Welcome to this week's presentation & conversation hosted by the **Canadian Association for the Club of Rome**, a Club dedicated to intelligent debate & action on global issues.

The views and opinions expressed in this presentation are those of the speaker & do not necessarily reflect the views or positions of CACOR.

Part 3: Do we have the Materials for a Green Transition?

Description: Climate change is an existential threat. Temperature records keep falling, climate emergencies are declared, yet we don't seem to be making much progress in addressing the threat. How much progress have we made? There is no doubt that we are going to continue to see average temperatures increase for some time. What are our prospects for keeping those increases low enough so that we can avoid total societal collapse and a return to the stone age? Are we too late? The most recent data coupled with some analysis and careful forecasting shows that there are some paths that would substantially limit temperature increases and create conditions for a "soft landing." For those paths to be realized, we need all hands-on deck and unprecedented cooperation because there is not a minute to waste.

Biography: Raymond Leury, who has always been interested in science & environmental issues. Ten years ago, he bought his first EV, which led him to become President of the Electric Vehicle Council of Ottawa (EVCO). Now retired from a long IT career, Raymond spends much of his time researching and advocating for EVs of all sizes from light duty to medium and heavy-duty vehicles. This led to a successful campaign to get OC Transpo to transition to e-buses.

The presentation will be followed by a conversation, questions, & observations from the participants.

CACOR acknowledges that we all benefit from sharing the traditional territories of local Indigenous peoples (First Nations, Métis, & Inuit in Canada) and their descendants.

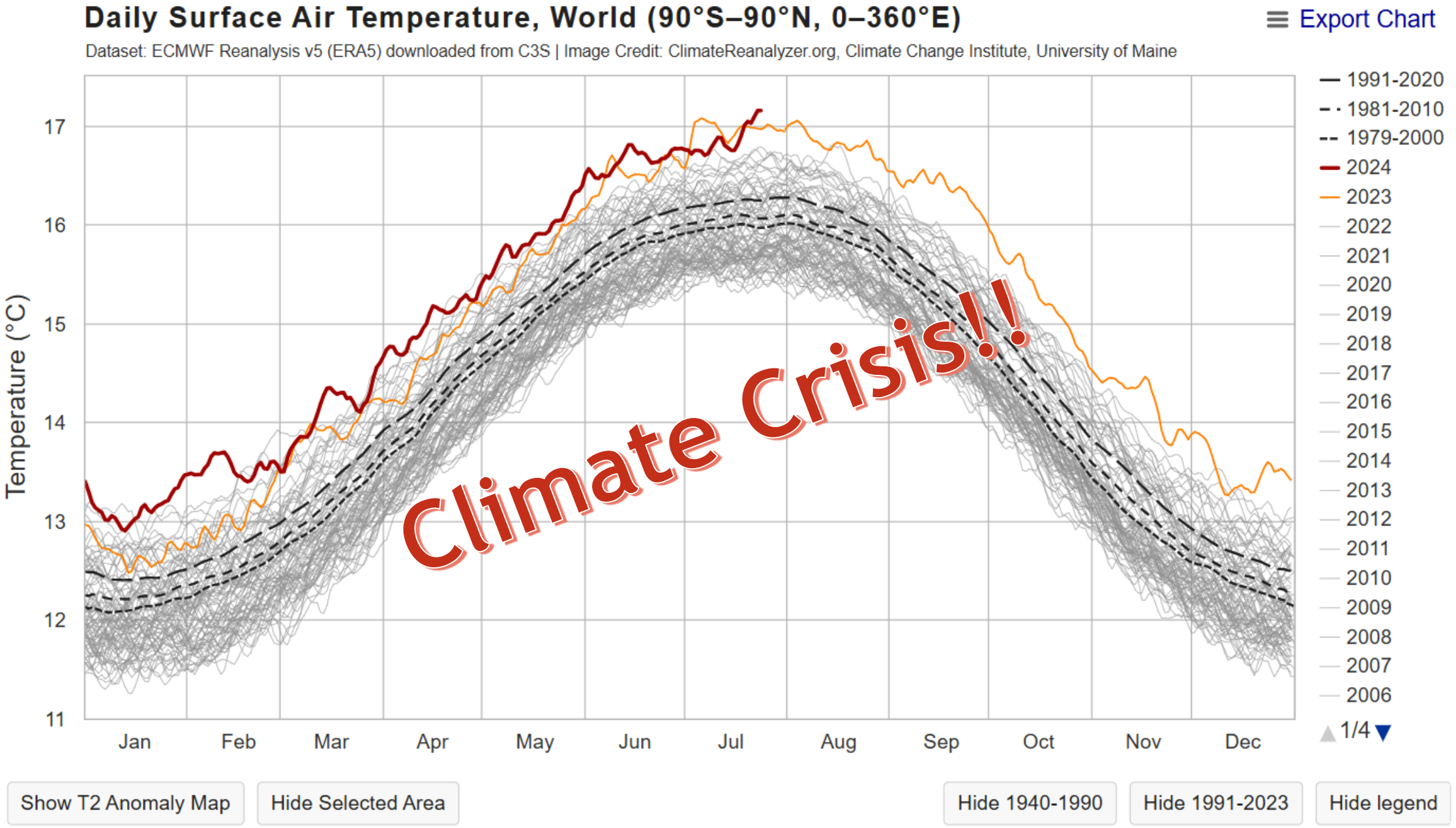
Website: canadiancor.com
Twitter: @cacor1968
YouTube: Canadian Association for the Club of Rome
2024 Aug 07 Zoom #209

Hope or reality?

Part 3: Do we have the Materials for a Green Transition?

