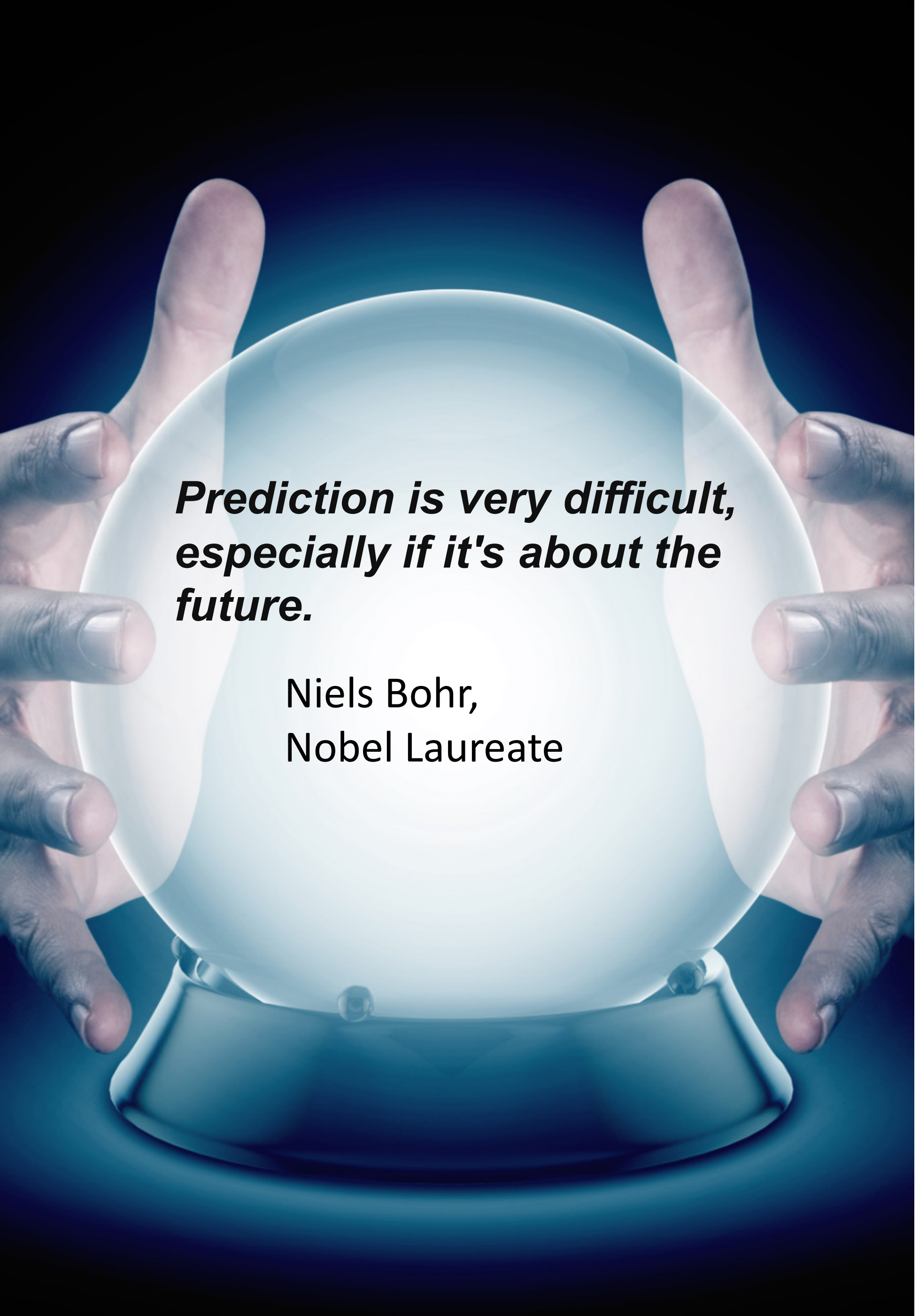


https://www.hgar.com/event/clearing-a-cloudy-crystal-ball-20200618

Energy Transitioning: Key Considerations

Jim Wimberly
Energy Security Partners, LLC
September 2021

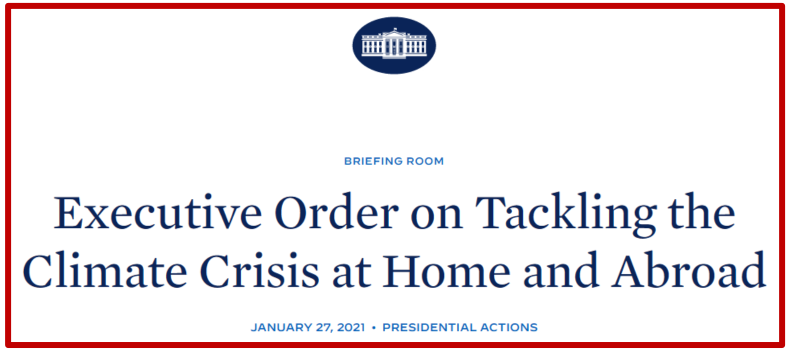
ESP ENERGY SECURITY PARTNERS

GTL AMERICAS

What does *Energy Transition* mean?

- The entire energy sector is under intense pressure to decarbonize… rapidly
  - To reduce greenhouse gas emissions (GHGs) and, in turn, global warming
  - Sentiments appear to be driven by concerns of catastrophic changes
- Two key strategies currently being promoted:
  - Transition to zero-carbon electricity generation
    - 100% decarbonization of the electricity sector by 2035
  - Transition to electric vehicles
    - 50% of new LDV sales to be EVs by 2030
- Key questions
  - Are these the right strategies?
  - Are these timeframes realistic?
  - What are the anticipated results?
  - What are some key considerations?

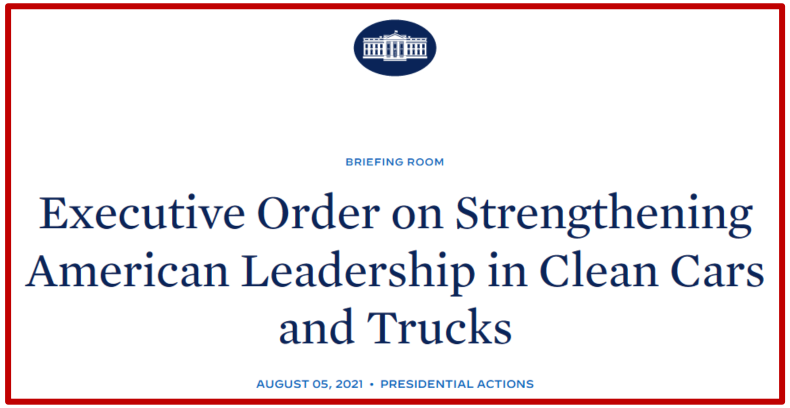
- Let's start with an overview of the energy sector



BRIEFING ROOM

Executive Order on Tackling the Climate Crisis at Home and Abroad

JANUARY 27, 2021 • PRESIDENTIAL ACTIONS



BRIEFING ROOM

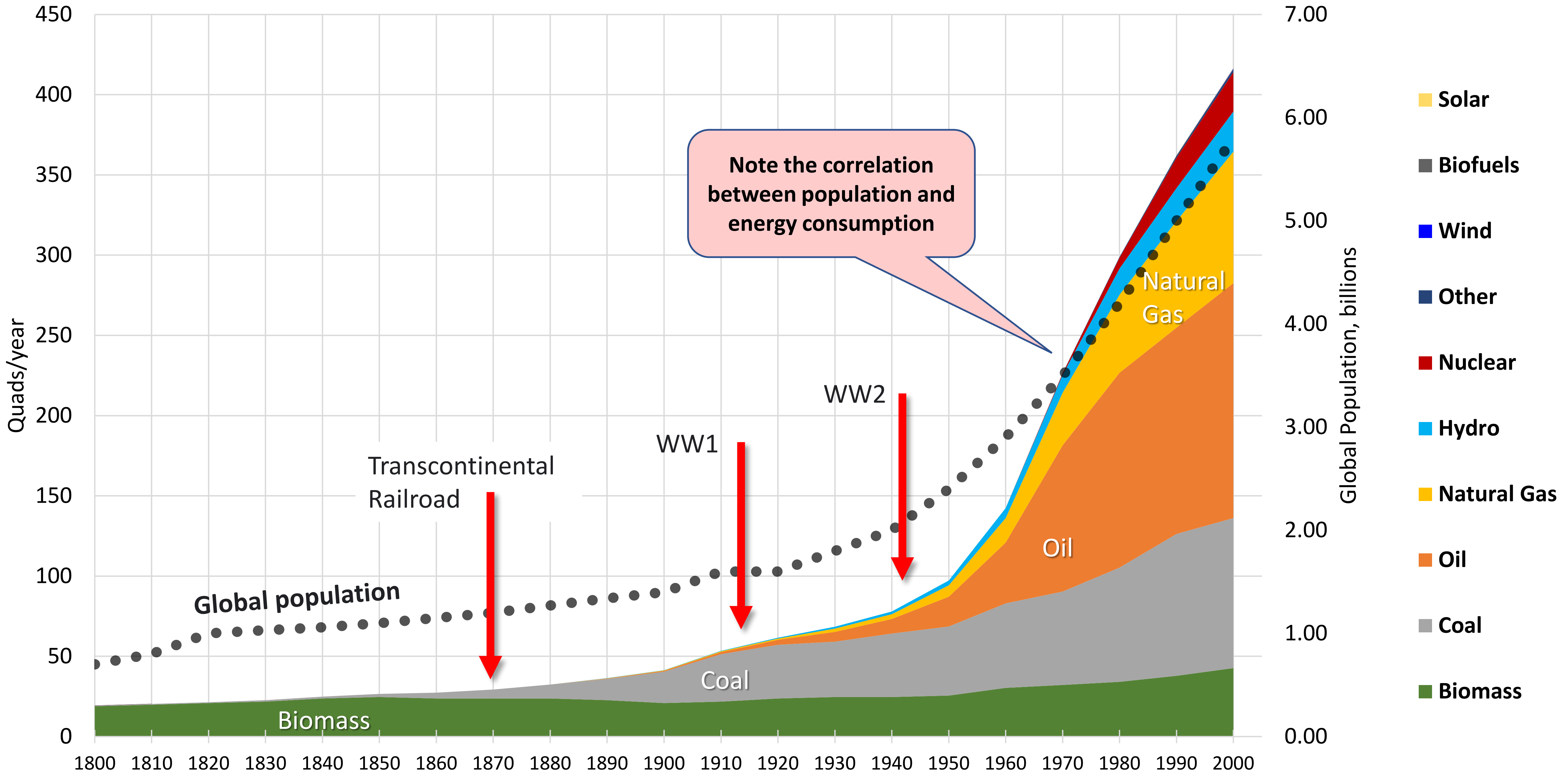
Executive Order on Strengthening American Leadership in Clean Cars and Trucks

