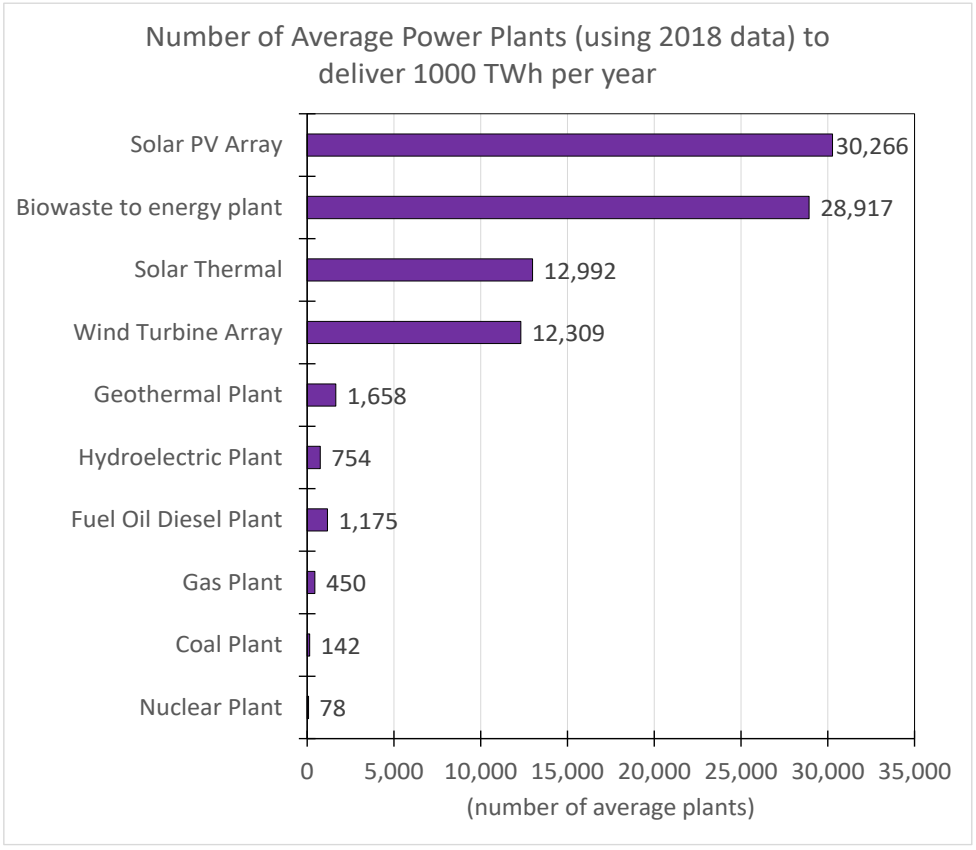
TO DELIVER 1000 TWH OF POWER TO THE GRID OVER 1 YEAR…

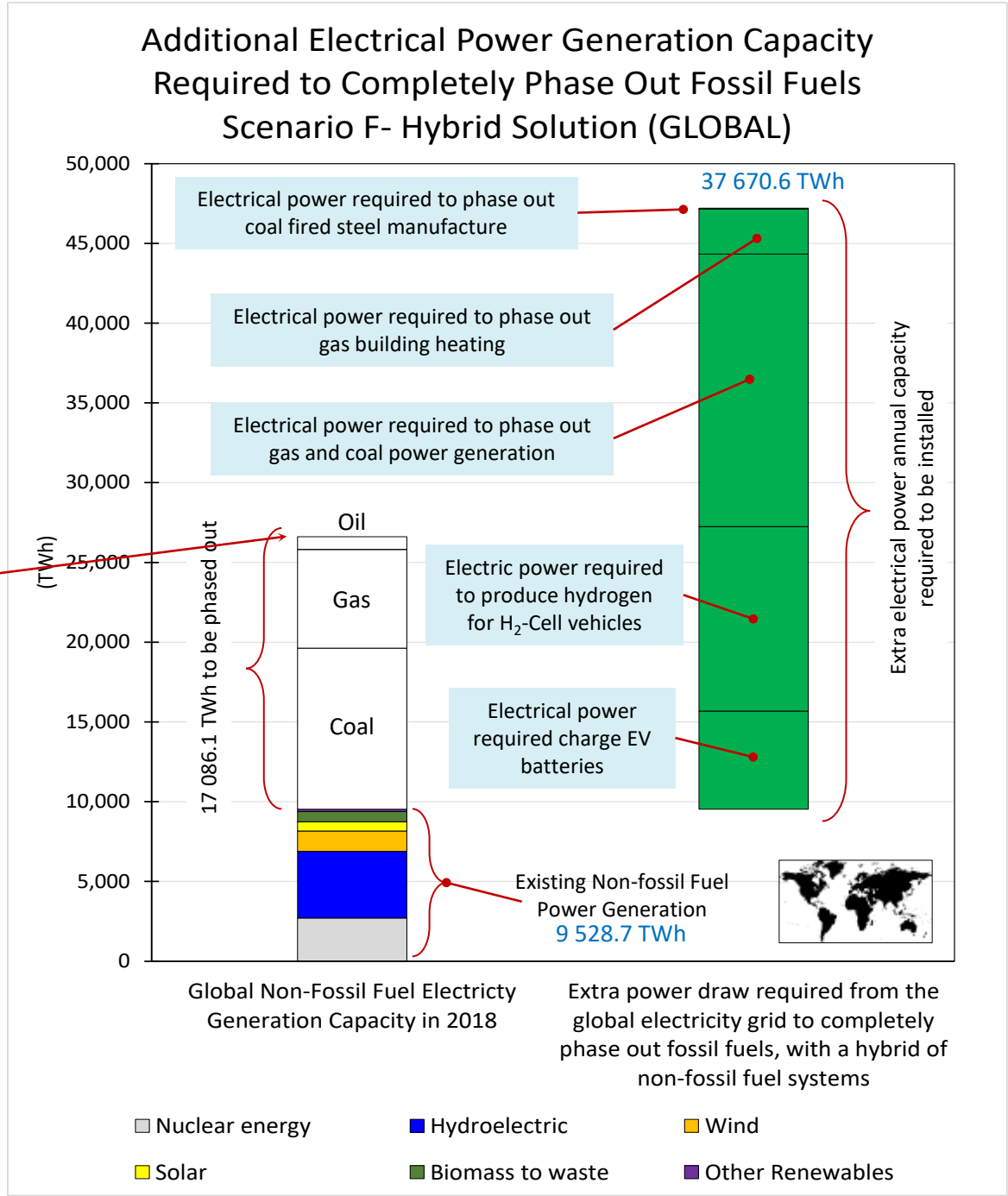




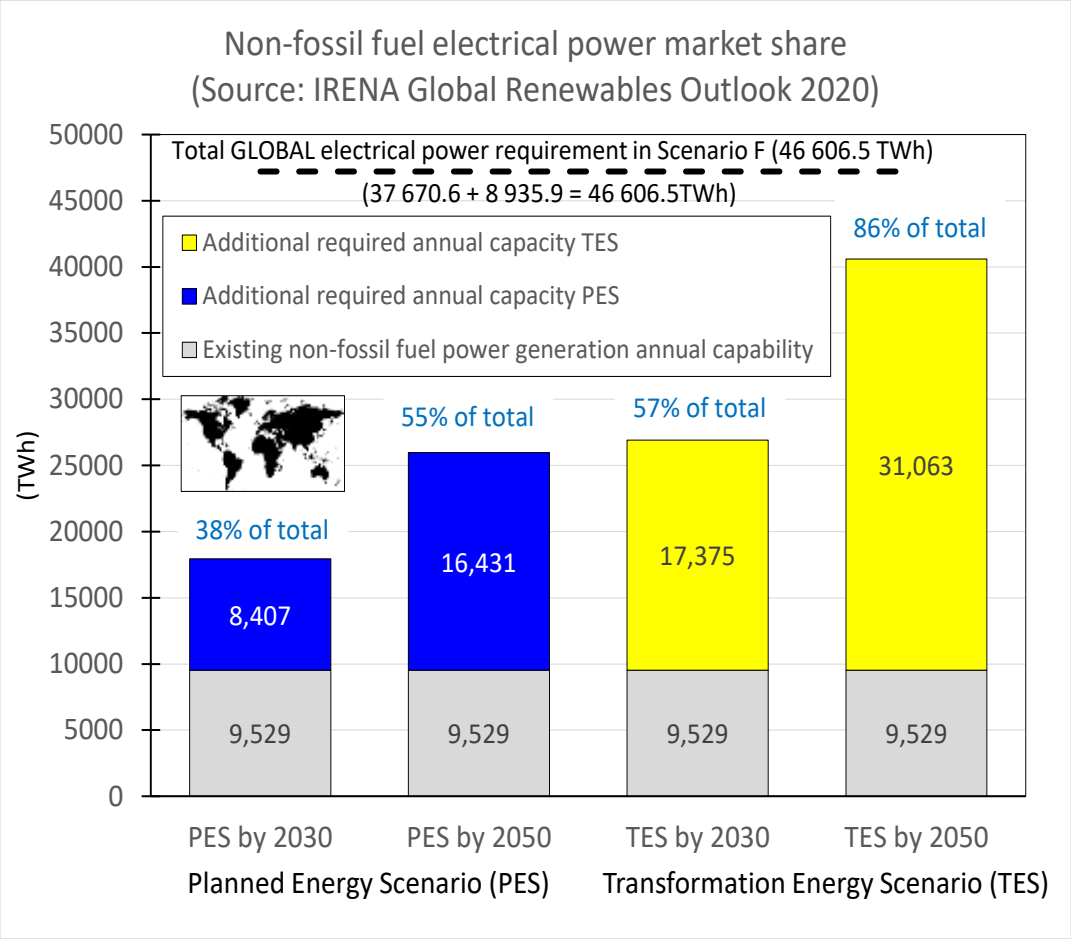
