# LIVABLE CALIFORNIA

**a Presentation by**

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**on**

## ELECTRIFICATION – Reality and Myths

**June 3, 2023**

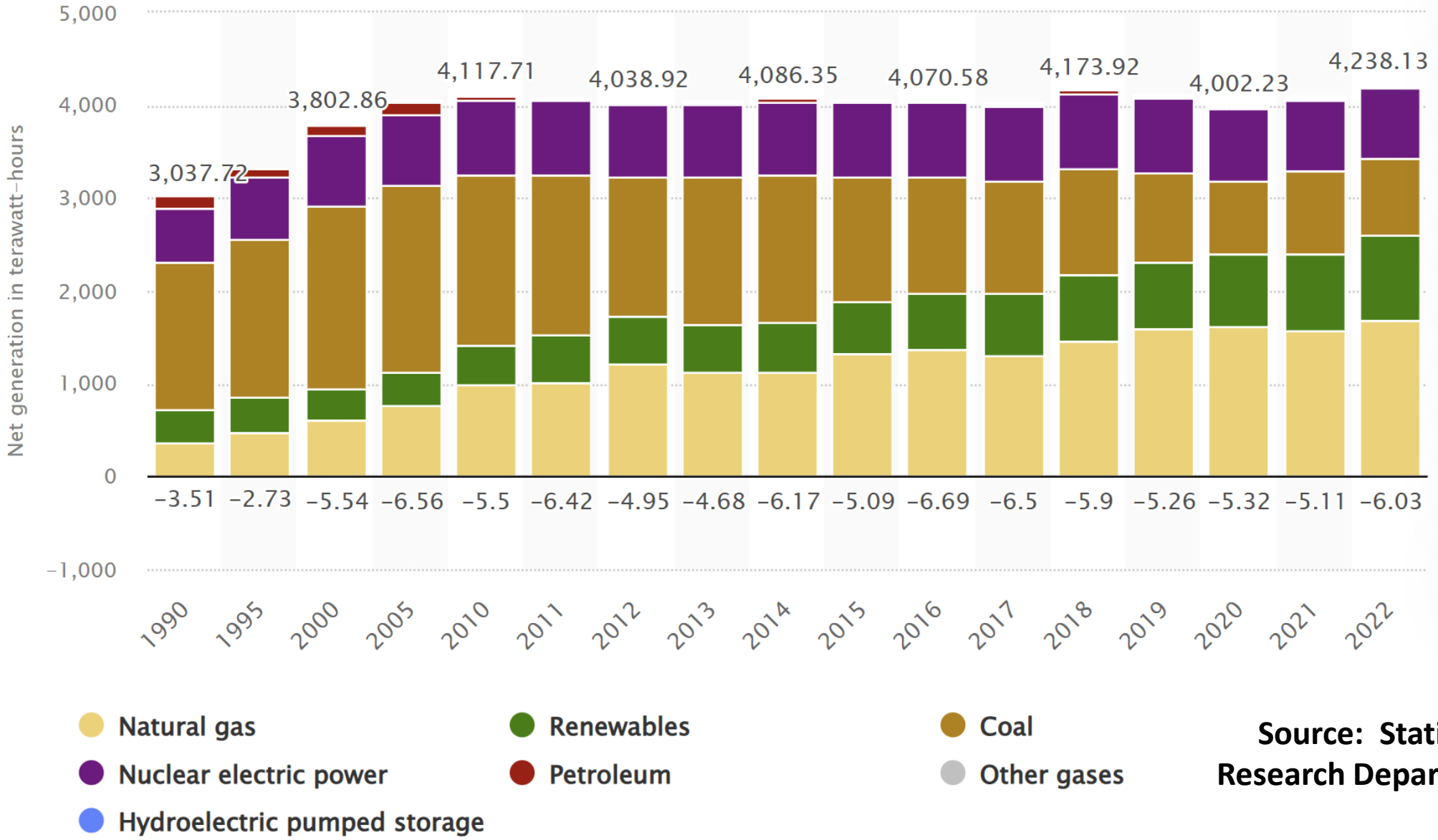
# Today's Topics (presented in no particular order)

- Electrification is The Answer – but what is the Question?
- Some initial concepts that must be understood
- California situation and initiatives
- Phasing out Internal Combustion Engines (ICE) for cars and trucks
- "Green" electric generation and its limitations
- Impacts on the electrical grid
- Costs – and cost-effectiveness
- THIS IS A VERY COMPLEX TOPIC:
  - We don't have much time today and we have to cover a broad selection of topics, so depth has to be limited
  - In these fields, there is so much out there, from researchers (and others) with various perspectives and positions being advocated, that it is quite simple for anyone to come up with studies to support whatever point they wish to make – so, proceed with care

# Review of Eighth Grade Science

- There are ***many*** forms of energy; principle ones for our instant purpose include:
  - Chemical
  - Electric
  - Gravitational
  - Magnetic
  - Mechanical
  - Nuclear
  - Thermal
  - Wave (light, sound, etc.)
- Energy is constantly transformed from one form to another, but there is a loss in each transformation of form and for each transformation within a form
- Energy, like everything else, has three elements of utility – form, place, and time; for example, to produce light in your home through electricity, it must be in the form of 120 volt alternating current, it must be in available in your home, and it must be there – in the right form and at the right place – when you need it
- Generation and use of energy almost always has unintended and frequently negative consequence – such as air, water, noise, light, and other pollutions
- In order to get energy in the form you want it, where you want it, when you want it, the initial energy transformation can be many times the ultimate usage

