LOCAL GAS FUEL DECARBONIZATION AND RESILIENCE FOR SOUTHERN CALIFORNIA

Integrated Renewable Energy Systems Network
www.iresn.org

Gerald Braun, Project Manager

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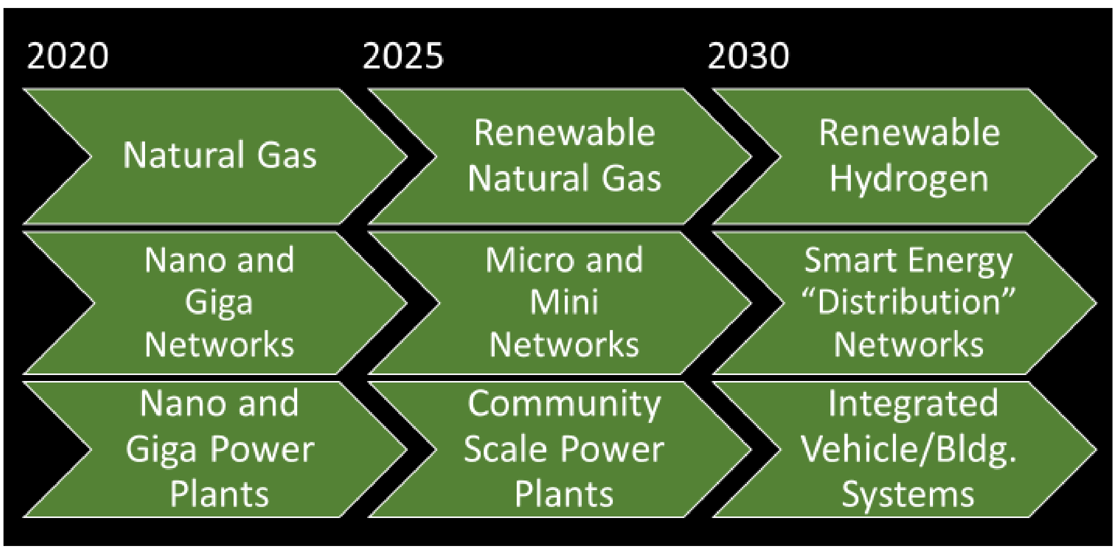

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Local Energy Collaboration Project Second Year Report – Final

Abstract

Technologies likely to have the greatest impact in reducing a community's carbon footprint are in most cases technologies that can be adopted by residents, businesses and public agencies. Therefore, timely local action empowered by collaboration with energy service providers will be crucial in the years ahead as southern California cities and counties act to reduce GHG emissions and improve energy resilience. On average, fifty percent of local GHG inventory reduction is locally actionable. Starting a decade ago many southern California cities and counties prepared and adopted Climate Action and Adaptation Plans (CAAPs). These plans addressed building energy use and opportunities to import low carbon electricity. Now cost-competitive renewable gas and electricity can both be produced and distributed locally, helping insulate communities from risks of being cut off from regional energy delivery networks. Specific immediate opportunities to decarbonize fuel production and usage for heating, transportation or industrial and agricultural operations are identified. Emerging opportunities that will be actionable later or by the end of the decade are identified. Potential local GHG inventory reductions that can result from taking local action are identified.

Acknowledgements

IRESN's Local Climate Action and Adaptation Project Advisory Committee supported preparation of the project work scope and met to review progress. Keith Davidson, Ron Edelstein, Tony Haske, Rob Hammon, and Veronica Holland continued to provide guidance once work was underway, as did Southern California Gas colleagues Geoff Danker, Tanya Peacock and Jenny Pezda. Discussions and exchanges with energy industry veteran and thought leader Chris Hodrien in the UK provided an essential test of basic technology and economic premises.

Cover illustration: Major elements of current energy systems are shown along with their transitions to more robust future elements. Communities that now enjoy the benefits of robust and diverse energy services can plan for evolutionary changes in fuel sourcing and electricity sourcing and transport networks. The evolution must be to smarter regional (Giga) energy transport networks handling current high volumes of gas fuel and electricity, flexible local (Micro) and (Mini) networks enabling smarter local energy flows and exchange, building energy management (Nano) networks that inform and control end use equipment, and on-site (Nano) power plants, e.g. rooftop solar, supplementing services that rely on aging state-wide and regional power plant fleets. Transitions from current natural gas sources to renewable natural gas and renewable hydrogen sources require local as well as state attention, as will transitions to smarter and more localized energy delivery and exchange networks. Community based power plants will be an essential complement to Nano and Giga scale plants resupplying vehicles with energy while parked. Community energy systems will use vehicle based systems to reduce energy user costs and make energy service more resilient.

About IRESN and the project manager: IRESN is a registered California non-profit dedicated to pragmatic local energy integration and collaboration. Gerald Braun is an energy utility and solar industry veteran who also, at other times, directed national, state, utility and university-based renewable energy RD&D programs.

Local Gas Fuel Decarbonization and Resilience for Southern California

PREFACE

Energy decisions are becoming more consequential. At any energy decision-making level, intuitively appealing scenarios will likely encounter technical and cost obstacles. For example, transitioning to 100 percent renewable electricity from large solar and wind power plants is now at least theoretically possible based on the combined capacity of two large global manufacturing industries. A successful transition in California would hinge on making provisions for replacing energy currently stored and transported as natural gas with energy stored and delivered in another fuel or form. Battery storage can be deployed to smooth out hourly and daily variations while energy stored in renewably produced hydrogen can be used to handle major seasonal variations and extreme short term variations. There is yet little experience with grid connected battery storage, and renewable hydrogen is not yet a proven and cost-effective bulk electricity production fuel. Transitioning to exclusive reliance on electricity for all energy uses in parallel with scaling up and decarbonizing electricity supply would confront a broader and higher range of technical and cost obstacles.

Theory aside, most national and sub-national governments are committed to a process of incrementally changing their electricity supply portfolios while developing more robust long term decarbonization and energy resilience policies. In this context, electricity sector transitions and gas fuel sector transitions will need to proceed in concert, globally, regionally and especially locally. Well planned local transitions will accelerate and reduce the societal cost of regional and national transitions.

Current natural gas transport infrastructure and services will be a crucial bridge enabling local energy transitions over the next decade or two. Local capacities and expertise required to deliver gas fuels safely and cost-effectively will be essential in the near and mid-term and must not be degraded if local climate action is to proceed on a timely and prudent track over the next fifteen years. Local climate action and adaptation plans must provide for local gas fuel decarbonization and resilience.

Summary

California has transformative climate action and adaptation policies. They may influence, and will certainly be influenced by, the on-going global energy transition, Federal and state policies, and, most importantly, by experience gained along the way. The cumulative effect of independent decisions by energy users and communities can either turbocharge or impede state policy implementation.

Thanks to California's Community Choice[1] movement and the proliferation of solar electricity systems on California buildings and parking structures, California city and county attention tends to focus on electricity sector opportunities in the left column of Figure 1. Climate action options involving gas fuel in the right column are comparably affordable and impactful. This report's purpose is to inform southern California city and county plans to implement gas fuel climate action and adaptation measures.

[1] Locally governed wholesale electricity procurement

Electricity	Gas Fuel
• On-site solar electricity production • Increased renewable electricity imports	• Renewable fuel from local waste • Increased renewable gas imports
• Renewable microgrids	• Renewable/gas hybrid microgrids
• Heat pump water heaters	• Hybrid solar/gas water heating
• Heat pump space heating	• RNG space heating
• Battery electric vehicles • Plug in hybrid electric vehicles	• RNG fueled commercial vehicles • RNG/RH2 fueled personal vehicles
• Competitive higher renewable content retail electricity	• Industrial combined heat and power

FIGURE 1. LOCAL CLIMATE ACTION OPTIONS AND RESILIENCE ENABLERS

Local climate action and adaptation is a relatively new local planning consideration. Carefully planned and diligently implemented, it can strengthen local economies, create local jobs, increase county and city tax revenues, and improve essential services. Local planning is essential because of local differences that cause large deviations from statewide average energy usage patterns, transportation infrastructure, renewable resource opportunities, environmental concerns, and demographics.

