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See attached pdf doc.

Additional submitted attachment is included below.

10 May   2026

RENEWABLE AND FIRM ZERO-CARBON RESOURCES REPORT
Required by SB 423 (2022 Stern)
Docket 21-ESR-01

https://efiling.energy.ca.gov/EComment/EComment.aspx?docketnumber=21-ESR-01

Hi CEC Staff,

Thanks for your deep dive into the performance characteristics of many energy generation technologies that are commonly regarded as firm and dispatchable baseload. However, none are dispatchable 24/7 to cover all hours in a year. The reasons why are considered below. Though your statistics-rich report compares some strengths and weaknesses of each, this comment takes a closer look. Comments below rely upon scientific research, not claims by industry or manufacturers. After presenting the less-appealing side of the most emissions-intensive firm technologies, systems of distributed resources that function at least as effectively as baseload reliance are outlined. Baseload portfolios alone are insufficient for meeting the needs of a decarbonized grid with highly variable loads. Systems of Grid Enhancing Technologies, demand-side resources, diversified distributed energy resources, efficiency, and electrified building codes are more nimble and responsive to fluctuations of demand and supply..

LIMITATIONS AND SIDE EFFECTS OF EACH FIRM GENERATION RESOURCE

Fossil Gas Turbine Plants with and without CCS

FG plants are inefficient because their design requires them to continue to idle even when not generating electricity. Plants with CCS are even more inefficient because CCS equipment devours about one-third of the energy produced by the turbine. Efficiency is also decreased due to energy expenditures and emissions from extraction and distribution of FG. CCS equipment increases construction and operating costs, costs of electricity, toxic emissions and GHG emissions. It typically captures only 30% to 40% of smokestack CO2 emissions, none of the toxics, and none of the emissions from extraction or distribution. Deferred maintenance of pipelines and high levels of fugitive emissions of FG are the norm. Adding CCS to FG plants increases longer use of more fossil energy - which is heavily subsidized by the federal government. Economically, they are not competitive with clean energy. Long-term subterranean storage policies are very sketchy, exposing society to many kinds of harm and liabilities. Most storage sites in the US have had substantial fugitive emissions within a few years of CO2 injection. Over 80% of captured CO2 is used for EOR. Estimates of the amount of CO2 that escape into the atmosphere during EOR is controversial and warrants more independent research. Lifecycle analyses of GHG emissions, toxic emissions, and other environmental impacts reveal enormous externalized costs (Social Cost of Carbon - SCC).

CCS has dismal efficacy and efficiency and daunting side effects. Worldwide, suitable sites for subterranean storage are very limited.
Carbon Capture Technologies : Efficacy & Costs

Many nations have plentiful electricity from clean energy, without use of any fossil fuels[1] and many more are generating 80 - 99% of their electricity from clean energy.[2] To enable profitable long-term planning, the business community depends upon policy signals from government, well in advance of the effective date.

Recent research studying nations indicates that the percentage of FG that escapes as fugitive emissions from distribution networks is 1% to over 15%.[3] When over 4.7%, lifecycle greenhouse gas (GHG) emissions from FG energy are comparable to that of coal energy.[4], [5], [6], [7], [8],[9] A FG leak rate of 3.3 - 4.7% was found in Boston pipeline systems.[10] Decades of research have shown increased levels of many toxics and medical problems in buildings with FG appliances.[11],[12]

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[1] Renewable success stories: the countries with 100% renewable generation — RatedPower

[2] 60 Countries/Territories Whose Electricity Generation in 2023 was 50-100% Wind-Water-Solar (WWS) (Including 12 With

[3] https://rmi.org/establishing-measures-to-achieve-near-zero-methane-waste-from-global-oil-and-gas-assets/?utm_medium=email&utm_source=spark&utm_campaign=2025_10_30&utm_content=spark&jobid=88547&sfmc_id=94727719

[4] Leaks Can Make Natural Gas as Bad for the Climate as Coal, a Study Says

[5] Evaluating net life-cycle greenhouse gas emissions intensities from gas and coal at varying methane leakage rates - IOPscience

[6] Liquefied natural gas carbon footprint is worse than coal | CALS

[7] Coal vs. Natural Gas

[8] Calculating Parity Between Gas and Coal Life-cycle Emissions - RMI

[9] A National Estimate of Methane Leakage from Pipeline Mains in Natural Gas Local Distribution Systems | Environmental Science & Technology

[10] Majority of US urban natural gas emissions unaccounted for in inventories | PNAS

[11] Natural Gas Used in Homes Contains Hazardous Air Pollutants | Harvard T.H. Chan School of Public Health

[12] National Building Pollution Report | Physicians for Social Responsibility

A search on fugitive emissions from Jan 2020 - Jul 2025 in Google Scholar revealed only two articles on the topic focused on California. These are reviewed in the next paragraph.

