PUBLIC UTILITIES COMMISSION OF THE STATE OF CALIFORNIA

ENERGY DIVISION **RESOLUTION G-3571**
November 5, 2020

R E S O L U T I O N

Resolution G-3571. The California Energy Commission requests approval of its Fiscal Year 2020-2021 natural gas research budget.

PROPOSED OUTCOME:

- Approves the California Energy Commission's (CEC's) *Natural Gas Research and Development Program, Proposed Budget Plan for Fiscal Year 2020-21* with a budget of $24 million, pursuant to California Public Utilities Commission Decision (D.) 04-08-010.
- Requests changes in how CEC submits future Natural Gas Research and Development Program Proposed Budget Plans to CPUC and requests other process changes to increase opportunities for public input.

SAFETY CONSIDERATIONS:

- This Resolution approves and prioritizes $9.1 million to advance natural gas infrastructure safety and integrity projects. Successful research in this area will support safe infrastructure operation including advancing pipeline corrosion detection and repair technologies.
- This Resolution approves up to $3 million to advance the safe use of natural gas blends in residential appliances.

ESTIMATED COST:

- Approves $24 million for Fiscal Year 2020-2021, as previously authorized under the formula developed in D.04-08-010.

SUMMARY

This Resolution approves the California Energy Commission's (CEC's) *Natural Gas Research and Development Program Proposed Budget Plan for Fiscal Year 2020-21* (the FY2020-21 Plan). The Natural Gas Research and Development Program (Gas R&D Program) was established pursuant to Decision (D.) 04-08-010. The California Public Utilities Commission (CPUC) approves CEC's proposed $24 million budget and provides additional implementation guidance.

To improve transparency and provide more substantial opportunities for public comment, this resolution also directs procedural changes the CEC should follow for approval of future Natural Gas Research and Development Program Proposed Budget Plans.

BACKGROUND

Procedural History

In 2002, the CPUC instituted Rulemaking (R.) 02-10-001 to implement Assembly Bill 1002 (Wright, 2000).[1] In that proceeding, the CPUC addressed various issues related to the design and implementation of a surcharge to fund gas public purpose programs, resulting in D.04-08-010 (Decision).

Decision 04-08-010 establishes certain criteria for gas research and development (Gas R&D) projects to be approved under this program, namely that the projects:

1) focus on energy efficiency, renewable technologies, conservation and environmental issues;
2) support State energy policy;
3) offer a reasonable probability of providing benefits to the general public; and
4) consider opportunities for collaboration and co-funding opportunities with other entities.

[1] Available at https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=199920000AB1002.

Additionally, the Decision defines public interest Gas R&D activities as those which "are directed towards developing science or technology, 1) the benefits of which accrue to California citizens and 2) are not adequately addressed by competitive or regulated entities."[2]

Decision 04-08-010 also designates the CEC as the administrator of the Gas R&D Program. The CEC administers various public interest research programs and is publicly accountable, being subject to the Bagley-Keene Open Meeting Act and the Public Records Act.[3] The CEC selects funding areas, which the CPUC then reviews and approves.

Decision 04-08-010 reserves ultimate oversight of this program for the CPUC. The CPUC is responsible for adopting the Gas R&D Program, and for setting the surcharge to fund it. The Decision clarifies that the CPUC has final responsibility to "approve and resolve administration, funding, project approval, or other matters, and make a final decision."[4] The Decision further designates the CPUC's Energy Division to serve as the CPUC's advisor.

Starting with the Fiscal Year (FY) 2014-15 Gas R&D Plan, Resolution G-3484 (2013) requires the CEC to provide an accounting, by research area, of then-current unspent funds in the Gas R&D Program, including encumbrances and expiration dates. This requirement shall remain in place for each fiscal year's proposed budget, until otherwise directed by the CPUC.

Budget

Decision 04-08-010 established a zero-based budget for the Gas R&D Program. Historically, each year CEC had requested, and the CPUC has approved, the maximum budget increase over the previous year. Starting at $12 million for 2005, the Gas R&D Program budget increased by the maximum annual amount allowed of $3 million each year until 2009. In 2009, the budget reached the

[2] D.04-08-010 at p.25.

[3] D.04-08-010 at p.31.

[4] D.04-08-010 at p.32.

maximum amount allowed of $24 million per year and has remained at this level to the present.[5]

In the FY 2020-21 Plan, the CEC continues to request the maximum $24 million. The CEC has historically been granted the use of 10 percent of Gas R&D funds for program administration. The FY 2020-21 Plan similarly requests $2.4 million, or 10 percent of the overall budget, for program administration.

Request for Fiscal Year 2020-2021

On March 31, 2020, the CEC submitted its request to the CPUC for Fiscal Year 2020-2021. In addition to providing its FY2020-21 Plan, the CEC also provided information on prior program activities and expenditures.

DISCUSSION

The CPUC has reviewed and evaluated the CEC's *Natural Gas Research and Development Program: Proposed Budget Plan for Fiscal Year 2020-21* based on the following:

- consistency with D.04-08-010,
- consistency with Resolution G-3484 (2013) Accounting Requirements,
- consistency with Resolution G-3555 (2019) Direction for FY2020-21 Plan, and
- reasonableness of budget request.

Consistency with D.04-08-010

Decision 04-08-010 requires the CEC to provide an annual plan to Energy Division outlining its proposed projects. The CEC presented a draft FY 2020-21 Plan in a public workshop held on January 21, 2020 and received feedback from stakeholders. In accordance with the Decision, the CEC provided the annual proposed Gas R&D Program FY2020-21 Plan to the CPUC's Energy Division on March 31, 2020. Energy Division reviewed CEC's plan and found it to be submitted properly in compliance with the Decision.

[5] D.04-08-010 at p. 38.

Decision 04-08-010 also requires that Gas R&D projects: 1) focus on energy efficiency, renewable technologies, conservation and environmental issues; 2) support State energy policy; 3) offer a reasonable probability of providing benefits to the general public; and 4) consider opportunities for collaboration and co-funding opportunities with other entities. Consistent with criteria 1 through 3, the CEC's proposed budget for the FY 2020-21 Plan allocates the $24 million budget to the following program areas:

- energy efficiency ($3.0 million),
- renewable energy and advanced generation ($4.0 million),
- energy infrastructure ($9.1 million),
- energy-related environmental research ($1.5 million), and
- natural gas transportation ($4.0 million).

Following guidance from the Decision, the CEC allocates 10 percent of the maximum annual plan budget ($2.4 million) to program administration. Appendix A of this Resolution delineates the CEC's proposed budget allocations and Appendix B provides a table of projects for FY2020-21.

The basic program areas meet the criteria for public interest Gas R&D projects identified in the Decision. The CEC reasonably selected Gas R&D program areas, allocated the program's budget to the different program areas, and provided a detailed accounting of stakeholder input on the proposed plan.

Consistent with criterion 4, the CEC discusses efforts to avoid duplication of funding and co-funding of projects in their FY 2020-21 Plan. Additionally, as ordered by Resolution G-3555, the CEC submitted a report "Natural Gas Research and Development Program Results for FY 2014-2015 to FY 2018-2019" to the CPUC in December 2019 that provided a detailed discussion of CEC's efforts at co-funding and leveraging funds for natural gas R&D.

The CEC's plan meets all requirements of D.04-08-010.

Consistency with Resolution G-3484 (2013) Accounting Requirements

Resolution G-3484 directed the CEC to include in their proposed budget an account, by research area, of then-current unspent funds in the program, including encumbrances and expiration dates. Guided by D.04-08-010, the research areas have historically included some variant of:

- energy efficiency,
- renewable energy and advanced generation,
- energy infrastructure,
- energy-related environmental research, and
- natural gas transportation.

Other research areas, however, are sometimes included in Gas R&D plans, such as the Natural Gas Small Grants research area from the FY 2019-20 Plan.

The CEC has two years to encumber[6] Gas R&D Program funds with projects, and an additional four years before such funds expire. After those six years, remaining funds must be approved for re-investment by the CPUC. Beginning with the FY 2014-15 proposed budget, the CEC has been required to include in its proposed budget an account of then-current, unspent funds in the Gas R&D Program, including encumbrances and expiration dates. The intent of this requirement is to show that the CEC has spent its cumulative authorized budgets in the areas in which the money was authorized and to provide an accounting of the status of cumulative unspent funds. This requirement shall remain in place for each fiscal year's proposed budget, until otherwise directed by the CPUC. The CEC provided Tables 5 and 6 within the FY2020-21 Plan, meeting the requirement. The CEC shall continue to adhere to this reporting requirement for unspent (or unencumbered) funds when it submits each future plan to the CPUC.

If future CEC plans request to use encumbered but unspent funds for new projects in the future, the request should identify the respective research areas

[6] Encumbered funds are funds committed to projects but which have not yet been spent (see www.ebudget.ca.gov/reference/GlossaryOfTerms.pdf).

the CPUC originally authorized the funding for, as well as encumbrances and expiration dates for these funds, consistent with the direction in G-3484. It is important for the CPUC to have information on which research areas received funds that went unspent in order to recognize any trends and better optimize the Gas R&D budget allocation across research areas.

Consistency with Resolution G-3555 (2019) Direction for FY 2020-21 Plan

Resolution G-3555 ordered that the CEC's FY2020-21 Plan address specific concerns on the development and direction of the program. The FY 2020-21 Plan requirements fell into three groups: budgeting and reporting, disadvantaged communities inclusion, and required research topic areas.

Budgeting and Reporting
As discussed above, Resolution G-3484 from 2013 requires the CEC to provide an account, by research area, of then-current unspent funds in the program, including encumbrances and expiration dates. Resolution G-3555 found that a full accounting of then-current unspent funds from FY 2014-15 to FY 2019-20 had never been supplied by the CEC. Therefore, Resolution G-3555 ordered[7] the CEC to provide a report within 120 days of the issuance of Resolution G-3555 for FY 2014 through 2019, and all future years, that included:

a) expenditures, by program area, for the Gas R&D program;
b) a full accounting of unspent funds, by program area, including encumbrances and expiration dates; and
c) summarized accomplishments of the Gas R&D Program, including a count of patents, copyrights, publications, and citations; an accounting of leveraged public and private funds; the successful commercialization of Gas R&D-funded projects; the development of any codes, standards, or protocols based on project results; and any other metrics of success CEC uses in tracking project and program accomplishments.

[7] Ordering Paragraph 4.

On December 2, 2019, the CEC submitted a report, *Natural Gas Research and Development Program Results for FY 2014-2015 to FY 2018-2019*, to the CPUC's Energy Division. On June 2, 2020, the CEC also supplied additional detailed budget information in response to an Energy Division Data Request. In response to requirements (a) and (b), the report provides Tables 8 and 9, which provide the approved, encumbered, and disencumbered funding amounts by program area for fiscal years 2014-2019 as of June 30, 2019. The text also addresses two supplemental budgets for FY 16-17 and FY 17-18, provides the amounts approved by program area from these supplemental budgets, and confirms these sums were encumbered.[8]

Resolution G-3555 also requested a summary of unspent funds by program area. Because encumbered funds are not available to be reallocated until a project is finished regardless of if they are spent or unspent, however, we find reasonable the CEC's summary of funds unencumbered by program area as an appropriate measure of potentially available funds.

In response to requirement (c), the CEC's report summarizes accomplishments, including how public and private funds were leveraged, a discussion of successful commercialization of funded projects, development of new codes, standards, and protocols, as well as provided a count of patents, open-access tools, publications, and citations in Table 5. Although G-3555 requested a count of copyrights, the CEC does not track this metric. The CEC instead offered a count of open-access tools (such as databases and visualization tools). The CEC also provided a high-level summary of program accomplishments in Table 7.

We find the CEC's reporting of budgets and accomplishments adequately meet CPUC's requirements for budgeting and reporting.

[8] The June 2, 2020 response to data request clarifies that the supplemental funding includes interest on unspent funds. As a result, the total budget may exceed the sum of the individual yearly appropriations.

Disadvantaged Communities
Resolution G-3555, in approving the FY2019-20 Plan, required in Ordering Paragraph 6, that the CEC:

a) Enhance outreach and engagement with representatives and members of disadvantaged communities. Within the FY2020-21 Gas R&D Plan, CEC must provide documentation showing which disadvantaged community stakeholders were engaged, how the CEC engaged them, what feedback they provided, and how the CEC incorporated this feedback. This requirement shall remain in effect for each fiscal year's proposed budget, until otherwise directed by the Commission.
b) Enhance outreach and engagement with all stakeholders and document outreach within the Gas R&D Plan.

The CEC's response to 6(a) includes an inventory of existing CEC diversity and outreach plans, such as the CEC's 2015 Diversity Policy Resolution. For specifics, the 2020-2021 Plan notes that the CEC notified the joint CEC-CPUC Disadvantaged Communities Advisory Group (DACAG) of the January stakeholder's workshop during development of the FY2020-21 Plan. The CEC did not present the draft plan to nor receive comment from the DACAG on the FY2020-21 Plan. The CEC's June 2, 2020 Response to Data Request further clarified that the CEC made an additional two follow-up communications to the DACAG soliciting comments after the workshop was held. Additional information from the CEC's DACAG liaison further clarified that, due to the scheduling dates for the December 2019 and January 2020 DACAG meetings, a presentation on the proposed FY2020-21 Plan to the DACAG could not be arranged. In addition to notifying representatives of disadvantaged communities, the CEC should seek to engage them. The CPUC directs that for the FY 2021-22 Plan, the CEC coordinate earlier with the DACAG to provide a presentation and receive comment from the DACAG on the plan, if the DACAG wishes.

The CEC's FY 2020-21 Plan also provided a list of other events where informational materials about the program were available. The CEC's June 2, 2020 Response to Data Request supplied additional information on several additional listservs that were notified of the CEC's workshop and notified of opportunities to comment on the FY 2020-21 Plan.

In implementing the Gas R&D Program, the CEC notes that for FY 2018-19, 41 of 129 project sites were in either a disadvantaged community, low-income community, or both. Twenty-nine percent ($23.5 million) of the $82 million awarded to active projects was allocated to projects sited in a disadvantaged or low-income community or both.[9]

Lastly, the FY 2020-21 Plan provides details of specific interactions between existing projects and disadvantaged communities as part of data collection or testing, however, these interactions are not related to providing feedback on the development of the plan itself.

The FY 2020-21 Plan also documents the launch of EmpowerInnovation.net, a CEC-wide networking platform aimed at reducing barriers to clean energy funding. The CEC notes several steps it has taken to onboard disadvantaged communities to Empower Innovation, such as webinars for tribes and a partnership with the BOOST program for local governments. The CEC does not provide any metrics or data on the results of these outreach efforts; it is not clear if participation from disadvantaged community members has increased or if these efforts need more time to be effective.

While these efforts to engage disadvantaged community stakeholders are admirable and supported by CPUC, it is unclear if they have or will yield any increase in disadvantaged community stakeholder participation in development of the annual program plan. Appendix B, "Public Comments," to the FY 2020-21 Plan provides the names of commenters and feedback provided to the CEC as well as the responses from the CEC. This includes one joint comment from Earthjustice, Sierra Club, and the California Environmental Justice Alliance; all other comments are from IOUs or industry and research stakeholders.

The CPUC remains dedicated to increasing the participation of disadvantaged community stakeholders in shaping the State's clean

[9] At 25.

energy future. To that end, in addition to earlier coordination with the DACAG, discussed above, for the FY 2021-22 Plan, we direct the CEC to identify and engage appropriate stakeholders to provide input on how to administer the program equitably. The CEC should consider whether it could offer small grants, participation stipends, or technical assistance to disadvantaged community stakeholders to encourage meaningful participation in the FY 2021-22 plan development cycle and future planning cycles. Engagement with air quality and public health advocates could also support the interests of disadvantaged communities in FY 2021-22 Plan to better focus on community environmental conditions including indoor air quality issues related to residential gas usage and larger natural gas facilities including distribution, transmission and storage. If tangible input from disadvantaged community groups on the draft FY 2021-22 Plan is not provided, the draft FY 2021-22 Plan needs to include a description of a good-faith engagement effort and outline additional steps the CEC will take in future years to better engage communities across the State.

The CEC was also required to improve outreach to all stakeholders. For the CEC's response to 6(b), the CEC's steps to generally enhance outreach are summarized as four broad activities: (1) increased social media, (2) coordinating with the CEC's Public Adviser to promote opportunities, (3) meeting with leaders, and (4) distributing materials at workshops, meetings, and other public events. These steps are consistent with the ordering paragraph.

Required Research Topic Areas
Ordering Paragraph 6 of Resolution G-3555 also ordered CEC to consider and coordinate with other State programs and goals, specifically to:

c) Continue examining the role of natural gas in our state's transition to a low carbon economy. This could include examining opportunities to use natural gas infrastructure to support hydrogen that will be generated and/or used in a way that reduces system GHG emissions.
d) Ensure coordination and consistency with goals of the Air Resources Board's 2017 Climate Change Scoping Plan Update by 1) Ensuring safety of the natural gas system; 2) Decreasing fugitive methane emissions; and 3) Reducing dependence on fossil fuel natural gas.

e) Continue targeting of Emissions-Intensive and Trade-Exposed Facilities consistent with state goals under Assembly Bill 32.
f) Consider the health impacts associated with natural gas usage inside homes.
g) Ensure coordination with the Commission's Methane Leak Proceeding (R.15-01-008) for any leakage-related Gas R&D work, especially energy-related environmental research.

The CEC addressed these requirements directly in the FY 2020-21 Plan, providing a crosswalk between these requirements, research areas, and proposed initiatives in Table 2.

Ordering Paragraph 7 of Resolution G-3555, also ordered the CEC to include projects for specific topic areas when developing the FY 2020-2021 Gas R&D Plan:

7. In developing their FY 2020-21 Gas R&D Plan, the CEC must consider research to do the following. If the CEC does not include any of the four topic areas listed below in their FY 2020-21 Gas R&D Plan, the CEC must provide their rationale within the Plan.
    a) Examine the causation, diagnostics, and mitigation of microbiologically influenced corrosion of pipelines and storage facilities in the California natural gas industry, especially as this relates to safety.
    b) Assess the effects of delivering hydrogen through the existing natural gas pipeline network, including the impact on pipeline facilities, natural gas generators, and end-use appliances.
    c) Research the operational, health, and safety consequences of various concentrations of siloxane in biomethane supplies.
    d) Perform research to establish a standard test method approved by the National Environmental Laboratory Accreditation Program (NELAP) and Department of Defense Environmental Laboratory Accreditation Program (DoD ELAP) for detecting siloxane in biomethane.

Again, Table 2 in the FY 2020-21 Plan provides a crosswalk between these requirements and proposed FY 2020-21 Plan initiatives.[10]

We find that the CEC's FY 2020-21 Plan sufficiently addresses the research topic areas required in G-3555.

Reasonableness of Budget Request

D.04-08-010 provides for CPUC review of the "reasonableness of the funding level, and the overall R&D program" after four years, i.e., sometime after FY 2009-10. The CPUC has not yet done a comprehensive review of the program. In the interim, we elect to maintain the CEC as the administrator and maximum funding level at $24 million per year.

We approve the CEC's proposed budget of $24 million for FY 2020-21. This funding level has no precedential value regarding the overall program review or funding levels beyond FY 2020-21, as the CEC must propose a zero-based budget for each fiscal year. Pending an assessment of the reasonableness of the overall R&D program, the maximum limit for program funding at $24 million is reasonable.

The CEC's request for administrative expenses ($2.4 million, or 10 percent of the total proposed budget) is an appropriate use of ratepayer funds. The approves the use of $2.4 million, or 10 percent of the total funding amount of $24.0 million, for program administration of the projects approved in this plan. We adopt this limit and require the CEC to adhere to it and direct the CEC to continue to keep such expenses at 10 percent or less of the maximum annual budget of $24 million for future budget proposals.

[10] The CEC's June 2, 2020 Response to Data Request further clarified the relationship of requirement (d) to the proposed projects. As several siloxane testing methods currently exist, the project will aim to prevent duplication of existing methods and aid NELAP in determining which method is most appropriate for laboratory use.

Summary of Assessment of FY 2020-21 Plan

The CPUC approves the CEC's proposed $24.0 million budget as described in its *Natural Gas Research and Development Program: Proposed Budget Plan for Fiscal Year 2020-2021*.

Additional CPUC Guidance for Fiscal Year 2020-21 Plan

In its FY 2020-21 Plan, under "Data Access Needs," the CEC mentions the need to access certain data to complete two of the proposed initiatives. CPUC staff has been working with CEC staff on securing access to geospatial data and condition assessment information of utility assets, which may be needed to build system models and predict future system costs and replacement schedules. As some of this data may be confidential or present security concerns if it were widely available, CPUC staff is working with data providers to ensure that any data transferred to the CEC will remain secure and that any public documents created from the use of this data will not present any security or other concerns for IOUs or for the public. The CEC's plan suggests that if it cannot obtain the necessary data, it will "reallocate funds to other proposed initiatives that can be successfully pursued."[11] If the CEC is unable to obtain the data it deems necessary, it must first consult with Energy Division staff overseeing this program before reallocating any funding.

CPUC Guidance for the Fiscal Year 2021-2022 Plan

In developing its Fiscal Year 2021-22 Plan, the CEC shall:

- Consider the report the CEC will produce to fulfill AB 3232 (Friedman, 2018) "Zero-emissions buildings and sources of heat energy" when it is released.
- When it becomes available, discusses how the Long-term Technological Development Strategy to Meet Aggressive Statewide Decarbonization Goals, funded in FY 2019-20 in response to direction from Resolution G-3546, was used to guide development of the plan.

[11] CEC Plan at 9-10.

- Coordinate more closely with the DACAG to solicit feedback, including earlier coordination to facilitate a presentation of the FY 2021- 22 Plan, if requested by the DACAG.
- Increase efforts to identify and engage appropriate disadvantaged community stakeholders to provide feedback on the FY 2021-22 Plan and document those efforts in the FY 2021-22 Plan. If feedback is not received by disadvantaged community groups on the draft plan, describe any barriers that must be overcome to receiving feedback on future plans.

Finally, the CPUC has identified the following topic area as needed to inform our proceedings and policies. In developing their FY 2021-22 Gas R&D Plan, the CEC must consider research to do the following. If the CEC does not include this topic area in their FY2021-22 Gas R&D Plan, the CEC must provide their rationale within the Plan.

- Quantify and document impacts to indoor air quality from natural gas appliances and the potential technically feasible improvements and potential risks to indoor air quality that could be achieved from fuel blending or electrification.

Submission Process Changes for the Fiscal Year 2021-2022 Plan and Beyond
As a public agency, the CPUC remains committed to public involvement and providing quality opportunities for all stakeholders to make meaningful comment on Commission actions. To that end, in this resolution the CPUC is requesting that the CEC change the process by which the CEC submits their annual Natural Gas Research and Development Program: Proposed Budget Plan to the CPUC. In developing its Fiscal Year 2021-22 and all future Proposed Budget Plans, the CPUC would prefer that the CEC amend their submission process to do the following:

Pre-formal submission to the CPUC:

- At least three weeks in advance of CEC's public workshop on the proposed budget plan, coordinate with CPUC staff in Energy Division and Safety and Enforcement Division. The goal of this additional step is to ensure the best possible use of funds across multiple programs.

- For as long as the pandemic continues to impact research efforts, consider any research gaps that might emerge due to recent budget decreases/reallocations in response to COVID-related economic impacts and potential co-funding opportunities that the natural gas R&D program can provide to limit the impact of these gaps on California energy goals.
- Post the Natural Gas Research and Development Program: Proposed Budget Plan publicly on the CEC's website before submitting an approval request to the CPUC and notify the CPUC of the web address when requesting approval of the plan.
- Distribute the Natural Gas Research and Development Program: Proposed Budget Plan through the CEC's research/R&D community listservs and include the names of the distribution lists served when requesting CPUC's approval of the plan.
- Consult with Energy Division staff on which CPUC listservs from ongoing CPUC proceedings the CEC should notice their proposed plan to.
- Consult with CPUC staff to allow for the option of presenting the Natural Gas Research and Development Program: Proposed Budget Plan to the CPUC Commissioners during a CPUC Commissioner Committee Meeting.

For formal submission to the CPUC:

Under the current process approved in D.04-08-010, each year the CEC submits their annual plan via business letter to the CPUC Energy Division. The public is not notified of the submission of the draft plan to Energy Division until a draft resolution is written by Energy Division staff and an item is placed on a Commission Voting Meeting Agenda. To provide opportunities for public engagement before the resolution is drafted, the CPUC requests that the CEC submit future requests in the form of a Tier 3 Advice Letter (or "business letter") pursuant to General Order 96-B to be served on the natural gas utilities' advice letter service lists. Using an advice letter process will notify parties and provide an opportunity for public comment prior to the release of a draft resolution. Energy Division staff will have the opportunity to include any such comments in the draft of the resolution.

Generally, only public utilities submit Advice Letters to the Commission. (See General Order 96-B, General Rule 1.1) The Commission's desire to facilitate an additional opportunity to comment upon the CEC's plans, however, may be facilitated without significantly increasing time for the approval of such plans or administrative burdens using the Advice Letter process.[12] We hereby request that the CEC use submit future Plans via the Tier 3 Advice Letter/business letter process so parties may comment upon it prior to the development of a Resolution to approve R&D funding.

For this year, the CPUC is attaching the CEC's *Natural Gas Research and Development Program, Proposed Budget Plan for Fiscal Year 2020-21* as Appendix C to this resolution to allow parties to provide feedback on the attached plan in comments to this resolution.

COMMENTS

Public Utilities Code section 311(g)(1) provides that this resolution must be served on all parties and subject to at least 30 days public review. Please note that comments are due 20 days from the mailing date of this resolution. Section 311(g)(2) provides that this 30-day review period and 20-day comment period may be reduced or waived upon the stipulation of all parties in the proceeding.

The 30-day review and 20-day comment period for the draft of this resolution was neither waived nor reduced. Accordingly, this draft resolution was mailed to parties for comments, and placed on the Commission's agenda no earlier than 30 days from the mail date.

The CEC submitted comments on this Draft Resolution on October 21, 2020. The CEC's letter contained five comments:

[12] General Order 96-B, General Rule 1.3 provides in part "The General Rules and Industry Rules shall be liberally construed to secure just, speedy, and inexpensive handling of informal matters, as set forth in this General Order. The Commission in a specific instance may authorize an exception to the operation of this General Order where appropriate."

(1) Providing Small Grants, Stipends, or Technical Assistance to Disadvantaged Community Stakeholders

The CEC commented that providing small grants, stipends, or technical assistance to disadvantaged community stakeholders concerns they CEC as they would be in effect selecting and funding stakeholders that would then be in a position to shape programs in ways that favors their organizations in future funding competitions. While CEC recognized the need to ensure diverse stakeholder engagement, the CEC seeks to find a way to do so without potentially influencing their competitive solicitation process. We maintain our desire for the CEC to explore these options and added clarifying language to the resolution that the CEC should consider these options, but is not required to implement them if it finds them to be infeasible.

(2) Investment Cycle

The CEC requests that the Commission modify the investment cycle of the Natural Gas R&D program by extending the investment cycle from one year to five years. The CEC states that the longer program cycle will support increased stakeholder engagement in a more continuous fashion and reduce time pressures on budget plan implementation.

The CEC cites a recent EPIC program Decision for the principle that such a modification may be beneficial for the CEC and CPUC's administration of the program. The CEC does not address the procedural propriety of modifying a program that has historically operated on an annual basis to a five-year investment cycle other than to state that if such a change is not possible within the current Resolution process then "the CEC seeks to discuss with the CPUC alternative pathways for adoption." (CEC Comments at p. 5.)

General Order 96-B provides that the advice letter process provides a quick and simplified review of the types of "requests that are expected neither to be controversial nor to raise important policy questions." (G.O. 96-B, General Rule 5.1.) The primary use of the advice letter process is to review a utility's request to change its tariffs in a manner previously authorized by statute or Commission order, to conform the tariffs to the requirements of a statute or Commission order, or to get Commission authorization to deviate from its tariffs." (*Ibid*.) General Rule 5.2 provides that "modification of a decision in a formal proceeding or otherwise seeks relief that the Commission can grant only after holding an evidentiary hearing or by decision rendered in a formal proceeding." Thus, to

modify a program developed in a formal proceeding and directed by a formal decision, the requestor must submit an application, an application for rehearing or petition for modification to modify the program through more formal proceedings than permitted in an Advice Letter process. The proposal to shift to a five-year horizon for this funding may have significant merit, but based upon the limited discussion provided in the CEC comments and the lack of opportunity for stakeholders to comment on the potential factual, policy or legal issues raised by this shift in response to the CEC's Comments on this Draft Resolution. Consistent with our finding in Resolution G-3527 on a similar request from the CEC[13] we decline to make such a change here, and urge the CEC to request such modification within a formal proceeding if they believe it to have merit.

(3) Timing of CPUC-CEC Coordination

The CEC suggested that, rather than a hard calendar deadline, the timing of early coordination between the CEC and CPUC be determined relative to their annual stakeholder workshop. As the most recent workshop was held January 21, 2020, altering the requirement from "no later than November" to "at least three weeks in advance of the workshop" is a minor change. We find this request reasonable and have modified the resolution as such.

