California's South Coast Air Quality Management District (SCAQMD) is Phasing Out Deadly Appliance Emissions in Homes

Households and Businesses CAN Afford this Change: Here's Why

Prepared By: Pete Marsh, March 2025
Comments welcome: [redacted]

Introduction:

This white paper summarizes numerous studies and analyses that illuminate the importance and affordability of two Proposed Amended Rules under consideration by California's South Coast Air Quality Management District (SCAQMD). The rules, PAR 1111 and PAR 1121, would deliver healthier air by driving down deadly emissions of Oxides of Nitrogen (NOx) and related toxic gases that are released into the atmosphere and in many cases into nearly six million Southern California dwelling units. The rules help households upgrade from polluting furnaces and water heaters to state-of-the-art and highly efficient equipment in the most cost-effective and equitable manner possible: as building owners replace existing appliances, usually at end of life, manufacturers must meet increasingly high sales targets of non-emitting appliances.

About the Author:

The author is a solar contractor, small business owner, and retired U.S. Coast Guard Commander (O-5) who held command assignments both afloat and ashore. He also held regional leadership roles with a highly successful startup company and a marquee international technology consulting firm, including enterprise resource allocation and budgeting responsibility in both his public and private sector roles. He holds pro bono leadership roles in numerous civic and educational commissions and nonprofit organizations focused on climate solutions, especially the decarbonization of the nation's existing building stock, including: USGBC California, AIA California, the Climate Reality Project, Climate Action California, and climate and sustainability commissions and task forces at large cities and and school districts. He holds multiple degrees: BS in Marine Science from the US Coast Guard Academy, and MS in Telecommunications Systems Management from the US Naval Postgraduate School (which is roughly half telecom engineering and half MBA).

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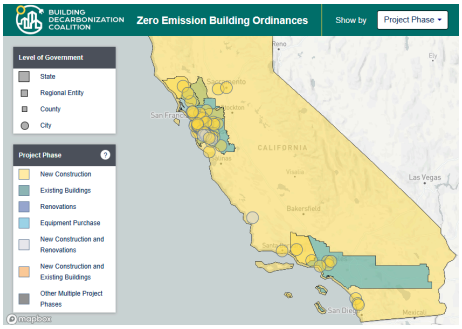
EXECUTIVE SUMMARY

California's South Coast Air Quality Management District (SCAQMD) is considering two Proposed Amended Rules that would phase out the deadly emissions of Oxides of Nitrogen (NOx) and dozens of related toxic fumes that are released into the atmosphere and in many cases into nearly six million Southern California dwelling units. These two rules phase out furnaces and water heaters that emit these pollutants in the most affordable and equitable manner possible: as existing appliances reach their end of life, building owners will upgrade to zero-NOx appliances. Primarily, these will be heat pumps and heat pump water heaters, which are both highly efficient and a mature / on the shelf technology[1].

These rules are needed because the Los Angeles area still has the highest levels of ozone in the nation, and is one of only two regions that are in extreme nonattainment of the 2015 US EPA 8-hour ozone standard, 70ppb. The 2022 AQMP concludes that only way to achieve the required ozone reductions is to reduce NOx through extensive use of zero emission technologies across all stationary and mobile sources[2].



These rules are among the most impactful policies for upgrading existing buildings with pollution-free technologies under consideration in the state, and perhaps the nation. SCAQMD is among the early adopters, but not the first: New York State and City, Massachusetts, Washington State, Colorado, Denver, Boston, the Bay Area Air Quality Management District, and other jurisdictions who care about their residents' health and livelihoods have already passed similar legislation or regulations. As of January 2025, The Building Decarbonization Coalition's policy tracker reflects 152 policies adopted by 130 local governments, 5 states, and 2 regional entities that address building specific operational fuel types and related emissions in the United States. An interactive map provides details[3].

Numerous legal mandates require CARB and California's 35 Air Districts to implement rules to reduce smog, air pollution, and greenhouse gases: the federal Clean Air Act (CAA)[4], California's Assembly Bill 32 (AB32)[5], the California Air Resources Board (CARB) 2022 State Implementation Plan (SIP)[6], the US Nationally Determined Contribution to the Paris Agreement[7], and more.

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[1] South Coast Air Quality Management District. "SCAQMD Proposed Amended Rules (PAR) 1111 and 1121." Accessed October 18, 2024. https://www.aqmd.gov/home/air-quality/air-quality-management-plans/air-quality-mgt-plan

[2] South Coast Air Quality Management District. "South Coast AQMD Air Quality Management Plan 2022," page ES-1 Accessed January 11, 2025. https://www.aqmd.gov/home/air-quality/air-quality-management-plans/air-quality-mgt-plan

[3] Building Decarbonization Coalition. "Zero Emission Building Ordinances." BDC. Accessed October 3, 2024. https://buildingdecarb.org/zeb-ordinances.

[4] US EPA. "US Clean Air Act, 42 U.S.C. §7401." Overviews and Factsheets, February 22, 2013. https://www.epa.gov/laws-regulations/summary-clean-air-act

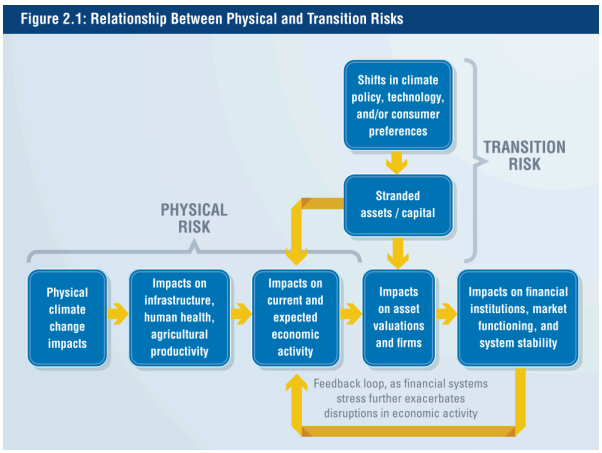
[5] Nunez. "AB32, California Global Warming Solutions Act of 2006: Air Pollution, Greenhouse Gases," September 27, 2006. https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=200520060AB32

[6] California Air Resources Board. "CARB 2022 State Implementation Plan Strategy," 2022. https://ww2.arb.ca.gov/sites/default/files/2022-08/2022_State_SIP_Strategy.pdf

[7] UNFCCC. "Nationally Determined Contribution (NDC) to the Paris Agreement Synthesis Report." Accessed January 11, 2025. https://unfccc.int/process-and-meetings/the-paris-agreement/nationally-determined-contributions-ndcs/ndc-synthesis-report/ndc-synthesis-report

These rules have co-benefits of eliminating other criteria pollutants and greenhouse gases, all of which create major positive impact for human health and the economy.

Opposition groups have expressed numerous objections to these draft rules, the most oft-stated being that Southern California households and businesses "can't afford to implement the rules"[8].



Extensive bodies of research conclude the opposite: the status quo or Business As Usual approach, in which ~80% of total US energy is derived from fossil fuel combustion, is already causing ruinous economic damages from air pollution and climate change-amplified extreme weather events such as the devastating Los Angeles area wildfires of January 2025. For instance, a September 2020 US Commodity Futures Trading Commission (CFTC) report concluded that if the world transitions to a zero carbon energy economy, "**the cumulative benefit in terms of avoided climate-related and air pollution damages ranges from $50 trillion to $142 trillion, and reducing fossil fuel subsidies would generate further savings of $15 trillion by 2050**."[9] Additionally, "the transition would result in $11.8 trillion in stranded assets by 2050, but delaying action would nearly double total stranded assets to $19.5 trillion by 2050."[10]

According to the World Bank, global subsidies to the fossil fuel industry impose over $7 trillion of cost onto the economy, about 7% of the global 2023 $106T GDP[11]. These include direct price support to consumers and producers and indirect subsidies from externalities such as the health and environmental costs of air pollution from fossil combustion, climate damages, and more.

Affordability of compliance for individual households, especially low income, has been a major concern of commenters concerned about these rules. Two separate analyses specific to the South Coast Air Basin found that zero-emission equipment actually costs less up-front than gas-fired in some cases.[12]

There's also a large body of peer-reviewed research which finds that fossil fuel combustion causes massive human health impacts, including 8 to 10 million premature deaths per year. [13], [14]

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[8] South Coast AQMD. "Comment Letters on SCAQMD Proposed Amended Rules 1111 and 1121." Accessed January 11, 2025. https://www.aqmd.gov/home/rules-compliance/rules/scaqmd-rule-book/proposed-rules/rule-1111-and-rule-1121/comment-letters
[9] Ibid
[10] Ibid
[11] International Monetary Fund. "Fossil Fuel Subsidies." IMF. Accessed March 21, 2023. https://www.imf.org/en/Topics/climate-change/energy-subsidies
[12] Laurie Stone, Jed Holtzman, and Rachel Golden, "Heat Pumps Reduce Smog in Southern California. Available Incentives Mean They Can Also Cost Less Than Gas Equipment.," RMI, February 21, 2025, https://rmi.org/heat-pumps-reduce-smog-in-southern-california-available-incentives-mean-they-can-also-cost-less-than-gas-equipment.
[13] Harvard T.H. Chan School of Public Health. "Fossil Fuel Air Pollution Responsible for 1 in 5 Deaths Worldwide," February 9, 2021. https://www.hsph.harvard.edu/c-change/news/fossil-fuel-air-pollution-responsible-for-1-in-5-deaths-worldwide
[14] Wallace-Wells, David. "Ten Million a Year." London Review of Books, December 2, 2021. https://www.lrb.co.uk/the-paper/v43/n23/david-wallace-wells/ten-million-a-year

In the SCAQMD region alone, fossil-fired air pollution is responsible for 76,000 asthma attacks, 30,000 days of missed school, 130 premature deaths, and $2 billion in health impacts[15].

At the local level, Long Beach city council members and community advocates often point out that some studies have found life expectancy in West Long Beach to be up to 17 years shorter than a few miles away in East Long Beach. A major part of causation is fossil combustion along Interstate 710, colloquially known as the "Diesel Death Corridor."

Numerous other objections are raised by written and verbal comments in this proceeding; while there are certainly challenges, the cost of taking action on existing buildings is far less than the cost of inaction. This white paper addresses many of those objections.

The drivers of both air pollution and climate change are primarily combustion of fossil fuels[16].

The solution to eliminating emissions of both criteria pollutants and greenhouse gases, which has become clear in the last decade, is strikingly straightforward: numerous studies conclude that we can power well over 80% of the US and global economies with electric end use devices that are on the shelf right now, while simultaneously shifting energy supply to low emission sources - primarily solar, wind, hydro, geothermal, and nuclear[17]. We can and must start immediately on this journey, while conducting research in the handful of "Difficult To Decarbonize" (DTD) sectors: long distance shipping, long distance aviation, and a few high heat industrial processes.

The existing building stock falls into the DTD category, not because of a lack of technology, but because of the sheer quantity of existing buildings that must be addressed, one at a time. There are over 120 million dwelling units in the United States, and about 70 million of them use gas furnaces and 60 million use gas water heaters. These appliances together contribute a significant fraction of NOx and other criteria pollutants, and roughly 10% of US greenhouse gas emissions, Until we replace them with non-emitting appliances, we'll continue to combust fossil fuels, continuing to impose cost and health impacts on humanity[18]. The sheer number of these appliances, and the relative uniqueness of each structure and its electrical wiring, makes it a huge challenge to upgrade homes to electric appliances.

Upgrading gas furnaces and water heaters to zero-NOx appliances as they reach end of life, and while we have large incentives available from the federal government, state, SoCalREN, and SCAQMD, is by far the most affordable and equitable way to accomplish this.

[15] Southern California's Hidden Air Pollution Problem: Gas Furnaces & Water Heaters," Coalition For Clean Air and Rocky Mountain Institute, 2024, https://www.ccair.org/wp-content/uploads/2024/12/South-Coast-Brief.pdf
[16] US Global Change Research Program. "Fifth US National Climate Assessment." Fifth National Climate Assessment. U.S. Global Change Research Program, Washington, DC, 2023. https://nca2023.globalchange.gov/downloads.
[17] Hausfather, Zeke, and Erik Olson. "What New Net-Zero Studies Tell Us About Electricity Decarbonization." The Breakthrough Institute. Accessed August 21, 2023. https://thebreakthrough.org/issues/energy/new-net-zero-studies-on-electricity-decarbonization.
[18] Griffith, Saul. "Electrify: The Book." Rewiring America, The MIT Press. October 04, 2022. https://www.rewiringamerica.org/electrify-the-book

FOSSIL FUEL COMBUSTION DRIVES AIR POLLUTION AND CLIMATE CHANGE

A doctor doesn't prescribe treatment before making a diagnosis. Similarly, we need to state clearly the diagnosis for earth's atmosphere before discussing solutions and whether or not they are affordable.

Air Pollution

California Air Resources Board 2022 State Implementation Plan Strategy

This section summarizes the statutory and federal regulatory framework that require these measures, mostly excerpts quoted from the CARB SIP.