(Source Data: Global Energy Observatory, Agora Energiewende and Sandbag 2019)

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

Total electrical power production in 2018 was 26 614 TWh



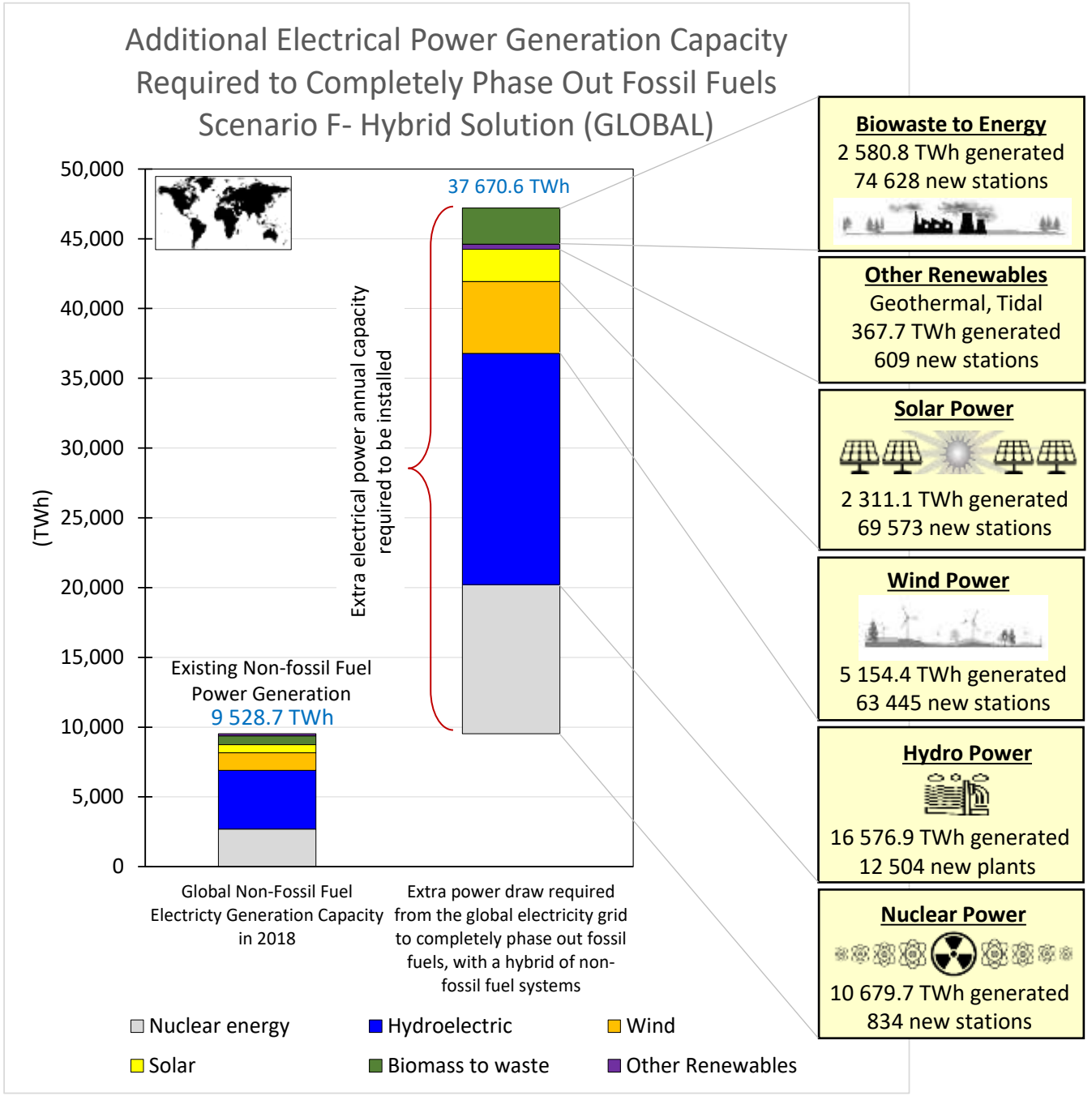
ESTIMATED ADDITIONAL ANNUAL GLOBAL NON-FOSSIL FUEL ELECTRICAL POWER CAPABILITY REQUIRED TO MEET PES AND TES SUSTAINABILITY TARGETS (SOURCE: IRENA GLOBAL RENEWABLES OUTLOOK 2020)