(4) Facilitating Stakeholder Comment and CPUC Commissioner Input

The CEC further requests that rather than submitting its future Proposed Budget Plans as a Tier 3 Advice Letter as proposed in the Draft Resolution, they should be directed to submit a "business letter," as directed in D. 15-09-005 rather than an "Advice Letter." We note that D. 15-09-005 states that "the term 'advice letter' in this discussion encompasses the term 'business letter.' " Thus, the CEC appears to agree with the use of an Advice Letter process for the submission of their Plan for Energy Division review and comment and/or protest by interested entities and individuals. We agree that the CEC may submit its Proposed Budget Plan under the nomenclature of a "business letter" using the guidelines provided in G.O. 96-B for a Tier 3 Advice Letter, which ordinarily results in a Commission vote for approval.

(5) Combining Workshop and Optional Commissioner Presentations

CEC discusses combining their existing stakeholder workshop with the optional presentation during a CPUC Commissioner Committee Meeting that CEC is newly directed to offer in Ordering Paragraph 5(e). However, the

[13] Resolution G-3527 Finding of Fact 11 states that "The CEC should submit additional information in a future formal application to inform Commission review of the overall funding levels of the program, and whether timing for the Natural Gas R&D Program should expand to a triennial cycle."

CEC does not suggest any edits to Ordering Paragraph 5(e). We decline to make any change here for two reasons. First, the audiences for each event are very different: CPUC Commissioners and public stakeholders are not similarly situated to engage in discussion or review of this program. Each presentation will likely be tailored differently by the CEC to fit each audience to maximize engagement and utility. Second, the presentation during a CPUC Commissioner Committee Meeting is optional, dependent on the interest of the CPUC Commissioners; the purpose of this presentation is for the CEC to share with Commissioners their proposed plan. The annual workshop is part of developing the plan, and receiving stakeholder questions and comments to shape the plan that is submitted to the CPUC. CPUC Commissioners, on the other hand, are likely to be more interested in reviewing the final CEC proposal.

FINDINGS

1. The California Energy Commission (CEC) submitted its Fiscal Year 2020-2021 Natural Gas Research and Development Program budget and program plan, per Decision (D.) 04-08-010.
2. The CEC's plan meets the requirements of D.04-08-010.
3. The CEC provided the CPUC with the expiration date, encumbrances, and respective research areas for approved funding. The CEC's reporting of budgets and accomplishments adequately meet The CPUC's requirements in Resolutions G-3484 and G-3555.
4. Only one environmental/disadvantaged community stakeholder provided comment to CEC's Proposed Natural Gas Research Initiatives workshop.
5. The CEC continued to improve the program's outreach efforts through increased presence both electronically on social media and in-person at conferences and events.
6. The CEC's FY2020-21 Plan sufficiently addresses the research topic areas required in G-3555.
7. The CEC's request for $2.4 million administrative expenses, 10 percent of the total budget, is appropriate.
8. The CEC's proposed R&D plan and budget in its *Natural Gas Research and Development Program, Proposed Budget for Fiscal Year 2020-2021* should be adopted for a maximum budget of $24 million.

THEREFORE IT IS ORDERED THAT:

1. The Gas R&D program funding level for FY 2020-21 is $24 million, with 10 percent of this allowed for program administration.
2. The CEC's administrative budget is 10 percent of the total budget of $24 million, or $2.4 million.
3. In the Fiscal Year 2021-2022 Gas R&D Plan, the CEC shall ensure that, for any use of encumbered and unspent funds the CEC requests for new projects, the CEC's request identifies the respective research areas for which the Commission originally authorized the funding.

4. If the CEC is unable to obtain data it deems necessary to complete any of the projects proposed in the Fiscal Year 2020-2021 plan, it must first consult with Energy Division staff overseeing this program before reallocating any funding.
5. In developing all future Natural Gas R&D Plans, the CPUC requests that the CEC:
    a) At least three weeks in advance of the public workshop on the proposed budget plan, coordinate with CPUC staff on development of the Draft Plan.
    b) Post the Natural Gas Research and Development Program: Proposed Budget Plan publicly on their website and notify CPUC of the web address when requesting approval of the plan.
    c) Distribute the Natural Gas Research and Development Program: Proposed Budget Plan through the CEC's research/R&D community listservs and include the names of the distribution lists served when requesting CPUC's approval of the plan.
    d) Consult with Energy Division staff on which CPUC listservs from ongoing CPUC proceedings the CEC should notice their proposed plan to.
    e) Consult with CPUC staff to allow for the option of presenting the Natural Gas Research and Development Program: Proposed Budget Plan to the CPUC Commissioners during a CPUC Commissioner Committee Meeting.
6. In developing the future Natural Gas R&D Plans, the CPUC requests that the CEC submit future Natural Gas R&D Plans via the Tier 3 Advice Letter/business letter process.
7. The CEC shall serve the Plan in subsequent years on the natural gas utilities' Advice Letter service lists. The CEC shall include in its filing an e-mail address where comments on the Plan shall be sent so they may respond.
8. In developing the Fiscal Year 2021-2022 Gas R&D Plan, the CPUC requests that the CEC:
    a) Coordinate with the DACAG at an earlier date to provide the

DACAG with the option of a live presentation, if desired by the DACAG.

b) Identify and engage appropriate disadvantaged community stakeholders to provide increased input on how to administer the program equitably. If feedback is not provided from any disadvantaged community stakeholders, CEC must demonstrate a good-faith engagement effort and describe any barriers that must be overcome to receiving feedback on future plans.

c) Consider the Assembly Bill 3232 (Friedman, 2018) report when developing the FY2021-22 Plan and future plans, when it becomes available.

d) Consider the Long-Term Technological Development Strategy to Meet Aggressive Statewide Decarbonization Goals, funded in FY2019-20, when developing the FY2021-22 Plan (if available) and future plans as they becomes available.

e) Consider any research gaps that might emerge due to recent budget decreases/reallocations in response to COVID-related economic impacts, behavioral changes such as stay-in-place leading to greater indoor air concerns and needs for efficiency and potential co-funding opportunities that the natural gas R&D program can provide to limit the impact of these gaps on California energy goals.

9. In developing their FY 2021-22 Gas R&D Plan, the CEC must consider research to do the following. If the CEC does not include the topic areas listed below in their FY 2021-22 Gas R&D Plan, the CEC must provide their rationale within the Plan.
    a) Impacts to indoor air quality from natural gas appliances and improvements that could be realized from technologically feasible levels of fuel blending or electrification.
10. The CEC's Natural Gas Research and Development Program: Proposed Budget Plan for Fiscal Year 2020-2021 is approved for a total budget of $24.0 million.

This Resolution is effective today.

I certify that the foregoing resolution was duly introduced, passed and adopted at a conference of the Public Utilities Commission of the State of California held on November 5, 2020; the following Commissioners voting favorably thereon:

/s/
RACHEL PETERSON
Acting Executive Director

MARYBEL BATJER
President
LIANE M. RANDOLPH
MARTHA GUZMAN ACEVES
CLIFFORD RECHTSCHAFFEN
GENEVIEVE SHIROMA
Commissioners

Appendix A

Table 1: Natural Gas R&D Budget Plan Summary FY2020-21

PROGRAM AREA	BUDGET
Energy Efficiency	$3,000,000
Renewable Energy and Advanced Generation	$4,000,000
Natural Gas Infrastructure Safety and Integrity	$9,100,000
Natural Gas-Related Transportation	$4,000,000
Energy-Related Environmental Research	$1,500,000
Program Administration	$2,400,000
TOTAL	**$24,000,000**

Source: California Energy Commission *Proposed Budget Plan for Fiscal Year 2020-2021*.

Appendix B

Table 2: Natural Gas R&D Proposed Projects FY2020-21

PROGRAM AREA	PROJECT	DESCRIPTION
Energy Efficiency	Examining the Effects of Hydrogen in End-use Applications	This research will address the knowledge gaps and identify key benefits and challenges associated with using hydrogen blends in appliances, including: • Establishing criteria for the "safe" use of hydrogen-blends in appliances. • Conducting laboratory experiments to identify the maximum upper limit of hydrogen blended with natural gas that could be "safely" used in end-use appliances. These experiments would involve: o Developing a method for categorizing and selecting a representative sample of unmodified end-use appliances. Appliances would be categorized based on sector (residential, commercial) and application (for example, space heating, cooking, process heating). o Examining and testing the effects of hydrogen-blended fuel on unmodified natural gas service lines of varying materials. o Exploring appliance retrofits or modifications that could enable higher blends of hydrogen beyond the maximum upper limit (for example, controls and burner modifications). o Identifying specific new appliances and equipment specifications needed to enable higher blends of hydrogen at or beyond the maximum upper limit. • Estimating the cost of retrofitting appliances and equipment to accommodate higher blends of hydrogen.

		• Measuring the impact varying levels of hydrogen blends would have on the carbon intensity of natural gas-fueled appliances and overall contribution to state climate and energy goals. • Optimizing fuel composition to produce the least amount of criteria air pollutants and maximize lean stability limits. The study results would identify the impact of natural gas blends on existing and new appliances and the maximum concentration of hydrogen that can be handled by these appliances with and without modifications. The results will inform policy makers and the private sector of the technical and economic feasibility of this strategy and identify additional research and infrastructure needs to enable large-scale deployment.
Energy Efficiency	Accelerating Adoption of Modular Solar Water Heating in Low-Income or Disadvantaged Communities	This initiative would fund the demonstration of modular solar water-heating systems in low-income and disadvantaged communities and include an analysis of the building applications and climate zones where it would be most cost-effective. The demonstrations should do the following: • Select applications that represent those with high market potential such as multifamily residential, community centers, retirement communities, schools, lodging, health care centers, and restaurants. • Achieve a minimum of 70 percent reduction in natural gas use for water heating. • Achieve a minimum 20 percent cost reduction compared to conventional solar thermal. • Document system performance that includes energy bill savings, system energy efficiency, and customer satisfaction. • Develop modular, plug-and-play methods for designing each system so that they can be easily replicated to other buildings. • Develop and distribute case studies based on documented performance. • Coordinate with community-based organizations to determine community needs and barriers related to adoption of solar water heating.

		• Develop guides for solar water heating system installers that provide the previously developed design methods, existing tools, and commercially available systems with a focus on disadvantaged and low-income community applications. • Develop guides to help customers understand the benefits of solar water heating systems, available incentives, and resources to find installers. The results are intended to provide specific data, establish a scientific basis for building standards, and inform decisions regarding California's low-carbon energy future.
Renewable Energy and Advanced Generation	DECARB 1: Emerging Renewable Hydrogen Production	This initiative proposes to advance precommercial or early market technologies and strategies for efficiently and cost-effectively producing hydrogen gas using emerging electrolysis and non-electrolysis solutions. Possible project strategies include: • Developing and demonstrating electrolysis technologies that can use renewable electricity and waste heat to produce hydrogen (for example, combinations of waste heat and solid oxide electrolysis cells). • Demonstrating methods for hydrogen production from renewable methane (for example, methane cracking into hydrogen with potential for carbon capture) and system integration that enables multiple product generation. • Investigating the potential and readiness of earlier stage systems involving gas or liquid reforming, emerging fermentation, and photolysis for renewable hydrogen production. Projects must demonstrate cost-effective hydrogen production for domestic industrial and transportation applications. Technologies should focus on improving hydrogen production efficiency, reducing costs, and delivering environmental benefits compared to conventional hydrogen production pathways.

Renewable Energy and Advanced Generation	DECARB 2: Emerging Gas Cleanup and Upgrading System for Biomethane	This initiative will advance precommercial biomethane technologies and enable strategies for the efficient and economic production of clean and high-quality biomethane. Given the considerable funding and efforts from other state agencies like the California Department of Food and Agriculture for dairy digesters, this initiative will emphasize biogas and biomethane derived from municipal organic wastes and food processing wastes that are typically found in wastewater treatment plants, landfills, and other digesters. Possible projects include the following: • Demonstrate biogas-to-biomethane technology that has been proven at a pilot scale. • Lower the costs and improve process efficiency of biomethane production via sorbent-based technology. • Demonstrate cost-effective and improved processes for removing siloxane and other impurities over a range of biogas quality levels and sources. • Develop, test, and validate biomethane upgrading processes, targeting siloxane removal from wastewater and landfill gas sources. • Investigate emerging methods and possible standards for removal of siloxane and other priority impurities from biogas derived from wastewater treatment and landfill sources.
Natural Gas Infrastructure Safety and Integrity	Pilot Test and Demonstration of Hydrogen Blending into Existing California Natural Gas Pipelines	This research initiative focuses on a pilot test and demonstration of hydrogen blending into existing California natural gas systems. Possible research includes: • Pilot testing to measure various impacts of hydrogen blending on the system integrity of existing natural gas infrastructure in California. • Demonstrating hydrogen blending to identify the best use cases, validate pilot test results, and develop replicable implementation strategies for safe blending. • Assessing natural gas system modifications required to maximize hydrogen blending levels. • Modifying integrity management and system maintenance practices for natural gas infrastructure to accommodate delivery of hydrogen.

		• Developing hydrogen-blending methods and deployment strategies based on the lessons learned from the pilot test and demonstration. The research will help shape and develop standards by identifying the requirements, steps, and procedures involved with interconnecting and authorizing the injection of hydrogen into the natural gas pipeline system. This research includes coordination with gas utilities to determine an optimal use case for hydrogen blending, identifying injection location(s) for interconnection, conducting research on system impacts due to hydrogen, obtaining permits for hydrogen blending into natural gas pipelines, and evaluating the overall performance of hydrogen injections and impacts to system integrity.
Natural Gas Infrastructure Safety and Integrity	Technologies to Inspect and Prevent Corrosion of Natural Gas Pipelines and Storage Facilities	This initiative focuses on research, development, and demonstration of innovative technologies that can diagnose and address microbiologically and soil property influenced corrosion of pipelines and storage facilities in the California natural gas industry. Possible research includes: • Addressing corrosion damages to natural gas infrastructure from various causes, including microbiologically influenced corrosion and soil property-influenced corrosion. • Developing and testing advanced coatings or chemical treatment on metal surfaces to prevent corrosion for pipelines as well as storage wells and demonstrating the performance of coatings or surface chemical treatment including resistance to degradation. • Improving cathodic protection technologies – commonly used to electrochemically control metal corrosion in underground gas pipelines and storage facilities – that are specific to different corrosion mechanisms and conditions. • Developing new technologies or improving existing technologies with better accuracy to detect, locate, and size corrosion defects or areas, including hydrostatic testing, direct assessment, and in-line inspection. • Developing and demonstrating advanced repair technologies for internal and external corrosion

		Proposed projects will diagnose corrosion from various causes by conducting studies that include the measurement of corrosion damage to samples exposed to real-world environments. To help evaluate the performance of the corrosion mitigation treatment, corrosion monitoring data and test data should be collected from the same locations. Inspection techniques commonly used to detect and monitor corrosion-related damage generally include ultrasonic testing, radiographic testing, and magnetic flux methods.
Natural Gas Infrastructure Safety and Integrity	Analytics for Pilot Demonstration of Strategic Electrification and Decommissioning of Natural Gas Infrastructure	This research initiative focuses on in-depth analytics to inform a pilot demonstration of pipeline decommissioning and electrification in California. It requires a multidisciplinary approach to address interrelated issues holistically, such as identification of the most applicable use cases for demonstrations, technical requirements, short- and long-term cost/benefit analysis for customers and utilities, customer acceptance information, and equity considerations. To this end, the research would: • Summarize the impacts of decommissioning and electrification on gas and electric infrastructure, including electric system upgrades, gas system depreciation, operational conditions, system maintenance costs, and integrity management. • Perform short-term and long-term cost/benefit analysis for customers and utilities. • Analyze and quantify GHG emission reduction and air quality improvement. • Identify at least one applicable location in California for a pilot demonstration, with low-income or disadvantaged community representation. • Engage and coordinate among community groups, customers, and utilities of the identified location and develop strategies to simplify gas-to-electricity transition. • Conduct surveys and collect user acceptance data.

		The result of this research would enable an analytically grounded pilot demonstration at an identified location in California.
Energy-Related Environmental Research	Development of a Data-Driven, Actionable Tool and Case Studies to Support Strategic and Equitable Natural Gas Decommissioning	The proposed research would build on FY 2019-20 methodological work to develop a data-driven, actionable tool to support strategic and equitable natural gas decommissioning. Furthermore, this decision-support tool would complement analytics for a demonstration pilot also proposed in this budget by promoting broader replication of decommissioning projects. The tool developed by this research would provide new capabilities to support a managed transition for California's retail gas system and ensure that as California decarbonizes its energy system, it does so cost-effectively and in a manner that is equitable and safe. The tool will illuminate geospatially specific cost and equity issues with broad regional coverage. Similar to previous research efforts to develop actionable planning tools like Cal-Adapt, the tool will be developed to support a variety of users – including utilities, community choice aggregators (CCAs), CPUC, and newly constructed communities (for example, to examine gas system cost savings) – and inform infrastructure investment decisions. This research would also support using the tool to analyze specific groups of buildings and proposed developments within a geographic zone. This application will deliver case studies that inform decommissioning options and impacts. Local communities, as well as the users of the tool, will be engaged to inform the analysis and ensure research results are actionable. As an example, a case study may include a jurisdiction with an electrification ordinance, including a low-income community or disadvantaged community portion of that jurisdiction. The success of this project depends on voluntary or required sharing of (potentially sensitive) data from natural gas IOUs (for example, on geospatial positioning, age,

		and condition of natural gas and electricity system infrastructure). For that reason, the proposed research may focus on regions within a single IOU territory.
Transportation Research	Technology Integration and Demonstration of Hydrogen Fuel Cell Trucks and Buses	This initiative advances research, development, and demonstration of precommercial heavy-duty fuel cell electric vehicles (FCEVs) and hydrogen fueling infrastructure technologies that may reduce total cost of ownership (TCO) and improve efficiency and performance. Projects should target truck and bus types that lack commercially available options. Demonstrations should gather real-world fleet operational data such as driving performance, refueling practices, durability, and qualitative feedback to inform continued technology development, infrastructure planning, cost models, and continued fleet deployment. Near-term opportunities for accelerating deployment of heavy-duty FCEV technologies include vehicles that operate near hydrogen production facilities or industrial centers already using hydrogen. Examples include warehouses with hydrogen fuel cell material handling equipment, refineries, and biogas production plants. Prioritizing demonstrations at these locations will also benefit disadvantaged and low-income communities near the facilities. Projects must integrate and demonstrate precommercial technologies, which may include: • Improved fuel cell system components and integration strategies to improve ease of assembly and maintenance access, alleviate supply chain challenges, lower costs, and increase efficiency. Examples include catalysts and electrodes with reduced platinum group metal loading, lower cost membranes, improved cell and stack assemblies, and lower cost balance of plant components. • Improved fuel cell system diagnostics to reduce the total cost of ownership of heavy-duty fuel cell vehicles. • Advanced onboard storage tanks that can reduce costs and increase storage capacity.

		Improved hydrogen fueling infrastructure technologies such as high-capacity nozzles, cryopumps, and compressors that can improve reliability, uptime, and cost-effectiveness when supporting medium- and heavy-duty vehicles.

Source: California Energy Commission *Proposed Program Budget Plan for Fiscal Year 2020-21*.

Appendix C

CEC's *Natural Gas Research and Development Program, Proposed Budget Plan for Fiscal Year 2020-21*

CALIFORNIA
ENERGY COMMISSION

Energy Research and Development Division

STAFF REPORT

Natural Gas Research and Development Program

Proposed Budget Plan for Fiscal Year 2020-21

Gavin Newsom, Governor

March 2020 | CEC-500-2020-0XX

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ACKNOWLEDGEMENTS

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PREFACE

The California Energy Commission's (CEC) Energy Research and Development Division manages the Natural Gas Research and Development Program, which supports energy-related research, development, and demonstration not adequately provided by competitive and regulated markets. These natural gas research investments spur innovation in energy efficiency, renewable energy and advanced clean generation, energy transmission and distribution, energy-related environmental protection, and transportation.

The Energy Research and Development Division conducts this public interest natural gas-related energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public and private research institutions. This program promotes greater natural gas reliability, lower costs, and increased safety for Californians and focuses on:

- Buildings End Use Energy Efficiency.
- Industrial, Agriculture, and Water Efficiency.
- Renewable Energy and Advanced Generation.
- Natural Gas Infrastructure Safety and Integrity.
- Energy-Related Environmental Research.
- Transportation.

The *Natural Gas Research and Development Program Proposed Budget Plan for Fiscal Year 2020-21* is a staff report prepared by the CEC's Energy Research and Development Division.

For more information about the Energy Research and Development Division, please visit Research and Development at the Energy Commission's website, or contact the CEC at 916-327-1551.

ABSTRACT

In 2000, Assembly Bill (AB) 1002 (Wright, Chapter 932, Statutes of 2000) was enacted, requiring the California Public Utilities Commission (CPUC) to add a surcharge on natural gas consumed in California. This surcharge funded various energy efficiency programs and public interest research and development to benefit natural gas ratepayers. AB 1002 also required the CPUC to designate an entity to administer the research component of AB 1002. In 2004, the CPUC issued Decision 04-08-010, designating the California Energy Commission (CEC) as the research fund administrator.

The *Natural Gas Research and Development Program Proposed Budget Plan for Fiscal Year 2020-21* describes the CEC's proposed natural gas research initiatives in energy efficiency, renewable energy and advanced generation, natural gas infrastructure safety and integrity, energy-related environmental research, and transportation. These initiatives support the state's energy policies and objectives, with several initiatives directly benefitting disadvantaged communities.

The proposed research funding for Fiscal Year 2020-21 is $24 million, and the budget plan covers July 1, 2020, through June 30, 2021. The budget plan was informed by input from California stakeholders, research institutions, equipment manufacturers, and governmental partners.

CEC staff appreciates the coordination with CPUC on the proposed research initiatives. To support the successful advancement of the initiatives, CEC staff requests CPUC's support in providing access to needed utility infrastructure data.

Keywords: California Energy Commission; California Public Utilities Commission; natural gas; energy efficiency; pipeline safety; climate change; drought; buildings end-use energy efficiency; industrial, agriculture, and water efficiency; renewable energy and advanced generation; energy infrastructure; natural gas pipeline integrity; energy-related environmental research; transportation; disadvantaged communities; low-income communities

Please use the following citation for this report:

Chen, Peter. 2020. Energy Research and Development Division. 2020. *Natural Gas Research and Development Program Proposed Budget Plan for Fiscal Year 2020-21.* California Energy Commission. Publication Number: CEC-500-2020-0XX.

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EXECUTIVE SUMMARY

As California continues to pursue its ambitious emission reduction and renewable energy targets to tackle climate change and improve public health and safety, the role of natural gas in the energy system will change. Continued public research and development investments in energy technologies are critical for supporting this transition and ensuring that the state's clean energy goals are met safely and cost-effectively.

Recent laws, executive orders, technology advancements, and environmental research continue to reshape the landscape for the Natural Gas Research and Development (R&D) Program. For example, in 2018, former Governor Edmund G. Brown Jr. set two of the most ambitious climate targets in history by signing Senate Bill 100 (De León, Chapter 312, Statutes of 2018), requiring that all retail sales of electricity in California be renewable or zero-carbon by 2045, and by issuing Executive Order B-55-18, requiring that the entire California economy achieve carbon neutrality by 2045. While these goals are 25 years in the future, planning must begin now for the state to transition successfully toward these goals cost-effectively.

In accordance with guidance from the California Public Utilities Commission (CPUC) and the California Energy Commission's (CEC) analysis of research gaps, the CEC proposes to pursue targeted research under the Natural Gas R&D Program in energy efficiency, renewable energy and advanced generation, natural gas infrastructure safety and integrity, energy-related environmental research, and transportation. This research will help build the technological foundation for achieving the goals of SB 100, Executive Order B-55-18, and other important state policies and objectives.

Natural gas plays a central role in California's energy system. It is used in homes and businesses — including for space and water heating, drying, and cooking. In the industrial and transportation sectors, it is used for process heating, combined heating and power, and vehicle operation. In 2018, Californians consumed about 1.8 trillion cubic feet of natural gas, with the power generation and residential sectors together accounting for more than half of the consumption at 45 percent and 24 percent, respectively. According to the *California Energy Demand 2018-2030 Revised Forecast*, these numbers are expected to grow slowly, with estimates showing an average demand increase for natural gas of about 0.34 percent per year through 2030. However, recent market trends and carbon reduction goals signal a transition away from the use of natural gas derived from fossil sources.

As the state reduces reliance on fossil natural gas, research and development will help drive innovations that ensure a safe natural gas system, minimize environmental impacts including methane leakage, and enable cost-effective pathways for producing and using renewable natural gas (RNG) and hydrogen. Key objectives of the Natural Gas R&D Program are to:

- Enhance engagement with low-income and disadvantaged communities to ensure all Californians have access to clean, affordable energy, building on recent and current engagement (discussed in Chapter 2).
- Improve understanding of health and safety-related issues as California transitions to low- and no-carbon substitutes for fossil natural gas.
- Assess the environmental and climate implications of new energy technologies using low- and no-carbon substitutes for fossil natural gas.
- Inform future policy deliberations about the future of natural gas in California as the state moves toward its decarbonization goals.
- Support technologies that provide significant efficiency and emissions improvements for sectors such as transportation and industry that have a longer horizon to zero-net greenhouse gas emissions.
- Avoid supporting energy technologies that would become stranded assets by 2030 or by 2045, considering the time needed to develop new low-carbon, market-ready technologies.
- Reduce the production costs of low- and no-carbon substitutes for fossil natural gas, such as synthetic natural gas, RNG, and hydrogen.
- Enable the safe and economical use of hydrogen as a sustainable energy resource and examine opportunities to use existing natural gas infrastructure to support hydrogen distribution.
- Develop and demonstrate energy technologies that can enable negative emissions, such as biomethane production technologies, which could be paired with carbon capture and storage.
- Measure and enable the reduction of methane leaks that contribute to greenhouse gas emissions.

Research Approach and Stakeholder Participation

The CEC's Energy Research and Development Division staff develops natural gas research initiatives based on state energy policies, plans, and guidance; analysis of research gaps; and stakeholder input. Key policies, plans, and guidance include:

- CPUC Resolution G-3555.
- CPUC Decision 04-08-010.
- Senate Bill 100 (De León, Chapter 312, Statutes of 2018).
- Executive Order B-55-18.
- Assembly Bill 32, the Global Warming Solutions Act (Núñez, Chapter 488, Statutes of 2006).
- Senate Bill 32 (Pavley, Chapter 249, Statutes of 2016).
- *Integrated Energy Policy Reports.*

- *Energy Action Plan.*
- *California Energy Efficiency Strategic Plan.*

On January 21, 2020, CEC staff held a public workshop to present the proposed budget plan for the FY 2020-21 Natural Gas R&D Program and received comments from stakeholders supporting the proposed initiatives and offering helpful input and perspective on specific research topics. CEC staff also received written public comments that have informed this proposed plan. See Appendices A and B for the staff workshop presentation and a summary of public comments and CEC responses.

Natural Gas R&D Program Proposed Budget Plan for Fiscal Year 2020-21

The Fiscal Year (FY) 2020-21 Natural Gas R&D Program proposed budget plan allocates $24 million across five research areas, with 10 percent for program administration support (Table ES-1).

Table ES-1: Fiscal Year 2020-21 Natural Gas Research and Development Program Proposed Budget Plan

Research Areas	Proposed FY 2020-21 Natural Gas Budget
Energy Efficiency	$3,000,000
Renewable Energy and Advanced Generation	$4,000,000
Natural Gas Infrastructure Safety and Integrity	$9,100,000
Energy-Related Environmental Research	$1,500,000
Transportation	$4,000,000
Program Administration	$2,400,000
TOTAL	$24,000,000

Source: California Energy Commission

Data Access Needs

CEC staff appreciates the coordination with the CPUC on the proposed research initiatives. To support the successful advancement of the initiatives, CEC staff requests CPUC's support in easing access to needed utility infrastructure data. This access will be particularly important for the following initiatives:

- Analytics for Pilot Demonstration of Strategic Electrification and Decommissioning of Natural Gas Infrastructure

- Development of a Data-Driven, Actionable Tool and Case Studies to Support Strategic and Equitable Natural Gas Decommissioning.

If access to needed data is not attained, CEC staff proposes to reallocate funds to other proposed initiatives that can be successfully pursued.

CHAPTER 1: Introduction

Recognizing the benefit of natural gas research to Californians, Assembly Bill 1002 (Wright, Chapter 932, Statutes of 2000) directed the California Public Utilities Commission (CPUC) to add a surcharge on all natural gas consumed in California to fund research and development specific to natural gas. The 2004 CPUC Decision 04-08-010 designated the California Energy Commission (CEC) as the administrator for the Natural Gas Research and Development (R&D) Program. The CPUC allocates $24 million annually and defines public interest natural gas research activities as those "directed towards developing science or technology, and 1) the benefits of which accrue to California citizens, and 2) are not adequately addressed by competitive or regulated entities."[1] The decision also directs Natural Gas R&D projects to:

- Focus on energy efficiency, renewable technologies, conservation, and environmental issues.
- Support state energy policy.
- Provide communitywide benefits including job creation, improved air quality, and economic stimulation.
- Consider opportunities for collaboration and cofunding with other entities, such as federal and local agencies.