Researchers have isolated many kinds of sources of FG fugitive emissions. Most research on production mentions venting, flaring, and pipeline controls (e.g., valves and compressors). However, it is important to read the methodology section to see whether a study included these emissions sources in their cumulative percentages.

Building interiors

Small-volume sources[13]

Super emitters (CA)[14]

Abandoned wells[15],[16],[17]

Offshore wells[18]

Storage tanks in Los Angeles[19]

A cursory review of fugitive emissions research revealed that emissions rates measured after 2020 were higher than those found before 2020. This is largely due to more sophisticated and accurate monitoring technologies being used, including hand-held sniffers, drones, and satellites. No research was found that included emissions from all of the above kinds of sources

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[13] Small emission sources in aggregate disproportionately account for a large majority of total methane emissions from the US oil and gas sector

[14] New Tool Maps the Health Impacts of Toxic Air Pollutants Released With Methane in Super-Emitter Events - Inside Climate News

[15] A review of methane leakage from abandoned oil and gas wells: A case study in Lubbock, Texas, within the Permian Basin - ScienceDirect

[16] https://pubs.acs.org/doi/full/10.1021/acs.est.4c05602

[17] https://academic.oup.coSevenfold Underestimation of Methane Emissions from Non-producing Oil and Gas Wells in Canada | Environmental Science & Technologym/nsr/article/12/7/nwaf184/8137905

[18] Calculating Methane Emissions from Offshore Facilities Using Bottom-Up Methods

[19] Quantifying Emissions of Natural Gas Storage Tanks in the Greater Los Angeles Metropolitan Area

: a) building interiors, b) pipelines from wells to buildings, c) wells (in-use and abandoned), d) storage tanks, e) offshore wells and pipelines, f) both super-emitter and small-volume sources. In fact, most research includes emissions from only one of these. Consequently, fugitive emissions are significantly underestimated. Comprehensive research would help us to obtain a more accurate estimate of total fugitive emissions and to formulate more effective national and international regulation.[20] More precise totals of fugitive emissions are essential for calculating total emissions volumes and externalized costs of the FG industry.[21]

EPA research conducted in 2022 found that each FG power plant emitted an average of over 382,000 metric tons of CO2 annually.[22] This does not include a) fugitive emissions from production and distribution systems, b) emissions during idling. A peaker plant that only operates nocturnally (12 hours daily) emits over 191,000 metric tons annually. Using the most current Social Cost of Carbon[23], a FG plant operating nearly full time has annualized externalized costs of over $108 million. A plant operating half time has costs exceeding $54million. This only includes costs from combustion of FG in a plant.

Sources of combustion of fossil fuels, including FG plants, emit toxic co-pollutants.[24] These cause significant amounts of morbidity and mortality, especially in EJ zones. Use of fossil fuels has high externalized costs.[25],[26] Taxpayers are forced to pay these costs via higher taxes, lower income, weather extremes, wildfires, increased property insurance, higher energy prices, higher

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[20] Rapid Increases in Methane Concentrations following August 2020 Suspension of the US Methane Rule | Environmental and Energy Policy and the Economy

[21] US methane emissions dwarf EPA's data

[22] https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator-calculations-and-references
See second to last page.

[23] Synthesis of evidence yields high social cost of carbon due to structural model variation and uncertainties | PNAS (Contrast the article with Cap & Trade results during 2025. Allowances have sold for between $25 to $29 per ton - an average of $27 per ton. However, half of allowances are handed out for free. So, in effect, revenue from allowances was about $14 per ton, which is less than 5% of the Social Cost of Carbon.)

[24] https://cacondor.substack.com/p/not-just-hot-air

[25] Synthesis of evidence yields high social cost of carbon due to structural model variation and uncertainties | PNAS (Contrast the article with Cap & Trade results during 2025. Allowances have sold for between $25 to $29 per ton - an average of $27 per ton. However, half of allowances are handed out for free. So, in effect, revenue from allowances was about $14 per ton, which is less than 5% of the Social Cost of Carbon.)