AUGUST 05, 2021 • PRESIDENTIAL ACTIONS

www.slashgear.com

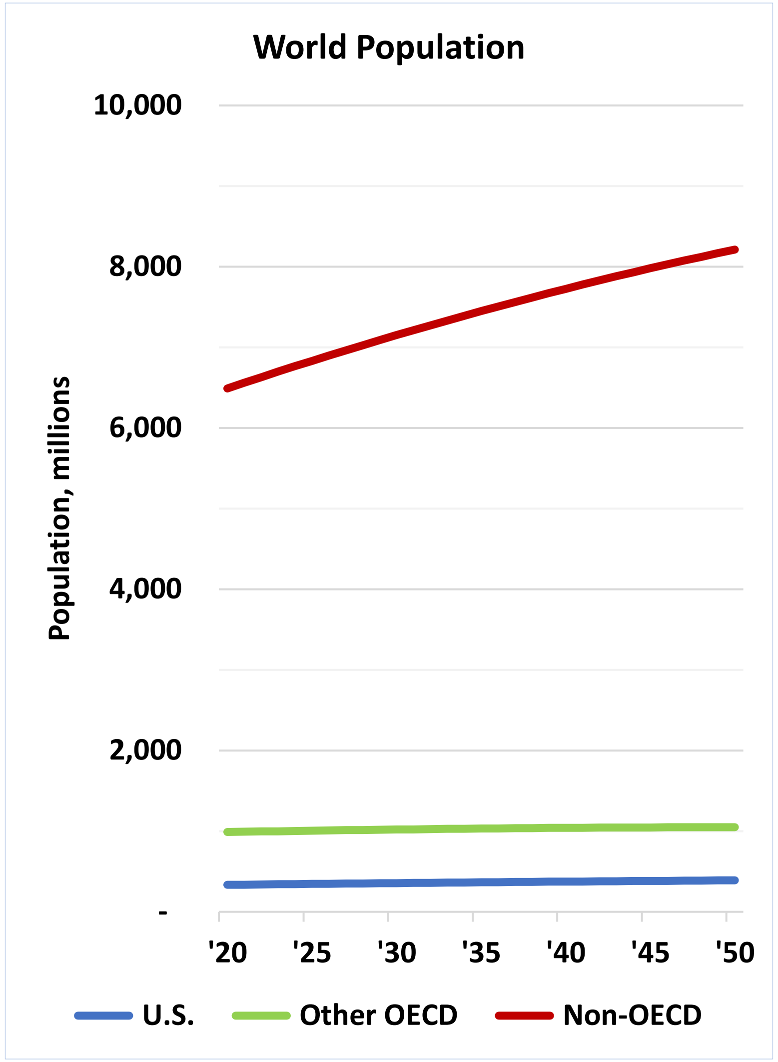
Global Energy Consumption: 1800 - 2000

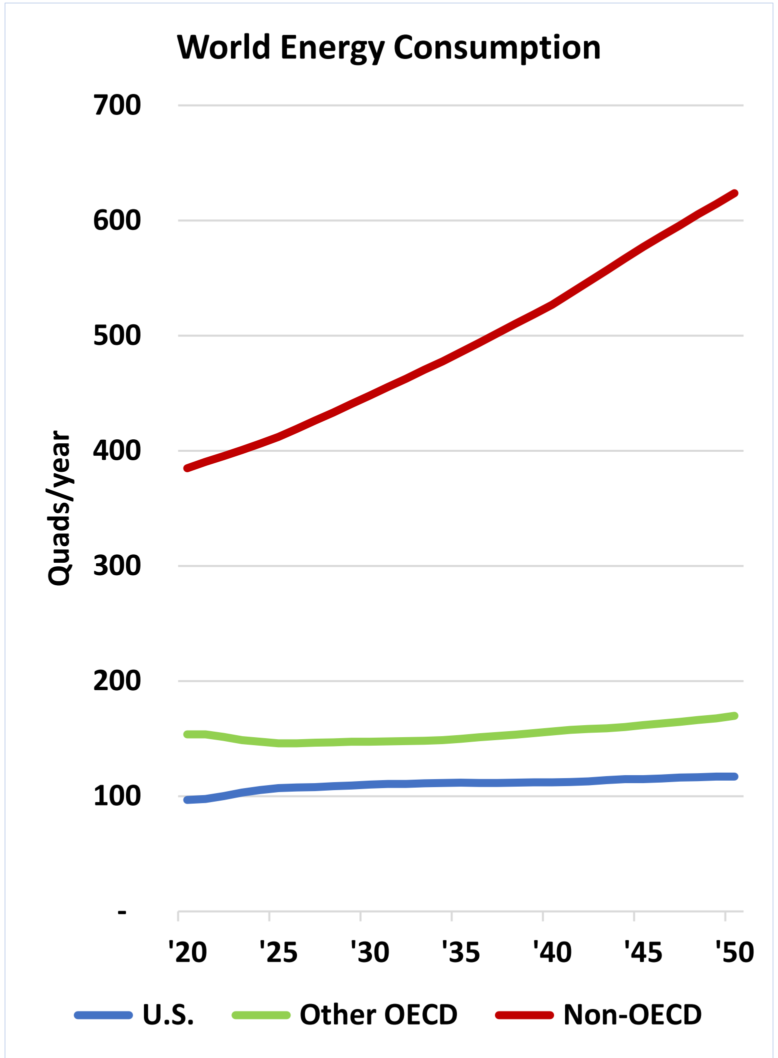
Data source: Our World in Data

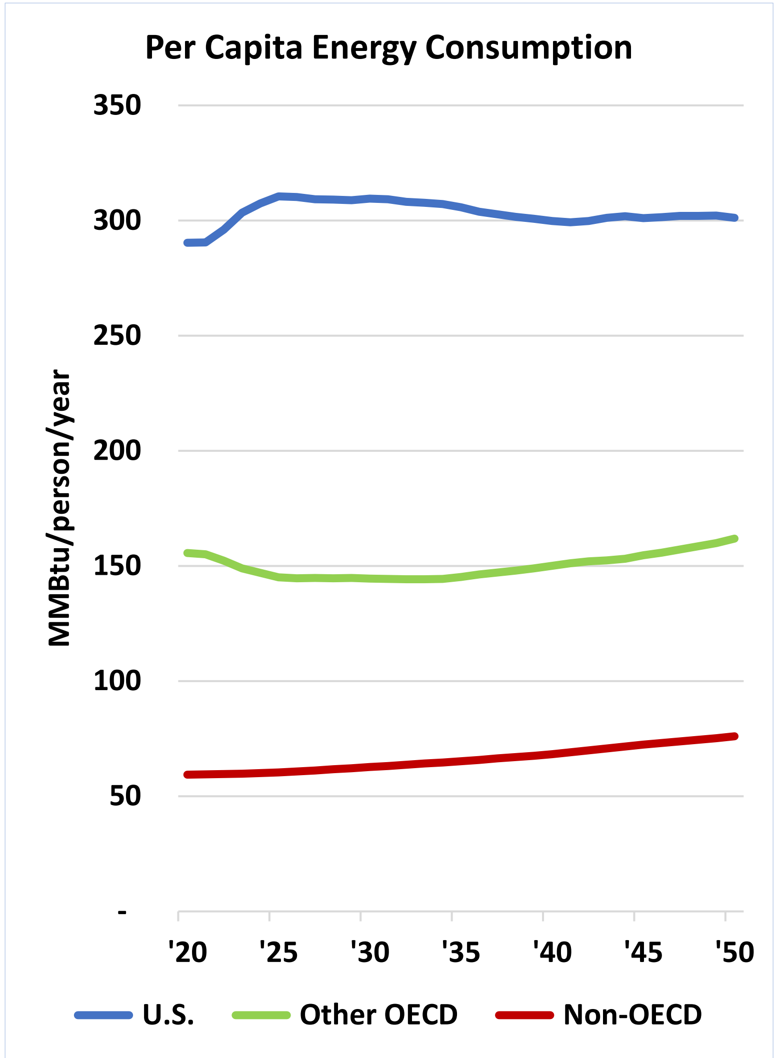


Global Energy Consumption: 2020 - 2050

Data source: International Energy Outlook 2020





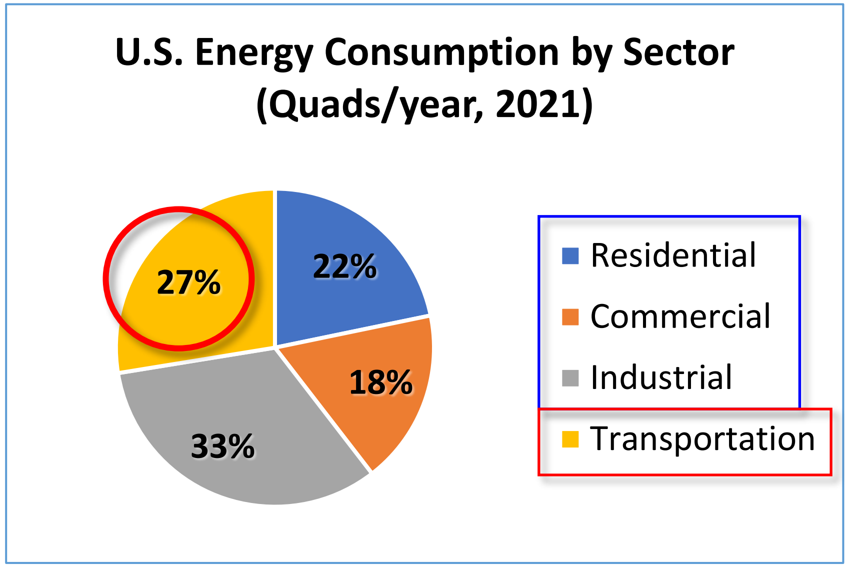


OECD = Organization for Economic Co-operation and Development

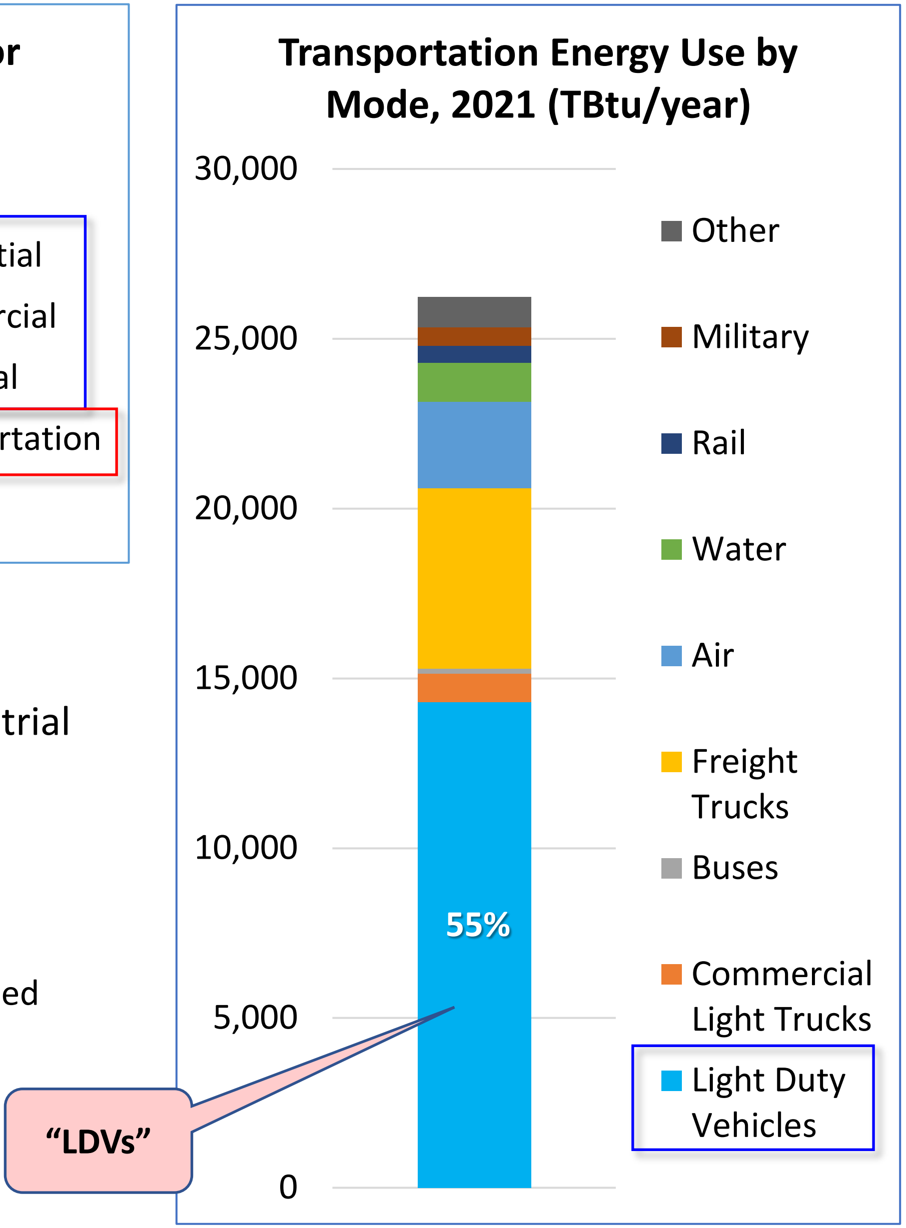
- ✓ United States & Canada
- ✓ Europe & U.K.
- ✓ Israel
- ✓ Australia & N.Z.
- ✓ Japan
- ✓ Korea
- ✓ Mexico, Costa Rica
- ✓ Chile, Columbia