Intersection of Research and Policy

The CEC's Natural Gas R&D Program responds to and informs state energy policies, plans, and guidance, including from the CPUC. For example, the program supports California's progress toward two landmark policies established in 2018: Senate Bill 100 (De León, Chapter 312, Statutes of 2018), requiring that all retail sales of electricity in California be renewable or zero-carbon by 2045, and Executive Order B-55-18, requiring that the entire California economy achieve carbon neutrality by 2045. While these goals are 25 years in the future, planning must begin now for the state to transition toward these end goals cost-effectively. Additional examples of policies supported by the Natural Gas R&D Program include the Short-Lived Climate Pollutant Reduction Strategy (Senate Bill 1383, Lara, Chapter 395, Statutes of 2016) and Senate Bill 350 (De León, Chapter 547, Statutes of 2015), which aims to increase clean energy funding directed to low-income and disadvantaged communities. The *2017 Climate Change Scoping Plan Update* underscores the pivotal role of innovative technologies in improving efficiency,

1 CPUC Decision 04-08-010, p. 24.

increasing the production of renewable natural gas, and reducing leakage from natural gas infrastructure in meeting future climate change targets.[2]

The Natural Gas R&D Program supports a range of CPUC policies, including:

- CPUC Resolution G-3555, which directs the CEC to consider research on topics based on CPUC proceedings and policies, such as pipeline corrosion, hydrogen blend impacts on infrastructure and end-use appliances, and biomethane impurities.
- CPUC's General Order No. 112-F, which addresses the rules for utilities to design, construct, test, operate, and maintain piping systems beyond the requirements set by federal regulations.
- CPUC Resolution G-3519, which directs the CEC to support research studies stemming from the Aliso Canyon leak.
- CPUC's Gas Safety Plan, which will improve the CPUC's safety and enforcement programs.

Additional examples of policies, plans, and guidance that drive or are informed by the Natural Gas R&D Program are shown in Table 1.

2 California Air Resources Board. California's 2017 Climate Change Scoping Plan.

Table 1: Examples of the Intersection of Research and Policy for the Natural Gas Research and Development Program

Research Area	Policies, Guidance, and Plans
Natural Gas R&D Program	• Executive Order B-55-18 requires that California's economy achieve carbon neutrality by 2045. • Senate Bill 100 (De León, Chapter 312, Statutes of 2018) requires 60% of retail sales of electricity be generated from eligible renewable energy resources by 2030 and all retail sales of electricity be renewable or zero-carbon by 2045. • Public Utilities Code Section 895 provides statutory authority for the CEC to administer the natural gas funds using the Public Interest Energy Research (PIER) statutes. • Senate Bill 32 (Pavley, Chapter 249, Status of 2016) requires California to reduce GHG emissions to 40 percent below 1990 levels by 2030. • Assembly Bill 32 (Núñez, Chapter 488 Statutes of 2006) — California Global Warming Solutions Act of 2006 requires the development of Scoping Plans to reduce GHG emissions. • Senate Bill 1250 (Perata, Chapter 512, Statutes of 2006) authorizes continuing investments in public interest energy research. • Integrated Energy Policy Report (IEPR) assesses major energy trends facing California's electricity, natural gas, and transportation fuel sectors and provides policy recommendations. • Energy Action Plan identifies actions necessary to meet California's energy goals to be reliable, affordable, technologically advanced, and environmentally sound. • Public Resources Code 25620 allows the state to undertake public interest energy research, development, and demonstration projects.

Research Area	Policies, Guidance, and Plans
Energy Efficiency	• Energy Efficiency Buildings Standards (Title 24, Part 6) — goals for 2019 Standards.[3] • Appliance Energy Efficiency Standards (Title 20, Division 2, Chapter 4, Article 4, Sections 1601–1608: Appliance Efficiency Regulations) • Senate Bill 350 (De León, Chapter 547, Statutes of 2015) establishes targets for statewide energy efficiency savings and demand reduction that will achieve a cumulative doubling of statewide energy efficiency savings for retail customers by 2030. • California Energy Efficiency Strategic Plan establishes goals for zero-net-energy buildings and to increase building energy efficiency cost effectively. • 2019 California Energy Efficiency Action Plan[4] addresses existing buildings, low-income barriers to energy efficiency, agriculture, industry, newly constructed buildings, conservation voltage reduction, and electrification.
Renewable Energy and Advanced Generation	• Senate Bill 100 (De León, Chapter 312, Statutes of 2018) requires 60% of retail sales of electricity be generated from eligible renewable energy resources by 2030 and all retail sales of electricity be renewable or zero-carbon by 2045. • Senate Bill 1383 (Lara, Chapter 395, Statutes of 2016) requires reductions in statewide emissions of methane by 40 percent, hydrofluorocarbon gases by 40 percent, and anthropogenic black carbon by 50 percent below 2013 levels by 2030. • Assembly Bill 1613, the Waste Heat and Carbon Emissions Reduction Act (Blakeslee, Chapter 713, Statutes of 2007) requires an electrical corporation to purchase excess electricity from combined-heat-and-power systems that comply with sizing, energy efficiency, and air pollution control requirements. • Governor Brown's Clean Energy Jobs Plan provides incentives for the increased use of cogeneration by 6,500 MW by 2030. • Bioenergy Action Plan[5] implements Executive Order S-06-06, which set goals for the production and use of electricity and fuels made from biomass.

3 Cox, Rory. October 24, 2017. It All Adds up to Zero, California's Zero- Net -Energy Future, California Public Utilities Commission, Bay REN Forum.

4 Kenney, Michael, Heather Bird, and Heriberto Rosales. 2019. 2019 California Energy Efficiency Action Plan. California Energy Commission. Publication Number: CEC-400-2019-010-SF.

5 O'Neill, Garry. 2012. *2012 Bioenergy Action Plan*. California Energy Commission, Efficiency and Renewables Division. Publication number: CEC-300-2012-XXX-XXX

Research Area	Policies, Guidance, and Plans
Natural Gas Infrastructure Safety and Integrity	• Senate Bill 887 (Pavley, Chapter 673, Statutes of 2016) issued requirements to ensure the safety and integrity of natural gas storage facilities. • Senate Bill 1371 (Leno, Chapter 525, Statutes of 2014) requires the CPUC to determine whether existing practices are effective at reducing methane leaks and promoting public safety, and whether alternative practices may be more effective. • CPUC Order Institution Investigation I1702002 under Senate Bill 380 (Pavley, Chapter 14, Statutes of 2016) determines the feasibility of minimizing or eliminating the use of the Aliso Canyon natural gas storage facility in Los Angeles County while maintaining energy and electric reliability for the region.
Energy-Related Environmental Research	• CPUC Decision 19-10-054, Rulemaking 18-04-019, outlines strategies and guidance for climate change adaptation. • Assembly Bill 1496 (Thurmond, Chapter 604, Statutes of 2015) requires the state to monitor methane hotspots. • CARB's Short-Lived Climate Pollutant Reduction Strategy recommends actions to reduce emissions of short-lived climate pollutants, including from dairies, organics disposal, and wastewater.
Transportation	• Executive Order B-32-15 directed the development of the Sustainable Freight Action Plan, which establishes targets to improve freight system efficiency by 25 percent by 2030, deploy more than 100,000 freight vehicles and equipment capable of zero-emission operation, and maximize near-zero freight vehicles and equipment powered by renewables by 2030. • 2016 Mobile Source Strategy reduces emissions from the heavy-duty truck sector with cleaner combustion engines, renewable fuels, and zero-emission technology to meet GHG reduction targets and attain federal health-based air quality standards for ozone and particulate matter. • Low Carbon Fuel Standard (LCFS) reduces the full fuel-cycle carbon intensity of the transportation fuels pool used in California by encouraging the transition to fuels that have a lower carbon footprint.

Source: California Energy Commission

CPUC Resolution G-3555 Guidance for Fiscal Year 2020-2021 Plan

CPUC Resolution G-3555 directed the CEC to do the following in developing the Fiscal Year 2020-21 budget plan.

a) **Disadvantaged communities outreach and engagement:** Enhance outreach and engagement with representatives and members of disadvantaged communities. Within the FY 2020-2021 Gas R&D Plan, CEC must provide documentation showing which disadvantaged community stakeholders were engaged, how the CEC engaged them, what feedback they provided, and how the CEC incorporated this feedback. This requirement shall remain in effect for each fiscal year's proposed budget, until otherwise directed by the Commission.

b) **Stakeholder outreach and engagement:** Enhance outreach and engagement with all stakeholders and document outreach within the Gas R&D Plan.

c) **Role of natural gas and hydrogen in a low-carbon economy:** Continue examining the role of natural gas in the state's transition to a low-carbon economy. This examination could include exploring opportunities to use natural gas infrastructure to support hydrogen that will be generated and used in a way that reduces system GHG emissions.

d) **Consistency with 2017 Climate Change Scoping Plan Update:** Ensure coordination and consistency with goals of the California Air Resources Board's (CARB) *2017 Climate Change Scoping Plan Update* by 1) ensuring safety of the natural gas system, 2) decreasing fugitive methane emissions, and 3) reducing dependence on fossil fuel natural gas.

e) **Emissions-Intensive and Trade-Exposed Facilities:** Continue targeting of emissions-intensive and trade-exposed facilities consistent with state goals under Assembly Bill 32.

f) **Health impacts inside homes:** Consider the health impacts associated with natural gas usage inside homes.

g) **Coordination for methane leakage research:** Ensure coordination with the Commission's Methane Leak Proceeding (R.15-01-008) for any leakage-related Gas R&D work, especially energy-related environmental research.

h) **Identify research areas when using encumbered and unspent funds:** Ensure that for any use of encumbered and unspent funds the CEC requests for new projects, CEC's request identifies the respective research areas for which the Commission originally authorized the funding.

CPUC Resolution G-3555 also directed the CEC to consider research in the following topic areas to inform the CPUC's proceedings and policies.

i) **Address microbiologically influenced corrosion:** Examine the causation, diagnostics, and mitigation of microbiologically influenced corrosion of pipelines

and storage facilities in the California natural gas industry, especially as they relate to safety.

j) **Assess effects of hydrogen on pipelines and end-uses:** Assess the effects of delivering hydrogen through the existing natural gas pipeline network, including the impact on pipeline facilities, natural gas generators, and end-use appliances.

k) **Research consequences of siloxane in biomethane:** Research the operational, health, and safety consequences of various concentrations of siloxane in biomethane supplies.

l) **Establish test method for detecting siloxane in biomethane:** Perform research to establish a standard test method approved by the National Environmental Laboratory Accreditation Program (NELAP) and Department of Defense Environmental Laboratory Accreditation Program (DoD ELAP) for detecting siloxane in biomethane.

This FY20-21 budget plan for the Natural Gas R&D Program closely aligns with the guidance provided in CPUC Resolution G-3555, as shown in Table 2. Additional discussions with CPUC staff helped develop the proposed initiatives for the FY20-21 budget plan by ensuring alignment with CPUC proceedings and policies. In connection with Guidance Items a and b, Chapter 2 details how the CEC continues to engage representatives from disadvantaged communities[6] and other stakeholders.

Table 2: Connections Among Proposed Initiatives for FY20-21 Budget Plan and CPUC Resolution G-3555 Guidance

Research Area	Proposed Initiatives for FY20-21 Budget Plan	CPUC Resolution G-3555 Guidance
Energy Efficiency Research	Examining the Effects of Hydrogen in End-Use Appliances	c. Role of natural gas and hydrogen in a low-carbon economy d. Consistency with *2017 Climate Change Scoping Plan Update* f. Health impacts inside homes j. Assess effects of hydrogen on pipelines and end-uses

6 Disadvantaged communities are defined as areas representing census tracts scoring in the top 25 percent in CalEnviroScreen 3.0.

Research Area	Proposed Initiatives for FY20-21 Budget Plan	CPUC Resolution G-3555 Guidance
Energy Efficiency Research	Accelerating Adoption of Modular Solar Water Heating in Low-Income or Disadvantaged Communities	a. Disadvantaged communities outreach and engagement c. Role of natural gas and hydrogen in a low-carbon economy d. Consistency with *2017 Climate Change Scoping Plan Update* f. Health impacts inside homes
Renewable Energy and Advanced Generation	Decarbonization via Efficient and Cost-Competitive Renewable Hydrogen and Biomethane (DECARB) 1: Emerging Renewable Hydrogen Production	c. Role of natural gas and hydrogen in a low-carbon economy *d.* Consistency with *2017 Climate Change Scoping Plan Update* e. Emissions-Intensive and Trade-Exposed Facilities
Renewable Energy and Advanced Generation	Decarbonization via Efficient and Cost-competitive Renewable Hydrogen and Biomethane (DECARB) 2: Emerging Gas Cleanup and Upgrading System for Biomethane	c. Role of natural gas and hydrogen in a low-carbon economy d. Consistency with *2017 Climate Change Scoping Plan Update* k. Research consequences of siloxane in biomethane l. Establish test method for detecting siloxane in biomethane
Natural Gas Infrastructure Safety and Integrity	Pilot Test and Demonstration of Hydrogen Blending into Existing California Natural Gas Pipelines	c. Role of natural gas and hydrogen in a low-carbon economy j. Assess effects of hydrogen on pipelines and end-uses

Research Area	Proposed Initiatives for FY20-21 Budget Plan	CPUC Resolution G-3555 Guidance
Natural Gas Infrastructure Safety and Integrity	Technologies to Inspect and Prevent Corrosion of Natural Gas Pipelines and Storage Facilities	g. Coordination with methane leakage research i. Address microbiologically influenced corrosion
Natural Gas Infrastructure Safety and Integrity	Analytics for Pilot Demonstration of Strategic Electrification and Decommissioning of Natural Gas Infrastructure	c. Role of natural gas and hydrogen in a low-carbon economy d. Consistency with *2017 Climate Change Scoping Plan Update* f. Health impacts inside homes
Energy-Related Environmental Research	Development of a Data-Driven, Actionable Tool and Case Studies to Support Strategic and Equitable Natural Gas Decommissioning	c. Role of natural gas and hydrogen in a low-carbon economy d. Consistency with *2017 Climate Change Scoping Plan Update* f. Health impacts inside homes
Transportation Research	Technology Integration and Demonstration of Hydrogen Fuel Cell Trucks and Buses	c. Role of natural gas and hydrogen in a low-carbon economy d. Consistency with *2017 Climate Change Scoping Plan Update*

Source: California Energy Commission

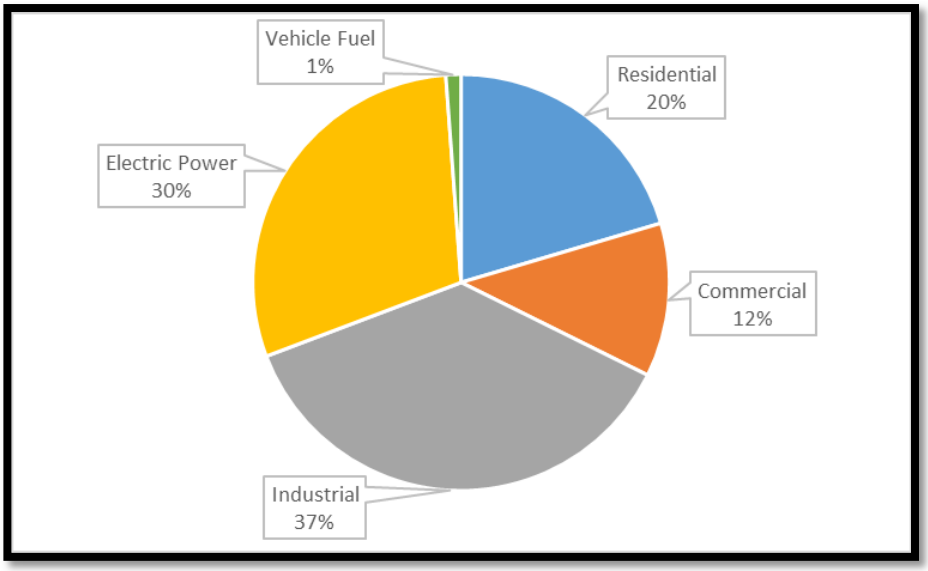
Importance of Natural Gas Research to Meet Decarbonization Goals

Natural gas is a major fuel in California's economy. In 2018, California's five end-use sectors—residential, commercial, industrial, transportation, and electricity generation—consumed about 2.1 trillion cubic feet (Tcf) per year, or about 5.8 billion cubic feet (Bcf) per day.[7] The electricity generation and the industrial sectors account for most of the natural gas use in California. Figure 1 provides a breakdown of natural gas use per sector in 2018. About 30 percent of the natural gas is used in electricity generation,

7 United States Energy Information Administration. Natural Gas Consumption by End Use (California, Annual, 2018).

which represented 46 percent of the total electricity produced in California in 2018.[8] Transportation accounts for only about 1 percent of natural gas consumption in California, though this number is likely to increase because of the growing number of natural gas trucks in the heavy-duty vehicles sector, where natural gas can serve as an alternative to diesel.[9]

Figure 1: Percentage Use of Natural Gas by Sector in California (2018)



Source: U.S. Energy Information Administration

Despite a 34 percent increase in California's population since 1990, natural gas demand in the residential sector has experienced a slight yet continuous decline, while demand has been relatively flat in the commercial, industrial, and power generation sectors.[10] These results reflect California's success in implementing energy efficiency standards for buildings, appliances, and utilities. Nevertheless, in the absence of additional near-term market or policy changes, overall demand for natural gas in California may grow slowly through 2030, with a 0.34 percent per year increase projected in the mid-demand case scenario of CEC's *California Energy Demand 2018-2030 Revised Forecast*. This projection scenario represents a "business-as-usual" environment, with consideration of current policies such as the Renewables Portfolio Standard, SB 350, and energy efficiency standards.[11]

8 California Energy Commission. 2018 Total System Electric Generation in Gigawatt Hours.
9 Bahrenian, Aniss, Jesse Gage, Sudhakar Konala, Bob McBride, Mark Palmere, Charles Smith, and Ysbrand van der Werf. 2017. *Transportation Energy Demand Forecast 2018—2030.* California Energy Commission. Publication Number: CEC-200-2017-010.
10 State of California, Department of Finance. California Population Estimates, with Components of Change and Crude Rates, July 1, 1900-2019. December 2019.
11 Kavalec, Chris, Asish Gautam, Mike Jaske, Lynn Marshall, Nahid Movassagh, and Ravinderpal Vaid. 2018. *California Energy Demand 2018–2030 Revised Forecast*. California Energy Commission, Energy Assessments Division. Publication Number: CEC-200-2018-002-CMF.

In the long term, the state's clean energy and climate goals signal a transition away from fossil natural gas for the power generation, residential, and commercial sectors. Building electrification is a key strategy for decarbonizing homes and businesses. Dozens of local authorities in California have adopted ordinances and building codes to advance building electrification and transition away from natural gas use. Developing cost-effective pathways for producing and using RNG and hydrogen is another key strategy for lowering GHG emissions. Use of the existing infrastructure to transport these fuels requires that pipeline leakage and other potential safety, operational, and environmental issues be addressed.[12] Improvements in the safe transport, including minimizing methane leakage, and efficient use of natural gas will also be important, especially in end-use sectors that are harder to electrify, such as certain industry subsectors and transportation, and potentially in electricity generation, as natural gas can be used to meet electricity demand when renewable generation is varying.

Since 2004, the Natural Gas R&D program has invested in research to develop technologies, tools, and strategies that increase energy efficiency, reduce energy cost, reduce air pollutants and GHG emissions, and improve the safety of pipeline infrastructure. The *Natural Gas Research and Development 2019 Annual Report* delivered to the CPUC provides a recent review of program achievements in FY 2018-19.[13] Since the inception of the program in 2004, research has focused on using natural gas as safely, cleanly, and efficiently as possible. These topics remain important, but the FY20-21 budget plan places greater emphasis on research areas that align with the state's current priorities for decarbonization — including research on areas such as strategic decommissioning and electrification, alternatives to fossil-based natural gas such as biomethane and hydrogen, and renewable alternatives for water heating. The full set of initiatives is presented in Chapter 2.

12 Campagna, Jennifer, Leon Brathwaite, Anthony Dixon, Jason Orta, and Peter Puglia. 2019. *2019 Natural Gas Market Trends and Outlook Report*. California Energy Commission. Publication Number: CEC-200-2019-018.

13 Henderson, Braden. 2019. Energy Research and Development Division. 2019. *Natural Gas Research and Development Program 2019 Annual Report*. California Energy Commission. Publication Number: CEC-500-2019-057.

CHAPTER 2:
Natural Gas R&D Program Proposed Plan for Fiscal Year 2020-2021

Developing Research Initiatives

Stakeholder Participation and Strategic Partnerships

The CEC engages with stakeholders to develop a research portfolio responding to challenges in the natural gas sector. Stakeholders provide invaluable input for the development of research initiatives, and in some cases, they become partners on research projects. For example, the current National Ambient Air Quality Standards requirements for ozone attainment cannot be achieved in California's air basins suffering from the lowest air quality without significant reductions in oxides of nitrogen (NO_x) emissions from heavy-duty vehicle fleets. The CEC cofunded research with the South Coast Air Quality Management District and Southern California Gas Company to develop an engine technology that reduces NO_x emission rates to 90 percent below the 2010 standard.[14] The research project will include a production readiness plan to help accelerate natural gas engine technologies on the path to commercialization. The CEC also collaborates with a wide range of California stakeholders, research institutions, governmental agencies, and industry and utility representatives to develop a shared vision of natural gas public interest energy research projects. This thoughtful outreach improves accountability, transparency, communication, and responsiveness. The CEC relies on these strategic partnerships to avoid duplication, build upon previous R&D work, generate new ideas, leverage public and private investments, and ensure the research portfolio delivers benefits to the state's natural gas ratepayers.

Commitment to Diversity

California is a diverse state in population and in geography. To serve all Californians better, the CEC strives to increase diversity in its programs through outreach, funding opportunities, and planning.

In 2015, the CEC unanimously approved a formal Diversity Policy Resolution, consistent with state and federal law, to improve fair and equal opportunities for small businesses; women-, disabled veteran-, minority-, and LGBTQ-owned business enterprises; and economically disadvantaged and underserved communities to participate in and benefit from CEC programs. Assembly Bill 865 (Alejo, Chapter 583, Statutes of 2015) provided additional guidance, requiring the CEC to develop and implement a comprehensive outreach plan to broaden and diversify the applicant pool to CEC programs and track

14 Observed rates below 0.02 grams per brake horsepower hour.

progress toward those objectives. Senate Bill 350 (De León, Chapter 547, Statutes of 2015) also took steps to ensure California's clean energy transformation includes a strong focus on equity to ensure all Californians realize benefits, especially those in the most vulnerable communities.

The CEC cofounded the Disadvantaged Communities Advisory Group, as outlined in SB 350, to advise the CEC and the CPUC on ways to help disadvantaged communities benefit from proposed clean energy and pollution reduction programs, expand access to clean energy technologies, and receive affordable energy services. Furthermore, in its SB 350 Barriers Report, the CEC recommended that the CEC and CPUC should direct research, development, demonstration, and market facilitation programs to include targeted benefits for low-income customers and disadvantaged communities.[15]

CEC staff continues to conduct activities to meet these important commitments. Some of these efforts include:

- Continuing and advancing an outreach plan to ensure women, minorities, LGBTQ individuals, and disabled veterans are informed and educated about R&D program activities and encouraged to participate in R&D project funding opportunities.
- Assisting applicants in understanding how to apply for funding from the CEC's programs.
- Continuing and advancing efforts to address energy-related challenges and opportunities in economically depressed communities.
- Continuing to track, monitor, and report on the participation of California-based entities and women-, minority-, disabled-veteran-owned, and small businesses as recipients of R&D awards, using the same definitions used by the investor-owned utilities in CPUC General Order 156.
- Notifying the Disadvantaged Communities Advisory Group of the January 21, 2020, Natural Gas Stakeholders Workshop and opportunities for public comment.

The CEC undertook activities in 2019 that bolstered its commitment to ensuring a diverse range of applicants can participate in R&D projects:

- Broadening the use of social media platforms to educate and inform.
- Collaborating with the Commission's Public Adviser to promote grant-funding opportunities.
- Meeting with community leaders, stakeholders, and business leaders.

15 Scavo, Jordan, Suzanne Korosec, Esteban Guerrero, Bill Pennington, and Pamela Doughman. 2016. *Low-Income Barriers Study, Part A: Overcoming Barriers to Energy Efficiency and Renewables for Low-Income Customers and Small Business Contracting Opportunities in Disadvantaged Communities.* California Energy Commission. Publication Number: CEC-300-2016-009-CMF.

- Distributing R&D informational materials at conferences, meetings, workshops and public events such as:
    - Webinar for public comments on the preliminary draft research roadmap on renewable energy generation technologies for utility-scale applications (June 2019).
    - IEPR Commission workshop on the 2019 preliminary transportation energy demand forecast, including discussions on economic, regulatory, and technology attributes-based forecasts of natural gas vehicle and hydrogen fuel cell vehicle adoption through 2030 (July 2019).
    - IEPR Commissioner workshop on the 2019 preliminary California energy demand electricity and natural gas demand forecast, including discussions on scenario development based on future efficiency improvements and technology costs (August 2019).
    - IEPR joint agency workshop on energy efficiency and building decarbonization, including a presentation on the CEC's research on GHG impacts of the natural gas system (August 2019).
    - Request for comments on innovative waste heat recovery technologies to inform future research initiatives and solicitations (August 2019).
    - Staff presentation on CEC's programs, including the Natural Gas Research Program, at the Industrial Environmental Association 2019 Environmental Training Symposium and Conference (October 2019).
    - Staff workshop to identify research needs and opportunities for demonstrating fuel cells systems in rail and marine applications at California ports (October 2019).
    - Staff presentation on CEC's programs, including the Natural Gas Research Program at the UC Solar Thermal Symposium (November 2019).
    - Workshop on energy storage research needs in California during the Energy Storage North America 2019 Conference and Exhibition, including discussions on long-term storage and green electrolytic hydrogen (November 2019).
    - Pre-Application Workshop for GFO-19-502 — Storage monitoring, smart shutoff and three-dimensional mapping technologies for safer natural gas infrastructure (November 2019).
    - Pre-Application Workshop for GFO-19-501 — Characterizing air quality impact from renewable natural gas and improving natural gas system climate resilience (December 2019).
    - Emerging Technologies Coordinating Council webinars (ETCC Webinars)
        - Costs and Benefits of Community vs. Individual End-Use for Solar Water Heating, Lawrence Berkeley National Laboratory (LBNL) (February 2019)

- Energy-Efficient Concentration of Food and Beverage Products by Porifera (August 2019)
- Energy-Efficient Infrared Drying of Healthy Snacks and Walnuts by UC Davis (August 2019)

More information about these and other CEC activities that support diversity are available on the CEC's website.

Advancing Clean Energy Equity

In CPUC Resolutions G-3546 and G-3555, the CEC was directed to enhance outreach and engagement with representatives and members of disadvantaged communities. Over the 2018-2019 fiscal year, the Natural Gas R&D Program included 78 active projects with 129 project sites, representing $82 million in allocated research funds. Of this total, 41 project sites were in either a disadvantaged community, low-income community, or both. Twenty-nine percent ($23.5 million) of the $82 million was allocated to project sites in a disadvantaged or low-income community or both (Table 3).[16] Figure 2 shows the locations of the project sites. Examples of Natural Gas R&D Program projects that are demonstrating clean energy technologies in and benefiting disadvantaged or low-income communities or both include the following:

- Element 16 Technologies, Inc. is demonstrating a low-temperature industrial heat capture system to reduce natural gas usage at Searles Valley Minerals, a chemical processing plant in a low-income community in Trona (San Bernardino County).
- University of California, Merced is demonstrating aluminum minichannel solar water-heating collectors to reduce natural gas usage at a multifamily home in a low-income community in Arleta in the San Fernando Valley.
- All Power Labs, Inc. is demonstrating a microscale combined cooling, heating, and power system integrated with a biomass gasification waste-to-energy system to reduce energy usage in industrial facilities in disadvantaged communities in Berkeley.
- Mazzetti, Inc. is demonstrating an advanced air distribution system to improve heating, ventilation, and air conditioning (HVAC) operational efficiency and reduce energy usage at a hospital in a disadvantaged community in Harbor City in the Los Angeles area.
- Terzo Power Systems, LLC is demonstrating a natural gas, hybrid-electric nut harvester to reduce emissions and fuel consumption in a disadvantaged community in Madera.

16 Henderson, Braden. 2019. Energy Research and Development Division. 2019. *Natural Gas Research and Development 2019 Annual Report*. California Energy Commission. Publication Number: CEC-500-2019-057.