Planning considerations include:

1. Zero Carbon Vision. Zero carbon buildings are being built now, zero carbon vehicles are being purchased, and some existing buildings are being retrofitted to minimize or eliminate their carbon footprint. However, until continental and regional energy networks are decarbonized, climate change will continue to disrupt economies and threaten eco-systems. So, we are at an "all hands on deck" moment. We must come quickly to rely on energy commodities derived from renewable electricity and renewable hydrogen. Progress to this end will be empowered by energy user and community decisions as much as by state and national policy.
2. Interdependent Local Energy Systems. Regional fuel and electricity networks are already interdependent, and interdependence will likely increase and begin to manifest in local energy systems. Interdependence manifests in the extent fuel is used to generate electricity, while electricity is used in fuel extraction and transport and in some cases for gas appliance start-up. In the longer term, state regulated fuel and electricity infrastructures may evolve to be highly locally interdependent as renewable power is converted to hydrogen for use in fuel cell electric vehicles and for seasonal energy storage purposes. Likewise, local and fuel and electricity infrastructure will be increasingly interdependent. Local resilience requires backing up larger, more vulnerable systems, making their vulnerabilities less consequential. Local microgrids, for example, have already demonstrated their value to the larger, more vulnerable systems they connect to when the latter are at risk of needing to deenergize.
3. Local Decarbonization via Substitution. The cost of replacing all current global energy infrastructure would be prohibitive. Plus, under-investment in local infrastructure is a fact of recessionary economic conditions now on the horizon. Many energy intensive national and local economies struggle. Nevertheless, southern California cities and counties must begin or continue to find ways to facilitate substitution of lower carbon and locally produced energy for imported energy until economic balance, full decarbonization and full local resilience are achieved. Existing infrastructure and know-how is key to fast and cost-effective introduction of lower carbon solutions.
4. Economically Beneficial Local Transitions. While incentives can speed the decarbonization process, substitutions must still be economically beneficial over the life cycle of existing local buildings, new vehicles, local energy supply and transport projects and enabling infrastructure. New low carbon technologies enter the market slowly at first, then accelerate when manufacturing and project scale economies kick in. Each

city and county will be proceeding from different starting points at different paces confronting different barriers and opportunities. They all must:

- Manage waste and minimize related GHG emissions.
- Anticipate changes that decarbonize local transportation.
- Collaborate with energy network owners.

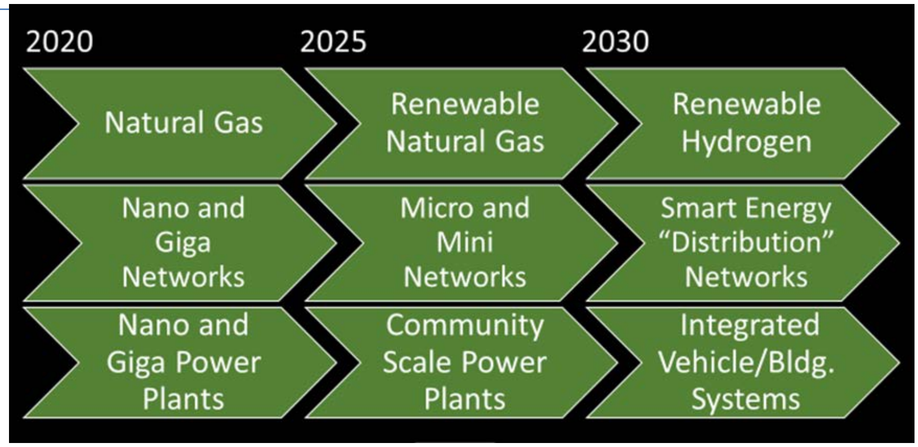

FIGURE 2. LOCAL DECARBONIZATION AND RESILIENCE PATHWAYS

5. Local Decarbonization and Resilience Pathways. Local climate action and adaptation plans (CAAPs) must consider both existing and emerging pathways. Southern California communities already enjoy the benefits of robust and diverse energy services. As outlined in Figure 2, they can plan for evolutionary changes in fuel sourcing, smarter regional (Giga) networks handling current high volumes of gas fuel and electricity, flexible local (Micro) and (Mini) networks enabling smarter building (Nano) networks that inform and control end use equipment, and on-site (Nano) power plants supplementing services that rely on both new and aging regional power plant fleets. In many cases tapping "community renewable" sources will be foundational to local decarbonization and resilience. Transitions from current natural gas sources to renewable natural gas and renewable hydrogen sources[2] require local as well as state attention, as will transitions to smarter and more localized energy delivery and exchange networks. Community based power plants will be an essential complement to Nano and Giga scale plants. Community renewable sources can resupply parked vehicles with fuel or electricity. Vehicle based power and storage capacities can be tapped in ways that benefit the vehicle owner and help make local energy service more resilient.

This report focuses on local pathways and action steps that have been too lightly considered in the past, i.e. regarding the gas fuel climate action options in the right column of Figure 1.

The report identifies, discusses and summarizes generally available action pathways, sequential steps to full implementation, collaborations necessary to remove roadblocks, and best-case GHG inventory reduction targets for a fifteen year period comprised of three 5-year phases. Report sections include decarbonization and resilience facts, discussion,

BEV – battery electric vehicle
CAAPs – climate action and adaptation plans
CHP – combined heat and power
DER – distributed energy resources
FCEV – fuel cell electric vehicle
GHGs – greenhouse gases
H2 - hydrogen
IRESN – Integrated Renewable Energy Systems Network
NG – (geological) natural gas
RH2 – renewable hydrogen
RNG – renewable natural gas
SCADA – supervisory control and data acquisition

FIGURE 3. ACRONYMS USED IN THIS REPORT

[2] Renewable hydrogen production requires either zero carbon electricity to electrolytically split water or the chemical "reforming" of methane (separation of hydrogen from carbon in the methane molecule) plus carbon capture and sequestration (CCS) of the CO2 byproduct of methane reforming. CCS is not yet a standard feature of industrial hydrogen production around the world.

and action/collaboration opportunities, followed by a summary table. Acronyms used in the report are defined in Figure 3.

Recommendations

This plan was written for southern California city and county public servants who plan and implement local climate action and adaptation measures. In the past, consultants and local non-profits prepared climate action and adaptation "plans" for local governments to adopt. Plans adopted over the last decade have been informative, aspirational and have helped build consensus and inspire commitment. Now, with renewable industries and renewable project implementation capacities much more mature, and renewable energy costs much lower and more predictable, cities and counties can set quantitative decarbonization goals, and take action to achieve them, while continually monitoring progress and adjusting plans according to what is being measured and learned. At this stage of the climate emergency, it is necessary to empower public employees, not just to commission planning efforts, but to aggressively implement plans, converting the consultant role to preparatory technical and economic modeling and analysis.

If a city or county has decided that investments in energy resilience are justified as insurance against economic disruption, this report will also be of use in evaluating and ranking potential investments. If a city or county has decided to engage and collaborate with energy service providers, local energy experts and university researchers to inform its investments in climate action and adaptation, this report points to the questions that data-driven analysis and expert advice must answer.

If these decisions have not yet been taken, cities and counties can support the work of local non-profits that help citizens and businesses consider resilient decarbonization investments that strengthen local economies.

This report outlines a long term program of mutually reinforcing steps and pathways. If purposeful local climate action and adaptation is not yet underway, the following areas of emphasis should be considered. One or more of them can be selected as an initial focus:

1. Integrated Energy Analysis to determine how a jurisdiction's carbon footprint and vulnerability to energy service disruption is changing and how long it will take to achieve carbon neutrality and acceptable levels of energy resilience in the absence of local government action.
2. Collaboration between local government and energy transport utilities to achieve specific changes, e.g. to supply locally produced renewable gas to local energy users by converting local waste streams renewable natural gas.
3. Partial or Full Renewable Resilience, i.e. upgrading backup power for critical facilities to make it and available indefinitely in all seasons and all weather because it relies on both renewable electricity and renewable gas.
4. Faster Renewable Substitution, i.e. substituting locally produced renewable electricity and renewable fuel to achieve full decarbonization of public buildings.
5. Renewable Electric Transportation, i.e. sufficient publicly available infrastructure for "refueling" battery and fuel cell vehicles with renewable gas and renewable electricity.
6. Voluntary Energy Conservation by commercial and industrial energy users via interactive sub-metering, data analytics and active management of on-site usage.