Non-fossil fuel generation System	Global PES non-fossil fuel power generation by 2030 (number of new plants)	Global PES non-fossil fuel power generation by 2050 (number of new plants)	Global TES non-fossil fuel power generation by 2030 (number of new plants)	Global TES non-fossil fuel power generation by 2050 (number of new plants)
Nuclear	338	489	507	764
Hydroelectric	5,063	7,328	7,595	11,459
Wind	25,691	37,184	38,536	58,142
Solar PV	28,057	40,609	42,086	63,498
Solar Thermal	114	166	172	259
Geothermal	247	357	370	559
Biowaste to energy	2,777	4,020	4,166	6,286
	8 754.5 TWh	16 683.1 TWh	17 614.7 TWh	31 122.9 TWh
	38% of global electrical power generation	55% of global electrical power generation	57% of global electrical power generation	86% of global electrical power generation

- **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.



Biowaste to Energy
2 580.8 TWh generated
74 628 new stations

Other Renewables
Geothermal, Tidal
367.7 TWh generated
609 new stations

Solar Power
2 311.1 TWh generated
69 573 new stations

Wind Power
5 154.4 TWh generated
63 445 new stations

Hydro Power
16 576.9 TWh generated
12 504 new plants

Nuclear Power
10 679.7 TWh generated
834 new stations

221 594 NEW Non-Fossil Fuel Power Stations

To put this in context, the total power plant fleet in 2018 (all types including fossil fuel plants) was only 46 423 stations