# Electricity Generation in the U.S. 1990-2022, By Fuel

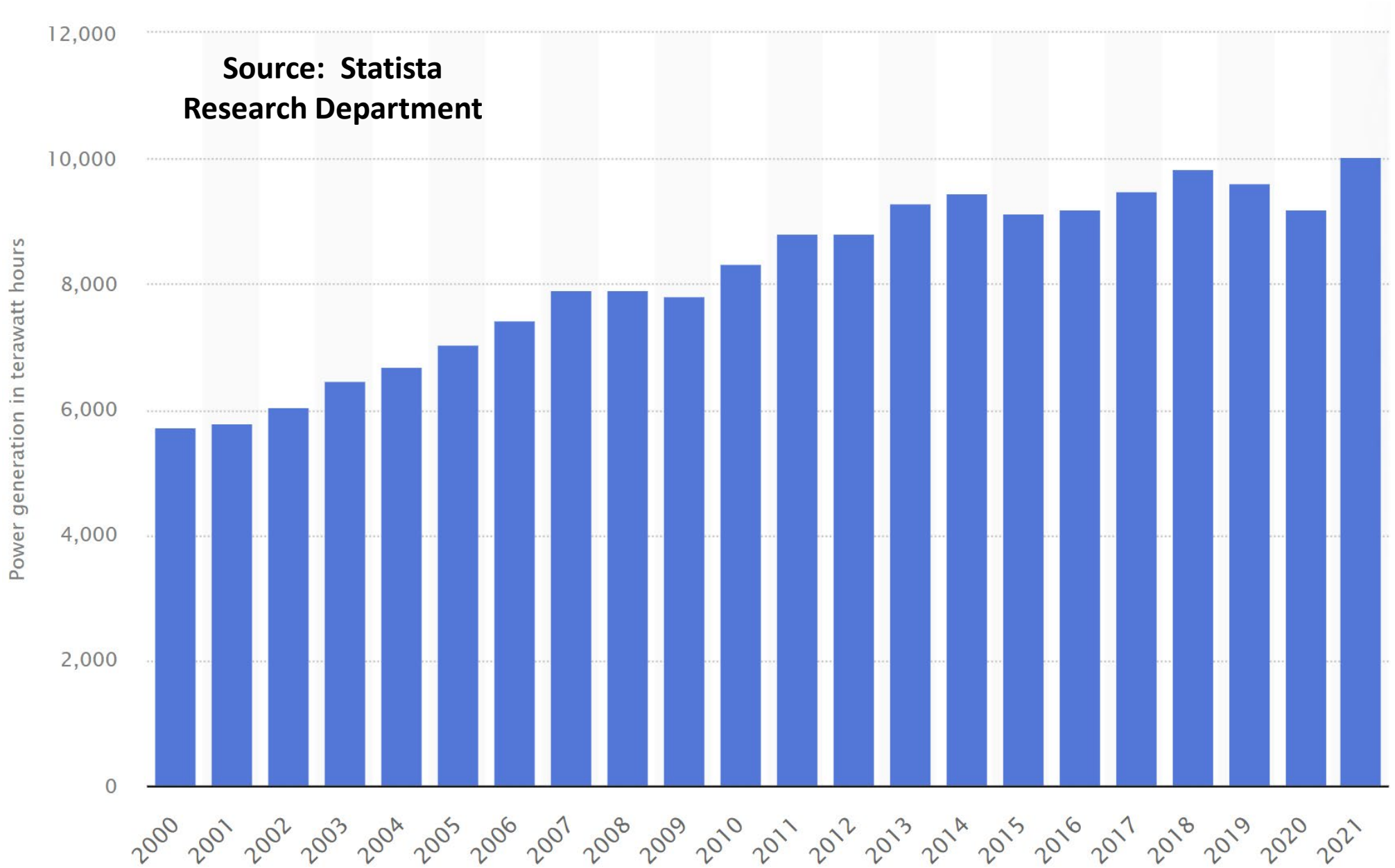



**Source: Statista Research Department**

# Changes in U.S. Electricity Production

- The preceding graph displays how U.S. electricity production has been shifting over the dozen years to 2021:
  - Coal:  From 52.5% of total generation to 19.6%; down 765 terawatt-hours, 48.0%
  - Natural Gas:  From 12.3% of total generation to 39.9%; up 1,316.7 tWHrs, 39.9%
  - Nuclear:  From 19.0% of total generation to 18.2%; up 194.68 tWHrs, 33.7%
  - Renewables – which includes hydro, geothermal, wind, and solar (among others):  From 11.8% of total generation to 21.5%, up 555.63 tWHrs, 155.5%
- These changes, to a very large extent, were driven by:
  - Widespread use of “fracking” to increase the production and drive down the cost of natural gas
  - Increased regulatory and emission-reduction requirements for coal-generated electricity
  - Major emphasis on renewables – but, while GHG reduction and other “green” considerations were always the primary rationale, the increases in electric generation were, to a large extent, driven by government-sponsored/mandated financial benefits to implementors

# Electric Production from Coal Worldwide 2000 to 2020



# So, What's Going On?

- While the developed nations, led by the U.S., have been phasing out coal for electricity, its use has continued to increase in much of the developing world, which, for this purpose, includes China and India, the two largest nations by population on Earth
- Their populations are hungry for the advantages of higher development that the developed nations of the world have achieved – and are now well known to the residents of less-developed nations
- Rapid industrialization and improvements in human well-being require large increases in electricity generation capacity – particularly ***reliable*** electricity
- The leaders of these nations understand that keeping their peoples happy is very important to the future successes of their nations – and their persons
- Coal is one of the fastest and easiest ways to add major generating capacity

(The post-2018 downturn is due primarily to COVID, not shifts to "green" power)

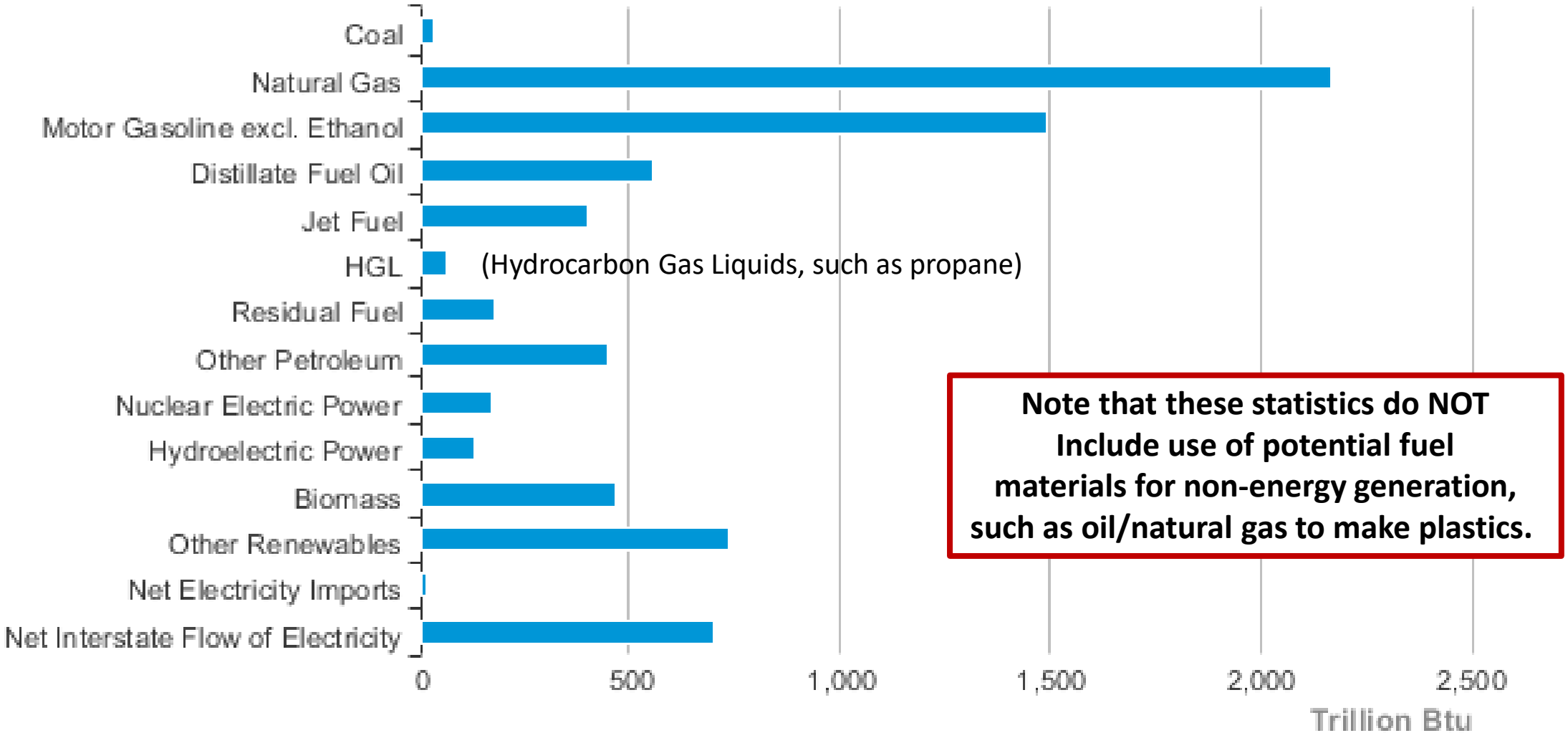
# The *REAL* Problem

- Earth is well along the path of eliminating global poverty, even the poorest of the poor are generally substantially better off now than they were 50 years ago
- These newly emerging better-off people want to continue to improve their conditions – to the type of developed nation status that they now know well through the internet, smart phones, and other communications and education
- While most of the developed world is now experiencing less-than-stabilization birth rates, the less-developed world, particularly sub-Sahara Africa, is still primed for rapid population growth – particularly with better access to clean water, improved health care and environmental conditions, education, etc., produce lower infant mortality and longer lifespans
- **THESE COMMUNITIES WILL BE DEMANDING MORE ELECTRIC POWER AND MORE MOTORIZED MOBILITY** – and they will be far less concerned about how GHG emissions could be changing the world between now and 2200 than how they can better their living conditions tomorrow – and it is hard to blame them

# California Energy Facts

- Largest population, largest number of motor vehicles, most vehicle miles traveled
- Energy usage is one-tenth of national motor gasoline consumption, one-seventh of jet fuel consumption
- State energy usage by sector:
  - Transportation: ~one-third
  - Industrial: ~one-fourth
  - Residential: ~one-fifth
  - Commercial ~one-fifth
- BUT, California *per capita* consumption in the residential and commercial sectors is lower than all other states except Hawaii
- California has been working very hard, for decades, to be the world leader in emissions reduction – including but not limited to greenhouse gases, clean energy generation, and energy use reduction – but the achievement of the objectives has not always been without the unexpecteds and downsides