Raymond J Leury, MBA

August 7th, 2024


Daily Surface Air Temperature, World (90°S–90°N, 0–360°E)
Export Chart
Dataset: ECMWF Reanalysis v5 (ERA5) downloaded from C3S | Image Credit: ClimateReanalyzer.org, Climate Change Institute, University of Maine
Temperature (°C)
17
16
15
14
13
12
11
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
1991-2020
1981-2010
1979-2000
2024
2023
2022
2021
2020
2019
2018
2017
2016
2015
2014
2013
2012
2011
2010
2009
2008
2007
2006
1/4
Climate Crisis!!
Show T2 Anomaly Map
Hide Selected Area
Hide 1940-1990
Hide 1991-2023
Hide legend
ERA5 2m Temperature (°C)
Tue, Jul 23, 2024 | 1-day Avg
ClimateReanalyzer.org
Climate Change Institute | University of Maine

Agenda

- Recap parts 1 and 2
- Dis/Misinformation
- Do we have enough materials?
- Can the green transition happen fast enough?

What can we conclude from Part 1?

- Green washing is real – and very well funded!
  - Not all technology is green washing
- Sole purpose of marketing is to change people's mind
- IEA and others woefully understates pace of change
  - Overstate challenges
- Solar, wind, batteries and EVs
  - Rapid, accelerating adoption
  - Much faster than IEA forecast
- Must take action – status quo bad

What can we conclude from Part 2?

- “There are no longer any so-called hard-to-abate sectors” - Michael Liebreich
  - Excuse for inaction
- Burning stuff is the main problem
  - Plastics aren’t burned
  - Plastic sequesters carbon
- We have the technology
  - “Green steel”
  - “Green cement”
  - Chemicals
  - Shipping, aviation
- What’s missing?
  - Long distance transport – SAF
  - Economics

Keep in mind

- Laws of nature are fixed – gravity, etc.
- Technology evolves
  - Technology answers change as technology evolves
  - That is the aim of much R&D
- Economics change
  - Solar and wind are *now* less expensive than alternatives
  - Favorable Economics will drive adoption
  - Wright's law
- "Accepting defeat on climate change is an indefensibly selfish position to take" Hannah Ritchie

Dis/Misinformation

- Existential crisis for the FF industry
- Hire best PR firms in the world
  - Same folks that told us cigarettes did not cause cancer
- “Merchants of Doubt”
- “Don’t ask a barber if you need a haircut” (Warren Buffet)
  - Should *never* assume that you are being told the truth
  - Ford losing money on EVs?
- Sometimes your “friend” is your “foe”
  - Nuclear bashing renewables, Toyota
  - “We need a diversity of solutions” - Québec

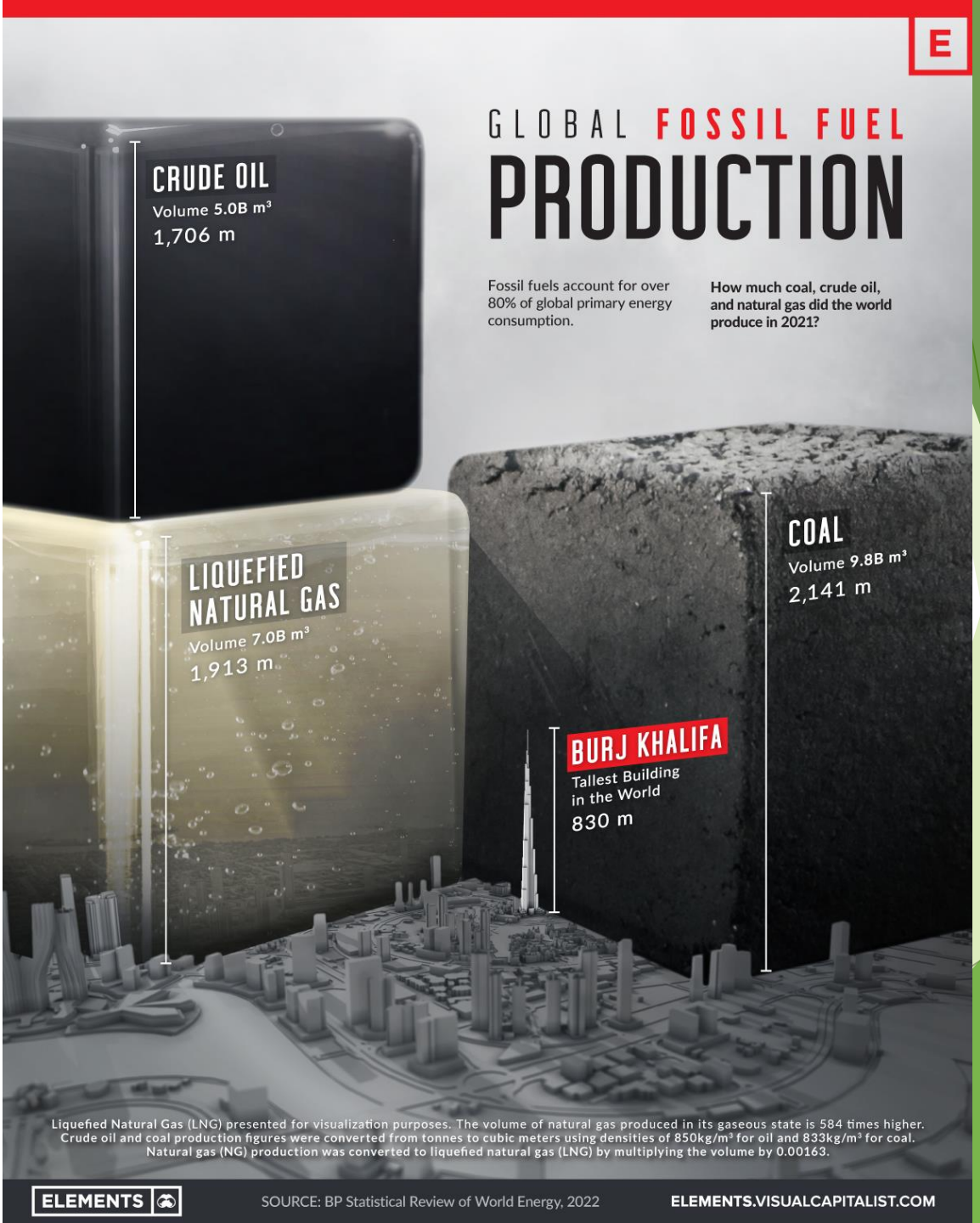
EV Dis/Misinformation

- Starts with a grain of truth
- Distort/exaggerate impact with regards to EVs
- Example – cobalt and child labour in the DRC
  - A small proportion of cobalt is possibly mined via child labour < 6% - Amnesty Int and DRC
  - EV batteries use cobalt (40% of world production in 2022)
  - No reasonable person likes child labour
  - Don’t buy an EV because cobalt means child labour
  - You only hear of cobalt in the context of EVs
  - Meanwhile we keep buying stuff made in sweatshops