[26]
https://www.nbcnews.com/science/climate-change/climate-change-data-costliest-6-months-weather-disasters-noaa-rcna238752

medical bills,[27] and shorter lifespans[28]. The CA government is spending $millions annually to decrease use of FG, while owners of FG assets spend $millions annually to defeat decarb policies. This is rarely mentioned as an externalized cost of fossil energy.

To call this technology clean is a misnomer by any measurable criteria. Many of the above flaws also characterize biomass energy with carbon capture (BECCS).

Biomass

IPCC recommends caution when considering BE (biomass energy) and BECCS,"The use of bioenergy can lead to either increased or reduced emissions, depending on the scale of deployment, conversion technology, fuel displaced, and how, and where, the biomass is produced (high confidence). {3.4)"..."biomass crops …, when poorly implemented, can have adverse socio-economic and environmental impacts, including on biodiversity, food and water security, local livelihoods and on the rights of Indigenous Peoples, especially if implemented at large scales and where land tenure is insecure (high confidence)."

https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_FullReport.pdf
Section C. 11. 2

BE, and especially BECCS, is not economically competitive with clean energy. The most expensive kind of BE is biomethane (RNG) because it requires refinement and cleaning processes.

Until about 2015, many scientific articles were published that declared BE to be carbon neutral. However, these did not perform lifecycle analyses or did not use complete lifecycle calculations. All independent research published more recently, that has used complete lifecycle analysis, has found that CO2 emissions exceed the CO2 captured by photosynthesis of future botanical growth and/or CCS capture. BE combustion releases an amount of CO2 that is up to 150% as much as coal combustion. Each biomass feedstock emits a wide array of toxic air contaminants (many having GHG properties).

Not just hot air - THE CONDOR

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[27] The Risks and Harms of Gas-Fired Residential Appliances

[28] Costs of Climate Change - UC Berkeley Law

The biomass boondoggle - THE CONDOR

Toxic air contaminants decrease sequestration by botanicals.This clashes with biomass energy plant owners seeking locations that are proximal to forests and crops.

https://carnegiescience.edu/improved-air-quality-could-enhance-natural-carbon-sequestration-plants

Instead of using land for dedicated bioenergy crops, about 10 times the electricity may be obtained by erecting solar farms. Alternatively, one may generate the same amount of electricity as BE crops by using only one-tenth of the acreage. The remaining 9/10ths of acreage could be used for planting crops dedicated to human nutrition, new forest, other botanicals that increase CO2 sequestration, or agrivoltaics. The efficiency and efficacy of botanical sequestration is far greater than that of energy-dependent sequestration technologies. And botanical sequestration is dirt cheap . IPCC version 6 has a cogent appraisal of BE revealing non-competitive costs and many other challenges. Subsidies given for BE, e.g., classifying them as renewable so they are eligible for tax credits, obscures the actual cost of BE. One example is the Low Carbon Fuel Standard. Based on the GREET model which includes only part of the lifecycle emissions of BE, this underestimates BE and biofuel emissions. This drives up electricity prices and income tax rates for all taxpayers while retarding the pace of grid decarbonization.

Ecologically informed solar enables a sustainable energy transition in US croplands | PNAS
The best technologies for effective climate action | SGR: Responsible Science

https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_Chapter_06.pdf#page=40
Pages 39 - 42.

There are higher and better uses of biomass, e.g., as compost and mulch. Dairy biomethane emissions may be significantly decreased via well-proven mitigation practices. The data reveal that BE is not clean energy.
Something Stinks: California Must End Manure Biomethane Accounting Gimmicks in its Low Carbon Fuel Standard - Union of Concerned Scientists

Evaluation of Biomass, Biofuels, and Biogas as Proposed Solutions to Air Pollution, Global Warming, and Energy Insecurity 8.8. W

Hydropower and Pumped Storage

Overall, this is a clean generation and storage technology. In addition to drought risk, which is increasing with climate change, lifecycle emissions are notable. Construction uses turbines, pumps, and massive amounts of concrete - each of which have high embedded carbon. Anthropogenic reservoirs flood land that has growing botanicals. This halts photosynthesis by the submerged botanicals, which decompose over the course of decades. Decomposition releases methane emissions continuously that escape into the atmosphere. Construction of dams may displace communities and wildlife while interfering with migration of fish. Existing hydro is RPS-qualified. New hydro is also RPS qualified if its capacity is less than 30 MW.

In contrast, run-of-the-river does not have most of the above problems, but is still subject to drought and seasonal volume variations.