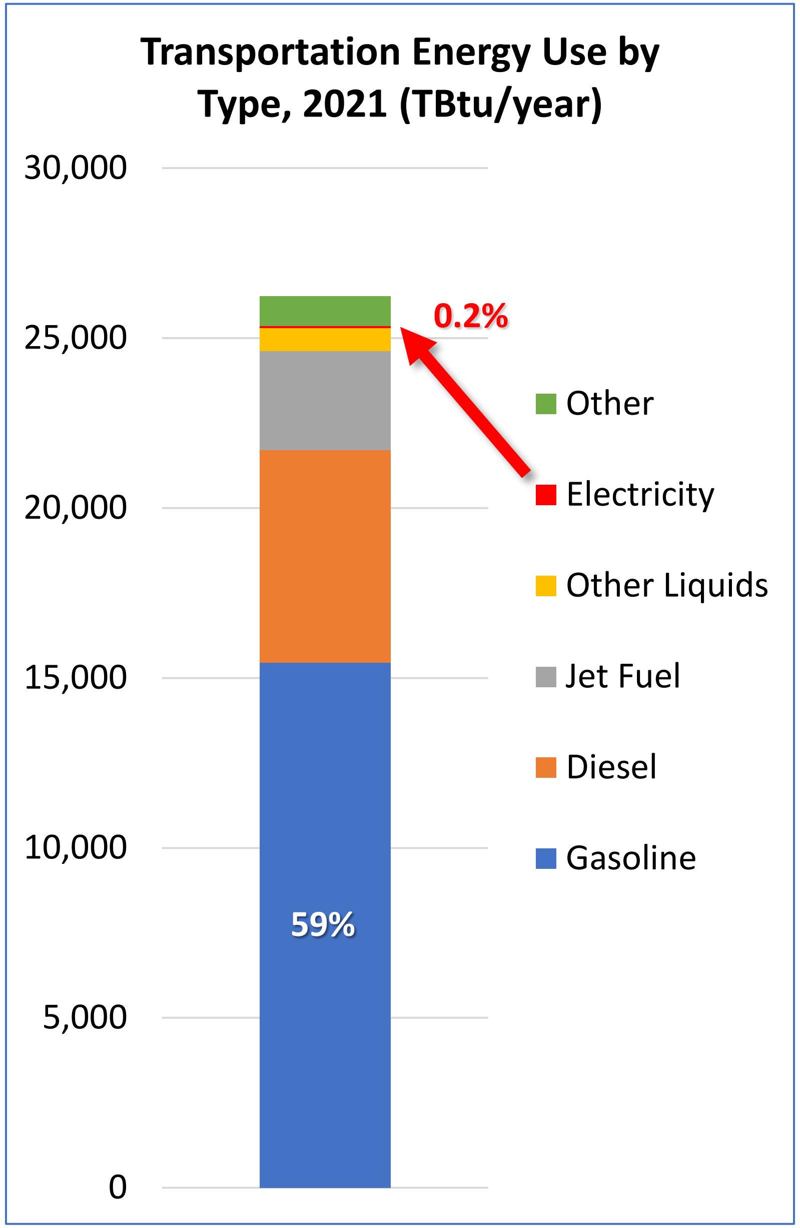
Energy Consumption in the U.S.

Data source: eia Annual Energy Outlook 2021 Reference Case



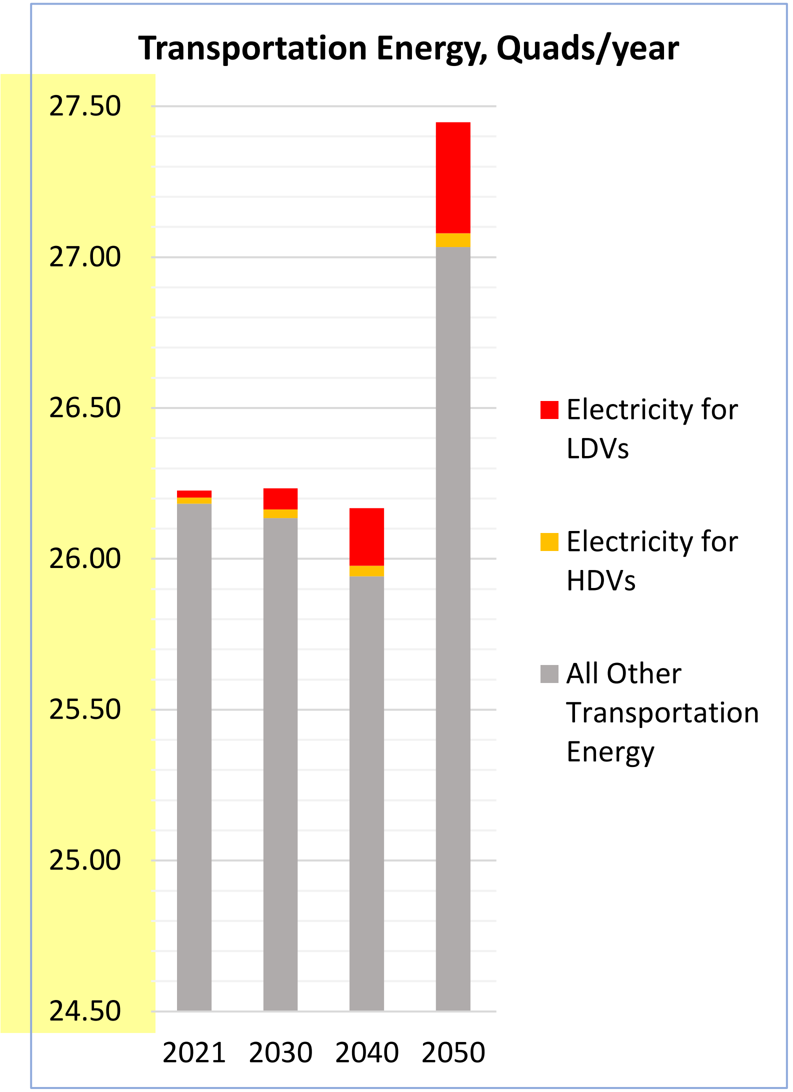
- Stationary energy consumption
  - Residential, Commercial, & Industrial
- Transportation sector
  - Transport of people and goods
  - Requires mobile forms of energy
    - ✓ We haul around the energy needed
    - ✓ And consume it as we go
  - Energy density is critical
    - ✓ Diesel ≈ 70x > Li-ion batteries