EV Dis/Misinformation

- Context - What they don't tell you
  - Smart phones, laptops, etc. have cobalt-based batteries (30%)
  - Oil industry uses cobalt to refine petroleum
    - Desulfurization
  - LFP batteries have no cobalt - ~50% EV market and growing
- If child labour is truly a concern/criteria
  - You shouldn't buy any portable electronics
  - You shouldn't buy gas
  - You should buy an EV with LFP batteries
- EV context is distorted
  - No reason to avoid buying an EV because of cobalt
  - Every reason to fight against child labour

Do we have enough materials? How big is the transition problem?



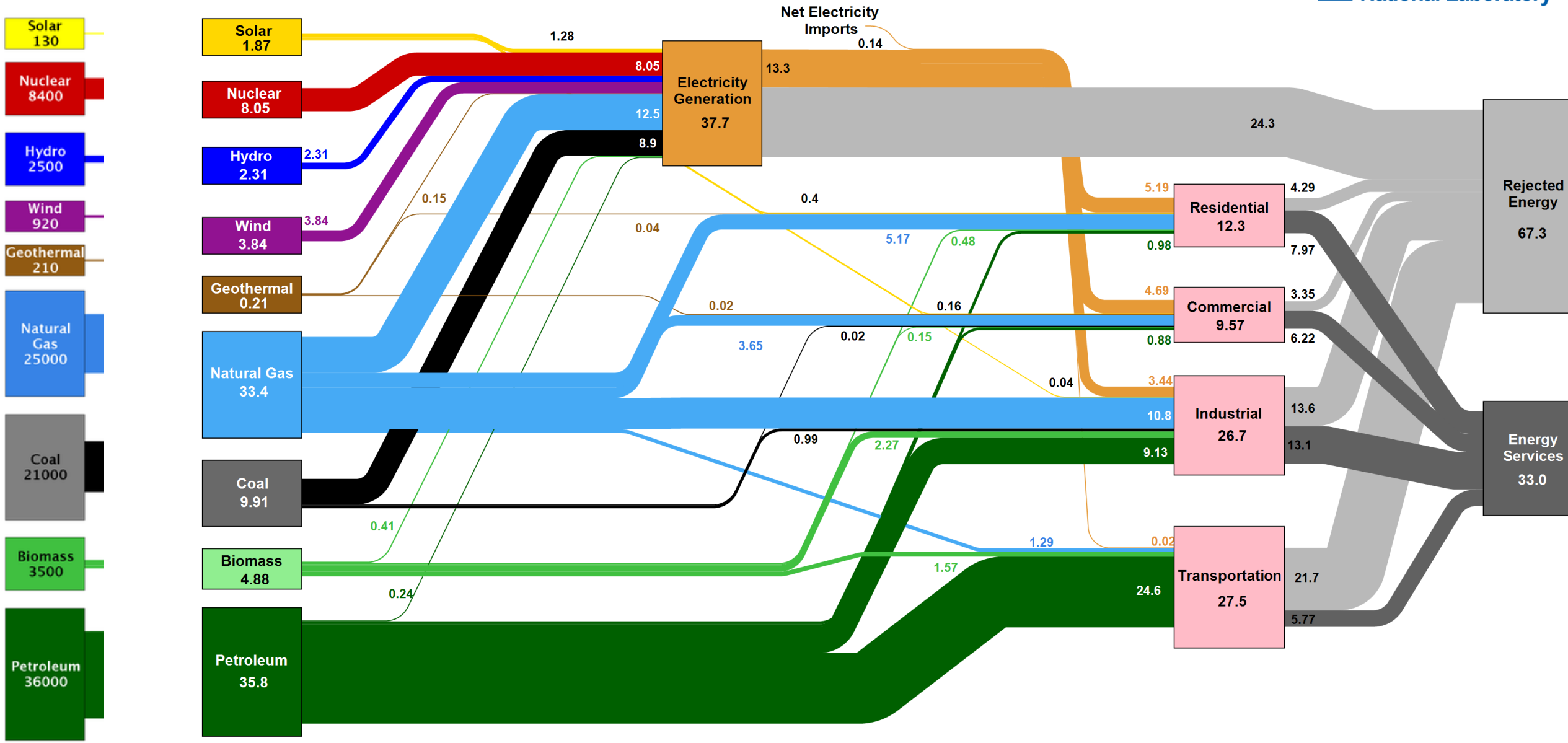
Status Quo: Fossil Fuels

- 80% of primary energy
- 21 billion tons of fossil fuels every year!!
- Non-renewable
- Very inefficient
- Do we need to replace this?