# California Energy Consumption Estimates, 2021



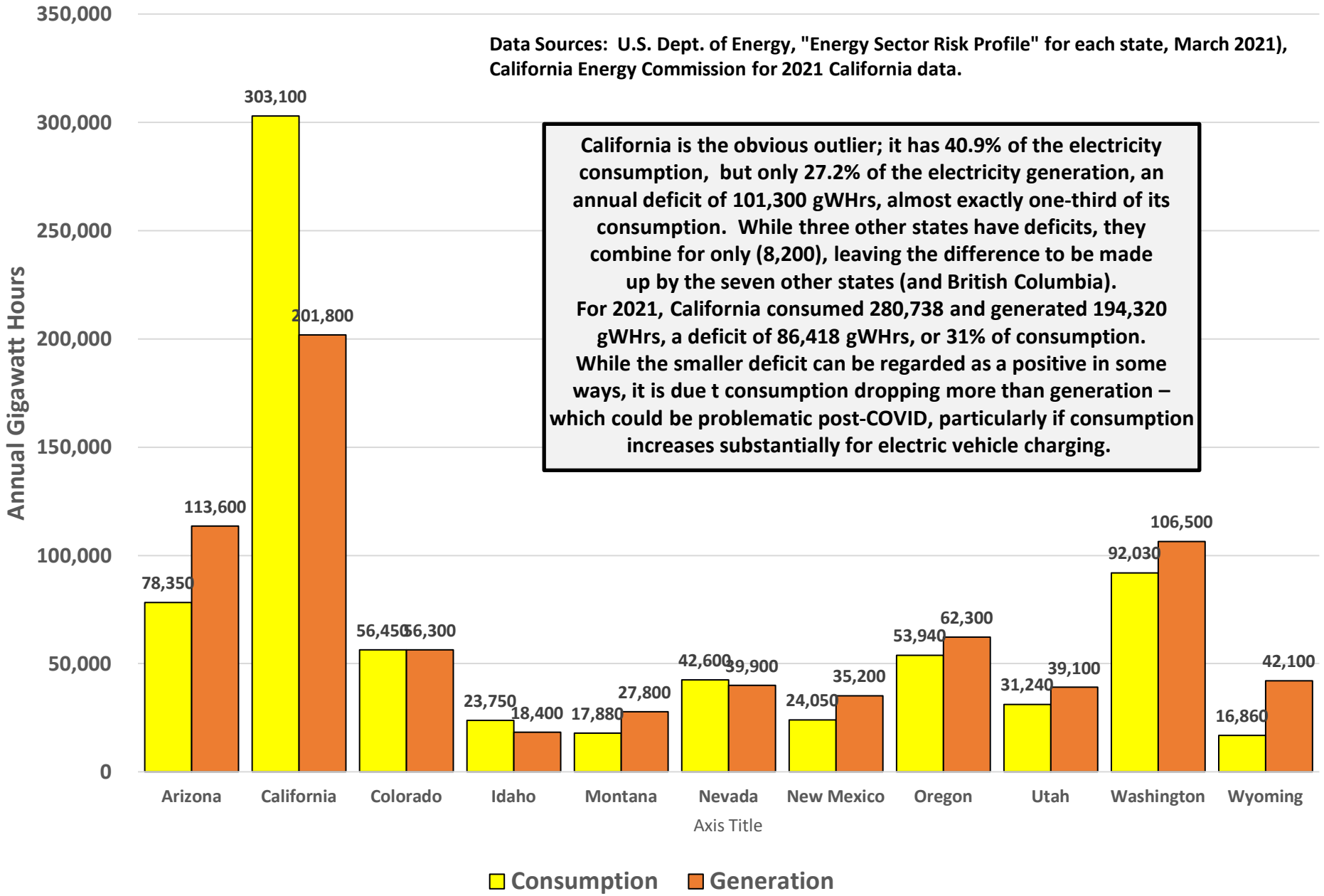

**Note that these statistics do NOT Include use of potential fuel materials for non-energy generation, such as oil/natural gas to make plastics.**

Source: Energy Information Administration, State Energy Data System

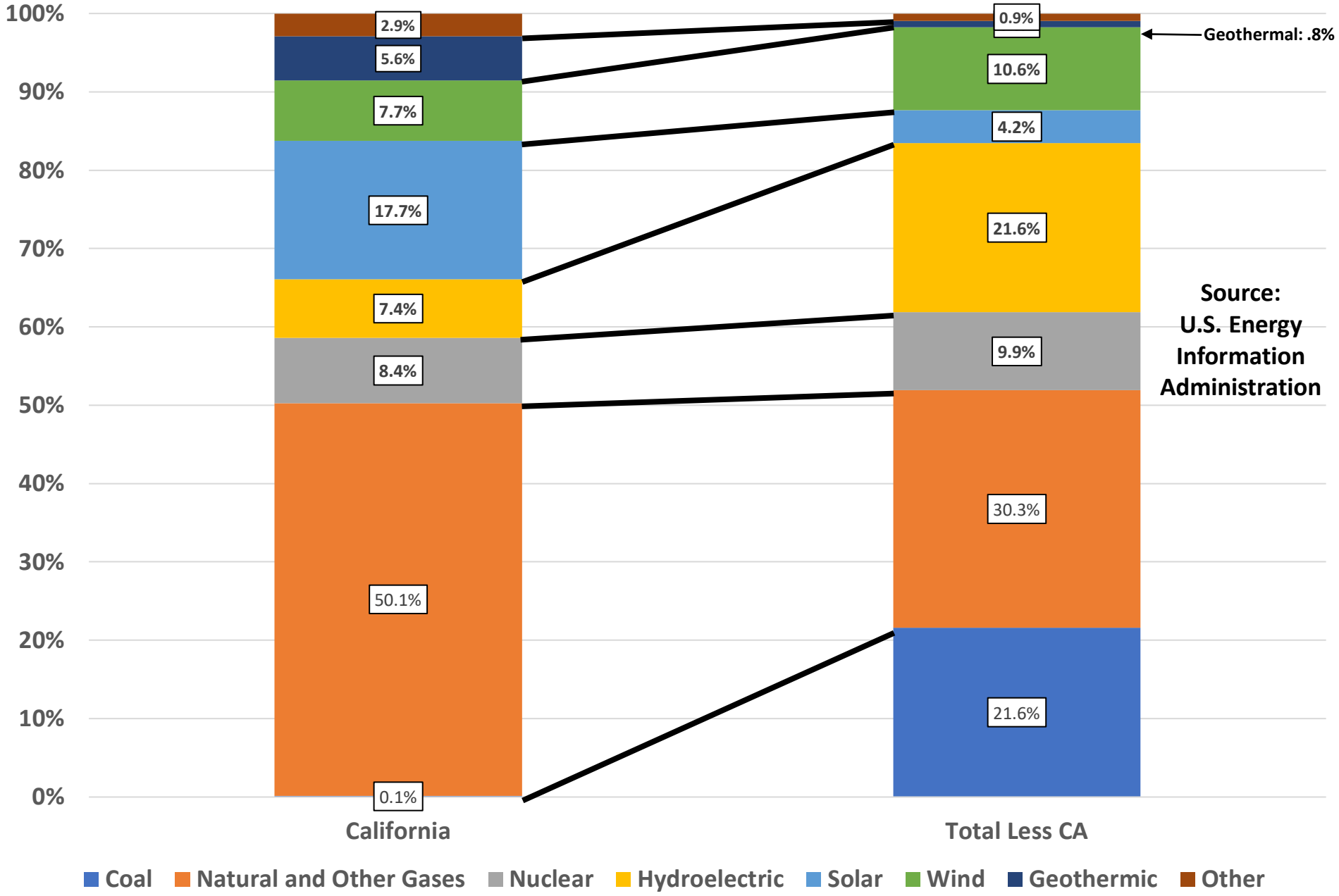
# California Energy Usage Observations

- California was never a large user of coal and has all but eliminated what it had
- By replacing in-State coal with natural gas, the State has reduced emissions
- The State is moving to eliminate nuclear, but shutting down the final plant – Diablo Canyon – is temporarily on hold
- California is no longer expanding hydropower generation and is actually moving to eliminate some existing dams; less rainfall means less hydropower
- The State is very actively pushing renewables – chiefly wind and solar – with some success, but this is not growing as fast as many decision-makers would like
- Note the last bar, “Net Interstate Flow of Electricity” – because of the high costs and strong restrictions and requirements on increasing California power supply, in-State electric generation has not kept pace with demand, meaning the State has become more of an importer of electricity from outside of California (and the U.S.) – where less stringent standards apply

# Western (Electric) Interconnection States
# Consumption and Generation (2018/2019)



# CALIFORNIA AND OTHER TEN WESTERN INTERCONNECTION STATES
## Electricity Generation by Source 2021



# California Exports Its Electricity Emissions

- If you look at the last two graphs together, you can see what is going on as the result of California becoming very stringent in the types of energy it is generating in-state, and increasing the costs thereof, resulting in a big shortfall of in-state generation against consumption – which means that a lot of the electricity we use comes from elsewhere, primarily the other Western Interconnection States
- While California has reduced its in-state coal-fired electricity to almost nothing, it is over one-fifth of the power source in the other states; this is particularly true for New Mexico, where the “Four Corners” coal-fired plants have been a major source of power for Los Angeles and the rest of Southern California – although these plants are being phased out over a multi-decade period
- California gets major hydropower through the Pacific Intertie from Oregon, Washington, and British Columbia – but, while Hydro power is very useful, particularly for “peaking” power, it is very dependent upon rainfall, which is a huge variable – and we are eliminating dams, not building new ones