Natural Gas R&D projects have and will continue to engage with residents of disadvantaged communities and low-income communities and representative community-based organizations (CBO) to realize targeted and equitable research benefits. Some current examples of such engagement include the following:

- The Effective Kitchen Ventilation for Healthy ZNE Homes With Natural Gas Appliances project, led by LBNL, will improve understanding of public health impacts associated with natural gas use inside multifamily homes. LBNL engaged building managers and residents of four income-qualifying apartment complexes in Hayward, San Francisco, Chula Vista, and Los Angeles to collect data on ventilation equipment conditions, usage, and indoor air quality representative of some of California's low-income homes. The data points are valuable because low-income homes are typically smaller and have higher occupant density than many single-family homes, which can result in higher indoor air pollutant concentrations from natural gas cooking appliances.
- The Phase Change Material-Enhanced Insulation for Residential Exterior Wall Retrofits project, led by UC Davis, will develop and test a phase change material-enhanced insulation solution for existing homes that have little or no wall insulation at three pilot sites, two of which are in low-income communities, while one is in an overlapping low-income and disadvantaged community. Cost-effective exterior wall retrofit solutions for the existing housing stock is highly applicable to low-income and disadvantaged communities and will reduce natural gas and electricity costs for heating and cooling while improving indoor air quality. UC Davis plans to engage with Merced County Community Action Agency (MCCAA) on the project's technical advisory committee to provide guidance on maximizing project benefits to low-income and disadvantaged communities. Through their Weatherization Assistance Program, MCCAA provides assessments to upgrade qualified homes to improve health, safety, comfort, and efficiency – delivering vital energy cost savings. The phase change material-enhanced insulation developed through this project can help improve their weatherization strategy.
- The Cost-Effective Technologies and Strategies to Improve Energy Efficiency and Reduce Emissions of Direct Heating Equipment in California with Health Benefits project, led by LBNL, will develop strategies to reduce natural gas usage from heating equipment commonly used in low-come households (for example, wall and floor furnaces and room heaters) to lower energy bills and improve indoor air quality and thermal comfort. LBNL plans to collaborate with the Rising Sun Center of Opportunity and Every Neighborhood Partnership, inviting both organizations to participate on the project's technical advisory committee of and facilitate recruitment of households in the communities they serve for field evaluation and demonstration of high-efficiency heating equipment.

The CEC has also funded projects that developed and demonstrated a broad range of tools to improve the safety and integrity of natural gas infrastructure throughout California, including disadvantaged and low-income communities. Examples of these tools include a high-accuracy mapping system that creates spatially accurate maps of the pipeline system populated with traceability information, and an excavation encroachment notification system that provides utility operators with real-time situation awareness to better avoid excavation damage to pipelines. These tools help identify gas system risks at an early stage, address system vulnerabilities effectively, and promote the resiliency of natural gas infrastructure in the communities being serviced.

Table 3: FY 2018-19 Active Project Sites in Disadvantaged and Low-Income Communities

Diversity Category	# of Project Site(s)	Estimated Funding Amount	Percent of Funding
Disadvantaged Community	7	$6.4	8%
Low-Income Community	34	$17.1	21%
Overlapping Disadvantaged & Low-Income Community	27	$19.2	23%
Total	41	$23.5	29%

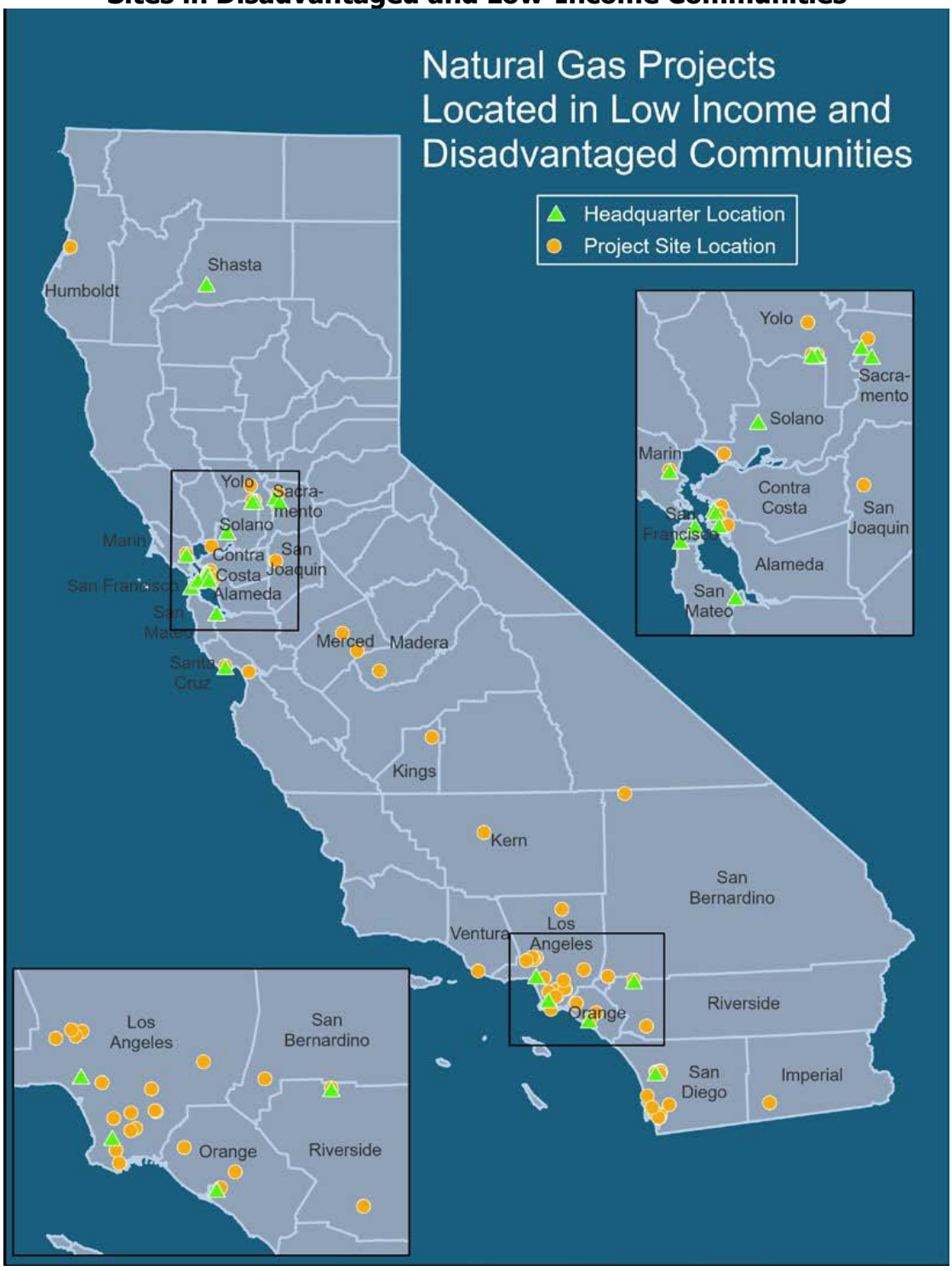
Source: California Energy Commission

To help diverse communities and businesses identify funding and partnering opportunities to advance a clean energy future for all, the CEC launched a professional networking platform — EmpowerInnovation.net. On Empower Innovation, technology developers, clean energy funders, and local communities can communicate directly about shared interests and create mutually beneficial partnerships to respond to funding opportunities. CEC staff has helped onboard underresourced entities to the platform, such as local governments and CBOs serving tribes, disadvantaged communities, low-income communities, and opportunity zones. As part of the recruitment, CEC staff held a webinar for tribes, partnered with the Institute for Local Government to support its BOOST program[17], supported the cities of Arvin and Paramount in creating their profiles, and is coordinating additional webinars targeted at local governments and CBOs. CEC staff continues to share information on how to use the Empower Innovation Platform, including at pre-application workshops for Natural Gas R&D Program funding opportunities. The Empower Innovation Platform is a powerful tool to break down barriers to accessing funding for clean energy projects and

17 The Institute for Local Government, in partnership with the California Strategic Growth Council, created the BOOST Pilot Program to help local governments build capacity and resources to develop projects and secure funding to increase access to clean air and water, clean transportation, affordable housing and economic opportunity.

creating partnerships, especially for communities that have historically been underrepresented.

Figure 2: Natural Gas R&D Program Projects with Headquarters and Project Sites in Disadvantaged and Low-Income Communities



Source: California Energy Commission

Collaborative Roadmaps and Technology Assessments

Roadmaps and technology assessments are planning mechanisms and communication tools that establish a clear link between research and energy policy goals. Research roadmaps define the topic area, significant issues and barriers, data gaps, information needs, research priorities, and potential partnerships. CEC staff and a wide range of energy researchers and consumers participate in "road mapping" in many program areas to gather cutting edge information that can help determine how to maximize the value of Natural Gas R&D Program investments.[18] Participants help identify natural gas research needs by program area. Collaborative thinking about energy solutions that cut across policy boundaries is integral to leveraging research dollars. Bringing natural gas and electricity stakeholders together to develop roadmaps minimizes resource shifting, encourages innovation, and promotes transparency.

As a recent example, ICF, a global consulting services company, developed a comprehensive assessment of the technical and market potential for small- and micro-scale combined heat and power (CHP) in California with funding from the Natural Gas R&D Program. The assessment summarized and compared the technical, economic, and environmental characteristics of various CHP technologies — including reciprocating engines, microturbines, and fuel cells — and examined integration issues and barriers that impede adoption of small- and micro-scale CHP systems and recommendations on how to address these barriers. Another example from the Natural Gas R&D Program is a new research roadmap that is underway (expected to be completed in 2020) for the chemical and allied products industry — the fourth largest consumer of natural gas among California industries—to identify technologies and approaches to reduce natural gas use.

An array of studies supplement roadmaps in the development of research priorities. For example, the *2015 Natural Gas Vehicle Research Roadmap*[19] provided research recommendations on natural gas vehicle range and storage, engine performance and availability, emissions and environmental performance, and analysis and information sharing. Two supplemental studies for this roadmap include (1) *The Feasibility, Issues, and Benefits Associated with Expanded Use of Natural Gas at Seaports and Other High Horsepower Applications,*[20] which evaluates scenarios where natural gas can beneficially displace diesel in locomotives or marine vessels at California ports, and (2) a technology assessment that is underway (due to be completed in 2020) to characterize real-world emissions and fuel usage across a variety of heavy-duty vehicle types, including natural

18 Various roadmaps can be found at the Energy Commission's publications database.
19 Schroeder, Alex. National Renewable Energy Laboratory. *2015 Natural Gas Vehicle Research Roadmap.* CEC-500-2015-091-CMF.
20 Leonard, Jonathan and Patrick Couch. Gladstein, Neandross & Associates. 2017. *The Feasibility, Issues, and Benefits Associated With Expanded Use of Natural Gas at Seaports and Other High Horsepower Applications.* CEC-500-2017-032.

gas trucks, and analyze technology benefits and shortfalls that can inform policies and future research priorities.

Proposed Budget

The proposed breakdown of the FY 2020-21 budget by research area is in Table 4. Detailed descriptions of proposed initiatives in each research area are provided below.

Table 4: FY 2020-21 Natural Gas Research and Development Program Proposed Budget Plan Summary

Research Areas	Proposed Budget
Energy Efficiency	$3,000,000
Renewable Energy and Advanced Generation	$4,000,000
Natural Gas Infrastructure Safety and Integrity	$9,100,000
Energy-Related Environmental Research	$1,500,000
Transportation	$4,000,000
Program Administration	$2,400,000
TOTAL	$24,000,000

Source: California Energy Commission

CPUC Resolution G-3507 — Unspent Funds

As requested by the CPUC in Resolution G-3507, the CEC has reviewed the unspent funds in the Public Interest Research Development and Demonstration Natural Gas Subaccount to identify the funds no longer available for future grants or contracts. The CEC has budget authority for a six-year fund life, including two years to encumber funding. After the two-year encumbrance cycle, an agreement term can be up to four years before the funds are liquidated and unusable for that agreement. While the Natural Gas R&D Program has succeeded in allocating all annual funding, it is common for some of these agreements to complete activities under budget with an amount of funds being unspent in the six-year cycle. In rare cases, the CEC stops work on a project before the term end date for various reasons, including challenges with finding replacement host sites for projects and unsatisfactory interim results on projects.

Each budget plan describes estimated allocations of funding among natural gas research and development areas. The CEC's Natural Gas R&D Program budget process allocates funding to CPUC-approved initiatives that are subsequently acted upon by developing specific projects selected through competitive solicitations. Depending on the strengths of proposals submitted to the CEC through this competitive process, the

CEC may vary the amount of funding among CPUC-approved budget plan research areas, especially when strong proposals are available in high-priority research areas.

Per the CPUC's request in Resolution G-3507, Table 5 and Table 6 show the research funds from FY 2014-15 to FY 2017-18 encumbered within two years of budget approval. For FY 2014-2015 to FY 2018-19, the earliest date that encumbered project funds expire is June 30, 2020. After this date (the last date for expenditures, also known as the "liquidation expiration date"), the CEC cannot use the expired funds unless subsequent authorization is provided by the CPUC and the state Legislature. Per CPUC's request in Resolution G-3555, the CEC will ensure that for any use of encumbered and unspent funds that the CEC requests for new projects, the request will identify the respective research areas for which the CPUC originally authorized the funding. Total expenditures from the FY 2014-15 through FY 2018-19 CPUC approved budget plans are not known at this date, since most of the projects are still in progress. An accounting of unspent funds can be determined after June 30, 2020 which is the last day that funds can be encumbered from the FY 2018-19 budget plan.

Table 5: Natural Gas Research Funds Encumbered Within Two Years of Budget Approval

Research Area	CPUC FY 2014-15 Approved Budget Plan	Total FY 2014-15 Funds Encumbered	Total FY 2014-15 Funds	CPUC FY 2015-16 Approved Budget Plan	Total FY 2015-16 Funds	Total FY 2015-16 Funds	CPUC FY 2016-17 Approved Budget Plan
Energy Efficiency	$8.60	$7.48	$0	$7.10	$7.10	$0	$7.10
Renewable Energy and Advanced Generation	$3.50	$2.48	$0	$5.80	$5.80	-$1.18	$4.40
NG Infra-structure Safety, Integrity*	$2.50	$4.68	$0	$1.00	$1.00	$0	$4.00
Energy-Related Environmental Research*	$3.00	$3.62	$0	$3.30	$3.30	$0	$2.60
Transportation	$4.00	$3.34	$0	$4.40	$4.40	-$1.50	$3.50
TOTAL	$21.60	$21.60	$0	$21.60	$21.60	-$2.68	$21.60

Amounts shown in table are in millions and rounded to the nearest $10,000.

Source: California Energy Commission

Table 6: Natural Gas Research Funds Encumbered Within Two Years of Budget Approval

Research Area	Total FY 2016-17 Funds Encumbered	Total FY 2016-17 Funds Disencumbered	CPUC FY 2017-18 Approved Budget Plan	Total FY 2017-18 Funds Encumbered	Total FY 2017-18 Funds Disencumbered	CPUC FY 2018-19 Approved Budget	Total FY 2018-19 Funds Encumbered**	Total FY 2018-19 Funds Disencumbered
Energy Efficiency	$5.20	$0	$6.60	$4.57	$0	$6.00	$0.00	$0
Renewable Energy and Advanced Generation	$5.02	$0	$4.00	$4.00	$0	$3.00	$0.00	$0
Natural Gas Infrastructure Safety, Integrity*	$3.87	$0	$5.00	$5.82	$0	$5.60	$0.00	$0
Energy-Related Environ-mental Research*	$2.69	$0	$3.00	$3.46	$0	$3.00	$0.00	$0
Transpor-tation	$4.81	-$1.99	$3.00	$3.75	$0	$4.00	$2.31	$0
TOTAL	$21.59	-$1.99	$21.60	$21.60	$0	$21.60	$2.31	$0

Amounts shown in table are in millions and rounded to the nearest $10,000.

*** In Resolution G-3507 (June 25, 2015), the CPUC directed the CEC to prioritize natural gas research and development projects on climate change, drought, and natural gas safety. The CEC shifted funding to these high-priority research areas when strong research proposals were received. For the FY 2014-15 to FY 2017-18 period, the CEC funded natural gas infrastructure safety and integrity research at about 120 percent of baseline funding.**

**** For the FY 2018-19 budget plan, approved on January 31, 2019, the CEC has committed the budget plan balance from FY 2018-19 and is executing agreements and encumbering funds.**

Source: California Energy Commission

Proposed Research Initiatives

This proposed FY 2020-21 Natural Gas R&D Budget Plan ($24M) includes research funding for energy efficiency, renewable energy and advanced generation, energy infrastructure (including pipeline safety), energy-related environmental research, transportation, and program administration (Table 4). A research initiative consists of one or more research projects, each designed to advance technology or an area of

science. The CEC's Natural Gas R&D budget allocates funding to CPUC-approved initiatives that are then implemented by developing specific projects selected through competitive solicitations.

Energy Efficiency

Energy efficiency continues to be important in reducing energy demand and greenhouse gas emissions in buildings and the industrial, agriculture, and water sectors. Residential and commercial buildings and the industrial sector together use about 69 percent of the natural gas in California. As a result, past energy efficiency research has focused on developing, testing, and demonstrating precommercial and emerging technologies, strategies, and tools to reduce natural gas use in buildings and the industrial, agriculture, and water sectors.

Market trends and the state's clean energy goals signal a transition away from use of fossil-based natural gas for appliances, HVAC, and water-heating systems. One technological strategy for helping meet California's long-term decarbonization goals is blending hydrogen with natural gas.[21] However, the potential effects of adding hydrogen into existing natural gas infrastructure is not well understood. These effects include those of varying levels of hydrogen on end-use appliances, safety issues, impacts on air quality, operational performance, and appliance modifications needed. Achieving residential and commercial building adoption of hydrogen-natural gas blends could reduce greenhouse gas emissions because of the high proportion of existing natural gas-fueled appliances. For example, more than 80 percent of appliances in existing California homes run on natural gas.

One major use of natural gas in buildings is water heating. Water heating accounts for nearly 40 percent of the natural gas used by California households and 32 percent in the commercial building sector. Solar thermal water heating (SHW) offers a clean, renewable alternative that can significantly reduce natural gas consumption in the building sector. Unfortunately, the uptake of SHW systems has been slow, even with incentives, because of customized installations, cost, maintenance, and the requirement for backup systems. Customized installations can be inefficient, costly, and difficult for installers to manage with limited resources. A modular and standardized SHW system with various tank sizes and corresponding equipment could reduce the pressure on installers and significantly lower costs for customers. Multifamily and commercial buildings such as senior care centers provide a good test environment to develop modular, plug-and-play methods that can be replicated in other buildings because of the constant and high hot-water demands.

In alignment with the state's GHG reduction targets for 2030 and beyond, the FY 2020-2021 budget plan for energy efficiency research focuses on two areas: (1) analyzing the effects and potential limits for hydrogen and natural gas blends for end use appliances

21 California Air Resources Board. 2017. *California's 2017 Climate Change Scoping Plan.*

in residential and commercial buildings, and (2) developing modular plug-and-play solar thermal systems for use in buildings in disadvantaged or low-income communities.

The proposed research budget for energy efficiency is $3 million (Table 7). Research will be coordinated with other research areas, as appropriate.

Table 7: FY 2020-2021 Proposed Natural Gas R&D Budget Plan Summary — Energy Efficiency

Research Area—Energy Efficiency	Proposed Budget
Proposed Research Initiatives: ▪ Examining the Effects of Hydrogen in End-Use Appliances ▪ Accelerating Adoption of Modular Solar Water Heating in Low-Income or Disadvantaged Communities	$3,000,000

Source: California Energy Commission

Energy Efficiency Program Goals

- Conduct technology research, development, and demonstration to increase energy efficiency while reducing equipment and operating costs, natural gas use, and greenhouse gases and other air emissions (for example, low NOx).
- Advance energy-efficient technologies that support decarbonization.
- Develop and demonstrate affordable energy-efficiency technologies, processes, and strategies.
- Maintain or increase productivity and increase industry competitiveness in the global market.
- Commercialize technologies with broad market potential.

Proposed Research Initiatives

Examining the Effects of Hydrogen in End-Use Appliances

The Issue

While California is in the vanguard of clean energy, it still relies heavily on natural gas to meet its energy needs. About 37 percent of natural gas in California is used for industrial processing, 30 percent for electricity generation, 20 percent by the residential sector, 12 percent for the commercial sector, and 1 percent for vehicles.[22] Though natural gas is lower-emitting than coal and petroleum, it still contributes significant greenhouse gas emissions, including from methane leakage in the natural gas supply

22 United States Energy Information Administration. Natural Gas Consumption by End Use (California, Annual, 2018).

chain. Hydrogen mixed with natural gas may prove to be a more sustainable option and could have a role in meeting California's long-term decarbonization goals.[23] However, the potential effects of adding hydrogen into existing natural gas infrastructure is not well understood, including the effects of varying levels of hydrogen on end-use appliances.

Research is needed to identify the maximum upper limit of hydrogen blended with natural gas that could be safely used in end-use appliances. There is uncertainty on the impact on air quality, operational performance, and residential appliance modifications needed. Achieving residential and commercial building adoption of hydrogen-natural gas blends could reduce greenhouse gas emissions because of the high proportion of existing natural gas-fueled appliances. For example, more than 80 percent of appliances in existing California homes run on natural gas. There is a need to understand the effect of hydrogen blends in building appliances — defined broadly here to include water heaters, boilers, furnaces, cooktop stoves, ovens, and dryers.

This research initiative aligns with Executive Order B-55-18, which sets a state goal to achieve carbon neutrality by 2045, among other state policies and plans (Table 1). This initiative also aligns with guidance from CPUC Resolution G-3555 to explore opportunities for hydrogen use that can reduce system GHG emissions, consider the health impacts associated with gas usage inside homes, and assess the effects of hydrogen delivered through the existing natural gas pipeline network on end-use appliances (Table 2).

The Research

The addition of hydrogen blends with natural gas could change combustion characteristics because of the differences in physical and chemical properties. The addition of hydrogen could also pose safety issues such as hydrogen embrittlement and other issues with end-use appliances caused by the presence of hydrogen.[24] There is a lack of experimental data, and further experimental work is needed to provide information that can be used to validate theoretical work.

This research will address the knowledge gaps and identify key benefits and challenges associated with using hydrogen blends in appliances, including:

- Establishing criteria for the "safe" use of hydrogen-blends in appliances.
- Conducting laboratory experiments to identify the maximum upper limit of hydrogen blended with natural gas that could be "safely" used in end-use appliances. These experiments would involve:
    - Developing a method for categorizing and selecting a representative sample of unmodified end-use appliances. Appliances would be

23 California Air Resources Board. 2017. *California's 2017 Climate Change Scoping Plan.*
24 Messaoudani, Z.L., Rigas, F., Hamid, M. D. B., & Hassan, C. R. C. 2016. "Hazards, Safety and Knowledge Gaps on Hydrogen Transmission via Natural Gas Grid: A Critical Review." *International Journal of Hydrogen Energy. 41*(39), 17511-17525.

categorized based on sector (residential, commercial) and application (for example, space heating, cooking, process heating).
    - Examining and testing the effects of hydrogen-blended fuel on unmodified natural gas service lines of varying materials.
    - Exploring appliance retrofits or modifications that could enable higher blends of hydrogen beyond the maximum upper limit (for example, controls and burner modifications).
    - Identifying specific new appliances and equipment specifications needed to enable higher blends of hydrogen at or beyond the maximum upper limit.
- Estimating the cost of retrofitting appliances and equipment to accommodate higher blends of hydrogen.
- Measuring the impact varying levels of hydrogen blends would have on the carbon intensity of natural gas-fueled appliances and overall contribution to state climate and energy goals.
- Optimizing fuel composition to produce the least amount of criteria air pollutants and maximize lean stability limits.

The study results would identify the impact of natural gas blends on existing and new appliances and the maximum concentration of hydrogen that can be handled by these appliances with and without modifications. The results will inform policy makers and the private sector of the technical and economic feasibility of this strategy and identify additional research and infrastructure needs to enable large-scale deployment.

The Benefits

- **Technology potential.** Increasing the amount of hydrogen that can be used in place of natural gas in appliances may be a cost-effective way of reducing GHG emissions.
- **Environmental benefits.** Use of hydrogen blends with natural gas in residential and commercial buildings could reduce criteria air pollutants,[25] particularly NOx and carbon monoxide (CO), which are known to be harmful to human health and the environment.

Accelerating Adoption of Modular Solar Water Heating in Low-Income or Disadvantaged Communities

The Issue

Water heating accounts for nearly 40 percent of the natural gas used by California households and 32 percent used in the commercial building sector. Solar thermal water

25 Zhao, Y., V. McDonell, and S. Samuelsen. 2019. "Influence of Hydrogen Addition to Pipeline Natural Gas on the Combustion Performance of a Cooktop Burner." *International Journal of Hydrogen Energy. 44*(23), 12239-12253.

heating (SHW) offers a clean, renewable alternative that can significantly reduce natural gas consumption in the building sector. For example, the commercial sectors of lodging, health, and restaurants have the highest potential savings from this technology because these building types typically use 20 to 60 percent of total energy for water heating. Furthermore, multifamily buildings, laundromats, and car washes are also ideal sites as they have large and constant hot water demands.

Unfortunately, the uptake of SHW systems has been slow, even with incentives, because of customized installations, cost, maintenance, and the requirement for backup systems. According to the California Solar Initiative (CSI) Thermal Incentive Program, the high amount of capital required upfront remains a major hurdle, as the installed costs of SHW systems have not declined in the 10 years since CSI began collecting SHW data.[26] Moreover, competition with solar photovoltaic systems, which require less capital to install, makes solar thermal systems less desirable. Current SHW systems could be good investments with available financial incentives, especially for customers with large domestic hot-water needs. For widespread adoption throughout California, however, a modular and standardized approach to SHW is needed.

This research initiative aligns with the goals set by the *2019 California Energy Efficiency Action Plan* – to double energy efficiency savings by 2030, reduce barriers to energy efficiency in low-income and disadvantaged communities, and reduce GHG emissions from buildings – as well as other state policies and plans (Table 1). This initiative also aligns with guidance from CPUC Resolution G-3555, including to increase engagement with disadvantaged communities and ensure consistency with the *2017 Climate Change Scoping Plan Update*, which calls for reducing dependence on fossil fuel natural gas (Table 2).

The Research

Solar thermal water heating systems require a large backup system to store hot water during nighttime and colder winters when solar insolation is absent. These backup systems, associated storage tanks, as well as other components of the system require extensive customization to meet the specific hot water needs and space constraints of each building. This customization approach is inefficient, costly, and difficult for installers to manage with limited resources. A modular and standardized SHW system with various tank sizes and corresponding equipment could ease the pressure on installers and significantly lower costs for customers. Research must be conducted to determine the optimal fraction of domestic hot water these systems can provide. Multifamily and commercial buildings such as senior care centers provide a good test

26 The average cost of a residential system ranges from $8,000 to $10,000 over the decade, without a clear long-term trend toward lower costs or higher performance. For details, see CSI Thermal Incentive Program database.

environment to develop modular, plug-and-play methods that can be replicated in other buildings due to constant and high hot water demands.

This initiative would fund the demonstration of modular solar water-heating systems in low-income and disadvantaged communities and include an analysis of the building applications and climate zones where it would be most cost-effective. The demonstrations should do the following:

- Select applications that represent those with high market potential such as multifamily residential, community centers, retirement communities, schools, lodging, health care centers, and restaurants.
- Achieve a minimum of 70 percent reduction in natural gas use for water heating.
- Achieve a minimum 20 percent cost reduction compared to conventional solar thermal.
- Document system performance that includes energy bill savings, system energy efficiency, and customer satisfaction.
- Develop modular, plug-and-play methods for designing each system so that they can be easily replicated to other buildings.
- Develop and distribute case studies based on documented performance.
- Coordinate with community-based organizations to determine community needs and barriers related to adoption of solar water heating.
- Develop guides for solar water heating system installers that provide the previously developed design methods, existing tools, and commercially available systems with a focus on disadvantaged and low-income community applications.
- Develop guides to help customers understand the benefits of solar water heating systems, available incentives, and resources to find installers.

The results are intended to provide specific data, establish a scientific basis for building standards, and inform decisions regarding California's low-carbon energy future.

The Benefits

- **Energy sector.** Solar water-heater systems could provide a cost-reducing building decarbonization solution that increases resilience during loss of power and can be applied in low-income and disadvantaged communities.
- **Environmental benefits.** Replacing natural gas hot water boilers with solar hot water systems will reduce GHG emissions.

Renewable Energy and Advanced Generation

The Renewable Energy and Advanced Generation (REAG) area covers research addressing cost and other barriers to increasing market penetration of renewable energy critical to meeting the state's GHG emissions goals. The REAG area has traditionally included research on renewable gas, distributed generation (DG),

renewable combined-heat-and-power (CHP) systems under the Natural Gas R&D Program. Technologies of focus have included hybrid, fuel-flexible, high-efficiency, and low-emission DG and CHP systems for use with fossil natural gas or renewable gas. For the past several years, this research area has advanced technologies for the conversion, cleanup, and upgrading of biomass resources (forest wood waste, landfill gas, and anaerobic digester gas) to renewable gas for onsite use, conveyance to remote use, or vehicle fuel applications. Recently, this research area has also helped reduce natural gas consumption in CHP systems and advance solar thermal technologies that can deliver process heat or boiler applications.

For this year, the research initiatives focus on reducing fossil-derived fuel gas for heating and power generation applications to help achieve the state's clean energy and greenhouse gas reduction goals. Meeting those goals will require increasing the production and availability of clean and renewable fuels that can replace fossil natural gas. The proposed initiatives focus on the cost-effective production of renewable hydrogen and biomethane as a potential replacement for or blending with fossil natural gas.

The proposed research budget for renewable energy and advanced generation is $4 million (Table 8). Research will be coordinated with other research areas, as appropriate.