REPORT

Resilient Decarbonization

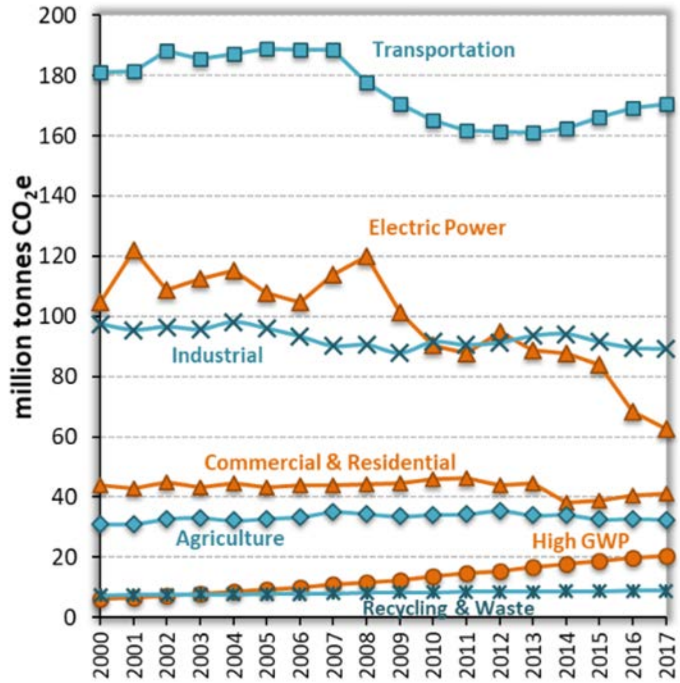

FIGURE 4. CALIFORNIA GHG EMISSIONS FOR 2000 TO 2017[1].

Most holistic (aka integrative) climate action starts with an inventory of GHG sources and their share of a state or local economy's total emissions. Figure 4[i] is the top level of a detailed inventory for California that shows comparative amounts and trends.

About 50% of California GHG emissions are attributable to energy use in locally owned vehicles and buildings. While state standards are gradually shrinking such emissions on a per capita basis, there is much local governments can do by preparing and implementing local Climate Action and Adaptation Plans (CAAPs).

Local governments have project permitting, code enforcement authority and local program delivery capacity. If they have goals and a plan, they can pilot, publicize, and lower barriers to the decarbonization and energy resilience choices available to local populations, businesses, and developers. They can make good choices in managing their own purchases, services and infrastructure. Plan implementation can lead to stronger local economies, job creation, tax revenue increases, and better integrated essential services.

Over the past decade, many Southern California cities and counties prepared and adopted Local Climate Action and Adaptation Plans (CAAPs). For the most part, these documents are clear and comprehensive, though some are outdated. They typically emphasize action to decarbonize over action to adapt. Putting more emphasis on adaptation will require greater resilience of local energy supply and delivery, thus creating a need for "resilient decarbonization".

Gas Fuel Climate Action and Adaptation Planning

Each southern California city and county undertaking new or updated CAAP development will be proceeding from different starting points at different paces and addressing different barriers and opportunities. Starting points depend on average per capita energy usage patterns, transportation infrastructure, renewable resource opportunities, environmental concerns and demographics. Change and pace of change depend on adoption the rate of adoption of new technologies. Faster local climate action becomes possible when adoption tipping points are reached, i.e. when costs begin to be driven downward by scale economies.

Local CAAP efforts therefore must be iterative, annually assessing progress, continuously monitoring technology and cost trends. One reason for this report is that existing CAAPs typically do not address decarbonized fuel production or lower carbon fuel usage for heating, transportation, or industrial and agricultural operations. To fill this gap, we identify gas fuel decarbonization and resilience actions southern California cities and counties can consider and include in new or updated CAAPs.[ii] It is intended to help assess the local effectiveness and GHG emissions benefits of specific pathways, strategies and interventions over the next fifteen years in the following six categories of current fuel production and use:

1. Local renewable fuel production has potential to significantly reduce GHG emissions from recycling and waste management and livestock manure management, which together comprise 5 percent of California's GHG inventory. It also has potential to reduce the amounts of geological natural gas (NG) being produced outside of California and the related methane leakage and water consumption impacts of NG production via fracking and long distance NG transport. Though difficult to quantify and not currently included in California GHG inventories, these indirect decarbonization and environmental benefits are comparable in magnitude to those deriving from the avoidance of waste management related emissions.
2. Resilient local power addresses climate goals by increasing local energy security while also reducing GHG emissions from centralized electric power generation that now comprise about 15 percent of California's GHG inventories.
3. Low carbon gas heat[iii] for buildings - water heating addresses GHG emissions attributable to on-site fuel use for water heating in buildings
4. Low carbon gas heat for buildings – space heating addresses GHG emissions attributable to on-site fuel use for space heating in buildings.
5. Low carbon transportation addresses the large (36 percent) portion of California's GHG inventory attributable to passenger and heavy duty vehicles.
6. Low carbon industrial and agricultural heat addresses the 5 percent of California's GHG inventory attributable to fuel use to produce heat for industrial and agricultural processes.

Local CAAP Development - General

Local CAAP development has important benefits for communities. It raises awareness and inspires action. Based on ten years of local climate action and adaptation experience, more systematic and impactful planning and implementation is now possible. Suggestions:

1. Local integrated energy analysis is foundational to local CAAP development and updating because of the need to align with and leverage local clean energy production and usage trends. Properly done, it quantitatively assesses local energy sector trends. It asks:

- How can trends that are already shrinking the local carbon footprint be accelerated?
- How can local renewable gas and renewable electricity investments work together toward greater local energy resilience and faster overall local decarbonization? What synergies can be exploited?
- How can progress toward greater energy resilience be weighed against related costs?

Results can be used to:

- Quantify substitution opportunities.
- Evaluate multiple longer term scenarios.
- Ensure valid metrics for both local decarbonization and resilience.[3]

Specific CAAP action steps should:

1. Increase reliance on locally available renewable resources to the extent possible and economically beneficial to both energy users and the community.

[3] For example, while decarbonization reduces GHG inventories, resilience results in measurably faster recovery from the effects of natural disasters.

2. Have lower life cycle costs than current choices.
3. Complement, not negate, action steps on parallel and future pathways.[4]
4. Recognize that local energy resilience depends on redundancy and diversity.
5. Be aligned with local energy usage and substitution trends and local utility service water and waste management capital improvement plans.
6. Recognize that collaboration is the key to timely, effective CAAP implementation.[5]

Local CAAP Development – Fuel Gas Decarbonization and Resilience

Additional suggestions:

1. Evaluate local fuel use and fuel related GHG emissions and consider how local inventories and trends differ from statewide trends and averages.
2. Engage collaborators, i.e. energy service providers, local energy sector retailers, and university based teams having energy modeling and/or technology assessment and forecasting capacity.
3. Consider engaging collaboratively with Southern California Gas (SCG) and local experts and energy users. Locally, where is there forward momentum that can be harnessed? What local programs and projects could attract the interest and engagement of companies able to offer proven solutions and mature implementation capacity?[iv]
4. Have a plan for follow up, including:
    a. Development of implementation plans for major action steps
    b. Periodic GHG inventory updates for GHG emissions targeted for reduction
    c. Annual reviews and progress reports

Using Information in This Report

The following sections identify, discuss and summarize primary action pathways[6], sequential steps to full implementation, collaborations necessary to remove roadblocks, and best case GHG inventory reduction targets for three 5-year phases. Each section includes decarbonization and resilience facts, discussion, and action/collaboration opportunities, followed by a summary table.

Tabular information can be used to summarize specific, planned action steps. For example, referring to Table 1 (Local Renewable Fuel from Waste), a local CAAP might specify that:

"Sharing data and otherwise collaborating with energy and waste management partners, the (city or County) will: 1) complete an inter-jurisdictional organics study, 2) increase the RNG share of its public facilities' gas usage to 25% of total usage, and 3) complete initial RNG production projects at landfill and wastewater treatment (WWT) plant sites with a five year goal of achieving a 0.25% reduction in overall (city or county) GHG inventory."

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[4] For example, policies that result in degradation of local gas fuel infrastructure and operations may have the unintended effect of impeding decarbonization of gas fuel transport and progress toward fully resilient local electricity supply systems.
[5] For example, gas and electricity transport infrastructure owners need to enforce fair, state-approved general terms for feeding "community renewable" energy into their networks, but they should be encouraged and empowered to collaborate with local jurisdictions to negotiate exceptions that unlock the environmental and economic potential of locally available renewable resources.
[6] Potentially effective specific actions are numerous and cannot all be included

Local CAAP preparation can also benefit greatly from experience with initiatives and programs already underway in other cities or counties. The Appendix includes links to information on exemplary initiatives and programs in southern California. End notes include references to information about relevant efforts elsewhere.

Local Renewable Fuel Production

Renewable Fuels. More than half the "renewable" component (corn ethanol) of petroleum-based transportation liquid fuels consumed globally is produced in the US and accounts for about 10 percent by volume of finished motor gasoline consumption.[7] Some fuel ethanol is also now produced from cellulosic (e.g. wood and corn fiber) waste materials.