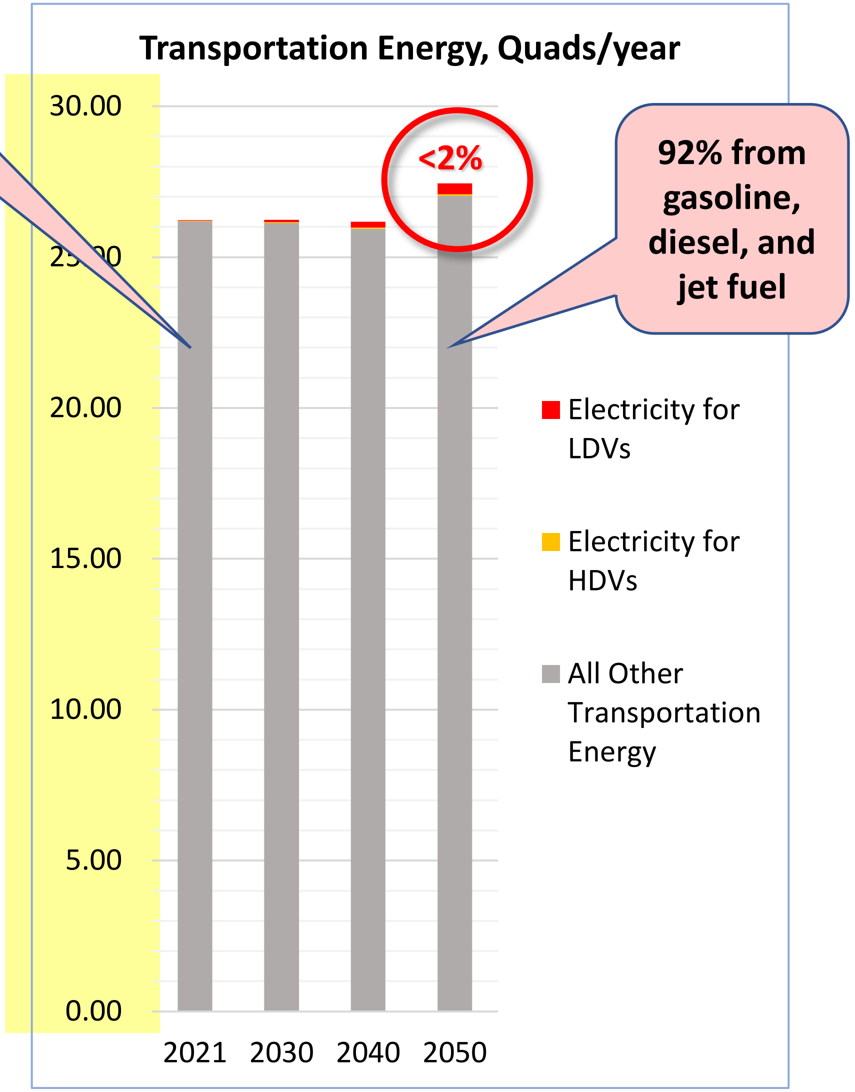


Forecasted Transportation Energy Consumption

Data source: eia Annual Energy Outlook 2021 Reference Case



Same data, but with “normal” Y-axis values



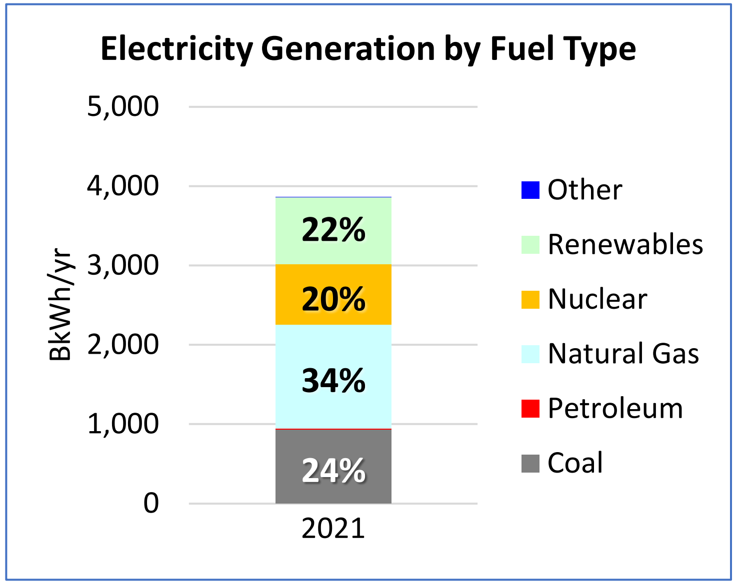
U.S. Energy Consumption & GHG Emissions

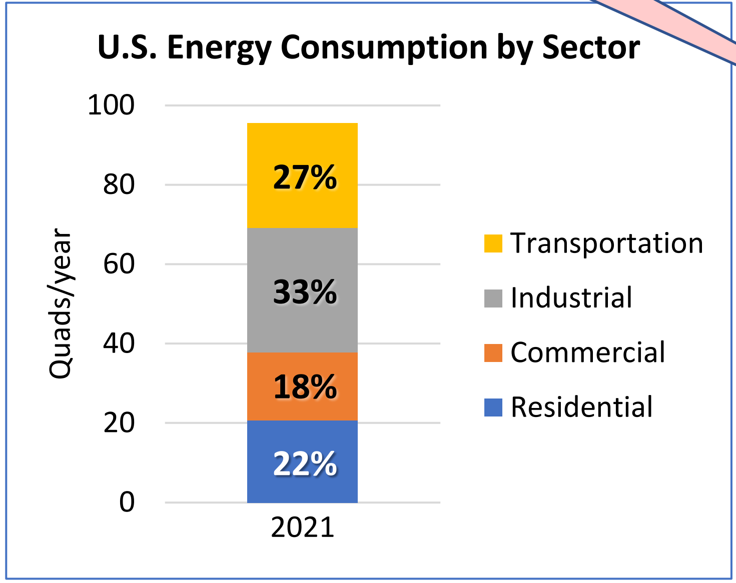
- Consider the amounts of oil & electricity consumed in the U.S.
  - Oil-derived products: 18 MM bbl/day
    - ✓ What's the equivalent capacity of Razorback Stadium?
  - Electricity: 460,000 MWh/hour
    - ✓ The average home in the U.S. consumes **0.0013 MWh/hour**

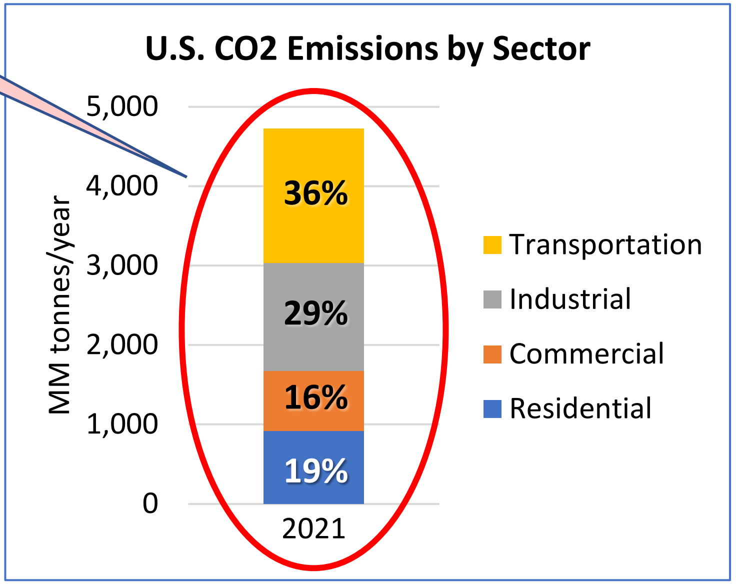
≈ **5 hours**

- GHG emissions
  - **32%** resulting from electricity generation
  - U.S. ≈ 15% of global emissions
  - China ≈ 30% of global emissions

32% from electricity generation







Decarbonization Goals, Transition Strategies, & Key Considerations

Electricity supplies

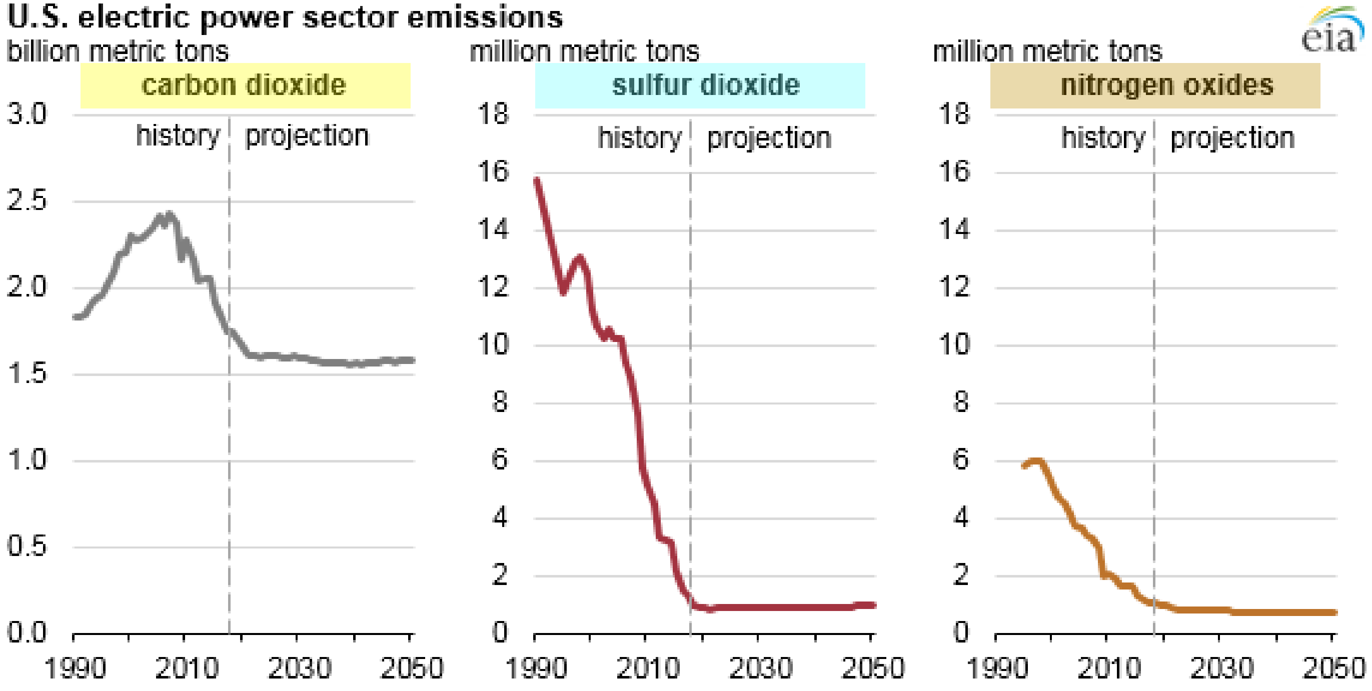
- Goal:
  - Achieve zero net carbon emissions by ~~2035~~ → 2030
- Transition strategies:
  - Increase generation from renewables (wind, solar, hydro)
  - Decarbonize existing coal & natural gas facilities (using CCS?)
  - Increase generation from nuclear ??
- Key considerations:
  - Generation from intermittent resources… back-up options?
    - When the sun's not shining and the wind's not blowing
  - Grid-level impacts?
    - Reliability & resiliency are critical
  - Land use
    - What are the requirements for generating options?
  - Manufacturing supply chains
    - How quickly can they be ramped up? Where?
  - Transmission
    - How many new TLs? Where? When?
  - Resulting reduction in global GHG emissions?
    - What about new coal-fired facilities in China, India, elsewhere?

Switch from ICE to electric vehicles (EVs)

- Goal:
  - 50% of LDV sales to be EVs by 2030
- Transition strategies:
  - ✓ Incentivize consumers to purchase EVs
  - ✓ Subsidize deployment of charging facilities & other infrastructure
  - ✓ Use lower-emissions fuels, improve ICE efficiencies
- Key considerations:
  - ✓ Increasing demand for electricity
    - EVs' emissions reflect grid average EFs (emissions factors)
  - ✓ Consumer acceptance
    - Range anxiety, charging access, charging time, degradation
  - ✓ Battery supply chains
    - Critical minerals (extraction, processing)
    - Battery manufacturing facilities
    - Spent battery recycling
  - Payload impacts
    - A critical consideration for commercial freight transport
  - Resulting reduction in global GHG emissions?
    - How much? Timeframe?

Electricity Supply: Generation Considerations

- How much is a MWh?
  - ≈ 1 month of electricity consumption for a typical U.S. residence
- Electricity Profile: Arkansas
  - Net generation > total retail sales
    - Some electricity is exported
  - Criteria pollutants are also important
    - Recently overshadowed by GHG concerns



https://www.eia.gov/todayinenergy/detail.php?id=38293

Arkansas Electricity Profile 2019

Table 1. 2019 Summary statistics (Arkansas)

Item	Value	Rank
Primary energy source		**Coal**
Net summer capacity (megawatts)	**14,782**	**30**
Electric utilities	13,503	20
IPP & CHP	1,279	42
Net generation (megawatthours)	**64,442,898**	**24**
Electric utilities	57,343,374	18
IPP & CHP	7,099,525	36
Emissions		
Sulfur dioxide (short tons)	52,747	9
Nitrogen oxide (short tons)	24,039	23
Carbon dioxide (thousand metric tons)	32,514	20
Sulfur dioxide (lbs/MWh)	1.6	5
Nitrogen oxide (lbs/MWh)	0.7	25
Carbon dioxide (lbs/MWh)	1,110	17
Total retail sales (megawatthours)	**48,093,032**	**31**

https://www.eia.gov/electricity/state/arkansas/

Electricity Supply: Generation Considerations

- **Zero-carbon generating sources**
  - Intermittent (low capacity factor)
    - ✓ Wind
    - ✓ Solar
  - Base-load (high capacity factor)
    - ✓ Nuclear
- **Capacity factor**
  - The percent of time a generating facility is available **at rated output**
  - Compare two generating sources:
    - Solar:
      - 1,000 MW facility x 8,760 hr/yr x 23% CF = 2.0 MM MWh/year
    - ✓ Nuclear
      - 1,000 MW facility x 8,760 hr/yr x 93% CF = 8.1 MM MWh/year