Table 8: FY 2020-2021 Proposed Natural Gas R&D Budget Plan Summary – Renewable Energy and Advanced Generation

Program Area — Renewable Energy and Advanced Generation	Proposed Budget
Proposed Research Initiatives: ▪ Decarbonization via Efficient and Cost-Competitive Renewable Hydrogen and Biomethane (DECARB) ○ Emerging Renewable Hydrogen Production ○ Emerging Gas Cleanup and Upgrading for Biomethane	$4,000,000

Source: California Energy Commission

Renewable Energy and Advanced Generation Program Goals

The goals for the Renewable Energy and Advanced Generation area are to reduce barriers, increase the amount of renewable energy, and reduce dependence on fossil-derived natural gas by:

- Advancing the development and market availability of clean and efficient DG and renewable combined heating, cooling, and power (CCHP) technologies.

- Developing cost-effective hybrid generation, fuel-flexible, energy-efficient, and low-emission DG technologies for renewable alternatives and natural gas.
- Accelerating decarbonization by developing technologies for the conversion, cleanup, and upgrading of biogas to renewable gas, as well as demonstrating diversified applications of advanced generation technologies that use renewable gas.

Proposed Research Initiatives

DECARB 1: Emerging Renewable Hydrogen Production

The Issue

Hydrogen produced from renewable sources could provide low-carbon energy and an alternative to fossil-based natural gas, helping meet California's GHG reduction goals of 40 percent below 1990 levels by 2030 and carbon neutrality by 2045.[27] California's industrial, commercial, and residential sectors account for two-thirds of natural gas consumption and generate roughly one-third of state GHG emissions.[28] Renewable hydrogen could replace or reduce this natural gas consumption and greenhouse gas emissions by providing an alternative for heating fuel and electricity generation and as an additive in natural gas pipelines (subject to pipeline safety and integrity limits).[29]

Today, 95 percent of commercially produced hydrogen comes from steam methane reforming processes using fossil fuels, mostly natural gas.[30] Although this pathway to hydrogen production is relatively low cost, steam methane reforming produces GHG emissions that do not align with the decarbonization goals of California. The costs of producing hydrogen from low-carbon sources — including solar or wind, biomass gasification, fermentation, photolysis, thermochemical water splitting, and anaerobic digestion[31] — remain high compared to the conventional pathways. Methods for generating low-costs renewable hydrogen are available but need further development for commercial readiness.

This research initiative aligns with Executive Order B-55-18, which sets a state goal to achieve carbon neutrality by 2045 – among other state policies and plans (Table 1). This initiative also aligns with guidance from CPUC Resolution G-3555 to explore opportunities to generate hydrogen to reduce system GHG emissions and target

27 Assembly Bill 398 (Garcia, Chapter 135, Statutes of 2017)
28 United States Energy Information Administration. Natural Gas Consumption by End Use (California, Annual, 2018).
29 Melaina, M. W., O. Antonia, and M. Penev. 2013. *Blending Hydrogen Into Natural Gas Pipeline Networks: A Review of Key Issues.*
30 United States Department of Energy. Fuel Cells Technologies Office. Hydrogen Production: Natural Gas Reforming.
31 International Renewable Energy Agency. 2018. *Hydrogen From Renewable Power: Technology Outlook for the Energy Transition.*

emissions-intensive and trade-exposed facilities that are challenging to decarbonize (Table 2).

The Research

This initiative proposes to advance precommercial or early market technologies and strategies for efficiently and cost-effectively producing hydrogen gas using emerging electrolysis and non-electrolysis solutions. Possible project strategies include:

- Developing and demonstrating electrolysis technologies that can use renewable electricity and waste heat to produce hydrogen (for example, combinations of waste heat and solid oxide electrolysis cells).
- Demonstrating methods for hydrogen production from renewable methane (for example, methane cracking into hydrogen with potential for carbon capture) and system integration that enables multiple product generation.
- Investigating the potential and readiness of earlier stage systems involving gas or liquid reforming, emerging fermentation, and photolysis for renewable hydrogen production.

Projects must demonstrate cost-effective hydrogen production for domestic industrial and transportation applications. Technologies should focus on improving hydrogen production efficiency, reducing costs, and delivering environmental benefits compared to conventional hydrogen production pathways.

The Benefits

- **Energy sector**. The technologies developed and demonstrated in this initiative will enable renewable hydrogen production and hydrogen enrichment of natural gas, which can reduce statewide consumption of natural gas.
- **Technology potential**. There is significant potential for hydrogen to decarbonize sectors that are hard to electrify, such as high-temperature industry.
- **Market connection**. Hydrogen can be used across sectors that currently use natural gas, including the commercial and industrial sectors, and in hydrogen fueling stations for fuel cell electric vehicles.
- **Energy and cost savings**. Cost reductions in renewable hydrogen production can result in cost reductions for heat, electricity, and vehicle fuel.
- **Environmental benefits**. Substitution of fossil-based natural gas with clean alternatives can help meet California's decarbonization goals. Developing renewable pathways for hydrogen production can play an important role. Some hydrogen production pathways may also be able to reduce waste heat and limit curtailment of valuable renewable energy sources.

DECARB 2: Emerging Gas Cleanup and Upgrading System for Biomethane

The Issue

A more fully developed market for biomethane can play an important role in meeting California's energy and environmental policies and objectives. Decomposition of organic wastes in digesters, landfills, and wastewater produces biogas — largely composed of methane and carbon dioxide — which is a significant source of greenhouse gas emissions (GHGs), accounting for nearly 82 percent of the state's total estimated methane emissions.[32] Using biogas in heating and power applications in place of fossil natural gas could provide environmental, financial, and energy productivity benefits. Furthermore, upgrading biogas into pipeline-grade biomethane will maximize related benefits by gaining access the broader gas market, as well as available incentives. However, upgrading biogas to pipeline-quality biomethane is expensive and must meet strict quality metrics to ensure safe delivery and consumption by end users.

Treating and upgrading biomethane to a level comparable to the characteristics of fossil-based natural gas are essential to ensuring the safety of end-user combustion devices. Removing contaminants from biomethane can increase the overall quality and heating value while meeting the appropriate energy content required for commonly used equipment. Southern California Gas Company completed a comprehensive study showing that biomethane with a heating value of "974 Btu/scf can be interchangeable with gas supplies," providing it meets other gas quality criteria.[33]

Contaminants in biomethane — such as siloxane, hydrogen sulfide, and volatile organic pollutants, among others — can create problems to commonly used downstream equipment, including combustion engines and appliances. For example, silica may lead to the formation of microcrystalline quartz which can build up on surfaces and cause clogging issues that will degrade end-user equipment such as fuel cells, heat exchangers, combustion engines, and so forth. The California Public Utilities Commission reaffirmed the maximum siloxane specification at 0.1 milligram (mg) Si/cubic meter (m^3), which was adopted in Decision D-14-01-034.[34]

Existing gas cleanup technologies need to improve to make biogas more competitive with fossil-based natural gas. This includes the need to clearly establish effective methods and standards for reducing contaminants to safe and acceptable levels. Advancing the emerging gas cleanup and upgrading technologies will stimulate increased production of biomethane, helping reduce fossil natural gas consumption and meet the state's decarbonization goals.

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32 Haines, Deanna. 2018. Getting the Facts on Renewable Natural Gas.
33 Lucas, Jim. 2017. Renewable Natural Gas and Interconnecting to the SoCalGas Pipeline.
34 California Council on Science and Technology. 2018. *Biomethane in California Common Carrier Pipelines: Assessing Heating Value and Maximum Siloxane Specifications: An Independent Review of Scientific and Technical Information.*

This research initiative aligns with state goals set by SB 1383 to increase the sustainable production of biomethane to reduce statewide short-lived climate pollutant emissions, among other state policies and plans (Table 1). This initiative also aligns with guidance from CPUC Resolution G-3555 to research the operational, health, and safety consequences of siloxane in biomethane and establish test methods for detecting siloxane in biomethane (Table 2).

The Research

This initiative will advance precommercial biomethane technologies and enable strategies for the efficient and economic production of clean and high-quality biomethane. Given the considerable funding and efforts from other state agencies like the California Department of Food and Agriculture for dairy digesters, this initiative will emphasize biogas and biomethane derived from municipal organic wastes and food processing wastes that are typically found in wastewater treatment plants, landfills, and other digesters. Possible projects include the following:

- Demonstrate biogas-to-biomethane technology that has been proven at a pilot scale.
- Lower the costs and improve process efficiency of biomethane production via sorbent-based technology.
- Demonstrate cost-effective and improved processes for removing siloxane and other impurities over a range of biogas quality levels and sources.
- Develop, test, and validate biomethane upgrading processes, targeting siloxane removal from wastewater and landfill gas sources.
- Investigate emerging methods and possible standards for removal of siloxane and other priority impurities from biogas derived from wastewater treatment and landfill sources.

The Benefits

- **Energy sector**. Upgraded biomethane can be injected into natural gas pipelines and delivered to power generation plants to serve the industrial, commercial, and residential sectors. Renewable gas can replace or supplement fossil-based natural gas, helping accelerate decarbonization.

- **Technology potential**. Upgrading biogas to biomethane and increasing the heating value remains expensive. However, support from state agencies and policies such as SB 1383 will advance these emerging cleanup and biomethane upgrade technologies.

- **Market connection**. There is a large market potential for biogas cleanup technologies to support biogas production systems. Already, California's Department of Food and Agriculture has funded more than $114 million for dairy

digester projects from 2014 through 2018.[35] Further research and development enable more biogas cleanup technology applications, for example, at wastewater treatment plants and landfills.

- **Energy and cost savings**. Increased production and utilization of biomethane could decrease demand of fossil natural gas and lower GHG emissions for various power generation, process heating, and fueling applications.
- **Environmental benefits**. Success of the research will drive reductions in GHG emissions and improve air quality, with positive impacts for public health.

Natural Gas Infrastructure Safety and Integrity

The infrastructure providing natural gas to customers is vast and covers most of the state. It includes producing wells, treatment plants, transmission lines, compressor stations, distribution lines, meters, and small pipes inside homes and buildings. Natural gas is highly combustible, contains toxic compounds, and has a very potent greenhouse gas, methane, as one of the main components.

California's natural gas wells and pipelines face risks that could cause damage or catastrophes. The massive natural gas leak at the Aliso Canyon natural gas storage field in Southern California focused attention on California's aging natural gas infrastructure. Furthermore, five years of extreme drought exacted a toll on transmission pipelines, prompting the CEC to research drought-induced subsidence impacts on natural gas pipelines. Events such as the 2015 Aliso Canyon leak and the 2010 San Bruno explosion are reminders of the importance of public safety, public health, and greenhouse gas emissions are considerations in natural gas research. Further, climate change exacerbates risks such as exposing natural gas infrastructure directly or indirectly to wildfires, landslides, coastal and inland flooding, and ground subsidence due to overdrafting of groundwater. Finally, the natural gas system must evolve substantially to contribute to the state's goals for a 40 percent GHG reduction by 2030 and carbon neutrality by 2045.

The CEC has historically funded research in energy infrastructure assessing the current vulnerability of the natural gas system to prevent damages from excavation and other risks. This work includes developing and demonstrating risk management tools and monitoring technologies to evaluate the integrity of the natural gas system. Independent research funded by the CEC complements research conducted by industry, helping address public safety issues and prevent catastrophic failures with a long-term, system-wide view and a focus on achieving the state's GHG reduction goals.

35 California Department of Food and Agriculture's Dairy Digester Research and Development Program. 2019. *Report of Funded Projects (2015-18).*

The proposed research budget for natural gas infrastructure safety and integrity is $9.1 million (Table 9). Research will be coordinated with other study areas, as appropriate.

Table 9: FY 2020-2021 Proposed Natural Gas R&D Budget Plan Summary Energy Infrastructure Safety and Integrity

Research Area — Natural Gas Infrastructure Safety and Integrity	Proposed Budget
Proposed Research Initiatives: ▪ Pilot Test and Demonstration of Hydrogen Blending Into Existing California Natural Gas Pipelines ▪ Technologies to Inspect and Prevent Corrosion of Natural Gas Pipelines and Storage Facilities ▪ Analytics for Pilot Demonstration of Strategic Electrification and Decommissioning of Natural Gas Infrastructure	$9,100,000

Source: California Energy Commission

Natural Gas Infrastructure Safety and Integrity Program Goals

The Natural Gas Infrastructure Safety and Integrity area seeks to increase safety and enhance the transmission and distribution capabilities of the natural gas system.

Proposed Research Initiatives

Pilot Test and Demonstration of Hydrogen Blending Into Existing California Natural Gas Pipelines

The Issue

Hydrogen can be a sustainable energy carrier and a promising means of storing renewable energy for California's clean energy future. However, this use of hydrogen requires developing infrastructure to connect hydrogen production, transmission, distribution, storage, and end-use equipment and appliances. Delivering hydrogen through the existing natural gas pipeline network has been proposed as a promising strategy to increase the percentage of renewable energy, such as solar and wind energy, in the current energy portfolio. Blending hydrogen at relatively low concentrations into existing natural gas systems helps avoid the cost of dedicated hydrogen pipelines.

Proposed initiatives under the Renewable Energy and Advanced Generation section (Emerging Renewable Hydrogen Production) and the Energy Efficiency section (Examining the Effects of Hydrogen in End-Use Appliances) will increase understanding of renewable hydrogen production and hydrogen blending for appliances. Research is also needed to understand the effects of hydrogen blending on the integrity and

performance of California's gas pipeline network, which could connect hydrogen production and end-uses. By researching production, pipeline distribution, and end-uses, improved system-wide planning for hydrogen blending will be possible.

There are a number of possible impacts of blending hydrogen into existing natural gas pipelines. Issues include material embrittlement, crack growth, gas permeation, interaction with reservoir caprock, sealant performance, and system leaks. Although some of these impacts have been researched individually, a research gap is identified, which necessitates the investigation of these impacts at the system level and how they affect the integrity and the overall performance of the natural gas pipeline network. In addition, the upper limit for hydrogen blending in the grid depends on the equipment connected to it, and this must be evaluated on a case-by-case basis. The case studies of hydrogen blending conducted in other states or countries may not be readily applicable to California's natural gas network since the systems were designed and constructed under different standards and conditions. Therefore, it is essential to develop hydrogen blending standards and deployment strategies tailored for California's gas system.

A pilot test or demonstration of hydrogen blending into existing California gas pipeline network will help quantify the impacts, suggest optimal integrity management practices, provide deployment strategies, and minimize system modifications to accommodate various blending levels.

This research initiative aligns with Executive Order B-55-18, which sets a state goal to achieve carbon neutrality by 2045, among other state policies and plans (Table 1). This initiative also aligns with guidance from CPUC Resolution G-3555 to explore opportunities to use natural gas infrastructure to support hydrogen to reduce system GHG emissions and assess the effects of hydrogen delivery through the existing natural gas pipeline network on pipeline facilities (Table 2).

The Research

This research initiative focuses on a pilot test and demonstration of hydrogen blending into existing California natural gas systems. Possible research includes:

- Pilot testing to measure various impacts of hydrogen blending on the system integrity of existing natural gas infrastructure in California.
- Demonstrating hydrogen blending to identify the best use cases, validate pilot test results, and develop replicable implementation strategies for safe blending.
- Assessing natural gas system modifications required to maximize hydrogen blending levels.
- Modifying integrity management and system maintenance practices for natural gas infrastructure to accommodate delivery of hydrogen.
- Developing hydrogen-blending methods and deployment strategies based on the lessons learned from the pilot test and demonstration.

The research will help shape and develop standards by identifying the requirements, steps, and procedures involved with interconnecting and authorizing the injection of hydrogen into the natural gas pipeline system. This research includes coordination with gas utilities to determine an optimal use case for hydrogen blending, identifying injection location(s) for interconnection, conducting research on system impacts due to hydrogen, obtaining permits for hydrogen blending into natural gas pipelines, and evaluating the overall performance of hydrogen injections and impacts to system integrity.

The Benefits

- **Energy sector.** The technologies developed and demonstrated in this initiative will increase renewable hydrogen production and use.
- **Technology potential.** Utilities could use the results and lessons learned from this initiative to develop guidelines and strategies for interconnecting and blending renewable hydrogen into existing natural gas infrastructure. The pilot test and demonstration will inform interconnection standards for hydrogen blending.
- **Market connection**. Research results will inform an array of market actors, including natural gas utilities, pipeline owners, gas operators, and hydrogen producers.
- **Energy and cost savings.** Blending hydrogen into existing natural gas pipeline networks would provide a boost to hydrogen supply technologies. Using the existing natural gas network to deliver hydrogen avoids the cost of building dedicated infrastructure for hydrogen.
- **Environmental benefits.** Blending renewable hydrogen into natural gas can significantly reduce GHG emissions.

Technologies to Inspect and Prevent Corrosion of Natural Gas Pipelines and Storage Facilities

The Issue

A significant portion of the existing natural gas infrastructure in California was constructed more than five decades ago. That has left California with the task of finding new technologies to address the issues of aging infrastructure, such as corrosion. According to the Pipeline and Hazardous Materials Safety Administration, a leading cause of pipeline failure is corrosion, and microbiologically influenced corrosion is one of the common failure modes for pipeline corrosion. An estimated 70 to 95 percent of pipeline internal leaks are due to localized corrosion caused mainly by microbiologically influenced corrosion.[36] In addition, the Gas Technology Institute (GTI) estimates microbiologically influenced corrosion costs the gas industry as much as $2 billion per

36 Little, Brenda and Jason Lee. 2007. Microbiologically Influenced Corrosion (Hoboken, NJ: John Wiley & Sons), p. 272.

year. With the potential risk of major leaks and the high cost of corrosion, it is imperative to address microbial corrosion within storage wells as well as pipelines.

California has 12 underground natural gas storage fields with 14 storage facilities and a total working gas capacity of 375 billion cubic feet of natural gas.[37] Many active wells in use for natural gas were designed for oil and gas production and constructed before 1970. Following the Aliso Canyon natural gas leak incident, an independent analysis of the leak identified that microbial corrosion on the well casing caused the rupture.[38] As a result of the well failure, California state legislators introduced Senate Bill 887 (Pavley, Chapter 673, Statutes of 2016), which included additional testing requirements for gas storage wells and required the operators of all gas storage wells to begin performing mechanical integrity testing before January 2018. The requirements included casing wall thickness inspection for possible degradation, including corrosion.

In addition, natural gas pipelines and storage facilities that may have been in the ground for as long as half a century are vulnerable to soil corrosivity. Soils of low pH level, low electric resistivity, or high concentration of aggressive ions such as chloride are more corrosive to metal materials. In October 2017, a gas transmission line in a Southern California desert ruptured, with contributing factors including corrosive desert soils and inaccurate assessment of pipe metal loss caused by corrosion. The development of new technologies and improvement of existing technologies will help inspect and prevent corrosion damages caused by the corrosive properties of soil.

This research initiative aligns with guidance from CPUC Resolution G-3555 – to examine the causation, diagnostics, and mitigation of microbiologically influenced corrosion of pipelines and storage facilities – as well as other state policies, plans, and guidance (Tables 1 and 2).

The Research

This initiative focuses on research, development, and demonstration of innovative technologies that can diagnose and address microbiologically and soil property-influenced corrosion of pipelines and storage facilities in the California natural gas industry. Possible research includes:

- Addressing corrosion damages to natural gas infrastructure from various causes, including microbiologically influenced corrosion and soil property-influenced corrosion.
- Developing and testing advanced coatings or chemical treatment on metal surfaces to prevent corrosion for pipelines as well as storage wells and demonstrating the performance of coatings or surface chemical treatment, including resistance to degradation.

37 California Department of Conservation, Division of Oil, Gas and Geothermal Resources.
38 Blade Energy Partners. 2019. *Root Cause Analysis of the Uncontrolled Hydrocarbon Release From Aliso Canyon SS-25.*

- Improving cathodic protection technologies – commonly used to electrochemically control metal corrosion in underground gas pipelines and storage facilities – that are specific to different corrosion mechanisms and conditions.
- Developing new technologies or improving existing technologies with better accuracy to detect, locate, and size corrosion defects or areas, including hydrostatic testing, direct assessment, and in-line inspection.
- Developing and demonstrating advanced repair technologies for internal and external corrosion.

Proposed projects will diagnose corrosion from various causes by conducting studies that include the measurement of corrosion damage to samples exposed to real-world environments. To help evaluate the performance of the corrosion mitigation treatment, corrosion monitoring data and test data should be collected from the same locations. Inspection techniques commonly used to detect and monitor corrosion-related damage generally include ultrasonic testing, radiographic testing, and magnetic flux methods.

The Benefits

- **Energy sector.** The technologies developed and demonstrated in this initiative are intended to improve safety and reliability and prevent failure of natural gas infrastructure by reducing the probability of incidents due to corrosion.
- **Technology potential.** The use of the technology helps assess, repair, and prevent corrosion damage in underground pipelines and storage wells.
- **Market connection**. Research results will inform an array of market actors, including natural gas utilities, pipeline owners and operators, as well as gas storage owners and operators.
- **Energy and cost savings.** The use of the technologies from this initiative will reduce failures from corrosion of pipelines and storage facilities and decrease down time and associated costs.
- **Environmental benefits.** Identifying and addressing corrosion can help curb methane leakage from the natural gas system.

Analytics for Pilot Demonstration of Strategic Electrification and Decommissioning of Natural Gas Infrastructure

The Issue

Aging natural gas infrastructure in California poses safety and integrity risks and challenges. Replacing aging pipelines is costly. It is estimated that cost per mile to replace pipelines varies from $1 million to $5 million.[39] Without some prior guarantee of

39 American Gas Association. 2014. AGA Guidelines for Reducing Natural Gas Emissions From Distribution Systems.

timely cost recovery, it is difficult for utilities to bear the relatively high cost of pipeline repair and replacement. The costs associated with the replacement are passed on to natural gas consumers, which raise concerns about ratepayer impact, particularly for disadvantaged and low-income communities. Furthermore, as California pursues a decarbonized energy system (Executive Order B-55-18), strategic electrification and decommissioning of natural gas infrastructure are key strategies for addressing aging infrastructure and avoiding future stranded assets. However, there is a need to develop analytics for demonstrating strategic decommissioning and electrification. Analytics can deliver information on project costs, benefits, feasibility, options, and equity considerations.

This research initiative aligns with guidance from CPUC Resolution G-3555 – to examine the role of natural gas in the state's transition to a low-carbon economy and ensure alignment with the goals of the *2017 Climate Change Scoping Plan Update* by 1) ensuring safety of the natural gas system, 2) decreasing fugitive methane emissions, and 3) reducing dependence on fossil fuel natural gas – as well as other state policies and plans (Tables 1 and 2).

The Research

This research initiative focuses on in-depth analytics to inform a pilot demonstration of pipeline decommissioning and electrification in California. It requires a multidisciplinary approach to address interrelated issues holistically, such as identification of the most applicable use cases for demonstrations, technical requirements, short- and long-term cost/benefit analysis for customers and utilities, customer acceptance information, and equity considerations. To this end, the research would:

- Summarize the impacts of decommissioning and electrification on gas and electric infrastructure, including electric system upgrades, gas system depreciation, operational conditions, system maintenance costs, and integrity management.
- Perform short-term and long-term cost/benefit analysis for customers and utilities.
- Analyze and quantify GHG emission reduction and air quality improvement.
- Identify at least one applicable location in California for a pilot demonstration, with low-income or disadvantaged community representation.
- Engage and coordinate among community groups, customers, and utilities of the identified location and develop strategies to simplify gas-to-electricity transition.
- Conduct surveys and collect user acceptance data.

The result of this research would enable an analytically grounded pilot demonstration at an identified location in California.

The Benefits

- **Energy sector.** The transition from natural gas to electricity would move the energy sector toward a low-carbon future.
- **Technology potential.** The research will address the technological barriers of electrification and pipeline decommissioning.
- **Market connection.** The research will engage and connect community groups, gas and electric utilities, ratepayers, and technology vendors.
- **Energy and cost savings.** The research will collect data and perform benefit analysis on the energy and cost savings for customers and utilities.
- **Environmental benefits.** Decommissioning part of the natural gas system lowers end-use emissions and can reduce methane leakage.

Energy-Related Environmental Research

In the Energy-Related Environmental Research area, the CEC continues to evaluate climate risks and resilience options for the natural gas sector, study strategies to decarbonize the natural gas system, and improve understanding of methane emissions from the natural gas system — in the field and commercial and multifamily buildings — and inform mitigation strategies.

The proposed research budget for energy-related environmental research is $1.5 million (Table 10). Research will be coordinated with other research areas, as appropriate.

Table 10: FY 2020-2021 Proposed Natural Gas R&D Budget Plan Summary Energy-Related Environmental Research

Research Area—Energy-Related Environmental Research	Proposed Budget
Proposed Research Initiative: ▪ Development of a Data-Driven, Actionable Tool and Case Studies to Support Strategic and Equitable Natural Gas Decommissioning	$1,500,000

Source: California Energy Commission

Energy-Related Environmental Research Program Goals

The goals of the Energy-Related Environmental Research area are to develop cost-effective approaches to evaluating and resolving environmental effects of energy production, delivery, and use in California; explore how new energy applications and products can solve or reduce environmental problems; identify vulnerabilities of the energy system to climate change; and develop cost-effective approaches to ensure reliable energy services.

Proposed Research Initiative

Development of a Data-Driven, Actionable Tool and Case Studies to Support Strategic and Equitable Natural Gas Decommissioning

The Issue

The Natural Gas R&D Program previously funded Energy and Environmental Economics, Inc. and the University of California, Irvine to develop a strategic assessment of the long-term role of natural gas in a carbon constrained and water efficient future. This research evaluated different technology scenarios — including electrification and different approaches to generating renewable natural gas — that achieve California's goals for midcentury reductions of greenhouse gas (GHG) emissions. The researchers performed cost analyses to illuminate implications of the different scenarios on natural gas customers, as well as air quality modeling to quantify impacts to ambient air quality and public health.

Among the key findings of the analysis is that electrification appears to be a lower-cost, lower-risk strategy for reaching midcentury emissions reduction goals in buildings than use of renewable natural gas (RNG), even with optimistic assumptions about technological learning to produce RNG more cheaply and pessimistic assumptions for electricity rates. Moreover, natural gas demand in the building sector is likely to fall, whether an RNG-based or electrification strategy is pursued to achieve decarbonization. With fewer customers and less natural gas demand, the cost of natural gas for remaining retail customers could rise. Thus, the prospect of significant reductions in retail customer demand for natural gas creates a planning imperative for the state. A strategic transition is needed to manage equity issues, safety, and cost-effectiveness. The need for a managed transition is also supported by leading external analyses, such as those conducted by GridWorks and the Environmental Defense Fund.[40,41]

Although there is a clear need for a managed transition to contain costs, ensure safety, and address equity concerns, decision-makers lack (1) a conceptual framework for charting a strategic transition and (2) a data-based tool to support strategic planning. The FY 2019-20 Natural Gas funding plan includes an initiative on (1): "natural gas infrastructure analysis and strategic pathway to a low-carbon energy future," which will support development of a methodology for strategic decommissioning, including concerns related to cost-effectiveness of investments, equity, and infrastructure safety. The proposed FY 2020-21 research addresses (2).

This research initiative aligns with Executive Order B-55-18, which sets a state goal to achieve carbon neutrality by 2045, among other state policies and plans (Table 1). This initiative also aligns with guidance from CPUC Resolution G-3555 to examine the role of

40 Gridworks. 2019. California's Gas System in Transition: Equitable, Affordable, Decarbonized and Smaller.

41 Bilich, Andy, Michael Colvin, and Timothy O'Connor. 2019. Environmental Defense Fund. Managing the Transition: Proactive Solutions for Stranded Gas Asset Risk in California.

natural gas in the state's transition to a low-carbon economy and ensure alignment with the goals of the *2017 Climate Change Scoping Plan Update* by 1) ensuring safety of the natural gas system, 2) decreasing fugitive methane emissions, and 3) reducing dependence on fossil fuel natural gas (Table 2).

The Research

The proposed research would build on the above-mentioned FY 2019-20 methodological work to develop a data-driven, actionable tool to support strategic and equitable natural gas decommissioning. Furthermore, this decision-support tool would complement analytics for a demonstration pilot proposed under the Natural Gas Infrastructure Safety and Integrity section (that is, *Analytics for pilot demonstration of strategic electrification and decommissioning of natural gas infrastructure*) by promoting broader replication of decommissioning projects.

The tool developed by this research would provide new capabilities to support a managed transition for California's retail gas system and ensure that as California decarbonizes its energy system, it does so cost-effectively and in a manner that is equitable and safe. The tool will illuminate geospatially specific cost and equity issues with broad regional coverage. Similar to previous research efforts to develop actionable planning tools like Cal-Adapt, the tool will be developed to support a variety of users – including utilities, community choice aggregators (CCAs), CPUC, and newly constructed communities (for example, to examine gas system cost savings) – and inform infrastructure investment decisions.

This research would also support using the tool to analyze specific groups of buildings and proposed developments within a geographic zone. This application will deliver case studies that inform decommissioning options and impacts. Local communities, as well as the users of the tool, will be engaged to inform the analysis and ensure research results are actionable. As an example, a case study may include a jurisdiction with an electrification ordinance, including a low-income community or disadvantaged community portion of that jurisdiction.