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



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

6 158.4 TWh

19 958.6 TWh

37 670.6 TWh
New annual capacity

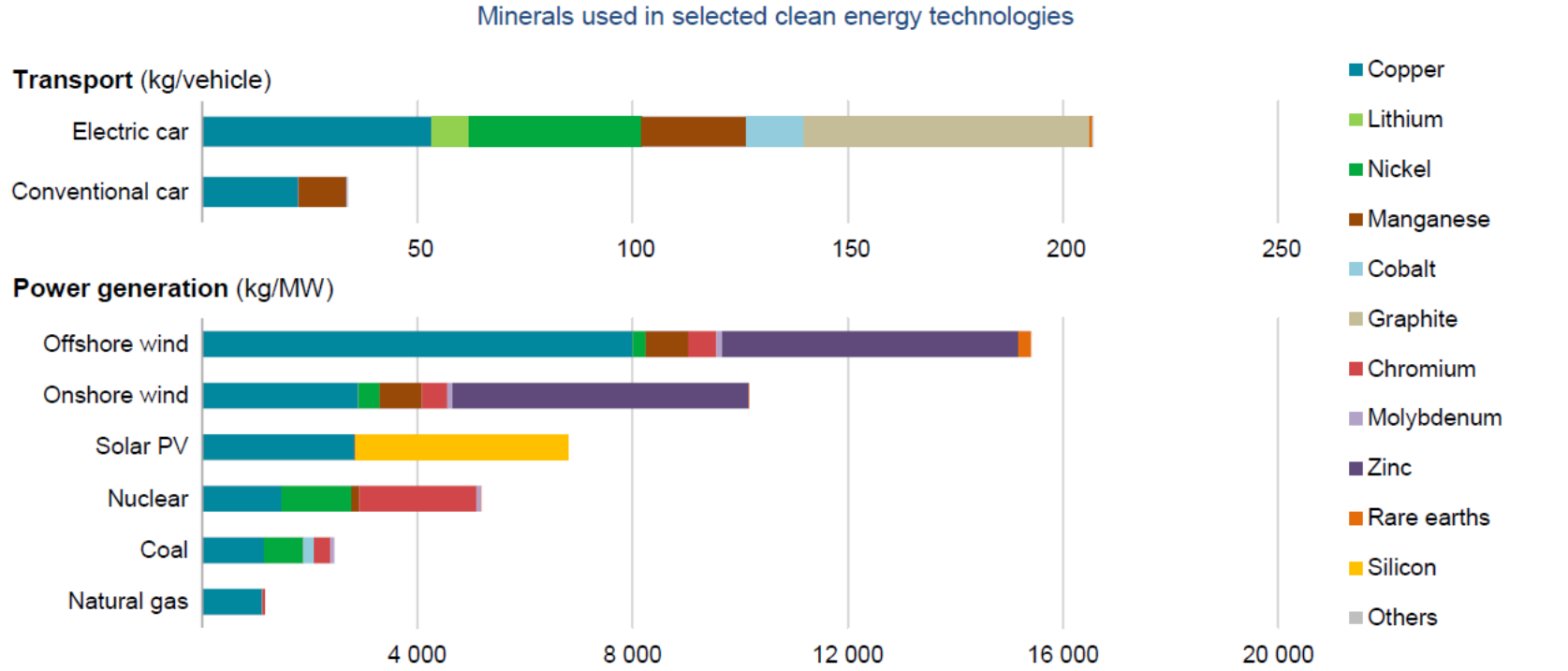
30% solar
11 301.2 TWh
342 039 average sized solar farms
(33.1 MW installed capacity)

4 weeks buffer power
storage 3 139 TWh

70 % wind
26 369.4 TWh
3 353 987 wind turbines (3.6 MW) in 324 579
average sized arrays (37.2 MW installed capacity)
90% onshore, 10% offshore



The rapid deployment of clean energy technologies as part of energy transitions implies a significant increase in demand for minerals