Geothermal Energy

Overall, this is a clean firm technology. Suitable sites are near hot springs or along intersections of tectonic plates. Drilling may induce seismic activity or cause subsidence. Excessive heat extraction may deplete subterranean reservoirs. Toxic and GHG gases may escape from the drill site. Some versions require fresh water input, which is scarce in some locations. (The development of geothermal is limited and delayed by permitting obstacles. It would help to make the Opt-In website operated by CEC more conducive to geothermal.)

Hydrogen (H2)

There are numerous technologies for production of H2. Over 95% of H2 is made from fossil fuel inputs. The technology with the lowest lifecycle toxic and GHG emissions is electrolytic green H2 that uses only wind or solar energy and is built on three pillars. These are a) using a proximal source of solar or wind energy. b) that is newly constructed for H2 production, c) is generating electricity during all hours of H2 production. This is the only kind of H2 production that will be addressed herein.

Green H2 has the most costly production method. Currently, the cost per kW of electricity from green H2 is several times higher than the cost of solar or wind generated electricity (without the intermediate step of making hydrogen). Its high cost is due in part to the inefficiency of energy conversions used in electrolysis. Such conversions devour 30 to 50% of the energy produced. It uses 5,000 liters of water per MW. It is difficult to store and transport without fugitive emissions because H2 is such a tiny molecule. Emissions of raw hydrogen have a GWP of slightly over 30. H2 is highly flammable and risky to use inside buildings. During combustion (e.g., in an internal combustion engine or turbine), the amount of NOx, i.e., NO, that is emitted is six times higher than is emitted from combustion of methane - the chief ingredient of FG. NOx has a GWP of 30, increases atmospheric methane and particulate matter - increasing risk of many kinds of chronic respiratory and cardiovascular disorders. Using current turbine technologies, GHG emissions can only be decreased by 13% in turbines that burn blends of H2 and FG.

Hydrogen: Future of Clean Energy or a False Solution? | Sierra Club

Nuclear Fission Reactors

Side effects, cost of electricity, limitations, hazards, externalized costs, and lifecycle emissions of toxics and GHGs have been studied and quantified in the literature. Reactor salesmen have made the same pitch to potential buyers for several decades, particularly for AMRs and SMRs.They have forecast lower construction costs, lower operating costs, better safety, shorter construction times, and lower costs of electricity. None of these have been realized. To call this technology clean is a misnomer by any measurable criteria.

https://beyondnuclear.org/wp-content/uploads/2026/04/2026-04-26-Urgewald_Debt-Delays-Dependencies-Report-Digital.pdf

Survey and assessment of the status of available nuclear reactor technologies and designs

MULTIGENERATIONAL HEALTH IMPACTS OF NUCLEAR WEAPONS TESTING AND PRODUCTION: A SURVEY

National analysis of cancer mortality and proximity to nuclear power plants in the United States | Nature Communications