As shown in Figure 5, other organic waste types suitable for conversion to renewable natural gas (RNG) arrive and/or accumulate at collection points throughout California. Some of these waste materials are being converted to gas fuels.

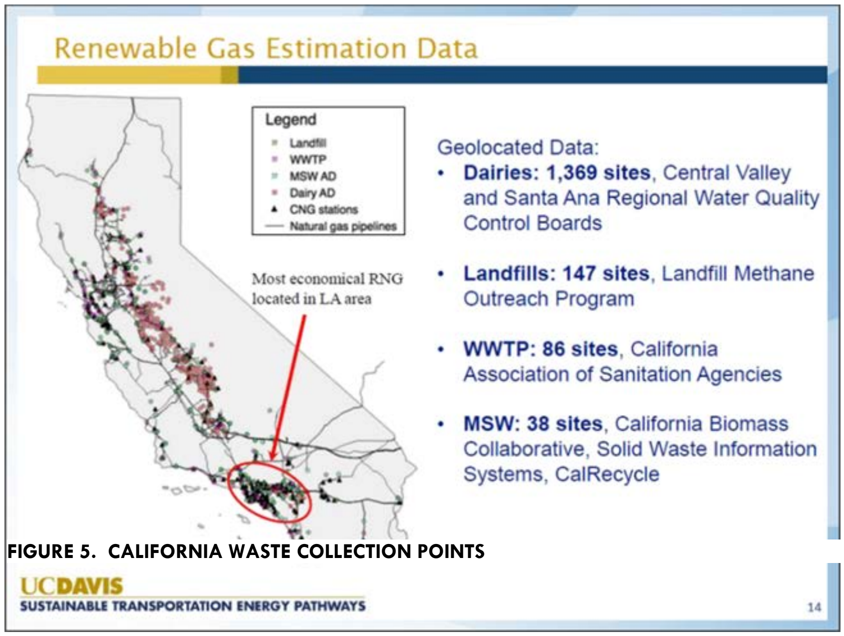

FIGURE 5. CALIFORNIA WASTE COLLECTION POINTS

California is imposing ever more ambitious requirements for organic waste diversion.[v] Cities and counties generally outsource waste collection services and pay "tipping fees" for the trash, recyclables, and organic materials that are collected. They may own and operate landfills and arrange for compost production and distribution. Private companies continue to develop and improve waste to energy conversion technologies and in some cases arrange for financing of commercial deployment.

For more than two decades, California Energy Commission and California utility R&D programs have sponsored studies, assessments, pilots and demos for conversion of organic waste materials to fuel and electricity. Other states and industrial countries have progressed well beyond the R&D stage and are employing a variety of commercial "community scale" technologies.

There is no shortage of information and experience, but there can be a local planning and integration deficit. For example, there are numerous options and scenarios for future diversion and conversion of food and yard waste. Evaluating organic waste options is typically not a local government skill set. Capital and operating costs and tipping fees can be forecast, summed and compared, but life cycle costs, operating revenues and GHG mitigation revenues are harder to predict and may not be accurately quantifiable. City and county roles may be complementary but lack coordination. For example, a county operated landfill or privately owned composting

[7]The U.S. Energy Information Administration (EIA) estimates that in 2019, the 142.17 billion gallons of finished motor gasoline consumed in the United States contained about 14.16 billion gallons of fuel ethanol, equal to about 10% of the total volume of finished motor gasoline consumption.

operation may have plans that are invisible to the cities that arrange for collection, sorting, and delivery of waste streams.

Local CAAP Considerations. Refer to Table 1. RNG delivered for residential use may be, on an energy content basis, nearly twice as expensive as NG today. However, only partial substitution can result in disproportionate decarbonization benefits. This is because RNG production diverts material that otherwise would decompose and release methane a potent GHG, into the atmosphere. For example, “30% emissions reductions in the (California) building sector can be achieved by switching to (as little as) 5% RNG”.[vi]

A helpful first step toward better inter-jurisdiction coordination may be a comprehensive multi-client, multi-jurisdictional organics study. [vii] In parallel, local governments can gain visibility to markets for RNG and consider purchasing RNG as a supplement to on-going NG purchases for public facilities. They can also lead or co-sponsor feasibility studies for construction and operation of local RNG production projects.

Local CAAPs can identify these steps, as well as follow up actions, e.g. more efficient and climate-friendly routing of waste streams and modernization of material recovery facilities for increased diversion and carbon capture. Based on their own experience purchasing RNG, they can facilitate RNG purchases by residents and businesses.

Local CAAPs can also target initial local RNG production, and later, expanded production of both RNG and RH2. Referring to Figure 6, RNG sources include landfills, dairies that operate manure digesters, and wastewater treatment plants that co-digest sewage treatment solids and food waste. Each has its own technical and economic constraints and opportunities. Although there are few or no commercial thermochemical biomass to RNG conversion facilities in operation in California, several gasification and pyrolysis technologies are undergoing pilot scale demonstration and development. [viii]

Renewable Hydrogen. Pathways to broad and large scale substitution of renewable fuels are opening, thanks to the emerging need to produce hydrogen (H2) for fuel cell electric vehicles (FCEVs).[ix] Local distribution of H2 for personal FCEV fueling will provide low-cost opportunities to expand availability of renewable H2 (RH2) for local microgrids, power generation, district heating, combined heat and power systems and some industrial energy needs. Possibilities for space and water heating are discussed in a later section.

As more local renewable electricity capacity comes on stream, there will be opportunities to expand local production and distribution of RH2, though project-specific safety and infrastructure limitations must first be resolved. Over the coming decade, local organic waste streams will be fully utilized in many cities and counties, at a minimum for low GHG emissions’ production of compost, and ideally for “carbon negative”[x] production of RNG. Full local fuel sector decarbonization will depend as well on substitution of RH2 for NG/RNG.

Global H2 production accounts for a significant share of global GHG emissions. Electrolytically produced H2 is still only about 2% of total global H2 supply.[xi] But new pathways for RH2 have opened in the power sector as costs of utility scale solar and wind electricity have plummeted. In countries that already rely heavily on variable renewable electricity resources like solar and wind, there are periods when the market price for variable renewable electricity is low or even goes to zero or negative.[xii] This increases the value of RH2 as an energy storage medium while reducing production costs. It creates opportunities to expand electrolytic production of H2, store it and then use it to produce electricity later.

RH2 is now being produced at costs around ten times the wholesale price of NG being imported into California and two to three times the price of retail NG used in the California buildings sector.[xiii] Increased RH2 production in areas subject to NG supply limitations, where wholesale prices are higher than in California, or where there are high penetrations of FCEVs into local vehicle markets, may help bring RH2 costs into the competitive range.[xiv]

Collaborations. Local southern California CAAPs should anticipate the need for collaboration regarding RH2, identifying progress review and coordination points, data sharing opportunities, and joint study topics. For example, gas distribution system upgrades may be needed to accommodate blends of NG and increasing percentages of RH2.

Element	Years 1-5	Years 5-10	Years 10-15	Total
Integrated Analysis Planning and Investment - Local Energy from Waste	Inter-jurisdictional organics study informing county and city plans	Rerouting of waste streams and modernization of MRFs	Maximum feasible energy production from waste streams	
Municipal or County RNG/RH2 Purchases	Increase RNG share of public facilities' gas usage to 25% of total	Increase RNG/RH2 share of public facilities' gas usage to 50% of total	Increase RNG/RH2 share of public facilities' gas usage to 100% of total	
Local GHG (%)	0.05%	0.1%	0.2%	0.35%
Local Carbon Negative RNG/RH2 Production at Landfills, WWTs, Dairies	Initial local RNG production projects	Increase local RNG/RH2 production to 20% of local usage	Increase local RNG/RH2 production to 50% of local usage	
Local GHG (%) (Landfill)	0.1%	0.2%	0.5%	0.8%
Local GHG (%) (Dairy)	See Note	See Note	See Note	
Local GHG (%) (WWT)	0.1%	0.2%	0.5%	0.8%
Collaborations	Data sharing/joint studies	Gas distribution upgrades	Gas distribution upgrades	
Totals	0.25%	0.5%	1.2%	~2%
Note: Homes, businesses and public facilities may purchase imported RNG and RNG blends from SGC, e.g. Dairy bio-gas injected into NG pipelines.				