2010

Estimated U.S. Energy Consumption in 2022: 100.3 Quads

Lawrence Livermore National Laboratory

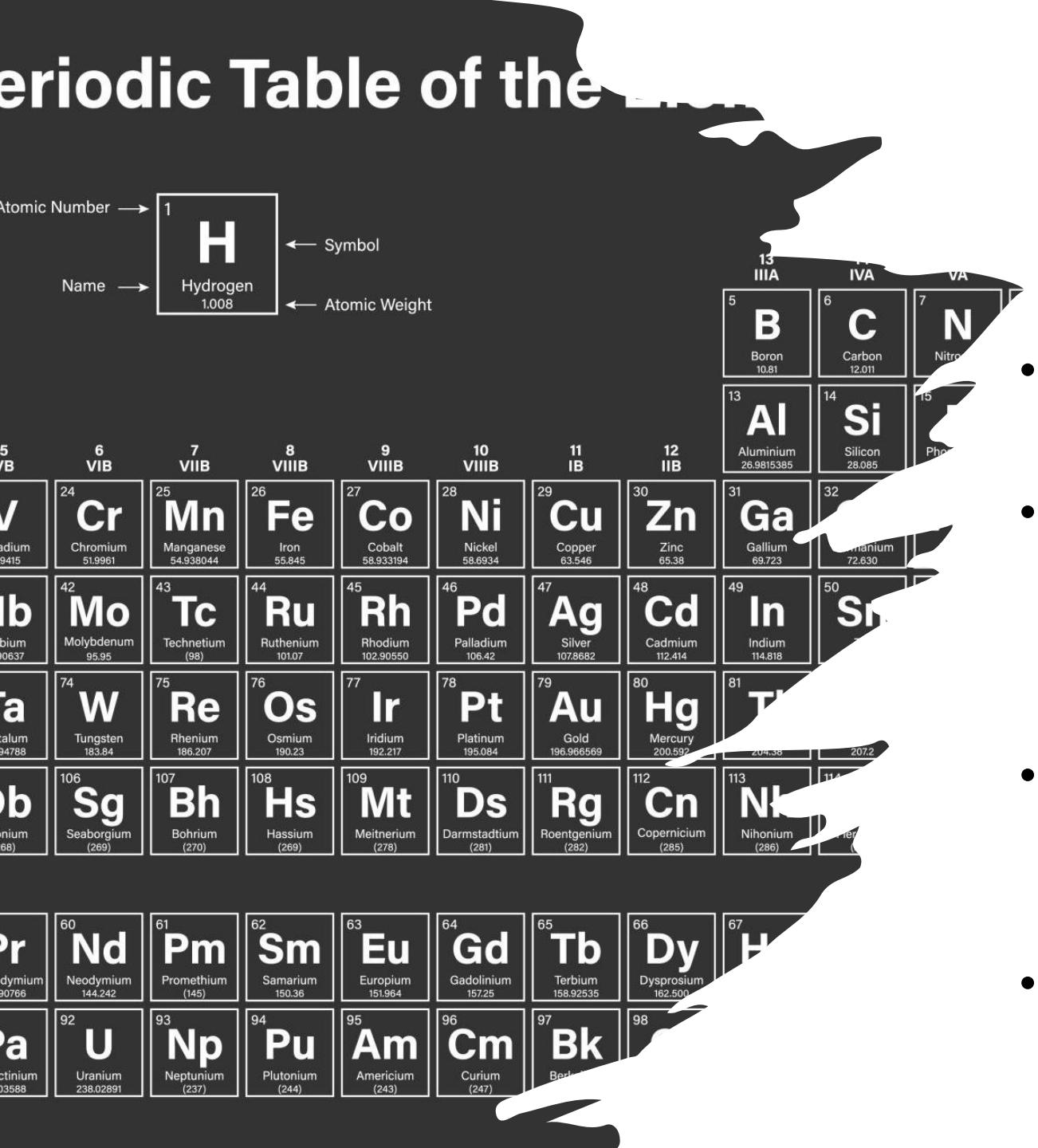


“We don’t have enough rare earths”

- Rare earths mainly used in permanent magnets
  - Used in EV motors (windmills)
- ICE vehicles have up to a dozen electric “motors”
  - Starter, Alternator
  - Wipers, Fans, Windows, Locks, etc.
- Catalytic converters
  - platinum, palladium, rhodium

“We don’t have enough rare earths”

- Lithium is not a rare earth
  - Confusion about child labour
- Rare earths are expensive
- Electric motor types
  - Permanent magnet
  - Induction – requires no rare earths
- Tesla (and others) – permanent magnets *without* rare earths
- We don’t need rare earths for EV motors
- Expensive – find alternatives



“We don’t have enough minerals”

- Nickel, Manganese, Cobalt (NMC)
  - Nickel and Cobalt expensive
- Lithium, Iron, Phosphate (LFP)
  - Iron and phosphate are cheap and abundant
  - Lithium expensive
- Sodium-ion
  - Sodium is cheap and abundant
  - Aluminium separator
- There is plenty of lithium, but sodium will *always* be cheaper
  - Processing sodium better for environment

All the Metals We Mined

IN ONE CHART

Total Metals 3,248,814,334 tonnes

Metals are the building blocks of the global economy, From iron ore to rare earths, here are all the metals we mined in 2019.

Metals vs. Ores

Ores are naturally occurring rocks that contain metals or metal compounds.

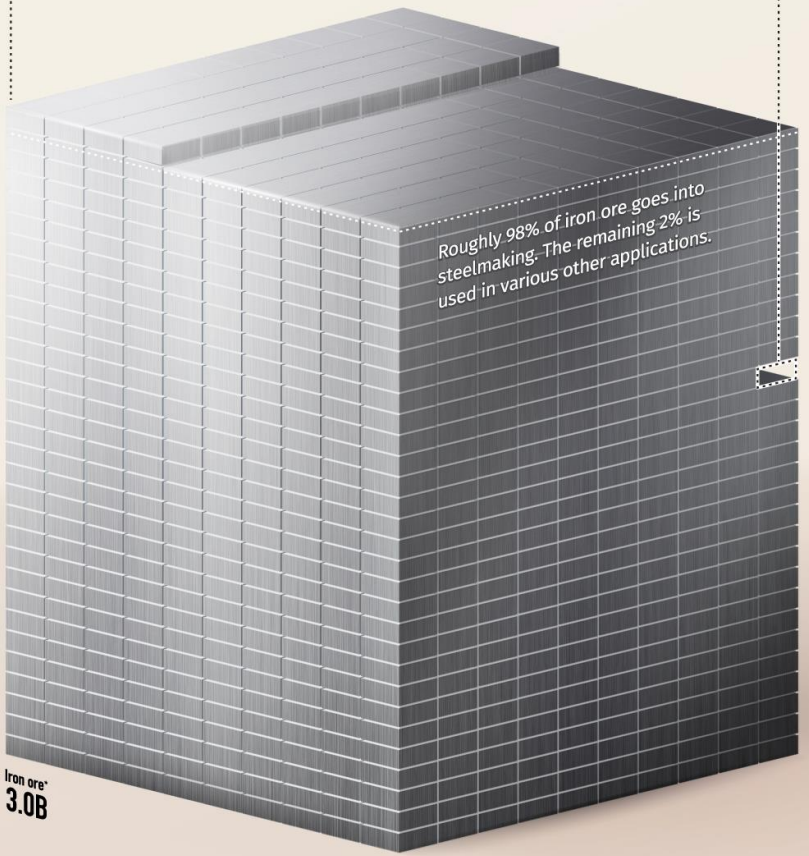
Metals are the valuable parts of ores that can be extracted and sold.