Installed capacity x **Capacity factor** = **Annual generation**

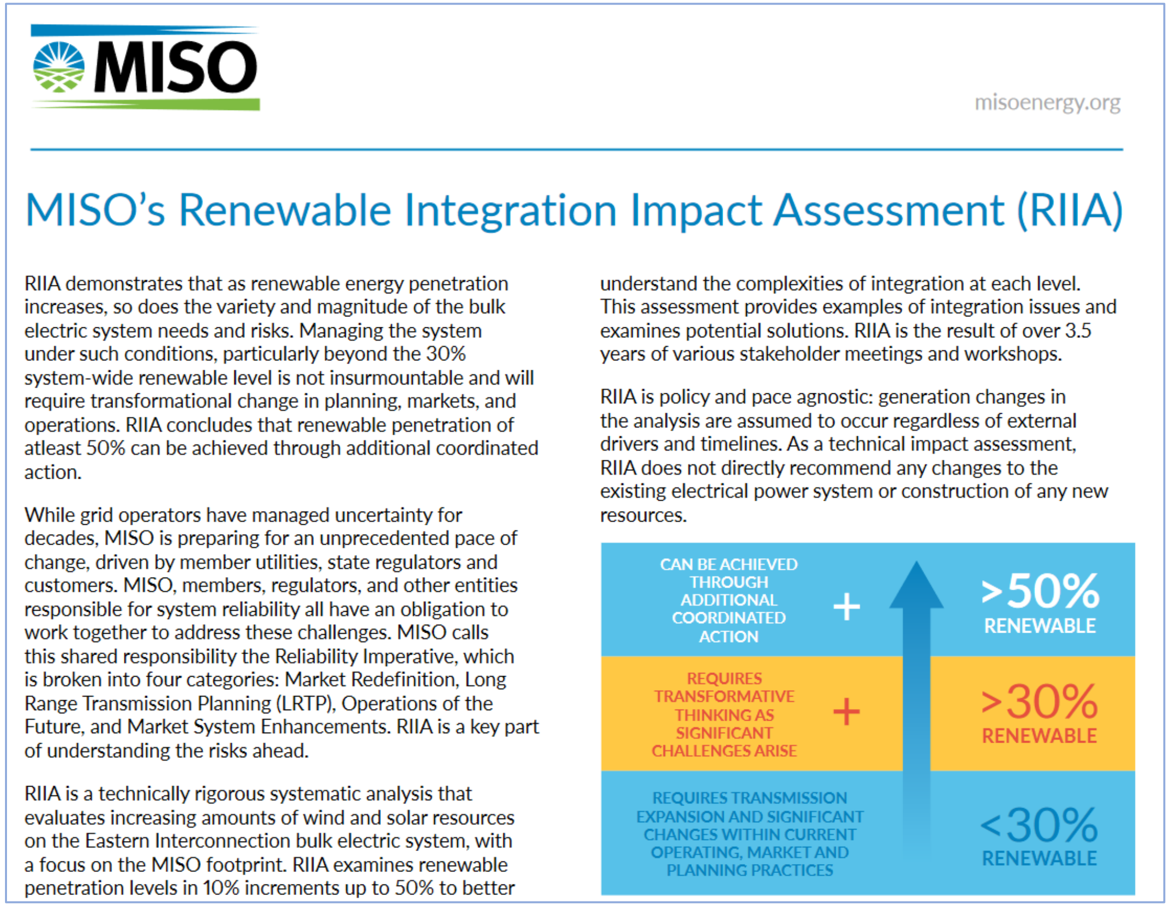
- **Intermittent sources require back-up generating sources**
  - Natural gas has been the most common (NGCT, NGCC)
    - ✓ But the low emissions factors set forth in the CEPP exclude natural gas units (EF limit = 220 lb/MWh)
      - *CEPP = Clean Electricity Performance Program (Sep'21)*

        House Energy & Commerce Committee's Infrastructure Bill
  - Grid-scale battery back-up systems
    - ✓ Design duration? (e.g., 4 hours or 4 days?)
    - ✓ Battery supply chain?
      - Every MWh used for grid applications is a MWh not available for EVs

Electricity Supply: Potential Grid-level Impacts

- A recent study by MISO
  - If intermittent sources exceed 30% of a grid's generation portfolio, then it could result in significant grid management challenges, jeopardizing the grid's **reliability**

- This issue is further underscored in NERC's 2021 Reliability Risk Priorities Report
  - "Changing Resource Mix" is now the **#1 reliability risk** to grids



MISO

misoenergy.org

MISO's Renewable Integration Impact Assessment (RIIA)

RIIA demonstrates that as renewable energy penetration increases, so does the variety and magnitude of the bulk electric system needs and risks. Managing the system under such conditions, particularly beyond the 30% system-wide renewable level is not insurmountable and will require transformational change in planning, markets, and operations. RIIA concludes that renewable penetration of atleast 50% can be achieved through additional coordinated action.

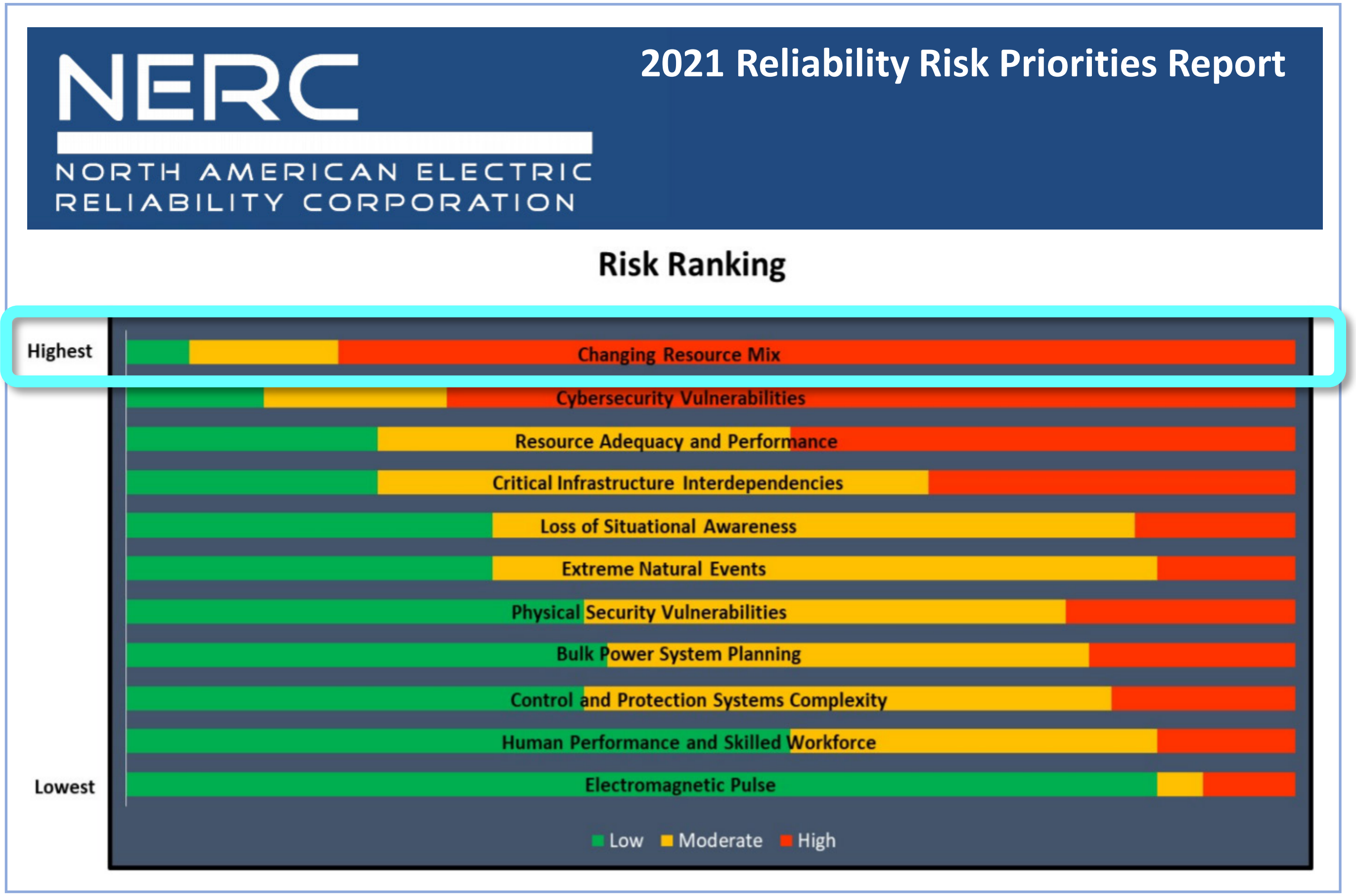
While grid operators have managed uncertainty for decades, MISO is preparing for an unprecedented pace of change, driven by member utilities, state regulators and customers. MISO, members, regulators, and other entities responsible for system reliability all have an obligation to work together to address these challenges. MISO calls this shared responsibility the Reliability Imperative, which is broken into four categories: Market Redefinition, Long Range Transmission Planning (LRTP), Operations of the Future, and Market System Enhancements. RIIA is a key part of understanding the risks ahead.

RIIA is a technically rigorous systematic analysis that evaluates increasing amounts of wind and solar resources on the Eastern Interconnection bulk electric system, with a focus on the MISO footprint. RIIA examines renewable penetration levels in 10% increments up to 50% to better understand the complexities of integration at each level. This assessment provides examples of integration issues and examines potential solutions. RIIA is the result of over 3.5 years of various stakeholder meetings and workshops.

RIIA is policy and pace agnostic: generation changes in the analysis are assumed to occur regardless of external drivers and timelines. As a technical impact assessment, RIIA does not directly recommend any changes to the existing electrical power system or construction of any new resources.

CAN BE ACHIEVED THROUGH ADDITIONAL COORDINATED ACTION +	>50% RENEWABLE
REQUIRES TRANSFORMATIVE THINKING AS SIGNIFICANT CHALLENGES ARISE +	>30% RENEWABLE
REQUIRES TRANSMISSION EXPANSION AND SIGNIFICANT CHANGES WITHIN CURRENT OPERATING, MARKET AND PLANNING PRACTICES	<30% RENEWABLE

https://cdn.misoenergy.org/RIIA%20One%20Pager521869.pdf



https://www.nerc.com/comm/RISC/Documents/RISC%20ERO%20Priorities%20Report_Final_RISC_Approved_July_8_2021_Board_Submitted_Copy.pdf