The success of this project depends on voluntary or required sharing of (potentially sensitive) data from natural gas IOUs (for example, on geospatial positioning, age, and condition of natural gas and electricity system infrastructure). For that reason, the proposed research may focus on regions within a single IOU territory.

The Benefits

- **Energy sector**. This research promotes strategic decommissioning informed by analyses of infrastructure status and safety concerns. The research supports development and execution of a long-term strategy for the role of the natural gas in the context of statewide decarbonization goals articulated by Executive Order B-55-18 and Senate Bill 100 (De León, 2018).
- **Energy and cost savings.** The tool developed under this research will enable data-driven development of a strategic transition for the retail natural gas system

that meets the state's energy-related environmental goals while managing cost and equity considerations.

- **Environmental benefits.** This tool would help achieve the state's decarbonization goals with associated health, environmental, and economic benefits.

Transportation Research

California's transportation sector is critical to the state's economy. For example, freight transportation is responsible for one-third of the state's economic product and jobs.[42] However, transportation is also the greatest contributor to the state's greenhouse gas emissions, directly accounting for 39 percent of GHG emissions and 80 percent of NO_x emissions. Heavy-duty trucks are the largest contributors to NO_x emissions and continue to impact air quality heavily in the state's severely polluted air basins. To address these concerns, extensive near-term use of zero- and near-zero emission technologies is necessary to meet current and future clean air standards. The development, demonstration, and deployment of transportation technologies that meet the state's sustainability goals while increasing freight transportation efficiency and competitiveness are vital.

When used as an alternative fuel to diesel, natural gas and hydrogen can reduce petroleum dependency, GHG emissions, local air pollution, and operating costs for businesses and consumers. The CEC funds transportation research to address market barriers and continuously advance the science of gaseous vehicle technology to reduce emissions to zero- or near-zero levels. Previous work includes developing near-zero NO_x engines, which led to the successful commercialization of several engines certified at CARB's optional low-NO_x standards. The CEC has funded research on a variety of technologies to increase the efficiency of natural gas vehicles, including high-energy ignition, hybridization, and advanced and innovative engine concepts. Research on improving fast-fill compressed natural gas fueling infrastructure continues with the goal of maximizing vehicle range and on-board storage use. The CEC has also funded demonstration of natural gas-powered off-road vehicles to expand the air quality benefits of natural gas to another highly polluting mobile source. The FY 2019-20 Budget Plan expanded the transportation research area to include fuel cell technologies in rail and marine applications.

The proposed budget for Transportation Research is $4 million (Table 11). Research will be coordinated with other research areas, as appropriate.

42 *California Sustainable Freight Action Plan.* July 2016.

Table 11: FY 2020-2021 Proposed Natural Gas R&D Budget Plan Summary Transportation Research

Program Area — Transportation Research	Proposed Budget
Proposed Research Initiative: ▪ Technology Integration and Demonstration of Hydrogen Fuel Cell Trucks and Buses	$4,000,000

Source: California Energy Commission

Transportation Research Program Goals

The goals of transportation-related research projects in selected sectors are to:

- Accelerate the beneficial commercial adoption of near-zero-emission gas vehicles.
- Improve the energy efficiency and performance of gas vehicles to reduce carbon emissions and compete with conventional fuel vehicles.
- Increase the use of renewable gas to reduce the GHG emissions of the transportation sector.
- Improve fueling infrastructure technology capabilities to promote the further adoption of low-carbon gas vehicles.

Proposed Research Initiative

Technology Integration and Demonstration of Hydrogen Fuel Cell Trucks and Buses

The Issue

Hydrogen production at scale can integrate more renewables into the electric grid by providing long-term grid-scale energy storage, decarbonizing difficult-to-electrify end uses, and enhancing energy security and resiliency. However, hydrogen faces several challenges to providing these benefits at scale such as high costs, need for lower carbon hydrogen, and lack of infrastructure. Existing policies such as Senate Bill 1505 (Lowenthal, Chapter 877, Statutes of 2006), which requires state-funded hydrogen stations to dispense 33 percent renewable hydrogen, and the Low Carbon Fuel Standard, which generates credits to encourage the adoption of fuels with low-carbon pathways, provide drivers for increasing renewable hydrogen to support growing demand from the transportation sector.

Heavy-duty vehicles are responsible for 20 percent of greenhouse gas emissions from the transportation sector. On-road trucks and buses emit 28 percent of statewide NO_x emissions, and recent studies have shown that real-world NO_x emissions may be

considerably higher than estimated in current emissions inventory models.[43] The South Coast Air Basin requires an additional 70 percent reduction in truck and bus emissions beyond current programs to attain national ambient air quality standards for ozone by 2031. California truck and bus fleets will be required to transition to zero-emission vehicles under forthcoming mandates such as the CARB's Innovative Clean Transit[44] and Advanced Clean Trucks (ACT)[45] regulations. In heavy-duty vehicle applications, hydrogen fuel cell electric vehicles (FCEV) are eligible zero-emission technology options that can provide more operational flexibility than battery-electric vehicles (BEV), such as longer driving range, faster refueling times, lower vehicle weight, and resiliency to extreme temperatures. Attributable to these benefits, FCEVs may be a preferable zero-emission technology option for certain fleets or vehicle applications.

FCEVs have high total cost of ownership (TCO), affecting competitiveness with conventional heavy-duty diesel vehicles. Other barriers for fleet adoption include uncertain fueling infrastructure needs and lack of durability and operational data for a variety of duty cycles. Although expanding, there is a limited number of hydrogen fuel cell truck and bus models available for purchase. There is a need to conduct real-world technology demonstrations to address these barriers and accelerate fleet adoption of hydrogen fuel cell trucks and buses.

This research initiative aligns with state goals set by the *Sustainable Freight Action Plan*, *2016 Mobile Source Strategy*, and Low Carbon Fuel Standard to deploy freight vehicles and equipment capable of zero-emission operation, reduce emissions from heavy-duty trucks, and reduce the life cycle carbon intensity of transportation fuels (Table 1). This initiative also aligns with guidance from CPUC Resolution G-3555 to explore opportunities for using hydrogen in a way to reduce system GHG emissions (Table 2).

The Research

This initiative advances research, development, and demonstration of precommercial heavy-duty FCEV and hydrogen fueling infrastructure technologies that may reduce TCO and improve efficiency and performance. Projects should target truck and bus types that lack commercially available options. Demonstrations should gather real-world fleet operational data such as driving performance, refueling practices, durability, and qualitative feedback to inform continued technology development, infrastructure planning, cost models, and continued fleet deployment.

Near-term opportunities for accelerating deployment of heavy-duty FCEV technologies include vehicles that operate near hydrogen production facilities or industrial centers already using hydrogen. Examples include warehouses with hydrogen fuel cell material handling equipment, refineries, and biogas production plants. Prioritizing

43 Tan, Yi, Paul; Henderick, Seungju Yoon, Jorn Herner, Thomas Montes, Kanok Boriboonsomsin, Kent Johnson, George Scora, Daniel Sandez, and Thomas Durbin. "On-Board Sensor-Based NOx Emissions From Heavy-Duty Diesel Vehicles." *Environmental Science & Technology* 2019, 53, 9, 5504-5511
44 California Air Resources Board. Innovative Clean Transit.
45 California Air Resources Board. Advanced Clean Trucks.

demonstrations at these locations will also benefit disadvantaged and low-income communities near the facilities.

Projects must integrate and demonstrate precommercial technologies, which may include:

- Improved fuel cell system components and integration strategies to improve ease of assembly and maintenance access, alleviate supply chain challenges, lower costs, and increase efficiency. Examples include catalysts and electrodes with reduced platinum group metal loading, lower cost membranes, improved cell and stack assemblies, and lower cost balance of plant components.
- Improved fuel cell system diagnostics to reduce the total cost of ownership of heavy-duty fuel cell vehicles.
- Advanced onboard storage tanks that can reduce costs and increase storage capacity.
- Improved hydrogen fueling infrastructure technologies such as high-capacity nozzles, cryopumps, and compressors that can improve reliability, uptime, and cost-effectiveness when supporting medium- and heavy-duty vehicles.

The Benefits

- **Energy sector**. Increasing demand for hydrogen in the transportation sector can lead to investments in renewable hydrogen production, which can benefit the grid by providing long-term energy storage for intermittent renewable electricity. Increased renewable hydrogen production can also help decarbonize the gas grid through pipeline blending and industrial processes that rely on hydrogen reformed from fossil gas.
- **Technology potential**. California has an estimated 1.6 million Class 2b-8 medium- and heavy-duty vehicles.[46] CARB's ACT regulation is estimated to result in the deployment of only around 75,000 zero-emission trucks by 2030. Accelerated progress to achieve cost parity of FCEVs with diesel can help exceed deployment estimates.
- **Market connection**. Sectors of interest include fleets with truck and bus operations suitable for FCEV deployment but lack access to commercially available options. This initiative also targets vehicles that operate near hydrogen production facilities and industrial centers that use hydrogen.
- **Energy and cost savings**. If projects succeed in integrating advanced technologies that can reduce the TCO of hydrogen fuel cell trucks and buses, cost savings can be realized by fleets. Increased investment in scaled

46 Bahrenian, Aniss, Jesse Gage, Sudhakar Konala, Bob McBride, Mark Palmere, Charles Smith, and Ysbrand van der Werf. 2018. *Revised Transportation Energy Demand Forecast, 2018-2030*. California Energy Commission. Publication Number: CEC-200-2018-003.

deployment of hydrogen for the transportation sector can also reduce costs related to renewable hydrogen production.

- **Environmental benefits**. Heavy-duty trucks and buses are responsible for 20 percent of greenhouse gas emissions from the transportation sector, 28 percent of statewide NO_x emissions, and 23 percent of statewide diesel particulate matter emissions. Accelerated deployment of hydrogen fuel cell trucks and buses can reduce greenhouse gas emissions and improve air quality in the communities where they operate.

LIST OF ACRONYMS

Term	Definition
AB	Assembly Bill
Bcf	Billion cubic feet
CARB	California Air Resources Board
CBO	Community-based organization
CHP	Combined heat and power
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
CPUC	California Public Utilities Commission
EPIC	Electric Program Investment Charge
GHG	Greenhouse gas
GFO	Grant funding opportunity
GWh	Gigawatt-hour
HVAC	Heating, ventilation, and air-conditioning
IoT	Internet of Things
kW/kWh	Kilowatt/kilowatt-hours
LCFS	Low Carbon Fuel Standard
MCF	Metric cubic feet
MGD	Million gallons per day
mm/Btu	Million British thermal units
NO_x	Oxides of nitrogen
PIER	Public Interest Energy Research

Term	Definition
PON	Program opportunity notice
R&D	Research and development
RNG	Renewable natural gas
SB	Senate Bill
Tcf	Trillion cubic feet
UC	University of California
U.S. EIA	United States Energy Information Administration

APPENDICES

Appendix A: Natural Gas Stakeholders Workshop Presentation and Appendix B: Summary of Public Comments and CEC Responses are available as a separate volume, Publication Number CEC-500-2020-0XX-APA-B.

CALIFORNIA
ENERGY COMMISSION

Energy Research and Development Division

STAFF REPORT

Natural Gas Research and Development Program

Proposed Budget Plan for Fiscal Year 2020-21: Appendices

Gavin Newsom, Governor

March 2020 | CEC-500-2020-0XX-APA-B

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APPENDIX A:
Staff Presentation January 21, 2020

FY 2020-2021 Proposed Natural Gas Research Initiatives

Stakeholders Workshop

Energy Research and Development Division

ERDD Staff

January 21, 2020

California Energy Commission

Agenda

Time	Item
9:00 am	Introduction and Purpose
9:30 am	Staff Presentations on Proposed Initiatives • Renewable Energy and Advanced Generation • Natural Gas Infrastructure Safety and Integrity • Energy Efficiency • Transportation Research • Energy-Related Environmental Research
11:30 am	Public Comments

Housekeeping

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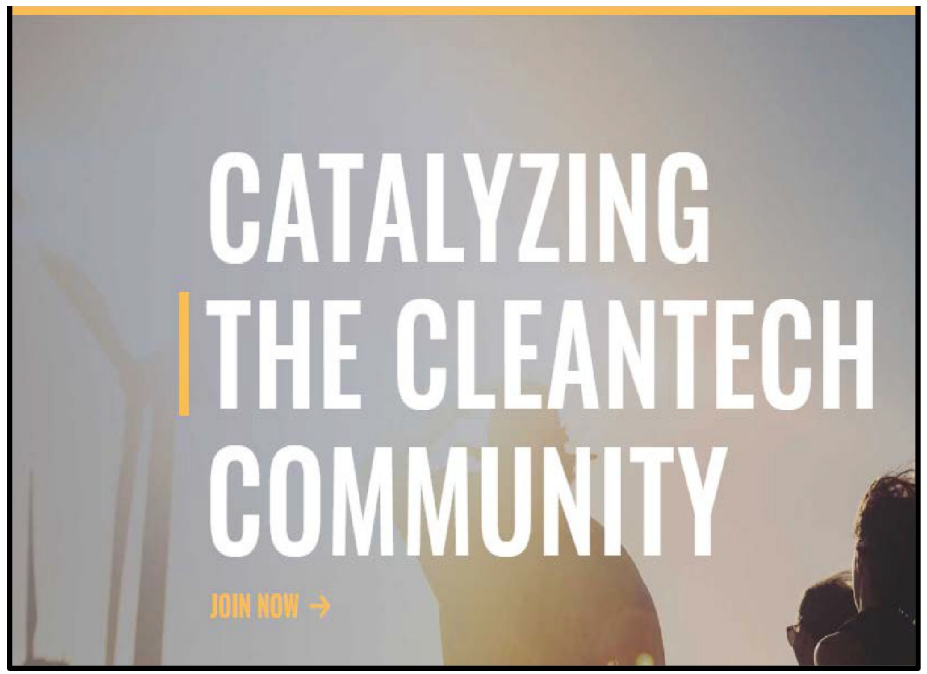
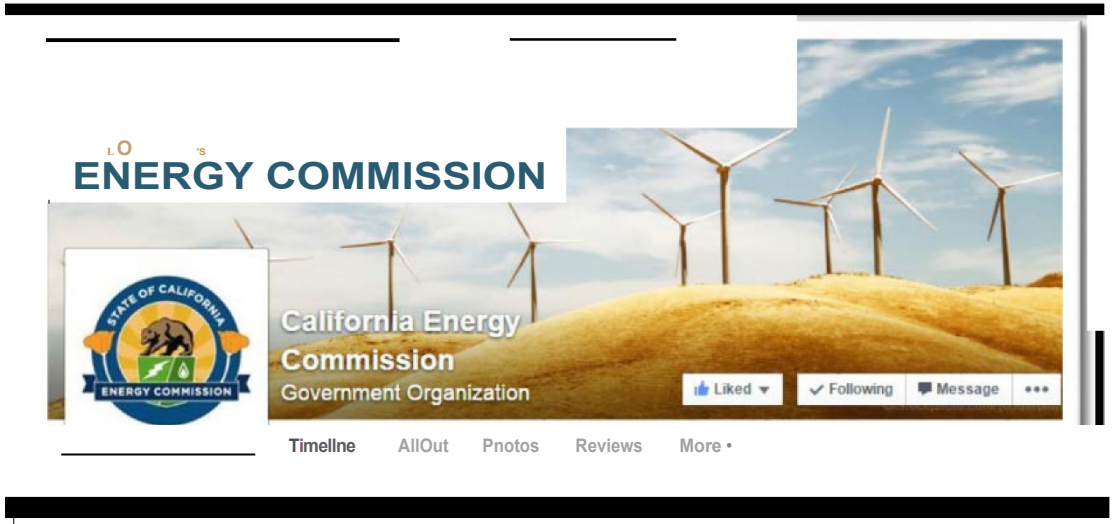




Commitment to Diversity

The Energy Commission adopted a resolution strengthening its commitment to diversity in our funding programs. We continue to encourage disadvantaged and underrepresented businesses and communities to engage in and benefit from our many programs.

To meet this commitment, Energy Commission staff conducts outreach efforts and activities to:

- Engage with disadvantaged and underrepresented groups throughout the state.
- Notify potential new applicants about the Energy Commission's funding opportunities.
- Assist applicants in understanding how to apply for funding from the Energy Commission's programs.
- Survey participants to measure progress in diversity outreach efforts.

Introduction

- Energy Commission R&D Program staff are holding this workshop seeking stakeholder comments on natural gas research initiatives for the Natural Gas FY 2020-21 budget plan.
- Specific “Questions for Stakeholders” will be posed during the workshop.

General Approach

- Identify research gaps for research initiatives through:
  - Discussion with utilities, public stakeholders, state and federal governmental agencies, other CEC programs;
  - Roadmaps;
  - Public meetings with industry and trade associations; and
  - Research ideas submitted by the public
- Research projects are selected through competitive solicitations
- Energy research priorities are guided by policy directives
- Need clearly identified benefits

Policy Drivers

- **Energy Action Plan**
  - Establishes goals to ensure adequate, reliable, and reasonably-priced natural gas supplies are achieved through policies, strategies, and actions.
- **EO B-55-18**
  - Establishes statewide goal to achieve carbon neutrality as soon as possible and no later than 2045.
- **SB 32**
  - Reduce GHG emissions to 40% below 1990 levels by 2030.
- **SB 100**
  - Requires 100% of retail electricity sales be met by renewable and zero carbon resources.
- **SB 1250**
  - *Public Goods Utilities* surcharge to support public interest for research and development.
- **SB 1383**
  - Reduce emissions of short-lived climate pollutants, including those from dairies, organics disposal, and waste water treatment plants.

FY 2020-21 Initiative Development

FY 2020-21 Natural Gas proposed research initiatives are framed around ***decarbonization***.

<u>Three primary areas:</u>

- Hydrogen
- Decommissioning/Electrification
- Safety and Integrity

Research Initiative Feedback

Here at the California Energy Commission we're always working to make our research initiatives better. Now, that you're here we would like to hear your thoughts.

Please provide feedback to our questions after each research area initiative presentation or email your comments to Nicole Dani at nicole.dani@energy.ca.gov by Friday, **January 24, 2020**.

CALIFORNIA ENERGY COMMISSION

Renewable Energy & Advanced Generation

Renewable Energy & Advanced Generation

Program Goals:

Reduce barriers, increase the amount of renewable energy in the grid, and reduce dependence on fossil-derived natural gas by:

- Advancing the development and market availability of clean and efficient distributed generation (DG) and renewable combined heating, cooling and power (CCHP) technologies.
- Developing cost-effective hybrid generation, fuel-flexible, energy-efficient, and low-emission DG technologies for renewable alternatives and natural gas.
- Accelerating decarbonization by developing technologies for the conversion, cleanup, and upgrading of biogas to renewable gas as well as demonstrating diversified applications of advanced generation technologies that use renewable gas.

Renewable Energy & Advanced Generation

Research Portfolio

- **Clean and Efficient Distributed Generation/Combined Heat and Power, including Waste Heat to Power Systems**
  - High compression ratio free piston engine for CHP
  - Novel CHP systems for cost and efficiency improvements, e.g. solar-CHP for electricity, hot water and space heating
  - Small-scale CCHP systems with thermally-driven cooling and/or thermal energy storage
  - Waste heat to power systems at industrial facilities for efficient use of natural gas
- **Decarbonization Solutions via Biogas and Renewable Gas**
  - Advancing cost-effective biogas production, cleanup, and upgrading to renewable gas
  - Solid-state low-pressure upgrading of biogas; optimizing micronutrients and operating methods; using biogas for heat, power and vehicle fuel
  - Cost-effectively convert California's forest biomass into pipeline-quality renewable natural gas

Image of combined heat and power engine. Source: EtaGen, Inc.

Photograph of solar combined heat and power system. Source: UC Merced

Renewable Energy & Advanced Generation

Research Portfolio

Cost Reduction for Biogas Upgrading via a Low-Pressure Solid-State Amine Scrubber

- **Recipient:** Mosaic Materials, Inc.
- **Project Goal:** Develop a solid-state amine scrubbing technology for biogas upgrading that provides a 40% reduction in capital and operating costs compared to current state-of-the-art scrubbers; increase efficiency and reduce the cost of removing contaminants from biogas and upgrade to pipeline quality renewable natural gas.
- **Highlights:**
  - Formulated sorbent material (called metal organic framework or MOF); scaled up production; and tested over long term repeated cycling.
  - Removed CO2 down to ≤2% for 1000+ cycles without capacity loss
  - Process shows 38% reduction in OpEx, 14% reduction in CapEx vs. standard chemical scrubbing system
  - New technology will enhance biomethane production and support CPUC's NG R&D Guidance and Resolution
  - Mosaic received follow on funding from DOE to demonstrate the technology at a wastewater treatment plant

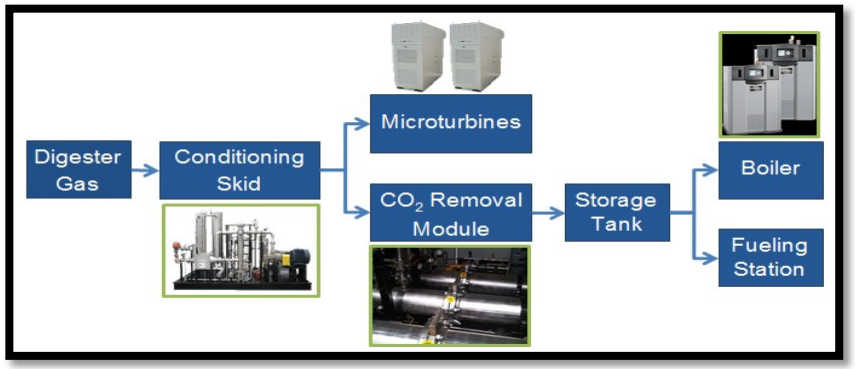
Sample of composite metal-organic framework pellets for exposure testing (top); tableted Gen-1 metal-organic framework adsorbent (bottom-left); Slipstream testing apparatus at the biogas site (bottom-right)
Source: Mosaic Materials, Inc.

Renewable Energy & Advanced Generation

Research Portfolio

Biogas Energy Recovery System

- **Recipient:** Las Gallinas Valley Sanitary District
- **Project Goal:** Install and operate a pre-commercial biogas energy recovery system at a small wastewater treatment plant (WWPT)
- **Highlight:**
  - Utilizes a biogas cleanup skid, microturbines, hydronic boiler, and a compressed natural gas (CNG) refueling station
  - New system replaces aging internal combustion engine and diesel-fueled vehicles with cleaner, more efficient technologies.
  - Combines existing technologies in a configuration new to California and at a small WWTP
  - Utilizes 100% of biogas produced by the existing digester to provide renewable electricity, heat, and transportation fuel
  - Replaces diesel vehicles with cleaner CNG vehicles



Simplified schematic of the biogas energy recovery system.

Photograph of microturbines, gas cleanup system, and digester.
Source: Las Gallinas Valley Sanitary District

Proposed Research Initiatives

Renewable Energy & Advanced Generation

- Decarbonization via Efficient and Cost-competitive Renewable hydrogen and Biomethane (DECARB)
  - Emerging Renewable Hydrogen Production
  - Emerging Gas Cleanup and Upgrading for Biomethane
- Demonstrate Geothermal Heating and Cooling for Low Income and Disadvantaged Communities

Renewable Energy & Advanced Generation

Proposed Research Initiative:

Emerging Renewable Hydrogen Production

Background:

- Hydrogen is clean alternative to fossil natural gas.
- Producing hydrogen through emerging electrolysis and renewable pathways remains costly.
- This initiative will advance the cost-competitiveness of producing renewable hydrogen.

Technology	Output Capacity (HHV basis)	Conversion Efficiency H2 out/Energy in (HHV)	Capital Cost ($/kW)	Levelized Costs ($/kg)
Steam methane Reforming (SMR)	400-700 MW	72%	380-480	1.7
Coal Gasification	160-820 MW	56%	940-1780	1.3-1.7
Biomass Gasification	32-320 MW	48%	700 -1200	2.1-2.3
Biogas via SMR	500-1000 MW	-	-	3.14-3.81
Water electrolysis Alkaline Photon Exchange Membrane Solid Oxide	 +150 MW +1 MW Lab Scale	 65-82% 65-78% 80-90%	 800-1500 1500-3800	 4.1-5.1 4.1-5.5 2.8-5.8

Hydrogen Production Costs for Different Technologies.

Source: Ogden, JM. 2018, https://escholarship.org/uc/item/52s28641

Purpose of Research

Emerging Renewable Hydrogen Production

Issues:

- California's industrial, commercial, and residential sectors consume two-thirds of natural gas and generate one-third of GHG emissions.
- Conventional method of hydrogen production.
  - Low cost, but emits GHGs
- Advance renewable hydrogen production to be competitive with conventional pathway(s).
  - Electrolysis and renewable hydrogen pathways need cost reductions to be competitive
  - Support new reforming methods using renewable feedstock, fermentation, and photolysis

Research Description

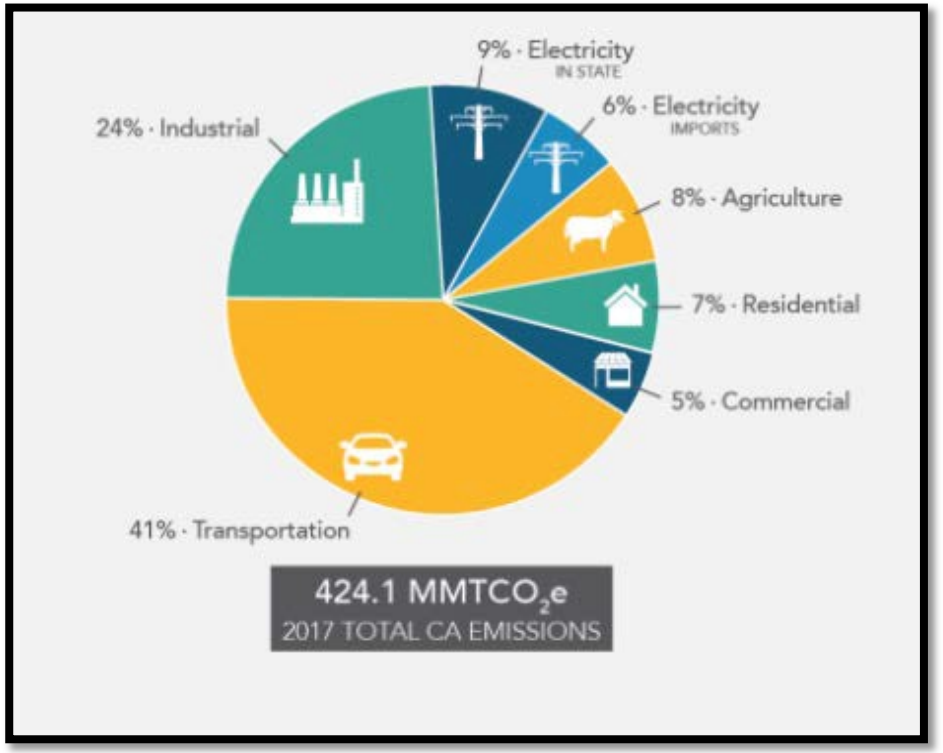
Emerging Renewable Hydrogen Production

- Advance H_2 production technology via emerging electrolysis or non-electrolysis solutions.
  - Using waste heat or renewable electricity to produce hydrogen; an example of such systems could include combinations of waste heat and Solid Oxide Electrolysis Cells (SOEC)
  - Hydrogen production from renewable methane (e.g., methane cracking into hydrogen with potential for carbon capture)
  - System integration that enables multiple product generation
- Investigate the potentials and readiness of early stage systems involving gas or liquid reforming, and emerging fermentation and photolysis for competitive renewable hydrogen production.

Projected Ratepayer Benefits

Emerging Renewable Hydrogen Production

- **Energy and Cost Savings.** Provide energy and cost savings through production of hydrogen as an alternative to natural gas.
- **Energy Sector.** Develop and support renewable pathways for hydrogen production that assist in meeting California's energy and emissions goals.
- **Environmental Benefits**. Reduce statewide consumption of natural gas and GHG emissions.



Pie chart of greenhouse gas emissions from different sectors in California.
Source: CARB, 2017. https://ww2.arb.ca.gov/ghg-inventory-data

Renewable Energy & Advanced Generation

Proposed Research Initiative:

Emerging Gas Cleanup and Upgrading for Biomethane

Background:

- Biomethane, an upgraded form of biogas, is now being produced in new dairy biogas projects.
- Other major sources of biogas, such as sewage and food processing wastes, require costly biogas cleanup and upgrading processes (e.g. need for siloxane removal).
- Contaminants in biomethane -- such as siloxane, hydrogen sulfide, and volatile organic pollutants, among others -- can create problems to commonly-used downstream equipment, including combustion engines and appliances.
- This initiative will demonstrate an emerging gas upgrading system, and investigate methods and standards for siloxane removal.

Purpose of Research

Emerging Gas Cleanup and Upgrading for Biomethane

Issues:

- Biomethane is sometimes left to evaporate or is flared when it does not meet end-use requirements (e.g. for combustion engines and the natural gas pipeline).
- Biogas cleanup and upgrading to biomethane are currently energy intensive and costly.
  - Existing gas cleanup technologies need to improve to make biogas more competitive with fossil-based natural gas.
- Cleanup processes for municipal organic wastes (e.g., siloxane removal) are challenging
  - Siloxane particles are difficult to remove and can have negative impacts on end-use equipment and health.
  - Methods and standards for effective reduction of these contaminants need to be established.