# Renewable Energy Has Issues – Solar

- Direct solar only works when the Sun is shining – for San Francisco, at 37$^{o}$ 46’ N.:
  - Maximum daylight: 14:47 (hours:minutes)
  - Minimum daylight: 9:33 (hours:minutes)
- Angle of Sun above horizon is important; best case, the Sun bears on solar panels as close to perpendicular as possible – and this means, best case, following the Sun like a sunflower from when it rises in the East to when it sets in the West
- As the Sun’s angle above the Earth decreases, the light goes through more air, which reduces its power to produce electricity
- Solar output is very directly reduced by weather, mainly clouds
- Large solar farms either are the sole users or real estate or must be on an elevated structure above ground (such as over flat parking lots)
- Thermal solar farms, which move many individual panels to fucus on a single point to do steam electric generation, can be deadly to flying creatures

# Renewable Energy Has Issues – Wind

- Wind farms are noisy and can create shadows
- Wind farms create bird losses
- Unlike solar, wind can generate electricity at night and is far less dependent on the sun or weather (except dead calm)
- While solar can be implemented small-scale, including individual homes, wind is generally not compatible with residential areas
- As a general rule, the larger the individual device, the higher the output and the return on investment
- In rare cases, windmill breakage can cause serious injury or property damage
- Installation of wind is generally far more complicated than solar:
  - Long-distance transportation of massive elements over back roads
  - Construction can require large cranes for on-site assembly after construction of the base

# Renewable Energy Has Issues – Solar and Wind

- Solar and wind are both unpredictable and rarely have output that corresponds to the demand curve
- Storage of electricity is still difficult and expensive – although the pace of improvement of battery and other technologies in recent years has been impressive, most likely with more improvements still to come
- Regulatory practices, particularly utility rate benefits for solar installers:
  - Have allowed residential solar homeowners to get very large electric bill discounts
  - In some cases, this is for selling power to the distribution network that is not useful
  - Utilities have complained that they are not being fairly paid for the use of their distribution network
  - This has caused a shift of tariff payments from solar homeowners to other residential – and commercial – users
  - Trying to change this promotional discount, first developed to encourage early adopters and grow the industry, to a more traditional utility rate structure causes outrage when the solar ratepayers learn that the low utility rates they were promised might not be forever

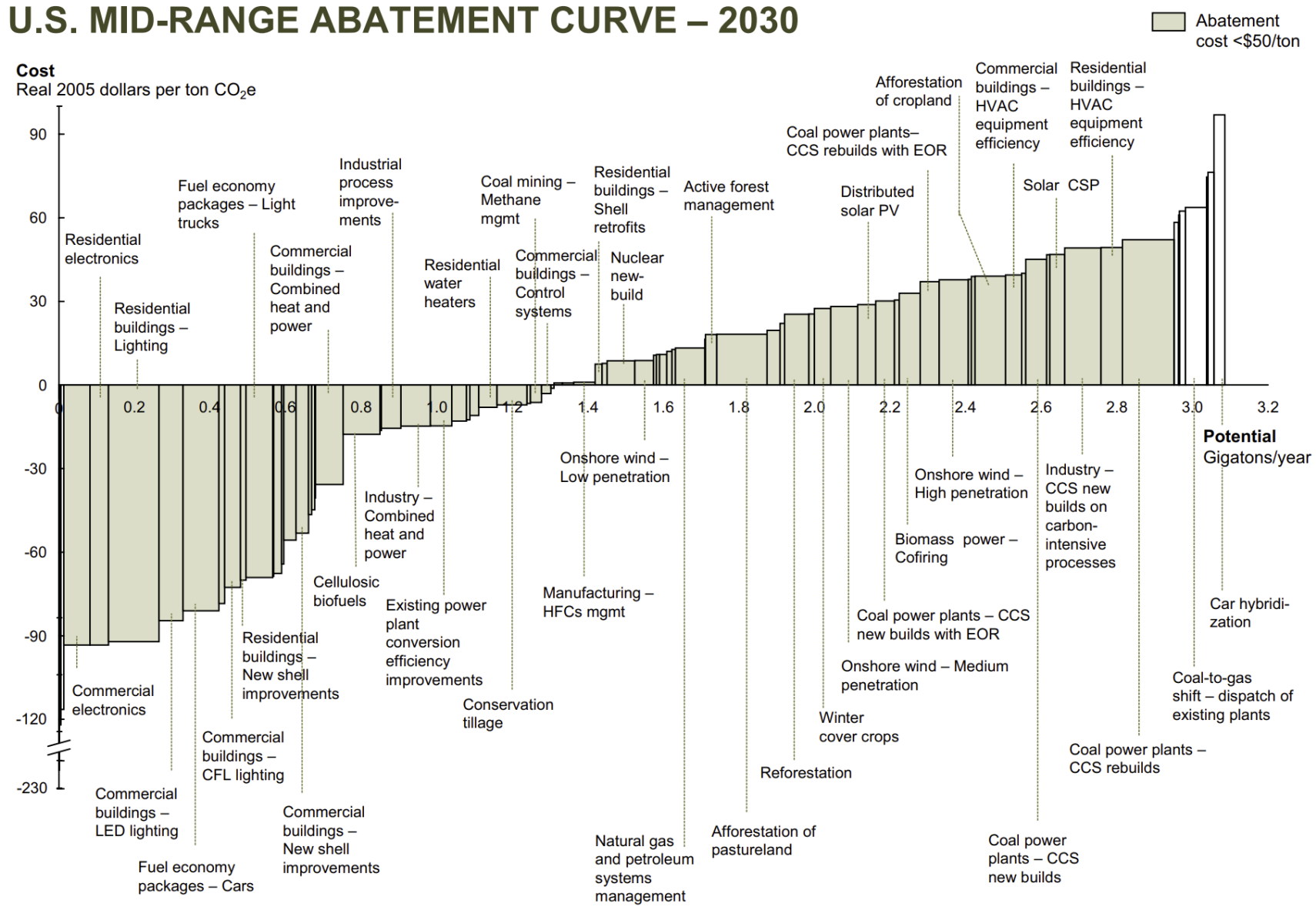
# The Underside of Climate Change Mitigation

- Unfortunately, we have evolved into a political culture where greenhouse gas (GHG) reduction has become of the holy grail of change advocates
- As a result, it has become extremely common, even necessary, for advocates for any social change program to promote its climate change benefits
- At the same time, there is a huge research industry that is very well funded by government and NGOs for climate change studies; BUT, to qualify for first-time and subsequent grants, and publication in refereed journals, you will be much more successful, and more recognized, for confirming the desired outcomes than by showing limited, or negative, positive outcomes
- As a result, many current programs being promoted for their climate change benefits may have less than claimed – or even negative – benefits
  - Battery Electric Vehicles
  - Hydrogen Fuel Cell Vehicles
  - California High Speed Rail
  - Public Transit

# Are There Any More Basic Ways to Reduce GHG?

- Most definitely, yes – if we are willing to entertain them
- Not only are many of these well proven, but, in many cases, no government or other subsidy should be required because they will produce real cash benefits to those who implement them
- Many of these are as simple as:
  - Turning the home thermostat up or down to reduce air conditioning and heating costs
  - Changing to a more fuel-efficient car
  - Longer-life, more energy efficient lightbulbs
  - Changing the heating/ventilation/air conditioning filter on a regular basis
- Most of these are primarily a matter of better public education – and, **NO**, I am not advocating for the mandatory State HVAC filter inspection twice a year