Table 1. Local Renewable Fuel from Waste – CAAP Elements, Pathways and Local GHG Inventory Reduction

Resilient Local Power

Resilient Fuel Sources. An expert assessment of the resilience of the US natural gas system[xv] concludes that it is not susceptible to widespread failure from a single point of disruption in the same manner as the nation's electricity system. The redundant nature and underground location of the nation's supply, transmission, and storage systems mean lower vulnerability to weather events. The resilient nature of the system allows it to come back online quickly in the rare event of a natural or manmade disruption. Accordingly, gas fuel delivery should be an important local climate adaptation consideration, mainly because resilient fuel sources can result in resilient local power sources.

Energy Resilient Critical Infrastructure. In recent years, microgrids have become better understood as reliable and resilient power sources that can maintain operation during storm events and grid outages.[xvi][xvii] Some California university, military and industrial campuses are powered by microgrids that rely on NG combined heat and power, RNG fueled fuel cell generators and other renewable electricity sources.[xviii] Generally, to the extent they can continue to power <u>all</u> campus interconnected electricity demand <u>indefinitely</u> when isolated from utility electricity "distribution" systems, they are "<u>fully resilient</u>"[8].

Bills have been introduced in the 2020 session of the California legislature[xix] to fund and provide for greater local electricity resilience in the wake of devastating and disruptive wildfires in recent years and extended-duration public safety power shutoffs in 2019.

Cities and counties have a stake in how and where proposed state funds are spent, and work is underway to locate them where their energy resilience benefits are maximized.[xx] According to consulting group ICF: *"Compared to current microgrids—many of which consist of a single CHP system or gas generator—we expect multiple DER technologies to work together more frequently in future microgrids, incorporating PV, storage, and other technologies into new roles and use cases. Each technology has benefits that produce stacked values when strategically combined to respond to the needs of end-users and utilities. CHP and gas generators can be used for resilient baseload power while renewables and storage can be used to reduce emissions, meet peak site loads, and avoid high demand or time-of-use charges. Additionally, all these generation sources can be used to participate in utility markets for capacity, demand response, and ancillary services."*[xxi]

49 major state government buildings
92 refrigerated food warehouses
147 digital TV transmitters
225 local emergency operational centers
273 AM towers
535 urgent care facilities
570 hospitals
728 colleges and universities
1,013 law enforcement facilities
1,751 passenger transportation terminals
1,193 cell towers
3,182 nursing homes
3,139 emergency medical service facilities
3,209 fire stations & equipment depots
10,465 public schools
12,388 child care centers

FIGURE 6. CALIFORNIA CRITICAL FACILITIES INVENTORY (SOURCE: CLIMATE PROTECTION CENTER)

<u>Local CAAP Considerations.</u> Refer to Table 2. Resilient local power is a key climate adaptation goal. Therefore, new and updated local CAAPs should identify the role low carbon microgrids can play in delivering adequate levels of resilience across a range of possible grid outages and a range of generally essential and operationally critical electricity needs. Low carbon can be a result of using either or both combined heat and power (CHP) and renewable electricity sources.

Local CAAPs present an opportunity to take inventory, not only of GHG emissions and sources, but also of critical local electricity and fueling requirements, i.e. those where public safety and essential services are at risk if the requirements are not met in the wake of a natural disaster or terrorist attack on energy transport infrastructure[xxii] or a cyber-attack on SCADA systems.

As with local renewable fuel production, there is no shortage of information and experience, but there is a local planning and integration deficit. Pathways to full resilience may involve incremental investments and incrementally increasing reliance on RNG and RH2, fuel cell based and CHP sources and/or retrofitting of existing backup generators with a mix of stationary and vehicle integrated fuel cells. Along these pathways there may be opportunities to locally decarbonize while accomplishing local energy resilience goals.

A suggested first step is to establish resilient local power goals in collaboration with southern California gas and electric utilities (SCG, SCE and SDG&E) and Community Choice providers.

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[8] The ability to serve 80% or more of daily average interconnected usage, indefinitely, in all seasons and with high reliability can be considered fully resilient for evaluation and comparison purposes.

In many cases, cities and counties provide non-energy services such as waste collection, water supply and distribution, sewer infrastructure and wastewater treatment, and storm water diversion and protection. These city and county departments may be capable of coordinating inter-departmental resilience assessments while expanding their purview to include resilient energy for government operations and community energy resilience planning.

	Years 1-5	Years 5-10	Years 10-15	Totals
Fully Resilient Microgrids*	Resilient microgrids for critical public services are fueled by 100% RNG	Resilient new community microgrids include generators fueled by >50% RNG or RH2	New and existing resilient community microgrids include generators fueled by 100% RNG or RH2	
Local GHG (%)	<0.1%	0.1%	0.2%	0.3%
Stand-alone CHP and Stationary Fuel Cells	New stationary fuel cell and CHP generators are fueled by >50% RNG	Additional new stationary fuel cell and CHP generators fueled by RH2 or 100% RNG	Additional new stationary fuel cell and CHP generators fueled by RH2 or 100% RNG	
Local GHG (%)	<0.1%	0.2%	0.5%	0.5%
Backup Generators	Replace 25% of diesel fueled backup generators with NG generators	Maintain year 1-5 replacement rate and pilot use of FCEVs as BUGs	Increase FCEV resiliency use to 50% of local BUG capacity	
Local GHG (%)	N/A	N/A	N/A	
Collaborations	Local energy resilience goals	Gas distribution upgrades	Gas distribution upgrades	
Totals	<0.1%	0.3%	0.8%	1.1%
*The ability to serve 80% of daily average interconnected usage indefinitely, in all seasons, and with high reliability qualifies as fully resilient.				

Table 2. Resilient Local Power - CAAP Elements, Pathways and Local GHG Inventory Reduction

Aligning with state policies and concerns, local CAAPs can specify 100% RNG for gas fueled generators used for powering microgrids[xxiii] and supporting critical public services, an inventory of which is shown in Figure 6. Generation technologies fit for the purpose of converting RNG to electricity in this context include community-scale fuel cell and reciprocating engine generators as well as small CHP, aka "micro CHP", plants relying on combustion turbines[xxiv] and heat recovery steam generators and heat exchangers.[xxv]

Within ten years, all new community microgrids powered by gas fueled generators can be fueled by a mix that includes at least 50% locally produced RNG and RH2. New and existing community microgrids should transition to include generators fueled with 100% RNG and RH2 by 2035. Decarbonization benefits of community microgrid deployment can be multiplied by co-locating the generators with heat energy uses that are compatible with CHP applications. Local CAAPs should have reference to specific energy requirements for specific critical facilities as well as to studies that identify optimal microgrid locations.

Stand-alone CHP and stationary fuel cell generators can also enhance local energy resilience, especially if fueled with locally produced RNG or RH2. Local CAAPs should identify incrementally more aggressive targets for fueling them with RH2 or 100% RNG. Backup generators fueled with pipeline RNG or renewable gas blends provide greater resilience and reliability than diesel units relying on diesel fuel stored on site, which typically suffices for only two or three days of operation. FCEVs should be envisioned and piloted as back-up generators (BUGs) where local fueling infrastructure exists.

Low Carbon Gas Heat for Buildings

Historically, NG has supplied most of the demand for building space and water heating in California. Residential and commercial buildings' share of total NG usage are 21 and 9 percent respectively, accounting for about 7 and 3 percent of state-wide GHG inventories.[xxvi] Most of this usage is for water heating (~ 40%) and space heating (>50%).

Energy efficient buildings can have lower carbon footprints than others per square foot of space, provided they rely on low carbon fuels and/or low carbon electricity. California energy utilities offer efficiency programs for most customer classes. Decarbonization benefits of these programs will be enhanced when there is more active and purposeful collaboration between energy service providers and local governments. At a minimum, cities and counties can direct public attention and provide supplemental support to utility programs likely to be especially effective in their jurisdictions and climate zones. Local CAAPs have not emphasized this opportunity in the past, because the importance of local energy collaboration[xxvii] was not well understood

Cities and counties provide important non-energy utility services, e.g. waste collection, water supply and water and waste management infrastructure. They have outreach to and collect revenues monthly from the same customers energy utilities serve. Through city and county sponsored programs and outreach, barriers to low carbon water and space heating retrofits can be lowered. Cities and counties are stable, protective of the people and businesses they serve and trusted accordingly, which makes them a crucial partner for retailers, installers and energy utilities. Without their constructive engagement, important existing and emerging decarbonization options for building and water heating will remain underutilized.