> "These measures are needed across the State of California for areas to meet the federal 70 parts per billion (ppb) 8-hour ozone standard (70 ppb ozone standard) set by the U.S. Environmental Protection Agency (U.S. EPA) in 2015….
>
> "California has the only two areas in the nation with an Extreme classification for the 70 ppb ozone standard, the South Coast Air Basin (South Coast) and the San Joaquin Valley (Valley). While the Proposed 2022 State SIP Strategy is being developed primarily as a roadmap for attaining the 70 ppb ozone standard, the emissions reductions will also support attainment of other ozone (e.g. 80 ppb, 75 ppb) and fine particulate (PM2.5) national ambient air quality standards (NAAQS), make progress towards the State air quality standards, and improve visibility across the State….
>
> "Residential and commercial buildings in California are the source of about 66 tpd NOx38 statewide due to natural gas combustion. Nearly 90 percent of building NOx emissions are due to space and water heating and the remaining 10 percent are due to cooking, clothes drying, and other miscellaneous end uses. At the regional level, approximately one-third of projected building related emissions in South Coast could be reduced by 2037 if zero-emission standards were implemented in 2030 for space and water heating…." [19]

South Coast Air Quality Management District Air Quality Management Plan

The California Air Resources Board (CARB) 2022 State Implementation Plan Strategy reports that the Los Angeles area has the highest levels of ozone (smog), which is created from NOx (oxides of nitrogen), in the nation.

The rules discussed in this white paper focus on Oxides of Nitrogen (NOx), because that criteria pollutant is the one for which the LA basin is in worst non-attainment. But there are a huge number of other co-benefits to eliminating fossil combustion, including significant reductions in emissions of other criteria pollutants and greenhouse gases.

On October 1, 2015, the U.S. Environmental Protection Agency (EPA) strengthened the National Ambient Air Quality Standards (NAAQS) for ground-level ozone, lowering the primary and secondary ozone standard levels to 70 parts per billion (ppb). The South Coast Air Basin is classified as in "extreme" nonattainment. The 2022 AQMP was developed to

[19] California Air Resources Board. "CARB 2022 State Implementation Plan Strategy," 2022. https://ww2.arb.ca.gov/sites/default/files/2022-08/2022_State_SIP_Strategy.pdf.

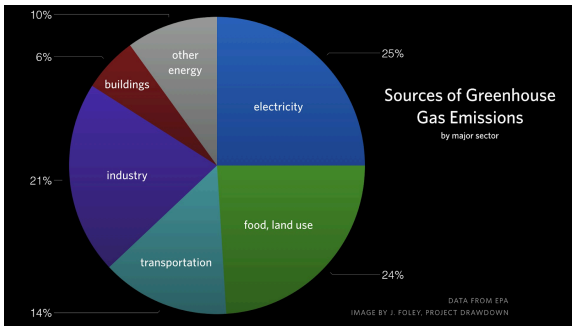
address the requirements for meeting this standard and was adopted December 2, 2022 by the South Coast AQMD Governing Board.[20]

Greenhouse Gases

While the rules herein specifically address the criteria pollutant NOx, since that is the legal authority of California's Air Districts, it is valuable to recognize that reducing NOx emissions will have significant co-benefits, particularly in driving down the greenhouse gas (GHG) emissions that drive global warming and the economic, human health, and ecosystem damages that it causes.

Intergovernmental Panel on Climate Change (IPCC)

The 2021 Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC) opens with the straightforward conclusion that "[A.1 It is unequivocal that human influence has warmed the atmosphere, ocean and land. Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred. [A.1.1]: Observed increases in well-mixed greenhouse gas (GHG) concentrations since around 1750 are unequivocally caused by human activities."[21]



Dr. Jonathan Foley of Project Drawdown has one of the most straightforward graphs that summarize the sources of GHGs. They are produced by six major sectors of the economy, five of which involve combustion of fossil fuel (coal, oil and gas) for energy: electricity, industry, transportation, buildings, and other energy emissions are about 75% of emissions. Food & land use contribute the remaining 25%, primarily deforestation, methane emissions from cattle and rice fields, and nitrogen fertilizer overuse.

US Fifth National Climate Assessment (NCA5)

The Fifth National Climate Assessment is the US Government's preeminent report on climate change science, impacts, risks, and responses. It is a congressionally mandated interagency effort that provides the scientific foundation to support informed decision-making across the US[22]. This graphic summarizes several critical realities about climate change:

- Climate change is happening right now in all regions of the US
- Without deeper cuts in global net emissions, climate risks to the US will continue to grow.
- How much more the US warms depends on choices made today.
- Action to limit future warming and reduce risks can have near-term benefits and opportunities.

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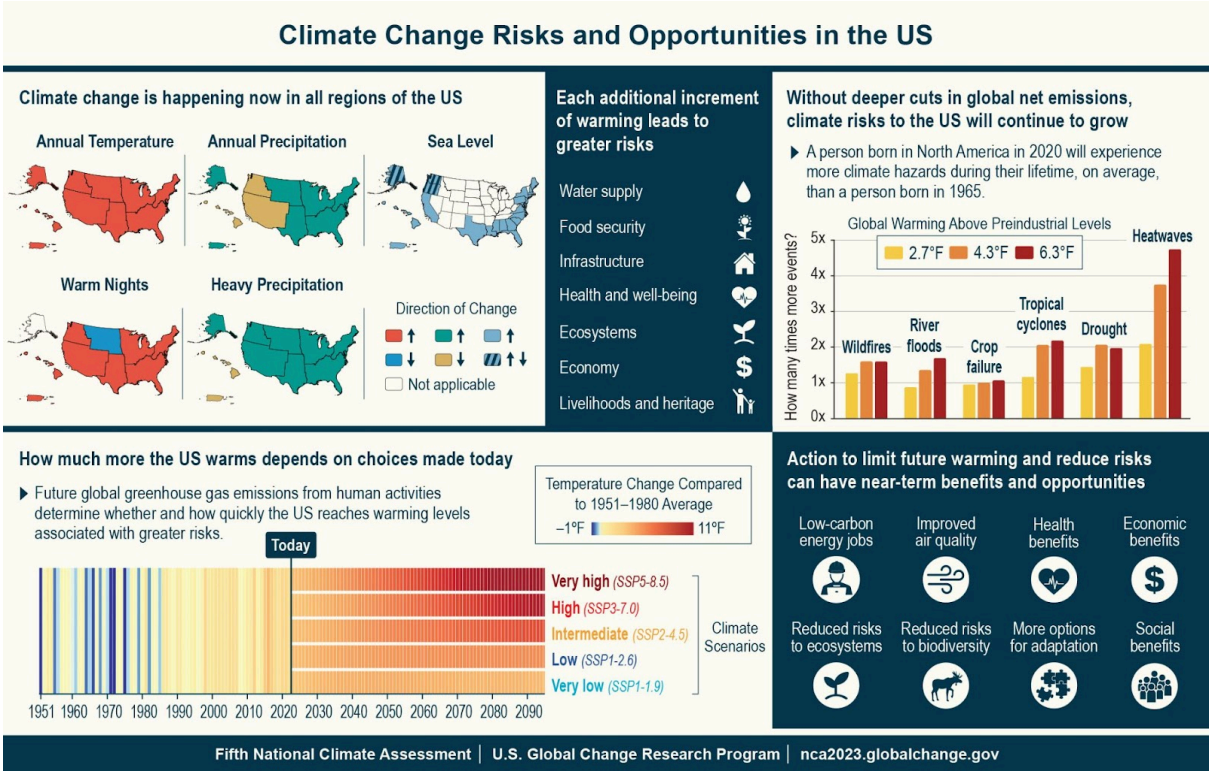
[20] South Coast Air Quality Management District. "South Coast AQMD Air Quality Management Plan 2022," page ES-1 Accessed January 11, 2025. https://www.aqmd.gov/home/air-quality/air-quality-management-plans/air-quality-mgt-plan.

[21] Masson-Delmotte, Valérie, Sarah L. Connors, et al., eds. "IPCC Assessment Report 6 - Climate Change 2021: Physical Science Basis." Sixth Assessment Report of the Intergovernmental Panel on Climate Change, 2021. https://www.ipcc.ch/report/sixth-assessment-report-working-group-i.

[22] US Global Change Research Program. "Fifth US National Climate Assessment." Fifth National Climate Assessment. U.S. Global Change Research Program, Washington, DC, 2023. https://nca2023.globalchange.gov/downloads.



California's Fourth Climate Change Assessment (CCA4)

California's Fourth Climate Change Assessment translates the state of climate science into actionable information. It "presents findings in the context of existing climate science, including strategies to adapt to climate impacts." From the abstract:

> In the absence of significant global mitigation action and regional adaptation efforts, rising temperatures, sea level rise, and changes in extreme events are expected to increasingly disrupt and damage critical infrastructure and property, labor productivity, and the vitality of our communities. Regional economies and industries that depend on natural resources and favorable climate conditions, such as agriculture, tourism, and fisheries, are vulnerable to the growing impacts of climate change.
>
> Rising temperatures, extreme heat, drought, wildfire on rangelands, and heavy downpours are expected to increasingly disrupt agricultural productivity in the United States. Expected increases in challenges to livestock health, declines in crop yields and quality, and changes in extreme events in the United States and abroad threaten rural livelihoods, sustainable food security, and price stability
>
> Our Nation's aging and deteriorating infrastructure is further stressed by increases in heavy precipitation events, coastal flooding, heat, wildfires, and other extreme events, as well as changes to average precipitation and temperature.[23]

[23] "California's Fourth Climate Change Assessment," California Natural Resources Agency, California Energy Commission, California Governor's Office of Planning and Research. January 16, 2019. https://climateassessment.ca.gov.

Reducing Air Pollution and Greenhouse Gases: #ElectrifyEverything Does Most of the Work

Climate journalist David Roberts, author of the newsletter ***Volts***, in 2021 Published an article in which he laid out "a simple framework to help people think about how to prioritize climate policies."[24] This quote from the article is a succinct summary of the key actions necessary to rapidly reduce both greenhouse gases and air pollution, including NOx (emphasis added):

> "While different climate models disagree about which policies and technologies will be needed to clean up remaining emissions after 2030, virtually all of them agree on what's needed over the next decade. It's clean electrification:
>
> 1. **clean up the electricity grid** by replacing fossil fuel power plants with renewable energy, batteries, and other zero-carbon resources;
> 2. **clean up transportation** by replacing gasoline and diesel vehicles — passenger vehicles, delivery trucks and vans, semi-trucks, small planes, agricultural and mining equipment, etc. — with electric vehicles; and
> 3. **clean up buildings** by replacing furnaces and other appliances that run on fossil fuels with electric equivalents.
>
> Or as I summarize it: electrify everything!
>
> Clean electrification is the entrée. **If you decarbonize electricity, transportation, and buildings, you've taken out the three biggest sources of emissions in virtually every country. The technologies and policies we need to do it exist today, ready to deploy**."

This concise summary has become a guiding principle for many organizations and researchers working to reduce air pollution and greenhouse gases. But until the last decade, it wasn't at all clear that it would be either technically feasible or affordable to shift the global energy economy - which constitutes over 15% of global GDP - from its current heavy reliance on coal, oil, and gas to zero air pollution and zero GHG emissions in both energy supply and energy usage. The last decade has proven, both empirically in actually deployed technologies and studies assessing growth, that it is both feasible and affordable.

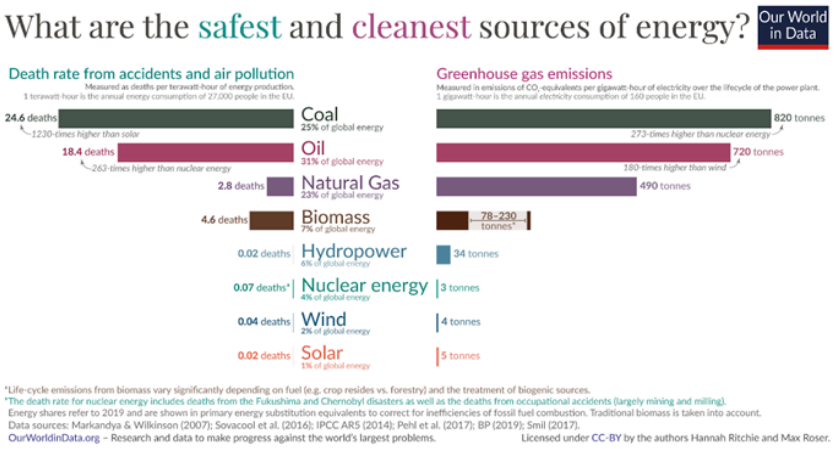
The next several sections summarize trends in the clean energy transition: history of energy sources, financials, manufacturing, and deployment of zero carbon energy sources. These, coupled with a clear eyed assessment of the high cost of doing nothing (stranded assets, externalities, and supply and demand), make it clear that not only can we afford the clean energy transition, we can't afford NOT to do it - and rapidly.

Safest and Cleanest Sources of Energy: Solar, Wind, Hydro, Nuclear, Geothermal

[24] Roberts, David. "On Climate Policy, There's One Main Thing and Then There's Everything Else," January 8, 2025. https://www.volts.wtf/p/on-climate-policy-theres-one-main

Since this paper discusses the clean energy transition, it's vital to establish what energy sources are considered clean. The chart below from Our World in Data summarizes their 2020 report which concludes "Fossil fuels are the dirtiest and most dangerous energy sources, while nuclear and modern renewable energy sources are vastly safer and cleaner."[25]

The greenhouse gas emissions intensity of eight energy sources on the right hand side of this chart make clear:



- **Clean energy includes wind, solar, and nuclear energy**, which each emit only 3 to 5 tonnes of CO2 equivalent per gigawatt hour (GWh) of electricity generated.
- **Gas, oil, and coal**, meanwhile, emit 490, 720 and 820 tonnes of CO2e per GWh, or from 100 to 200 times more greenhouse gases per unit of electricity generated. These are the sources we need to rapidly phase out.
- Hydropower is generally considered both clean energy generation and also Long Duration Energy Storage (LDES), shifting power generation from the west's rainy winter season to the dry summer season.
- Biomass is complicated, and a small fraction of power generation.
- Enhanced geothermal energy is not shown on the chart, but is a recently emerging very low emissions generating technology that is not weather-dependent.