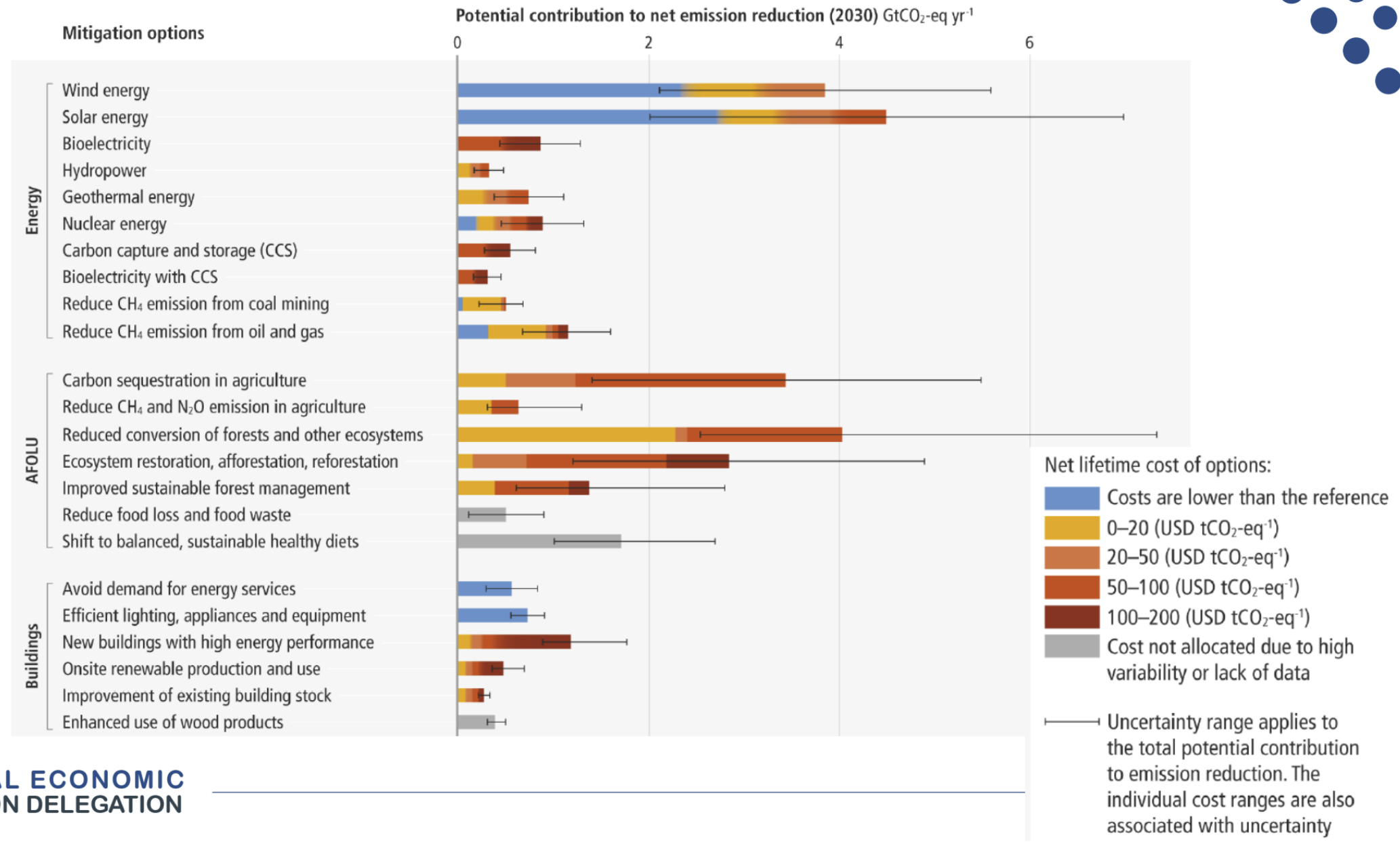
# GHG Reductions Don't Have To Be Painful




Source: McKinsey analysis

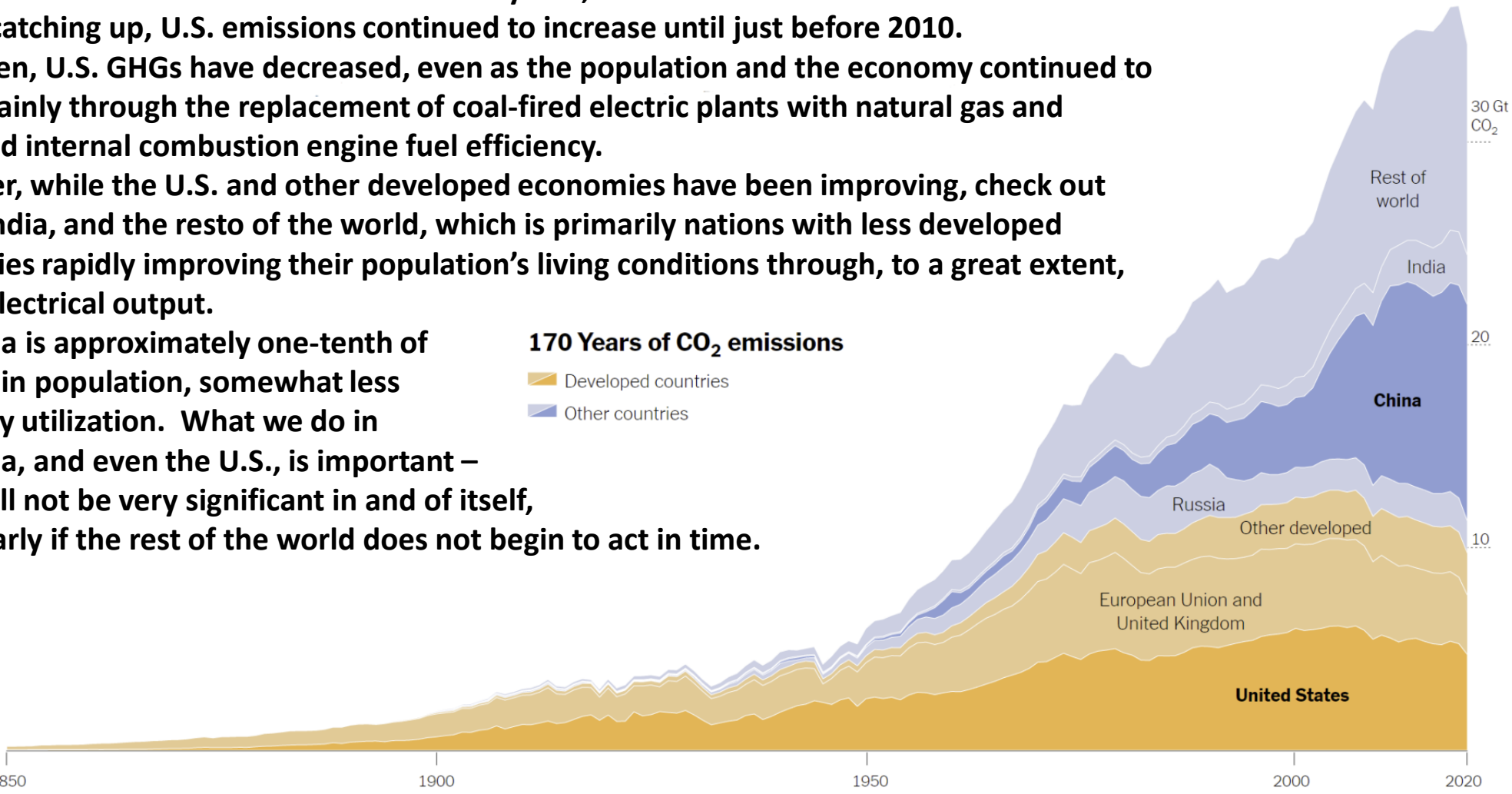
- Graph at left is from McKinsey & Company/The Conference Board, *Reducing U.S. Greenhouse Gas Emission: How Much at What Cost?* – ***December 2007*** (has been updated since)
- The colored bars have an abatement cost <$50/ton – which, in the day, was the accepted social cost of GHG emissions
- The bars below the zero horizontal axis had a net cost BENEFIT to the user, such as shifting to more energy-efficient lighting and heating