<u>Local CAAP Considerations.</u> Generally, local CAAPs should identify steps that are currently actionable plus steps that may become actionable within the next decade. For example, a transition to greater RNG use will not affect the technology or economics of gas fuel usage, but the availability of H2 and RH2 would. As with NG and RNG, H2 and RH2 have identical properties, but there is little experience yet with H2 fuel distribution and use for building water and space heating purposes. The feasibility of transitions envisioned in years 10-15 in Tables 3 and 4 are being evaluated through demonstration projects around the world[xxviii] but are not yet adequately confirmed. Nevertheless, it is likely that fuel cell electric vehicle market growth will result in much faster maturation of safe and reliable H2 and RH2 distribution and storage technologies than would occur otherwise, making possible distribution of RH2 for heating as well as transportation purposes.

Low Carbon Gas Heat for Buildings – Water Heating

<u>Status and Experience.</u> 30 million solar water heating systems have been deployed over recent decades globally vs. 8 thousand in California. The primary adoption considerations were presumably comparative costs vs. other options. It is reasonable to ask if the solar water heating's decarbonization "bang for the buck" might be a game changer in California. According to a recent assessment sponsored by the California Energy Commission and SCG, "*well-functioning solar water heaters can theoretically displace 50 to 80 percent of the output of a NG-fueled household water heater, depending on how hot water usage aligns with production and storage capacities…they offer tremendous potential for reducing greenhouse gas emissions, fuel consumption, and energy bills… 40 percent of the NG used in California households is used to produce hot water. However, only a specialty market for solar water heaters has developed…the California Solar Initiative - Thermal program offers financial incentives for systems qualifying under a carefully crafted set of specifications. The program has had some limited success since its inception in 2010.*"[xxix]

Relatively generous incentives have been on offer in California for nearly a decade, as well as Federal tax credits. Why were funds for solar PV rebates used up in a few years, and the solar thermal rebates not? A partial answer may be lack of local climate action planning attention.

Barriers. The California Solar Initiative provided incentives for both solar electricity and solar water heating. The program's thoughtful and experience-based design fit solar electricity much better than solar water heating. In general, solar electricity retrofits produce greater quantities of energy and cost proportionately more while delivering comparable value per dollar of investment. Because solar electricity retrofits have much higher installed costs than solar water heating retrofits, customer acquisition costs (about the same for both single family residential solar options)[9], can be recovered without jeopardizing customer economic benefits. This is not the case for residential solar water heating systems.

Rooftop solar electricity (solar PV) is also more readily marketable than solar water heating. One reason is flexible timing for adoption decisions. Solar PV reduces or minimizes grid electricity usage but does not replace existing equipment. The opportune time to adopt is whenever the customer decides to; the decision may be under consideration for years. Solar/NG hybrid water heating replaces or modified the operation of existing equipment. The need to replace the existing water heater is usually immediate (because it failed unexpectedly). Like-for-like replacements are quick and involve a much small capital outlay than solar/NG hybrid retrofits.[10] Also, solar water heating retrofits reduce but do not eliminate GHG emissions or utility bills.

Customer acquisition costs are less of an impediment for larger solar water heating installations, e.g. sized for rental apartment buildings. But this case has its own special economic impediment, i.e. the so-called "split incentive" which occurs when those responsible for paying energy bills (tenants) are not the parties making capital investment decisions (building owners). In these circumstances, the building owner may choose not to make decarbonization upgrades when resulting costs savings accrue to the tenant.

In a slow and uncertain market, competent, stable, trusted installers with capacity to complete an emergency replacement involving unfamiliar technology may be hard for homeowners to find. More importantly, such installers have other more predictable and familiar opportunities. The key to a successful local hybrid solar/NG water heating deployment program may be to focus on residential projects that cost as much or more than residential solar PV retrofits, e.g. solar/NG water heating for apartment complexes. In this case innovative solutions to the "split incentive" problem are available but may require local government engagement to implement.

Local CAAP Considerations. Ten year old California Solar Initiative incentives will no longer be available to stimulate energy user interest. But local governments can partner with gas utilities and appliance installers to develop programs to present solar and other low carbon water heating as affordable, ready to implement and climate friendly investments. Solar water heating retrofits will continue to be cost effective on a life cycle basis if fuel and electricity cost trends are considered. In cities and counties where rental housing is prevalent, local governments and utilities can collaborate to offer programs and facilitate financing, leveraging available incentives and tapping into rapidly growing community support for local climate action and adaptation.

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[9] "Customer acquisition costs" typical of residential solar PV may be 20 or 30 percent of the average cost of a single family home solar PV retrofit,

[10] A completely new solar/NG hybrid system for a single family home may involve a capital outlay five times that of a like-for-like replacement, greatly increasing the importance of budgeting and timing.

Retrofit programs will likely have the greatest and fastest CAAP impact in low and modest growth communities. Locally adopted mandates for hybrid solar/gas water heating may be appropriate for new construction in high growth communities, especially those with expanding low income housing and high current proportions of rental housing. Local CAAP development should account for local contractor experience as well as product and system choices.

In general, cities and counties can consider two CAAP pathways. One for retrofits that relies on local program design and implementation and offers additional options as they become available. Another for new construction could start with a focus on low-income housing and expand to include other multi-family housing.

Initial retrofit program options might include tankless RNG water heating or solar thermal/NG and solar thermal/RNG water heating. Options having comparable decarbonization benefits can be added as they become commercially mature, including NG heat pump[xxx] water heaters and RH2 on demand water heaters for homes with RH2 service.

Options for new multifamily and rental construction will include solar thermal/RNG water heating. Later, fully net zero new buildings may use RNG and RH2 for both water and space heating while matching on-site solar supply to electricity use.

	Years 1-5	Years 5-10	Years 10-15	Totals
Hybrid Solar/NG Water Heating Retrofits	Plan/launch/implement a program for tankless RNG water heating and hybrid solar thermal/RNG systems	Modify program to cover more options, e.g. NG heat pump water heating	Modify program to cover more options, e.g. RH2 on demand water heaters	
Local GHG (-%)	0.5	.8	1.2	2.5
Hybrid Solar/NG Water Heating-New Construction	Mandate hybrid solar thermal/NG water heating for new low-income housing and starting in 2022	Mandate hybrid solar thermal/RNG systems for all major multifamily rental construction starting in 2025	Continue program, exempting new zero carbon buildings from mandates that heat water with RH2	
Local GHG (-%)	<0.1	0.2	0.2	0.4
Collaborations	Data sharing/code updates	Data sharing/code updates	Data sharing/code updates	
Totals	0.5	1	1.4	2.9

Table 3. Low Carbon Water Heating for Buildings - Local CAAP Elements, Pathways and Local GHG Inventory Reductions

Low Carbon Gas Heat for Buildings - Space Heating

So-called "passive" solar employs measures to regulate solar heat and sunlight gain and use a building's thermal mass as storage. Passive solar measures are now considered and implemented by architects and builders along with other building envelope energy efficiency measures, especially in cases where levels of building energy efficiency exceeding state standards are targeted. By contrast, "active" solar space heating and cooling, though it got considerable attention in Southern California in the 70s and beyond, faces similar and even higher barriers than those confronting solar water heating.

Hybrid Heating Systems. An emerging option, "hybrid heating"[xxxi], illustrated pictorially in Figure 7, is getting attention in parts of the US and Europe where winters are colder and longer than in southern California. From a resilience and life cycle affordability perspective, hybrid heating merits consideration in defining local CAAP pathways in southern California.

FIGURE 7. HYBRID HEATING SYSTEM IMAGE SHOWING HEAT PUMP OUTDOOR COIL AND INDOOR EQUIPMENT AND DUCTING

In some regions, short payback periods and subsequent cost-savings can be captured without sizing the heat pump in a conventional HVAC appliance to fully meet heating demand caused by the coldest outdoor weather.[xxxii] Hybrid heating systems are starting to be offered in northern and Midwest states, because in colder states such systems offer more attractive life cycle heating and cooling costs and more resilient heating and cooling.[xxxiii] In all regions, the motivation for hybrid heating may also include reducing GHG emissions attributable to space heating.

Residential heating, ventilation, and air conditioning (HVAC) in California typically combines a gas furnace for heating with an electric heat pump for cooling. By repurposing such configurations so that the heat pump serves all heating as well as cooling demand, "all electric" heating and cooling becomes feasible. The gas furnace is no longer needed. When powered by on-site solar electricity production in temperate regions like California, life cycle economics of integrated heat pump heating and cooling can be attractive, though the resulting heating service is less resilient. Meanwhile, as grid electricity rates continue to escalate in California, life cycle cost competitiveness of space heating and cooling powered by grid electricity may remain unaffordable some cases and only marginally affordable in others.

Local CAAP Considerations. The lion's share of residential NG use in California is for space heating. Active early markets may suffice to accelerate product technical and economic maturation and make hybrid NG/electric heating commercially available in California. Local CAAPs should account for this possibility because it has significant decarbonization potential. If initially successful, a local space heating decarbonization program can be expanded to include zero carbon hybrid solutions based on renewable gas and on-site solar PV.