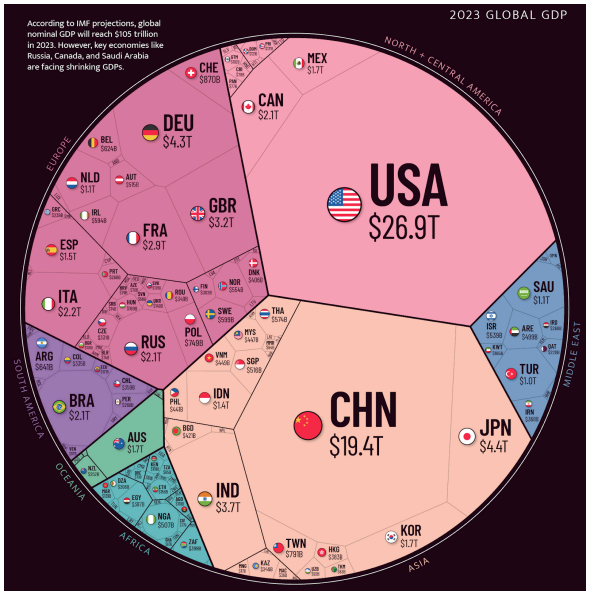
[25] "What Are the Safest and Cleanest Sources of Energy?," Our World in Data, February 10, 2020, https://ourworldindata.org/safest-sources-of-energy

AFFORDABILITY - MACROECONOMICS: FINANCIAL IMPACTS OF FOSSIL FUEL COMBUSTION

The objection most often posed to the low emissions energy transition is “We cannot afford to phase out fossil fuels.”

In fact, **the opposite is true: we can’t afford NOT to transition away from fossil fuel** combustion.

The majority of stated objections center around individual households, and cite high - often exaggerated - costs for low-NOx space and water heating appliances. This paper will address those. But in order to understand why it’s important to eliminate emissions from each individual dwelling unit, we must first understand the staggering magnitude of cost imposed on society as a whole by fossil fuel combustion. Once we establish that context, the value of addressing each and every end use machine becomes much more clear.



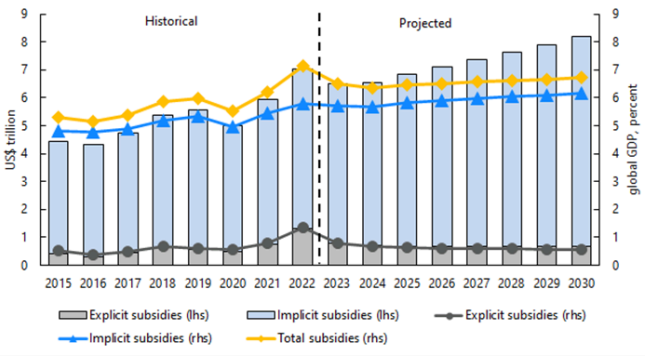
The status quo, in which ~75% of total US energy is derived from fossil fuel combustion, will cause tremendous economic damage from air pollution and climate change-amplified extreme weather events such as the devastating Los Angeles area wildfires of January 2025. This section summarizes a few of the many sobering analyses about climate change economic impacts, followed by the good news regarding low carbon energy generation.

Many of these reports refer to global, national, or regional economies; the 2023 scale of each was:

- Global GDP: $106.2T[26], [27]
- US GDP: $27.7T[28]
- California GDP: $3.2T[29]
- Southern California GDP: $1.95T[30]

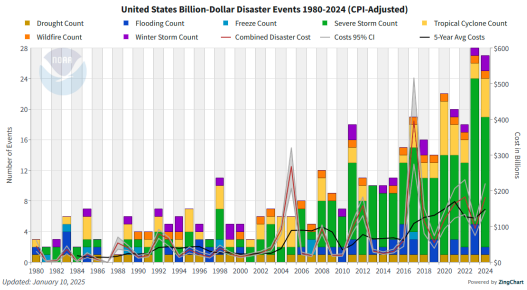
[26] World Bank. “GDP Ranking by Nation 2023.” Accessed January 12, 2025. https://datacatalog.worldbank.org/search/dataset/0038130.
[27] Rao, Pallavi. “Visualizing the $105 Trillion World Economy in One Chart.” Visual Capitalist, August 9, 2023. https://www.visualcapitalist.com/visualizing-the-105-trillion-world-economy-in-one-chart.
[28] ibid
[29] Statista. “Real GDP California U.S. 2023.” Statista. Accessed January 12, 2025. https://www.statista.com/statistics/187834/gdp-of-the-us-federal-state-of-california-since-1997.
[30] St. Louis Fed. “Real Gross Domestic Product by County 2023: California.” Accessed January 12, 2025. https://fred.stlouisfed.org/release/tables?rid=397&eid=1071149.

Fossil Fuel Subsidies: $1.2 Trillion per Year of Direct Subsidies, and $6T Indirect



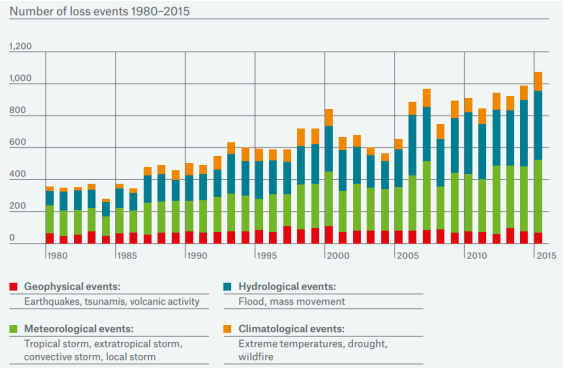
The International Monetary Fund reports that in 2023, **global fossil fuel subsidies were $7 trillion, or 7% of GDP**. 18% ($1.26T) of the 2022 subsidies are explicit support from governments to fossil fuel producers, primarily undercharging for supply costs. The remaining 82% are implicit (indirect) subsidies, primarily underpricing for local air pollution costs and climate damages (about 30% each). Other implicit subsidies include broader road transport externalities such as congestion and road accidents (17%), and forgone consumption tax revenue (5%)[31]. Essentially, this means that fossil fuel combustion imposes a seven percent tax on the global economy.

NOAA: Billion Dollar Disasters Show Rapidly Increasing Disasters and Cost Due to Climate Forcing



The National Oceanic and Atmospheric Administration (NOAA) has tracked Billion Dollar Disasters since 1980. These are primarily extreme weather events, which have been made more likely, more frequent, and more severe by the 2 degree Fahrenheit increase in global average temperature since pre-industrial times. As of January 2025, the US has sustained 403 weather and climate disasters since 1980 where overall damages/costs reached or exceeded $1 billion (CPI adjusted to 2024 US dollars). The total cost of these 403 events exceeds $2.9 trillion. The average in the 1980s was 3.3 events per year, costing 299 human lives and $22B CPI adjusted. In the last five years (2020-2024) 23.0 events per year, costing 504 human lives and $149B CPI adjusted[32].

Insurance and and Reinsurance Industry is Pulling Out of HIgh Risk Areas Due to Climate Risk



The reinsurance industry is in the business of providing insurance to insurance companies. Munich Re is one of the largest reinsurers. Their website lists 12 categories of risk to their global capital assets, and one of those is climate change and its consequences.

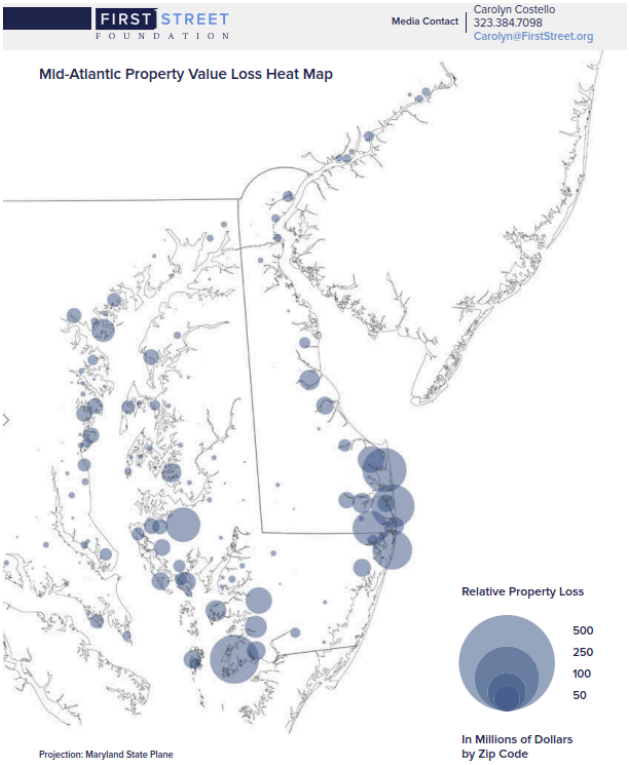
They introduce the topic thus: “For five decades, Munich Re has been analysing the effects that global warming and natural climate variations have on weather-related natural disasters. We focus on the risks involved as well as on loss prevention and new risk transfer concepts. We make use of long-term meteorological and loss data to understand changes in

[31] International Monetary Fund. “Fossil Fuel Subsidies.” IMF. Accessed March 21, 2023. https://www.imf.org/en/Topics/climate-change/energy-subsidies

[32] NOAA. “Billion-Dollar Weather and Climate Disasters, 1980 - 2024.” NOAA National Centers for Environmental Information, 2020. https://doi.org/10.25921/STKW-7W73

risk and to adjust our risk models accordingly. With this expertise, we can continue to provide our clients with the usual level of risk capacity. The current scientific consensus is that human greenhouse gas emissions since the industrial revolution are overwhelmingly responsible for rising temperatures in the atmosphere and oceans. The consequences of global warming are many and varied."[33]

Munich Re's 2015 report "Natural catastrophes 2015 - Analyses, assessments, positions," was headlined "The earth's 'hotting up,' " and included the graph at left which shows that the costs attributable to extreme weather disasters globally have been increasing rapidly, in a pattern very similar to NOAA's billion dollar disasters.



The risk analytics firm First Street Foundation describes itself as "The Standard for Climate Risk Financial Modeling. We exist to make the connection between climate change and financial risk at scale for financial institutions, companies and governments.… Real estate, the bedrock of the American economy, is worth over 45 trillion dollars. Climate change has started to erode that foundation."[34] Data scientists from First Street Foundation and Columbia University performed housing market research along the US East and Gulf coasts, and found that increased tidal flooding caused by sea level rise has eroded $15.8 billion in property values between 2005 and 2017.[35]

They estimate that "39 million homes are covered at prices artificially lower than their true risk. They predict that as disasters continue surging, what they call the "growing climate bubble in the housing market" will pop — leaving millions of homes uninsurable and destroying their value. The average homeowner who loses an insurance policy automatically sees a drop of more than 10 percent in the home's value."

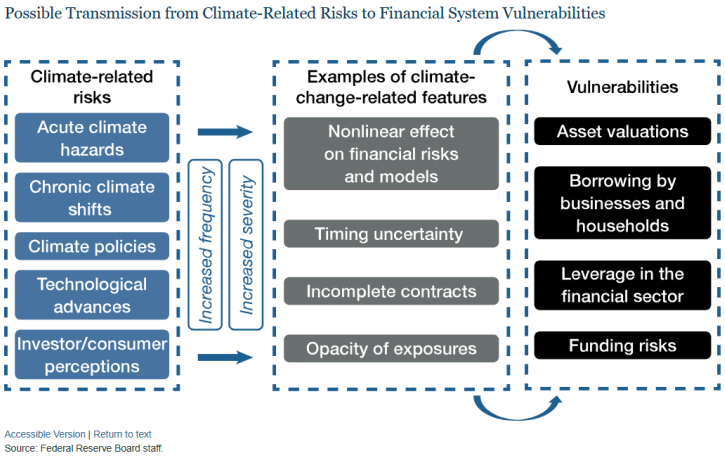
Reinsurers are particularly exposed to these hazards because many insurance companies seek primarily to cover catastrophic risks — major events like hurricanes that are intensifying as the world warms."

As a result, the reinsurance industry has paid dearly for much of the last decade; underwriting losses drove $115 billion in global reinsurance losses in 2022. "There's a tension over a business model that's retrospective, with a risk that's emerging," said Frank Nutter, president of the Reinsurance Association of America. The financial foundation of insurance, in other words, is cracking.

[33] Munich Re. "Climate Change and Its Consequences." Accessed January 15, 2025. https://www.munichre.com/en/risks/climate-change.html.
[34] First Street Foundation. "The Standard for Climate Risk Financial Modeling." FirstStreet. Accessed February 16, 2023. https://firststreet.org.
[35] First Street Foundation. "Rising Seas Erode $15.8 Billion in Home Value from Maine to Mississippi." Accessed January 17, 2025. https://assets.firststreet.org/uploads/2019/03/Rising-Seas-Erode-15.8-Billion-in-Home-Value-from-Maine-to-Mississippi.pdf.