# Newer Estimated Abatement Cost Curve



# Sources of the Global Flow of Emissions

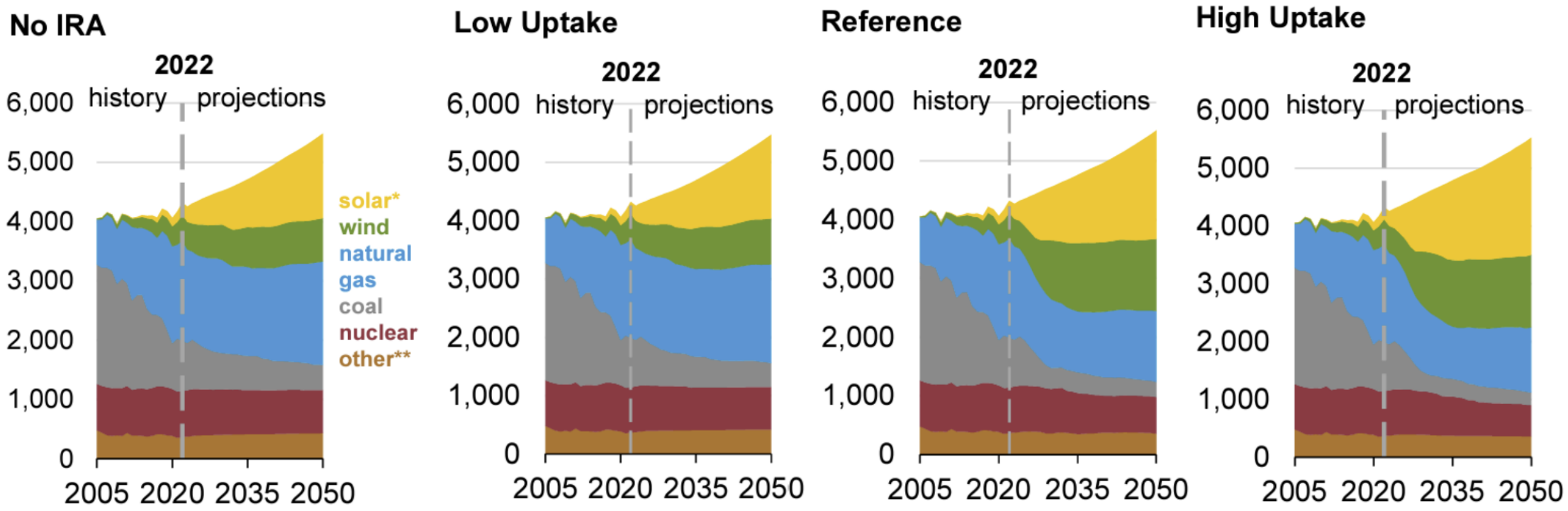
**As this time series clearly indicates, the U.S. produced as much as half Of total GHG emissions over the first half of the 20th century and, while the rest of the world had been rapidly catching up, U.S. emissions continued to increase until just before 2010.**
**Since then, U.S. GHGs have decreased, even as the population and the economy continued to grow, mainly through the replacement of coal-fired electric plants with natural gas and improved internal combustion engine fuel efficiency.**
**However, while the U.S. and other developed economies have been improving, check out China, India, and the resto of the world, which is primarily nations with less developed economies rapidly improving their population's living conditions through, to a great extent, higher electrical output.**
**California is approximately one-tenth of the U.S. in population, somewhat less In energy utilization. What we do in California, and even the U.S., is important – but it will not be very significant in and of itself, particularly if the rest of the world does not begin to act in time.**




Source: Sarah Jacobson. on behalf Of CEED.

# US Electricity Sources

**U.S. net electricity generation by fuel**
billion kilowatthours




Data source: U.S. Energy Information Administration, *Annual Energy Outlook 2023* (AEO2023)
Note: IRA=Inflation Reduction Act
*Includes utility-scale and end-use photovoltaic generation and excludes off-grid photovoltaics.
**Includes petroleum, conventional hydroelectric power, geothermal, wood and other biomass, pumped storage, non-biogenic municipal waste in the electric power sector, refinery gas, still gas, batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, and miscellaneous technologies.

# So, What's Really Happening?

- First, much thanks to NEED for their data analysis and presentations
- As the previous graph clearly shows, while U.S. total electricity generation was fairly constant for the first two decades of the 21st century, all projections are for increases well over 20% through 2050
- Coal will continue to be used for the foreseeable future, but will continue to decline significantly
- Renewables, chiefly solar and wind, will increase significantly and, in the "High Uptake" case, will not only amount for all of the total increase, but will significantly eat into natural gas production and the remaining coal – which will still be significant, even in the "High Uptake" case, through 2050
- Nuclear, depending upon the case, will be constant to declining

# Perfection is the Enemy of Good Enough

- First, we need to stop “feel good” energy choices – before new statutes and regulations are implemented, we must demand stronger, ***independent*** verification of outcomes
- Statutes and regulations should require outcomes, not methods, to achieve outcomes, not technologies but results
- We must figure out how to change our decision-making process from the current, no-one-can-green-light-it-but-everyone-has-the-power-to-veto-or-at-least-delay-and-increase-cost decision-making methodology
- We should rethink what we have discarded, particularly in regard to modern nuclear power for electricity generation
- When a “solution” is not living up to expectations, there must be intense review and the willingness to cut it off; this can be extremely difficult politically, as we have seen with California High Speed Rail

# BEVs and PHEVs – a Bit of a Reality Check

- California has already moved to totally stop the sale of internal combustion engine (ICE) light-duty vehicles and other states – and the Federal government – are following
- The adopted "solution" is "zero-emission" vehicles (ZEV), chiefly:
  - BEV – battery electric vehicles
  - Hydrogen fuel cell vehicles
  - Plug-in hybrid electric vehicles (PHEV) are seen as transitional improvement until full ZEV is workable
- Similar conversions are being implemented for medium- and high-duty vehicles, mostly semi-tractor trailer and larger box trucks and passenger buses, but will take longer due primarily to the difficulty in creating vehicles with sufficiently long operating ranges with excessive weight for batteries
- Toyota, one of the two largest auto manufacturers in the world, has been a very strong promoter of BEVs for years – but, let's take a look at what it is now saying

# Toyota's Commitments

- "Toyota is committed to offering a full array of electrified vehicle options to give all our customers to opportunity to reduce their carbon footprints
- "Toyota has committed to be carbon neutral in all our facilities by 2035 and all our products by 2050
- "Lexis will be 100% battery electric vehicles by 2035"
- *While Toyota is not retreating from these commitments, it goes into detail as to why the transition to 100% BEV will require that substantial difficulties be overcome – which are slowing the transition to pure battery electric*

# “There are **three major barriers** to widespread battery electric vehicle adoption in the United States.”

“1. **Critical materials**: More than 300 new lithium, cobalt, nickel, cobalt, and graphite mines are needed to meet the expected battery demand by 2035. While US battery manufacturing is expected to increase significantly in the next few years, the pace of mineral mining and processing will not keep up, likely creating an imbalance between the raw materials and final production.

“2. **Changing infrastructure:** Only 12% of public chargers are fast chargers, taking 20-60 minutes to get to 80%. Most public chargers can take anywhere from 8-30 hours to charge. To meet the federal ZEV vehicle sales target, 1.2M public chargers are needed by 2030. That amounts to approximately 400 new chargers per day. The pace in 2021 was about 50 per day. That is in addition to the 28 million private EV chargers needed.

“3. **Affordability:** The average transaction price for a non-battery electric vehicle is $48,000. The average price for a battery-electric vehicle is $58,000. To make a BEV convenient, customers will also need to install an at home chargers, which adds an additional $1,300.”

# A Practical Path Forward

While we work to address the challenges, the most immediate way to reduce carbon emissions is through a mix of electrified options, which includes battery electric, plug-in hybrid, and hybrid vehicles.

Taking limited battery resources and sharing them among different options allows lower carbon options in every vehicle segment, will get more customers, regardless of status or income, in electrified vehicles, and will take more carbon off the road.

## The 1:6:90 Rule

The amount of raw materials in one long-range battery electric vehicle could instead be used to make 6 plug-in hybrid electric vehicles or 90 hybrid electric vehicles. For the same limited resources, instead of replacing one internal combustion engine vehicle, you can replace 90. **The overall carbon reduction of those 90 hybrids over their lifetimes is 37 times as much as a single battery electric vehicle.**

**1** Battery Electric Vehicle

**6** Plug-in Hybrid Electric Vehicles

**90** Hybrid Electric Vehicles

# Impact on the Electrical Grid

- To say that there is a very wide range of possible outcomes on the U.S. electric generating and distribution system from the projected rapid growth in BEV would be an understatement
- “The electrification of the transportation sector will catch most utilities a little bit off guard,” said Ben Kroposki, director of the Power Systems Engineering Center at the National Renewable Energy Laboratory. The organization estimates that, by 2050, the electrification of transportation and other sectors will require a doubling of U.S. generation capacity. (Groom & Bellon, Reuters)
- A model utility with two to three million customers would need to invest between $1,700 and $3,800 in grid upgrades per EV through 2030, according to Boston Consulting Group. Assuming 40 million EVs on the road, that investment could reach $200 billion. (Groom & Bellon, Reuters)
- “We’re talking about a pretty gradual transition over the course of the next few decades,” said Ryan Gallentine, transportation policy director at Advanced Energy Economy. “It’s well within the utilities” ability to add that kind of capacity.” (Picon, E&E News)