Research Description

Emerging Gas Cleanup and Upgrading for Biomethane

- Advance pre-commercial biomethane technologies and enabling strategies.
  - Emphasis on biogas and biomethane derived from municipal organic wastes and food processing wastes
- Demonstrate biogas-to-biomethane technology that has been proven at a pilot scale.
  - Lower the cost and improve process efficiency of biomethane production via sorbent-based technology
  - Demonstrate cost-effective and improved processes for the removal of siloxane and impurities
- Investigate emerging methods and possible standards for removal of siloxane.

Projected Ratepayer Benefits

Emerging Gas Cleanup and Upgrading for Biomethane

- **Energy Sector.** Enabling wide-scale production of biomethane (renewable gas) can support statewide reductions in the consumption of fossil natural gas.
  - Provides cleaner alternative to natural gas for various power generation, process heating, and fueling applications.
  - Provides a low-carbon gas option as the state moves towards decarbonization.
- **Environmental Benefits.** Driving reductions in GHG emissions and improvements in air quality, with benefits for public health, the environment, and the economy.

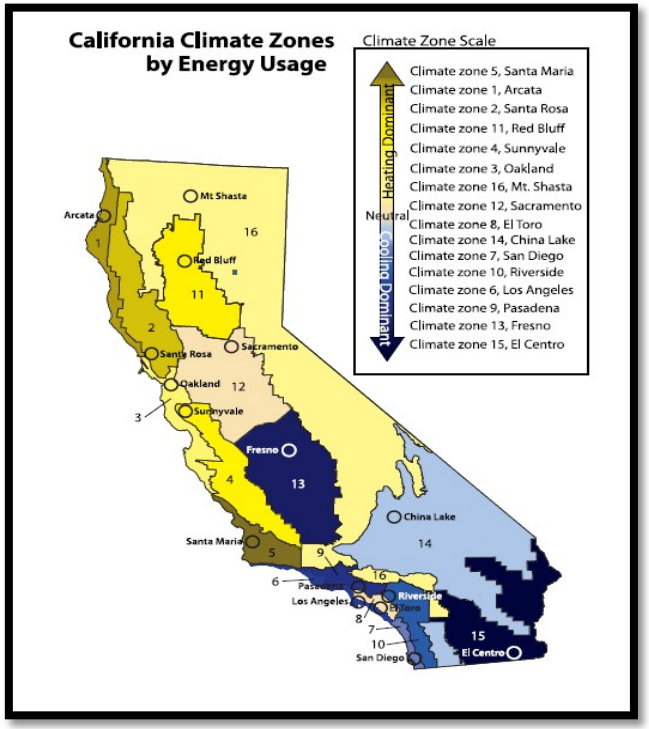
Renewable Energy & Advanced Generation

Proposed Research Initiative:

Demonstrate Geothermal Heating and Cooling for Low Income and Disadvantaged Communities

Background:

- A CEC-funded study on geothermal heat pump systems in 16 distinct climate zones in California showed reductions in energy and natural gas demand and emissions (between 20% and 70%).
- Costs and other barriers remain for the deployment of geothermal heat pump systems.
- This initiative will improve the viability of geothermal heat pumps and demonstrate in low income and disadvantaged communities.



Map of California showing energy usage by climate zone. Source: https://ww2.energy.ca.gov/2014publications/CEC-500-2014-060/CEC-500-2014-060.pdf

Purpose of Research

Demonstrate Geothermal Heating and Cooling for Low Income and Disadvantaged Communities

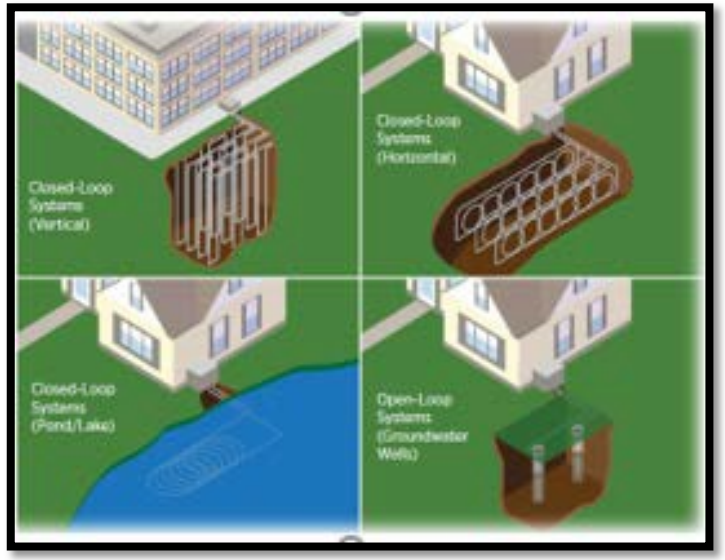
Issues:

- Barriers beyond regulatory and permitting inhibit deployment of geothermal heat pumps.
- High first cost of geothermal heat pump systems and lack of knowledge and confidence in these systems require new approaches to lower the cost and demonstrate benefits.
- Development in geothermal heat pump systems is slow, and design and installation infrastructure remain limited.
- Techniques to improve cost and performance are needed.

Research Description

Demonstrate Geothermal Heating and Cooling for Low Income and Disadvantaged Communities

- Deploy and demonstrate geothermal heat pumps in a low-income and/or disadvantaged community; document technological and operational parameters for future further development and deployment.
- Identify technological improvements for existing geothermal heating and cooling systems, with the goal of reducing upfront costs for installation and equipment.
- Improve ground loop technologies that can reduce the heat pump's overall electric consumption and increase the coefficient of performance.
- Leverage existing database on existing geothermal heat pump systems with the goal of identifying future design improvements and deploying more efficient systems.



Schematic of different geothermal heat pump design configurations. Source: https://www.energy.gov/eere/geothermal/downloads/geovision-harnessing-heat-beneath-our-feet

Project Ratepayer Benefits

Demonstrate Geothermal Heating and Cooling for Low Income and Disadvantaged Communities

- **Energy and Cost Savings.** Increase energy savings with an average of 44% in California's commercial and residential sectors.
- **Energy Sector.** The deployment and demonstration of technologies in this initiative are intended to support the reduction of natural gas consumption and GHG emissions.

Climate Zone	Conventional Energy [kWh]	GHP Energy [kWh]	Difference [kWh]	% Energy Reduction
1	17539.453	3926.300	-13613.153	77.61%
2	14674.521	5431.800	-9242.721	62.98%
3	9828.197	3462.000	-6366.197	64.77%
4	10213.580	4219.600	-5993.980	58.69%
5	11216.380	3979.700	-7236.680	64.52%
6	4288.449	3127.800	-1160.649	27.06%
7	4050.907	2942.900	-1108.007	27.35%
8	4659.066	3620.100	-1038.966	22.30%
9	7598.957	5308.100	-2290.857	30.15%
10	8692.673	5510.200	-3182.473	36.61%
11	15967.354	7845.400	-8121.954	50.87%
12	14706.879	6805.100	-7901.779	53.73%
13	13770.913	7775.400	-5995.513	43.54%
14	16161.329	9318.900	-6842.429	42.34%
15	10147.299	10650.900	503.601	-4.96%
16	15510.346	7666.800	-7843.546	50.57%
			Average =	44.26%

Table showing results of ground-source heat pump study, including a 44% average energy savings.
Source: https://ww2.energy.ca.gov/2014publications/CEC-500-2014-060/CEC-500-2014-060.pdf

Questions for the Stakeholders

Renewable Energy & Advanced Generation

- Are we effectively targeting research and technological development needs to support California's decarbonization goals and provide natural gas ratepayer benefits?
- Of the three technology areas presented -- renewable hydrogen, biomethane, and geothermal heating and cooling -- is it important to prioritize one in particular?
- Do you have suggestions for research and development needed to improve the technical and economic aspects of the proposed technologies?

CALIFORNIA ENERGY COMMISSION

Natural Gas Infrastructure Safety & Integrity Research

Natural Gas Infrastructure Safety & Integrity

Program Goals:

- Conduct research in natural gas infrastructure (pipelines and storage) to increase public safety, system integrity, and climate resiliency
- Enhance transmission and distribution capabilities of the natural gas system
- Address issues not adequately addressed by the regulatory and competitive markets

Natural Gas Infrastructure Safety & Integrity

Research Portfolio

- **Damage Prevention and Detection (*Pipeline*)**
  - In-line inspection technology
  - Excavator-mounted equipment
  - Low-cost pressure and flow sensors
- **Risk and Integrity Management (*Pipeline*)**
  - High accuracy mapping technology
  - Risk assessment tool
  - Pipeline right of way monitoring and notification system
- **Risk Assessment Model (*Storage*)**
  - Risk assessment model specific to wellheads
  - Storage system holistic risk model

Proposed Research Initiatives

Natural Gas Infrastructure Safety & Integrity

- Pilot Test and Demonstration of Hydrogen Blending to the Existing California Natural Gas Infrastructure
- Technologies for Microbiologically Influenced Corrosion Prevention of Natural Gas Pipelines and Storage Facilities
- Analytically-Grounded Plan for Pilot Demonstration of Strategic Electrification and Decommissioning of Natural Gas Infrastructure

Natural Gas Infrastructure Safety & Integrity

Proposed Research Initiative:

Pilot Test and Demonstration of Hydrogen Blending to the Existing California Natural Pipeline Network

Background:

Blending renewable hydrogen into NG and delivering it through existing infrastructure helps to decarbonize the gas industry and reduce GHG emission.

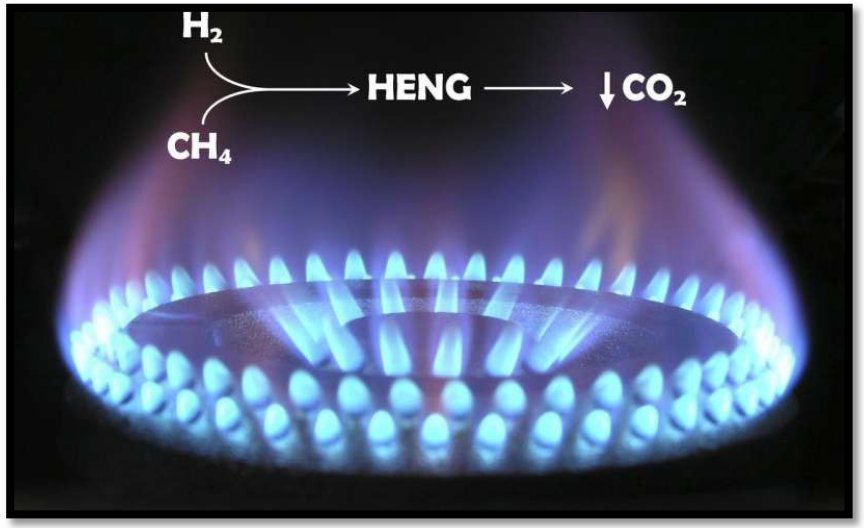


Image showing that hydrogen combined with methane can reduce CO2 emissions.
Source: https://scx1.b-cdn.net/csz/news/800/2018/30oftheuksna.jpg

Purpose of Research

Pilot Test and Demonstration of Hydrogen Blending to the Existing California Natural Gas Infrastructure

Issues:

- Hydrogen blending may cause issues to existing natural gas systems, including material embrittlement, gas permeation, sealant performance, system leak rate, etc.
- Existing case studies of hydrogen blending conducted in other states or countries may not be readily applicable to California natural gas network.
- It remains unclear how hydrogen blending affects the overall safety and integrity of the specific NG system in CA and the connected gas equipment.

Photograph of hydrogen mixed into natural gas pipelines.
Source: https://scx1.b-cdn.net/csz/news/800/2018/1-30oftheuksna.jpg

Research Description

Pilot Test and Demonstration of Hydrogen Blending to the Existing California Natural Gas Infrastructure

- Demonstration of hydrogen blending to identify optimal use cases, validate pilot test results, and develop replicable implementation strategies.
- Assessment of natural gas system modifications required to maximize hydrogen blending levels.
- Modifications of integrity management and system maintenance practices for natural gas infrastructure to accommodate delivery of hydrogen.
- Development of hydrogen blending methodology and deployment strategies based on the lessons learned from the pilot test and demonstration.

Projected Ratepayer Benefits

Pilot Test and Demonstration of Hydrogen Blending to the Existing California Natural Gas Infrastructure

- **Energy Sector.** The research helps to increase renewable hydrogen production and better prepare the energy sector for a clean energy future while protecting the integrity and safety of the natural gas pipeline infrastructure.
- **Market Connection.** Sectors and user groups of interest in the proposed initiative include natural gas utilities, pipeline owners, gas operators, and hydrogen producers.
- **Energy and Cost Savings.** Using existing natural gas network to deliver hydrogen avoids the cost of building dedicated infrastructure specific for hydrogen.
- **Environmental Benefits.** Blending hydrogen into natural gas can significantly reduce GHG emission if the hydrogen is produced from renewable energy sources.

Natural Gas Infrastructure Safety & Integrity

Proposed Research Initiative:

Technologies for Microbiologically Influenced Corrosion Prevention of Natural Gas Pipelines and Storage Facilities

Background:

The natural gas infrastructure in CA is aging and becoming more vulnerable to corrosion damage.

Photograph of internal corrosion in pipelines.
Source:https://cdn.corrosionpedia.com/images/uploads/tunnel.jpg?height=580&width=940

Purpose of Research

Technologies for Microbiologically Influenced Corrosion Prevention of Natural Gas Pipelines and Storage Facilities

Issues:

- Microbiologically influenced corrosion is one of the common modes for pipeline corrosion, which is one of the leading causes of pipeline failure.
- Microbiological corrosion is estimated to cost the gas industry $2 billion per year.
- Inspection of pipelines and storage is extensive and costly.
- Existing management methods require the pipeline to be shut down, resulting in revenue losses for the utility and disruption to consumers.

Photogaph of corrosion damage to a pipeline.
Source: https://blog.applus.com/wp-content/uploads/2016/04/corrosion-management-300x200.jpg

Research Description

Technologies for Microbiologically Influenced Corrosion Prevention of Natural Gas Pipelines and Storage Facilities

- Address microbiological corrosion risks to natural gas pipeline and storage facilities.
- Develop advanced coatings or chemical treatment to prevent microbiologically influenced corrosion.
- Demonstrate advanced inspection and repair technologies for both internal and external corrosion.
- Perform cost effectiveness analysis of technology application to specific pipeline or storage facilities.

Projected Ratepayer Benefits

Technologies for Microbiologically Influenced Corrosion Prevention of Natural Gas Pipelines and Storage Facilities

- **Energy Sector.** The technologies are to improve safety and reliability and prevent failure of natural gas infrastructure by reducing the probability of incidents due to microbial corrosion.
- **Technology Potential.** The use of the technology helps to assess, repair, and prevent microbial corrosion damage in underground pipelines and storage wells.
- **Energy and Cost Savings.** The technology from this initiative will reduce failures from corrosion of pipelines and storage facilities and decrease down time and associated costs.
- **Environmental Benefits.** Addressing potential corrosion can reduce the chances of GHG leaks.

Natural Gas Infrastructure Safety & Integrity

Proposed Research Initiative:

Analytically-Grounded Plan for Pilot Demonstration of Strategic Electrification and Decommissioning of Natural Gas Infrastructure

Background:

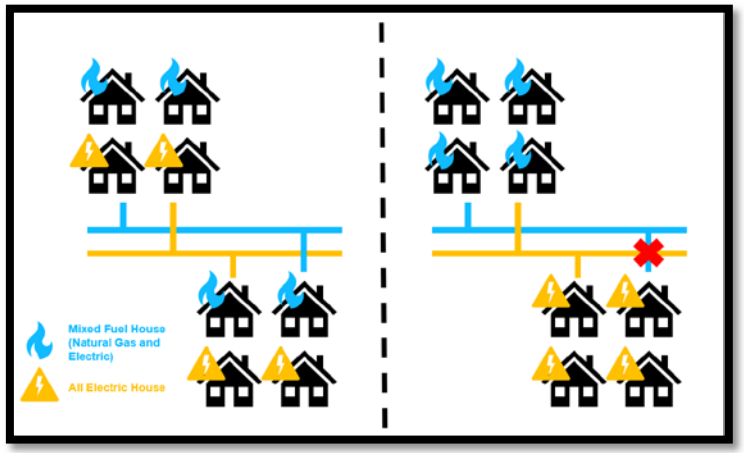
There is increasing interest in accelerating replacement of aging natural gas pipelines for safety, reliability and environmental benefits. Electrification is a potential option that can support a carbon neutral future.

Purpose of Research

Analytically-Grounded Plan for Pilot Demonstration of Strategic Electrification and Decommissioning of Natural Gas Infrastructure

Issues:

- Replacement of aging natural gas pipelines can be costly and average cost per mile to replace pipelines varies from $1 to $5 million.
- Utilities are unlikely to undertake replacement programs without some prior guarantee of timely cost recovery.
- Low-income and disadvantaged communities are most vulnerable to the high ratepayer impact.
- Electrification and decommissioning are viable options, which need strategic planning and pilot demonstration.



Schematic of electrification and natural gas decommissioning. Source: E3

Research Description

Analytically-Grounded Plan for Pilot Demonstration of Strategic Electrification and Decommissioning of Natural Gas Infrastructure

- Develop criteria and guidelines to determine the best use cases for pilot demonstration including low-income or disadvantaged communities
- Develop an analytically-grounded plan for a pilot demonstration, which includes engaging and coordinating among community groups, customers and utilities, conduct surveys, collect user acceptance data, etc.
- Perform short term and long term cost-benefit analysis for both customers and utilities
- Summarize the impacts of electrification and decommissioning on electric and gas infrastructure

Projected Ratepayer Benefits

Analytically-Grounded Plan for Pilot Demonstration of Strategic Electrification and Decommissioning of Natural Gas Infrastructure

- **Energy Sector.** The transition from natural gas to electricity would move the energy sector towards the low carbon future, and decarbonize the energy sector.
- **Market Connection.** The research will engage and connect community groups, gas and electric utilities, rate payers, and technology vendors.
- **Energy and Cost Savings.** The research will collect data and perform cost benefit analysis for ratepayers and utilities.
- **Environmental Benefits.** Decommissioning part of the natural gas system brings down gas consumption and reduces methane leaks.

Questions for the Stakeholders

Natural Gas Infrastructure Safety & Integrity

Hydrogen Blending

- What would be the most suitable use cases for a demonstration project? For instance, a power plant or isolated community.
- What would be the challenges to demonstrate hydrogen blending in the existing CA natural gas system?
- Are there any recommendations on research approach(es)?

Corrosion Prevention

- What are the most desirable improvements on current technologies for microbial corrosion detection, monitoring and prevention?
- Given the limited research funds, are there components of gas pipeline and storage assets that are most vulnerable to corrosion damage during the degradation process, which we should focus on?

Electrification and Decommissioning

- Best practices in surveying customer engagement on gas-to-electricity transition?
- Recommendations on how to minimize the cost impacts and ensure equity on energy accessibility?
- How will the gas-to-electricity transition impact the energy (gas & electricity) supply and demand at community or regional level?

CALIFORNIA ENERGY COMMISSION

Energy Efficiency

Energy Efficiency

Program Goals:

- Conduct research, development, and demonstration to advance strategies and technologies to support decarbonization in the building and industrial sectors.
- Enhance outreach and demonstration opportunities with low income or disadvantaged communities.
- Increase energy efficiency while reducing operating costs, natural gas use and greenhouse gases and other air emissions (for example low NOx).
- Develop and demonstrate affordable energy-efficiency technologies, processes, and strategies.

Energy Efficiency

Research Portfolio

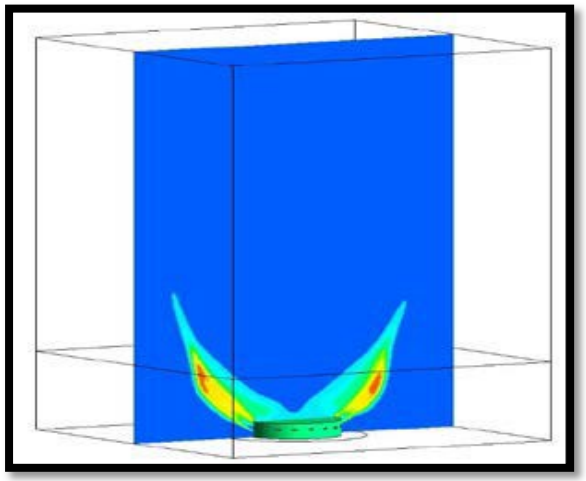
- Past research focused on using natural gas more efficiently in buildings and industries.
- Our proposed initiatives focus on supporting decarbonization, evaluating future transition needs, and enhancing efforts in low income or disadvantaged communities.
- Proposed initiatives targets **two areas**:
  - Implications on the use of hydrogen blends in existing end use appliances
  - Reduce the cost of solar thermal applications in low income or disadvantaged communities

Energy Efficiency

Research Portfolio

- **Project Highlight:** PIR-16-017, Implications of Increased Renewable Natural Gas on Appliances
- **Research Goal:** evaluate the stability, operational, and emissions implications of operating dual fuel appliances (natural gas + CO_2 or H_2)
  - Experimentally tested **4 appliances** and applied simulation methodologies to 9
- **Key Findings:**
  - For these un-modified appliances, when H_2 concentration increases above 10% by volume, probability of combustion instability increases (e.g. flashback)
  - At 10% H_2 level, NO_x and CO level decrease in general
  - Modelling approach shows a lot of variance—needs to be anchored in more experimental testing
  - There is a need for more standardized testing procedures

(a) Photograph of experiment setup.



(b) Figure from 3-D model for cooktop burner

Proposed Research Initiatives

Energy Efficiency

- Examining the Effects of Hydrogen in End-Use Appliances
- Accelerating Adoption of Next Generation Modular Solar Water Heating

Energy Efficiency

Proposed Research Initiative:

Examining the Effects of Hydrogen in End-Use Appliances

Background:

- Hydrogen blending with natural gas could be used as a fuel in residential and commercial buildings applications
  - Reduce natural gas consumption
  - Reduce greenhouse gas emissions
  - Provide pathway for decarbonization
- End-use appliances combustion safety and stability are critical for the blending process

Purpose of Research

Examining the Effects of Hydrogen in End-Use Appliances

Issues:

- Research needs to:
  - Identify the maximum upper limit (MUL) of hydrogen blended with natural gas that could be “safely” used in end-use appliances
  - Understand the impact of hydrogen in appliances without any modifications to the existing equipment
  - Gather sufficient data to adequately characterize the potential impacts of hydrogen-blending

Research Description

Examining the Effects of Hydrogen in End-Use Appliances

- Conduct experimental work in a laboratory setting to determine the maximum upper limit (MUL) of hydrogen blended with natural gas that can be safely used in end-use appliances.
  - Develop methodology for categorizing and selecting a sample of unmodified end-use appliances.
  - Explore appliance retrofits or modifications that could enable higher blends of hydrogen beyond the MUL (e.g., controls, burner modifications).
  - Identify specific new appliances and process equipment specifications needed to enable higher blends of hydrogen at or beyond the MUL

Research Description

Examining the Effects of Hydrogen in End-Use Appliances

Continued…

- Research focuses on residential and commercial natural gas appliances
- Establish criteria to define “safe” in the context of a hydrogen-blended natural gas supply
- Evaluate fuel composition that reduces emissions (e.g. NOx, CO) and maximizes efficiency
- Estimate the cost of retrofitting appliances to accommodate higher blends of hydrogen
- Quantify the impact of varying levels of hydrogen blends on the carbon intensity of natural gas-fueled appliances and its overall contribution to state climate and energy goals

Projected Ratepayer Benefits

Examining the Effects of Hydrogen in End-Use Appliances

- **Technology Potential.** Increasing the amount of hydrogen that can replace a portion of natural gas in end-use appliances may be a cost-effective way of reducing CO2 emissions.
- **Environmental Benefits.**
  - Could reduce GHG emissions due to large numbers of existing natural gas fueled appliances.
  - Potential for criteria air pollutant reductions, for example NOx and CO, which are known to be harmful to human health and the environment.

Energy Efficiency

Proposed Research Initiative:

Accelerating Adoption of Next Generation Modular Solar Water Heating

Background:

Water heating accounts for approximately 40 percent of natural gas used by California households and 32 percent used by the commercial building sector. Solar thermal water heating can significantly reduce natural gas consumption in the building sector. However uptake of these systems has been slow, even with incentives.

Purpose of Research

Accelerating Adoption of Next Generation Modular Solar Water Heating

Issues:

- Current solar thermal water heating systems have high cost due to the need for customized installations, high maintenance, and the requirement for large backup systems. A modular and standardized approach is needed.
- Competition with solar photovoltaics, especially in single-family settings, makes solar thermal systems less desirable.
- Resources for both solar thermal installers and potential buyers are limited.
- Disadvantaged and low-income communities with higher energy cost burden need pathways for decarbonization. Modular solar water heating is one potential pathway.

Research Description

Accelerating Adoption of Next Generation Modular Solar Water Heating

The initiative would fund the demonstration of modular solar water heating systems in low-income and/or disadvantaged communities and include an analysis of the building applications and climate zones where it would be most cost-effective.

- The selected applications should be representative of those with high market potential and hot water needs, such as multi-family residential, community centers, retirement communities, laundries, and schools.
- Achieve a minimum of 70% reduction in natural gas use for water heating.
- Achieve a minimum 20% cost reduction compared to conventional solar thermal.
- Document system performance that includes but is not limited to energy bill savings, system energy efficiency, and customer satisfaction.

Research Description

Accelerating Adoption of Next Generation Modular Solar Water Heating

Continued…

- Develop modular, plug-and-play methods for designing each system so that they can be easily replicated to other buildings to minimize cost.
- Prepare and distribute case studies based on documented performance.
- Coordinate with Community-Based Organizations to determine community needs and barriers related to adoption of solar water heating in low income/disadvantaged communities.
- Create guides for solar water heating system installers which provide information on design methods, tools, and commercially-available systems with a focus on disadvantaged and low-income community applications.
- Develop guides to help customers understand the benefits and costs of solar water heating systems, available incentives, and resources to find installers.
- Explore opportunities for demand response with there systems.

Projected Ratepayer Benefits

Accelerating Adoption of Next Generation Modular Solar Water Heating

- **Energy and Cost Savings.** Provide decarbonization pathway for natural gas ratepayers, especially low-income communities with natural gas-fired water heating systems.
- **Environmental Benefits.** Reduce greenhouse gas emissions.
- **Energy Sector.** Increase system resilience.

Questions for the Stakeholders

Energy Efficiency

Hydrogen Blending

- What should be the targeted building sectors, such as residential, commercial offices, retail, restaurants, institutional, etc.? And why?
- What should be the targeted appliances and why?
- Are there sectors or appliances to avoid?

Solar Thermal

- How can our research to help create replicable solutions?
- What are the targeted building types and climate zones or other factors that are the best candidates for cost effective solar thermal?
- What technological improvements are needed to reduce cost, space requirements, and backup system sizing of solar thermal systems?

CALIFORNIA ENERGY COMMISSION

Transportation Research

Transportation Research

Program Goals:

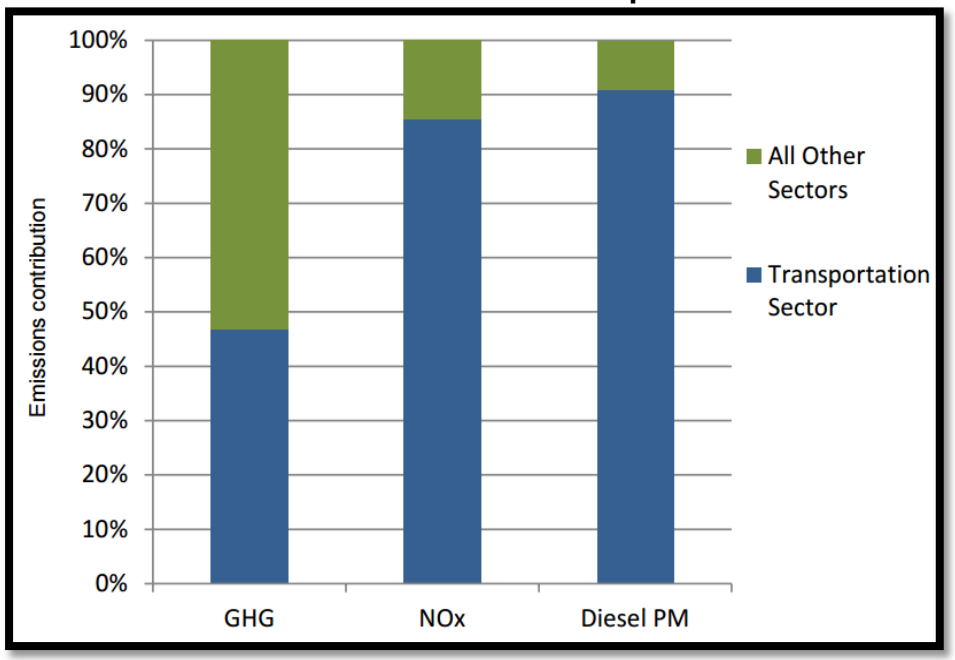
- Accelerate the beneficial commercial adoption of near-zero and zero emission gaseous fueled vehicles to improve air quality.
- Improve the energy efficiency and performance of gaseous fueled vehicles to reduce carbon emissions and improve competitiveness with conventional fuel vehicles.
- Increase the use of renewable gas to reduce the GHG emissions of the transportation sector.
- Improve fueling infrastructure technology capabilities to promote the further adoption of low-carbon gaseous fueled vehicles.