US Federal Reserve Bank: Climate Change Likely to Increase Financial Shocks and Financial System Vulnerabilities

The Federal Reserve System ("the Fed," the central bank of the United States), was created by Congress to provide the nation with a safe, flexible, and stable monetary and financial system. In its November 2020 Financial Stability Report, the Fed addressed climate change for the first time, and the message was stark: "Climate change, which increases the likelihood of dislocations and disruptions in the economy, is likely to increase financial shocks and financial system vulnerabilities…. Acute hazards, such as storms, floods, droughts, or wildfires, can quickly alter, or reveal new information about, future economic conditions or the value of real or financial assets…. One example of how climate change is likely to increase financial stability risks is through real estate exposures…. As inundations [from sea level rise] or storm surges become more frequent, the expected value of exposed real estate may decrease, which may in turn pose risks to real estate loans, mortgage-backed securities, the holders of these loans and securities, and the profitability of nonfinancial firms using such properties."[36]



CFTC: Climate Change Poses a Major Risk to the Stability of the US Financial System

The mission of the US Commodity Futures Trading Commission (CFTC) is "to promote the integrity, resilience, and vibrancy of the U.S. derivatives markets through sound regulation." In September 2020, CFTC issued a sobering report titled "Managing Climate Risk in the U.S. Financial System."[37] The report presents 53 recommendations to mitigate risks to financial markets posed by climate change. The opening paragraph of the Executive Summary states starkly:

> "Climate change poses a major risk to the stability of the U.S. financial system and to its ability to sustain the American economy. Climate change is already impacting or is anticipated to impact nearly every facet of the economy, including infrastructure, agriculture, residential and commercial property, as well as human health and labor productivity. Over time, if significant action is not taken to check rising global average temperatures, climate change impacts could impair the productive capacity of the economy and undermine its ability to generate employment, income, and opportunity. Even under optimistic emissions-reduction scenarios, the United States, along with countries around the world, will have to continue to cope with some measure of climate change-related impacts."

Chapter 8, "A Closer Look at Financing the Net-Zero Transition," includes this paragraph which puts the investments and savings for the status quo versus the path for limiting [global] warming in perspective:

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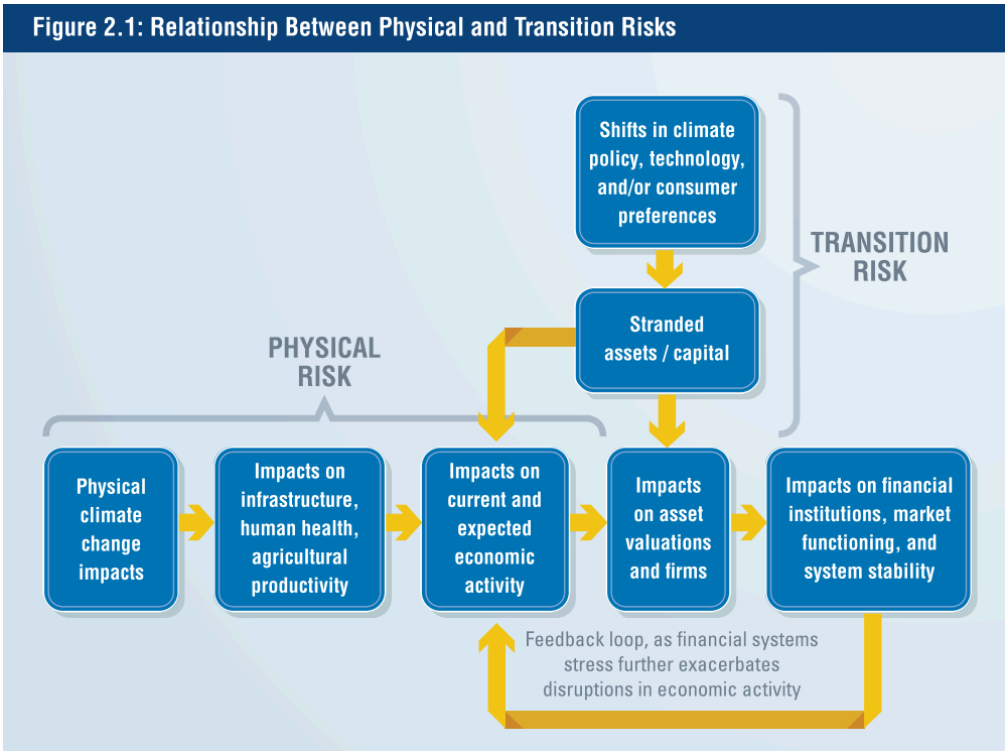
[36] Federal Reserve Board of Governors. "Near-Term Risks to the U.S. Financial System." Accessed January 15, 2025. https://www.federalreserve.gov/publications/2020-november-financial-stability-report-near-term-risks.htm

[37] Litterman, Bob. "Managing Climate Risk in the U.S. Financial System," September 9, 2020. https://www.cftc.gov/sites/default/files/2020-09/9-9-20%20Report%20of%20the%20Subcommittee%20on%20Climate-Related%20Market%20Risk%20-%20Managing%20Climate%20Risk%20in%20the%20U.S.%20Financial%20System%20for%20posting.pdf.

"Investment needs are broadly estimated to be in the trillions of dollars. One estimate comes from the International Renewable Energy Agency (IRENA), which charts an ambitious yet technically and economically feasible path for limiting warming to "well below" 2 degrees Celsius, in line with the Paris Agreement. IRENA estimates that $110 trillion of cumulative worldwide investment in the energy sector will be needed leading up to 2050 (IRENA, 2019). That equates to roughly 2 percent of average global gross domestic product (GDP) per year over the period. **Of the $110 trillion, $95 trillion is already required** under the reference case scenario of current plans and policies but would need to be redirected from investments in high-carbon to low-carbon activities. An additional $15 trillion is necessary to further reduce emissions. This transformation is estimated to boost total global GDP by 2.5 percent, or 5.3 percent when considering the avoided climate-related damages relative to the reference case (maintenance of current plans and policies). **The transition would result in $11.8 trillion in stranded assets by 2050, but delaying action would nearly double total stranded assets to $19.5 trillion** by 2050. However, **the cumulative benefit in terms of avoided climate-related and air pollution damages ranges from $50 trillion to $142 trillion**, and reducing fossil fuel subsidies would generate further savings of $15 trillion by 2050, relative to the reference case."[38]

This figure illustrates the complexity of the risks posed by air pollution and climate change to the global economy.



Additional takeaways from the CFTC report:

- "A world racked by frequent and devastating shocks from climate change cannot sustain the fundamental conditions supporting our financial system;"
- "U.S. financial regulators must recognize that climate change poses serious emerging risks to the U.S. financial system, and they should move urgently and decisively to measure, understand, and address these risks."

[38] Ibid

This report was prepared by a subcommittee of 34 executives and researchers from industry, public interest groups, and academia. Notably, the subcommittee was appointed by a decision of the five CFTC Commissioners, all five appointed by President Trump during his first term.[39] Subcommittee Chair Bob Litterman, founding partner and Risk Committee Chairman of Kepos Capital, said "I was amazed and gratified that the CFTC asked for this report, and I was honored to chair the subcommittee, but I think what is most unique about this effort is that more than 30 financial market participants agreed on so much."[40]

Social Cost of Carbon: Accounting for Externalities

The social cost of carbon (SCC) is an economic field of study that quantifies the costs imposed on society from combustion of fossil fuels beyond the price paid "at the pump," by the direct consumer. Technically, it's an estimate of the present discounted value of the future damage caused by 1 tonne of CO2 emissions[41]. Dr. William Nordhaus won the 2018 Nobel Prize in Economics for his 1980s work on the Social Cost of Carbon, and President Obama's Executive Order (EO) 12866 in 2010 established an Interagency Working Group on the Social Cost of Greenhouse Gases (IWG), which developed a methodology for estimating the SCC[42].

The costs considered in the IWG's current SCC methodology are the financial impacts of climate change, including changes in agricultural productivity, property damage from increased flooding, increased extreme weather events, increased wildfires, reduced labor productivity, and declines in human health from hotter ecosystems[43]. The IWG methodology does not currently include several other factors, although a 2017 report by the National Academies of Science, Engineering, and Medicine (NASEM) to the IWG contains recommendations for considering them. These include global factors such as forced migration and economic and political destabilization; global biodiversity and species extinction; and health damages from air pollution, ozone pollution, and wildfire smoke[44].

The IWG SCC was calculated at $42 during the Obama administration, then reduced to $3 at the beginning of the Trump administration. In 2021, EO 13990 restored it to $51 ($42 plus inflation), and also ordered a review; that review, delivered in September 2022, implements many of the NASEM suggestions and concludes that SCC is $190/MT[45].

Federal agencies are required to use SCC to evaluate proposed regulations. California and 11 other states have adopted the federal SCC, and also use it in policy analysis[46]. Globally, about 70 nations or sub-nations covering 23% of global emissions place an actual price on carbon, in the form of either a Cap-and-Trade system like California's or a carbon tax[47].

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[39] CFTC. "Former Commissioners of the US Commodity Futures Trading Commission." Accessed January 18, 2025. https://www.cftc.gov/About/Commissioners/FormerCommissioners/index.htm.
[40] "CFTC's Climate-Related Market Risk Subcommittee Releases Report." Accessed January 11, 2025. https://www.cftc.gov/PressRoom/PressReleases/8234-20.
[41] K. Rennert and C. Kingdon, "Social Cost of Carbon 101," Resources for the Future, Feb. 03, 2022. https://www.rff.org/publications/explainers/social-cost-carbon-101 (accessed Apr. 11, 2023).
[42] US Interagency Working Group on Social Cost of Greenhouse Gases, "Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide," Feb. 2021. https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf
[43] Ibid.
[44] Ibid.
[45] US EPA, "EPA External Review Draft of 'Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances,'" Sep. 22, 2022. https://www.epa.gov/environmental-economics/scghg
[46] "States Using the SCC." https://costofcarbon.org/states
[47] "Which countries have put a price on carbon?," Our World in Data. https://ourworldindata.org/carbon-pricing

California AB-766, "Climate change: corporate disclosures" (Gabriel, Bennett, 2021-2022) did not pass, but would have required "covered corporations" to begin to account for the cost of emissions[48].

State Lands Commission Order # W 17166 of 12 April 2023 was clear: "incorporate **risk identification and analysis** to provide the transparency necessary to **evaluate the efficacy of current and future operations,**" with SCC #9 of 11 areas of consideration. For decades, ER has not quantified the damages caused by extraction, focusing only on the dollars flowing into city coffers. SCC gives City Council a tool to understand the magnitude of the health and budget impacts.

Cost of Doing Nothing / Business as Usual / Status Quo

The numerous reports described in this section emphasize a critical thread, too often ignored or downplayed, that runs through every discussion of air pollution and climate change: **the cost of doing nothing**.

When an enterprise or its board consultants analyze alternatives, a fundamental principle is that in addition to whatever options are evaluated, the analysis must assess feasibility and cost of maintaining the status quo.

The reports just summarized make clear that the global, national, and regional economies cannot afford to continue with the status quo, which involves powering over 80% of the US economy with coal, oil, and gas. In fact, if the US delays its transition to a low emissions energy economy, it will give away global leadership in the energy economy of the 21st century. China is already racing far ahead; every policy proposal that gives the US opportunities to more rapidly build our clean energy economy positions this nation better to compete.

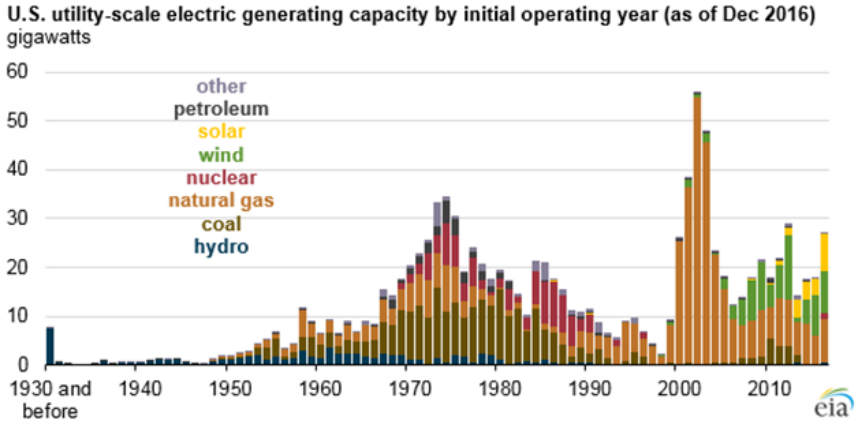
[48] AB-766 (proposed, not passed) Climate change: corporate disclosures. (Gabriel, Bennett, 2021-2022. https://leginfo.legislature.ca.gov/faces/billStatusClient.xhtml?bill_id=202120220AB766

AFFORDABILITY - ENERGY SYSTEM ECONOMICS

Electricity Generation: History and Recent Trends

Before looking to the future of the US energy system, it's useful to review the past. In 2016, the US Energy Information Administration published this 80+ year look-back at utility-scale electric generating capacity by initial operating year, 1930-2016.[49]

This chart doesn't show total electrical energy generation each year; it shows how much generating capacity was added each year, and from which sources. This is important context as we consider how the grid might further change in the future. The historical view of how the electric grid has evolved over nearly a century reveals several takeaways:

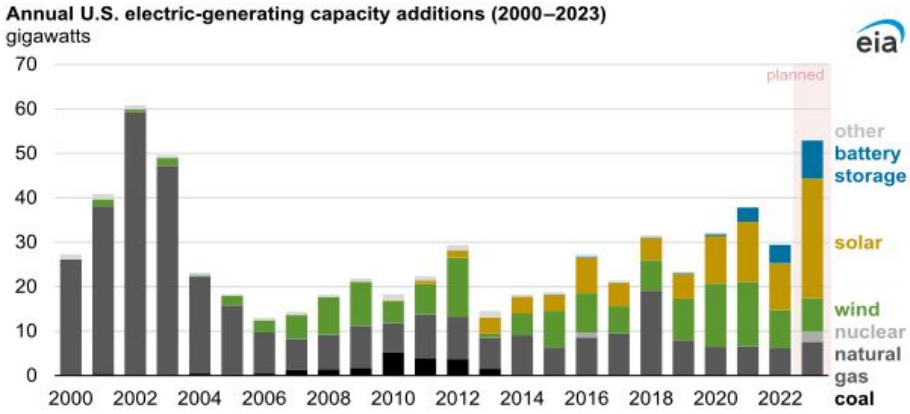


- The grid is not constant - as the saying goes, the only constant is change.
- The electric grid added enough capacity to double in the 1950s, and doubled again in the 1960s. By comparison, the expansion by 2X to 3X over the next three decades that will be discussed in a subsequent section looks almost modest. It's not: there's plenty of complexity. But the grid has achieved significant growth in the past, and if we trust American engineering, ingenuity, and innovation, we should be able to do so in the future.
- The chart shows the dominance of coal from the 1950's into the 1980's, when the saying "Coal is King" was prominent.
- The fracking boom of the 2000's brought that to an end, and for a half decade the US built the most generating capacity ever, with about 180GW added from 2002 to 2006. One common objection to transforming the grid by building a lot of renewable energy is "it can't be done." The incredible expansion of gas plants in the 2000's shows that isn't true: in a little over a decade, the US grid transformed from being dominated by coal to being dominated by gas, whose emissions intensity for onsite combustion is just half that of coal.
- The US built most of its approximately 100 nuclear power plants in the 1970's and 1980's; all but a few remain online today, and are receiving service life extensions from public service commissions around the country, since they provide almost 100 GW of clean electricity generation at capacity factors over 90%.
- In the mid-2000's wind began to grow, and in the mid-2010's solar followed suit. This EIA chart only extends through 2016, so it doesn't show a lot of renewable generation, but a subsequent section focused on the most recent decade will show the next phase of the transformation in the electrical grid.

Growth of Zero Carbon Electricity Generation in the 2010s to 2020s

[49] US Energy Information Administration (EIA). "U.S. Utility-Scale Electric Generating Capacity by Initial Operating Year, 1930-2016." February 27, 2017. https://www.eia.gov/todayinenergy/detail.php?id=30112.

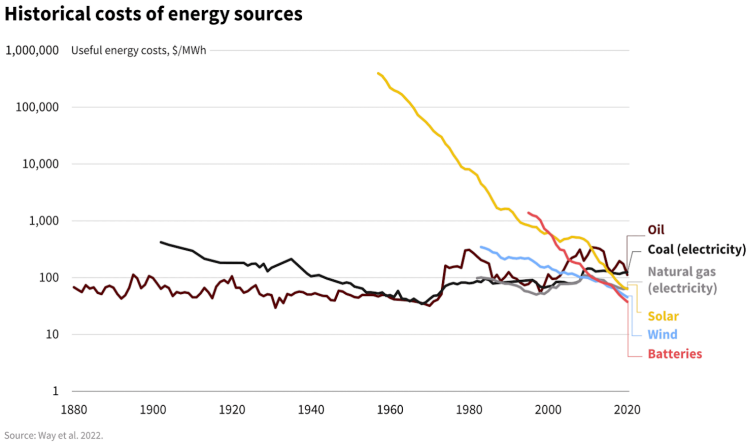
The previous section described US electricity generating sources over nearly a century. This section zooms in to the most recent timeframe. This chart from the US Energy Information Administration shows a dramatic shift over the last two and a half decades: gas plans dominated from 2000 to 2007, when wind began to comprise a significant portion of annual capacity additions; by 2015 wind and solar combined were over half of new capacity and have been every year since except 2018. By 2023, wind and solar and batteries were over 82% of new capacity, and in 2024 - not shown on this chart - they comprised 94% of new capacity.[50]



What has caused the rapid deployment of clean energy generation? The same things that have powered each industry transformation in our economy (steam engine, the internal combustion engine, 20th century labor-saving household appliances, and the computing and internet revolutions): innovation, R&D, manufacturing, demand, supply, increasing scale, judicious government incentives in many cases, and declining prices.

The following chart and summary from the annual energy transition presentation by the independent nonpartisan nonprofit, RMI, describes the pace and scale of the clean energy transition. [51] "The energy system is being disrupted by the exponential forces of renewables, electrification, and efficiency."

"In economic parlance, we say knowledge exhibits increasing returns: the more we discover, the more we realize there is to find out. Commodities, on the contrary, exhibit decreasing returns: the more oil we dig, the more onerous our efforts need to become. These decreasing returns from oil or coal are offset by improvements in the technologies that extract them. The net effect, however, is no structural decline in cost. Oil prices today, in real terms, are roughly the same as they were 140 years ago, and coal electricity prices are the same as they were 100 years ago.



Solar and battery prices, on the other hand, fall by about 20 percent for every doubling of deployment. And deployment has been doubling every two to three years. As a result, prices

[50] Elesia Fasching and US Energy Information Administration (EIA), "Wind, Solar, and Batteries Increasingly Account for More New U.S. Power Capacity Additions," Today in Energy, March 6, 2023, https://www.eia.gov/todayinenergy/detail.php?id=55719.
[51] Kingsmill Bond, Sam Butler-Sloss, and Daan Walter, "The Cleantech Revolution - It's Exponential, Disruptive, and Now," RMI, June 2024, https://rmi.org/insight/the-cleantech-revolution

have plummeted. Solar prices are down 99.9 percent since the 1950s. Batteries prices are down 97 percent since the 1990s.

The more solar panels and batteries we make, the more we learn how to make them, and the cheaper they get… and the more we can afford and thus the more we demand.

Developing an energy source that gets cheaper the more we make of it is a milestone for humanity. The positive repercussions of which will be a defining thread of our era.

The energy transition can be seen as a shift from commodities to technologies; from digging to manufacturing; and from hunting to harvesting. It is a story of brains beating brawn."

Humanity is still relatively early in the clean energy transition, as can be seen in the previous EIA chart of US generating capacity from 1930-2016. But the structural economic, manufacturing, and deployment of renewable energy revealed in the RMI report makes clear that change is coming, and rapidly.

#ElectrifyEverything: the Technology Exists Today, and is Less Expensive than the Status Quo

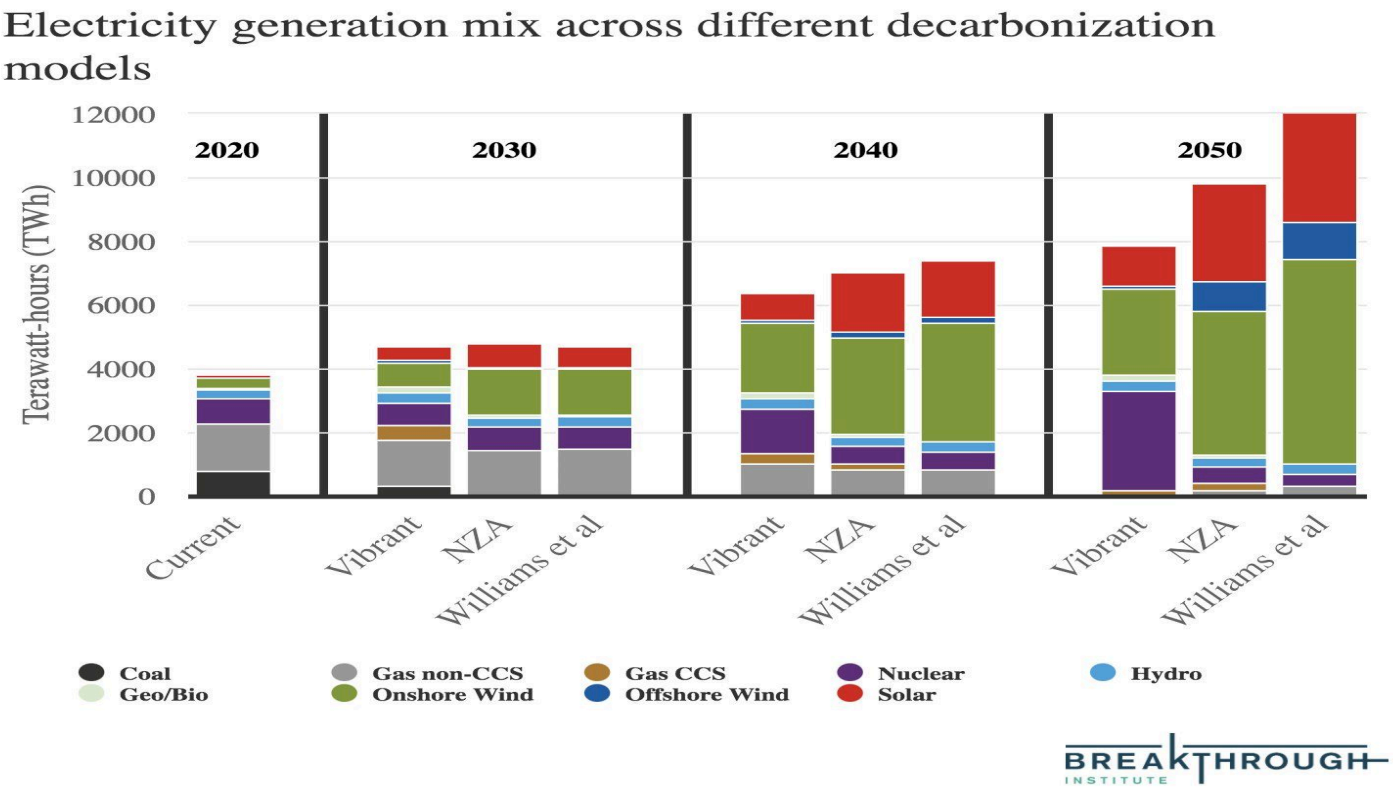
Previous sections showed the large scale and rapid pace of clean energy deployment in recent years. Building on that success, and looking 20 to 30 years into the future, numerous studies in the late 2010s and early 2020s evaluated national and global energy use across all sources and uses. Three respected peer-reviewed net zero studies were summarized by Dr. Zeke Hausfather in a 2021 meta-study.[52] All three concluded that the US economy can reach net zero emissions by 2050:

"A slew of new net-zero studies have been published in recent months, including Princeton's Net Zero America (NZA) project, the Vibrant Clean Energy Zero By Fifty scenario, and by a team of researchers led by Jim Williams at USF. **All three of these take a deep-dive into how the US could reach net-zero emissions by 2050**, down to the level of where each new generating facility might be located, where new transmission lines would be built, and how electricity generation sources can meet hourly grid demand in different regions of the country. Each study contains multiple scenarios looking at the sensitivity to future technology prices, land use constraints, and other factors.

While the models differ in important ways, they all paint a broadly similar picture. Wind and solar expand rapidly in the next three decades. US coal use falls off a cliff, reaching zero by 2030 or 2035. At the same time, natural gas use stays rather flat — or even increases modestly — between 2020 and 2030, as it serves a key role in filling in the gaps in variable renewable generation. Gas capacity actually increases in two of the three decarbonization models through 2050, though capacity factors — how often the gas plants are run — fall rapidly, and gas increasingly becomes a blend of hydrogen and methane closer to 2050."

Hausfather created this graph to summarize the 2020 US electricity generation mix, as well as the three studies' projected generation mix in 2030, 2040, and 2050. The top level takeaway is that each study concludes

[52] Zeke Hausfather and Erik Olson, "What New Net-Zero Studies Tell Us About Electricity Decarbonization," The Breakthrough Institute, February 22, 2021, https://thebreakthrough.org/issues/energy/new-net-zero-studies-on-electricity-decarbonization.



Takeaways:

- Future electricity demand: 2050 generation in the three models ranges from about twice the 4,000 Terawatt hour level of 2020 to three times that. These variations are driven by differing projections of economy-wide electrification rates, and the degree to which other sectors of the economy can be effectively electrified and their pace of change.
- All three models find that wind and solar - variable renewable energy , or VRE - deliver between 51% and 91% of total electricity generation by 2050. The remainder is a mix of clean firm generation (hydro, nuclear, and geothermal) with large expansions of transmission capacity, demand management, battery storage, and other dispatchable energy storage.
- One model forecasts a large expansion of nuclear energy, while the other two project a bigger role for offshore wind.

Dr. Hausfather concludes his meta study with this summary:

> "The future electricity mix is difficult to foresee perfectly, and history is a graveyard of failed energy model predictions. All models are wrong, as the saying goes, but some are useful. These deep decarbonization models give us a sense of what may be needed. We should not fixate too much on the specific generation mixes in any particular scenario, but we should take heed of where the models agree: on the importance of near-term renewables deployment, the medium-term role of gas capacity to fill in the gaps, and the importance of clean firm generation and complementary technologies to wean the power system off its dependence on natural gas in the longer term."

AFFORDABILITY - MICROECONOMICS: INDIVIDUAL HOUSEHOLD IMPACTS

The South Coast Air District is home to about 17.5 million people, about 44% of California's population, and 5% of the US population.[53] This scale presents challenges for reducing NOx and other pollutants. It also means that actions taken here will have impact around the nation and the world.

- The region has about 5.9 million housing units, or 43% of California's 13.7 million total; these include roughly 5 million gas furnaces and 5 million gas water heaters.
- Approximately 48% of residential buildings are occupied by renters.
- In 2018, residential combustion emitted 19.1 tons of NOx per day, 32% of the total emissions from stationary sources.