# Too Early to Be Able To Know the Result

- The potential impact is substantial
- Proper planning and preparation for what may come is essential
- To say the least, U.S. utilities, the U.S. utility regulatory system, and the California Legislature have not always been the most admired for their work in figuring out what is needed to advance the public interest in having a reliable, responsive, and cost-effective electrical system
- California electric rates are among the nation's highest:
  - San Diego has the highest electric rates in the U.S.
  - Californians' electric bills are 30% more than the national average – even through electric usage is lower
  - The average California electric rate per kWHr is approximately double the national average
- Given the historical record, it appears proper to be concerned if the national – and particularly the California – electric grids and electric generation capabilities will be sufficient to projected BEV expansion

# Zero Tailpipe Vehicle "Upstream" Emissions

- "Upstream" emissions, in reference to light duty vehicle (LDV) emissions, refer to greenhouse gas and other emissions created in the creation and the distribution of power to vehicles; in other words, there are significant vehicle emissions ***besides*** tailpipe emissions – an BEV has emissions, even though it doesn't have a tailpipe
- For this is the creation and distribution, and the emissions therefrom, for the electricity to charge the batteries
- While, in almost all cases, the total emissions for BEVs and PHEVs are lower than for convention internal combustion engine (ICE) LDFs, they are not inconsequential – and will vary significantly by location as the fuel for electric generation varies
- The graphic following is the result for the emissions calculator for a lower-emission BEV and a larger-emission PHEV in low- and high-fossil fuel electricity-generation locations, respectively

# Emissions for Representative BEV and PHEV

**Beyond Tailpipe Emissions Calculator**

**Vehicle:**

2023

Tesla Model X

**Your Location:**

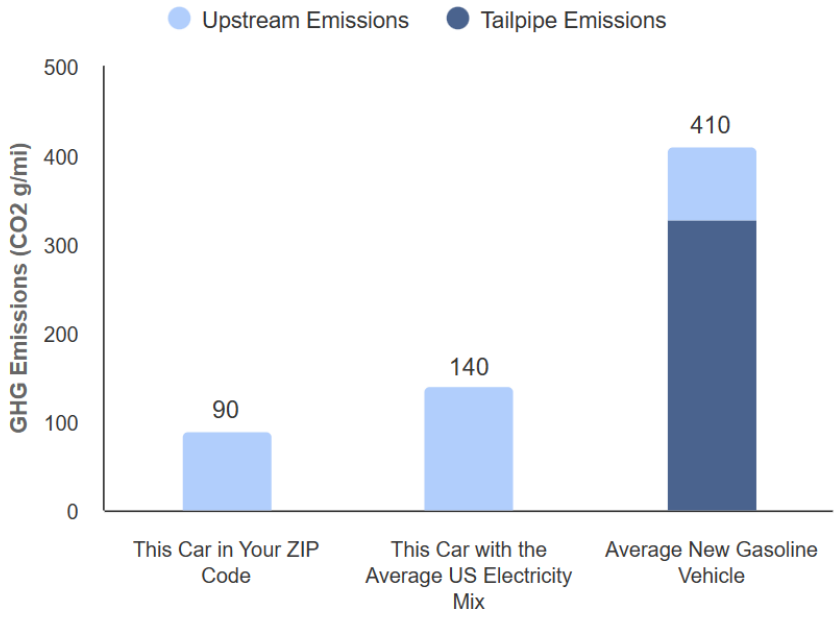
94103 (San Francisco, CA)

*GHG emissions depend on how electricity is generated in your area.*

Select vehicle

**The Tesla Model X is an all-electric vehicle.**

**Comparing Total GHG Emissions***




**Beyond Tailpipe Emissions Calculator**

**Vehicle:**

2023

Lincoln Aviator PHEV AWD

**Your Location:**

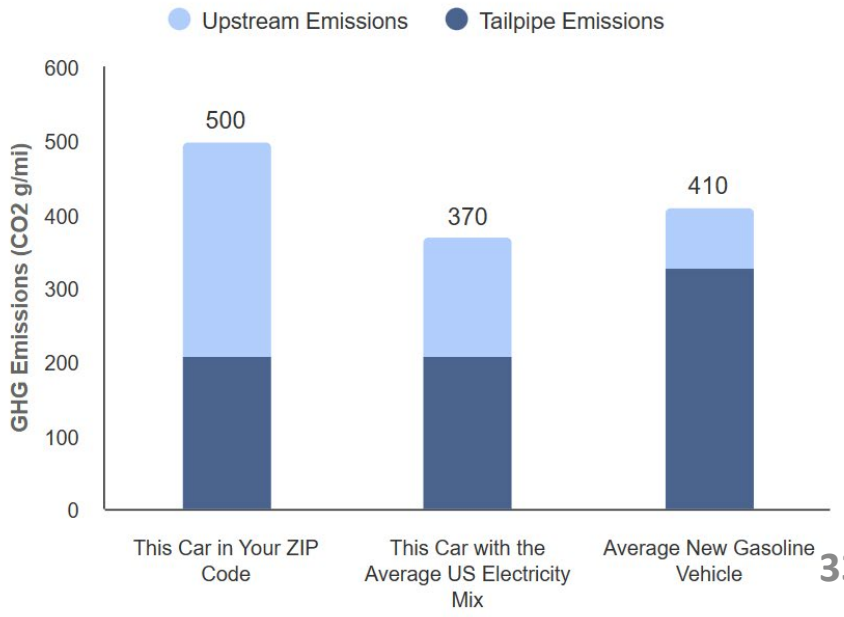
96801 (Honolulu, HI)

*GHG emissions depend on how electricity is generated in your area.*

Select vehicle

**The Lincoln Aviator PHEV AWD is a plug-in hybrid.**

**Comparing Total GHG Emissions***



# *BUT* – The Proposed EPA Emission Standards …

- Environmental Protection Agency, "Multi-Pollutant Emission Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles," Proposed Rule, May 5, 2023:

  > "EPA is proposing to revise multiplier incentives currently in place for MDVs through MY 2027, established in the heavy-duty Phase 2 rule, to end the multipliers a model year earlier, in MY 2026. EPA is also proposing that the requirement for upstream emissions accounting for BEVs and PHEVs as part of a manufacturer's compliance calculation, which under the current regulations would begin in MY 2027, would be removed under the proposed program; thus, BEVs would continue to be counted as zero grams/mile in a manufacturer's compliance calculation as has been the case since the beginning of the light-duty GHG program in MY 2012."

- This regulatory decision significantly overstates the GHG and other emission reduction potential of BEV and, therefore, makes the performance of other emission-reduction options appear inferior – BEVs and PHEVs will simply not be anywhere near as good for the environment as EPA stats will make them appear

# Replacing Natural Gas with Electricity for Residences

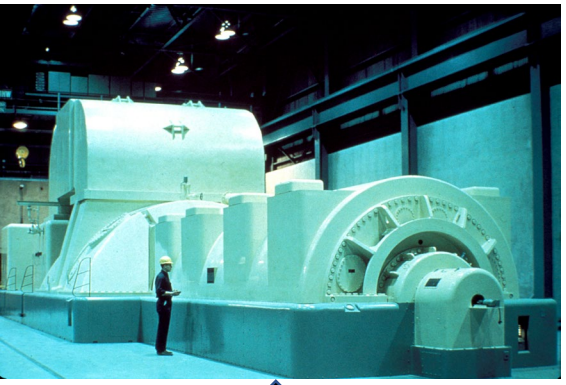
- The City of Berkeley was the first in the U.S. to set a cut-off date for when natural gas would no longer be allowed for new building hook-ups, effective January 1, 2020
- Since then, several other cities have followed Berkeley's lead and many others around the nation, and some states, are considering such bans
- Let us examine how the larger energy system picture works for home utilities