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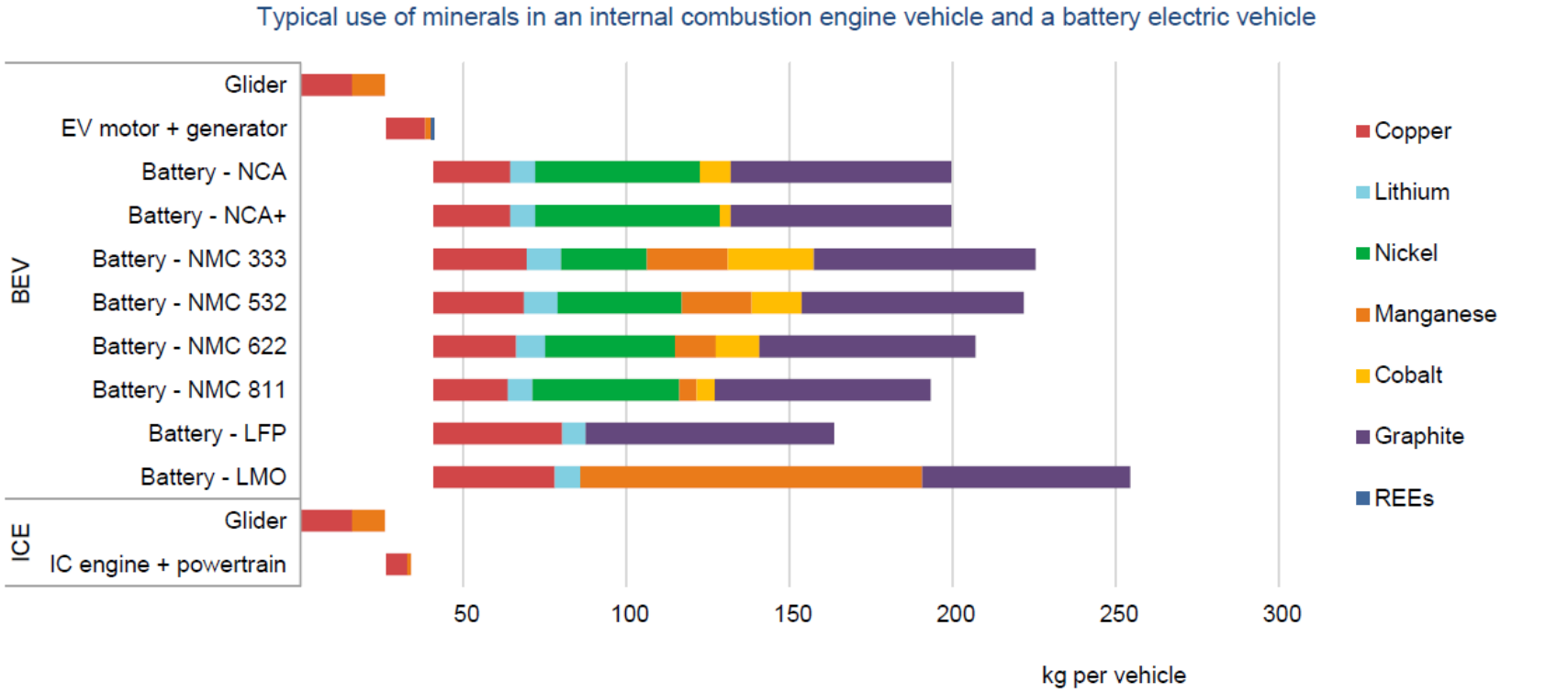
Notes: kg = kilogramme; MW = megawatt. Steel and aluminium not included. See Chapter 1 and Annex for details on the assumptions and methodologies.