Micro CHP space heating retrofits that enhance local resilience, initially for commercial and public buildings and later for residential buildings can be promoted depending on price and availability of RNG and RH2. Local new residential construction should be on a path to zero carbon and ultimately vehicle enabled building level resilience.

Table 4 identifies programs, promotions and options local CAAPs can target if there is local retailer support and interest. Engaging with local HVAC retailers is an important step in any case. Options like hybrid systems that may be attractive to residents and businesses for economic and environmental reasons may not otherwise attract local retailer attention.

	Years 1-5	Years 5-10	Years 10-15	Totals
Hybrid Low Carbon Space Heating Retrofits	Design a program for local contractors to sell/install low cost/low carbon NG/electric hybrid solutions	Modify program to ensure zero carbon hybrids (RNG and on-site solar) have attractive life cycle costs	Modify program to ensure that zero carbon hybrids (on-site solar PV and RH2) have attractive life cycle costs	
Local GHG (-%)	N/A	TBD	TBD	TBD
Resilient Space Heating Retrofits	Promote RNG fueled CHP for commercial/public buildings needing to be resilient as well as cost/carbon effective	Expand promotion to residential buildings	Expand promotion to RH2 fueled CHP for both residential and commercial/public buildings	
Local GHG (-%)	N/A	TBD	TBD	TBD
Integration	Design a program for home builders to specify low cost/low carbon NG/electric hybrid solutions	Modify program for homebuilders to specify zero carbon hybrid solutions (RNG plus on-site solar PV)	Expand program to include RH2 and building vehicle to building electricity	
Collaborations	Data sharing/code updates and SCG outreach to OEMs	Data sharing/code updates	Data sharing/code updates	
Totals	N/A	TBD	TBD	TBD

Table 4. Low Carbon Gas Space Heating for Buildings – CAAP Elements, Pathways and Local GHG Inventory Reduction

Low Carbon Transportation

Cities and counties will be impacted by, and can significantly influence, a transition to lower carbon transportation. The transition has already begun. There are two basic pathways having comparable decarbonization benefits, i.e. battery electric vehicles (BEVs) and fuel cell vehicles (FCEVs).

BEVs and FCEVs appear to have market growth rates comparable to solar PV, with BEV market growth lagging rooftop solar by about 5 years and FCEVs lagging BEVs by an additional 5 years. Southern California is an emerging market and manufacturing hub for both BEVs and FCEVs. FCEVs are projected to have generally comparable GHG emissions in future decades[xxxiv], depending on how and where electricity and H2 fuels are produced. The lowest long term carbon emissions scenarios for personal transportation feature long range BEVs charged with solar electricity instead of grid electricity, and fuel cell electric vehicles fueled with RH2 produced electrolytically from 100 percent renewable electricity.

In parallel, waste collection truck fleets are being converted from diesel fuel to compressed RNG, resulting in cleaner air and 30% lower GHG emissions.

<u>Local CAAP Considerations.</u> Local governments can have an important role in fueling the low carbon transportation transition. Their effectiveness will depend on integrative, collaborative planning with both electric and gas fuel distribution utilities.

See Table 5. Conversion of public transport bus and waste collection fleets from diesel to NG should be accelerated. In later phases private vehicle fleets can be transitioned to RNG or to comparably low carbon RH2 blends.

Likewise, local CAAPs can serve to initiate preparation of "roadmaps" to create publicly accessible local FCEV fueling capacity that expands over time to serve 100 percent of forecast local H2 demand. Local FCEV fueling services can rely on a mix of imported and locally produced RH2 until the goal of 100 percent locally produced RH2 is achieved. Active, purposeful collaboration between local governments and SCG will ensure efficient fueling services for both public and private vehicle fleets. It will lead to progress toward local RH2 supply and distribution infrastructure with capacity to fully meet local demand.

	Years 1-5	Years 5-10	Years 10-15	Totals
CNG Fueled Vehicle Fleets	Convert 50% of private commercial and waste collection fleets to RNG	Complete public fleet conversions to RNG or comparably low carbon RH2 blends	Complete private delivery fleet conversions to RNG or RH2	
Local GHG (-%)	<0.1	0.1	0.2	0.3
Fuel Cell Electric Vehicles	Ensure publicly accessible local FCEV fueling capacity to serve 100% of forecast local demand	Locally produce 50% of RH2 needed for FCEV fueling	Locally produce 100% of RH2 for FCEV fueling	
Local GHG (-%)	<0.1	0.5	2	2.5
Collaborations	RNG blend fueling stations for public fleets and private CNG vehicles	RH2 fueling stations for public and private FCEVs	Local RH2 supply and distribution infrastructure	
Totals	<0.1	0.6	2.2	2.8

Table 5. Low Carbon Transportation – CAAP Elements, Pathways and Local GHG Inventory Reduction

6. Low Carbon Industrial and Agricultural Heat

Reducing heavy industry (e.g. steel and cement production) GHG emissions will be costly but crucial to global decarbonization.[xxxv] This essential decarbonization process is difficult for local government to influence, since states and local governments compete to attract the jobs and tax revenues industrial operations generate.

Requirements for industrial and agricultural heat vary over a wide range of system sizes, heat transfer media and temperatures. Temperature requirements range from low grade heat for agricultural drying to industrial process heat at temperatures that can only be achieved by combusting hydrogen and specialty fuels. Further, the industries and agricultural operations needing heat are diverse as well, both process and scale.

Heat for food processing and crop drying is needed in rural areas, while industrial process heat needs are generally concentrated in urban industrial centers. GHG emissions from industrial and agricultural heating may not be major local GHG inventory components in all (or even most) cases. However, some steps in some cases are both affordable and effective in reducing emissions. For example, hybrid solar thermal/natural gas systems offer a significant decarbonization pathway for food processing and craft brewing industries.

Local CAAP Considerations. Refer to Table 6. Local CAAP development under these circumstances must be a collaboration. Utility account representatives understand and coordinate with industrial and large agricultural operation planners and managers. Decarbonization and resilience projects they undertake can be incorporated in local CAAPs and in some cases inform or inspire public sector actions. Local CAAP development conversations should involve the city or county, the company or farm, and fuel gas providers.

Questions for conversation. Regarding complex industrial operations and public facilities (e.g. airports), a key question is whether on-site energy use is sub-metered and whether real time data available for purposes of identifying excessive or unnecessary gas fuel or electricity use? In some cases, investments in modeling and measurement can eliminate more than ten percent of annual energy use. What are current decarbonization and resilience plans and policies? How is progress being tracked? Will there be opportunities for on-site RH2 production in the longer term, and will excess production be available to meet growing demand for vehicle fuel? For agricultural and forestry operations, are there opportunities for carbon negative or carbon neutral conversion of cellulosic materials generated by crop production and forest fire and wildfire prevention activities?

In all cases, are there permitting and tax considerations that impede decarbonization projects? How can utilities and local governments collaborate to remove barriers and accomplish infrastructure upgrades?

	Years 1-5	Years 5-10	Years 10-15	Totals
Industrial Process Heat	Assess current industrial NG user policies and plans and track their decarbonization investments.	Continue to track progress to goal of 50% reduction in emissions from local industrial fuel use below 2020 levels.	Arrange for purchases of excess renewable hydrogen produced at local industrial sites for FCEV fueling and blending with NG and RNG	
Local GHG (-%)	N/A	N/A	TBD	
Agricultural Process Heat	Co-sponsor assessments of converting agricultural and forestry waste to fuel	Disseminate relevant information and results from pilot projects	Increase carbon negative agricultural waste conversion and reduce emissions from agricultural drying, etc.	
Local GHG (-%)	N/A	N/A	TBD	
Collaborations with SCG	Assess permitting and local tax obstacles to industrial and agricultural decarbonization projects	Co-sponsor industrial decarbonization projects and collaborate to secure state funding and incentives	Gas distribution upgrades	
Totals				

Table 6. Low Carbon Industrial and Agricultural Energy – CAAP Elements, Pathways and Local GHG Inventory Reduction

Appendix – Links to News of Climate Action and Adaptation Collaborations in Southern California

Local Renewable Fuel

- Calgren Dairy Fuels Renewable Natural Gas Production Facility in Pixley, California
- Conversion of Food Waste from University of California Irvine Campus to Renewable Natural Gas at a Waste-Water Treatment Plant in Carson California[11]
- Biogas Conditioning to Produce Renewable Natural Gas at City of Corona Waste-water Treatment Plant[12]
- Renewable Hydrogen Production in the Ports of Long Beach and Los Angeles