# Conventional Natural Gas Water Heater


**Natural Gas Water Heater – Burn natural gas to heat water to ~115-140$^{o}$ F.**

# Use Electricity to Heat Water in the Home

**Steam Turbine**



**Transformer for long-Distance Distribution**

**Long Lines To Local Utility**

**Transformer to reduce voltage for local distribution**

**Final Step-Down to 120v**

**Electric Water Heater – to heat water to ~115-140° F.**


**Superheated Steam ~600-1,200° F.**

**Natural Gas Fire**

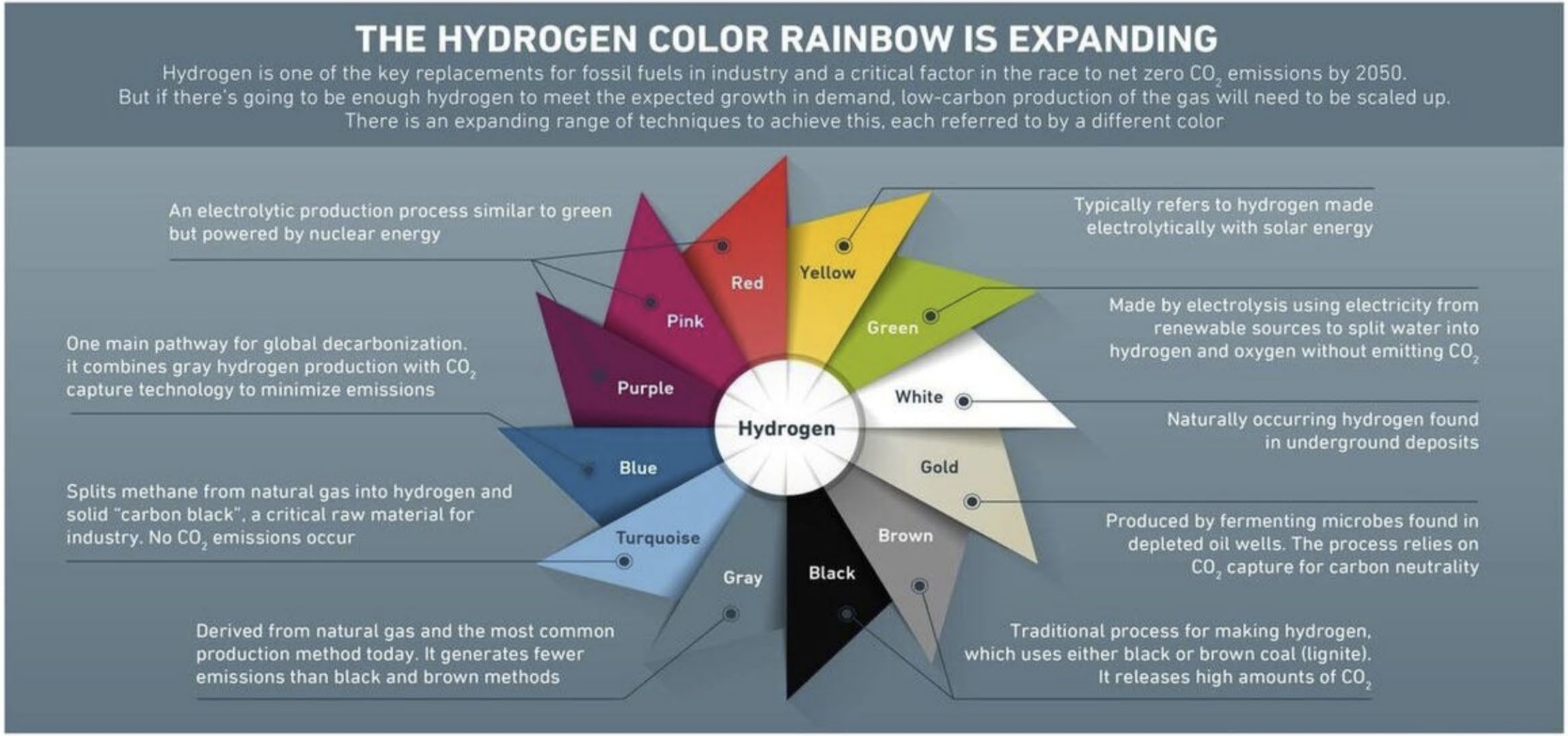
# Energy Transitions

- Gas Water Heater:
  - Chemical (natural gas) to heat (fire)
  - Heat to heat – warms water to 115-140$^{o}$ F.
- Gas Turbine Electrical to Electric Water Heater:
  - Chemical (natural gas) to heat (fire)
  - Heat to heat – warms water to ~600-1,200$^{o}$ F. superheated steam
  - Heat (steam) to motion (steam)
  - Motion (steam) to motion (turbine blades)
  - Motion (turbine blades) to high-voltage electricity for long-distance transmission
  - High voltage electricity to mid-voltage electricity for urban area distribution
  - Mid-voltage electricity to 120v electricity for residential power supply
  - 120v electricity to water heater heating element
  - Water heater heating element heats water to 115-140$^{o}$ F.
  - Also, electric distribution line loss

# Hydrogen Fuel Cell Vehicles

- The main alternative to battery electric propulsion for zero-emission vehicles, light-duty, medium/heavy-duty, and buses is Hydrogen ($H_2$) fuel cell propulsion
- In a fuel cell, the oxidation of the hydrogen is used to generate electricity, but ***not*** by being burned in an internal combustion engine.
- The product of "burning" $H_2$ is $H_2O$ – water vapor, and almost nothing else
- $H_2O$ has minor GHG impact when compared to fossil fuels that combust both Hydrogen and Carbon to produce $H_2O$ and Carbon Dioxide – $CO_2$
- $CO_2$ is, of course, widely considered the principle GHG – and is the standard of measurement for other GHGs, with impact measured in terms of equivalent tonnes of $CO_2$
- The primary problem with Hydrogen Fuel Cells is how to obtain the $H_2$ fuel – which does not exist in large quantities on Earth; as it is lighter than air, free $H_2$ will immediate rise up and mix with the other atmosphere gases

# Fuel Cell $H_2$ Comes in Many "Colors" – as to How Made




**Source: Andrea Willige for Mitsubishi Heavy Industries Group**

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# Right Now, "Gray" is King

- Although there are many ways to create $H_2$ – which is also an important resource for many industrial purposes – at the present time, about half the world-wide production is "Gray"
- Natural gas, which is mainly methane ($CH_4$), is heated to ~1,000$^o$ C., mixed with steam in the presence of nickel as a catalyst
- When $CH_4$ is combined with $H_2O$, if all the Hydrogen is extracted through the above and follow-on processes, what remains is C (carbon) and O (oxygen) – which forms $CO_2$, the GHG that Hydrogen Fuel Cells are designed to avoid
- Depending on the fuel stock and other factors, for each "Gray" ton of $H_2$ produced for fuel cell fuel, approximately ten tons of carbon dioxide is created
- If this $CO_2$ is captured, then we have "Blue" Hydrogen
- If it isn't captured, but released onto the air, while the ten tons of carbon dioxide may appear to be a lot, compared to a conventional diesel engine in a standard transit bus, this a reduction of approximately 60% in GHG
- Diesel powerplants also produce CO, $SO_2$, $NO_x$, $O_3$, $PM_{10}$, $PM_{2.5}$, among others

# More Problems with Hydrogen Fuel

- It takes substantial energy to create $H_2$ fuel – far more than then the energy that the $H_2$ produces in a fuel cell. While this may seem counterproductive at first reflection, what is important is producing a fuel that can be used in a moving vehicle to create green transportation – or, at least, green***er*** transportation
- The Fuel Cell holy grail is "Green" $H_2$ fuel – which uses "Green" electricity, such as solar, to power electrolysis, splitting water ($H_2O$) to create Hydrogen ($H_2$) and Oxygen ($O_2$) – and no GHG or other emissions in any significant quantity
- Gray Hydrogen is the most commonly-utilized process because it is the least expensive and is now well known from many years of use; most of the other processes are "greener" (but not "Brown" or "Black," which are powered by coal-generated electricity), but are more expensive and have other requirements.
- The "clean Green" evaluation of renewable-electricity created $H_2$ has a logic flaw – if this clean electricity was not being used to create this "clean" fuel, it could be used for other purposes – like reducing the amount of coal-generated electricity
- Finally, all gases escape, and $H_2$, being the smallest and lightest gas there is, is the hardest to contain – and many scientists are very concerned that it is a strong GHG

# Conclusions

- We now live in the time of the fastest technological advancement in the history of mankind – and the pace of change is constantly accelerating
- The problems with climate change and other human-caused environmental issues ***must*** be addressed, and addressed now, but …
- Before we make changes, before we allocate major funding to proposed solutions, we must have a high degree of confidence that the proposed actions will actually achieve productive results, and that there are no other clear better ways of achieving the desired outcomes
- Unfortunately, claims of climate change and other environmental benefits are being made by proponents of projects and programs of all types that may have little, if any, such benefits – and, in some cases, are actually contra-indicated
- All I can recommend is, watch out and be careful – trust your gut, do your own research where possible, don't be reluctant to ask questions, and look for unbiased experts without any skin in the game

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