Household Affordability: Space and Water Heating

The existing building stock is a challenging sector in which to reduce NOx, other air pollutants, and greenhouse gases: in addition to the South Coast air district housing stock described above, nationwide there are over 120M households, with ~70M gas furnaces and ~60M gas water heaters.[54] Each of those are unique installations, which means that installers can rarely achieve economies of scale which would reduce costs. When a building owner switches an appliance from gas to electric power, there can be additional Capital Expenses (CAPEX) beyond what a like-for-like replacement with a gas appliance would cost. These fall into three categories: Appliance Cost, Electrical Circuit Cost, and Electrical Panel Upgrades, which are discussed in detail below.

The nonpartisan think tank RMI published a blog post in February 2025 that compares the cost of retrofitting an air-source heat pump to replace a combined furnace and air conditioner. Their analysis found that zero-emission equipment can deliver more than $10,000 in up-front cost savings in some cases. Even without federal home energy rebate funding, low-income households can save between $2,400 and $4,200 when choosing an air-source heat pump over a traditional furnace and AC system. And low-income households switching to heat pump water heaters from traditional gas units can save from $2,125 to $2,925.[55]

In addition to the RMI analysis, this white paper analyzed actual installation data from the TECH Clean California program, a statewide initiative to accelerate the adoption of clean space and water heating technology across California homes in order to help California meet its goal of being carbon-neutral by 2045. In the four counties of the AQMD region, empirical cost data from 15,552 actual appliance replacements showed that on average, retrofitting heat pumps in place of a gas furnace with accompanying air conditioner resulted in lower CAPEX than replacing with like-for-like. The retrofits presented in this data set were performed by licensed California contractors in the TECH Clean California program.[56]

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[53] SCAQMD, "Proposed Amended Rule 1111 and PAR 1121 Working Group Meeting (WGM) #1," October 5, 2023, https://www.aqmd.gov/home/news-events/calendar_v2?month=10&day=5&year=2023&id=f892dbef-c2b6-6f27-bf6f-ff00004a91a9

[54] Saul Griffith, "Electrify: The Book," Rewiring America, accessed January 16, 2024, https://www.rewiringamerica.org/electrify-the-book

[55] Laurie Stone, Jed Holtzman, and Rachel Golden, "Heat Pumps Reduce Smog in Southern California. Available Incentives Mean They Can Also Cost Less Than Gas Equipment.," RMI, February 21, 2025, https://rmi.org/heat-pumps-reduce-smog-in-southern-california-available-incentives-mean-they-can-also-cost-less-than-gas-equipment.

[56] TECH Clean CA, "TECH Clean California Data Repository: Project Locations, Costs, and Incentives," data extracted February 7th, 2025, https://techcleanca.com/heat-pump-data/heat-pump-data-visuals

Appliance Retrofit Cost Summary Table:

	4-County Total / Average	San Bernardino County	Riverside County	Orange County	Los Angeles County
HPWH installations	2,357	355	811	224	967
HP HVAC installations	13,165	1,507	5,067	2,422	4,169
Average HPWH project cost per residence	$6,096	$5,343	$7,270	$5,583	$6,187
Average HPWH incentive per residence	$4,841	$4,130	$6,542	$3,902	$4,789
Average HPWH out of pocket cost per residence	$1,255	$1,213	$728	$1,681	$1,398
Average HPWH percent savings per residence	79%	77%	90%	70%	77%
Average Gas WH project cost per residence	$3,000				
Average HPWH out of pocket cost vs higher (lower) than like-for-like per residence	($1,745)				
Average Heat Pump project cost per residence	$18,373	$15,996	$17,687	$19,336	$20,472
Average Heat Pump total incentive per residence	$1,929	$2,021	$2,086	$1,784	$1,825
Average Heat Pump out of pocket cost per residence	$16,444	$13,975	$15,601	$17,552	$18,647
Average Heat Pump percent savings per residence	10%	13%	12%	9%	9%
Average Gas Furnace plus AC project cost per residence	$18,800				
Average Heat Pump out of pocket cost vs higher (lower) than gas furnace plus ac per residence	($2,356)				
Average Gas Furnace project cost per residence	$10,000				
Average Heat Pump out of pocket cost vs higher (lower) than like-for-like per residence	$6,444				

Each project involved installing either a heat pump water heater or heat pump space conditioning system. This summary table also compares the costs of fuel-switching retrofits to the costs of like-for-like retrofits, as presented in SCAQMD's Working Group Meeting #2[57]; these costs were taken from a 2019 study by the energy consulting firm E3.[58]

So while it is absolutely appropriate to carefully examine household budget impacts, empirical data shows that on average, retrofitting with zero-NOx appliances is affordable. Here are further details on the three components of retrofit costs:

- **Appliance cost (CAPEX)**: A heat pump is usually more expensive than a gas furnace, and usually less expensive than a furnace plus accompanying air conditioner. Heat pump water heaters (HPWH) are more expensive than gas or electric resistance water heaters. The Summary Table above shows that of the 15,000 retrofits performed:
    - Heat pump water heater retrofits in the project set were almost $3,100 greater than like-for-like gas, but the average $4,841 incentives made the replacement about $1,800 less expensive than like-for-like.

[57] SCAQMD, "Proposed Amended Rule 1111 and PAR 1121 Working Group Meeting (WGM) #2," November 28, 2023, https://www.aqmd.gov/home/news-events/calendar_v2?month=11&day=28&year=2023&id=4601deef-c2b6-6f27-bf6f-ff00004a91a9
[58] Charles Li et al., "Residential Building Electrification in California," April 15, 2019, https://www.ethree.com/e3-quantifies-the-consumer-and-emissions-impacts-of-electrifying-california-homes

    - When a heat pump retrofit replaces both a gas furnace and an air conditioner, the average price is a few hundred dollars less than replacing with a gas furnace and air conditioner. And with the average $1,929 incentives, savings increased to an average $2,356. **Since 87% of SCAQMD region homes already have AC, this metric applies to the vast majority of households**.
    - When a heat pump retrofit replaces a gas furnace but not air conditioning, the cost is about $6,400 more than replacing with a like-for-like gas furnace, even with incentives. This condition is found in only about 13% of SCAQMD region households; and it means that the household now has AC, which they didn't have before.
- **Electrical Circuit Cost**: To switch these appliances from gas to electric, some homes will need an upgraded electrical circuit: larger wire gauge, and in rare cases a four wire circuit instead of a three wire circuit. But the majority of 240 volt heat pumps and heat pump water heaters can use the same two current carrying conductors and ground conductor that were in place for the gas furnace or water heater being replaced. If an upsized circuit is needed, that can cost a few hundred to a few thousand dollars.
- **Main Panel Upgrades**: As recently as 2022, Rewiring America and other groups estimated that as many as about 50% of homes switching from gas to electric would need to upgrade their main electrical panel, and estimated the cost at $2K~$4K each. But in 2023, New Buildings Institute and Redwood Energy collected empirical data from over 70,000 households in California's PG&E utility territory, and over 20,000 in PG&E territory. Over the course of a full year, only 2% of households ever exceeded 88 amps. And the average peak load in all-electric homes was just 32 amps.[59] This means that **most houses with 100 amp panels should be able to electrify without upgrading, and even add EV charging**. (Some will need to add a subpanel, or upgrade the main panel, if they have no more physical circuit breaker spaces available; and others will choose to replace old panels that appear to be safety concerns. Nationwide, the US electrical code was upgraded in 1962 to require 100 amp panels, and since the early 1990s most California homes have been built with 200 amp panels. By using efficient appliances, circuit sharing devices, and other efficient design techniques, Redwood Energy shows how to operate a 3,000 square foot home all-electric.[60]

This section has focused on the existing built environment. For new construction, building all-electric is less expensive than dual-fuel homes with both gas and electric. New Buildings Institute found that "The all-electric single-family home is $7,500-$8,200 cheaper to construct than the baseline code home." The reason: an all-electric house doesn't have to have a trench dug to the gas distribution pipe in the street; doesn't have to have the lateral (pipe from street to meter) installed; doesn't need a gas meter; doesn't need any gas piping inside the house; and doesn't need any venting for combustion exhaust.[61] Similar studies have found that for multifamily residential, the construction cost savings are about $3,500 per dwelling unit.

[59] Amruta Khanolkar, Sean Armstrong, and Tom Kabat, "We Can Power the Homes of the Future with Electric Panels of the Past," New Buildings Institute, July 25, 2023, https://newbuildings.org/we-can-power-the-homes-of-the-future-with-electric-panels-of-the-past

[60] Sean Armstrong, "How to Electrify A Residence Without A Panel Upgrade," Lawrence Berkeley Laboratory, December 2021, https://homes.lbl.gov/sites/default/files/2021-12/How%20to%20Electrify%20A%20Residence%20Without%20Panel%20Upgrades.pdf

[61] Sean Denniston et al, "Cost Study of the Building Decarbonization Code - New Buildings Institute," April 2022, https://newbuildings.org/resource/cost-study-of-the-building-decarbonization-code

HEALTH IMPACTS

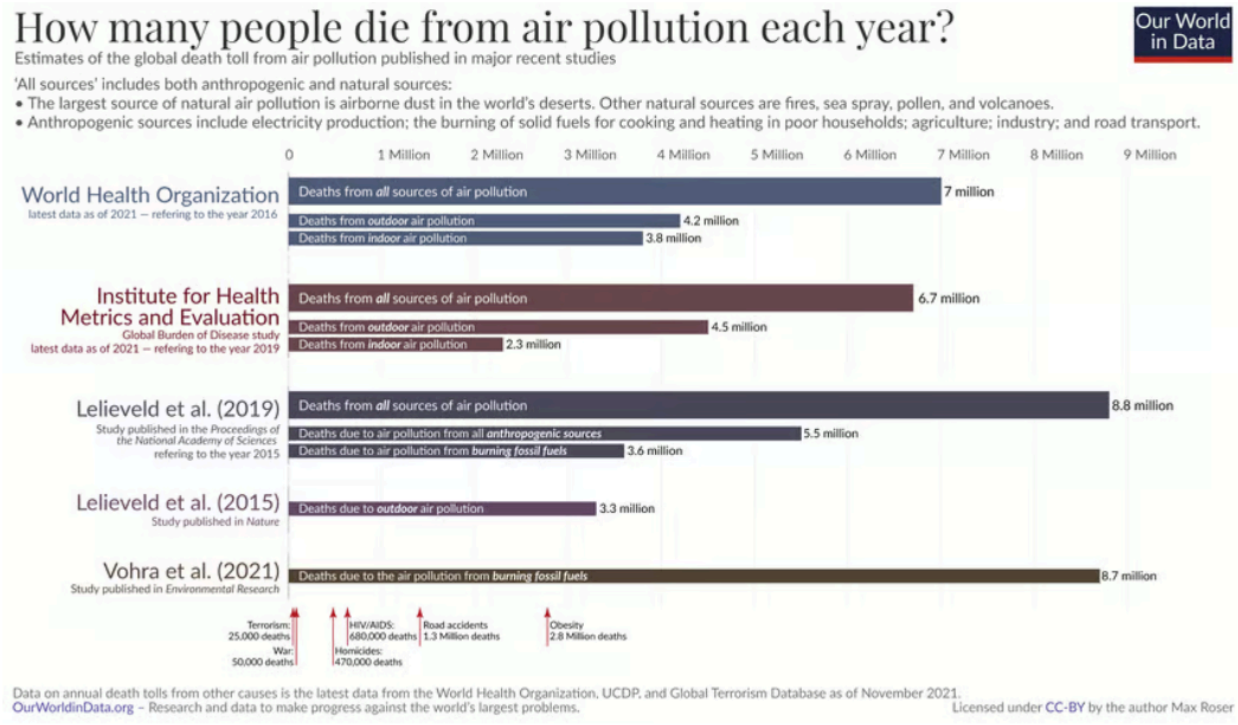
Global Health Impacts

Air Pollution Causes 8M~10M Premature Deaths Per Year

Our World in Data performed a detailed review of several studies that estimate the global death toll from air pollution. They found that "**the two most widely-cited estimates attribute around 7 million deaths per year to air pollution**. But the published estimates span a wide range. More recent studies tend to find a higher death toll than earlier studies. This is not because air pollution – at a global level – is worsening, but because the more recent scientific evidence suggests that the health impacts of exposure to pollution is larger than previously thought…. Exposure to air pollutants increases our risk of developing a range of diseases, in three major categories: cardiovascular diseases, respiratory diseases, and cancers."[62]

It makes sense to think of these estimates as 'avoidable deaths' – they are the number of deaths that would be avoided if air pollution was reduced to levels that would not increase the risk of developing these lethal diseases.

Death is, of course, not the only negative consequence of air pollution. Many millions more suffer from poor health as a result.