Iron ore*

3,040,000,000 tonnes

Iron ore made up roughly 94% of the 3.2 billion tonnes of metals mined in 2019.

= 1,000,000 tonnes



Industrial metals

207,478,486 tonnes

Aluminum is the world's second-most used metal after iron, found in everything from electronic devices to aircraft parts.

Copper production is one-third that of aluminum, though it has several uses ranging from wiring to construction.

Manganese is mainly used in iron and steel manufacturing and is a key ingredient in lithium-ion batteries.

Chromium enhances the hardenability and corrosion resistance of stainless steel.

Tech and precious metals

1,335,848 tonnes

Niobium is a rare metal used in superalloys for jet and rocket engines.

Lithium and cobalt are critical ingredients of lithium-ion batteries for electric vehicles.

Indium is used to make indium tin oxide, an important part of touch screens, TVs, and solar panels.

ELEMENTS
elements.visualcapitalist.com

The Earth's natural resources power our everyday lives. VC Elements breaks down the building blocks of the universe.

Source: *British Geological Survey (2019), USGS Mineral Commodity Summaries (2021)*

**Ore production does not reflect actual metal production as metals only make up a certain portion of ores. Graphic excludes semi-metals and metalloids. Hafnium is contained in Zircon.*

We live in a material world.

Minerals in Perspective

- Rare earths
  - Technology “need”
  - Cost/benefit tradeoff
- All have substitutes that are more abundant and less expensive
  - Aluminium
  - Iron
  - Sodium
- “If you want your product to be as cheap as dirt, use dirt to make the product” – Dr Donald Sadoway, MIT
- IRA and R&D

Table 2. Comparison of cumulative 2020–2050 power sector generation infrastructure material demand to current estimates of existing reserves and resources for each material of interest

	Units	1.5°C cumulative demand, 2020–2050	2°C cumulative demand, 2020–2050	Estimated reserves	Estimated resources
Aluminum	Mt	241 (110–380)	141 (58.4–310)	30,000	75,000
Cement	Mt	1,300 (683–2,050)	1,120 (562–1,820)	N/A	N/A
Copper	Mt	81.8 (40.8–109)	49.5 (23.7–100)	880	3,500
Fiberglass	Mt	69.5 (22.5–99.6)	37.7 (15.4–135)	N/A	N/A
Glass	Mt	446 (234–756)	280 (113–525)	N/A	N/A
Manganese	Mt	0.892 (0.167–7.60)	1.26 (0.155–44.9)	150	1,730
Nickel	Mt	3.80 (1.11–4.70)	2.13 (0.901–6.28)	95	300
Solar-grade polysilicon	Mt	22.5 (7.21–48.9)	11.8 (3.45–33.2)	N/A	N/A
Steel	Mt	1,960 (1,100–2,950)	1,330 (724–3,360)	N/A	N/A
Cadmium	T	37,700 (13,700–82,300)	20,000 (6,410–55,000)	500,000	6,000,000
Dysprosium	T	87,200 (32,900–159,000)	53,400 (22,000–203,000)	1,100,000	1,980,000
Gallium	T	771 (312–1,470)	414 (146–1,060)	110,000	1,000,000
Indium	T	2,280 (976–4,430)	1,230 (454–3,090)	15,000	47,000
Neodymium	T	929,000 (360,000–1,390,000)	546,000 (251,000–1,890,000)	12,800,000	23,000,000
Selenium	T	10,100 (3,310–23,800)	5,350 (1,570–15,600)	100,000	171,000
Silver	T	67,600 (36,900–106,000)	45,100 (19,300–79,100)	530,000	1,310,000
Tellurium	T	42,300 (14,600–95,900)	22,300 (6,730–63,700)	31,000	48,000

Cumulative demand values are expressed as median cumulative demand (2.5th percentile value to 97.5th percentile value) for each material under 1.5°C end-of-century warming scenarios and 2°C end-of-century warming scenarios. t, metric tons; Mt, million metric tons.

Transition Ancillary Benefits

- 15% of energy is used for fossil fuel production
- 30% of ships/40% shipping emissions from fossil fuels
- Heat pumps can use clean electricity
- Ships, refineries, pipelines need steel and concrete
- In Canada, 25-30% of emissions from fossil fuel production
- Less air pollution

Mark Jacobson - Stanford

- Source: Can We Rapidly Move to 100% Renewables? - Interview with Stanford's Mark Jacobson – YouTube
- “fossil fuels cause two orders of magnitude more mining than we will need for a renewable infrastructure”
- Need about 1% of materials than needed for FF infrastructure
- For every one ton of lithium, we extract 50,000 tons of oil and 100,000 tons of coal
- 50,000 new oil and gas wells every year in NA alone
- 1.3 million active wells
- 3.2 million abandoned wells
- 1.3% of land area in US and growing used by FF production
- Only 1% of US land needed for full renewable system
- Mines will be 100% renewable

“We don’t have enough materials/minerals”

- We need 28-40 **million** tons of critical materials for transition
  - recyclable
- We mine 21 **billion** tons of fossil fuels every year
  - Non-renewable
- We need much less materials than people are led to believe
  - Have enough
  - Can substitute

What Drives Electrification?