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

EVs use around six times more minerals than conventional vehicles



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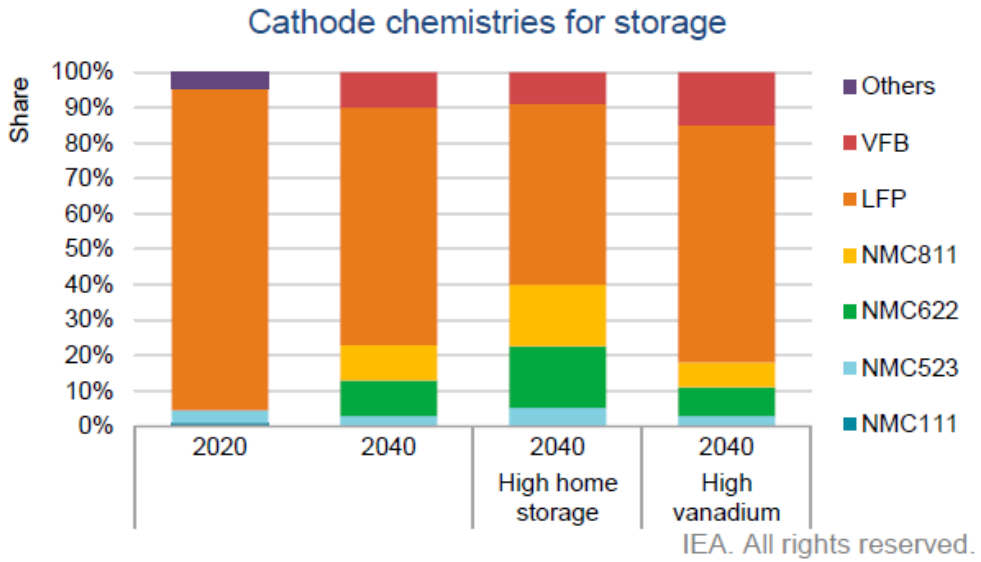
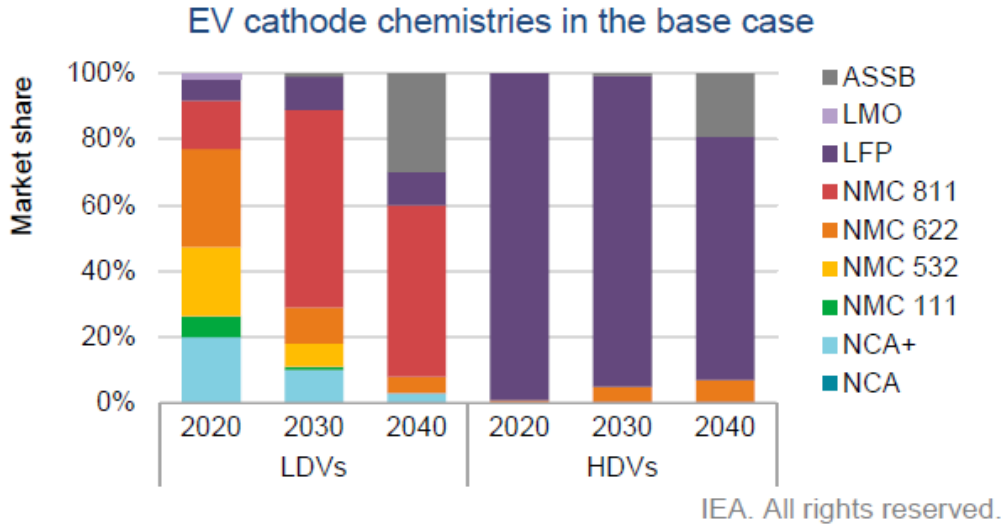
Notes: For this figure, the EV motor is a permanent-magnet synchronous motor (neodymium iron boron [NdFeB]); the battery is 75 kilowatt hours (kWh) with graphite anodes.

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)

HOW MUCH METAL WILL BE NEEDED TO PHASE OUT FOSSIL FUELS (JUST ONE GENERATION)?

Production will be a function of market forces …

	Total (including storage batteries) (million tonnes)
Copper	6 682,9
Nickel	1 352,0
Lithium	1 386,4
Cobalt	318,7
Graphite	13 216,6
Silver	3,2

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

Just open more mines…

		Total (including storage batteries)
Copper	(million tonnes)	6 682,9
Nickel	(million tonnes)	1 352,0
Lithium	(million tonnes)	1 386,4
Cobalt	(million tonnes)	318,7
Graphite	(million tonnes)	13 216,6
Silver	(million tonnes)	3,24

Just explore for more…

- 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

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YOU CAN'T RECYCLE SOMETHING THAT IS NOT YET CONSTRUCTED OR MANUFACTURED