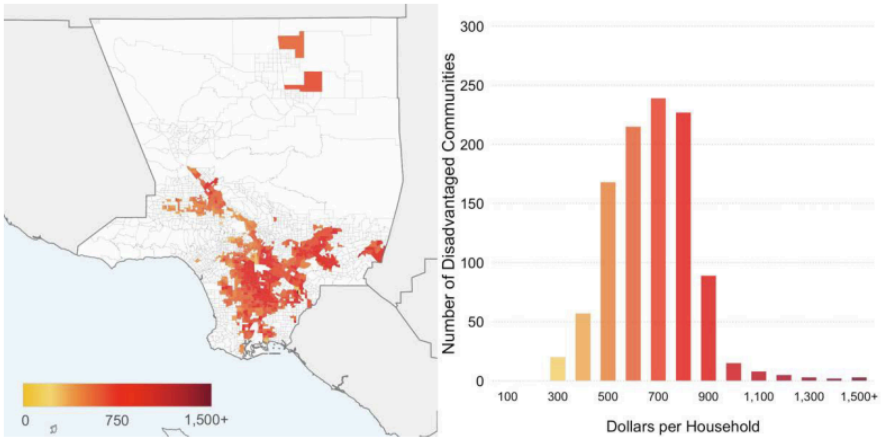
[62] Roser, Max. "Our World in Data: How Many People Die Each Year from Air Pollution?" Our World in Data. Accessed March 21, 2023. https://ourworldindata.org/data-review-air-pollution-deaths.

California Health Impacts

A recent detailed analysis suggests that adoption of low-carbon energy in California to reduce GHG emissions 80 percent below 1990 levels would lead to a 55 percent reduction in air pollution mortality rates relative to 2010 levels[63] These public health improvements have a value of $11-20 billion/year in California. The majority of these public health savings are associated with reductions in PM concentrations, which is the primary air quality challenge in California.

A 2018 report for the California Energy Commission quantified the health benefits of deep air pollution and GHG emission reductions in California in financial terms.

Figure 1: Medium Cost Scenario Health Benefits in 2030 for Los Angeles ($ per Household)



Source: Berkeley Economic Advising and Research

The analysis examined the co-benefits of reducing greenhouse gases and air pollutants that accrue when fossil fuel combustion declines. It concluded that "Using recent evidence on links between pollution mitigation and public health, the model was able to estimate long-term economic benefits from averted deaths and medical care attributable to California climate policy. The team estimated the economic value of these health benefits is comparable to the direct costs of the entire energy system buildout. Thus, the state's climate initiative, still controversial for some, could be justified solely on public health grounds."[64]

South Coast Air District Health Impacts

Despite progress over the last three decades to reduce ozone pollution in the South Coast AQMD, progress has leveled off recently. We still violate federal health-based ozone standards more than 100 days a year. The 2022 Air Quality Management Plan (AQMP), the blueprint for cleaning the air in the region, noted that the prior strategy of incrementally cleaner combustion was not sufficient to make it safe to breathe. In fact, the 2022 AQMP stated clearly that "the only way to achieve the required NOx reductions is through extensive use of zero-emission technologies across all stationary and mobile sources." In particular, the AQMP noted we need to go to zero-emissions everywhere feasible. Upgrading homes with zero-emission technologies like heat pumps for space and water heating is not only feasible but will deliver enormous co-benefits like expanding access to cooling in homes.

A recent analysis from the Coalition for Clean Air and RMI noted that "methane gas-burning equipment in residential and commercial buildings in the South Coast Air Basin is responsible for:

[63] Zapata, Christina B., Chris Yang, Sonia Yeh, Joan Ogden, and Michael J. Kleeman. "Low-Carbon Energy Generates Public Health Savings in California." Atmospheric Chemistry and Physics 18, no. 7 (April 10, 2018): 4817–30. https://doi.org/10.5194/acp-18-4817-2018.

[64] California Energy Commission. "Exploring Economic Impacts in Long-Term California Energy Scenarios." California Energy Commission, current-date. https://www.energy.ca.gov/publications/2018/exploring-economic-impacts-long-term-california-energy-scenarios.

- Approximately 76,000 asthma attacks per year.
- About 30,000 lost school days annually.
- 130 premature deaths each year.
- Annual health impacts valued at $2 billion[65]

These vital rules are the largest emission reduction effort in more than three decades. Upgrading homes with zero-emission technologies for space and water heating when appliances need replacement will dramatically cut pollution in the region and help bring the region's air into compliance with state and federal standards.

[65] Southern California's Hidden Air Pollution Problem: Gas Furnaces & Water Heaters," Coalition For Clean Air and Rocky Mountain Institute, 2024, https://www.ccair.org/wp-content/uploads/2024/12/South-Coast-Brief.pdf

OTHER OBJECTIONS

Numerous other objections to the actions necessary to phase out fossil fuel emissions are have been raised in written and verbal comments. These commenters may not be aware of the current state of heat pump, grid, and other technologies that make the transition to zero carbon space and water heating not just feasible, but lower lifecycle cost in the vast majority of cases. This section addresses several common objections:

Modern Heat Pumps Work Well Below Negative 20 Degrees Fahrenheit

Several commenters have argued that heat pumps don't work in cold climates. A couple of decades ago, it was true that heat pumps only worked above about positive 20 or 30 degrees Fahrenheit. Several advancements in the last decade have combined to allow heat pumps to operate down to 20 or more degrees F below zero.

- Variable capacity compressors and fans
- Variable Refrigerant Flow (VRF)
- Inverter drive[66]
- Computer control
- Vapor injection and liquid injection [67]
- Advanced Refrigerants
- Using waste heat to prevent icing below freezing.[68]

The Consumer Reports article cited above includes this very balanced quote: “Of course, you’ll also find people who say that after spending tens of thousands of dollars on the installation, they’re left with a chilly home and sky-high utility bills. But that’s more likely to happen only if you end up with a contractor unfamiliar with heat pumps. Chances are, if you pick the right equipment for your home and your climate, make any recommended weather-sealing upgrades, and hire a reputable contractor with experience installing heat pumps, you should have a good outcome.”

The next generation of cold climate heat pump advancements is underway in the Department of Energy’s Cold Climate Heat Pump Challenge, in which eight manufacturers are involved: Bosch, Carrier, Daikin, Johnson Controls, Lennox, Midea, Rheem, and Trane Technologies.[69]

How can heat pumps work at temperatures so low? Because physics tells us that any matter contains heat energy whenever its temperature is above **absolute zero**, which is -273 °C or -459 °F. An easier way to think about it is to use the Kelvin scale, which reads zero at absolute zero, instead of Celsius, which physicists set for easy reference to water, which freezes at 0 °C (273 °K) and boils at 100 °C (373 °K).[70]

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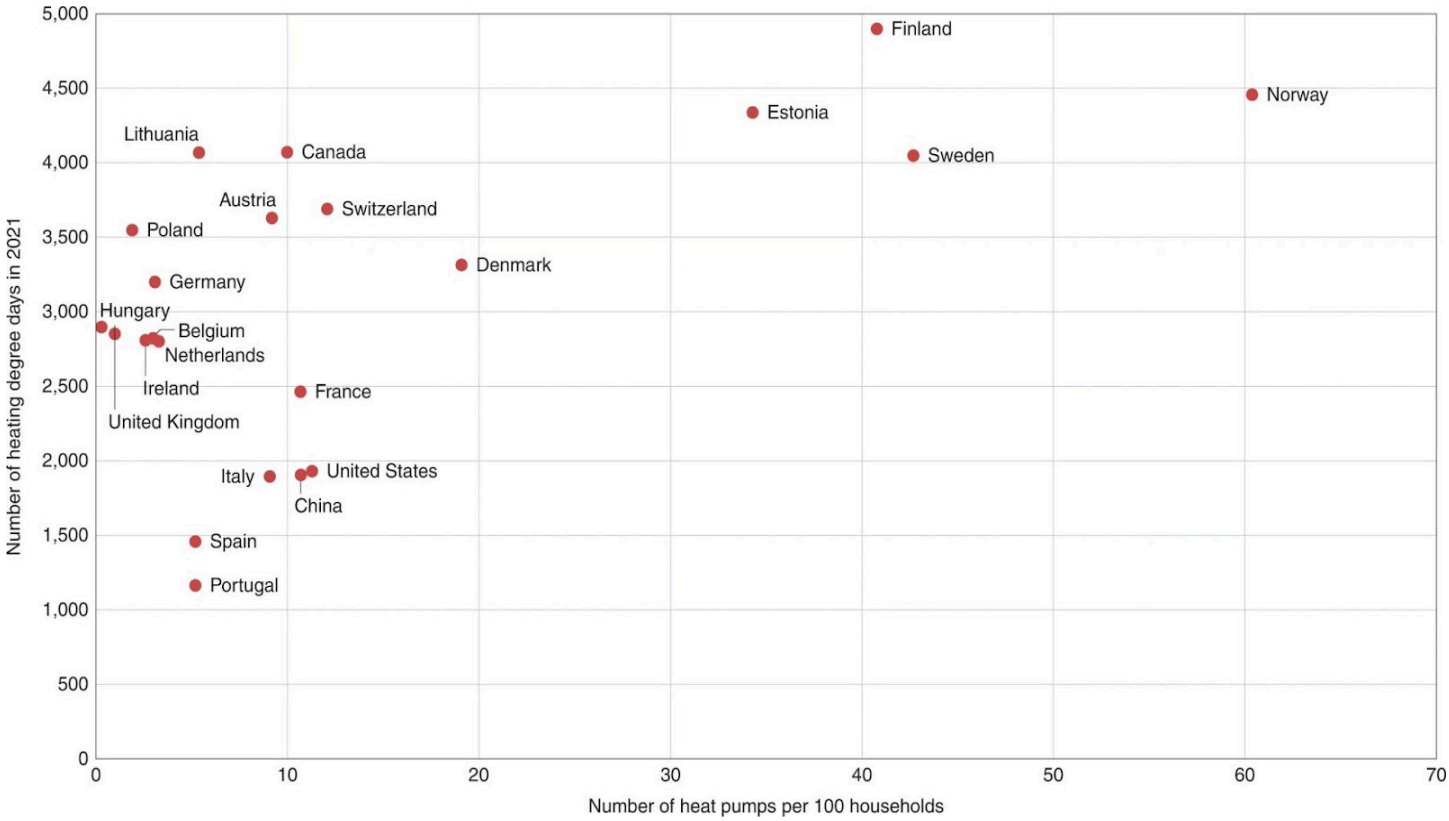
[66] Liam McCabe, “Can Heat Pumps Actually Work in Cold Climates?,” Consumer Reports, April 9, 2024, https://www.consumerreports.org/heat-pumps/can-heat-pumps-actually-work-in-cold-climates-a4929629430/.
[67] Jon Reed, “Bring Home the Latest Cold Climate Heat Pumps - CNET,” CNET, January 23, 2025, https://www.cnet.com/home/energy-and-utilities/bring-home-the-latest-cold-climate-heat-pumps/.
[68] Chris Baraniuk, “Meet the Heat Pump: An Old Technology That’s the Future of Home…,” Canary Media, February 28, 2023, https://www.canarymedia.com/articles/heat-pumps/meet-the-heat-pump-an-old-technology-thats-the-future-of-home-heating.
[69] US DoE, “Residential Cold Climate Heat Pump Challenge,” US Department of Energy, October 2021, https://www.energy.gov/eere/buildings/residential-cold-climate-heat-pump-challenge.
[70] Wikipedia, “Absolute Zero,” in Wikipedia, accessed February 24, 2025, https://en.wikipedia.org/w/index.php?title=Absolute_zero&oldid=1277312264.

The improvement in heat pump performance is not just theoretical: the chart below shows very high penetration in nations with the highest incidence of heating degree days: Norway, Sweden, Finland, and Estonia. [71] And in the United States, Maine is a recognized leader in heat pump deployment.



Another practical approach to cold climates is to use a backup source of heat. Sometimes called dual fuel, hybrid, or supplemental, these systems use heat pumps until the temperature drops below its capability; at that time, a backup source of heat comes online. These systems are often only needed for the coldest few nights per year. The backup source can be one of many choices:

- Electric resistance, whether integrated into the central system or as simple as a plug in space heater.
- A previously existing furnace or boiler, which are sometimes left in place as the backup.
- Wood burning stove, which already exist in many cold climate residences.

"The Technology Just Isn't Ready" (It Is)

Many of the public comments consisted of assertions that "the technology just isn't ready yet" (meaning heat pumps and heat pump water heaters). Most of these comments were based on either outdated information, misperceptions, or simply disingenuous.

The previous section addressed the fact that cold climate heat pumps are in fact able to fully capable of delivering comfortable dwellings.

[71] Jan Rosenow et al., "Heating up the Global Heat Pump Market," Nature Energy 7, no. 10 (September 7, 2022): 901–4, https://doi.org/10.1038/s41560-022-01104-8.

Other commenters stated that heat pumps can't handle larger buildings. Yet, Trane, Daikin, and more offer heat pumps up to 2,000 kilowatts (6.8MBtu/hr input).[72], [73]. One of Daikin's highlighted projects is a building the size of over 23 football pitches (~football fields). [74]

Heat pump water heating is also readily available for commercial and multifamily buildings. The Advanced Water Heating Initiative (AWHI) has held several annual conferences highlighting the availability and capabilities of these systems. [75]

Yes, the Electric Grid Can Handle Electrification of the Economy

Some commenters suggested that electrifying our buildings could have negative impacts on the electric grid, or that the grid can't handle full electrification. Most of these assert that electric loads are increasing, but do not acknowledge that grid capacity is also rapidly expanding.

Southern California Edison submitted a letter to SCAQMD on October 16th, 2024 stating clearly that they are indeed expanding their grid, and that it will be able to handle electrification.

> "SCE is proactively transforming the electric grid to accommodate significant advancements in decarbonized generation, the widespread adoption of customer-owned distributed energy resources, and the increasing use of electric vehicles and zero-emission appliances like heat pumps. As outlined in Edison's whitepapers "Countdown to 2045" and, most recently, "Reaching Net Zero," electrification is the most cost-effective path to decarbonize California's economy and we are proactively working to plan for grid infrastructure needs. the necessary grid planning efforts required."[76]

They also point out the value of using demand response to shift demand away from peaks, such as configuring a heat pump water heater to heat to water at lowest demand times of day, which in most Time Of Use tariff schedules are also the lowest price per kilowatt hour.