- At first it was GHG emissions
  - Government regulation/incentives
  - Getting the cost curve down
- Economics is the new driver
  - Total cost of ownership for EVs
  - Solar, wind and batteries – cheapest electricity
  - Already rapid transition to renewables
- Cost of renewables continues to drop
- Cost of fossil fuels continue to increase
- -> Transition will accelerate

F150 Real World Example

- Ford F150 Lightning 2023 with the extended range battery
- 910km in NFLD
- Total time DCFC charging: 4hrs 5 minutes
  - Assume only waiting for charge
    - No bio or meal break
  - Charging was slow at about 50kW – F150 supports 150kW
- Cost of electricity ~$60.00.
  - Home charging closer to $18.00

F150 Real World Example

- Compare this to ~$260 for the same trip in a gas-powered pickup
- Savings of $200 or $50/hour after taxes
  - Equivalent to ~$75/hour before taxes
  - Avg wages for truck driver is $26.86/hour in Canada
  - Faster charging would significantly increase – 3x
    - $150/hr…assuming you are stopping for anything else
- Similar, but larger numbers will drive HD electrification

Heavy-Duty Transport

- Charging time seen as obstacle – time is money
- Charging is dependent on individual cells
  - C-rate – ratio of current to capacity – higher is better
  - 20-40 minutes is typical charge time
  - Expected to get faster – 5C – 12 min for full charge
  - Diesel fueling takes 10-15 minutes
- Larger batteries have more cells
  - Charging time unaffected
  - Heavy-duty charge in 20-40 minutes
  - Europe – “Breaks of at least 45 minutes should be taken after 4 ½ hours at the latest”
- Charger capacity is the limit

Heavy-Duty Transport

- More powerful chargers are needed
  - Megawatt level in development
  - Projects underway
  - Slower nighttime charging is an option
- Saving ~2-10x more
  - Faster charging and more “fuel”
  - More than offsets cost of waiting for charge
  - Ex:
    - F150 example – 4 hours to charge and save $200
    - 4x bigger battery – 4 times more energy – save $800
    - Faster charging – two charges for 1 hour total
    - One hour of wait time for $800 saving…
  - Economics will drive rapid electrification

VOLVO

4X2 STRAIGHT TRUCK | 6X4 STRAIGHT TRUCK | 4X2 TRACTOR | 6X2 TRACTOR | 6X4 TRACTOR

6x4 Tractor Our 6x4, 6 battery offering can cover up to 275 miles on a single charge.

Transport – Light Duty

EXXONMOBIL AT THE CROSSROADS

Every new passenger car sold in the world will be electric by 2040, says Exxon Mobil CEO Darren Woods

PUBLISHED SAT, JUN 25 2022•7:05 AM EDT

Lindsey Jacobson
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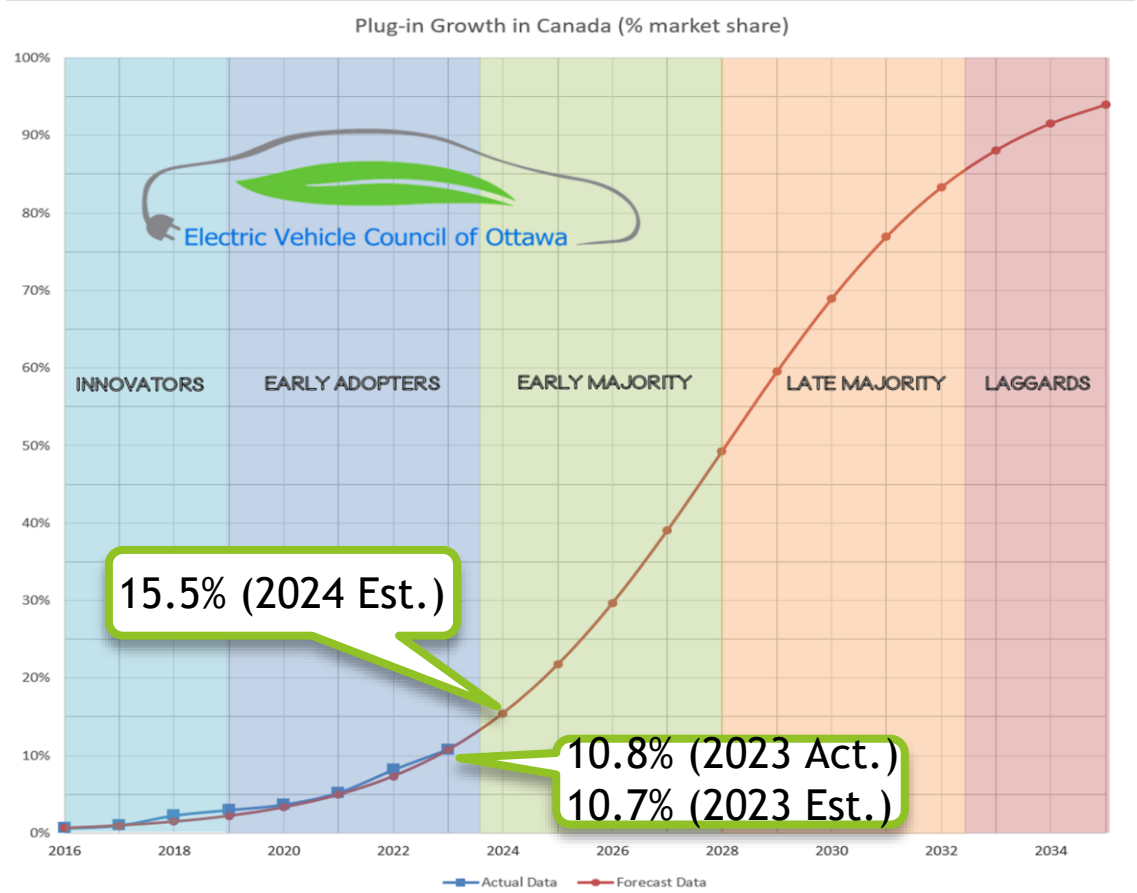
@LINDSEYTWEETED