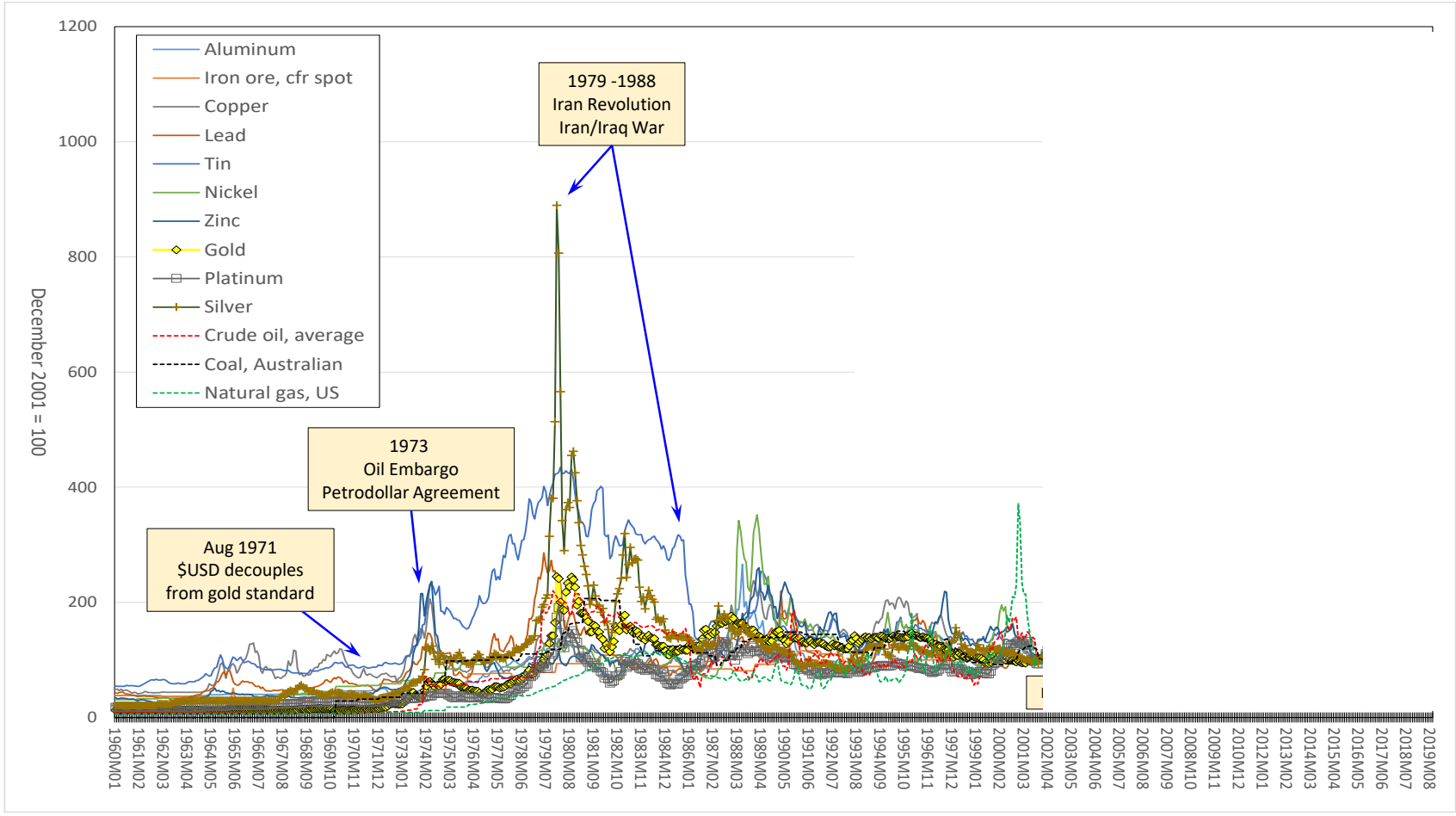
- 0.7% is EV in 2020
- 83.2% of global primary energy in 2020 was fossil fuel based
  - *Renewable 5.7%*
- 61.3% of global electricity generation in 2020 was fossil fuel based
  - *Renewable 11.7%*
- If it was all built tomorrow, most EOL units would be discarded between 2032 – 2042 (10 to 20 years)





Required metal will have to come from mining

THE INDUSTRY CHANGED IN 2005



WHAT IT ALL MEANS…

- We are currently heavily dependent on oil
- The ‘After Oil/Gas/Coal’ plan is needed now
- A vast amount of metal will be required to manufacture the needed solar panels, wind turbines, EV’s and H_2-Cells
- Recycling cannot deliver the volumes of metals needed
- The mining of minerals must be the primary source
- Existing production & reserves are not enough to deliver the volume required
- More mines and mining in Europe will happen

Minerals are the new oil



PARADIGM CHANGING INFORMATION IS RIGHT IN FRONT OF US IF WE CHOOSE TO SEE IT…



Everyone should try thinking for themselves at least once

Now would be a good time



KIITOS
&
THANK YOU

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THE CURRENT PARADIGM



THE REQUIRED PARADIGM