Transportation Research

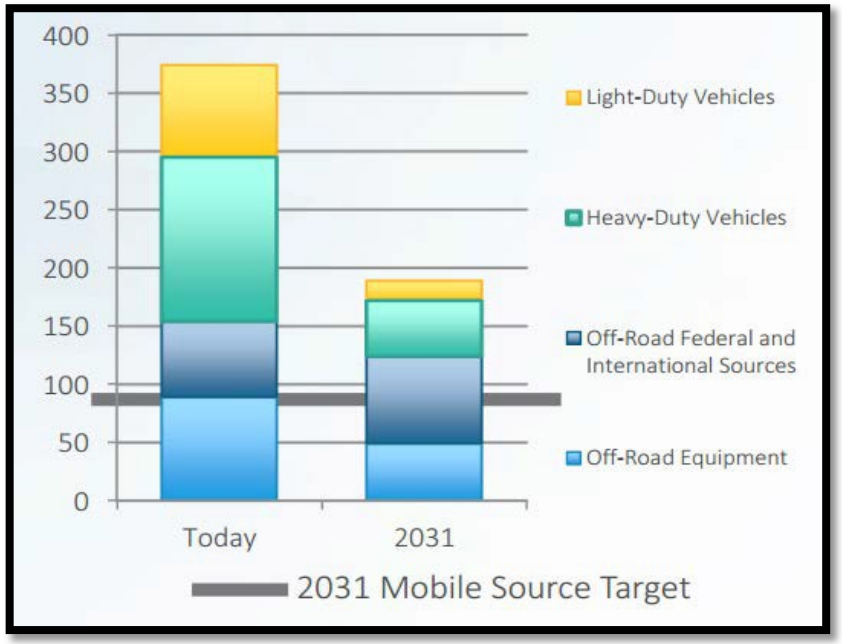
Research Portfolio

- Heavy-duty trucks and buses emit 20% of GHG emissions from the transportation sector, 28% of statewide NOx emissions, and 23% of statewide PM emissions.
- The South Coast needs an additional ~70% reduction in NOx emissions from heavy-duty vehicles to attain to federal ambient air quality standards by 2031.

Emission Contributions from the Transportation Sector



NOx Emission Reductions Needed in the South Coast



Transportation Research

Research Portfolio

- **Natural Gas Engine Efficiency Research**
  - Demonstrated >12% efficiency improvement in 12-liter natural gas engine using dedicated exhaust gas recirculation.
  - Demonstrated pathway to increasing efficiency by 20% using transient plasma ignition technology on a commercially available low NOx engine.
- **Natural Gas Vehicle Research Consortium**
  - 9 projects kicked off with ~$16M in co-funding from DOE VTO and SCAQMD.
  - Advancing engine technology and hybridization to enable high efficiency natural gas vehicles capable of performance beyond forthcoming 2024 GHG Phase 2 and Low NOx Standards.
- **Expansion to Focus on Fuel Cell Technologies**
  - Integrate and demonstrate fuel cell technologies in rail and commercial harbor craft.
  - Leverage opportunities at ports to achieve scaled hydrogen fuel demand.
  - Focus on vehicle/vessel integration and demonstrate ability to meet duty cycle, reliability, maintainability, and operating range.

Proposed Research Initiative

Transportation Research

- Technology Integration and Demonstration of Hydrogen Fuel Cell Trucks and Buses

Transportation Research

Proposed Research Initiative

Technology Integration and Demonstration of Hydrogen Fuel Cell Trucks and Buses

Background:

Hydrogen fuel cell electric vehicles (FCEV) are zero emission technology options with comparable operational flexibility to conventional vehicles such as long range, fast refueling times, and resiliency to ambient temperature extremes.

Transportation Research

Continued…

- SB 1505 and the Low Carbon Fuel Standard provide drivers for increasing renewable hydrogen production to support growing demand from the transportation sector.
- Achieving scaled renewable hydrogen production can support decarbonizing other end uses, including the natural gas system through pipeline blending.
- Forthcoming zero emission fleet rules will transition California truck and bus fleets to zero emission vehicles. R&D to advance the state of fuel cell vehicle and hydrogen infrastructure technology can assist in accelerating this transition.

Purpose of Research

Issues:

- Although heavy-duty FCEVs are estimated to achieve cost parity with conventional diesel vehicles by 2030, this can be accelerated with additional reductions in total cost of ownership.
- Fleets have limited data on fuel cell durability and performance in duty cycles relevant to their operations. Demonstrations are needed to inform fleet adoption.
- There are few commercially available fuel cell trucks and buses and a low number of deployed vehicles.
- Current hydrogen refueling technology contributes to the high cost of dispensed hydrogen.

Research Description

This initiative will fund the demonstration of heavy-duty hydrogen fuel cell trucks and buses that integrate pre-commercial vehicle or fueling infrastructure technologies to improve economics, performance, and durability.

- Address weight and space constraints, route and range requirements, and other vehicle integration barriers.
- Target vehicles that operate near hydrogen production facilities or industrial centers already using hydrogen.
- Demonstrate in real world fleet operation.

Research Description

Continued…

- Advance pre-commercial technologies that can improve total cost of ownership. Examples include but are not limited to:
  - Improved fuel cell system diagnostics.
  - Advanced on-board storage tanks.
  - Improved fuel cell system components and integration strategies.
  - Improved hydrogen fueling infrastructure technologies.

Projected Ratepayer Benefits

- **Energy Sector.** Increasing demand for renewable hydrogen in the transportation sector can drive scaled production of renewable hydrogen for a variety of end uses, including grid energy storage, industrial processes, and pipeline blending for gas system decarbonization.
- **Environmental Benefits.**
  - Reduce greenhouse gas, NOx, and particulate matter emissions from medium and heavy-duty vehicles.
  - Prioritizing zero emission vehicle demonstrations at industrial facilities can improve air quality and public health in nearby disadvantaged and/or low income communities.

Questions for the Stakeholders

Transportation Research

- What are some vehicle uses that should be targeted by this initiative?
- What are some pre-commercial FCEV or hydrogen fueling infrastructure technologies that will be ready for real world demonstration in the near term?
- What are some opportunities for this research to inform component standardization for further cost reductions?
- How can the value of these demonstrations be maximized?

CALIFORNIA ENERGY COMMISSION

Energy-Related Environmental Research

Energy-Related Environmental Research

Program Goals:

- Develop cost-effective approaches to evaluating and resolving environmental effects of energy production, delivery, and use in California;
- Explore how new energy applications and products can solve or reduce environmental problems;
- Identify climate- and environment-related vulnerabilities and resilience options for the energy system.

Energy-Related Environmental Research

Research Portfolio

SUper eMitters of Methane Detection Using Aircraft, Towers, and Intensive Observational Network (SUMMATION)

- **Goal**: Establish a continuous, cost-effective regional-scale methane emissions monitoring network in the southern San Joaquin Valley.
- Project responds to AB 1496 by improving monitoring and measurement of methane emissions, particularly high-emission methane hot spots (super emitters).
- Development of scalable methane monitoring approach will support cost-effective infrastructure investments and monitoring.
- Project will decrease GHG emissions, reduce resource losses, and may lower maintenance costs.

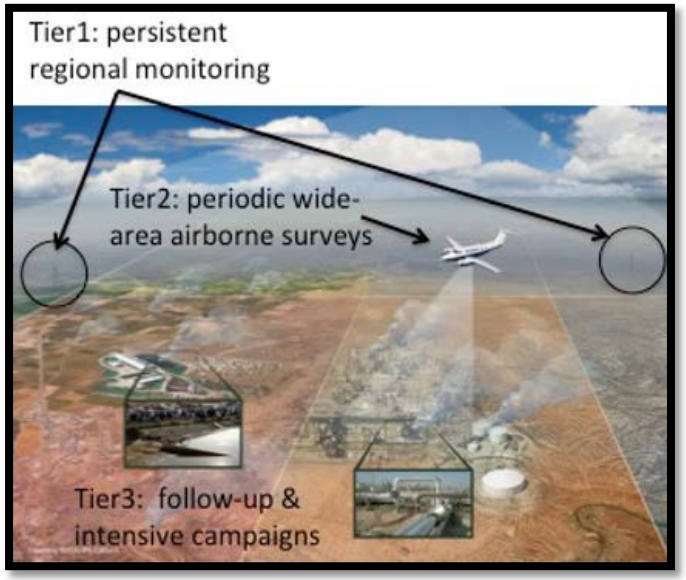


Figure: Proposed design for a regional, continuous methane emissions monitoring network in the southern San Joaquin Valley.

Energy-Related Environmental Research

Research Portfolio

Using Chemical and Isotopic Analyses to Improve Life-Cycle Assessments of the Natural Gas Consumed in CA

- **Goal**: Collaborate to characterize chemical and isotopic composition of natural gas samples from 20+ production basins and develop methodology to identify the basin of origin of the natural gas consumed in California.
- PG&E collecting and providing regular samples from at least seven critical locations within their delivery network.
- Researchers plan to sample at all identified locations by summer of 2020.
- Research will enable accounting for full fuel cycle impacts of natural gas consumed in California, including fugitive emissions from originating basins.

Figures: PG&E technician using a standardized procedure for sampling (*top*). Conditioned gas canisters await pressure testing (*bottom*).

Proposed Research Initiative

Energy-Related Environmental Research

- Development of Data-Driven, Actionable Tool and Case Studies to Support Strategic and Equitable Natural Gas Decommissioning

Energy-Related Environmental Research

Proposed Research Initiative:

Development of Data-Driven, Actionable Tool and Case Studies to Support Strategic and Equitable Natural Gas Decommissioning

Background:

Prior NG-funded work indicates that managing the evolution of the retail gas distribution system as the state transitions to a low-carbon future is imperative to ensure equitable access to energy services, a safe gas distribution system, and cost-effective ratepayer investments.

Purpose of Research

Development of Data-Driven, Actionable Tool and Case Studies to Support Strategic and Equitable Natural Gas Decommissioning

Issue:

Although prior research indicates that a strategic transition of the retail gas system is desirable, data and tools available at present do not enable spatial planning of decommissioning with consideration of cost and equity issues.

Research Description

Development of Data-Driven, Actionable Tool and Case Studies to Support Strategic and Equitable Natural Gas Decommissioning

- FY 20-21 funds would develop a data-driven, actionable tool to support strategic, equitable decommissioning of retail natural gas (*primarily buildings*).
- Leverage a methodological framework developed through FY 19-20 funds to illuminate strategic pathways to a low-carbon energy future.
- Tool will illuminate geospatially-specific cost and equity issues with broad regional coverage.
- Application of the tool to analyze specific groups of buildings and/or facilities will deliver case studies that inform decommissioning options and impacts.
- Local communities, potentially disadvantaged and low-income, will be engaged to inform the analysis and ensure research results are actionable.

Projected Ratepayer Benefits

Development of Data-Driven, Actionable Tool and Case Studies to Support Strategic and Equitable Natural Gas Decommissioning

- **Energy and Cost Savings**. Provide support for cost-effective, equitable transition of the retail gas distribution system.
- **Energy Sector.** Facilitate strategic decommissioning informed by analyses of infrastructure status and safety concerns.
- **Environmental Benefits**. Support achievement of state decarbonization goals, with associated health, environmental, and economic benefits.

Questions for the Stakeholders

Energy-Related Environmental Research

- How can California's natural gas IOUs be effectively engaged in this study? What synergies with IOU priorities and planning could be leveraged to enhance the study?
- What other natural gas sector stakeholders (e.g., other state agencies, CCAs, community-based organizations, jurisdictions with electrification ordinances) could serve important roles in ensuring the study delivers useful results?
- Are there externally funded efforts that might provide fruitful collaborations?

Comments & Questions

- Please introduce yourself by stating your name and affiliation.
- Keep questions under 3 minutes to allow time for others.
- Note that our official response will be given in writing and posted on: https://ww2.energy.ca.gov/research/annual_reports.html

Additional Comments & Questions

Please send all questions related to the FY 2020-21 Natural Gas R&D Budget Plan to:

Nicole Dani

nicole.dani@energy.ca.gov

Deadline to submit questions:

Friday, January 31, 2020 5:00 PM

APPENDIX B:
Public Comments

The CEC appreciates the thoughtful and helpful comments from stakeholders received in response to CEC's January 21, 2020 staff workshop on proposed initiatives for the FY 2020-21 Natural Gas R&D Program. The CEC requested comments at the January 21, 2020 workshop and via notifications on the CEC website, listservs, and docket. A summary of the comments and CEC's responses are provided below. Please note that, for brevity, footnotes included in public comments are not included in this summary.

CEC staff also appreciate continued coordination with CPUC staff to increase the expected impact of the research plan, including for the research initiatives on strategic decommissioning and pipeline corrosion and assessment (e.g., expanding the research initiative on corrosion to include desert mineral corrosion).

Energy Efficiency

CEC Initiative and Question:

Examining the Effects of Hydrogen in End-Use Appliances: What should be the targeted building sectors, such as residential, commercial offices, retail, restaurants, institutional, etc.? And why?

SoCalGas Comment:

The residential market has the largest number of equipment units deployed and the greatest throughput. Therefore, serving the existing equipment stock with a decarbonized fuel supply consisting of hydrogen-natural gas blends can have the greatest GHG emissions reduction impact with the lowest amount of consumer cost and inconvenience.

Industrial equipment is the most difficult (if not impossible) to electrify. Hydrogen blending is a promising decarbonization solution for industrial applications, e.g. food processing, textiles, chemical refining, manufacturing.

Finally, hydrogen-natural gas blends delivered through our existing natural gas system represents a very compelling method for meeting California's winter heating demand while reducing GHG emissions. In 2017, California's peak demand was 8,380 Mms per day. Electrifying that demand would require 2,544 GWh/day of electric power and conservatively, more than 100 GW of new wind, solar, and back-up generation capacity, depending on assumptions for electric system efficiencies (transmission and distribution power losses) and availability.

CEC Initiative and Question:

Examining the Effects of Hydrogen in End-Use Appliances: What should be the targeted appliances and why?

SoCalGas Comment:

For hydrogen blending to work at scale and across the natural gas system, we need to understand the potential impacts on all appliances. Recognizing the need for a comprehensive assessment, work is underway by SoCalGas and others to understand hydrogen concentration limits and performance for appliances across the board. Current research suggests that appliances are not the limiting factor as most appliance can accept 10-20% hydrogen today without modification.

Compressed natural gas (CNG) vehicle limits are setting the system hydrogen blend levels. For example, Germany has two blend limits, one for areas with CNG fueling and a higher limit for those without fueling infrastructure. SoCal Gas's RD&D Program is conducting research with the University of California, at Riverside and Cummings Westport Inc. to understand what is driving CNG blend limits and how to increase the tolerance of CNG engines for hydrogen blended fuels.

CEC Initiative and Question:

Examining the Effects of Hydrogen in End-Use Appliances: Are there sectors or appliances to avoid?

SoCalGas Comment:

No, please see above. A comprehensive understanding is required to advance hydrogen blending in the natural gas system. The CEC is well positioned to coordinate various research efforts across the State, nation, and globe to help advance hydrogen blending in California.

CEC Response:

For the FY20-21 budget plan, we are focusing on a targeted set of appliances in the residential and commercial sectors given funding limitations. Available funding will target specific appliances prioritized based on analysis of impact potential during solicitation development. We will consider research on additional sectors and appliances in future years. We are aware of existing research initiatives in this area led by natural gas IOUs and others and are interested to collaborate on these topics.

CEC Question:

Examining the Effects of Hydrogen in End-Use Appliances: What should be the targeted building sectors, such as residential, commercial offices, retail, restaurants, institutional, etc.? And why?

PG&E Comment:

Consider testing hydrogen blending on CNG engines. Heavy duty trucking is a promising end-use for natural gas going forward and knowing the impact of hydrogen blending on truck engines would be valuable.

CEC Response:
For the FY20-21 budget plan, we are focusing on the residential and commercial sectors given funding limitations. We will track research on hydrogen blend limits for CNG engines (e.g., in SoCalGas's RD&D Program) and consider this research area in a future budget plan.

CSA Group Comment:
Is the CEC aware of a research program for hydrogen blending and the impact on end use appliances?

There is an on-going project that Appliance Engineering Inc. is conducting that is funded by the CSA Group, AGA, and AHRI. At this point, there is no public results available. However, the focus appears to be similar to what ongoing research is being conducted and we would be interested in aligning efforts with the CEC.

CEC Response:
The CEC will consider all publicly available research results pertaining to hydrogen blends for appliances in solicitation development. The CEC will continue to collaborate with CSA group and others to leverage results of existing studies.

Renewable Energy and Advanced Generation

CSA Group Comment:
What is the timing of these proposed projects being initiated?

CEC Response:
The timing is dependent on CPUC approval of the initiatives and CEC issuance of solicitations. Typically, the funding for this program needs to be awarded to a project within two fiscal years (for the FY20-21 budget plan, that would be before the end of June 2022).

CEC Question:
Of the three technology areas presented – renewable hydrogen, biomethane, and geothermal heating and cooling – is it important to prioritize one in particular?

SoCalGas Comment:
Yes, hydrogen should be the top priority. While hydrogen technologies have the broadest and most impactful applications, they are in the earliest stages of development and require the most support. Biomethane is also important to help California decarbonize, however, biogas technology is commercially available and the market is developing.

Geothermal heating and cooling is not a suitable technology for funding through the natural gas research and development program as it relies on electrification. There are sufficient funds under Electric Program Investment Charge program to support electric heating and

cooling technologies. It is not appropriate to have gas ratepayers fund electric technology development.

CEC Response:
Hydrogen remains a priority research area given the noted broad applications and research need, with initiatives on hydrogen production, pipeline blending, and end use. Biomethane upgrading is included in the proposed initiatives. The initiative on geothermal heating and cooling has been removed.

PG&E Comment:
Geothermal heat pump system should not be included in Natural Gas Research priorities. Developing and demonstrating decarbonization solutions such as hydrogen, biomethane and Renewable Natural Gas should be put first.

CEC Response:
Hydrogen and biomethane are included in the proposed initiatives. The initiative on geothermal heating and cooling has been removed.

T2M Global Comment:
Burners and boilers typically generate low level waste heat that is vented or wasted. Technologies that can upgrade these to higher value such as electricity or hydrogen or RNG should be prioritized and recognized as a valuable tool for CA to meet its GHG goals.

CEC Response:
Waste heat-assisted hydrogen or RNG production is within the scope of the proposed DECARB research initiatives and will be considered in solicitation development. We note also that the CEC has included research on the use of waste heat from burners and boilers in previous years of the Natural Gas R&D Program.

CEC Research Initiative:

Emerging Gas Cleanup and Upgrading for Biomethane

PG&E Comment:
PG&E recommends including small scale cleanup process solutions for removing hydrogen sulfide, often found in dairies. The smaller scale processes need to be cost competitive. For example, membranes are a promising solution, however, membranes may be poisoned by hydrogen sulfide. Having an upgrading system that can handle hydrogen sulfide directly would be more cost effective and efficient.

CEC Response:
Hydrogen sulfide removal is included as part of the biomethane upgrading initiative. We will consider the cost-competitiveness of small-scale processes in the solicitation development. We agree that biogas cleanup processes need to be cost competitive and

that effective removal of hydrogen sulfide is essential in achieving high-quality biomethane.

PG&E Comment:
Consider adding woody biomass, especially forest waste as a source of biomethane thorough gasification and methanation.

CEC Response:
Last year, CEC issued a grant funding opportunity on this topic under the natural gas research and development program (GFO-18-501), resulting in two research projects (PIR-18-001 and PIR-18-004 – both concluding in 2023) that will demonstrate gasification and methanation of woody biomass to high-quality renewable gas. The proposed initiatives do not include woody biomass given these recent investments.

PG&E Comment:
Consider pairing emerging methods for removal of siloxane with the technology development for an online siloxane analyzer. Specifically, the online analyzer could be installed at an upgrading site as a field test. The data can be compared to traditional methods of siloxane analysis.

CEC Response:
A range of methodologies – including an online analyzer – will be considered in the solicitation development for the biomethane initiative.

Natural Gas Infrastructure Safety & Integrity

CEC Research Initiative:
Pilot Test and Demonstration of Hydrogen Blending to the Existing California Natural Gas Infrastructure

PG&E Comment:
PG&E is interested in partnering on this initiative. The pilot test could be using a portion of the natural gas system or designing a new system for the test.

CEC Response:
The CEC appreciates PG&E's interest in coordinating. The pilot tests and demonstrations of hydrogen blending would benefit from collaboration with California natural gas utilities.

CEC Research Initiative:
Analytics for Pilot Demonstration of Strategic Electrification and Decommissioning of Natural Gas Infrastructure

Earthjustice, Sierra Club, California Environmental Justice Alliance Comment
Earthjustice, Sierra Club and the California Environmental Justice Alliance write to support the proposed Pilot Demonstration of Strategic Electrification and Decommissioning of Natural Gas Infrastructure as part of the California Energy Commission ("CEC") Natural Gas Research Initiative for Fiscal Year 2020-2021. Studies examining the future of the gas system in California have found that building electrification can be the most feasible and cost-effective path to zero emission buildings and that a managed transition from the gas system will be critical to lower cost, protect vulnerable Californians and provide a just transition for workers. These studies also make clear that a managed transition requires data, analysis and intentionality, where the gas system is mapped to identify those areas where targeted electrification would have the greatest impact on reducing future capital expenditures. The proposed Pilot Demonstration is therefore critical research that will provide valuable insights into executing strategic electrification and decommissioning of gas infrastructure. The Pilot will also will yield climate and air quality benefits through reduced gas combustion and ratepayer savings by avoiding future capital expenditures and stranded assets on the gas system.

We also support the pilot's intended focus on low-income and disadvantaged communities. As observed in the Gridworks report, California's Gas System in Transition, "[o]ne of the greatest equity concerns that arises in the context of declining use of the gas system is that economically disadvantaged customers could be 'left behind' and remain dependent on increasingly expensive gas service." Developing experience in transitioning low-income customers from gas will be critical to ensuring equitable decarbonization. To develop best practices, we recommend starting with the outreach and the bill protections in the California Public Utility Commission proceeding that approved pilot projects for San Joaquin Valley Disadvantaged Communities.

Finally, we encourage the CEC to coordinate with the California Public Utilities Commission ("CPUC"), particularly on ensuring data on the gas system transition is as public and transparent as possible. Data gathering on the gas system in now contemplated under the Proposed Decision Establishing Building Decarbonization Pilot Programs ("Building Decarbonization PD"). The Building Decarbonization PD requires each gas corporation to "release downloadable planned natural gas infrastructure extension maps on a publicly accessible website" on July 1 of each year as well as "non-confidential downloadable map-based data that shows the book value, age, and location of existing natural gas distribution and transmission infrastructure." For an effective pilot, the CEC will likely need more information, such as the condition of pipes, leakage rates, asset depreciation schedules and planned and foreseeable future investments to identify preferred locations for targeted electrification efforts. Utility-imposed restrictions on data access to consultants retained by the CEC can impede the effectiveness of the Pilot Program and thwart meaningful public participation. Because the CPUC has jurisdiction over California's investor owned gas utilities, it can help ensure necessary data is provided to the CEC and CEC consultants and define the categories of information that have a legitimate basis for confidentiality to maximize transparency in gas system planning.

CEC Response:
The final budget plan includes the initiative to support a pilot demonstration for strategic electrification and decommissioning, as well as the initiative on a data-driven actionable tool for strategic decommissioning. We will consider the recommended resources in the solicitation development process. Coordination of CEC and CPUC on access to needed infrastructure data is underway.

CEC Initiative and Question:

Pilot Test and Demonstration of Hydrogen Blending into Existing California Natural Gas Pipelines: Challenges/limitations to demonstrating hydrogen blending in the existing CA natural gas system?

PG&E Comment:

- Consider a section that could be isolated and controlled so that the data is clear on direct impacts from hydrogen (no outside influences)
- Consider a sufficiently representative infrastructure in the demonstration (i.e. range of pipeline materials, assets and end user equipment)
- Consider a control group with duplicate infrastructure and operating conditions with only natural gas

CEC Response:
The suggestions are helpful and will be considered in the development of the solicitation.

CEC Initiative and Question:

Pilot Test and Demonstration of Hydrogen Blending into Existing California Natural Gas Pipelines: Recommendations on research approach(es)?

PG&E Comment:
PG&E recommends a connection with the HyDeploy project in the UK to learn about how the team is implementing their pilot demonstration. The California demonstration may be able to use the same or a similar approach.

CEC Response:
The proposed research initiative will be informed by and leverage existing research and demonstrations in the United States and other countries.

CEC Research Initiative:

Technologies for Microbiologically Influenced Corrosion Prevention of Natural Gas Pipelines and Storage Facilities

PG&E Comment:

The largest gap pertains to our limited understanding of the relationship between Cathodic Protection and Microbiologically Influenced Corrosion. PG&E recommends focusing on this aspect.

CEC Response:

The proposed research will address the link between cathodic protection and microbiologically influenced corrosion.

Energy-Related Environmental Research

CEC Research Initiative:

Development of Data-Driven, Actionable Tool and Case Studies to Support Strategic and Equitable Natural Gas Decommissioning

SoCalGas Comment:

Natural gas ratepayer funding should not be used to fund research into decommissioning the natural gas system. Decommission portions of the natural gas system will adversely impact rates for the remaining ratepayers using the system. This research does not provide ratepayer benefit and, in fact, will increase energy costs generally.

This research needs to include a cost-effectiveness study (i.e., determine the cost per unit of GHG emissions eliminated) of multiple decarbonization options, including using the natural gas system to deliver: 1) renewable natural gas, 2) hydrogen blended fuel, and 3) pure hydrogen, as well as 4) to provide long-duration, utility scale energy storage to support wind and solar resources.

CEC Response:

Research on natural gas decommissioning will be important to effectively manage impacts to ratepayers and utilities. The proposed research on a pilot demonstration and data-driven tool to support strategic decommissioning does include analysis of cost and can inform evaluation of cost-effectiveness. The proposed initiative builds on previous research under the Natural Gas R&D Program on options for decarbonization in the natural gas system.

The proposed research also includes initiatives on the production of renewable gas (which could be delivered in part through the natural gas system) and hydrogen blending in the natural gas system.

CEC Initiative and Questions:

Development of Data-Driven, Actionable Tool and Case Studies to Support Strategic and Equitable Natural Gas Decommissioning: How can California's natural gas IOUs be effectively engaged in this study? What synergies with IOU priorities and planning could be leveraged to enhance the study?

SoCalGas Comment:
The research should include a detailed analysis of electric utility impact:

What transmission and distribution upgrades will be required to the electric grid to support electrification and how will this affect retail rates and customer bills?

- How will reliability be impacted if residential energy supplies are reduced to a single energy currency, especially given increased wildfire risk, public safety power shutoffs, and seismic issues?
- What will be the GHG emissions impact of decommissioning natural gas systems given the marginal electricity production mix?
- How can renewable gas driven microgrids be used to enhance energy resilience and reliability?

CEC Response:
We recognize the need for examination of the electricity system as well as the natural gas system. In solicitation development, we will take into consideration the need to work with electricity IOUs as well as natural gas IOUs to gain detailed insight into impacts of changes to the energy system to either system.

Transportation Research

CEC Initiative and Question:

Technology Integration and Demonstration of Hydrogen Fuel Cell Trucks and Buses: What are some vehicle uses that should be targeted by this initiative?

SoCalGas Comment:
Fuel cell electric vehicles (FCEVs) are well suited to help electrify transit fleets. For example, the Sunline Transit Agency in Riverside County is demonstrating a number FCEV buses due to their ability to serve long-range routes, function effectively under extreme temperature conditions, and refuel quickly.

SoCalGas also recommends that service fleets also be targeted. The California Department of Transportation (Caltrans) operates a fleet of over 3,300 light- and medium-duty trucks that are required to travel long distances to support California roads and infrastructure projects and, as such, cannot be served by current battery electric vehicle technology. Development of FCEV products for these applications would provide significant environmental benefit given the size of the fleet and vehicle miles traveled.

CEC Response:
The proposed initiative focuses on heavy-duty fuel cell electric vehicles (FCEVs) and infrastructure, and we agree that FVECs may be well suited zero emission options for vehicle uses that require long operating ranges, effectiveness under extreme temperature

conditions, and quick refueling times. We will consider transit and service fleets in the development of the solicitation.

CEC Initiative and Question:

Technology Integration and Demonstration of Hydrogen Fuel Cell Trucks and Buses: How can the value of these demonstrations be maximized?

SoCalGas Comment:

SoCalGas recommends partnering with large fleets, including the Los Angeles County Metropolitan Transportation Authority, the Los Angeles Department of Transportation, and Caltrans, so that the technology demonstrations also serve to de-risk the technology for these potential customers.

CEC Response:

We will consider opportunities to partner with large fleets and to target demonstrations that are relevant to large fleets in the development of the solicitation.