SHARE

- He is arguing against his self-interest…likely true statement
- Actually, it's likely to happen before 2035



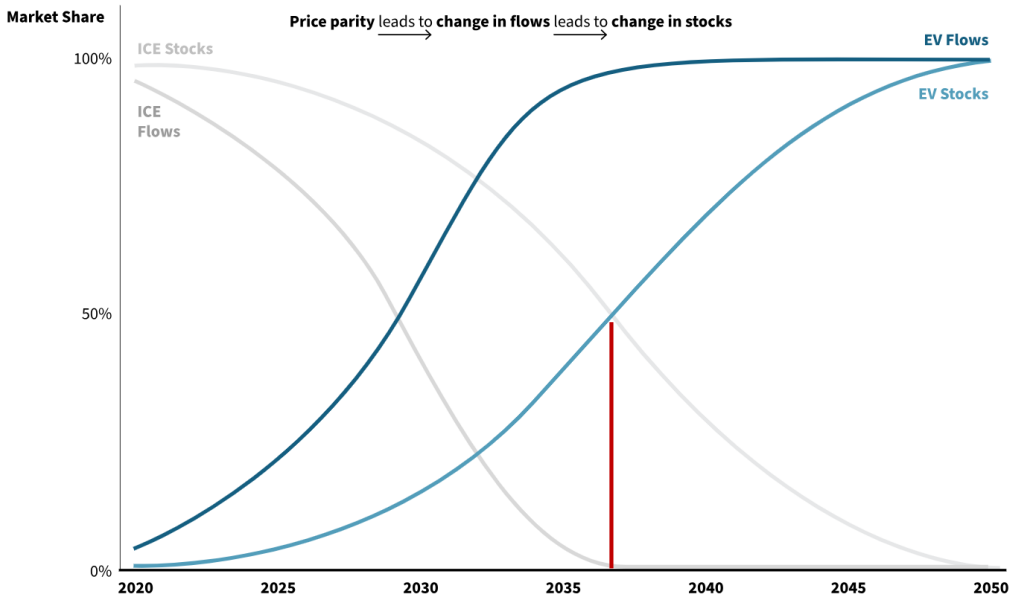
EV Slowdown? Sales Are Just Getting Started!

- The idea that EV sales are in decline has been widely reported and taken as fact by many media outlets and the public.
- The fact is the plug-in market GREW last year 49.38% beating the 43.62% growth rate from last year.
- Not only were more EVs sold last year than ever before but the rate of that growth has also increased.
- 10.8% of all new vehicles sold in 2023 were plug-in models.
- 184,578 new plug-ins hit the road last year out of 1.7 million new vehicles in Canada.

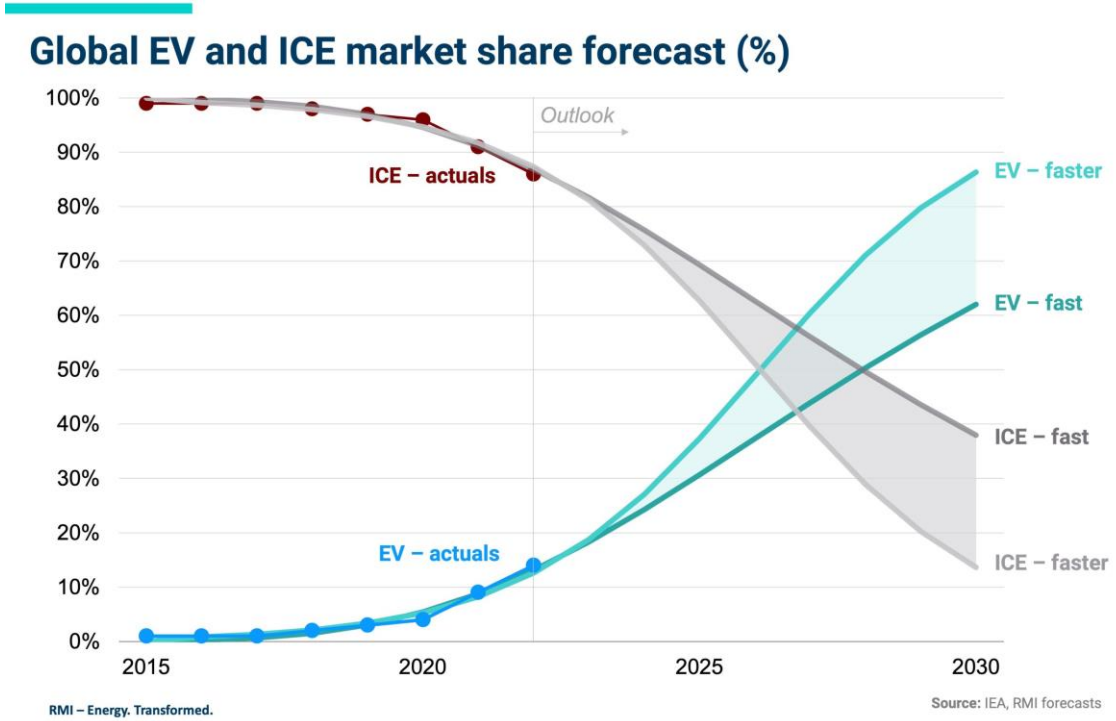
EV vs ICE

- China is expected to see 90% EV market share by 2030.
- The EU is expected to be close behind with 80% EV market share by 2030
- RMI expects the US to be around 50% market share by that date
- EVCO prediction for Canadian EV market share in 2030 is 70%

Exhibit 7: Market share of flows and stocks in the global car sector



Source: BNEF NZE scenario



How fast can the transition happen?