Grid capacity and resilience are important considerations. The good news is that the nation's 3,000 electric utilities are hard at work on grid expansion, and there are many excellent companies, nonprofits, and academics working on these exact issues. As discussed in a previous section, numerous studies over the last half decade have concluded that it is not only technically feasible to electrify 80 to 90% of the US economy, but also that high electrification is the most cost effective approach. These studies analyze the dual demands: converting all current fossil fired equipment to electric, and economic growth in all sectors. They conclude that the US national electric grid must expand from today's generation of approximately 4,000 terawatt hours per year to between 10,000 and 12,000 terawatt hours per year in nearly three decades. For comparison, the United States doubled our grid capacity in the 1950s, and doubled it again in the 1960s. So the task before us, a 2x-3x expansion in about three decades, is arguably more modest.

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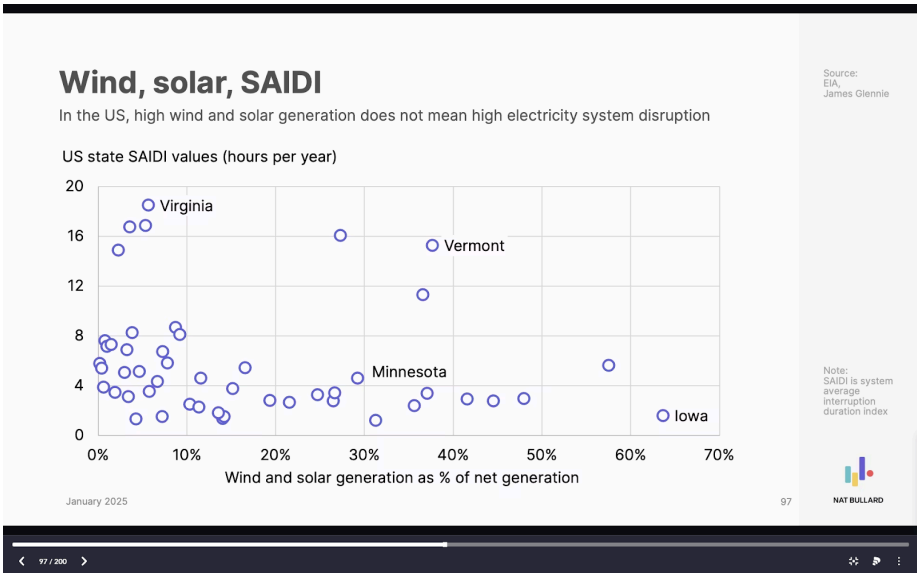
[72] "Decarbonising Commercial Buildings with Heat Pumps," Daikin, accessed February 24, 2025, https://www.daikin-ce.com/en_us/product-group/commercial-heatpumps.html.
[73] "Heat Pumps," Trane Corp, accessed February 24, 2025, https://www.trane.com/commercial/north-america/us/en/products-systems/heat-pumps.html.
[74] "Daikin Heat Pump Solutions for Commercial Buildings," Daikin Internet, accessed February 24, 2025, https://www.daikin-ce.com/en_us/solutions/heat-pumps-for-commercial-buildings.html.
[75] New Buildings Institute, "Heat Pump Water Heater Day," Advanced Water Heating Initiative, accessed November 13, 2023, https://www.advancedwaterheatinginitiative.org/hpwh-day-resources.
[76] Rosalie Barcinas, "Public Workshop for Proposed Amended Rules 1111 and 1121," Southern California Edison, October 16th 2024, https://www.aqmd.gov/docs/default-source/rule-book/Proposed-Rules/1111-and-1121/comment-letter-from-socal-edison-20241016.pdf?sfvrsn=4.

Grid Outage Risk: Clean Energy is the Most Reliable Energy

We often hear assertions that wind and solar energy are unreliable. In particular, after winter storm Uri in Texas, numerous politicians from fossil-heavy states quickly blamed wind. However, that proved to be wrong: thorough analysis by the Federal Energy Regulatory Commission (FERC) found that coal and gas plants made up 73 percent of the generator capacity that experienced unplanned outages or substantially reduced output.[77] The reality is that renewable energy resources have proven track records of both reducing peak demand and high reliability

This chart from energy transition researcher and advisor Nat Bullard shows the 2022 System Average Interruption Duration Index for each of the 50 states, as reported by utility companies to the US Energy Information Administration (EIA).[78] Virginia, with only 5% penetration of renewables, had the highest average service interruption rate at over 18 hours that year, while Iowa with over 60% renewables penetration was among the lowest average service interruption rates, at less than two hours. In California, our 2022 SAIDI was 3.3 hours, in the best one-third of states.



In California, the Public Utilities Commission tracks outages in detail for every Investor Owned Utility (IOU).[79] SCE's 2023 SAIDI was 115 minutes or 1.9 hours, and its ten year average is 144 minutes or 2.4 hours. These are better than the state and national averages. In fact, with outages of only 2.4 hours out of 8,760 hours per year, SCE's grid has a reliability up-time of 99.97% over the last ten years.

The evidence is clear: The US electrical grid can handle electrification. California's grid has higher reliability than the national average. And SCE territory, which has a high degree of overlap with the South Coast Air Basin, os more reliable than the California average.

Resilience: How Households and Communities Deal with Grid Outages

The US and Southern California electric grids are, as discussed above, highly reliable. But as with any human-engineered system, outages occur. Resilience is the measure of households' ability to withstand and recover when outages happen.

[77] Aaron Schwartz and Ashtin Massie, "Reality Check: Keeping the Lights on in Extreme Winter Weather," RMI, December 13, 2023, https://rmi.org/reality-check-keeping-the-lights-on-in-extreme-winter-weather.
[78] Nat Bullard, "Annual Presentation on the State of Decarbonization," January 30, 2025, https://www.nathanielbullard.com/presentations.
[79] California Public Utilities Commission, "Electric System Reliability Annual Reports,"CPUC, accessed February 13, 2025, https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/infrastructure/electric-reliability/electric-system-reliability-annual-reports.

One common assertion by fossil fuel advocates is that keeping gas as a part of the energy mix provides a hedge against electric grid outages. At first blush, this "dual fuel" approach sounds like a plausible way to avoid "putting all your eggs in one basket." But that appearance is false: most modern gas-fired appliances in homes depend on electricity to function. (While some existing appliances use pilot lights, those are no longer allowed in most appliances and so replacements would require electricity).

- Gas furnaces require electricity for blower fan motors, control relays, and thermostats.
- Most gas water heaters require electricity for ignition, thermostat, and sensors.
- Gas dryers require electricity for cycle controls, tumbler, and control.
- Modern gas stoves have electronic ignition for igniting the gas. It is possible to light most with a match or lighter, though many have a thermal flame sense system that requires the flame heats up enough to keep the gas valve on. Gas ovens generally cannot be lit with a match.

So the positioning of gas as an element of a resilience scheme is a myth.

Actual resilience involves preparedness on the part of both households and communities. A 2018 report by the Center for Climate and Energy Solutions (C2ES) describes household resilience measures including batteries attached to the building, gas-fired backup generators, and neighbors helping neighbors.[80] Heat pump water heaters constitute a large thermal battery, with 40 to 80 gallons of hot water that in a well-insulated tank will last for over 24 hours. Whole-home batteries have low penetration today, but it is rapidly increasing as battery prices continue to fall steeply, and since the CPUC's 2024 introduction of Net Billing Tariffs by utility companies. And portable power stations, sometimes known as "solar generators," are portable batteries that can provide backup power for moderate loads for several hours. And while the economy is still in the early stages of the energy transition, propane heaters and camp stoves provide short-term resilience.

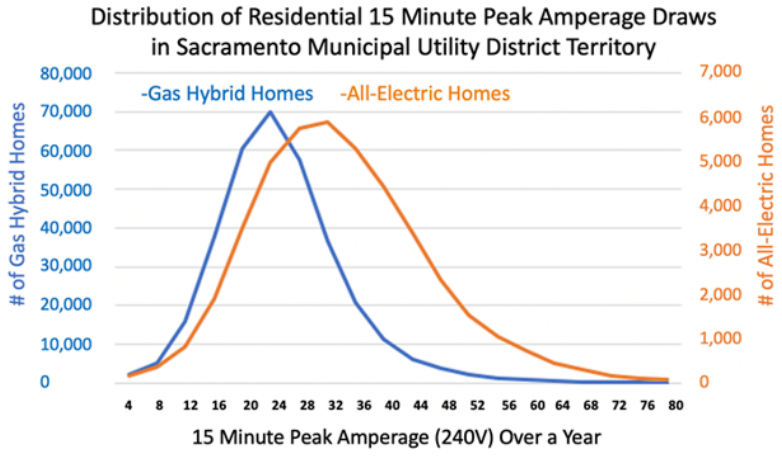
Cities and communities also have resilience strategies. At the high end, since Hurricane Katrina New Orleans has implemented electricity system hardening, microgrids, efficiency programs for homes and businesses, and improved disaster preparedness communication. Community resilience centers are common in many cities, providing residents a place with space heating and cooling, hot water, and cooking.

Reliable energy supply is vital in modern society. The nation's and state's utility companies make it one of their highest priorities.

[80] Ashley Lawson, "Resilience Strategies for Power Outages," Center for Climate and Energy Solutions (C2ES) (blog), August 2018, https://www.c2es.org/document/resilience-strategies-for-power-outages.

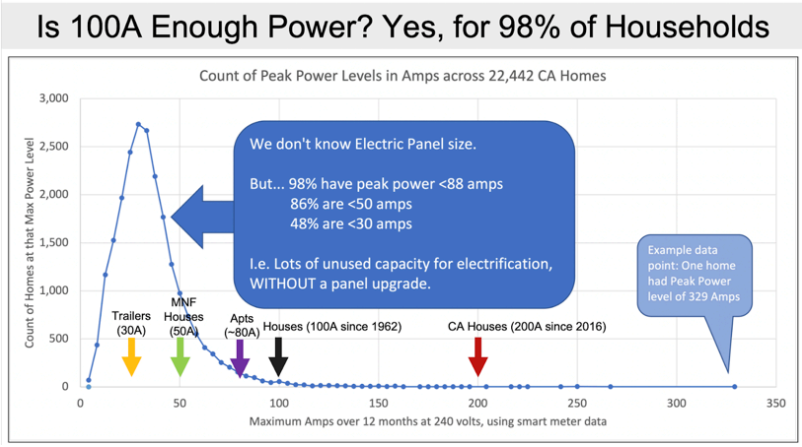
100 Amp Panels: Over 90% of Electrical Panels Can Handle Full Electrification

Another common objection to electrification is the concern that many electrical panels will have to be upgraded; Rewiring America as recently as 2022 projected that a few tens of millions of homes would need electric panel upgrades from 100 amps to 200 amps.



However, recent studies have found that panel upgrades will not be required nearly as often. A July 2023 report from New Buildings Institute and Redwood Energy points out that in 1962 the "Live Better Electrically" movement succeeded in changing the National Electric Code, requiring all new houses to be built with 100 amps of power at 240 volts, up from 60 amps. And in the 1990s, the residential standard panel size increased to 200 amps. NBI described a study of over 75,000 Sacramento (CA) Municipal Utility District (SMUD) homes, which recorded their one-hour peak power demands over one year and showed that the average all-electric home peaked at just 32 amps, far less than a 100 amp panel's capacity. (By comparison, gas-burning homes peaked at about 20 amps). [81]

The NBI report also described a study of over 22,000 California homes in Pacific Gas and Electric (PG&E) territory, in which only 2% of households peaked above 88 amps.



These two large samples of empirical real-world data show that panel upgrades will not be needed for the majority of homes.

The NBI report concluded that "there is a cheaper and easier way to electrify our homes of the future: keep 100-150 amp panels in place and help homeowners go on a 'watt diet.' A watt diet means intentionally selecting energy-efficient, correctly sized, low power equipment, and allocating available power to that equipment just when needed." A valuable tool here is circuit splitters, which allow two or more devices to share a single electrical circuit, with only one operating at a time. For instance, an EV charger and a clothes dryer can share a 240V / 40A circuit.

[81] Amruta Khanolkar, Sean Armstrong, and Tom Kabat, "We Can Power the Homes of the Future with Electric Panels of the Past," New Buildings Institute, July 25, 2023, https://newbuildings.org/we-can-power-the-homes-of-the-future-with-electric-panels-of-the-past.

Similar conclusions were reached by the San Francisco Bay Area Planning and Urban Research Association (SPUR).[82] They found that electric panel and service upgrades are often the most expensive and time-consuming aspects of electrification, and discourage building owners from undertaking electrification projects. SPUR recommends electrifying buildings without touching the electrical panel or service.

CONCLUSION

This report is respectfully submitted to show that the zero-NOx rules under consideration by the South Coast Air Quality Management District, Proposed Amended Rules 1111 and 1121, are not only technically feasible, but are in fact the most affordable and equitable way to eliminate the health hazards from Nitrogen Oxides by upgrading space heating and water heating appliances as they reach end of life.

[82] Sam Fishman et al., "Solving the Panel Puzzle | SPUR," San Francisco Bay Area Planning and Urban Research Association (SPUR), May 13, 2024, https://www.spur.org/publications/policy-brief/2024-05-14/solving-panel-puzzle.