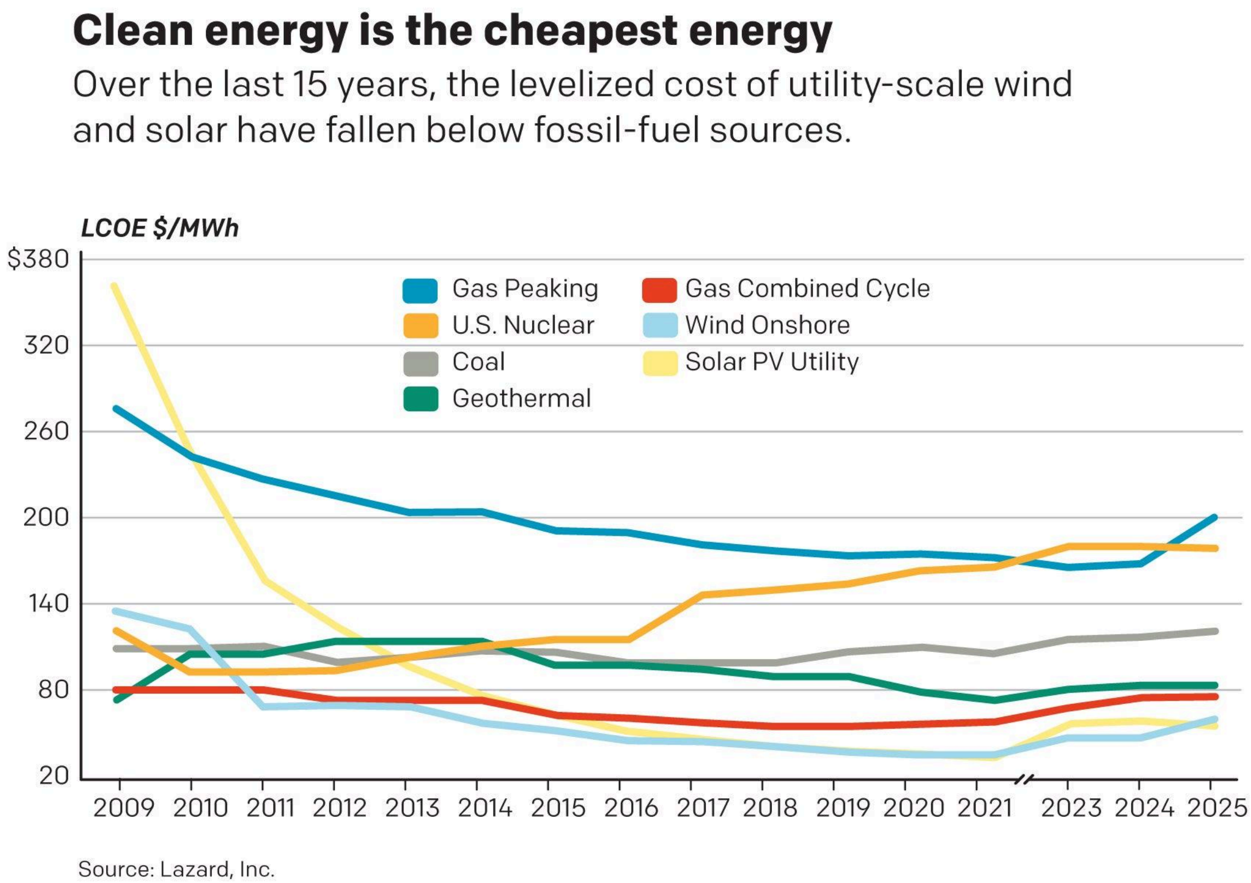
Residential proximity to nuclear power plants and cancer incidence in Massachusetts, USA (2000–2018) | Environmental Health

Exposure to protracted low-dose ionizing radiation and incident dementia in a cohort of Ontario nuclear power plant workers - PMC

Radioactivity in Food by David Bezanson

In the Race Between Clean Energy and Nuclear Reactors, Which One is Leading?

[Synthesis of evidence yields high social cost of carbon due to structural model variation and uncertainties | PNAS](#)



The chart from Lazard Investment Bank shows that the cost of reactor electricity has been increasing since 2010 (despite the staggering costs of decommissioning and long-term fissile trash storage being excluded by Lazard), while the cost of wind and solar have decreased significantly. Not shown is the cost of storage batteries. These have become more economical for ten years, especially in the last two years (because the current federal administration has attacked wind and solar generation, but not batteries).

[Lazard Releases 2025 Levelized Cost of Energy+ Report](#)
For ten years, wind and solar energy have been the most economical generation technologies and have the shortest construction time (less than 1.5 years). In contrast, the cost and construction duration of fossil gas plants and nuclear reactors has been climbing for ten years - to over 5 years and 15 years respectively. See Lazard annual reports, released in June. This is a must read for those who value affordability.

SYSTEMS OF CLEAN RESOURCES

The primary objective of SB 423 is grid reliability. Systems modelling is the best approach to achieve this. Optimized systems (OS) of diversified distributed energy resources are more cost effective and have lower side effects than reliance on baseload capacity. Examples include vehicle-to-grid cables, VPPs, smart meters; building codes requiring highly insulated, all-electric construction codes; all appliance standards to be high-efficiency, requiring new heat pumps to have natural refrigerants with a GWP of 1, EV charging requirements for new multi-family housing, dynamic line rating, load shifting, GETs, demand-response policies, and community solar. (The latter is common in many other states, but nonexistent in CA. Legislation was passed requiring CPUC to create a model for community solar, but CPUC has not finalized plans.They may need a little help from CEC.)

Calculation of optimal ratios of different resources is important. To swiftly eradicate curtailment of clean energy, what is the optimal ratio of new-build generation to new-build long-term storage? Planning requires systems thinking. This diagrams models of interactions between technologies, efficient smart grid policies, and CAISO's refinement of day ahead market software and platform as well as planning of CA integration into the Pathways RO.