Electricity Supply: Land Use

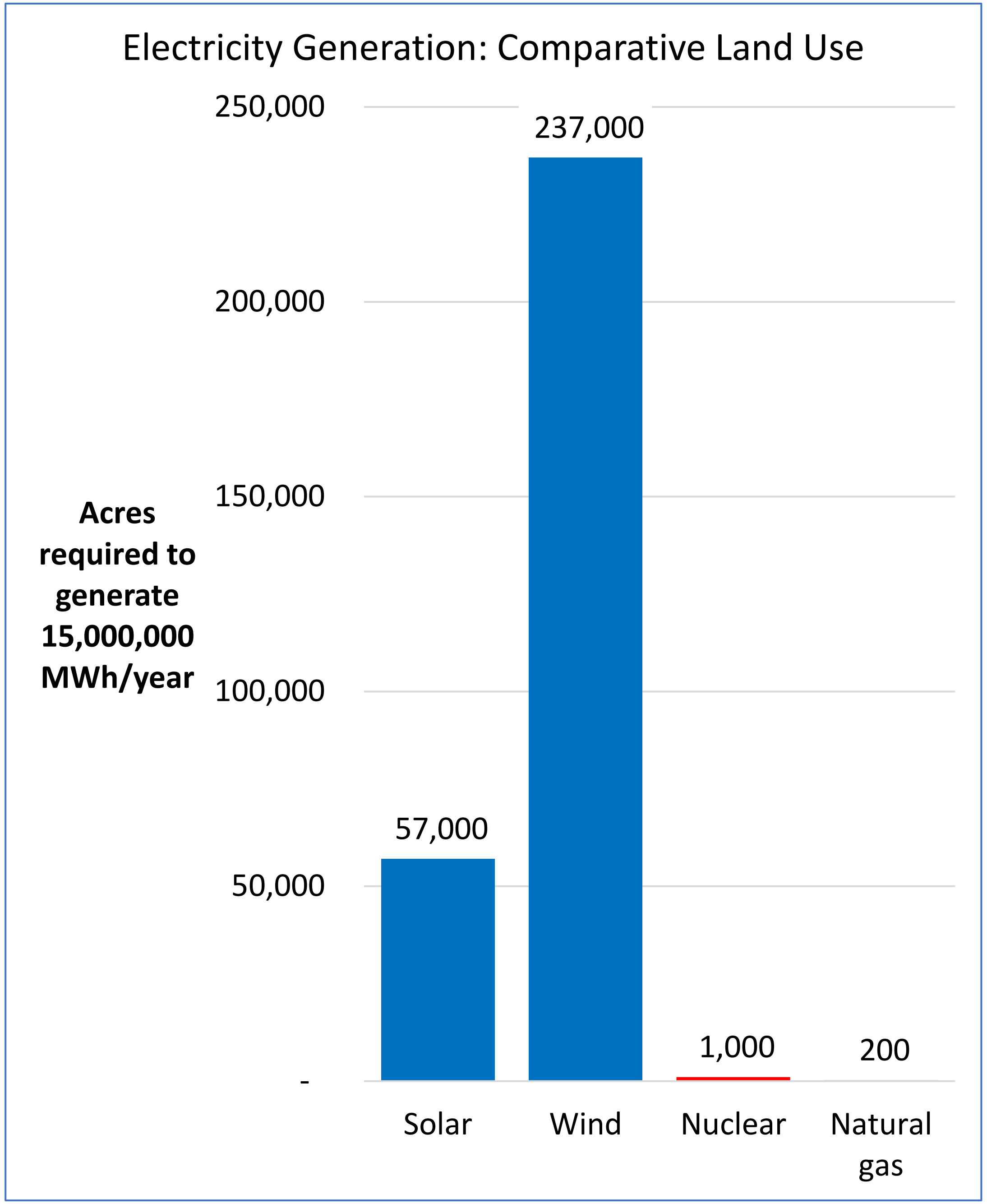
- Illustrative resource footprints:[1]
  - Wind farm: 52.5 acres / MW
  - Solar farm: 8.3 acres / MW
  - Nuclear:[2] 0.6 acres / MW
  - Natural gas: 0.1 acres / MW
- For each generating source
  - Footprint and capacity factor are used to determine required land area
    - Let's assume a target generation of 15 MM MWh/year…
    - Land required for solar ≈ 300x land required for natural gas
    - Land required for wind ≈ 1000x land required for natural gas
  - *Example calculation:*
    To determine acreage required for a solar farm for a target generation amount…

    15,000,000 MWh/year

    x 8.3 acres/MW

    ÷ (25% x 8760 hours/year)

    ≈ 57,000 acres

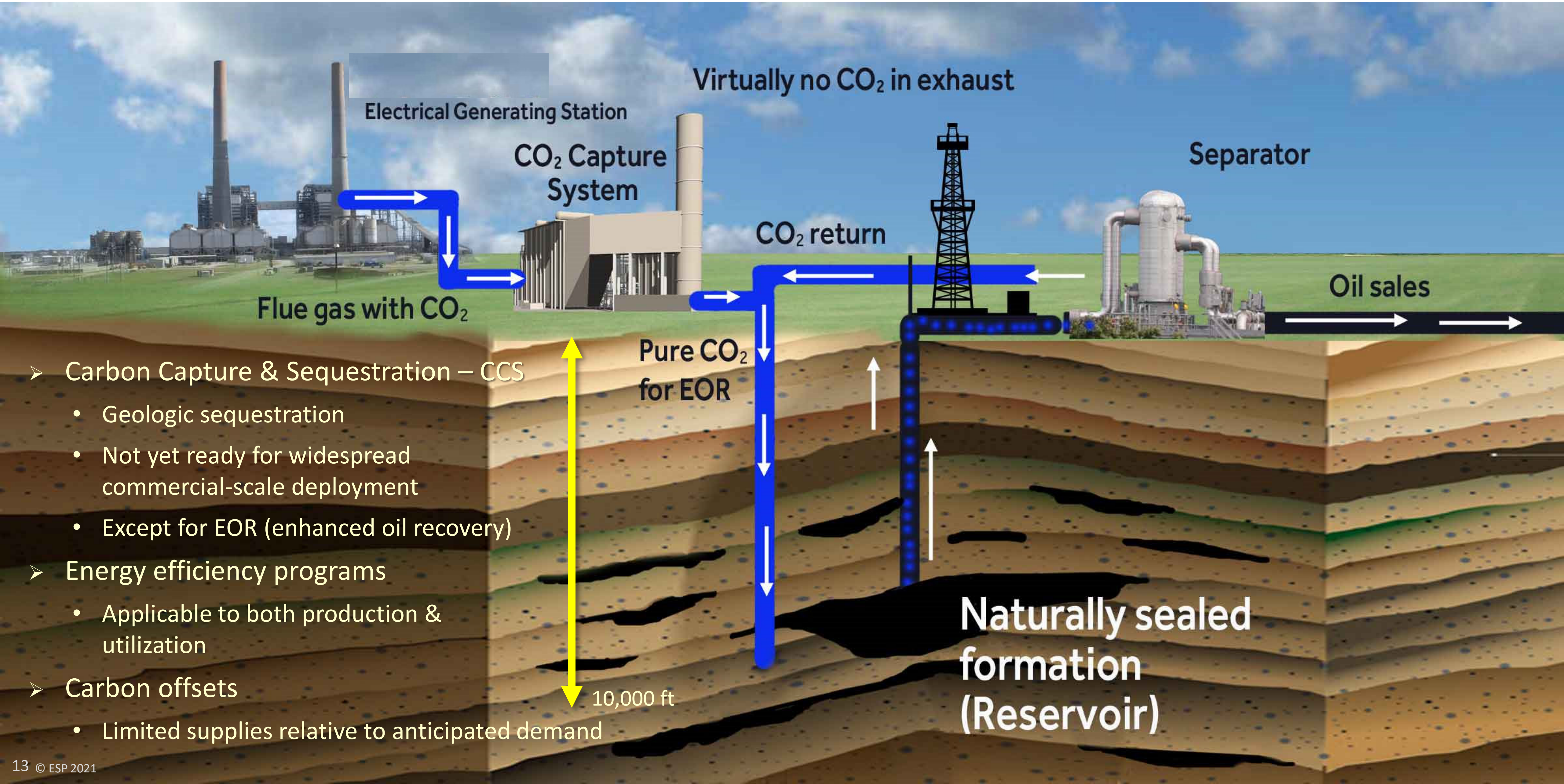


[1] These are illustrative values, sufficient for high-level comparisons; actual values have wide ranges and are site-specific

[2] including buffer areas

Electricity Supply: Decarbonization

http://www.rtoinsider.com/wp-content/uploads/CarbonCaptureSourcePEtraNova.jpg



- Carbon Capture & Sequestration – CCS
  - Geologic sequestration
  - Not yet ready for widespread commercial-scale deployment
  - Except for EOR (enhanced oil recovery)
- Energy efficiency programs
  - Applicable to both production & utilization
- Carbon offsets
  - Limited supplies relative to anticipated demand

Light Duty Vehicles (LDVs)

Passenger cars and pickup trucks

- ICE LDVs: conventional vehicles using Internal Combustion Engines (ICE)
  - ✓ Fueled by gasoline, diesel, or other liquid fuels
- Electric LDVs (Electric vehicles, or EVs)
  - ✓ Battery electric vehicles (BEVs)
  - ✓ Plug-in hybrid EVs (PHEVs)

Energy consumed by LDVs

- 55% of transportation energy
- 15% of U.S.' total energy

- Most EVs will be charged from the grid
- Such EVs are not "zero-carbon"
- Refer to the grid's average emissions factor

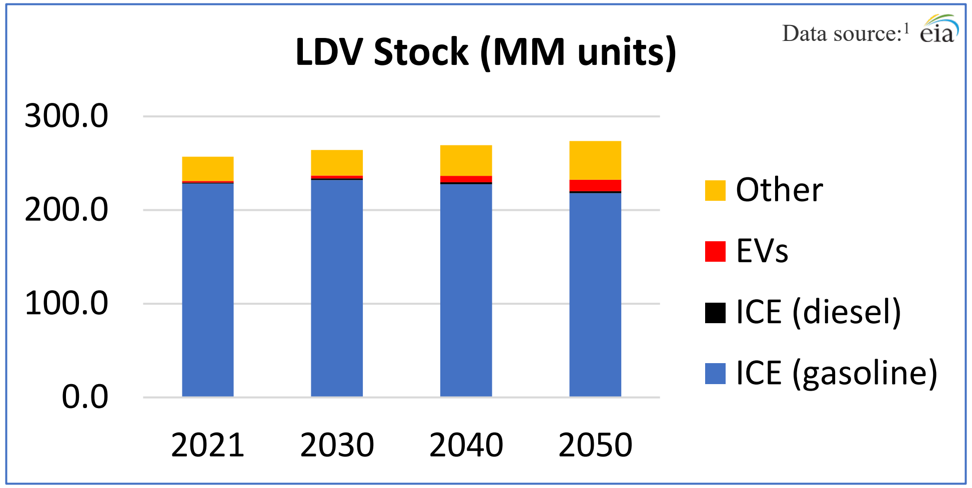
LDV stock [1]

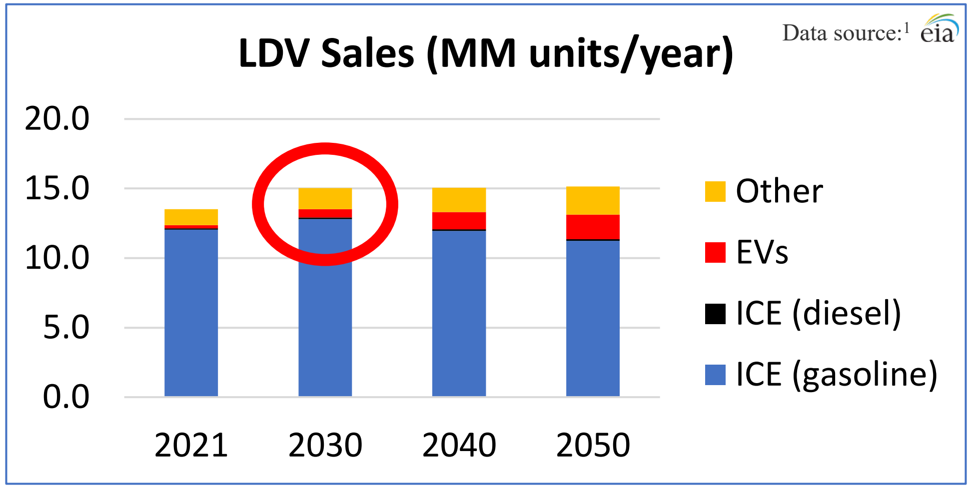
- Total stock forecasted to increase by 6% by 2050
- EV stock forecasted to increase by 700% by 2050

LDV sales [1]

- Total annual sales of LDVs forecasted to increase by 12% by 2050
- EV annual sales forecasted to increase by 700% by 2050
- By 2030
  - ✓ EV annual sales forecasted to be **4%** of total LDVs
  - ✓ The Administration's goal is **50%**

Is this 12x increase (within 9 years) feasible?