Resilient Local Power in Southern California[13]

- Campus Microgrid Providing Electricity, Heating and Cooling for UC San Diego
- Microgrid project at Marine Corps Air Station Miramar near San Diego
- Emergency Power Microgrid at Port of Los Angeles

Tri-generation

- Integrated Production of Electricity, Hydrogen and Water at the Port of Los Angeles
- Tri-generation at Cal State Fullerton

Low Carbon Gas Heat for Buildings – Water Heating

- Marshall College Student Apartments at UC San Diego

Low Carbon Gas Heat for Buildings – Space Heating

- Trigeneration at Cal State Fullerton[14]

Low Carbon Transportation[15]

- Integrated Production of Electricity, Heat and Hydrogen for FCEVs at the Orange County Waste-Water Treatment Plant, Fountain Valley, California
- RNG Fueled Trucks at the Ports of Long Beach and Los Angeles
- RNG Fueling for School District Buses in Moreno Valley, California

Low Carbon Industrial and Agricultural Energy

High Efficiency Drying System at an Industrial Food Processing Site in Corona, California

[11] See also https://dpw.lacounty.gov/epd/SoCalConversion/PDFS/FoodWasteCloggingUpCalifornia.pdf
[12] See also https://microgridknowledge.com/renewable-natural-gas-microgrids/
[13] See also https://microgridknowledge.com/renewable-natural-gas-microgrids/ and https://www.utilitydive.com/news/los-angeles-solar-plus-storage-microgrid-pilot-to-slash-carbon-emissions-b/423519/
[14] See also https://www.gti.energy/enhancing-efficiency-in-space-conditioning-and-water-heating/
[15] See also https://www.maersk.com/news/articles/2019/10/24/alcohol-biomethane-and-ammonia-are-the-best-positioned-fuels-to-reach-zero-net-emissions

References and End Notes:

[i] Source: https://ww3.arb.ca.gov/cc/inventory/pubs/reports/2000_2017/ghg_inventory_trends_00-17.pdf
[ii] Refer to the Appendix for links to news of climate action and adaptation collaborations in southern California
[iii] Roughly 15 percent of the 20 year global warming potential of California's GHG emissions is attributable to on-site fuel use in buildings. Source: https://www.nrdc.org/experts/joe-vukovich/real-climate-impact-californias-buildings
[iv] The Appendix includes references to relevant southern California program and project implementation experience.
[v] Cf. https://www.calrecycle.ca.gov/75percent
[vi] https://www.socalgas.com/1443741887279/SoCalGas_Renewable_Gas_Final-Report.pdf
[vii] E.g. cf. City of Davis Organics Processing Facility Feasibility Analysis
[viii] https://ncst.ucdavis.edu/project/renewable-natural-gas-rng-potential-evaluation
[ix] A kg of H2 has about the same energy content as a gallon of gasoline. So, at current prices for industrial hydrogen, i.e. around $2.5-3/kg, FCEVs can have competitive fueling costs and the fuel providers can have a profitable business long term, provided they invest or co-invest in local fueling infrastructure.
[x] https://ww2.arb.ca.gov/resources/documents/lcfs-pathway-certified-carbon-intensities
[xi] Cf. https://www.iea.org/reports/the-future-of-hydrogen
[xii] For example, in Denmark, wind power production matches annual electricity use, resulting in an average wholesale electricity price around or a little above $30/MWh which translates to $30/kg for RH2, or around $30/MBTU. Cf. https://www.irena.org/-media/Files/IRENA/Agency/Publication/2018/Sep/IRENA_Hydrogen_from_renewable_power_2018.pdf
[xiii] NG prices in CA are currently between $3.5-4/MBTU for utility scale power projects and $13/MBTU for residential. Cf. https://www.eia.gov/dnav/ng/NG_PRI_SUM_DCU_SCA_M.htm Studies that look at the trajectory for electrolytic RH2 prices getting to $1-1.5/kg probably key off current long term power contracts for solar and wind, some of which are coming in under $20/MWh in TX and CA.
[xiv] It will help bring electrolytic RH2 prices into the competitive range locally if the range moves up. Recent analysis (cf. https://gridworks.org/initiatives/cagas-system-transition/) based on models using northern California NG sector assumptions suggest this may happen if there is massive and complete substitution of electric heat pumps for gas furnaces resulting in NG usage decline in the buildings sector decreases and resulting upward pressure on transport costs as economies of scale erode and safety and leakage concerns are addressed. This hypothesis has not been confirmed for southern California.
[xv] Resiliency of the U.S. Natural Gas System, Ron Edelstein, January 2019
[xvi] https://www.icf.com/insights/energy/microgrid-database
[xvii] The most basic solar microgrids are the circuits in buildings equipped with on-site solar arrays. These arrays provide a minimum level of energy resilience that depends on whether all or just some energy demand is electric and when it is used. Greater resilience is achievable with on-site battery storage. At the neighborhood and community level, solar and battery enabled microgrids may provide an acceptable level of resilience short term disruption but not robust energy resilience. Robust resilience is required where power service continuity is essential in all seasons and must be sustained without degradation when regional and local electricity grids may be disabled for extended periods, i.e. weeks or months. This means being able to deliver power indefinitely based on a mix sources that together can meet demand continuously with high reliability. CHP and gas generators can be used for resilient baseload power while renewables and storage can be used to reduce emissions, meet peak site loads, and avoid high demand or time-of-use charges. In the past, this meant There are coastal regions in southern California especially vulnerable to such outages. These and other areas depend on electricity that is imported from other area via transmission lines traversing forested areas prone fire or other natural disasters. Where the risk of long term outages is relatively high, fully resilient microgrids and backup power systems will include NG fueled generators, i.e. combustion turbine, fuel cell or reciprocating engine based generation or NG fueled combined heat and power capability.
[xviii] Cf. https://building-microgrid.lbl.gov/ucsd
[xix] E.g., The Community Energy Resilience Act (SB 1314) requires the Strategic Growth Council to develop and implement a grant program for local governments interested in developing clean energy-based community energy resilience plans. Because of the pandemic, the bill will be carried over to next year.
[xx] https://clean-coalition.org/wp-content/uploads/2020/03/Identifying-optimal-locations-for-Community-Microgrids-webinar-06_rf-19-Mar-2020.pdf
[xxi] https://www.icf.com/insights/energy/microgrid-technology-trends
[xxii] https://www.reuters.com/article/electric-grid-attacks/column-snipers-wont-blackout-us-power-grid-but-sun-may-kemp-idUSL6N0M729K20140310
[xxiii] Some local microgrids may rely on solar PV and battery storage. Including gas fueled generators is the key to full resilience.
[xxiv] Combustion turbines with ratings between 25 and 500kW are referred to as "microturbines".
[xxv] The potential decarbonization benefits of micro CHP are quantified in a recent report: Assessment of Small CHP Technical and Market Potential in California
[xxvi] Sources: https://ww2.energy.ca.gov/almanac/naturalgas_data/overview.html and https://ww3.arb.ca.gov/cc/inventory/pubs/reports/2000_2017/ghg_inventory_trends_00-17.pdf

[xxvii] Cf. State Policies for Local Energy Collaboration.
[xxviii] https://www.northerngasnetworks.co.uk/wp-content/uploads/2017/04/H21-Report-Interactive-PDF-July-2016.compressed.pdf
[xxix] Source: Solar Water Heating Assessment Project Final Report, December 2019
[xxx] At least one gas heat pump product has been introduced in the US for space heating and other products for water heating service are in development. See https://d1io3yog0oux5.cloudfront.net/_f1027d6e93bca940110ba3ea55f07944/tecogen/db/271/840/pdf/IliosDataSheet-AirSource-8-15.pdf
[xxxi] https://www.wwutilities.co.uk/media/2829/freedom-project-final-report-october-2018.pdf and https://www.economist.com/technology-quarterly/2018/11/29/in-the-rush-to-renewables-decarbonising-heating-has-been-overlooked
[xxxii] https://www.bobvila.com/articles/hybrid-heat-pump-system/#.WdZQ2mhSzIV
[xxxiii] https://www.drenergysaver.com/heating-systems/hybrid-hvac-system.html
[xxxiv] Greenhouse Gas Emissions for Battery Electric and Fuel Cell Electric Vehicles with Ranges Over 300 Km
[xxxv] Cf. https://www.newscientist.com/article/mg24432563-200-tackling-emissions-from-heavy-industry-is-key-to-fixing-climate-change/