Cost-benefit analyses are recommended to contrast each baseload technology with OS. The variables to include are

cost-effectiveness
lifecycle toxic and GHG emissions
non-energy benefits
opportunity costs
externalized costs (SCC)*
efficiency and other performance characteristics
potential to create more long-term clean energy careers in CA
impact on electricity and income tax rates
EJ impacts and other antisocial side effects and risks
avoidance of curtailment of clean energy generation
ability to meet emissions and air quality targets set for dates between 2030 and 2045
decommissioning costs
duration to construct
cost to construct/MW
cost to operate/MW
costs and emissions of long-term storage of hazmat

* Using the most recent scientific meta-analysis at a zero discount rate

Planning requires systems thinking. This diagrams models of interactions between technologies and efficient, flexible smart grid policies.
[Still No Miracles Needed: How Today's Technology Can Save Our Climate and Clean Our Air]

RECOMMENDATIONS AND CONCLUSION

Include complete lifecycle toxic and GHG emissions analyses in all Three Scopes for each generation technology. Most lifecycle analyses of energy in scientific publications are incomplete, incomparable to lifecycle analyses in other research, and often misleading. They usually underestimate emissions intensity.

Some sections of the report are rather dated. The section on battery storage mentioned that most utility-scale batteries are charged with dirty generation sources such as the grid. Front-of-the-meter and behind-the-meter storage batteries have been charged primarily with clean energy (wind, PV solar, Concentrated Solar Power, hydro) in CA since about 2024. Innovations are rapidly emerging. If further public feedback is planned, please update the report first.

In any future reports, include bidirectional EV charging port technologies for vehicles and buildings. This is a firm, low emissions, low cost storage innovation that may decrease grid demand in certain time periods each day or be dispatched on demand in emergencies. They could dramatically increase the amount of behind the meter power delivered by VPPs. This would decrease the cost of electricity and their capacity should be included in resource adequacy calculations. Retired EV batteries that currently have less than 90% of their original capacity are being used for behind-the-meter and utility-scale applications. To save space, these are usually removed from the vehicle. For conditions of high outage risk, cables that can safely discharge electricity from EV batteries to the grid, via building circuits and outlet upgrades, are needed.

Much material in the report about technical engineering challenges to improvements in each technology reads like inconclusive musings on the part of manufacturers. Omit such from future drafts because a) engineers in manufacturers of firm equipment and in academia are well aware of such, b) there is probably little interest on the part of others in this esoteric topic.This would significantly decrease the length of a future draft. CEC offers grant funding with associated webinars for developers, inventors, entrepreneurs, and engineers. These are a more suitable forum for addressing technical limitations and potential solutions.

In general, portrayal of each firm technology highlights strengths while minimizing content about drawbacks, side effects, and externalized costs. There is no comparison with performance characteristics of clean generation technologies. Such material would be welcome in future drafts. Without this, much content about each reads more like an advertisement than an evaluation.

The Warren-Ahlquist Act prohibits permitting and construction of new reactors, including AMR and SMR. As long as permitting of new reactors is prohibited, exclude this technology from future drafts. Until fusion is available on a commercial scale and legal in CA, exclude it from future drafts. I have read articles about many dozens of innovative clean energy technologies over the years. Nearly all of them fail to reach *beta* testing, let alone production.

Delete technologies that are not near commercial availability, e.g., fusion. Fusion technology is very far from practicality. The breakeven referred to in the report in 2022 is that the amount of energy coming out of the implosion was greater than the beam energy required to implode the pellet of fuel. This did not include the energy required to create the beams or to maintain conditions of the reactor chamber. Creating a laser beam from electricity is about 10% efficient so 90% of the reactor energy must go to creating the beams. Also, there is no credible design for the reaction chamber for a power plant which must capture the neutron and gamma radiation from the imploding pellet at a rate of 1 kiloton of TNT per second for a terawatt reactor and convert it to high pressure steam to run a generator. The reactor must be able to survive the radiation damage and pressure damage for decades with high reliability. This sort of technology will require many decades to develop which will make it impossible for it to contribute to a climate solution by 2050.

Legislation requires reaching grid decarbonization milestones by certain target dates - *or sooner*. Earlier achievement provides earlier benefits and decreases the magnitude of future costs for mitigation. While inventors are embroiled in designing better mousetraps, we need a parallel track of implementing well-proven technologies with the most sparkling benefit to cost ratios. Help the Legislature and agencies to select the most effective proven solutions.

Please delete the word Zero Carbon from the title. If you use the term in the report, please differentiate it from lifecycle carbon intensity. Do not use the word clean in the report or separate tables and sections into clean and non-clean based on quantity of lifecycle emissions.

Thanks,

David Bezanson, Ph.D.
CA voter