[1] Energy Information Administration (EIA) Annual Energy Outlook (AEO), February 2021, Reference Case

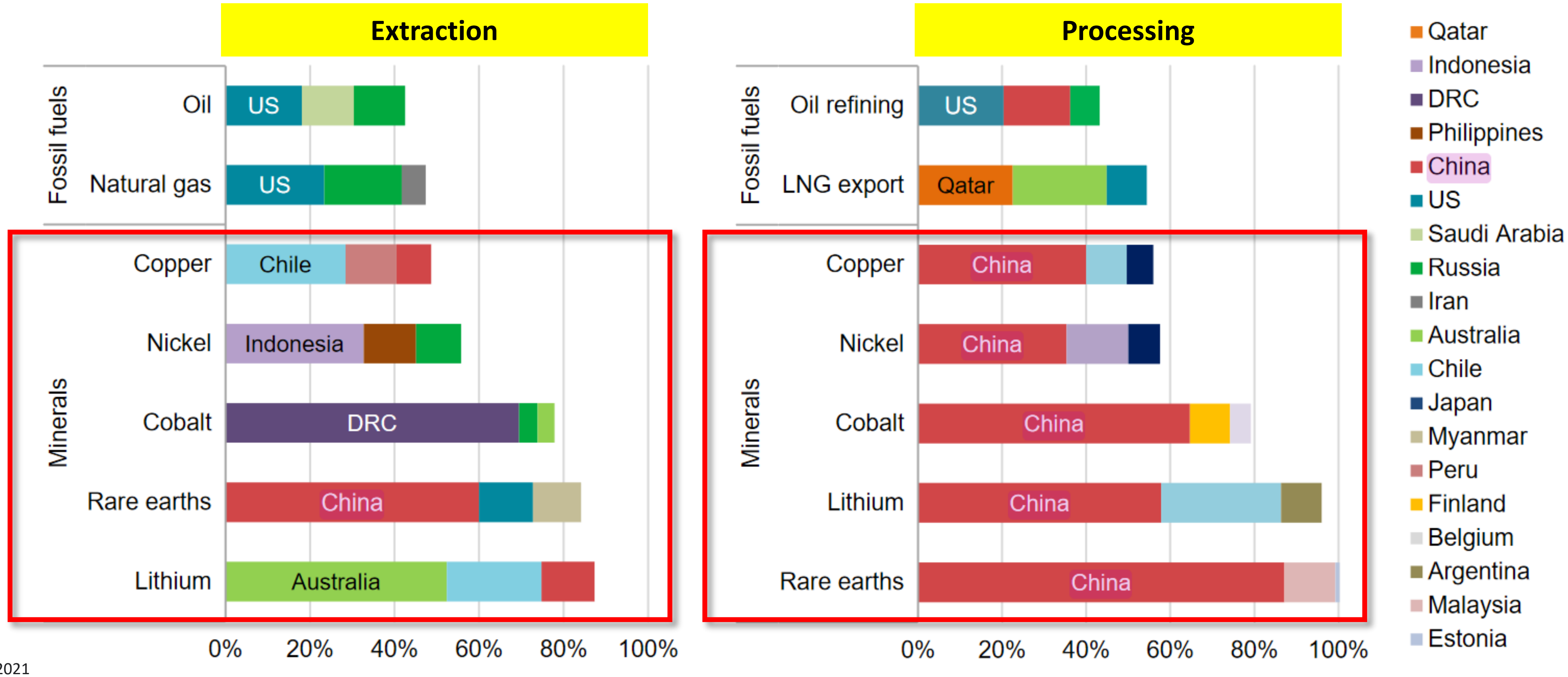
EV Battery Supply Chain Considerations

- Critical minerals
  - "A typical electric car requires six times the mineral inputs of a conventional car."
  - "Mineral demand for use in EVs and batteries … [will grow] at least 30 times to 2040."
  - "Production of many energy transition minerals today is more geographically concentrated than that of oil or natural gas."

The Role of Critical Minerals in Clean Energy Transitions; World Energy Outlook Special Report; IEA. May 2021.

https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions

Share of top three producing countries in production of selected minerals and fossil fuels, 2019



Observation:
- Increased deployment of EVs in the U.S. will lead to increased reliance on China and other countries for critical minerals.

EV Battery Supply Chain Considerations

- Battery manufacturing capacity

  - There are currently 3 large Li-ion battery manufacturing facilities in the U.S.

  - How many would be needed to achieve the Administration's goal of 50% LDV sales by 2030?

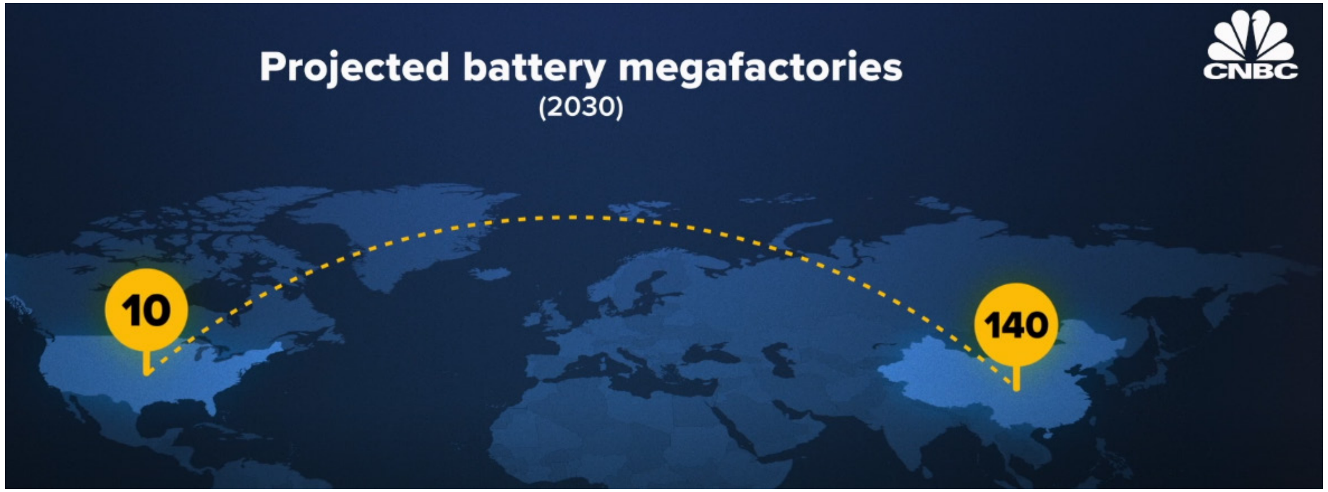
https://www.teslarati.com/wp-content/uploads/2019/04/tesla-gigafactory-1-profile-1a.jpg

https://claycorp.com/project/sk-battery-america-inc/

https://electrek.co/2021/03/29/tesla-hiring-spree-gigafactory-texas-prepares-battery-cell-factory/

EV Battery Supply Chain Considerations

- ➢ CNBC estimated 10 large factories in the US by 2030
  - However, that estimate was made in April 2021, which was prior to the August 5th Executive Order (EO)
- ➢ How many would be needed to meet the EO?
  - Tesla's NV GigaFactory produces 25 GWh / year
    - ✓ Sufficient for 100,000 EVs[1]
      - Assuming 50% of production would be used for grid / residential applications
  - The EO's goal is 7.5 MM EVs sold in 2030
    - ✓ Requiring 75 equivalent battery manufacturing facilities
  - Back-of-the-envelope estimate:
    - ✓ Assume a 4-year lead time per facility
      - For siting, design, permitting, financing, & construction
    - ✓ Then 72 new facilities required within next 9 years
      - This would be reduced if some batteries are produced offshore and imported into the U.S.
      - This would require FID for 70+ facilities (@ $3-5 B each) within the next 7 years



https://www.cnbc.com/2021/04/08/the-us-is-facing-a-lithium-ion-battery-shortage-with-ev-growth.html

- ➢ But, according to CNBC (Apr'21) …
  - *"As companies ramp up their EV ambitions, current battery production in the U.S. won't be able to keep up with demand."*
- ➢ And, according to IBIS World (Dec'20) …
  - *The Lithium Battery Manufacturing industry will likely experience supply chain disruptions due to the industry's reliance on Asia Pacific and South American sources of lithium and other raw materials.*

  https://www.ibisworld.com/united-states/market-research-reports/lithium-battery-manufacturing-industry/

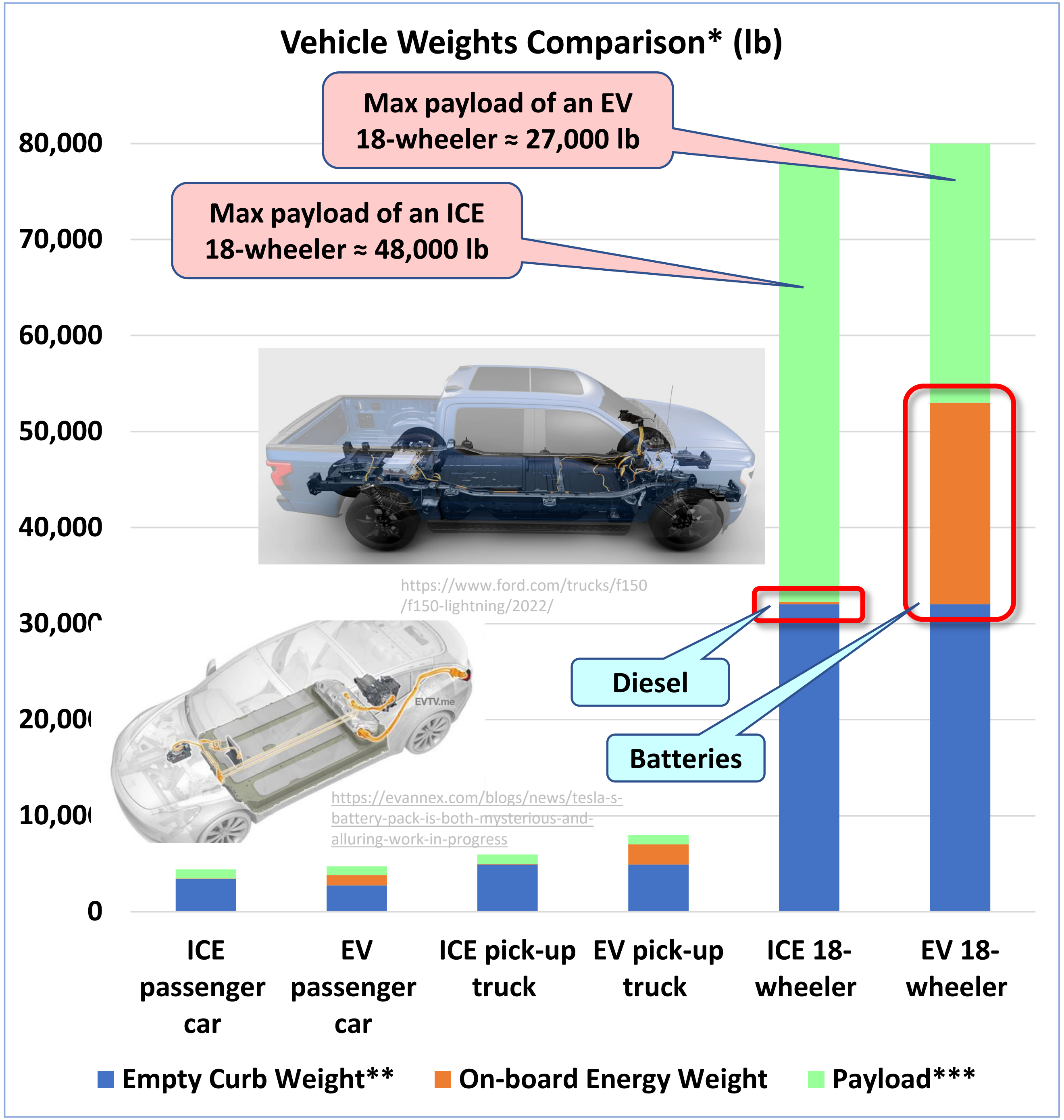
  IBISWorld — WHERE KNOWLEDGE IS POWER

- ➢ **Observation**:
  - Such a ramp-up of EV battery production reflects an unrealistically ambitious plan.