- You saw the forecasts for EVs
  - Zero to 100% takes about 10 years
  - China – more than 50% of new registrations are “NEV”
  - Commercial EVs likely to transition faster
    - Cost is the driver
    - Charging time doesn’t matter when you save that much on fuel and maintenance
- Cheap solar and wind are revolutionizing the energy sector
  - Batteries are helping too
- Forecasting such rapid change is “hard” and risky
  - EVCO forecast – are you guys out of your mind?
  - How come it’s better than BNEF and IEA?

How fast can the transition happen?

- China's emissions likely to have peaked in 2023
  - 7 years earlier than commitment in Paris 9 years ago
  - Renewable deployments continue to accelerate
  - China has glut of PV prod capacity
- The transition will happen faster than people think

What is fast enough?

- There is no specific date or temperature that is a hurdle
  - Faster is better
  - Lower temperature is better
- Tipping points are a concern
  - Could cause rapid change
  - AMOC – Atlantic meridional overturning circulation
    - Has already slowed down significantly
- Accelerate transition as much as possible

Stopping Emissions is not Enough

Addressing, slowing, or arresting emissions is **necessary, but insufficient**. If you are traveling down the wrong road, you are still on the wrong road if you slow down. The **only goal** that makes sense for humanity is to **reverse global warming**

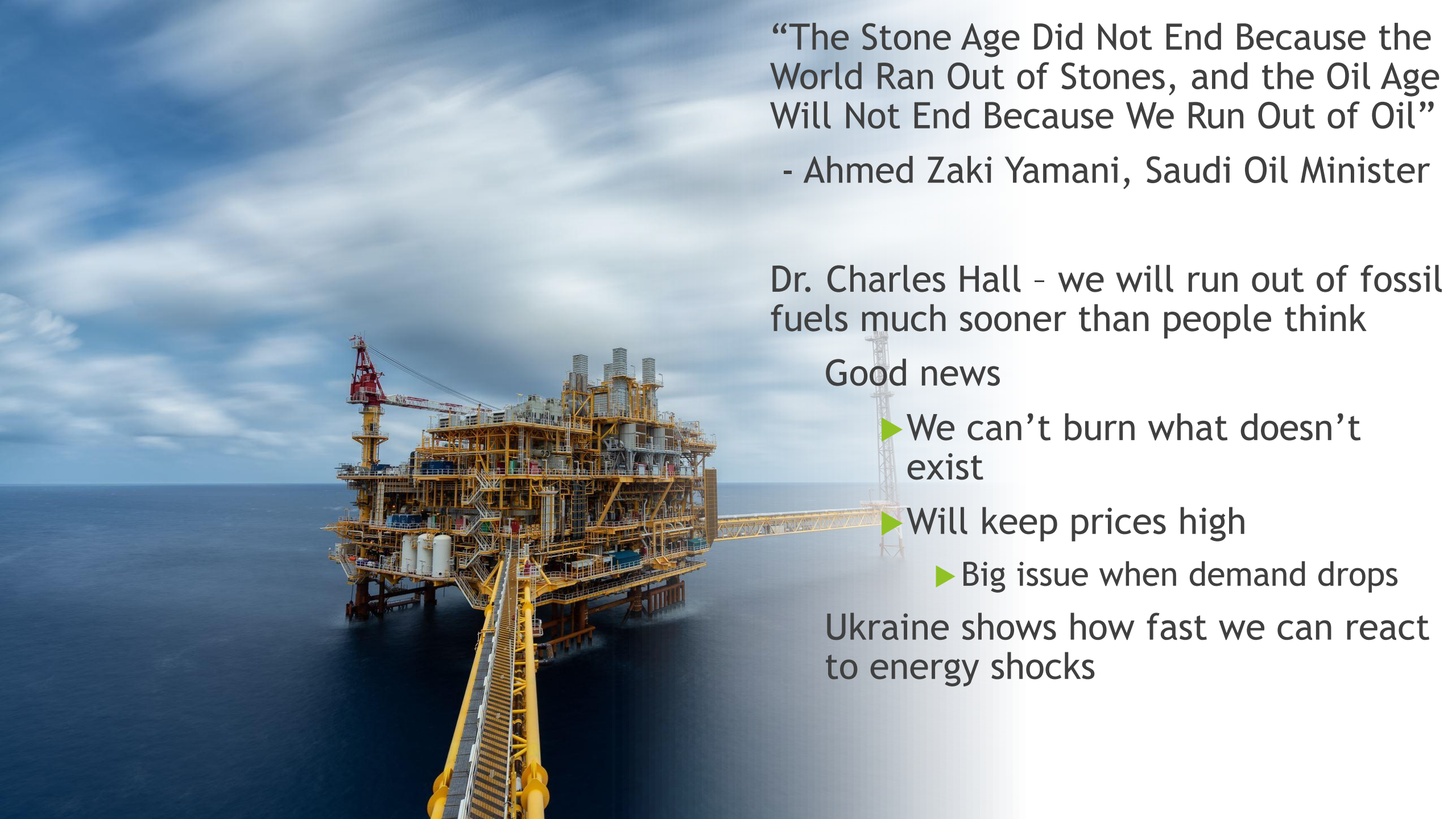
Hawken, Paul. Drawdown: The Most Comprehensive Plan Ever Proposed to Reverse Global Warming

-> Natural processes will help

-> We need some form of CCUS

Summary

- We need to get on with the transition
  - Take action!
  - Lots of low hanging fruit
  - Stop wasting money on solutions we know won't work
    - H2 for transport and energy
- Governments focus on making cleantech economically viable
  - Scaling to get to economics of Wright's Law
  - CCUS that produces useful product
- Some people are tying to slow down
  - Alberta renewables



"The Stone Age Did Not End Because the World Ran Out of Stones, and the Oil Age Will Not End Because We Run Out of Oil"

- Ahmed Zaki Yamani, Saudi Oil Minister

Dr. Charles Hall – we will run out of fossil fuels much sooner than people think

Good news

- We can't burn what doesn't exist
- Will keep prices high
  - Big issue when demand drops

Ukraine shows how fast we can react to energy shocks