[1] At an average capacity of 120 kWh per vehicle.

Electric Vehicles: Payload Considerations

- **Battery weight**
  - The weights of on-board batteries scale linearly with the vehicle weight
    - ✓ An EV that has 2x the GVW requires 2x the battery pack (for the same range)
- **Heavy-duty long-haul freight truck (18-wheeler)**
  - Payload considerations
    - ✓ The max payload for an EV version is estimated to be about less than 60% that of a diesel-fueled rig
    - ✓ For equivalent economics for the freight hauler, transport charges would have to increase substantially
  - Charging considerations
    - ✓ The on-board battery pack would be roughly 20x that of an EV sedan's battery pack (for 300-mile range)
      - The approximate time required for an 80% charge for an EV sedan is 30 minutes (at a commercial station)
- **Observation:**
  - Payload impacts will constrain EV deployment for heavy-duty commercial transport systems



* All values are approximate, based on 300-mile range
** Excluding weight of on-board energy source
*** Does not include a pick-up truck's towing capacity

Electric Vehicles: Potential GHG Reductions

➢ How much could LDV fuel switching (ICE to EV) reduce GHG emissions?

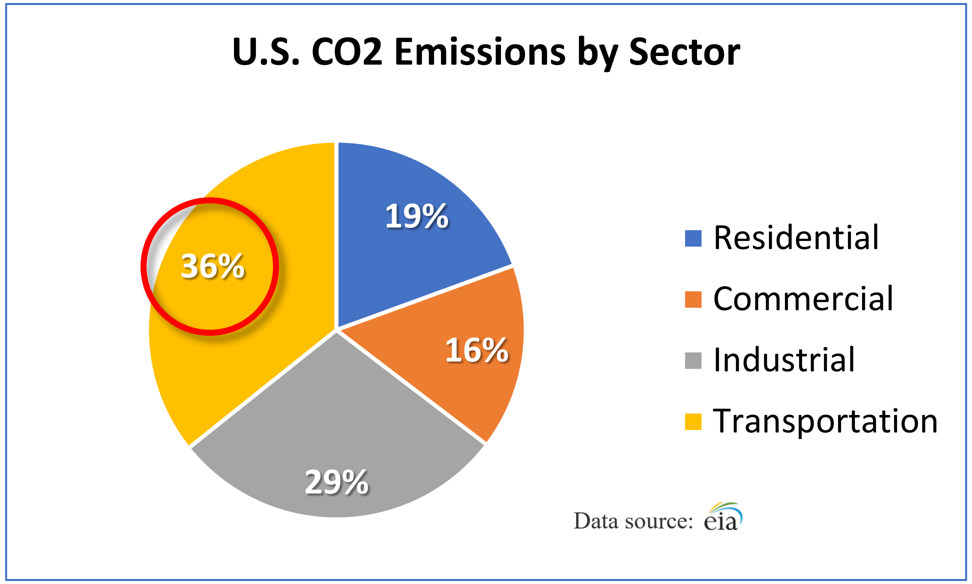
- Per EIA, 36% of all GHG emissions are from transportation
- An EV sedan has ≈ 25% of the GHG emissions of an ICE sedan
  - ✓ I.e., EV LDVs reduce GHG emissions by ≈ 75% vs ICE LDVs
- Per EIA, 55% of transportation energy is consumed by LDVs
- If 50% of LDV ICE stock were to be replaced by LDV EVs

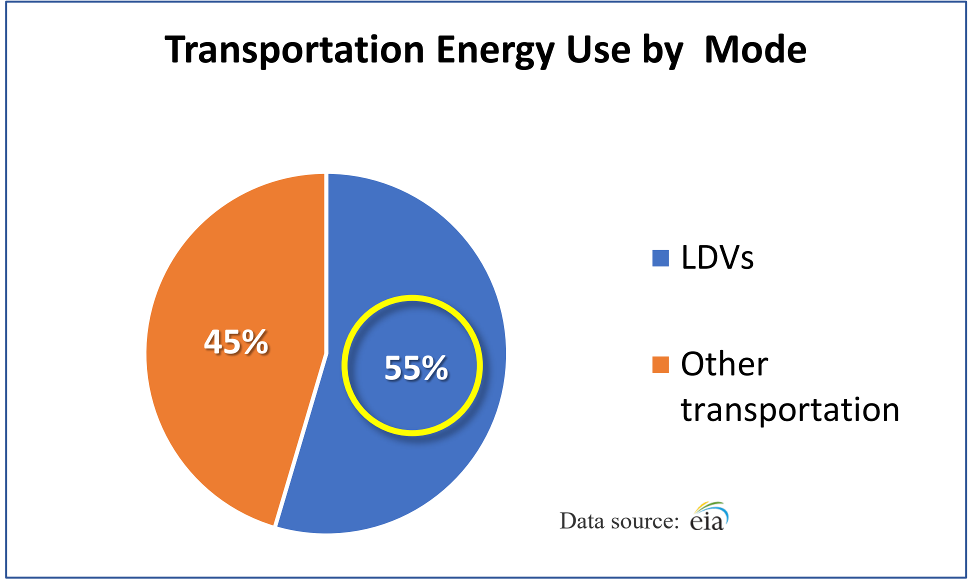
Then overall reduction of the U.S.' GHG emissions would be ≈ 7%

36% x 75% x 55% x 50% = 7.4%

➢ Observation:

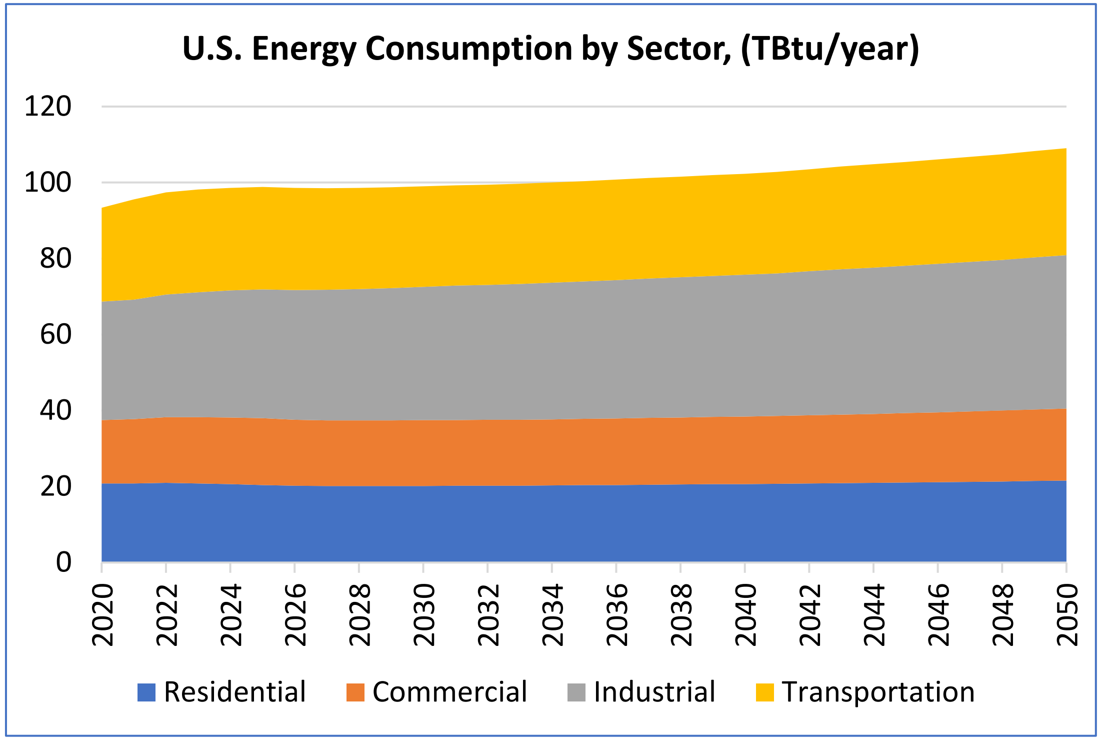
- Switching half of the U.S.' LDV fleet from ICE to EV would result in ≈ 7% reduction in GHG emissions in the U.S.





In Summary

- Energy consumption is forecast to increase by 2050
  - ✓ In the U.S. (and worldwide)
  - 26% of energy consumption is for transportation
    - ✓ Moving people and goods



- Transitioning to lower-carbon-emitting energy sources is being driven by concerns re GHG emissions
  - Two primary approaches entail:
    - ✓ Decarbonizing the electricity sector
    - ✓ Decarbonizing the transportation sector (via EV LDVs)
- Numerous factors need to be considered:
  - Decarbonizing the electricity sector
    - ✓ Increasing reliance on *intermittent* generating sources
    - ✓ *Reliability* & resiliency of the grid
    - ✓ Increased *land use* with solar and wind
    - ✓ Increasing reliance on *global supply chains*
    - ✓ Will decarbonization also occur in China and elsewhere?
  - Decarbonizing the transportation sector
    - ✓ Increasing *demand for electricity*
    - ✓ New *transmission* lines
    - ✓ Battery supply chain: *critical minerals*
    - ✓ Battery supply chain: *manufacturing facilities*
    - ✓ *Payload* impacts on commercial freight systems
    - ✓ Effectiveness vis-à-vis *GHG reductions*?

Recommendations

1. Demand for EVs needs to be better understood before public policies are enacted and massive expenditures are undertaken by Federal & State agencies.
   a) Will consumers accept the range limitations, charging times, and other challenges associated with EVs?
   b) What would be the full extent of consumers' and taxpayers' costs associated with fuel switching?
2. Additional R&D is needed to increase the energy density of batteries.
   a) Energy density is critical for the transportation sector (i.e., mobile applications).
   b) Existing battery technology for mobile applications needs to be improved significantly to compete (technically and economically) with high-energy-density liquid fuels.
3. Issues associated with battery supply chains must be addressed.
   a) We should not stimulate rapid demand of EVs until the uncertain-ties associated with battery supply chains have been addressed.
   b) Potential increases in geopolitical tensions from the U.S.' reliance on (often unfriendly) foreign governments must be addressed.
4. Increase the domestic production and use of lower-emissions fuels that can use the existing transportation sector infrastructure.
5. Issues regarding additional electricity must be addressed.
   a) Additional generation, transmission, and distribution facilities will be needed to meet the increased demands for electricity from EVs.
   b) Grid reliability and resiliency are critical, and should not be jeopardized by excessive reliance on intermittent resources.
   c) Costing methodologies (e.g., LCOE) for electrical generating options need to fully reflect each option's *reliability*; this will help utilities, grid managers, and regulatory agencies pursue more effective planning for future generation vis-à-vis grid-level reliability.
6. Is switching from ICE to electric vehicles an effective strategy for reducing GHG emissions?
   a) Comprehensive assessments are needed regarding the costs and benefits of this proposed fuel-switching strategy.
      - ✓ The full spectrum of deployment considerations must be evaluated: technical, economic, logistical, financing, social, etc.
   b) Other decarbonization strategies must also be fully evaluated.
      - ✓ Comparative cost-benefit analyses are needed for all strategies (e.g., reductions in GHG emissions per $$ expended).
   c) Ultimately, the potential GHG reductions associated with the massive expenditures that would be required to meet the Administration's decarbonization objectives need to be quantified.
      - ✓ Policy makers, business decision makers, ratepayers, vehicle operators, and all other stakeholders need to better understand the numbers underlying the various energy transition strategies.

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